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APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/168,466	11/14/2017	9819449	CSC-002	3872
74284	7590	10/25/2017		
Steven J Shattil P.O. Box 17355 Boulder, CO 80308-0355				

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b) (application filed on or after May 29, 2000)

The Patent Term Adjustment is 744 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (<http://pair.uspto.gov>).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site <http://pair.uspto.gov> for additional applicants):

Steve J. Shattil, Cheyenne, WY;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		14164254	
	Filing Date		2014-01-27	
	First Named Inventor	Shattil		
	Art Unit	2475		
	Examiner Name	Kevin Lee		
	Attorney Docket Number	CBF-001C2		

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /K.L./

	9	7283799		2007-10-16	Shattil	
	10	7406261		2008-07-29	Shattil	
	11	7010048		2006-03-07	Shattil	
	12	7317750		2008-01-08	Shattil	
	13	6686879		2004-02-03	Shattil	
	14	7286604		2007-10-23	Shattil	
	15	6211671		2001-04-03	Shattil	
	16	5955992		1999-09-21	Shattil	
Change(s) applied to document, N.W.S./ 10/6/2017	17	7976168		~~07/2011~~ ~~2006-07-11~~	Shattil Nicolaescu et al.	
	18	7418043		2008-08-26	Shattil	
	19	5943332		1999-08-24	Liu et al	

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
 or **Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

74284 7500 19/02/2017
 Steven J Shattil
 P.O. Box 17355
 Boulder, CO 80308-0355

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

Steven J Shattil	(Depositor's name)
/Steven J Shattil/	(Signature)
10/10/2017	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/168,466	01/30/2014	Steve J. Shattil	CSC-002	3872

TITLE OF INVENTION: COOPERATIVE SUBSPACE DEMULTIPLEXING IN CONTENT DELIVERY NETWORKS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEES DUE	DATE DUE
nonprovisional	SMALL	\$480	\$0	\$0	\$480	01/02/2018

EXAMINER	ART UNIT	CLASS-SUBCLASS
LEE, KEVIN H	2478	370-329000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

- ☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" indication form PTO/SB/47; Rev 03-02 or more recent) attached. Use of a Customer Number is required.

2. For printing on the patent front page, list

- (1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
 (2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1. Steven J Shattil

2. _____

3. _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

Genghiscomm Holdings, LLC

(B) RESIDENCE (CITY AND STATE OR COUNTRY)

Boulder, CO

Please check the appropriate assignee category or categories (will not be printed on the patent): ☐ Individual ☒ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☒ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
☒ Payment by credit card. Form PTO-2038 is attached.
☐ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ Applicant certifying micro entity status. See 37 CFR 1.29
☐ Applicant asserting small entity status. See 37 CFR 1.27
☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /Steven J Shattil/

Date 10/10/2017

Typed or printed name Steven J Shattil

Registration No. 40170

Electronic Patent Application Fee Transmittal				
Application Number:		14168466		
Filing Date:		30-Jan-2014		
Title of Invention:		COOPERATIVE SUBSPACE DEMULTIPLEXING IN CONTENT DELIVERY NETWORKS		
First Named Inventor/Applicant Name:		Steve J. Shattil		
Filer:		Steven J Shattil		
Attorney Docket Number:		CSC-002		
Filed as Small Entity				
Filing Fees for Utility under 35 USC 111(a)				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
LATE FILING FEE FOR OATH OR DECLARATION	2051	1	70	70
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
UTILITY APPL ISSUE FEE	2501	1	480	480
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				550

Electronic Acknowledgement Receipt	
EFS ID:	30609459
Application Number:	14168466
International Application Number:	
Confirmation Number:	3872
Title of Invention:	COOPERATIVE SUBSPACE DEMULTIPLEXING IN CONTENT DELIVERY NETWORKS
First Named Inventor/Applicant Name:	Steve J. Shattil
Customer Number:	74284
Filer:	Steven J Shattil
Filer Authorized By:	
Attorney Docket Number:	CSC-002
Receipt Date:	10-OCT-2017
Filing Date:	30-JAN-2014
Time Stamp:	13:12:42
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	\$550
RAM confirmation Number	101017INTEFSW13160000
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	CSC_002_PTO_85B.pdf	303466	no	1
			848d1a0de8028cae5554d96dd53275abf548360		
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	31915	no	2
			447ee663c64fa4f83c5b89f920c709d4970f89dc		
Warnings:					
Information:					
Total Files Size (in bytes):			335381		
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					



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NOTICE OF ALLOWANCE AND FEE(S) DUE

74284 7590 10/02/2017
Steven J Shattil
P.O. Box 17355
Boulder, CO 80308-0355

EXAMINER

LEE, KEVIN H

ART UNIT

PAPER NUMBER

2478

DATE MAILED: 10/02/2017

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/168,466	01/30/2014	Steve J. Shattil	CSC-002	3872

TITLE OF INVENTION: COOPERATIVE SUBSPACE DEMULTIPLEXING IN CONTENT DELIVERY NETWORKS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	\$480	\$0	\$0	\$480	01/02/2018

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Maintenance fees are due in utility patents issuing on applications filed on or after Dec. 12, 1980. It is patentee's responsibility to ensure timely payment of maintenance fees when due. More information is available at www.uspto.gov/PatentMaintenanceFees.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or **Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

74284 7590 10/02/2017
Steven J Shattil
P.O. Box 17355
Boulder, CO 80308-0355

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/168,466	01/30/2014	Steve J. Shattil	CSC-002	3872

TITLE OF INVENTION: COOPERATIVE SUBSPACE DEMULTIPLEXING IN CONTENT DELIVERY NETWORKS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	\$480	\$0	\$0	\$480	01/02/2018

EXAMINER	ART UNIT	CLASS-SUBCLASS
LEE, KEVIN H	2478	370-329000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively, 1 _____
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed. 2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:

- ☐ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): (Please first reapply any previously paid issue fee shown above)

- ☐ A check is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☐ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. Change in Entity Status (from status indicated above)

- ☐ Applicant certifying micro entity status. See 37 CFR 1.29
☐ Applicant asserting small entity status. See 37 CFR 1.27
☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____

Date _____

Typed or printed name _____

Registration No. _____



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United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/168,466	01/30/2014	Steve J. Shattil	CSC-002	3872
74284	7590	10/02/2017	EXAMINER	
Steven J Shattil			LEE, KEVIN H	
P.O. Box 17355			ART UNIT	PAPER NUMBER
Boulder, CO 80308-0355			2478	

DATE MAILED: 10/02/2017

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)

(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 14/168,466	Applicant(s) SHATTIL, STEVE J.	
	Examiner KEVIN LEE	Art Unit 2478	AIA (First Inventor to File) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to After Final on 7/19/2017.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☒ The allowed claim(s) is/are 1, 3-7, 9-13, and 15-20 (renumbered as 1, 2-6, 7-11, and 12-17 respectively). As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:
a) ☐ All b) ☐ Some *c) ☐ None of the:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. _____.
3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).
* Certified copies not received: _____.

Applicant has **THREE MONTHS FROM THE "MAILING DATE"** of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in **ABANDONMENT** of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ **CORRECTED DRAWINGS** (as "replacement sheets") must be submitted.
☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).

6. ☐ **DEPOSIT OF and/or INFORMATION** about the deposit of **BIOLOGICAL MATERIAL** must be submitted. Note the attached Examiner's comment regarding **REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL**.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)	5. ☐ Examiner's Amendment/Comment
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____	6. ☐ Examiner's Statement of Reasons for Allowance
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material	7. ☐ Other _____
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____	

/SHAQ TAHA/ Primary Examiner, Art Unit 2478	/KEVIN LEE/ Examiner, Art Unit 2478
--	--

Search Notes 	Application/Control No. 14168466	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.
	Examiner KEVIN LEE	Art Unit 2478

CPC- SEARCHED		
Symbol	Date	Examiner
H04L 1/0681	6/25/2016	KL
ABOVE UPDATED	2/15/2017	KL
ABOVE UPDATED	6/26/2017	KL
ABOVE UPDATED	8/29/2017	KL
H04B7/026	8/29/2017	KL
H04J13/0003	8/29/2017	KL
H04J13/004	8/29/2017	KL
H04L1/0077	8/29/2017	KL
H04L27/2602	8/29/2017	KL
H04L45/24	8/29/2017	KL

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES		
Search Notes	Date	Examiner
Inventor name search for double patenting	6/25/2016	KL
EAST search (see search history printout)	6/25/2016 (2/15/2017, 6/26/2017, 8/29/2017)	KL (KL, KL, KL)
Consulted with Primary Shaq Taha	8/24/2017	KL

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SEARCH NOTES		
Search Notes	Date	Examiner
Checked US 8,942,082 for double patenting. US 8,942,082 is directed to a different invention ('selecting transmitting nodes') with a few similar limitations. Invention in the Current Application is directed to 'selecting receiving nodes' and has additional limitations such as "and in response to a user input, selecting a destination node... and combining the coded components and the corresponding vectors at the destination node". Thus, no ODP issue here.	8/29/2017	KL

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
TEXT	see search history printout	8/29/2017	KL
H04L1/0681		8/29/2017	KL

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Issue Classification 	Application/Control No. 14168466	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.	
	Examiner KEVIN LEE	Art Unit 2478	

CPC					
Symbol				Type	Version
H04L	1	0681		F	2013-01-01
H04B	7	026		I	2013-01-01
H04J	13	0003		I	2013-01-01
H04J	13	004		I	2013-01-01
H04L	5	0021		A	2013-01-01
H04L	27	2601		A	2013-01-01
H04L	27	2602		I	2013-01-01
H04L	27	2614		A	2013-01-01
H04W	72	046		A	2013-01-01
H04L	45	24		I	2013-01-01
H04W	52	346		A	2013-01-01
H04L	1	0077		I	2013-01-01
H04L	2001	0097		A	2013-01-01

CPC Combination Sets				
Symbol	Type	Set	Ranking	Version

/KEVIN LEE/ Examiner.Art Unit 2478 (Assistant Examiner)	8/29/2017 (Date)	Total Claims Allowed: 17	
/SHAQ TAHA/ Primary Examiner.Art Unit 2478 (Primary Examiner)	08/31/2017 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

Issue Classification 	Application/Control No. 14168466	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.
	Examiner KEVIN LEE	Art Unit 2478

US ORIGINAL CLASSIFICATION						INTERNATIONAL CLASSIFICATION									
CLASS		SUBCLASS				CLAIMED					NON-CLAIMED				
						H	O	4	L	1 / 06 (2006.01.01)					
CROSS REFERENCE(S)															
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)														

/KEVIN LEE/ Examiner.Art Unit 2478 (Assistant Examiner)	8/29/2017 (Date)	Total Claims Allowed: 17	
/SHAQ TAHA/ Primary Examiner.Art Unit 2478 (Primary Examiner)	08/31/2017 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

Issue Classification 	Application/Control No. 14168466	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.
	Examiner KEVIN LEE	Art Unit 2478

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47															
Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
1	1	14	17												
-	2	15	18												
2	3	16	19												
3	4	17	20												
4	5														
5	6														
6	7														
-	8														
7	9														
8	10														
9	11														
10	12														
11	13														
-	14														
12	15														
13	16														

/KEVIN LEE/ Examiner.Art Unit 2478 (Assistant Examiner)	8/29/2017 (Date)	Total Claims Allowed: 17	
/SHAQ TAHA/ Primary Examiner.Art Unit 2478 (Primary Examiner)	08/31/2017 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1

<i>Index of Claims</i> 	Application/Control No. 14168466	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.
	Examiner KEVIN LEE	Art Unit 2478

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant						☐ CPA		☐ T.D.		☐ R.1.47	
CLAIM		DATE									
Final	Original	06/27/2016	02/15/2017	06/26/2017	08/29/2017						
1	1	=	✓	✓	=						
-	2	=	O	O	-						
2	3	=	✓	✓	=						
3	4	=	✓	✓	=						
4	5	=	✓	✓	=						
5	6	=	✓	✓	=						
6	7	=	✓	✓	=						
-	8	✓	O	O	-						
7	9	=	✓	✓	=						
8	10	=	✓	✓	=						
9	11	=	✓	✓	=						
10	12	=	✓	✓	=						
11	13	=	✓	✓	=						
-	14	✓	O	O	-						
12	15	=	✓	✓	=						
13	16	✓	✓	✓	=						
14	17	=	✓	✓	=						
15	18	=	✓	✓	=						
16	19	=	✓	✓	=						
17	20	=	✓	✓	=						

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	79	(H04L1/0681).cpc.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/08/29 21:45
S149	2117	(select\$5 choos\$3 determin\$3 pick\$3) with (client target destination receiver receiving adj node) and (combin\$5 aggregat\$3 build\$3) with (packet code) with vector	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/08/15 17:22
S153	342	(rank dimension near2 subspace degree near2 freedom) with (insufficient inadequate deficient) same (component packet vector)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/08/15 17:25
S154	18	S149 and S153	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/08/15 17:25
S159	4775	(rank dimension near2 subspace degree near2 freedom) with (insufficient inadequate deficient enough low less) same (component packet vector)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/08/15 18:10
S161	36	S159 and (select\$5 choos\$3 determin\$3 pick\$3) with (client target destination receiver receiving adj node) and (combin\$5 aggregat\$3 build\$3) with (packet code) with vector	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/08/15 18:10
S162	4775	(rank dimension near2 subspace degree near2 freedom) with (insufficient inadequate deficient enough low less) same (component packet vector)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/08/15 19:39
S163	47	S162 and (combin\$5 aggregat\$3 build\$3) with (packet code) with vector	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/08/15 19:39
S165	13083	(H04L1/0681 H04B7/026 H04J13/0003 H04J13/004 H04L1/0077 H04L27/2602 H04L45/24).cpc.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/08/29 17:47
S168	4413	(rank dimension near2 subspace degree near2 freedom) with (insufficient inadequate deficient less low) same (component packet	US-PGPUB; USPAT; EPO; JPO; DERWENT;	OR	ON	2017/08/29 17:50

EAST Search History

		vector)	IBM_TDB			
S170	35	S165 and S168	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/08/29 17:53

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S171	1	(content and delivery and linearly and independent and code and component and vector and rank and insufficient and dimension and subspace).clm.	USPAT	OR	ON	2017/08/29 16:23
S172	1	(content and delivery and linearly and degree and freedom and code and component and vector and destination).clm.	USPAT	OR	ON	2017/08/29 16:27
S173	1	(content and delivery and linearly and degree and freedom and code and vector and destination).clm.	USPAT	OR	ON	2017/08/29 17:05
S174	0	(content and delivery and channel and linearly and rank and insufficient and code and vector and destination and user-selectable).clm.	USPAT	OR	ON	2017/08/29 17:08
S175	2	(content and delivery and linearly and independent and code and component and vector and rank and insufficient and destination).clm.	USPAT	OR	ON	2017/08/29 17:44
S176	22	H04L1/0681.cpc.	USPAT	OR	ON	2017/08/29 17:45

8/ 29/ 2017 10:26:09 PM

C:\Users\klee9\Documents\EAST\Workspaces\14-168466.wsp

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 14/168,466		Filing Date 01/30/2014		☐ To be Mailed	
ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO									
APPLICATION AS FILED – PART I									
(Column 1)		(Column 2)							
FOR		NUMBER FILED		NUMBER EXTRA		RATE (\$)		FEE (\$)	
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))		N/A		N/A		N/A			
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))		N/A		N/A		N/A			
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))		N/A		N/A		N/A			
TOTAL CLAIMS (37 CFR 1.16(i))		minus 20 =		*		X \$ =			
INDEPENDENT CLAIMS (37 CFR 1.16(h))		minus 3 =		*		X \$ =			
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))		If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).							
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))									
* If the difference in column 1 is less than zero, enter "0" in column 2.						TOTAL			
APPLICATION AS AMENDED – PART II									
(Column 1)		(Column 2)		(Column 3)					
AMENDMENT	07/19/2017	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)		ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	* 17	Minus	** 20	= 0	X \$40 =		0	
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X \$210 =		0	
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
						TOTAL ADD'L FEE		0	
(Column 1)		(Column 2)		(Column 3)					
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)		ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =			
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =			
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
						TOTAL ADD'L FEE			
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.									

SLIE
 DIANIECE JACOBS

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appn. Number: 14/168,466

Filing Date: 01/30/2014

Inventor: Shattil

Title: "Cooperative Subspace Demultiplexing in Content Delivery Networks"

Examiner: Lee, Kevin H

G.A.U.: 2475

Atty. Docket No. CSC-002

OFFICE ACTION RESPONSE

Boulder, CO 80308

July 19, 2017

Commissioner of Patents

PO Box 1450

Alexandria, Virginia 22313-1450

Dear Sir:

This letter is responsive to the Office Letter mailed on 07/03/2017.

The listing of the claims begins on page 2 of this paper. Remarks begin on page 6 of this paper.

Claims

1. (Currently Amended) A processing method for retrieving data in a content delivery network, comprising:
 - selecting a plurality of receiving nodes to cooperatively receive a plurality of linearly independent coded components and a plurality of corresponding code vectors, wherein a rank of at least one of the receiving nodes is insufficient for decoding the coded components;
 - building up a dimension of a subspace spanned by collected code vectors by collecting the coded components and the corresponding code vectors from the plurality of receiving nodes, and in response to a user input, selecting a destination node from a plurality of user-selectable client devices, and combining the coded components and the corresponding code vectors at the destination node; and
 - decoding the coded components.
2. (Cancelled).
3. (Original) The processing method recited in Claim 1, wherein at least one of selecting and building comprises at least one of ensuring that a code matrix generated from the corresponding code vectors has sufficient rank to enable decoding, and ensuring the code matrix is sufficiently well-conditioned to permit decoding.
4. (Original) The processing method recited in Claim 1, further comprising transmitting at least one acknowledgement to at least one source node upon at least one of receiving a coded component and decoding the coded components.
5. (Original) The processing method recited in Claim 1, wherein decoding is configured for decoding at least one of a set of coded components, the set comprising block coded components and sliding window coded components.
6. (Original) A non-transitory computer-readable medium storing a computer program configured for implementing the method of Claim 1.

7. (Currently Amended) A method for processing data in a content delivery network, comprising:
- determining a required number of degrees of freedom for decoding a set of linearly coded packets;
 - based on the required number of degrees of freedom, selecting at least one additional receiving node for cooperatively receiving at least one coded packet and associated code vector;
 - collecting a plurality of coded packets and associated code vectors from a plurality of cooperating receiving nodes, including the at least one additional receiving node, to provide the required number of degrees of freedom, wherein the plurality of receiving nodes comprises a destination node and at least one user-selectable client device, and wherein collecting comprises, in response to a user input, selecting one of the at least one user-selectable client device as a new destination node and combining the plurality of coded packets and associated code vectors at the new destination node to enable the new destination node to decode the plurality of coded packets; and
 - decoding the plurality of coded packets.
8. (Cancelled).
9. (Original) The method recited in Claim 7, wherein at least one of selecting and collecting comprises ensuring that a code matrix produced from the associated code vectors is sufficiently well-conditioned to permit decoding.
10. (Original) The method recited in Claim 7, further comprising transmitting at least one acknowledgement to at least one source node upon at least one of collecting a coded packet and decoding the coded packets.
11. (Original) The method recited in Claim 7, wherein decoding is configured to employ at least one of block codes and sliding window codes.

12. (Original) A non-transitory computer-readable medium storing a computer program configured for implementing the method of Claim 7.
13. (Currently Amended) A method for receiving data in a content delivery network, comprising:
- connecting to a first network channel and at least a second network channel to simultaneously receive a plurality of linearly coded packets and corresponding code vectors transmitted from a source node;
 - receiving a first subset of the plurality of linearly coded packets and corresponding code vectors on the first network channel and receiving a second subset of the plurality of linearly coded packets and corresponding code vectors on the at least second network channel, wherein at least one of the first subset and the second subset has a rank that is insufficient for decoding the plurality of linearly coded packets, and wherein a sum of ranks of the first subset and the second subset is sufficient for decoding the plurality of linearly coded packets, and in response to a user input, selecting a destination node from a plurality of user-selectable client devices;
 - combining the first subset with the second subset at the destination node; and
 - decoding the plurality of linearly coded packets.
14. (Cancelled).
15. (Original) The method recited in Claim 13, wherein the first network channel resides on a first network and the at least second network channel resides on a second network, the second network different than the first network.
16. (Previously Amended) The method recited in Claim 13, further comprising monitoring at least one real-time property of the first network channel and the at least second network channel; and instructing the source node to adjust at least one of coding and transmitting the plurality of linearly coded packets and corresponding code vectors.

17. (Original) The method recited in Claim 13, wherein receiving the first subset and receiving the second subset comprises ensuring that a code matrix produced from the corresponding code vectors is sufficiently well-conditioned to permit decoding.
18. (Original) The method recited in Claim 13, further comprising transmitting at least one acknowledgement to the source node upon at least one of collecting a linearly coded packet and decoding the plurality of linearly coded packets.
19. (Original) The method recited in Claim 13, wherein decoding comprises decoding at least one of a set of coded packets, the set comprising block coded packets and sliding window coded packets.
20. (Original) A non-transitory computer-readable medium storing a computer program implementing the method of Claim 13.

Remarks – Claims

Claims 1-20 are pending.

Claim 1 was amended to include all the limitations recited in Claim 2 so it is equivalent to Claim 2 rewritten in independent form.

Claim 7 was amended to include all the limitations recited in Claim 8 so it is equivalent to Claim 8 rewritten in independent form.

Claim 13 was amended to include all the limitations recited in Claim 14 so it is equivalent to Claim 14 rewritten in independent form.

Claims 2, 8, and 14 were cancelled.

No new matter was added.

Remarks – Examination Report

Applicant has carefully reviewed the office action mailed on 07/03/2017. Applicant thanks the Examiner for the careful consideration given to this application. Reconsideration and allowance of the present application is now respectfully requested in view of the following remarks.

1. Allowable Subject Matter

The Office indicated that Claims 2, 8, and 14 would be allowable if rewritten in independent form including all the limitations of the base claim and any intervening claims.

The amended Claim 1 includes all the limitations of Claim 2, and therefore is equivalent to Claim 2 rewritten in independent form. Similarly, the amended Claim 7 is equivalent to Claim 8 rewritten in independent form, and the amended Claim 13 is equivalent to Claim 14 rewritten in independent form.

2. Claim Rejections 35 U.S.C. 103(a)

Claims 1, 6, 7, 12, 13, 15, 16, and 20 were rejected under 35 U.S.C. 103(a) as being unpatentable over U.S. Pub. No. 20140348253 (Mobasher) in view of U.S. Pub. No. 20120113816 (Bhattad).

The dependent Claims 3-5, 9-11, and 17-19 were rejected under 35 U.S.C. 103 as being unpatentable in further views of 20110305284 (Mueck), 20140064392 (Jonsson), and 20120057660 (Nguyen).

Since the independent Claims 1, 7, and 13 were amended to recite the Allowable Subject Matter indicated by the Office, Applicant respectfully requests reconsideration of the U.S.C. 103 rejections.

3. Conclusion

The Applicant has endeavored to address all of the examiner's concerns as expressed in the outstanding Office Action. Accordingly, arguments in support of the patentability of the pending

claims are presented above. In light of the above remarks and amendment, reconsideration and withdrawal of the outstanding rejections is specifically requested.

If the Examiner finds any remaining impediments to the prompt allowance of these claims that could be clarified with a telephone call, the Examiner is respectfully requested to initiate the same with the undersigned.

Respectfully submitted,

/Steven J Shattil/

Steven J. Shattil, Reg. No. 40,170

P.O. Box 17355

Boulder, CO 80308-0355

(720) 234-4351

Electronic Acknowledgement Receipt	
EFS ID:	29825576
Application Number:	14168466
International Application Number:	
Confirmation Number:	3872
Title of Invention:	Cooperative Subspace Demultiplexing in Content Delivery Networks
First Named Inventor/Applicant Name:	Steve J. Shattil
Customer Number:	74284
Filer:	Steven J Shattil
Filer Authorized By:	
Attorney Docket Number:	CSC-002
Receipt Date:	19-JUL-2017
Filing Date:	30-JAN-2014
Time Stamp:	12:06:10
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Applicant Arguments/Remarks Made in an Amendment	CSC_002_OA_3_response.pdf	142660 4ba782a03ee1b4579047d34ad33b3f7b659ecf22	no	8
Warnings:					

Information:	
Total Files Size (in bytes):	142660
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.	



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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/168,466	01/30/2014	Steve J. Shattil	CSC-002	3872
74284	7590	07/03/2017	EXAMINER	
Steven J Shattil P.O. Box 17355 Boulder, CO 80308-0355			LEE, KEVIN H	
			ART UNIT	PAPER NUMBER
			2478	
			MAIL DATE	DELIVERY MODE
			07/03/2017	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 14/168,466	Applicant(s) SHATTIL, STEVE J.	
	Examiner KEVIN LEE	Art Unit 2478	AIA (First Inventor to File) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1) ☒ Responsive to communication(s) filed on 6/7/2017.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on ____.

2a) ☒ This action is **FINAL**. 2b) ☐ This action is non-final.

3) ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on ____; the restriction requirement and election have been incorporated into this action.

4) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5) ☒ Claim(s) 1-20 is/are pending in the application.
5a) Of the above claim(s) ____ is/are withdrawn from consideration.

6) ☐ Claim(s) ____ is/are allowed.

7) ☒ Claim(s) 1,3-7,9-13 and 15-20 is/are rejected.

8) ☒ Claim(s) 2,8 and 14 is/are objected to.

9) ☐ Claim(s) ____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10) ☐ The specification is objected to by the Examiner.

11) ☐ The drawing(s) filed on ____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☐ All b) ☐ Some** c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.

2. ☐ Certified copies of the priority documents have been received in Application No. ____.

3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)

2) ☐ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b)
Paper No(s)/Mail Date ____.

3) ☐ Interview Summary (PTO-413)
Paper No(s)/Mail Date. ____.

4) ☐ Other: ____.

The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

DETAILED ACTION

Claim Rejections - 35 USC § 103

1. The following is a quotation of 35 U.S.C. 103 which forms the basis for all obviousness rejections set forth in this Office action:

A patent for a claimed invention may not be obtained, notwithstanding that the claimed invention is not identically disclosed as set forth in section 102, if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art to which the claimed invention pertains. Patentability shall not be negated by the manner in which the invention was made.

2. The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103 are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating

obviousness or nonobviousness.

3. **Claims 1, 6, 7, 12, 13, 15, 16, and 20** is/are rejected under 35 U.S.C. 103 as being unpatentable over **Mobasher et al.** (US 2014/0348253 A1) in view of **Bhattad et al.** (US 2012/0113816 A1).

For **claim 1, Mobasher** discloses 'A processing method for retrieving data in a content delivery network, comprising: selecting a plurality of receiving nodes to cooperatively receive a plurality of linearly independent coded components and a plurality of corresponding code vectors (see [0015] lines 8-16 and [0019] lines 24-27), wherein a rank of at least one of the receiving nodes is insufficient for decoding the coded components; building up a dimension of a subspace spanned by collected code vectors by collecting the coded components and the corresponding code vectors (see [0014] lines 9-13, where 'combining matrix' is derived by predetermined vectors, i.e. a dimension of a subspace spanned by collected code vectors, and 'building a combining matrix for decoding rank d data signal' means that the receiver itself has an insufficient rank for decoding rank d data signal without a combining matrix); and decoding the coded components (see [0014] lines 9-10).

Mobasher does not expressly disclose that the coded vectors are collected 'from the plurality of receiving nodes'. However, **Bhattad** from same or similar field of endeavor discloses that signals are collected 'from the plurality of receiving nodes' (see Fig. 2 and [0054] lines 8-11 and [0092] lines 5-11, collected from both eNB and Relay). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to apply **Bhattad's** function of collect signals from multiple receiving nodes in **Mobasher's** function of collecting coded vectors for the motivation of providing better signal quality for decoding.

For **claim 6, Mobasher** discloses 'A non-transitory computer-readable medium storing a computer program' (see [0038] lines 19-22). **Mobasher** and **Bhattad**

discloses 'configured for implementing the method of Claim 1' (see rejections on claim 1).

For **claim 7, Mobasher** discloses 'A method for processing data in a content delivery network, comprising: determining a required number of degrees of freedom for decoding a set of linearly coded packets (see [0014] lines 9-13, where 'rank d', i.e. required number of degrees of freedom, is identified, and see [0019] lines 24-27); based on the required number of degrees of freedom, selecting at least one additional receiving node for cooperatively receiving at least one coded packet and associated code vector (see [0015] lines 8-16); collecting a plurality of coded packets and associated code vectors, to provide the required number of degrees of freedom; and decoding the plurality of coded packets (see [0014] lines 9-13). **Mobasher** does not expressly disclose 'from a plurality of cooperating receiving nodes, including the at least one additional receiving node'. However, **Bhattad** from same or similar field of endeavor discloses that signals are collected 'from a plurality of cooperating receiving nodes, including the at least one additional receiving node' (see Fig. 2 and [0054] lines 8-11 and, collected from both eNB and Relay [0052] for receiving packet). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to apply **Bhattad's** function of collect signals from multiple receiving nodes including an additional node in **Mobasher's** function of collecting coded vectors for the motivation of providing better signal quality for decoding.

For **claim 12, Mobasher** discloses 'A non-transitory computer-readable medium storing a computer program' (see [0038] lines 19-22). **Mobasher** and **Bhattad**

discloses 'configured for implementing the method of Claim 7' (see rejections on claim 7).

For **claim 13, Mobasher** discloses 'A method for receiving data in a content delivery network, comprising: connecting to a first network channel and at least a second network channel to simultaneously receive a plurality of linearly coded packets and corresponding code vectors transmitted from a source node (see [0014] lines 4-6, [0021] lines 21-25, and [0025] lines 12-18,) and; receiving a first subset of the plurality of linearly coded packets and corresponding code vectors on the first network channel and receiving a second subset of the plurality of linearly coded packets and corresponding code vectors on the at least second network channel (see [0014] lines 4-6), wherein at least one of the first subset and the second subset has a rank that is insufficient for decoding the plurality of linearly coded packets (see [0014] lines 9-13, where using 'a combining matrix for decoding rank d data signal' means that the receiver itself has an insufficient rank for decoding rank d data signal without a combining matrix); and decoding the plurality of linearly coded packets (see [0014] lines 9-11). **Mobasher** does not expressly disclose 'and wherein a sum of ranks of the first subset and the second subset is sufficient for decoding the plurality of linearly coded packets; combining the first subset with the second subset'. However, **Bhattad** from same or similar field of endeavor discloses 'and wherein a sum of ranks of the first subset and the second subset is sufficient for decoding the plurality of linearly coded packets (see [0092] lines 6-9, where rank 2, i.e. sum of ranks of the data transmission from both eNB and a relay, is supported, i.e. enough to decode packets); combining the

first subset with the second subset (see [0092] lines 10-12). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to apply **Bhattad's** function of combining first and second packets for decoding in **Mobasher's** data receiving method for the motivation of providing better signal quality for decoding.

For **claim 15, Mobasher** discloses 'wherein the first network channel resides on a first network and the at least second network channel resides on a second network, the second network different than the first network' (see [0014] lines 4-6 and Fig. 1).

For **claim 16, Mobasher** discloses 'further comprising 'monitoring at least one real-time property of the first network channel and the at least second network channel; and instructing the source to adjust at least one of coding and transmitting the plurality of linearly coded packets and corresponding code vectors' (see [0031] lines 4-10 CQI and transmitter link adaptation).

For **claim 20, Mobasher** discloses 'A non-transitory computer-readable medium storing a computer program' (see [0038] lines 19-22). **Mobasher** and **Bhattad** discloses 'configured for implementing the method of Claim 13' (see rejections on claim 13).

4. **Claims 3, 9, and 17** is/are rejected under 35 U.S.C. 103 as being unpatentable over **Mobasher et al.** (US 2014/0348253 A1) in view of **Bhattad et al.** (US 2012/0113816 A1) and further in view of **Mueck et al.** (US 2011/0305284 A1).

For **claim 3, Mobasher** and **Bhattad** do not expressly disclose 'wherein at least one of selecting and building comprises at least one of ensuring that a code matrix

generated from the corresponding code vectors has sufficient rank to enable decoding, and ensuring the code matrix is sufficiently well-conditioned to permit decoding’.

However, **Mueck** from same or similar field of endeavor discloses ‘ensuring that a code matrix generated from the corresponding code vectors has sufficient rank to enable decoding, and ensuring the code matrix is sufficiently well-conditioned to permit decoding’ (see [0075] lines 1-7). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Mueck**’s function of ensuring the generated code matrix is sufficiently well conditioned in **Mobasher** and **Bhattad**’s processing method for the motivation of efficient decoding.

For **claim 9**, **Mobasher** and **Bhattad** do not expressly disclose ‘wherein at least one of selecting and collecting comprises ensuring that a code matrix produced from the associated code vectors is sufficiently well-conditioned to permit decoding’. However, **Mueck** from same or similar field of endeavor discloses ‘wherein at least one of selecting and collecting comprises ensuring that a code matrix produced from the associated code vectors is sufficiently well-conditioned to permit decoding’ (see [0075] lines 1-7). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Mueck**’s function of ensuring the generated code matrix is sufficiently well conditioned in **Mobasher** and **Bhattad**’s data processing method for the motivation of efficient decoding.

For **claim 17**, **Mobasher** and **Bhattad** do not expressly disclose ‘wherein receiving the first subset and receiving the second subset comprises ensuring that a code matrix produced from the corresponding code vectors is sufficiently well-

conditioned to permit decoding'. However, **Mueck** from same or similar field of endeavor discloses 'wherein receiving the first subset and receiving the second subset comprises ensuring that a code matrix produced from the corresponding code vectors is sufficiently well-conditioned to permit decoding' (see [0075] lines 1-7). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Mueck's** function of ensuring the generated code matrix is sufficiently well conditioned in **Mobasher** and **Bhattad's** data receiving method for the motivation of efficient decoding.

5. **Claims 4, 10, and 18** is/are rejected under 35 U.S.C. 103 as being unpatentable over **Mobasher et al.** (US 2014/0348253 A1) in view of **Bhattad et al.** (US 2012/0113816 A1) and further in view of **Jonsson et al.** (US 2014/0064392 A1).

For **claim 4**, **Mobasher** and **Bhattad** do not expressly disclose 'further comprising transmitting at least one acknowledgement to at least one source node upon at least one of receiving a coded component and decoding the coded components'. However, **Jonsson** from same or similar field of endeavor discloses 'transmitting at least one acknowledgement to at least one source node upon at least one of receiving a coded component and decoding the coded components' (see [0074] lines 13-16). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Jonsson's** function of transmitting ACK to a source node upon receiving and decoding a data block in **Mobasher** and **Bhattad's** processing method for the motivation of efficient data retransmission.

For **claim 10, Mobasher** and **Bhattad** do not expressly disclose 'further comprising transmitting at least one acknowledgement to at least one source node upon at least one of collecting a coded packet and decoding the coded packet. However, **Jonsson** from same or similar field of endeavor discloses 'transmitting at least one acknowledgement to at least one source node upon at least one of collecting a coded packet and decoding the coded packet' (see [0074] lines 13-16). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Jonsson's** function of transmitting ACK to a source node upon receiving and decoding a data packet in **Mobasher** and **Bhattad's** processing method for the motivation of efficient data retransmission.

For **claim 18, Mobasher** and **Bhattad** do not expressly disclose 'further comprising transmitting at least one acknowledgement to the source node upon at least one of collecting a linearly coded packet and decoding the plurality of linearly coded packets'. However, **Jonsson** from same or similar field of endeavor discloses 'transmitting at least one acknowledgement to the source node upon at least one of collecting a linearly coded packet and decoding the plurality of linearly coded packets' (see [0074] lines 13-16). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Jonsson's** function of transmitting ACK to a source node upon receiving and decoding a data packet in **Mobasher** and **Bhattad's** data receiving method for the motivation of efficient data retransmission.

6. **Claims 5, 11, and 19** is/are rejected under 35 U.S.C. 103 as being unpatentable over **Mobasher et al.** (US 2014/0348253 A1) in view of **Bhattad et al.** (US 2012/0113816 A1) and further in view of **NGUYEN** (US 2012/0057660 A1).

For **claim 5**, **Mobasher** and **Bhattad** do not expressly disclose 'wherein decoding is configured for decoding at least one of a set of coded components, the set comprising block coded components and sliding window coded components'. However, **NGUYEN** from same or similar field of endeavor discloses 'wherein decoding is configured for decoding at least one of a set of coded components, the set comprising block coded components and sliding window coded components' (see [0055]). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **NGUYEN**'s function of decoding block coded components and sliding window coded components in **Mobasher** and **Bhattad**'s coded components for the motivation of efficient data decoding.

For **claim 11**, **Mobasher** and **Bhattad** do not expressly disclose 'wherein decoding is configured to employ at least one of block codes and sliding window codes'. However, **NGUYEN** from same or similar field of endeavor discloses 'wherein decoding is configured to employ at least one of block codes and sliding window codes' (see [0055]). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to employ **NGUYEN**'s decoding block coded components and sliding window coded components in **Mobasher** and **Bhattad**'s decoding for the motivation of increasing efficiency in data decoding.

For **claim 19, Mobasher and Bhattad** do not expressly disclose 'wherein decoding comprises decoding at least one of a set of coded packets, the set comprising block coded packets and sliding window coded packets'. However, **NGUYEN** from same or similar field of endeavor discloses 'wherein decoding comprises decoding at least one of a set of coded packets, the set comprising block coded packets and sliding window coded packets' (see [0055]). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to employ **NGUYEN's** decoding block coded packets and sliding window coded packets in **Mobasher and Bhattad's** decoding for the motivation of increasing efficiency in data decoding.

Allowable Subject Matter

7. **Claims 2, 8, 14** are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Response to Arguments

Applicant's arguments filed 6/7/2017 have been fully considered but they are not persuasive.

8. Applicant argues that **Mobasher and Bhattad** are not prior art references because present application contains a proper priority chain which includes US application number 10/145854 filed on May 14, 2002. Applicant further provides the

supports in US application number 10/313163, which is incorporated by US application number 10/145854.

9. Examiner respectfully disagrees with Applicant. Applicant argues that limitations 'wherein a rank of at least one of the receiving nodes is insufficient for decoding the coded components' in claim 1 is supported by US application number 10/313163 [0578]-[0581]. However, cited portion suggests that it is necessary for the channel matrix H to have sufficient rank (i.e., rank = N) in order to recover the transmitted data vector x , but not that a rank of at least one of the receiving nodes is insufficient for decoding the coded components as disclosed in claim 1.

10. Therefore, it seems that there is no adequate support for limitations of claim 1 in the argued applications, and **Mobasher** and **Bhattad** are qualified for prior arts.

Conclusion

1. **THIS ACTION IS MADE FINAL.** Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the

shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to KEVIN LEE whose telephone number is (571)270-5651. The examiner can normally be reached on Monday-Friday, 9:30AM-5:00PM.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at <http://www.uspto.gov/interviewpractice>.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Derrick W. Ferris can be reached on (571)272-3123. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/K. L./
Examiner, Art Unit 2478

KEVIN LEE
Examiner
Art Unit 2478

/DERRICK FERRIS/
Supervisory Patent Examiner, Art Unit 2478

<i>Index of Claims</i> 	Application/Control No. 14168466	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.
	Examiner KEVIN LEE	Art Unit 2478

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant		☐ CPA		☐ T.D.		☐ R.1.47			
CLAIM		DATE							
Final	Original	06/27/2016	02/15/2017	06/26/2017					
	1	=	✓	✓					
	2	=	○	○					
	3	=	✓	✓					
	4	=	✓	✓					
	5	=	✓	✓					
	6	=	✓	✓					
	7	=	✓	✓					
	8	✓	○	○					
	9	=	✓	✓					
	10	=	✓	✓					
	11	=	✓	✓					
	12	=	✓	✓					
	13	=	✓	✓					
	14	✓	○	○					
	15	=	✓	✓					
	16	✓	✓	✓					
	17	=	✓	✓					
	18	=	✓	✓					
	19	=	✓	✓					
	20	=	✓	✓					

Search Notes 	Application/Control No. 14168466	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.
	Examiner KEVIN LEE	Art Unit 2478

CPC- SEARCHED		
Symbol	Date	Examiner
H04L 1/0681	6/25/2016	KL
ABOVE UPDATED	2/15/2017	KL
ABOVE UPDATED	6/26/2017	KL

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES		
Search Notes	Date	Examiner
Inventor name search for double patenting	6/25/2016	KL
EAST search (see search history printout)	6/25/2016 (2/15/2017, 6/26/2017)	KL (KL,KL)

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

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EAST Search History**EAST Search History (Prior Art)**

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L3	5	"14168466"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/06/26 13:40
L4	34	"10145854"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/06/26 13:42
L5	73	decod\$3 same block near3 code\$2 and sliding near3 window near3 code\$2	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/06/26 14:01
L6	103	(select\$5 choos\$3 determin\$3 pick\$3) with (receiver receiving) same (combin\$5 aggregat\$3 build\$3) with (packet code) with vector	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/06/26 14:02
L7	205	(aggregat\$3 collect\$3 combin\$3) with vector near5 rank	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/06/26 14:02
L12	79	H04L1/0681.cpc.	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/06/26 14:09

EAST Search History (Interference)

< This search history is empty >

6/ 26/ 2017 2:14:53 PM**C:\ Users\ klee9\ Documents\ EAST\ Workspaces\ 14-168466.wsp**

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 14/168,466		Filing Date 01/30/2014		☐ To be Mailed	
ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO									
APPLICATION AS FILED – PART I									
(Column 1)		(Column 2)							
FOR		NUMBER FILED		NUMBER EXTRA		RATE (\$)		FEE (\$)	
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))		N/A		N/A		N/A			
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))		N/A		N/A		N/A			
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))		N/A		N/A		N/A			
TOTAL CLAIMS (37 CFR 1.16(i))		minus 20 =		*		X \$ =			
INDEPENDENT CLAIMS (37 CFR 1.16(h))		minus 3 =		*		X \$ =			
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))		If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).							
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))									
* If the difference in column 1 is less than zero, enter "0" in column 2.						TOTAL			
APPLICATION AS AMENDED – PART II									
(Column 1)		(Column 2)		(Column 3)					
AMENDMENT	06/07/2017	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)		ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X \$40 =		0	
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X \$210 =		0	
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
						TOTAL ADD'L FEE		0	
(Column 1)		(Column 2)		(Column 3)					
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)		ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =			
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =			
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
						TOTAL ADD'L FEE			
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.									
						LIE BRENDA TURNER			

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appn. Number: 14/168,466

Filing Date: 01/30/2014

Inventor: Shattil

Title: "Cooperative Subspace Demultiplexing in Content Delivery Networks"

Examiner: Lee, Kevin H

G.A.U.: 2475

Atty. Docket No. CSC-002

OFFICE ACTION RESPONSE

Boulder, CO 80308

June 7, 2017

Commissioner of Patents

PO Box 1450

Alexandria, Virginia 22313-1450

Dear Sir:

This letter is responsive to the Office Letter mailed on 02/21/2017.

A petition for extension of time of one month and the corresponding fee accompany this letter.

The listing of the claims begins on page 2 of this paper. Remarks begin on page 6 of this paper.

Claims

1. (Original) A processing method for retrieving data in a content delivery network, comprising:
 - selecting a plurality of receiving nodes to cooperatively receive a plurality of linearly independent coded components and a plurality of corresponding code vectors, wherein a rank of at least one of the receiving nodes is insufficient for decoding the coded components;
 - building up a dimension of a subspace spanned by collected code vectors by collecting the coded components and the corresponding code vectors from the plurality of receiving nodes; and
 - decoding the coded components.
2. (Original) The processing method recited in Claim 1, wherein building up comprises, in response to a user input, selecting a destination node from a plurality of user-selectable client devices, and combining the coded components and the corresponding code vectors at the destination node.
3. (Original) The processing method recited in Claim 1, wherein at least one of selecting and building comprises at least one of ensuring that a code matrix generated from the corresponding code vectors has sufficient rank to enable decoding, and ensuring the code matrix is sufficiently well-conditioned to permit decoding.
4. (Original) The processing method recited in Claim 1, further comprising transmitting at least one acknowledgement to at least one source node upon at least one of receiving a coded component and decoding the coded components.
5. (Original) The processing method recited in Claim 1, wherein decoding is configured for decoding at least one of a set of coded components, the set comprising block coded components and sliding window coded components.
6. (Original) A non-transitory computer-readable medium storing a computer program configured for implementing the method of Claim 1.

7. (Original) A method for processing data in a content delivery network, comprising:
- determining a required number of degrees of freedom for decoding a set of linearly coded packets;
 - based on the required number of degrees of freedom, selecting at least one additional receiving node for cooperatively receiving at least one coded packet and associated code vector;
 - collecting a plurality of coded packets and associated code vectors from a plurality of cooperating receiving nodes, including the at least one additional receiving node, to provide the required number of degrees of freedom; and
 - decoding the plurality of coded packets.
8. (Previously Amended) The processing method recited in Claim 7, wherein the plurality of receiving nodes comprises a destination node and at least one user-selectable client device, and wherein collecting comprises, in response to a user input, selecting one of the at least one user-selectable client device as a new destination node and combining the plurality of coded packets and associated code vectors at the new destination node to enable the new destination node to decode the plurality of coded packets.
9. (Original) The method recited in Claim 7, wherein at least one of selecting and collecting comprises ensuring that a code matrix produced from the associated code vectors is sufficiently well-conditioned to permit decoding.
10. (Original) The method recited in Claim 7, further comprising transmitting at least one acknowledgement to at least one source node upon at least one of collecting a coded packet and decoding the coded packets.
11. (Original) The method recited in Claim 7, wherein decoding is configured to employ at least one of block codes and sliding window codes.

12. (Original) A non-transitory computer-readable medium storing a computer program configured for implementing the method of Claim 7.
13. (Original) A method for receiving data in a content delivery network, comprising:
- connecting to a first network channel and at least a second network channel to simultaneously receive a plurality of linearly coded packets and corresponding code vectors transmitted from a source node;
 - receiving a first subset of the plurality of linearly coded packets and corresponding code vectors on the first network channel and receiving a second subset of the plurality of linearly coded packets and corresponding code vectors on the at least second network channel, wherein at least one of the first subset and the second subset has a rank that is insufficient for decoding the plurality of linearly coded packets, and wherein a sum of ranks of the first subset and the second subset is sufficient for decoding the plurality of linearly coded packets;
 - combining the first subset with the second subset; and
 - decoding the plurality of linearly coded packets.
14. (Previously Amended) The method recited in Claim 13, wherein receiving comprises, in response to a user input, selecting a destination node from a plurality of user-selectable client devices, and wherein combining comprises combining the first subset and the second subset at the destination node.
15. (Original) The method recited in Claim 13, wherein the first network channel resides on a first network and the at least second network channel resides on a second network, the second network different than the first network.
16. (Previously Amended) The method recited in Claim 13, further comprising monitoring at least one real-time property of the first network channel and the at least second network channel; and instructing the source node to adjust at least one of coding and transmitting the plurality of linearly coded packets and corresponding code vectors.

17. (Original) The method recited in Claim 13, wherein receiving the first subset and receiving the second subset comprises ensuring that a code matrix produced from the corresponding code vectors is sufficiently well-conditioned to permit decoding.
18. (Original) The method recited in Claim 13, further comprising transmitting at least one acknowledgement to the source node upon at least one of collecting a linearly coded packet and decoding the plurality of linearly coded packets.
19. (Original) The method recited in Claim 13, wherein decoding comprises decoding at least one of a set of coded packets, the set comprising block coded packets and sliding window coded packets.
20. (Original) A non-transitory computer-readable medium storing a computer program implementing the method of Claim 13.

Remarks – Claims

Claims 1-20 are pending. No amendment was made.

Remarks – Examination Report

Applicant has carefully reviewed the office action mailed on 02/21/2017. Applicant thanks the Examiner for the careful consideration given to this application. Reconsideration and allowance of the present application is now respectfully requested in view of the following remarks.

1. Claim Rejections 35 U.S.C. 103(a)

Claims 1, 6, 7, 12, 13, 15, 16, and 20 were rejected under 35 U.S.C. 103(a) as being unpatentable over U.S. Pub. No. 20140348253 (Mobasher) in view of U.S. Pub. No. 20120113816 (Bhattad).

This rejection is respectfully traversed, and reconsideration is requested for the following reasons.

Mobasher is not a prior-art reference under 35 U.S.C. 102 or 35 U.S.C. 103.

Bhattad is not a prior-art reference under 35 U.S.C. 102 or 35 U.S.C. 103.

With regard to the rejection of the above Claims under 35 U.S.C. 103(a), Mobasher and Bhattad are not Prior-Art references because the present application contains a proper priority chain which includes a claim of priority to U.S. patent application Ser. No. 10/145,854 (the ‘854 application), filed on May 14, 2002, which has an earlier filing date than the publication date of Mobasher (published Nov. 27, 2014) and its priority date (Feb. 2, 2011), and which has an earlier filing date than the publication date of Bhattad (May 10, 2012) and its priority date (Nov. 5, 2010); and the specification of the ‘854 application presents adequate written description for the Claims in order to satisfy the statutory conditions of 35 U.S.C. Section 112.

The present application has the benefit of the earlier filing date of the ‘854 application under 35 U.S.C. 120, because it contains a specific reference to the ‘854 application in accordance with 37 CFR 1.78(a), and the ‘854 application satisfies the enablement and written description requirements of 35 U.S.C. 112, first paragraph.

The 35 U.S.C. 102(b) rejection of the Claims based on Mobasher and Bhattad is not proper because the Claims are entitled to the filing date of the '854 application, which is earlier than the publication date and the filing date of both Mobasher and Bhattad.

“ . . . [T]he Patent Office may make priority determinations of CIP claims when making rejections. For example, an examiner may look at a claim in a CIP and then reject the claim based on an “intervening reference” having a date between the date of filing of the priority parent application and the CIP application. However, such a rejection is only proper if the claim in question was only entitled to the filing date of the CIP (i.e.: the claim is directed to the new matter of the CIP).” - *Poweroasis Inc. v. T-Mobile*, 522 F.3d 1299 (Fed. Cir. 2008).

Support for the claims can be found throughout the disclosure of the parent application of this family, Appl. Ser. No. 10/145,854 and is indicated with respect to exemplary paragraphs in the published application, U.S. Pat. Pub. No. 20080095121 (referred to as the '854 application), as well as others of Applicant's patent applications which are incorporated by reference in the '854 application.

Due to the large amount of disclosure that supports the claimed features, the following discussion mentions only some of the many examples in the lengthy specifications. Other examples that are not mentioned also support the claimed features.

Independent Claim 1

Claim 1 recites the following features:

- a) selecting a plurality of receiving nodes to cooperatively receive a plurality of linearly independent coded components and a plurality of corresponding code vectors, wherein a rank of at least one of the receiving nodes is insufficient for decoding the coded components;

- b) building up a dimension of a subspace spanned by collected code vectors by collecting the coded components and the corresponding code vectors from the plurality of receiving nodes; and
- c) decoding the coded components.

Feature a) is illustrated, for example, in FIG. 9C, which shows a “plurality of nodes 926, 927, 902, 920, 921, and 922,” which collectively function as an antenna array for receiving and/or transmitting signals, such as disclosed in Pars. [0218]-[0220] of the published ‘854 application. By way of example, and without limitation,

Par. [0219] recites, “Nodes in a wireless network may generate weighted transmissions (or process received signals) to perform various types of array processing.”

Par. [0220] recites “Selection of transmitting and receiving nodes in an array-processing network can be adapted to changing node positions, network loads, throughput requirements, user services, bandwidth availability, frequency-reuse requirements, channel conditions, etc.”

The feature, “receive a plurality of linearly independent coded components,” is described throughout the specification, such as in

Par. [0208], which recites, “CI codes of a given set of CI code words may be constructed from a combination of linearly independent code vectors that form the CI code generation matrix G.”

Furthermore, the ‘854 application discloses network codes for encoding transmissions that are routed on different paths through a network, such as converging paths shown in FIG. 9H. The network codes can comprise channel-specific codes and/or beamforming weights, such as described in Par. [0239]. Coding can be implemented with, or as part of, array processing (Par. [0245]). The orthonormal basis codes (e.g., Pars. [0200] and [0203]) constitute linearly independent codes.

Similarly, Par. [0131] recites:

“a plurality of receiving antennas are adapted to produce a plurality of algebraically unique combinations of the transmitted signals.”

The feature, “(receive) a plurality of corresponding code vectors,” is disclosed, for example, in Par. [0238], which recites:

“For example, signals routed along a first path may provide a coded information signal to a predetermined destination. Signals routed along a second path to the same destination may provide a decode sequence to decode the coded information signal.”

Feature c) decoding the coded components (using the plurality of corresponding code vectors) is described throughout the ‘854 Specification, such as Par. [0117], which recites, “A decoder typically decodes an encoded signal with respect to one or more **reference signals** (e.g., codes, decode sequences, code keys, etc.).”

In array-processing examples disclosed in the ‘854 application, the received reference signals constitute the “plurality of corresponding code vectors,” as they are used in channel estimation and channel compensation to decode the received signals. For example,

Par. [0108] recites: “Channel estimation describes any combination of blind adaptive techniques and reference-signal processing...”

Par. [0107] recites: “Channel compensation may employ a combination of adaptive and reference-signal processing.”

Par. [0267] recites, “Signals received by the distributed network transceivers are coupled to the central processor, which performs channel estimation 1160 to characterize one or more communication channels.”

Signals received by an antenna array can be characterized by vectors, such as described throughout U.S. Pat. Appl. 10/313,163 (corresponding paragraphs of the Specification are noted with respect to U.S. Pub. No. 20070211786, which contains the same Specification as the ‘163

application), which is incorporated by reference in the '854 application. For example, Par. [0684] of the '163 application recites:

“Received spatial-gain patterns are characterized by a plurality of complex vectors β_{nl} . The vectors may indicate... complex-values associated with signals collected at each receiver element 3908.1 to 3908.N' over some predetermined time interval. Received signals are processed in a beam-forming system 3910 that may be adapted to perform sub-space processing...”

The feature, “a rank of at least one of the receiving nodes is insufficient for decoding the coded components,” is shown in the '163 application. For example, for subspace processing described in Pars. [0578]-[0581], it is necessary for the channel matrix H to have sufficient rank (i.e., rank = N) in order to recover the transmitted data vector x .

With respect to a receiver comprising an antenna array, this condition is expressed, for example, in Par. [0563] of the '163 application by the phrase,

“The number of transmitted signals $s_{\text{sub},j}(t)$ in each received signal $d_{\text{sub},k}(t)$ is preferably less than or equal to the number of received signals $d_{\text{sub},k}(t)$ (e.g., number of receiver elements) having algebraically unique combinations of the unknown transmitted signals $s_{\text{sub},j}(t)$.”

The number of “algebraically unique combinations” mentioned here and in Par. [0131] of the '854 application denotes rank. Since the data vector has length N and the channel matrix H has dimension $N \times N$, any subset of the N receiver elements implicitly has a rank less than N , and therefore is insufficient for decoding the coded components. As illustrated in FIG. 9C in the '854 application, for example, separate nodes collectively function as an array-processing network.

Furthermore, the '163 application discloses that subspace processing can be applied to code spaces to effect decoding, such as, for example, in Par. [0583].

The feature, “a rank of at least one of the receiving nodes is insufficient for decoding the coded components,” is also disclosed, for example, in Par. [0238] of the '854 application, which recites:

“In another set of embodiments, each of a plurality of signals routed along different paths to a given node may provide necessary keys (or equivalent information) necessary for decoding. For example, signals routed along a first path may provide a coded information signal to a predetermined destination. Signals routed along a second path to the same destination may provide a decode sequence to decode the coded information signal... The first code $c.sub.1(n)$ may include a public key and the second code $c.sub.2(n)$ may include a private key wherein the two codes $c.sub.1(n)$ and $c.sub.2(n)$ contribute the necessary code keys for decoding a coded information signal transmitted along the first and/or second paths, or along a third path. Various pluralities of codes, paths, and/or coded information signals may be employed.”

FIG. 9I in the ‘854 application shows how nodes 903 and 904 together provide sufficient rank by providing codes $c.sub.1(n)$ and $c.sub.2(n)$, respectively, to node 905 to permit decoding, whereas either node 903 or 904 alone has insufficient rank to permit decoding. Thus, FIG. 9I and related descriptions in the ‘854 application disclose the claimed feature, b) “building up a dimension of a subspace spanned by collected code vectors by collecting the coded components and the corresponding code vectors from the plurality of receiving nodes.”

Furthermore, Par. [0219] in the ‘854 application recites, “signals from each node may be combined in a central processor to perform sub-space (i.e., directional) processing,” which denotes that the signals from each node, when combined, build up the dimension of the subspace.

Similarly, Par. [0233] in the ‘854 application recites, “Furthermore, two or more decode values (e.g., $C^*(6)$ and $C^*(5)$) may be exploited in appropriate combinations to provide beam forming (or equivalent array processing) operations. Various combining operations may be performed to provide any combination of interference rejection, diversity enhancement, and sub-space processing (i.e., capacity enhancement).”

As described above, the claimed feature c) “decoding the coded components,” is disclosed throughout the ‘854 application.

Independent Claims 7 and 13

The independent Claims 7 and 13 recite similar features as Claim 1, and therefore, are patentable for the same reasons cited above.

Although Claim 7 recites, “number of degrees of freedom” instead of “rank,” Claim 7 recites similar subject matter as Claim 1, as supported extrinsically by the definitions of the above terms in the field of mathematics.

“Where vectors are constrained to lie in a linear subspace, the number of degrees of freedom is the dimension of the subspace” ([https://en.wikipedia.org/wiki/Degrees_of_freedom_\(statistics\)\)](https://en.wikipedia.org/wiki/Degrees_of_freedom_(statistics))).

“The rank of a matrix or a linear transformation is the dimension of the image of the matrix or the linear transformation, corresponding to the number of linearly independent rows or columns of the matrix, or to the number of nonzero singular values of the map” (<http://mathworld.wolfram.com/MatrixRank.html>).

Thus, the ‘854 application provides sufficient support for all the claimed features in Claims 1, 7, and 13.

Claims 6, 12, 20

Claims 6, 12, and 20 are dependent upon Claims 1, 7, and 13, respectively, and comprise the additional limitation of a non-transitory computer-readable medium storing a computer program. The ‘854 application discloses the additional limitation, such as, for example, in

Par. [0131]: “algorithms and/or processors are provided to separate at least one desired signal from at least one interfering signal.”

Par. [0219]: “signals from each node may be combined in a central processor to perform sub-space (i.e., directional) processing.”

And Par. [0267]: “FIG. 11F illustrates an array-processing method that employs at least one central processor to provide beam-forming operations across a plurality of spatially distributed network transceivers. Signals received by the distributed network transceivers are coupled to the central processor, which performs channel estimation 1160 to characterize one or more communication channels. Various operational characteristics and/or objectives (e.g., network parameters) are evaluated 1161. The evaluation 1161 can affect calculations of array-processing weights in a step 1162 that provides control information to a plurality of network transceivers. Alternatively, the step of providing control information 1162 may include applications of array-processing weights to signals received from and/or transmitted to the network transceivers by the central processor.”

Thus, the ‘854 application provides sufficient support for all the claimed features in Claims 6, 12, and 20.

Claim 15

Claim 15 is dependent upon Claim 13, which is discussed above. Claim 15 recites the additional limitation, “wherein the first network channel resides on a first network and the at least second network channel resides on a second network, the second network different than the first network.” This limitation is disclosed throughout the ‘854 application, such as, for example, in Par. [0244], which recites:

“At least one macro-cell 1021 is subdivided into one or more micro-cells 1031. Various multiple-access techniques may be used to separate communications in different cells. For example, a predetermined code may be provided to transmissions within the macro-cell 1021. Macro-cell codes may be provided for inter-cell multiple access or radio isolation. Micro-cell codes may be provided for intra-cell multiple access.”

Thus, the ‘854 application provides sufficient support for all the claimed features in Claim 15.

Claim 16

Claim 16 is dependent upon Claim 13, which is discussed above. Claim 15 recites the additional limitation, “monitoring at least one real-time property of the first network channel and the at

least second network channel; and instructing the source node to adjust at least one of coding and transmitting the plurality of linearly coded packets and corresponding code vectors.” This limitation is disclosed throughout the ‘854 application, such as, for example, in Par. [0116], which recites:

“Control information, as used herein, includes any information used to set, monitor, identify, adapt, or change communications and/or transceiver operations in a network. Control information may be provided for power control, synchronization, routing, channel assignments, code assignments, addressing, identification, acknowledgment, transfer of network control, etc.”

Par. [0125], which recites:

“A network control station (also referred to as a base station) is any network transceiver adapted to perform network control operations, such as communication control, power control, synchronization, assignment of operating parameters to other network transceivers, spectrum management, load balancing, network configuration, code assignment, channel selection, performance monitoring, performance optimization, routing, authentication, verification, channel estimation, etc.”

And in Par. [0129], which recites:

“A source node is a transceiver in a network from which a transmission originates. A source node may be defined relative to a given network. For example, although a base station may receive a transmission and retransmit the information into a given network, the base station may be regarded as the source node relative to the given network. ”

Thus, the ‘854 application provides sufficient support for all the claimed features in Claim 16.

Claims 3-5, 9-11, and 17-19

The dependent Claims 3-5, 9-11, and 17-19 were rejected under 35 U.S.C. 103 as being unpatentable in further views of 20110305284 (Mueck), 20140064392 (Jonsson), and 20120057660 (Nguyen).

As explained above, the present application contains a proper priority chain which includes a claim of priority to the '854 application, which was filed on May 14, 2002. The '854 has an earlier filing date than both the publication date and priority date of each of Mueck, Jonsson, and Nguyen. The cited references Mueck, Jonsson, and Nguyen are not prior art for Claims 3-5, 9-11, and 17-19 because the '854 application satisfies the enablement and written description requirements of 35 U.S.C. 112, first paragraph.

Claims 3, 9, 17

Claims 3, 9, 17 recite ensuring that a code matrix generated from the corresponding code vectors has sufficient rank to enable decoding, and ensuring the code matrix is sufficiently well-conditioned to permit decoding. This feature is disclosed throughout the '854 application, such as, for example,

Par. [0208]: "CI codes of a given set of CI code words may be constructed from a combination of linearly independent code vectors that form the CI code generation matrix G."

And Par. [0131]: "Preferably, a plurality of receiving antennas are adapted to produce a plurality of algebraically unique combinations of the transmitted signals. Accordingly, algorithms and/or processors are provided to separate at least one desired signal from at least one interfering signal."

Implicitly, in order "to separate at least one desired signal from at least one interfering signal," the code matrix requires sufficient rank and must be sufficiently well-conditioned to permit decoding;

"If the condition number is not too much larger than one (but it can still be a multiple of one), the matrix is well conditioned which means its inverse can be computed with good accuracy. If the condition number is very large, then the matrix is said to be ill-conditioned. Practically, such a matrix is almost singular, and the computation of its

inverse, or solution of a linear system of equations is prone to large numerical errors.”
(https://en.wikipedia.org/wiki/Condition_number#Matrices)

The code matrix, as disclosed in the ‘854 application, can include the matrix G and/or the channel matrix.

Claims 4, 10, 18

Claims 4, 10, 18 recite transmitting at least one acknowledgement to at least one source node upon at least one of receiving a coded component and decoding the coded components. This feature is disclosed throughout the ‘854 application, such as, for example,

Par. [0275] recites, “A header may include a field indicating whether an acknowledgment is required from the destination node. Acknowledgments may be requested upon receipt, reading, and/or printing of received information.”

Claims 5, 11, 19

Claims 5, 11, 19 recite decoding is configured for decoding at least one of a set of coded components, the set comprising block coded components and sliding window coded components. This feature is disclosed throughout the ‘854 application. Block coding is disclosed in the ‘854 application, for example, in Par. [0186].

Sliding window is disclosed in Appl. Ser. No. 11/187,107, filed 7/22/2005 (the ‘107 application), to which the present application claims priority. For example, in Pub. No. 20080075033, which comprises the disclosure of the ‘107 application, Par. [0079] incorporates by reference Pub. No. 20040086027, which discloses sliding-window transforms (e.g., Par. [0041]). The ‘107 application provides support for all the features in the independent claims at least by virtue of its incorporation by reference of the ‘854 application.

Since the filing date of the ‘107 application predates the publication and priority dates of each of the cited references, Mobasher, Bhattad, Mueck, Jonsson, and Nguyen, these cited references do not constitute prior art to Claims 5, 11, 19.

For at least the above reasons, Claims 1-20 are patentable over the cited references. Applicant requests reconsideration of the U.S.C. 103 rejections.

2. Allowable Subject Matter

Claims 2, 8, and 14 were objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

The Office indicated that allowability of claims 1, 3-7, 9-13, and 15-20 was withdrawn in view of references Mobasher, Bhattad, Jonsson, and Nguyen. However, as shown above, the cited references are not prior art. Therefore, Applicant respectfully requests that the Office allow all of the claims.

3. Conclusion

The Applicant has endeavored to address all of the examiner's concerns as expressed in the outstanding Office Action. Accordingly, arguments in support of the patentability of the pending claims are presented above. In light of the above remarks and amendment, reconsideration and withdrawal of the outstanding rejections is specifically requested.

If the Examiner finds any remaining impediments to the prompt allowance of these claims that could be clarified with a telephone call, the Examiner is respectfully requested to initiate the same with the undersigned.

Respectfully submitted,

/Steven J Shattil/

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PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a)		Docket Number (Optional) CSC-002																																		
Application Number 14/168,466	Filed 01/30/2014																																			
For Cooperative Subspace Demultiplexing in Content Delivery Networks																																				
Art Unit 2475	Examiner Lee, Kevin H																																			
This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above-identified application. The requested extension and fee are as follows (check time period desired and enter the appropriate fee below): <table style="width: 100%; border-collapse: collapse;"><thead><tr><th></th><th style="text-align: center;"><u>Fee</u></th><th style="text-align: center;"><u>Small Entity Fee</u></th><th style="text-align: center;"><u>Micro Entity Fee</u></th><th></th></tr></thead><tbody><tr><td>☒ One month (37 CFR 1.17(a)(1))</td><td style="text-align: center;">\$200</td><td style="text-align: center;">\$100</td><td style="text-align: center;">\$50</td><td style="text-align: right;">\$ <u>100</u></td></tr><tr><td>☐ Two months (37 CFR 1.17(a)(2))</td><td style="text-align: center;">\$600</td><td style="text-align: center;">\$300</td><td style="text-align: center;">\$150</td><td style="text-align: right;">\$ _____</td></tr><tr><td>☐ Three months (37 CFR 1.17(a)(3))</td><td style="text-align: center;">\$1,400</td><td style="text-align: center;">\$700</td><td style="text-align: center;">\$350</td><td style="text-align: right;">\$ _____</td></tr><tr><td>☐ Four months (37 CFR 1.17(a)(4))</td><td style="text-align: center;">\$2,200</td><td style="text-align: center;">\$1,100</td><td style="text-align: center;">\$550</td><td style="text-align: right;">\$ _____</td></tr><tr><td>☐ Five months (37 CFR 1.17(a)(5))</td><td style="text-align: center;">\$3,000</td><td style="text-align: center;">\$1,500</td><td style="text-align: center;">\$750</td><td style="text-align: right;">\$ _____</td></tr></tbody></table> ☒ Applicant asserts small entity status. See 37 CFR 1.27. ☐ Applicant certifies micro entity status. See 37 CFR 1.29. Form PTO/SB/15A or B or equivalent must either be enclosed or have been submitted previously. ☐ A check in the amount of the fee is enclosed. ☐ Payment by credit card. Form PTO-2038 is attached. ☐ The Director has already been authorized to charge fees in this application to a Deposit Account. ☐ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account Number _____. ☒ Payment made via EFS-Web. WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038. I am the ☐ applicant. ☒ attorney or agent of record. Registration number <u>40170</u> ☐ attorney or agent acting under 37 CFR 1.34. Registration number _____. <table style="width: 100%; border-collapse: collapse;"><tr><td style="width: 50%; padding: 5px;"><u>/Steven J Shattil/</u> Signature</td><td style="width: 50%; padding: 5px;"><u>06/07/2017</u> Date</td></tr><tr><td style="padding: 5px;"><u>Steven J Shattil</u> Typed or printed name</td><td style="padding: 5px;"><u>720-234-4351</u> Telephone Number</td></tr></table> NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. Submit multiple forms if more than one signature is required, see below*.				<u>Fee</u>	<u>Small Entity Fee</u>	<u>Micro Entity Fee</u>		☒ One month (37 CFR 1.17(a)(1))	\$200	\$100	\$50	\$ <u>100</u>	☐ Two months (37 CFR 1.17(a)(2))	\$600	\$300	\$150	\$ _____	☐ Three months (37 CFR 1.17(a)(3))	\$1,400	\$700	\$350	\$ _____	☐ Four months (37 CFR 1.17(a)(4))	\$2,200	\$1,100	\$550	\$ _____	☐ Five months (37 CFR 1.17(a)(5))	\$3,000	\$1,500	\$750	\$ _____	<u>/Steven J Shattil/</u> Signature	<u>06/07/2017</u> Date	<u>Steven J Shattil</u> Typed or printed name	<u>720-234-4351</u> Telephone Number
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<u>Steven J Shattil</u> Typed or printed name	<u>720-234-4351</u> Telephone Number																																			

☐ * Total of _____ forms are submitted.
This collection of information is required by 37 CFR 1.136(a). The information is required to obtain or retain a benefit by the public, which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 6 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Mail Stop PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

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8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
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Electronic Patent Application Fee Transmittal				
Application Number:		14168466		
Filing Date:		30-Jan-2014		
Title of Invention:		Cooperative Subspace Demultiplexing in Content Delivery Networks		
First Named Inventor/Applicant Name:		Steve J. Shattil		
Filer:		Steven J Shattil		
Attorney Docket Number:		CSC-002		
Filed as Small Entity				
Filing Fees for Utility under 35 USC 111(a)				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension - 1 month with \$0 paid	2251	1	100	100
Miscellaneous:				
Total in USD (\$)				100

Electronic Acknowledgement Receipt	
EFS ID:	29420786
Application Number:	14168466
International Application Number:	
Confirmation Number:	3872
Title of Invention:	Cooperative Subspace Demultiplexing in Content Delivery Networks
First Named Inventor/Applicant Name:	Steve J. Shattil
Customer Number:	74284
Filer:	Steven J Shattil
Filer Authorized By:	
Attorney Docket Number:	CSC-002
Receipt Date:	07-JUN-2017
Filing Date:	30-JAN-2014
Time Stamp:	12:49:08
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	CARD
Payment was successfully received in RAM	\$ 100
RAM confirmation Number	060717INTEFSW12571400
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Amendment/Req. Reconsideration-After Non-Final Reject	CSC_002_OA_2_response.pdf	210433	no	19
			a35a8a34840891b378cdca141ef64917f511408		
Warnings:					
Information:					
2	Extension of Time	aia0022.pdf	162582	no	2
			bda33a6204ef928aea367b637d9010ab106c00c7		
Warnings:					
Information:					
3	Fee Worksheet (SB06)	fee-info.pdf	30026	no	2
			e1b86b90362230d845d810ba411b529ff408f0afe		
Warnings:					
Information:					
Total Files Size (in bytes):			403041		
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/168,466	01/30/2014	Steve J. Shattil	CSC-002	3872
74284	7590	02/21/2017	EXAMINER	
Steven J Shattil P.O. Box 17355 Boulder, CO 80308-0355			LEE, KEVIN H	
			ART UNIT	PAPER NUMBER
			2475	
			MAIL DATE	DELIVERY MODE
			02/21/2017	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 14/168,466	Applicant(s) SHATTIL, STEVE J.	
	Examiner KEVIN LEE	Art Unit 2475	AIA (First Inventor to File) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1) ☒ Responsive to communication(s) filed on 10/10/2016.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on ____.

2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.

3) ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on ____; the restriction requirement and election have been incorporated into this action.

4) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5) ☒ Claim(s) 1-20 is/are pending in the application.
5a) Of the above claim(s) ____ is/are withdrawn from consideration.

6) ☐ Claim(s) ____ is/are allowed.

7) ☒ Claim(s) 1,3-7,9-13 and 15-20 is/are rejected.

8) ☒ Claim(s) 2,8 and 14 is/are objected to.

9) ☐ Claim(s) ____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10) ☐ The specification is objected to by the Examiner.

11) ☐ The drawing(s) filed on ____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☐ All b) ☐ Some** c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.

2. ☐ Certified copies of the priority documents have been received in Application No. ____.

3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☐ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b)
Paper No(s)/Mail Date ____.

3) ☐ Interview Summary (PTO-413)
Paper No(s)/Mail Date. ____.

4) ☐ Other: ____.

1. The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

DETAILED ACTION

Claim Rejections - 35 USC § 103

2. The following is a quotation of 35 U.S.C. 103 which forms the basis for all obviousness rejections set forth in this Office action:

A patent for a claimed invention may not be obtained, notwithstanding that the claimed invention is not identically disclosed as set forth in section 102, if the differences between the claimed invention and the prior art are such that the claimed invention as a whole would have been obvious before the effective filing date of the claimed invention to a person having ordinary skill in the art to which the claimed invention pertains. Patentability shall not be negated by the manner in which the invention was made.

3. The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103 are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating

obviousness or nonobviousness.

4. **Claims 1, 6, 7, 12, 13, 15, 16, and 20** is/are rejected under 35 U.S.C. 103 as being unpatentable over **Mobasher et al.** (US 2014/0348253 A1) in view of **Bhattad et al.** (US 2012/0113816 A1).

For **claim 1, Mobasher** discloses 'A processing method for retrieving data in a content delivery network, comprising: selecting a plurality of receiving nodes to cooperatively receive a plurality of linearly independent coded components and a plurality of corresponding code vectors (see [0015] lines 8-16 and [0019] lines 24-27), wherein a rank of at least one of the receiving nodes is insufficient for decoding the coded components; building up a dimension of a subspace spanned by collected code vectors by collecting the coded components and the corresponding code vectors (see [0014] lines 9-13, where 'combining matrix' is derived by predetermined vectors, i.e. a dimension of a subspace spanned by collected code vectors, and 'building a combining matrix for decoding rank d data signal' means that the receiver itself has an insufficient rank for decoding rank d data signal without a combining matrix); and decoding the coded components (see [0014] lines 9-10).

Mobasher does not expressly disclose that the coded vectors are collected 'from the plurality of receiving nodes'. However, **Bhattad** from same or similar field of endeavor discloses that signals are collected 'from the plurality of receiving nodes' (see Fig. 2 and [0054] lines 8-11 and [0092] lines 5-11, collected from both eNB and Relay). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to apply **Bhattad's** function of collect signals from multiple receiving nodes in **Mobasher's** function of collecting coded vectors for the motivation of providing better signal quality for decoding.

For **claim 6, Mobasher** discloses 'A non-transitory computer-readable medium storing a computer program' (see [0038] lines 19-22). **Mobasher** and **Bhattad**

discloses 'configured for implementing the method of Claim 1' (see rejections on claim 1).

For **claim 7, Mobasher** discloses 'A method for processing data in a content delivery network, comprising: determining a required number of degrees of freedom for decoding a set of linearly coded packets (see [0014] lines 9-13, where 'rank d', i.e. required number of degrees of freedom, is identified, and see [0019] lines 24-27); based on the required number of degrees of freedom, selecting at least one additional receiving node for cooperatively receiving at least one coded packet and associated code vector (see [0015] lines 8-16); collecting a plurality of coded packets and associated code vectors, to provide the required number of degrees of freedom; and decoding the plurality of coded packets (see [0014] lines 9-13). **Mobasher** does not expressly disclose 'from a plurality of cooperating receiving nodes, including the at least one additional receiving node'. However, **Bhattad** from same or similar field of endeavor discloses that signals are collected 'from a plurality of cooperating receiving nodes, including the at least one additional receiving node' (see Fig. 2 and [0054] lines 8-11 and, collected from both eNB and Relay [0052] for receiving packet). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to apply **Bhattad's** function of collect signals from multiple receiving nodes including an additional node in **Mobasher's** function of collecting coded vectors for the motivation of providing better signal quality for decoding.

For **claim 12, Mobasher** discloses 'A non-transitory computer-readable medium storing a computer program' (see [0038] lines 19-22). **Mobasher** and **Bhattad**

discloses 'configured for implementing the method of Claim 7' (see rejections on claim 7).

For **claim 13, Mobasher** discloses 'A method for receiving data in a content delivery network, comprising: connecting to a first network channel and at least a second network channel to simultaneously receive a plurality of linearly coded packets and corresponding code vectors transmitted from a source node (see [0014] lines 4-6, [0021] lines 21-25, and [0025] lines 12-18,) and; receiving a first subset of the plurality of linearly coded packets and corresponding code vectors on the first network channel and receiving a second subset of the plurality of linearly coded packets and corresponding code vectors on the at least second network channel (see [0014] lines 4-6), wherein at least one of the first subset and the second subset has a rank that is insufficient for decoding the plurality of linearly coded packets (see [0014] lines 9-13, where using 'a combining matrix for decoding rank d data signal' means that the receiver itself has an insufficient rank for decoding rank d data signal without a combining matrix); and decoding the plurality of linearly coded packets (see [0014] lines 9-11). **Mobasher** does not expressly disclose 'and wherein a sum of ranks of the first subset and the second subset is sufficient for decoding the plurality of linearly coded packets; combining the first subset with the second subset'. However, **Bhattad** from same or similar field of endeavor discloses 'and wherein a sum of ranks of the first subset and the second subset is sufficient for decoding the plurality of linearly coded packets (see [0092] lines 6-9, where rank 2, i.e. sum of ranks of the data transmission from both eNB and a relay, is supported, i.e. enough to decode packets); combining the

first subset with the second subset (see [0092] lines 10-12). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to apply **Bhattad's** function of combining first and second packets for decoding in **Mobasher's** data receiving method for the motivation of providing better signal quality for decoding.

For **claim 15, Mobasher** discloses 'wherein the first network channel resides on a first network and the at least second network channel resides on a second network, the second network different than the first network' (see [0014] lines 4-6 and Fig. 1).

For **claim 16, Mobasher** discloses 'further comprising 'monitoring at least one real-time property of the first network channel and the at least second network channel; and instructing the source to adjust at least one of coding and transmitting the plurality of linearly coded packets and corresponding code vectors' (see [0031] lines 4-10 CQI and transmitter link adaptation).

For **claim 20, Mobasher** discloses 'A non-transitory computer-readable medium storing a computer program' (see [0038] lines 19-22). **Mobasher** and **Bhattad** discloses 'configured for implementing the method of Claim 13' (see rejections on claim 13).

5. **Claims 3, 9, and 17** is/are rejected under 35 U.S.C. 103 as being unpatentable over **Mobasher et al.** (US 2014/0348253 A1) in view of **Bhattad et al.** (US 2012/0113816 A1) and further in view of **Mueck et al.** (US 2011/0305284 A1).

For **claim 3, Mobasher** and **Bhattad** do not expressly disclose 'wherein at least one of selecting and building comprises at least one of ensuring that a code matrix

generated from the corresponding code vectors has sufficient rank to enable decoding, and ensuring the code matrix is sufficiently well-conditioned to permit decoding’.

However, **Mueck** from same or similar field of endeavor discloses ‘ensuring that a code matrix generated from the corresponding code vectors has sufficient rank to enable decoding, and ensuring the code matrix is sufficiently well-conditioned to permit decoding’ (see [0075] lines 1-7). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Mueck**’s function of ensuring the generated code matrix is sufficiently well conditioned in **Mobasher** and **Bhattad**’s processing method for the motivation of efficient decoding.

For **claim 9**, **Mobasher** and **Bhattad** do not expressly disclose ‘wherein at least one of selecting and collecting comprises ensuring that a code matrix produced from the associated code vectors is sufficiently well-conditioned to permit decoding’. However, **Mueck** from same or similar field of endeavor discloses ‘wherein at least one of selecting and collecting comprises ensuring that a code matrix produced from the associated code vectors is sufficiently well-conditioned to permit decoding’ (see [0075] lines 1-7). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Mueck**’s function of ensuring the generated code matrix is sufficiently well conditioned in **Mobasher** and **Bhattad**’s data processing method for the motivation of efficient decoding.

For **claim 17**, **Mobasher** and **Bhattad** do not expressly disclose ‘wherein receiving the first subset and receiving the second subset comprises ensuring that a code matrix produced from the corresponding code vectors is sufficiently well-

conditioned to permit decoding'. However, **Mueck** from same or similar field of endeavor discloses 'wherein receiving the first subset and receiving the second subset comprises ensuring that a code matrix produced from the corresponding code vectors is sufficiently well-conditioned to permit decoding' (see [0075] lines 1-7). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Mueck's** function of ensuring the generated code matrix is sufficiently well conditioned in **Mobasher** and **Bhattad's** data receiving method for the motivation of efficient decoding.

6. **Claims 4, 10, and 18** is/are rejected under 35 U.S.C. 103 as being unpatentable over **Mobasher et al.** (US 2014/0348253 A1) in view of **Bhattad et al.** (US 2012/0113816 A1) and further in view of **Jonsson et al.** (US 2014/0064392 A1).

For **claim 4**, **Mobasher** and **Bhattad** do not expressly disclose 'further comprising transmitting at least one acknowledgement to at least one source node upon at least one of receiving a coded component and decoding the coded components'. However, **Jonsson** from same or similar field of endeavor discloses 'transmitting at least one acknowledgement to at least one source node upon at least one of receiving a coded component and decoding the coded components' (see [0074] lines 13-16). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Jonsson's** function of transmitting ACK to a source node upon receiving and decoding a data block in **Mobasher** and **Bhattad's** processing method for the motivation of efficient data retransmission.

For **claim 10, Mobasher** and **Bhattad** do not expressly disclose 'further comprising transmitting at least one acknowledgement to at least one source node upon at least one of collecting a coded packet and decoding the coded packet. However, **Jonsson** from same or similar field of endeavor discloses 'transmitting at least one acknowledgement to at least one source node upon at least one of collecting a coded packet and decoding the coded packet' (see [0074] lines 13-16). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Jonsson's** function of transmitting ACK to a source node upon receiving and decoding a data packet in **Mobasher** and **Bhattad's** processing method for the motivation of efficient data retransmission.

For **claim 18, Mobasher** and **Bhattad** do not expressly disclose 'further comprising transmitting at least one acknowledgement to the source node upon at least one of collecting a linearly coded packet and decoding the plurality of linearly coded packets'. However, **Jonsson** from same or similar field of endeavor discloses 'transmitting at least one acknowledgement to the source node upon at least one of collecting a linearly coded packet and decoding the plurality of linearly coded packets' (see [0074] lines 13-16). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **Jonsson's** function of transmitting ACK to a source node upon receiving and decoding a data packet in **Mobasher** and **Bhattad's** data receiving method for the motivation of efficient data retransmission.

7. **Claims 5, 11, and 19** is/are rejected under 35 U.S.C. 103 as being unpatentable over **Mobasher et al.** (US 2014/0348253 A1) in view of **Bhattad et al.** (US 2012/0113816 A1) and further in view of **NGUYEN** (US 2012/0057660 A1).

For **claim 5**, **Mobasher** and **Bhattad** do not expressly disclose 'wherein decoding is configured for decoding at least one of a set of coded components, the set comprising block coded components and sliding window coded components'. However, **NGUYEN** from same or similar field of endeavor discloses 'wherein decoding is configured for decoding at least one of a set of coded components, the set comprising block coded components and sliding window coded components' (see [0055]). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to include **NGUYEN**'s function of decoding block coded components and sliding window coded components in **Mobasher** and **Bhattad**'s coded components for the motivation of efficient data decoding.

For **claim 11**, **Mobasher** and **Bhattad** do not expressly disclose 'wherein decoding is configured to employ at least one of block codes and sliding window codes'. However, **NGUYEN** from same or similar field of endeavor discloses 'wherein decoding is configured to employ at least one of block codes and sliding window codes' (see [0055]). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to employ **NGUYEN**'s decoding block coded components and sliding window coded components in **Mobasher** and **Bhattad**'s decoding for the motivation of increasing efficiency in data decoding.

For **claim 19, Mobasher** and **Bhattad** do not expressly disclose 'wherein decoding comprises decoding at least one of a set of coded packets, the set comprising block coded packets and sliding window coded packets'. However, **NGUYEN** from same or similar field of endeavor discloses 'wherein decoding comprises decoding at least one of a set of coded packets, the set comprising block coded packets and sliding window coded packets' (see [0055]). Thus it would have been obvious to one of ordinary skill in the art at the time of invention to employ **NGUYEN's** decoding block coded packets and sliding window coded packets in **Mobasher** and **Bhattad's** decoding for the motivation of increasing efficiency in data decoding.

Allowable Subject Matter

8. The indicated allowability of **claims 1, 3-7, 9-13, 15-20** is withdrawn in view of the newly discovered reference(s) to **Mobasher et al.** (US 2014/0348253 A1), **Bhattad et al.** (US 2012/0113816 A1), **Jonsson et al.** (US 2014/0064392 A1), and **NGUYEN** (US 2012/0057660 A1).

9. For rejections based on the newly cited reference(s), see 'Claim Rejections' section of this Office Action.

10. **Claims 2, 8, 14** are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to KEVIN LEE whose telephone number is (571)270-5651. The examiner can normally be reached on Monday-Friday, 9:30AM-5:00PM.

Examiner interviews are available via telephone, in-person, and video conferencing using a USPTO supplied web-based collaboration tool. To schedule an interview, applicant is encouraged to use the USPTO Automated Interview Request (AIR) at <http://www.uspto.gov/interviewpractice>.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Hassan Kizou can be reached on (571)272-3088. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/K. L./
Examiner, Art Unit 2475

KEVIN LEE
Examiner
Art Unit 2475

Application/Control Number: 14/168,466
Art Unit: 2475

Page 13

/DERRICK FERRIS/
Supervisory Patent Examiner, Art Unit 2478

Notice of References Cited	Application/Control No. 14/168,466		Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.	
	Examiner KEVIN LEE		Art Unit 2475	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-2014/0348253 A1	11-2014	Mobasher; Amin	H04B7/0452	375/267
*	B	US-2012/0113816 A1	05-2012	Bhattad; Kapil	H04L5/0032	370/246
*	C	US-2014/0064392 A1	03-2014	Jonsson; Anders	H04L1/0026	375/267
*	D	US-2012/0057660 A1	03-2012	NGUYEN; QUANG	H04L1/005	375/341
	E	US-				
	F	US-				
	G	US-				
	H	US-				
	I	US-				
	J	US-				
	K	US-				
	L	US-				
	M	US-				

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	CPC Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

<i>Index of Claims</i> 	Application/Control No. 14168466	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.
	Examiner KEVIN LEE	Art Unit 2475

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant				☐ CPA		☐ T.D.		☐ R.1.47	
CLAIM		DATE							
Final	Original	06/27/2016	02/15/2017						
	1	=	✓						
	2	=	O						
	3	=	✓						
	4	=	✓						
	5	=	✓						
	6	=	✓						
	7	=	✓						
	8	✓	O						
	9	=	✓						
	10	=	✓						
	11	=	✓						
	12	=	✓						
	13	=	✓						
	14	✓	O						
	15	=	✓						
	16	✓	✓						
	17	=	✓						
	18	=	✓						
	19	=	✓						
	20	=	✓						

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S55	353	(cooperat\$6 joint\$4) with receiv\$3 and decod\$3 with (rank dimension) and linear\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/07 13:13
S59	203	(cooperat\$6 joint\$4) with receiv\$3 and decod\$3 with (rank dimension) and linear\$3 and independent\$3 and packet	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/07 13:13
S60	151	(cooperat\$6 joint\$4) with receiv\$3 and decod\$3 with (rank dimension) and linear\$3 same independent\$3 and packet	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/07 13:14
S61	16	(cooperat\$6 joint\$4) with receiv\$3 same vector and decod\$3 with (rank dimension) and linear\$3 same independent\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/07 13:14
S62	21	(cooperat\$6 joint\$4) with receiv\$3 same vector and decod\$3 with (rank dimension) and linear\$3 and independent\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/07 13:17
S63	25	(cooperat\$6 joint\$4) with receiv\$3 same vector and decod\$3 with (rank dimension freedom) and linear\$3 and independent\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/07 13:17
S64	47	(cooperat\$6 joint\$4) with receiv\$3 same vector and decod\$3 same (rank dimension freedom) and linear\$3 and independent\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/07 13:21
S65	57	(cooperat\$6 joint\$4) with receiv\$3 same vector and decod\$3 same (rank dimension freedom) and linear\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/07 13:21
S66	32	decod\$3 with (insufficient inadequate deficient) with rank\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/07 16:25
S67	3	"14168466"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 10:55

S68	103	(aggregat\$3 collect\$3) with (code code near3 vector) same decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 14:15
S69	1175	cooperative near3 mimo	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 14:28
S73	81	((subspace vector) near3 code) same decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 17:26
S74	8745	decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 18:05
S76	18	build\$3 with vector same decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 18:07
S77	781	vector same decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 18:08
S78	599	vector with decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 18:08
S81	44	decod\$3 with (enough insufficient inadequate deficient) near5 (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 18:17
S82	140	(aggregat\$3 collect\$3 combin\$3) with (code code near3 vector) same decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 21:32
S83	43	(combin\$3) with (code code near3 vector) same decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 21:32
S84	46	(combin\$3) with (code\$2 code near3 vector) same decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 21:33
S85	299089	(aggregat\$3 collect\$3 combin\$3) with channel decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 21:39

S86	76	(aggregat\$3 collect\$3 combin\$3) with channel same decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 21:40
S87	128	(aggregat\$3 collect\$3 combin\$3 assembl\$3) with (vector channel) same decod\$3 with (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 22:17
S88	52	S87 not S86	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 22:17
S89	2336	(aggregat\$3 collect\$3 combin\$3 assembl\$3) with (vector channel) with destination	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 22:29
S90	71	(aggregat\$3 collect\$3 combin\$3 assembl\$3) with (vector channel) with destination same (rank dimension)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 22:30
S91	3	"14168466"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 22:40
S92	3	"14967633"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 22:47
S93	2	"20160006594"	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/08 22:47
S94	395	(aggregat\$3 collect\$3 combin\$3) with vector with rank	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 00:10
S95	47	(aggregat\$3 collect\$3 combin\$3) with vector with rank with receiv\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 00:10
S97	62	(aggregat\$3 collect\$3 combin\$3 assembl\$3 build\$5) same (enough insufficient inadequate deficient lower) near\$5 (rank dimension) same decod\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:26
S98	76	(aggregat\$3 collect\$3 combin\$3 assembl\$3 build\$5) same (enough insufficient inadequate deficient lower) near\$5 (rank dimension) same decod\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:26

S99	82	(aggregat\$3 collect\$3 combin\$3 assembl\$3 build\$5) same (enough insufficient inadequate deficient lower less) near5 (rank dimension) same decod\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:26
S100	95	(aggregat\$3 collect\$3 combin\$3 assembl\$3 build\$5) same (enough insufficient inadequate deficient lower low less) near5 (rank dimension) same decod\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:26
S101	63	S100 not S96	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:26
S102	65	(aggregat\$3 collect\$3 combin\$3 assembl\$3 build\$5) same (enough insufficient inadequate deficient lower low less) with rank same decod\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:38
S103	5	S102 not S100	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:39
S104	3	"14168466" and decod\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:40
S105	751	(decod\$3 demultiplex\$3) same (enough insufficient inadequate deficient lower low less) with rank	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:43
S106	409	(decod\$3 demultiplex\$3) with (enough insufficient inadequate deficient lower low less) with rank	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:43
S107	393	(decod\$3) with (enough insufficient inadequate deficient lower low less) with rank	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:43
S108	379	S107 and (@ad<"20140130" @rlad<"20140130" @ptad<"20140130")	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 10:44
S109	2383	(destination target) near5 (node client) with user with select\$5	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:29
S111	4944	user with select\$5 with (combin\$5 aggregat\$3 collect\$3 build\$3 assembl\$3) with (code vector)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:32

S112	2620	user with select\$5 with (combin\$5 aggregat\$3 collect\$3 build\$3 assembl\$3) near8 (code vector)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:32
S113	1838	user with select\$5 with (combin\$5 aggregat\$3 build\$3) near8 (code vector)	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:33
S115	53	(select\$5 choos\$3 determin\$3 pick\$3) with (client target destination) with (combin\$5 aggregat\$3 build\$3) with code with vector	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:37
S116	1018	(select\$5 choos\$3 determin\$3 pick\$3) with (client target destination) with (combin\$5 aggregat\$3 build\$3) with vector	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:37
S117	1424	(select\$5 choos\$3 determin\$3 pick\$3) with (combin\$5 aggregat\$3 build\$3) with (code packet) with vector	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:43
S118	1370	(select\$5 choos\$3 determin\$3 pick\$3) with (combin\$5 aggregat\$3) with (code packet) with vector	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:43
S120	62	(select\$5 choos\$3 determin\$3 pick\$3) with (client target destination) with (combin\$5 aggregat\$3 build\$3) with (packet code) with vector	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:47
S121	90	(select\$5 choos\$3 determin\$3 pick\$3) with (client target destination) same (combin\$5 aggregat\$3 build\$3) with (packet code) with vector	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:47
S122	86	S121 not S119	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:47
S123	98	(select\$5 choos\$3 determin\$3 pick\$3) with (receiver receiving) same (combin\$5 aggregat\$3 build\$3) with (packet code) with vector	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 17:55
S124	1	(US-20140348253-\$).did.	US-PGPUB	OR	ON	2017/02/09 18:06
S125	1	(US-20140348253-\$).did.	US-PGPUB	OR	ON	2017/02/09 18:06
S126	1	S125 and rank	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 18:06

S127	25	(US-20020181509-\$ or US-20020127978-\$ or US-20140380133-\$ or US-20110110290-\$ or US-20140169409-\$ or US-20150103753-\$ or US-20130301747-\$ or US-20060159194-\$ or US-20140086351-\$ or US-20080192717-\$ or US-20110305284-\$ or US-20140169490-\$ or US-20150271004-\$ or US-20150131751-\$ or US-20140348253-\$ or US-20140376366-\$ or US-20140140189-\$ or US-20120113816-\$ or US-20140064392-\$).did. or (US-8780830-\$ or US-8396153-\$ or US-8223874-\$ or US-8121209-\$).did. or (US-20140146924-\$ or WO-2012114148-\$).did.	US-PGPUB; USPAT; DERWENT	OR	ON	2017/02/09 19:40
S128	6	S127 and (ack acknowledgement) same decod\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 19:40
S129	3	S127 and code\$2 and window	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 19:52
S131	73	decod\$3 same block near3 code\$2 and sliding near3 window near3 code\$2	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 19:54
S132	66	decod\$3 with block near3 code\$2 and sliding near3 window near3 code\$2	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/09 19:54
S133	28	(US-20020181509-\$ or US-20020127978-\$ or US-20140380133-\$ or US-20110110290-\$ or US-20140169409-\$ or US-20150103753-\$ or US-20130301747-\$ or US-20060159194-\$ or US-20140086351-\$ or US-20080192717-\$ or US-20110305284-\$ or US-20140169490-\$ or US-20150271004-\$ or US-20150131751-\$ or US-20140348253-\$ or US-20140376366-\$ or US-20140140189-\$ or US-20120113816-\$ or US-20140064392-\$ or US-20140281789-\$ or US-20120057660-\$ or US-20040205446-\$).did. or (US-8780830-\$ or US-8396153-\$ or US-8223874-\$ or US-8121209-\$).did. or (US-20140146924-\$ or WO-2012114148-\$).did.	US-PGPUB; USPAT; DERWENT	OR	ON	2017/02/10 16:15
S134	11	S133 and adjust\$3	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/10 16:15
S135	12	S133 and adjust\$4	US-PGPUB;	OR	ON	2017/02/10

EAST Search History

			USPAT; EPO; JPO; DERWENT; IBM_TDB			16:17
S136	18	S133 and adapt\$6	US-PGPUB; USPAT; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2017/02/10 16:26

EAST Search History (Interference)

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2/ 15/ 2017 3:18:02 PM

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Search Notes 	Application/Control No. 14168466	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.
	Examiner KEVIN LEE	Art Unit 2475

CPC- SEARCHED		
Symbol	Date	Examiner
H04L 1/0681	6/25/2016	KL
ABOVE UPDATED	2/15/2017	KL

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES		
Search Notes	Date	Examiner
Inventor name search for double patenting	6/25/2016	KL
EAST search (see search history printout)	6/25/2016 (2/15/2017)	KL (KL)

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appn. Number: 14/168,466

Filing Date: 01/30/2014

Inventor: Shattil

Title: "Cooperative Subspace Demultiplexing in Content Delivery Networks"

Examiner: Lee, Kevin H

G.A.U.: 2475

Atty. Docket No. CSC-002

AMENDMENT

Boulder, CO 80308

October 10, 2016

Commissioner of Patents

PO Box 1450

Alexandria, Virginia 22313-1450

Dear Sir:

This letter is responsive to the Office Letter mailed on 07/14/2016.

The listing of the claims begins on page 2 of this paper. Remarks begin on page 6 of this paper.

Claims – Amendments

1. (Original) A processing method for retrieving data in a content delivery network, comprising:
 - selecting a plurality of receiving nodes to cooperatively receive a plurality of linearly independent coded components and a plurality of corresponding code vectors, wherein a rank of at least one of the receiving nodes is insufficient for decoding the coded components;
 - building up a dimension of a subspace spanned by collected code vectors by collecting the coded components and the corresponding code vectors from the plurality of receiving nodes; and
 - decoding the coded components.
2. (Original) The processing method recited in Claim 1, wherein building up comprises, in response to a user input, selecting a destination node from a plurality of user-selectable client devices, and combining the coded components and the corresponding code vectors at the destination node.
3. (Original) The processing method recited in Claim 1, wherein at least one of selecting and building comprises at least one of ensuring that a code matrix generated from the corresponding code vectors has sufficient rank to enable decoding, and ensuring the code matrix is sufficiently well-conditioned to permit decoding.
4. (Original) The processing method recited in Claim 1, further comprising transmitting at least one acknowledgement to at least one source node upon at least one of receiving a coded component and decoding the coded components.
5. (Original) The processing method recited in Claim 1, wherein decoding is configured for decoding at least one of a set of coded components, the set comprising block coded components and sliding window coded components.
6. (Original) A non-transitory computer-readable medium storing a computer program configured for implementing the method of Claim 1.

7. (Original) A method for processing data in a content delivery network, comprising:
 - determining a required number of degrees of freedom for decoding a set of linearly coded packets;
 - based on the required number of degrees of freedom, selecting at least one additional receiving node for cooperatively receiving at least one coded packet and associated code vector;
 - collecting a plurality of coded packets and associated code vectors from a plurality of cooperating receiving nodes, including the at least one additional receiving node, to provide the required number of degrees of freedom; and
 - decoding the plurality of coded packets.
8. (Currently Amended) The processing method recited in Claim 7, wherein the plurality of receiving nodes comprises a [[the]] destination node and at least one user-selectable client device, and wherein collecting comprises, in response to a user input, selecting one of the at least one user-selectable client device as a new destination node and combining the plurality of coded packets and associated code vectors at the new destination node to enable the new destination node to decode the plurality of coded packets.
9. (Original) The method recited in Claim 7, wherein at least one of selecting and collecting comprises ensuring that a code matrix produced from the associated code vectors is sufficiently well-conditioned to permit decoding.
10. (Original) The method recited in Claim 7, further comprising transmitting at least one acknowledgement to at least one source node upon at least one of collecting a coded packet and decoding the coded packets.
11. (Original) The method recited in Claim 7, wherein decoding is configured to employ at least one of block codes and sliding window codes.

12. (Original) A non-transitory computer-readable medium storing a computer program configured for implementing the method of Claim 7.
13. (Original) A method for receiving data in a content delivery network, comprising:
- connecting to a first network channel and at least a second network channel to simultaneously receive a plurality of linearly coded packets and corresponding code vectors transmitted from a source node;
 - receiving a first subset of the plurality of linearly coded packets and corresponding code vectors on the first network channel and receiving a second subset of the plurality of linearly coded packets and corresponding code vectors on the at least second network channel, wherein at least one of the first subset and the second subset has a rank that is insufficient for decoding the plurality of linearly coded packets, and wherein a sum of ranks of the first subset and the second subset is sufficient for decoding the plurality of linearly coded packets;
 - combining the first subset with the second subset; and
 - decoding the plurality of linearly coded packets.
14. (Currently Amended) The ~~processing~~ method recited in Claim 13, wherein receiving comprises, in response to a user input, selecting a destination node from a plurality of user-selectable client devices, and wherein combining comprises combining the first subset and the second subset at the destination node.
15. (Original) The method recited in Claim 13, wherein the first network channel resides on a first network and the at least second network channel resides on a second network, the second network different than the first network.
16. (Currently Amended) The method recited in Claim 13, further comprising monitoring at least one real-time property of the first network channel and the at least second network channel; and instructing the source node to adjust at least one of coding and transmitting the plurality of linearly coded packets and corresponding code vectors.

17. (Original) The method recited in Claim 13, wherein receiving the first subset and receiving the second subset comprises ensuring that a code matrix produced from the corresponding code vectors is sufficiently well-conditioned to permit decoding.
18. (Original) The method recited in Claim 13, further comprising transmitting at least one acknowledgement to the source node upon at least one of collecting a linearly coded packet and decoding the plurality of linearly coded packets.
19. (Original) The method recited in Claim 13, wherein decoding comprises decoding at least one of a set of coded packets, the set comprising block coded packets and sliding window coded packets.
20. (Original) A non-transitory computer-readable medium storing a computer program implementing the method of Claim 13.

Remarks – Claims

Claims 1-20 are pending.

Claims 8, 14, and 16 were amended to correct deficiencies noted by the Office. The amendment to the claims consists of only minor editorial changes. No new matter was added.

Remarks – Examination Report

Applicant has carefully reviewed the office action mailed on 07/14/2016. Applicant thanks the Examiner for the careful consideration given to this application. Reconsideration and allowance of the present application is now respectfully requested in view of the following remarks.

1. Claim Rejections - 35 U.S.C. 112

Claims 8, 14, and 16 were rejected under 35 U.S.C. 112.

Claim 8 was amended to correct the insufficient antecedent basis noted by the Office. Specifically, the term “—the destination node—” was rewritten as “—a destination node—”.

Claim 14 was amended to correct the insufficient antecedent basis noted by the Office. Specifically, “—the processing method—” was rewritten as “—the method—”.

Claim 16 was amended to correct the insufficient antecedent basis noted by the Office. Specifically, the term “—the source—” was rewritten as “—the source node—”.

Accordingly, Applicant respectfully requests reconsideration of the 35 U.S.C. 112 rejection of claims 8, 14, and 16.

2. Allowable Subject Matter

Claims 1-7, 9-13, 15, and 17-20 were allowed over the prior art.

3. Conclusion

The Applicant has endeavored to address all of the examiner's concerns as expressed in the outstanding Office Action. Accordingly, arguments in support of the patentability of the pending claims are presented above. In light of the above remarks and amendment, reconsideration and withdrawal of the outstanding rejections is specifically requested.

If the Examiner finds any remaining impediments to the prompt allowance of these claims that could be clarified with a telephone call, the Examiner is respectfully requested to initiate the same with the undersigned.

Respectfully submitted,

/Steven J Shattil/

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TRANSMITTAL FORM <i>(to be used for all correspondence after initial filing)</i>	Application Number	14/168,466	
	Filing Date	01/30/2004	
	First Named Inventor	Shattil, Steve J	
	Art Unit	2475	
	Examiner Name	Lee, Kevin H	
Total Number of Pages in This Submission	9	Attorney Docket Number	CSC-002

ENCLOSURES <i>(Check all that apply)</i>		
☐ Fee Transmittal Form ☐ Fee Attached ☒ Amendment/Reply ☐ After Final ☐ Affidavits/declaration(s) ☐ Extension of Time Request ☐ Express Abandonment Request ☐ Information Disclosure Statement ☐ Certified Copy of Priority Document(s) ☐ Reply to Missing Parts/ Incomplete Application ☐ Reply to Missing Parts under 37 CFR 1.52 or 1.53	☐ Drawing(s) ☐ Licensing-related Papers ☐ Petition ☐ Petition to Convert to a Provisional Application ☐ Power of Attorney, Revocation Change of Correspondence Address ☐ Terminal Disclaimer ☐ Request for Refund ☐ CD, Number of CD(s) _____ ☐ Landscape Table on CD	☐ After Allowance Communication to TC ☐ Appeal Communication to Board of Appeals and Interferences ☐ Appeal Communication to TC (Appeal Notice, Brief, Reply Brief) ☐ Proprietary Information ☐ Status Letter ☐ Other Enclosure(s) (please identify below):
Remarks This letter is responsive to the Office Letter mailed on 07/14/2016.		

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT			
Firm Name			
Signature	/Steven J Shattil/		
Printed name	Steven J Shattil		
Date	10/10/2016	Reg. No.	40170

CERTIFICATE OF TRANSMISSION/MAILING			
I hereby certify that this correspondence is being facsimile transmitted to the USPTO or deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450 on the date shown below:			
Signature	/Steven J Shattil/		
Typed or printed name	Steven J Shattil	Date	10/10/2016

This collection of information is required by 37 CFR 1.5. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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Privacy Act Statement

The **Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (*i.e.*, GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Acknowledgement Receipt	
EFS ID:	27167432
Application Number:	14168466
International Application Number:	
Confirmation Number:	3872
Title of Invention:	Cooperative Subspace Demultiplexing in Content Delivery Networks
First Named Inventor/Applicant Name:	Steve J. Shattil
Customer Number:	74284
Filer:	Steven J Shattil
Filer Authorized By:	
Attorney Docket Number:	CSC-002
Receipt Date:	10-OCT-2016
Filing Date:	30-JAN-2014
Time Stamp:	15:37:16
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Amendment/Req. Reconsideration-After Non-Final Reject	CSC_002_OA_1_response.pdf	142165 227555e884ffd4642dca87f6b5ff0e6ccd8d491d	no	8
Warnings:					

Information:					
2	Transmittal Letter	sb0021.pdf	294647	no	2
			e64b62a9ba9aa9b78bcbf418ab96594e6ea3a662b		
Warnings:					
Information:					
Total Files Size (in bytes):				436812	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.					

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 14/168,466		Filing Date 01/30/2014		☐ To be Mailed	
ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO									
APPLICATION AS FILED – PART I									
(Column 1)		(Column 2)							
FOR		NUMBER FILED		NUMBER EXTRA		RATE (\$)		FEE (\$)	
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))		N/A		N/A		N/A			
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))		N/A		N/A		N/A			
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))		N/A		N/A		N/A			
TOTAL CLAIMS (37 CFR 1.16(i))		minus 20 =		*		X \$ =			
INDEPENDENT CLAIMS (37 CFR 1.16(h))		minus 3 =		*		X \$ =			
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))		If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).							
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))									
* If the difference in column 1 is less than zero, enter "0" in column 2.						TOTAL			
APPLICATION AS AMENDED – PART II									
(Column 1)		(Column 2)		(Column 3)					
AMENDMENT	10/10/2016	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)		ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X \$40 =		0	
	Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 0	X \$210 =		0	
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
						TOTAL ADD'L FEE		0	
(Column 1)		(Column 2)		(Column 3)					
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)		ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =			
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =			
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
						TOTAL ADD'L FEE			
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.									

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
14/168,466	01/30/2014	Steve J. Shattil	CSC-002	3872
74284	7590	07/14/2016	EXAMINER	
Steven J Shattil P.O. Box 17355 Boulder, CO 80308-0355			LEE, KEVIN H	
			ART UNIT	PAPER NUMBER
			2475	
			MAIL DATE	DELIVERY MODE
			07/14/2016	PAPER

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Office Action Summary	Application No. 14/168,466	Applicant(s) SHATTIL, STEVE J.	
	Examiner KEVIN LEE	Art Unit 2475	AIA (First Inventor to File) Status Yes

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1) ☒ Responsive to communication(s) filed on 1/30/2014.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on ____.

2a) ☐ This action is **FINAL**. 2b) ☒ This action is non-final.

3) ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on ____; the restriction requirement and election have been incorporated into this action.

4) ☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5) ☒ Claim(s) 1-20 is/are pending in the application.
5a) Of the above claim(s) ____ is/are withdrawn from consideration.

6) ☐ Claim(s) 8, 14 and 16 is/are allowed.

7) ☒ Claim(s) 1-7, 9-13, 15 and 17-20 is/are rejected.

8) ☐ Claim(s) ____ is/are objected to.

9) ☐ Claim(s) ____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10) ☐ The specification is objected to by the Examiner.

11) ☒ The drawing(s) filed on 1/30/2014 is/are: a) ☒ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a) ☐ All b) ☐ Some** c) ☐ None of the:

1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. ____.
3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☐ Notice of References Cited (PTO-892)

2) ☒ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b)
Paper No(s)/Mail Date 9/4/2015, 4/29/2014.

3) ☐ Interview Summary (PTO-413)
Paper No(s)/Mail Date. ____.

4) ☐ Other: ____.

The present application, filed on or after March 16, 2013, is being examined under the first inventor to file provisions of the AIA.

DETAILED ACTION

Claim Rejections - 35 USC § 112

1. The following is a quotation of 35 U.S.C. 112(b):
(b) CONCLUSION.—The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the inventor or a joint inventor regards as the invention.

The following is a quotation of 35 U.S.C. 112 (pre-AIA), second paragraph:
The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

2. **Claim 8** recites the limitation "the destination node" in line 2. There is insufficient antecedent basis for this limitation in the claim.
3. **Claim 14** recites the limitation "the processing method" in line 1. There is insufficient antecedent basis for this limitation in the claim.
4. **Claim 16** recites the limitation "the source" in line 3. There is insufficient antecedent basis for this limitation in the claim.

Allowable Subject Matter

5. Claims 1-7, 9-13, 15, and 17-20 allowed over prior art.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to KEVIN LEE whose telephone number is (571)270-5651. The examiner can normally be reached on Monday-Friday, 9:30AM-5:00PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Dang Ton can be reached on (571)272-3171. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/K. L./
Examiner, Art Unit 2475

KEVIN LEE
Examiner
Art Unit 2475

/DANG TON/
Supervisory Patent Examiner, Art Unit 2475/D. T./
Supervisory Patent Examiner, Art Unit 2475

Application/Control Number: 14/168,466
Art Unit: 2475

Page 4



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BIB DATA SHEET

CONFIRMATION NO. 3872

SERIAL NUMBER 14/168,466	FILING or 371(c) DATE 01/30/2014 RULE	CLASS 370	GROUP ART UNIT 2475	ATTORNEY DOCKET NO. CSC-002		
APPLICANTS INVENTORS Steve J. Shattil, Cheyenne, WY; ** CONTINUING DATA YES, 6/25/2016 K.L. This application is a CIP of 11/187,107 07/22/2005 PAT 8670390 which claims benefit of 60/598,187 08/02/2004 and is a CIP of 10/145,854 05/14/2002 ABN ** FOREIGN APPLICATIONS NONE ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** ** SMALL ENTITY ** 02/14/2014						
Foreign Priority claimed ☐ Yes ☒ No 35 USC 119(a-d) conditions met ☐ Yes ☒ No Verified and /KEVIN H LEE/ Acknowledged Examiner's Signature		☐ Met after Allowance Initials	STATE OR COUNTRY WY	SHEETS DRAWINGS 18	TOTAL CLAIMS 20	INDEPENDENT CLAIMS 3
ADDRESS Steven J Shattil P.O. Box 17355 Boulder, CO 80308-0355 UNITED STATES						
TITLE Cooperative Subspace Demultiplexing in Content Delivery Networks						
FILING FEE RECEIVED 730	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:			☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit		

Search Notes 	Application/Control No. 14168466	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.
	Examiner KEVIN LEE	Art Unit 2475

CPC- SEARCHED		
Symbol	Date	Examiner
H04L 1/0681	6/25/2016	KL

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES		
Search Notes	Date	Examiner
Inventor name search for double patenting	6/25/2016	KL
EAST search (see search history printout)	6/25/2016	KL

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

--	--

Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (03-15)

Approved for use through 07/31/2016. OMB 0651-0031

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		14168466
	Filing Date		2014-01-30
	First Named Inventor	Shattil	
	Art Unit	2475	
	Examiner Name	Kevin Lee	
	Attorney Docket Number	CSC-002	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /K.L./

U.S.PATENTS						Remove
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1	5630154		1997-05-13	Bolstad et al.	
	2	5704013		1997-12-30	Watari et al.	
	3	5793759		1998-08-11	Rakib et al.	
	4	6144711		2000-11-07	Raleigh et al.	
	5	6778514		2004-08-17	Boccussi et al.	
	6	6907270		2005-06-14	Blanz	
	7	8396153		2013-03-12	Shen et al.	
	8	8780830		2014-07-15	Doppler et al.	
If you wish to add additional U.S. Patent citation information please click the Add button.						Add

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		14168466
	Filing Date		2014-01-30
	First Named Inventor	Shattil	
	Art Unit	2475	
	Examiner Name	Kevin Lee	
Attorney Docket Number		CSC-002	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /K.L./

U.S.PATENT APPLICATION PUBLICATIONS						Remove
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear
	1	20020051433		2002-05-02	Affes et al.	
	2	20020118727		2002-08-29	Kim et al.	
	3	20020118781		2002-08-29	Thomas et al.	
	4	20020127978		2002-09-12	Khatri	
	5	20030072380		2003-04-17	Huang	

If you wish to add additional U.S. Published Application citation information please click the Add button. **Add**

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Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ² j	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages,Columns,Lines where Relevant Passages or Relevant Figures Appear	T ⁵
	1							☐

If you wish to add additional Foreign Patent Document citation information please click the Add button **Add**

NON-PATENT LITERATURE DOCUMENTS				Remove
Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.		T ⁵

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		14168466
	Filing Date		2014-01-30
	First Named Inventor	Shattil	
	Art Unit	2475	
	Examiner Name	Kevin Lee	
Attorney Docket Number		CSC-002	

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	1		☐
If you wish to add additional non-patent literature document citation information please click the Add button Add			
EXAMINER SIGNATURE			
Examiner Signature	/Kevin Lee/		Date Considered 6/25/2016
*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.			
¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.			

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		14168466
	Filing Date		2014-01-30
	First Named Inventor	Shattil	
	Art Unit	2475	
	Examiner Name	Kevin Lee	
Attorney Docket Number		CSC-002	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /K.L./

CERTIFICATION STATEMENT			
Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):			
☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).			
OR			
☒ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).			
☐ See attached certification statement.			
☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.			
☐ A certification statement is not submitted herewith.			
SIGNATURE			
A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.			
Signature	/Steven J Shattil/	Date (YYYY-MM-DD)	2015-09-04
Name/Print	Steven J Shattil	Registration Number	40170
This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.			

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The information provided by you in this form will be subject to the following routine uses:

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2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
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9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		14164254
	Filing Date		2014-01-27
	First Named Inventor	Shattil	
	Art Unit	2475	
	Examiner Name	Kevin Lee	
	Attorney Docket Number	CBF-001C2	

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Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1	6996076		2006-02-07	Forbes et al.	
	2	6292473		2001-09-18	Duske et al.	
	3	6532224		2003-03-11	Dailey	
	4	7508798		2009-03-24	Tong et al.	
	5	7391804		2008-06-24	Shattil	
	6	7606137		2009-10-20	Shattil	
	7	7593449		2009-09-22	Shattil	
	8	7787514		2010-08-31	Shattil	

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	9	7283799		2007-10-16	Shattil	
	10	7406261		2008-07-29	Shattil	
	11	7010048		2006-03-07	Shattil	
	12	7317750		2008-01-08	Shattil	
	13	6686879		2004-02-03	Shattil	
	14	7286604		2007-10-23	Shattil	
	15	6211671		2001-04-03	Shattil	
	16	5955992		1999-09-21	Shattil	
	17	7976168		2006-07-11	Shattil	
	18	7418043		2008-08-26	Shattil	
	19	5943332		1999-08-24	Liu et al	

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	20	6674999		2004-01-06	Ramachandran	
	21	6233248		2001-05-15	Sautter et al	
	22	6389034		2002-05-14	Guo et al	
	23	6320897		2001-11-20	Fattouche et al	
	24	6728295		2004-04-27	Nallanathan et al	
	25	6567482		2003-05-20	Popovic	
	26	5940379		1999-08-18	Startup et al	
	27	6507319		2003-01-14	Sikina	
	28	6266702		2001-07-24	Darnell et al	
	29	7031309		2006-04-18	Startup et al	
	30	7155255		2006-12-26	Blum et al	

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	31	6704794		2004-03-09	Kejriwal et al	
	32	4550402		1985-10-29	Gable et al	
	33	6650645		2003-11-18	Scott et al	
	34	5412648		1995-05-02	Fan	
	35	7194766		2007-03-20	Noehring et al	
	36	7149211		2006-12-12	Bennett et al	
	37	6236642		2001-05-22	Shaffer et al	
	38	6980768		2005-12-27	Arend et al	
	39	6944168		2005-09-13	Paatela et al	
	40	4700341		1987-10-13	Huang	
	41	6665521		2003-12-16	Gorday et al	

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	42	6982968		2006-01-03	Barratt et al	
	43	6832251		2004-12-14	Gelvin et al	
	44	7594010		2009-09-22	Dohler et al	
	45	6243581		2001-06-05	Jawanda	
	46	7057555		2006-06-06	Lewis	
	47	6785513		2004-08-31	Sivaprakasam	
	48	6662024		2003-12-09	Walton et al	

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	1	20030026222		2003-02-06	Kotzin	
	2	20050198199		2005-09-08	Dowling	

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	3	20020034191		2002-03-21	Shattil	
	4	20030206527		2003-11-06	Yim	
	5	20030133469		2003-07-17	Brockmann et al	
	6	20050265275		2005-12-01	Howard et al	
	7	20030154262		2003-08-14	Kaiser et al	
	8	20020137472		2002-09-26	Quinn et al	
	9	20040223476		2004-11-11	Jose et al	
	10	20050286476		2005-12-29	Crosswy et al	
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	1	0237771	WO		2002-05-01	Lindoff et al.		☐
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	1	Y. TANG and M.C. VALENTI, "Coded transmit macrodiversity: Block space-time codes over distributed antennas," in Proc. IEEE Vehicular Tech. Conf (VTC), Rhodes, Greece, May 2001, pp. 1435-1438.						☐
	2	Non-Final Office Action dated 04/27/2006 from corresponding US Application Number 10/145,854 (Our Ref. No. CINET-001).						☐
	3	Non-Final Office Action dated 11/27/2006 from corresponding US Application Number 10/145,854 (Our Ref. No. CINET-001).						☐
	4	Non-Final Office Action dated 04/09/2007 from corresponding US Application Number 10/145,854 (Our Ref. No. CINET-001).						☐
	5	Non-Final Office Action dated 09/09/2008 from corresponding US Application Number 10/145,854 (Our Ref. No. CINET-001).						☐
	6	Notice of Allowance dated 02/25/2009 from corresponding US Application Number 10/145,854 (Our Ref. No. CINET-001).						☐
	7	G. Barriac, et al. Distributed Beamforming for Information Transfer in Sensor Networks, April 26-27, 2004, Berkeley, CA, ACM 1-58113-6/04/0004						☐
	8	Non-Final Office Action dated 04/08/2008 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).						☐

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	9	Final Office Action dated 02/25/2009 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	10	Non-Final Office Action dated 11/02/2009 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	11	Non-Final Office Action dated 05/25/2010 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	12	Non-Final Office Action dated 10/18/2010 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	13	Non-Final Office Action dated 03/30/2011 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	14	Non-Final Office Action dated 01/04/2012 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	15	Non-Final Office Action dated 10/04/2012 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	16	Non-Final Office Action dated 07/25/2013 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	17	Notice of Allowance dated 11/20/2013 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	18	Non-Final Office Action dated 10/14/2011 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐
	19	Final Office Action dated 02/28/2012 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐

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	20	Non-Final Office Action dated 10/05/2012 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐
	21	Non-Final Office Action dated 06/06/2013 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐
	22	Final Office Action dated 01/02/2014 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐
	23	Notice of Allowance dated 04/14/2014 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐

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CERTIFICATION STATEMENT			
Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):			
☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).			
OR			
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☐ See attached certification statement.			
☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.			
☒ A certification statement is not submitted herewith.			
SIGNATURE			
A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.			
Signature	/Steven J Shattil/	Date (YYYY-MM-DD)	2014-04-28
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EAST Search History**EAST Search History (Prior Art)**

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
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<i>Index of Claims</i> 	Application/Control No. 14168466	Applicant(s)/Patent Under Reexamination SHATTIL, STEVE J.
	Examiner KEVIN LEE	Art Unit 2475

✓	Rejected
=	Allowed

-	Cancelled
÷	Restricted

N	Non-Elected
I	Interference

A	Appeal
O	Objected

☐ Claims renumbered in the same order as presented by applicant			☐ CPA			☐ T.D.			☐ R.1.47		
CLAIM			DATE								
Final	Original	06/27/2016									
	1	=									
	2	=									
	3	=									
	4	=									
	5	=									
	6	=									
	7	=									
	8	✓									
	9	=									
	10	=									
	11	=									
	12	=									
	13	=									
	14	✓									
	15	=									
	16	✓									
	17	=									
	18	=									
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Doc description: Information Disclosure Statement (IDS) Filed

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	Filing Date		2014-01-30
	First Named Inventor	Shattil	
	Art Unit		
	Examiner Name		
	Attorney Docket Number		CSC-002

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	1	5630154		1997-05-13	Bolstad et al.	
	2	5704013		1997-12-30	Watari et al.	
	3	5793759		1998-08-11	Rakib et al.	
	4	6144711		2000-11-07	Raleigh et al.	
	5	6778514		2004-08-17	Boccussi et al.	
	6	6907270		2005-06-14	Blanz	
	7	8396153		2013-03-12	Shen et al.	
	8	8780830		2014-07-15	Doppler et al.	
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	1	20020051433		2002-05-02	Affes et al.	
	2	20020118727		2002-08-29	Kim et al.	
	3	20020118781		2002-08-29	Thomas et al.	
	4	20020127978		2002-09-12	Khatri	
	5	20030072380		2003-04-17	Huang	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		14168466
	Filing Date		2014-01-30
	First Named Inventor	Shattil	
	Art Unit		
	Examiner Name		
	Attorney Docket Number		CSC-002

	1		☐
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.			
¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.			

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		14168466
	Filing Date		2014-01-30
	First Named Inventor	Shattil	
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	Examiner Name		
	Attorney Docket Number		CSC-002

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☒ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ The fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☐ A certification statement is not submitted herewith.

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Steven J Shattil/	Date (YYYY-MM-DD)	2015-09-04
Name/Print	Steven J Shattil	Registration Number	40170

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 1 hour to complete, including gathering, preparing and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Electronic Acknowledgement Receipt	
EFS ID:	23416708
Application Number:	14168466
International Application Number:	
Confirmation Number:	3872
Title of Invention:	Cooperative Subspace Demultiplexing in Content Delivery Networks
First Named Inventor/Applicant Name:	Steve J. Shattil
Customer Number:	74284
Filer:	Steven J Shattil
Filer Authorized By:	
Attorney Docket Number:	CSC-002
Receipt Date:	04-SEP-2015
Filing Date:	30-JAN-2014
Time Stamp:	20:47:33
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	IDS_Cover_Letter_CSC_002.pdf	54879 89ddb696eb75251db10d76acc01bd17ed7d5abdb	no	2
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	updated_IDS.pdf	1035432 19d2290a7c07de579720a700c9b02b21b16877f0	no	5
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Total Files Size (in bytes):				1090311	
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Application Number: 14/168,466

Filing Date: 06/01/2015

Inventor: Shattil

Title: "Cooperative Subspace Demultiplexing in Content Delivery Networks"

Atty. Docket No. CSC-002

SUBMISSION OF SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT

Transmission Date: September 4, 2015

Commissioner of Patents

PO Box 1450

Alexandria, Virginia 22313-1450

Dear Sir:

The Applicant respectfully requests that the references in the attached PTO/SB/08A forms be considered in the examination of the above-identified application.

The Applicant reserves the right to establish that any of the references listed on the attached PTO/SB/08A form are not prior art to the above-captioned application.

No fee is believed to be due.

Respectfully submitted,

/Steven J Shattil/

Steven J. Shattil, Reg. No. 40,170

P.O. Box 17355

Boulder, CO 80308-0355

(720) 234-4351



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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
14/168,466	01/30/2014	Steve J. Shattil	CSC-002

CONFIRMATION NO. 3872

74284
Steven J Shattil
P.O. Box 17355
Boulder, CO 80308-0355

PUBLICATION NOTICE



Title:Cooperative Subspace Demultiplexing in Content Delivery Networks

Publication No.US-2014-0146924-A1

Publication Date:05/29/2014

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publicly available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently <http://www.uspto.gov/patft/>.

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	Filing Date		2014-01-27
	First Named Inventor	Shattil	
	Art Unit		
	Examiner Name		
	Attorney Docket Number		CBF-001C2

U.S.PATENTS						Remove
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear
	1	6996076		2006-02-07	Forbes et al.	
	2	6292473		2001-09-18	Duske et al.	
	3	6532224		2003-03-11	Dailey	
	4	7508798		2009-03-24	Tong et al.	
	5	7391804		2008-06-24	Shattil	
	6	7606137		2009-10-20	Shattil	
	7	7593449		2009-09-22	Shattil	
	8	7787514		2010-08-31	Shattil	

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	9	7283799		2007-10-16	Shattil	
	10	7406261		2008-07-29	Shattil	
	11	7010048		2006-03-07	Shattil	
	12	7317750		2008-01-08	Shattil	
	13	6686879		2004-02-03	Shattil	
	14	7286604		2007-10-23	Shattil	
	15	6211671		2001-04-03	Shattil	
	16	5955992		1999-09-21	Shattil	
	17	7976168		2006-07-11	Shattil	
	18	7418043		2008-08-26	Shattil	
	19	5943332		1999-08-24	Liu et al	

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	20	6674999		2004-01-06	Ramachandran	
	21	6233248		2001-05-15	Sautter et al	
	22	6389034		2002-05-14	Guo et al	
	23	6320897		2001-11-20	Fattouche et al	
	24	6728295		2004-04-27	Nallanathan et al	
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	26	5940379		1999-08-18	Startup et al	
	27	6507319		2003-01-14	Sikina	
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	29	7031309		2006-04-18	Startup et al	
	30	7155255		2006-12-26	Blum et al	

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	31	6704794		2004-03-09	Kejriwal et al	
	32	4550402		1985-10-29	Gable et al	
	33	6650645		2003-11-18	Scott et al	
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	35	7194766		2007-03-20	Noehring et al	
	36	7149211		2006-12-12	Bennett et al	
	37	6236642		2001-05-22	Shaffer et al	
	38	6980768		2005-12-27	Arend et al	
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	Attorney Docket Number		CBF-001C2	

	42	6982968		2006-01-03	Barratt et al	
	43	6832251		2004-12-14	Gelvin et al	
	44	7594010		2009-09-22	Dohler et al	
	45	6243581		2001-06-05	Jawanda	
	46	7057555		2006-06-06	Lewis	
	47	6785513		2004-08-31	Sivaprakasam	
	48	6662024		2003-12-09	Walton et al	

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	1	20030026222		2003-02-06	Kotzin	
	2	20050198199		2005-09-08	Dowling	

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	3	20020034191		2002-03-21	Shattil	
	4	20030206527		2003-11-06	Yim	
	5	20030133469		2003-07-17	Brockmann et al	
	6	20050265275		2005-12-01	Howard et al	
	7	20030154262		2003-08-14	Kaiser et al	
	8	20020137472		2002-09-26	Quinn et al	
	9	20040223476		2004-11-11	Jose et al	
	10	20050286476		2005-12-29	Crosswy et al	
	11	20020181509		2002-12-05	Mody et al	

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	1	0237771	WO		2002-05-01	Lindoff et al.		☐
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	1	Y. TANG and M.C. VALENTI, "Coded transmit macrodiversity: Block space-time codes over distributed antennas," in Proc. IEEE Vehicular Tech. Conf (VTC), Rhodes, Greece, May 2001, pp. 1435-1438.	☐	
	2	Non-Final Office Action dated 04/27/2006 from corresponding US Application Number 10/145,854 (Our Ref. No. CINET-001).	☐	
	3	Non-Final Office Action dated 11/27/2006 from corresponding US Application Number 10/145,854 (Our Ref. No. CINET-001).	☐	
	4	Non-Final Office Action dated 04/09/2007 from corresponding US Application Number 10/145,854 (Our Ref. No. CINET-001).	☐	
	5	Non-Final Office Action dated 09/09/2008 from corresponding US Application Number 10/145,854 (Our Ref. No. CINET-001).	☐	
	6	Notice of Allowance dated 02/25/2009 from corresponding US Application Number 10/145,854 (Our Ref. No. CINET-001).	☐	
	7	G. Barriac, et al. Distributed Beamforming for Information Transfer in Sensor Networks, April 26-27, 2004, Berkeley, CA, ACM 1-58113-6/04/0004	☐	
	8	Non-Final Office Action dated 04/08/2008 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐	

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	Attorney Docket Number		CBF-001C2

	9	Final Office Action dated 02/25/2009 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	10	Non-Final Office Action dated 11/02/2009 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	11	Non-Final Office Action dated 05/25/2010 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	12	Non-Final Office Action dated 10/18/2010 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	13	Non-Final Office Action dated 03/30/2011 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	14	Non-Final Office Action dated 01/04/2012 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	15	Non-Final Office Action dated 10/04/2012 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	16	Non-Final Office Action dated 07/25/2013 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	17	Notice of Allowance dated 11/20/2013 from corresponding US Application Number 11/187,107 (Our Ref. No. CBF-001).	☐
	18	Non-Final Office Action dated 10/14/2011 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐
	19	Final Office Action dated 02/28/2012 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐

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	20	Non-Final Office Action dated 10/05/2012 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐
	21	Non-Final Office Action dated 06/06/2013 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐
	22	Final Office Action dated 01/02/2014 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐
	23	Notice of Allowance dated 04/14/2014 from corresponding US Application Number 12/545,572 (Our Ref. No. CBF-002).	☐

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¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

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OR

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Signature	/Steven J Shattil/	Date (YYYY-MM-DD)	2014-04-28
Name/Print	Steven J Shattil	Registration Number	40170

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The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

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1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these records.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Acknowledgement Receipt	
EFS ID:	18890463
Application Number:	14168466
International Application Number:	
Confirmation Number:	3872
Title of Invention:	Cooperative Subspace Demultiplexing in Content Delivery Networks
First Named Inventor/Applicant Name:	Steve J. Shattil
Customer Number:	74284
Filer:	Steven J Shattil
Filer Authorized By:	
Attorney Docket Number:	CSC-002
Receipt Date:	29-APR-2014
Filing Date:	30-JAN-2014
Time Stamp:	14:41:49
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment		no			
File Listing:					
Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	IDS_Cover_Letter_CBF_001C2.pdf	68169 1ad9b896d4f8fced7539bb1c5f349f95d874a21f	no	2
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	updated_IDS_CBF_001C2.pdf	614170	no	11
			be469da793454f8820d325388f8db6885933d66		
Warnings:					
Information:					
3	Non Patent Literature	11187107_final_02_25_2009.pdf	360448	no	11
			63410c5ba2a475f41bb064c251f241d0f9edcc7c		
Warnings:					
Information:					
4	Non Patent Literature	11187107_NOA_11_20_2013.pdf	421188	no	9
			13f138e448e9b17a888d42e3cfce4d4c0f38eda3		
Warnings:					
Information:					
5	Non Patent Literature	11187107_non_final_01_04_2012.pdf	605536	no	17
			f2ff2557bbabe3ebcfe34db9b03cd4d43cc76cf60		
Warnings:					
Information:					
6	Non Patent Literature	11187107_non_final_03_30_2011.pdf	269160	no	8
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Warnings:					
Information:					
7	Non Patent Literature	11187107_non_final_04_08_2008.pdf	227459	no	7
			a5b92b4fba7bec0074126ab887dfb9a2c603bc7		
Warnings:					
Information:					
8	Non Patent Literature	11187107_non_final_05_25_2010.pdf	253256	no	7
			1dd951280722a212c3b798443dc7ae1a06f22eb5		
Warnings:					
Information:					
9	Non Patent Literature	11187107_non_final_07_25_2013.pdf	1052751	no	27
			17d3a9364e1f280a15ff98c895d4da58a8780c5		
Warnings:					
Information:					
10	Non Patent Literature	11187107_non_final_10_04_2012.pdf	476264	no	14
			364c70ae9c1982984aa643c3d19d2e183b6fc946		
Warnings:					
Information:					

11	Non Patent Literature	11187107_non_final_10_18_2010.pdf	311024 eca716591225acda092272c5423073381a93e33c	no	9
Warnings:					
Information:					
12	Non Patent Literature	11187107_non_final_11_02_2009.pdf	305099 699a7f0e6f1a467bb532a19d30394acb8e2ca520	no	10
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Information:					
13	Non Patent Literature	Cited_Ref_Tang_and_Valenti.pdf	155648 6bc7470218597c374abab1cd9c6c7364582559f2	no	4
Warnings:					
Information:					
14	Non Patent Literature	12545572_final_office_action_01_02_2014.pdf	707043 8b3c6c87b75502bc807138c56cf3ddf01ac0e53	no	21
Warnings:					
Information:					
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Warnings:					
Information:					
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Warnings:					
Information:					
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Information:					
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Warnings:					
Information:					
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Warnings:					
Information:					

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Information:					
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Information:					
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Warnings:					
Information:					
23	Non Patent Literature	10145854_non_final_rejection_11_27_2006.pdf	390968 93be6ca7ece0add229390b71a1573176f8a9c198	no	8
Warnings:					
Information:					
24	Non Patent Literature	10145854_Notice_of_Allowance.pdf	246194 f10181550fa105a43866dd9b22665dfa8072e3dd	no	4
Warnings:					
Information:					
25	Non Patent Literature	Barriac.pdf	179784 ace600a5bfdded9047b886d6e033948fbaa50942a	no	8
Warnings:					
Information:					
Total Files Size (in bytes):			11710794		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Appn. Number: 18/164,254

Filing Date: January 27, 2014

Inventor: Shattil

Title: "Cooperative Subspace Demultiplexing in Communication Networks"

Examiner:

G.A.U.:

Atty. Docket No. CBF-001C2

SUBMISSION OF INFORMATION DISCLOSURE STATEMENT

Date: 04/28/2014

Commissioner of Patents

PO Box 1450

Alexandria, Virginia 22313-1450

Dear Sir:

The Applicant respectfully requests that the references in the attached PTO/SB/08A forms be considered in the examination of the above-identified application. The non-patent references indicated on PTO/SB/08A are included with this correspondence.

The Applicant reserves the right to establish that any of the references listed on the attached PTO/SB/08A form are not prior art to the above-captioned application.

The Examiner is advised that the following co-pending applications contain subject matter that may be related to the present application. By bringing these applications to the Examiner's attention, Applicant does not waive the confidentiality provisions of 35 U.S.C. 122.

Application Number: 14/164,253

Filing Date: January 26, 2014

Application Number: 14/168,442

Filing Date: January 30, 2014

Application Number: 14/168,466

Filing Date: January 30, 2014

No fee is believed to be due.

Respectfully submitted,

/Steven J Shattil/

Steve J. Shattil, Reg. No. 40,170

P.O. Box 17355

Boulder, CO 80308-0355

(720) 234-4351

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875						Application or Docket Number 14/168,466			
APPLICATION AS FILED - PART I									
(Column 1)		(Column 2)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY			
FOR	NUMBER FILED	NUMBER EXTRA	RATE(\$)	FEE(\$)		RATE(\$)	FEE(\$)		
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	70		N/A			
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A	300		N/A			
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	360		N/A			
TOTAL CLAIMS (37 CFR 1.16(i))	20	minus 20 = *	x 40 =	0.00	OR				
INDEPENDENT CLAIMS (37 CFR 1.16(h))	3	minus 3 = *	x 210 =	0.00					
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$310 (\$155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00					
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00					
* If the difference in column 1 is less than zero, enter "0" in column 2.				TOTAL		TOTAL			
				730					
APPLICATION AS AMENDED - PART II									
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY		OR OTHER THAN SMALL ENTITY	
AMENDMENT A	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)	ADDITIONAL FEE(\$)	
	Total (37 CFR 1.16(i))	*	Minus **	x	=	OR	x	=	
	Independent (37 CFR 1.16(h))	*	Minus ***	x	=	OR	x	=	
	Application Size Fee (37 CFR 1.16(s))					OR			
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					OR			
				TOTAL ADD'L FEE		TOTAL ADD'L FEE			
AMENDMENT B	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)		RATE(\$)	ADDITIONAL FEE(\$)	
	Total (37 CFR 1.16(i))	*	Minus **	x	=	OR	x	=	
	Independent (37 CFR 1.16(h))	*	Minus ***	x	=	OR	x	=	
	Application Size Fee (37 CFR 1.16(s))					OR			
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					OR			
				TOTAL ADD'L FEE		TOTAL ADD'L FEE			
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20". *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3". The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.									



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
14/168,466	01/30/2014	2112	730	CSC-002	20	3

CONFIRMATION NO. 3872

FILING RECEIPT



0000000066630747

74284
Steven J Shattil
P.O. Box 17355
Boulder, CO 80308-0355

Date Mailed: 02/18/2014

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Inventor(s)

Steve J. Shattil, Cheyenne, WY;

Applicant(s)

Steve J. Shattil, Cheyenne, WY;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CIP of 11/187,107 07/22/2005
which claims benefit of 60/598,187 08/02/2004
and is a CIP of 10/145,854 05/14/2002 ABN

Foreign Applications for which priority is claimed (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see <http://www.uspto.gov> for more information.) - None.

Foreign application information must be provided in an Application Data Sheet in order to constitute a claim to foreign priority. See 37 CFR 1.55 and 1.76.

Permission to Access - A proper **Authorization to Permit Access to Application by Participating Offices** (PTO/SB/39 or its equivalent) has been received by the USPTO.

If Required, Foreign Filing License Granted: 02/14/2014

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 14/168,466**

Projected Publication Date: 05/29/2014

Non-Publication Request: No

Early Publication Request: No

page 1 of 3

**** SMALL ENTITY ****

Title

Cooperative Subspace Demultiplexing in Content Delivery Networks

Preliminary Class

714

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications: Yes

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at <http://www.uspto.gov/web/offices/pac/doc/general/index.html>.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, <http://www.stopfakes.gov>. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4258).

LICENSE FOR FOREIGN FILING UNDER
Title 35, United States Code, Section 184
Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign Assets Control, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

SelectUSA

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The U.S. offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to promote and facilitate business investment. SelectUSA provides information assistance to the international investor community; serves as an ombudsman for existing and potential investors; advocates on behalf of U.S. cities, states, and regions competing for global investment; and counsels U.S. economic development organizations on investment attraction best practices. To learn more about why the United States is the best country in the world to develop technology, manufacture products, deliver services, and grow your business, visit <http://www.SelectUSA.gov> or call +1-202-482-6800.

UTILITY PATENT APPLICATION TRANSMITTAL <i>(Only for new nonprovisional applications under 37 CFR 1.53(b))</i>		Attorney Docket No. CSC-002	
		First Named Inventor Shattil	
		Title Cooperative Subspace Demultiplexing in Content Delivery Networks	
		Express Mail Label No.	

APPLICATION ELEMENTS <i>See MPEP chapter 600 concerning utility patent application contents.</i>	Commissioner for Patents P.O. Box 1450 Alexandria, VA 22313-1450										
1. ☒ Fee Transmittal Form (PTO/SB/17 or equivalent) 2. ☒ Applicant asserts small entity status. See 37 CFR 1.27 3. ☐ Applicant certifies micro entity status. See 37 CFR 1.29. Applicant must attach form PTO/SB/15A or B or equivalent. 4. ☒ Specification [Total Pages <u>85</u>] Both the claims and abstract must start on a new page. (See MPEP § 608.01(a) for information on the preferred arrangement) 5. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets <u>18</u>] 6. ☒ Inventor's Oath or Declaration [Total Pages <u>2</u>] (including substitute statements under 37 CFR 1.64 and assignments serving as an oath or declaration under 37 CFR 1.63(e)) a. ☒ Newly executed (original or copy) b. ☐ A copy from a prior application (37 CFR 1.63(d)) 7. ☒ Application Data Sheet * See note below. See 37 CFR 1.76 (PTO/AIA/14 or equivalent) 8. CD-ROM or CD-R in duplicate, large table, or Computer Program (Appendix) ☐ Landscape Table on CD 9. Nucleotide and/or Amino Acid Sequence Submission (if applicable, items a. – c. are required) a. ☐ Computer Readable Form (CRF) b. ☐ Specification Sequence Listing on: i. ☐ CD-ROM or CD-R (2 copies); or ii. ☐ Paper c. ☐ Statements verifying identity of above copies	ACCOMPANYING APPLICATION PAPERS 10. ☐ Assignment Papers (cover sheet & document(s)) Name of Assignee _____ 11. ☐ 37 CFR 3.73(c) Statement ☐ Power of Attorney (when there is an assignee) 12. ☐ English Translation Document (if applicable) 13. ☐ Information Disclosure Statement (PTO/SB/08 or PTO-1449) ☐ Copies of citations attached 14. ☐ Preliminary Amendment 15. ☐ Return Receipt Postcard (MPEP § 503) (Should be specifically itemized) 16. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed) 17. ☐ Nonpublication Request Under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent. 18. ☐ Other: _____ _____ _____ _____										
*Note: (1) Benefit claims under 37 CFR 1.78 and foreign priority claims under 1.55 must be included in an Application Data Sheet (ADS). (2) For applications filed under 35 U.S.C. 111, the application must contain an ADS specifying the applicant if the applicant is an assignee, person to whom the inventor is under an obligation to assign, or person who otherwise shows sufficient proprietary interest in the matter. See 37 CFR 1.46(b).											
19. CORRESPONDENCE ADDRESS											
☒ The address associated with Customer Number: <u>74284</u> OR ☐ Correspondence address below											
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td colspan="2">Name</td> </tr> <tr> <td colspan="2">Address</td> </tr> <tr> <td>City</td> <td>State</td> </tr> <tr> <td>Country</td> <td>Zip Code</td> </tr> <tr> <td>Telephone</td> <td>Email</td> </tr> </table>		Name		Address		City	State	Country	Zip Code	Telephone	Email
Name											
Address											
City	State										
Country	Zip Code										
Telephone	Email										
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <td>Signature</td> <td>/Steven J Shattil/</td> <td>Date</td> <td>01/30/2014</td> </tr> <tr> <td>Name (Print/Type)</td> <td>Steven J Shattil</td> <td>Registration No. (Attorney/Agent)</td> <td>40170</td> </tr> </table>		Signature	/Steven J Shattil/	Date	01/30/2014	Name (Print/Type)	Steven J Shattil	Registration No. (Attorney/Agent)	40170		
Signature	/Steven J Shattil/	Date	01/30/2014								
Name (Print/Type)	Steven J Shattil	Registration No. (Attorney/Agent)	40170								

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Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		Cooperative Subspace Demultiplexing in Content Delivery Networks		
First Named Inventor/Applicant Name:		Steve J Shattil		
Filer:		Steven J Shattil		
Attorney Docket Number:		CSC-002		
Filed as Small Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Utility filing Fee (Electronic filing)	4011	1	70	70
Utility Search Fee	2111	1	300	300
Utility Examination Fee	2311	1	360	360
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				730

Electronic Acknowledgement Receipt	
EFS ID:	18070909
Application Number:	14168466
International Application Number:	
Confirmation Number:	3872
Title of Invention:	Cooperative Subspace Demultiplexing in Content Delivery Networks
First Named Inventor/Applicant Name:	Steve J Shattil
Customer Number:	74284
Filer:	Steven J Shattil
Filer Authorized By:	
Attorney Docket Number:	CSC-002
Receipt Date:	30-JAN-2014
Filing Date:	
Time Stamp:	15:12:51
Application Type:	Utility under 35 USC 111(a)

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RAM confirmation Number	1500
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1	Drawings-only black and white line drawings	Drawings_CSC_001_002bw.pdf	331989 0d1a51c5dfc06d1e84c26d5cc4ba819b1ae988f8	no	18
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2		CSC_002_Spec.pdf	678250 4b61a9274491a6162aa9774004c16dfc7c4648f7	yes	91
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	Document Description		Start	End	
	Specification		1	86	
	Claims		87	90	
	Abstract		91	91	
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3	Oath or Declaration filed	aia0001ss.pdf	197511 ab9bc9bd72f118aa4e5ceae37a894c1f1269f26	no	2
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4	Application Data Sheet	aia0014.pdf	1560684 550ee0ff4115b4dad1ef377fb3a1bf8a8d75cbb3	no	7
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5	Transmittal of New Application	aia0015.pdf	309740 a4cb82245855418a53e4017e1d905c5687306bf8	no	2
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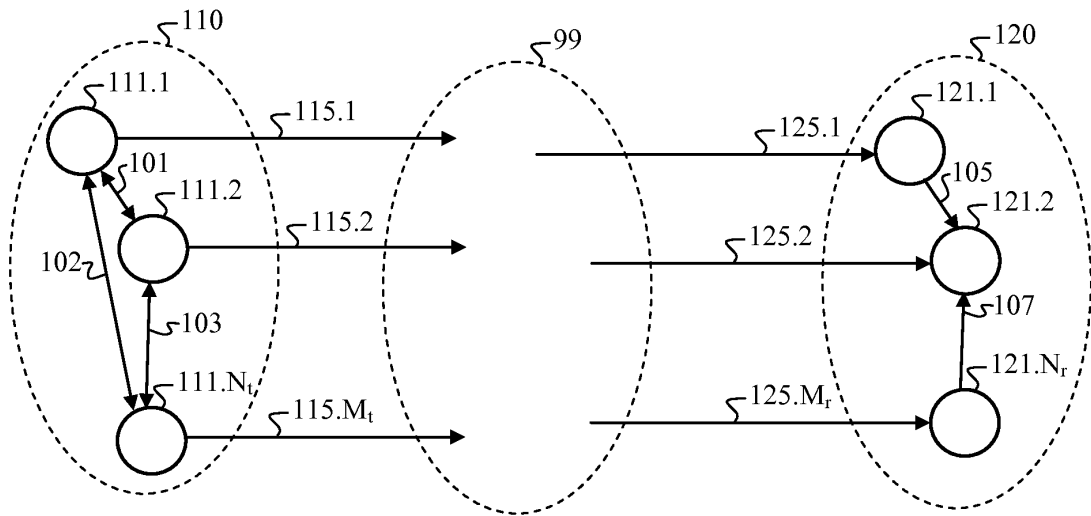


FIGURE 1

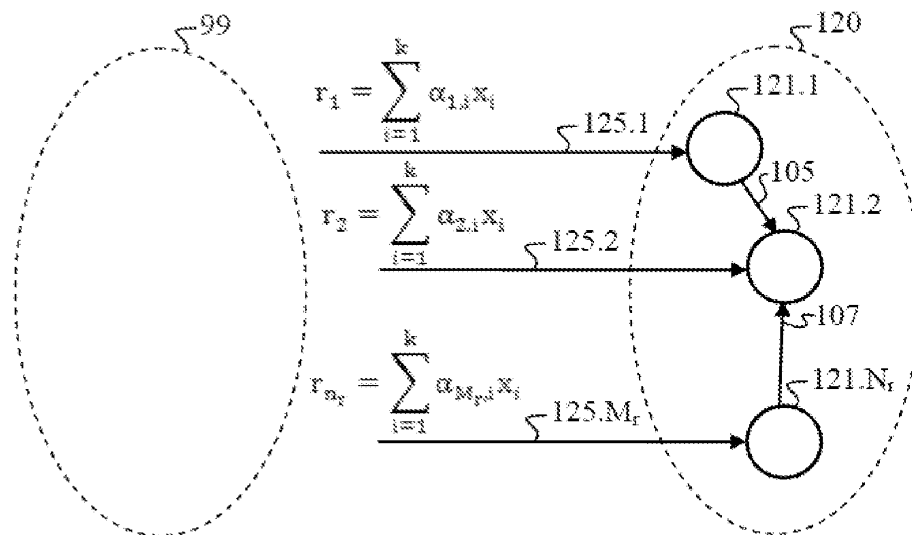


FIGURE 2

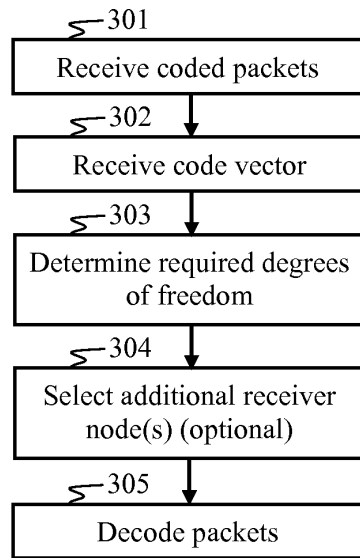


FIGURE 3

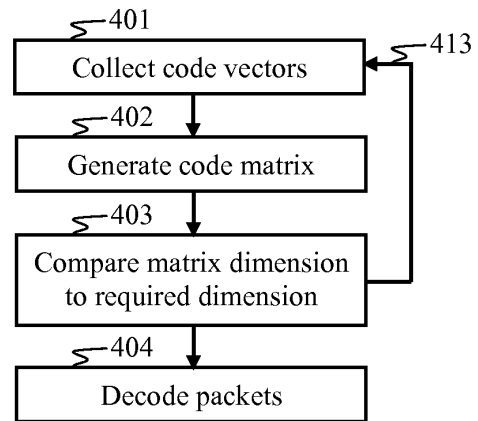
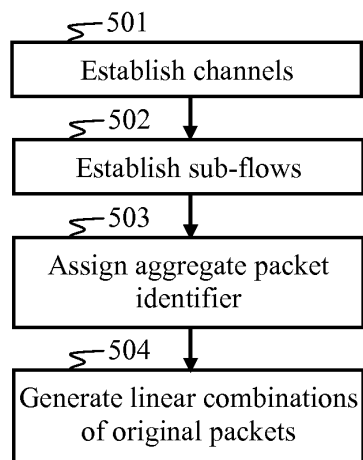
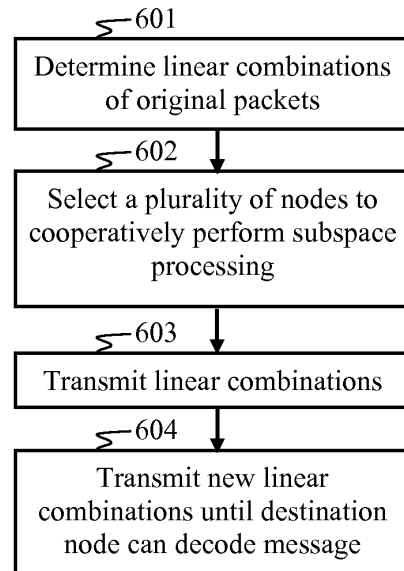


FIGURE 4

**FIGURE 5****FIGURE 6**

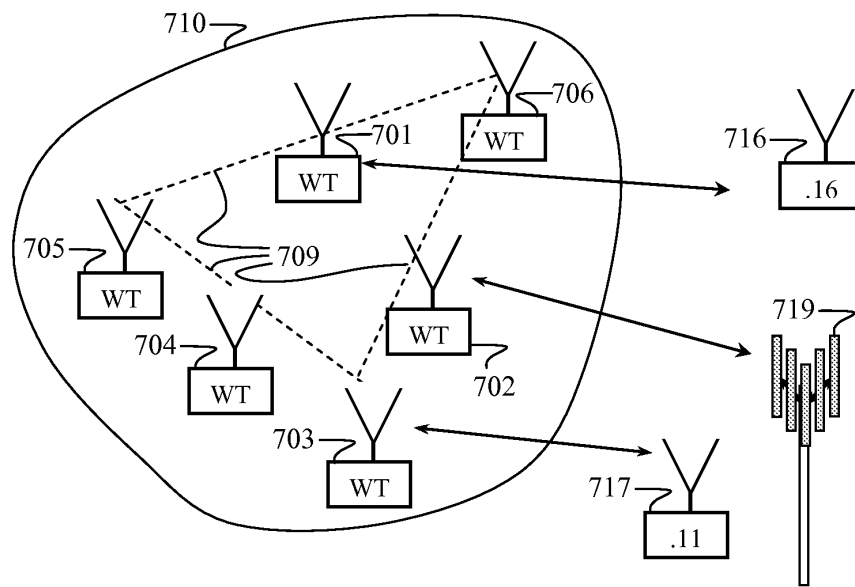


FIGURE 7

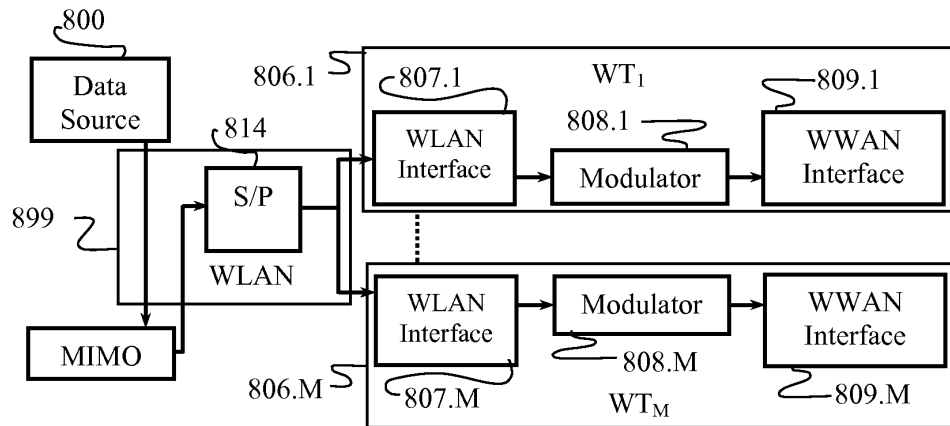
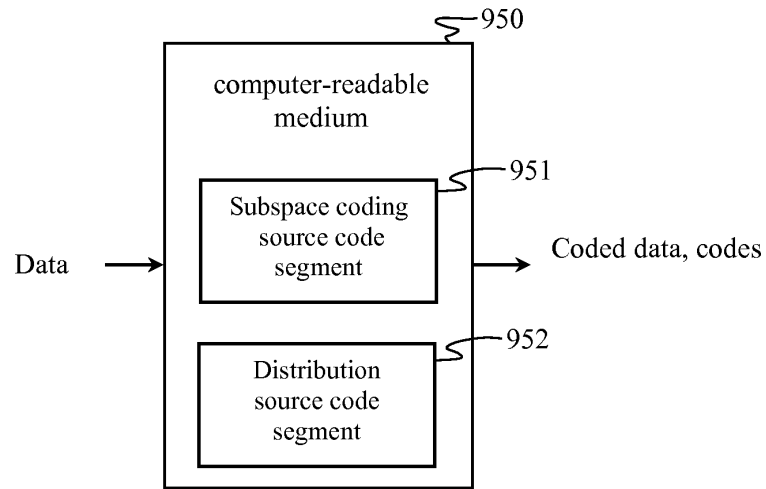
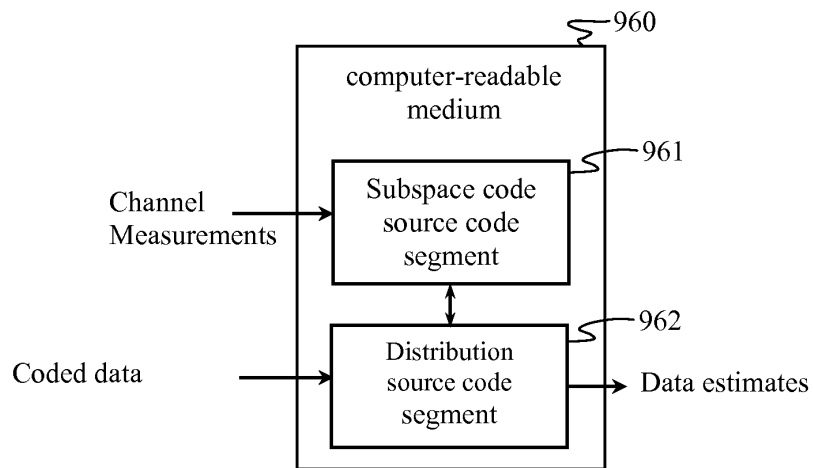


FIGURE 8

**FIGURE 9A****FIGURE 9B**

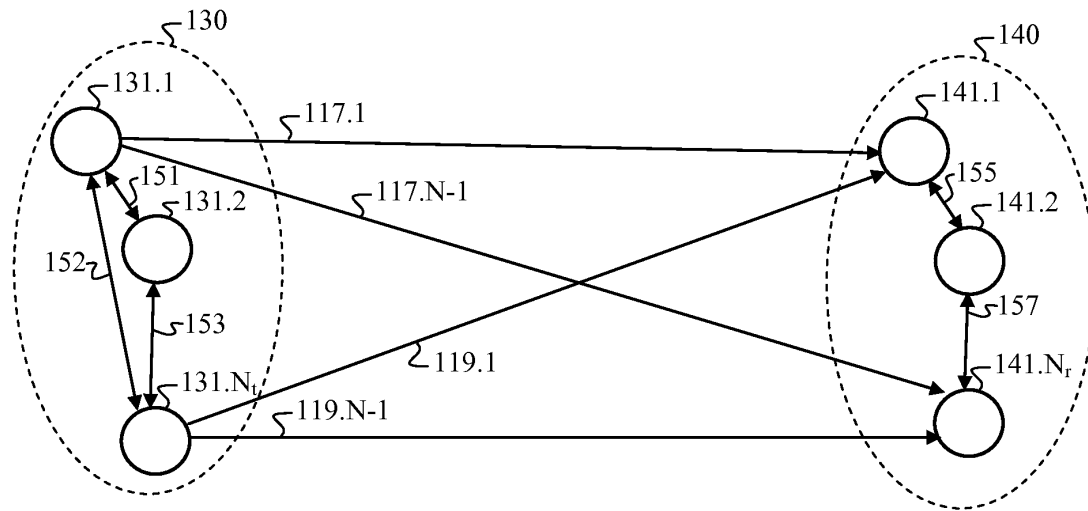


FIGURE 10

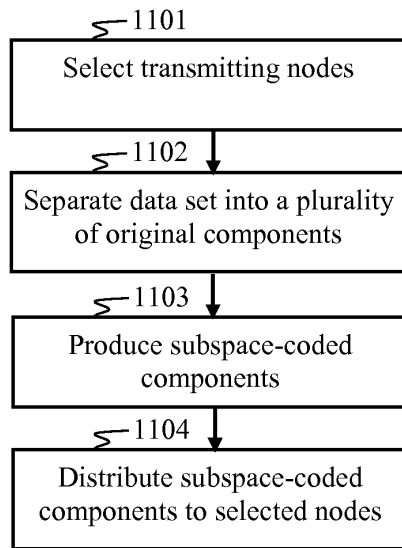


FIGURE 11A

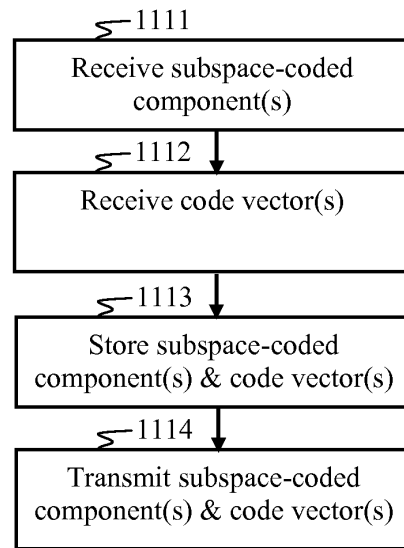


FIGURE 11B

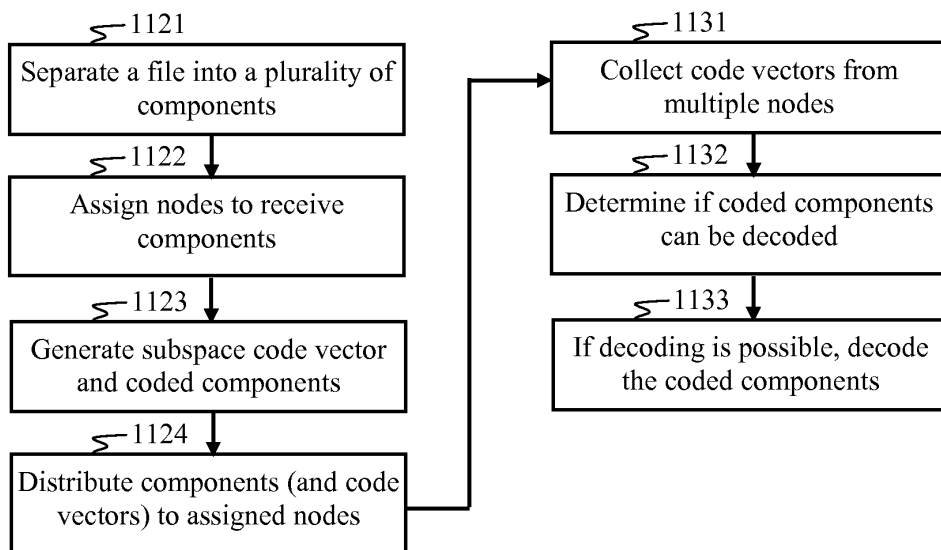
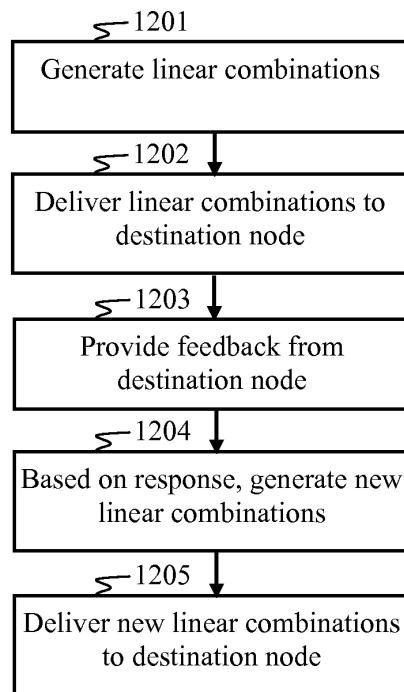
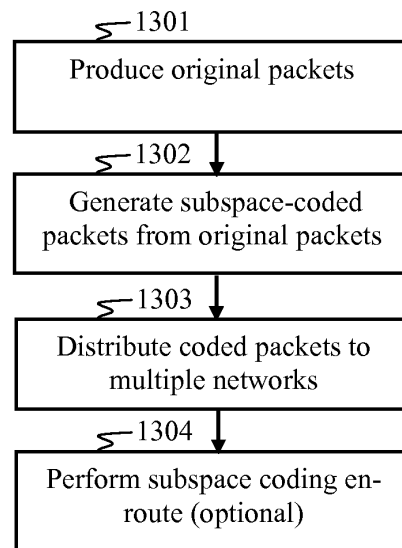
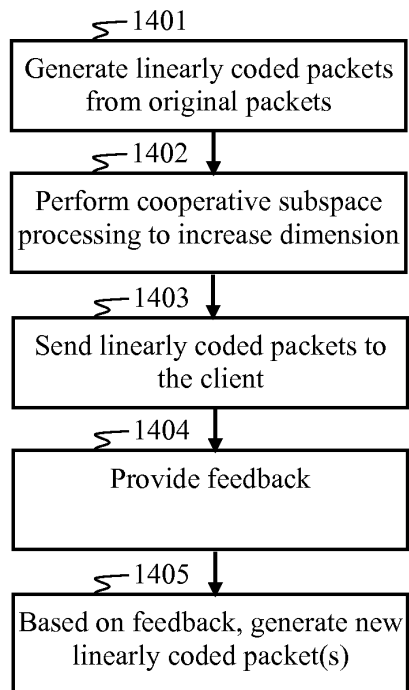


FIGURE 11C

**FIGURE 12****FIGURE 13**

**FIGURE 14**

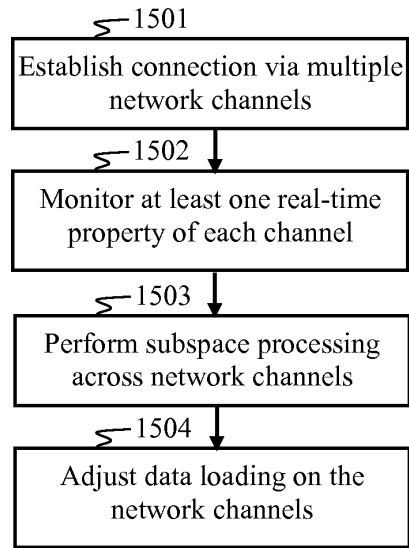


FIGURE 15A

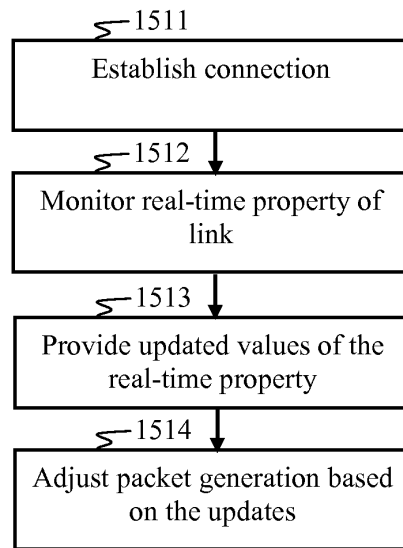
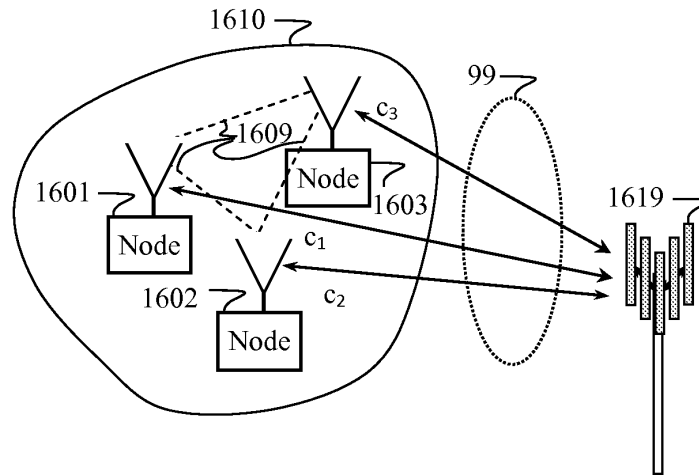
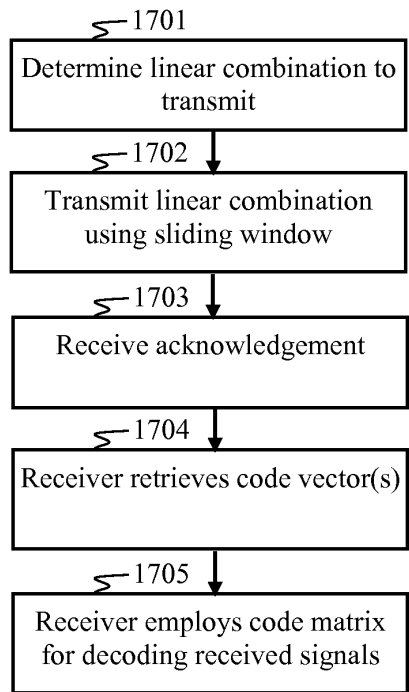
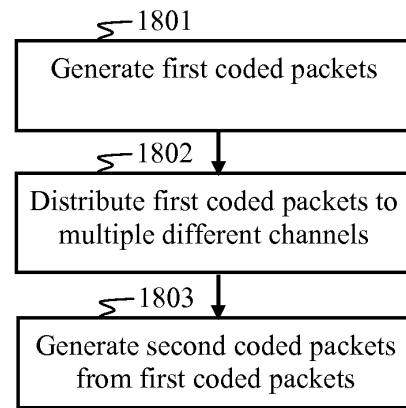


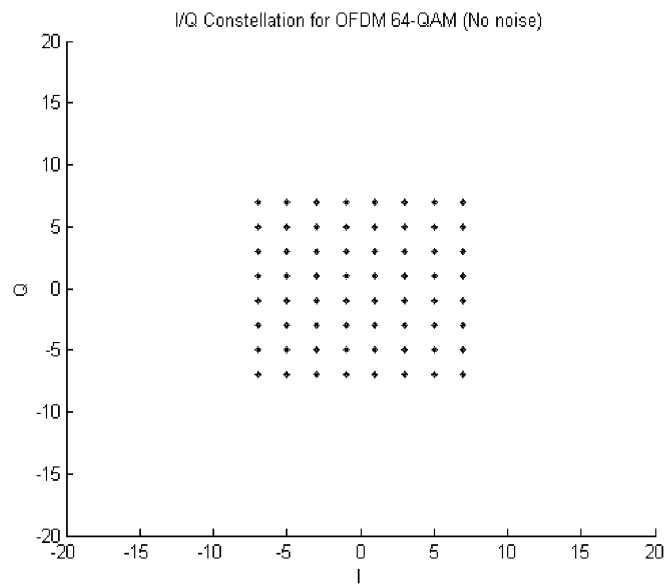
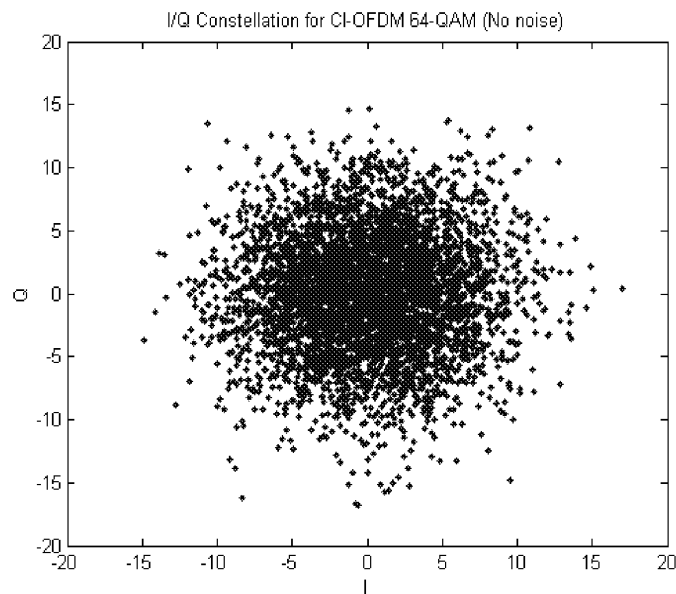
FIGURE 15B

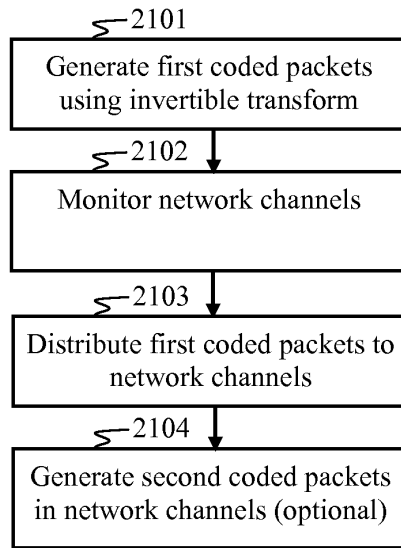
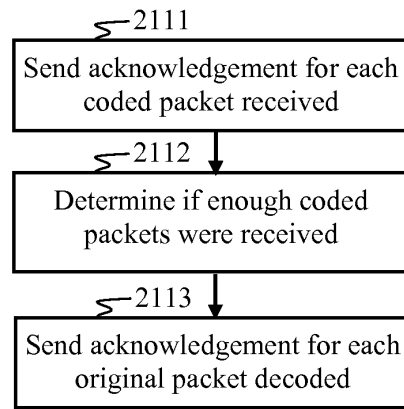
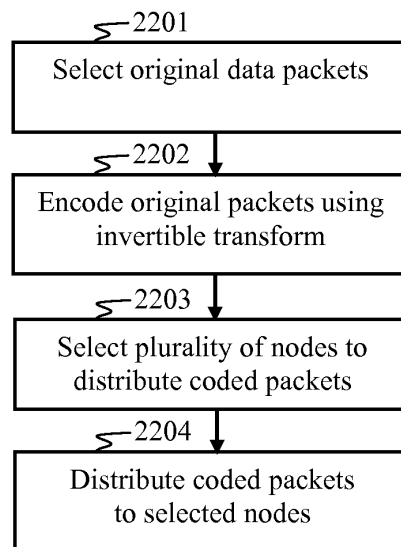
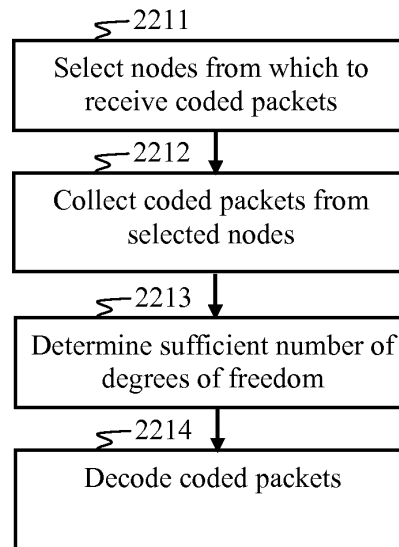
**FIGURE 16**

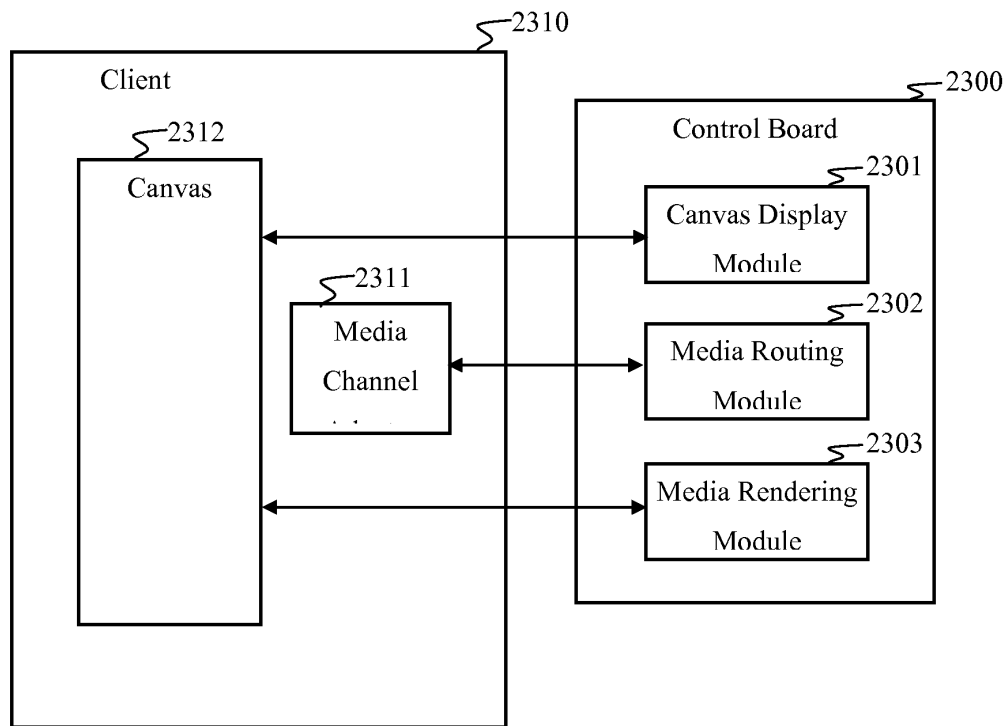
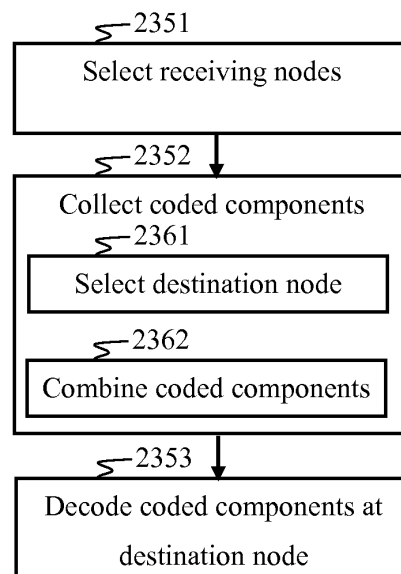
**FIGURE 17****FIGURE 18**

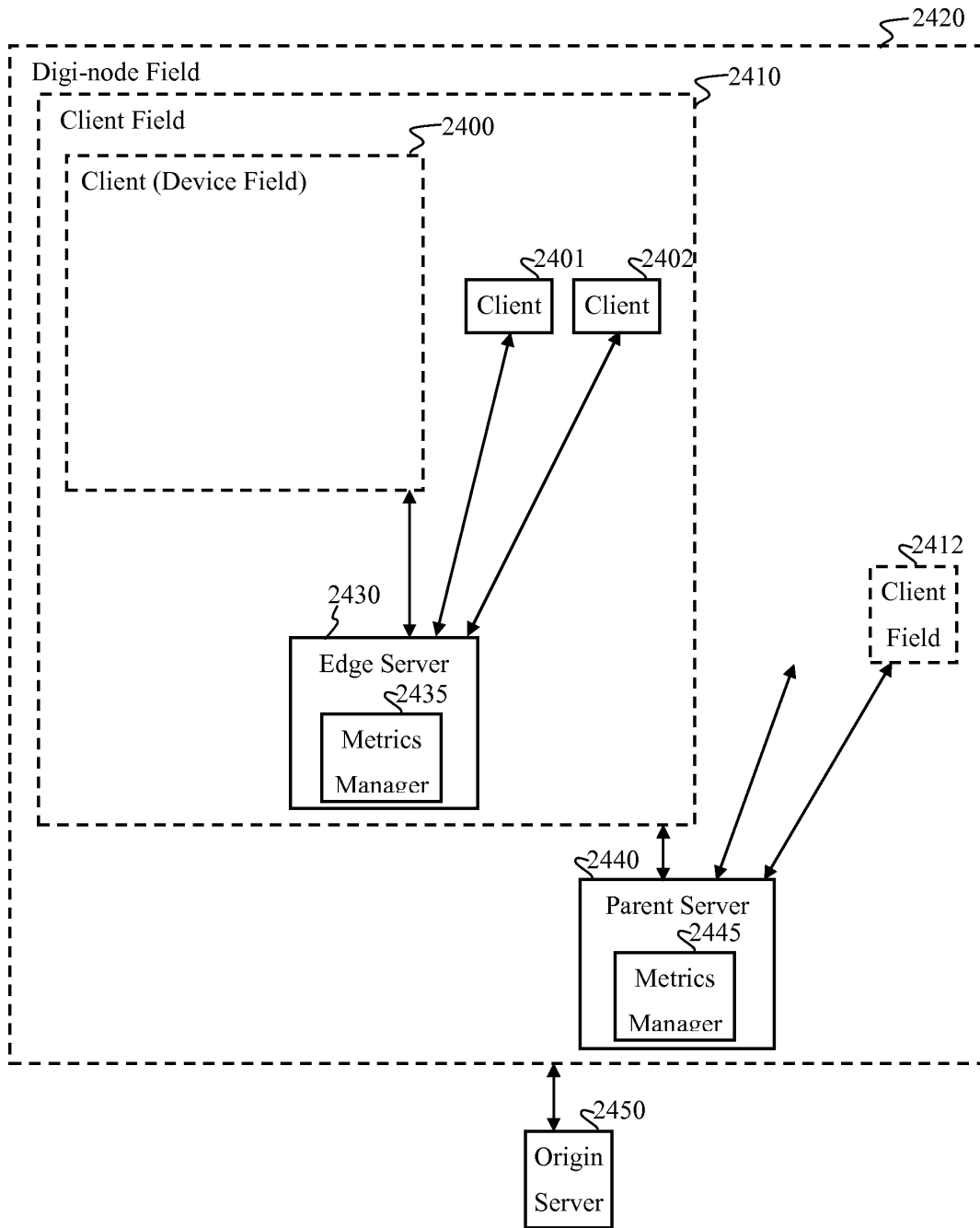
$$\begin{array}{cccc}
 e^{i2\pi(0)(0)/(N-1)} & e^{i2\pi(1)(0)/(N-1)} & \dots & e^{i2\pi(N-1)(0)/(N-1)} \\
 e^{i2\pi(0)(1)/(N-1)} & e^{i2\pi(1)(1)/(N-1)} & \dots & e^{i2\pi(N-1)(1)/(N-1)} \\
 \vdots & \vdots & \ddots & \vdots \\
 e^{i2\pi(0)(N-1)/(N-1)} & e^{i2\pi(1)(N-1)/(N-1)} & \dots & e^{i2\pi(N-1)(N-1)/(N-1)}
 \end{array}$$

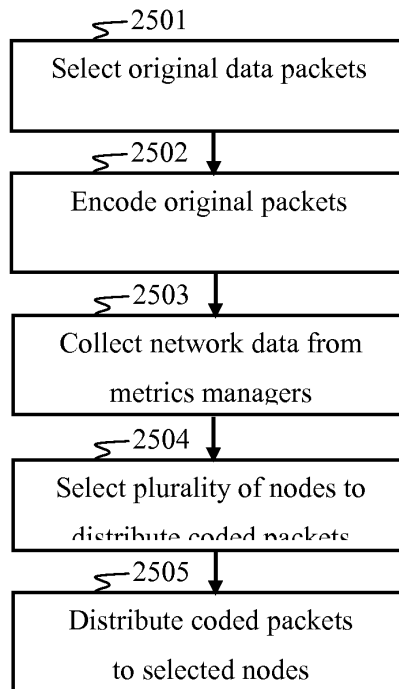
FIGURE 19

**FIGURE 20A****FIGURE 20B**

**FIGURE 21A****FIGURE 21B****FIGURE 22A****FIGURE 22B**

**FIGURE 23A****FIGURE 23B**

**FIGURE 24**

**FIGURE 25**

Application for
United States Letters Patent
of
Steve J. Shattil
for
Cooperative Subspace Demultiplexing in Content Delivery Networks

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a Continuation-in-Part of U.S. Patent Application Ser. No. 11/187,107 filed July 22, 2005, which claims priority to Provisional Appl. No. 60/598,187, filed August 2, 2004, and which is a Continuation-in-Part of U.S. Patent Application Ser. No. 10/145,854, filed May 14, 2002, all of which are hereby incorporated by reference in their entireties.

BACKGROUND

1. Field of the Invention

Subject matter disclosed herein relates generally to data communications, and more particularly, to techniques, systems, and protocols for use in employing cooperative subspace processing when transferring data between locations.

2. Introduction

Limited storage of mobile devices is driving cloud services in which data and software are stored on the network. However, in wireless networks, limited wireless bandwidth, variable reliability of the communication channels, and mobility of the client devices discourages off-site data storage and produces significant challenges to media distribution.

Wireless communication devices (e.g., smart phones and other handheld communicators, tablet computers with communication functionality, etc.) often possess multiple network interfaces for use with different network technologies having different connectivity characteristics. The different network technologies may each have, for example, different delay, throughput, and reliability characteristics. A mobile device that is connected to a remote source node through both a cellular network (i.e., a wireless wide area network (WWAN)) and an IEEE 802.11 wireless local area network (i.e., a WLAN) may, for example, observe different usage costs and quality of service through each interface. It would be desirable to be able to utilize multiple available network resources to carry out a data transfer operation for a communication device to, for example, increase throughput, decrease data transit time, and/or make efficient use of available resources. It would also be desirable if this could be done in a reliable and efficient manner that takes advantage of already existing communication techniques and protocols.

Accordingly, content delivery mechanisms need to adapt to highly variable network topologies and operating conditions in order to provide reliable media and data services. These and other needs in the field may be addressed by aspects of the present invention.

SUMMARY

Techniques, devices, systems, and protocols are described herein that support efficient and reliable data transfer between communication nodes via multiple different paths, such as subchannels, channels, and network channels involving different network technologies. In aspects of the disclosure, subspace coding generates linear combinations of original data sets for multiplexing the original data sets into subspace-coded data sets, which are transmitted over the multiple paths. Subspace decoding is provided for demultiplexing received subspace-coded data sets. In some aspects, multiple transmitting nodes are configured to cooperatively perform subspace coding to build the dimension spanned by the subspace of the transmitted signals. In some aspects, multiple receiving nodes are configured to cooperatively perform subspace decoding, such as to build the dimension of the subspace spanned by the received signals.

The solution set to any homogeneous system of linear equations with n variables is a subspace in the coordinate space K^n , wherein the coordinate space K^n is the prototypical example of an n -dimensional vector space over a field K . Every subspace of K^n can be described as the null space of some matrix. For example, in a finite-dimensional space, a homogeneous system of linear equations can be written as a single matrix equation: $\mathbf{Ax} = 0$, wherein the set of solutions to this equation is the null space of the matrix $\mathbf{A}$. Given a set of n independent functions, the dimension of the subspace in K^k will be the dimension of the null set of $\mathbf{A}$, the composite matrix of the n functions.

In accordance with one aspect of the concepts, systems, circuits, and techniques described herein, a machine implemented method for use in transferring data from a source node to a destination node comprises selecting a plurality of original packets to transfer to a destination node; selecting a plurality of transmitting nodes to perform cooperative encoding; cooperatively encoding the original packets for generating a plurality of coded packets and a corresponding code matrix of coefficients, the coded packets and the corresponding code matrix comprising a plurality of independent equations having a plurality of independent variables in a system of linear equations, wherein the independent variables comprise the original packets; and transmitting the plurality of coded packets and corresponding code matrix to a destination node.

In one aspect of the disclosure, the code matrix comprises a matrix of random coefficients. For example, the coded packets may comprise random linear combinations of the original packets. The coefficients may comprise scalar and/or complex coefficients. Coding may employ sliding window and/or block codes. In another aspect of the disclosure, the code matrix is an invertible transform matrix, such as a block transform or a sliding window transform. For example, CI codes may be employed.

Aspects of the disclosure describe methods for ensuring that the number of independent equations is sufficient for enabling the destination node to decode the plurality of independent variables. Methods are also disclosed for ensuring the corresponding code matrix is well-conditioned.

In accordance with some aspects of the disclosure, coding is provided to the coded packets and corresponding code vectors of the code matrix at intermediate nodes, such as by applying linear coding to the coded packets and the code vectors.

In accordance with another aspect of the concepts, systems, circuits, and techniques described herein, a machine implemented method for use in processing coded packets received from a source node comprises: selecting a plurality of receiving nodes for cooperatively receiving a transmission from the source node, the plurality of receiving nodes being selected to provide a sufficient number of independent equations for decoding a plurality of original packets encoded in the transmission; collecting a plurality of coded packets and a corresponding code matrix from the receiving nodes; and decoding the packets, wherein decoding comprises calculating a solution for a system of linear equations comprising the independent equations having a plurality of independent variables, the independent equations comprising the plurality of coded packets and the corresponding code matrix, and the plurality of independent variables comprising the plurality of original packets.

In one aspect of the disclosure, the coded packets are encoded by the source node. In another aspect, encoding is provided by transmitting signals in a multipath channel. In a wireless channel, selecting the transmitting and/or receiving nodes may comprise any adaptive array

processing techniques. In some aspects, it is disclosed how selecting the nodes can build the rank of the code matrix and/or improve the conditioning of the code matrix. For example, as the destination node collects code vectors, it may build up the dimension of the subspace spanned by the received code vectors.

In one aspect of the disclosure, the solution can be calculated when the number of degrees of freedom received at least equals the number of original packets. In another aspect of the disclosure, the solution may be calculated when the number of degrees of freedom received is less than the number of original packets, such as when a CI code matrix is employed for coding. In accordance with certain aspects, a destination node determines whether coded packets are linearly independent, such as by performing a row-reduction operation (or other algorithms for solving systems of linear equations) on the code matrix.

In accordance with another aspect of the concepts, systems, circuits, and techniques described herein, a machine implemented method for use in transferring data from a source node to a destination node comprises: selecting a plurality of original packets to transfer to the destination node; selecting a plurality of transmitting nodes to cooperatively encode the original packets for generating a plurality of coded packets and a corresponding code matrix; and providing for transmitting from each of the transmitting nodes a subset of the plurality of coded packets and corresponding code matrix, wherein at least one of the transmitting nodes has a rank that is insufficient for decoding the plurality of coded packets.

In some aspects of the disclosure, cooperative encoding is configured to ensure that the code matrix has sufficient rank and is sufficiently well-conditioned to enable the destination node to decode the coded packets. In some aspects, at least one intermediate node provides additional encoding to the plurality of coded packets and corresponding code matrix. For example, additional subspace coding may be provided to the coded packets and the code vector at each intermediate node by applying linear coding to the coded packets and the code vector.

In some aspects of the disclosure, the transmitting nodes may retransmit coded packets, such as when an acknowledgement has not been received from the destination node after a

predetermined amount of time. In some aspects, new linear combinations of the original packets are transmitted, such as when retransmission occurs after a delay that at least equals the coherence time of the channel.

In accordance with another aspect of the concepts, systems, circuits, and techniques described herein, a machine implemented method for use in processing coded packets received from a source node comprises: selecting a plurality of receiving nodes to cooperatively receive a plurality of linearly coded packets and a plurality of corresponding code vectors, wherein the rank of at least one of the receiving nodes is insufficient for decoding the coded packets; building up a dimension of a subspace spanned by code vectors received at the destination node by collecting the coded packets and the corresponding code vectors from the plurality of receiving nodes; and decoding the coded packets.

In one aspect of the disclosure, when the receiving nodes transmit their received signals to the destination node, they provide additional linear encoding to the coded packets and the corresponding code vectors. In some aspects, the destination node (and/or the receiving nodes) transmit an acknowledgement to the source node upon at least one of receiving a coded packet and decoding an original packet. In some aspects, building up the dimension of the subspace spanned by the code vectors may further comprise collecting at least one additional coded packet and corresponding code vector transmitted by the source node during a later time interval.

In accordance with some aspects of the disclosure, the plurality of receiving nodes is configured to cooperatively receive the linearly coded packets and corresponding code vectors transmitted over a plurality of different network channels. The different network channels may comprise different multiple-access channels on the same network and/or channels on different networks. The destination node and/or the receiving nodes may employ different network technologies.

In accordance with another aspect of the concepts, systems, circuits, and techniques described herein, a machine implemented method for use in processing coded packets received from a source node comprises: determining a required number of degrees of freedom for decoding a plurality of linearly coded packets received from a source node; based on the required number of

degrees of freedom, selecting at least one additional receiving node for cooperatively receiving at least one coded packet and associated code vector; collecting a plurality of coded packets and associated code vectors from a plurality of cooperating receiving nodes, including the at least one additional receiving node; and decoding the plurality of coded packets.

In some aspects of the disclosure, determining the required number of degrees of freedom comprises counting the number of collected code vectors, determining the number of collected linearly independent code vectors, and/or determining the rank of a matrix comprising the collected code vectors. Selecting additional receiving nodes and collecting coded packets and/or associated code vectors therefrom may be performed until the number of received linearly independent coded packets is at least equal to the required number of degrees of freedom. In some aspects, decoding comprises arranging the associated code vectors in a matrix, and then performing at least one matrix operation on the plurality of coded packets.

In accordance with another aspect of the concepts, systems, circuits, and techniques described herein, a machine implemented method for transmitting a file between a server and a client comprises: generating a plurality of linearly coded packets from a plurality of original packets; selecting a plurality of transmitting nodes to perform cooperative subspace processing; and coordinating the plurality of transmitting nodes to increase a dimension of a subspace spanned by the linearly coded packets to provide the client with a sufficient number of linearly independent coded packets from which to retrieve the plurality of original packets.

In accordance with certain aspects of the disclosure, the plurality of transmitting nodes comprises a plurality of intermediate nodes between the server and the client, the intermediate nodes being configured to receive and retransmit the coded packets.

In accordance with another aspect of the concepts, systems, circuits, and techniques described herein, a machine implemented method for transmitting data from a source node via multiple different network channels comprises: encoding a plurality of original packets for generating a plurality of linearly coded packets and corresponding code vectors for transfer to a destination node; selecting a first network channel and at least a second network channel to simultaneously

employ in the transfer; and distributing a first subset of the plurality of linearly coded packets and corresponding code vectors to the first network channel and distributing a second subset of the plurality of linearly coded packets and corresponding code vectors to the at least second network channel, wherein at least one of the first subset and the second subset has a rank that is insufficient for decoding the plurality of coded packets, and wherein a sum of ranks of the first subset and the second subset is sufficient for decoding the plurality of coded packets.

In one aspect of the disclosure, the first network channel resides on a first network and the second network channel resides on a second network that is different than the first network. In some aspects, distributing comprises network load balancing whereby a lesser number of packets is distributed to a network channel having a lesser capacity and a greater number of packets is distributed to a network channel having a greater capacity. Aspects of the disclosure provide for coordinating a plurality of transmitting nodes to cooperatively transmit the linearly coded packets and/or coordinating a plurality of receiving nodes to cooperatively receive the linearly coded packets. The linearly coded packets may comprise random linearly coded packets with coefficients generated at random and/or deterministically.

An aspect of the disclosure further comprises monitoring at least one real-time property of the first network channel and the second network channel, and encoding and/or distributing may be adjusted based on the monitoring to provide for network load balancing.

In some aspects, encoding comprises selecting a plurality of transmitting nodes to build the dimension of the subspace of a transmitted signal comprising the coded packets. Similarly, a plurality of cooperating receiving nodes may be selected to build the dimension of the subspace of a received signal. In some aspects of the disclosure, encoding and distributing are performed such that the destination node needs to receive coded packets from a plurality of network channels in order to have a sufficient number of degrees of freedom to decode the coded packets.

In accordance with another aspect of the concepts, systems, circuits, and techniques described herein, a machine implemented method for use in processing data to be transmitted from a source node on multiple different paths comprises: selecting a plurality of original packets for subspace

coding to generate a plurality of linearly coded packets from a plurality of original packets; selecting a plurality of nodes to cooperatively perform subspace processing, whereby the plurality of nodes employs a plurality of transmission paths for transmitting the plurality of linearly coded packets and associated code vectors to a destination node, each of the plurality of transmission paths providing a linearly independent combination of the original packets to the destination node; and coordinating the plurality of nodes to produce a sufficient number of the plurality of transmission paths to enable the destination node to perform decoding to retrieve the plurality of original packets.

In some aspects of the disclosure, the above-recited plurality of nodes comprises one or more intermediate nodes. In an aspect of the disclosure, the method above further comprises transmitting new linear combinations until the destination node decodes the coded packets.

In accordance with another aspect of the concepts, systems, circuits, and techniques described herein, a machine implemented method for use in processing and distributing data comprises: generating a plurality of sub-space coefficients to encode a plurality of original data packets; generating a plurality of subspace-encoded data packets by employing the plurality of sub-space coefficients to produce linear combinations of the original data packets; and distributing the sub-space coefficients and the subspace-encoded data to a plurality of transmitting nodes for transmission to a destination node.

In some aspects of the disclosure, the plurality of transmitting nodes may comprise edge servers in a content delivery network. The sub-space coefficients and subspace-encoded data packets may be stored on the transmitting nodes before being served to the destination node.

In accordance with another aspect of the concepts, systems, circuits, and techniques described herein, a machine implemented method for use in processing and distributing data comprises: selecting a plurality of receiving nodes for cooperatively receiving a plurality of subspace-encoded data packets and corresponding subspace codes; distributing the plurality of subspace-encoded data packets and the subspace codes collected by the plurality of receiving nodes to a

destination node; and decoding the subspace-encoded data packets to retrieve a plurality of original data packets encoded in the subspace-encoded data packets.

In some aspects of the disclosure, the plurality of receiving nodes may comprise edge servers in a content delivery network. The sub-space coefficients and subspace-encoded data packets may be stored on the receiving nodes before being collected by the destination node.

In accordance with another aspect of the concepts, systems, circuits, and techniques described herein, at least one source node is configured to transmit a plurality of original data packets; and a plurality of coding nodes are configured to output a plurality of coded packets comprising linear combinations of the original data packets. The coding nodes are configured to provide a sufficient number of degrees of freedom to enable a destination node to decode the coded packets. The coefficients of the linear combinations may be randomly chosen. A deterministic process may be employed for generating random coefficients. In some aspects, an invertible transform matrix may be employed for generating the coefficients.

In accordance with another aspect of the concepts, systems, circuits, and techniques described herein, a machine implemented method for use in distributing subspace-encoded data comprises: selecting a plurality of nodes to cooperatively function as a subspace multiplexing process; separating a data set into a plurality N of original components; generating a plurality of subspace-coded components by generating at least N linear combinations of the original components; and distributing the plurality of subspace-coded components and a plurality of associated subspace code vectors to the plurality of nodes, such that at least one of the plurality of nodes has a number of coded components that is less than a number of required degrees of freedom to decode the plurality of subspace-coded components.

In accordance with an aspect of the disclosure, the above method further comprises: at a destination node, collecting a plurality of the subspace-coded components and associated subspace code vectors from a plurality of the nodes until a sufficient number of linearly independent code vectors have been collected to decode the coded components; and decoding the subspace-coded components.

In some aspects of the disclosure, the selected nodes are nearby a destination node in a peer-to-peer network. In some aspects, the plurality of nodes comprises end nodes in a content delivery network. The physical wireless channel may provide the required statistical randomness for the coding. Codes may be based on measurements of the physical wireless channel. Codes may be generated deterministically. In some aspects, coding may comprise employing a sliding coding window.

In another aspect of the disclosure, a method for transmitting data from a source node to a destination node comprises forming linear combinations of original packets from a source node to produce subspace-coded packets, and delivering the subspace-coded packets to the destination node over one or more network paths. Based on the responsiveness of the destination node, the source node may produce new linear combinations of the original packets, and deliver the new subspace-coded packets to the destination node. This adaptive technique can be used to select the number of transmitting antennas and/or receiving antennas in a wireless network.

Additional features and advantages of the invention will be set forth in the description which follows, and in part will be obvious from the description, or may be learned by practice of the invention. The features and advantages of the invention may be realized and obtained by means of the instruments and combinations particularly pointed out in the appended claims. These and other features of the present invention will become more fully apparent from the following description and appended claims, or may be learned by the practice of the invention as set forth herein.

BRIEF DESCRIPTION OF THE DRAWINGS

Flow charts depicting disclosed methods comprise "processing blocks" or "steps" may represent computer software instructions or groups of instructions. Alternatively, the processing blocks or steps may represent steps performed by functionally equivalent circuits, such as a digital signal processor or an application specific integrated circuit (ASIC). The flow diagrams do not depict the syntax of any particular programming language. Rather, the flow diagrams illustrate the

functional information one of ordinary skill in the art requires to fabricate circuits or to generate computer software to perform the processing required in accordance with the present disclosure. It should be noted that many routine program elements, such as initialization of loops and variables and the use of temporary variables are not shown. It will be appreciated by those of ordinary skill in the art that unless otherwise indicated herein, the particular sequence of steps described is illustrative only and can be varied. Unless otherwise stated, the steps described below are unordered, meaning that the steps can be performed in any convenient or desirable order.

FIG. 1 is a diagram of a cooperative-MIMO system in which multiple cooperating nodes are employed at both the transmitter side and the receiver side of a wireless link in accordance with some aspects of the invention.

FIG. 2 is a block diagram of cooperating receiver nodes in relation to methods, devices, and systems employed for performing cooperative-MIMO processing in aspects of the invention.

FIG. 3 is a flowchart illustrating methods for processing coded packets received at a destination node from a source node via multiple different WWAN paths in some aspects of the invention.

FIG. 4 is a flowchart illustrating methods for processing coded packets received at a destination node from a plurality of intermediate nodes in accordance with aspects of the invention.

FIG. 5 is a flow diagram of a method for distributing data across a plurality of subchannels in a cooperative network according to some aspects of the invention.

FIG. 6 is a flow diagram depicting methods for distributing data across a plurality of subchannels in a cooperative network in accordance with aspects of the invention.

FIG. 7 is a block diagram depicting a cooperative system of nodes configured to simultaneously employ a plurality of different networks for delivering and/or receiving a data transmission in accordance with aspects of the invention.

FIG. 8 is a block diagram of a plurality of cooperating nodes configured in accordance with aspects of the invention.

FIGs. 9A and 9B depict software components residing on a non-transitory computer-readable memory configured to operate in accordance with aspects of the invention.

FIG. 10 is a network diagram of a cooperative subspace processing system in accordance with an aspect of the invention.

FIGs. 11A, 11B, and 11C are flow diagrams illustrating cooperative subspace multiplexing methods used in accordance with aspects of the invention.

FIGs. 12, 13, and 14 are flow diagrams depicting subspace processing methods in accordance with aspects of the invention.

FIG. 15A is a flow diagram depicting subspace processing with data interleaving across multiple network channels in accordance with an aspect of the invention.

FIG. 15B is a flow diagram depicting a method for managing quality of service in a node in accordance with an aspect of the invention.

FIG. 16 is a block diagram of a cooperating group of nodes employing a plurality of different code spaces for communicating in a wide area network according to aspects of the invention.

FIGs. 17 and 18 are flow diagrams depicting coding methods configured in accordance with aspects of the invention.

FIG. 19 shows an invertible transform matrix that may be employed for coding in some aspects of the invention.

FIG. 20A is a constellation plot of original data values before coding.

FIG. 20B is a constellation plot of coded data values in accordance with an aspect of the invention.

FIG. 21A is a flowchart illustrating a method for transmitting data from a source node to a destination node via multiple different channels in accordance with an aspect of the invention.

FIG. 21B is a flowchart illustrating a method for receiving data at a destination node via multiple different channels in accordance with an aspect of the invention.

FIG. 22A is a flowchart illustrating a method for transmitting data from a source node to a destination node in accordance with aspects of the invention.

FIG. 22B is a flowchart illustrating a method for receiving data at a destination node in accordance with aspects of the invention.

FIG. 23A is a block diagram of a control board configured in accordance with an aspect of the invention.

FIG. 23B is a flowchart illustrating a method for retrieving data in a content delivery network in accordance with some aspects of the invention.

FIG. 24 is a block diagram of a content delivery network configured to operate in accordance with some aspects of the invention.

FIG. 25 is a flowchart illustrating a method for delivering data in a content delivery network in accordance with some aspects of the invention.

DETAILED DESCRIPTION

Various aspects of the disclosure are described below. It should be apparent that the teachings herein may be embodied in a wide variety of forms and that any specific structure, function, or both being disclosed herein are merely representative. Based on the teachings herein one skilled in the art should appreciate that an aspect disclosed herein may be implemented independently of any other aspects and that two or more of these aspects may be combined in various ways. For example, an apparatus may be implemented or a method may be practiced using any number of the aspects set forth herein. In addition, such an apparatus may be implemented or such a method may be practiced using other structure, functionality, or structure and functionality in addition to or other than one or more of the aspects set forth herein.

In the following description, for the purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of the invention. It should be understood, however, that the particular aspects shown and described herein are not intended to limit the invention to any particular form, but rather, the invention is to cover all modifications, equivalents, and alternatives falling within the scope of the invention as defined by the claims.

FIG. 1 is a diagram illustrating one possible aspect of a cooperative-MIMO system in which multiple nodes are employed at both the transmitter side and the receiver side of a WWAN (i.e., long-haul) transmission link. This figure and the figures that follow are for demonstrative purposes only and are not intended to limit the scope of the pending claims.

A node, as used herein, is an active electronic device that is communicatively connected to a network via one or more connectors and is configured for sending, receiving, and/or forwarding information over a communication channel. A device may have multiple network connectors for a given network. For example, a device may have multiple antennas. However, a single device with multiple network connectors is a single node. In a distributed network, nodes are clients, servers, or peers. A peer may sometimes serve as a client and sometimes as a server. Nodes may include super nodes, which route data for other networked devices as well as themselves.

On the transmit side, a first local group 110 comprises a plurality N_t of transmitting nodes 111.1, 111.2, ..., 111. N_t . Each node 111.1, 111.2, ..., 111. N_t may employ a WLAN (i.e., local transmissions 101-103) to broadcast its data to one or more of the other transmitting nodes 111.1, 111.2, ..., 111. N_t . Thus, the local group 110 of transmitting nodes may comprise all nodes 111.1, 111.2, ..., 111. N_t that are communicatively coupled together by a WLAN.

In alternative aspects, the nodes 111.1, 111.2, ..., 111. N_t do not share their data with the other transmitting nodes 111.1, 111.2, ..., 111. N_t . In such aspects, the local group 110 may comprise transmitting nodes 111.1, 111.2, ..., 111. N_t that self organize or that are configured by a WWAN controller (not shown) to simultaneously employ the same WWAN channel (e.g., frequency band, time slot, and/or code space).

Each transmitting node 111.1, 111.2, ..., 111. N_t transmits at least a respective WWAN signal 115.1, 115.2, ..., 115. M_t into a WWAN channel 99. In some aspects of the invention, one or more of the transmitting nodes 111.1, 111.2, ..., 111. N_t may comprise a plurality of (M_t) antennas. In such aspects, the transmitting nodes 111.1, 111.2, ..., 111. N_t may generate a number up to M_t of simultaneous transmissions that exceeds the number N_t of nodes.

On the receiver side, a second local group 120 comprises a plurality N_r of receiving nodes 121.1, 121.2, ..., 121. N_r that join together for cooperative reception. Each of the receiving nodes 121.1, 121.2, ..., 121. N_r receives at least a respective WWAN signal 125.1, 125.2, ..., 125. M_r from the WWAN channel 99. In some aspects of the invention, one or more of the receiving nodes 121.1, 121.2, ..., 121. N_r may comprise multiple antennas. Thus, the receiving nodes 121.1, 121.2, ..., 121. N_r may receive a number M_r of received signals that exceeds the number N_r of receiving nodes. However, signals received on multiple antennas at a single node may be combined, such as may be performed for diversity combining, especially when the received signals are correlated. Thus, the number of spatial subchannels (e.g., the effective number M_r of received signals) may be less than the total number of antennas, M_r , employed by the receiver array depending on whether or not received signals are diversity combined prior to spatial processing.

One or more of the receiving nodes 121.1, 121.2, ..., 121.N_r may be designated as a destination node. For example, the local group 120 comprises nodes 121.1, 121.2, ..., 121.N_r, which are communicatively coupled together via a WLAN, and wherein node 121.1 and node 121.N_r communicate their received WWAN data to node 121.2 (which, in this case, is designated as the destination node) for further processing. In such aspects of the invention, peer-to-peer or multi-hop communications are a natural part of cooperative-MIMO processing.

The receiving nodes 121.1, 121.2, ..., 121.N_r may perform any of various combining techniques to provide MIMO subspace demultiplexing of the received signals, including EGC, MRC, Minimum Mean Squared Error Combining, other types of optimal combining, Successive Interference Cancellation, and other matrix-reduction/matrix diagonalization techniques. Some aspects may employ Cholesky triangularization (or other matrix decomposition approaches), overlapped subspace detection, maximum likelihood detection, and/or maximum a posteriori probability detection. Gaussian elimination, also known as row reduction, is a well-known algorithm for solving systems of linear equations. Using row operations to convert a matrix into reduced row echelon form is sometimes called Gauss–Jordan elimination. Some authors use the term Gaussian elimination to refer to the process until it has reached its upper triangular, or (non-reduced) row echelon form. For computational reasons, when solving systems of linear equations, it is sometimes preferable to halt row operations before the matrix is completely reduced.

This MIMO-based system may require additional energy for local communication between the transmitting nodes 111.1, 111.2, ..., 111.N_t and the receiving nodes 121.1, 121.2, ..., 121.N_r, but simultaneously introduces important gains for the long-haul (i.e., WWAN) communication. Based on the richness of the scattering environment, there is a critical distance between the transmitter and receiver above which MIMO transmission is more energy efficient than single-input, single output (SISO), e.g., purely multi-hop peer-to-peer transmission.

The following mathematical explanation shows why a rich scattering environment in the WWAN channel produces capacity gains for MIMO subspace processing.

The time-invariant WWAN channel is described by:

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{w},$$

where $\mathbf{y}$ is a vector of length M_r of baseband data symbols received by the receiver array having M_r antennas, $\mathbf{x}$ is a vector of length M_t of transmitted baseband data symbols from the transmitter array having M_t antennas, $\mathbf{H}$ is the $M_r \times M_t$ WWAN channel matrix, and $\mathbf{w}$ is a vector of length M_r of white Gaussian noise.

In some aspects of the invention, nodes transmit random linear combinations of the packets they receive by virtue of a rich scattering environment. In a MIMO system, a rich scattering environment typically provides a full rank, well-conditioned channel matrix $\mathbf{H}$, which indicates that the system may exploit the maximum number of spatial degrees of freedom ($d = \min(M_r, M_t)$). In some aspects, the dimension of the subspace spanned by the system of linear equations (such as may be indicated by $\mathbf{H}$) is the number of spatial degrees of freedom.

If the spatial subchannels are sufficiently uncorrelated, the probability that the receiver array will obtain linearly independent combinations (and therefore obtain innovative information) approaches 1. However, if a receiver obtains an insufficient number of linearly independent combinations of the transmitted data symbols, it may be unlikely that it can recover the original packets. For example, the receiver array may comprise fewer operable antennas than the number of spatial degrees of freedom employed by the transmitter. Specifically, the receiver may comprise fewer than the required minimum number of antennas ($M_r < d$), and/or some of the spatial subchannels may be correlated. In such cases, some aspects of the invention provide additional linear combinations until the receiver obtains a sufficient amount of information to perform spatial demultiplexing.

The capacity may be computed by decomposing the vector channel into a set of parallel independent scalar Gaussian sub-channels. From basic linear algebra, every linear transformation can be represented as a composition of three operations: a rotation operation, a scaling operation, and another rotation operation. In the notation of matrices, the matrix $\mathbf{H}$ has a *singular value decomposition* (SVD):

$$\mathbf{H} = \mathbf{U}\mathbf{A}\mathbf{V}^*,$$

where $\mathbf{U}$ and $\mathbf{V}$ are unitary matrices, and $\mathbf{\Lambda}$ is an $M_r \times M_t$ rectangular matrix whose diagonal elements are non-negative real numbers and whose off-diagonal elements are zero. The diagonal elements $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_{M(\min)}$ are the ordered singular values of matrix $\mathbf{H}$, where $M(\min)$ is the smaller of M_r and M_t .

Since $\mathbf{H}\mathbf{H}^* = \mathbf{U}\mathbf{\Lambda}\mathbf{\Lambda}^H\mathbf{U}^*$, the squared values λ_i^2 are the eigenvalues of the matrix $\mathbf{H}\mathbf{H}^*$ and also $\mathbf{H}^*\mathbf{H}$.

$\mathbf{H}$ can be rewritten as: $\mathbf{H} = \sum_{i=1}^{M(\min)} \lambda_i \mathbf{u}_i \mathbf{v}_i^*$, which is the sum of rank-one matrices $\lambda_i \mathbf{u}_i \mathbf{v}_i^*$. Thus, the rank of $\mathbf{H}$ is the sum of non-zero singular values λ_i . Each value λ_i corresponds to an eigenmode of the channel (i.e., an eigenmode corresponds to an eigen-channel, or subspace channel). Each non-zero eigenmode can support a data stream. Thus the MIMO channel can support k subspace channels, where k is the number of non-zero eigenvalues λ_i .

In the case where the SNR is high, and equal amounts of power are allocated to the non-zero eigenmodes, the channel capacity is expressed by:

$$C \approx \sum_{i=1}^k \log \left(1 + \frac{P\lambda_i^2}{kN_0} \right) \approx k \log \text{SNR} + \sum_{i=1}^k \log \left(\frac{\lambda_i^2}{k} \right) \text{ bits/s/Hz}$$

where P is the total transmit power of the transmitter array, N_0 is the noise power, so the signal-to-noise ratio is $\text{SNR} = P/N_0$, and k is the number of non-zero eigenvalues λ_i , which is the number of spatial degrees of freedom per second per hertz. This is equal to the rank of matrix $\mathbf{H}$. If $\mathbf{H}$ has full rank, the MIMO channel provides $M(\min)$ spatial degrees of freedom. However, the rank of $\mathbf{H}$ is just a crude measure of channel capacity. To better characterize channel capacity, one can consider the individual values of λ_i , particularly, the log of the values of λ_i^2 , which are summed in the above capacity equation.

In the above analysis, since the same amount of power is transmitted in each eigenmode, the channel $\mathbf{H}$ whose eigenvalues are all equal has the highest capacity. More generally, the less spread out the singular values, the greater the channel capacity is. This relates to the condition number of the matrix $\mathbf{H}$, which is the ratio: $(\max \lambda_i / \min \lambda_i)$. The matrix is said to be well-conditioned when the condition number is close to 1.

This means that in a MIMO system with a sufficient SNR, a well-conditioned channel matrix $\mathbf{H}$ facilitates communication. However, one of the problems with antenna arrays employed on portable transceivers, such as cellular handsets or other wireless mobile devices, is that the antennas cannot be sufficiently separated to guarantee uncorrelated spatial sub-channels, even in rich scattering environments. Therefore, aspects of the invention, when implemented in a WWAN, employ a WLAN to communicatively couple together multiple nodes and configure the nodes to cooperatively function as a MIMO system. Typically, the separation between the mobile nodes is sufficient to ensure uncorrelated spatial structure for MIMO processing.

FIG. 2 is a block diagram that depicts a configuration of receiver nodes in relation to methods, devices, and systems employed for cooperative-MIMO processing in accordance with certain aspects of the invention. A local group 120 comprises a plurality N_r of wireless nodes 121.1-121. N_r communicatively coupled together by a WLAN (depicted as WLAN links 105 and 107). At least one of the nodes 121.1-121. N_r (such as node 121.2) is a destination for a transmitted signal in a WWAN. At least one of the nodes 121.1-121. N_r that is not a destination node assists the destination in receiving WWAN signals. Although the WWAN transmission source(s) is (are) not shown, any type of WWAN transmission source may be employed, such as a conventional antenna array configured for transmitting WWAN signals, a plurality of WWAN base stations or access points, a plurality of cooperative-MIMO transmitters, and/or any type of WWAN peer-to-peer or multi-hop network. Accordingly, some aspects of the invention may employ techniques and structure referred to as Coordinated Multi-Point (CoMP) transmission and/or reception.

In the diagram shown in FIG. 2, a plurality M_r of WWAN signals 125.1-125. M_r are received by the N_r nodes 121.1-121. N_r . However, for simplicity of the following discussion, $M_r = N_r$. In a WWAN that employs cooperative MIMO, a WWAN source node (not shown) having a number of original data packets to transfer to the destination node 121.2 may combine the packets together into a "coded packet" that is transmitted in the WWAN. In one aspect of the invention, the rich scattering channel naturally "encodes" the packets. In another aspect of the invention, the source node (not shown) encodes the packets by employing channel pre-coding. In another

aspect of the invention, the source node (not shown) employs an invertible transform that maps original data symbols to a pseudo-random constellation of code symbols.

The destination node 121.2 receives the coded packet and may then store the packet for eventual decoding. The destination node 121.2 will typically require a particular number of coded packets before it decodes the coded packets to extract the original data packets. The decoding process may involve, for example, the solution of a system of linear equations having a number of independent variables (i.e., the original packets) and a number of independent equations (such as represented by the coded packets and their associated codes (e.g., code matrix)). Before the destination node 121.2 can reliably solve for the original data packets, the number of degrees of freedom received must typically equal or exceed the number of original packets. However, in some special cases, such as when certain combining techniques are employed, when certain types of error correction are employed, or when the CI invertible transform is employed, the original data packets may be recovered without requiring the number of degrees of freedom to at least equal the number of independent variables. The following methods described herein may be adapted to these and other special cases.

In some aspects of the invention, the missing degrees of freedom may be defined as the number of unknown independent variables of a system of equations less the number of independent equations. In some implementations, each coded packet successfully received at a destination node (assuming the coded packet is linearly independent of previously received coded packets) may provide another equation for use in decoding (such as in MIMO subspace demultiplexing). Thus, each linearly independent combination (e.g., uncorrelated subspace) reduces the number of degrees of freedom needed for decoding by one.

In the cooperative-MIMO receiver 120 shown in FIG. 2, the nodes 121.1-121.N_r start collecting linear combinations of the transmitted messages, $x_i, i = \{1, \dots, k\}$. For example, a signal r_1 received by the first node 121.1 can be expressed by the following linear combination:

$$r_1 = \sum_{i=1}^k \alpha_{1,i} x_i$$

where k typically equals the number of transmitted subspaces (e.g., spatial subchannels), M_i , from a transmitter array (not shown), and $\alpha_{1,i}$ denotes the i^{th} random channel coefficient corresponding to the first node 121.1. The set of coefficients $\alpha_{1,i}, i = \{1, \dots, k\}$ may be regarded as the i^{th} subspace code, or subspace code vector.

A signal r_{n_r} received by an n_r^{th} node (e.g., node 121. N_r) is expressed by:

$$r_{n_r} = \sum_{i=1}^k \alpha_{n_r,i} x_i$$

where the coefficient $\alpha_{n_r,i}$ denotes the i^{th} random channel coefficient corresponding to the n_r^{th} node 121. N_r . The set of coefficients $\alpha_{n_r,i}, i = \{1, \dots, k\}$ is regarded as the n_r^{th} subspace code, or subspace code vector.

If all N_r spatial subchannels are uncorrelated, then the set of receiving nodes 121.1-121. N_r provides a well-conditioned channel matrix $\mathbf{H}$ having rank N_r to the destination node 121.2. In one aspect of the invention, each of the nodes 121.1-121. N_r calculates its own code vector by estimating its channel coefficients α_i . In such aspects, the subspace code matrix determined at the destination node 121.2 may be the estimated channel matrix $\mathbf{H}$. Channel estimation may be performed by measuring known transmitted symbols, such as known training symbols, pilot tones, and the like. In some aspects of the invention, nodes may estimate a channel's impulse response. These code vectors, along with the received signals r_i are coupled to the destination node, such as via a WLAN (e.g., WLAN links 105 and 107).

As the destination node 121.2 collects code vectors, it builds up the dimension of the subspace spanned by the received code vectors. The dimension of the subspace spanned by the code vectors received at any receiving node, such as the destination node 121.2, is also referred to as the "dimension of the node" or "rank of the node." Similarly, the dimension of the subspace spanned by the code vectors corresponding to a transmission from a transmitting node is also referred to as the "dimension of the node" or "rank of the node."

In some aspects of cooperative MIMO, one of the functions of a network controller (e.g., one of the nodes 121.1-121.N_r) comprises selecting nodes in the local group 120 to cooperatively transmit and/or receive WWAN signals. Adaptive array processing may be coordinated by the network controller, such as to perform “antenna selection” in which the nodes 121.1-121.N_r are selected based on their channel conditions to provide a sufficiently well-conditioned channel matrix **H** having sufficient rank to demultiplex (i.e., decode) the transmitted signals x_i . For example, adaptive array processing may comprise adapting the selection of nodes 121.1-121.N_r until there are $N_r \geq M_t$ uncorrelated subchannels (i.e., a sufficient number of independent linear combinations of the transmitted signals x_i to permit the receiver to demultiplex the signals x_i). Once there are $N_r \geq M_t$ received independent linear combinations, the destination node 121.2 can recover all the messages x_i successfully.

In one aspect of the invention, only the destination node 121.2 decodes the received signals r_i . For example, the destination node 121.2 may begin a decoding process by constructing an estimated channel matrix **H**. Since the component channel vectors may be determined by measuring known transmissions (e.g., pilots, training signals, other known transmitted signals, etc.), the cooperative-MIMO system may include relays that simply forward received signals (e.g., signals r_1 and r_{n_r}) to the destination node 121.2.

In accordance with some aspects of the invention, node 121.1 relays its received WWAN signal r_1 to the destination node 121.2 via WLAN link 105. A relay channel, such as the WLAN channel, may produce linear combinations of r_1 :

$$r'_1 = \sum_{j=1}^{J_{12}} \beta_j r_1 = \sum_{j=1}^{J_{12}} \beta_j \left(\sum_{i=1}^k \alpha_{1,i} x_i \right)$$

where β_j denotes a j^{th} subchannel coefficient of a number J_{12} of subchannels in the WLAN link 105. Thus, r'_1 is also a linear combination of the x_i values with an effective code vector:

$$\gamma_i = \sum_{j=1}^{J_{12}} \beta_j \alpha_{1,i}$$

If the relay channel 105 comprises only one channel (i.e., $J_{12} = 1$), then the effective code vector values γ_i may equal the $\alpha_{1,i}$ values scaled by a constant β .

The destination node 121.2 does not need to know the values of α and β . Rather, in some aspects of the invention, the node 121.2 directly estimates the effective channel values, γ . In some aspects of the invention, the node 121.1 relays the unequalized signal r_1 , which comprises unequalized known transmissions (e.g., pilots, known symbols, etc.) in addition to unequalized data portions. In some aspects, the node 121.1 does not need to estimate its WWAN channel coefficients. Upon receiving the unequalized known transmissions, the destination node 121.1 calculates an effective channel vector (i.e., γ values). This effective channel vector may then be used with other estimated channel vectors to construct the estimated cooperative-MIMO channel matrix, $\mathbf{H}$, prior to decoding.

In some aspects, the node 121.1 estimates its WWAN channel and transmits those estimates in the WLAN link 105. For example, the node 121.1 may employ its estimated WWAN channel coefficients as weights on pilot tones, or it may otherwise synthesize “distortions” on known transmission signals based on its WWAN channel estimates. When the relayed signal is received at the destination node 121.2, any WLAN distortions are imparted onto the synthesized distortions. Then the node 121.2 calculates the aggregate (i.e., effective) channel vector.

The cooperative-MIMO protocol employed in aspects of the invention does not depend on the underlying communication model. The protocol can be applied to any environment where multiple messages are to be simultaneously demultiplexed over a bandwidth-limited environment.

FIG. 3 is a flowchart illustrating a method for use in processing coded packets received at a destination node from a source node via multiple different WWAN paths in accordance with an aspect of the invention. The method comprises receiving coded packets at a receiver via multiple transmission paths 301. The receiver also receives one or more code vectors 302 corresponding to the codes that encode the packets. The number of degrees of freedom required to decode the message are determined in step 303. A plurality of receiver nodes are selected to provide the required number of degrees of freedom in step 304.

As described above, the coded packets comprise random linear combinations of original packets that are input to at least one transmitting node (not shown). In the discussion above, this random coding may be achieved by transmitting the original packets in a scattering-rich channel. However, other techniques can be employed to achieve this random coding, including, but not limited to, employing coding at the transmitter (not shown), such as channel precoding based on estimates of a random channel. In some aspects, which are described below, the coding employed at the transmitter (not shown) may employ an invertible transform, such as a CI transform, which may include block transforms and/or sliding transforms.

The multiple transmission paths may comprise a plurality of WWAN subchannels, such as the WWAN subchannels described above. The multiple transmission paths may comprise non-WWAN transmission paths, such as WLAN paths 105 and 107, and/or waveguide (i.e., wired) transmission paths. In some aspects of the invention, which are described below, the multiple transmission paths comprise parallel transmission paths employed by different networks (i.e., network channels).

The steps of receiving the coded packets 301 and receiving the code vectors 302 may be performed simultaneously, as the coded vectors may be transmitted with the coded packets. For example, in some aspects wherein the channel is employed for encoding the transmitted packets, pilot tones and/or other known transmitted signals may provide information about the channel, and, thus, the codes. In some aspects of the invention, the receiver may perform channel estimation to determine (i.e., receive) the code vectors.

The term, receiver, as used with reference to FIG. 3 may include one or more of the receiving nodes 121.1-121.N_r communicatively coupled together in the local group 120. The receiver may comprise a destination node, such as node 121.2 and/or one or more intermediate nodes, such as nodes 121.1 and 121.N_r. A receiver may denote the collection of receiving nodes 121.1-121.N_r.

In some aspects of the invention, intermediate nodes (such as relay nodes) in the transmission path(s) may provide encode the packets. In accordance with some aspects, intermediate nodes may convey code vectors to the receiver. In other aspects, the intermediate nodes modify the

coding of the transmissions they receive, as well as the corresponding code vectors. In such aspects, the intermediate nodes may provide linear coding to linearly coded transmissions they receive such that the aggregate coding seen by the destination node is also a linear combination of the original data packets. Intermediate nodes may convey channel estimates to other nodes in the transmission path, either directly (such as by transmitting those estimates as data), or indirectly, such as by imparting the channel estimate values on pilot signals and/or other known transmission signals used for channel estimation.

In Patent Application Serial No. 10/145,854, to which the present application claims priority, and which is hereby incorporated by reference in its entirety, linear coding applied to a transmission encapsulates (i.e., masks) the network address in the packet header. In one aspect, this problem is remedied by appending a “message address” and header. Acknowledgements are returned upon receiving either or both the encapsulating message and the individual “network” packets. The message may be retransmitted until an acknowledgement is received from the destination node or after a predetermined number of retransmissions. In some aspects of the invention, the message address may be changed as the message propagates (e.g., hops) through the network. This is described in the ‘854 application with respect to each peer providing its own linear coding to the packets it receives before forwarding the packets.

As described above, in some aspects of the invention, either or both steps 301 and 302 may comprise transmitting an acknowledgement in response to receiving each coded combination of packets and/or upon decoding the original packets.

In step 303, the receiver determines if there are a sufficient number of degrees of freedom to decode the encoded transmission. Specifically, the receiver determines if there are a sufficient number of linearly independent packets at the destination node to allow for recovering the original data packets. For example, if there are M_T uncorrelated transmitted subspaces bearing M_T transmitted packets, then at least $M_R = M_T$ uncorrelated WWAN receiving paths are selected to provide the necessary degrees of freedom to decode the transmission. Spatial subchannels that have different spatial structure (e.g., subspaces that have minimal eigenspace alignment) are said

to be uncorrelated. Step 303 may comprise measuring the correlation between receiver nodes and then adapting the selection of WWAN-active nodes when receiver nodes become correlated.

One method for determining if receiver nodes are uncorrelated comprises determining if their received signals are linearly independent. For example, a Gaussian-Jordan elimination operation (or similar process) may be performed on a coefficient matrix associated with received packets. If a packet from a receiving node is not linearly independent with respect to other received packets, the packet may be discarded (or diversity combined with correlated packets). The network controller may proceed to look for new coded packets, such as by selecting another receiving node, thus building the dimension of the subspace spanned by the set of received coded packets.

In accordance with one aspect of the invention, a destination node in a cooperative-MIMO system determines that it has an insufficient number of degrees of freedom to decode a received coded message 303. Then selecting an additional receiver node 304 comprises receiving from at least one additional receiver node at least one linearly independent combination of original packets. New coded packets may be added until the destination node can decode the coded message. In some aspects of the invention, selecting 304 may be performed by the destination node, at least one other receiver node functioning as a network controller, or by the WWAN.

In one aspect of the invention, if an acknowledgement is not returned to the transmitter after a predetermined amount of time, then the transmitter retransmits the message. If the interval between transmissions is at least equal to the channel coherence time, then the retransmitted messages provide additional degrees of freedom at the receiver. Thus, a step of retransmitting the message with a different linear combination of original data packets (not shown) may be performed instead of, or in addition to step 304.

If a sufficient number of linearly independent packets have been received to decode the coded packets, then decoding 305 may be performed.

FIG. 4 is a flowchart illustrating a method for use in processing coded packets received at a destination node from a plurality of intermediate nodes in accordance with an aspect of the invention. The method comprises collecting code vectors from at least one peer 401. The collected code vectors may be arranged as a matrix 402. A processing step 403 determines if a dimension of the matrix (e.g., the number of collected code vectors) is equal to a predetermined number (e.g., the number of degrees of freedom required to decode the packets). When the dimension of the matrix does not equal the predetermined number, the method calls for repeating 413 the collecting step 401, the arranging step 402, and the processing step 403 until the dimension of the matrix equals the predetermined number. Then the original data packets are decoded 404 using the collection of code vectors in the matrix.

As described above, information about the code vectors may be transmitted with the coded packets. For example, transmissions in a wireless network typically include known control information (such as pilot tones, training sequences, etc.) that can be used for channel estimation. Generating the code matrix 402 may comprise estimating a MIMO channel matrix $\mathbf{H}$. Comparing the matrix dimension 403 may comprise determining the rank of $\mathbf{H}$, determining the number of code vectors, or determining the number of linearly independent code vectors. In some aspects of the invention, step 403 may comprise performing an eigenvalue decomposition of the $M_r \times M_t$ correlation matrix $\mathbf{R} = \mathbf{H}^H \mathbf{H}$.

In a MIMO communication system, signals transmitted from M_t transmit sources interfere with each other at a receiver comprising the receiving nodes 121.1-121.N_r. Thus, interference cancellation (such as matrix inversion and/or various forms of adaptive filtering) may be employed by one or more MIMO combiners to separate the signals. The received signal is expressed by:

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{n}$$

where the received signal, $\mathbf{y}$, is a vector with M_r terms $\{y_i, i = 1, \dots, M_r\}$ corresponding to signals received by M_r receiver elements (i.e., receiving nodes 121.1-121.N_r); $\mathbf{x}$ represents the transmitted signal, which is a vector having M_t terms $\{x_i, i = 1, \dots, M_t\}$ corresponding to signals transmitted by M_t transmitter elements (i.e., transmitting nodes 111.1-111.N_t); $\mathbf{H}$ is an $M_r \times M_t$ channel-response matrix that characterizes the complex gains (i.e., transfer function, or spatial

gain distribution) from the M_t transmission elements to the M_r receive elements; and $\mathbf{n}$ represents AWGN having zero mean and zero variance.

In the case where the channel is characterized by flat fading, such as when a narrowband signal is employed (e.g., a sub-carrier of a multi-carrier signal), the elements in matrix $\mathbf{H}$ are scalars. Thus, some aspects of the invention that provide for generating linear combinations of the data may provide for generating scalar coefficients. For example, pre-coding or spatial multiplexing based on the matrix $\mathbf{H}$ performed on the transmit side of a link may comprise generating linear combinations of signals in which the signal values are multiplied by scalar coefficients. Simultaneously transmitting multiple signals in a flat-fading environment can produce linear combinations in which the signals are scaled by scalar coefficients. Spatial demultiplexing performed on the receive side of the link may employ the scalar matrix $\mathbf{H}$ values, and, thus, comprise generating linear combinations of the received signals.

In one aspect of the invention, the channel-response matrix $\mathbf{H}$ may be diagonalized by performing an eigenvalue decomposition of the $M_t \times M_t$ correlation matrix $\mathbf{R}$, where $\mathbf{R} = \mathbf{H}^H \mathbf{H}$. Eigenvalue decomposition is expressed by:

$$\mathbf{R} = \mathbf{E} \mathbf{D} \mathbf{E}^H \mathbf{R}$$

where $\mathbf{E}$ is an $M_t \times M_t$ unitary matrix with columns corresponding to the eigenvectors $\mathbf{e}_i$ of $\mathbf{R}$, and $\mathbf{D}$ is an $M_t \times M_t$ diagonal matrix wherein the diagonal elements are eigenvalues λ_i of $\mathbf{R}$. The diagonal elements of $\mathbf{D}$ indicate the channel gain for each of the independent MIMO channels. Alternatively, other eigenvalue-decomposition approaches, such as singular value decomposition, may be employed.

One process for diagonalizing the MIMO channel response is initiated by multiplying a data vector $\mathbf{d}$ with the unitary matrix $\mathbf{E}$ to produce the transmitted vector $\mathbf{x}$: $\mathbf{x} = \mathbf{E} \mathbf{s}$. This requires the transmitter to have some information corresponding to the channel-response matrix $\mathbf{H}$, or related information thereof. The received vector $\mathbf{y}$ is then multiplied with $\mathbf{E}^H \mathbf{H}^H$ to provide an estimate of data vector $\mathbf{s}$, which is expressed by:

$$\hat{\mathbf{s}} = \mathbf{E}^H \mathbf{H}^H \mathbf{y} = \mathbf{E}^H \mathbf{H}^H \mathbf{H} \mathbf{E} \mathbf{s} + \mathbf{E}^H \mathbf{H}^H \mathbf{n} = \mathbf{D} \mathbf{s} + \hat{\mathbf{n}}$$

where $\hat{\mathbf{n}}$ is AWGN having a mean vector of 0 and a covariance matrix of $\mathbf{\Lambda}_n = \sigma^2 \mathbf{D}$.

The data vector $\mathbf{s}$ is transformed by an effective channel response represented by the diagonal matrix $\mathbf{D}$. Thus, there are N_s non-interfering subchannels, wherein each subchannel i has a power gain of λ_i^2 and a noise power of $\sigma^2 \lambda_i$. Subchannels with higher SNR are able to support higher information flows. Thus, some aspects of the invention provide for bit loading. Bit loading assigns bits to subchannels based on subchannel quality, which means that it allows more bits to be transmitted in higher-quality (i.e., higher-capacity) subchannels and fewer bits to be transmitted in lower-quality subchannels.

In the case where MIMO subspace processing is performed on a multicarrier (e.g., OFDM) signal or some other wideband signal that is spectrally decomposed into narrowband components, eigenmode decomposition may be performed for each frequency bin f_n .

If multicarrier spreading codes are employed (e.g., orthogonal DFT, or CI codes), the channel-response matrix $\mathbf{H}$ can cause inter-symbol interference between spread data symbols, even in a SISO arrangement. Accordingly, the eigenmode decomposition technique described above is applicable to multicarrier spreading and despreading. In one aspect of the invention, eigenmode decomposition may be applied across two or more dimensions (e.g., both spatial and frequency dimensions). In another embodiment of the invention, eigenmode decomposition may be applied across a single dimension (e.g., spatial or frequency dimensions). For example, multicarrier spreading codes (for example, orthogonal codes for data multiplexing in a given multiple-access channel) may be generated and processed via eigenmode decomposition.

Any of various water-filling or water-pouring schemes may be employed to optimally distribute the total transmission power over the available transmission channels, such as to maximize spectral efficiency. For example, water-filling can be used to adapt individual node transmission powers such that channels with higher SNRs are provided with correspondingly greater portions of the total transmit power. A transmission channel, as defined herein, may include a spatial subspace channel, a space-frequency channel, or some other channel defined by a set of orthogonalizing properties. Similarly, water filling may be used at a physically connected (i.e., wired) antenna array. The transmit power allocated to a particular transmission channel may be

determined by some predetermined channel-quality measurement, such as SNR, SINR, BER, packet error rate, frame error rate, probability of error, etc. However, different or additional criteria may be employed with respect to power allocation, including, but not limited to, wireless terminal battery life, load balancing, spatial reuse, power-control instructions, and near-far interference.

In conventional water filling, power allocation is performed such that the total transmission power P_T is some predetermined constant:

$$P_T = \sum_{j \in K} \sum_{k \in L} P_j(k)$$

where $L = \{1, \dots, N_s\}$ signifies the available spatial sub-spaces and $K = \{1, \dots, N_f\}$ represents the available sub-carrier frequencies f_n . The received SNR (expressed by $\psi_j(k)$) for each transmission channel is expressed by:

$$\psi_j(k) = \frac{P_j(k)\lambda_j(k)}{\sigma^2}, \text{ for } j = \{1, \dots, N_s\} \text{ and } k = \{1, \dots, N_f\}$$

The aggregate spectral efficiency for the $N_s N_f$ transmission channels is expressed by:

$$C = \sum_{j=1}^{N_s} \sum_{k=1}^{N_f} \log_2(1 + \psi_j(k))$$

The modulation and channel coding for each transmission channel may be adapted with respect to the corresponding SNR. Alternatively, transmission channels may be grouped with respect to their data-carrying capability. Thus, groups of transmission channels may share common modulation/coding characteristics. Furthermore, transmission channels having particular SNRs may be used for particular communication needs. For example, voice communications may be allocated to channels having low SNRs, and thus, low data-carrying capabilities. In some cases, transmission channels that fail to achieve a predetermined threshold SNR may be eliminated. In one embodiment of the invention, water filling is employed such that the total transmission power is distributed over a plurality of selected transmission channels such that the received SNR is approximately equal for all of the selected channels.

An aspect of the invention may employ reliability assessment for determining required processing and virtual-array size (e.g., the number of active nodes functioning as WWAN

receiver elements). Received bits or symbols that have low reliability may require more processing. Bits or symbols with high reliability may be processed with fewer elements (e.g., nodes) or provided with lower processing requirements. More information typically needs to be combined for data streams having less reliability and less information may need to be combined for data streams having more reliability. Also, nodes with good channel quality may share more information via the WLAN than nodes with poor channel quality. Optimization algorithms, such as water-filling algorithms may be employed in the reliability domain.

FIG. 5 is a flow diagram depicting a method of distributing data across a plurality of subchannels in a cooperative network, such as a communication network wherein at least a portion of the network employs multiple inputs and multiple outputs associated with a link between a server (i.e., a source node) and a client (i.e., a destination node). Aspects of the invention associated with FIG. 5, as well as with the other figures of the disclosure, are described in the '107 application and the '829 application (both of which are incorporated by reference in their entireties, and to which this disclosure claims priority). For example, in some aspects of the invention, disclosures in '107 and '829 relating to adaptive array processing, bit loading, soft handoff, antenna switching, antenna selection, and simultaneously employing multiple network channels (including channels from different WANs) are pertinent to methods and devices associated with FIG. 5.

Referring now to FIG. 5, a client-server system comprises a server coupled to a client through at least one communication link. Portions of the link may include at least one WWAN channel. A plurality of network channels are established 501 for transmitting a data block (e.g., a file, one or more data packets, etc.) from the server to the client. In one aspect of the invention, the plurality of network channels may comprise a plurality of spatial subchannels in a cooperative-MIMO system, such as depicted in FIG. 1. In another aspect of the invention, the network channels may comprise multiple WANs, such as depicted in FIG. 1J of the '107 application.

When step 501 comprises establishing a plurality of spatial subchannels in a WWAN, a number of transmitting antennas M_t and a number of receiving antennas M_r may be determined. In a cooperative-MIMO system, a plurality of nodes may be employed at the transmitting side and/or

at the receiving side in a wireless network. Step 501 may further comprise selecting which antennas are employed. Such antenna selection may be part of adaptive-array (e.g., smart antenna) processing performed by either or both the client and the server, and/or by one or more intermediate nodes in the link. In some aspects, antenna selection may comprise node selection in a cooperative-MIMO system.

Multiple sub-flows are established 502, wherein each sub-flow comprises a portion of the data to be transmitted. In one aspect of the invention, the sub-flows are established by determining amounts of data (e.g., number of packets) to be allocated to each of a plurality of channels and distributing the allocated amounts to the channels. Each channel may be provided with a predetermined number of packets to transmit in a particular unit time.

In one aspect, the channel quality of each subspace may be determined (such as by employing any of the eigenmode processes described above), followed by a bit-loading process. Various adaptive antenna array techniques may be employed. The basic idea is to use channel information to adaptively vary the transmission scheme. This adaptation may comprise varying the number of spatial subchannels and the sub-flow rate of each subchannel in a precoded spatial multiplexing system. In some aspects, a water-filling process, such as described above, may be employed for bit loading. For example, as a higher-quality subchannel is allocated more power, this increases the subchannel's SNR, which allows larger modulation constellations, higher coding rates, etc. to be employed. A higher-quality subchannel may also have fewer re-transmissions. In some aspects of the invention, step 502 may be performed concurrently with step 501, or it may follow step 501.

Since subspace encoding employed in aspects of the invention produces an aggregate signal in which the original data portions (i.e., components) are encapsulated, if the original data portions comprise packets, then header information in those original packets, such as addresses, sequence numbers, and the like are similarly masked. Step 503 assigns an identifier to the aggregate signal. For example, the identifier may comprise a WWAN identifier (e.g., WWAN-access information) that distinguishes WWAN messages from each other. The WWAN-access information typically identifies a particular destination node to which the message is addressed. The WWAN-access

information may comprise channel-access information for a WWAN channel to which the destination node is assigned. Similarly, the WWAN identifier may comprise a network address. The '854 application discloses a message address appended to a message encoded to encapsulate an aggregation of linearly encoded packets in which the network addresses of the individual component packets are hidden by the encapsulation. A receiving node may acknowledge receipt of the encapsulating message and/or receipt of the component (i.e., original) packets once they have been decoded.

In step 504, linear combinations of the component packets are generated. These linear combinations are distributed across the previously determined sub-flows based on the amounts of data (e.g., number of packets) allocated to each sub-flow in step 502. When the linear combinations are transmitted, they are provided with the identifier provided in step 503.

In one aspect of the invention, step 504 comprises sub-space coding that employs an invertible transform. For example, in the case of a linear transform from R^n to R^m given by $\mathbf{y} = \mathbf{Ax}$, where $\mathbf{A}$ is an $m \times n$ matrix, the transformation is invertible if $\mathbf{Ax} = \mathbf{y}$ has a unique solution. If $m = n$, the system $\mathbf{Ax} = \mathbf{y}$ has a unique solution if the rank of $\mathbf{A}$ equals n .

In one aspect of the invention, parallel transmissions (i.e., simultaneous, same-band transmissions) of the original data packets in a rich scattering environment produce linear combinations of the original data packets. Each "encoded" packet received at a receiving antenna comprises a random superposition of the original packets, wherein the randomness is provided by the random scattering channel. In accordance with one aspect of the invention, step 504 comprises coordinating a plurality of transmitting nodes to cooperatively transmit the original data packets. Step 504 may comprise antenna selection and/or node selection at the transmitting side, such as to produce an $m \times m$ channel matrix $\mathbf{H}$ with rank m in which the m subchannels are sufficiently decorrelated from each other. In accordance with another aspect of the invention, step 504 comprises coordinating a plurality of receiving nodes to receive the transmitted signals. Step 504 may comprise antenna selection and/or node selection at the receiving side, such as to produce an $n \times n$ channel matrix $\mathbf{H}$ with rank n in which the n subchannels are sufficiently decorrelated from each other.

In another aspect of the invention, pre-coding applied to the original data on the transmitting side produces linear combinations of the original data packets. Each “encoded” packet transmitted by a transmitting antenna comprises a random superposition of the original packets, wherein the randomness is provided by estimations of the random scattering channel. Aspects of the invention comprise either or both coordinating a plurality of transmitting nodes to cooperatively transmit the linear combinations of original packets and coordinating a plurality of receiving nodes to cooperatively receive the transmitted signals.

The linear combinations can be generated at random or deterministically involving all or any subset of the original packets. The coding strategy may affect the decoding complexity at the receiver. A particularly efficient coding method is to form linear combinations of packets using a CI transform, which is explained below.

In order to decode the received coded packets, the receiver needs a predetermined number of linearly independent combinations of the original packets, denoted as degrees of freedom. The effects of losing coded packets can be mitigated by providing for redundant transmissions across the subspaces. Similarly, a failure to return an acknowledgement for the original packets can naturally cause retransmission of the coded packets until the receiver can decode the encoded packets and acknowledge receipt of the original packets.

FIG. 6 is a flow diagram depicting a method of distributing data across a plurality of subchannels in a cooperative network, such as a network in which a plurality of transmitting nodes, a plurality of intermediate nodes, and/or a plurality of receiving nodes cooperatively function together to perform subspace processing.

Step 601 comprises determining a plurality of linear combinations of original packets to transmit from at least one source node to at least one destination node. For example, packets in a transmit queue may be partitioned into sets, each set comprising a plurality of packets. In one aspect of the invention, the number of packets in each set equals the number of transmitted subchannels. In another aspect of the invention, responsive to feedback from one or more receiving nodes, the

number of packets in each set equals the number of received subchannels. In one aspect, the linear combinations comprise coding provided to the original packets by one or more transmitting nodes. In another aspect, step 601 comprises which packets are transmitted simultaneously into a multipath channel, and the channel produces random linear combinations of the transmitted packets.

Step 602 comprises selecting a plurality of nodes to cooperatively perform subspace processing. In one aspect of the invention, a plurality of transmitting nodes is selected by a source node to transmit the linear combinations. For example, each transmitting node may transmit a different linear combination. In some aspects, each transmitting node may generate a different linear combination of original packets. In another aspect of the invention, a plurality of intermediate nodes is selected to cooperatively perform subspace processing. For example, intermediate nodes may combine signals they receive and then transmit those linear combinations. Intermediate nodes may share signals with each other before forwarding their received signals. In another aspect of the invention, a plurality of receiving nodes is selected to cooperatively perform subspace processing. For example, a destination node may select one or more receiving nodes to provide a requisite number of independent linear combinations so the destination node can decode the received signals to recover the original packets.

Step 603 comprises transmitting the linear combinations. In one aspect of the invention, step 603 comprises employing multiple transmission paths for transmitting original packets and/or coded packets, wherein the multiple transmission paths provide for mixing the transmitted signals. In one aspect, intermediate nodes that have multiple simultaneous inputs may combine the input signals. In another aspect of the invention, step 603 may employ transmission paths from a plurality of networks. In such aspects, transmitting 603 may employ similar bit-loading and/or water-filling techniques employed for subspaces, as described above.

Since many aspects of the invention employ data communication protocols that typically employ some type of acknowledgement mechanism, step 603 may be repeated until the destination node acknowledges receipt of the original packets. Thus, in some aspects, the destination node will ordinarily not be able to return acknowledgements for the original packets until after it decodes

its received signals. Thus, the ordinary retransmission process may generate new linear combinations 604 until the destination node can return an acknowledgement. For example, new linear combinations will be generated if the retransmission is delayed by an amount equal to or greater than the channel coherence time. Similarly, new linear combinations will typically be generated if the transmission channel is changed in other ways, such as if a different set of transmitting nodes, intermediate nodes, and/or receiving nodes is (are) employed. Alternatively, new linear combinations can be generated if new precoding values are selected.

FIG. 7 is a block diagram depicting a cooperative system of nodes configured to simultaneously employ a plurality of different WWAN connections, such as to deliver a data stream or data file to (or from) a destination (source) node. In one aspect of the invention, a local group 710 of nodes 701-706 employs connections to a plurality of different WWANs 716, 717, and 719 to transfer data to or from one of the nodes 701-706. In accordance with some aspects of the invention, the destination (or source node), i.e., one of the nodes 701-706 may simultaneously employ a plurality of WWAN user channels, including at least one of the user channels allocated to at least one of the other nodes 701-706, to transmit and/or receive data.

In some aspects of the invention, one or more nodes depicted in the figures may comprise an edge of a content delivery network. For example, an edge server may comprise one or more of the WWAN terminals 716, 717, and 719. In some aspects, one or more of the nodes 701-706 may be configured to perform edge-server functions.

In some aspects of the invention, a source or destination node may employ one or WANS to which it does not have direct access, but that one of the cooperating nodes 701-706 in the group 710 may access. For example, node 701 is shown with a communication to an IEEE 802.16 access-point terminal 716 in an IEEE 802.16 network, node 102 is shown with access capabilities to a 3G-cellular terminal 719, and node 703 has connectivity to an IEEE 802.11 access point 717. Connectivity between the nodes 701-706, such as via WLAN links 709, enables any of the nodes 701-706 in the group 710 to access any of the plurality of WAN (802.16, 3G, and 802.11) services.

A WAN-access controller (not shown), which may take the form of software residing on a physical device, such as one or more nodes 701-706, may be provided for managing access to the WAN services, including partitioning information flows across multiple WAN services, user channels within those WAN services, and/or subspace channels. Such access may be performed with respect to a combination of technical rules and business rules. For example, WAN access is typically managed using technical rules, such as network load balancing. For example, network load balancing may comprise balancing traffic across two or more WAN links. This capability can balance network sessions, such as Web, email, streaming media, etc., over multiple connections in order to spread out the amount of bandwidth used by each node 701-706, thus increasing the total amount of bandwidth available.

In some aspects of the invention, WAN access can also be influenced by business rules, such as employing cost/service ratios when determining whether and how to different WAN services. For example, the WAN-access controller (not shown) can anticipate the economic cost of particular WAN services to the user, as well as user communication needs, when assigning WAN access to individual nodes 701-706. A destination or source node 701-706 may provide the WAN-access controller (not shown) with a cost tolerance, which can be updated relative to the type of communication link desired. For example, high-priority communication needs (such as particular voice communications or bidding on an online auction) may include permissions to access more expensive WAN services in order to ensure better reliability.

The overall goal of WAN access may be to achieve optimal connectivity with minimum cost. Accordingly, WAN-access algorithms may include optimization techniques, including stochastic search algorithms (like multi-objective genetic algorithms). Multi-objective optimization are well known in the art, such as described in E. Zitzler and L. Thiele, "Multi objective evolutionary algorithms: A comparative case study and the strength pareto approach," IEEE Tran. on Evol. Comput., vol. 3, no. 4, November 1999, pp. 257-271 and J. D. Schaffer, "Multiple objective optimization with vector evaluated genetic algorithms," Proceedings of 1st International Conference on Genetic Algorithms, 1991, pp. 93-100, both of which are incorporated by reference.

Some aspects of the invention may employ the multiple WANs depicted in FIG. 7 to perform subspace processing, as described throughout this disclosure. As shown, a first node (e.g., one of the nodes 701-706) may wish to exchange information with a second node, such as a server (not shown) via a plurality of WAN services. As is known, WAN access may comprise multiple different routes or paths that data packets can traverse between the first and second nodes. In addition, some of the different routes may involve different network technologies.

In one aspect, a first path between the first and second nodes may comprise a WiFi-based network (i.e., based on the IEEE 802.11 family of wireless networking standards), such as depicted by the path to the 802.11 access point 717. A second path may comprise a 4G cellular network, such as a Long term Evolution (LTE) based cellular network or an 802.16 WiMax network, depicted by the path to the 802.16 access-point terminal 716. To use either of these different WAN paths the first node 701-706 comprises (or has access to) appropriate hardware and software to be able to communicate according to the corresponding standards. Many modern communication devices (e.g., cell phones, smart phones, handheld communicators, computers or servers with communication functionality, network gateways, wireless access points, audio/video devices with communication functionality, appliances with communication functionality, wearable communication devices, etc.) include network adapters for multiple different network technologies. Nodes 701-706 configured to cooperatively perform subspace processing in a MIMO system can also enable the first node (i.e., one of the nodes 701-706) to access WAN services that it would otherwise not be able to access.

Some aspects of the invention employ multiple different network technologies to support a single data transfer operation (or a single connection) between communication nodes. The use of multiple different network technologies associated with multiple different communication paths to support a single data transfer operation or other function may be referred to as "heterogeneous networking." Thus, cooperative subspace processing, such as subspace coding and/or subspace decoding, may employ heterogeneous networking.

FIG. 8 is a block diagram of a plurality M of transmitting nodes 806.1-806.M configured in accordance with aspects of the invention. A data source 800 is coupled to a sub-space coder,

such as a MIMO processor 802. The nodes 806.1-806.M are in close proximity to each other and are communicatively coupled together, such as by a WLAN 899. The MIMO processor 802 provides sub-space coding to the data. Sub-space coding may comprise spreading codes and/or channel codes, such as block channel codes, which spreads each data symbol over multiple code symbols (i.e., coded data symbols). The resulting coded data is then grouped by the MIMO processor 802 and distributed to the plurality of nodes 806.1-806.M, which may comprise wireless terminals (denoted as WTs) configured to communicate in a WWAN.

In one aspect of the invention, each node 806.1-806.M comprises a WLAN interface 807.1-807.M configured to receive and/or transmit coded data from/to the MIMO processor 802. The MIMO processor 802 may comprise one or more of the nodes 806.1-806.M. For example, the MIMO processor 802 may reside in one of the nodes 806.1-806.M that is a source node.

In one aspect of the invention, each of the nodes 806.1-806.M is configured to transmit signals into a WWAN, and, thus, each comprises a modulator 808.1-808.M and a WWAN interface 809.1-809.M. Modulation may include channel coding. In one aspect of the invention, modulation 808.1-808.M comprises employs WWAN channel weights, such as may be used for sub-space processing. The channel weights may be provided by the MIMO processor 802. Thus, in some aspects of the invention, the MIMO processor 802 couples coded data symbols and sub-space codes to the each of the nodes 806.1-806.M.

FIG. 9A illustrates software components residing on a non-transitory computer-readable memory 950. A subspace coding source-code segment 951 is configured to generate a plurality of subspace coefficients to encode a plurality of original data packets. The subspace coding source-code segment 951 is configured to accept as input at least one of a set of information inputs, including data signals (e.g., original data packets), training signals (e.g., known symbols), WWAN channel estimates, and WWAN-control information.

The subspace coding source-code segment 951 is configured to provide as output at least one of a set of signals, including coefficients for subspace coding and subspace-encoded data. In one aspect of the invention, a distribution source code segment 952 is provided for distributing the

coefficients for subspace coding and the subspace-encoded data received from source-code segment 951 to a plurality of nodes. The distribution source code segment 952 may optionally function to couple at least one of a set of information inputs to the source-code segment 951, including data packets from other nodes.

FIG. 9B illustrates software components of a receiver residing on a non-transient computer-readable memory 960. A subspace code source-code segment 961 is configured to acquire subspace code coefficients from a plurality of cooperating receiving nodes. These coefficients are subsequently used to decode received subspace-coded data. In one aspect of the invention, the source-code segment 961 may estimate subspace coefficients from measurements of the propagation channel. For example, pilot tones and/or other control information in a received signal may convey code vectors that encode the original packets. For an antenna array comprising a plurality of wireless terminal nodes, the subspace coefficients may comprise space-frequency codes (e.g., subcarrier/antenna array weight vectors) and/or space-time codes (e.g., weighted Rake taps). The subspace code source-code segment 961 is configured to accept at least one of a set of inputs, including signals that convey code vectors (including received signals in which known symbol values are scaled by subspace code coefficients), coded data, channel estimates, and WWAN-control information.

The subspace code source-code segment 961 is configured to provide as output at least one of a set of information signals, including subspace coefficients, encoded data packets (such as to be distributed to one or more nodes), combined data packets (e.g., data packets received from a plurality of nodes and then combined, wherein the data received may comprise encoded data), and estimates of original data packets after decoding. A distribution source code segment 962 is provided for distributing at least one of a set of signals, including subspace coefficients (used for subspace coding and/or decoding), encoded data packets, combined data packets, and estimates of original data packets following decoding. The distribution source code segment 962 may optionally function to couple at least one of a set of information inputs to the source-code segment 961, including data packets received by other WTs, training signals (including code vectors) received by other nodes, channel estimates (either of both locally estimated and received from other nodes), WWAN-control information, code vectors (including decoding values)

received from at least one other node, and decoded data received from at least one other node. Accordingly, the source code segment 1962 may select which WTs to receive information from to cooperatively perform subspace demultiplexing.

Since software implementations of the invention may reside on one or more computer-readable memories, the term computer-readable memory is meant to include more than one memory residing on more than one node.

Aspects of the invention described herein may employ subspace processing methods (including software implementations) and apparatus implementations employing cooperative antenna arrays in a WWAN. While in some aspects of the invention, nodes in a cooperating group share the same WWAN access, other aspects of the invention provide for nodes with access to different WWANs. In some aspects, one or more nodes may have access to a plurality of WWANs and WWAN services. In some cases, one or more nodes may not be able to directly access any WWAN.

FIG. 10 is a network diagram of a cooperative subspace processing system in accordance with aspects of the invention. For example, some aspects described with reference to FIG. 1 are depicted in FIG. 10. A method for transmitting data from at least one source node, such as node 131.2, to at least one destination node, such as node 141.2, may comprise employing one or more coding nodes, such as nodes 131.1, 131.N_t, 141.1, and 141.N_r. In one aspect of the invention, coding nodes on the transmitting side (e.g., nodes 131.1 and 131.N_t) are employed. In another aspect, coding nodes on the receiving side (e.g., nodes 141.1 and 141.N_r) are employed. In yet another aspect, coding nodes at both sides (e.g., a transmitting group 130 and a receiving group 140) of the link are employed (e.g., nodes 131.1, 131.N_t, 141.1, and 141.N_r). The aforementioned aspects, as well as other aspects of the invention, may employ intermediate nodes (not shown) in the communication link.

In one aspect depicted in FIG. 10, the source node 131.2 is communicatively coupled to a plurality N_t of transmitting nodes 131.1 and 131.N_t. For example, the nodes 131.1-131.N_t may comprise a local group 130 communicatively coupled together via WLAN links 151-153. A

plurality of data packets at the source node 131.2 are coupled to one or more of the other nodes (e.g., nodes 131.1 and 131.N_t) in the group 130 for transmission to a receiving group 140 that includes the destination node. For example, nodes 131.1 and 131.N_t may transmit signals into a scattering-rich WWAN channel (such as depicted by the channel 99 in FIG. 1). An equivalent network path model for the scattering-rich channel is depicted by network links 117.1, 117.N-1, 119.1, and 119.N-1.

To simplify the discussion of this aspect of the invention, N_t and N_r are equal (denoted by the value N). Another simplification that characterizes this particular aspect is that there are no network paths directly from the source node 131.2 to the receiving group 140, and there are no network paths from the transmitting group 130 that go directly to the destination node 141.2. In other aspects of the invention, the communication scheme may include network paths directly from the source node 131.2 to the receiving group 140 and/or network paths from the transmitting group 130 directly to the destination node 141.2.

The destination node 141.2 may be communicatively coupled to other nodes (e.g., nodes 141.1 and 141.N_r) in the receiving group 140. For example, a WLAN (depicted by WLAN links 155 and 157) may couple the destination node 141.2 to other receiving nodes 141.1 and 141.N_r, such as to assist the destination node 141.2 in subspace de-multiplexing (i.e., decoding) linear combinations of the signals transmitted from the transmitting group 130.

As depicted in FIG. 10, the receiving node 141.1 receives a linear combination of transmitted signals from network paths 117.1 and 119.1 originating at nodes 131.1 and 131.N_t, respectively. The receiving node 141.N_r receives a linear combination of transmitted signals from network paths 117.N-1 and 119.N-1 transmitted by nodes 131.1 and 131.N_t, respectively. For example, when the transmissions reside in the same band and time interval, the resulting aggregate signal (i.e., superposition) comprises a linear combination of the transmitted signals, typically referred to as interfering signals. In a MIMO system, subspace demultiplexing (i.e., subspace decoding) may be employed to separate the interfering signals at the receiver. This requires the linear combinations of signals received at nodes 141.1 and 141.N_r to be linearly independent (i.e.,

uncorrelated). Depending on the type of signaling protocol, the linear combinations may comprise scalar and/or complex coefficients.

In one aspect of the invention, the randomness of a scattering-rich WWAN channel encodes the transmitted signal such that the coefficients of the linear combinations are random. In another aspect of the invention, subspace multiplexing is performed by the transmitting group 130, which may comprise precoding and/or other subspace coding. When the subspace multiplexing coefficients are based on channel measurements, as they typically are when performing precoding, the coefficients of the linear combination are randomly chosen by virtue of the randomness of the channel. In some aspects of the invention, the transmitting group 130 may employ an invertible transform to spread data packets across multiple subcarriers and/or subspaces. Such invertible transforms may include CI transforms, as will be discussed below. A CI transform maps a set of data points with discrete values into a pseudo-random (i.e., statistically random) set of coded data points.

In one aspect of the invention, the coding nodes 131.1, 131.N_t, 141.1, and/or 141.N_r are selected to build up the dimension of the subspace spanned by the received coded signals. For example, in a multipath channel, the transmitting nodes 131.1 and 131.N_t may be selected to ensure a set of uncorrelated subchannels (e.g., spatially separated nodes 131.1 and 131.N_t are selected, or the nodes 131.1 and 131.N_t may be provided with different antenna polarizations or directivity). The receiving nodes 141.1 and 141.N_r may be selected to provide a sufficient number (e.g., at least *N*) of uncorrelated subchannels. In other aspects of the invention, coding nodes may include intermediate nodes (not shown) in the transmission path. The intermediate nodes may be selected to provide sufficient degrees of freedom at the receiving group 140.

In one aspect of the invention, a network comprises one or more source nodes, one or more destination nodes, and one or more coding nodes. The source nodes are configured to transmit a plurality of original data packets. The coding nodes are configured to output linear combinations of the original data packets wherein coefficients of the linear combinations are randomly chosen. The coding nodes are selected to provide a sufficient number of degrees of freedom to enable the one or more destination nodes to decode the linear combinations.

In one aspect of the invention, a vector of subspace coefficients accompanies the linear combinations. For example, pilot tones (and/or other control data) may convey channel information used to encode the data packets. Precoding coefficients may be distributed to the transmitting nodes (e.g., nodes 131.1 and 131.N_t) along with coded data. Channel estimates used for decoding may be conveyed by the receiving nodes 141.1 and 141.N_r to the destination node 141.2 along with received linear combinations.

In some aspects of the invention, signals are relayed through the network. The channel of each relay link (i.e., hop) introduces its own channel distortions equally to the data payload and any pilots and/or other signals used to convey the vector of coefficients. For example, the naturally occurring linear combinations produced on each relay link are applied to the data payload and the pilot signals in an OFDM signal. The values of the received pilot tones in an OFDM signal may constitute the vector of coefficients. In other types of signals, overhead signals, such as known sequences used for synchronization and/or known values used for other control purposes, sometimes reside in packet headers. Measurements of these control values at a receiver may constitute the vector of coefficients. At each relay node, the linear combinations applied to the vector of coefficients are the same as the linear combinations applied to the data.

FIG. 11A is a flow diagram illustrating a method for performing cooperative subspace multiplexing in accordance with some aspects of the invention. A plurality of transmitting nodes is selected to receive a plurality of subspace-coded components 1101. A data set (e.g., a data file) is separated into a plurality N of original components 1102, where N equals a number of required degrees of freedom to decode the subspace-coded components. The number N may be determined based on the number of transmitting nodes to which the subspace-coded components will be distributed. An optional step (not shown) may comprise determining a number of the coded components to be distributed to each transmitting node (such as may be determined by each node's storage capacity, processing capability, and/or its number of uncorrelated transmitting antennas). The subspace-coded components are produced 1103 by generating at least N random linear combination of the original components. The coded components and any associated code vectors are distributed to the selected transmitting nodes 1104 such that at least

one of the selected transmitting nodes has a number of coded components that is less than the number of required degrees of freedom. The selected transmitting nodes store the coded components and any associated code vectors before transmitting this data. In some aspects of the invention, the selected transmitting nodes comprise edge nodes of a content delivery network.

In one aspect of the invention, selecting the transmitting nodes 1101 comprises selecting one or more nodes nearby a source node in a peer-to-peer network. If a selected node can transmit a unique linear combination of the original data components (relative to the other selected nodes), then that node builds up the dimension of the subspace spanned by the transmitted coded signals until the dimension of the subspace equals the number of the original components. Therefore, in some aspects of the invention, if there are N original components (e.g., step 1102) to be transmitted simultaneously, then at least N coded components comprising unique linear combinations of the original components are generated (e.g., step 1103), such that the transmission subspace is provided with a dimension of at least N . If the dimension of the transmission subspace is greater than the dimension of the subspace spanned by the coded signals (e.g., in a WWAN, if the number of transmitting antennas is greater than the number of original data components), then there is at least one unused dimension in the transmission subspace. This can be regarded as redundancy in the transmission, and, in a wireless network, it may serve to increase gain.

In another aspect of the invention, selecting the transmitting nodes 1101 comprises selecting one or more nodes nearby a destination node in a peer-to-peer network. If each selected node receives a unique linear combination of the original data components and then retransmits its received data to the destination node, then each selected node builds up the dimension of the subspace spanned by the coded signals received at the destination node until the dimension of the subspace equals the number of the original components. In a wireless network, any additional linear combinations of the original data components may be used to increase gain.

In other aspects of the invention, selecting the transmitting nodes 1101 comprises selecting one or more intermediate nodes of the communication path(s) in a peer-to-peer network.

In aspects of the invention, the source node, the transmitting nodes, and/or the channel may encode the original components 1103. For example, the source node and/or the transmitting nodes may provide subspace coding, such as precoding, to the original data components. Nodes in between the source node and the destination node may provide subspace coding, such as by combining received signals and then retransmitting the combined signals. Signals that are transmitted in a wireless channel are typically received by more than one receiver. Thus, if the channel is characterized by rich scattering, then the linear combinations received by different receivers are more likely to be independent. Thus, selected transmitting nodes nearby the destination node employed for receiving signals may forward the received coded signals to the destination node for decoding.

FIG. 11B is a flow diagram illustrating a method for performing cooperative subspace multiplexing in accordance with some aspects of the invention. The method comprises receiving at a node in a peer to peer network, at least one of a set of subspace-coded components 1111 comprising a linear combination of original data components characterized by a number of degrees of freedom required to decode the set of subspace-coded components. The method further comprises receiving at said node, at least one code vector associated with the at least one subspace-coded component 1112; and storing at said node, the subspace coded component(s) and the code vector(s) 1113 to provide a stored set, the stored set having a number of the subspace coded component(s) that is less than the required number degrees of freedom. The method may optionally comprise transmitting the subspace-coded component(s) and the code vector(s) from the node to a destination node 1114, which collects a sufficient number of the subspace-coded components and code vectors to decode the coded components. For example, the destination node may collect the code vectors, which are then used to construct a code matrix. When the rank of the matrix equals the number of original components, then matrix operations employing the collection of code vectors can decode the subspace-coded components. In some aspects of the invention, nodes that store the coded components and the code vectors comprise edge servers in a content delivery network.

In one aspect of the invention, a Cooperative-MIMO system configured to operate in a WWAN efficiently stores data in a distributed manner. For example, multiple components (i.e., original

components) of a data set (e.g., a data file) may be transmitted in parallel (i.e., at the same time in the same channel). Each antenna of a receiver receives a single coded piece, which comprises a linear combination of the transmitted components. In a cooperative-MIMO receiver, a plurality of nodes may be configured to cooperatively process received signals. A node with more than one antenna may receive more than one coded piece. For example, if the antennas (specifically, their channels) are not correlated, then each antenna receives a unique linear combinations of the original components. Signals that are correlated may simply be combined, which may provide certain diversity benefits.

With reference to FIG. 11A, in one aspect of the invention, the number of original components in step 1102 is related to the number of spatial subchannels. For example, the number of original components may be less than or equal to the number of uncorrelated spatial subchannels, the number of transmit antennas, and/or the number of receive antennas. In some aspects, higher-quality subchannels (e.g., those associated with greater eigenvalues) may carry more data, such as by employing higher modulation schemes. Thus, multiple coded components may be allocated to a single subchannel.

In one aspect of the invention, the number of wireless nodes selected to store components (e.g., step 1101) may depend on a number of factors, including (but not limited to) the total number of transmit antennas, the number of antennas on each node, the quality of subspace channels, network topology, the number of nodes near the destination node, etc.

In some aspects of the invention, step 1103 may comprise determining a random combination of original components to store at a particular node. In one aspect, the physical wireless channel provides the required statistical randomness for the coding, since temporal and spatial variations of the channel are random. Channel reciprocity (i.e., radio waves propagating in both directions of a radio link between a pair of transceivers experience the same multipath channel distortions at the same time and frequency), may be exploited by the transceivers at opposite ends of a wireless link to agree on a random code, which depends on their common channel. For example, each transceiver may estimate the common channel from known control signals (such as pilot tones in an OFDM

signal) received from the other transceiver. Thus, in some aspects, the code vector can be determined from channel estimation.

In one aspect of the invention, there is no coordination between the selected nodes to decide which nodes store which components of the file. Rather, in a wireless network, each node's channel(s) may determine what combination(s) of components it receives.

In some aspects of the invention, a central controller is not required to maintain a state of the contents of all the nodes and differentiate between the nodes. A selected node may not know exactly what the other selected nodes have stored. For example, each node can estimate its own channel, from which it derives information about the linear combination(s) that it receives. However, if the node's channel is not correlated with any other node's channel, the node cannot directly estimate channels employed by the other nodes. Thus, the node does not know what linear combinations other nodes receive unless that information is shared by the other nodes.

In some aspects, the selected nodes do not coordinate for storing components. Rather, a destination node or a WLAN controller accesses the selected nodes to download the linear combinations and channel estimates (e.g., subspace weights) until a sufficient amount of information is obtained to decode the coded components. The destination node completes its download once it has enough information to recover the original components of the data set.

FIG. 11C is a diagram depicting processing methods and processing devices in accordance with aspects of the invention. A file is partitioned into a plurality of original components in processing block 1121. Each original component may comprise one or more data packets. In processing block 1122, each of a plurality of nodes in a peer-to-peer network is assigned to receive one or more of the original components and/or subspace-coded versions of the components. In processing block 1123, subspace-coded components and the associated subspace code vectors are generated. The components and, optionally, their subspace code vectors are distributed to the assigned nodes (from block 1122) 1124.

In processing block 1122, the nodes assigned to receive the components may be selected based on their locations in the network. In one aspect of the invention, nodes that are nearby a source node are selected as transmitting nodes. In another aspect, nodes nearby the destination node are selected as receiving nodes. Since these so-called receiving nodes convey their received signals to the destination node, they may be referred to as transmitting nodes. In other aspects, intermediate nodes are selected to the components.

In block 1122, the number of components assigned to each peer may be related to a combination of various factors, including (but not limited to) the bandwidth to the peer (which may include subchannel quality and the number of subchannels), the bandwidth from the peer to the destination node, and the peer's storage and/or processing capability.

In processing block 1123, code vectors may be generated from channel measurements. For example, pilot tones and/or other known signals accompanying a data transmission may be used to estimate the channel. When coding comprises the effects of scattering, then the code vector may comprise channel estimates. When precoding is performed, and the precoding is based on channel measurements, then a receiver may employ channel estimates to estimate the precoding values. In some aspects, handshaking between two peers may be employed to determine code vectors. For example, such handshaking is commonly used to ensure key match by two parties employing the randomness in the channel for key generation. In other aspects, a transmitter may employ a code matrix based on an invertible transform, such as a CI transform.

In block 1123, each coded component r_{n_r} received at an n_r^{th} node may be expressed by

$$r_{n_r} = \sum_{i=1}^k \alpha_{n_r,i} x_i$$

where the coefficient $\alpha_{n_r,i}$ denotes the i^{th} random coefficient corresponding to the n_r^{th} assigned node, and x_i is the i^{th} original component. The set of coefficients $\alpha_{n_r,i}, i = \{1, \dots, k\}$ is regarded as the n_r^{th} subspace code, or subspace code vector.

In some aspects of the invention, block 1123 precedes block 1124. In one aspect, signals distributed to an assigned node comprise transmitted original components that are linearly coded

by the communication channel. For example, the source node may comprise an antenna array for transmitting the original components to the assigned nodes. However, in order to achieve this linear coding and ensure the codes are uncorrelated, the transmitters and receivers are selected to provide uncorrelated subchannels.

In another aspect of the invention, block 1124 may precede block 1123. The coefficients $\alpha_{n_r,i}$ may comprise subspace antenna array weights, such as precoding weights, distributed to the assigned nodes. The assigned nodes may then apply the weights to the original components and/or previously coded components to generate coded components. In one aspect of the invention, the subspace code vector and the coded components are generated (1123) by scattering in the channel after the original components (and/or previously coded components) are distributed (1124) to the assigned nodes.

In one aspect of the invention, the coded components and/or original components are stored at their assigned nodes, which do not transmit the data until directed to do so. The recipient(s) of the transmitted data may comprise other coding nodes and/or the destination node.

Processing blocks 1131-1133 depict a method for decoding the file that was encoded and distributed to a plurality of nodes, such as in the manner described with respect to processing blocks 1121-1124. In processing block 1131, code vectors are collected from at least one peer. The coded components may also be collected in this step 1131, or in a subsequent step 1132 and/or 1133. In processing block 1132, a determination is made if a sufficient number of linearly independent code vectors have been collected to decode the coded components. If a sufficient number of code vectors have been collected, then decoding is performed (i.e., processing block 1133). If not, then more code vectors may be selected (e.g., control returns to block 1131).

In accordance with one aspect of the invention, processing block 1132 may provide for assembling the collected code vectors as a matrix. The matrix may comprise a $((\sum_{n=1}^{n_r} k_n) \times N)$ matrix wherein k_n is the number of coded components stored at an n^{th} peer, n_r is the number of peers, and N is the number of original components.

In one aspect, a determination is made regarding whether the dimension $\sum_{n=1}^{n_r} k_n$ is sufficient to decode the coded components collected from the peers. For example, if $(\sum_{n=1}^{n_r} k_n) = N$, then it may be possible to decode the N equations (e.g., the coded components) having N unknowns (i.e., the original components). Processing block 1132 may be configured to calculate the rank of the matrix. For example, if the rank = N , then the matrix may be diagonalized.

Processing block 1132 may be configured to determine how well-conditioned the matrix is. For example, the eigenmodes may be evaluated, which may comprise calculating the corresponding eigenvalues. If the matrix is sufficiently well-conditioned, then decoding 1133 is performed. In some aspects of the invention, a requirement for what constitutes well-conditioned may depend on the SNR of the received signals. Thus, block 1132 may provide for measuring SNR (or some similar measure of link quality), determining a threshold of what constitutes a well-conditioned matrix (e.g., threshold eigenvalues), and then determining if the matrix is sufficiently well-conditioned to decode the subspace-coded components. If the matrix is not sufficiently well-conditioned, block 1132 may discard one or more highly correlated code vectors (and the associated coded component(s), if relevant), or combine at least some of the correlated code vectors. Then control passes back to block 1131, whereby one or more additional code vector(s) are collected.

In some aspects of the invention, block 1131 comprises adaptive array processing to dynamically select (and/or de-select) transmitting and/or receiving antennas, such as to increase the rank and/or improve the conditioning of the channel matrix, $\mathbf{H}$. Such array processing may comprise changing the number N of simultaneously transmitted original components. In cooperative-MIMO processing, adaptive array processing may comprise dynamically selecting and/or de-selecting peers (transmitting nodes and/or receiving nodes) employed to perform cooperative subspace processing. Adaptive array processing may include changing the antenna array weights at the transmitting and/or receiving array, such as to change the rank and/or improve the subspace channels. When the processing of block 1131 is repeated, block 1131 may provide for selecting code vectors (and, thus, coded components) from new nodes.

In some aspects of the invention, upon failure of the destination node (or its cooperative receiving nodes) to acknowledge transmitted packets, the packets are retransmitted. In response to the requirement to retransmit the data, the source node may adapt the subspace processing provided to the transmitted signals (such as by providing adaptive array processing). If a wireless channel is employed in the link, and the delay between transmission and retransmission is equal to or greater than the wireless channel's coherence time, then new linear combinations of the original components are generated. Thus, block 1131 may collect new code vectors from the same nodes, which are then processed with previously received code vectors in block 1132.

FIG. 12 is a diagram depicting processing methods and processing devices in accordance with aspects of the invention. In a network, a method of transmitting data from a source node to a destination node comprises forming linear combinations of original packets from a source node to produce subspace-coded packets (processing block 1201), and delivering the subspace-coded packets to the destination node over one or more network paths (processing block 1202). The destination node transmits feedback (such as acknowledgements) back to the source node (processing block 1203). Based on the responsiveness of the destination node (which includes a failure to respond), the source node causes new linear combinations of the original packets to be formed (processing block 1204) to generate new subspace-coded packets, and delivers the new subspace-coded packets to the destination node (processing block 1205).

In one aspect of the invention, a cooperative-MIMO system is employed whereby cooperating nodes are configured to perform subspace processing, such as subspace multiplexing (e.g., on the transmitting side of a link) and/or subspace demultiplexing (e.g., on the receiving side of a link). The processing block 1201 may perform array processing, such as selecting antennas of a fixed array and/or nodes of a cooperative-MIMO array to transmit signals in a wireless channel. The block 1201 may select subspace antenna weights for encoding the transmitted signals.

In some aspects of the invention, parallel transmissions in a multipath channel produce random combinations of the transmitted signals. In one aspect, precoding applied to the transmitted signals may be selected such that propagation in the multipath channel provides at least some

degree of decoding. In such aspects, the channel (and, thus, processing block 1202) does not encode the transmitted signals.

In one aspect of the invention, block 1203 comprises providing acknowledgements from the destination node to the source node upon receipt of a container packet (i.e., coded packet, which effectively encapsulates the original packets) and/or upon decoding the encapsulated packets (i.e., the original packets), such as described in the '854 application, which is incorporated by reference in its entirety. In another aspect of the invention corresponding to block 1203, feedback from the destination node may comprise control signals (e.g., pilot tones), which are employed by the source node for channel estimation, and, subsequently, encoding the original packets. In accordance with some aspects of the disclosure, adaptive array processing performed by at least the source node relies on feedback from the destination node, such as to select an appropriate subspace dimension and/or optimize the subspace channels.

With reference to block 1204, adaptive array processing at the transmit side of the link may reselect the transmitting nodes, add new nodes, and/or adapt precoding and/or antenna array weights. This generates new subspace codes, thus providing new linear combinations of the original packets. In some aspects, block 1204 may comprise performing adaptive array processing at the receive side of the link. At the receive side, cooperating receiver nodes may be reselected and/or added. In some aspects, the antenna array weights and/or other subspace coding weights at the receive side may be adapted. Thus, adaptive array processing in a cooperative network may comprise adapting the degrees of freedom spanned by the subspace signals.

In one aspect of the invention, the receiver may convey to the transmitter how many degrees of freedom it has received and/or is capable of receiving. This technique can be used to select the number of transmitting antennas (M_t) and/or receiving antennas (M_r) in a cooperative-MIMO system. Similarly, communicating information about degrees of freedom in either or both directions in a link can be used to select transmitting and/or receiving nodes in a cooperative-MIMO system. In some aspects of the invention, the source node may respond to feedback (including the absence thereof) from the destination node by transmitting new linear combinations of the original packets.

As described with respect to FIG. 7, the network links 117.1, 117.N-1, 119.1, and 119.N-1 depicted in FIG. 10 may comprise two or more different WANs.

FIG. 13 is a diagram depicting processing methods in accordance with aspects of the invention. In one aspect of the invention, a communication device comprises at least a first WAN interface configured for communicating in a first WAN, and has access to a second WAN interface configured for communicating in a second WAN, the first WAN being different than the second WAN. A network controller (such as a processor) manages data transfer between the communication device and a destination node using multiple different network routes, such as the first WAN and the second WAN. The network controller may be configured to perform the steps shown in FIG. 13.

In accordance with one aspect of the invention, the network controller produces a plurality of original packets 1301 to be transferred to the destination node. A plurality of subspace-coded packets is generated 1302 from the original packets by employing subspace coding to linearly combine the original data packets. The coded packets are distributed across the plurality of different WANs to the destination node 1303. Optionally, additional subspace coding may be provided to the coded packets while they are en-route to the destination node 1304.

In one aspect of the invention, the number of original packets is selected to be less than or equal to the total dimension of the subspace between the source and destination nodes. For example, the total dimension of the subspace may equal the sum of subspaces in each of the different WANs. The total dimension of the subspace may be used to select subspace codes. In some aspects, the dimensions of subspaces in one or more of the different networks may be used to select subspace codes. For example, in one aspect, first subspace code(s) corresponding to a first WAN may encode a first set of packets, and second subspace code(s) corresponding to a second WAN may encode a second set of packets. Furthermore, a universal code(s) may be employed for encoding values transmitted over both first and second WANs. In such an aspect, one or more receivers at the destination would perform WWAN-specific subspace decoding and universal subspace decoding.

In some aspects of the invention, step 1302 comprises generating subspace codes corresponding with the subspace coded packets. In step 1303, the subspace codes may be distributed with the coded packets. In some aspects of the invention, step 1302 and/or 1303 comprises selecting at least one set of transmitting nodes, coding nodes, and/or receiving nodes to cooperatively perform subspace coding. Such selection(s) may depend on the dimension of the codes (and the coded packets). In some aspects of the invention, the selection(s) may be based on adaptive array processing algorithms, which may adapt either or both the number of nodes and the subspace codes based on the degrees of freedom at the receiver.

In some aspects of the invention, if packets are lost or the bit-error rate is high, it may be desirable to decrease the transmission rate, such as by removing one or more low-quality subchannels, adapting the coding to increase the processing gain, or otherwise introducing more redundancy in the transmitted information.

In one aspect of the invention, subspace codes are generated at the destination node. In another aspect of the invention, subspace codes are generated by a plurality of transmitting nodes communicatively coupled to the source node. In another aspect of the invention, subspace codes are generated by transmitting a plurality of known signals from a transmitting array through a scattering-rich channel to a receiving array. In another aspect of the invention, a MIMO processor coupled to a receiving array is configured to produce subspace codes. Subspace codes may be produced and/or modified by intermediate nodes in a link between the source node and the destination node.

Since subspace multiplexing and subspace demultiplexing are coordinated between the source and destination node (respectively), different networks may be employed simultaneously without requiring those networks' servers to coordinate data transfers with each other.

FIG. 14 is a diagram depicting processing methods in accordance with aspects of the invention. In one aspect of the invention, a method for transmitting a file between a server and a client through one or more network paths comprises generating a plurality of linearly coded packets

from a plurality of original packets 1401, and performing cooperative subspace processing to increase a dimension of a subspace spanned by the linearly coded packets 1402. The linearly coded packets are sent to the client 1403, which, upon reception of at least one of the coded packets, provides feedback to the server 1404. Based on the feedback, new linearly coded packets may be transmitted to the client 1405.

In one aspect of the invention, the linearly coded packets are generated 1401 as linear combinations of the original packets. If a scattering channel is employed (directly or indirectly) for generating coefficients of the linear combinations, then such linear combinations may be random. In other aspects, a deterministic process may be employed for generating the coefficients. The deterministic process may employ an invertible transform characterized by a mapping of original data packets into a set of pseudo-random coded packets.

In processing block 1402, cooperative subspace processing is performed by a plurality of nodes to build the dimension of the subspace spanned by the linearly coded packets. For example, the plurality of nodes may cooperate to produce parallel (i.e., simultaneously transmitted) transmissions of the coded packets. In one aspect, the plurality of nodes is selected to receive a plurality of coded packets (e.g., precoded packets) from the server (e.g., a source node) and then simultaneously transmit the coded packets to the client (e.g., a destination node). In another aspect, the plurality of nodes is selected to receive the original packets and then encode the original packets to produce the coded packets before coordinating a simultaneous transmission of the coded packets to the client. In another aspect, the plurality of nodes comprises multiple transmitting nodes selected to transmit original packets and/or coded packets into a multipath channel, which linearly encodes the transmitted packets. In another aspect, the plurality of nodes comprises one or more intermediate nodes between the server and the client, the intermediate node(s) configured to receive and retransmit the coded packets. Intermediate nodes may optionally provide additional linear coding to the packets they receive. In other aspects, the plurality of nodes comprises one or more receiving nodes communicatively coupled to the client and configured to cooperatively receive transmitted coded packets and forward the received packets to the client. In such aspects, the receiving node(s) are selected to build the dimension of

the subspace of signals received by the client. In some aspects of the invention, processing blocks 1401 and 1402 may be combined.

In some aspects of the invention, the processing block 1403 comprises sending the linearly coded packets to the client over a plurality of different networks. In these aspects, packets to be transmitted are distributed over the different network paths. Subspace multiplexing (e.g., coding) may comprise interleaving the coded packets over the different networks, and subspace de-multiplexing (e.g., decoding) may comprise collecting the coded packets received from the different networks, followed by a combining process in which the received coded packets are combined and decoded to retrieve the original packets.

In some aspects of the invention, interleaving the linearly coded packets to the client over a plurality of different networks may comprise network load balancing (e.g., bit loading) the multiple channels employed in the link, such as distributing more packets to channels able to support higher bandwidth and fewer packets to channels that support relatively lower bandwidth. In some aspects of the invention, these channels may comprise channels on different networks (e.g., WANs), such as channels employed by block 1403.

In block 1404, upon reception of any of the coded packets at the client, the client may provide feedback. For example, the client may transmit an acknowledgement to the server upon retrieving each of the original packets after decoding the received coded packets. However, as described in the '879 application (which is incorporated by reference in its entirety), the coded packets encapsulate the original packets, thus concealing header information in the original packets. Thus, the coded packets may comprise their own headers and employ different protocols than those used with the original packets.

Different acknowledgement protocols may be employed depending on the message layer (i.e., original packet, and coded (or encapsulating) packet). For example, TCP may be employed for the original packet, whereas the acknowledgement mechanism employed with the coded packets may be similar to mechanisms employed to coordinate adaptive antenna array processing. As mentioned in the '107 application (which is incorporated by reference in its entirety), latency can

severely impede TCP. Thus, in links with high latency, such as satellite links, it is common to automatically transmit TCP acknowledgements whether packets are received or not, and then utilize a different type of transmission control protocol that tolerates latency. In aspects of the invention, the receiver, or even the transmitter, may automatically send acknowledgements for each transmission, thus, effectively short-circuiting the TCP mechanism. Then any of the adaptive array mechanisms employed in MIMO may be used as a substitute control protocol.

In processing block 1405, based upon the feedback, the server (and/or any intermediate nodes) may transmit at least one new linearly coded packet to the client. For example, absence of an acknowledgement after a predetermined amount of time may trigger retransmission of the coded packet(s).

In some aspects of the invention, network load balancing may be employed for distributing data loads across different network channels. For example, when data is to be interleaved over multiple channels (e.g., subchannels and/or network channels, including network channels in different networks), bit loading may be employed for loading more data into higher-bandwidth channels and less data into lower-bandwidth channels. In related discussions, more error correction (such as lower code rates) may be employed in lower-quality channels, which essentially reduces the amount of information transmitted in those channels. With respect to subchannels, more data may be loaded on subchannels with higher eigenvalues, such as discussed above. Various techniques for distributing data over multiple channels with respect to the effective channel bandwidth are described throughout the '107 application, which is incorporated by reference in its entirety. Similarly, reliability assessments of all the individual channels (which may be based on BER, SNR, and/or other qualitative measures of a channel) may provide a basis for allocating processing resources, such as the number of nodes employed to perform subspace processing.

FIG. 15A is a diagram depicting processing methods in accordance with aspects of the invention. In one aspect of the invention, a method is provided to manage data interleaving in a communication network that simultaneously employs multiple network channels to transmit data from a source node to a destination node. As used herein, a network channel may comprise a

user channel separated from other user channels by at least one of the following multiple-access schemes: frequency division multiple access (e.g., OFDMA), time division multiple access (TDMA), and code division multiple access (e.g., CDMA). For example, a first CDMA channel may be encoded with a first Walsh code and a second CDMA channel may be encoded with a second Walsh code, wherein the first and second Walsh codes are orthogonal to each other. In the '107 application, which is incorporated by reference in its entirety, the user channels are also referred to as physical channels. If the first and second Walsh codes are orthogonal, then the first user channel is a network channel, and the second user channel is a different network channel. In one aspect of the invention, the multiple network channels may comprise a plurality of different networks, such as depicted in FIG. 7.

In one aspect of the invention, multiple network channels are established 1501 to provide a connection from a single source node to each of at least one destination node. At least one real-time property of each network channel is monitored 1502. Subspace processing is performed to interleave data across the network channels 1503. Based on variations of the monitored property (or properties), network load balancing (e.g., bit loading, or interleaving) may be adjusted 1504.

As described above with respect to FIG. 7, processing block 1501 may employ multiple network technologies (e.g., different WANs) to simultaneously transmit data from a source node to a destination node. In some aspects, the processing block 1501 interleaves data across different non-interfering user channels.

In processing block 1502, at least one channel quality parameter is measured and/or determined for each of the network channels. For example, BER, probability of error, SNR, and/or any other quality metric may be determined.

In processing block 1503, subspace processing may comprise subspace coding to spread data across the non-interfering network channels. Optionally, one or more of the network channels may comprise a plurality of subspaces. In one aspect, the subspace-coded data is distributed across the network channels such that the destination node needs to receive coded data from a plurality of the network channels in order to have a sufficient number of degrees of freedom to

decode the received data. In another aspect of the invention, subspace processing 1503 comprises de-multiplexing the received subspace-coded data.

In some aspects of the invention, subspace processing 1503 comprises employing a plurality of transmitting nodes to cooperatively perform subspace processing, such as described above. In such aspects, selecting the cooperating transmit nodes may effectively build the dimension of the subspace of the transmitted signal. In some aspects of the invention, subspace processing 1503 comprises employing a plurality of receiving nodes to cooperatively perform subspace processing, such as described above. In such aspects, selecting the cooperating receiving nodes may effectively build the dimension of the subspace of the received signal. In some aspects of the invention, a local group of cooperating nodes may provide a source and/or destination node with access to network interfaces, and, thus, network channels that it would otherwise not have.

In processing block 1504, multiple network channels may be employed for transmitting data from a single source node to a single destination node. For example, in one aspect of the invention, a source node (e.g., one of the nodes 701-706 shown in FIG. 7) may employ at least one other node to simultaneously provide multiple network channels that reside on different networks (e.g., networks 716, 717, and 719) for communicating a data stream to a destination node. Similarly, one of the nodes 701-706 may employ the multiple network channels for receiving a data stream from a remote source. In some aspects of the invention, the servers in the networks 716, 717, and 719 are not required to coordinate with each other to manage data flows on the network channels to/from any of the nodes 701-706. Rather, each node (e.g., any of the nodes 701-706) having a WAN interface manages its own connection(s) with its respective network(s) (e.g., networks 716, 717, and 719). The source/destination node amongst the nodes 701-706, or one of the nodes 701-706 configured to function as a network controller manages data flow across the network channels. Such management may comprise selecting and/or adapting data interleaving (e.g., bit loading, network load balancing) across the network channels. Channels that can support higher data rates may be allocated more coded data than channels that support only lower data rates.

FIG. 15B is a diagram depicting processing methods in accordance with aspects of the invention. In one aspect of the invention, a method is provided to manage quality of service in a node, such as a mobile wireless device. In the mobile wireless device, an application service connection is established 1511 between an application processor and a remote device through a wireless communication network. A transceiver monitors at least one real-time property 1512 of a radio frequency access link between the mobile wireless device and the wireless communication network. The transceiver provides the application processor with updated values of the monitored at least one real time property 1513 of the radio frequency access link. The application processor adjusts packet data generation in response to the updated values 1514 to manage a quality of service property of the application service connection.

In one aspect of the invention, establishing the connection 1511 comprises employing a plurality of nodes to establish a plurality of network channels and/or subchannels. The real-time property that is monitored 1512 may comprise a channel estimate, a data rate, a BER, an SNR, and/or any other link-quality metric.

In some aspects of the invention, processing block 1514 may comprise adaptive array processing, which is sometimes performed in coordination with monitoring link quality 1512. In some aspects of the invention, processing block 1514 may comprise performing network load balancing (e.g., bit loading across network channels) when multiple network channels are employed, and/or bit loading across subchannels when multiple subchannels are employed.

In some aspects of the invention, block 1514 may comprise adjusting subspace coding. If the node is a receiving node (e.g., a destination node), the receiver may adjust the rate over each network channel by the way it responds to receiving packets. For example, sending acknowledgements (or failing to send acknowledgements) can change the data rates. This can also affect the coding and redundancy of the data transmissions.

FIG. 16 is a block diagram depicting communications between a WWAN node 1619 and a cooperating group of nodes 1610 (such as a plurality of wireless terminal nodes 1601-1603) employing a plurality of different, yet complementary, code spaces c_1 , c_2 , and c_3 . In one aspect of

the invention, the term complementary means that the coded transmissions corresponding to the code spaces c_1 , c_2 , and c_3 can sum to produce at least one predetermined WWAN coded data sequence. This may be a weighted sum (i.e., a random linear combination), such as due to the given channel conditions. A predetermined WWAN coded data sequence may employ a code that would ordinarily (in view of the prior art) be employed in whole. That is, it would not ordinarily be partitioned into sub-codes to be transmitted by different transmitters or received by different receivers.

In one aspect of the invention, the code spaces c_1 , c_2 , and c_3 correspond to direct-sequence codes, such as may be used to provide for spreading and/or multiple access. A superposition of signals transmitted across the code spaces c_1 , c_2 , and c_3 may provide at least one predetermined WWAN coded data sequence received by at least one WWAN node 1619. Similarly, a superposition of signals received by nodes 1601-1603 and mapped onto the code spaces c_1 , c_2 , and c_3 may provide at least one predetermined WWAN coded data sequence that would ordinarily (in view of the prior art) be intended for a single node 1601-1603. Some aspects of the invention may provide for channel corrections (e.g., pre-distortion and/or receiver-side channel compensation) by either or both the cooperating group 1610 and the WWAN node 1619. Accordingly, the code spaces c_1 , c_2 , and c_3 may be adapted to account for channel conditions.

In another aspect of the invention, the code spaces c_1 , c_2 , and c_3 may correspond to direct-sequence codes having predetermined spectral characteristics. It is well known that different time-domain data sequences may be characterized by different spectral distributions. Some aspects of the invention may provide for selecting complementary codes c_1 , c_2 , and c_3 having predetermined spectral characteristics with respect to WWAN channel conditions affecting the links between the nodes 1601-1603 and the WWAN node 1619. Thus, in some aspects, the codes c_1 , c_2 , and c_3 may be selected according to the same criteria employed for selecting OFDM subcarriers.

A direct-sequence code may comprise a pseudo random noise code, such as is known in the art. Pseudo-random noise is a deterministic set of values or signals that satisfies one or more tests for statistical randomness. A direct sequence code may comprise an orthogonal code, such as a

Walsh code, such as is known in the art. Direct sequence is a type of signaling in which each data symbol is modulated (or otherwise impressed) onto (or represented by) a sequence of code symbols. Thus, information about each data symbol resides on a plurality of coded data symbols. In this respect, each data symbol is “spread” across multiple code symbols, and the resulting coded data symbols are transmitted in sequence. Furthermore, each coded data symbol may contain information about a plurality of data symbols.

A receiver that receives the sequence of coded data symbols may decode the received signals if it knows the direct-sequence code and if a sufficient number of the coded data symbols are received. In one aspect of the invention, if M_t code spaces $c_1, c_2, \dots, c_{M_t}$ comprise M_t linear combinations of up to M_t data symbols, then the coded transmissions provide a sufficient number of degrees of freedom for decoding the data symbols. In another aspect, the code spaces $c_1, c_2, \dots, c_{M_t}$ may indicate codes produced by an invertible transform. In some instances, if the number of coded data symbols is less than the number of data symbols, decoding produces a certain amount of inter-symbol interference that can be corrected.

The distribution of the inter-symbol interference to each estimated data symbol can depend on the type of coding employed. In some aspects, of the invention, CI codes may be employed, such as described in U.S. Patent Application Publication No. 20040086027, which is incorporated by reference in its entirety. The ‘107 application incorporates by reference U.S. Patent Application Publication Nos. 20040086027 and 20030147655, which are hereby incorporated by reference in their entireties. CI codes may comprise either or both block-type codes and sliding transform codes. Block codes often uniformly distribute inter-symbol interference due to each data symbol across all the other data symbols encoded by the block code, whereas sliding transform codes may non-uniformly distribute inter-symbol interference of each data symbol across the other symbols in the sliding transform window.

In one aspect of the invention, transmitting a sequence of symbols into a multipath channel produces a sliding transform of those symbols. A random channel produces a random sliding transform. For example, in a multipath channel, some paths are longer (and, thus, introduce more delay) than other paths. Inter-symbol interference occurs when earlier-transmitted symbols arrive

at a receiver at the same time that later-transmitted symbols are received. In some aspects of the invention, the length of this sliding transform window equals the delay spread of the channel.

In some aspects, the coding window may be the number of resolvable multipath delays. A time-domain receiver typically employs a Rake receiver having a number of taps. For example, the number of Rake taps in an efficient receiver may equal the number of resolvable delays. The coding window may be increased by employing a larger number of transmitters and/or receivers. Increasing the coding window may comprise increasing the number of transmit and/or receive directions. In some aspects, the angle of the transmitted and/or received signals may be increased. In multipath environments, paths received at higher angles relative to line-of-sight (i.e., zero incidence) between a transmitter and receiver often have greater delays than paths received closer to the line-of-sight.

In another aspect of the invention, a sliding window transform is synthesized by a transmitter, such as by deliberately time-offsetting signals transmitted from antennas of an array. In such aspects, one or more of a node's transmissions may be provided with time-varying complex weights (e.g., amplitudes and/or phases), such as described in S. A. Zekavat, C. R. Nassar and S. Shattil, "Combined Directionality and Transmit Diversity via Smart Antenna Spatial Sweeping," proceedings of 38th Annual Allerton Conference on Communication, Control, and Computing, University of Illinois in Urbana-Champaign, pp. 203-211, Urbana-Champaign, IL, USA, Oct. 2000, S. A. Zekavat, C. R. Nassar and S. Shattil, "Smart antenna spatial sweeping for combined directionality and transmit diversity," *Journal of Communications and Networks (JCN), Special Issue on Adaptive Antennas for Wireless Communications*, Vol. 2, No. 4, pp. 325-330, Dec. 2000, and S. A. Zekavat, C. R. Nassar and S. Shattil, "Merging multi-carrier CDMA and oscillating-beam smart antenna arrays: Exploiting directionality, transmit diversity and frequency diversity," *IEEE Transactions on Communications*, Vol. 52, No. 1, pp. 110 – 119, Jan. 2004, which are incorporated by reference herein.

In some aspects of the invention, a Rake receiver performs sliding-transform processing. For example, a k^{th} direct-sequence transmission signal $s^k(t)$ that includes N code symbols $\{b^k[n]\}_{n=1}^N$ is given by:

$$s^k(t) = \sum_{n=0}^{N-1} b^k[n] g_{T_b}(t - nT_b) g_r(t) a^k(t - iT_b) \cos(2\pi f_c t)$$

where $a^k(t) = \sum_{i=0}^{G-1} C_i^k g_{T_c}(t - iT_c)$, C_i^k is the Direct Sequence spreading signal, G represents processing gain, T_c is the chip duration, T_b is the bit duration, and $g_{T_c}(t)$, $g_{T_b}(t)$, and $g_r(t)$ represent the chip, bit, and transmitted pulse shapes, respectively.

A plurality M of nodes linked together by a WLAN comprises elements of an M -element antenna array capable of receiving K transmission channels. In a frequency-selective channel, the received signal at the array is:

$$r(t) = \sum_{k=1}^K \sum_{l=0}^{L^k-1} \sum_{n=0}^{N-1} \alpha_l^k \vec{V}(\mathcal{G}_l^k) b_k[n] g(t - \tau_l^k - nT_b) \cos(2\pi f_c t + \phi_l^k) + v(t)$$

where $\vec{V}(\mathcal{G})$ is an array-response vector, K is the number of received transmission channels, L^k is the number of distinct fading paths corresponding to the k^{th} user, α_l^k is the fade amplitude associated with path l and user k , $\phi_l^k = U[0, 2\pi]$ represents the associated fade phase, τ_l^k is the path time-delay (which occurs below a predetermined duration threshold T_{max}), and $\mathcal{G}_l^k$ denotes angle of arrival. The array response vector $\vec{V}(\mathcal{G})$ is expressed by:

$$\vec{V}(\mathcal{G}) = [1 \quad e^{-2\pi j d_1 \cos \theta / \lambda} \quad \dots \quad e^{-2\pi j d_{M-1} \cos \theta / \lambda}]$$

where d_m is the antenna separation, and λ is the wavelength corresponding to carrier frequency f_c .

For a j^{th} user's l^{th} path, the n^{th} bit at the beamformer output is given by:

$$z_l^j[n] = W^H(\mathcal{G}_l^j) \int_{(n-1)T_b}^{nT_b} r(t) \cos(2\pi f_c t + \phi_l^j) a^j(t - \tau_l^j - (n-1)T_b) dt$$

where $W(\mathcal{G}_l^j)$ is the weighting vector of the beamforming system. $z_l^j[n]$ can be expressed by four components:

$$z_l^j[n] = S_i^j[n] + ISI_i^j[n] + IXI_i^j[n] + v_i^j[n]$$

where S is the desired signal, ISI is inter-symbol interference, IXI is cross interference (i.e., multiple-access interference), and v is the AWGN contribution. These components can be expressed as follows:

$$S_i^j[n] = \alpha_l^j W^H(\mathcal{G}_l^j) \vec{V}(\mathcal{G}_l^j) b^j[n] G$$

$$\begin{aligned}
ISI_i^j[n] &= \sum_{\substack{h=0 \\ h \neq l}}^{L^k-1} \sum_{n=0}^{N-1} \alpha_i^k W^H(\mathcal{G}_h^j) \tilde{V}(\mathcal{G}_l^j) b^j[n] \cos(\varphi_h^j - \varphi_l^j) R_{jj}(\tau_h^j - \tau_l^j - nT_b) \\
LXI_i^j[n] &= \sum_{\substack{k=1 \\ k \neq j}}^K \sum_{\substack{h=0 \\ h \neq l}}^{L^k-1} \sum_{n=0}^{N-1} \alpha_i^k W^H(\mathcal{G}_h^k) \tilde{V}(\mathcal{G}_l^j) b^j[n] \cos(\varphi_h^k - \varphi_l^j) R_{kj}(\tau_h^k - \tau_l^j - nT_b) \\
v_l^j[n] &= \int_{+(n-1)T_b}^{+nT_b} W^H(\mathcal{G}_l^j) n(t) a^j(t - \tau_l^j) \cos(2\pi f_c t + \varphi_l^j) dt
\end{aligned}$$

where $W^H(\mathcal{G}_l^j) \tilde{V}(\mathcal{G}_l^j)$ represents the spatial correlation, φ_l^j and τ_l^j are the random phase and time delay for the j^{th} user's l^{th} path, G is the processing gain, and R_{jj} and R_{kj} are the partial auto-correlation and cross-correlation of the direct sequence code(s):

$$R_{kj}(\tau) = \int_{\tau}^T a^k(t) a^j(t - \tau) dt$$

Maximal ratio combining produces an output:

$$z^j[n] = \sum_{l=0}^{L-1} \alpha_l^j z_l^j[n]$$

which can be processed by a decision processor. In this case, the BER is given by:

$$P_e = \int_0^{\infty} Q(2r_o) f(r_o | \bar{r}_o) dr_o$$

where $\bar{r}_o$ is the mean value of the instantaneous SINR, r_o , and $Q(\cdot)$ represents the complementary error function.

It should be appreciated that the nodes may be adapted to perform either or both time-domain (e.g., Rake) or frequency-domain processing as part of a receiver operation. Signals received by a plurality of nodes may be combined with respect to any combining technique, including EGC, MRC, Minimum Mean Squared Error Combining, other types of optimal combining, Successive Interference Cancellation, and other matrix-reduction/matrix diagonalization techniques. Successive Interference Cancellation may be particularly useful for decoding signals encoded with a sliding transform.

FIG. 17 is a diagram depicting processing methods in accordance with aspects of the invention. In one aspect of the invention, a method is provided in which a transmitting node determines a linear combination of original packets to transmit 1701, transmits the linear combination of

packets across a network using a sliding window protocol 1702, and receives an acknowledgement when a receiving node receives the linear combination of packets 1703.

In one aspect, the process of transmitting 1702 and/or a process of receiving the transmitted linear combination (not shown) comprises at least one of the transmitting node and the receiving node enlisting at least one cooperating node to increase the dimension of the subspace spanned by the linear combination. For example, the at least one cooperating node may increase the rank of the coding matrix generated at the receiver and/or may improve the conditioning of the matrix.

In one aspect of the invention, the receiving node retrieves coding coefficients (i.e., at least one code vector) from the linear combination of packets 1704. The receiver may produce a code matrix from the coding coefficients. The coding coefficients (which may be appended to a code matrix) are employed in a decoding process for decoding the received linear combinations 1705. Since the coding comprises a sliding transform, decoding 1705 may comprise successive interference cancellation, or some other matrix-reduction process.

In accordance with still another aspect of the systems, circuits, and techniques described herein, a communication device comprises a first network interface unit configured for communication in a first network, a second network interface unit configured for communication in a second network that is different from the first network, and at least one processor to manage data transfer between the communication device and a destination node using multiple different channels.

In one aspect of the invention, a method depicted in FIG. 18 is provided in which the at least one processor employs a plurality of cooperating nodes to generate first coded packets and/or second coded packets. In one aspect of the invention, first coded packets are generated by linearly combining original data packets 1801. Coding 1801 may employ subspace codes and/or codes derived from an invertible transform, such as a CI code matrix. The first coded packets are distributed to multiple different channels 1802, such as different network channels and/or different subchannels, for transmission to a destination node. Second coded packets are generated within the different channels 1803, such as by linearly combining first coded packets

distributed to the channels, and/or by employing codes derived from an invertible transform, such as a CI code matrix. In some aspects of the invention, intermediate nodes in a multi-hop path may perform second coding 1803, and/or the destination node may provide second coding 1803 when combining signals received from its local group.

In one aspect of the disclosure, the at least one processor is configured to generate first coded packets by linearly combining original data packets within a sliding coding window. In another aspect, a first of the multiple different channels is associated with the first network interface unit and a second of the multiple different channels is associated with the second network interface unit. In some aspects of the invention, the first and second network interface units reside on different nodes that are communicatively coupled together (such as by a WLAN) and configured to cooperatively process the first coded packets.

Aspects of the invention may employ CI coding for direct sequence coding, spread-OFDM coding, and/or coding across subspaces, such as described throughout the '854 application, which is incorporated by reference in its entirety.

In OFDM, the transmission bandwidth is partitioned into a plurality N (which typically equals 2 raised to some integer power) of orthogonal subcarrier frequencies. Multicarrier spread-spectrum employs spreading across the subcarriers to produce a transmit signal expressed by $\mathbf{x} = \mathbf{F}^{-1}\mathbf{S}\mathbf{b}$, where $\mathbf{F}^{-1}$ is an inverse discrete Fourier transform (DFT), $\mathbf{S}$ is a spread-OFDM code matrix, and $\mathbf{b}$ is the transmitted symbol vector. The inverse DFT typically employs an over-sampling factor, so its dimension is $K \times N$ (where $K > N$ is the number of time-domain samples per OFDM symbol block), whereas the dimension of the spread-OFDM code matrix is $N \times N$.

At the receiver, the received spread-OFDM signal is expressed by $\mathbf{r} = \mathbf{H}\mathbf{F}^{-1}\mathbf{S}\mathbf{b}$, where $\mathbf{H}$ is a channel matrix for the transmission channel. A cyclic prefix in OFDM changes the Toeplitz-like channel matrix into a circulant matrix. The circulant channel matrix $\mathbf{H}$ is expressed by

$$\mathbf{H} = \mathbf{F}^{-1}\mathbf{\Lambda}_H\mathbf{F},$$

wherein Λ_H is a diagonal matrix whose diagonal elements correspond to the first column of the circulant channel matrix $\mathbf{H}$.

Thus, the received signal is represented by

$$\mathbf{r} = \mathbf{F}^{-1} \Lambda_H \mathbf{F} \mathbf{F}^{-1} \mathbf{S} \mathbf{b},$$

which is

$$\mathbf{r} = \mathbf{F}^{-1} \Lambda_H \mathbf{S} \mathbf{b}.$$

The receiver processes $\mathbf{r}$ with a DFT to produce

$$\mathbf{y} = \Lambda_H \mathbf{S} \mathbf{b}.$$

In order to facilitate the estimation of $\mathbf{b}$, it is advantageous to employ a spreading code matrix $\mathbf{S}$ that commutes with Λ_H . For example, the matrix $\mathbf{S} = \Lambda_C \mathbf{F}$ may be employed, wherein Λ_C is the diagonal matrix of the circulant matrix $\mathbf{C}$, which is defined by $\mathbf{C} = \mathbf{F}^{-1} \Lambda_C \mathbf{F}$.

In this case, the received signal, $\mathbf{r}$, is expressed as

$$\mathbf{r} = \mathbf{F}^{-1} \Lambda_H \mathbf{F} \mathbf{F}^{-1} (\Lambda_C \mathbf{F}) \mathbf{b},$$

which can be written as

$$\begin{aligned} \mathbf{r} &= \mathbf{F}^{-1} \Lambda_H \Lambda_C \mathbf{F} \mathbf{b} \\ &= \mathbf{F}^{-1} \Lambda_C \Lambda_H \mathbf{F} \mathbf{b}. \end{aligned}$$

Following DFT processing, but prior to equalization, the signal, $\mathbf{y}$, is expressed by $\mathbf{y} = \Lambda_C^{-1} \mathbf{F} \mathbf{r}$.

In the simplest case, the spreading matrix $\mathbf{S} = \Lambda_C \mathbf{F}$ may be implemented with $\Lambda_C = \mathbf{I}$, such that the spreading matrix $\mathbf{S}$ is just an $N \times N$ DFT matrix. Since OFDM's over-sampled DFT is $K \times N$, the spreading matrix $\mathbf{S}$ may partially resemble a sinc pulse-shaping filter, except that it maps each data symbol to a cyclically shifted (and orthogonally positioned) superposition of OFDM subcarriers. In this case, the transmitter employs the spreading matrix $\mathbf{C}$ for spreading the data vector $\mathbf{b}$: $\mathbf{C} = \mathbf{F}^{-1} \Lambda_C \mathbf{F}$.

Since each spread symbol comprises a linear combination of the data vector's $\mathbf{b}$ values, if a spread symbol is lost during transmission, that loss is mitigated because it is effectively distributed across all the data values of $\mathbf{b}$. Thus, spreading permits accurate estimation of a received signal despite substantial losses, even before error-correction coding is employed.

Furthermore, this type of spreading permits a receiver to decode a transmission without requiring all of the spread symbols. For example, a receiver may accurately decode N data values by employing $M < N$ spread symbols.

Since the spread symbols employ predetermined linear relationships between the data symbols of $\mathbf{b}$, techniques typically employed in multi-user detection (such as, but not limited to, successive interference cancellation and mixed-decision symbol estimation) can enhance performance at the receiver. Thus, in some aspects of the invention, orthogonality of the spreading codes is not required if the spreading coefficients are known at the receiver. Rather, the code spaces processed by the receiver may simply need to be sufficiently de-correlated from each other to estimate the data symbols $\mathbf{b}$.

In one aspect of the invention, the above-mentioned spreading matrix $\mathbf{S}$ is employed as an invertible transform to produce a sequence of coded data symbols $\mathbf{x}$ from an input data vector $\mathbf{b}$: $\mathbf{x} = \mathbf{S}\mathbf{b}$. This implementation of the invertible transform matrix $\mathbf{S}$ takes the form of direct-sequence coding.

FIG. 19 illustrates an invertible transform matrix that may be employed in some aspects of the invention. In one aspect, the invertible transform matrix $\mathbf{S}$ is an $N \times N$ matrix. Each row (e.g., row 1901) of the matrix $\mathbf{S}$ multiplies original data vector $\mathbf{b}$ (which comprises N values) to produce a coded data symbol x_i . Specifically, each coded data symbol x_i comprises a linear combination of the original data symbols $\mathbf{b}$, wherein the coefficients of the linear combination are values of the invertible transform matrix $\mathbf{S}$.

To estimate an i^{th} value b_i of the original data vector $\mathbf{b}$, a decoding vector $\mathbf{s}_i$ comprising an i^{th} row or column of a decoding matrix may be used to multiply the vector of coded data symbols $\mathbf{x}$ to produce an inner product, from which the estimated value $\hat{b}_i$ is derived. The vector $\mathbf{s}_i$ may be regarded as corresponding to an i^{th} subspace of the decoding matrix. Since the inner product requires vectors of equal length, if the number of coded data symbols $\mathbf{x}$ is deficient relative to the rank of the decoding matrix, then the decoding vector $\mathbf{s}_i$ may be reduced accordingly. For example, a j^{th} value s_{ij} of the decoding vector $\mathbf{s}_i$ corresponding to a j^{th} missing coded data symbol

x_j may be omitted from the vector $\mathbf{s}_i$ before the multiplication. The decoding vector $\mathbf{s}_i$ functions as a matched filter. In one aspect, the corresponding decoding matrix may comprise the complex conjugate of the matrix $\mathbf{S}$. However, other aspect of the invention may employ different types of invertible CI matrices, including scalar code matrices and other complex code matrices. Gauss–Jordan elimination can be used to determine whether a given matrix is invertible and to find the inverse. An alternative is LU decomposition, which generates upper and lower triangular matrices, which are easier to invert.

The first element of each matrix row (indicated by the first column 1910 of matrix $\mathbf{S}$) multiplies the first data symbol b_0 of the data vector $\mathbf{b}$. In this case, all the values in the first column 1910 equal one. The corresponding decoding vector $\mathbf{s}_0$ also has all of its values equal to one, so to retrieve the first data symbol b_0 , all the coded data symbols $\{x_0, x_1, \dots, x_{N-1}\}$ are summed. This can be regarded as a “baseband” matched filter. One of the advantages of employing the type of CI coding matrix shown in FIG. 19 is that data mapped to this baseband subspace can be retrieved regardless of the order in which the coded data symbols $\{x_0, x_1, \dots, x_{N-1}\}$ are summed. Thus, in some aspects of the invention, certain control information may be included in packets that are encoded to this subspace. In some aspects of the invention, a decoding matrix may be included in the baseband subspace. In some aspects, information relating to the order and/or identity of the coded data symbols may be included in the baseband subspace.

To retrieve original data from a non-baseband subspace, a decoding vector may effectively map its corresponding subspace to baseband so the information in the other subspaces cancels out. For example, the data encoded in the target subspace combines coherently while data in all the other subspaces cancel. The decoding process may comprise an inner product of the coded data packets with one or more vectors of decoding coefficients. In some aspects, information about the intended order of the coded data (such as may be used for decoding) may be included in the baseband subspace such that the coded data can be arranged correctly if it is received out of order. In some aspects, information in the baseband subspace may be used to identify missing coded data such that decoding can be adapted accordingly. For example, in one aspect, values of the decoding vector(s) may be removed with respect to which coded data is missing.

Some advantages of employing these types of CI codes are that information can be decoded using fast transforms, such as processes that employ fast Fourier transforms, the codes can have any code length, and information can be re-encoded by intermediate nodes without requiring decoding. In some aspects of the invention, intermediate nodes participate in the coding process. For example, intermediate nodes may combine received packets and generate new packets. The encoded packets encapsulate the original packets, thus, sequence numbers and other control information in the original packets can remain concealed until they are decoded. Decoding only requires that a specified number of the coded packets be received. The order in which those packets are received is inconsequential. This permits a client to simultaneously employ multiple channels, even multiple different networks, with different bandwidths, latencies, and/or channel conditions to download a file or receive streaming media without requiring network servers to coordinate their transmissions. The destination node needs only to assemble a sufficient number of received packets in order to decode the flow. Since the code is either already known at the receiver or it is conveyed in the baseband subspace, the packets are interchangeable and the arrival order is irrelevant. No scheduling or route coordination is necessary at the source. Such advantages are particularly relevant in cloud networks.

As described above, some aspects of the invention may employ an invertible transform matrix $\hat{\mathbf{S}} = \mathbf{F}^{-1}\mathbf{S}$, where $\mathbf{F}^{-1}$ is a $K \times N$ inverse DFT (where $K > N$ is the number of time-domain samples per OFDM symbol block), and $\mathbf{S}$ is an $N \times N$ spread-OFDM code matrix. In this case, the vector of coding coefficients that multiply OFDM subcarriers constitute a random linear mapping of the data vector $\mathbf{b}$, as will be described with respect to FIGS. 20A and 20B.

FIG. 20A is a constellation plot of original data values $\mathbf{b}$, which clearly have a 64-QAM structure. In conventional OFDM, these data values would ordinarily modulate the OFDM subcarriers. FIG. 20B is a constellation plot of subcarrier coefficients produced by employing a CI code matrix, such as the code matrix depicted in FIG. 19. The coded symbols comprise linear combinations of the original data determined by the invertible CI transform matrix.

The constellation plot in FIG. 20B is a Gaussian distribution that is statistically random. In accordance with one aspect of the invention, a sequence of coded data symbols is generated from the operation $\mathbf{x} = \mathbf{F}^{-1}\mathbf{S}\mathbf{b}$ and transmitted into one or more channels. In some aspects of the invention, the aforementioned subcarrier coefficients may instead be employed as coefficients in random linear combinations of the original data values. In such aspects, the coefficients may be derived from an invertible transform matrix (such as a CI matrix) and information about the original data symbols. Decoding may employ an iterative process for estimating the original data.

FIG. 21A is a flowchart illustrating a method for transmitting data from a source node to a destination node via multiple different channels in accordance with an aspect of the invention. As described previously, the multiple different channels may be associated with different communication technologies.

First coded data packets are generated by combining original data packets using an invertible transform, such as a CI transform 2101. The first coded packets may be generated using a block and/or sliding CI transform by forming a linear combination of the original packets currently within a coding window. For example, coded data may be generated by multiplying a vector of original data with a CI code matrix. Thus, each coded data packet comprises a different linear combination of the original data packets, and, thus, constitutes a degree of freedom. If a sliding transform is employed, as each new original packet is added to the coding window, an oldest original packet in the window may be shifted out. In some aspects, a new first coded packet may be generated for each new original packet added to the coding window. The size of the first coding window may be fixed or variable.

The multiple different channels may be monitored 2102 to identify one or more channels to insert a new first coded packet at a particular time. This monitoring process may continue until all of the data has been successfully transferred to and decoded at the destination node. When a channel is identified, one or more first coded packets may be distributed to the identified channel 2103. Different first coded packets may be injected into different channels using the above-described technique. For example, in one aspect of the invention, a first coded packet is

transmitted on a first channel and at least a second coded packet is transmitted on at least a second channel, wherein the first coded packet and the at least second coded packet together are necessary to provide a sufficient number of degrees of freedom to decode the original packet.

For each channel, one or more second coded packets may be generated 2104 by linearly combining the first coded packets that currently reside within a corresponding second coding window using an invertible transform, such as a CI transform. In some aspects, CI coefficients may comprise statistically random coefficients may be used to perform the linear combination.

FIG. 21B is a flowchart illustrating a method for receiving data at a destination node via multiple different channels in accordance with an aspect of the invention. Upon receiving a coded packet at a destination node, the destination node may send an acknowledgement message to the source node 2111. The destination node determines if a sufficient number of coded packets have been received to allow the receiver to decode the packets 2112. If an invertible transform is employed for coding, a sufficient number of coded packets may be less than the number of original packets. Packets may need to be retransmitted until a sufficient number of packets are received. In some cases, the coding may be adapted (e.g., the coding window may be adjusted, the code rate may be adjusted, etc.) based on feedback from the destination node. Upon decoding, the receiver may send an acknowledgement for each original packet received 2113.

FIG. 22A is a flowchart illustrating a method for employing an invertible transform, such as CI coding, for distributing data from a source node to be received by a destination node via multiple routes through at least one network. The method comprises selecting a set of original data, such as original data packets, for encoding 2201. The selected data is encoded using an invertible transform 2202, such as a CI transform. A multiple distribution nodes are selected to distribute the coded data 2203, and the coded packets are distributed to the selected nodes 2204.

Selecting the original data 2201 may comprise partitioning the data into a predetermined number of data sections, such as packets or other data sets, wherein the predetermined number may comprise the dimension of the invertible transform used for coding. The predetermined number may comprise the length of a coding window employed, such as when a sliding CI transform is

employed. In some aspects, the predetermined number may be related to a number of distribution nodes to which the coded data will be distributed 2203, the storage capability of each distribution node, network conditions (e.g., traffic load, latency, bandwidth, link quality, etc.) in the vicinity of each node, demand for the original data, and/or other factors that can affect the flow and timely delivery of the original data to one or more clients. In some aspects, the predetermined number may be related to a number of network paths or channels used for delivering data to the destination node.

Coding 2202 may comprise employing a block transform or a sliding transform, or some combination thereof. In some aspects of the invention, the coded packets and the corresponding code matrix comprise a plurality of independent equations having a plurality of independent variables in a system of linear equations, wherein the independent variables comprise the original packets. In some aspects of the invention, control information may be encoded into the baseband subspace of the coded data. For example, the control information may help a receiver identify individual coded packets such that if a coded packet is lost, decoding can be adapted accordingly. The control information may identify a preferred sequence of the coded packets, so a receiver can correctly arrange received packets such as to facilitate decoding of the non-baseband subspaces.

Selecting the distribution nodes 2203 may comprise selecting nodes that are nearby the destination node. The distribution nodes may comprise edge servers in a content delivery network. In some aspects, the selection of distribution nodes 2203 may be based on anticipated and/or actual demand for the original data. The distribution nodes may be selected 2203 to best serve requesting clients, such as to offload network loads from the network backbone to the network edges, reduce latency when serving data to the clients, and/or reduce distribution costs for content providers. In peer-to-peer networks, some of the clients may be selected as distribution nodes. For example, a client requesting the original data may be directed to retain a set of coded packets containing the original data such that the client may serve other clients requesting the same original data.

Distributing the coded packets to the distribution nodes 2204 may comprise determining how much data to store on each node. In one aspect, distributing may first comprise determining storage capability of each candidate distribution node. Distributing 2204 may comprise calculating a cost per unit flow on each link, and/or determining link capacity, link traffic, and/or other factors affecting how data is distributed. Distributing 2204 may comprise determining demand topology in a network, such as to determine how much and where coded data is distributed.

In some aspects of the invention, distributing 2204 comprises providing each of a plurality of the distribution nodes with a number of coded components that is less than a number of required degrees of freedom to decode the coded components. A destination node can acquire a sufficient number of the coded components to perform decoding by collecting coded components from more than one distribution node. This can reduce the amount of data stored on each distribution node while still being able to serve the clients. Thus, distributing 2204 may comprise determining a network demand topology to use for calculating which coded packets to distribute to which nodes in a manner that serves the requesting client(s) while reducing network traffic and storage requirement on the distribution nodes. In other aspects, distributing 2204 may be based on network bandwidth, latency, link quality, and/or other link metrics pertaining to each of a plurality of channels employed by the distribution nodes serving a client.

FIG. 22B is a flowchart illustrating a method for employing an invertible transform, such as CI coding, for receiving data from a plurality of routes through at least one network. The method comprises a destination node selecting a plurality of distribution nodes from which to receive coded packets 2211, collecting the coded packets from the selected distribution nodes 2212, and determining if a sufficient number of unique coded packets have been collected to decode the packets 2213. If the destination node determines that a sufficient number of degrees of freedom are available with respect to the collected packets, then it performs decoding 2214. Otherwise, control returns to processing block 2211, and at least one more distribution node is selected. In some aspects, one of the distribution nodes may request additional coded packets (not shown), such as from other distribution nodes and/or a source node.

In one aspect of the invention, the nodes are selected 2211 to provide a sufficient number of coded packets (e.g., which, along with their respective code matrix, represent linearly independent equations) for decoding the original packets (e.g., unknown variables). In some aspects, the invertible transform matrix is known at the receiver, so the coding matrix is not transmitted to the distribution nodes. However, information about the relation of each coded packet to the coding matrix may be provided to the distribution nodes and transmitted to the destination node.

In one aspect, decoding 2214 comprises calculating a solution for a system of linear equations comprising the independent equations and their independent variables. In this aspect, the independent equations comprise the coded packets and the corresponding invertible transform matrix, and the independent variables comprise the plurality of original packets.

As described throughout the '107 application, distributing data on network routes may be performed in a manner that achieves one or more cost objectives, including cost objectives related to combinations of technical and business objectives. Such aspects of the invention may be applied to communication systems in which multiple different networks are simultaneously employed for transmitting data from a source to a destination.

In one aspect of the invention, a method of providing minimum-cost routing comprises modeling a network between a source node and a destination node as a trellis graph, wherein each state node of the trellis corresponds to a network node, and each transition between states corresponds to a communication link between network nodes. A cost is associated with each link, and then a path is calculated through the trellis that minimizes the total cost for routing data between the source and destination nodes. The cost for each link may be based on various combinations of factors, including link capacity, available storage at each node, network traffic loads, link latency, quality of service, etc. In some aspects, coding is part of the routing operation, and it may directly affect the cost associated with the links. As a route for each data set (e.g., coded data packet) is determined, the cost for each link may be updated, and then the process is repeated for the next data set (e.g., coded packet). This process may be repeated for a plurality of

coded packets, such as to determine an optimal number of coded packets, code rate, code matrix, and/or other coding parameters prior to encoding and routing the coded data.

Aspects of the invention may employ client-side and/or server-side techniques, devices, systems, and/or protocols for providing content delivery management, such as disclosed in U.S. Patent Application Ser. No. 13/036,778, filed February 28, 2011, U.S. Patent Application Ser. No. 13/036,171, filed February 28, 2011, and U.S. Patent Application Ser. No. 13/036,812, filed February 28, 2011, which are hereby incorporated by reference in their entireties.

FIG. 23A is a block diagram of a control board 2300 configured in accordance with an aspect of the invention. The control board 2300 may comprise any combination of hardware and software that enables content providers to manage user interactions with media resources. In one aspect, the control board 2300 may comprise a distributed system, meaning that control board components 2301-2303 may reside on multiple devices. For example, control board components 2301-2303 may reside on multiple servers and/or on multiple client devices.

In one aspect of the invention, the control board 2300 comprises software residing on non-transient computer-readable media configured to perform control board functions. In another aspect of the invention, the control board 2300 comprises hardware configured to perform control board functions.

According to one aspect of the invention, the control board 2300 comprises a client-device canvas display module 2301, a media routing module 2302, and a media rendering module 2303. The canvas display module 2301 is configured for interacting with a canvas 2312 displayed on the media interface on a client device 2310. The client device 2310 is one of a plurality of user-selectable client devices. The canvas 2312 is part of a graphical user interface that displays user-controllable devices and available media resources. The canvas 2312 may comprise windows, icons, menus, and/or other display items. Mapped onto the canvas 2312 are all user-controllable devices, such as laptops, handsets, PDAs, tablets, other mobile client devices, and set-top boxes. The canvas 2312 includes canvas display and control software that allows users to experience

and control media across multiple client devices, and assign control and viewing interfaces (e.g., windows) to the devices.

In one aspect of the invention, the canvas 2312 allows for human-computer interaction by enabling the display items to be manipulated by user input, such as by a mouse, keyboard, touch screen, and/or other user controls. The canvas 2312 software converts user inputs to messages, which are transmitted to the canvas display module 2301 and/or the media routing module 2302. The control board 2300 may receive information about the client device 2310 and other user-selectable client devices (not shown) automatically, without the need for user input. For example, the media routing module 2302 may receive messages from the canvas 2312, such as messages indicating which client devices are present, presentation capabilities of each client device, and communication bandwidth available to each client device. The media routing module 2302, in response to the canvas 2312 messages, may allocate media resources to each client device. The media routing module 2302 is responsive to at least one of client device information and user inputs received from the canvas 2312 for allocating the media resources to the client device 2310 and other user-selectable client devices. The canvas display module 2301 may be responsive to user input and/or client device information to configure and/or reconfigure the canvas 2312 display. The canvas display module 2301 may be responsive to the media routing module for configuring and/or reconfiguring the canvas 2312 display.

In one aspect of the invention, the media routing module 2302 may select which media resources are available to a particular client device based on link performance to that client device. Specifically, link performance may comprise an estimate of average data rate, a prediction of future data rate, latency measurements, and/or other measurements or calculations indicating link quality. The link performance may be compared to transmission requirements of the available media resources (e.g., bandwidth, tolerance to latency, activity factor, etc.) and characteristics of the client devices (e.g., buffer size, storage capacity, bandwidth, etc.) in order to determine which media resources are suitable for being delivered to each client device.

FIG. 23B is a flowchart illustrating a method for retrieving data in a content delivery network in accordance with some aspects of the invention. Multiple receiving nodes are selected 2351 to

cooperatively receive a plurality of linearly independent coded components and a plurality of corresponding code vectors. In one aspect, the rank of each of the receiving nodes is insufficient for decoding the coded components. The coded components and the corresponding code vectors are collected 2352 from the plurality of receiving nodes to build up the dimension of the subspace spanned by the collected code vectors. In one aspect of the invention, step 2352 comprises, in response to a user input, selecting 2361 a destination node from a plurality of user-selectable client devices, and combining 2362 the coded components and the corresponding code vectors at the destination node. Once the destination node has sufficient rank for decoding, the coded components are decoded 2353.

The media routing module 2302 is responsive to user selections of media resources and is configured for routing selected media resources to a destination client device, such as the client device 2310. For example, the media routing module 2302 may be responsive to a user's selection of a streaming video channel and information about the selected client device's display 2310 capabilities for allocating an available stream bandwidth and delivering the selected video at the allocated stream bandwidth. While multiple receiving nodes are selected 2351 to receive the transmission, the media routing module 2302 configures stream bandwidth relative to the display capabilities of the destination device, and the media rendering module 2303 configures the media based on characteristics of the destination device. If the destination device is changed by the user, the routing and rendering may be adapted accordingly.

FIG. 24 is a block diagram of a CDN configured to operate in accordance with some aspects of the invention. A client comprises a device field 2400, which may include one or more client devices, such as client devices 2421 and 2422 communicatively coupled to a client-side metrics manager 2425. The metrics manager 2425 may reside on one or more of the client devices 2421 and 2422. The metrics manager 2425 collects data from the client devices 2421 and 2422 and manages client interactions with the CDN. Information about the client devices 2421 and 2422 may be collected from the metrics manager 2425 and used to select nodes that are used for distributing coded media files to a destination device (e.g., one of the client devices 2421 and 2422).

The metrics manager 2425 is configured to manage client interactions with the network. For example, media transmissions to a destination node may be based on wireless network performance data for each client device in the destination node's device field. Other factors, such as the amount of data stored in a client device's buffer, or a low-bandwidth status warning from a device may be employed. In one aspect of the invention, information about a device field is used to select which client devices receive coded data transmissions for a destination node in the device field. The client devices are configured to cooperatively receive the transmitted data and forward the coded data to the destination node. Upon receiving a sufficient amount of coded data, the destination node performs decoding.

An edge server 2430 serves one or more clients, such as clients 2400-2402. Clients 2401 and 2402 each comprise one or more client devices (not shown) and a client-side metrics manager (not shown). The edge server 2430 comprises a network node metrics manager 2435 configured for collecting data from one or more client-side metrics managers (e.g., metrics manager 2425) and brokering network resources from the CDN to the clients 2400-2402. The edge server 2430 and the clients 2400-2402 it serves are part of a client field 2410. The client field 2410 is managed by the metrics manager 2435 for distributing network resources (e.g., media services) to the clients 2400-2402. In one aspect of the invention, information about which clients are connected to which edge servers is managed by the metrics manager 2435 and may be used for distributing coded data to a plurality of edge servers for transmission to a destination node. For example, coded data intended for a destination node may be distributed to multiple edge servers to which the destination node is communicatively coupled. In some aspects, information from both the client-side metrics manager 2425 and the network node metrics manager 2435 is employed by the CDN for selecting nodes to transmit coded data to a destination node. For example, information about which edge servers each device in the destination node's device field 2400 may be used to select which edge servers will serve the coded data.

The data employed by the metrics manager 2435 may comprise raw and/or processed client-side data. For example, the data may comprise a number of requests for media resources, types of media resources requested, and/or bandwidths of the requested media resources. The data may comprise aggregations of the client-side data, such as the total bandwidth requested. The data

may comprise indications of changing network loads (e.g., the number of requests for increased/decreased bandwidth) and/or changes in network performance (e.g., number of acknowledgements, number of requests for retransmission, measured latency, packet error rate, etc.). The metrics manager 2435 allocates the network resources from the CDN to the clients 2400-2402 based, at least in part, on the data collected from the client-side metrics managers 225.

According to one aspect of the invention, the network node metrics manager 2435 receives a request from one of the clients 2400-2402. The metrics manager 2435 may check to determine if coded parts of the requested object are available at the edge server's 2430 cache. If a sufficient number of coded parts of the requested object are available, the edge server 2430 transmits the coded parts to the client. In some cases, it may be necessary to deliver coded parts from multiple edge servers to the destination node. The method may further comprise transmitting a request for coded parts to a parent server 2440 or an origin server if a sufficient number of coded parts are not available at the edge server(s) to enable the destination node to perform decoding. In some aspects of the invention, the metrics manager 2435 (or a node cloud metrics manager 2445) may reassign the client field 2410 to a different edge server.

The parent server 2440 comprising the node cloud metrics manager 2445 is communicatively coupled to a plurality of client fields, such as client fields 2410-2412. The metrics manager 2445 is configured for collecting data from multiple network node metrics managers, such as network node metrics manager 2435, for distributing network services between edge servers 2430. The parent server 2440 and the client fields 2410-2412 it serves is denoted as a digi-node field 2420. The digi-node field 2420 is managed by the metrics manager 2445 for distributing network services to the edge servers, such as edge server 2430.

The data employed by the metrics manager 2445 may comprise raw and/or processed data from the network node metrics managers (such as metrics manager 2435). The data may comprise aggregations of the client-side data and/or data from the network node metrics managers. For example, the data may comprise the total bandwidth requested, or the amount of bandwidth requested at each edge server. The data may comprise indications of changing network loads

(e.g., the number of requests for increased/decreased bandwidth) and/or changes in network performance (e.g., number of acknowledgements, number of requests for retransmission, measured latency, packet error rate, etc.). The metrics manager 2435 distributes the network resources of the CDN between the network nodes (e.g., edge servers) based, at least in part, on the data collected from the metrics managers 2435.

FIG. 25 is a flowchart illustrating a method for delivering data in a content delivery network in accordance with some aspects of the invention. A plurality of original data components (e.g., packets) are selected 2501 to be transferred to at least one destination node. The original data packets are encoded 2502 for generating a plurality of subspace coded packets and a corresponding code matrix. Network data, which may comprise a combination of network topology data and network performance data, is collected 2503 from metrics managers, such as client-side metrics managers and network-node metrics managers. A plurality of transmitting nodes are selected 2504 to which the coded packets are distributed 2505. Each of the transmitting nodes stores a subset of the plurality of subspace coded packets and corresponding code matrix, such that each transmitting node has a rank that is insufficient for decoding the coded packets.

Additional aspects of the invention include a computerized device configured to process all the method operations disclosed herein. In such aspects, the computerized device may include a memory system, a processor, communications interface in an interconnection mechanism connecting these components. The memory system may be encoded with a process that provides the coding techniques as explained herein that, when performed (e.g. when executing) on the processor, operates as explained herein within the computerized device to perform methods and operations explained herein as aspects of the invention.

Other aspects of the invention that are disclosed herein may include software programs to perform the methods and operations described above. More particularly, a computer program product is one aspect that has a non-transient computer-readable medium including computer program logic encoded thereon that when performed in a computerized device provides associated operations providing the functions explained herein. The computer program logic, when executed on at least one processor with a computing system, causes the processor to

perform the operations (e.g., the methods) indicated herein as aspects of the invention. Such aspects are typically provided as software, code and/or other data structures arranged or encoded on a non-transient computer readable medium such as an optical medium (e.g., CD-ROM), floppy or hard disk or other a medium such as firmware or microcode in one or more ROM or RAM or PROM chips or as an Application Specific Integrated Circuit (ASIC) or as downloadable software images in one or more modules, shared libraries, etc. The software or firmware or other such configurations can be installed onto a computerized device to cause one or more processors in the computerized device to perform the techniques explained herein. Software processes that operate in a collection of computerized devices, such as in a group of data communications devices or other entities can also provide a system in accordance with aspects of the invention. The system can be distributed between many software processes on several data communications devices, or all processes could run on a small set of dedicated computers, or on one computer alone.

For clarity of explanation, the illustrative system and method aspects is presented as comprising individual functional blocks. The functions these blocks represent may be provided through the use of either shared or dedicated hardware, including, but not limited to, hardware capable of executing software. For example the functions of one or more blocks may be provided by a single shared processor or multiple processors. Use of the term "processor" should not be construed to refer exclusively to hardware capable of executing software. Illustrative aspects may comprise microprocessor and/or digital signal processor (DSP) hardware, read-only memory (ROM) for storing software performing the operations discussed below, and random access memory (RAM) for storing results. Very large scale integration (VLSI), field-programmable gate array (FPGA), and application specific integrated circuit (ASIC) hardware aspects may also be provided.

The methods and systems described herein merely illustrate particular aspects of the invention. It should be appreciated that those skilled in the art will be able to devise various arrangements, which, although not explicitly described or shown herein, embody the principles of the invention and are included within its scope. Furthermore, all examples and conditional language recited herein are intended to be only for pedagogical purposes to aid the reader in understanding the

principles of the invention. This disclosure and its associated references are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles and aspects of the invention, as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents as well as equivalents developed in the future, i.e., any elements developed that perform the same function, regardless of structure.

Claims

1. A processing method for retrieving data in a content delivery network, comprising:
 - selecting a plurality of receiving nodes to cooperatively receive a plurality of linearly independent coded components and a plurality of corresponding code vectors, wherein a rank of at least one of the receiving nodes is insufficient for decoding the coded components;
 - building up a dimension of a subspace spanned by collected code vectors by collecting the coded components and the corresponding code vectors from the plurality of receiving nodes; and
 - decoding the coded components.
2. The processing method recited in Claim 1, wherein building up comprises, in response to a user input, selecting a destination node from a plurality of user-selectable client devices, and combining the coded components and the corresponding code vectors at the destination node.
3. The processing method recited in Claim 1, wherein at least one of selecting and building comprises at least one of ensuring that a code matrix generated from the corresponding code vectors has sufficient rank to enable decoding, and ensuring the code matrix is sufficiently well-conditioned to permit decoding.
4. The processing method recited in Claim 1, further comprising transmitting at least one acknowledgement to at least one source node upon at least one of receiving a coded component and decoding the coded components.
5. The processing method recited in Claim 1, wherein decoding is configured for decoding at least one of a set of coded components, the set comprising block coded components and sliding window coded components.
6. A non-transitory computer-readable medium storing a computer program configured for implementing the method of Claim 1.

7. A method for processing data in a content delivery network, comprising:
 - determining a required number of degrees of freedom for decoding a set of linearly coded packets;
 - based on the required number of degrees of freedom, selecting at least one additional receiving node for cooperatively receiving at least one coded packet and associated code vector;
 - collecting a plurality of coded packets and associated code vectors from a plurality of cooperating receiving nodes, including the at least one additional receiving node, to provide the required number of degrees of freedom; and
 - decoding the plurality of coded packets.
8. The processing method recited in Claim 7, wherein the plurality of receiving nodes comprises the destination node and at least one user-selectable client device, and wherein collecting comprises, in response to a user input, selecting one of the at least one user-selectable client device as a new destination node and combining the plurality of coded packets and associated code vectors at the new destination node to enable the new destination node to decode the plurality of coded packets.
9. The method recited in Claim 7, wherein at least one of selecting and collecting comprises ensuring that a code matrix produced from the associated code vectors is sufficiently well-conditioned to permit decoding.
10. The method recited in Claim 7, further comprising transmitting at least one acknowledgement to at least one source node upon at least one of collecting a coded packet and decoding the coded packets.
11. The method recited in Claim 7, wherein decoding is configured to employ at least one of block codes and sliding window codes.
12. A non-transitory computer-readable medium storing a computer program configured for implementing the method of Claim 7.

13. A method for receiving data in a content delivery network, comprising:
- connecting to a first network channel and at least a second network channel to simultaneously receive a plurality of linearly coded packets and corresponding code vectors transmitted from a source node;
 - receiving a first subset of the plurality of linearly coded packets and corresponding code vectors on the first network channel and receiving a second subset of the plurality of linearly coded packets and corresponding code vectors on the at least second network channel, wherein at least one of the first subset and the second subset has a rank that is insufficient for decoding the plurality of linearly coded packets, and wherein a sum of ranks of the first subset and the second subset is sufficient for decoding the plurality of linearly coded packets;
 - combining the first subset with the second subset; and
 - decoding the plurality of linearly coded packets.
14. The processing method recited in Claim 13, wherein receiving comprises, in response to a user input, selecting a destination node from a plurality of user-selectable client devices, and wherein combining comprises combining the first subset and the second subset at the destination node.
15. The method recited in Claim 13, wherein the first network channel resides on a first network and the at least second network channel resides on a second network, the second network different than the first network.
16. The method recited in Claim 13, further comprising monitoring at least one real-time property of the first network channel and the at least second network channel; and instructing the source to adjust at least one of coding and transmitting the plurality of linearly coded packets and corresponding code vectors.

17. The method recited in Claim 13, wherein receiving the first subset and receiving the second subset comprises ensuring that a code matrix produced from the corresponding code vectors is sufficiently well-conditioned to permit decoding.
18. The method recited in Claim 13, further comprising transmitting at least one acknowledgement to the source node upon at least one of collecting a linearly coded packet and decoding the plurality of linearly coded packets.
19. The method recited in Claim 13, wherein decoding comprises decoding at least one of a set of coded packets, the set comprising block coded packets and sliding window coded packets.
20. A non-transitory computer-readable medium storing a computer program implementing the method of Claim 13.

Abstract

A source node selects a plurality of original data components to transfer to at least one destination node. A plurality of transmitting nodes cooperatively encodes the original data components to generate a plurality of subspace coded components and a corresponding code matrix. Each of the transmitting nodes transmits a subset of the plurality of subspace coded components and corresponding code matrix, wherein at least one of the transmitting nodes has a rank that is insufficient for decoding the plurality of subspace coded components. A destination node may employ a plurality of receiving nodes to cooperatively receive a plurality of subspace coded components and their corresponding code vectors, wherein the rank of at least one of the receiving nodes is insufficient for decoding the subspace coded components. The destination node builds up the dimension of the subspace spanned by code vectors it collects from the receiving nodes and then decodes the subspace coded components.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

**DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN
APPLICATION DATA SHEET (37 CFR 1.76)**

Title of Invention	Cooperative Subspace Demultiplexing in Content Delivery Networks
-------------------------------	--

As the below named inventor, I hereby declare that:

This declaration is directed to: ☒ The attached application, or
☐ United States application or PCT international application number _____
filed on _____.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than five (5) years, or both.

WARNING:

Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO, petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available.

LEGAL NAME OF INVENTOR

Inventor: Steve J Shattil Date (Optional): 01/30/2014
Signature: /Steve J Shattil/

Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form or must have been previously filed. Use an additional PTO/AIA/01 form for each additional inventor.

This collection of information is required by 35 U.S.C. 115 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CSC-002
		Application Number	
Title of Invention	Cooperative Subspace Demultiplexing in Content Delivery Networks		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Inventor Information:

Inventor 1					Remove	
Legal Name						
Prefix	Given Name	Middle Name	Family Name	Suffix		
	Steve	J	Shattil			
Residence Information (Select One) ☒ US Residency ☐ Non US Residency ☐ Active US Military Service						
City	Cheyenne	State/Province	WY	Country of Residence i	US	
Mailing Address of Inventor:						
Address 1		P.O. Box 17355				
Address 2						
City	Boulder	State/Province	CO			
Postal Code	80308	Country i	US			
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.						

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).		
☐ An Address is being provided for the correspondence information of this application.		
Customer Number	74284	
Email Address	genghiscomm@gmail.com	Add Email Remove Email

Application Information:

Title of the Invention	Cooperative Subspace Demultiplexing in Content Delivery Networks		
Attorney Docket Number	CSC-002	Small Entity Status Claimed	☒
Application Type	Nonprovisional		
Subject Matter	Utility		
Total Number of Drawing Sheets (if any)	18	Suggested Figure for Publication (if any)	8
Filing By Reference :			

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CSC-002
		Application Number	
Title of Invention	Cooperative Subspace Demultiplexing in Content Delivery Networks		

Only complete this section when filing an application by reference under 35 U.S.C. 111(c) and 37 CFR 1.57(a). Do not complete this section if application papers including a specification and any drawings are being filed. Any domestic benefit or foreign priority information must be provided in the appropriate section(s) below (i.e., "Domestic Benefit/National Stage Information" and "Foreign Priority Information").

For the purposes of a filing date under 37 CFR 1.53(b), the description and any drawings of the present application are replaced by this reference to the previously filed application, subject to conditions and requirements of 37 CFR 1.57(a).

Application number of the previously filed application	Filing date (YYYY-MM-DD)	Intellectual Property Authority or Country

Publication Information:

☐ Request Early Publication (Fee required at time of Request 37 CFR 1.219)

☐ **Request Not to Publish.** I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application **has not and will not** be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Either enter Customer Number or complete the Representative Name section below. If both sections are completed the customer Number will be used for the Representative Information during processing.

Please Select One:			
☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)	
Customer Number	74284		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78.

When referring to the current application, please leave the application number blank.

Prior Application Status	Pending	Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
	Continuation in part of	11187107	2005-07-22
Prior Application Status	Expired	Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
11187107	Claims benefit of provisional	60598187	2004-08-02
Prior Application Status	Abandoned	Remove	

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CSC-002
		Application Number	
Title of Invention	Cooperative Subspace Demultiplexing in Content Delivery Networks		
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
11187107	Continuation in part of	10145854	2002-05-14
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.			Add

Foreign Priority Information:

This section allows for the applicant to claim priority to a foreign application. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(d). When priority is claimed to a foreign application that is eligible for retrieval under the priority document exchange program (PDX) the information will be used by the Office to automatically attempt retrieval pursuant to 37 CFR 1.55(h)(1) and (2). Under the PDX program, applicant bears the ultimate responsibility for ensuring that a copy of the foreign application is received by the Office from the participating foreign intellectual property office, or a certified copy of the foreign priority application is filed, within the time period specified in 37 CFR 1.55(g)(1).

			Remove
Application Number	Country ⁱ	Filing Date (YYYY-MM-DD)	Access Code ^j (if applicable)
Additional Foreign Priority Data may be generated within this form by selecting the Add button.			Add

Statement under 37 CFR 1.55 or 1.78 for AIA (First Inventor to File) Transition Applications

This application (1) claims priority to or the benefit of an application filed before March 16, 2013 and (2) also contains, or contained at any time, a claim to a claimed invention that has an effective filing date on or after March 16, 2013.

☒ NOTE: By providing this statement under 37 CFR 1.55 or 1.78, this application, with a filing date on or after March 16, 2013, will be examined under the first inventor to file provisions of the AIA.

Authorization to Permit Access:

☒ Authorization to Permit Access to the Instant Application by the Participating Offices

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CSC-002
		Application Number	
Title of Invention	Cooperative Subspace Demultiplexing in Content Delivery Networks		

If checked, the undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the instant patent application is filed access to the instant patent application. See 37 CFR 1.14(c) and (h). This box should not be checked if the applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the instant patent application is filed to have access to the instant patent application.

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the instant patent application with respect to: 1) the instant patent application-as-filed; 2) any foreign application to which the instant patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the instant patent application; and 3) any U.S. application-as-filed from which benefit is sought in the instant patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing this Authorization.

Applicant Information:

Providing assignment information in this section does not substitute for compliance with any requirement of part 3 of Title 37 of CFR to have an assignment recorded by the Office.				
Applicant 1				Remove
If the applicant is the inventor (or the remaining joint inventor or inventors under 37 CFR 1.45), this section should not be completed. The information to be provided in this section is the name and address of the legal representative who is the applicant under 37 CFR 1.43; or the name and address of the assignee, person to whom the inventor is under an obligation to assign the invention, or person who otherwise shows sufficient proprietary interest in the matter who is the applicant under 37 CFR 1.46. If the applicant is an applicant under 37 CFR 1.46 (assignee, person to whom the inventor is obligated to assign, or person who otherwise shows sufficient proprietary interest) together with one or more joint inventors, then the joint inventor or inventors who are also the applicant should be identified in this section.				
Clear				
☐ Assignee	☐ Legal Representative under 35 U.S.C. 117		☐ Joint Inventor	
☐ Person to whom the inventor is obligated to assign.		☐ Person who shows sufficient proprietary interest		
If applicant is the legal representative, indicate the authority to file the patent application, the inventor is:				
Name of the Deceased or Legally Incapacitated Inventor :				
If the Applicant is an Organization check here. ☐				
Prefix	Given Name	Middle Name	Family Name	Suffix

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CSC-002
		Application Number	
Title of Invention	Cooperative Subspace Demultiplexing in Content Delivery Networks		

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Address 1			
Address 2			
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Country i		Postal Code	
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Email Address			
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Assignee Information including Non-Applicant Assignee Information:

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Assignee 1				
Complete this section if assignee information, including non-applicant assignee information, is desired to be included on the patent application publication. An assignee-applicant identified in the "Applicant Information" section will appear on the patent application publication as an applicant. For an assignee-applicant, complete this section only if identification as an assignee is also desired on the patent application publication.				
				Remove
If the Assignee or Non-Applicant Assignee is an Organization check here.				☐
Prefix	Given Name	Middle Name	Family Name	Suffix
Mailing Address Information For Assignee including Non-Applicant Assignee:				
Address 1				
Address 2				
City		State/Province		
Country i		Postal Code		
Phone Number		Fax Number		
Email Address				
Additional Assignee or Non-Applicant Assignee Data may be generated within this form by selecting the Add button. Add				

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	CSC-002
		Application Number	
Title of Invention	Cooperative Subspace Demultiplexing in Content Delivery Networks		

Signature:

Remove

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications					
Signature	/Steven J Shattil/			Date (YYYY-MM-DD)	2014-01-30
First Name	Steven	Last Name	Shattil	Registration Number	40170
Additional Signature may be generated within this form by selecting the Add button.					Add

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7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
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SCORE Placeholder Sheet for IFW Content

Application Number: 14168466

Document Date: 01/30/2014

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Form Revision Date: September 30, 2013