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September 5, 2001

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

EXPRESS MAIL RECEIPT NO. ET 649646520 US

Re: U.S. Patent Application for "WIRELESS ACCESS SYSTEM USING SELECTIVELY ADAPTABLE BEAM FORMING IN TDD FRAMES AND METHOD OF OPERATION"
Our File: WEST14-00103

Dear Sir:

Enclosed please find the following documents for filing:

Express Mail Certificate of Mailing;
Patent Application (93 pages including cover sheet);
Informal Drawings (14 sheets);
Declaration and Power of Attorney (unsigned); and
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Very truly yours,

Novakov Davis & Munck, P.C.

William A. Munck

WAM/kl
Enclosures

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DOCKET NO. WEST14-00103 **PATENT**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: : Paul F. Struhsaker

For : WIRELESS ACCESS SYSTEM USING SELECTIVELY ADAPTABLE BEAM FORMING IN TDD FRAMES AND METHOD OF OPERATION

BOX PATENT APPLICATION
Commissioner for Patents
Washington, D.C. 20231

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1) Patent Application (93 pages including cover page);
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relating to the above application, were deposited as "Express Mail", Mailing Label No. ET649646520US with the United States Postal Service, addressed to Box Patent Application, Commissioner for Patents, Washington, D.C. 20231, on this 5th day of September, 2001.

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Date: Sept. 5, 2001 _____

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ATTY. DOCKET NO. WEST14-00103 PATENT

WIRELESS ACCESS SYSTEM USING SELECTIVELY ADAPTABLE BEAM FORMING IN TDD FRAMES AND METHOD OF OPERATION

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WIRELESS ACCESS SYSTEM USING SELECTIVELY ADAPTABLE BEAM FORMING IN TDD FRAMES AND METHOD OF OPERATION

CROSS-REFERENCE TO RELATED APPLICATIONS

The present invention is related to those disclosed in the following United States Provisional and Non-Provisional Patent Applications:

1) Serial No. 09/713,684, filed on November 15, 2000, entitled "SUBSCRIBER INTEGRATED ACCESS DEVICE FOR USE IN WIRELESS AND WIRELINE ACCESS SYSTEMS" [Docket No. WEST14-00004];

2) Serial No. 09/838,810, filed April 20, 2001, entitled "WIRELESS COMMUNICATION SYSTEM USING BLOCK FILTERING AND FAST EQUALIZATION-DEMODULATION AND METHOD OF OPERATION" [Docket No. WEST14-00005];

3) Serial No. 09/839,726, filed April 20, 2001, entitled "APPARATUS AND ASSOCIATED METHOD FOR OPERATING UPON DATA SIGNALS RECEIVED AT A RECEIVING STATION OF A FIXED WIRELESS ACCESS COMMUNICATION SYSTEM" [Docket No. WEST14-00014];

4) Serial No. 09/839,729, filed April 20, 2001, entitled "APPARATUS AND METHOD FOR OPERATING A SUBSCRIBER INTERFACE IN A FIXED WIRELESS SYSTEM" [Docket No. WEST14-00015];

5) Serial No. 09/839,719, filed April 20, 2001, entitled

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"APPARATUS AND METHOD FOR CREATING SIGNAL AND PROFILES AT A RECEIVING STATION" [Docket No. WEST14-00016];

6) Serial No. 09/838,910, filed April 20, 2001, entitled "SYSTEM AND METHOD FOR INTERFACE BETWEEN A SUBSCRIBER MODEM AND SUBSCRIBER PREMISES INTERFACES" [Docket No. WEST14-00017];

7) Serial No. 09/839,509, filed April 20, 2001, entitled "BACKPLANE ARCHITECTURE FOR USE IN WIRELESS AND WIRELINE ACCESS SYSTEMS" [Docket No. WEST14-00018];

8) Serial No. 09/839,514, filed April 20, 2001, entitled "SYSTEM AND METHOD FOR ON-LINE INSERTION OF LINE REPLACEABLE UNITS IN WIRELESS AND WIRELINE ACCESS SYSTEMS" [Docket No. WEST14-00019];

9) Serial No. 09/839,512, filed April 20, 2001, entitled "SYSTEM FOR COORDINATION OF TDD TRANSMISSION BURSTS WITHIN AND BETWEEN CELLS IN A WIRELESS ACCESS SYSTEM AND METHOD OF OPERATION" [Docket No. WEST14-00020];

10) Serial No. 09/839,259, filed April 20, 2001, entitled "REDUNDANT TELECOMMUNICATION SYSTEM USING MEMORY EQUALIZATION APPARATUS AND METHOD OF OPERATION" [Docket No. WEST14-00021];

11) Serial No. 09/839,457, filed April 20, 2001, entitled "WIRELESS ACCESS SYSTEM FOR ALLOCATING AND SYNCHRONIZING UPLINK AND DOWNLINK OF TDD FRAMES AND METHOD OF OPERATION"

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[Docket No. WEST14-00022];

12) Serial No. 09/839,075, filed April 20, 2001, entitled "TDD FDD AIR INTERFACE" [Docket No. WEST14-00023];

13) Serial No. 09/839,499, filed April 20, 2001, entitled "APPARATUS, AND AN ASSOCIATED METHOD, FOR PROVIDING WLAN SERVICE IN A FIXED WIRELESS ACCESS COMMUNICATION SYSTEM" [Docket No. WEST14-00024];

14) Serial No. 09/839,458, filed April 20, 2001, entitled "WIRELESS ACCESS SYSTEM USING MULTIPLE MODULATION" [Docket No. WEST14-00026];

15) Serial No. 09/839,456, filed April 20, 2001, entitled "WIRELESS ACCESS SYSTEM AND ASSOCIATED METHOD USING MULTIPLE MODULATION FORMATS IN TDD FRAMES ACCORDING TO SUBSCRIBER SERVICE TYPE" [Docket No. WEST14-00027];

16) Serial No. 09/838,924, filed April 20, 2001, entitled "APPARATUS FOR ESTABLISHING A PRIORITY CALL IN A FIXED WIRELESS ACCESS COMMUNICATION SYSTEM" [Docket No. WEST14-00028];

17) Serial No. 09/839,858, filed April 20, 2001, entitled "APPARATUS FOR REALLOCATING COMMUNICATION RESOURCES TO ESTABLISH A PRIORITY CALL IN A FIXED WIRELESS ACCESS COMMUNICATION SYSTEM" [Docket No. WEST14-00029];

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18) Serial No. 09/839,734, filed April 20, 2001, entitled "METHOD FOR ESTABLISHING A PRIORITY CALL IN A FIXED WIRELESS ACCESS COMMUNICATION SYSTEM" [Docket No. WEST14-00030];

19) Serial No. 09/839,513, filed April 20, 2001, entitled "SYSTEM AND METHOD FOR PROVIDING AN IMPROVED COMMON CONTROL BUS FOR USE IN ON-LINE INSERTION OF LINE REPLACEABLE UNITS IN WIRELESS AND WIRELINE ACCESS SYSTEMS" [Docket No. WEST14-00033];

20) Serial No. 60/262,712, filed on January 19, 2001, entitled "WIRELESS COMMUNICATION SYSTEM USING BLOCK FILTERING AND FAST EQUALIZATION-DEMODULATION AND METHOD OF OPERATION" [Docket No. WEST14-00005];

21) Serial No. 60/262,825, filed on January 19, 2001, entitled "APPARATUS AND ASSOCIATED METHOD FOR OPERATING UPON DATA SIGNALS RECEIVED AT A RECEIVING STATION OF A FIXED WIRELESS ACCESS COMMUNICATION SYSTEM" [Docket No. WEST14-00014];

22) Serial No. 60/262,698, filed on January 19, 2001, entitled "APPARATUS AND METHOD FOR OPERATING A SUBSCRIBER INTERFACE IN A FIXED WIRELESS SYSTEM" [Docket No. WEST14-00015];

23) Serial No. 60/262,827, filed on January 19, 2001, entitled "APPARATUS AND METHOD FOR CREATING SIGNAL AND PROFILES AT A RECEIVING STATION" [Docket No. WEST14-00016];

24) Serial No. 60/262,826, filed on January 19, 2001, entitled

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"SYSTEM AND METHOD FOR INTERFACE BETWEEN A SUBSCRIBER MODEM AND SUBSCRIBER PREMISES INTERFACES" [Docket No. WEST14-00017];

25) Serial No. 60/262,951, filed on January 19, 2001, entitled "BACKPLANE ARCHITECTURE FOR USE IN WIRELESS AND WIRELINE ACCESS SYSTEMS" [Docket No. WEST14-00018];

26) Serial No. 60/262,824, filed on January 19, 2001, entitled "SYSTEM AND METHOD FOR ON-LINE INSERTION OF LINE REPLACEABLE UNITS IN WIRELESS AND WIRELINE ACCESS SYSTEMS" [Docket No. WEST14-00019];

27) Serial No. 60/263,101, filed on January 19, 2001, entitled "SYSTEM FOR COORDINATION OF TDD TRANSMISSION BURSTS WITHIN AND BETWEEN CELLS IN A WIRELESS ACCESS SYSTEM AND METHOD OF OPERATION" [Docket No. WEST14-00020];

28) Serial No. 60/263,097, filed on January 19, 2001, entitled "REDUNDANT TELECOMMUNICATION SYSTEM USING MEMORY EQUALIZATION APPARATUS AND METHOD OF OPERATION" [Docket No. WEST14-00021];

29) Serial No. 60/273,579, filed March 5, 2001, entitled "WIRELESS ACCESS SYSTEM FOR ALLOCATING AND SYNCHRONIZING UPLINK AND DOWNLINK OF TDD FRAMES AND METHOD OF OPERATION" [Docket No. WEST14-00022];

30) Serial No. 60/262,955, filed January 19, 2001, entitled "TDD FDD AIR INTERFACE" [Docket No. WEST14-00023];

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31) Serial No. 60/262,708, filed on January 19, 2001, entitled "APPARATUS, AND AN ASSOCIATED METHOD, FOR PROVIDING WLAN SERVICE IN A FIXED WIRELESS ACCESS COMMUNICATION SYSTEM" [Docket No. WEST14-00024];

32) Serial No. 60/273,689, filed March 5, 2001, entitled "WIRELESS ACCESS SYSTEM USING MULTIPLE MODULATION" [Docket No. WEST14-00026];

33) Serial No. 60/273,757, filed March 5, 2001, entitled "WIRELESS ACCESS SYSTEM AND ASSOCIATED METHOD USING MULTIPLE MODULATION FORMATS IN TDD FRAMES ACCORDING TO SUBSCRIBER SERVICE TYPE" [Docket No. WEST14-00027];

34) Serial No. 60/270,378, filed February 21, 2001, entitled "APPARATUS FOR ESTABLISHING A PRIORITY CALL IN A FIXED WIRELESS ACCESS COMMUNICATION SYSTEM" [Docket No. WEST14-00028];

35) Serial No. 60/270,385, filed February 21, 2001, entitled "APPARATUS FOR REALLOCATING COMMUNICATION RESOURCES TO ESTABLISH A PRIORITY CALL IN A FIXED WIRELESS ACCESS COMMUNICATION SYSTEM" [Docket No. WEST14-00029]; and

36) Serial No. 60/270,430, filed February 21, 2001, entitled "METHOD FOR ESTABLISHING A PRIORITY CALL IN A FIXED WIRELESS ACCESS COMMUNICATION SYSTEM" [Docket No. WEST14-00030].

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The above applications are commonly assigned to the assignee of the present invention. The disclosures of these related patent applications are hereby incorporated by reference for all purposes as if fully set forth herein.

TECHNICAL FIELD OF THE INVENTION

The present invention is directed, in general, to wireless access systems and, more specifically, to a burst packet transmission media access system using selectively adaptable beam forming in a fixed wireless access network.

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BACKGROUND OF THE INVENTION

Telecommunications access systems provide for voice, data, and multimedia transport and control between the central office (CO) of the telecommunications service provider and the subscriber (customer) premises. Prior to the mid-1970s, the subscriber was provided phone lines (e.g., voice frequency (VF) pairs) directly from the Class 5 switching equipment located in the central office of the telephone company. In the late 1970s, digital loop carrier (DLC) equipment was added to the telecommunications access architecture. The DLC equipment provided an analog phone interface, voice CODEC, digital data multiplexing, transmission interface, and control and alarm remotely from the central office to cabinets located within business and residential locations for approximately 100 to 2000 phone line interfaces. This distributed access architecture greatly reduced line lengths to the subscriber and resulted in significant savings in both wire installation and maintenance. The reduced line lengths also improved communication performance on the line provided to the subscriber.

By the late 1980s, the limitations of data modem connections over voice frequency (VF) pairs were becoming obvious to both subscribers and telecommunications service providers. ISDN (Integrated Services Digital Network) was introduced to provide

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universal 128 kbps service in the access network. The subscriber interface is based on 64 kbps digitization of the VF pair for digital multiplexing into high speed digital transmission streams (e.g., T1/T3 lines in North America, E1/E3 lines in Europe). ISDN was a logical extension of the digital network that had evolved throughout the 1980s. The rollout of ISDN in Europe was highly successful. However, the rollout in the United States was not successful, due in part to artificially high tariff costs which greatly inhibited the acceptance of ISDN.

More recently, the explosion of the Internet and deregulation of the telecommunications industry have brought about a broadband revolution characterized by greatly increased demands for both voice and data services and greatly reduced costs due to technological innovation and intense competition in the telecommunications marketplace. To meet these demands, high speed DSL (digital subscriber line) modems and cable modems have been developed and introduced. The DLC architecture was extended to provide remote distributed deployment at the neighborhood cabinet level using DSL access multiplexer (DSLAM) equipment. The increased data rates provided to the subscriber resulted in upgrade DLC/DSLAM transmission interfaces from T1/E1 interfaces (1.5/2.0 Mbps) to high speed DS3 and OC3 interfaces. In a similar fashion,

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the entire telecommunications network backbone has undergone and is undergoing continuous upgrade to wideband optical transmission and switching equipment.

Similarly, wireless access systems have been developed and deployed to provide broadband access to both commercial and residential subscriber premises. Initially, the market for wireless access systems was driven by rural radiotelephony deployed solely to meet the universal service requirements imposed by government (i.e., the local telephone company is required to serve all subscribers regardless of the cost to install service). The cost of providing a wired connection to a small percentage of rural subscribers was high enough to justify the development and expense of small-capacity wireless local loop (WLL) systems.

Deregulation of the local telephone market in the United States (e.g., Telecommunications Act of 1996) and in other countries shifted the focus of fixed wireless access (FWA) systems deployment from rural access to competitive local access in more urbanized areas. In addition, the age and inaccessibility of much of the older wired telephone infrastructure makes FWA systems a cost-effective alternative to installing new, wired infrastructure. Also, it is more economically feasible to install FWA systems in developing countries where the market penetration is limited (i.e.,

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the number and density of users who can afford to pay for services is limited to small percent of the population) and the rollout of wired infrastructure cannot be performed profitably. In either case, broad acceptance of FWA systems requires that the voice and data quality of FWA systems must meet or exceed the performance of wired infrastructure.

Wireless access systems must address a number of unique operational and technical issues including:

1) Relatively high bit error rates (BER) compared to wire line or optical systems; and

2) Transparent operation with network protocols and protocol time constraints for the following protocols:

a) ATM;

b) Class 5 switch interfaces (domestic GR-303 and international V5.2);

c) TCP/IP with quality-of-service QoS for voice over IP (VoIP) (i.e., RTP) and other H.323 media services;

d) Distribution of synchronization of network time out to the subscribers;

3) Increased use of voice, video and/or media compression and concentration of active traffic over the air interface to conserve bandwidth;

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4) Switching and routing within the access system to distribute signals from the central office to multiple remote cell sites containing multiple cell sectors and one or more frequencies of operation per sector; and

5) Remote support and debugging of the subscriber equipment, including remote software upgrade and provisioning.

Unlike physical optical or wire systems that operate at bit error rates (BER) of 10^{-11}, wireless access systems have time varying channels that typically provide bit error rates of 10^{-3} to 10^{-6}. The wireless physical (PHY) layer interface and the media access control (MAC) layer interface must provide modulation, error correction and ARQ (automatic request for retransmission) protocol that can detect and, where required, correct or retransmit corrupted data so that the interfaces at the network and at the subscriber site operate at wire line bit error rates.

The wide range of equipment and technology capable of providing either wireline (i.e., cable, DSL, optical) broadband access or wireless broadband access has allowed service providers to match the needs of a subscriber with a suitable broadband access solution. However, in many areas, the cost of cable modem or DSL service is high. Additionally, data rates may be slow or coverage incomplete due to line lengths. In these areas and in areas where

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the high cost of replacing old telephone equipment or the low density of subscribers makes it economically unfeasible to introduce either DSL or cable modem broadband access, fixed wireless broadband systems offer a viable alternative. Fixed wireless broadband systems use a group of transceiver base stations to cover a region in the same manner as the base stations of a cellular phone system. The base stations of a fixed wireless broadband system transmit forward channel (i.e., downstream) signals in directed beams to fixed location antennas attached to the residences or offices of subscribers. The base stations also receive reverse channel (i.e., upstream) signals transmitted by the broadband access equipment of the subscriber.

Media access control (MAC) protocols refer to techniques that increase utilization of two-way communication channel resources by subscribers that use the channel resources. The MAC layer may use a number of possible configurations to allow multiple access. These configurations include:

1. FDMA - frequency division multiple access. In a FDMA system, subscribers use separate frequency channels on a permanent or demand access basis.

2. TDMA - time division multiple access. In a TDMA system, subscribers share a frequency channel but allocate spans of time to

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different users.

3. CDMA - code division multiple access. In a CDMA system, subscribers share a frequency but use a set of orthogonal codes to allow multiple access.

4. SDMA - space division multiple access - In a SDMA system, subscribers share a frequency but one or more physical channels are formed using antenna beam forming techniques.

5. PDMA - polarization division multiple access - In a PDMA system, subscribers share a frequency but change polarization of the antenna.

Each of these MAC techniques makes use of a fundamental degree of freedom (physical property) of a communications channel. In practice, combinations of these degrees of freedom are often used. As an example, cellular systems use a combination of FDMA and either TDMA or CDMA to support a number of users in a cell.

To provide a subscriber with bi-directional (two-way) communication in a shared media, such as a coaxial cable, a multi-mode fiber (optical), or an RF radio channel, some type of duplexing technique must be implemented. Duplexing techniques include frequency division duplexing (FDD) and time division duplexing (TDD). In FDD, a first channel (frequency) is used for transmission and a second channel (frequency) is used for

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reception. To avoid physical interference between the transmit and receive channels, the frequencies must have a separation know as the duplex spacing. In TDD, a single channel is used for transmission and reception and specific periods of time (i.e., slots) are allocated for transmission and other specific periods of time are allocated for reception.

Finally, a method of coordinating the use of bandwidth must be established. There are two fundamental methods: distributed control and centralized control. In distributed control, subscribers have a shared capability with or without a method to establish priority. An example of this is CSMA (carrier sense multiple access) used in IEEE802.3 Ethernet and IEEE 802.11 Wireless LAN. In centralized control, subscribers are allowed access under the control of a master controller. Cellular systems, such as IS-95, IS-136, and GSM, are typical examples. Access is granted using forms of polling and reservation (based on polled or demand access contention).

A number of references and overviews of demand access are available including the following:

1. Sklar, Bernard. "Digital Communications Fundamentals and Applications," Prentice Hall, Englewood Cliffs, New Jersey, 1988. Chapter 9.

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2. Rappaport, Theodore. "Wireless Communications, Principles and Practice," Prentice Hall, Upper Saddle River, New Jersey, 1996. Chapter 8.

3. TR101-173V1.1. "Broadband Radio Access Networks, Inventory of Broadband Radio Technologies and Techniques," ETSI, 1998. Chapter 7.

The foregoing references are hereby incorporated by reference into the present disclosure as if fully set forth herein.

In 1971, the University of Hawaii began operation of a random access shared channel ALOHA TDD system. The lack of channel coordination resulted in poor utilization of the channel. This lead to the introduction of time slots (slotted Aloha) that set a level of coordination between the subscribers that doubled the channel throughput. Finally, the researchers introduced the concept of a central controller and the use of reservations (reservation Aloha). Reservation techniques made it possible to make trade-offs between throughput and latency.

This work was fundamental to the development of media access control (MAC) techniques for dynamic random access and the use of ARQ (automatic request for retransmission) to retransmit erroneous packets. While the work at the University of Hawaii explored the fundamentals of burst transmission and random access, the work did

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not introduce the concept of a frame and/or super-frame structure to the TDD/TDMA access techniques. One of the more sophisticated systems developed in the 1970s and in current use is Joint Tactical Information Distribution System (JTIDS). This system was based on the joint use of TDMA and time duplexing over frequency-hopping spread-spectrum channels. This was the culmination of research to allow flexible allocation of bandwidth to a large group of users. The key aspect of the JTIDS system was the introduction of dynamic allocation of bandwidth resources and explicit variable symmetry (downlink vs. uplink bandwidth) in the link.

IEEE 802.11 Wireless LAN equipment provides for a centrally coordinated TDD system that does not have a specific frame or slotting structure. IEEE 802.11 did introduce the concept of variable modulation and spreading inherent in the structure of the transmission bursts. A significant improvement was incorporated in United States Patent No. 6,052,408, entitled "Cellular Communications System with Dynamically Modified Data Transmission Parameters." This patent introduced specific burst packet transmission formats that provide for adaptive modulation, transmit power, and antenna beam forming and an associated method of determining the highest data rate for a defined error rate floor for the link between the base station and a plurality of

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subscribers assigned to that base station. With the exception of variable spreading military systems and NASA space communication systems, this was one of the first commercial patents that address variable transmission parameters to increase system throughput.

Another example of TDD systems are digital cordless phones, also referred to as low-tier PCS systems. The Personal Access Communications (PAC) system and Digital European Cordless Telephone (DECT, as specified by ETSI document EN 300-175-3) are two examples of these systems. Digital cordless phones met with limited success for their intended use as pico-cellular fixed access products. The systems were subsequently modified and repackaged for wireless local loop (WLL) applications with extended range using increased transmission (TX) power and greater antenna gain.

These TDD/TDMA systems use fixed symmetry and bandwidth between the uplink and the downlink. The TDD frame consists of a fixed set of time slots for the uplink and the downlink. The modulation index (or type) and the forward error correction (FEC) format for all data transmissions are fixed in these systems. These systems did not include methods for coordinating TDD bursts between systems. This resulted in inefficient use of spectrum in the frequency planning of cells.

While DECT and PAC systems based on fixed frames with fixed

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and symmetric allocation of time slots (or bandwidth) provides excellent latency and low jitter, and can support time bounded services, such as voice and Nx64 Kbps video, these systems do not provide efficient use of the spectrum when asymmetric data services are used. This has lead to research and development of packet based TDD systems based on Internet protocol (IP) or asynchronous transfer mode (ATM), with dynamic allocation of TDD time slots and the uplink-downlink bandwidth, combined with efficient algorithms to address both best efforts and real-time low-latency service for converged media access (data and multi-media).

One example of a TDD system with dynamic slot and bandwidth assignment is the ETSI HYPERLAN II specification based on the Dynamic Slot Assignment algorithm described in "Wireless ATM: Performance Evaluation of a DSA++ MAC Protocol with Fast Collision resolution by Probing Algorithm," D. Petras and A. Kramling, International Journal of Wireless Information Networks, Vol. 4, No. 4, 1997. This system allows both contention-based and contention-free access to the physical TDD channel slots. This system also introduced the broadcast of resource allocation at the start of every frame by the base station controller. Other wireless standards, including IEEE 802.16 wireless metropolitan network standards, use this combination of an allocation map of the

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uplink and downlink at the start of the dynamic TDD frame to set resource use for the next TDD frame.

An further improvement to this TDD system was described in "Multiple Access Control Protocols for Wireless ATM: Problem Definition and Design Objectives," O. Kubbar and H. Mouftah, IEEE Communications, November 1997, pp. 93-99. This system expanded on the packet reservation multiple access (PRMA) method developed in 1989 at Rutgers University WINLAB for ATM and IP based transport [see "Packet Reservation Multiple Access for Local Wireless Communications," Goodman et al., IEEE Transaction on Communications, Vol. 37, No. 8, pp. 885-890]. Like PRMA, this system logically arranged all the downlink transmissions in the start of a fixed duration TDD frame and all uplink transmissions at the end of the TDD frame. This eliminated the inefficiencies in the DCA++ Hyperlan II protocol. Adaptive allocation of uplink and downlink bandwidth is supported. The system provided for fixed, random, and demand assignment mechanisms. Priority is given to quality of service (QoS) applications with resources being removed from best efforts demand access users as required.

The above-described prior art concern the allocation of services in an individual sector of a cell. A cell may consist of M sectors, wherein each sector generally covers a 360/M degree arc

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around the cell site. Each sector serves N_m subscribers, where m=1 to M. These references did not expressly provide protocol mechanisms or rules for the operation of a given system.

United States Patent No. 6,016,311 expressly addresses one possible implementation to the TDD bandwidth allocation problem. The system described continuously measures and adapts the bandwidth requirements based on the evaluation of the average bandwidth required by all the subscribers in a cell and the number of times bandwidth is denied to the subscribers. Changes to the bandwidth allocation are applied based on a set of rules described in Patent No. 6,016,311. While measurements of multiple sectors are performed and recorded at a central base station controller, no global coordination of bandwidth allocation of multiple sectors in a cell or across multiple cells is provided.

Thus, the prior art does not address two very important factors in allocation of bandwidth. First, bandwidth allocation must contemplate stringent bandwidth availability requirements for specific groups of services based on planning of the network. For example, consider life-line toll quality voice service. Toll quality voice requires that a system guarantee a specific maximum blocking probability for all voice users based on peak busy hour call usage. A description of voice traffic planning is provided in

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"Digital Telephony - 2nd Edition," by J. Bellamy, John Wiley and Sons, New York, New York, 1990. If a TDD system is designed to meet life-line voice requirements, the allocation protocol must be able to rapidly (i.e., less than 100 msec) reallocate bandwidth resources up to the capacity necessary to meet the call blocking requirements. Another service group example is a guaranteed service level agreements (SLA). Again, bandwidth must be rapidly restored to meet the SLA conditions. More generally, one may consider G possible service groups having a set of weighted priority level and associated minimum and maximum levels. The weighted priority levels and minimum and maximum levels may be used to bound the bandwidth dynamics of the TDD bandwidth allocation. Minimum levels set a floor for bandwidth allocation and maximum levels set a ceiling. Then averaging can be applied.

Second, the TDD bandwidth allocation must consider adjacent and co-channel interference from both modems and sectors within a cell and between cells. Cell planning tools can be used to establish the relationships for interference. For systems that operate below 10 GHz, antennas and antenna placement at a cell site will not provide adequate signal isolation. These co-channel interference issues are well documented in "Frequency Reuse and System Deployment in Local Multipoint Distribution Service," by V.

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Roman, IEEE Personal Communications, December 1999, pp. 20 to 27.

Therefore, there is a need in the art for a fixed wireless access network that maximizes spectral efficiency between the base stations of the fixed wireless access network and the subscriber access devices located at the subscriber premises. In particular, there is a need for a fixed wireless access network that implements an air interface that minimizes uplink and downlink interference between different sectors within the same base station cell site. There also is a need for a fixed wireless access network that implements an air interface that minimizes uplink and downlink interference between different cell sites within the fixed wireless access network.

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SUMMARY OF THE INVENTION

To address the above-discussed deficiencies of the prior art, it is a primary object of the present invention to provide a transceiver for use in a wireless access network comprising a plurality of base stations, each of the plurality of base stations capable of bidirectional time division duplex (TDD) communication with wireless access devices disposed at a plurality of subscriber premises in a corresponding cell site of the wireless access network. According to an advantageous embodiment of the present invention, the transceiver is associated with a first of the plurality of base stations and comprises transmit path circuitry associated with a beam forming network capable of transmitting directed scanning beam signals in a sector of a cell site associated with the first base station. The transmit path circuitry transmits at a start of a TDD frame a broadcast beam signal comprising a start of frame field and subsequently transmits downlink data traffic in a downlink portion of the TDD frame to at least one of the wireless access devices using at least one directed scanning beam.

According to one embodiment of the present invention, the broadcast beam signal further comprises a first beam map containing scanning beam information usable by the at least one wireless

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access device to detect the least one directed scanning beam.

According to another embodiment of the present invention, the scanning beam information identifies a downlink time slot in the downlink portion during which the at least one directed scanning beam transmits the downlink data traffic.

According to still another embodiment of the present invention, the scanning beam information identifies at least one modulation format associated with the at least one directed scanning beam.

According to yet another embodiment of the present invention, the scanning beam information identifies at least one forward error correction code level associated with the at least one directed scanning beam.

According to a further embodiment of the present invention, the transceiver further comprising receive path circuitry associated with the beam forming network capable of receiving uplink data traffic transmitted by the at least one wireless access device in an uplink portion of the TDD frame.

According to a still further embodiment of the present invention, the first beam map further contains uplink transmission information identifying an uplink time slot in the uplink portion during which the at least one wireless access device transmits the

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uplink data traffic.

According to a yet further embodiment of the present invention, the uplink transmission information further identifies at least one modulation format used by the at least one wireless access device to transmit the uplink data traffic.

According to still another embodiment of the present invention, the uplink transmission information further identifies at least one at least one forward error correction code level used by the at least one wireless access device to transmit the uplink data traffic.

The foregoing has outlined rather broadly the features and technical advantages of the present invention so that those skilled in the art may better understand the detailed description of the invention that follows. Additional features and advantages of the invention will be described hereinafter that form the subject of the claims of the invention. Those skilled in the art should appreciate that they may readily use the conception and the specific embodiment disclosed as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the invention in its broadest form.

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Before undertaking the DETAILED DESCRIPTION OF THE INVENTION below, it may be advantageous to set forth definitions of certain words and phrases used throughout this patent document: the terms "include" and "comprise," as well as derivatives thereof, mean inclusion without limitation; the term "or," is inclusive, meaning and/or; the phrases "associated with" and "associated therewith," as well as derivatives thereof, may mean to include, be included within, interconnect with, contain, be contained within, connect to or with, couple to or with, be communicable with, cooperate with, interleave, juxtapose, be proximate to, be bound to or with, have, have a property of, or the like; and the term "controller" means any device, system or part thereof that controls at least one operation, such a device may be implemented in hardware, firmware or software, or some combination of at least two of the same. It should be noted that the functionality associated with any particular controller may be centralized or distributed, whether locally or remotely. Definitions for certain words and phrases are provided throughout this patent document, those of ordinary skill in the art should understand that in many, if not most instances, such definitions apply to prior, as well as future uses of such defined words and phrases.

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BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawings, wherein like numbers designate like objects, and in which:

FIGURE 1 illustrates an exemplary fixed wireless access network according to one embodiment of the present invention;

FIGURE 2 illustrates in greater detail an alternate view of selected portions of the exemplary fixed wireless access network according to one embodiment of the present invention;

FIGURE 3 illustrates an exemplary time division duplex (TDD) time division multiple access (TDMA) frame according to one embodiment of the present invention;

FIGURE 4 illustrates the timing recovery and distribution circuitry in an exemplary RF modem shelf according to one embodiment of the present invention;

FIGURE 5A illustrates an exemplary time division duplex (TDD) frames according to one embodiment of the present invention;

FIGURE 5B illustrates an exemplary transmission burst containing a single FEC block according to one embodiment of the present invention;

FIGURE 5C illustrates an exemplary transmission burst

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containing multiple FEC blocks according to one embodiment of the present invention;

FIGURE 6 is a flow diagram illustrating the adaptive modification of the uplink and downlink bandwidth in the air interface in wireless access network according to one embodiment of the present invention;

FIGURE 7 is a flow diagram illustrating the adaptive assignment of selected link parameters, such as modulation format, forward error correction (FEC) codes, and antenna beam forming, to the uplink and downlink channels used by each subscriber in the exemplary wireless access network according to one embodiment of the present invention;

FIGURE 8 is a flow diagram illustrating the adaptive assignment of selected link parameters to the different service connections used by each subscriber in the wireless access network according to one embodiment of the present invention;

FIGURE 9 illustrates selected portions of the receive path of an exemplary conventional analog beam-forming system.

FIGURE 10 represents an exemplary spatial response of the receive path of the exemplary analog beam-forming system in FIGURE 9;

FIGURE 11 illustrates selected portions of the transmit path

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and the receive path of an exemplary conventional digital beam-forming system;

FIGURE 12A illustrates an exemplary beam scanning pattern according to one embodiment of the present invention;

FIGURE 12B represents the spatial response of the transmit and receive scanning beams in the exemplary beam scanning pattern in FIGURE 12A;

FIGURE 13A illustrates an exemplary broadcast pattern according to one embodiment of the present invention;

FIGURE 13B represents the spatial response of the broadcast beam in FIGURE 13A; and

FIGURE 14 illustrates the use of broadcast beams and scanning beams in exemplary time division duplex (TDD) frames according to one embodiment of the present invention.

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DETAILED DESCRIPTION OF THE INVENTION

FIGURES 1 through 14, discussed below, and the various embodiments used to describe the principles of the present invention in this patent document are by way of illustration only and should not be construed in any way to limit the scope of the invention. Those skilled in the art will understand that the principles of the present invention may be implemented in any suitably arranged wireless access system.

FIGURE 1 illustrates exemplary fixed wireless access network 100 according to one embodiment of the present invention. Fixed wireless network 100 comprises a plurality of transceiver base stations, including exemplary transceiver base station 110, that transmit forward channel (i.e., downlink or downstream) broadband signals to a plurality of subscriber premises, including exemplary subscriber premises 121, 122 and 123, and receive reverse channel (i.e., uplink or upstream) broadband signals from the plurality of subscriber premises. Subscriber premises 121-123 transmit and receive via fixed, externally-mounted antennas 131-133, respectively. Subscriber premises 121-123 may comprise many different types of residential and commercial buildings, including single family homes, multi-tenant offices, small business enterprises (SBE), medium business enterprises (MBE), and so-called

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"SOHO" (small office/home office) premises.

The transceiver base stations, including transceiver base station 110, receive the forward channel (i.e., downlink) signals from external network 150 and transmit the reverse channel (i.e., uplink) signals to external network 150. External network 150 may be, for example, the public switched telephone network (PSTN) or one or more data networks, including the Internet or proprietary Internet protocol (IP) wide area networks (WANs) and local area networks (LANs). Exemplary transceiver base station 110 is coupled to RF modem shelf 140, which, among other things, up-converts baseband data traffic received from external network 150 to RF signals transmitted in the forward channel to subscriber premises 121-123. RF modem shelf 140 also down-converts RF signals received in the reverse channel from subscriber premises 121-123 to baseband data traffic that is transmitted to external network 150.

RF modem shelf 140 comprises a plurality of RF modems capable of modulating (i.e., up-converting) the baseband data traffic and demodulating (i.e., down-converting) the reverse channel RF signals. In an exemplary embodiment of the present invention, each of the transceiver base stations covers a cell site area that is divided into a plurality of sectors. In an advantageous embodiment of the present invention, each of the RF modems in RF modem

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shelf 140 may be assigned to modulate and demodulate signals in a particular sector of each cell site. By way of example, the cell site associated with transceiver base station 110 may be partitioned into six sectors and RF modem shelf 140 may comprise six primary RF modems (and, optionally, a seventh spare RF modem), each of which is assigned to one of the six sectors in the cell site of transceiver base station 110. In another advantageous embodiment of the present invention, each RF modem in RF modem shelf 140 comprises two or more RF modem transceivers which may be assigned to at least one of the sectors in the cell site. For example, the cell site associated with transceiver base station 110 may be partitioned into six sectors and RF modem shelf 140 may comprise twelve RF transceivers that are assigned in pairs to each one of the six sectors. The RF modems in each RF modem pair may alternate modulating and demodulating the downlink and uplink signals in each sector.

RF modem shelf 140 is located proximate transceiver base station 110 in order to minimize RF losses in communication line 169. RF modem shelf 140 may receive the baseband data traffic from external network 150 and transmit the baseband data traffic to external network 150 via a number of different paths. In one embodiment of the present invention, RF modem shelf 140 may

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transmit baseband data traffic to, and receive baseband data traffic from, external network 150 through central office facility 160 via communication lines 166 and 167. In such an embodiment, communication line 167 may be a link in a publicly owned or privately owned backhaul network. In another embodiment of the present invention, RF modem shelf 140 may transmit baseband data traffic to, and receive baseband data traffic from, external network 150 directly via communication line 168 thereby bypassing central office facility 160.

Central office facility 160 comprises access processor shelf 165. Access processor shelf 165 provides a termination of data traffic for one or more RF modem shelves, such as RF modem shelf 140. Access processor shelf 165 also provides termination to the network switched circuit interfaces and/or data packet interfaces of external network 150. One of the principal functions of access processor shelf 165 is to concentrate data traffic as the data traffic is received from external network 150 and is transferred to RF modem shelf 140. Access processor shelf 165 provides data and traffic processing of the physical layer interfaces, protocol conversion, protocol management, and programmable voice and data compression.

FIGURE 2 illustrates in greater detail an alternate view of

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selected portions of exemplary fixed wireless access network 100 according to one embodiment of the present invention. FIGURE 2 depicts additional transceiver base stations, including exemplary transceiver base stations 110A through 110F, central office facilities 160A and 160B, and remote RF modem shelves 140A through 140D. Central office facilities 160A and 160B comprise internal RF modems similar to RF modem shelves 140A through 140D. Transceiver base stations 110A, 110B, and 110C are disposed in cells sites 201, 202, and 203, respectively. In the exemplary embodiment, cell sites 201-203 (shown in dotted lines) are partitioned into four sectors each. In alternate embodiments, sites 201, 202, and 203 may be partitioned into a different number of sectors, such as six sectors, for example.

As in FIGURE 1, RF modem shelves 140A-140D and the internal RF modems of central office facilities 160A and 160B transmit baseband data traffic to, and receive baseband data traffic from, access processors in central office facilities 160A and 160B of the PSTN. RF modem shelves 140A-140D and the internal RF modems of central office facilities 160A and 160B also up-convert incoming baseband data traffic to RF signals transmitted in the forward (downlink) channel to the subscriber premises and down-convert incoming RF signals received in the reverse (uplink) channel to baseband data

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traffic that is transmitted via a backhaul network to external network 150.

Baseband data traffic may be transmitted from remote RF modem shelves 140A-140D to central office facilities 160A and 160B by a wireless backhaul network or by a wireline backhaul network, or both. As shown in FIGURE 2, baseband data traffic is carried between central office facility 160A and remote RF modem 140A by a wireline backhaul network, namely wireline 161, which may be, for example, a DS3 line or one to N T1 lines. A local multipoint distribution service (LMDS) wireless backhaul network carries baseband data traffic between central office facilities 160A and 160B and remote RF modem shelves 140B, 140C, and 140D. In a LMDS wireless backhaul network, baseband data traffic being sent to remote RF modem shelves 140B, 140C, and 140D is transmitted by microwave from microwave antennas mounted on transceiver base stations 110A, 110C, and 110F to microwave antennas mounted on transceiver base stations 110B, 110D, and 110E. Baseband data traffic being sent from remote RF modem shelves 140B, 140C, and 140D is transmitted by microwave in the reverse direction (i.e., from transceiver base stations 110B, 110D, and 110E to transceiver base stations 110A, 110C, and 110F).

At each of transceiver base stations 110B, 110D, and 110E,

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downlink data traffic from central office facilities 160A and 160B is down-converted from microwave frequencies to baseband signals before being up-converted again for transmission to subscriber premises within each cell site. Uplink data traffic received from the subscriber premises is down-converted to baseband signals before being up-converted to microwave frequencies for transmission back to central office facilities 160A and 160B.

Generally, there is an asymmetry of data usage in the downlink and the uplink. This asymmetry is typically greater than 4:1 (downlink:uplink). Taking into account the factors of data asymmetry, channel propagation, and available spectrum, an advantageous embodiment of the present invention adopts a flexible approach in which the physical (PHY) layer and the media access (MAC) layer are based on the use of time division duplex (TDD) time division multiple access (TDMA). TDD operations share a single RF channel between a transceiver base station and a subscriber premises and use a series of frames to allocate resources between each user uplink and downlink. A great advantage of TDD operation is the ability to dynamically allocate the portions of a frame allocated between the downlink and the uplink. This results in an increased efficiency of operation relative to frequency division duplex (FDD) techniques. TDD operations typically may achieve a

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forty to sixty percent advantage in spectral efficiency over FDD operations under typical conditions. Given the short duration of the transmit and receive time slots relative to changes in the channel, TDD operations also permit open loop power control, switched diversity techniques, and feedforward and cyclo-stationary equalization techniques that reduce system cost and increase system throughput.

To aid with periodic functions in the system, TDD frames are grouped into superframes (approximately 10 to 20 milliseconds). The superframes are further grouped into hyperframes (approximately 250 to 1000 milliseconds). This provides a coordinated timing reference to subscriber integrated access devices in the system. FIGURE 3 illustrates an exemplary time division duplex (TDD) time division multiple access (TDMA) framing hierarchy according to one embodiment of the present invention. At the highest level, the TDD-TDMA framing hierarchy comprises hyperframe 310, which is X milliseconds (msec.) in length (e.g., 250 msec. < X < 1000 msec.). Hyperframe 310 comprises N superframes, including exemplary superframes 311-316. Each of superframes 311-316 is 20 milliseconds in duration.

Superframe 313 is illustrated in greater detail. Superframe 313 comprises ten (10) TDD frames, including exemplary

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TDD frames 321-324, which are labeled TDD Frame 0, TDD Frame 1, TDD Frame 2, and TDD Frame 9, respectively. In the exemplary embodiment, each TDD frame is 2 milliseconds in duration. A TDD transmission frame is based on a fixed period of time during which access to the channel is controlled by the transceiver base station.

Exemplary TDD frame 321 is illustrated in greater detail. TDD frame 321 comprises a downlink portion (i.e, base station to subscriber transmission) and an uplink portion (i.e., subscriber to base station transmission). In particular, TDD frame 321 comprises:

Frame header 330 - Frame header 330 is a broadcast message that synchronizes the start of frame and contains access control information on how the remainder of TDD frame 321 is configured. The modulation format of frame header 330 is chosen so that all subscribers in a sector of the transceiver base station can receive frame header 330. Generally, this means that frame header 330 is transmitted in a very low complexity modulation format, such as binary phase shift keying (BPSK or 2-BPSK), or perhaps quadrature phase shift keying (QPSK or 4-BPSK).

D downlink slots - The D downlink slots, including exemplary downlink slots 341-343, contain transceiver base station-to-

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subscriber transmissions of user traffic and/or control signals. The modulation format of each slot is optimized for maximum possible data transmission rates. Downlink slots may be grouped in blocks to form modulation groups as shown in FIGURE 5A. Subscribers who receive data using the same modulation format (or modulation index) and the same forward error correction (FEC) codes are grouped together in the same modulation group. In some embodiment of the present invention, two or more modulation groups may have the same modulation format and FEC codes. In alternate embodiments of the present invention, downlink slots may be grouped in blocks based on physical beam forming, rather than on modulation format and FEC codes. For example, a transceiver base station may transmit data to several subscribers that are directionally along the same antenna beam in consecutive bursts. In still other embodiments of the present invention, downlink slots may be grouped in blocks based on any combination of two or more of: 1) physical beam forming, 2) modulation format, and 3) FEC codes. For the purpose of simplicity, the term "modulation group" shall be used hereafter to refer to a group of downlink slots that are transmitted to one or more subscribers using a common scheme consisting of one or more of modulation format, FEC codes, and physical beam forming.

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U uplink slots - The U uplink slots, including exemplary uplink slots 361-363, contain subscriber-to-transceiver base station transmissions of user traffic and/or control signals. Again, the modulation format (modulation index) is optimized for maximum possible data transmission rates. Generally, the modulation format and FEC codes in the uplink slots are less complex than in the downlink slots. This moves complexity to the receivers in the base stations and lowers the cost and complexity of the subscriber access device. Uplink slots may be grouped in blocks to form sub-burst groups as shown in FIGURE 5A. Subscribers who transmit data using the same modulation format (or modulation index) and the same forward error correction (FEC) codes are grouped together in the same sub-burst group. In some embodiments of the present invention, two or more sub-burst groups may have the same modulation format and FEC codes. In other embodiments of the present invention, uplink slots may be grouped in blocks based on physical beam forming, rather than on modulation format and FEC codes. In other embodiments, uplink slots may be grouped in blocks based on any combination of two or more of: 1) physical beam forming, 2) modulation format, and 3) FEC codes. For the purpose of simplicity, the term "sub-burst group" shall be used hereafter to refer to a group of uplink slots that are transmitted to one or

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more subscribers using a common scheme consisting of one or more of modulation format, FEC codes, and physical beam forming.

Contention slots 360 - Contention slots 360 precede the U uplink slots and comprise a small number of subscriber-to-base transmissions that handle initial requests for service. A fixed format length and a single modulation format suitable for all subscriber access devices are used during contention slots 360. Generally, this means that contention slots 360 are transmitted in a very low complexity modulation format, such as binary phase shift keying (BPSK or 2-BPSK), or perhaps quadrature phase shift keying (QPSK or 4-BPSK). Collisions (more than one user on a time slot) result in the use of back-off procedures similar to CSMA/CD (Ethernet) in order to reschedule a request.

TDD transition period 350 - TDD transition period 350 separates the uplink portion and the downlink portion and allows for transmitter (TX) to receiver (RX) propagation delays for the maximum range of the cell link and for delay associated with switching hardware operations from TX to RX or from RX to TX. The position of TDD transition period 350 may be adjusted, thereby modifying the relative sizes of the uplink portion and the downlink portion to accommodate the asymmetry between data traffic in the uplink and the downlink.

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