

the standard DAS architecture still requires each source BTS to include an expensive RF module, and to support a high-power digital interface to the DAS head end. Further, the physical distance of this interface link is limited, unless some form of repeater is employed. In addition, the transport technologies supported are limited to those of traditional BTSs, making integration with native packet-based transport more difficult.

The distinct approaches offered by the two DAS architectures present service providers and network operators with a set of "either-or" of solutions, none of which may fully and simultaneously address challenges such as diversity of transport technologies, common access infrastructure, and versatility of coverage configurations, among others.

A more versatile DAS architecture is needed to address these and other challenges of configuring and deploying wireless access infrastructures. Accordingly, various embodiments of the present invention provide a flexible DAS that can: support a wide and expandable array of transport technologies from the network side; or support concurrent processing, transmission, and reception of communications according to some, or any or all of the relevant technologies; or support simultaneous RF transmission and reception on different RF carriers; or support versatile and diverse coverage topologies among a distribution of antenna nodes; or incorporate intelligent routing of signals to antenna nodes, and support load balancing among the antenna nodes; or enable different service providers to share a common wireless access infrastructure; or some combination of some or all of the forgoing.

Hence, in one respect, there is provided an apparatus comprising: a radio frequency (RF) conditioning module having a plurality of first physical interfaces and being configured to: receive respective input digital RF physical signals via at least two of the plurality of first physical interfaces, wherein the respective input digital RF physical signals include a plurality of RF base transceiver station (BTS) signals, split each received respective input digital RF physical signal into a respective number of duplicate signals, combine

particular duplicate signals selected from among each of the respective number of duplicate signals into one or more superposition RF signals, and route and transmit the one or more superposition RF signals to an array of remote antenna nodes to which the apparatus is configured to be communicatively coupled; and
5 one or more low-power RF modules each having a communicative connection to a respective one of the plurality of first physical interfaces, and each configured to: receive respective baseband digital optical signals via a respective second physical interface, wherein the respective baseband digital optical signals include a plurality of baseband signals in a baseband frequency range, modulate the
10 received respective baseband digital optical signal to a respective RF passband signal, and send the respective RF passband signal to the RF conditioning module via the communicative connection to the one of the plurality of first physical interfaces as one of the respective input digital RF physical signals.

In another respect, embodiments of the present system provide an
15 apparatus comprising: a radio frequency (RF) conditioning module having a plurality of first physical interfaces; one or more low-power RF modules each having a communicative connection to one of the plurality of first physical interfaces; a processor; and machine logic executable by the processor to cause the apparatus to: receive respective input digital RF physical signals via at least
20 two of the plurality of first physical interfaces of the RF conditioning module, wherein the respective input digital RF physical signals include a plurality of RF base transceiver station (BTS) signals, at the RF conditioning module, split each received respective input digital RF physical signal into a respective number of duplicate signals, at the RF conditioning module, combine particular duplicate
25 signals selected from among each of the respective number of duplicate signals into one or more superposition RF signals, at the RF conditioning module, route and transmit the one or more superposition RF signals to an array of remote antenna nodes to which the apparatus is configured to be communicatively coupled, at a given one of the one or more low-power RF modules, receive
30 baseband digital optical signals via a respective second physical interface, wherein the baseband digital optical signals include a plurality of baseband signals in a baseband frequency range, at the given one of the one or more low-power RF modules, modulate the received respective baseband digital optical signals to an RF passband signal, and at the given one of the one or more low-
35 power RF modules, send the RF passband

signal to the RF conditioning module via the communicative connection to the one of the plurality of first physical interfaces as one of the respective input digital RF physical signals.

In yet another respect, embodiments of the present system provide, in an apparatus comprising (i) a radio frequency (RF) conditioning module having a plurality of first physical interfaces and (ii) one or more low-power RF modules each having a communicative connection to one of the plurality of first physical interfaces, a method comprising: at the RF conditioning module, receiving respective input digital RF physical signals via at least two of the plurality of first physical interfaces, wherein the respective input digital RF physical signals include a plurality of RF base transceiver station (BTS) signals; at the RF conditioning module, splitting each received respective input digital RF physical signal into a respective number of duplicate signals; at the RF conditioning module, combining particular duplicate signals selected from among each of the respective number of duplicate signals into one or more superposition RF signals; at the RF conditioning module, routing and transmitting the one or more superposition RF signals to an array of remote antenna nodes to which the apparatus is communicatively coupled; at a given one or more of the one or more low-power RF modules, receiving respective baseband digital optical signals via a respective second physical interface, wherein the respective baseband digital optical signals include a plurality of baseband signals in a baseband frequency range; at the given one or more of the one or more low-power RF modules, modulating the received respective baseband digital optical signals to a respective RF passband signal; and at the given one or more of the one or more low-power RF modules, sending the respective RF passband signal to the RF conditioning module via the communicative connection to the one of the plurality of first physical interfaces as one of the respective input digital RF physical signals.

These as well as other aspects, advantages, and alternatives will become apparent to those of ordinary skill in the art by reading the following detailed description, with reference where appropriate to the accompanying drawings. Further, it should be understood that this

What is claimed:

1. An apparatus comprising:

a radio frequency (RF) conditioning module having a plurality of first physical interfaces and being configured to:

5 receive respective input digital RF physical signals via at least two of the plurality of first physical interfaces, wherein the respective input digital RF physical signals include a plurality of RF base transceiver station (BTS) signals,

 split each received respective input digital RF physical signal into
10 a respective number of duplicate signals,

 combine particular duplicate signals selected from among each of the respective number of duplicate signals into one or more superposition RF signals,

 and route and transmit the one or more superposition RF signals to
15 an array of remote antenna nodes to which the apparatus is configured to be communicatively coupled; and

 one or more low-power RF modules each having a communicative connection to a respective one of the plurality of first physical interfaces, and each configured to:

20 receive respective baseband digital optical signals via a respective second physical interface, wherein the respective baseband digital optical signals include a plurality of baseband signals in a baseband frequency range,

 modulate the received respective baseband digital optical signal to
25 a respective RF passband signal,

 and send the respective RF passband signal to the RF conditioning module via the communicative connection to the one of the plurality of first physical interfaces as one of the respective input digital RF physical signals.

2. The apparatus of claim 1, wherein at least one of the plurality of first physical interfaces is configured to receive an input digital RF physical signal from a base transceiver station (BTS) device in a wireless service provider network that operates according to a CDMA family of protocols.
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3. The apparatus of claim 2, wherein the input digital RF physical signal from the BTS device is a passband signal.
4. The apparatus of claim 2, wherein the respective second physical interface is
- 10 configured to receive a digital signal from at least one of a base station controller in a wireless service provider network and a network routing device in a wireless service provider network.
5. The apparatus of claim 4, further comprising a smart antenna interface having a
- 15 communicative connection with the RF conditioning module and being configured to:
- receive traffic load information from at least one of the BTS device and the BBU device; and
- based on the received traffic load information, cause the RF conditioning
- 20 module to adjust a distribution of transmission power applied to the one or more superposition RF signals that the RF conditioning module routes and transmits to the array of remote antenna nodes.
6. The apparatus of claim 4, wherein the RF conditioning module is further
- 25 configured to:
- receive respective reverse superposition RF signals from one or more remote antenna nodes of the array of antenna nodes;
- deconstruct each of the received respective superposition RF signals into a one or more respective reverse passband signals; and

route and transmit each of the one or more respective reverse passband signals to a respective destination, wherein the respective destination is selected from the group consisting of the BTS device, and the BBU device.

- 5 7. The apparatus of claim 1, wherein the array of remote antenna nodes comprises a number of antenna nodes,

and wherein the RF conditioning module is configured to split each received respective input digital RF physical signal into a respective number of duplicate signals by being configured to:

- 10 split each received respective input digital RF physical signal into a number of duplicate signals that equals the number of antenna nodes.

8. The apparatus of claim 7, wherein the RF conditioning module is configured to combine particular duplicate signals selected from among each of the respective
15 number of duplicate signals into one or more superposition RF signals by being configured to:

- combine one of the number of duplicate signals from each split respective input digital RF physical signal into each of a number of superposition RF signals, wherein the number of superposition RF signals equals the number of antenna
20 nodes.

9. The apparatus of claim 1, further comprising a plurality of electrooptical converters each having a communicative connection to one of a plurality of third physical interfaces of the RF conditioning module, and each given electro-optical
25 converter of the plurality of electro-optical converters being configured to:

receive one of the one or more superposition RF signals from the RF conditioning module;

convert the received one of the one or more superposition RF signals into an optical superposition RF signal; and

transmit the optical superposition RF signal to an antenna node of the array of remote antenna nodes via a respective fourth physical interface of the given electro-optical converter that is configured for communication with the antenna node.

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10. The apparatus of claim 9, wherein the RF conditioning module is configured to route and transmit the one or more superposition RF signals to the array of remote antenna nodes by being configured to:

route and send each of the one or more superposition RF signals to one of
10 the plurality of electro-optical converters via one of the plurality of third physical interfaces.

11. An apparatus comprising:

a radio frequency (RF) conditioning module having a plurality of first
15 physical interfaces;

one or more low-power RF modules each having a communicative connection to one of the plurality of first physical interfaces;

a processor; and

machine logic executable by the processor to cause the apparatus to:

20 receive respective input digital RF physical signals via at least two of the plurality of first physical interfaces of the RF conditioning module, wherein the respective input digital RF physical signals include a plurality of RF base transceiver station (BTS) signals,

at the RF conditioning module, split each received respective input
25 digital RF physical signal into a respective number of duplicate signals,

at the RF conditioning module, combine particular duplicate signals selected from among each of the respective number of duplicate signals into one or more superposition RF signals,

at the RF conditioning module, route and transmit the one or more superposition RF signals to an array of remote antenna nodes to which the apparatus is configured to be communicatively coupled,

5 at a given one of the one or more low-power RF modules, receive baseband digital optical signals via a respective second physical interface, wherein the baseband digital optical signals include a plurality of baseband signals in a baseband frequency range,

at the given one of the one or more low-power RF modules, modulate the received respective baseband digital optical signals to an RF passband signal,

10 and at the given one of the one or more low-power RF modules, send the RF passband signal to the RF conditioning module via the communicative connection to the one of the plurality of first physical interfaces as one of the respective input digital RF physical signals.

15 12. The apparatus of claim 11, wherein at least one of the plurality of first physical interfaces is configured to receive an input digital RF physical signal from a base transceiver station (BTS) device in a wireless service provider network that operates according to a CDMA family of protocols.

20 13. The apparatus of claim 12, wherein the input digital RF physical signal from the BTS device is a passband signal.

14. The apparatus of claim 12, wherein the second physical interface is configured
25 to receive a digital signal from at least one of a base station controller in a wireless service provider network and a network routing device in a wireless service provider network.

15. The apparatus of claim 14, further comprising a smart antenna interface
30 having a communicative connection with the RF conditioning module,

wherein the machine logic is executable by the processor to further cause the apparatus to:

at the smart antenna interface, receive traffic load information from at least one of the BTS device and the BBU device; and

5 at the smart antenna interface, based on the received traffic load information, cause the RF conditioning module to adjust a distribution of transmission power applied to the one or more superposition RF signals that the RF conditioning module routes and transmits to the array of remote antenna nodes.

10 16. The apparatus of claim 14, wherein the machine logic is executable by the processor to further cause the apparatus to:

at the RF conditioning module, receive respective reverse superposition RF signals from one or more remote antenna nodes of the array of antenna nodes;

15 at the RF conditioning module, deconstruct each of the received respective superposition RF signals into a one or more respective reverse passband signals; and

20 at the RF conditioning module, route and transmit each of the one or more respective reverse passband signals to a respective destination, wherein the respective destination is selected from the group consisting of the BTS device, and the BBU device.

17. The apparatus of claim 11, further comprising a plurality of electrooptical converters each having a communicative connection to one of a plurality of third physical interfaces of the RF conditioning module,

25 wherein the machine logic is executable by the processor to further cause the apparatus to:

at a given one of the plurality of electro-optical converters, receive one of the one or more superposition RF signals from the RF conditioning module;

at the given one of the plurality of electro-optical converters, convert the received one of the one or more superposition RF signals into an optical superposition RF signal; and

5 at the given one of the plurality of electro-optical converters, transmit the optical superposition RF signal to an antenna node of the array of remote antenna nodes via a respective fourth physical interface of the given one of the electro-optical converters that is configured for communication with the antenna node.

18. The apparatus of claim 11, wherein the machine logic is at least one of (i) software instructions stored in machine readable memory accessible by the processor, (ii) hardware logic, and (iii) firmware logic.

19. In an apparatus comprising (i) a radio frequency (RF) conditioning module having a plurality of first physical interfaces and (ii) one or more lowpower RF modules each having a communicative connection to one of the plurality of first physical interfaces, a method comprising:

20 at the RF conditioning module, receiving respective input digital RF physical signals via at least two of the plurality of first physical interfaces, wherein the respective input digital RF physical signals include a plurality of RF base transceiver station (BTS) signals;

at the RF conditioning module, splitting each received respective input digital RF physical signal into a respective number of duplicate signals;

25 at the RF conditioning module, combining particular duplicate signals selected from among each of the respective number of duplicate signals into one or more superposition RF signals;

at the RF conditioning module, routing and transmitting the one or more superposition RF signals to an array of remote antenna nodes to which the apparatus is communicatively coupled;

30 at a given one or more of the one or more low-power RF modules, receiving respective baseband digital optical signals via a respective second

physical interface, wherein the respective baseband digital optical signals include a plurality of baseband signals in a baseband frequency range;

at the given one or more of the one or more low-power RF modules, modulating the received respective baseband digital optical signals to a respective RF passband signal; and

at the given one or more of the one or more low-power RF modules, sending the respective RF passband signal to the RF conditioning module via the communicative connection to the one of the plurality of first physical interfaces as one of the respective input digital RF physical signals.

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20. The method of claim 19, wherein receiving the respective input digital RF physical signals via the at least two of the plurality of first physical interfaces comprises receiving at least one input digital RF physical signal from a base transceiver station (BTS) device in a wireless service provider network that operates according to a CDMA family of protocols.

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21. The method of claim 20, wherein the at least one input digital RF physical signal from the BTS device is a passband signal.

22. The method of claim 20, wherein receiving the respective baseband digital optical signal via the respective second physical interface comprises receiving a digital signal from at least one of a base station controller in a wireless service provider network and a network routing device in a wireless service provider network.

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23. The method of claim 22, wherein the apparatus further comprises a smart antenna interface having a communicative connection with the RF conditioning module,

and wherein the method further comprises:

at the smart antenna interface, receiving traffic load information from at least one of the BTS device and the BBU device; and

at the smart antenna interface, based on the received traffic load information, causing the RF conditioning module to adjust a distribution of transmission power applied to the one or more superposition RF signals that the RF conditioning module routes and transmits to the array of remote antenna nodes.

24. The method of claim 22, further comprising:

at the RF conditioning module, receiving respective reverse superposition RF signals from one or more remote antenna nodes of the array of antenna nodes;

at the RF conditioning module, deconstructing each of the received respective superposition RF signals into a one or more respective reverse passband signals; and

at the RF conditioning module, routing and transmitting each of the one or more respective reverse passband signals to a respective destination, wherein the respective destination is selected from the group consisting of the BTS device, and the BBU device.

25. The method of claim 19, wherein the array of remote antenna nodes comprises a number of antenna nodes,

and wherein splitting each received respective input digital RF physical signal into the respective number of duplicate signals comprises:

splitting each received respective input digital RF physical signal into a number of duplicate signals that equals the number of antenna nodes.

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26. The method of claim 25, wherein combining the particular duplicate signals selected from among each of the respective number of duplicate signals into the one or more superposition RF signals comprises:

combining one of the number of duplicate signals from each split respective input digital RF physical signal into each of a number of superposition

RF signals, wherein the number of superposition RF signals equals the number of antenna nodes.

27. The method of claim 19, wherein the apparatus further comprises a plurality
5 of electro-optical converters each having a communicative connection to one of a plurality of third physical interfaces of the RF conditioning module,

and wherein the method further comprises:

at each of one or more of the plurality of electro-optical converters,
receiving one of the one or more superposition RF signals from the RF
10 conditioning module;

at each of the one or more of the plurality of electro-optical converters,
converting the received one of the one or more superposition RF signals into an optical superposition RF signal; and

at each of the one or more of the plurality of electro-optical converters,
15 transmitting the optical superposition RF signal to an antenna node of the array of remote antenna nodes via a respective fourth physical interface of the each of the one or more of the plurality of electro-optical converters.

28. The method of claim 27, wherein routing and transmitting the one or more
20 superposition RF signals to an array of remote antenna nodes comprises:

routing and sending each of the one or more superposition RF signals to the one or more of the plurality of electro-optical converters via one of the plurality of third physical interfaces.