[0007] According to the second aspect of the present invention, there is provided a method of operating a virtual DAS network, the method comprising: receiving a first signal including a first plurality of carriers from a first BTS; receiving a second signal including a second plurality of carriers from a second BTS; routing the first and second signals to a first DRU; and routing the first and second signals to a second DRU.

[0007a] The method may further include: associating the first and second signals with one of a plurality of DRUs based on a geographic usage pattern, the plurality of DRUs comprising the first DRU and the second DRU. Routing the first and second signals to the second DRU may include routing the first ~~a~~ and second signals through a plurality of DAUs.

[0008] According to the third aspect of the present invention, there is provided a method of operating a virtual DAS network, the method comprising: receiving a first signal from a first BTS; receiving a second signal from a second BTS; routing the first signal to a first DRU; routing the second signal to a second DRU; receiving a third signal from the first BTS; and routing the third signal to the second DRU.

[0008a] The method may further include: repeatedly assigning the first DRU to one of a plurality of BTSs, the plurality of BTSs including the first BTS and the second BTS. The first DRU may be assigned at least partly in an attempt to evenly distribute combined BTS resources across DRUs in the network. Routing the third signal to the second DRU may include: routing the third signal through a plurality of DAUs.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIGs. 1A and 1B illustrates two types of wireless networks: a non-virtualized wireless network and a virtualized wireless network according to an embodiment of the present invention;

[0010] FIG. 2 is a simplified schematic diagram of a virtual DAS network according to an embodiment of the present invention;

[0011] FIG. 3 is a simplified flowchart illustrating a method of operating a virtual DAS network according to an embodiment of the present invention;

[0012] FIG. 4 is a simplified flowchart illustrating a method of operating a virtual DAS network according to an embodiment of the present invention;

[0013] FIG. 5 is a block diagram showing a multi-channel High Power Remote Radio Head Unit according to one embodiment of the present invention;

[0014] FIG. 6 is a block diagram according to one embodiment of the invention showing the basic structure and an example of a Flexible Simulcast downlink transport scenario based on having 2 DAU and 4 DRU;

[0015] FIG. 7 is a block diagram in accordance with an embodiment of the invention showing the basic structure and an example of a Flexible Simulcast uplink transport scenario based on having 2 DAU and 4 DRU;

[0016] FIG. 8 shows an embodiment of an indoor system employing multiple Remote Radio Head Units (RRUs) and a central Digital Access Unit (DAU);

[0028] The current exponential growth of demand for mobile data capacity results in a need for exponential over-provisioning for many wireless network operators. Even if an operator had an exponential growth in capital to build capacity supply, there are physical limitations that may prevent exponential growth in installations of conventional wireless equipment such as physical space, municipality zoning requirements, power availability, and the like.

[0029] Embodiments of the present invention provide solutions to the widening gap discussed above with game-changing SCR technologies for broadband mobile networks. SCR may comprise a complex interplay of digital signal processing (DSP) algorithms, RF technologies, intelligent network protocols, and system architectures. SCR-based distributed antenna systems (DAS) and small cell solutions may impact the user experience for wireless operators, enterprises and end users. In particular, the virtualization technology described herein may enable massive, scalable broadband data throughput while providing efficiency, flexibility, and control that is unparalleled in the wireless infrastructure industry. The increased efficiency and utilization of new and existing assets may fundamentally change the way operators plan and deploy their wireless networks.

[0030] Embodiments of the present invention provide a flexible, cloud-like architecture not available using conventional systems. FIGs. 1A and 1B illustrates two types of wireless networks: a non-virtualized wireless network 100 and a virtualized wireless network 150. Referring to FIG. 1A, ~~In~~ in the non-virtualized wireless network 100, base station hotels merely co-locate conventional systems together in the same locations. BTS equipment inside base station hotels may have limited, if any, interoperability among different BTS OEM vendors. For example, BTS OEM vendors may have architected their BTS equipment to work mostly with their own kind because of technical issues and/or economic motivations. From a technical viewpoint, BTS have sophisticated management and control signals that are proprietary to a particular OEM, and so BTS interoperability among different BTS OEM vendors may be difficult to achieve. Some BTS OEM vendors would claim that their BTS equipment had virtualization features, but a closer look may reveal that such claimed virtualization only occur within similar systems of the same vendor. From the economic side, BTS OEM may be incentivized to monopolize or "lock-up" as many operator customers as possible and therefore BTS OEM vendors have historically demonstrated strong resistance and reluctance to make their BTS architecture a true open standard. For example, vendors may sell BTS equipment initial at substantial discounts to wireless operators, though they may then later make substantial

economic benefits against their operator customers by charging a premium on service agreements or upgrades. BTS equipment used in conjunction with conventional DAS system in a base station hotel may provide some form of joint-operation on the conventional DAS network, but again the BTS's of different OEM vendors are not interoperable with respect to each other.

[0031] Referring to FIG. 1B, As virtualized wireless network 150 may include a base station "farm" in which base stations are provisioned in a novel way, enabling underlying BTS hardware to be commoditized and used in a freely interoperable and scalable configurations. As described herein, embodiments of the present invention may enable the mix-and-match usage of base station from different OEM vendors. RF outputs of each BTS may be subject to rigorous industry standard. However, virtualized wireless networks may include one or more DAUs connected to one or more BTSs, such that the DAUs receive standard RF output of the BTSs. Thus, the DAUs may connect to BTSs from any OEM vendor, and BTSs from any OEM vendor can thus be added heterogeneously to the network, forming a basis of a base station farm. Similarly, DAUs may connect to one or more BTSs which provide a signal including a plurality of carriers using different broadcast protocols (e.g., CDMA, WCDMA or LTE). Also, due to the novel SCR-based architecture of the DAS network, all BTS from any BTS OEM vendors can supply capacity resources interoperable to the same network. Thus, embodiments of the present invention may provide a form of true virtualization not available using conventional systems. Embodiments of the present invention may provide for virtualization of base station farms to harness massive, scalable capacity resources. Some embodiments of the present invention are applicable in relation to mixed-mode air-interfaces in which LTE is included as one of the carriers (along with a mix of other signals such as WCDMA).

[0032] As described herein, virtualization of wireless network may provide significant benefits to wireless operators.: For example, multiple BTSs can be pooled into one or more BTS farms. This may vastly simplify network management and maintenance. Since each BTS in a conventional wireless network may be provisioned inflexibly to a particular coverage area, virtualization as disclosed herein may eliminate one-to-one dependency between a BTS and an associated fixed coverage area. Instead, each BTS can be flexibility provisioned for a large number of DRUs on a virtual DAS network at any time. If coverage is needed for a new area, additional DRUs can easily be added and configured to the existing virtual DAS network at the new area for the new coverage. This virtualization scheme may ensure provisioning of highest capacity availability and performance, while at the same time increasing efficiency, utilization,

covers a fixed cell area, and over-provisioning is needed to accommodate peak time traffic. Wireless operators would need to add BTS with more capacity. This is a non-scalable approach.

[0036] Embodiments of the present invention provide a virtualized wireless network that is characterized by a number of benefits and improvements over conventional systems. For example, a virtualized wireless network such as one disclosed herein may allow one wireless network to serve one wireless operator exclusively or the same wireless network to serve multiple wireless operators, as in a "neutral host" environment. Further, since all heterogeneous BTSs in the BTS farm or cloud-farm need not be fixed to any particular cell site (as in the case of conventional wireless network), each of the BTS in the farm or cloud-farm can provide capacity and coverage to one of the multiple configurable areas where a suitable DRU is located. As a result, unlimited capacity can, in theory, be harnessed from the BTS farm or cloud-farm to the virtualized wireless network. This is a novel and highly scalable approach.

[0037] FIG. 3 is a simplified flowchart illustrating a method of operating a virtual DAS network according to an embodiment of the present invention. At 310, a first signal including a first plurality of carriers from a first BTS may be received. At 312, a second signal including a second plurality of carriers from a second BTS may be received. At 314, the first and second signal may be routed to a first DRU. At 316, the first and second signal may be routed to a second DRU.

[0038] FIG. 4 is a simplified flowchart illustrating a method of operating a virtual DAS network according to an embodiment of the present invention. At 410, a first signal from a first BTS may be received. At 412, a second signal from a second BTS may be received. At 414, the first signal may be routed to a first DRU. At 416, the second signal may be routed to a second DRU. Signals subsequently received from the BTSs may be routed differently (e.g., based on network demands). For example, at 418, a third signal may be received from the first BTS. At 420, the third signal may be routed to the second DRU, rather than the first DRU. It may be apparent that the descriptions of FIG. 3 and 4 may correspond to any of the descriptions provided in ~~FIGs. 1 and 2~~ FIGS. 1B and 2.

[0039] It should be appreciated that the specific steps illustrated in FIG. 3 or FIG. 4 provide a particular method of operating a virtual DAS network according to some embodiments of the present invention. Other sequences of steps may also be performed according to alternative embodiments. For example, alternative embodiments of the present invention may perform the

[0064] Referring next to FIG. 14, the software embedded in the DAU and DRU, which controls the operation of key functions of these devices, can be better understood. In particular, the DAU embedded software control module 1400 comprises a DAU Management Control Module 1405 and a DAU monitoring module 1410. The DAU Management Control Module 1405 communicates with the NOC 1415, and also the DAU monitoring module 1410. One such key function is determining and/or setting the appropriate amount of radio resources (such as RF carriers, CDMA codes or TDMA time slots) assigned to a particular DRU or group of DRUs to meet desired capacity and throughput objectives. As noted previously, the NOC 1415 monitors the DAS operation and sends commands to the DAU's for configuring various functions of the DRU's as well as the DAU, in at least some embodiments.

[0065] The DAU Monitoring module, in addition to other functions, detects which carriers and corresponding time slots are active for each DRU. The DAU Management Control module communicates with the DRU Embedded Software Control module 1420 over a fiber optic link control channel via a control protocol. In an embodiment, the control protocol comprises headers together with packets of data, such that both control information and data are transmitted to the DRU's together as a message. DRU functions or features that the header would control in the DRU are typically implementation specific and can include, among other things, measuring uplink and downlink power, measuring gain of uplink and downlink, and monitoring alarms in the DRU.

[0066] In turn, the DRU Management Control module 1425 within the DRU Embedded Software Control Module sets the individual parameters of all the DRU Digital Up-Converters 1430 to enable or disable specific radio resources from being transmitted by a particular DRU or group of DRUs, and also sets the individual parameters of all the DRU Digital Down-Converters 1435 to enable or disable specific radio resources from being transmitted by a particular DRU or group of DRUs. In addition, the DRU Embedded Software Control Module comprises a DRU Pilot Beacon Control Module 1440, which communicates with a DRU Pilot Beacon 1445.

[0067] Referring next to FIG. 15, an embodiment of a daisy-chained configuration of DAU's is illustrated, together with a daisy-chained configuration of DRU's. In an embodiment, a plurality of base stations 1500A-1500n are each associated with one of DAU's 1505A-n. The DAU's are daisy-chained, and each DAU communicates with one or more daisy-chains 1510A-1510m of

WHAT IS CLAIMED IS:

1. A network comprising:

a first base transceiver station (BTS) operable to provide a first signal including a plurality of first carriers;

a first digital access unit (DAU) coupled to the first BTS;

a second BTS operable to provide a second signal including a plurality of second carriers;

~~a set of one or more digital access units (DAUs), each of the one or more DAUs being coupled to at least one of the first BTS or the second BTS~~a second DAU coupled to the second BTS;

a first digital remote unit (DRU) coupled to the first DAU and the second DAU and operable to broadcast one or more of the first plurality of carriers and one or more of the second plurality of carriers; and

~~a set of one or more digital remote units (DRUs), each of the DRUs being coupled to one of the one or more DAUs and operable to broadcast the first signal or the second signal~~a second DRU coupled to the first DAU and the second DAU and operable to broadcast one or more of the first plurality of carriers and one or more of the second plurality of carriers.

2. The network of claim 1 wherein the first BTS is associated with a first infrastructure supplier and the second BTS is associated with a second infrastructure supplier.

3. The network of claim 2 wherein the first infrastructure supplier and the second infrastructure supplier are a same infrastructure supplier.

4. The network of claim 1 wherein the ~~one or more BTSs~~ first BTS and the second BTS provide the first signal including the plurality of first carriers and the second signal including the second plurality of carriers using differing broadcast protocols.

5. The network of claim 4 wherein the different broadcast protocols comprise at least one of CDMA or WCDMA

6. The network of claim 4 wherein the different broadcast protocols comprise LTE.

7. The network of claim 1 wherein the ~~one or more DAUs comprise a plurality of DAUs~~ first DAU and the second DAU are coupled via at least one of Ethernet cable, Optical Fiber, Microwave Line of Sight Link, Wireless Link, or Satellite Link.

8. The network of claim 7 wherein the ~~one or more DAUs comprise a plurality of DAUs~~ first DAU and the second DAU are coupled to the ~~plurality of DRUs~~ first DRU and the second DRU via at least one of Ethernet cable, Optical Fiber, Microwave Line of Sight Link, Wireless Link, or Satellite Link.

9. The network of claim 1 wherein the ~~one or more DRUs comprise a plurality of DRUs~~ first DRU and the second DRU are connected in a daisy chain configuration.

10. The network of claim 1 wherein the ~~one or more DRUs comprise a plurality of DRUs~~ first DRU and the second DRU are connected to the ~~one or more DAUs~~ first DAU and the second DAU in a star configuration.

11. The network of claim 1 wherein ~~each of the one or more DAUs~~ the first DAU and the second DAU are coupled to at least one of the first BTS or the second BTS via at least one of a Ethernet cable, Optical Fiber, Microwave Line of Sight Link, Wireless Link, or Satellite Link.

12. A method of operating a virtual ~~DAS~~ Distributed Antenna System (DAS) network, the method comprising:

receiving a first signal including a first plurality of carriers from a first ~~BTS~~ base transceiver station (BTS);

receiving a second signal including a second plurality of carriers from a second BTS;

routing the first signal and the second signal~~s~~ to a first ~~DRU~~ digital remote unit (DRU), wherein the first DRU is operable to broadcast one or more of the first plurality of carriers and one or more of the second plurality of carriers; ~~and~~

routing the first signal and the second signal~~s~~ to a second DRU, wherein the second DRU is operable to broadcast one or more of the first plurality of carriers and one or more of the second plurality of carriers.

13. The method of claim 12 further comprising:

associating the first signal and the second signals ~~with one of a plurality of DRUs~~ based on a geographic usage pattern, the plurality of DRUs comprising the first DRU and the second DRU.

14. The method of claim 12 wherein routing the first signal and the second signals to the second DRU comprises routing the first signal ~~s~~ and the second signals through a plurality of ~~DAUs~~digital access units (DAU).

15. The method of claim 12 wherein the first BTS is associated with a first infrastructure supplier and the second BTS is associated with a second infrastructure supplier.

16. The method of claim 15 wherein the first infrastructure supplier and the second infrastructure supplier are a same infrastructure supplier.

17. A method of operating a virtual ~~DAS~~ Distributed Antenna System (DAS) network, the method comprising:

receiving a first signal including a first plurality of carriers from a first base transceiver station (BTS)~~BTS~~;

receiving a second signal including a second plurality of carriers from a second BTS;

routing ~~the first signal~~ a first subset of the first plurality of carriers and a first subset of the second plurality of carriers to a first ~~DRU~~ digital remote unit (DRU), wherein the DRU is operable to broadcast the first subset of the first plurality of carriers and the first subset of the second plurality of carriers;

routing ~~the second signal~~ a second subset of the first plurality of carriers and a second subset of the second plurality of carriers to a second DRU, wherein the second DRU is operable to broadcast the second subset of the first plurality of carriers and the second subset of the second plurality of carriers;

~~receiving a third signal from the first BTS; and~~

~~routing the third signal to the second DRU~~.

18. The method of claim 17 further comprising:

repeatedly assigning the first DRU to one of a plurality of BTSs, the plurality of BTSs including the first BTS and the second BTS.

19. The method of claim 18 wherein the first DRU is assigned at least partly in an attempt to evenly distribute combined BTS resources across DRUs in the network.

20. The method of claim 17 wherein routing ~~the third signal to the second DRU comprises routing the third signal~~ the first subset of the first plurality of carriers and the first subset of the second plurality of carriers and the second subset of the first plurality of carriers and the second subset of the second plurality of carriers including routing through a plurality of ~~DAUs~~ digital access units (DAU).

21. The method of claim 17 wherein the first BTS is associated with a first infrastructure supplier and the second BTS is associated with a second infrastructure supplier.

22. The method of claim 21 wherein the first infrastructure supplier and the second infrastructure supplier are a same infrastructure supplier.