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(54) **CONTROLLING WIRELESS DEVICE COMMUNICATION WITH ACCESS NODES**

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(22) Filed: **Feb. 19, 2014**

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H04W 36/22 (2009.01)

(52) **U.S. Cl.**
CPC *H04W 36/22* (2013.01)

(58) **Field of Classification Search**
CPC H04W 36/22
USPC 455/436–448, 453
See application file for complete search history.

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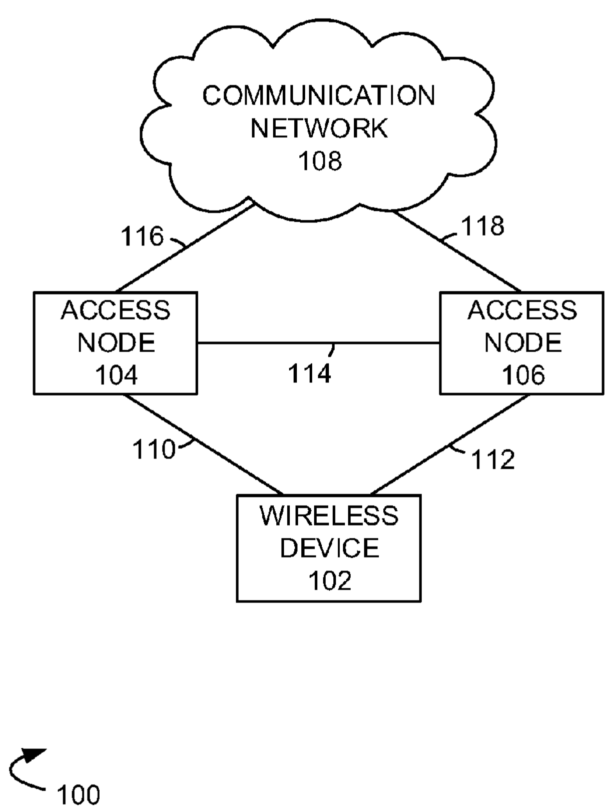
Primary Examiner — Brandon Miller

(57) **ABSTRACT**

When a first loading of a first access node is determined to meet a loading criteria, a handover criteria is decreased for a second access node comprising a coverage area at least a portion of which is within a coverage area of the first access node. A handover is performed of at least one of a plurality of wireless devices from the first access node to the second access node when a signal level of the second access node received at the at least one of the plurality of wireless devices meets the decreased handover criteria. Changes are determined in the first loading and in a throughput provided to the at least one of the wireless devices, and the handover criteria for the second access node is adjusted based on the changes in the first loading and the throughput provided to the at least one wireless device.

14 Claims, 6 Drawing Sheets



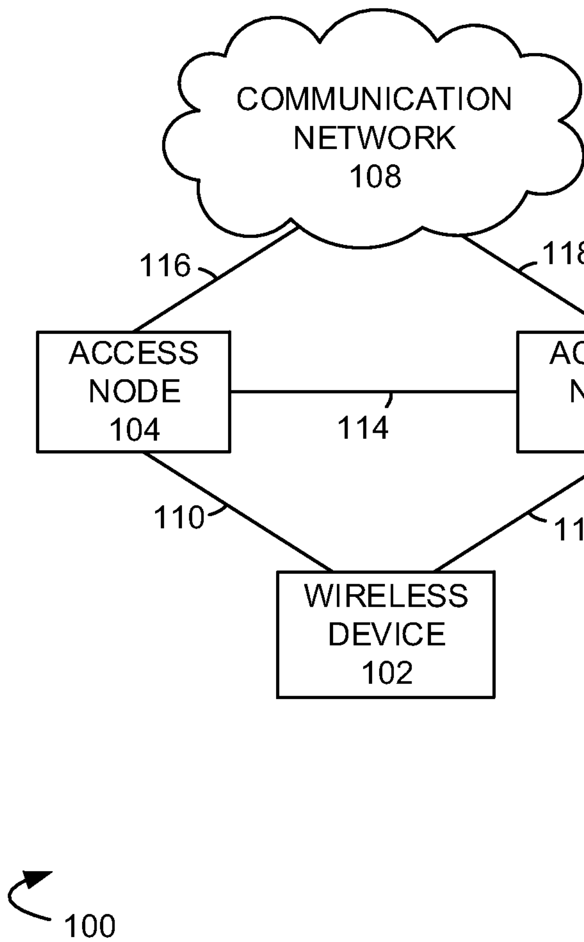

COMMUNICATION
NETWORK
108
116
118
ACCESS
NODE
104
114
ACCESS
NODE
106
110
112
WIRELESS
DEVICE
102
100

FIG. 1

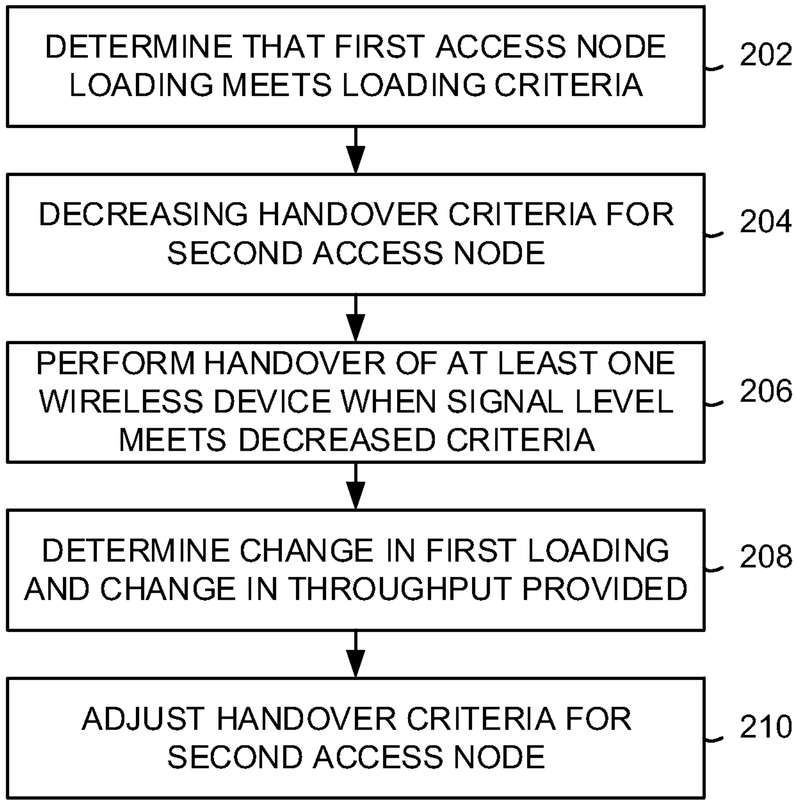

DETERMINE THAT FIRST ACCESS NODE LOADING MEETS LOADING CRITERIA
202
DECREASING HANDOVER CRITERIA FOR SECOND ACCESS NODE
204
PERFORM HANDOVER OF AT LEAST ONE WIRELESS DEVICE WHEN SIGNAL LEVEL MEETS DECREASED CRITERIA
206
DETERMINE CHANGE IN FIRST LOADING AND CHANGE IN THROUGHPUT PROVIDED
208
ADJUST HANDOVER CRITERIA FOR SECOND ACCESS NODE
210

FIG. 2

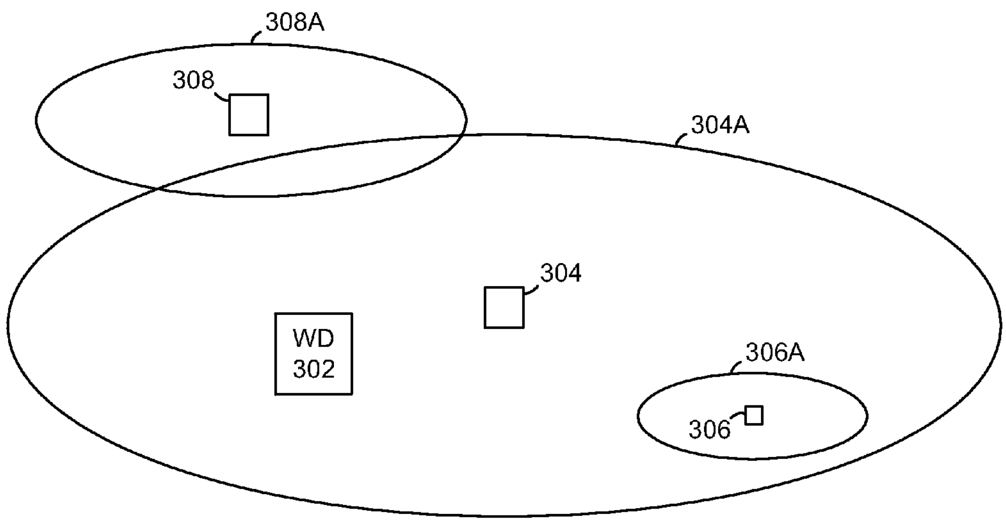


FIG. 3

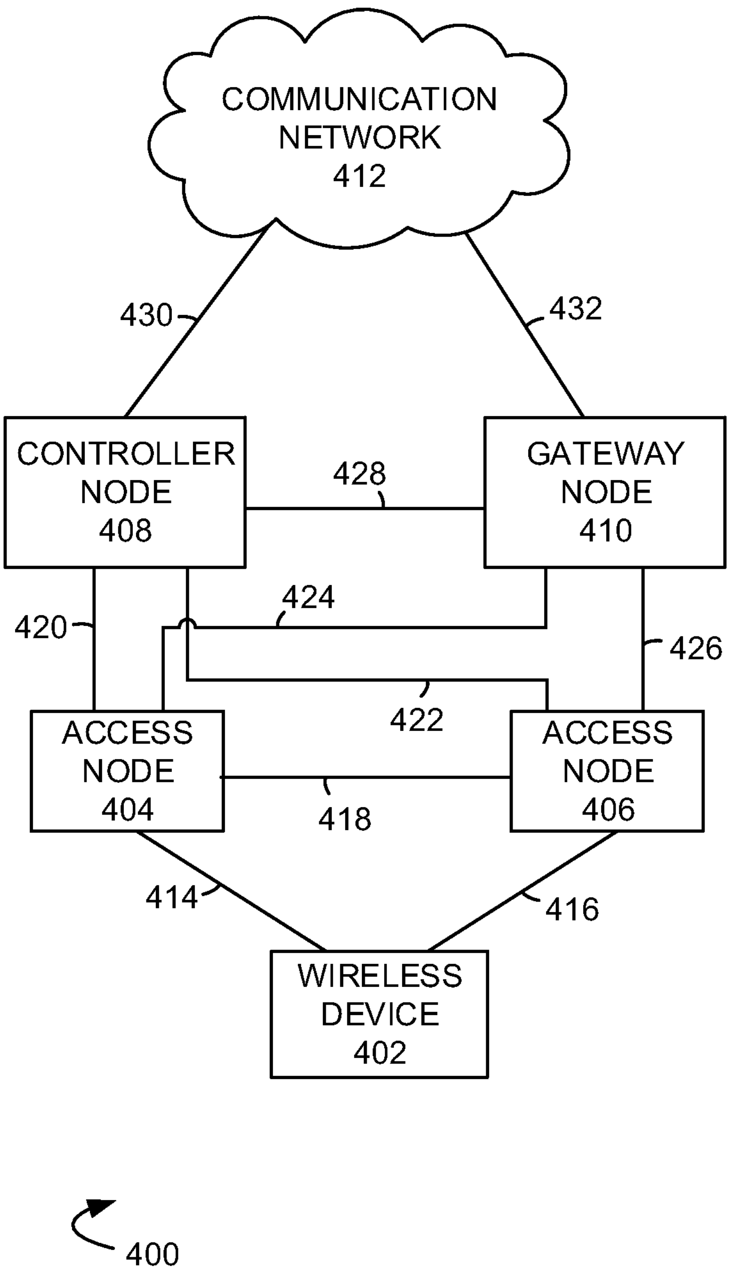

COMMUNICATION NETWORK 412
430
432
CONTROLLER NODE 408
428
GATEWAY NODE 410
424
420
426
422
ACCESS NODE 404
ACCESS NODE 406
418
414
416
WIRELESS DEVICE 402
400

FIG. 4

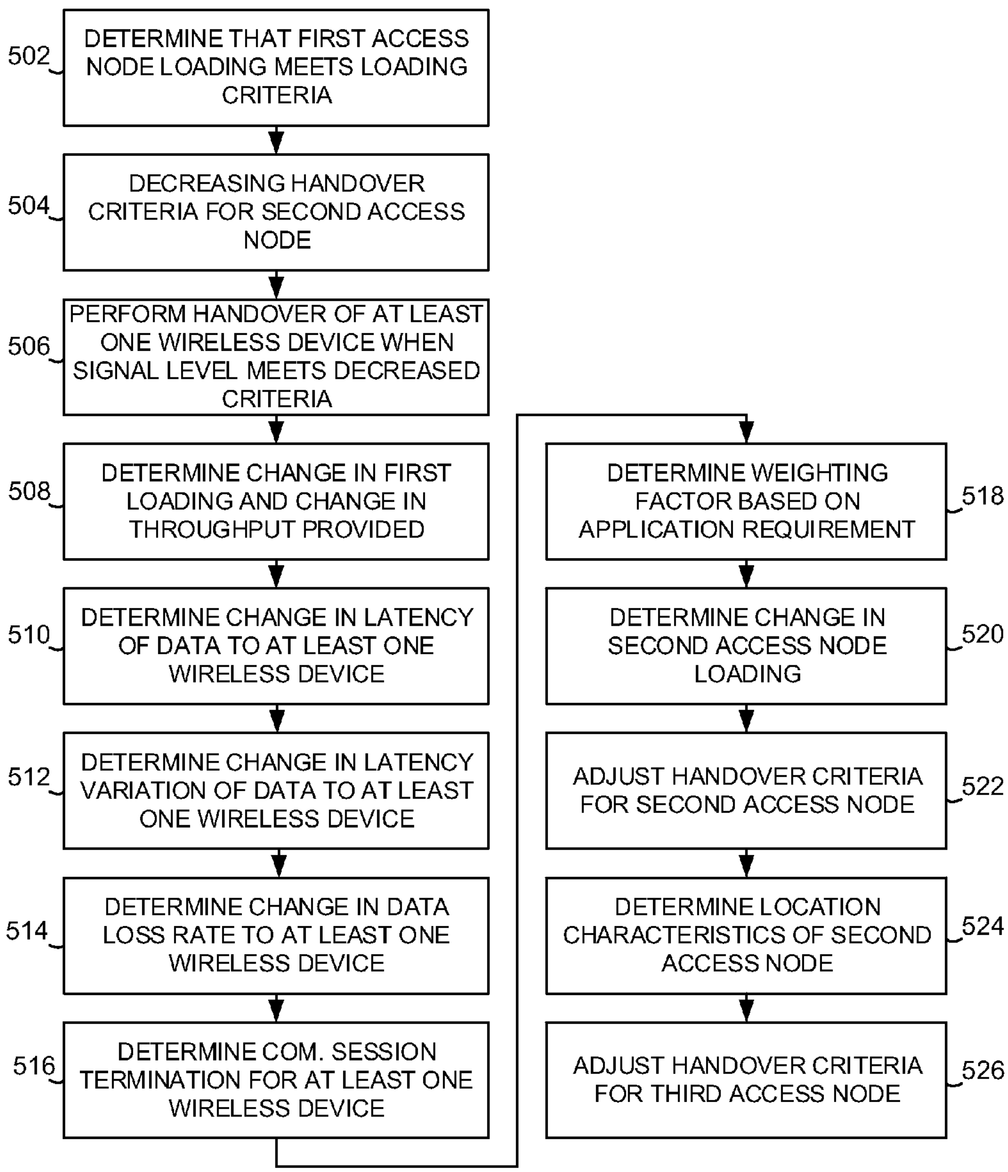

502
DETERMINE THAT FIRST ACCESS NODE LOADING MEETS LOADING CRITERIA
504
DECREASING HANDOVER CRITERIA FOR SECOND ACCESS NODE
506
PERFORM HANDOVER OF AT LEAST ONE WIRELESS DEVICE WHEN SIGNAL LEVEL MEETS DECREASED CRITERIA
508
DETERMINE CHANGE IN FIRST LOADING AND CHANGE IN THROUGHPUT PROVIDED
510
DETERMINE CHANGE IN LATENCY OF DATA TO AT LEAST ONE WIRELESS DEVICE
512
DETERMINE CHANGE IN LATENCY VARIATION OF DATA TO AT LEAST ONE WIRELESS DEVICE
514
DETERMINE CHANGE IN DATA LOSS RATE TO AT LEAST ONE WIRELESS DEVICE
516
DETERMINE COM. SESSION TERMINATION FOR AT LEAST ONE WIRELESS DEVICE
518
DETERMINE WEIGHTING FACTOR BASED ON APPLICATION REQUIREMENT
520
DETERMINE CHANGE IN SECOND ACCESS NODE LOADING
522
ADJUST HANDOVER CRITERIA FOR SECOND ACCESS NODE
524
DETERMINE LOCATION CHARACTERISTICS OF SECOND ACCESS NODE
526
ADJUST HANDOVER CRITERIA FOR THIRD ACCESS NODE

FIG. 5

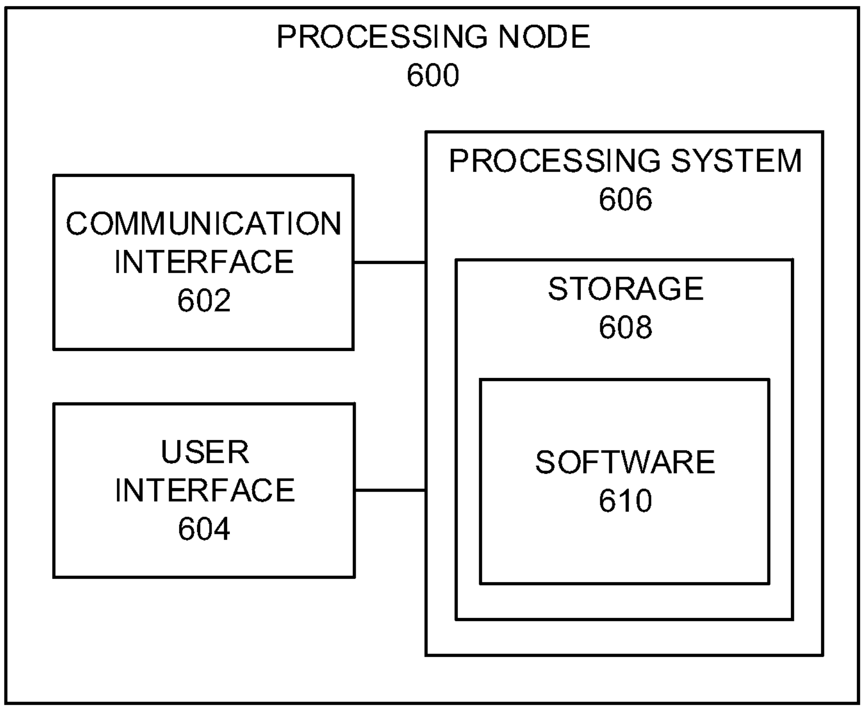

PROCESSING NODE
600
COMMUNICATION INTERFACE
602
USER INTERFACE
604
PROCESSING SYSTEM
606
STORAGE
608
SOFTWARE
610

FIG. 6

CONTROLLING WIRELESS DEVICE COMMUNICATION WITH ACCESS NODES

TECHNICAL BACKGROUND

Wireless communication networks increasingly comprise a variety of access nodes having different capabilities, including signal transmission power, coverage area, supported frequency bands, number of channels supported, and total number of wireless connections supported, among other things. A coverage area of a larger access node (such as a macro access node) can include second coverage areas of one or more smaller access nodes (such as a micro access node, pico access node, femto access node, and the like). The coverage area of the larger access node can partially or completely overlap with the one or more smaller access node coverage areas.

OVERVIEW

In operation, it is determined that a first loading of a first access node meets a loading criteria, where the first access node is in communication with a plurality of wireless devices in a first coverage area. A handover criteria for a second access node is decreased, where the second access node comprises a second coverage area and least a portion of the second coverage area is within the first coverage area. A handover is performed of at least one of the plurality of wireless devices to the second access node when a signal level of the second access node received at the at least one of the plurality of wireless devices meets the decreased handover criteria. Changes are then determined in the first loading and in a throughput provided to the at least one of the plurality of wireless devices, and the handover criteria for the second access node is adjusted based on the change in the first loading and the change in the throughput provided to the at least one of the plurality of wireless devices.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an exemplary communication system to control wireless device communication with access nodes.

FIG. **2** illustrates an exemplary method of controlling wireless device communication with access nodes.

FIG. **3** illustrates another exemplary communication system to control wireless device communication with access nodes.

FIG. **4** illustrates another exemplary system to control wireless device communication with access nodes.

FIG. **5** illustrates another exemplary method of controlling wireless device communication with access nodes.

FIG. **6** illustrates an exemplary processing node.

DETAILED DESCRIPTION

FIG. **1** illustrates an exemplary communication system **100** to control wireless device communication with access nodes comprising wireless device **102**, access node **104**, access node **106**, and communication network **108**. Examples of wireless device **102** can comprise a cell phone, a smart phone, a computing platform such as a laptop, palmtop, or tablet, a personal digital assistant, or an internet access device, including combinations thereof. Wireless device **102** can communicate with access node **104** over communication link **110**, and can communicate with access node **106** over communication link **112**. While one wireless device **102** is illustrated in

FIG. **1** for conciseness, a greater number of wireless devices can communicate with access node **104** and/or access node **106**.

Access nodes **104** and **106** are each a network node capable of providing wireless communications to wireless device **102**, and can comprise, for example, a base transceiver station, a radio base station, an eNodeB device, or an enhanced eNodeB device. Access nodes **104** and **106** can be in communication over communication link **114**. Access node **104** can communicate with communication network **108** over communication link **116**, and access node **106** can communicate with communication network **108** over communication link **118**.

Communication network **108** can be a wired and/or wireless communication network, and can comprise processing nodes, routers, gateways, and physical and/or wireless data links for carrying data among various network elements, including combinations thereof, and can include a local area network, a wide area network, and an internetwork (including the Internet). Communication network **108** can be capable of carrying voice information and other data, for example, to support communications by a wireless device such as wireless device **102**. Wireless network protocols may comprise code division multiple access (CDMA) 1xRTT, Global System for Mobile communications (GSM), Universal Mobile Telecommunications System (UMTS), High-Speed Packet Access (HSPA), Evolution Data Optimized (EV-DO), EV-DO rev. A, Worldwide Interoperability for Microwave Access (WiMAX), and Third Generation Partnership Project Long Term Evolution (3GPP LTE). Wired network protocols that may be utilized by communication network **108** comprise Ethernet, Fast Ethernet, Gigabit Ethernet, Local Talk (such as Carrier Sense Multiple Access with Collision Avoidance), Token Ring, Fiber Distributed Data Interface (FDDI), and Asynchronous Transfer Mode (ATM). Communication network **108** may also comprise a wireless network, including base stations, wireless communication nodes, telephony switches, internet routers, network gateways, computer systems, communication links, or some other type of communication equipment, and combinations thereof.

Communication links **110**, **112**, **114**, **116** and **118** can be wired or wireless communication links. Wired communication links can comprise, for example, twisted pair cable, coaxial cable or fiber optic cable, or combinations thereof. Wireless communication links can comprise a radio frequency, microwave, infrared, or other similar signal, and can use a suitable communication protocol, for example, Global System for Mobile telecommunications (GSM), Code Division Multiple Access (CDMA), Worldwide Interoperability for Microwave Access (WiMAX), or Long Term Evolution (LTE), or combinations thereof. Other wireless protocols can also be used.

Other network elements may be present in communication system **100** to facilitate wireless communication but are omitted for clarity, such as base stations, base station controllers, gateways, mobile switching centers, dispatch application processors, and location registers such as a home location register or visitor location register. Furthermore, other network elements may be present to facilitate communication between access node **104**, access node **106**, and communication network **108** which are omitted for clarity, including additional processing nodes, routers, gateways, and physical and/or wireless data links for carrying data among the various network elements.

In an embodiment, access node **104** can comprise a larger access node, such as a macro access node, and access node **106** can comprise a smaller access node than access node **104**, such as a micro access node, a pico access node, a femto access node, and the like. Access node **106** can be deployed such that a coverage area of access node **106** is overlapped partially or completely by a coverage area of access node **104**. A smaller access nodes (such as access node **106**) may be deployed adjacent to or within a coverage area of a larger access node (such as access node **104**) to provide additional wireless communication coverage, for example, in a coverage hole of access node **104**, in an area of poor radio frequency coverage by access node **104**, and so forth.

Access node **106** may be deployed to provide an access node to which wireless devices may be offloaded from communication with access node **104**, for example, when a loading of access node **104** meets a loading criteria. Larger access nodes typically are capable of transmitting signals at a greater signal level or signal power than smaller access nodes. The greater transmit signal level of the larger access node may reduce the effective coverage area of the smaller access node by masking or interfering with a signal from the smaller access node. Accordingly, a wireless device (such as wireless device **102**) which is within both a coverage area of access node **104** and a coverage area of access node **106** may not determine that access node **106** is a viable candidate to provide wireless communications to wireless device **102**. This can result in inefficient resource utilization of the larger access node and the smaller access node, as well as a degradation of the quality of wireless communications provided to a wireless device which is unable to determine the superior access node.

In operation, it is determined that a first loading of first access node **104** in communication with a plurality of wireless devices (such as wireless device **102**) in a first coverage area meets a loading criteria. A handover criteria is decreased for second access node **106**, which comprises a second coverage area, at least a portion of which is within the first coverage area of access node **104**. A handover is performed of at least one of the plurality of wireless devices from first access node **104** to second access node **106** when a signal level of second access node **106** which is received at the at least one of the plurality of wireless devices meets the decreased handover criteria. When the one or more wireless devices have changed to communicating with access node **106**, a change in the first loading and a change in a throughput provided to the at least one of the plurality of wireless devices are determined. Based on the change in the first loading and the change in the throughput provided to the at least one of the plurality of wireless devices, the decreased handover criteria is adjusted for the second access node.

FIG. **2** illustrates an exemplary method of controlling wireless device communication with access nodes. In operation **202**, it is determined that a first loading of a first access node in communication with a plurality of wireless devices in a first coverage area meets a loading criteria. The first loading can comprise a utilization or requested utilization of communication link resources of the access node, for example, an amount of data sent to or from the plurality of wireless devices, a number of physical resource blocks or other wireless communication link resource utilized by the plurality of wireless devices, a requested amount of data to be sent to or from the plurality of wireless devices (as may be determined from a buffer status report or similar request for wireless communication link resources), an amount of data buffered for transmission to or from the plurality of wireless devices, and the like, including combinations thereof. The first access node can comprise a first coverage area in which a signal from the first access node can be detected by a wireless device at or above a signal level threshold. For example, referring to FIG. **3**, access node **304** can comprise coverage area **304**A. Similarly, access node **306** can comprise coverage area **306**A, and access node **308** can comprise coverage area **308**A. While a single wireless device **302** is illustrated in coverage area **304**A, coverage area **304**A can comprise a plurality of wireless devices, which can be in communication with access node **304**.

Returning to FIG. **2**, when it is determined that the first loading of the first access node in communication with the plurality of wireless devices in the first coverage area meets the loading criteria, a handover criteria is decreased for a second access node (operation **204**). The second access node can comprise a second coverage area, wherein at least a portion of the second coverage area is within the first coverage area. For example, second access node **306** (FIG. **3**) can comprise coverage area **306**A, which is substantially overlapped by coverage area **304**A. As another example, second access node **308** can comprise coverage area **308**A, which is partially overlapped by coverage area **304**A. The handover criteria can comprise a signal level of a signal from the second access node, such as a reference signal receive power (RSRP), a received signal strength indication (RSSI), a signal-to-noise ratio (SNR), a carrier to noise ratio (CNR) value, a signal noise and distortion (SINAD), a signal to interference (SII), a signal to noise plus interference (SNIR), a signal to quantization noise ratio (SQNR), and the like. The handover criteria can also comprise a reference signal receive quality (RSRQ), a channel quality indicator (CQI), or another measurement of signal quality. The handover criteria can further comprise combinations of the foregoing. Different second access nodes may comprise different handover criteria. For example, access node **306** may comprise a first handover criteria, and access node **308** may comprise a second handover criteria.

Returning to FIG. **2**, the handover criteria for the second access node can be decreased, for example, from a first threshold to a second threshold, to decrease the level of the handover criteria required for a handover to be requested to change the wireless device from communicating with the first access node to communicating with the second access node. When a signal level of the second access node received at the at least one of the plurality of wireless devices meets the decreased handover criteria, a handover is performed of at least one of the plurality of wireless devices to the second access node (operation **206**). For example, wireless device **302** (FIG. **3**) may approach access node **306** to within coverage area **306**A. For example, wireless device **302** may detect a signal from access node **306** (such as a pilot signal, a reference signal, and the like) which meets a threshold signal level. The signal level received at wireless device **302** from access node **306** may meet the decreased handover criteria, which can comprise a reduced signal level threshold (i.e., reduced from a previous, higher signal level threshold).

Referring again to FIG. **2**, after the handover is performed of the at least one of the plurality of wireless devices to the second access node, the first loading (of the first access node) and a throughput provided to the at least one of the at least one of the plurality of wireless devices can be monitored. A change can be determined in the first loading and in a throughput provided to the at least one of the plurality of wireless devices (operation **208**). For example, when one or more wireless devices **302** (FIG. **3**) are handed over to the second access node (for example, access node **306**), a change in the loading of access node **304**, and a change in the throughput provided to wireless device **302** (as between a throughput provided by access node **304** and a throughput provided by access node **306**) can be determined.

Returning to FIG. **2**, based on the change in the first loading and the change in the throughput provided to the at least one of the plurality of wireless devices, the decreased handover criteria for the second access node can be adjusted (operation **210**). For example, when a decrease in the first loading is relatively small, and the throughput provided decreases, the handover criteria can be adjusted to reduce the likelihood of performing additional handovers of wireless devices to the second access node. As another example, when a decrease in the first loading is relatively large, and the throughput provided increases, the handover criteria can be adjusted to increase the likelihood of performing additional handovers of wireless devices to the second access node.

FIG. **4** illustrates another exemplary communication system **400** to control wireless device communication with access nodes comprising wireless device **402**, access node **404**, access node **406**, controller node **408**, gateway node **410**, and communication network **412**. Examples of wireless device **402** can comprise a cell phone, a smart phone, a computing platform such as a laptop, palmtop, or tablet, a personal digital assistant, or an internet access device, including combinations thereof. Wireless device **402** can communicate with access node **404** over communication link **414**, and with access node **406** over communication link **416**.

Access nodes **404** and **406** are each a network node capable of providing wireless communications to wireless device **402**, and can be, for example, a base transceiver station, a radio base station, an eNodeB device, or an enhanced eNodeB device. Access node **304** is in communication with controller node **408** over communication link **420** and with gateway node **410** over communication link **424**. Access node **406** is in communication with controller node **408** over communication link **422** and with gateway node **410** over communication link **426**. Access nodes **404** and **406** can also communicate with each other over communication link **418**. In an embodiment, access nodes **404** and **406** comprise neighboring access nodes of comparable coverage area and/or signal power, for example, two macro eNodeB towers and the like. In an embodiment, access node **406** may comprise a coverage area at least a portion of which is within a coverage area of access node **404**, for example, where access node **406** is a smaller access node than access node **404**. For example, access node **404** can comprise a macro cell, and access node **406** can comprise a smaller cell such as a micro cell, pico cell, femto cell, and so forth. Other examples are also possible, including combinations of the foregoing.

Controller node **408** can comprise a processor and associated circuitry to execute or direct the execution of computer-readable instructions, and can be configured to control the setup and maintenance of a communication session over communication network **412** for wireless device **402**. Controller node **408** can comprise a mobile switching center (MSC), a dispatch call controller (DCC), a mobility management entity (MME), or another similar network node. Controller node **408** can retrieve and execute software from storage, which can include a disk drive, flash drive, memory circuitry, or some other memory device, and which can be local or remotely accessible. The software comprises computer programs, firmware, or some other form of machine-readable instructions, and may include an operating system, utilities, drivers, network interfaces, applications, or some other type of software, including combinations thereof. Controller node **408** can receive instructions and other input at a user interface. Controller node **408** is in communication with communication network **412** over communication link **430**, and with gateway node **410** over communication link **428**.

Gateway node **410** can comprise a processor and associated circuitry to execute or direct the execution of computer-readable instructions, and can be configured to mediate data communications related to wireless device **402** which is sent between communication network **412** and access node **404** and/or access node **406**. Gateway node **410** can retrieve and execute software from storage, which can include a disk drive, flash drive, memory circuitry, or some other memory device, and which can be local or remotely accessible. The software comprises computer programs, firmware, or some other form of machine-readable instructions, and may include an operating system, utilities, drivers, network interfaces, applications, or some other type of software, including combinations thereof. Gateway node **410** can receive instructions and other input at a user interface. Examples of gateway node **410** can include a standalone computing device, a computer system, or a network component, such as an access service network gateway (ASN-GW), a packet data network gateway (P-GW), a serving gateway (S-GW), a mobile switching controller (MSC), a packet data serving node (PDSN), call processing equipment, a home agent, a radio node controller (RNC), a subscriber profile system (SPS), authentication, authorization, and accounting (AAA) equipment, and a network gateway, including combinations thereof. Gateway node **410** is in communication with communication network **412** over communication link **432**.

Communication network **412** can be a wired and/or wireless communication network, and can comprise processing nodes, routers, gateways, and physical and/or wireless data links for carrying data among various network elements, including combinations thereof, and can include a local area network, a wide area network, and an internetwork (including the Internet). Communication network **412** can be capable of carrying voice information and other data, for example, to support communications by a wireless device such as wireless device **402**. Wireless network protocols may comprise code division multiple access (CDMA) 1xRTT, Global System for Mobile communications (GSM), Universal Mobile Telecommunications System (UMTS), High-Speed Packet Access (HSPA), Evolution Data Optimized (EV-DO), EV-DO rev. A, Worldwide Interoperability for Microwave Access (WiMAX), and Third Generation Partnership Project Long Term Evolution (3GPP LTE). Wired network protocols that may be utilized by communication network **412** comprise Ethernet, Fast Ethernet, Gigabit Ethernet, Local Talk (such as Carrier Sense Multiple Access with Collision Avoidance), Token Ring, Fiber Distributed Data Interface (FDDI), and Asynchronous Transfer Mode (ATM). Communication network **412** may also comprise a wireless network, including base stations, wireless communication nodes, telephony switches, internet routers, network gateways, computer systems, communication links, or some other type of communication equipment, and combinations thereof.

Communication links **414**, **416**, **418**, **420**, **422**, **424**, **426**, **428**, **430**, and **432** can be wired or wireless communication links. Wired communication links can comprise, for example, twisted pair cable, coaxial cable or fiber optic cable, or combinations thereof. Wireless communication links can comprise a radio frequency, microwave, infrared, or other similar signal, and can use a suitable communication protocol, for example, Global System for Mobile telecommunications (GSM), Code Division Multiple Access (CDMA), Worldwide Interoperability for Microwave Access (WiMAX), or Long Term Evolution (LTE), or combinations thereof. Other wireless protocols can also be used.

Other network elements may be present in communication system **400** to facilitate wireless communication but are omitted for clarity, such as base stations, base station controllers, gateways, mobile switching centers, dispatch application processors, and location registers such as a home location register or visitor location register. Furthermore, other network elements may be present to facilitate communication among access node **404**, access node **406**, controller node **408**, gateway node **410**, and communication network **412** which are omitted for clarity, including additional processing nodes, routers, gateways, and physical and/or wireless data links for carrying data among the various network elements.

FIG. **5** illustrates an exemplary method of controlling wireless device communication with access nodes. In operation **502**, it is determined that a first loading of a first access node in communication with a plurality of wireless devices in a first coverage area meets a loading criteria. The first loading can comprise a loading of access node **404**, such as a utilization or requested utilization of communication link resources of the access node, for example, an amount of data sent to or from the plurality of wireless devices, a number of physical resource blocks or other wireless communication link resource utilized by the plurality of wireless devices, a requested amount of data to be sent to or from the plurality of wireless devices (as may be determined from a buffer status report or similar request for wireless communication link resources), an amount of data buffered for transmission to or from the plurality of wireless devices, and the like, including combinations thereof. The first access node can comprise a first coverage area in which a signal from the first access node can be detected by a wireless device at or above a signal level threshold.

When it is determined that the first loading of the first access node in communication with the plurality of wireless devices in the first coverage area meets the loading criteria, a handover criteria is decreased for a second access node (operation **504**). The second access node, such as access node **406**, can comprise a second coverage area, wherein at least a portion of the second coverage area is within the first coverage area. The handover criteria can comprise a signal level of a signal from the second access node, such as a reference signal receive power (RSRP), a received signal strength indication (RSSI), a signal-to-noise ratio (SNR), a carrier to noise ratio (CNR) value, a signal noise and distortion (SINAD), a signal to interference (SII), a signal to noise plus interference (SNIR), a signal to quantization noise ratio (SQNR), and the like. The handover criteria can also comprise a reference signal receive quality (RSRQ), a channel quality indicator (CQI), or another measurement of signal quality. The handover criteria can further comprise combinations of the foregoing. In an embodiment, the coverage area of access node **404** may comprise more than one second access node coverage area, and each second access node can comprise a different handover criteria.

The handover criteria for the second access node can be decreased, for example, from a first threshold to a second threshold, to decrease the level of the handover criteria required for a handover to be requested to change the wireless device from communicating with the first access node to communicating with the second access node. When a signal level of the second access node received at the at least one of the plurality of wireless devices meets the decreased handover criteria, a handover is performed of at least one of the plurality of wireless devices to the second access node (operation **506**). For example, wireless device **402** may approach access node **406** to within coverage area of access node **406**, and a signal level received at wireless device **402** from access node **406** may meet the decreased handover criteria, which can comprise a reduced signal level threshold (i.e., reduced

from a previous, higher signal level threshold). In an embodiment, the handover of wireless device **402** to access node **406** is performed when the loading of access node **404** meets or exceeds a first threshold, and when a loading of access node **406** meets or is below a second threshold.

After the handover is performed of the at least one of the plurality of wireless devices to the second access node, the first loading (of the first access node) and a throughput provided to the at least one of the at least one of the plurality of wireless devices can be monitored. A change can be determined in the first loading and in a throughput provided to the at least one of the plurality of wireless devices (operation **508**). For example, when one or more wireless devices (such as wireless device **402**) are handed over to the second access node (for example, access node **306**), a change in the loading of access node **404**, and a change in the throughput provided to wireless device **402** (as between a throughput provided by access node **404** and a throughput provided by access node **406**) can be determined. The change in the throughput for the plurality of wireless device can comprise an average change in throughput, a total change in throughput for all of the handed over wireless devices, and the like.

In addition to determining a change in throughput provided to wireless device **402**, additional factors can be evaluated after the handover is performed of the at least one of the plurality of wireless devices to the second access node. A change in a latency of data sent to the at least one of the plurality of wireless devices can also be determined (operation **510**). The change in latency can be determined based on a delay of data sent to or received from wireless device **402**. For example, data sent to wireless device **402** from access node **404** before the handover is performed may comprise a first delay time, and data sent to wireless device **402** from access node **406** after the handover is performed may comprise a second delay time. A difference between the first delay time and the second delay time can be determined. The difference between the first delay time and the second delay time for the plurality of wireless device can comprise an average difference over the total number of handed-over wireless devices, a total difference for all of the handed-over wireless devices, and the like.

Additionally, a change in a variation of latency of data sent to the at least one of the plurality of wireless devices can be determined (operation **512**). The variation of latency of the data can comprise a variation in the periodicity or smoothness of data sent to or received from wireless device **402**, such as jitter, burstiness, and the like. For example, data sent to wireless device **402** from access node **404** before the handover is performed may comprise a first variation of latency, and data sent to wireless device **402** from access node **406** after the handover is performed may comprise a second variation of latency. A difference between the first variation of latency and the second variation of latency can be determined. The difference between the first variation of latency and the second variation of latency for the plurality of wireless device can comprise an average difference over the total number of handed-over wireless devices, a total difference for all of the handed-over wireless devices, and the like.

Further, a change in a data loss rate of data sent to the at least one of the plurality of wireless devices can be determined (operation **514**). The data loss rate can comprise a measurement over a period of time of data which is sent from an access node to wireless device **402**, or which is sent from wireless device **402** to an access node, but which does not arrive. For example, data sent to wireless device **402** from access node **404** before the handover is performed may comprise a first data loss rate, and data sent to wireless device **402** from access node **406** after the handover is performed may comprise a second data loss rate. A difference between the first data loss rate and the second data loss rate can be determined. The difference between the first data loss rate and the second data loss rate for the plurality of wireless device can comprise an average difference over the total number of handed-over wireless devices, a total difference for all of the handed-over wireless devices, and the like.

Moreover, it can be determined that a communication session of the at least one of the plurality of wireless devices is terminated when the handover is performed of at least one of the plurality of wireless devices to the second access node (operation **516**). For example, wireless device **402** can be conducting a communication session, such as a voice communication session or a data communication session, through access node **404**. Then, when the handover is performed of wireless device **402** from access node **404** to access node **406**, the communication session is unintentionally terminated. For example, the voice communication session may be dropped, or the data communication session may be unintentionally discontinued. Termination of a communications session can be caused, among other things, by radio frequency interference, or when a signal level from the second access node is insufficient to support the communication session. In an embodiment, a number of terminations of communication sessions of the at least one of the plurality of wireless devices can be determined when the at least one of the plurality of wireless devices is handed over from access node **404** to access node **406**.

In addition, an application requirement can be determined for an application running on each of the at least one of the plurality of wireless devices, and a weighting factor can be determined based on the determined application requirement (operation **518**). The application requirement can comprise a minimum data rate, a maximum permitted data delay, a minimum throughput, a maximum error rate, a maximum data loss rate, and the like, of an application running on a wireless device. The application requirement can also be determined based on the application type, such as whether the application is a relatively delay sensitive application (such as a streaming audio application a streaming video application, a voice application, and the like) or a relatively delay insensitive application (such as an email application, a messaging application, a web browsing application, and the like). The application requirement can also be determined based on the application's utilization or requested utilization of communication link resources, for example, an amount of data sent to or from the wireless device, a number of physical resource blocks or other wireless communication link resource utilized by the wireless device, a requested amount of data to be sent to or from the wireless device (as may be determined from a buffer status report or similar request for wireless communication link resources), an amount of data buffered for transmission to or from the wireless device, and the like, including combinations thereof. Further, the application requirement can also be determined based on a traffic class indicator associated with bearer data being sent from the wireless device, such as a quality of service class indicator (QCI) or similar traffic class indicator.

The application requirement can be determined based on information received from the wireless device. The application requirement can also be determined based on deep packet inspection (e.g., at gateway node **410**) of information received from wireless device **402**. Deep packet inspection generally involves an inspection of packets beyond Open Systems Interconnection (OSI) layer 2 including an inspection of the data portion (also referred to as the payload portion) of a packet (and possibly also the header of a packet). That is deep packet inspection can involve an examination of any of layers 2 through 7 of the OSI model. The data portion of a packet remains distinct from a header portion, even where the packet receives additional header information (such as by packet encapsulation or a similar process). In other words, when a packet is encapsulated, any additional header information does not combine information from the data portion with any header portion.

Based on the determined application requirement, a weighting factor can be determined, and the weighting factor can be applied to the determined change in the throughput provided to the at least one of the plurality of wireless devices (operation **518**). For example, a relatively delay sensitive application of a first wireless device may be strongly affected by a decrease in throughput provided to the wireless device by the second access node; accordingly, the weighting factor determined for the first wireless device may be greater. As another example, a relatively delay insensitive application of a second wireless device may be minimally affected by a decrease in throughput provided to the wireless device by the second access node; accordingly, the weighting factor determined for the second wireless device may be smaller.

Further, after the handover is performed of the at least one of the plurality of wireless devices to the second access node, a change in a second loading of the second access node can be determined (operation **520**). The second loading can comprise a loading of access node **406**, such as a utilization or requested utilization of communication link resources of the access node, for example, an amount of data sent to or from the plurality of wireless devices, a number of physical resource blocks or other wireless communication link resource utilized by the plurality of wireless devices, a requested amount of data to be sent to or from the plurality of wireless devices (as may be determined from a buffer status report or similar request for wireless communication link resources), an amount of data buffered for transmission to or from the plurality of wireless devices, and the like, including combinations thereof.

Then, in operation **522**, the decreased handover criteria for the second access node can be adjusted based on some or all of the change in the first loading, and the change in the throughput provided to the at least one of the plurality of wireless devices, the change in a latency of data, the change in the variation of the latency of data, the change in the data loss rate, whether the communication session is terminated with one or more of the plurality of wireless devices, the weighting factor determined based on the application requirements, and the change in the second loading of the second access node.

Next, location characteristics of the second access node are determined (operation **524**). Location characteristics can comprise a location of access node **406** relative to access node **404**, a distance of access node **406** from access node, an amount of overlap of a coverage area of access node **406** and a coverage area of access node **404**, and wireless communication link conditions of access node **406** (such as radio frequency interference, wireless communication link congestion, communication resource utilization, and the like).

Based on the determined location characteristics of the second access node, a handover criteria for a third access node is adjusted (operation **526**). The third access node can comprise an access node having substantially similar location characteristics as the location characteristics of the second access node. Thus, the determination of the handover criteria for the second access node, and the adjustment of the handover criteria of the second access node, can be applied to a third access node which is similarly situated as compared to the second access node.

FIG. **6** illustrates an exemplary processing node **600** in a communication system. Processing node **600** comprises communication interface **602**, user interface **604**, and processing system **606** in communication with communication interface **602** and user interface **604**. Processing node **600** can be control wireless device communication with access nodes. Processing system **606** includes storage **608**, which can comprise a disk drive, flash drive, memory circuitry, or other memory device. Storage **608** can store software **610** which is used in the operation of the processing node **600**. Storage **608** may include a disk drive, flash drive, data storage circuitry, or some other memory apparatus. Software **610** may include computer programs, firmware, or some other form of machine-readable instructions, including an operating system, utilities, drivers, network interfaces, applications, or some other type of software. Processing system **606** may include a microprocessor and other circuitry to retrieve and execute software **610** from storage **608**. Processing node **600** may further include other components such as a power management unit, a control interface unit, etc., which are omitted for clarity. Communication interface **602** permits processing node **600** to communicate with other network elements. User interface **604** permits the configuration and control of the operation of processing node **600**.

Examples of processing node **600** include controller node **408** and gateway node **410**. Processing node **600** can also be an adjunct or component of a network element, such as an element of controller node **408** or gateway node **410**. Processing node **600** can also be another network element in a communication system. Further, the functionality of processing node **600** can be distributed over two or more network elements of a communication system.

The exemplary systems and methods described herein can be performed under the control of a processing system executing computer-readable codes embodied on a computer-readable recording medium or communication signals transmitted through a transitory medium. The computer-readable recording medium is any data storage device that can store data readable by a processing system, and includes both volatile and nonvolatile media, removable and non-removable media, and contemplates media readable by a database, a computer, and various other network devices.

Examples of the computer-readable recording medium include, but are not limited to, read-only memory (ROM), random-access memory (RAM), erasable electrically programmable ROM (EEPROM), flash memory or other memory technology, holographic media or other optical disc storage, magnetic storage including magnetic tape and magnetic disk, and solid state storage devices. The computer-readable recording medium can also be distributed over network-coupled computer systems so that the computer-readable code is stored and executed in a distributed fashion. The communication signals transmitted through a transitory medium may include, for example, modulated signals transmitted through wired or wireless transmission paths.

The above description and associated figures teach the best mode of the invention. The following claims specify the scope of the invention. Note that some aspects of the best mode may not fall within the scope of the invention as specified by the claims. Those skilled in the art will appreciate that the features described above can be combined in various ways to form multiple variations of the invention, and that various modifications may be made to the configuration and methodology of the exemplary embodiments disclosed herein without departing from the scope of the present teachings. Those skilled in the art also will appreciate that various features disclosed with respect to one exemplary embodiment herein may be used in combination with other exemplary embodiments with appropriate modifications, even if such combinations are not explicitly disclosed herein. As a result, the invention is not limited to the specific embodiments described above, but only by the following claims and their equivalents.

What is claimed is:

1. A method of controlling wireless device communication with access nodes, comprising:

determining that a first loading of a first access node in communication with a plurality of wireless devices in a first coverage area meets a loading criteria;

decreasing a handover criteria for a second access node, wherein the second access node comprises a second coverage area that overlaps at least a portion of the first coverage area;

performing a handover of at least one of the plurality of wireless devices to the second access node when a signal level of the second access node received at the at least one of the plurality of wireless devices meets the decreased handover criteria;

determining a change in the first loading and a change in a throughput provided to the at least one of the plurality of wireless devices;

determining a change in a periodicity of data sent to the at least one of the plurality of wireless devices; and

adjusting the decreased handover criteria for the second access node based on the change in the first loading, the change in the throughput provided to the at least one of the plurality of wireless devices, and the change in the periodicity of data sent to the at least one of the plurality of wireless devices.

2. The method of claim **1**, further comprising:

determining a change in a latency of data sent to the at least one of the plurality of wireless devices; and

adjusting the handover criteria for the second access node based on the change in the first loading, the change in the throughput provided to the at least one of the plurality of wireless devices, the change in the periodicity of data sent to the at least one of the plurality of wireless devices, and the change in the latency of data sent to the at least one of the plurality of wireless devices.

3. The method of claim **1**, further comprising:

determining a change in a data loss rate of data sent to the at least one of the plurality of wireless devices; and

adjusting the handover criteria for the second access node based on the change in the first loading, the change in the throughput provided to the at least one of the plurality of wireless devices, the change in the periodicity of data sent to the at least one of the plurality of wireless devices, and the change in the a change in the data loss rate.

4. The method of claim **1**, further comprising:

determining that a communication session of the at least one of the plurality of wireless devices is terminated when the handover is performed of at least one of the plurality of wireless devices to the second access node; and

adjusting the handover criteria for the second access node based on the change in the first loading and whether the communication session is terminated.

5. The method of claim **1**, further comprising:

determining an application requirement of an application running on the at least one of the plurality of wireless devices;

determining a weighting factor based on the determined application requirement and applying the weighting factor to the determined change in the throughput provided to the at least one of the plurality of wireless devices; and

adjusting the handover criteria for the second access node based on the change in the first loading, the weighted change in the throughput provided to the at least one of the plurality of wireless devices, and the change in the periodicity of data sent to the at least one of the plurality of wireless devices.

6. The method of claim **1**, further comprising:

determining location characteristics of the second access node relative to the first access node;

adjusting a handover criteria for a third access node based on the adjusted handover criteria for the second access node when the third access node comprises location characteristics relative to the first access node which are substantially similar to the location characteristics of the second access node.

7. The method of claim **1**, further comprising:

determining a change in a second loading of the second access node; and

adjusting the handover criteria for the second access node based on the change in the first loading, the change in the second loading, the change in the throughput provided to the at least one of the plurality of wireless devices, and the change in the periodicity of data sent to the at least one of the plurality of wireless devices.

8. The system of claim **1**, wherein the processing node is further configured to:

determine a change in a latency of data sent to the at least one of the plurality of wireless devices; and

adjust the handover criteria for the second access node based on the change in the first loading, the change in the throughput provided to the at least one of the plurality of wireless devices, the change in the periodicity of data sent to the at least one of the plurality of wireless devices, and the change in the latency of data sent to the at least one of the plurality of wireless devices.

9. A system of controlling wireless device communication with access nodes, comprising:

a processing node, configured to

determine that a first loading of a first access node in communication with a plurality of wireless devices in a first coverage area meets a loading criteria;

decrease a handover criteria for a second access node, wherein the second access node comprises a second coverage area that overlaps at least a portion of the first coverage area;

perform a handover of at least one of the plurality of wireless devices to the second access node when a signal level of the second access node received at the at least one of the plurality of wireless devices meets the decreased handover criteria;

determine a change in the first loading and a change in a throughput provided to the at least one of the plurality of wireless devices;

determine a change in a periodicity of data sent to the at least one of the plurality of wireless devices; and

adjust the decreased handover criteria for the second access node based on the change in the first loading, the change in the throughput provided to the at least one of the plurality of wireless devices, and the change in the periodicity of data sent to the at least one of the plurality of wireless devices.

10. The system of claim **9**, wherein the processing node is further configured to:

determine a change in a data loss rate of data sent to the at least one of the plurality of wireless devices; and

adjust the handover criteria for the second access node based on the change in the first loading, the change in the throughput provided to the at least one of the plurality of wireless devices, the change in the periodicity of data sent to the at least one of the plurality of wireless devices, and the change in the a change in the data loss rate.

11. The system of claim **9**, wherein the processing node is further configured to:

determine that a communication session of the at least one of the plurality of wireless devices is terminated when the handover is performed of at least one of the plurality of wireless devices to the second access node; and

adjust the handover criteria for the second access node based on the change in the first loading and whether the communication session is terminated.

12. The system of claim **9**, wherein the processing node is further configured to:

determine an application requirement of an application running on the at least one of the plurality of wireless devices;

determine a weighting factor based on the determined application requirement and applying the weighting factor to the determined change in the throughput provided to the at least one of the plurality of wireless devices; and

adjust the handover criteria for the second access node based on the change in the first loading, the weighted change in the throughput provided to the at least one of the plurality of wireless devices, and the change in the periodicity of data sent to the at least one of the plurality of wireless devices.

13. The system of claim **9**, wherein the processing node is further configured to:

determine location characteristics of the second access node relative to the first access node;

adjust a handover criteria for a third access node based on the adjusted handover criteria for the second access node when the third access node comprises location characteristics relative to the first access node which are substantially similar to the location characteristics of the second access node.

14. The system of claim **9**, wherein the processing node is further configured to:

determine a change in a second loading of the second access node; and

adjusting the handover criteria for the second access node based on the change in the first loading, the change in the second loading, the change in the throughput provided to the at least one of the plurality of wireless devices, and the change in the periodicity of data sent to the at least one of the plurality of wireless devices.

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