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CARRIER AGGREGATION BASED ON USER LOCATION AND USER PROFILE

Abstract

A base station establishes a mobile communications network utilizing multiple component carriers. The base station receives one or both of location data and profile data associated with user equipment devices connected to the mobile communications network. The base station selects carrier aggregation schemes for each of the user equipment devices based on one or both of the location data and the profile data.

Related U.S. Application Data

Publication Classification

Background/Summary

BACKGROUND

Technical Field

[0001] The present disclosure relates to mobile wireless communication systems, and more particularly relates to mobile communication systems that use carrier aggregation.

Description of the Related Art

[0002] Wireless mobile communication technology uses various standards and protocols to transmit data between a base station and user equipment (user equipment device). Wireless wide area network communication system standards and protocols can include, for example, the 3rd Generation Partnership Project (3GPP).

[0003] Current 3GPP for 5G specifications support specific component carrier bandwidths such as 5 MHz, 10 MHz, 15, MHz or 20 MHz. Individual component carriers, however, to meet the International Mobile Telecommunications Advanced (IMT-Advanced) requirements for very high data rates, the concept of carrier aggregation has been introduced to support bandwidths larger than 20 MHz. Also, carrier aggregation helps wireless operators to increase their data rates over the chunks of spectrum they own, intraband or interband. Currently, the carrier aggregation concept in LTE allows up to 32 component carriers of the same frame structure to be aggregated such that the total bandwidth available to a mobile terminal is the sum of the bandwidths of the cells. The 5G New Radio (NR) allows carrier aggregation of up to 16 component carriers. As used herein, a component carrier may be referred to as a cell.

[0004] While carrier aggregation may provide various benefits, it can still be difficult to provide satisfying service to all user equipment devices. For example, simply providing carrier aggregation may not address the variations in user traffic in a communication system from moment to moment. Accordingly, in many circumstances individual user equipment devices may experience reduced data speeds from a particular base station. This can result in unsatisfied users.

BRIEF SUMMARY

[0005] Embodiments of the present disclosure provide, from a base station, a mobile communication network that dynamically selects carrier aggregation schemes for each of a plurality of user equipment devices based on current traffic characteristics in the mobile communication network. The base station selects, for each user equipment device, a respective carrier aggregation scheme that results in high spectral efficiency for the mobile communication network based on current traffic characteristics in the mobile network. The carrier aggregation scheme for a user equipment device indicates which of the component carriers supported by the base station will be made available to the user equipment device.

[0006] In one embodiment, the base station obtains location data for each user equipment device. The location data indicates the current location of the user equipment device. The base station selects, for each user equipment device, a carrier aggregation scheme based on the location of the user equipment device. The base station may select, for each user equipment device, a carrier aggregation scheme based on the locations of all of the user equipment devices currently connected to the mobile communication network.

[0007] In one embodiment, the base station obtains profile data for each user equipment device. The profile data for a user equipment device indicates uplink and downlink data rates needed by the user equipment device. The base station selects a carrier aggregation scheme for the user equipment device based on the profile data. The base station may select, for each user equipment device, a carrier aggregation scheme based on the profile data of all of the user equipment devices currently connected to the mobile communication network.

[0008] In one embodiment, the base station trains an analysis model for a machine learning process

to select carrier aggregation schemes for all of the user equipment devices currently connected to the base station. The analysis model can select a carrier aggregation scheme based on either or both of the location data and the profile data associated with the user equipment devices connected to the base station. The result is a high spectral efficiency for the mobile communication network.

[0009] In one embodiment, a method includes supporting a plurality of component carriers with a first base station and establishing, with the first base station, a network connection with a first user equipment device. The method includes receiving, with the first base station, first location data indicating a location of the first user equipment device and selecting a first carrier aggregation scheme for the first user equipment device based on the first location data.

[0010] In one embodiment, a method includes supporting a plurality of component carriers with a first base station and establishing, with the first base station, a cellular connection with a first user equipment device. The method includes storing, with the first base station, first profile data indicating bandwidth needs of the user equipment device; and selecting a first carrier aggregation scheme for the first user equipment device based on the first profile data.

[0011] In one embodiment, a method includes storing training data. The training data includes historical profile data including bandwidth needs of a plurality of a plurality of historical user equipment devices previously connected to a base station supporting multiple component carriers. The training data includes historical carrier aggregation schemes assigned to the historical user equipment and historical spectral efficiency data of the base station. The method includes training, with a machine learning process using the training data, an analysis model to select carrier aggregation schemes for user equipment devices based on bandwidth needs.

Description

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0012] FIG. **1** is a block diagram of a wireless communication system, according to one embodiment.

[0013] FIG. **2**A is a representation of component carriers in a frequency spectrum, according to one embodiment.

[0014] FIG. **2**B is a representation of carrier aggregation schemes assigned to user equipment devices in a mobile communications network, according to one embodiment.

[0015] FIG. **3** is a block diagram of a base station, according to one embodiment.

[0016] FIG. **4** is a flow diagram of a method for operating a mobile communication network base station, according to one embodiment.

[0017] FIG. **5** is a flow diagram of a method for operating a mobile communication network base station, according to one embodiment.

[0018] FIG. **6** is a flow diagram of a method for operating a mobile communication network base station, according to one embodiment.

DETAILED DESCRIPTION

[0019] FIG. **1** is a block diagram of a wireless communication system **100**, according to one embodiment. The wireless communication system **100** includes a base station **102** and a plurality of user equipment devices **104**. The base station **102** enables the user equipment devices **104** to communicate with other user equipment devices or to send and receive data via the Internet. As will be set forth in more detail below, the base station **102** selects carrier aggregation schemes for the user equipment devices **104** based on profile data **108** and location data **110**.

[0020] User equipment devices **104** can include one or more of mobile phones, tablets, gaming devices, wearable smart devices, Internet of Things devices, and other types of devices. The user equipment devices **104** can include other types of devices without departing from the scope of the present disclosure.

[0021] The base station **102** includes a transceiver **114**, a transmission filter **116**, a receiving filter **118**, and a control system **119**. The transceiver **114** transmits mobile communication signals to the user equipment device **104**, to other base stations, and to other communication systems to enable mobile communication and access to the Internet.

[0022] The control system **119** includes one or more computer readable media that store software instructions for establishing a mobile communication network with the base station **102**. The control system **118** includes one or more processors configured to execute the instructions stored in one or more computer readable media.

[0023] In one embodiment, the communication system **100** is a 3GPP network. The communication system **100** can include a new radio (NR) fifth generation (5G) network. The communication system **100** can include other types of networks without departing from the scope of the present disclosure.

[0024] 3GPP standards have defined specific bandwidths that can be utilized by 5G NR user equipment device. In particular, user equipment devices can utilize bandwidths of 5 MHZ, 10 MHZ, 15 MHZ, 20 MHz, etc. 3GPP standards for 5G do not provide for user equipment devices utilizing bandwidths that are below 5 MHz or that are not multiples of 5 MHz.

[0025] Organizations and companies that wish to provide wireless communication network services typically purchase the rights to a particular portion of wireless spectrum. For example, 3GPP standards define a large number of evolved universal mobile telecommunications system (E-UTRA) bands in the radio frequency spectrum. Wireless service providers can purchase, license, or otherwise acquire bandwidth within one or more of these bands and can then provide mobile communication services within that portion of the band.

[0026] The base station **102** includes a plurality of component carriers **106**. The component carriers can include bandwidth block of 5 MHz, 10, MHz, 15 MHZ or 20 MHz, or sizes of frequency ranges as standards permit. In many cases, the component carriers are separated from each other in the frequency spectrum. The wireless communication system **100** utilizes carrier aggregation to promote high spectral efficiency. Carrier aggregation is a technique enabled in 3GPP standards that enables multiple component carriers to be assigned to the same user equipment device. The maximum possible data rate per user equipment device is increased the more component carriers are assigned to the user equipment device. Traditionally, three types of carrier aggregation have been utilized: intraband continuous carrier aggregation, intraband noncontiguous carrier aggregation, and interband carrier aggregation. Intraband contiguous carrier aggregation corresponds to a situation in which the component carriers are contiguous of each other, i.e. one component carrier begins where the other component carrier ends. Intraband noncontiguous carrier aggregations correspond to a situation in which component carriers are in the same frequency band but are separated by a gap. Interband carrier aggregation corresponds a situation in which the component carriers lie in different frequency bands.

[0027] In one embodiment, in order to comply with 3GPP channel bandwidth, the base station **102** will be configured as a channel having a bandwidth that is the sum of the bandwidths of all of the component carriers. In one embodiment, the base station **102** includes a transmission filter **116**. The transmission filter **116** is a bandpass filter with a strict passband. The passband corresponds to the bandwidth that is assigned for the base station **102**. Any signals with frequencies outside the passband are filtered so that they are not transmitted from the base station **102**. This can help ensure that transmissions from the base station **102** do not infringe on bandwidth assigned to adjacent networks, while meeting the out of band emissions.

[0028] In one embodiment, the base station **102** includes a receiving filter **118**. The receiving filter **118** is configured to ensure that the base station **102** will reject any signals outside of its designated bandwidth. Accordingly, the receiving filter **118** is a bandpass filter with a strict passband corresponding to the assigned bandwidth of the communication system **100**. Thus, communications from networks in neighboring bandwidths will not be received by the base station **102**.

[0029] When large numbers of user equipment devices **104** are connected to the mobile communication network established by the base station **102**, even with carrier aggregation it can be difficult to ensure a high spectral efficiency. For a given mobile communications network, there is a theoretical maximum transmission bit rate based on the amount of bandwidth available and how many bits per second can be transmitted, in both uplink and downlink, for a given amount of bandwidth. Spectral efficiency corresponds to how much of the bandwidth is utilized.

[0030] In one embodiment, the base station **102** improves spectral efficiency by assigning carrier aggregation schemes to individual user equipment devices **104** by dynamically assigning carrier aggregation schemes to individual user equipment devices based on selected criteria. Details regarding the selected criteria will be provided further below. The dynamic assignment of carrier aggregation schemes to individual user equipment devices **104** can greatly improve spectral efficiency of the base station **102**.

[0031] The base station **102** may support multiple component carriers **106** in particular frequency ranges. However, an individual user equipment device **104** may or may not support using multiple component carriers. Some user equipment devices **104** may only support communication on a single component carrier. Some user equipment devices may support simultaneously using multiple component carriers. Some user equipment devices may only support multiple component carriers in particular frequency ranges.

[0032] When the base station **102** establishes a network connection with the user equipment device **104**, the base station **102** requests the carrier aggregation capabilities of the user equipment device **104**. The user equipment device **104** responds by indicating whether or not the user, device **104** is capable of carrier aggregation. The user equipment device **104** may indicate the maximum number of component carriers that can be utilized by the user equipment device **104**. The user equipment device **104** may also indicate the frequency bands supported by the user equipment device **104** in carrier aggregation.

[0033] After the base station **102** receives the carrier aggregation capability information from the user equipment device **104**, the base station **102** assigns a carrier aggregation scheme to the user equipment device **104**. The carrier aggregation scheme can include assigning all of the available component carriers to the user equipment device **104**, multiple component carriers but not all available component carriers, or only a single component carrier. The base station **102** can make this assignment based on the carrier aggregation capabilities of the user equipment device **104** as well as other factors, as will be described in more detail below.

[0034] A carrier aggregation scheme will indicate which component carrier is the primary component carrier in which component carriers are secondary component carriers for a user equipment device **104**. A user equipment device **104** will primarily utilize the primary component carrier for data transmission and reception. If the primary component carrier does not, by itself, satisfy the data transmission requests of the user equipment device **104**, then the user equipment device **104** can utilize the additional component carriers assigned to it in the carrier aggregation scheme. If no secondary component carriers are made available by the base station **102** to the user equipment device **104**, then all data transmission will occur on the primary component carrier.

[0035] In one embodiment, the base station **102** assigns carrier aggregation schemes to the user equipment devices **104** based on the locations of the user equipment devices **104**. Each component carrier has a particular frequency range. In general, component carriers do not have overlapping frequency range. Some component carriers' frequency ranges may be separated from each other by hundreds of MHz. In general, signals with lower frequencies travel farther than signals with higher frequencies without dissipating. A user equipment device **104** that is farther from the base station **102** may benefit from utilizing a component carrier in a lower frequency band, whereas a user equipment device **104** that is near the base station may benefit from utilizing a component carrier in a higher band. Accordingly, the base station **102** can assign component carriers to individual user equipment devices **104** based on the locations of the user equipment devices **104**.

[0036] In one example, the base station **102** supports two component carriers. The base station **102** may assign to a relatively distant user equipment device **104** a carrier aggregation scheme in which the primary component carrier is the lower frequency component carrier and the secondary component carrier is the higher frequency component carrier. The base station **102** may assign to a relatively nearby user equipment device **104** a carrier aggregation scheme in which the higher frequency component carrier is the primary component carrier and the secondary component carrier is the lower frequency component carrier. This can improve the overall spectral efficiency of the base station **102**. Alternatively, the base station **102** may assign carrier aggregation schemes in which both user equipment devices **104** are able to use only a single component carrier.

[0037] In one embodiment, the base station **102** dynamically adjusts carrier aggregation schemes assigned to user equipment devices **104** based on changing location distributions of the user equipment devices. From moment to moment, the number of connected user equipment devices **104**, and the distribution of distances from the base station **102** may change. Initially, there may be a small number of user equipment devices **104** that are near the base station **102** and a small number of user equipment devices **104** that are distant from the base station **102**. The base station **102** may initially assign only a higher frequency component carrier to the user equipment devices **104** that are near the base station **102**. However, after some amount of time there may be a larger number of user equipment devices **104** near the base station **102**. In this case, the base station **102** may assign to one or more of the user equipment devices **104** carrier aggregation schemes in which a lower frequency component carrier is made available as a secondary component carrier. This may improve the spectral efficiency of the base station **102**. Likewise, the base station **102** may adjust carrier aggregation schemes for one or more user equipment devices **104** that are distant from the base station **102** in a similar manner.

[0038] The base station **102** may obtain location data **110** associated with a user equipment device **104** in various ways. In some cases, the base station **102** may request location data **110** from user equipment device **104**. The base station **102** may provide location data **110** to the base station **102** including GPS coordinates of the user equipment device **104**.

[0039] In one example, the base station **102** may request location data **110** from the user equipment device **104** and the user equipment device **104** may not have GPS coordinates or other location data. In this case, the base station **102** may request that the user equipment device **104** outputs a reference signal that is received by the base station **102** and multiple other base stations. The other base stations record timestamp indicating the time that the reference signal was received. The other base stations pass these timestamps to the base station **102**. The base station **102** then calculates the location of the user equipment device **104** based on the timestamps and no locations received from the other base stations.

[0040] The base station **102** may obtain location data **110** from each connected user equipment device **104** periodically. For example, the base station **102** may obtain new location data **110** are each connected user equipment device every minute, several times per minute, or at other intervals so that the base station **102** can continuously update carrier aggregation schemes for the various user equipment devices **104**.

[0041] In one embodiment, the base station **102** may receive a hand off for a particular user equipment device **104** from a nearby base station. In other words, the user equipment device **104** may initially be connected to a base station near the base station **102**. As the user equipment device **104** travels closer to the base station **102**, a hand off may occur so that the base station **102** connects to the user, device **104**. During this hand off, the other base station may indicate the current carrier aggregation scheme assigned to user equipment device **104**. The base station **102** may elect to maintain the same carrier aggregation scheme or may elect to change the carrier aggregation scheme based on current conditions.

[0042] In one embodiment, the base station **102** obtains profile data **108** associated with each user equipment device **104** currently connected to the base station **102**. The profile data **108** indicates

the current data transmission needs or requests of the user equipment device **104**. The base station **102** selects, for each user equipment device connected to the base station **102**, a carrier aggregation scheme based on the profile data **108** of all of the user equipment devices **104** currently connected to the base station **102**.

[0043] In one embodiment, the profile data **108** for a user equipment device **104** indicates both the uplink and downlink data needs of the user equipment device **104**. The base station **102** selects carrier aggregation schemes for the user equipment devices **104** based on the uplink and downlink data needs or requests of the user equipment devices **104**. The base station **102** selects a combination of carrier aggregation schemes to promote high spectral efficiency.

[0044] In one example, some users may have heavy data utilization on the downlink direction unless data utilization on the uplink direction. The base station **102** may provide carrier aggregation schemes for the various user equipment devices **104** that provide more bandwidth on the downlink direction to boost downlink throughputs. For user equipment devices with heavy utilization on the uplink channels and less traffic on the downlink channels, the base station **102** may provide carrier aggregation schemes that combine more bandwidth on the uplink direction to boost uplink throughputs. This can lead to better user experiences.

[0045] The base station **102** can dynamically adjust carrier aggregation schemes based on changing conditions of the mobile communication network. For example, data uplink and downlink utilization may vary from moment to moment for the various user equipment devices **104**. Furthermore, the number of user equipment devices **104** that are connected to the base station **102** can change from moment to moment. The base station **102** can dynamically adjust carrier aggregation schemes for the user equipment devices **104** based on the current profile data **108** of the currently connected user equipment devices **104**.

[0046] The base station **102** can obtain the profile data **108** for each user equipment device **104** by analyzing the current fit rate utilization or requested bit rate utilization of the user equipment device **104**. Because all transmitted data on the mobile communication network goes to the base station **102**, the base station **102** can know at all times the data needs or requests of each user equipment device **104**.

[0047] In one embodiment, the base station **102** maintains an analysis model **112**. The analysis model **112** can include an algorithm or other type of model that determines carrier aggregation schemes for each of the user equipment devices **104**. The analysis model can determine the carrier aggregation schemes based on the number of currently connected user equipment devices **104**, the location data **110** associated with each user equipment device **104**, and the profile data **108** of each user equipment device **104**.

[0048] One embodiment, the base station **102**, or another system in communication with the base station **102**, generates the analysis model **112** with a machine learning process. The machine learning process can include assigning carrier aggregation schemes to user equipment devices **104** in accordance with one or both of the location data **110** and the profile data **108** (as per use case) and determining the spectral efficiency for each distribution of carrier aggregation schemes. The machine learning process can utilize this data as training data. The spectral efficiency can be determined for a large number of distributions of carrier aggregation schemes. The machine learning process can determine the distribution carrier aggregation schemes that results in high spectral efficiencies for various sets of location data profile data. After the machine learning processes train the analysis model **112**, the analysis model **112** can use one or both of location data **110** profile data **108** of each currently connected the user equipment device **104** as inputs in order to generate carrier aggregation schemes for each user equipment device **104**. Further details regarding the machine learning process are provided in relation to FIG. **3**.

[0049] FIG. **2**A is a graph illustrating multiple component carriers supported by a base station **102**, according to one embodiment. In the example of FIG. **3**, a first component carrier **106***a* has a frequency band between frequencies f**1** and f**2**. A second component carrier **106***b* has a frequency

band between frequencies f**3** and f**4**. A third component carrier **106***c* has a frequency band between frequencies f**5** and f**6**.

[0050] In one example, the component carriers **106***a* and **106***c* each have a same amount of bandwidth, though in different frequency ranges. The component carrier **106***b* has a larger amount of bandwidth than the component carriers **106***a* and **106***c*. In one example, the component carriers **106***a* and **106***c* each have a 5 MHz bandwidth and the component carrier **106***b* has a bandwidth of 10 MHz. The component carriers **106***a-c* can have other bandwidths without departing from the scope of the present disclosure.

[0051] Though not shown in FIG. **2**A, in one example, two or more of the component carriers can be contiguous with each other. In this case, the frequency range one component carrier begins at the end of the frequency of another component carrier. There are various possible distributions of component carriers.

[0052] While FIG. **2**A illustrates three component carriers **106***a-c*, in practice, the base station **102** may support to component carriers or more than three component carriers. Various numbers of component carriers can be utilized by the base station **102** without departing from the scope of the present disclosure.

[0053] FIG. **2**B illustrates carrier aggregation schemes assigned to each of four user equipment devices **104***a-d*, according to one embodiment. In the example of FIG. **2**B, the base station **102** supports the three component carriers shown in FIG. **2**A. In the illustrated carrier aggregation schemes, the asterisk indicates the primary component carrier in the carrier aggregation scheme. The other component carriers in a carrier aggregation scheme are secondary component carriers.

[0054] In the example of FIG. **2**B, the base station **102** has signed a carrier aggregation scheme to the user equipment device **104***a* in which the first component carrier is the primary component carrier and the second component carrier is a secondary component carrier. The base station **102** has assigned the carrier aggregation scheme to the user equipment device **104***b* in which the third component carrier is the primary component carrier and the second component carrier is the secondary component carrier. The base station **102** has assigned a carrier aggregation scheme to the user equipment device **104***c* in which the second component carrier is the primary component carrier and the first and third component carriers are secondary component carriers. The base station **102** has assigned the carrier aggregation scheme to the user equipment device **104***d* in which only the third component carrier is made available. Accordingly, the third component carrier is the primary component carrier for the user equipment device **104***d* and no secondary component carriers are signed.

[0055] FIG. **3** is a block diagram of the base station **102**, according to one embodiment. The block diagram of the base station **102** indicates data and assets of the base station **102** that may participate in generating an analysis model **120**. Although the various data and resources are shown as part of the base station **102**, in practice, another computing system can include the data and resources and to generate the analysis model **120** and provide the analysis model to the base station **102**. Furthermore, the various data and resources can be distributed among the various computing systems.

[0056] FIG. **3** is a block diagram of the control system **119** of a base station **102**, according to one embodiment. The control system **119** is one example of the control system **119** of the base station **102** of FIG. **1**. The control system **119** is configured to generate an analysis model **112**, according to one embodiment. The analysis model **112** of FIG. **3** is one example of the analysis model **112** of FIG. **1**. The control system **119** utilizes the analysis model to dynamically select and adjust carrier aggregation schemes for user equipment devices **104** connected to a base station **102**.

[0057] In one embodiment, the control system **119** includes an analysis model **112** and a training module **122**. The training module **122** trains the analysis model **112** with a machine learning process. The machine learning process trains the analysis model **112** to select carrier aggregation schemes for connected user equipment devices **104** that will result in high spectral efficiency.

Although the training module **122** is shown as being separate from the analysis model **112**, in practice, the training module **122** may be part of the analysis model **112**. The control system **119** can train the analysis model **112** with new user data regularly.

[0058] The control system **119** includes, or stores, training set data **124**. The training set data **124** includes historical profile data **126**, historical location data **128**, historical carrier aggregation data **130**, and historical spectral efficiency data **132**. The historical profile data corresponds to profile data associated with user equipment devices connected to the base station **102** in the past. The historical location data **128** corresponds to location data associated with user equipment devices **104** connected to the base station **102** in the past. The historical carrier aggregation data **130** corresponds to carrier aggregation schemes that were assigned to the user equipment devices **104** associated with the historical location data **128** and the historical carrier aggregation data **130**. The historical spectral efficiency data **132** corresponds to spectral efficiency measurements associated with the historical carrier aggregation schemes. The training module **122** utilizes the training set data **124** to train the analysis model **112** with a machine learning process to learn to select carrier aggregation schemes that results in high spectral efficiencies based on one or both of profile data **108** and location data **110**.

[0059] In one embodiment, the historical profile data **126**, the historical location data **128**, the historical carrier aggregation data **130**, and the historical spectral data **132** are arranged in sets. For example, a first set of historical profile data **126**, historical location data **128**, historical carrier aggregation data **130**, and historical spectral efficiency data **132** may be gathered or measured for a second time period. For example, a second set of historical profile data **126**, historical location data **128**, historical carrier aggregation data **130**, and historical spectral efficiency data **132** may be gathered or measured for a second time period. A large number of sets of these data may be gathered for large number of periods of time. Each of the steps, the historical carrier aggregation schemes are different from each other so that a large variety of historical carrier aggregation schemes are utilized in the training set data **124**.

[0060] In an initial portion of the machine learning process, the various sets of historical profile data **126**, historical location data **128**, and historical carrier aggregation data **130** are used as inputs, while the historical spectral efficiency data **132** is used as labels. During this initial portion of the machine learning process, the analysis model **112** is trained through iterations to predict the historical spectral efficiencies based on the historical profile data **126**, the historical location data **128**, and the historical carrier aggregation data **130**. During a second portion of the machine learning process, the analysis model **112** is trained to generate distributions of carrier aggregation schemes that will result in high spectral efficiencies based on historical profile data **126** and historical location data **128**.

[0061] In one embodiment the analysis model **112** includes a neural network. However, other types of analysis models or algorithms can be used without departing from the scope of the present disclosure. The training module **122** utilizes the training set data **124** to train the neural network with a machine learning process. During the training process, the neural network receives, as input, the historical profile data **126**, the historical location data **128**, and the historical carrier aggregation data **130**. During the training process, the neural network outputs predictions of spectral efficiency based on the training data. The training process also trains the neural network to generate carrier aggregation scheme distributions that will result in high spectral efficiencies.

[0062] In one embodiment, the neural network includes a plurality of neural layers. Each neural layer includes internal functions. The internal functions include weighting values associated with the neural layer of the neural network. During training, the control system **119** compares, for each set of historical profile data **126**, historical location data **128**, and historical carrier aggregation data **130**, the predicted spectral efficiency and compares the predicted spectral efficiency with the actual historical spectral efficiency values. The control system generates an error function indicating how closely the predicted spectral efficiency values match the historical spectral efficiency values. The

control system **119** then adjusts the internal functions of the neural network. Because the neural network generates predicted structural efficiency data based on the internal functions, adjusting the internal functions will result in the generation of different predicted spectral efficiency data for a same set of historical profile, location, and carrier aggregation data. Adjusting the internal functions can result in smaller or larger error values.

[0063] After adjusting the internal functions of the neural network, the historical profile data, location data and the carrier aggregation data is again passed to the neural network and the analysis model **112** again generates predicted spectral efficiency data. The training module **122** again compares the predicted spectral efficiency data to the historical spectral efficiency data. The training module **122** again adjusts the internal functions of the neural network. This process is repeated in a very large number of iterations of monitoring the error functions and adjusting the internal functions of the neural network until a set of internal functions is found that results in predicted spectral efficiency data that matches the historical spectral efficiency data **132**.

[0064] In one embodiment, the analysis model **112** includes two neural networks coupled together in an encoder decoder configuration. The encoder neural network is trained with the training process described above to generate predicted spectral efficiencies. The decoder network is trained to receive the predicted spectral efficiencies and to reproduce the historical carrier aggregation data **130** that resulted in the predicted historical spectral efficiencies.

[0065] The training of the decoder neural network is similar to the training of the encoder neural network. The decoder neural networks includes a plurality of neural layers as described above in relation to the encoder neural network. The decoder neural network receives as inputs a spectral efficiency value and historical profile location data and generates as output historical carrier aggregation data. The training process utilizes the historical carrier aggregation data **130** as labels. For each spectral efficiency value, the decoder neural network generates predicted carrier aggregation data. The predicted carrier aggregation data is compared to the historical carrier aggregation data and an error function is generated. The internal functions of the decoder neural network are adjusted in iterations until the decoder neural network can generate predicted carrier aggregation data carrier data that historical carrier aggregation data **130** within an error tolerance.

[0066] In one embodiment, after the analysis model **112** has been trained, the analysis model **112** can be utilized to generate sets of carrier aggregation schemes that will result in high spectral efficiencies. For example, current profile data **108** and/or location data **110** of the user equipment devices **104** currently connected to the base station **102**, as well as a desire high spectral efficiency value are provided to the decoder as inputs. The decoder neural network generates carrier aggregation schemes that will result in the high spectral efficiency value based on the profile data **108** and the location data **110**. The base station **102** can then assign carrier aggregation schemes to each of the currently connected user equipment devices.

[0067] In one embodiment, the control system **119** includes processing resources **134**, memory resources **136**, and communication resources **138**. The processing resources **134** can include one or more controllers or processors. The processing resources **134** are configured to execute software instructions, process data, make carrier aggregation scheme decisions, perform signal processing, read data from memory, write data to memory, and to perform other processing operations. The processing resources **134** can include physical processing resources **134** located at the base station **102**. The processing resources can include virtual processing resources **134** remote from the base station **102**. The processing resources **134** can include cloud-based processing resources including processors and servers accessed via one or more cloud computing platforms.

[0068] In one embodiment, the memory resources **136** can include one or more computer readable memories. The memory resources **136** are configured to store software instructions associated with the function of the control system and its components, including, but not limited to, the analysis model **112**. The memory resources **136** can store data associated with the function of the control system **119** and its components. The data can include the training set data **124**, current process

conditions data, and any other data associated with the operation of the control system **119** or any of its components. The memory resources **136** can include physical memory resources located at the base station **102**. The memory resources can include virtual memory resources located remotely from base station **102**. The memory resources **136** can include cloud-based memory resources accessed via one or more cloud computing platforms.

[0069] In one embodiment, the communication resources **138** can include resources that enable the control system **119** to communicate with components of the base station **102**. For example, the communication resources **138** can include wired and wireless communication resources that enable the control system **119** to communicate with components of the base station **102** or with other systems. In one embodiment, the analysis model **112** is implemented via the processing resources **134**, the memory resources **136**, and the communication resources **138**. The control system **119** can be a dispersed control system with components and resources and locations remote from each other and from base station **102**.

[0070] FIG. **4** is a flow diagram of a method **400** for operating a base station, in accordance with some embodiments. The method **400** can utilize the systems, components, and processes described in relation to FIGS. **1**-**3**. At **402**, the method **400** includes supporting a plurality of component carriers with a first base station. At **404**, the method **400** includes establishing, with the first base station, a network connection with a first user equipment device. At **406**, the method **400** includes receiving, with the first base station, first location data indicating a location of the first user equipment device. At **408**, the method **400** includes selecting a first carrier aggregation scheme for the first user equipment device based on the first location data.

[0071] FIG. **5** is a flow diagram of a method **500** for operating a base station, in accordance with some embodiments. The method **500** can utilize the systems, components, and processes described in relation to FIGS. **1**-**3**. At **502**, the method **500** includes supporting a plurality of component carriers with a first base station. At **504**, the method **500** includes establishing, with the first base station, a cellular connection with a first user equipment device. At **506**, the method **500** includes storing, with the first base station, first profile data indicating bandwidth needs of the user equipment device. At **508**, the method **500** includes selecting a first carrier aggregation scheme for the first user equipment device based on the first profile data.

[0072] FIG. **6** is a flow diagram of a method **600** for training an analysis model for a base station, in accordance with some embodiments. The method **600** can utilize the systems, components, and processes described in relation to FIGS. **1**-**3**. At **602**, the method **600** includes storing training data. The training set data includes historical profile data including bandwidth needs of a plurality of a plurality of historical user equipment devices previously connected to a base station supporting multiple component carriers. The training set data includes historical carrier aggregation schemes assigned to the historical user equipment. The training set data includes historical spectral efficiency data of the base station. At **604**, the method **600** includes training, with a machine learning process using the training data, an analysis model to select carrier aggregation schemes for user equipment devices based on bandwidth needs.

[0073] The various embodiments described above can be combined to provide further embodiments. Aspects of the embodiments can be modified, if necessary, to employ concepts of the various patents, applications and publications to provide yet further embodiments.

[0074] These and other changes can be made to the embodiments in light of the above-detailed description. In general, in the following claims, the terms used should not be construed to limit the claims to the specific embodiments disclosed in the specification and the claims, but should be construed to include all possible embodiments along with the full scope of equivalents to which such claims are entitled. Accordingly, the claims are not limited by the disclosure.

Claims

1. A method, comprising: obtaining historical profile data for a plurality of user equipment devices previously connected to a base station, wherein the historical profile data identifies bandwidth needs of the plurality of user equipment devices; obtaining historical location data for the plurality of user equipment devices, wherein the historical location data identifies a location of each of the plurality of user equipment devices relative to the base station when previously connected to the base station; obtaining historical carrier aggregation data for the plurality of user equipment devices, wherein the historical carrier aggregation data identifies carrier aggregation schemes assigned to the plurality of user equipment devices when previously connected to the base station; generating a model from the historical location data, the historical profile data, and the historical carrier aggregation data, wherein the model is trained to generate carrier aggregation schemes for different location distributions relative to the base station; determining a location and a profile of a user equipment device currently connected to the base station, wherein the profile identifies bandwidth needs of the user equipment device; and dynamically selecting a carrier aggregation scheme for the user equipment device by employing the model using the location and the profile of the user equipment device.

2. The method of claim 1, wherein generating the model comprises: obtaining historical spectral efficiency data for the carrier aggregation schemes identified in the historical carrier aggregation data, wherein the historical spectral efficiency data indicates an amount of bandwidth utilized by the plurality of user equipment devices when previously connected to the base station; and generating the model from the historical spectral efficiency data, the historical location data, the historical profile data, and the historical carrier aggregation data.

3. The method of claim 1, further comprises: wherein determining the profile of the user equipment device currently connected to the base station comprises: determining uplink bandwidth needs of the user equipment; and wherein dynamically selecting the carrier aggregation scheme for the user equipment device comprises: dynamically selecting the carrier aggregation scheme for the user equipment device by employing the model using the location and the uplink bandwidth needs of the user equipment device.

4. The method of claim 1, further comprises: wherein determining the profile of the user equipment device currently connected to the base station comprises: determining downlink bandwidth needs of the user equipment; and wherein dynamically selecting the carrier aggregation scheme for the user equipment device comprises: dynamically selecting the carrier aggregation scheme for the user equipment device by employing the model using the location and the downlink bandwidth needs of the user equipment device.

5. The method of claim 1, further comprises: wherein determining the profile of the user equipment device currently connected to the base station comprises: determining uplink and downlink bandwidth needs of the user equipment; and wherein dynamically selecting the carrier aggregation scheme for the user equipment device comprises: dynamically selecting the carrier aggregation scheme for the user equipment device by employing the model using the location and the uplink and downlink bandwidth needs of the user equipment device.

6. The method of claim 1, further comprises: determining a second location and a second profile of a second user equipment device currently connected to the base station, wherein the profile identifies second bandwidth needs of the second user equipment device; and dynamically selecting a second carrier aggregation scheme for the second user equipment device by employing the model using the second location and the second profile of the second user equipment device.

7. A base station system, comprising: a memory configured to store computer instructions; and a processor configured to execute the computer instructions to: obtain historical bandwidth needs data for a plurality of user equipment devices previously connected to a base station; obtain historical location data identifying locations of the plurality of user equipment devices relative to the base station when previously connected to the base station; obtain historical carrier aggregation

data identifying carrier aggregation schemes assigned to the plurality of user equipment devices when previously connected to the base station; and train a model to generate carrier aggregation schemes for different location distributions relative to the base station from the historical location data, the historical bandwidth needs data, and the historical carrier aggregation data.

8. The base station system of claim 7, wherein the processor generates the model by being configured to further execute the computer instructions to: obtain historical spectral efficiency data indicating bandwidth utilization of the plurality of user equipment devices using the carrier aggregation schemes identified in the historical carrier aggregation data; and train the model to generate carrier aggregation schemes for different location distributions relative to the base station from the historical location data, the historical bandwidth needs data, the historical spectral efficiency data, and the historical carrier aggregation data.

9. The base station system of claim 7, wherein the processor is configured to further execute the computer instructions to: establish a connection between the base station and a user equipment device; determine a location and bandwidth needs of the user equipment device; and dynamically select a carrier aggregation scheme for the user equipment device by employing the model using the location and the bandwidth needs of the user equipment device.

10. The base station system of claim 9, comprises: wherein the processor determines the bandwidth needs of the user equipment device by being configured to further execute the computer instructions to: determine uplink bandwidth needs of the user equipment; and wherein the processor dynamically selects the carrier aggregation scheme for the user equipment device by being configured to further execute the computer instructions to: dynamically select the carrier aggregation scheme for the user equipment device by employing the model using the location and the uplink bandwidth needs of the user equipment device.

11. The base station system of claim 9, comprises: wherein the processor determines the bandwidth needs of the user equipment device by being configured to further execute the computer instructions to: determine downlink bandwidth needs of the user equipment; and wherein the processor dynamically selects the carrier aggregation scheme for the user equipment device by being configured to further execute the computer instructions to: dynamically select the carrier aggregation scheme for the user equipment device by employing the model using the location and the downlink bandwidth needs of the user equipment device.

12. The base station system of claim 9, comprises: wherein the processor determines the bandwidth needs of the user equipment device by being configured to further execute the computer instructions to: determine uplink and downlink bandwidth needs of the user equipment; and wherein the processor dynamically selects the carrier aggregation scheme for the user equipment device by being configured to further execute the computer instructions to: dynamically select the carrier aggregation scheme for the user equipment device by employing the model using the location and the uplink and downlink bandwidth needs of the user equipment device.

13. The base station system of claim 9, wherein the processor is configured to further execute the computer instructions to: establish a second connection between the base station and a second user equipment device; determine a second location and second bandwidth needs of the second user equipment device; and dynamically select a second carrier aggregation scheme for the second user equipment device by employing the model using the second location and the second bandwidth needs of the second user equipment device.

14. The base station system of claim 7, wherein the processor is configured to further execute the computer instructions to: establish connections between the base station and a second plurality of user equipment devices; determine location and bandwidth needs of the second plurality of user equipment devices; and dynamically select carrier aggregation schemes for each of the second plurality of user equipment devices by employing the model using the location and bandwidth needs of the second plurality of user equipment device.

15. A non-transitory computer-readable storage medium that stores instructions that, when executed

by a processor in a computing system, cause the processor to perform actions, the actions comprising: training a model from historical location data for a plurality of user equipment devices previously connected to a base station, historical profile data for the plurality of user equipment devices, and historical carrier aggregation data for the plurality of user equipment devices, wherein the model generates carrier aggregation schemes for user equipment devices at different location distributions relative to the base station; establishing a current connection between the base station and a user equipment device; determining a location and a bandwidth needs of a user equipment device currently connected to the base station; and dynamically selecting a carrier aggregation scheme for the user equipment device by employing the model using the location and the bandwidth needs of the user equipment device.

16. The non-transitory computer-readable storage medium of claim 15, wherein generating the model comprises: obtaining historical spectral efficiency data for the carrier aggregation schemes identified in the historical carrier aggregation data, wherein the historical spectral efficiency data indicates an amount of bandwidth utilized by the plurality of user equipment devices when previously connected to the base station; and generating the model from the historical spectral efficiency data, the historical location data, the historical profile data, and the historical carrier aggregation data.

17. The method of claim 1, the actions comprising: wherein determining the profile of the user equipment device currently connected to the base station comprises: determining uplink bandwidth needs of the user equipment; and wherein dynamically selecting the carrier aggregation scheme for the user equipment device comprises: dynamically selecting the carrier aggregation scheme for the user equipment device by employing the model using the location and the uplink bandwidth needs of the user equipment device.

18. The non-transitory computer-readable storage medium of claim 15, the actions comprising: wherein determining the profile of the user equipment device currently connected to the base station comprises: determining downlink bandwidth needs of the user equipment; and wherein dynamically selecting the carrier aggregation scheme for the user equipment device comprises: dynamically selecting the carrier aggregation scheme for the user equipment device by employing the model using the location and the downlink bandwidth needs of the user equipment device.

19. The non-transitory computer-readable storage medium of claim 15, the actions comprising: wherein determining the profile of the user equipment device currently connected to the base station comprises: determining uplink and downlink bandwidth needs of the user equipment; and wherein dynamically selecting the carrier aggregation scheme for the user equipment device comprises: dynamically selecting the carrier aggregation scheme for the user equipment device by employing the model using the location and the uplink and downlink bandwidth needs of the user equipment device.

20. The non-transitory computer-readable storage medium of claim 15, the actions comprising: establishing a second current connection between the base station and a second user equipment device; determining a second location and second bandwidth needs of the second user equipment device; and dynamically selecting a second carrier aggregation scheme for the second user equipment device by employing the model using the second location and the second bandwidth needs of the second user equipment device.