

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A SUBMISSION UNDER 35 U.S.C. 371		ATTORNEY'S DOCKET NUMBER 612408017US1 U.S. APPLICATION NO. (if known, see 37 CFR 1.5)
INTERNATIONAL APPLICATION NO. PCT/US2006/038149	INTERNATIONAL FILING DATE 28 September 2006	PRIORITY DATE CLAIMED 28 September 2005
TITLE OF INVENTION METHOD AND SYSTEM FOR MULTI-CARRIER PACKET COMMUNICATION WITH REDUCED OVERHEAD		
APPLICANT(S) FOR DO/EO/US Li et al.		
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:		
1. ☒ This is a FIRST submission of items concerning a submission under 35 U.S.C. 371. 2. ☐ This is a SECOND or SUBSEQUENT submission of items concerning a submission under 35 U.S.C. 371. 3. ☐ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below. 4. ☐ The US has been elected (Article 31). 5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c)(2)) a. ☐ is attached hereto (required only if not communicated by the International Bureau). b. ☐ has been communicated by the International Bureau. c. ☒ is not required, as the application was filed in the United States Receiving Office (RO/US). 6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)). a. ☐ is attached hereto. b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4). 7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)) a. ☐ are attached hereto (required only if not communicated by the International Bureau). b. ☐ have been communicated by the International Bureau. c. ☐ have not been made; however, the time limit for making such amendments has NOT expired. d. ☒ have not been made and will not be made. 8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)). 9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)). 10. ☐ An English language translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)). Items 11 to 20 below concern document(s) or information included: 11. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98. 12. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included. 13. ☐ A preliminary amendment. 14. ☐ An Application Data Sheet under 37 CFR 1.76. 15. ☐ A substitute specification. 16. ☐ A power of attorney and/or change of address letter. 17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 37 CFR 1.821 – 1.825. 18. ☐ A second copy of the published International Application under 35 U.S.C. 154(d)(4). 19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).		

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.

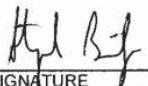
U.S. APPLICATION NO. (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO. PCT/US2006/038149	ATTORNEY'S DOCKET NUMBER 612408017US1
20. ☐ Other items or information:		
The following fees have been submitted		
21. ☒ Basic national fee (37 CFR 1.492(a))	\$300	CALCULATIONS \$ 300.00
22. ☒ Examination fee (37 CFR 1.492(c)) If the written opinion prepared by ISA/US or the international preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4) All other situations	\$0 \$200	\$ 200.00
23. ☒ Search fee (37 CFR 1.492(b)) If the written opinion of the ISA/US or the international preliminary examination report prepared by IPEA/US indicates all claims satisfy provisions of PCT Article 33(1)-(4) Search fee (37 CFR 1.445(a)(2)) has been paid on the international application to the USPTO as an International Searching Authority International Search Report prepared by an ISA other than the US and provided to the Office or previously communicated to the US by the IB All other situations	\$0 \$100 \$400 \$500	\$ 0.00
TOTAL OF 21, 22 and 23 =		\$ 500.00
☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing in compliance with 37 CFR 1.821(c) or (e) or computer program listing in an electronic medium) (37 CFR 1.492(j)). The fee is \$250 for each additional 50 sheets of paper or fraction thereof.		
Total Sheets	Extra Sheets	Number of each additional 50 or fraction thereof (round up to a whole number)
28 - 100 =	/50 =	x \$250.00
Surcharge of \$130 for furnishing any of the search fee, examination fee, or the oath or declaration after the date of commencement of the national stage (37 CFR 1.492(h)).		\$
CLAIMS	NUMBER FILED	NUMBER EXTRA
Total claims	33 - 20 =	13
Independent claims	2 - 3 =	0
MULTIPLE DEPENDENT CLAIM(S) (if applicable)		+
TOTAL OF ABOVE CALCULATIONS =		\$ 1,150.00
☒ Applicant claims small entity status. See 37 CFR 1.27. Fees above are reduced by 1/2.		575.00
SUBTOTAL =		\$ 575.00
Processing fee of \$130.00 for furnishing the English translation later than 30 months from the earliest claimed priority date (37 CFR 1.492(j)).		\$
TOTAL NATIONAL FEE =		\$ 575.00
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property		\$
TOTAL FEES ENCLOSED =		\$ 575.00
Amount to be refunded:		\$
Amount to be charged		\$

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.

- a. ☒ Payment by EFT of \$ 575.00 to cover the above fees is enclosed. EFT Account No. SEA1PIRM.
- b. ☐ Please charge my Deposit Account No. 50-0665 in the amount of \$ _____ to cover the above fees.
A duplicate copy of this sheet is enclosed.
- c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 50-0665.
- d. ☐ Fees are to be charged to a credit card. **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

NOTE: Where an appropriate time limit under 37 CFR 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the International Application to pending status.

SEND ALL CORRESPONDENCE TO:


SIGNATURE

Stephen Bishop
NAME

CUSTOMER NUMBER: 25096

38,829
REGISTRATION NUMBER

Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		METHOD AND SYSTEM FOR MULTI-CARRIER PACKET COMMUNICATION WITH REDUCED OVERHEAD		
First Named Inventor/Applicant Name:		Xiaodong Li		
Filer:		Christopher J. Daley-Watson/CHRISTINE HURDLE		
Attorney Docket Number:		612408017US1		
Filed as Small Entity				
U.S. National Stage under 35 USC 371 Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Basic National Stage Fee	2631	1	150	150
Natl Stage Search - U.S. as IPEA or ISA	2640	1	0	0
Natl Stage Exam Fee - all other cases	2633	1	100	100
Pages:				
Claims:				
Claims in excess of 20	2615	13	25	325
Miscellaneous-Filing:				
Petition:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				575

Electronic Acknowledgement Receipt

EFS ID:	2178418
Application Number:	11908257
International Application Number:	PCT/US06/38149
Confirmation Number:	1928
Title of Invention:	METHOD AND SYSTEM FOR MULTI-CARRIER PACKET COMMUNICATION WITH REDUCED OVERHEAD
First Named Inventor/Applicant Name:	Xiaodong Li
Customer Number:	25096
Filer:	Christopher J. Daley-Watson/CHRISTINE HURDLE
Filer Authorized By:	Christopher J. Daley-Watson
Attorney Docket Number:	612408017US1
Receipt Date:	10-SEP-2007
Filing Date:	
Time Stamp:	17:49:26
Application Type:	U.S. National Stage under 35 USC 371

Payment information:

Submitted with Payment	yes
Payment was successfully received in RAM	\$575
RAM confirmation Number	2553
Deposit Account	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes) /Message Digest	Multi Part /.zip	Pages (if appl.)
-----------------	----------------------	-----------	----------------------------------	------------------	------------------

1	Transmittal of New Application	Transmittal.pdf	134381 9ac4b28109ecaea71da20db1e16766b0 fd2776ac	no	3
Warnings:					
Information:					
2	Fee Worksheet (PTO-06)	fee-info.pdf	8598 93b39cc514605b42e4020377508d83c 21c582113	no	2
Warnings:					
Information:					
Total Files Size (in bytes):				142979	
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.					

(19) World Intellectual Property Organization
International Bureau(43) International Publication Date
5 April 2007 (05.04.2007)

PCT

(10) International Publication Number
WO 2007/038750 A1(51) International Patent Classification:
H04B 11/00 (2006.01)(21) International Application Number:
PCT/US2006/038149(22) International Filing Date:
28 September 2006 (28.09.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/721,451 28 September 2005 (28.09.2005) US(71) Applicant (for all designated States except US): **NEO-CIFIC, INC.** [US/US]; 13312 SE 43rd Street, Bellevue, WA 98006 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **LI, Xiaodong** [US/US]; 9919 129th PL NE, Kirkland, WA 98033 (US). **HUANG, Haiming** [CN/US]; 605 141st CT SE #D203, Bellevue, WA 98007 (US). **LO, Titus** [CA/US]; 13312 SE 43rd St, Bellevue, WA 98006 (US). **WANG, Ruifeng** [CA/US]; 656 237th PL SE, Sammamish, WA 98074 (US).(74) Agent: **BISHOP, Stephen, C.**; Perkins Coie LLP, P.O. Box 1247, Seattle, WA 98111-1247 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

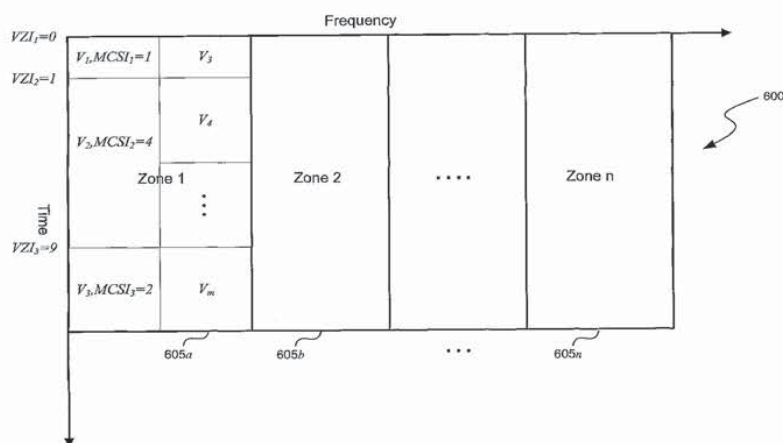
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND SYSTEM FOR MULTI-CARRIER PACKET COMMUNICATION WITH REDUCED OVERHEAD



(57) **Abstract:** A method and system for minimizing the control overhead in a multi-carrier wireless communication network that utilizes a time-frequency resource is disclosed. In some embodiments, one or more zones in the time-frequency resource are designated for particular applications, such as a zone dedicated for voice-over-IP (VoIP) applications. By grouping applications of a similar type together within a zone, a reduction in the number of bits necessary for mapping a packet stream to a portion of the time-frequency resource can be achieved. In some embodiments, modular coding schemes associated with the packet streams may be selected that further reduce the amount of necessary control information. In some embodiments, packets may be classified for transmission in accordance with application type, QoS parameters, and other properties. In some embodiments, improved control messages may be constructed to facilitate the control process and minimize associated overhead.

METHOD AND SYSTEM FOR MULTI-CARRIER PACKET COMMUNICATION WITH REDUCED OVERHEAD

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 60/721,451, filed on September 28, 2005.

TECHNICAL FIELD

[0002] The disclosed technology relates, in general, to wireless communication and, in particular, to multi-carrier packet communication networks.

BACKGROUND

[0003] Bandwidth efficiency is one of the most important system performance factors for wireless communication systems. In packet based data communication, where the traffic has a bursty and irregular pattern, application payloads are typically of different sizes and with different quality of service (QoS) requirements. In order to accommodate different applications, a wireless communication system should be able to provide a high degree of flexibility. However, in order to support such flexibility, additional overhead is usually required. For example, in a wireless system based on the IEEE 802.16 standard ("WiMAX"), multiple packet streams are established for each mobile station to support different applications. At the medium access control (MAC) layer, each packet stream is mapped into a wireless connection. The MAC scheduler allocates wireless airlink resources to these connections. Special scheduling messages, DL-MAP and UL-MAP, are utilized to broadcast the scheduling decisions to the mobile stations.

[0004] In the MAP scheduling message defined by IEEE802.16, there is significant control overhead. For example, each connection is identified by a 16 bits connection ID (CID). The CID is included in the MAP message to identify the mobile station. The maximum number of connections that a system can support is therefore 65,536. Each mobile station has at least two management connections for control and management messages and a various number of traffic connections for

application data traffic. As another example, each connection includes the identification of an airlink resource that can correspond to any time/frequency region that is allocated for communication. The resource allocation is identified in the time domain scale with a start symbol offset (8 bits) and a symbol length (7 bits) and in the frequency domain scale with a start logical subchannel offset (6 bits) and a number of allocated subchannels (6 bits). Due to the fact that different applications have different resource requirements, the allocated resource region is irregular from connection to connection. As a still further example, the modulation and coding scheme for each connection is identified by a 4-bit MCS code, identified as either a downlink interval usage code (DIUC) or an uplink interval usage code (UIUC). Another 2 bits are used to indicate the coding repetition in addition to 3 bits for power control. Overall, the overhead of a MAP message is 52 bits. For applications such as voice-over-IP (VoIP), the payload of an 8Kbps voice codec is 20 bytes in every 20ms. The overhead of the MAP message alone can therefore account for as much as 32.5% of the overall data communication, thereby resulting in a relatively low spectral efficiency. It would therefore be beneficial to reduce the overhead in a multi-carrier packet communication system to improve the spectral efficiency of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Figure 1 illustrates the coverage of a wireless communication network that is comprised of a plurality of cells.

[0006] Figure 2 is a block diagram of a receiver and a transmitter, such as might be used in a multi-carrier wireless communication network.

[0007] Figure 3 is a block diagram depicting a division of communication capacity in a physical media resource.

[0008] Figure 4 is a graphical depiction of the relationship between a sampling frequency, a channel bandwidth, and usable subcarriers in a channel.

[0009] Figure 5 is a graphical depiction of the structure of a multi-carrier signal in the frequency domain.

[0010] Figure 6 is a block diagram of a time-frequency resource utilized by a wireless communication network.

[0011] Figure 7 is a block diagram of a classifier for classifying received packets by application, QoS, or other factor.

[0012] Figures 8A and 8B are block diagrams of representative control message formats.

[0013] Figure 9 is a block diagram of a special resource zone with unit sequence defined in time-first order.

[0014] Figures 10A-10C are block diagrams illustrating the reallocated of resources within a resource zone.

DETAILED DESCRIPTION

[0015] A system and method for minimizing the control overhead in a multi-carrier wireless communication network that utilizes a time-frequency resource is disclosed. In some embodiments, one or more zones in the time-frequency resource are designated for particular applications, such as a zone dedicated for voice-over-IP (VoIP) applications. By grouping applications of a similar type together within a zone, a reduction in the number of bits necessary for mapping a packet stream to a portion of the time-frequency resource can be achieved. In some embodiments, modular coding schemes associated with the packet streams may be selected that further reduce the amount of necessary control information.

[0016] In some embodiments, packets may be classified for transmission in accordance with application type, QoS parameters, and other properties. An application connection-specific identifier (ACID) may also be assigned to a packet stream. Both measures reduce the overhead associated with managing multiple application streams in a communication network.

[0017] In some embodiments, improved control messages may be constructed to facilitate the control process and minimize associated overhead. The control messages may include information such as the packet destination, the modulation and coding method, and the airlink resource used. Control messages of the same

application type or subtype, modulation and coding scheme, or other parameter may be grouped together for efficiency.

[0018] While the following discussion contemplates the application of the disclosed technology to an Orthogonal Frequency Division Multiple Access (OFDMA) system, those skilled in the art will appreciate that the technology can be applied to other system formats such as Code Division Multiple Access (CDMA), Multi-Carrier Code Division Multiple Access (MC-CDMA), or others. Without loss of generality, OFDMA is therefore only used as an example to illustrate the present technology. In addition, the following discussion uses voice-over-IP as a representative application to which the disclosed technology can be applied. The disclosed technology is equally applicable to other applications including, but not limited to, audio and video.

[0019] The following description provides specific details for a thorough understanding of, and enabling description for, various embodiments of the technology. One skilled in the art will understand that the technology may be practiced without these details. In some instances, well-known structures and functions have not been shown or described in detail to avoid unnecessarily obscuring the description of the embodiments of the technology. It is intended that the terminology used in the description presented below be interpreted in its broadest reasonable manner, even though it is being used in conjunction with a detailed description of certain embodiments of the technology. Although certain terms may be emphasized below, any terminology intended to be interpreted in any restricted manner will be overtly and specifically defined as such in this Detailed Description section.

I. Wireless Communication Network

[0020] Figure 1 is a representative diagram of a wireless communication network 100 that services a geographic region. The geographic region is divided into a plurality of cells 105, and wireless coverage is provided in each cell by a base station (BS) 110. One or more mobile devices (not shown) may be fixed or may roam within the geographic region covered by the network. The mobile devices are used as an interface between users and the network. Each base station is connected to the backbone of the network, usually by a dedicated link. A base station serves as a focal point to transmit information to and receive information from

the mobile devices within the cell that it serves by radio signals. Note that if a cell is divided into sectors, from a system engineering point of view each sector can be considered as a cell. In this context, the terms "cell" and "sector" are interchangeable.

[0021] In a wireless communication system with base stations and mobile devices, the transmission from a base station to a mobile device is called a downlink (DL) and the transmission from a mobile device to a base station is called an uplink (UL). Figure 2 is a block diagram of a representative transmitter 200 and receiver 205 that may be used in base stations and mobile devices to implement a wireless communication link. The transmitter comprises a channel encoding and modulation component 210, which applies data bit randomization, forward error correction (FEC) encoding, interleaving, and modulation of an input data signal. The channel encoding and modulation component is coupled to a subchannel and symbol construction component 215, an inverse fast Fourier transform (IFFT) component 220, and a radio transmitter component 225. Those skilled in the art will appreciate that these components construct and transmit a communication signal containing the data that is input to the transmitter 200. Other forms of transmitter may, of course, be used depending on the requirements of the communication network. :

[0022] The receiver 205 comprises a reception component 230, a frame and synchronization component 235, a fast Fourier transform component 240, a frequency, timing, and channel estimation component 245, a subchannel demodulation component 250, and a channel decoding component 255. The channel decoding component de-interleaves, decodes, and derandomizes a signal that is received by the receiver. The receiver recovers data from the signal and outputs the data for use by the mobile device or base station. Other forms of receiver may, of course, be used depending on the requirements of the communication network.

[0023] Figure 3 is a block diagram depicting the division of communication capacity in a physical media resource 300 (e.g., radio or cable) into frequency and time domains. The frequency is divided into two or more subchannels 305, represented in the diagram as subchannels 1, 2,...m. Time is divided into two or more time slots 310, represented in the diagram as time slots 1, 2,...n. The

canonical division of the resource by both time and frequency provides a high degree of flexibility and fine granularity for resource sharing between multiple applications or multiple users of the resource.

[0024] Figure 4 is a block diagram representing the relationship between the bandwidth of a given channel and the number of usable subcarriers within that channel. A multi-carrier signal in the frequency domain is made up of subcarriers. In Figure 4, the sampling frequency is represented by the variable f_s , the bandwidth of the channel is represented by the variable B_{ch} , and the effective bandwidth by the variable B_{eff} (where the effective bandwidth is a percentage of the channel bandwidth). The number of usable subcarriers within the channel is defined by the following equation:

$$\#_usable_subcarriers = \frac{B_{eff}}{f_s} \times N_{fft}$$

Where N_{fft} is the length of the fast Fourier transform. Those skilled in the art will appreciate that for a given bandwidth of a spectral band or channel (B_{ch}), the number of usable subcarriers is finite and limited, and depends on the size of the FFT, the sampling frequency (f_s), and the effective bandwidth (B_{eff}) in accordance with equation 1.

[0025] Figure 5 is a signal diagram depicting the various subcarriers and subchannels that are contained within a given channel. There are three types of subcarriers: (1) data subcarriers, which carry information data; (2) pilot subcarriers, whose phases and amplitudes are predetermined and made known to all receivers, and which are used for assisting system functions such as estimation of system parameters; and (3) silent subcarriers, which have no energy and are used for guard bands and as a DC carrier. The data subcarriers can be arranged into groups called subchannels to support scalability and multiple-access. The subcarriers forming one subchannel may or may not be adjacent to each other. Each mobile device may use some or all of the subchannels.

[0026] A multi-carrier signal in the time domain is generally made up of time frames, time slots, and OFDM symbols. A frame consists of a number of time slots, and each time slot is comprised of one or more OFDM symbols. The OFDM time domain waveform is generated by applying an inverse-fast-Fourier-transform (IFFT)

to the OFDM symbols in the frequency domain. A copy of the last portion of the time domain waveform, known as the cyclic prefix (CP), is inserted in the beginning of the waveform itself to form an OFDM symbol.

[0027] In some embodiments, a mapper such as the subchannel and symbol construction component 215 in Figure 2 is designed to map the logical frequency/subcarrier and OFDM symbol indices seen by upper layer facilities, such as the MAC resource scheduler or the coding and modulation modules, to the actual physical subcarrier and OFDM symbol indices. A contiguous time-frequency area before the mapping may be actually discontinuous after the mapping, and vice versa. On the other hand, in a special case, the mapping may be a "null process", which maintains the same time and frequency indices before and after the mapping. The mapping process may change from time slot to time slot, from frame to frame, or from cell to cell. Without loss of generality, the terms "resource", "airlink resource", and "time-frequency resource" as used herein may refer to either the time-frequency resource before such mapping or after such mapping.

II. Airlink Resource Zones

[0028] Various technologies are now described that may be utilized in conjunction with the wireless communication network 100 in order to reduce the amount of control overhead associated with the use of system resources. By reducing the control overhead, greater spectral efficiency is achieved allowing the system to, among other benefits, maximize the amount of simultaneously supported communications.

[0029] Figure 6 is a map of a time-frequency resource 600 that is allocated for use by the wireless communication network 100. As described above, in a typical wireless system based on the IEEE 802.16 standard ("WiMAX"), multiple packet streams are established for each mobile device to support different applications. At the medium access control (MAC) layer, each packet stream is mapped into a wireless connection. As a result, various applications carried in packet streams may be spread throughout the available time-frequency resource. To overcome the inefficiencies associated with maintaining this mapping, Figure 6 depicts an alternative way of managing multiple packet streams. The time-frequency resource 600 may be divided into one or more zones 605a, 605b,...605n. Each of

the zones 605a, 605b,...605n is associated with a particular type of application. For example, zone 605a may be associated with voice applications (e.g., VoIP), zone 605b may be associated with video applications, and so on. As will be described in additional detail below, by grouping like applications together the amount of control overhead in MAC headers is reduced. Zones may be dynamically allocated, modified, or terminated by the system.

[0030] When applications of a similar type are grouped together within a zone, a reduction in the number of bits necessary for mapping a packet stream to a time-frequency segment can be achieved. In some embodiments, the identification of the time-frequency segment associated with a particular packet stream can be indicated by the starting time-frequency coordinate and the ending time-frequency coordinate relative to the starting point of the zone. The granularity in the time coordinates can be one or multiple OFDM symbols, and that in the frequency coordinates can be one or multiple subcarriers. If the time-frequency resource is divided into two or more zones, the amount of control information necessary to map to a location relative to the starting point of the zone may be significantly less than the amount of information necessary to map to an arbitrary starting and ending coordinate in the entire time-frequency resource.

[0031] Within each zone 605a, 605b,...605n, the time-frequency resource may be further divided in accordance with certain rules to accommodate multiple packet streams $V_1, V_2, \dots, V_m$. For example, as depicted in Figure 6, zone 605a is divided into multiple columns and the packet streams are arranged from top down in each column and from left to right across the columns. The width of each column can be a certain number of subcarriers. Each packet stream $V_1, V_2, \dots, V_m$ may be associated with an application. For example, V_1 is the resource segment to be used for the first voice packet stream, V_2 is the resource segment to be used for the second voice packet stream, etc. While the zone 605a is divided and the packet streams numbered starting at an origin of the zone, it will be appreciated that the division of the time-frequency resource in accordance with certain rules may start at other origin locations within the zone as well. Segments within each zone may be dynamically allocated by the system as requested and released by the system when expressly or automatically terminated.

[0032] When the zones are further subdivided into time-frequency segments in accordance with certain rules, a mapping of packet streams to segment may be achieved using a one-dimensional offset with respect to the origin of the zone rather than the two-dimensional (i.e. starting time-frequency coordinate and ending time-frequency coordinate relative to the starting point of the zone) mapping method discussed above. Calculation of such an offset may require knowledge of a modulation and coding scheme that is associated with a particular packet stream. For example, Table 1 below sets forth representative modulation and forward-error correction (FEC) coding schemes (MCS) that may be used for voice packet streams under various channel conditions.

Table 1

MCSI	Modulation	Coding rate	Information bits	Raw symbols	Units
1	16QAM	1/2	160	80	1
2	QPSK	1/2	160	160	2
3	QPSK	1/4	160	320	4
4	QPSK	1/8	160	640	8

[0033] In some embodiments, the MCS may be selected to utilize modular resources. For example, as illustrated in Table 1, 80 raw modulation symbols are needed to transmit 160 information bits using 16QAM modulation and rate- $\frac{1}{2}$ coding, the highest available MCS in the table. The resource utilized by this highest MCS is called a basic resource unit ("Unit"), i.e., 80 raw symbols in this example. The resource utilized by other MCS is simply an integer multiple of the basic unit. For example, four units are required to transmit the same number of information bits using QPSK modulation with rate- $\frac{1}{4}$ coding. The MCS index (MCSI) conveys the information about modulation and coding schemes. For a known vocoder, MCSI also implies the number of AMC resource units required for a voice packet. Those skilled in the art will appreciate that coding and signal repetition can be combined to

provide lower coding rates. For example, rate-1/8 coding can be realized by a concatenation of rate-1/2 coding and 4-time repetition.

[0034] The decision process for selecting the proper MCS of a packet can vary by application. In some embodiments, the process for voice packets can be more conservative than that for general data packets due to the QoS requirements of the voice applications. For example, when the signal to interference noise ratio (SINR) is used as a threshold for selecting the MCS, the threshold value for voice packets is set higher than that for general data packets. For example, the SINR threshold of QPSK with rate-1/2 coding for voice packets is 12 dB, while that for general data packets is 10 dB.

[0035] If a MCS from Table 1 is selected for each packet stream contained in a particular zone, the offset to a segment representing a particular packet stream may be easily calculated. For example, an index $VZI_1, VZI_2, \dots, VZI_m$ is shown at the origin of each segment that is contained in the zone 605a. The index for any selected packet stream is defined as the sum of all basic resource units associated with each packet stream preceding the selected packet stream, with an optional adjustment depending on the location where the division of the time-frequency resource is started (typically no adjustment is required since the division starts at the origin of the zone). For example, the location index for the first voice packet stream is $VZI_1=0$ since it starts at the origin of the zone 605a. The first packet stream has an MCS of 1, which implies that one basic resource unit is used. As a result, the index for the second voice packet stream is $VZI_2 = 1$. The second packet stream has an MCS of 4, which implies that eight basic resource units are used. As a result, the index for the third voice packet stream is $VZI_3=9$, arrived by summing the basic resource units used for the preceding first and second packet streams. .

[0036] Using basic resource units as the granularity of a location offset to the packet packet stream reduces the number of bits required to represent its location with the zone 605a. For example, to support a maximum of 64 VoIP calls in a cell, a maximum of $64 \times 8 = 512$ units might be used, assuming that every voice packet is transmitted using the lowest MCS. Therefore, a 9-bit number is sufficient to represent a VZI. In practice, different voice packets may be transmitted using different MCSs, some with MCS=1, some with MCS=4, so on so forth. According to

statistics, a shorter bit-length than the maximum needed, for example 8 bits, may be used for VZI for practical purpose.

[0037] In some embodiments, control information necessary to map a packet stream to a resource segment may be still further reduced. In the case where an MCS is used with packet streams that are located sequentially in the zone, the index of a packet can be inferred from the MCSI of the packets located before the subject packet. For example, if the first voice packet stream uses $MCSI_1=1$, 16QAM with $\frac{1}{2}$ coding, and the second voice packet stream uses $MCSI_2=4$, QPSK with $\frac{1}{8}$ coding, then the first two voice packet streams occupy $1+8=9$ units, and the starting location of the third voice packet stream is the 9th unit. Rather than encode the index for each packet stream in the control information, the index can be omitted in the control message and the offset from the origin of the zone calculated as necessary.

[0038] Allocation of the time-frequency resource 600 can be carried out in a variety of ways. In some embodiments, an application zone may contain all subcarriers of one or multiple OFDM symbols or time slots. In some embodiments, the definition of an application zone, such as the location and size of the zone, may be different from cell-to-cell 105. In some embodiments, in order to avoid inter-cell interference the zones of similar applications are allocated at different locations in neighboring cells. For example, voice applications may be located at a lower frequency range in the time-frequency resource in one cell, and at a higher frequency range in the time-frequency range in an adjacent cell. In some embodiments, the system allocates a fixed amount of resource to each voice connection. The system uses AMC and matches it with adaptive multi-rate (AMR) voice coding to improve the voice quality. Moreover, unused resources in one application zone may be allocated for other applications.

[0039] In a system with one or multiple application zones, the remaining resource unused by the application zones can be treated as a special resource zone. The special resource zone may be irregular in shape. For example, Figure 9 depicts a time-frequency resource 900 having three defined zones 905, 910, and 915. The remaining resource area that is shaded in the figure represents the special resource zone. The MAC scheduler may track the time-frequency resources in this special zone and broadcast the resource allocation in a special zone MAP message. In

some embodiments, the special zone MAP message explicitly identifies the resource zone, for example using the time and frequency coordinates of a resource block. A mobile device can identify its own resource by decoding the MAP message.

[0040] In some embodiments, both the base station and the mobile device share the configuration information of the special resource zone, and view the special zone as a contiguous resource zone. The MAP message only includes the resource allocation information in the special resource zone, using connection ID (described below), resource identification parameters and MCS index.

[0041] In some embodiments, the MAP message can be further compressed if the special resource zone is further divided into a sequence of pre-defined resource units. For example, the shaded area in Figure 9 has been further divided into forty-two resource units 920, first numbered sequentially along the time axis and then continuing in columns along the frequency axis. If the size of each resource unit is pre-defined, the location within the special resource zone may be determined based on a mapping to a sequence number.

III. Application Connection IDs

[0042] When a mobile device enters a wireless network, it is first assigned a basic connection identification (BCID) for each direction of the wireless connection: downlink and uplink. A BCID can be used for control messages or generic (unclassified) application connections. The BCID for downlink may or may not be the same as that of the uplink.

[0043] In some embodiments, a classification of packet streams may be performed by the system. Figure 7 is a block diagram of a system component 700 for receiving IP packets and sorting the received packets into various streams. The system component 700 includes a classifier 705 having associated classification rules 710. The classifier receives incoming packets, each packet having various header information such as an Ethernet header 715, an IP header 720, a UDP header 725, an RTP header 730 and an RTP payload 735. The packets are classified by the classifier 705 and output into different application data queues 740 where they will subsequently be transmitted by an OFDMA transmitter 745.

[0044] The classifier 705 is able to classify the packets based on application type, quality of service (QoS) requirement, or other properties. For example, packets from a voice application stream are identified based on a special value in the type of service (ToS) field in the IP header 720 of the packets. A new combination of RTP/UDP/IP headers with the special IP ToS field value indicates a new voice application stream. Such a new stream is identified by peeking into voice session setup protocol messages, such as session initiation protocol (SIP). The classification performed by the classifier is based on one or more classification rules 710. The classification rules can be configured statically or dynamically by a control process. Each classification rule is defined using parameters, such as application type, QoS parameters, and other properties that may be determined from the received packets.

[0045] In some embodiments, the incoming packets may also be assigned an application connection-specific identifier (ACID) in addition to or in lieu of a BCID. Each ACID can be assigned to a corresponding packet stream. For example, an ACID can be assigned to voice packets that together make up a voice application. When an ACID is assigned to a voice application, the ACID may also be referred to as a voice connection ID (VCID). As another example, an ACID can be assigned to a packet stream that requires a particular QoS. Furthermore, an application packet stream can be further classified into different sub-types, based on certain properties of that application. For example, voice applications can be further classified into different sub-types based on the voice source coding (vocoder) methods (e.g., G.711 and G.729A). When further classified in this manner, the sub-types may each be assigned their own ACID. For certain multi-casting applications, an ACID may also be shared by multiple base stations or mobile devices.

[0046] Once established, the connection IDs, including BCIDs and ACIDs, are disseminated, through broadcasting messages for example, to the corresponding base station(s) and mobile device(s) for proper packet transmission and reception. As was previously discussed, the medium access control (MAC) scheduler may allocate specific zones of airlink resources for certain types of packet streams.

[0047] A connection ID is released once the wireless system determines that there is no need to continue the connection. For example, a voice connection and

its VCID are released once the system detects deactivation of the voice stream. In some embodiments, the voice connection is deactivated if the voice session disconnect is detected through snooping SIP signaling. In some embodiments, the voice connection is released if there is no voice packet activity on the connection for a certain period of time.

[0048] In some embodiments, the same bit length is used in different types of connections IDs, including BCIDs and ACIDs. In some embodiments, different types of connection IDs may have different bit lengths. For example, in a typical implementation for voice applications, a BCID may be 16-bits to accommodate a large number of mobile devices and unclassified applications, while a VCID is 6-bits to accommodate up to 64 simultaneous voice connections in a cell. A shorter ACID length is beneficial for reducing control overhead, especially when an application utilizes many small data packets, such as VoIP packets.

[0049] In some embodiments, an ACID is further augmented by other properties of the utilized airlink resources, such as time or frequency indices, to identify an application connection. This can be used to further reduce ACID bit length or to increase the maximum number of accommodated application connections given a certain ACID bit length. For example, a voice codec generates voice application data periodically. The allocation period is usually a multiple of the airlink frame duration. In this case, the airlink frame number can be combined with a VCID to identify a voice connection. For example, the voice codec of G.723.1 generates a voice frame once every 30 milliseconds. The MAC scheduler allocates airlink resource to such a voice connection once every 30ms. In a wireless cellular system using 5ms frame duration, a single VCID can be shared by 6 voice streams, each associated with a different frame number to uniquely identify a voice connection.

IV. Control Messages

[0050] When airlink resource zones or application-specific IDs are utilized by the system, various improved control messages, often called Information Elements (IEs), may be constructed to facilitate the control process and minimize the control overhead. Various control message improvements are described herein.

[0051] In some embodiments, the IE is sent prior to transmitting an application packet to indicate information associated with the packet, such as the packet destination, the modulation and coding method, and the airlink resource used. For example, the IE for a voice packet may include the VCID (indicative of the packet destination), the MCSI (encoding scheme), and the VZI (index to location for the packet stream within the airlink resource). In some embodiments, the VCID is 6 bits, the MCSI is 2 bits, and the VZI is 8 bits, thereby resulting in a 2-byte IE overhead for each voice packet. Alternatively, the IE for a voice packet may include only the VCID and the MCSI, with the VZI inferred from the MCSIs of previous packet streams in the airlink resource as described above. When using only the VCID and MCSI, the IE overhead for each voice packet is reduced to only 1 byte. Additional control information, such as power control information, can be added to the IE with additional bit fields. The reduction in control bits improves the overall bandwidth efficiency of the wireless communication network.

[0052] In some embodiments, a base station sends the IE before a downlink packet to inform the mobile device for proper reception of the packet, and the base station sends the IE before an uplink packet to inform the mobile device for proper transmission of the packet. The downlink and uplink packet IEs may be separately grouped together. The IEs may be broadcasted or multi-casted to corresponding destinations.

[0053] In some embodiments, the IEs of the same application type or subtype may be grouped together. A special field, called an Application MAP (AMAP) subheader, for a specific application type, may be added to the IE. The subheader may indicate the application type and the length of the IE group. Figure 8A is a block diagram of a representative IE 800 with an AMAP subheader 805, in this case used for voice applications. The AMAP subheader 805 includes a type variable and a length variable. As depicted in Figure 8A, type = 01 indicates that the application type is voice. Length = 3 indicates that the subheader is followed by three voice IEs. The remainder of the IE contains the three voice IEs 810a, 810b, and 810c. For example, if the AMAP subheader was associated with streams in the zone 605a depicted in Figure 6, then voice IE 810a would pertain to packet stream V₁, voice IE 810b would pertain to packet stream V₂, and voice IE 810c would

pertain to packet stream V_3 . Those skilled in the art will appreciate that the although text is used to indicate the contents of the IE in Figure 8A, in an actual implementation the text would be replaced by appropriately coded information.

[0054] In some embodiments, the IEs for all packets that are transmitted with the same modulation and coding schemes (MCS) are grouped together for efficiency. Figure 8B is a block diagram of a block 850 of IEs that are grouped by MCS. A frame control header (FCH) 855 or other control message is transmitted prior to the block to indicate the length and the MCS used for each segment of the block. In some embodiments, adaptive modulation and coding (AMC) is used for the transmission of the IE's. A special rule, which is known to both base stations and mobile devices, can be used to determine the IE MCS, based on the MCS of its corresponding packet for proper reception of the IE. In some embodiments, the MCS for an IE is maintained the same as that of its corresponding application packet. In some embodiments, the MCS for an IE is one level more conservative than that of its corresponding packet. For example, if the MCSI for a packet is 2 (QPSK with rate- $\frac{1}{2}$ coding), then the MCSI for its IE is 3 (QPSK with rate- $\frac{1}{4}$ coding).

V. Voice Activity Detection

[0055] Typical voice conversations contain approximately 50 percent silence. In order to take advantage of the fact that about half of the time data does not need to be transmitted at the same rate as when a user is speaking, the system may rely upon detecting the period of silence and reducing the effective data transfer rate during that period. The silence period in conversation is detected by a vocoder using technologies such as Voice Activity Detection (VAD). Voice packets are only generated when voice activity is detected. During the silence period, the voice packet data rate is greatly reduced.

[0056] In addition to reducing the voice packet data rate during periods of silence, the bandwidth allocation for the voice connection may also be reduced. The MAC scheduler at the base station may use the indication of voice activity to adjust the bandwidth allocation for the voice connection. In the uplink direction, the mobile device sends a special MAC message once a VAD indication is received from its vocoder. The MAC message indicates to the base station that the voice data rate is temporarily reduced. When such an indication is received, the MAC scheduler

can reduce the airlink resource allocated to the voice connection. Similarly, if the VAD indicates new voice activity, the mobile device notifies the base station using a MAC message and the original resource allocation is re-applied to the voice connection.

[0057] In the downlink direction, if there is no voice packet to be transmitted over a voice connection, the MAC scheduler allocates the resource to other voice connections. As a consequence, a resource block previously allocated for the connection in a particular zone may become vacant. Several methods can be used to deal with such fragmentation in the zone.

[0058] In some embodiments, the MAC scheduler at the base station reallocates the resource with the objective of minimizing the impact to other voice connections, such as their adaptive modulation and coding processes.

[0059] In some embodiments, the MAC scheduler maintains the resource allocation of the other voice connections, and allocates the resource vacated by the silent voice connection to new voice connections or other application packets.

[0060] In some embodiments, the MAC scheduler moves all the subsequent allocations up to fill the resource gap. As shown in Figure 10A, once a voice connection, identified by VCID 2 enters a silent period, the other voice connections are moved by the MAC scheduler to occupy the resource vacated by VCID 2.

[0061] In some embodiments, the MAC scheduler uses the last voice time-frequency resource in the same zone to fill the resource gap of a silent voice connection. Figure 10B illustrates such a case, when the MAC scheduler moves the last voice connection VCID 12 to occupy the resource allocation gap that is vacated by the voice connection VCID 2.

[0062] In some embodiments, the MAC scheduler uses the last voice time-frequency resource that has the same coding and modulation scheme, and is contained in the same zone, to fill the resource gap. The resource gap that is introduced by such a replacement is then filled by the voice time-frequency resource that is subsequent to the voice time-frequency resource that was moved. As shown in Figure 10C, voice connection VCID 6 uses the same coding and modulation scheme as voice connection VCID 2, and is the last connection having that scheme

in the zone. When voice connection VCID 2 goes into a silent period, the MAC scheduler allocates the voice connection VCID 2 resource to voice connection VCID 6.. The MAC scheduler then moves resources after voice connection VCID 6, specifically VCID 7 in Figure 10C, to occupy the resource allocation gap that is caused by moving voice connection VCID 6.

[0063] The above detailed description of embodiments of the system is not intended to be exhaustive or to limit the system to the precise form disclosed above. While specific embodiments of, and examples for, the system are described above for illustrative purposes, various equivalent modifications are possible within the scope of the system, as those skilled in the relevant art will recognize. For example, while processes are presented in a given order, alternative embodiments may perform routines having steps in a different order, and some processes may be deleted, moved, added, subdivided, combined, and/or modified to provide alternative or subcombinations. Each of these processes may be implemented in a variety of different ways. Further any specific numbers noted herein are only examples: alternative implementations may employ differing values or ranges.

[0064] These and other changes can be made to the invention in light of the above Detailed Description. While the above description describes certain embodiments of the technology, and describes the best mode contemplated, no matter how detailed the above appears in text, the invention can be practiced in many ways. Details of the system may vary considerably in its implementation details, while still being encompassed by the technology disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the technology should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the technology with which that terminology is associated. In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention under the claims.

CLAIMS

We claim:

[c1] 1. A method of communication between base stations and mobile devices in a multi-carrier packet communication system that utilizes an airlink resource and covers a plurality of geographic cells, the method comprising:

allocating a zone in the airlink resource, wherein the zone is designated for a type of application and is capable of carrying two or more packet streams associated with the type of application, and wherein the portion of the airlink resource falling outside of the zone is capable of carrying two or more packet streams not associated with the type of application;

for at least some of the two or more packet streams within the zone, creating a control message associated with each packet stream wherein the control message is used in part to ensure proper communication of the packet stream;

aggregating the created control messages associated with each packet stream in accordance with a common characteristic of the packet streams; and transmitting the control messages in a group.

[c2] 2. The method of claim 1, wherein the common characteristic is the coding and modulation scheme of the packet streams.

[c3] 3. The method of claim 1, wherein the common characteristic is a location of the packet stream within the airlink resource.

[c4] 4. The method of claim 1, further comprising adding a header to the group of control messages, wherein the header comprises the number of control messages, the length of the control messages, and the common characteristics of the associated packet streams.

- [c5] 5. The method of claim 1, wherein the zone in one geographic cell is assigned to a different time-frequency location in the airlink resource than the zone in a neighboring geographic cell in order to mitigate inter-cell interference.
- [c6] 6. The method of claim 1, further comprising:
assigning a basic connection identification (BCID) value to a packet stream communicated via the airlink resource;
assigning an application connection identification (ACID) value to a second packet stream communicated via the airlink resource, wherein the ACID value contains a lesser number of bits than the BCID value; and
incorporating the ACID value in the control message associated with the identified second packet stream.
- [c7] 7. The method of claim 6, wherein an ACID value may be reused by base stations or mobile devices.
- [c8] 8. The method of claim 6, wherein an ACID value may include additional information representing a location index within the airlink resource.
- [c9] 9. The method of claim 1, wherein each of the two or more packet streams associated with the type of application utilize one of a plurality of modulation and coding schemes, and a modulation and coding scheme index associated with each packet stream carries information about the utilized modulation and coding scheme for the packet stream.
- [c10] 10. The method of claim 9, wherein the plurality of modulation and coding schemes utilize a basic time-frequency resource unit and integer multiples of the basic time-frequency resource unit.
- [c11] 11. The method of claim 1, further comprising using adaptive modulation and coding for the transmission of the group of control messages.

[c12] 12. The method of claim 11, wherein the modulation and coding for the group of control messages is the same as the modulation and coding used for the packet streams associated with the group of control messages.

[c13] 13. The method of claim 11, wherein the modulation and coding for the group of control messages is one level lower than the modulation and coding used for the packet streams associated with the group of control messages

[c14] 14. The method of claim 11, wherein the common characteristic is the coding and modulation scheme of the packet streams and further comprising a header transmitted prior to the group of control messages to indicate the length of the group and the modulation and coding scheme used for the group.

[c15] 15. The method of claim 1, wherein a starting time-frequency coordinate and an ending time-frequency coordinate are used to specify a location of a packet stream within the zone.

[c16] 16. The method of claim 1, wherein the zone is divided into a plurality of rows and a plurality of columns to thereby form a coordinate system.

[c17] 17. The method of claim 16, wherein a location of a packet stream within the zone may be specified by an offset from the origin of the zone.

[c18] 18. The method of claim 16, wherein a location of a packet stream within the zone may be specified by a starting row and column coordinate and an ending row and column coordinate.

[c19] 19. The method of claim 16, wherein a granularity of a time coordinate is an OFDM symbol and a granularity of a frequency coordinate is a subcarrier.

[c20] 20. The method of claim 1, wherein the portion of the airlink resource falling outside of the zone is treated as a second zone and wherein a resource

allocation message pertaining to the second zone is communicated to a base station and a mobile station.

[c21] 21. The method of claim 20, wherein the resource allocation message identifies a connection identifier, a resource identification parameter, and a modulation and coding index for at least some of the packet streams in the second zone.

[c22] 22. The method of claim 20, further comprising dividing the second zone into a plurality of units, wherein the resource allocation message identifies at least some of the packet streams in the second zone based on the plurality of units.

[c23] 23. A method of communication between base stations and mobile devices in a multi-carrier packet communication system that utilizes an airlink resource and covers a plurality of geographic cells, the method comprising:

- allocating a zone in the airlink resource for voice-over-IP packet streams, wherein the zone is capable of carrying two or more packet streams and the packet streams are arranged sequentially in the zone;
- for at least some of the voice-over-IP packet streams within the zone, creating a control message associated with each packet stream wherein the control message is used in part to ensure proper communication of the packet stream;
- aggregating the created control messages associated with each packet stream in accordance with a common characteristic of the packet streams; and
- transmitting the control messages in a group.

[c24] 24. The method of claim 23, wherein packet streams are arranged sequentially in the zone starting at an origin.

[c25] 25. The method of claim 24, wherein the location of a packet stream in the zone is specified by an offset to the origin, wherein the offset is one or more units of

airlink resource that is determined by a type of modulation and coding associated with the packet streams.

[c26] 26. The method of claim 25, wherein the offset is included in the control message associated with the packet stream.

[c27] 27. The method of claim 25, wherein the offset is not included in the control message associated with the packet stream and is instead calculated from the type of modulation and coding associated with other packet streams that precede the packet stream in the sequence of packet streams.

[c28] 28. The method of claim 23, wherein an airlink resource associated with each of the two or more packet streams within the zone is allocated based on voice activity carried in the corresponding packet stream.

[c29] 29. The method of claim 28, wherein the allocated airlink resource is an initial amount of resource and adaptive modulation and coding with an adaptive multi-rate voice coding is used to improve voice quality carried in the packet stream.

[c30] 30. The method of claim 28, further comprising reallocating an airlink resource associated with a first packet stream having a silent voice connection to a second packet stream having an active voice connection.

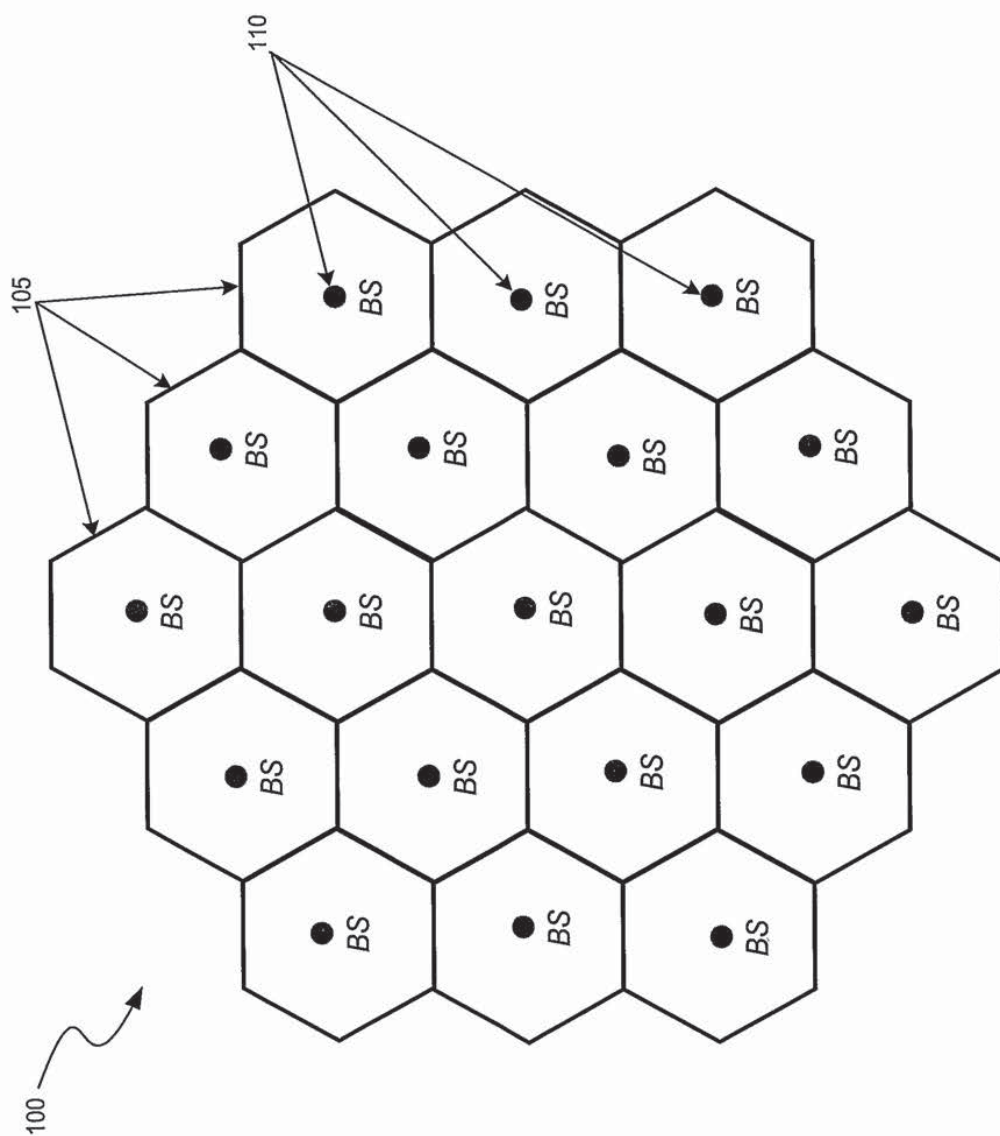
[c31] 31. The method of claim 30, wherein the second packet stream is the next packet stream in sequence after the first packet stream.

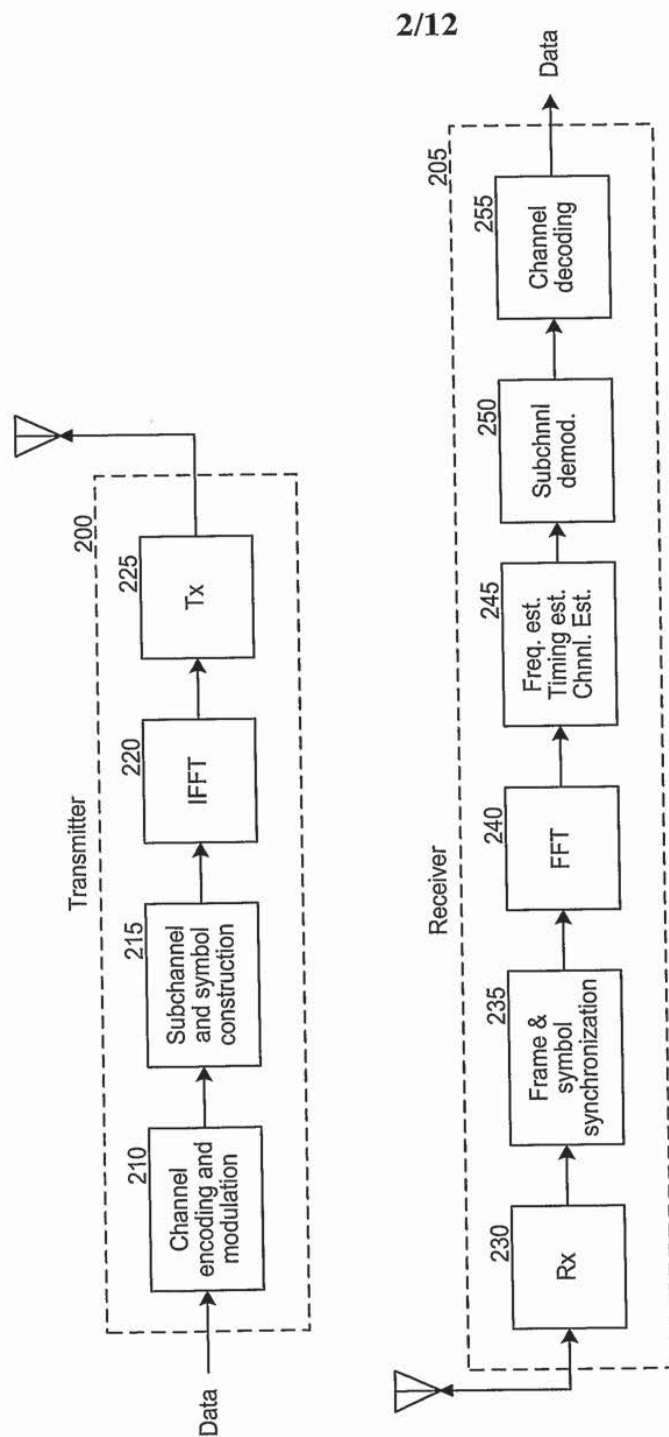
[c32] 32. The method of claim 30, wherein the second packet stream is the last packet stream in the sequence of packet streams.

[c33] 33. The method of claim 30, wherein the second packet stream is the last packet stream in the sequence of packet streams that has the same coding and modulation scheme as the first packet stream, and further comprising reallocating the packet streams subsequent to the second packet stream in the sequence of

packet streams in order to fill the airlink resource that was vacated by the second packet stream.

1/12

**FIG. 1**



3/12

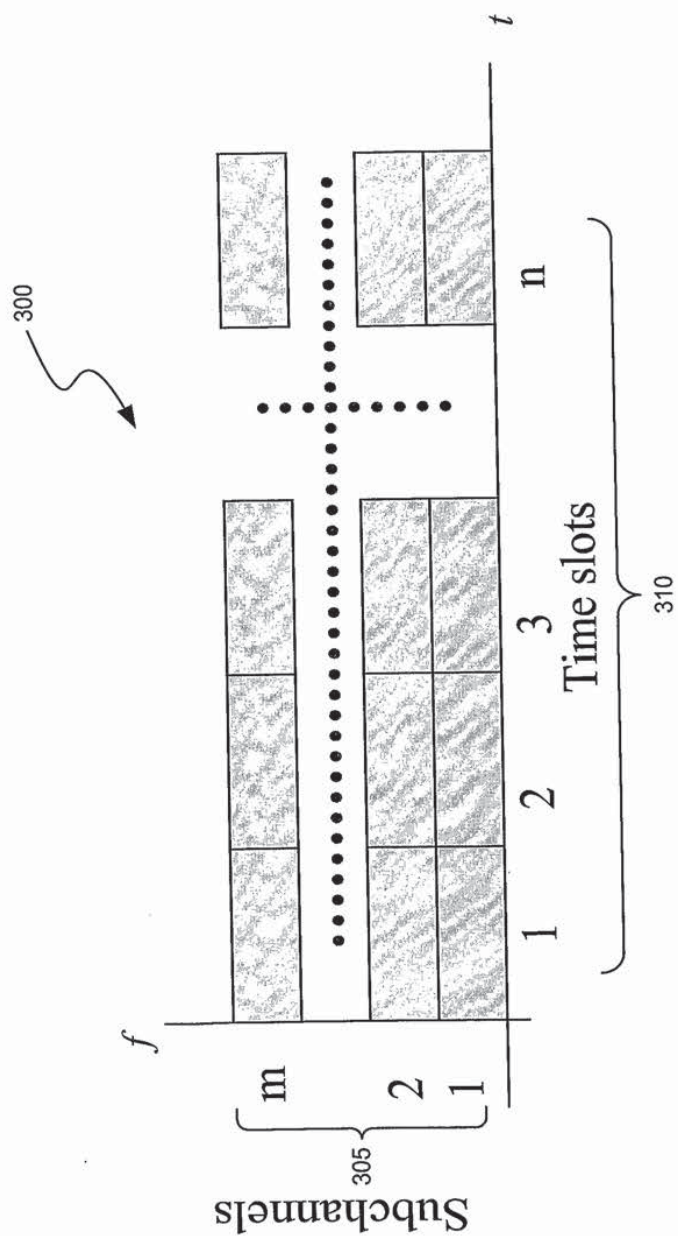
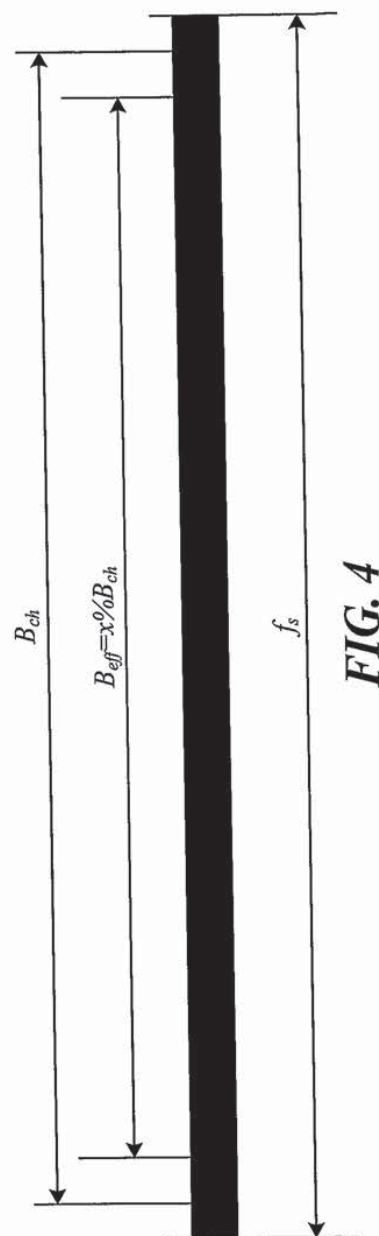


FIG. 3

4/12



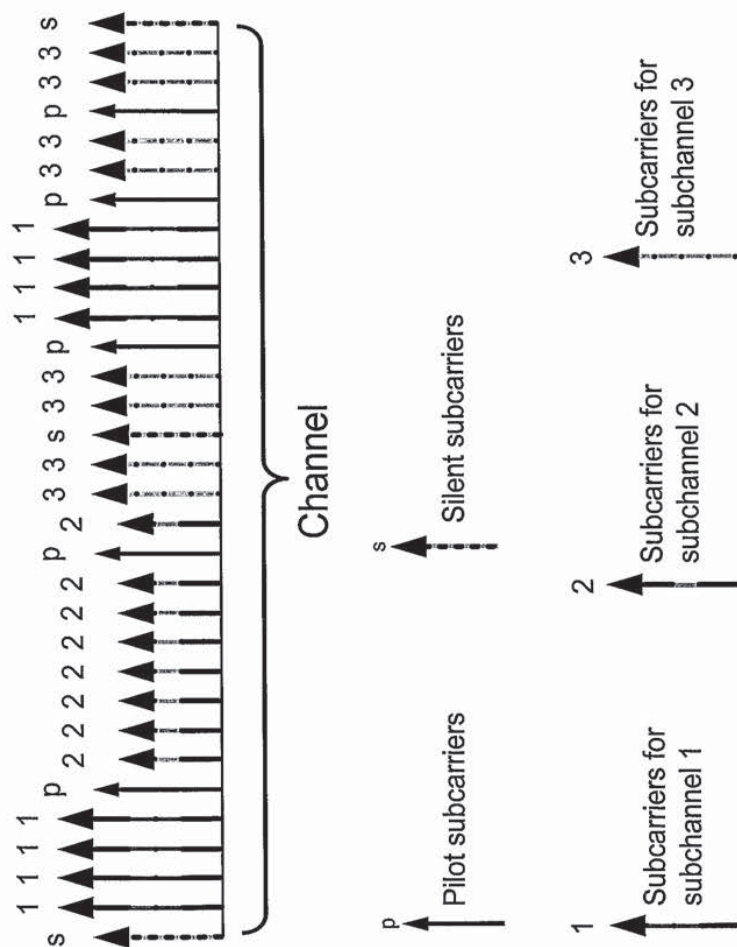


FIG. 5

6/12

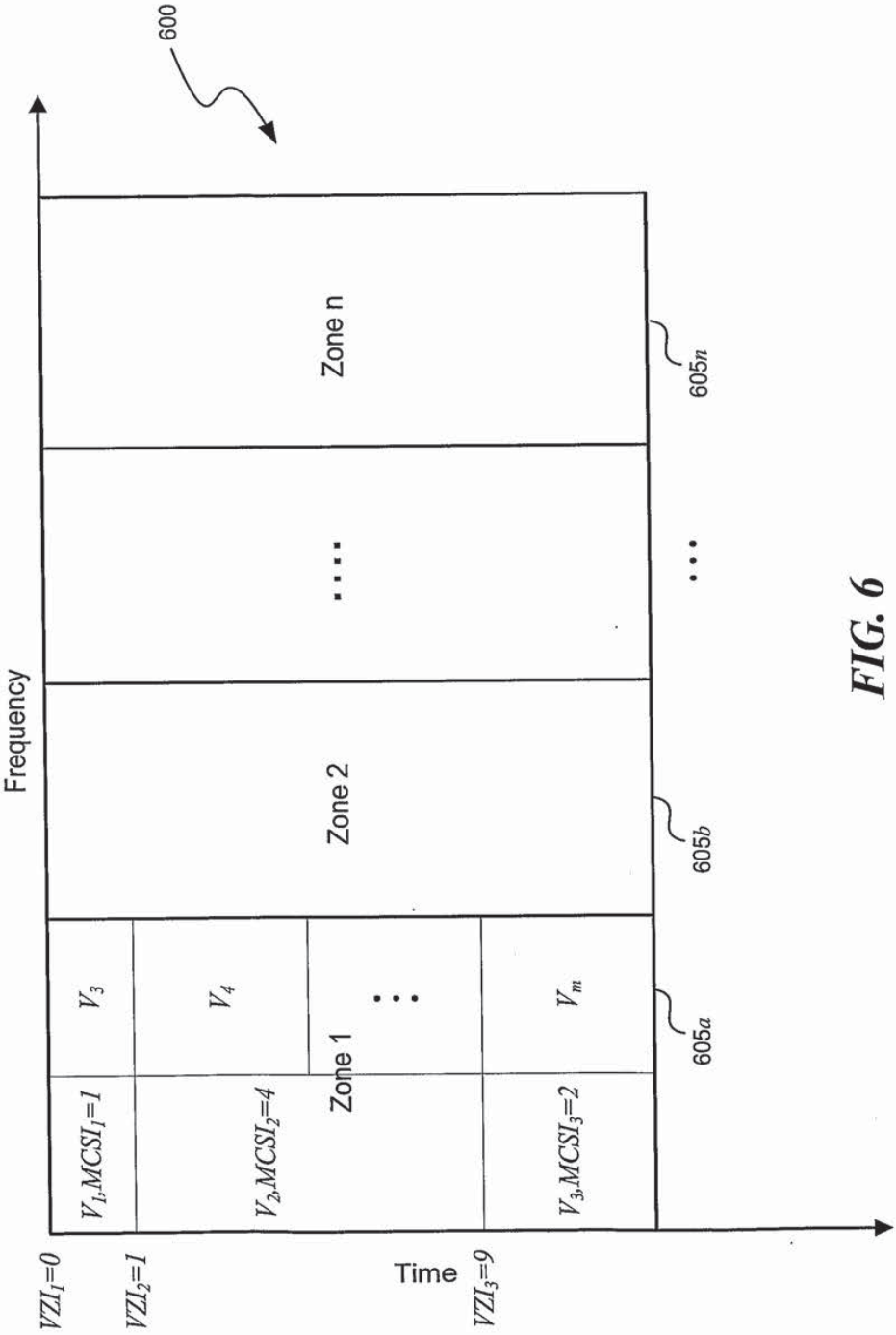


FIG. 6

7/12

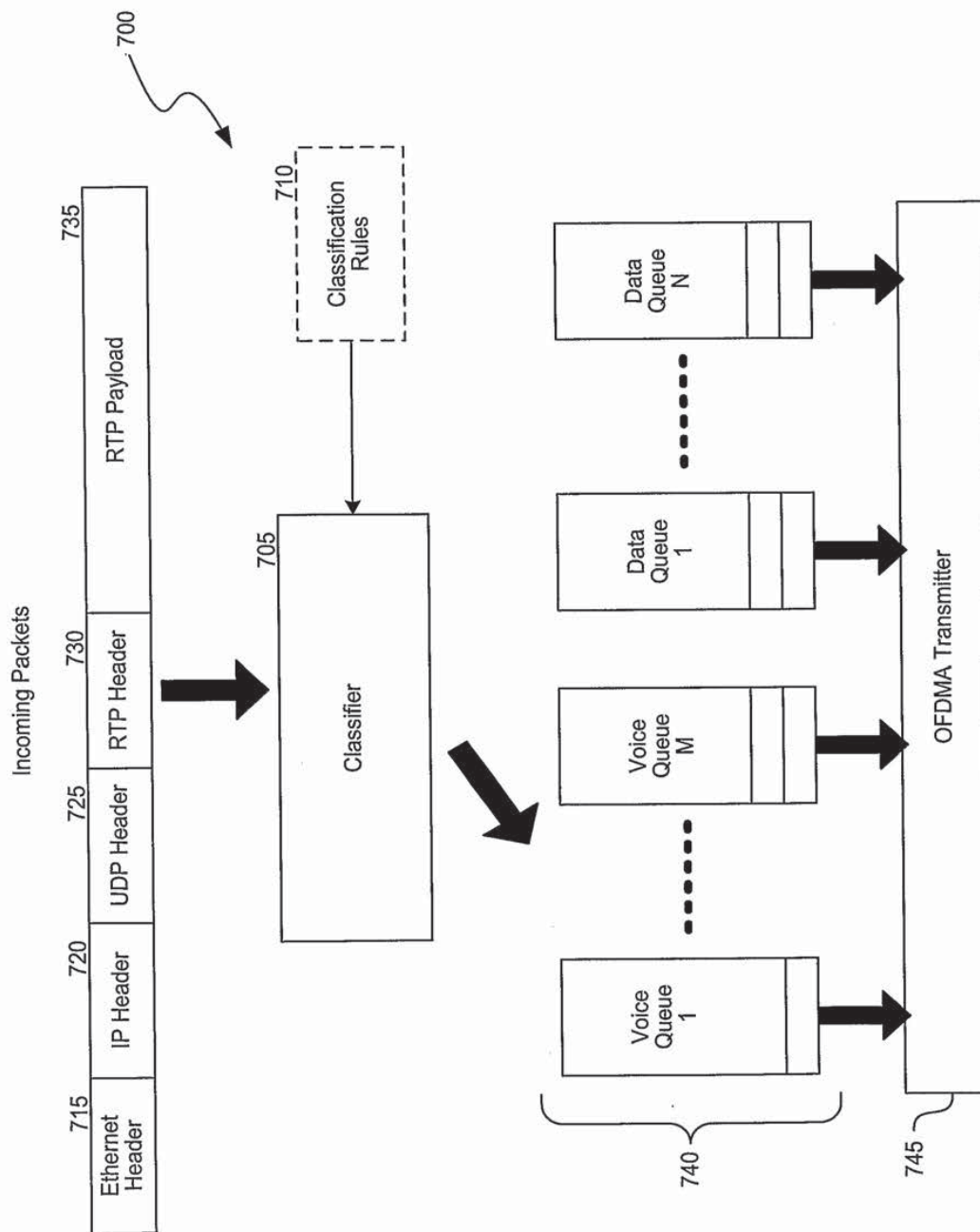


FIG. 7

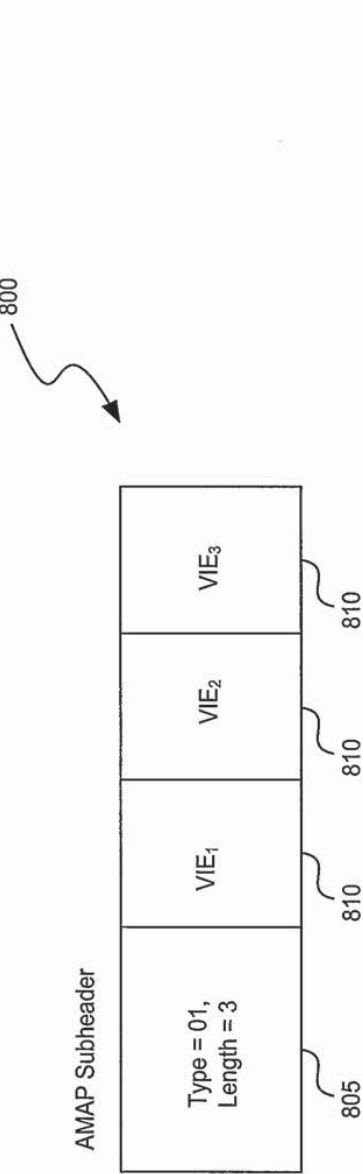


FIG. 8A

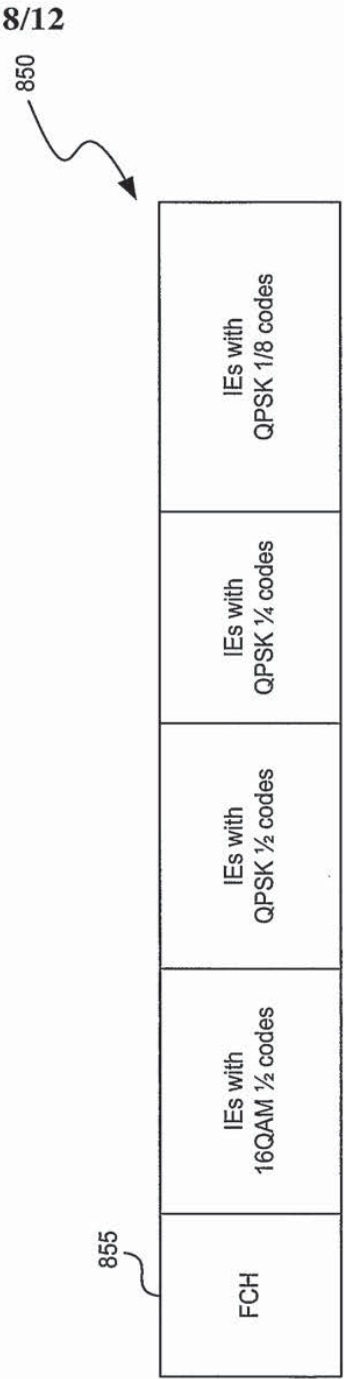
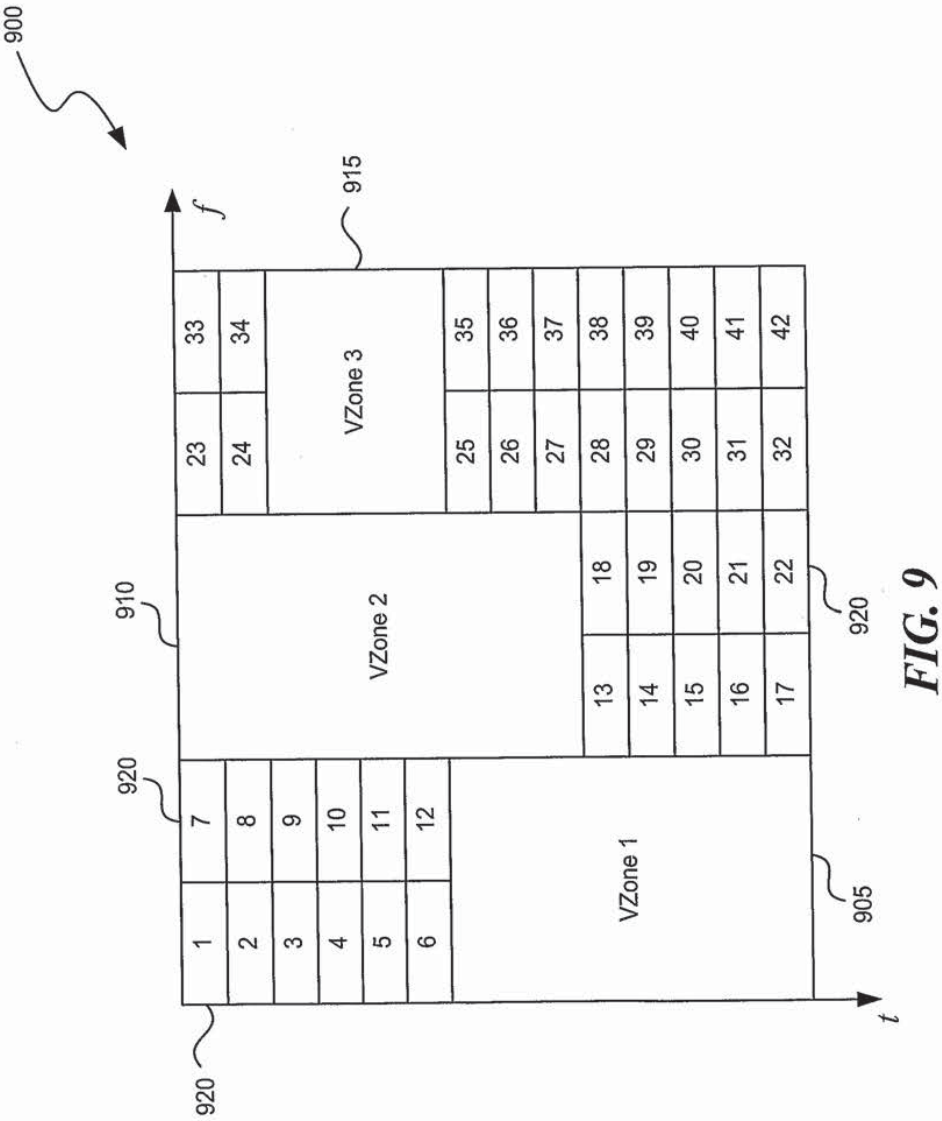


FIG. 8B



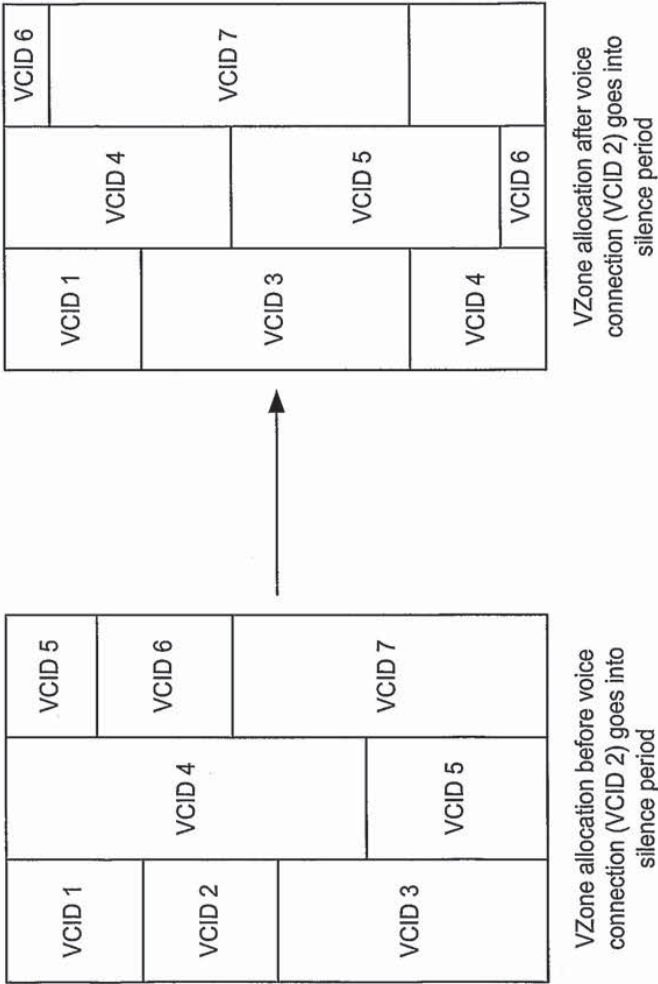


FIG. 10A

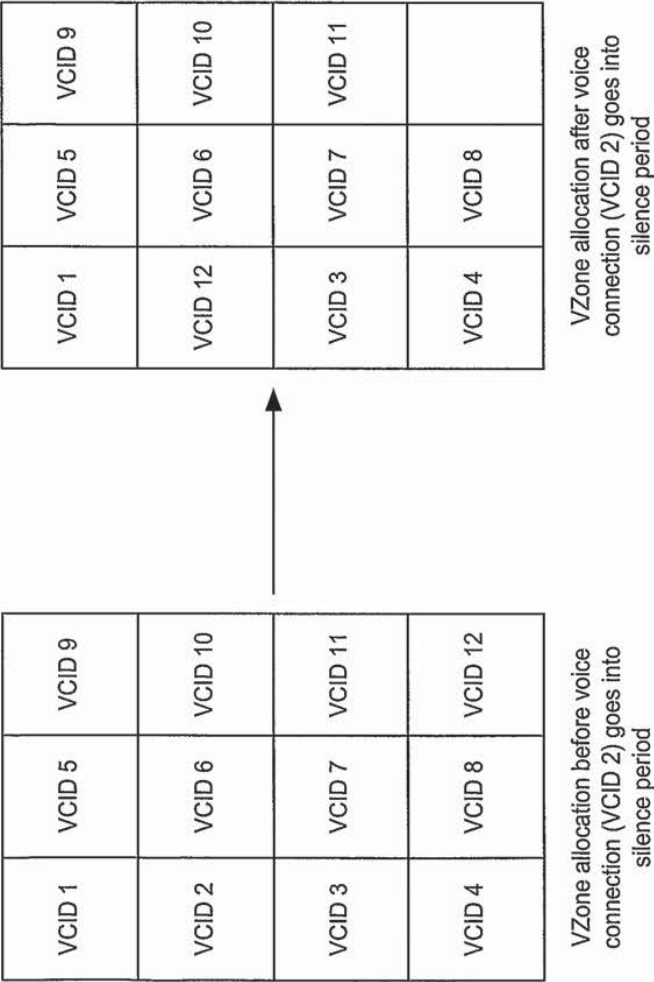


FIG. 10B

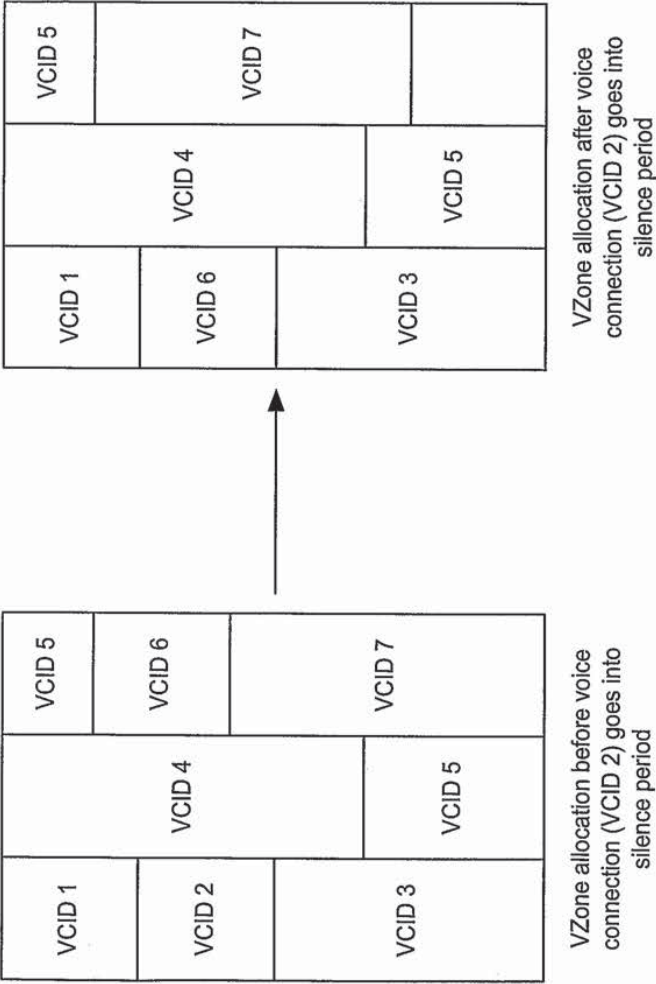


FIG. 10C

Document made available under the Patent Cooperation Treaty (PCT)

International application number: PCT/US2006/038149

International filing date: 28 September 2006 (28.09.2006)

Document type: Certified copy of priority document

Document details: Country/Office: US
Number: 60/721,451
Filing date: 28 September 2005 (28.09.2005)

Date of receipt at the International Bureau: 13 November 2006 (13.11.2006)

Remark: Priority document submitted or transmitted to the International Bureau in compliance with Rule 17.1(a) or (b)



World Intellectual Property Organization (WIPO) - Geneva, Switzerland
Organisation Mondiale de la Propriété Intellectuelle (OMPI) - Genève, Suisse

1538154

THE UNITED STATES OF AMERICA

TO ALL TO WHOM THESE PRESENTS SHALL COME:

UNITED STATES DEPARTMENT OF COMMERCE

United States Patent and Trademark Office

November 01, 2006

THIS IS TO CERTIFY THAT ANNEXED HERETO IS A TRUE COPY FROM THE RECORDS OF THE UNITED STATES PATENT AND TRADEMARK OFFICE OF THOSE PAPERS OF THE BELOW IDENTIFIED PATENT APPLICATION THAT MET THE REQUIREMENTS TO BE GRANTED A FILING DATE.

APPLICATION NUMBER: 60/721,451

FILING DATE: *September 28, 2005*

RELATED PCT APPLICATION NUMBER: *PCT/US06/38149*

THE COUNTRY CODE AND NUMBER OF YOUR PRIORITY APPLICATION, TO BE USED FOR FILING ABROAD UNDER THE PARIS CONVENTION, IS *US60/721,451*



Certified by

Under Secretary of Commerce
for Intellectual Property
and Director of the United States
Patent and Trademark Office

092805

20427 U.S. PTO

PTO/SB/16 (01-04)

Approved for use through 07/31/2006. OMB 0651-0032

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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.

PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

Express Mail Label No.

33464 U.S. PTO
60/721451

092805

INVENTOR(S)						
Given Name (first and middle (if any))		Family Name or Surname		Residence (City and either State or Foreign Country)		
Xiaodong		Li		Kirkland, WA		
Additional inventors are being named on the _____ separately numbered sheets attached hereto						
TITLE OF THE INVENTION (500 characters max)						
Method and Apparatus for Multi-Carrier Packet Communication with Reduced Overhead						
Direct all correspondence to: CORRESPONDENCE ADDRESS						
☐ Customer Number: _____						
OR						
☒ Firm or Individual Name		WALTICAL SOLUTION, INC.				
Address		1750 112TH AVENUE, Suite D159				
Address						
City	Bellevue	State	WA	Zip	98004	
Country	USA	Telephone	(425)4518278	Fax	(425)4518254	
ENCLOSED APPLICATION PARTS (check all that apply)						
☒ Specification Number of Pages		11		☐ CD(s), Number _____		
☒ Drawing(s) Number of Sheets		13		☐ Other (specify) _____		
☐ Application Data Sheet. See 37 CFR 1.76						
METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT						
☒ Applicant claims small entity status. See 37 CFR 1.27.				FILING FEE Amount (\$)		
☒ A check or money order is enclosed to cover the filing fees.				\$100.00		
☐ The Director is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: _____						
☐ Payment by credit card. Form PTO-2038 is attached.						
The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.						
☒ No.						
☐ Yes, the name of the U.S. Government agency and the Government contract number are: _____						

[Page 1 of 2]

Respectfully submitted,

Date 09/27/2005

SIGNATURE



REGISTRATION NO. _____

TYPED or PRINTED NAME

Titus Lo

(if appropriate)

Docket Number: _____

TELEPHONE

(425) 451-8278

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. 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 8 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: Mail Stop Provisional Application, 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.

PROVISIONAL APPLICATION COVER SHEET
Additional Page

PTO/SB/16 (08-03)

Approved for use through 07/31/2006. OMB 0651-0032

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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.

Docket Number

INVENTOR(S)/APPLICANT(S)		
Given Name (first and middle [if any])	Family or Surname	Residence (City and either State or Foreign Country)
Haiming	Huang	Bellevue, WA
Titus	Lo	Bellevue, WA
Ruifeng	Wang	Sammamish, WA

[Page 2 of 2]

Number 1 of 1

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.

Method and Apparatus for Multi-Carrier Packet Communication with Reduced Overhead

Xiaodong Li, Haiming Huang, Titus Lo, and Ruifeng Wang

1 Background of the Invention

Bandwidth efficiency is one of the most important system performance factors for wireless communication systems. In packet based data communication, where the mixed traffic has a bursty and irregular pattern, application payloads are of different sizes and with different quality of service (QoS) requirements. In order to accommodate different applications, a wireless communication system should be able to provide a high degree of flexibility. However, in order to support such flexibility, additional overhead are usually required. For example, in a wireless system based on the IEEE 802.16 standard, multiple service flows are established for each mobile station to support different applications. At the medium access control (MAC) layer, each service flow is mapped into a wireless connection. The MAC scheduler allocates wireless air link resources to these connections. Special scheduling messages, DL-MAP and UL-MAP are defined to broadcast the scheduling decisions to the mobile stations.

In the MAP message in IEEE802.16, there is a significant overhead. First of all, each connection is identified by a 16 bits connection ID (CID). The CID is included in the MAP to identify the mobile station. The maximum number of connections that a system can support is therefore 65,536. Each mobile station has minimal two management connections for control and management messages and various number of traffic connections for application data traffic. Secondly, the airlink resource allocation can be correspondent to any time/frequency region. It is identified by the time domain scale with start symbol offset (8 bits) and symbol length (7 bits) and the frequency domain scale with start logical subchannel offset (6 bits) and numbers of allocated subchannels (6 bits). Due to the fact that different application has different resource requirement, the allocated resource region is irregular from connection to connection. Thirdly, the modulation and coding scheme is identified by MCS code, called as either downlink interval usage code (DIUC) or uplink interval usage code (UIUC), which is 4 bits. Another 2 bits are used to indicate the coding repetition in addition to 3 bits for power control. Overall, the overhead of a MAP element is 52 bits. For applications such as voice over IP, the payload of an 8Kbps voice codec is 20 bytes in every 20ms. The overhead of the MAP element alone can be as much as 32.5%, thereby resulting in a relatively low spectral efficiency.

The present invention describes the method and apparatus to reduce overhead in a multi-carrier packet communication system, thereby improve the spectral efficiency of the system.

2 Summary of the Invention

In this invention are described method and apparatus for a multi-carrier packet communication

WALTICAL SOLUTIONS, INC.
Confidential and Proprietary

Rev. 0.1 9/27/2005

system with reduced overhead. A specific area in the time-frequency resource is designated for certain applications, such as VoIP. Adaptive modulation and coding method with modular resource utilization is designed to improve transmission spectral efficiency, while minimizing the control overhead. Method and apparatus are designed to take advantage of the special characteristics of the applications to minimize the number of bits to identify the destination of the packets. A control message is sent prior to the transmission of an application packet to indicate the packet destination, the radio resource utilized by the packet, and the modulation and coding method for the packet.

The system mentioned in this invention can be of any special formats such as Code Division Multiple Access (CDMA), Orthogonal Frequency Division Multiple Access (OFDMA), or Multi-Carrier Code Division Multiple Access (MC-CDMA). Without loss of generality, OFDMA is taken as an example to illustrate the present invention. In addition, without loss of generality, voice applications are used as example applications to illustrate the present invention.

The subtitles are introduced for illustrating the aspects of the invention, and should not be interpreted as limiting the aspects of the invention.

3 Brief Description of the Drawings

The present invention will be thoroughly understood from the detailed description given below and from the accompanying drawings of various embodiments of the invention, which, however, should not be taken to limit the invention to the specific embodiments, but are for explanation and understanding only.

Figure 1: A basic multi-carrier wireless communication system consists of a transmitter and a receiver, which consist of the necessary functions for transmission and reception, respectively.

Figure 2: A cellular wireless network is comprised of a plurality of cells, in each of which the coverage is provided by a base station (BS). Within each coverage area, there are distributed mobile stations. A base station is connected to the backbone of the network via a dedicated link and also provides radio links to the mobile stations within its coverage.

Figure 3: The radio resource is divided into small units in both the frequency and time domains: subchannels and time slots. Subchannels are formed by subcarriers. The basic structure of a multi-carrier signal in the time domain is made up of time slots.

Figure 4: The relationship is shown between the sampling frequency, the channel bandwidth, and the usable subcarriers. For a given bandwidth of a spectral band or channel (B_{ch}), the number of usable subcarriers is finite and limited, whose value depends on the size of the FFT and the sampling frequency (f_s).

Figure 5: The basic structure of a multi-carrier signal in the frequency domain is made up of subcarriers. Data subcarriers can be grouped into subchannels in a particular way. Each subchannel may be set at a different power level.

-
- Figure 6: An illustration of an OFDMA system with Classifier. Incoming application packets are classified by the Classifier based on classification rules. The classification rules can be configured statically or dynamically by a control process. Each classification rule is defined using parameters, such as application type, QoS parameters and other properties. Different application packets will be put into different data queues and transmitted by the OFDMA transmitter.
- Figure 7: AMC resource for voice applications, where each unit is the time-frequency resource required for carrying the same specific amount of voice data using a given MCS.
- Figure 8: A time-frequency zone, which is specially allocated for voice applications.
- Figure 9: AMC is applied to MAP transmission, where subchannels using the same MCS are specified or defined using a MAP, to which the same MCS is also applied.
- Figure 10: An illustration of special resource region with unit sequence defined in time-first order.
- Figure 11: An illustration of a resource allocation scheme in the same VZone before and after a voice connection goes into the silence period. All subsequent resource allocations shift up to fill the gap.
- Figure 12: Another example that illustrates a resource allocation scheme in the same VZone before and after a voice connection goes into silence period. In this scheme, the last resource unit occupies the resource gap.
- Figure 13: Yet another example in case not all the resource units are using the same modulation and coding scheme in the same VZone. In this scheme, the last one using the same MCS scheme as the one which goes in to the silence period occupies the resource gap.

4 Detailed Description

4.1 Cellular Wireless Networks

In a cellular wireless network, the geographical region to be serviced by the network is normally divided into smaller areas called cells. In each cell the coverage is provided by a base station. Thus, this type of structure is normally referred to as the cellular structure (Figure 1). Within each coverage area, there are located mobile stations to be used as an interface between the users and the network. A base station is connected to the backbone of the network, usually by a dedicated link. A base station also serves as a focal point to distribute information to and collect information from its mobile stations by radio signals.

In a wireless network, there are a number of base stations, each of which provides coverage to its designated area, normally called a cell. If a cell is divided in to sectors, from system engineering point of view each sector can be considered as a cell. In this context, the terms “cell” and “sector” are interchangeable.

4.2 Multi-Carrier Communication System

In a wireless communication system with base stations and mobile stations, the transmission from a base station to a mobile station is called a downlink (DL) and the transmission from a mobile station to a base station is called an uplink (UL). In multi-carrier communication system, a transmitter may consist of the following functional blocks (Figure 2):

1. Channel encoding and modulation, including
 - a. data bit randomization
 - b. FEC encoding
 - c. interleaving
 - d. Modulation
2. Subchannel and symbol construction
3. Inverse fast Fourier transform (IFFT)
4. Transmission

A receiver may consist of the following functional blocks:

1. Reception
2. Frame and symbol synchronization
3. Fast Fourier transform (FFT)
4. Frequency, timing, and channel estimation
5. Subchannel demodulation
6. Channel decoding, including
 - a. De-interleaving
 - b. Decoding
 - c. De-randomization

4.3 Multi-Carrier Signal Format

The physical media resource (e.g., radio or cable) in a multi-carrier communication system can be divided in both the frequency and time domains, as depicted in Figure 3. This canonical division provides a high flexibility and fine granularity for resource sharing.

The basic structure of a multi-carrier signal in the frequency domain is made up of subcarriers. For a given bandwidth of a spectral band or channel (B_{ch}), the number of usable subcarriers is finite and limited, whose value depends on the size of the FFT and the sampling frequency (f_s) and the effective bandwidth (B_{eff}), as depicted in Figure 4. There are three types of subcarriers, as illustrated in Figure 5.

1. Data subcarriers, which carries information data;

-
2. Pilot subcarriers, whose phases and amplitudes are predetermined and made known to all receivers and which are used for assisting system functions such as estimation of system parameters; and
 3. Silent subcarriers, which have no energy and are used for guard bands and DC carrier.

The data subcarriers can be arranged, in a particular manner, into groups called subchannels to support scalability and multiple-access. The subcarriers forming one subchannel may or may not be adjacent to each other. Each user may use some or all of the subchannels.

The basic structure of a multi-carrier signal in the time domain is generally made up of time frames, time slots, and OFDM symbols. A frame consists of a number of time slots, whereas each time slot is comprised of one or more OFDM symbols. The OFDM time domain waveform is generated by applying the inverse-fast-Fourier-transform (IFFT) to the OFDM signals in the frequency domain. A copy of the last portion of the time waveform, known as the cyclic prefix (CP), is inserted in the beginning of the waveform itself to form the OFDM symbol.

In one embodiment, a mapper, as implied by the “Subchannel and Symbol Construction” box in Figure 2, is designed to map the logical frequency/subcarrier and OFDM symbol indices seen by upper layer facilities, such as the MAC resource scheduler or the coding and modulation modules, to the actual physical subcarrier and OFDM symbol indices. A contiguous time-frequency area before the mapping may be actually discontinuous after the mapping, and vice versa. On the other hand, in a special case, the mapping may be a “null process”, which maintains the same time and frequency indices before and after the mapping. The mapping process may change from time slot to time slot, from frame to frame, or from cell to cell. Without loss of generality, in the invention, the terms “resource”, “airlink resource”, “physical resource”, “radio resource”, and “time-frequency resource” may refer to either the time-frequency resource before such mapping or that after such mapping.

4.4 Basic Connection ID's and Application Connection ID's

In accordance with aspects of certain embodiments of this invention, both basic connection identification (BCID) and application connection-specific identification (ACID) are employed to facilitate the control process.

When a mobile station enters the wireless network, it is first assigned a BCID for each direction of the wireless connection: downlink and uplink. A BCID can be used for control messages or generic (unclassified) application connections. The BCID for downlink may or may not be the same as that of the uplink.

In one embodiment, certain application data are classified into different application packet streams based on the application type, quality of service (QoS) requirement, or other properties. For example, voice application stream is identified based on the special value in the type of service (ToS) field of its IP header. A new combination of RTP/UDP/IP headers with the special IP ToS field value indicates a new voice application stream. Such a new stream is identified by peeking into the voice session setup protocol messages, such as session initiation protocol (SIP).

Figure 6 illustrates the design of an OFDMA system with a system component called Classifier.

Incoming application packets are classified by the Classifier based on classification rules. The classification rules can be configured statically or dynamically by a control process. Each classification rule is defined using parameters, such as application type, QoS parameters and other properties. Different application packets will be put into different data queues and transmitted by the OFDMA transmitter.

In one embodiment, a special connection is set up to transmit a special application stream to/from a mobile station over the air. An ACID can be assigned for the corresponding application packet flow. For example, for voice application, the ACID is a voice connection ID (VCID) that is assigned for voice packets. Furthermore, an application type can be further classified into different sub-types, based on certain properties of that application. For example, voice applications can be further classified into different sub-types based on the voice source coding (vocoder) methods (e.g., G.711 and G.729A) and are given corresponding sub-types of VCID's.

For certain multi-casting application, an ACID may be shared by multiple base stations or mobile stations.

Once established, the connection ID's, including BCID's and ACID's, are disseminated, through broadcasting messages for example, to the corresponding base station(s) and mobile station(s) for proper packet transmission and reception.

The medium access control (MAC) scheduler allocates airlink resource to different connections. A certain application types may be associated with a certain airlink resource block, such as a time and frequency region. Such correspondence is made known to base stations and mobile stations through default configuration or additional broadcasting messages. More details regarding the usage of airlink resources for certain application is described in the subsequent sections.

A connection ID is released once the wireless system determines that there is no need to continue the connection. For example, a voice connection and its VCID are released once the system detects deactivation of the voice stream. In one embodiment, the voice connection is deactivated if the voice session disconnect is detected through snooping SIP signaling. In another embodiment, the voice connection is released if there is no voice packet activity on the connection for a certain period of time.

In one embodiment, the same bit length is used in different types of connections ID's, including BCID's, and ACID's. In another embodiment, different types of connection ID's may have different bit length. For example, in a typical implementation, a BCID is 16-bit, to accommodate a large number of mobile stations and unclassified applications, while a VCID is 6-bit, to accommodate up to 64 simultaneous voice connections in a cell. The shorter ACID length, such as that of VCID, is beneficial for reducing the control overhead, especially when an application utilizes many small data packets, such as VoIP packets.

In another embodiment, an ACID is further augmented by other properties of the utilized airlink resources, such as time or frequency indices, to identify an application connection. This can be used to further reduce ACID bit length or to increase the maximum number of accommodated application connection given a certain ACID bit length. For example, a voice codec generates voice application data periodically. The allocation period is usually multiple times of the air link

frame duration. In this case, the air link frame number can be combined with a VCID to identify a voice connection. For example, the voice codec of G.723.1 generates a voice frame once every 30 milliseconds. The MAC scheduler allocates airlink resource to such a voice connection once every 30ms. In a wireless cellular system using 5ms frame duration, a single VCID can be shared by 6 voice streams, each associated with a different frame number to uniquely identify a voice connection.

4.5 Adaptive Modulation and Coding

In accordance with aspects of certain embodiments of this invention, a particular set of modulation and forward-error correction (FEC) coding schemes (MCS) are used for transmission of a particular type of applications under various channel conditions. For example, a prescribed set of MCS can be used for voice applications, as shown in Table 1.

In one embodiment, the MCS are designed to utilize modular resources. For example, as illustrated in Table 1, 80 raw modulation symbols are needed to transmit 160 information bits using 16QAM modulation and rate- $\frac{1}{2}$ coding, the highest available MCS in the table. The resource utilized by this highest MCS is called a basic resource unit (Unit), i.e., 80 raw symbols in this example. The resource utilized by other MCS is simply an integer multiple of the basic unit. For example, 4 units are required to transmit the same number of information bits using QPSK modulation with rate- $\frac{1}{4}$ coding. The relationship of MCS and required number of basic units to carry the same specific amount of voice data is illustrated in Figure 7. Such modular utilization of resources of various MCS leads to significant reduction of control overhead, which becomes more evident in the subsequent sections.

Table 1. Modulation and coding schemes used for voice packets

MCSI	Modulation	Coding rate	Information bits	Raw symbols	Units
1	16QAM	1/2	160	80	1
2	QPSK	1/2	160	160	2
3	QPSK	1/4	160	320	4
4	QPSK	1/8	160	640	8

The MCS index (MCSI) conveys the information about modulation and coding schemes. For a known vocoder, MCSI also implies the number of AMC resource units required for a voice packet.

Coding and signal repetition can be combined to provide lower coding rates. For example, rate- $\frac{1}{8}$ coding can be realized by a concatenation of rate- $\frac{1}{2}$ coding and 4-time repetition.

The decision process for selecting proper MCS of a packet can vary by applications. In one

embodiment, the process for voice packets can be more conservative than that for general data packets due to the QoS requirements of the voice applications. For example, when the signal to interference noise ratio (SINR) is used as a threshold for selecting the MCS, the threshold value for voice packets is set higher than that for general data packets. For example, the SINR threshold of QPSK with rate- $\frac{1}{2}$ coding for voice packets is 12 dB, while that for general data packets is 10 dB.

4.6 Special Airlink Resource Region for Certain Applications

In accordance with aspects of certain embodiments of this invention, a particular region/zone of time-frequency resources are designated for a particular type of application so as to reduce the control overhead in MAC headers. Unused resources in one application zone may be allocated for other applications.

In one embodiment, a special time-frequency zone is allocated for voice applications, as shown in Figure 7, where VZone is the region designated for voice application, and V1 is the resource to be used for the first voice packet, and V2 is the resource to be used for the second voice packet, so on so forth.

In another embodiment, the time-frequency resource used for a voice packet, i.e., V1, or V2, ... , is indicated by the starting time-frequency coordinates and the ending coordinates, relative to the starting point of the VZone. The granularity in the time coordinates can be one or multiple OFDM symbols, and that in the frequency coordinates can be one or multiple subcarriers. The amount of control information may be significant to indicate certain arbitrary starting and ending coordinates of a voice packet.

In yet another embodiment, voice packets are arranged sequentially with certain rules in the VZone, as shown in Figure 7, where the VZone is divided into multiple columns and the voice packets are arranged from top down in each column and from left to right over columns. The width of each column can be a certain number of subcarriers.

In still another embodiment, the two-dimensional time-frequency coordinates are converted to a one dimensional offset to the origin of the VZone. Such offset is shown as VZone index (VZI) in Figure 7. For example, with MCS and modular resource, the granularity of the offset is defined as a basic resource Unit as described in the previous sections. For instance, the location offset for the first voice packet $VZI_1=0$ and its $MCSI_1=1$, which implies that one basic resource unit is used; the offset for the second voice packet $VZI_2 = 1$ and its $MCSI_2=4$, which implies that eight basic resource units are used; and the offset for the third voice packet $VZI_3=9$ and its $MCSI_3=2$, which implies that two basic resource units are used.

Using MCS resource Unit as the granularity of location offset of a packet (instead of OFDM symbol and subcarrier coordinates) reduces the number of bits required to represent its VZone indices. For example, to support a maximum of 64 calls in a cell, a maximum of $64 \times 8 = 512$ units might be used, assuming that every voice packet is transmitted using the lowest MCS. Therefore, a 9-bit number is sufficient to represent a VZI. In practice, different voice packets may be transmitted using different MCS's, some with $MCSI=1$, some with $MCSI=4$, so on so forth. According to statistics, a shorter bit-length than the maximum needed, for example 8 bits, may

be used for VZI for practical purpose.

In the case where an MCS is used with modular resource and voice packets are located sequentially in the VZone, the overhead required to indicate the location of a voice packet can be further reduced. In one embodiment, the VZone index of a packet can be inferred from the MCSI of the packets located before the subject packet. For example, if the first voice packet uses $MCSI_1=1$, 16QAM with $\frac{1}{2}$ coding, and the second voice packet uses $MCSI_2=4$, QPSK with $\frac{1}{8}$ coding, then the first two voice packets occupy $1+8=9$ units, and the starting location of the third voice packet is the 9th unit. Therefore, the VZone index for each packet can be skipped in the control message and the overhead is further reduced.

In accordance with aspects of certain embodiments of this invention, resource allocation can be carried out in various manners. In one embodiment, an application zone may contain all subcarriers of one or multiple OFDM symbols or time slots. In another embodiment, the definition, such as the location and size, of an application zone, may be different from cell to cell. In yet another embodiment, the VZones of voice applications are allocated at different locations for neighboring cells to avoid inter-cell interference. In still another embodiment, the system allocates fixed amount of resource to each voice connection. The system uses AMC and matches it with adaptive multi-rate (AMR) voice coding to improve the voice quality.

4.7 Control Messages and Headers

In accordance with aspects of certain embodiments of this invention, a control message, often called Information Element (IE), is used to facilitate the control process.

In one embodiment, the IE is sent prior to transmitting an application packet to indicate the information on the packet, such as the packet destination, modulation and coding method, and the airlink resource used. For example, the IE for a voice packet includes (VCID, MCSI, VZI). In one embodiment, VCID is 6 bits, MCSI is 2 bits, and VZI is 8 bits, thereby resulting in a 2-byte IE overhead for each voice packet. In some cases, the IE regarding each voice packet includes only VCID and MCSI, thereby effectively reducing the IE overhead for each voice packet to 1 byte. The VZI can be inferred from the MCSI of the voice packets located before the subject voice packet. Additional control information, such as power control information, can be added to the IE with additional bit fields.

In another embodiment, the base station sends the IE for a downlink packet to inform the mobile station for proper reception of the packet, and the base station sends the IE for an uplink packet to inform the mobile station for proper, subsequent transmission of the packet. The downlink and uplink packet IE's may be separately grouped together. The IE's may be broadcasted or multicasted to corresponding destinations.

In yet another embodiment, the IE's of the same application type or subtype are grouped together. A special field, called Application MAP (AMAP) subheader, for a specific application type, may be added to the IE group. The subheader may indicate the application type and the length of the IE group. For example, as shown in Figure 8, an AMAP subheader for voice application (shown as VMAP) is followed by IE's for voice packets (Shown as VIE), where Length = 3 indicates that the subheader is followed by three voice IE's, and Type = 01 indicates

that the application type is voice.

In one embodiment, the IE's for all packets are transmitted with the same modulation and coding schemes (MCS). In another embodiment, adaptive modulation and coding (AMC) is used for the transmission of the IE's, as illustrated in Figure 9. A special rule, which is known to both base stations and mobile stations, can be used to determine the IE MCS, based on the MCS of its corresponding packet for proper reception of the IE. In one embodiment, the MCS for an IE is maintained the same as that of its corresponding application packet. In another embodiment, the MCS for an IE is one level more conservative than that of its corresponding packet. For example, if the MCSI for a packet is 2 (QPSK with rate- $\frac{1}{2}$ coding), then the MCSI for its IE is 3 (QPSK with rate- $\frac{1}{4}$ coding).

In an embodiment, multiple IE's with the same MCS are grouped together into a block. An additional control message is transmitted prior to such block to indicate the length and the MCS used for the block.

In a system with one or multiple application zones, the remaining resource unused by the application zones can be treated as a special resource zone. The special resource zone may be irregular in shape. A particular mechanism in MAC scheduler tracks the time-frequency resources in this special zone and broadcasts the resource allocation in a special zone MAP message.

In one embodiment, the special zone MAP message explicitly identifies the resource region, for example using the time and frequency coordinates of a resource block. The mobile station can identify its own resource by decoding the MAP message.

In another embodiment, both the base station and the mobile station share the configuration information of the special resource region, and view the special region as a contiguous resource region. The MAP message only includes the resource allocation information in the special resource zone, using connection ID, resource identification parameters and MCS index.

In yet another embodiment, the MAP message can be further compressed if the sequence of the resource units in the special resource region is pre-defined. A so-called time first sequence assigns smaller sequence number to the units in the time axle. Figure 10 shows the time first sequence definition. The special resource region is illustrated in the shaded area. Similarly, the unit sequence number can be assigned along the frequency axle.

4.8 Voice Activity Detection

Typical voice conversations contain approximately 50 percent silence. The silence period in conversation is detected by a vocoder using technologies such as Voice Activity Detection (VAD). Voice packets are only generated when voice activity is detected. During the silence period, the voice packet data rate is greatly reduced.

The VAD indication can also be used by the MAC scheduler at the base station to adjust the bandwidth allocation for the voice connection.

In the uplink direction, the mobile station sends a special MAC message once the VAD indication is received from its vocoder. The MAC message indicates to the base station that the

voice data rate is reduced temporarily. By receiving such an indication, the MAC scheduler can reduce the airlink resource allocation to the voice connection. Similarly, if the VAD indicates new voice activity, the mobile station notifies the base station using a similar mechanism and the original resource allocation schedule is re-applied to the voice connection.

In the downlink direction, if there is no voice packet to be transmitted over a voice connection, the MAC scheduler allocates the resource to other voice connections.

Once a voice connection is in the silence period, the MAC scheduler reduces the resource allocation to the mobile station. As a consequence, a resource block previously allocated for the connection in the VZone may become vacant. Several methods can be used to deal with such fragmentation in the VZone.

In one embodiment, the MAC scheduler at the base station reallocates the resource with the objective of minimizing the impact to other voice connections, such as their adaptive modulation and coding processes.

In another embodiment, the MAC scheduler maintains the resource allocation of the other voice connections, and allocates the resource vacated by the silent voice connection to new voice connections or other application packets.

In another embodiment, the MAC scheduler moves all the subsequent allocations up to fill the resource gap. As shown in Figure 11, once voice connection, identified by VCID 2, is in the silence period, the other voice connections occupy the resource used to allocate for VCID 2.

In another embodiment, the MAC scheduler uses the last voice time-frequency resource, in the same VZone, to fill the resource gap of a silent voice connection. Figure 12 illustrates such a case, the last voice connection, identified by VCID 12, occupies the resource allocation gap of the voice connection (VCID 2).

In yet another embodiment, the MAC scheduler uses the last voice time-frequency resource, with the same coding and modulation scheme, in the same VZone, to fill the resource gap. The new resource gap introduced by such a replacement is filled by the subsequent voice time-frequency resource. As shown in Figure 13, voice connection (VCID 6) uses the same coding and modulation scheme as voice connection (VCID 2), and is the last one in the same VZone. Once voice connection (VCID 2) goes into silence period, the MAC scheduler allocates its resource to voice connection (VCID 6). And other voice connections after voice connection (VCID 6) are allocated with subsequent resources.

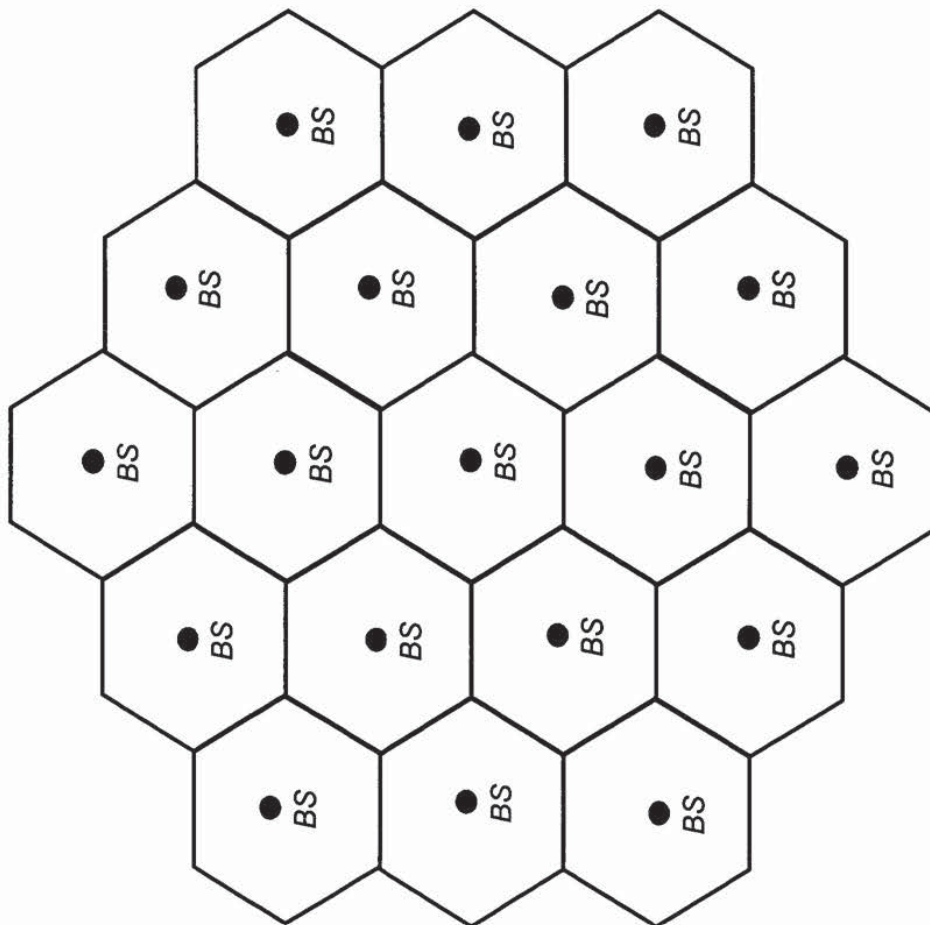


Figure 1

Best Available Copy

Confidential and Proprietary
WALTICAL SOLUTIONS, INC.

WALTICAL
SOLUTIONS, INC.

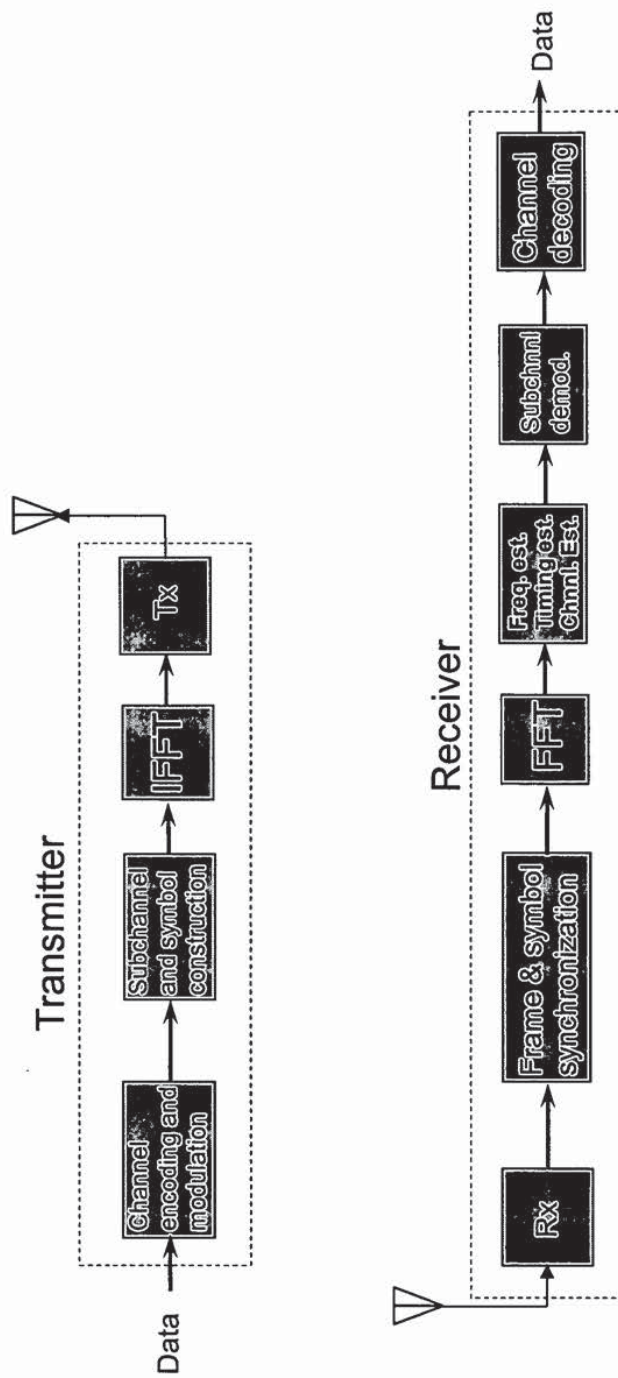


Figure 2

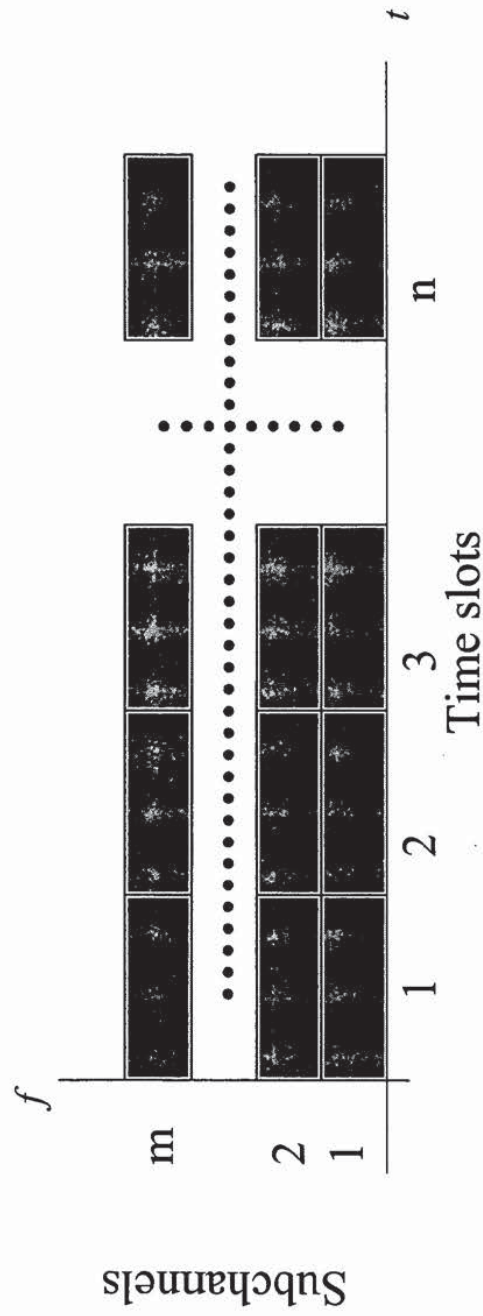
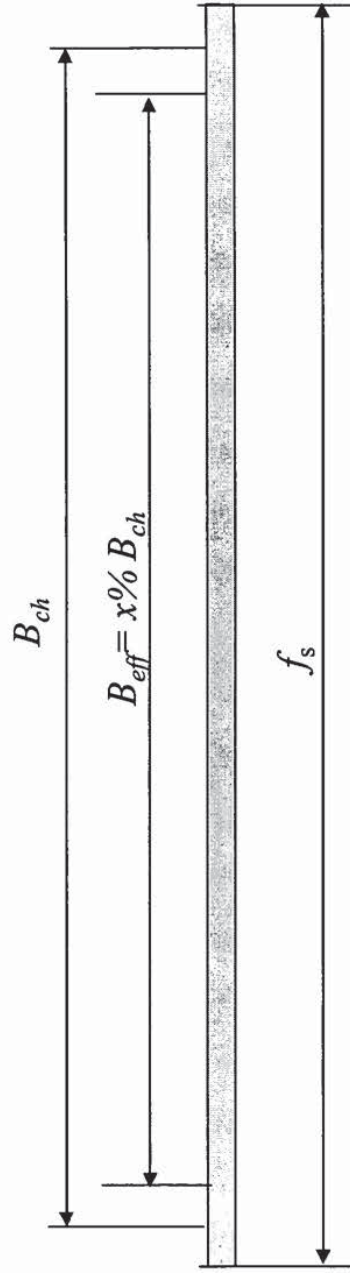


Figure 3



$$\# \text{ of usable subcarriers} = \frac{B_{eff}}{f_s} \times N_{fft}$$

Figure 4

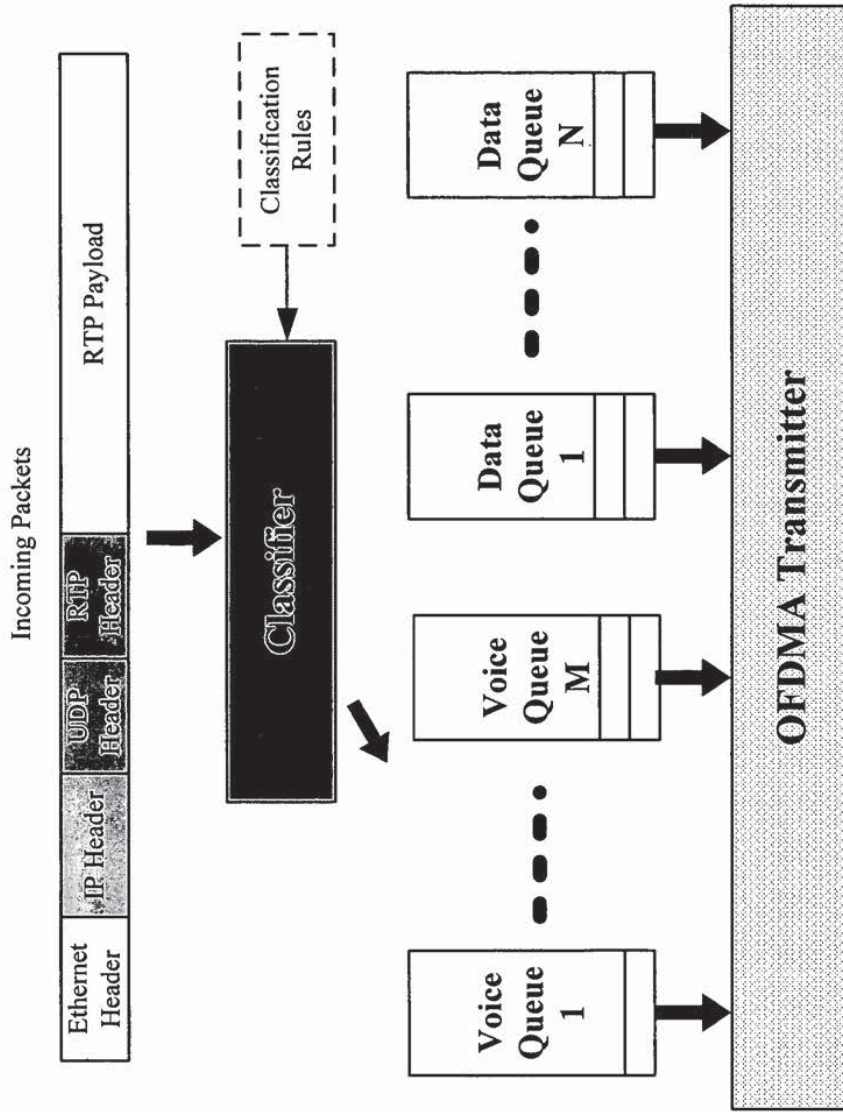


Figure 6

Confidential and Proprietary
WALTICAL SOLUTIONS, INC.

WALTICAL
SOLUTIONS, INC.

AMC with Modular Resource Utilization

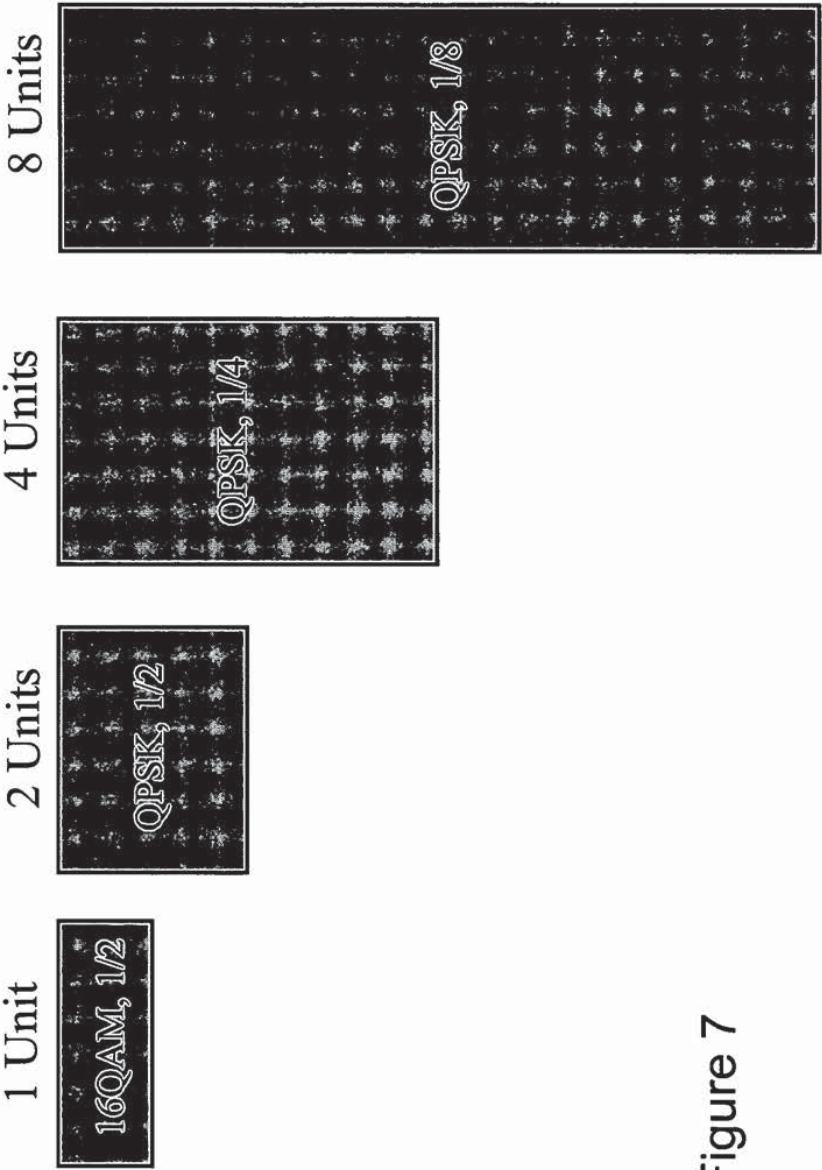


Figure 7

Confidential and Proprietary
WALTICAL SOLUTIONS, INC.

WALTICAL
SOLUTIONS, INC.

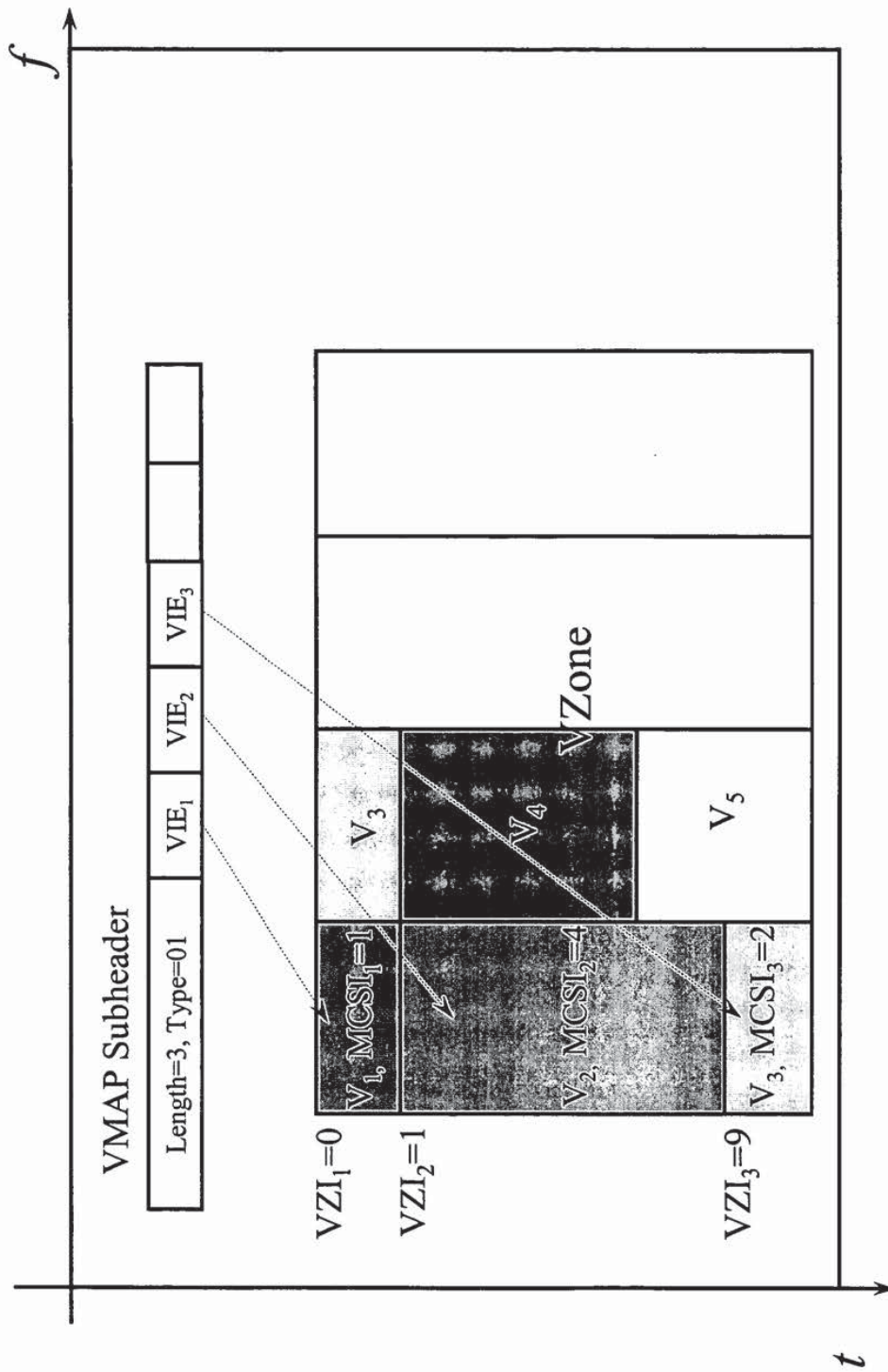


Figure 8

Confidential and Proprietary
WALTICAL SOLUTIONS, INC.

WALTICAL
SOLUTIONS, INC.

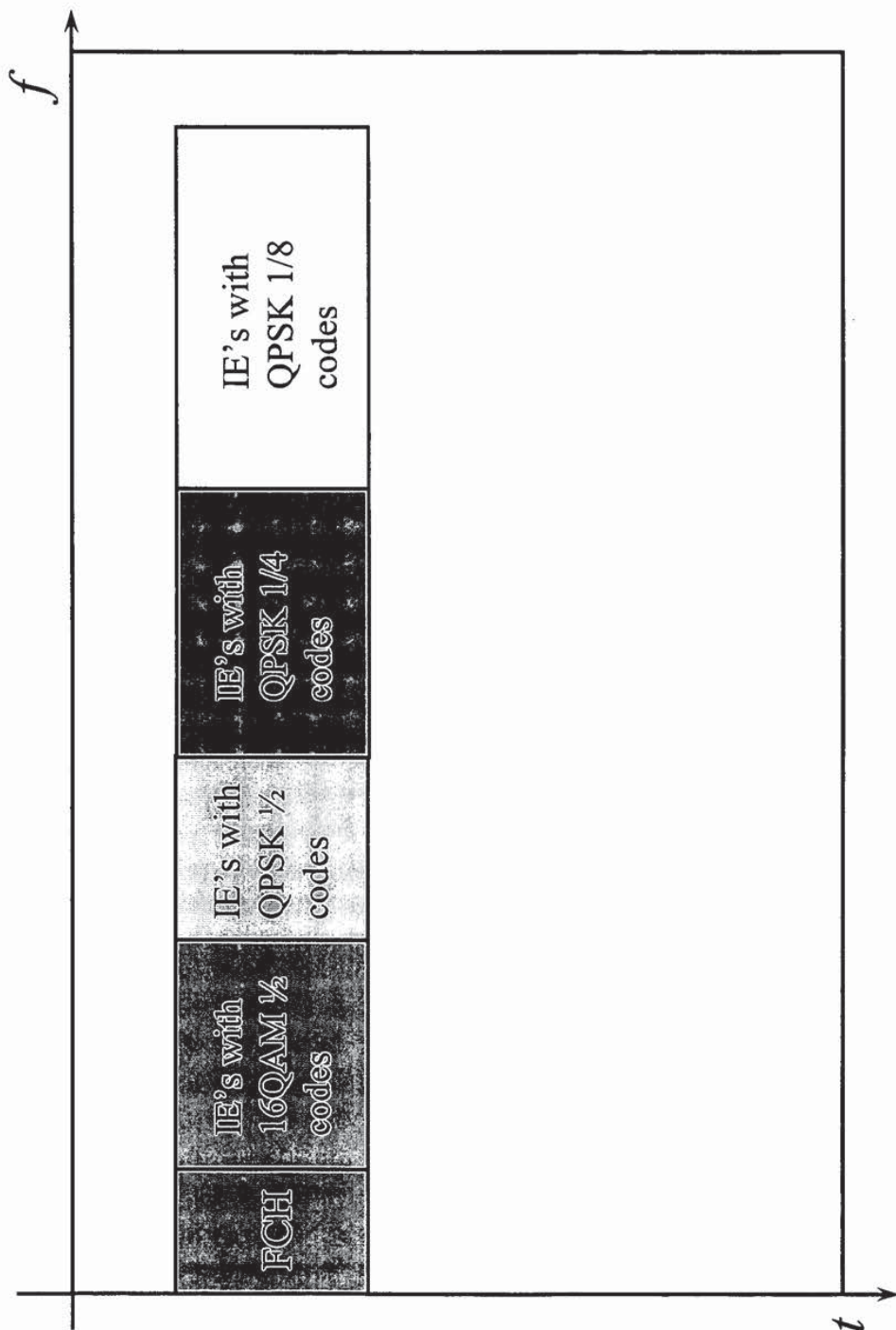


Figure 9

Confidential and Proprietary
WALTICAL SOLUTIONS, INC.

WALTICAL
SOLUTIONS, INC.

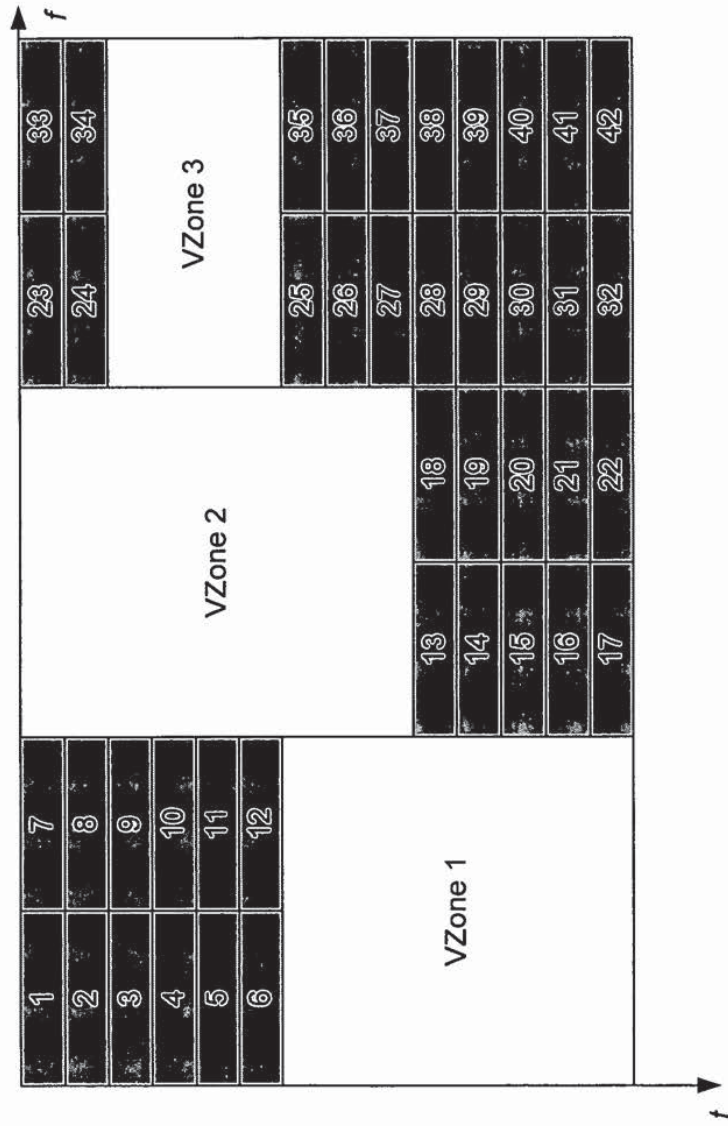


Figure 10

Confidential and Proprietary
WALTICAL SOLUTIONS, INC.

WALTICAL
SOLUTIONS, INC.

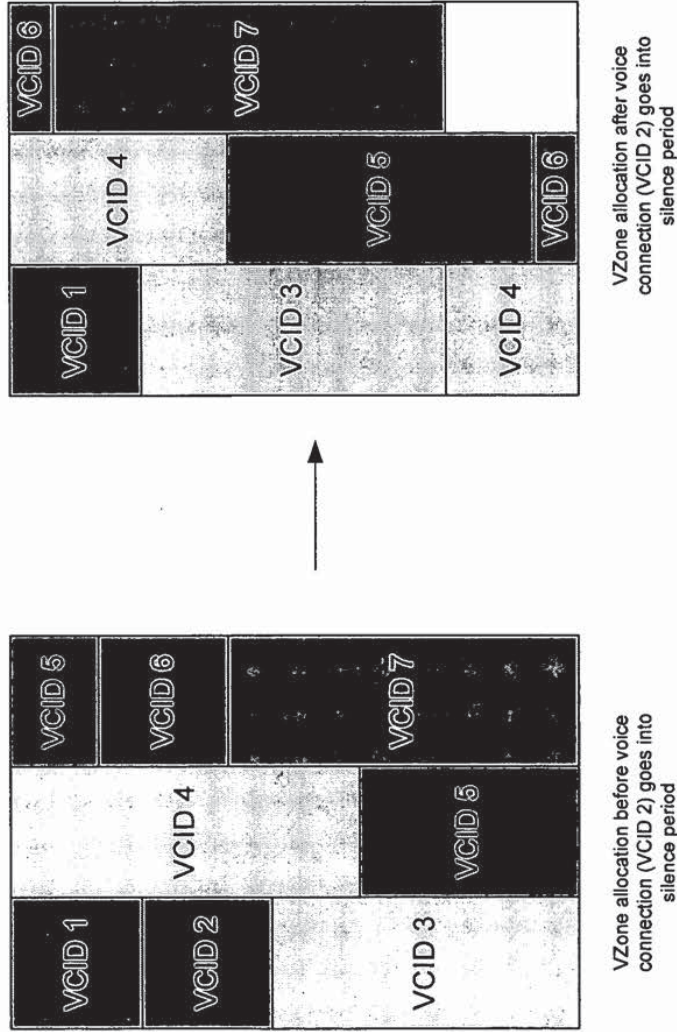


Figure 11

Confidential and Proprietary
WALTICAL SOLUTIONS, INC.

WALTICAL
SOLUTIONS, INC.

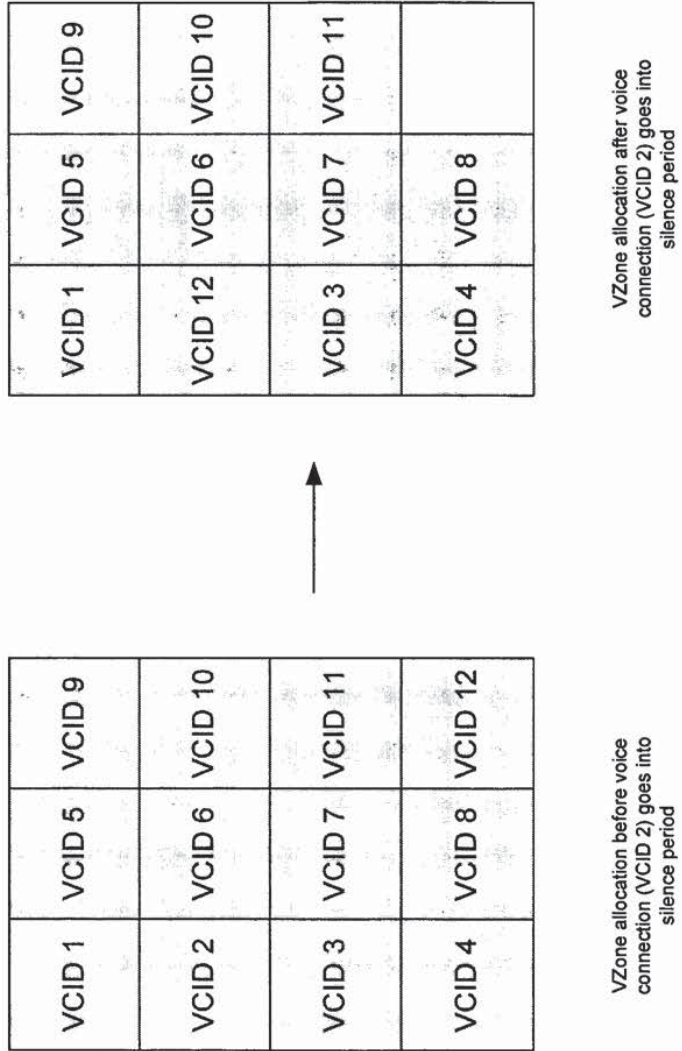


Figure 12

Confidential and Proprietary
WALTICAL SOLUTIONS, INC.

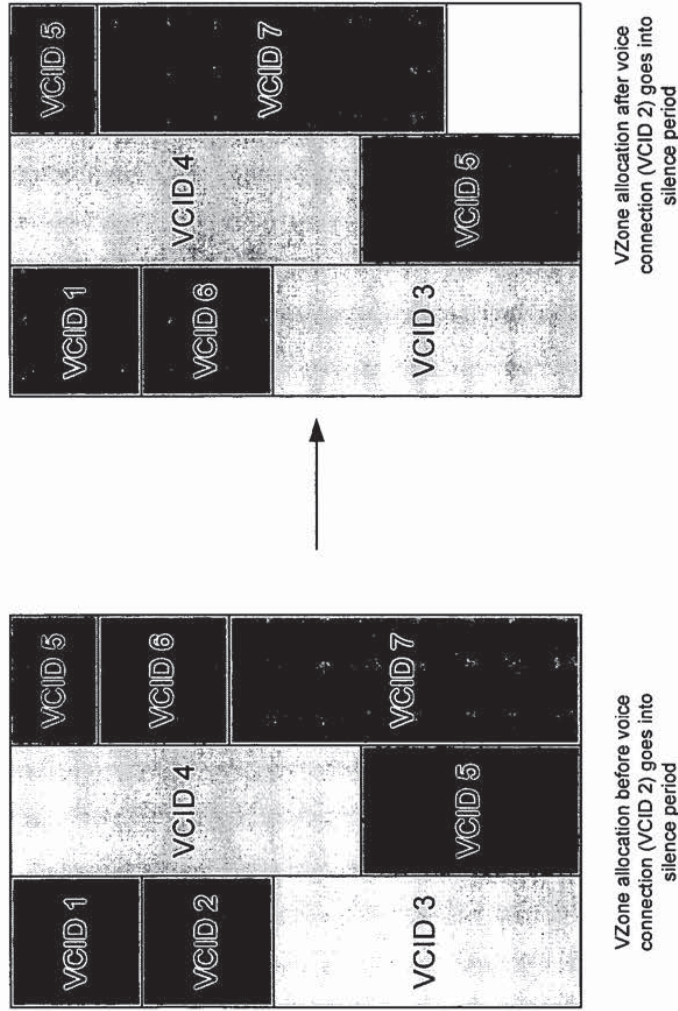


Figure 13

Confidential and Proprietary
WALTICAL SOLUTIONS, INC.

WALTICAL
SOLUTIONS, INC.

**This Page is Inserted by IFW Indexing and Scanning
Operations and is not part of the Official Record**

BEST AVAILABLE IMAGES

Defective images within this document are accurate representations of the original documents submitted by the applicant.

Defects in the images include but are not limited to the items checked:

- ☐ **BLACK BORDERS**
- ☐ **IMAGE CUT OFF AT TOP, BOTTOM OR SIDES**
- ☐ **FADED TEXT OR DRAWING**
- ☐ **BLURRED OR ILLEGIBLE TEXT OR DRAWING**
- ☐ **SKEWED/SLANTED IMAGES**
- ☒ **COLOR OR BLACK AND WHITE PHOTOGRAPHS**
- ☐ **GRAY SCALE DOCUMENTS**
- ☐ **LINES OR MARKS ON ORIGINAL DOCUMENT**
- ☐ **REFERENCE(S) OR EXHIBIT(S) SUBMITTED ARE POOR QUALITY**
- ☐ **OTHER:** _____

IMAGES ARE BEST AVAILABLE COPY.

As rescanning these documents will not correct the image problems checked, please do not report these problems to the IFW Image Problem Mailbox.

Document code: WFEE

United States Patent and Trademark Office
Sales Receipt for Accounting Date: 05/12/2008

KMCLEAN1	ADJ #00000003	Mailroom Dt: 09/10/2007	
	Seq No: 2553	Sales Acctg Dt: 09/11/2007	11908257
	02 FC : 2633	-100.00	OP

(19) World Intellectual Property Organization
International Bureau(43) International Publication Date
5 April 2007 (05.04.2007)

PCT

(10) International Publication Number
WO 2007/038750 A1(51) International Patent Classification:
H04B 11/00 (2006.01)(21) International Application Number:
PCT/US2006/038149(22) International Filing Date:
28 September 2006 (28.09.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/721,451 28 September 2005 (28.09.2005) US(71) Applicant (for all designated States except US): **NEO-CIFIC, INC.** [US/US]; 13312 SE 43rd Street, Bellevue, WA 98006 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **LI, Xiaodong** [US/US]; 9919 129th PL NE, Kirkland, WA 98033 (US). **HUANG, Haiming** [CN/US]; 605 141st CT SE #D203, Bellevue, WA 98007 (US). **LO, Titus** [CA/US]; 13312 SE 43rd St, Bellevue, WA 98006 (US). **WANG, Ruifeng** [CA/US]; 656 237th PL SE, Sammamish, WA 98074 (US).(74) Agent: **BISHOP, Stephen, C.**; Perkins Coie LLP, P.O. Box 1247, Seattle, WA 98111-1247 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

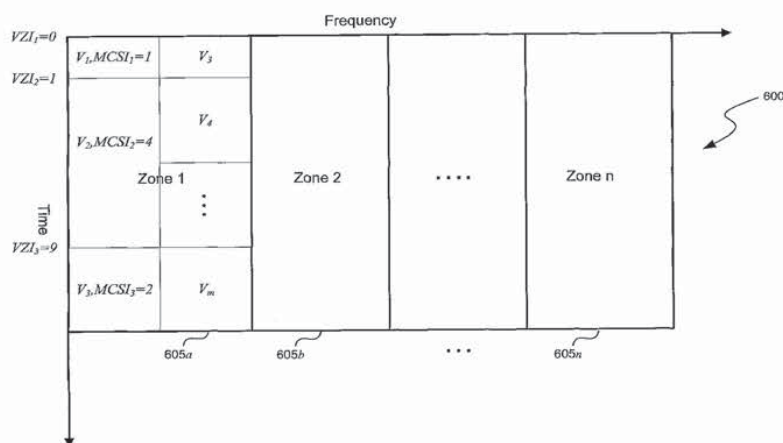
(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

- with international search report
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND SYSTEM FOR MULTI-CARRIER PACKET COMMUNICATION WITH REDUCED OVERHEAD



(57) **Abstract:** A method and system for minimizing the control overhead in a multi-carrier wireless communication network that utilizes a time-frequency resource is disclosed. In some embodiments, one or more zones in the time-frequency resource are designated for particular applications, such as a zone dedicated for voice-over-IP (VoIP) applications. By grouping applications of a similar type together within a zone, a reduction in the number of bits necessary for mapping a packet stream to a portion of the time-frequency resource can be achieved. In some embodiments, modular coding schemes associated with the packet streams may be selected that further reduce the amount of necessary control information. In some embodiments, packets may be classified for transmission in accordance with application type, QoS parameters, and other properties. In some embodiments, improved control messages may be constructed to facilitate the control process and minimize associated overhead.

METHOD AND SYSTEM FOR MULTI-CARRIER PACKET COMMUNICATION WITH REDUCED OVERHEAD

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims the benefit of U.S. Provisional Patent Application No. 60/721,451, filed on September 28, 2005.

TECHNICAL FIELD

[0002] The disclosed technology relates, in general, to wireless communication and, in particular, to multi-carrier packet communication networks.

BACKGROUND

[0003] Bandwidth efficiency is one of the most important system performance factors for wireless communication systems. In packet based data communication, where the traffic has a bursty and irregular pattern, application payloads are typically of different sizes and with different quality of service (QoS) requirements. In order to accommodate different applications, a wireless communication system should be able to provide a high degree of flexibility. However, in order to support such flexibility, additional overhead is usually required. For example, in a wireless system based on the IEEE 802.16 standard ("WiMAX"), multiple packet streams are established for each mobile station to support different applications. At the medium access control (MAC) layer, each packet stream is mapped into a wireless connection. The MAC scheduler allocates wireless airlink resources to these connections. Special scheduling messages, DL-MAP and UL-MAP, are utilized to broadcast the scheduling decisions to the mobile stations.

[0004] In the MAP scheduling message defined by IEEE802.16, there is significant control overhead. For example, each connection is identified by a 16 bits connection ID (CID). The CID is included in the MAP message to identify the mobile station. The maximum number of connections that a system can support is therefore 65,536. Each mobile station has at least two management connections for control and management messages and a various number of traffic connections for

application data traffic. As another example, each connection includes the identification of an airlink resource that can correspond to any time/frequency region that is allocated for communication. The resource allocation is identified in the time domain scale with a start symbol offset (8 bits) and a symbol length (7 bits) and in the frequency domain scale with a start logical subchannel offset (6 bits) and a number of allocated subchannels (6 bits). Due to the fact that different applications have different resource requirements, the allocated resource region is irregular from connection to connection. As a still further example, the modulation and coding scheme for each connection is identified by a 4-bit MCS code, identified as either a downlink interval usage code (DIUC) or an uplink interval usage code (UIUC). Another 2 bits are used to indicate the coding repetition in addition to 3 bits for power control. Overall, the overhead of a MAP message is 52 bits. For applications such as voice-over-IP (VoIP), the payload of an 8Kbps voice codec is 20 bytes in every 20ms. The overhead of the MAP message alone can therefore account for as much as 32.5% of the overall data communication, thereby resulting in a relatively low spectral efficiency. It would therefore be beneficial to reduce the overhead in a multi-carrier packet communication system to improve the spectral efficiency of the system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Figure 1 illustrates the coverage of a wireless communication network that is comprised of a plurality of cells.

[0006] Figure 2 is a block diagram of a receiver and a transmitter, such as might be used in a multi-carrier wireless communication network.

[0007] Figure 3 is a block diagram depicting a division of communication capacity in a physical media resource.

[0008] Figure 4 is a graphical depiction of the relationship between a sampling frequency, a channel bandwidth, and usable subcarriers in a channel.

[0009] Figure 5 is a graphical depiction of the structure of a multi-carrier signal in the frequency domain.

[0010] Figure 6 is a block diagram of a time-frequency resource utilized by a wireless communication network.

[0011] Figure 7 is a block diagram of a classifier for classifying received packets by application, QoS, or other factor.

[0012] Figures 8A and 8B are block diagrams of representative control message formats.

[0013] Figure 9 is a block diagram of a special resource zone with unit sequence defined in time-first order.

[0014] Figures 10A-10C are block diagrams illustrating the reallocated of resources within a resource zone.

DETAILED DESCRIPTION

[0015] A system and method for minimizing the control overhead in a multi-carrier wireless communication network that utilizes a time-frequency resource is disclosed. In some embodiments, one or more zones in the time-frequency resource are designated for particular applications, such as a zone dedicated for voice-over-IP (VoIP) applications. By grouping applications of a similar type together within a zone, a reduction in the number of bits necessary for mapping a packet stream to a portion of the time-frequency resource can be achieved. In some embodiments, modular coding schemes associated with the packet streams may be selected that further reduce the amount of necessary control information.

[0016] In some embodiments, packets may be classified for transmission in accordance with application type, QoS parameters, and other properties. An application connection-specific identifier (ACID) may also be assigned to a packet stream. Both measures reduce the overhead associated with managing multiple application streams in a communication network.

[0017] In some embodiments, improved control messages may be constructed to facilitate the control process and minimize associated overhead. The control messages may include information such as the packet destination, the modulation and coding method, and the airlink resource used. Control messages of the same

application type or subtype, modulation and coding scheme, or other parameter may be grouped together for efficiency.

[0018] While the following discussion contemplates the application of the disclosed technology to an Orthogonal Frequency Division Multiple Access (OFDMA) system, those skilled in the art will appreciate that the technology can be applied to other system formats such as Code Division Multiple Access (CDMA), Multi-Carrier Code Division Multiple Access (MC-CDMA), or others. Without loss of generality, OFDMA is therefore only used as an example to illustrate the present technology. In addition, the following discussion uses voice-over-IP as a representative application to which the disclosed technology can be applied. The disclosed technology is equally applicable to other applications including, but not limited to, audio and video.

[0019] The following description provides specific details for a thorough understanding of, and enabling description for, various embodiments of the technology. One skilled in the art will understand that the technology may be practiced without these details. In some instances, well-known structures and functions have not been shown or described in detail to avoid unnecessarily obscuring the description of the embodiments of the technology. It is intended that the terminology used in the description presented below be interpreted in its broadest reasonable manner, even though it is being used in conjunction with a detailed description of certain embodiments of the technology. Although certain terms may be emphasized below, any terminology intended to be interpreted in any restricted manner will be overtly and specifically defined as such in this Detailed Description section.

I. Wireless Communication Network

[0020] Figure 1 is a representative diagram of a wireless communication network 100 that services a geographic region. The geographic region is divided into a plurality of cells 105, and wireless coverage is provided in each cell by a base station (BS) 110. One or more mobile devices (not shown) may be fixed or may roam within the geographic region covered by the network. The mobile devices are used as an interface between users and the network. Each base station is connected to the backbone of the network, usually by a dedicated link. A base station serves as a focal point to transmit information to and receive information from

the mobile devices within the cell that it serves by radio signals. Note that if a cell is divided into sectors, from a system engineering point of view each sector can be considered as a cell. In this context, the terms "cell" and "sector" are interchangeable.

[0021] In a wireless communication system with base stations and mobile devices, the transmission from a base station to a mobile device is called a downlink (DL) and the transmission from a mobile device to a base station is called an uplink (UL). Figure 2 is a block diagram of a representative transmitter 200 and receiver 205 that may be used in base stations and mobile devices to implement a wireless communication link. The transmitter comprises a channel encoding and modulation component 210, which applies data bit randomization, forward error correction (FEC) encoding, interleaving, and modulation of an input data signal. The channel encoding and modulation component is coupled to a subchannel and symbol construction component 215, an inverse fast Fourier transform (IFFT) component 220, and a radio transmitter component 225. Those skilled in the art will appreciate that these components construct and transmit a communication signal containing the data that is input to the transmitter 200. Other forms of transmitter may, of course, be used depending on the requirements of the communication network. :

[0022] The receiver 205 comprises a reception component 230, a frame and synchronization component 235, a fast Fourier transform component 240, a frequency, timing, and channel estimation component 245, a subchannel demodulation component 250, and a channel decoding component 255. The channel decoding component de-interleaves, decodes, and derandomizes a signal that is received by the receiver. The receiver recovers data from the signal and outputs the data for use by the mobile device or base station. Other forms of receiver may, of course, be used depending on the requirements of the communication network.

[0023] Figure 3 is a block diagram depicting the division of communication capacity in a physical media resource 300 (e.g., radio or cable) into frequency and time domains. The frequency is divided into two or more subchannels 305, represented in the diagram as subchannels 1, 2,...m. Time is divided into two or more time slots 310, represented in the diagram as time slots 1, 2,...n. The

canonical division of the resource by both time and frequency provides a high degree of flexibility and fine granularity for resource sharing between multiple applications or multiple users of the resource.

[0024] Figure 4 is a block diagram representing the relationship between the bandwidth of a given channel and the number of usable subcarriers within that channel. A multi-carrier signal in the frequency domain is made up of subcarriers. In Figure 4, the sampling frequency is represented by the variable f_s , the bandwidth of the channel is represented by the variable B_{ch} , and the effective bandwidth by the variable B_{eff} (where the effective bandwidth is a percentage of the channel bandwidth). The number of usable subcarriers within the channel is defined by the following equation:

$$\#_usable_subcarriers = \frac{B_{eff}}{f_s} \times N_{fft}$$

Where N_{fft} is the length of the fast Fourier transform. Those skilled in the art will appreciate that for a given bandwidth of a spectral band or channel (B_{ch}), the number of usable subcarriers is finite and limited, and depends on the size of the FFT, the sampling frequency (f_s), and the effective bandwidth (B_{eff}) in accordance with equation 1.

[0025] Figure 5 is a signal diagram depicting the various subcarriers and subchannels that are contained within a given channel. There are three types of subcarriers: (1) data subcarriers, which carry information data; (2) pilot subcarriers, whose phases and amplitudes are predetermined and made known to all receivers, and which are used for assisting system functions such as estimation of system parameters; and (3) silent subcarriers, which have no energy and are used for guard bands and as a DC carrier. The data subcarriers can be arranged into groups called subchannels to support scalability and multiple-access. The subcarriers forming one subchannel may or may not be adjacent to each other. Each mobile device may use some or all of the subchannels.

[0026] A multi-carrier signal in the time domain is generally made up of time frames, time slots, and OFDM symbols. A frame consists of a number of time slots, and each time slot is comprised of one or more OFDM symbols. The OFDM time domain waveform is generated by applying an inverse-fast-Fourier-transform (IFFT)

to the OFDM symbols in the frequency domain. A copy of the last portion of the time domain waveform, known as the cyclic prefix (CP), is inserted in the beginning of the waveform itself to form an OFDM symbol.

[0027] In some embodiments, a mapper such as the subchannel and symbol construction component 215 in Figure 2 is designed to map the logical frequency/subcarrier and OFDM symbol indices seen by upper layer facilities, such as the MAC resource scheduler or the coding and modulation modules, to the actual physical subcarrier and OFDM symbol indices. A contiguous time-frequency area before the mapping may be actually discontinuous after the mapping, and vice versa. On the other hand, in a special case, the mapping may be a "null process", which maintains the same time and frequency indices before and after the mapping. The mapping process may change from time slot to time slot, from frame to frame, or from cell to cell. Without loss of generality, the terms "resource", "airlink resource", and "time-frequency resource" as used herein may refer to either the time-frequency resource before such mapping or after such mapping.

II. Airlink Resource Zones

[0028] Various technologies are now described that may be utilized in conjunction with the wireless communication network 100 in order to reduce the amount of control overhead associated with the use of system resources. By reducing the control overhead, greater spectral efficiency is achieved allowing the system to, among other benefits, maximize the amount of simultaneously supported communications.

[0029] Figure 6 is a map of a time-frequency resource 600 that is allocated for use by the wireless communication network 100. As described above, in a typical wireless system based on the IEEE 802.16 standard ("WiMAX"), multiple packet streams are established for each mobile device to support different applications. At the medium access control (MAC) layer, each packet stream is mapped into a wireless connection. As a result, various applications carried in packet streams may be spread throughout the available time-frequency resource. To overcome the inefficiencies associated with maintaining this mapping, Figure 6 depicts an alternative way of managing multiple packet streams. The time-frequency resource 600 may be divided into one or more zones 605a, 605b,...605n. Each of

the zones 605a, 605b,...605n is associated with a particular type of application. For example, zone 605a may be associated with voice applications (e.g., VoIP), zone 605b may be associated with video applications, and so on. As will be described in additional detail below, by grouping like applications together the amount of control overhead in MAC headers is reduced. Zones may be dynamically allocated, modified, or terminated by the system.

[0030] When applications of a similar type are grouped together within a zone, a reduction in the number of bits necessary for mapping a packet stream to a time-frequency segment can be achieved. In some embodiments, the identification of the time-frequency segment associated with a particular packet stream can be indicated by the starting time-frequency coordinate and the ending time-frequency coordinate relative to the starting point of the zone. The granularity in the time coordinates can be one or multiple OFDM symbols, and that in the frequency coordinates can be one or multiple subcarriers. If the time-frequency resource is divided into two or more zones, the amount of control information necessary to map to a location relative to the starting point of the zone may be significantly less than the amount of information necessary to map to an arbitrary starting and ending coordinate in the entire time-frequency resource.

[0031] Within each zone 605a, 605b,...605n, the time-frequency resource may be further divided in accordance with certain rules to accommodate multiple packet streams $V_1, V_2, \dots, V_m$. For example, as depicted in Figure 6, zone 605a is divided into multiple columns and the packet streams are arranged from top down in each column and from left to right across the columns. The width of each column can be a certain number of subcarriers. Each packet stream $V_1, V_2, \dots, V_m$ may be associated with an application. For example, V_1 is the resource segment to be used for the first voice packet stream, V_2 is the resource segment to be used for the second voice packet stream, etc. While the zone 605a is divided and the packet streams numbered starting at an origin of the zone, it will be appreciated that the division of the time-frequency resource in accordance with certain rules may start at other origin locations within the zone as well. Segments within each zone may be dynamically allocated by the system as requested and released by the system when expressly or automatically terminated.

[0032] When the zones are further subdivided into time-frequency segments in accordance with certain rules, a mapping of packet streams to segment may be achieved using a one-dimensional offset with respect to the origin of the zone rather than the two-dimensional (i.e. starting time-frequency coordinate and ending time-frequency coordinate relative to the starting point of the zone) mapping method discussed above. Calculation of such an offset may require knowledge of a modulation and coding scheme that is associated with a particular packet stream. For example, Table 1 below sets forth representative modulation and forward-error correction (FEC) coding schemes (MCS) that may be used for voice packet streams under various channel conditions.

Table 1

MCSI	Modulation	Coding rate	Information bits	Raw symbols	Units
1	16QAM	1/2	160	80	1
2	QPSK	1/2	160	160	2
3	QPSK	1/4	160	320	4
4	QPSK	1/8	160	640	8

[0033] In some embodiments, the MCS may be selected to utilize modular resources. For example, as illustrated in Table 1, 80 raw modulation symbols are needed to transmit 160 information bits using 16QAM modulation and rate- $\frac{1}{2}$ coding, the highest available MCS in the table. The resource utilized by this highest MCS is called a basic resource unit ("Unit"), i.e., 80 raw symbols in this example. The resource utilized by other MCS is simply an integer multiple of the basic unit. For example, four units are required to transmit the same number of information bits using QPSK modulation with rate- $\frac{1}{4}$ coding. The MCS index (MCSI) conveys the information about modulation and coding schemes. For a known vocoder, MCSI also implies the number of AMC resource units required for a voice packet. Those skilled in the art will appreciate that coding and signal repetition can be combined to

provide lower coding rates. For example, rate-1/8 coding can be realized by a concatenation of rate-1/2 coding and 4-time repetition.

[0034] The decision process for selecting the proper MCS of a packet can vary by application. In some embodiments, the process for voice packets can be more conservative than that for general data packets due to the QoS requirements of the voice applications. For example, when the signal to interference noise ratio (SINR) is used as a threshold for selecting the MCS, the threshold value for voice packets is set higher than that for general data packets. For example, the SINR threshold of QPSK with rate-1/2 coding for voice packets is 12 dB, while that for general data packets is 10 dB.

[0035] If a MCS from Table 1 is selected for each packet stream contained in a particular zone, the offset to a segment representing a particular packet stream may be easily calculated. For example, an index $VZI_1, VZI_2, \dots, VZI_m$ is shown at the origin of each segment that is contained in the zone 605a. The index for any selected packet stream is defined as the sum of all basic resource units associated with each packet stream preceding the selected packet stream, with an optional adjustment depending on the location where the division of the time-frequency resource is started (typically no adjustment is required since the division starts at the origin of the zone). For example, the location index for the first voice packet stream is $VZI_1=0$ since it starts at the origin of the zone 605a. The first packet stream has an MCS of 1, which implies that one basic resource unit is used. As a result, the index for the second voice packet stream is $VZI_2 = 1$. The second packet stream has an MCS of 4, which implies that eight basic resource units are used. As a result, the index for the third voice packet stream is $VZI_3=9$, arrived by summing the basic resource units used for the preceding first and second packet streams. .

[0036] Using basic resource units as the granularity of a location offset to the packet packet stream reduces the number of bits required to represent its location with the zone 605a. For example, to support a maximum of 64 VoIP calls in a cell, a maximum of $64 \times 8 = 512$ units might be used, assuming that every voice packet is transmitted using the lowest MCS. Therefore, a 9-bit number is sufficient to represent a VZI. In practice, different voice packets may be transmitted using different MCSs, some with MCS=1, some with MCS=4, so on so forth. According to

statistics, a shorter bit-length than the maximum needed, for example 8 bits, may be used for VZI for practical purpose.

[0037] In some embodiments, control information necessary to map a packet stream to a resource segment may be still further reduced. In the case where an MCS is used with packet streams that are located sequentially in the zone, the index of a packet can be inferred from the MCSI of the packets located before the subject packet. For example, if the first voice packet stream uses $MCSI_1=1$, 16QAM with $\frac{1}{2}$ coding, and the second voice packet stream uses $MCSI_2=4$, QPSK with $\frac{1}{8}$ coding, then the first two voice packet streams occupy $1+8=9$ units, and the starting location of the third voice packet stream is the 9th unit. Rather than encode the index for each packet stream in the control information, the index can be omitted in the control message and the offset from the origin of the zone calculated as necessary.

[0038] Allocation of the time-frequency resource 600 can be carried out in a variety of ways. In some embodiments, an application zone may contain all subcarriers of one or multiple OFDM symbols or time slots. In some embodiments, the definition of an application zone, such as the location and size of the zone, may be different from cell-to-cell 105. In some embodiments, in order to avoid inter-cell interference the zones of similar applications are allocated at different locations in neighboring cells. For example, voice applications may be located at a lower frequency range in the time-frequency resource in one cell, and at a higher frequency range in the time-frequency range in an adjacent cell. In some embodiments, the system allocates a fixed amount of resource to each voice connection. The system uses AMC and matches it with adaptive multi-rate (AMR) voice coding to improve the voice quality. Moreover, unused resources in one application zone may be allocated for other applications.

[0039] In a system with one or multiple application zones, the remaining resource unused by the application zones can be treated as a special resource zone. The special resource zone may be irregular in shape. For example, Figure 9 depicts a time-frequency resource 900 having three defined zones 905, 910, and 915. The remaining resource area that is shaded in the figure represents the special resource zone. The MAC scheduler may track the time-frequency resources in this special zone and broadcast the resource allocation in a special zone MAP message. In

some embodiments, the special zone MAP message explicitly identifies the resource zone, for example using the time and frequency coordinates of a resource block. A mobile device can identify its own resource by decoding the MAP message.

[0040] In some embodiments, both the base station and the mobile device share the configuration information of the special resource zone, and view the special zone as a contiguous resource zone. The MAP message only includes the resource allocation information in the special resource zone, using connection ID (described below), resource identification parameters and MCS index.

[0041] In some embodiments, the MAP message can be further compressed if the special resource zone is further divided into a sequence of pre-defined resource units. For example, the shaded area in Figure 9 has been further divided into forty-two resource units 920, first numbered sequentially along the time axis and then continuing in columns along the frequency axis. If the size of each resource unit is pre-defined, the location within the special resource zone may be determined based on a mapping to a sequence number.

III. Application Connection IDs

[0042] When a mobile device enters a wireless network, it is first assigned a basic connection identification (BCID) for each direction of the wireless connection: downlink and uplink. A BCID can be used for control messages or generic (unclassified) application connections. The BCID for downlink may or may not be the same as that of the uplink.

[0043] In some embodiments, a classification of packet streams may be performed by the system. Figure 7 is a block diagram of a system component 700 for receiving IP packets and sorting the received packets into various streams. The system component 700 includes a classifier 705 having associated classification rules 710. The classifier receives incoming packets, each packet having various header information such as an Ethernet header 715, an IP header 720, a UDP header 725, an RTP header 730 and an RTP payload 735. The packets are classified by the classifier 705 and output into different application data queues 740 where they will subsequently be transmitted by an OFDMA transmitter 745.

[0044] The classifier 705 is able to classify the packets based on application type, quality of service (QoS) requirement, or other properties. For example, packets from a voice application stream are identified based on a special value in the type of service (ToS) field in the IP header 720 of the packets. A new combination of RTP/UDP/IP headers with the special IP ToS field value indicates a new voice application stream. Such a new stream is identified by peeking into voice session setup protocol messages, such as session initiation protocol (SIP). The classification performed by the classifier is based on one or more classification rules 710. The classification rules can be configured statically or dynamically by a control process. Each classification rule is defined using parameters, such as application type, QoS parameters, and other properties that may be determined from the received packets.

[0045] In some embodiments, the incoming packets may also be assigned an application connection-specific identifier (ACID) in addition to or in lieu of a BCID. Each ACID can be assigned to a corresponding packet stream. For example, an ACID can be assigned to voice packets that together make up a voice application. When an ACID is assigned to a voice application, the ACID may also be referred to as a voice connection ID (VCID). As another example, an ACID can be assigned to a packet stream that requires a particular QoS. Furthermore, an application packet stream can be further classified into different sub-types, based on certain properties of that application. For example, voice applications can be further classified into different sub-types based on the voice source coding (vocoder) methods (e.g., G.711 and G.729A). When further classified in this manner, the sub-types may each be assigned their own ACID. For certain multi-casting applications, an ACID may also be shared by multiple base stations or mobile devices.

[0046] Once established, the connection IDs, including BCIDs and ACIDs, are disseminated, through broadcasting messages for example, to the corresponding base station(s) and mobile device(s) for proper packet transmission and reception. As was previously discussed, the medium access control (MAC) scheduler may allocate specific zones of airlink resources for certain types of packet streams.

[0047] A connection ID is released once the wireless system determines that there is no need to continue the connection. For example, a voice connection and

its VCID are released once the system detects deactivation of the voice stream. In some embodiments, the voice connection is deactivated if the voice session disconnect is detected through snooping SIP signaling. In some embodiments, the voice connection is released if there is no voice packet activity on the connection for a certain period of time.

[0048] In some embodiments, the same bit length is used in different types of connections IDs, including BCIDs and ACIDs. In some embodiments, different types of connection IDs may have different bit lengths. For example, in a typical implementation for voice applications, a BCID may be 16-bits to accommodate a large number of mobile devices and unclassified applications, while a VCID is 6-bits to accommodate up to 64 simultaneous voice connections in a cell. A shorter ACID length is beneficial for reducing control overhead, especially when an application utilizes many small data packets, such as VoIP packets.

[0049] In some embodiments, an ACID is further augmented by other properties of the utilized airlink resources, such as time or frequency indices, to identify an application connection. This can be used to further reduce ACID bit length or to increase the maximum number of accommodated application connections given a certain ACID bit length. For example, a voice codec generates voice application data periodically. The allocation period is usually a multiple of the airlink frame duration. In this case, the airlink frame number can be combined with a VCID to identify a voice connection. For example, the voice codec of G.723.1 generates a voice frame once every 30 milliseconds. The MAC scheduler allocates airlink resource to such a voice connection once every 30ms. In a wireless cellular system using 5ms frame duration, a single VCID can be shared by 6 voice streams, each associated with a different frame number to uniquely identify a voice connection.

IV. Control Messages

[0050] When airlink resource zones or application-specific IDs are utilized by the system, various improved control messages, often called Information Elements (IEs), may be constructed to facilitate the control process and minimize the control overhead. Various control message improvements are described herein.

[0051] In some embodiments, the IE is sent prior to transmitting an application packet to indicate information associated with the packet, such as the packet destination, the modulation and coding method, and the airlink resource used. For example, the IE for a voice packet may include the VCID (indicative of the packet destination), the MCSI (encoding scheme), and the VZI (index to location for the packet stream within the airlink resource). In some embodiments, the VCID is 6 bits, the MCSI is 2 bits, and the VZI is 8 bits, thereby resulting in a 2-byte IE overhead for each voice packet. Alternatively, the IE for a voice packet may include only the VCID and the MCSI, with the VZI inferred from the MCSIs of previous packet streams in the airlink resource as described above. When using only the VCID and MCSI, the IE overhead for each voice packet is reduced to only 1 byte. Additional control information, such as power control information, can be added to the IE with additional bit fields. The reduction in control bits improves the overall bandwidth efficiency of the wireless communication network.

[0052] In some embodiments, a base station sends the IE before a downlink packet to inform the mobile device for proper reception of the packet, and the base station sends the IE before an uplink packet to inform the mobile device for proper transmission of the packet. The downlink and uplink packet IEs may be separately grouped together. The IEs may be broadcasted or multi-casted to corresponding destinations.

[0053] In some embodiments, the IEs of the same application type or subtype may be grouped together. A special field, called an Application MAP (AMAP) subheader, for a specific application type, may be added to the IE. The subheader may indicate the application type and the length of the IE group. Figure 8A is a block diagram of a representative IE 800 with an AMAP subheader 805, in this case used for voice applications. The AMAP subheader 805 includes a type variable and a length variable. As depicted in Figure 8A, type = 01 indicates that the application type is voice. Length = 3 indicates that the subheader is followed by three voice IEs. The remainder of the IE contains the three voice IEs 810a, 810b, and 810c. For example, if the AMAP subheader was associated with streams in the zone 605a depicted in Figure 6, then voice IE 810a would pertain to packet stream V_1 , voice IE 810b would pertain to packet stream V_2 , and voice IE 810c would

pertain to packet stream V_3 . Those skilled in the art will appreciate that the although text is used to indicate the contents of the IE in Figure 8A, in an actual implementation the text would be replaced by appropriately coded information.

[0054] In some embodiments, the IEs for all packets that are transmitted with the same modulation and coding schemes (MCS) are grouped together for efficiency. Figure 8B is a block diagram of a block 850 of IEs that are grouped by MCS. A frame control header (FCH) 855 or other control message is transmitted prior to the block to indicate the length and the MCS used for each segment of the block. In some embodiments, adaptive modulation and coding (AMC) is used for the transmission of the IE's. A special rule, which is known to both base stations and mobile devices, can be used to determine the IE MCS, based on the MCS of its corresponding packet for proper reception of the IE. In some embodiments, the MCS for an IE is maintained the same as that of its corresponding application packet. In some embodiments, the MCS for an IE is one level more conservative than that of its corresponding packet. For example, if the MCSI for a packet is 2 (QPSK with rate- $\frac{1}{2}$ coding), then the MCSI for its IE is 3 (QPSK with rate- $\frac{1}{4}$ coding).

V. Voice Activity Detection

[0055] Typical voice conversations contain approximately 50 percent silence. In order to take advantage of the fact that about half of the time data does not need to be transmitted at the same rate as when a user is speaking, the system may rely upon detecting the period of silence and reducing the effective data transfer rate during that period. The silence period in conversation is detected by a vocoder using technologies such as Voice Activity Detection (VAD). Voice packets are only generated when voice activity is detected. During the silence period, the voice packet data rate is greatly reduced.

[0056] In addition to reducing the voice packet data rate during periods of silence, the bandwidth allocation for the voice connection may also be reduced. The MAC scheduler at the base station may use the indication of voice activity to adjust the bandwidth allocation for the voice connection. In the uplink direction, the mobile device sends a special MAC message once a VAD indication is received from its vocoder. The MAC message indicates to the base station that the voice data rate is temporarily reduced. When such an indication is received, the MAC scheduler

can reduce the airlink resource allocated to the voice connection. Similarly, if the VAD indicates new voice activity, the mobile device notifies the base station using a MAC message and the original resource allocation is re-applied to the voice connection.

[0057] In the downlink direction, if there is no voice packet to be transmitted over a voice connection, the MAC scheduler allocates the resource to other voice connections. As a consequence, a resource block previously allocated for the connection in a particular zone may become vacant. Several methods can be used to deal with such fragmentation in the zone.

[0058] In some embodiments, the MAC scheduler at the base station reallocates the resource with the objective of minimizing the impact to other voice connections, such as their adaptive modulation and coding processes.

[0059] In some embodiments, the MAC scheduler maintains the resource allocation of the other voice connections, and allocates the resource vacated by the silent voice connection to new voice connections or other application packets.

[0060] In some embodiments, the MAC scheduler moves all the subsequent allocations up to fill the resource gap. As shown in Figure 10A, once a voice connection, identified by VCID 2 enters a silent period, the other voice connections are moved by the MAC scheduler to occupy the resource vacated by VCID 2.

[0061] In some embodiments, the MAC scheduler uses the last voice time-frequency resource in the same zone to fill the resource gap of a silent voice connection. Figure 10B illustrates such a case, when the MAC scheduler moves the last voice connection VCID 12 to occupy the resource allocation gap that is vacated by the voice connection VCID 2.

[0062] In some embodiments, the MAC scheduler uses the last voice time-frequency resource that has the same coding and modulation scheme, and is contained in the same zone, to fill the resource gap. The resource gap that is introduced by such a replacement is then filled by the voice time-frequency resource that is subsequent to the voice time-frequency resource that was moved. As shown in Figure 10C, voice connection VCID 6 uses the same coding and modulation scheme as voice connection VCID 2, and is the last connection having that scheme

in the zone. When voice connection VCID 2 goes into a silent period, the MAC scheduler allocates the voice connection VCID 2 resource to voice connection VCID 6.. The MAC scheduler then moves resources after voice connection VCID 6, specifically VCID 7 in Figure 10C, to occupy the resource allocation gap that is caused by moving voice connection VCID 6.

[0063] The above detailed description of embodiments of the system is not intended to be exhaustive or to limit the system to the precise form disclosed above. While specific embodiments of, and examples for, the system are described above for illustrative purposes, various equivalent modifications are possible within the scope of the system, as those skilled in the relevant art will recognize. For example, while processes are presented in a given order, alternative embodiments may perform routines having steps in a different order, and some processes may be deleted, moved, added, subdivided, combined, and/or modified to provide alternative or subcombinations. Each of these processes may be implemented in a variety of different ways. Further any specific numbers noted herein are only examples: alternative implementations may employ differing values or ranges.

[0064] These and other changes can be made to the invention in light of the above Detailed Description. While the above description describes certain embodiments of the technology, and describes the best mode contemplated, no matter how detailed the above appears in text, the invention can be practiced in many ways. Details of the system may vary considerably in its implementation details, while still being encompassed by the technology disclosed herein. As noted above, particular terminology used when describing certain features or aspects of the technology should not be taken to imply that the terminology is being redefined herein to be restricted to any specific characteristics, features, or aspects of the technology with which that terminology is associated. In general, the terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification, unless the above Detailed Description section explicitly defines such terms. Accordingly, the actual scope of the invention encompasses not only the disclosed embodiments, but also all equivalent ways of practicing or implementing the invention under the claims.

CLAIMS

We claim:

[c1] 1. A method of communication between base stations and mobile devices in a multi-carrier packet communication system that utilizes an airlink resource and covers a plurality of geographic cells, the method comprising:

allocating a zone in the airlink resource, wherein the zone is designated for a type of application and is capable of carrying two or more packet streams associated with the type of application, and wherein the portion of the airlink resource falling outside of the zone is capable of carrying two or more packet streams not associated with the type of application;

for at least some of the two or more packet streams within the zone, creating a control message associated with each packet stream wherein the control message is used in part to ensure proper communication of the packet stream;

aggregating the created control messages associated with each packet stream in accordance with a common characteristic of the packet streams; and transmitting the control messages in a group.

[c2] 2. The method of claim 1, wherein the common characteristic is the coding and modulation scheme of the packet streams.

[c3] 3. The method of claim 1, wherein the common characteristic is a location of the packet stream within the airlink resource.

[c4] 4. The method of claim 1, further comprising adding a header to the group of control messages, wherein the header comprises the number of control messages, the length of the control messages, and the common characteristics of the associated packet streams.

- [c5] 5. The method of claim 1, wherein the zone in one geographic cell is assigned to a different time-frequency location in the airlink resource than the zone in a neighboring geographic cell in order to mitigate inter-cell interference.
- [c6] 6. The method of claim 1, further comprising:
assigning a basic connection identification (BCID) value to a packet stream communicated via the airlink resource;
assigning an application connection identification (ACID) value to a second packet stream communicated via the airlink resource, wherein the ACID value contains a lesser number of bits than the BCID value; and
incorporating the ACID value in the control message associated with the identified second packet stream.
- [c7] 7. The method of claim 6, wherein an ACID value may be reused by base stations or mobile devices.
- [c8] 8. The method of claim 6, wherein an ACID value may include additional information representing a location index within the airlink resource.
- [c9] 9. The method of claim 1, wherein each of the two or more packet streams associated with the type of application utilize one of a plurality of modulation and coding schemes, and a modulation and coding scheme index associated with each packet stream carries information about the utilized modulation and coding scheme for the packet stream.
- [c10] 10. The method of claim 9, wherein the plurality of modulation and coding schemes utilize a basic time-frequency resource unit and integer multiples of the basic time-frequency resource unit.
- [c11] 11. The method of claim 1, further comprising using adaptive modulation and coding for the transmission of the group of control messages.

[c12] 12. The method of claim 11, wherein the modulation and coding for the group of control messages is the same as the modulation and coding used for the packet streams associated with the group of control messages.

[c13] 13. The method of claim 11, wherein the modulation and coding for the group of control messages is one level lower than the modulation and coding used for the packet streams associated with the group of control messages

[c14] 14. The method of claim 11, wherein the common characteristic is the coding and modulation scheme of the packet streams and further comprising a header transmitted prior to the group of control messages to indicate the length of the group and the modulation and coding scheme used for the group.

[c15] 15. The method of claim 1, wherein a starting time-frequency coordinate and an ending time-frequency coordinate are used to specify a location of a packet stream within the zone.

[c16] 16. The method of claim 1, wherein the zone is divided into a plurality of rows and a plurality of columns to thereby form a coordinate system.

[c17] 17. The method of claim 16, wherein a location of a packet stream within the zone may be specified by an offset from the origin of the zone.

[c18] 18. The method of claim 16, wherein a location of a packet stream within the zone may be specified by a starting row and column coordinate and an ending row and column coordinate.

[c19] 19. The method of claim 16, wherein a granularity of a time coordinate is an OFDM symbol and a granularity of a frequency coordinate is a subcarrier.

[c20] 20. The method of claim 1, wherein the portion of the airlink resource falling outside of the zone is treated as a second zone and wherein a resource

allocation message pertaining to the second zone is communicated to a base station and a mobile station.

[c21] 21. The method of claim 20, wherein the resource allocation message identifies a connection identifier, a resource identification parameter, and a modulation and coding index for at least some of the packet streams in the second zone.

[c22] 22. The method of claim 20, further comprising dividing the second zone into a plurality of units, wherein the resource allocation message identifies at least some of the packet streams in the second zone based on the plurality of units.

[c23] 23. A method of communication between base stations and mobile devices in a multi-carrier packet communication system that utilizes an airlink resource and covers a plurality of geographic cells, the method comprising:

- allocating a zone in the airlink resource for voice-over-IP packet streams, wherein the zone is capable of carrying two or more packet streams and the packet streams are arranged sequentially in the zone;
- for at least some of the voice-over-IP packet streams within the zone, creating a control message associated with each packet stream wherein the control message is used in part to ensure proper communication of the packet stream;
- aggregating the created control messages associated with each packet stream in accordance with a common characteristic of the packet streams; and
- transmitting the control messages in a group.

[c24] 24. The method of claim 23, wherein packet streams are arranged sequentially in the zone starting at an origin.

[c25] 25. The method of claim 24, wherein the location of a packet stream in the zone is specified by an offset to the origin, wherein the offset is one or more units of

airlink resource that is determined by a type of modulation and coding associated with the packet streams.

[c26] 26. The method of claim 25, wherein the offset is included in the control message associated with the packet stream.

[c27] 27. The method of claim 25, wherein the offset is not included in the control message associated with the packet stream and is instead calculated from the type of modulation and coding associated with other packet streams that precede the packet stream in the sequence of packet streams.

[c28] 28. The method of claim 23, wherein an airlink resource associated with each of the two or more packet streams within the zone is allocated based on voice activity carried in the corresponding packet stream.

[c29] 29. The method of claim 28, wherein the allocated airlink resource is an initial amount of resource and adaptive modulation and coding with an adaptive multi-rate voice coding is used to improve voice quality carried in the packet stream.

[c30] 30. The method of claim 28, further comprising reallocating an airlink resource associated with a first packet stream having a silent voice connection to a second packet stream having an active voice connection.

[c31] 31. The method of claim 30, wherein the second packet stream is the next packet stream in sequence after the first packet stream.

[c32] 32. The method of claim 30, wherein the second packet stream is the last packet stream in the sequence of packet streams.

[c33] 33. The method of claim 30, wherein the second packet stream is the last packet stream in the sequence of packet streams that has the same coding and modulation scheme as the first packet stream, and further comprising reallocating the packet streams subsequent to the second packet stream in the sequence of

packet streams in order to fill the airlink resource that was vacated by the second packet stream.

1/12

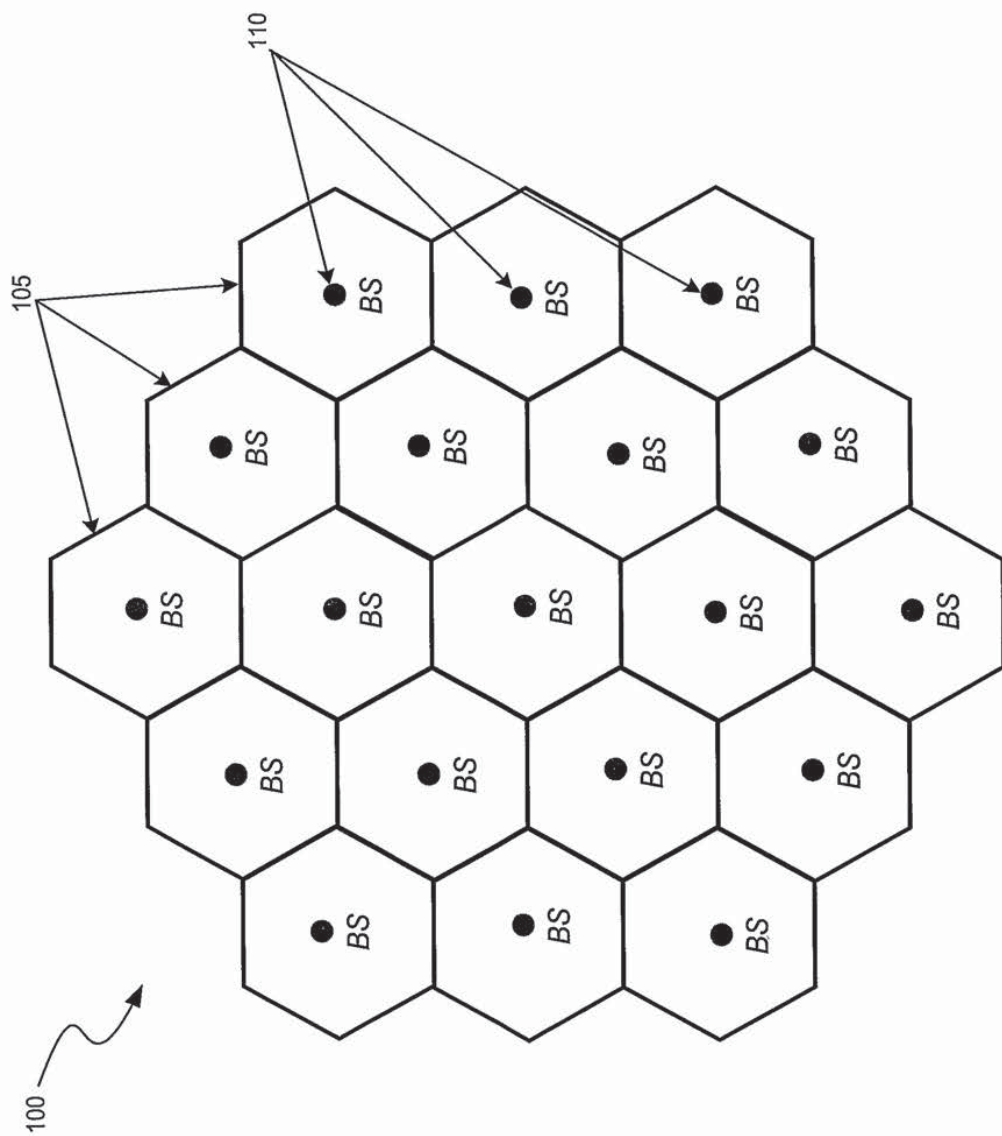


FIG. 1