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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
60/420,930	10/24/2002	Jerry D. Burchfiel	02-4099PRO1

CONFIRMATION NO. 1879

POWER OF ATTORNEY NOTICE



OC000000097786377

32127
VERIZON LEGAL DEPARTMENT
PATENT MANAGEMENT GROUP
1320 N. COURTHOUSE ROAD
9TH FLOOR
ARLINGTON, VA 22201-2525

Date Mailed: 03/05/2018

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 02/23/2018.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at (571) 272-4000 or (571) 272-4200 or 1-888-786-0101.

/tmwilliams/



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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
60/420,930	10/24/2002	Jerry D. Burchfiel	USTAP030+

CONFIRMATION NO. 1879

POA ACCEPTANCE LETTER

92045
The Caldwell Firm, LLC
PO Box 59655
Dept. SVIPGP
Dallas, TX 75229



Date Mailed: 03/05/2018

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 02/23/2018.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at (571) 272-4000 or (571) 272-4200 or 1-888-786-0101.

/tmwilliams/

POWER OF ATTORNEY OR REVOCATION OF POWER OF ATTORNEY WITH A NEW POWER OF ATTORNEY AND CHANGE OF CORRESPONDENCE ADDRESS	Application Number	60/420,930
	Filing Date	10-24-2002
	First Named Inventor	Jerry D. Burchfiel
	Title	Spectrum-adaptive networking
	Art Unit	
	Examiner Name	
	Attorney Docket Number	USTAP030+

I hereby revoke all previous powers of attorney given in the above-identified application.

☐ A Power of Attorney is submitted herewith.

OR

☒ I hereby appoint Practitioner(s) associated with the following Customer Number as my/our attorney(s) or agent(s) to prosecute the application identified above, and to transact all business in the United States Patent and Trademark Office connected therewith:

92045

OR

☐ I hereby appoint Practitioner(s) named below as my/our attorney(s) or agent(s) to prosecute the application identified above, and to transact all business in the United States Patent and Trademark Office connected therewith:

Practitioner(s) Name	Registration Number

Please recognize or change the correspondence address for the above-identified application to:

☒ The address associated with the above-mentioned Customer Number.

OR

☐ The address associated with Customer Number:

OR

☐ Firm or Individual Name

Address

City

State

Zip

Country

Telephone

Email

I am the:

☐ Applicant/Inventor.

OR

☒ Assignee of record of the entire interest. See 37 CFR 3.71.
Statement under 37 CFR 3.73(b) (Form PTO/SB/96) submitted herewith or filed on _____.

SIGNATURE of Applicant or Assignee of Record

Signature	/Andrew Gordon/	Date	2/23/2018
Name	Andrew Gordon	Telephone	
Title and Company	Manager, Usta Technology, LLC		

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

☐ *Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.31, 1.32 and 1.33. 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 3 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.

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.

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.

STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Usta Technology, LLC

Application No./Patent No.: 60/420,930

Filed/Issue Date: 10-24-2002

Titled:

Usta Technology, LLC

, a Limited Liability Company

(Name of Assignee)

(Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. ☒ the assignee of the entire right, title, and interest in;
2. ☐ an assignee of less than the entire right, title, and interest in
(The extent (by percentage) of its ownership interest is _____ %); or
3. ☐ the assignee of an undivided interest in the entirety of (a complete assignment from one of the joint inventors was made)

the patent application/patent identified above, by virtue of either:

- A. ☐ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy therefore is attached.

OR

- B. ☒ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: BURCHFIEL, JERRY D. To: BBNT SOLUTIONS LLC

The document was recorded in the United States Patent and Trademark Office at
Reel 014638, Frame 0084, or for which a copy thereof is attached.

2. From: BBNT SOLUTIONS LLC To: BBN TECHNOLOGIES CORP.

The document was recorded in the United States Patent and Trademark Office at
Reel 017274, Frame 0318, or for which a copy thereof is attached.

3. From: BBN TECHNOLOGIES CORP. To: RAYTHEON BBN TECHNOLOGIES CORP.

The document was recorded in the United States Patent and Trademark Office at
Reel 024456, Frame 0537, or for which a copy thereof is attached.

☒ Additional documents in the chain of title are listed on a supplemental sheet(s).

☒ As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Andrew Gordon/

2/23/2018

Signature

Date

Andrew Gordon

Manager

Printed or Typed Name

Title

This collection of information is required by 37 CFR 3.73(b). 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 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.**

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:

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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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STATEMENT UNDER 37 CFR 3.73(b)

Applicant/Patent Owner: Usta Technology, LLC

Application No./Patent No.: 60/420,930

Filed/Issue Date: 10-24-2002

Titled:

Usta Technology, LLC

, a Limited Liability Company

(Name of Assignee)

(Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that it is:

1. ☒ the assignee of the entire right, title, and interest in;
2. ☐ an assignee of less than the entire right, title, and interest in
(The extent (by percentage) of its ownership interest is _____ %); or
3. ☐ the assignee of an undivided interest in the entirety of (a complete assignment from one of the joint inventors was made)

the patent application/patent identified above, by virtue of either:

- A. ☐ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy therefore is attached.

OR

- B. ☒ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: RAYTHEON BBN TECHNOLOGIES CORP. To: MIRAI VENTURES LLC

The document was recorded in the United States Patent and Trademark Office at
Reel 042347, Frame 0371, or for which a copy thereof is attached.

2. From: MIRAI VENTURES LLC To: USTA TECHNOLOGY LLC

The document was recorded in the United States Patent and Trademark Office at
Reel 044933, Frame 0544, or for which a copy thereof is attached.

3. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at
Reel _____, Frame _____, or for which a copy thereof is attached.

☒ Additional documents in the chain of title are listed on a supplemental sheet(s).

☒ As required by 37 CFR 3.73(b)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/Andrew Gordon/

2/23/2018

Signature

Date

Andrew Gordon

Manager

Printed or Typed Name

Title

This collection of information is required by 37 CFR 3.73(b). 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 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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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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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:	31878466
Application Number:	60420930
International Application Number:	
Confirmation Number:	1879
Title of Invention:	Spectrum-adaptive networking
First Named Inventor/Applicant Name:	Jerry D. Burchfiel
Customer Number:	32127
Filer:	Patrick Edgar Caldwell
Filer Authorized By:	
Attorney Docket Number:	02-4099PRO1
Receipt Date:	23-FEB-2018
Filing Date:	24-OCT-2002
Time Stamp:	23:12:26
Application Type:	Provisional

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	Power of Attorney	USTAP030plus_POA.pdf	185845	no	2
			030465bd54a0a706bc527176468ef703326983f7		

Warnings:

Information:					
2	Assignee showing of ownership per 37 CFR 3.73	USTAP030plus_373b.pdf	428822	no	2
			7d7b17ede9d991cdb930656e022c47648b911bee		
Warnings:					
Information:					
3	Assignee showing of ownership per 37 CFR 3.73	USTAP030plus_373b2.pdf	427557	no	2
			c743b9fd04506f2876619fa930fe15d8479a4053		
Warnings:					
Information:					
Total Files Size (in bytes):			1042224		
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.					

10/24/02
ejc80 U.S. PTO

10-25-02 60420930 102402
APPROV. \$

'Practitioner's Docket No. 02-4099PRO1

PATENT

Preliminary Classification

Proposed Class:

Subclass:

U.S. PTO
60/420930
10/24/02

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: Burchfiel, Jerry D.

For: SPECTRUM-ADAPTIVE NETWORKING

Box Provisional Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

COVER SHEET FOR FILING PROVISIONAL APPLICATION (37 C.F.R. SECTION 1.51(c)(1))

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 C.F.R. section 1.51(c)(1)(i). The following comprises the information required by 37 C.F.R. Section 1.51(c)(1):

CERTIFICATION UNDER 37 C.F.R. SECTION 1.10*

(Express Mail label number is mandatory.)

(Express Mail certification is optional.)

I hereby certify that this correspondence and the documents referred to as attached therein are being deposited with the United States Postal Service on 10/24/02 (date), in an envelope as "EXPRESS MAIL POST OFFICE TO ADDRESSEE" service under 37 C.F.R. Section 1.10, Mailing Label Number EL029403607US addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231.

Mary Anza

(type or print name of person mailing paper)

Mary Anza

Signature of person mailing paper

WARNING: Certificate of mailing (first class) or facsimile transmission procedures of 37 C.F.R. Section 1.8 cannot be used to obtain a date of mailing or transmission for this correspondence.

***WARNING:** Each paper or fee filed by "Express Mail" must have the number of the "Express Mail" mailing label placed thereon prior to mailing. 37 C.F.R. Section 1.10(b).
"Since the filing of correspondence under [Section] 1.10 without the Express Mail mailing label thereon is an oversight that can be avoided by the exercise of reasonable care, requests for waiver of this requirement will not be granted on petition." Notice of Oct. 24, 1996, 60 Fed. Reg. 56,439, at 56,442.

(Cover Sheet for Filing Provisional Application--page 1)

1. The name of the inventor is (37 C.F.R. Section 1.51(c)(1)(ii)):
 1. Jerry D. Burchfiel
2. Residence address of the inventor, as numbered above (37 C.F.R. Section 1.51(c)(1)(iii)):
 1. 270 Bishops Forst Dr.
Waltham, MA 02452

3. The title of the invention is (37 C.F.R. Section 1.51(c)(1)(iv)):

SPECTRUM-ADAPTIVE NETWORKING

4. The name, registration, and telephone numbers of the practitioner are (37 C.F.R. Section 1.51(c)(1)(v)):

Name of practitioner: James K. Weixel
 Reg. No. 44,399
 Tel. No. 781-466-2220

5. The docket number used to identify this application is (37 C.F.R. Section 1.51(c)(1)(vi)):

Docket No. 02-4099PRO1

6. The correspondence address for this application is (37 C.F.R. Section 1.51(c)(1)(vii)):

Leonard Charles Suchyta
 c/o Christian Andersen
 Verizon Corporate Services Group Inc.
 600 Hidden Ridge, HQE03H01
 Irving, TX 75038

7. Statement as to whether invention was made by an agency of the U.S. Government or under contract with an agency of the U.S. Government. (37 C.F.R. Section 1.51(c)(1)(viii)).

This invention was NOT made by an agency of the United States Government, or under contract with an agency of the United States Government.

8. Identification of documents accompanying this cover sheet:

A. Documents required by 37 C.F.R. Section 1.51(c)(2)-(3):

Specification:	No. of pages	8
Drawings:	No. of sheets	0

(Cover Sheet for Filing Provisional Application--page 2)

B. Additional documents:

None.

9. Fee

The filing fee for this provisional application, as set in 37 C.F.R. Section 1.16(k), is \$160.00 for other than a small entity.

10. Fee payment

Fee payment in the amount of \$160.00 is being made at this time.

11. Method of fee payment

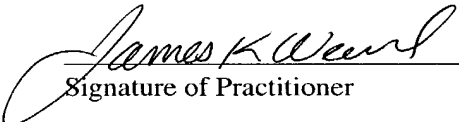
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Signature of Practitioner
James K. Weixel
Verizon Corporate Services Group Inc.
600 Hidden Ridge, HQE03H01
Irving, TX 75038

00420930 102402

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Spectrum-Adaptive Networking

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R&D White Paper: Spectrum-Adaptive Networking for the Next Generation (XG) Communications Program

Section A: Task Objective

The real "Y2K crisis" is the disappearance of available network bandwidth as Military spectrum allocations continue to shrink. The US Military will not become 'JV2010 Information Dominant' without a solution to this pressing problem. There is no more bandwidth. We must develop new innovative ways to use the spectrum we have more efficiently.

This effort addresses both individual spectrum management technologies and an integrated system concept for dynamic, adaptive, radio frequency spectrum assignment and use. The goal is far greater spectrum efficiency, resulting in megabit/sec rate communications networks that can extend strategic military networks (e.g., SIPRNET, NIPRNET) forward to the tactical forces. The thrust of this development and demonstration is to show that we can overlay these new services on existing bandwidth allocations with minimal interference to, and from, existing legacy users, while providing the digitized forces 30 times greater throughput than the current SINCGARS-based Tactical Internet. To accomplish this, each node of the network will:

- Continuously carry out real-time sensing and characterization of the local spectrum usage by (potentially interfering) narrowband and wideband emitters
- Dynamically and autonomously adapt (on a time scale of milliseconds) to the local spectrum environment by selecting and controlling the waveforms (power spectral density and Media Access Control (MAC) protocols) that its network neighbors use when transmitting to this node
- Automatically carry out a closed loop power control algorithm with each neighbor to enhance Low Probability of Detection (LPD)
- Apply TRANSEC parameters to the spread spectrum modulation process in order to enhance Low Probability of Intercept (LPI)
- Carry out packet forwarding (routing) in a way that balances aggregate network throughput against average end-to-end delay. This results in real time traffic (e.g., voice) being sent with higher power (minimizing latency due to channel access delays at multiple hops), and bulk traffic being sent with lower power (minimizing network self-interference, maximizing spatial reuse of frequencies and enhancing LPI/LPD).

Security Goals and COMSEC Approach. We adopt a system architecture where user traffic will be encrypted end-to-end (remain covered throughout the wireless network) by inline network encryptors (INEs) that create an independently-keyed virtual private network (VPN) for each security level and community of interest. With this approach, the network itself can operate at Sensitive but Unclassified (SBU, like the NIPRNET), and we can use Federal Information Processing Standard software encryption approaches (e.g., the NIST Advanced Encryption Standard, <http://csrc.nist.gov/encryption/aes/>) to accomplish NETSEC. This also means that we can deploy unattended relays such as unmanned air vehicles (UAVs) and advantaged/elevated nodes that are not COMSEC-controlled items (CCI) because they do not contain Type 1 encryption devices.

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Attorney Docket No. 02-4099PRO1**Section B: Technical Summary****B.1 Technical Approach: Spectrum-Adaptive Networking on Software Radios**

We propose to design, develop, and demonstrate a highly advanced networking communications architecture for , based upon a software radio foundation. The design is revolutionary in combining dynamic spectrum management techniques with matching adaptive networking, implementation on a software radio, and full exploitation of multiple transceivers per communications node. It also has the flexibility and scalability to be an evolutionary solution, and this technology will be applicable as an applique to JTRS, WIN-T, FCS, and other forward-looking defense communications systems.

We propose to solve the military's "Spectrum Crisis" by demonstrating how to overlay spectrum-efficient megabit rate networking, capable of supporting NIPRNET and SIPRNET, onto bands allocated for other purposes. This approach can overlay military networking on top of any narrowband-channelized spectrum where individual channels have less than 100% duty cycle, such as commercial cellular, without interfering with existing legacy users of these bands. Our specific focus is an overlay onto the military VHF (30 – 88 MHz), UHF (225 – 400 MHz), and L-Band (1710 – 1850 MHz) without interference to legacy military systems such as SINCGARS, HaveQuick, EPLRS, and NTDR.

Initial use of existing military frequency allocations ensures that these systems will be usable during peacetime training in CONUS. In overseas locations and in wartime, we will not be restricted to these particular bands, and the flexible hardware and software we are demonstrating will also operate in other frequencies without hardware modification. This approach will provide 30 times the data rates achieved in today's SINCGARS-based Tactical Internet.

The transceiver design will utilize a software radio architecture developed by Vanu Inc. Software radio implementation enables a COTS processor-based radio that can grow over time, incorporating new signaling protocols as they become available, and incorporating ever more efficient components in terms of size, weight, and power (SWAP) (made possible by Moore's Law). For example, Intel Pentium 4 processors currently operate at clock rates of 2 GHz, and Intel is projecting increases of the clock rate beyond 10 GHz by 2005. The best available COTS processors will be used for JTRS, WIN-T, and FCS fielding in 2005 with no additional development because Vanu software is portable. In addition, Vanu will leverage its RF-to-digital front-end technology to provide all necessary analog functions on a compact card. Future technology improvements will make these front ends quite affordable, so there is no impediment to operating each network node with multiple independent transceivers. We see this rapid evolution in transceiver technology in today's two-chip CMOS implementations of IEEE 802.11a 54 Mb/s OFDM transceivers.

The BBN/Vanu XG Team is uniquely qualified to provide with these revolutionary new technologies for spectrum-adaptive networking on software radios.

B.1.1 Technical Innovations

In this effort, we develop the enabling technologies and the system concepts to provide dramatic improvements in assured military communications by dynamic redistribution of allocated spectrum and advanced Media Access Control (MAC) protocols. Figure 1 shows our Architecture for Spectrum-Adaptive Networking, with functions allocated to their appropriate protocol layers.

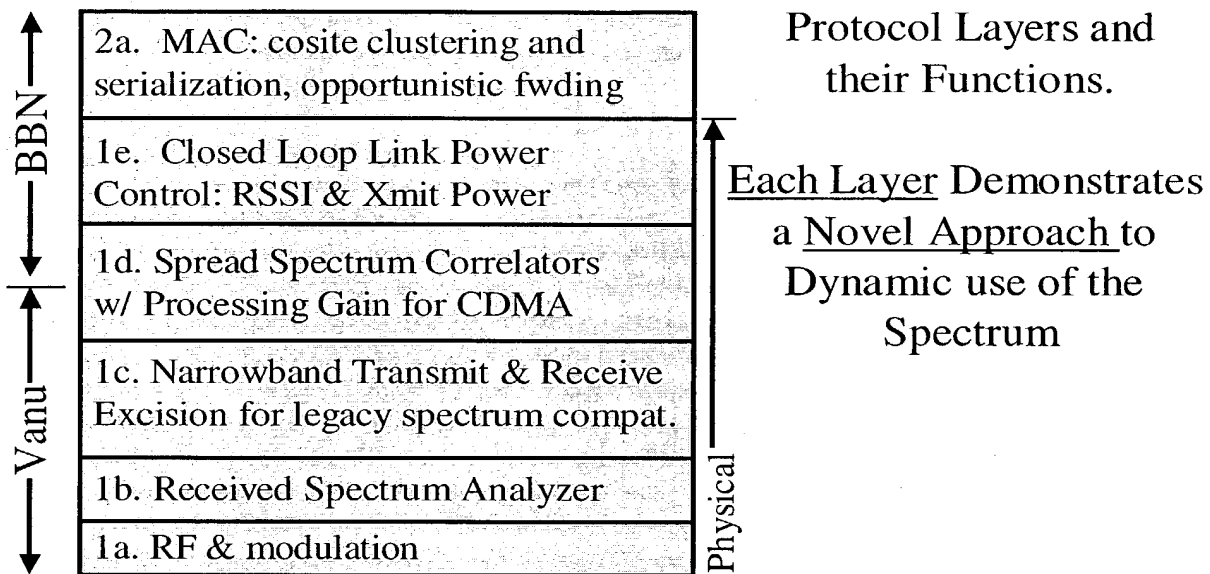


Figure 1: Architecture of the Spectrum-Adaptive Network

The technologies proposed for use at each layer of this protocol stack, as well as the overall network architecture concept, are novel approaches appropriate for high-risk, high-payoff exploration. Not all of these innovations have to succeed for the overall system to be successful, but they function synergistically, providing complementary performance improvements. The following section describes our proposed approach at each layer of the design.

B.2 Network Architecture Concept

- Adopt the widest bandwidth (BW) use that meets SWAP and cost constraints. Spread spectrum Processing Gain (PG) provides LPI/LPD and antijam (AJ).
- Adopt local, metropolitan, and wide-area network (LAN, MAN, and WAN) bands for megabit speed networking and seamless interoperability with DII / GIG / SIPRNET / NIPRNET. Take advantage of military L-Band, UHF and VHF allocations (cross-banding within a single network) as shown in the table to create links for these different purposes.

Band	Use	Per-Hop Range	Path Loss	Data Rate	Analogy
Mil – 3: 1710 – 1850 MHz	W-LANs (Squad)	0.2 Km	60 – 90 dB	~10 Mb/s	Star Trek “Comm Badge”
Mil –UHF: 225 – 400 MHz	W-CANs (Company)	5 Km	90 – 120 dB	~ 2 Mb/s	Star Trek “Communicator”
Mil –VHF: 30 – 88 MHz	W-MANs (Bde)	30 Km	120-150 dB	~0.5 Mb/s	SINCGARS *30 data rate

This approach, namely providing a range of different link types, all integrated into a single network with automatic cross-banding in nodes with multiple independent transceivers, provides all the benefits needed for successful megabit rate tactical networking, bringing SIPRNET and NIPRNET services forward to the WarFighters.

The Mil-VHF band provides much better propagation (longer range) for modest power, as the effective area of an omni-directional antenna is $\propto \lambda^2/4\pi$. This results in almost a 30 dB improvement in path loss, for 30 times the line of sight (LOS) range compared to the Mil-3 band. Diffraction around wavelength-sized obstacles (e.g., 10 meter hills or buildings) can make an even greater difference beyond LOS. In contrast, the Mil-3 band provides much higher available bandwidth, permitting far higher data rates over short ranges. In fact, the short range here results in both high spatial reuse of the frequency allocation, and a low power, LPI/LPD signal with wide spectrum spreading. Having an unobtrusive signal eliminates the need to contest spectrum “ownership”¹. The Mil-UHF band is intermediate between these two in both range and available bandwidth, filling in the need for medium range links.

- Network Routing and Forwarding. The adaptive networking layers will carry out forwarding of packets based on their indicated (differential services, or diffserv) quality of service. Bulk traffic is forwarded via low-power multi-hop routing, to maximize spatial reuse of frequencies and enhance LPI/LPD. Real-time voice traffic traverses fewer hops at higher power to minimize end-to-end latency.

The following sections describe the novel functionality of each numbered layer of Figure 1.

2a. The MAC Layer

One key problem in efficient spectrum use is co-site interference, which occurs when transmissions to distant nodes overwhelm reception by local nodes. We solve the co-site interference problem by using multiple independent transceivers of different frequencies (bands) to establish short links (60 – 90 dB PL), medium links (90 – 120 dB PL), and long links (120 – 150 dB PL) as shown above, plus innovative MAC protocols that:

- Automatically define W-LAN groups (good internal connectivity with short range links), in which use of any medium range link is serialized. Define W-MAN groups (good internal connectivity using medium range links) in which use of any long range link is serialized.
- Use a K-Means vector quantization algorithm to define co-site clusters and dynamically update them. Within each cluster (squad W-LAN), use a point coordination function

¹ To paraphrase the movie “Love Story”, using LPI/LPD means never having to say you’re sorry for frequency violations.

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(PCF) to serialize the usage of a medium link. Each cluster alternates between receiving over multiple medium links, and transmitting over one medium link. Use multiple correlators and a different spread spectrum code for each W-LAN to permit simultaneous use of medium links by different squads without interference.

- Plan the deployment of some number of advantaged nodes (elevated antennas) to provide long links for "Small World" latency reduction and low-latency quality of service (QoS) traffic. Use a specialized MAC protocol to handle the very high fan-in here.
- Opportunistic forwarding: for extremely low delay traffic, forward a packet to any node in the direction of the destination (lower hop count) that isn't transmitting now (like a quarterback looking for an open receiver downfield). This violates the customary practice of strict protocol layering, by using instantaneous information from the MAC layer to guide network forwarding decisions. It eliminates the dominant end-to-end latency effect of channel access delay at each hop.

1e. Closed Loop Power Control

- Feedback from each receiver to a neighboring transmitter to minimize transmit power for a reliable link. This maximizes spatial reuse of frequencies, minimizes network self interference, improves LPI/LPD, and minimizes battery drain for portable nodes.
- Adopt the goal of keeping transmit power density $< 50 \text{ mW/MHz}$ (1 W. per 20 MHz) in any frequency or time interval, subject to topology control to maintain a connected network. This also enhances spectrum compatibility with other friendly narrowband and wideband (NB and WB) systems². This limit on power density also helps achieve LPI by thwarting linear (spectrum analyzer) interceptors.

1d. Variable-Gain Spread Spectrum

- Vary the PG by use of different modes during different phases of the battle: Very high PG (e.g., 30 dB) during covert insertion and special operations, Medium PG (e.g., 20 dB, higher data rate) for entry and positioning of major forces, and Modest PG (e.g., 10 dB, highest data rates) during battle. Flexible software radio is key to enable variable PG.
- Use multiple receive correlators to receive simultaneously from multiple neighbors. Spread spectrum signaling costs bandwidth by a factor of PG. This approach recoups spectrum efficiency by factor of the number of neighbors, up to the square root of PG.

1c. Narrowband R & T Excision

"Dancing Between the Raindrops" is our term for a novel orthogonal frequency division multiplexing (OFDM) waveform with 25 KHz channels that supports transmit and receive NB excision to eliminate interference with legacy systems (SINCGARS, Havequick, etc.). The OFDM signal (sum of many complex exponentials with independent phase) approximates a Gaussian envelope featureless waveform for LPI/LPD. We adjust this excision on a very dynamic (milliseconds) basis to overlay onto spectrum allocated for a legacy channelized NB system.

- Measure the short-term ($< 1 \text{ sec}$) power spectrum at the receiver, and apply NB (25 KHz) excision of spectral spikes to minimize interference from legacy systems.
- Command a matching NB excision of channels at neighboring transmitters to eliminate interference to friendly NB systems

² This choice mandates the use of wideband waveforms to achieve the desired ranges.

1b. Receiver Spectral Analysis

- Each receiver does its own spectrum analysis of local interference, assigns its own receive frequencies automatically, and reports them to its neighbors over a common, low data rate, configuration channel. Selecting low-interference frequency ranges minimizes transmit power requirements and avoids congested spectrum.

1a. Radio Frequency (RF)-to-Baseband, Using Multiple Transceivers

- Use multiple transceivers to support simultaneous operation in multiple bands, simultaneous spectral analysis and communications, and other novel functions.
- Use fragmented spectrum for wide bandwidth with maximum flexibility
- Use Wide-sense Stationary waveform to thwart 2nd order cyclo-stationary interceptors. Zero mean, equal power, uncorrelated I and Q signals conceal the carrier frequency. Nyquist filtered symbols conceal the symbol clock.
- In multi-antenna nodes, assign a time division duplex (TDD) transceiver to each directional antenna. This provides far more throughput than a single-transceiver architecture that switches one transceiver among multiple antennas. Use node coloring to assign a distinct receive frequency to each node for multiple, non-interfering beams

The use of a software radio provides the flexibility to handle a multitude of different commercial cellular standards on a single hardware platform intermixed within a band. For the XG Communications Program, it provides the flexibility to make dynamic adaptive use of spectrum under rapidly varying interference conditions, and the ability to support advanced adaptive Media Access Control (MAC) protocols.

Our software radios are characterized by the use of portable object-oriented code - the most sophisticated known computer science theory for maximum performance - and modern software engineering techniques and tools that minimize cost and time-to-market for radio development and upgrades.

B.2.1 Current Technology and Products Relevant to XG Efforts

A variety of technologies and products may provide substantial leverage for implementing the advanced techniques developed in this project. Examples of some of these products are:

- The Sprockit™ middleware and library of preexisting signal processing modules substantially reduce the time and effort required to implement a new waveform.
- The Radio Description Language (RDL) language, compiler, and runtime system enable rapid waveform modifications and reduce the cost of running a variety of experiments.
- The transmit and receive sides of the Eureka 147 waveform (ETSI EN 300 401). This is an OFDM waveform used in Europe, Canada, and the Far East for digital audio broadcast service, both terrestrial and satellite. Experience with OFDM, and the resulting reusable software modules, provides confidence in the ability to rapidly implement the new OFDM waveform proposed for Spectrum Adaptive Networking.

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- Highly flexible RF-to-digital board by Hand Technologies, Inc. Initial evaluation boards will be available in early summer 2002, with boards available in sufficient volume by September 1, 2002 to support all the experiments planned in this effort.

Bandwidth	1.3 MHz
Ranges:	30 – 512 MHz
	700 – 956 MHz
	1850 – 1990 MHz

This small-form-factor transceiver provides an excellent prototype of the multi-band tunable RF front ends that will be available as single-chip devices by the 2005–2006 time frame. Technology development towards an Integrated XG system