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Feder et al.

(54) METHOD AND APPARATUS FOR CELLULAR COMMUNICATION OVER DATA NETWORKS

(76) Inventors: **Peretz Moshes Feder**, Englewood, NJ (US); **Jungsang Kim**, Chapel Hill, NC (US); **Zhengxiang Ma**, Summit, NJ (US); **Anatoli Olkhovets**, Piscataway, NJ (US); **Arnold B. Siegel**, Alpine, NJ (US); **Theodore Sizer II**, Little Silver, NJ (US); **Michael George Zierdt**, Belle Mead, NJ (US)

Correspondence Address:
Lucent Technologies Inc.
Docket Administrator
Room 3J-219
101 Crawfords Corner Road
Holmdel, NJ 07733-3030 (US)

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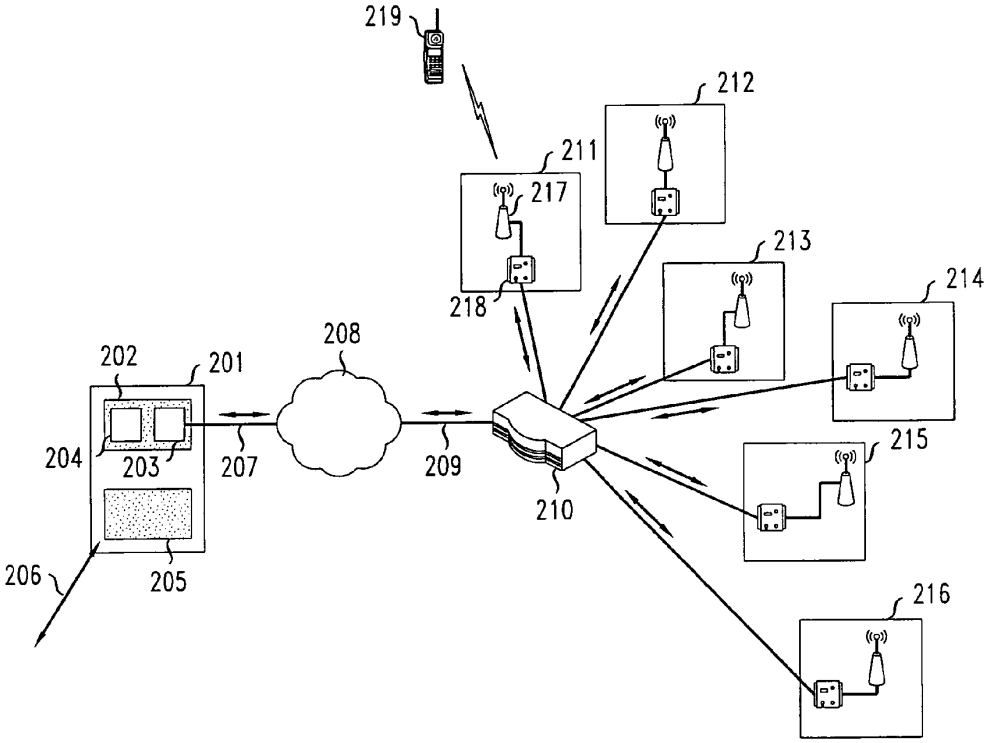
(57) **ABSTRACT**

Cellular signals or other wireless signals/messages are introduced into a building or to an outside location by transmitting packets corresponding to those signals over a data network and low cost cables to designated locations within the data network. Once the designated packets containing the signals reach the destination, they are then broadcast over the air to a terminal capable of receiving the wireless message. In a first embodiment, an in-building gigabit Ethernet network, such as that currently existing presently in many buildings, is used to distribute radio signals indoors. Instead of transmitting the radio signals over the air from a repeater connected to a base station, coded baseband signals generated by the coding processor (e.g., a CDMA Modem Unit) in the base station are packetized and sent over the Ethernet network to radio processing equipment and antennas distributed throughout the building. The radio processing equipment strips the packet headers from the baseband signal packets so those signals can be broadcast via the antennas to one or more mobile terminals.



CommScope Ex. 1013

FIG. 1

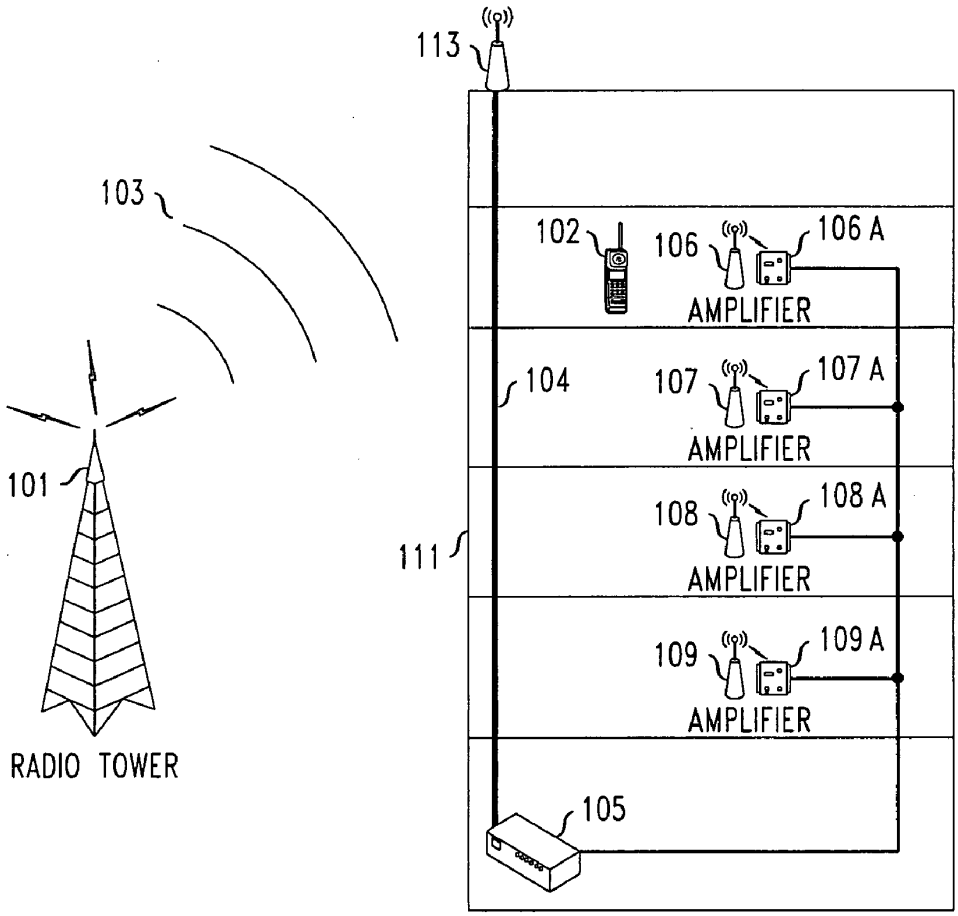

113
103
102
106
106 A
AMPLIFIER
104
107
107 A
AMPLIFIER
101
108
108 A
AMPLIFIER
111
109
109 A
AMPLIFIER
RADIO TOWER
105

FIG. 2

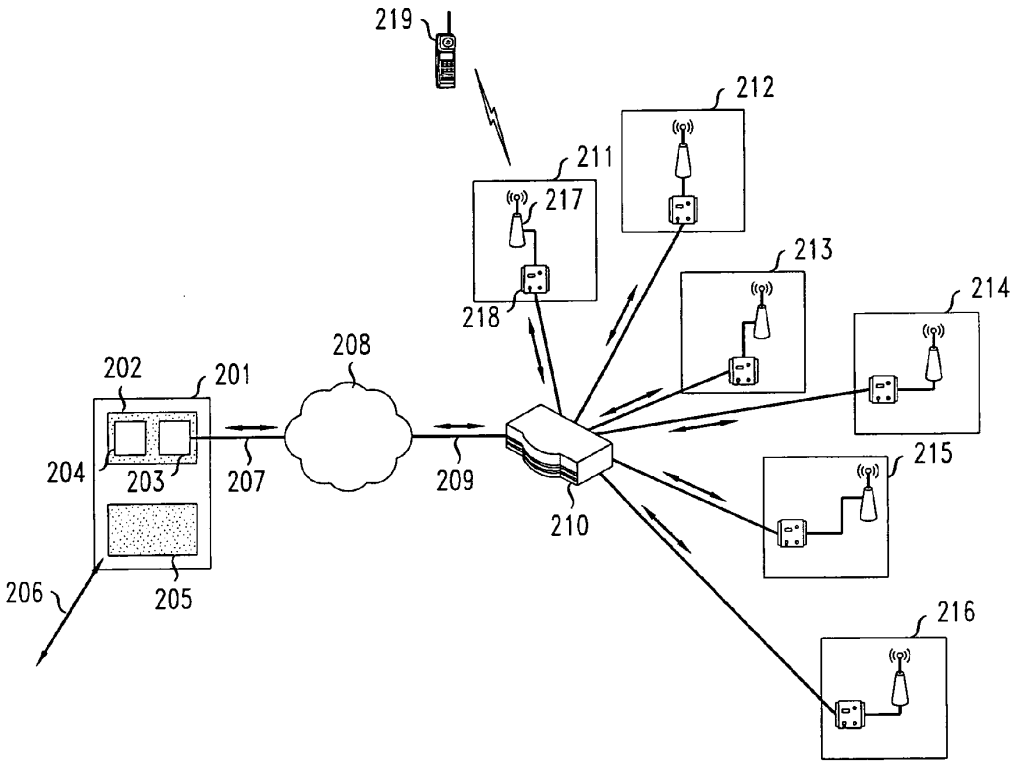
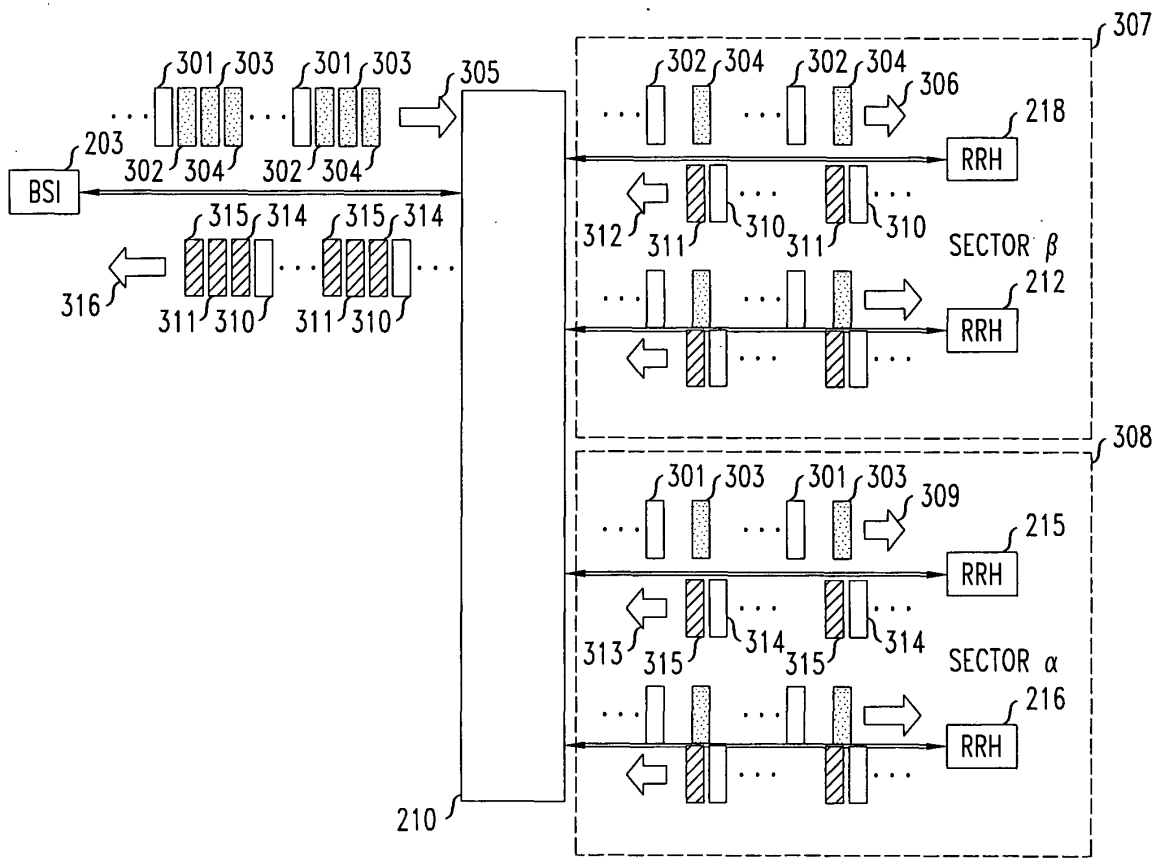

219
212
211
217
213
214
218
208
202
201
204
203
207
209
210
215
206
205
216

FIG. 3


BSI
203
301
303
302
304
305
315
314
316
311
310
307
306
218
RRH
312
SECTOR β
212
308
309
215
313
SECTOR α
216
210

METHOD AND APPARATUS FOR CELLULAR COMMUNICATION OVER DATA NETWORKS

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application Ser. No. 60/536871 filed Jan. 16, 2004.

FIELD OF THE INVENTION

[0002] The present invention is related generally to wireless communications in buildings.

BACKGROUNDS OF THE INVENTION

[0003] Wireless communications systems are becoming an increasingly integral aspect of modern communications. In fact, recent trends show that an increasing number of users are replacing all wire-line methods of communications with their wireless counterparts such as, for example, cellular telephones in place of traditional wire-line telephones. Since such cellular telephones are essentially radios, it is well known that signal quality between a cellular base station and a handset degrades under certain circumstances. The most significant source of degradation occurs when a user moves from an outside location to an indoor location where the radio signals are required to pass through or around various obstructions. Since many users place the majority of cellular calls from within buildings or other structures, achieving high quality consistent indoor coverage is becoming more essential.

[0004] Several methods for achieving indoor cellular network coverage are known. For example, one method of achieving such coverage, known as a distributed antenna system (DAS), is illustratively shown in **FIG. 1**. A DAS uses a base station and a repeater or a power amplifier that is typically located within a building to retransmit within the building a signal received at an external antenna. Referring to the illustrative DAS of **FIG. 1**, when a signal **103** is transmitted from an antenna in a cellular communications network, such as antenna **101** (e.g., an antenna in a cellular communications network), antenna **113**, which is external to building **111**, receives signal **103**. Signal **103** is then passed along connection **104** which is, illustratively, a coaxial cable, to component **105** which is, in this example, a radio repeater. Repeater **105** forwards the signal to amplifiers **106***a*, **107***a*, **108***a* and **109***a*. These amplifiers amplify the signal which is then transmitted over in-building antennas **106**, **107**, **108** and **109**. Thus, the result is that cellular telephone **102** receives the signal transmitted from antenna **113** via antenna **109**. By passing the signal along a wired connection from antenna to repeater **105** and rebroadcasting the signal over antennas **106-109**, the problems associated with poor signal quality in buildings are alleviated.

[0005] While DAS systems are advantageous in many aspects, they are limited in certain regards. For example, in order to install a DAS, cabling (such as coaxial cabling) must be installed throughout the building at each location where an in-building antenna is desired. Thus, installation expense is relatively high. Additionally, such systems are not flexibly expandable and there is typically no mechanism for reprovisioning or reallocating the bandwidth available to different locations within the building.

[0006] Another method for achieving indoor cellular network coverage relies on the use of small in-building base transceiver stations (BTSs), which are smaller versions of well-known base stations such as are used in a traditional cellular network, to provide essentially an entire in-building cellular network. The result of using such small BTSs is a network of so-called pico-cells (cells with a short range) that operate similarly to a low-powered traditional cellular network in provisioning bandwidth and managing data and voice calls within one or more individual buildings. However, since such a system is essentially a miniaturized cellular network, management of a multitude of such BTSs within a building would be problematic as it would require network components (such as a Radio Network Controller (RNC) and/or a Mobile Switching Center (MSC) in a CDMA network) to provision bandwidth and manage calls across the large number of pico-cells. Hence, a mini-BTS system is relatively cost-prohibitive and complex to install and maintain.

[0007] As cellular usage increases there is a need to provide increased and cost effective capacity and coverage outdoors in dense urban areas, outdoor malls, or in business or academic campuses. Many of the same techniques that are used indoors can also be used in these environments. Typically a base station remotely serves a given outdoor location using DAS systems in an architecture known as "hoteling". However, these architectures require the use of proprietary RF or fiber links to connect the base stations and the remote antennas.

SUMMARY OF THE INVENTION

[0008] The aforementioned problems related to in-building wireless communications are essentially solved by the present invention. In accordance with the principles of the present invention, cellular signals or other wireless signals/messages are introduced into a building by transmitting packetized messages corresponding to those messages over a shared or dedicated data network to designated locations within the building. Once the designated destination is reached, the packet headers are stripped from the packets and the wireless message is then broadcast over the air to an intended recipient.

[0009] In a first embodiment, base station interface cards (BSIs) are used in place of RF generating equipment in a base station such as that used in a cellular communications network (e.g., a CDMA network). For downlink signals, when a BSI receives coded baseband signals from a processor, such as a CDMA Modem Unit (CMU) in a CDMA system, the BSI then buffers the baseband signals and periodically creates data packets each containing a plurality of coded baseband signals. The BSI then forwards the data packets over a high-speed data network, such as a gigabit Ethernet network, to one or more illustrative Gigabit switches. These switches duplicate and route the packets to one or more specific ports corresponding to a cellular CDMA sector which in turn corresponds to one or more radio transceivers, at least one of which corresponds to the address of the intended recipient of the message. In one embodiment, the radio transceivers contain equipment that extracts the baseband signals from the packets, process the base band signal, convert to RF format, amplify the signals, and broadcast the signals to an intended recipient over associated antennas.

[0010] For uplink signals, the radio transceivers receive uplink signals from a mobile user, the transceivers convert it to a digital format and generate packets of the coded signals and forward them through the network to the aforementioned switches and then to the BSI and CMU for transmission through the traditional wireless network to an intended recipient. In another embodiment, lo in order to increase the possible number of available radio transceivers, one or more special summing nodes sum the base band data in incoming uplink packets in order to reduce the number of packet streams passing through the BSI to the CMU. Since the signals are coded (e.g., with Walsh codes), the CMU can differentiate between the signals in the summed data packets and forward those signals to an intended destination in the wireless network. These summing nodes can be separate units, integrated with switches, or their functionality can be integrated into one or more of the radio transceivers.

BRIEF DESCRIPTION OF THE DRAWING

[0011] **FIG. 1** shows a prior art distributed antenna system (DAS);

[0012] **FIG. 2** shows an in-building cellular network in accordance with the principles of the present invention; and

[0013] **FIG. 3** shows how uplink signals in the network of **FIG. 2** are aggregated.

DETAILED DESCRIPTION OF THE INVENTION

[0014] **FIG. 2** shows an in-building communications network in accordance with the principles of the present invention. In the network of **FIG. 2**, base station **201** sends and receives messages from a wireless network via path **206**. Base station **201** is, for example, similar to a base station used in a traditional CDMA network such as a OneBTS base station manufactured by Lucent Technologies, Murray Hill, N.J. One skilled in the art will recognize that such a base station traditionally has three main components: 1) a network interface for interfacing with the other components of the cellular network (e.g., a radio network controller (RNC)); 2) a digital baseband shelf typically having a processor (e.g., a CDMA modem unit (CMU)) for coding and decoding incoming and outgoing message traffic, as well as a radio (e.g., a Universal CDMA Radio (UCR)) for modulating/demodulating the coded digital message traffic onto/from a carrier signal; and 3) an RF shelf for amplifying the modulated signal and transmitting that signal over the air to a mobile user.

[0015] While the base station **201** of **FIG. 2** in accordance with the principles of the present invention is similar to a traditional CDMA base station, there are some differences. Specifically, in accordance with the principles of the present invention, both the RF shelf and external base station antenna functions are not used in the in-building base station **201**. This modified base station **201** may be physically located within a building to be serviced by the base station or, alternatively, external to that building. Additionally, the UCR of the digital baseband shelf **202** in base station **201** is replaced by a component herein referred to as a base station interface card (BSI) **203**. The illustrative BSI **203** may be a component of similar form factor to the UCR and illustratively plugs into the same physical slot in the digital shelf traditionally occupied by the UCR. For downlink signals, as described more fully below, instead of receiving and transmitting coded cellular radio signals over the air, the BSI **203** in base station **201** functions to forward mobile user-coded baseband signals over a high-speed data network, such as illustrative gigabit Ethernet network **208** to a switch/summing node, also referred to herein referred to as a Radio Distributor/Aggregator **210** (RDA), and subsequently to a desired end destination where the baseband signals are converted to RF and then broadcast over the air to a message recipient, such as mobile terminal **219**. Similarly, as also discussed below, on the uplink, when a user, once again such as mobile terminal **219**, transmits messages from, for example, a cellular telephone, those messages are transmitted via the illustrative RDA **210** and illustrative gigabit Ethernet network **208** to the BSI **203** and CMU **204** for further processing and distribution via the network interface equipment **205** and the wireless network via path **206**. The below illustrative example specifically discusses one implementation of the present invention in a CDMA network. One skilled in the art, however, will recognize that the principles of the invention as herein described will be equally applicable to a GSM, UMTS or other wireless communications networks.

[0016] Specifically, on the downlink in a CDMA system, when a signal is addressed to a mobile terminal in a building, such as, referring to **FIG. 1**, mobile terminal **102** in building **111**, the illustrative BSI **203**, discussed above, receives digital I and Q baseband signals generated by the CMU **204** and stores them in a buffer. Illustratively, I and Q signals are received every **0.5** microseconds. Once the buffer reaches a predetermined level, or a predetermined amount of time has passed, the BSI **203** forms an Ethernet packet of those signals having a destination address (e.g., a MAC address) corresponding to a sector in which an intended recipient is present, such as a sector that is distinguished by the time offset of the pseudorandom number (PN) code of a pilot channel to which the mobile terminal **219** is tuned. One skilled in the art will recognize that other configurations and operations of the BSI are possible. For example, instead of connecting directly to the physical slot in the digital shelf, the BSI can be a separate component that connects to a digital, radio frequency (RF), or intermediate frequency (IF) port. In such a configuration, the BSI may receive digital coded baseband signals, as described above or, alternatively, may receive RF or IF signals and then convert those signals to digital form for buffering and packetizing.

[0017] The packets are then sent via gigabit Ethernet from the BSI to the RDA **210** over, illustratively, gigabit Ethernet. For downlink signals, the RDA acts essentially as a switch having, illustratively, a plurality of ports. Each port on the RDA illustratively corresponds to an addressable sector for the routing of messages. For example, each port of an RDA may be identified as a separate sector or, if a greater coverage area is desired, for example, then multiple ports may be designated as corresponding to a single sector. Each sector, in turn, corresponds to a one or more radio transceivers, referred to herein as remote radio heads (RRHs), such as RRHs **211**, **212**, **213**, **214**, **215** and **216** corresponding to an area of wireless coverage within a building. As one skilled in the art will recognize, RDAs can be connected as flexibly as regular data switches: multiple RDAs may be used in a cascaded fashion to facilitate greater control over the routing of messages to end recipients and to permit more granularity in the management of bandwidth allocation, or

no RDA may be necessary for a point-to-point link between the BSI and a particular RRH. Alternatively, in some implementations, a single RRH on a single port of the RDA may suffice to serve a relatively large sector. One skilled in the art will recognize that the number of RRHs necessary to provide coverage to a sector will depend upon environmental factors such as, illustratively, the number of obstructions (e.g., walls or other such obstacles) in proximity to the RRH.

[**0018**] When the RDA **210** receives a message from the BSI **203** having a particular address (for example a Medium Access Control (MAC) address) corresponding to a particular sector, the RDA **210** compares that address to, for example, a look-up table to identify which ports on the RDA **210** correspond to the designated sector. This look-up procedure can use a variety of existing Ethernet protocols, such as using special multicast addresses, or having all RRHs belonging to a particular sector be a part of the same virtual LAN (VLAN), and broadcasting packets on that VLAN. Once the RDA **210** has identified the ports corresponding to the recipient sector(s), the RDA **210** will replicate the packet (if necessary to forward to multiple end destination RRHs) and forward a copy of the packet to the appropriate ports for further dissemination to the designated sectors and the corresponding RRHs **211-216**. Each RRH **211-216** has, illustratively, network interface equipment, timing and frequency synchronization equipment, signal processing elements, a power amplifier and one or more antennas. The network interface equipment of the destination RRH such as, in this case, RRH **211** corresponding to mobile user **219**, receives the packets from the network and removes the headers from the packets. The I and Q baseband signals are then forwarded to the timing and synchronization equipment where the signals are buffered. As described more fully below, the signals are then processed, converted to RF format and played out to the power amplifier and broadcast over the air via the antenna(s) to a recipient end mobile user.

[**0019**] Since CDMA networks and Ethernet networks were designed for different uses (i.e., CDMA was designed for circuit switched voice applications and Ethernet was designed for packet switched data applications), manners of transmitting data across those networks differ relative to one another. One of the more critical differences is in how frequency and timing are managed in the different networks. Specifically, CDMA networks were designed with a tight timing/jitter tolerance of less than 2-3 microseconds using a synchronous frequency as required by the air-interface. Ethernet, on the other hand, was designed with a loose timing/jitter tolerance and an asynchronous frequency that is adequate for packet-switched data networking in, for example, a star network configuration. Overcoming these timing and frequency differences to achieve synchronization is critical to passing timely packets of CDMA data over an Ethernet network.

[**0020**] More specifically, timing synchronization is especially crucial for downlink traffic since the offsets in the pilot channels are used to identify the base station sectors in the network. On the uplink, however, while timing synchronization is important, one skilled in the art will recognize that it is sufficient to assure a certain, fixed delay among the uplink signals from the RRHs **211-216**—precisely synchronizing the exact time is not necessary. In both uplink and downlink scenarios, timing synchronization may illustratively be achieved by first determining the minimum feasible time that a packet will spend transiting the data network between the BSI **203** and the RRH **210**, hereinafter referred to as the minimum packet delay, τ_{min}. This minimum packet delay is, for example, measured as a function of delays in buffering baseband signals in the BSI **203** to form the packets, transmission through the gigabit Ethernet MAC, the physical layer and the switches in the RDA **210**, as well as the delay experienced traveling over cables. Thus, τ_{min} is a basic, illustrative reference time between the BSI **203** and the RRH **210** for a given Ethernet network topology.

[**0021**] This minimum reference time τ_{min}, of course, is not the time typically experienced by a packet transiting the data network, only the feasible minimum based on known delays. The actual timing delays of packets through the data network are a function of, in part, queuing delays in the presence of other data traffic in the data network. This actual timing delay may vary from one packet to the next and, over a given number of packets, a spread in the timing delay, $\Delta\tau$, can be determined. Over a sufficient number of packets, the spread $\Delta\tau$ can be **1**o measured such that a maximum timing delay of $\tau_{min+}\Delta\tau$ may be determined.

[**0022**] Therefore, in order to broadcast packets from an RRH, such as RRH **210**, to mobile **219**, and ensure continuity between the packets transiting the network, a timing delay can illustratively be introduced into the RRH broadcast such that each successive packet is guaranteed to be present at the RRH and ready for broadcast at its appointed time. Specifically, if the RRH broadcast delay is established at a time greater than $\tau_{min+}\Delta\tau$, with, illustratively, an additional timing tolerance delay added to τ_{min} to manage additional timing jitter, then each packet will be at the RRH when it is scheduled for broadcast.

[**0023**] The timing delay and spread can be determined by either a hardware or a software solution, or a combination of both. In an exemplary hardware solution, the timing delay can be calculated through knowledge of the topology of the network and the delay properties of the routing equipment and cables. By setting higher priority to CDMA packets, and knowing maximum allowable packet length (for example, 1500 bytes), one can predict the maximum delay spread $\Delta\tau$. Alternatively, timing delays and spread can be directly measured using a variety of software methods, such as methods involving an exchange of time stamps between endpoints and using statistical techniques to determine the time delay and spread. One illustrative example of such a software method is the well known Network Time Protocol (NTP). One skilled in the art will recognize that many such hardware and software methods may be used to determine the timing delay and spread.

[**0024**] As previously mentioned, in addition to timing synchronization, frequency synchronization across the network is also important. Frequency synchronization is achieved in accordance with the principles of the present invention by either a hardware solution or a software solution. An illustrative hardware solution to frequency synchronization is achieved by using the physical layer in Gigabit Ethernet networks to synchronize the CDMA signals. In order to achieve this synchronization, a frequency oscillator is illustratively used in each RRH as a frequency reference for all the frequency synthesizers in the RRH. These frequency oscillators are locked, using well known clock and data recovery methods, to the clock rate of the data coming

in on the Ethernet connection. This clock rate, in turn, is set by the clock which BSI **203** uses to encode the Ethernet signals. The BSI **203** can use, for example, a stable and accurate stand-alone reference oscillator to generate all its clocks or, alternatively, may derive its reference from the base station clock. One skilled in the art will recognize that such a hardware implementation of frequency synchronization will require forwarding a frequency reference from each network node, thus requiring additional overhead to maintain synchronization in this manner. In addition, one skilled in the art will recognize that similar synchronization techniques may be used in other network transport methods.

[**0025**] On the other hand, if a software solution to frequency synchronization is used, a timestamp is illustratively applied by the BSI **203** to each downlink CDMA packet marking the time it is transmitted from BSI **203**. At the RRH **210**, the arrival time of each CDMA packet is recorded using a local clock and the difference between the embedded time stamp and the measured arrival time is calculated as the delay D. If the illustrative clocks at the BSI and RRH are synchronized, then D should be held constant. Thus the local RRH clock can be adjusted to the remote BSI **203** clock using well-known statistical methods. For example, a number of timestamp-minus-local-clock measurements corresponding to multiple packets can be used to calculate the frequency deviation over time. Over a desired period of time, the frequency error can be inferred from the total delay change that is detected. A frequency correction corresponding to this frequency error is used compensate for the frequency deviation. In this way, the software controls the RRH **210** local clock by tracking and correcting the frequency in relation to the BSI **203** clock. Furthermore, to reduce the packet arrival jitter, and thus the accuracy of the frequency tracking mechanism, only specific packets can be used for frequency tracking. More particularly, in this example, the delay is recorded over a selected number of packets and is used for software synchronization. By selectively using an **1**o ensemble of packets with a measured delay, such as the smallest delay, the effect of switch jitters due to background traffic may be significantly reduced. Uplink signals are transmitted in a similar fashion as described above in association with downlink signals. When an uplink signal is received by an RRH, such as RRH **211**, from, for example, illustrative mobile terminal **219**, that RRH is will convert the signal to a digital format and will buffer the digital signals and packetize them at a predetermined time interval or until a predetermined buffer fill level reached. The RRH **211** will then send the packets of digital signals to the corresponding RDA **210** to which it is attached. As discussed above, each RDA **210** can have a plurality of ports associated with a plurality of addressable sectors. And, as also discussed above, multiple RDAs can be cascaded to in a way such that numerous RDA ports can be addressed to even more numerous remote radio heads. However, the CMU **204** typically can only accept a smaller, limited number of signal channels (e.g., 6 channels). This is not an issue on the downlink as the RDAs simply replicate the downlink packets and retransmit identical packets to multiple addresses. However, on the uplink, the packets flowing into the RDAs to the BSI **203** and CMU **204** are not identical—they are potentially each from different mobile users. Thus, a problem arises as to how to reduce the potential relatively large number of unique uplink packet data streams into the limited number of channels acceptable to the CMU **204**.

[**0026**] This problem is overcome by the principles of the present invention. Specifically, referring to **FIG. 3**, in order for a large number of RDAs to communicate with the CMU in BSI **203**, an illustrative processor at each RDA in a cascaded structure of RDAs, such as RDA **210**, strips the headers off the packets corresponding to a unique sector, sums the data in those packets, and repacketizes the data before forwarding it to another RDA or the BSI **203**. One skilled in the art will recognize that this processor may not be located within the RDA and that it may also be located in an independent unit attached to the RDA. Alternatively, the functionality of this processor may be located within one or more of the RRHs. In the case of cascaded RDAs each having such a processor, each RDA in the cascade will accomplish this summing function until the packets flowing to from a particular RDA **210** to the BSI **203** on the uplink correspond only to one of the channels of the CMU. While summing the data in packets traditionally would result in irreparably destroying the packets (i.e., because reconstruction of the original packets would be impossible), the data in the packets of the present invention correspond to coded baseband signals of all the traffic on a particular sector. Thus, using traditional processing well known in the art, the CMU can process and identify signals in the summed packets corresponding to a uniquely CDMA coded mobile user. These unique signals are then forwarded to end destinations within the cellular network.

[**0027**] More particularly, **FIG. 3** shows an in-building network having two illustrative sectors, **307** and **308**, each comprising two RRHs, each of which supports two traffic carriers (frequencies). As described above, on the downlink data packets **301-304** are transmitted by BSI **203** in direction **305** to RDA **210**. The RDA then uses the addresses on each of those packets to determine to which sector (and in turn to which RRHs) a packet is routed. As shown in **FIG. 3**, packets **302** and **304** are, illustratively, encode information for traffic carriers in sector **307**. Accordingly, RDA **210** replicates packets **302** and **304** and multicasts those packets in direction **306** to both RRH **212** and RRH **218** for radiation. Similarly, packets **301** and **303** are multicast in direction **309** to RRH **215** and RRH **216** which in turn will radiate these traffic carriers in sector **308**.

[**0028**] On the uplink, however, and also as briefly discussed above, the RDA **210** acts as a summing node and aggregates the uplink data packets. Specifically, when RRHs support several mobile carriers (frequencies), those RRHs will each buffer the packets and forward them to RDA **210**. Thus, for example, RRHs **218** and **212** will send out packets **310** and **311** in direction **312** to RDA **210** and RRH **215** will illustratively send packets **314** and **315** in direction **313** to RDA **210**. When those packets arrive at the RDA, the headers of the packets are removed and the data in any packets in the same sector are summed together. The RDA **210** then interleaves all unique baseband signals together and forwards out a single data stream containing packets of baseband signals from all sectors of the RDA **210**. In a cascade of RDAs, this process is repeated at each RDA so that only a desired number of data streams containing packets of baseband symbols arrive at the BSI **203** in **FIG. 2** and the CMU **204** in **FIG. 2** in the base station. One skilled

in the art will recognize that such a summing function is illustrative and may not be necessary depending upon the particular implementation of the network described herein. Additionally, if such a summing function is used, one skilled in the art will realize that this function can be performed at network nodes other than the RDA, such as at an RRH.

[**0029**] One skilled in the art will recognize that the above network structure facilitates flexible bandwidth management. For example, a network controller may be used (e.g., incorporated into the BSI) to dynamically assign ports on each RDA to a sector within the building. Thus, depending on the desired coverage and network usage, individual ports could each be assigned to individual sectors or, alternatively, any number of ports of the RDA could be assigned to an individual sector. Thus, in accordance with the principles of the present invention, wireless cellular network coverage can be extended by adapting an existing base station to broadcast coded cellular baseband signals over gigabit Ethernet networks using existing cabling within buildings. In fact, recently gigabit-over-Ethernet has been implemented over a wide variety of types of cabling, such as fiber, coaxial cable, as well as low cost category **5**, category **6**, and category **7** networking cables. Thus, the expense of installing additional cabling may be avoided. Additionally, relatively inexpensive switches (RDAs) and low powered radio equipment at the RRHs are used to broadcast the baseband signals to designated recipients.

[**0030**] One skilled in the art will also recognize that, since standard networking protocols may be used according to the principles of the present invention, the network of the present invention could be used to transmit and receive various other wireless network protocols in a similar fashion. For example, by adding 802.11 (WiFi) access points to the remote radio heads, the network of the present invention could be used in a similar fashion as described above to distribute 802.11 protocol signals to desired destinations. Additionally, since Ethernet can also provide power to network devices (i.e., via the Power-over-Ethernet 802.3af standard), the cost of installing the aforementioned radios and other equipment can be further reduced by supplying power to such components without an independent power source connection. Finally, one skilled in the art will also recognize that the network of the present invention could be used in place of a DAS in a "hoteling" arrangement associated with one or more remote antennas in an outdoor environment, such as that used in the aforementioned dense urban areas to provide increased coverage in such environments.

[**0031**] The foregoing merely illustrates the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are within its spirit and scope. Furthermore, all examples and conditional language recited herein are intended expressly only to be for pedagogical purposes to aid the reader in understanding the principles of the invention and are to be construed as being without limitation to such specifically recited examples and conditions.

What is claimed is:

1. A method for wireless communication comprising:

creating a first plurality of data packets, wherein each packet in said first plurality comprises a plurality of coded cellular signals;

addressing each of said first plurality of data packets to at least a first sector of a cellular network, said sector comprising at least one radio transceiver, wherein said at least one radio transceiver comprises an antenna adapted to broadcast said plurality of coded cellular signals;

transmitting said first plurality of data packets over a data network associated with said at least a first sector to said at least one radio transceiver; and

broadcasting said cellular signals over the air.

2. The method of claim 1 wherein said radio transceivers are located within a building.

3. The method of claim 1 wherein said at least a first sector is associated with a first port on a network switch.

4. The method of claim 1 wherein said at least a first sector is associated with a plurality of ports on at least a first network switch.

5. The method of claim 1 wherein said data network comprises a Gigabit Ethernet network.

6. The method of claim 5 further comprising:

transmitting a second plurality of data packets across said Gigabit Ethernet network; and

broadcasting said second plurality of data packets over the air in a signal conforming to at least a first IEEE 802.11 standard.

7. A method for transmitting a first plurality of data packets over a data network, each packet in said first plurality comprising a plurality of coded cellular signals, said data network comprising at least a first sector of a cellular network, said at least a first sector comprising at least a first radio transceiver, said method comprising:

addressing each of said packets in said plurality of data packets to a first address associated with said at least a first sector, wherein said at least a first radio transceiver in said at least a first sector is adapted to transmit and receive cellular signals.

8. The method of claim 7 further comprising:

addressing each packet in said plurality of data packets to at least a second address associated with said at least a first sector.

9. The method of claim 7 wherein said at least a first radio transceiver is located within a building.

10. The method of claim 7 wherein said at least a first sector is associated with a first port on a data network switch.

11. The method of claim 7 wherein said at least a first sector is associated with a plurality of ports on at least a first data network switch.

12. The method of claim 7 wherein said data network comprises a Gigabit Ethernet network.

13. The method of claim 12 further comprising:

transmitting a second plurality of data packets across said Gigabit Ethernet network; and

addressing each packet in said second plurality of data packets to said at least a first radio transceiver, wherein

said at least a first radio transceiver is further adapted to transmit and receive wireless signals conforming to at least a first IEEE 802.11 standard.

14. A radio transceiver comprising:

means for receiving data packets, said data packets comprising coded cellular signals; and

means for transmitting said cellular signals.

15. The radio transceiver of claim 14 further comprising:

means for receiving cellular signals over the air;

means for generating a plurality of data packets comprising said received cellular signals;

means for addressing each packet in said plurality of data packets to at least a first summing device associated with at least a first sector of a cellular network; and

means for transmitting said first plurality of data packets over a data network associated with said at least a first sector to said summing device.

16. The radio transceiver of claim 14 wherein said means for transmitting comprises means for extracting said cellular signals from said packets.

17. The radio transceiver of claim 16 wherein said means for transmitting is adapted to transmit said cellular signals at a predetermined time relative to at least one other cellular signal.

18. The radio transceiver of claim 16 wherein said means for transmitting is adapted to transmit said cellular signals at a predetermined frequency.

19. The radio transceiver of claim 14 further comprising:

access equipment adapted to transmit and receive wireless signals conforming to at least a first IEEE 802.11 standard.

20. A network switch for use in a wireless communication system, said wireless communication system comprising at least a first sector, said network switch comprising:

means for receiving a plurality of data packets, said data packets comprising a plurality of coded cellular signals associated with said sector;

means for extracting the coded cellular signals from said data packets;

means for summing the coded cellular signals, thus forming a data stream comprising summed coded baseband signals; and

means for forming data packets containing said summed coded cellular signals.

21. A network switch for use in a wireless communication system, said network comprising at least a first sector, said network switch comprising:

means for receiving a first plurality of data packets, said data packets comprising a plurality of coded cellular signals associated with said sector;

means for duplicating said data packets, thus forming a second plurality of data packets;

means for transmitting said second plurality of data packets to at least a first destination in said data network.

22. A method for use in a wireless communication system, said network comprising at least a first sector, said method comprising:

receiving a first plurality of data packets, said first plurality of data packets comprising a plurality of coded cellular signals associated with said sector;

extracting the coded cellular signals from said first plurality-of data packets;

summing the coded cellular signals, thus forming a data stream comprising summed coded cellular signals; and

forming a second plurality of data packets containing said summed coded coded cellular signals.

23. The method of claim 22 further comprising:

transmitting said second plurality of data packets to a first node in said data network.

24. The method of claim 23 further comprising:

extracting said summed coded cellular signals; and

transmitting said coded cellular signals to at least a first destination within a cellular network.

25. Apparatus for interfacing a cellular network with a data network, said apparatus comprising:

means for receiving cellular signals from said cellular network;

means for creating a plurality of packets containing said cellular signals; and

means for transmitting said packets to at least a first destination within said data network.

26. The apparatus of claim 25 wherein said cellular signals comprise coded baseband signals.

27. The apparatus of claim 25 wherein said cellular signals comprise radio frequency signals.

28. The apparatus of claim 25 wherein said cellular signals comprise intermediate frequency signals.

29. The apparatus of claim 25 wherein said cellular signals comprise transmit diversity signals.

30. A method for interfacing a cellular network with a data network, said method comprising:

receiving cellular signals from said cellular network;

creating a plurality of packets containing said cellular signals; and

transmitting said packets to at least a first destination within said data network.

31. Apparatus for interfacing a cellular network with a data network, said apparatus comprising:

means for receiving packets from said data network, said packets comprising a plurality of cellular signals;

means for extracting said cellular signals from said packets; and

means for transmitting said cellular signals to at least a first destination within said cellular network.

32. The apparatus of claim 31 wherein said cellular signals comprise coded baseband signals.

33. The apparatus of claim 31 wherein said cellular signals comprise radio frequency signals.

34. The apparatus of claim 31 wherein said cellular signals comprise intermediate frequency signals.

35. The apparatus of claim 31 wherein said cellular signals comprise receive diversity signals.

36. A method for interfacing a cellular network with a data network, said method comprising:

receiving packets from said data network, said packets comprising a plurality of cellular, signals;

extracting said cellular signals from said packets; and

transmitting said cellular signals to at least a first destination within said cellular network.

37. A method for use in synchronizing the timing between a wireless network and a data network, said method comprising:

determining the minimum time for transmission between two points in said data network;

estimating a delay spread over a first plurality of data packets transmitted across said data network;

delaying the transmission of a second plurality of data packets from at least a first node in said data network.

38. The method of claim 37 wherein said step of estimating comprises measuring a delay spread over said first plurality of data packets.

39. The method of claim 37 wherein said node comprises a remote radio head.

40. A method for use in synchronizing the frequency between a wireless network and a data network, said method comprising:

forwarding to a remote radio head a frequency reference associated with a first clock, said first clock associated with a data network; and

locking the frequency associated with a second clock with said frequency reference, said second clock associated with said remote radio head.

41. A method for use in synchronizing the frequency between a wireless network and a data network, said method comprising:

applying a first indication of a time to at least a first data packet, said data packet comprising a plurality of coded cellular signals;

recording at a first node in said data network the arrival time of said at least a first data packet;

determining a difference between said first indication and said arrival time of said at least a first data packet; and

maintaining said difference between said first indication and said arrival time by altering a clock associated with said first node in said data network.

42. The method of claim 41 wherein said coded cellular signals comprise coded cellular baseband signals.

43. The method of claim 41 wherein said at least a first data packet is selected as having a small said difference between said first indication and said arrival time relative to the value of said difference for at least a second data packet in a plurality of data packets.

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