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Hou

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(54) **MANAGING ACCESS NODE SELECTION FOR A WIRELESS DEVICE**

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H04W 36/24 (2009.01)
H04W 36/08 (2009.01)

(52) **U.S. Cl.**
CPC ***H04W 36/22*** (2013.01); ***H04W 36/24*** (2013.01); *H04W 36/08* (2013.01)

(58) **Field of Classification Search**
None
See application file for complete search history.

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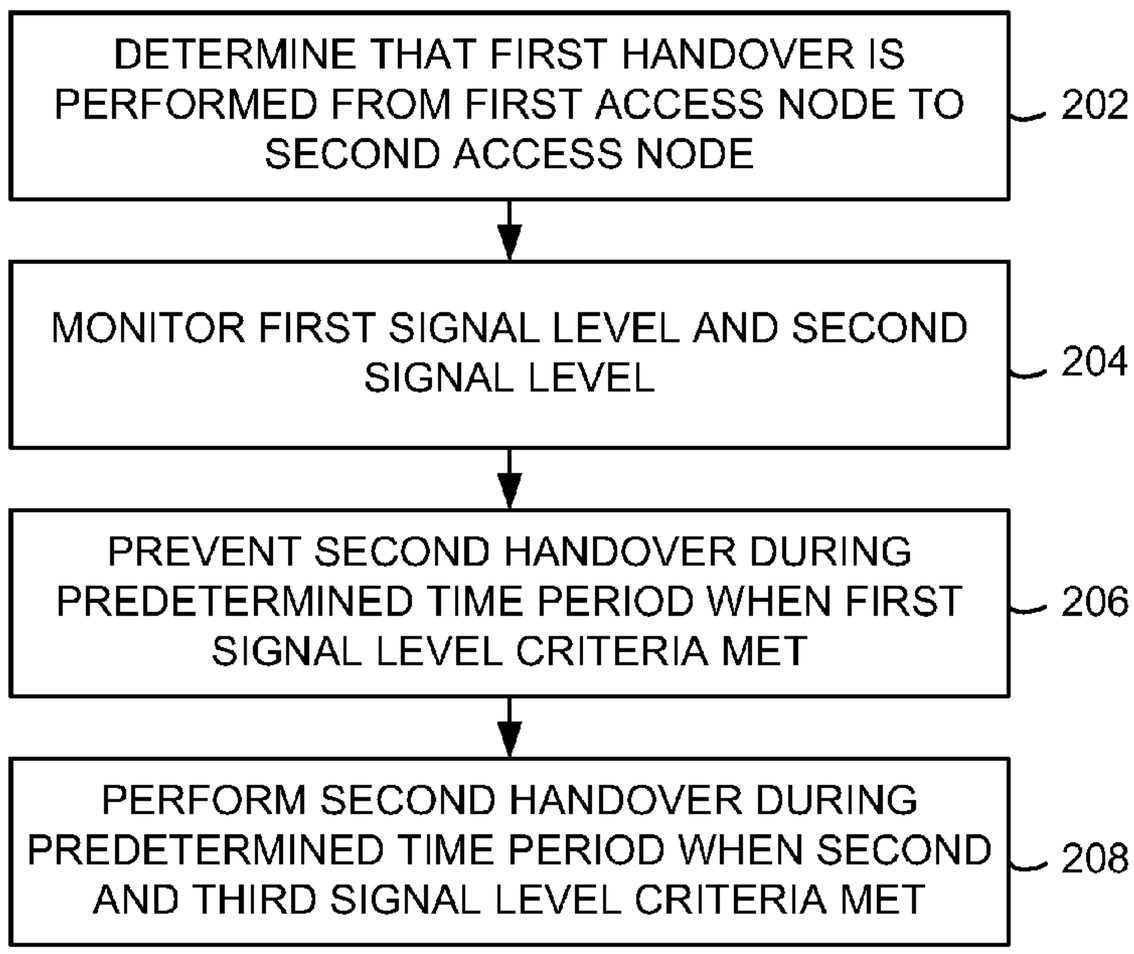
Primary Examiner — Hoon J Chung

(57) **ABSTRACT**

In systems and methods of managing access node selection for a wireless device, a first handover of a wireless device from a first access node to a second access node is performed based on a traffic load of the first access node meeting a traffic load threshold, and a first signal level of the first access node and a second signal level of the second access node are monitored. During a predetermined time period, the performance of a second handover of the wireless device from the second access node to the first access node is prevented when the second signal level meets a first signal level criteria, but the second handover of the wireless device is performed from the second access node to the first access node when the second signal level meets a second signal level criteria and the first signal level meets a third signal level criteria.

20 Claims, 8 Drawing Sheets



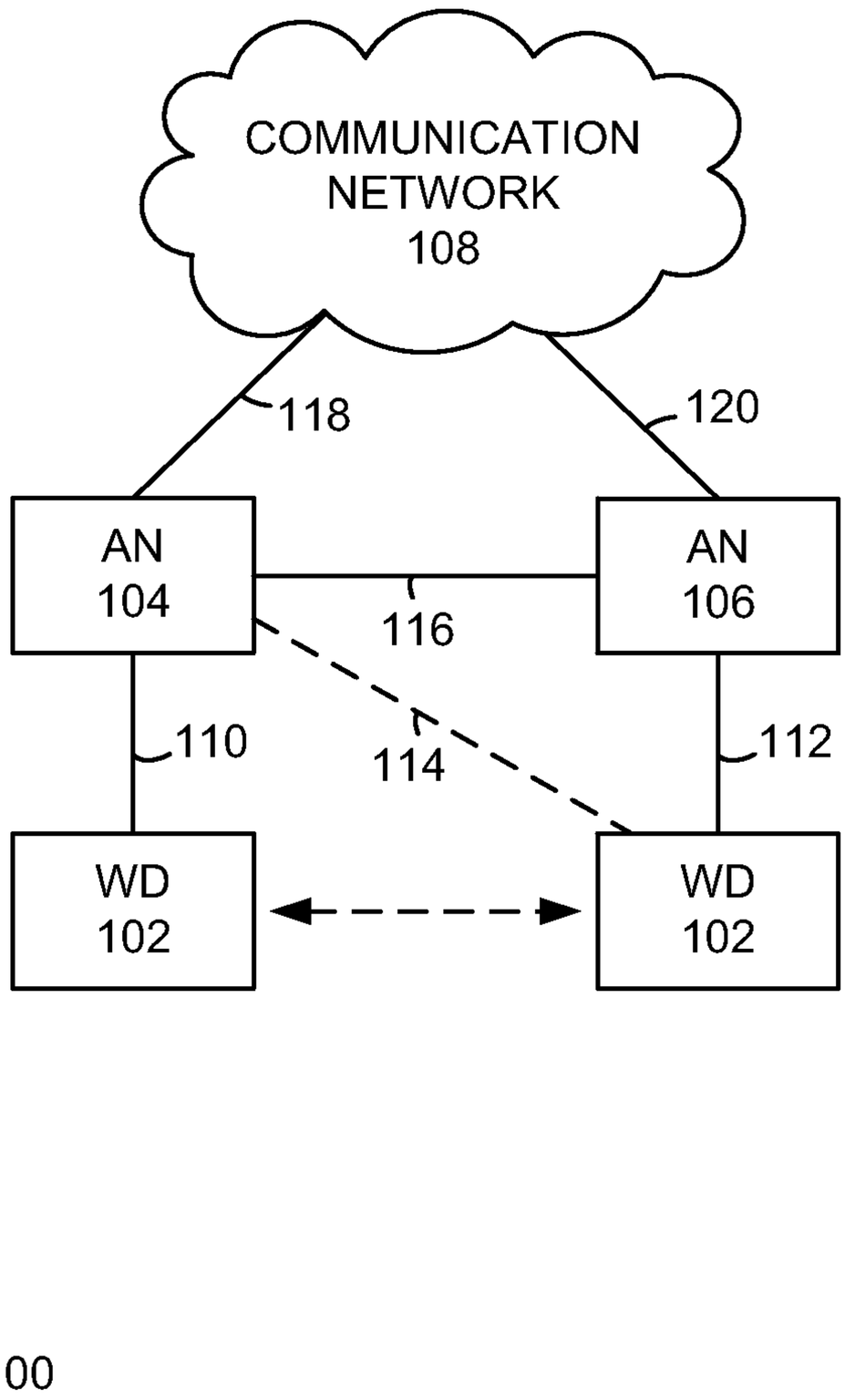

COMMUNICATION
NETWORK
108
118
120
AN
104
AN
106
116
110
114
112
WD
102
WD
102
100

FIG. 1

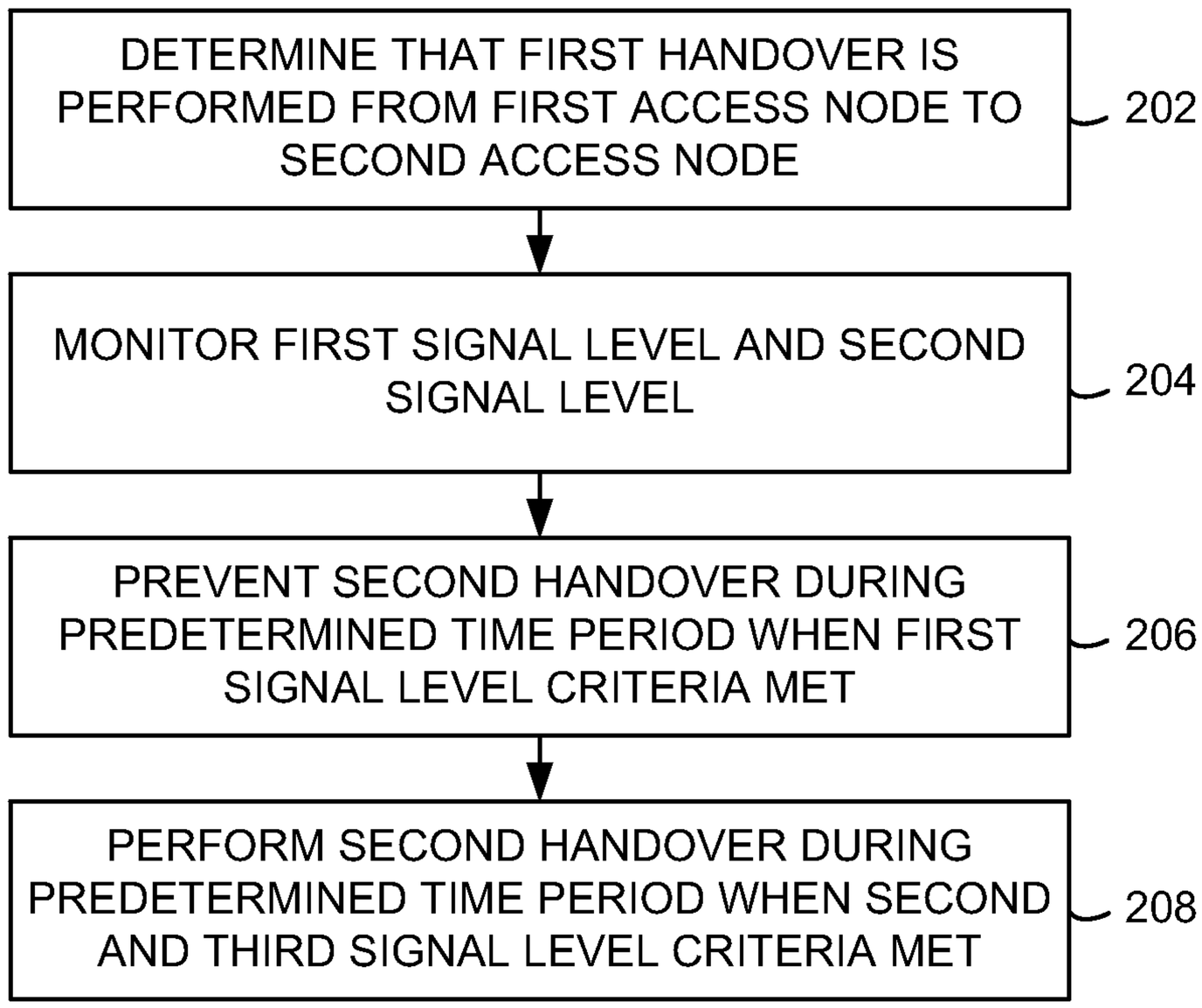

DETERMINE THAT FIRST HANDOVER IS PERFORMED FROM FIRST ACCESS NODE TO SECOND ACCESS NODE
202
MONITOR FIRST SIGNAL LEVEL AND SECOND SIGNAL LEVEL
204
PREVENT SECOND HANDOVER DURING PREDETERMINED TIME PERIOD WHEN FIRST SIGNAL LEVEL CRITERIA MET
206
PERFORM SECOND HANDOVER DURING PREDETERMINED TIME PERIOD WHEN SECOND AND THIRD SIGNAL LEVEL CRITERIA MET
208

FIG. 2

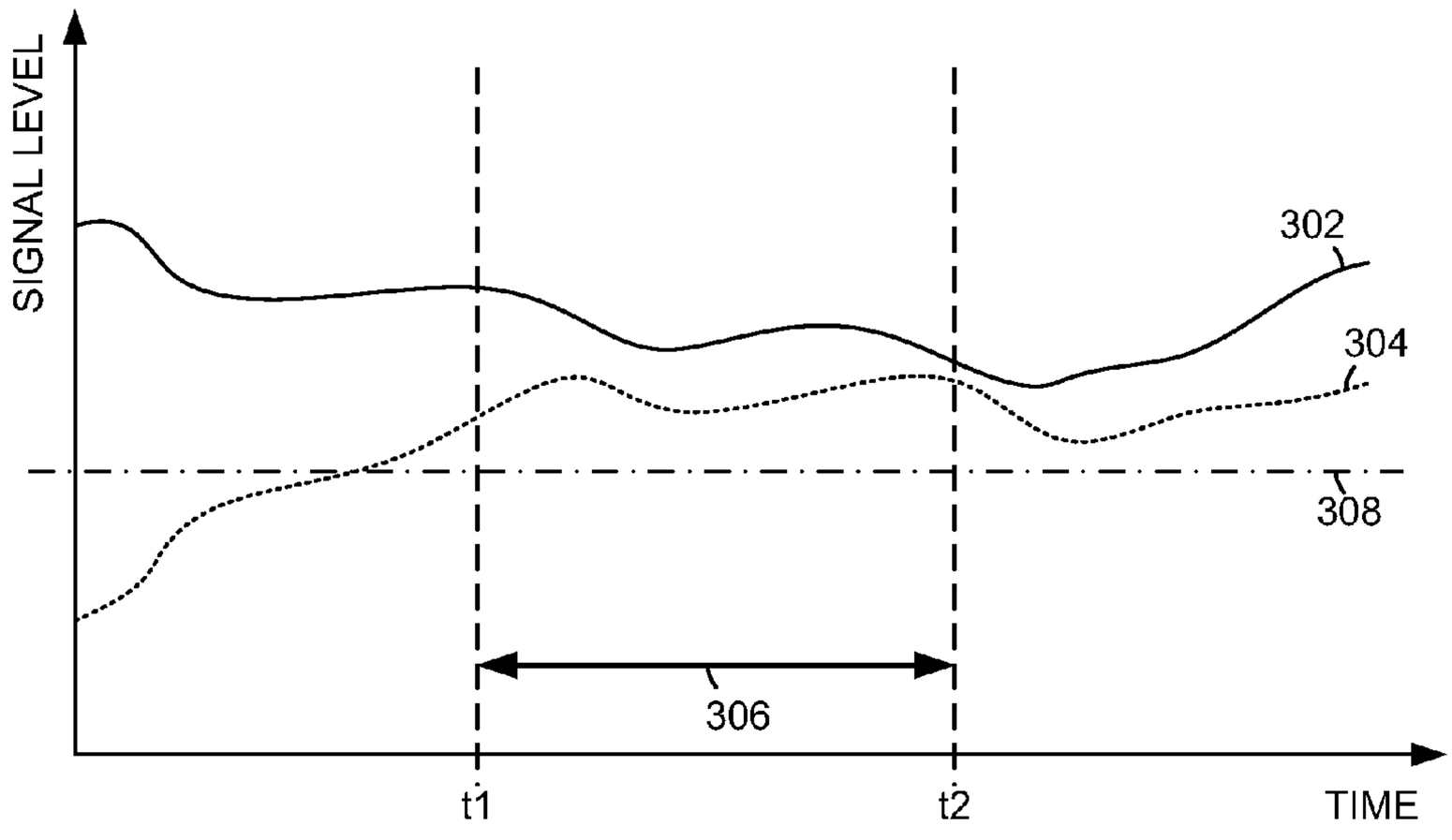


FIG. 3

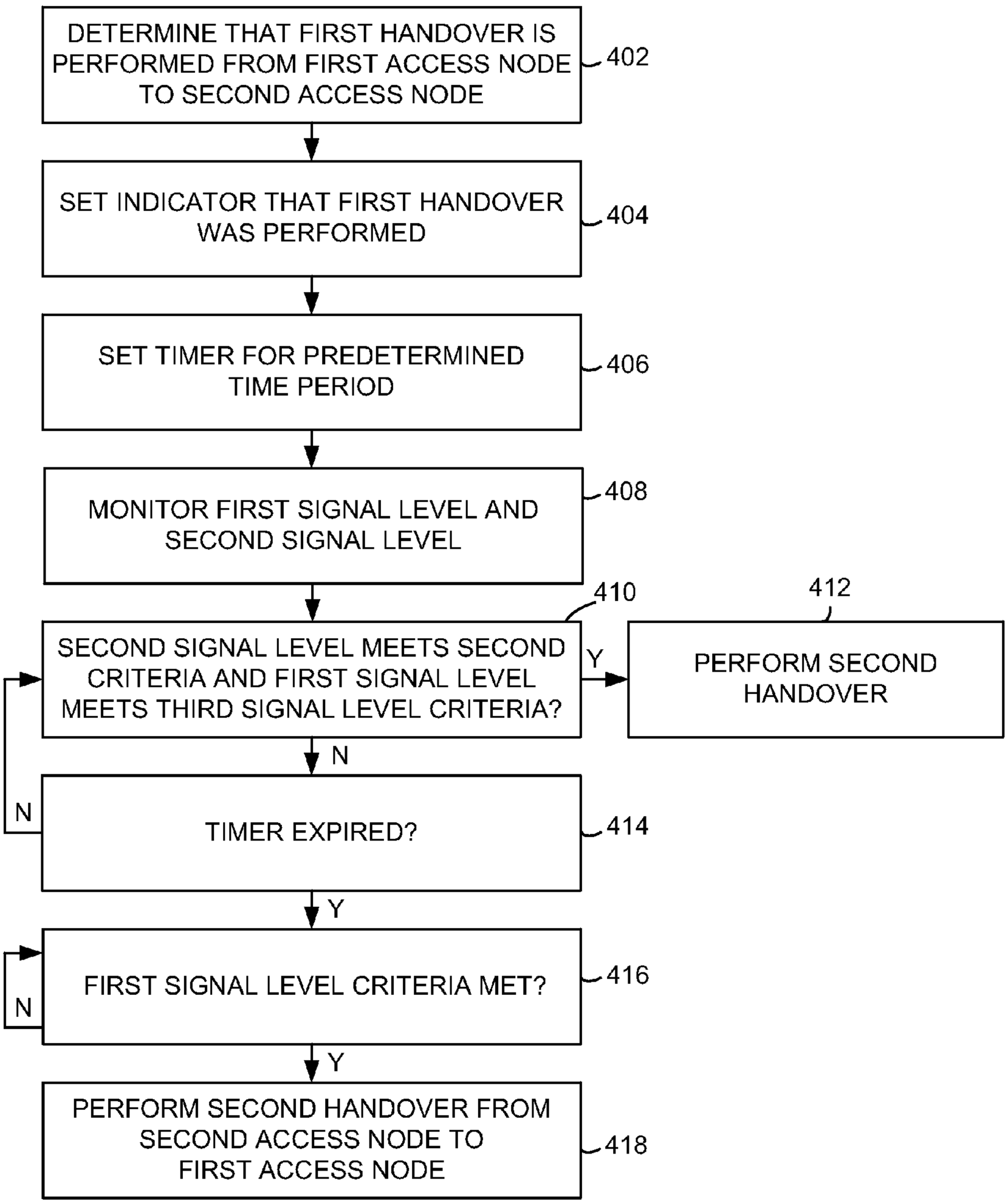

DETERMINE THAT FIRST HANDOVER IS PERFORMED FROM FIRST ACCESS NODE TO SECOND ACCESS NODE
402
SET INDICATOR THAT FIRST HANDOVER WAS PERFORMED
404
SET TIMER FOR PREDETERMINED TIME PERIOD
406
MONITOR FIRST SIGNAL LEVEL AND SECOND SIGNAL LEVEL
408
SECOND SIGNAL LEVEL MEETS SECOND CRITERIA AND FIRST SIGNAL LEVEL MEETS THIRD SIGNAL LEVEL CRITERIA?
410
Y
PERFORM SECOND HANDOVER
412
N
TIMER EXPIRED?
414
N
Y
FIRST SIGNAL LEVEL CRITERIA MET?
416
N
Y
PERFORM SECOND HANDOVER FROM SECOND ACCESS NODE TO FIRST ACCESS NODE
418

FIG. 4

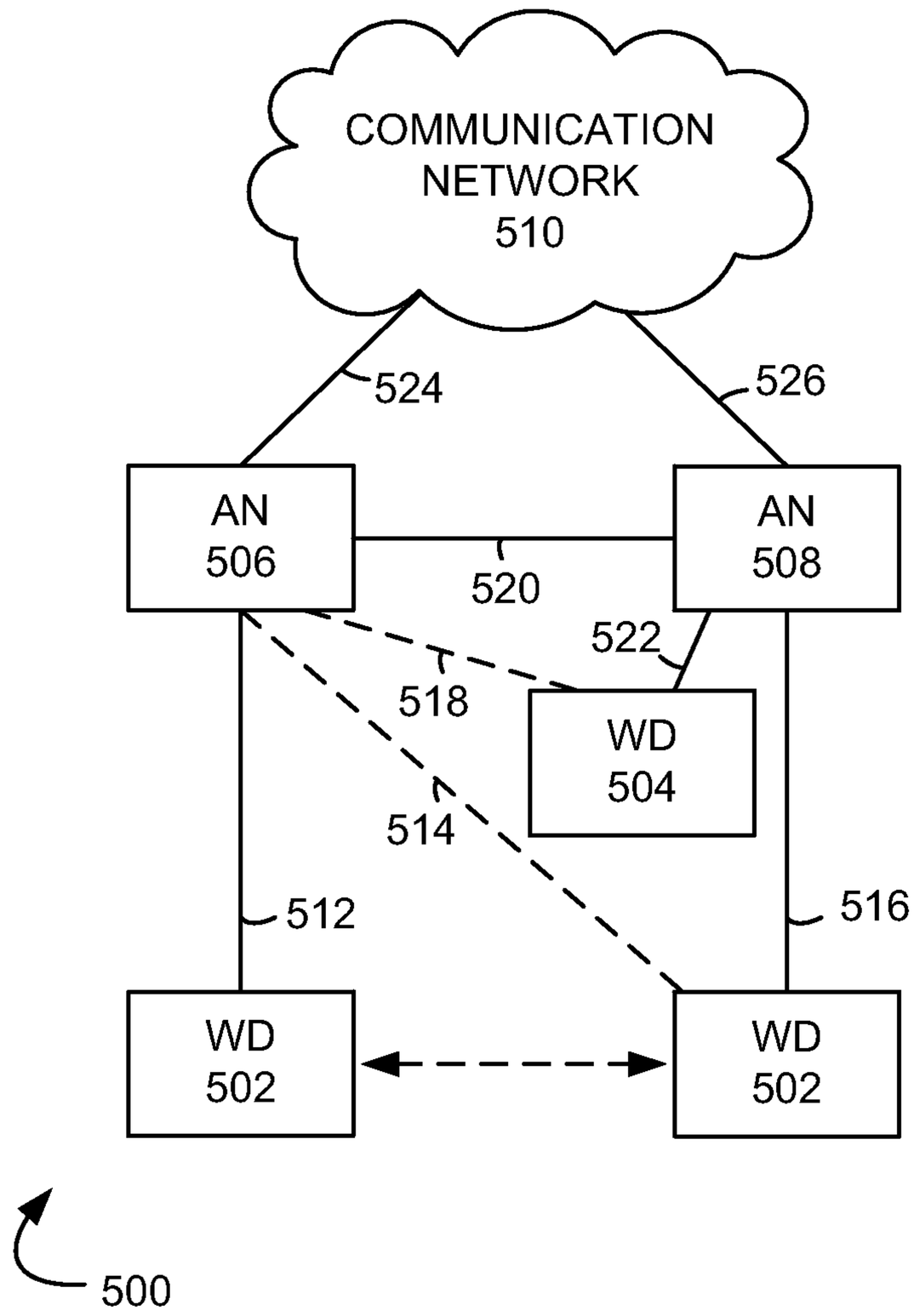

COMMUNICATION
NETWORK
510
524
526
AN
506
AN
508
520
522
518
WD
504
514
512
516
WD
502
WD
502
500

FIG. 5

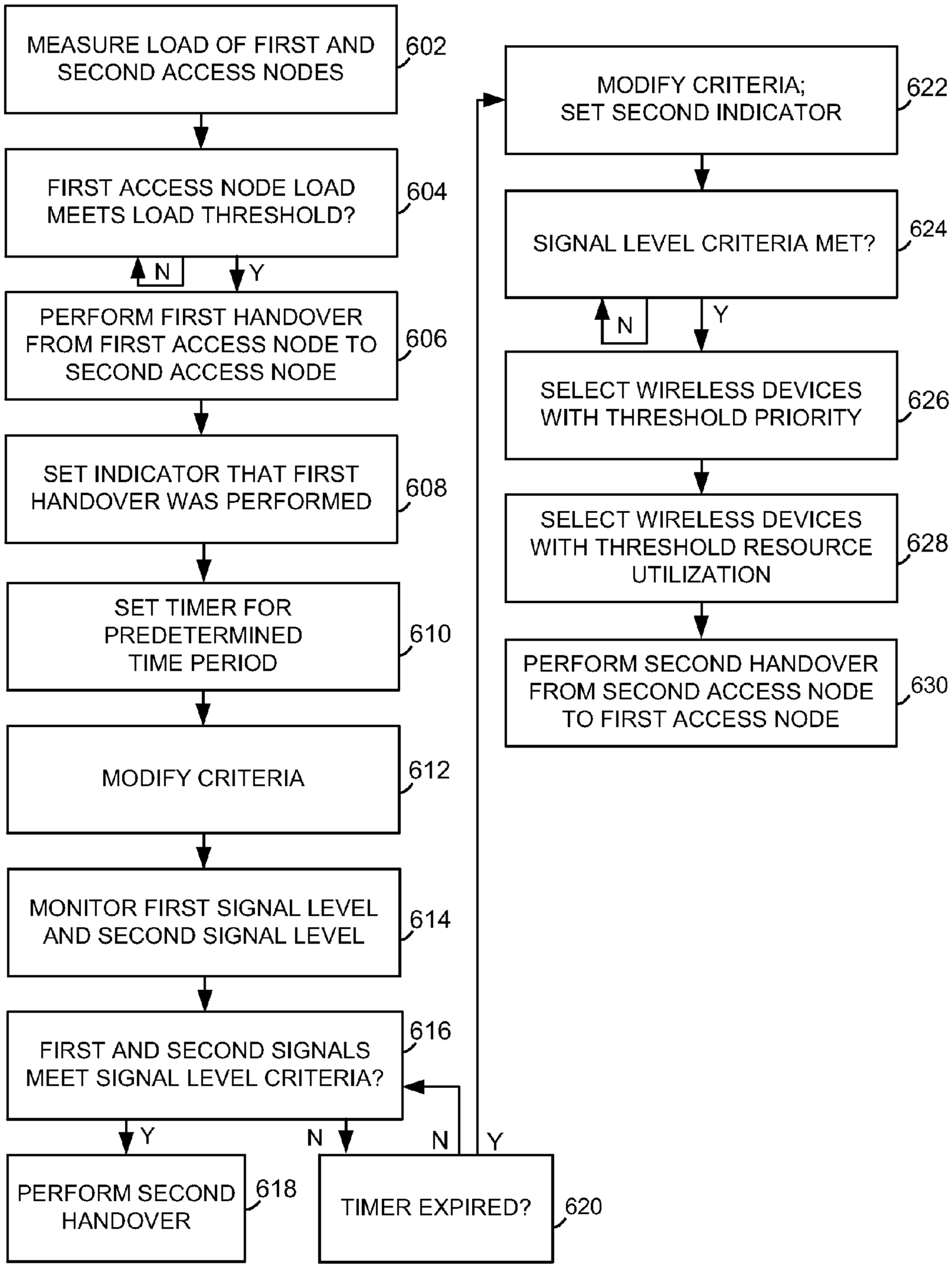

MEASURE LOAD OF FIRST AND SECOND ACCESS NODES
602
FIRST ACCESS NODE LOAD MEETS LOAD THRESHOLD?
604
N
Y
PERFORM FIRST HANDOVER FROM FIRST ACCESS NODE TO SECOND ACCESS NODE
606
SET INDICATOR THAT FIRST HANDOVER WAS PERFORMED
608
SET TIMER FOR PREDETERMINED TIME PERIOD
610
MODIFY CRITERIA
612
MONITOR FIRST SIGNAL LEVEL AND SECOND SIGNAL LEVEL
614
FIRST AND SECOND SIGNALS MEET SIGNAL LEVEL CRITERIA?
616
Y
N
PERFORM SECOND HANDOVER
618
TIMER EXPIRED?
620
N
Y
MODIFY CRITERIA; SET SECOND INDICATOR
622
SIGNAL LEVEL CRITERIA MET?
624
N
Y
SELECT WIRELESS DEVICES WITH THRESHOLD PRIORITY
626
SELECT WIRELESS DEVICES WITH THRESHOLD RESOURCE UTILIZATION
628
PERFORM SECOND HANDOVER FROM SECOND ACCESS NODE TO FIRST ACCESS NODE
630

FIG. 6

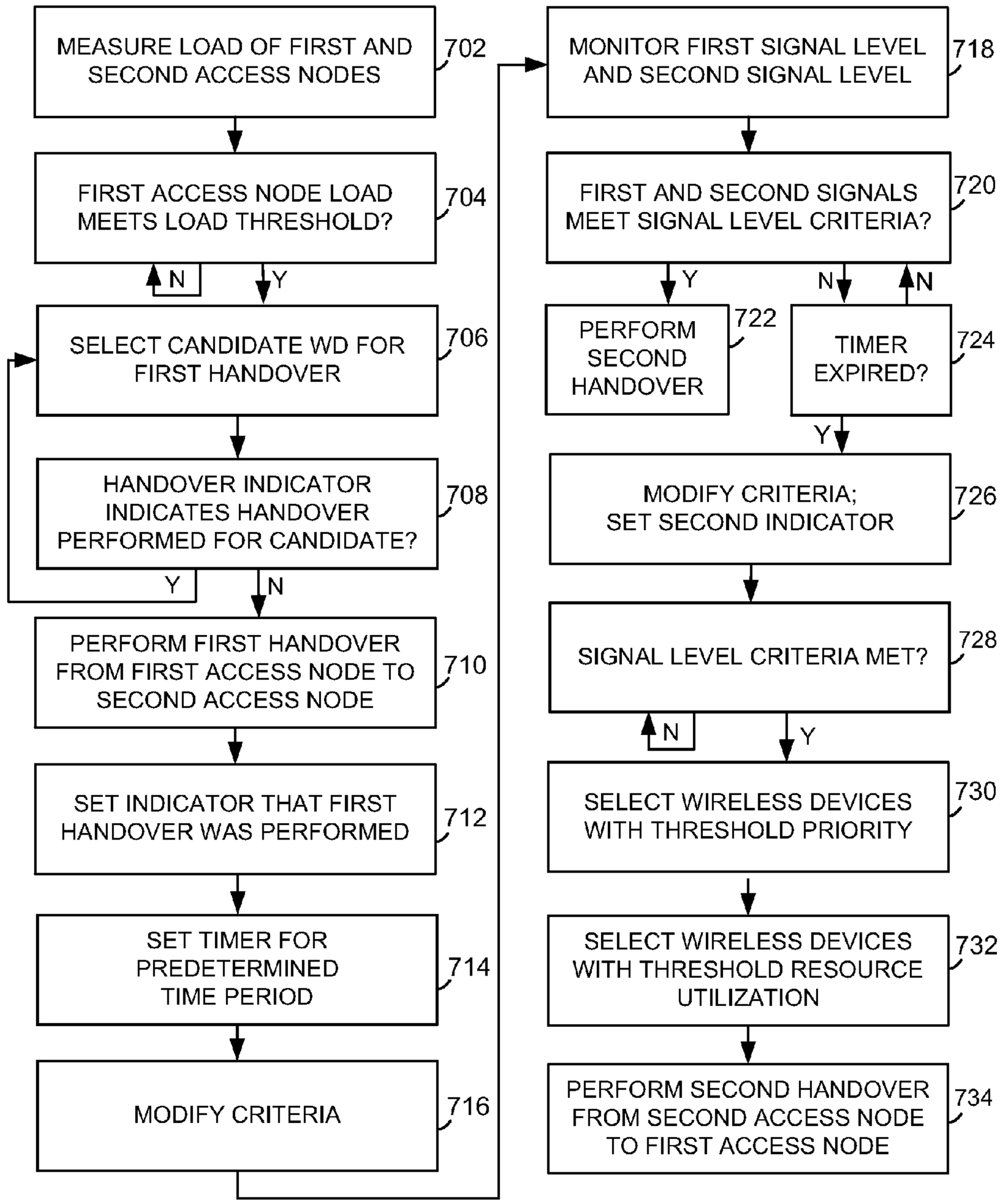

MEASURE LOAD OF FIRST AND SECOND ACCESS NODES
702
FIRST ACCESS NODE LOAD MEETS LOAD THRESHOLD?
704
N
Y
SELECT CANDIDATE WD FOR FIRST HANDOVER
706
HANDOVER INDICATOR INDICATES HANDOVER PERFORMED FOR CANDIDATE?
708
Y
N
PERFORM FIRST HANDOVER FROM FIRST ACCESS NODE TO SECOND ACCESS NODE
710
SET INDICATOR THAT FIRST HANDOVER WAS PERFORMED
712
SET TIMER FOR PREDETERMINED TIME PERIOD
714
MODIFY CRITERIA
716
MONITOR FIRST SIGNAL LEVEL AND SECOND SIGNAL LEVEL
718
FIRST AND SECOND SIGNALS MEET SIGNAL LEVEL CRITERIA?
720
Y
N
N
PERFORM SECOND HANDOVER
722
TIMER EXPIRED?
724
Y
MODIFY CRITERIA; SET SECOND INDICATOR
726
SIGNAL LEVEL CRITERIA MET?
728
N
Y
SELECT WIRELESS DEVICES WITH THRESHOLD PRIORITY
730
SELECT WIRELESS DEVICES WITH THRESHOLD RESOURCE UTILIZATION
732
PERFORM SECOND HANDOVER FROM SECOND ACCESS NODE TO FIRST ACCESS NODE
734

FIG. 7

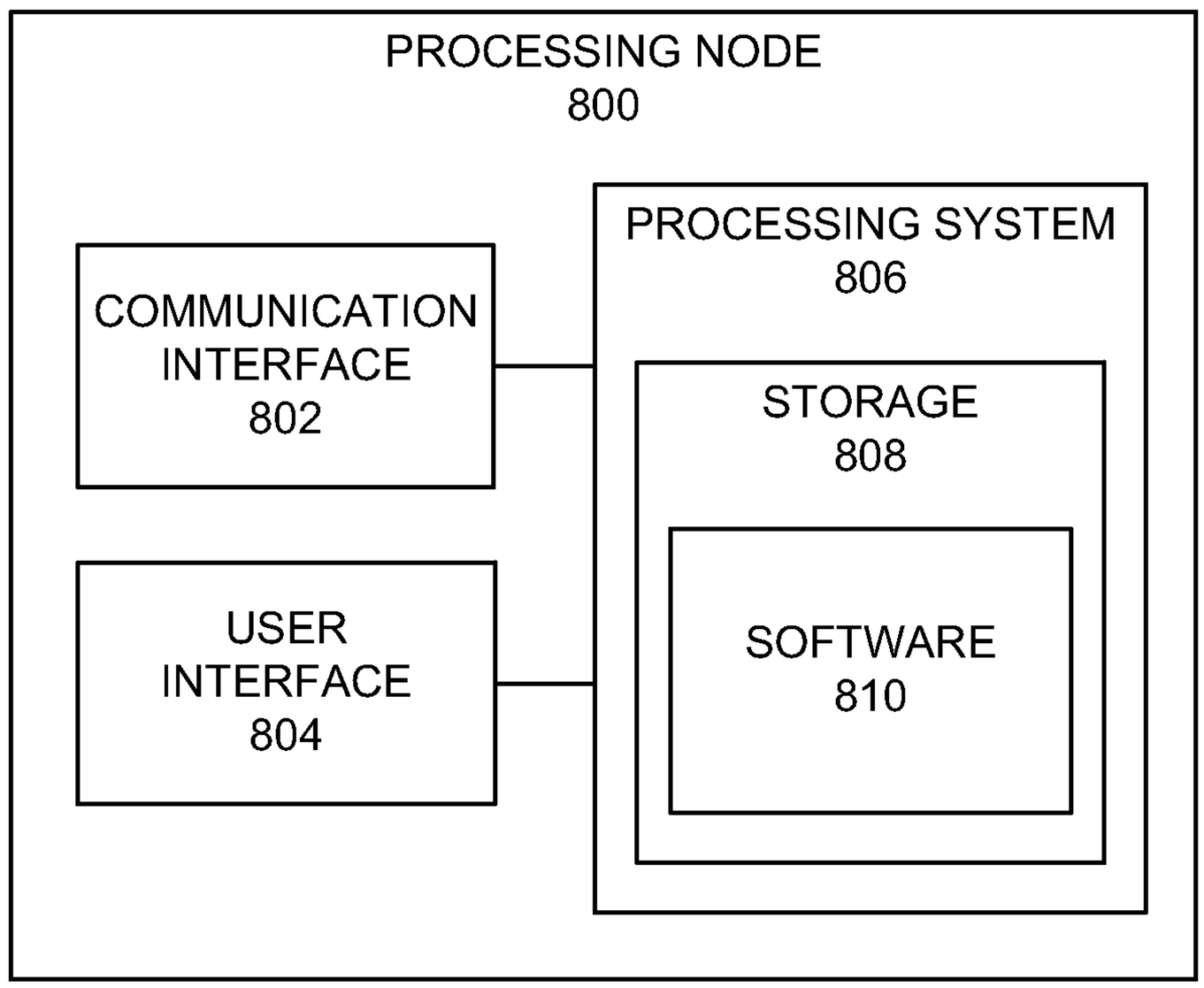

PROCESSING NODE
800
PROCESSING SYSTEM
806
COMMUNICATION INTERFACE
802
STORAGE
808
SOFTWARE
810
USER INTERFACE
804

FIG. 8

MANAGING ACCESS NODE SELECTION FOR A WIRELESS DEVICE

TECHNICAL BACKGROUND

The ability of a wireless device to communicate with a variety of access nodes is a vital function of a wireless communication system. A wireless device can be instructed to change from communicating with a first access node to communicating with a second access node for a variety of reasons. For example, based on the mobility of the wireless device, the communication system may determine to perform a handover of the wireless device to a new access node. As another example, an access node may perform a load balancing operation or a similar function and may perform a handover of the wireless device to another access node, for example, for purposes of load equalization, inter-frequency offloading, intra-frequency offloading, and the like. Typically, the performance of a handover is triggered at least in part due to load conditions at an access node, as well as received signal levels of access nodes at the wireless device.

OVERVIEW

In operation, it is determined that a first handover of a wireless device from a first access node to a second access node is performed based on a traffic load of the first access node meeting a traffic load threshold. A first signal level of the first access node and a second signal level of the second access node received at the wireless device are monitored. During a predetermined time period, the performance of a second handover of the wireless device from the second access node to the first access node is prevented when the second signal level meets a first signal level criteria. However, during the predetermined time period, the second handover of the wireless device is performed from the second access node to the first access node when the second signal level meets a second signal level criteria and the first signal level meets a third signal level criteria.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates an exemplary communication system to manage access node selection for a wireless device.

FIG. **2** illustrates an exemplary method of managing access node selection for a wireless device.

FIG. **3** illustrates exemplary signal levels over time.

FIG. **4** illustrates another exemplary method of managing access node selection for a wireless device.

FIG. **5** illustrates another exemplary system to manage access node selection for a wireless device.

FIG. **6** illustrates another exemplary method of managing access node selection for a wireless device.

FIG. **7** illustrates another exemplary method of managing access node selection for a wireless device.

FIG. **8** illustrates an exemplary processing node.

DETAILED DESCRIPTION

FIG. **1** illustrates an exemplary communication system **100** to manage access node selection for a wireless device 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 with access node **106** over communication link **112**. Wireless device **102** can also receive a signal level of access node **104** over communication link **114**.

Access nodes **104** and **106** are each a network node capable of providing wireless communications to wireless device **102**, and can be, for example, a base transceiver station, a radio base station, an eNodeB device, or an enhanced eNodeB device. Access node **104** is in communication with communication network **108** over communication link **118**, and access node **106** is in communication with communication network **108** over communication link **120**. Access nodes **104** and **106** can also communicate with each other over communication link **116**.

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**, **118** and **120** 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.

Wireless devices can be handed over from one access node to another access node in two general scenarios, mobility-

based and load-based. A mobility-based handover can be performed when a wireless device detects a neighboring access node signal level which is superior to a serving access node signal level, such as when a wireless device is moving away from the serving access node and toward the neighboring access node. A load-based handover can be performed as a traffic or load management operation, for example, to balance the loading of the serving access node and the neighboring access node, or for inter- or intra-frequency offloading, and the like.

Signal levels determined at the wireless device, or determined at a network element based on signals received at the wireless device, can be used to decide whether to perform a mobility-based or load-based handover. Where different signal level measurements or signal level thresholds are used to trigger different types of handovers, there is the potential for conflict between mobility-based and load-based handover mechanisms. For example, a wireless device in an active communication session with a first access node may be handed over from the first access node to a second access node in a load-based handover, only to detect a stronger signal from the first access node than from the second access node. Based on the stronger signal from the first access node, the wireless device may then be handed over to the first access node. Such repeated handovers between the first and second access nodes unnecessarily consume network resources, degrades communication services provided to the wireless device, and consumes wireless device battery resources as well.

In operation, when it is determined that a first handover of a wireless device is performed from a first access node to a second access node, and the handover is based on a traffic load of the first access node meeting a traffic load threshold, then a first signal level of the first access node and a second signal level of the second access node received at the wireless device are monitored. During a predetermined time period, when the second signal level meets a first signal level criteria, the performance of a second handover of the wireless device from the second access node to the first access node is prevented. However, when the second signal level meets a second signal level criteria and the first signal level meets a third signal level criteria during the predetermined time period, the second handover of the wireless device from the second access node to the first access node is performed.

FIG. **2** illustrates an exemplary method of managing access node selection for a wireless device. It is determined that a first handover of a wireless device is performed from a first access node to a second access node (operation **202**). For example, wireless device **102** can be handed over from access node **104** to access node **106**. The first handover can be performed when a traffic load of the first access node meets a traffic load threshold. For example, the first handover can be a load-based handover, which can be triggered based on load information of the serving cell (e.g., access node **104**), and which may also be based on load information of the neighboring cell (e.g., access node **106**). The target (neighboring) cell can be selected based on load information, and/or based on load information and a received signal level. In addition, wireless device **102** can be selected from among a plurality of wireless devices communicating with access node **104** on the basis of, for example, signal levels received at the wireless device, as well as wireless resource utilization (for example, utilization of physical resource blocks or other units of resource allocation by wireless device **102**).

After the wireless device is handed over to the second access node, a first signal level of the first access node and a second signal level of the second access node which are received at the wireless device are monitored (operation **204**). A signal level can comprise a signal strength determination, a signal quality determination, and the like, and can include a reference signal received power (RSRP), a reference signal received quality (RSRQ), a received signal strength indicator (RSSI), a received signal power code (RSCP), and other similar determinations. Wireless device **102**, while communicating with access node **106** over communication link **112**, can also receive a signal from access node **104** over communication link **114**. The signal received from access node **104** can comprise a pilot signal, a reference signal, and the like, and wireless device **102** can determine a signal level of the signal received from access node **104**. Additionally, wireless device **102** can determine a signal level of a signal and/or communications from access node **106**. Each of the first and second signal levels received at wireless device **102** can be monitored. For example, referring to FIG. **3**, the first handover of wireless device **102** can be performed at time t**1**, and signal level **302** associated with access node **104** and signal level **304** associated with access node **106** can be monitored based on signals received at wireless device **102**.

Returning to FIG. **2**, the performance of a second handover of the wireless device from the second access node to the first access node is prevented during a predetermined time period when the second signal level meets a first signal level criteria (operation **206**). For example, after wireless device **102** is handed over to access node **106**, wireless device **102** may receive signals or information from access node **104** over communication link **114**. A signal level of the information or signals can be determined by wireless device **102** (or by a network element based on the information or signals received by wireless device **102**), and further, the signal level from access node **104** can be compared with a signal level received from access node **106** (the access node presently serving wireless device **102**). Referring to FIG. **3**, signal level **302** associated with access node **104** can be compared with signal level **304** associated with access node **306**. Where signal level **302** (from access node **104**) is superior to signal level **304** (from access node **106**), a handover may be requested for wireless device **102** from access node **106** to access node **104**. However, during predetermined time period **306**, the second handover will be prevented when the second signal level meets the first signal level criteria. During predetermined time period **306**, the second handover can be prevented to avoid performing repeated handovers of wireless device **102** between access nodes **104** and **106**.

An offset value can be applied such that a handover is not requested until the signal level from access node **104** is greater than the signal level from access node **106** plus the offset value. For example, in the Long Term Evolution (LTE) standard, conditions for an Event A3 defining certain handover conditions can be expressed as:

$$Mn+Ofn+Ocn-Hys>Ms+Ofs+Ocs+Off \text{ (entering condition);} \quad \text{[Equation 1]}$$

$$Mn+Ofn+Ocn+Hys<Ms+Ofs+Ocs+Off \text{ (leaving condition),} \quad \text{[Equation 2]}$$

where Mn is a measurement result of the neighboring cell, Ofn is a frequency specific offset of the frequency of the neighbor cell, Ocn is the cell specific offset of the neighbor cell, Hys is a hysteresis parameter for this event, Ofs is the frequency specific offset of the serving frequency, Ocs is the cell specific offset of the serving cell, and Off is the offset parameter for this event. An Event A3 is one example of when the second signal level can be determined to meet the first signal level criteria.

However, during the predetermined time period, the second handover will be prevented when the second signal level

meets the first signal level criteria. For example, during predetermined time period **306** from time t**1** to time t**2**, although signal level **302** (associated with access node **104**) is superior to signal level **304** (associated with access node **106**) with or without the offset value, a handover of wireless device **102** from access node **106** to access node **104** will be prevented. The first signal level criteria can comprise a minimum signal level, a minimum data rate, a minimum throughput, a maximum permitted error rate, a maximum permitted data loss rate, or another similar measure of the signal from access node **106**. The first signal level criteria can also comprise a signal level of access node **104** which is superior to the signal level from access node **106**, with or without the application of an offset.

Returning to FIG. **2**, in operation **208**, when the second signal level meets a second signal level criteria and the first signal level meets a third signal level criteria during the predetermined time period, the second handover of the wireless device from the second access node to the first access node is performed. Although the second handover is prevented when the second signal level meets the first signal level criteria, the ability of the access nodes to provide a level of communication services to wireless device **102** (as reflected in received signal levels) is monitored and considered. Signal levels from each of access nodes **104** and **106** can be monitored, and when each satisfies a criteria during the predetermined time period the second handover will be performed.

For example, signal levels **302** and **304** can be monitored with respect to threshold **308**, illustrated in FIG. **3**. Threshold **308** can comprise a signal level threshold. For example, threshold **308** can comprise a reception sensitivity of wireless device **102**, or it can comprise a minimum signal level of signal levels **302** and/or **304**. During predetermined time period **306**, when the second signal level (signal level **304**) meets a second signal level criteria and the first signal level (signal level **302**) meets a third signal level criteria, the second handover of the wireless device from the second access node to the first access node can be performed. For example, when a signal level of access node **106** falls below a certain signal level threshold and when a signal level of access node **104** rises above a certain signal level threshold, the second handover can be performed during the predetermined time period, to maintain a level of services provided to wireless device **102**.

In an embodiment, in the Long Term Evolution (LTE) standard, conditions for an Event A5 defining certain handover conditions can be expressed as:

$$Ms+Hys<\text{Thresh1 AND } Mn+Ofn+Ocn-Hys>\text{Thresh2} \quad \text{(entering condition);} \quad \text{[Equation 3]}$$

$$Ms-Hys>\text{Thresh1 OR } Mn+Ofn+Ocn+Hys<\text{Thresh2} \quad \text{(leaving condition),} \quad \text{[Equation 4]}$$

where Thresh1 and Thresh2 are threshold signal level parameters defined for Event A5, Mn is a measurement result of the neighboring cell, Ofn is a frequency specific offset of the frequency of the neighbor cell, Ocn is the cell specific offset of the neighbor cell, Hys is a hysteresis parameter for this event, Ofs is the frequency specific offset of the serving frequency, Ocs is the cell specific offset of the serving cell, and Off is the offset parameter for this event. During the predetermined time period, when the signal levels from access nodes **104** and **106** meet respective thresholds, it can be determined that the second signal level meets a second signal level criteria and the first signal level meets a third signal level criteria. In an embodiment, when signal level **304** meets or is below threshold **308**, signal level **304** can be determined to meet the second signal level criteria, and when signal level **302** meets or exceeds threshold **308**, signal level **302** can be determined to meet the third signal level criteria. When the second signal level meets the second signal level criteria and the first signal level meets the third signal level criteria, the second handover of the wireless device from the second access node to the first access node is performed during a predetermined time period.

FIG. **4** illustrates another exemplary method of managing access node selection for a wireless device. In operation **402**, it is determined that a first handover of a wireless device is performed from a first access node to a second access node. The first handover can be performed when a traffic load of the first access node meets a traffic load threshold. For example, the first handover can be a load-based handover, which can be triggered based on load information of the serving cell (e.g., access node **104**), and which may also be based on load information of the neighboring cell (e.g., access node **106**). The target access node can be selected based on load information, and/or based on load information and a received signal level. In addition, wireless device **102** can be selected from among a plurality of wireless devices communicating with access node **104** on the basis of, for example, signal levels received at the wireless device, as well as wireless resource utilization (for example, utilization of physical resource blocks or other units of resource allocation by wireless device **102**).

An indicator is set in a network element of communication system **100** indicating that the first handover has been performed, to prevent the performance of the second handover during the predetermined time period (operation **404**). The indicator can be set at access node **106**, or at another element of communication system **100**, such as a controller node, a gateway node, or another network element. In addition a timer is set for a predetermined period of time (operation **406**). The timer can be set at access node **106**, or at another element of communication system **100**, such as a controller node, a gateway node, or another network element. The timer can be set for a predetermined time period, such as time period **306** (FIG. **3**).

In operation **408**, a first signal level of the first access node and a second signal level of the second access node which are received at the wireless device are monitored. Wireless device **102**, while communicating with access node **106** over communication link **112**, can also receive a signal from access node **104** over communication link **114**. The signal received from access node **104** can comprise a pilot signal, a reference signal, and the like and wireless device **102** can determine a signal level of the signal received from access node **104**. Additionally, wireless device **102** can determine a signal level of a signal and/or communications from access node **106**. Each of the first and second signal levels received at wireless device **102** can be monitored.

During the predetermined time period, it can be determined whether the second signal level meets a second signal level criteria and the first signal level meets a third signal level criteria (operation **410**). When the second signal level meets a second signal level criteria and the first signal level meets a third signal level criteria during the predetermined time period (operation **410**-Y), a second handover of the wireless device from the second access node to the first access node is performed (operation **412**). Although the second handover is prevented for other conditions during the predetermined time period, to provide a level of communication services provided to wireless device **102** the signal levels from access nodes **104** and **106** are monitored and considered, and when signal levels from each access node satisfy a respective criteria during the

predetermined time period, the second handover will be performed. When either the second signal level does not meet the second signal level criteria or the first signal level does not meet the third signal level criteria (operation **410**-N), the timer value is checked (operation **414**).

For example, signal levels **302** and **304** can be monitored with respect to threshold **308**, illustrated in FIG. **3**. Threshold **308** can comprise a signal level threshold, such as a reception sensitivity of wireless device **102**, or a minimum signal level of signal levels **302** and/or **304**, and the like. During predetermined time period **306** from time t**1** to time t**2**, when the second signal level (signal level **304**) meets a second signal level criteria and the first signal level (signal level **302**) meets a third signal level criteria, the second handover of the wireless device from the second access node to the first access node can be performed. Thus, for example, when a signal level of access node **106** falls below a certain signal level threshold and when a signal level of access node **104** rises above a certain signal level threshold, the second handover can be performed during the predetermined time period, to maintain a level of services provided to wireless device **102**.

Returning to FIG. **4**, after the predetermined time period expires (operation **414**-Y), then when the second signal level meets a first signal level criteria (operation **416**-Y) the second handover is performed. For example, where signal level **302** in FIG. **3** (associated with access node **104**) is superior to signal level **304** (associated with access node **106**), a handover may be performed for wireless device **102** from access node **106** to access node **104**. In an embodiment, an offset value can be applied such that a handover to access node **106** is not requested until the signal level from access node **104** is greater than the signal level from access node **106** plus the offset value. When the signal level from access node **104** is superior to the signal level from access node **106** (with or without the application of an offset), the second signal level can be determined to meet the first signal level criteria.

FIG. **5** illustrates another exemplary system **500** to manage access node selection for a wireless device comprising wireless devices **502** and **504**, access nodes **506** and **508**, and communication network **510**. Examples of wireless devices **502** and **504** 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 **502** can communicate with access node **506** over communication link **512** and with access node **508** over communication link **516**. Wireless device **502** can also receive a signal level of access node **506** over communication link **514**. Wireless device **504** can communicate with access node **508** over communication link **522**, and can also receive a signal level of access node **506** over communication link **518**.

Access nodes **506** and **508** are each a network node capable of providing wireless communications to wireless devices **502** and **504**, and can be, for example, a base transceiver station, a radio base station, an eNodeB device, or an enhanced eNodeB device. Access node **506** is in communication with communication network **510** over communication link **524**, and access node **508** is in communication with communication network **510** over communication link **526**. Access nodes **506** and **508** can also communicate with each other over communication link **520**.

Communication network **510** 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 **510** can be capable of carrying voice information and other data, for example, to support communications by a wireless device such as wireless devices **502** and **504**. 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 **510** 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 **510** 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 **512**, **514**, **516**, **518**, **520**, **522**, **524** and **526** 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 **500** 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 **506**, access node **508**, and communication network **510** 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. **6** illustrates another exemplary method of managing access node selection for a wireless device. Loading of the first and second access nodes is measured (operation **602**). When the first access node load meets a load threshold (operation **604**-Y), a first handover is performed to hand over a wireless device from the first access node to the second access node (operation **606**). The first handover can be triggered based on load information of the serving cell (e.g., access node **506**), and which may also be based on load information of the neighboring cell (e.g., access node **508**). The target (neighboring) cell can be selected based on load information, and/or based on load information and a received signal level. In addition, wireless device **502** can be selected from among a plurality of wireless devices communicating with access node **506** on the basis of, for example, signal levels received at the wireless device, as well as wireless resource utilization (for example, utilization of physical resource blocks or other units of resource allocation by wireless device **502**). The first handover can be performed at a first point in time.

An indicator is set in a network element of communication system **500** indicating that the first handover has been per-

formed, to prevent the performance of the second handover during the predetermined time period (operation **608**). The indicator can be set at access node **508**, or at another element of communication system **500**, such as a controller node, a gateway node, or another network element.

In addition, a timer is set for a predetermined period of time (operation **610**). The timer can be determined to start at the first point in time, and can be set for a predetermined time period. The timer can be set at access node **508**, or at another element of communication system **500**, such as a controller node, a gateway node, or another network element.

In operation **612**, criteria for triggering a request to hand over the wireless device are modified. For example, before the first handover is performed, the criteria for requesting a handover of wireless device can be whether a signal level from a neighboring access node is superior to a signal level from a serving access node. In an embodiment, the criteria for triggering a request to hand over the wireless device can be an Event A3. In operation **612**, when or after the first handover is performed (e.g., to hand over wireless device **502** from access node **506** to access node **508**), the trigger criteria can be modified. For example, the trigger criteria can be modified so that a handover of wireless device **502** will be prevented unless the neighboring access node (access node **506**) signal level is greater than or equal to a signal level threshold minimum and the serving access node (access node **508**) signal level is less than the signal level threshold. In an embodiment, the modified criteria for triggering a request to hand over the wireless device can be an Event A5.

When the trigger criteria are modified, the first and second signal levels are monitored (operation **614**). When a signal level of access node **508** falls below a certain signal level threshold and when a signal level of access node **506** rises above a certain signal level threshold (operation **616**-Y), the second handover can be performed during the predetermined time period, to maintain a level of services provided to wireless device **502** (operation **618**).

When the signal level of access node **508** does not fall below a certain signal level threshold and/or when the signal level of access node **506** does not rise above a certain signal level threshold (operation **616**-N), then it is determined whether the timer has expired (operation **620**). When the timer has expired (operation **620**-Y), then a second indicator is set to indicate that the timer has expired, and the trigger criteria for triggering a request to hand over the wireless device are modified (operation **622**). The second indicator can be set at access node **508**, or at another element of communication system **500**, such as a controller node, a gateway node, or another network element, to permit the request for a performance of a handover based on the modified criteria. The trigger criteria modified in operation **622** can comprise, for example, permitting the request of a handover when the signal level from access node **506** is superior to the signal level from access node **508** (with or without the application of an offset). In an embodiment, the modified criteria can comprise an Event A3.

In operation **624**, it is determined whether the signal level from the serving access node meets the signal level criteria. When the signal level criteria is met (operation **624**-Y), wireless devices in communication with access node **508** are selected as candidates for a second handover from access node **508** to access node **506** (operation **626**). Candidate wireless devices (such as wireless devices **502** and **504**) are selected when they comprise a threshold level of priority. The threshold level of priority can comprise an application requirement of an application running on each wireless device, which may require, for example, a minimum data rate, a minimum throughput, a maximum permitted data error rate, a maximum permitted packet loss rate, and the like. The threshold level of priority can also comprise a traffic class indicator associated with bearer data being sent from a wireless device, such as a quality of service class indicator (QCI) or similar traffic class indicator. The threshold level of priority can also comprise a level of priority provisioned within communication system **500** for each wireless device, such as may be associated with a premium-level subscriber, an emergency responder, and the like. For example, wireless devices **502** and **504** can comprise a threshold level of priority, and can be selected as candidates for the second handover.

Further, candidate wireless devices are evaluated to determine a wireless resource utilization of each wireless device (operation **628**). Wireless resource utilization can comprise utilization of physical resource blocks and/or other units of resource allocation by a wireless device. For example, wireless devices **502** and **504** can comprise a threshold level of wireless resource utilization, and can be retained as candidates for the second handover.

In operation **630**, the second handover is performed of the selected wireless device from the second access node to the first access node. For example, wireless device can be handed over to access node **506**. In an embodiment, the wireless device to be handed over is also selected based on received signal levels of access nodes **506** and **508**. For example, where possible one or more wireless devices will be selected which receive the lowest signal strength from the serving access node (access node **508**) from among the candidate wireless devices. Further, where possible one or more wireless devices will be selected which receive the highest signal strength from the neighboring access node (access node **506**).

FIG. **7** illustrates another exemplary method of managing access node selection for a wireless device. Loading of the first and second access nodes is measured (operation **702**). When the first access node load meets a load threshold (operation **704**-Y), a candidate wireless device is selected from among a plurality of wireless device in communication with the first access node.

Wireless devices can be evaluated as candidates for the performance of a handover based on various criteria. For example, an application requirement of an application running on a wireless device can be determined. 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 wireless device can also be evaluated based on its 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 wireless device can be evaluated 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. Moreover, the wireless device can be evaluated based on a level of priority provisioned within communication system **500** for the wireless device, such as may be associated with a premium-level subscriber, an emergency responder, and the like. Other criteria for evaluating wireless devices are also possible, including combinations of the foregoing. In an embodiment, the selected candidate wireless device can comprise a wireless device with the highest application requirement, the highest resource utilization, etc., from among a plurality of wireless devices in communication with the first access node.

When the candidate wireless device is selected, a handover indicator associated with the wireless device is checked (operation **708**). The handover indicator can indicate whether the wireless device has been recently handed over to the first access node, for example, within a predetermined period of time. When the handover indicator indicates that a handover was recently performed (operation **708**-Y), then another candidate wireless device is selected.

When the handover indicator does not indicate that a handover was recently performed (operation **708**-N), a first handover is performed to hand over a wireless device from the first access node to the second access node (operation **710**). The first handover can be triggered based on load information of the serving cell (e.g., access node **506**), and which may also be based on load information of the neighboring cell (e.g., access node **508**). The target (neighboring) cell can be selected based on load information, and/or based on load information and a received signal level. In addition, wireless device **502** can be selected from among a plurality of wireless devices communicating with access node **506** on the basis of, for example, signal levels received at the wireless device, as well as wireless resource utilization (for example, utilization of physical resource blocks or other units of resource allocation by wireless device **502**). The first handover can be performed at a first point in time.

An indicator is set in a network element of communication system **500** indicating that the first handover has been performed, to prevent the performance of the second handover during the predetermined time period (operation **712**). The indicator can be set at access node **508**, or at another element of communication system **500**, such as a controller node, a gateway node, or another network element.

In addition, a timer is set for a predetermined period of time (operation **714**). The timer can be determined to start at the first point in time, and can be set for a predetermined time period. The timer can be set at access node **508**, or at another element of communication system **500**, such as a controller node, a gateway node, or another network element.

In operation **716**, criteria for triggering a request to hand over the wireless device are modified. For example, before the first handover is performed, the criteria for requesting a handover of wireless device can be whether a signal level from a neighboring access node is superior to a signal level from a serving access node. In an embodiment, the criteria for triggering a request to hand over the wireless device can be an Event A3. In operation **716**, when or after the first handover is performed (e.g., to hand over wireless device **502** from access node **506** to access node **508**), the trigger criteria can be modified. For example, the trigger criteria can be modified so that a handover of wireless device **502** will be prevented unless the neighboring access node (access node **506**) signal level is greater than or equal to a signal level threshold minimum and the serving access node (access node **508**) signal level is less than the signal level threshold. In an embodiment, the modified criteria for triggering a request to hand over the wireless device can be an Event A5.

When the trigger criteria are modified, the first and second signal levels are monitored (operation **718**). When a signal level of access node **508** falls below a certain signal level threshold and when a signal level of access node **506** rises above a certain signal level threshold (operation **720**-Y), the second handover can be performed during the predetermined time period, to maintain a level of services provided to wireless device **502** (operation **722**).

When the signal level of access node **508** does not fall below a certain signal level threshold and/or when the signal level of access node **506** does not rise above a certain signal level threshold (operation **720**-N), then it is determined whether the timer has expired (operation **724**). When the timer has expired (operation **724**-Y), then a second indicator is set to indicate that the timer has expired, and the trigger criteria for triggering a request to hand over the wireless device are modified (operation **726**). The second indicator can be set at access node **508**, or at another element of communication system **500**, such as a controller node, a gateway node, or another network element, to permit the request for a performance of a handover based on the modified criteria. The trigger criteria modified in operation **726** can comprise, for example, permitting the request of a handover when the signal level from access node **506** is superior to the signal level from access node **508** (with or without the application of an offset). In an embodiment, the modified criteria can comprise an Event A3.

In operation **728**, it is determined whether the signal level from the serving access node meets the signal level criteria. When the signal level criteria is met (operation **728**-Y), wireless devices in communication with access node **508** are selected as candidates for a second handover from access node **508** to access node **506** (operation **730**). Candidate wireless devices (such as wireless devices **502** and **504**) are selected when they comprise a threshold level of priority. The threshold level of priority can comprise an application requirement of an application running on each wireless device, which may require, for example, a minimum data rate, a minimum throughput, a maximum permitted data error rate, a maximum permitted packet loss rate, and the like. The threshold level of priority can also comprise a traffic class indicator associated with bearer data being sent from a wireless device, such as a quality of service class indicator (QCI) or similar traffic class indicator. The threshold level of priority can also comprise a level of priority provisioned within communication system **500** for each wireless device, such as may be associated with a premium-level subscriber, an emergency responder, and the like. For example, wireless devices **502** and **504** can comprise a threshold level of priority, and can be selected as candidates for the second handover.

Further, candidate wireless devices are evaluated to determine a wireless resource utilization of each wireless device (operation **732**). For example, wireless devices **502** and **504** can comprise a threshold level of wireless resource utilization, and can be retained as candidates for the second handover. Wireless resource utilization can comprise 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. The wireless resource utilization can further be based on 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. Other examples of wireless resource utilization are possible, including combinations of the foregoing.

In operation **734**, the second handover is performed of the selected wireless device from the second access node to the first access node. For example, wireless device can be handed over to access node **506**. In an embodiment, the wireless device to be handed over is also selected based on received signal levels of access nodes **506** and **508**. For example, where possible one or more wireless devices will be selected which receive the lowest signal strength from the serving access node (access node **508**) from among the candidate wireless devices. Further, where possible one or more wireless devices will be selected which receive the highest signal strength from the neighboring access node (access node **506**).

FIG. **8** illustrates an exemplary processing node **800** in a communication system. Processing node **800** comprises communication interface **802**, user interface **804**, and processing system **806** in communication with communication interface **802** and user interface **804**. Processing node **800** can be configured to manage access node selection for a wireless device. Processing system **806** includes storage **808**, which can comprise a disk drive, flash drive, memory circuitry, or other memory device. Storage **808** can store software **810** which is used in the operation of the processing node **800**. Storage **808** may include a disk drive, flash drive, data storage circuitry, or some other memory apparatus. Software **810** 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 **806** may include a microprocessor and other circuitry to retrieve and execute software **810** from storage **808**. Processing node **800** may further include other components such as a power management unit, a control interface unit, etc., which are omitted for clarity. Communication interface **802** permits processing node **800** to communicate with other network elements. User interface **804** permits the configuration and control of the operation of processing node **800**.

Examples of processing node **800** include access nodes **104**, **106**, **506** and **508**. Processing node **800** can also be an adjunct or component of a network element, or processing node **800** can be another network element in a communication system. Further, the functionality of processing node **800** can be distributed over two or more 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 managing access node selection for a wireless device, comprising:

performing a load-based handover of a selected wireless device from a first access node to a second access node, wherein the load-based handover is triggered based on a traffic load of the first access node;

detecting a first signal level of the first access node, wherein the first signal level of the first access node is stronger than a second signal level of the second access node;

setting an indicator to prevent performance of a first handover of the selected wireless device between the second access node and the first access node for a predetermined period of time when the second signal level of the second access node meets a first signal level criteria; and,

permitting the first handover of the selected wireless device from the second access node to the first access node during the predetermined period of time when the second signal level of the second access node is less than a second signal level criteria and the first signal level of the first access node is greater than a third signal level criteria.

2. The method of claim **1**, wherein preventing the performance of the first handover of the selected wireless device further comprises instructing the selected wireless device to not request the performance of the first handover when the second signal level meets the first signal level criteria during the predetermined period of time.

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

permitting the selected wireless device to request the performance of the first handover after the predetermined period of time expires when the second signal level meets the first signal level criteria.

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

permitting the selected wireless device to request the performance of the first handover after the predetermined period of time expires when the second signal level is greater than or equal to the first signal level plus a first signal level offset.

5. The method of claim **2**, wherein instructing the selected wireless device further comprises instructing the selected wireless device to not request the performance of the first handover during the predetermined period of time unless the first signal level of the first access node is greater than or equal to a signal level threshold minimum and the second signal level of the second access node is less than a signal level threshold.

6. The method of claim 5, wherein the signal level threshold is a minimum receive sensitivity of the wireless device.

7. The method of claim 1, wherein preventing the performance of the first handover further comprises preventing the performance of the first handover when the selected wireless device requests the performance of the first handover during the predetermined period of time.

8. The method of claim 7, wherein preventing the performance of the first handover further comprises setting the indicator at a network element indicating that the load-based handover has been performed, to prevent the performance of the first handover during the predetermined period of time.

9. The method of claim 8, further comprising:

setting a second indicator at the network element after the predetermined period of time expires to permit the selected wireless device to request the performance of the first handover.

10. A method of managing access node selection for a wireless device, comprising:

instructing a load-based handover of the wireless device from a first access node to a second access node based on a traffic load of the first access node meeting a traffic load threshold;

monitoring a first signal level of the first access node and a second signal level of the second access node received at the wireless device;

preventing the performance of a first handover of the wireless device from the second access node to the first access node during a predetermined time period when the second signal level meets a first signal level criteria;

determining that the wireless device comprises a highest wireless resource utilization from among a plurality of wireless devices in communication with the second access node; and

performing the first handover of the wireless device from the second access node to the first access node during the predetermined time period when the second signal level of the second access node is less than a second signal level criteria and the first signal level of the first access node is greater than a third signal level criteria.

11. The method of claim 10, further comprising performing the first handover of the wireless device from the second access node to the first access node during the predetermined time period when the second signal level received at the wireless device is the lowest from among the plurality of wireless devices in communication with the second access node.

12. The method of claim 10, further comprising performing the first handover of the wireless device from the second access node to the first access node during the predetermined time period when the first signal level is the highest from among the plurality of wireless devices in communication with the access node.

13. The method of claim 10, wherein preventing the performance of the first handover further comprises instructing the wireless device to not request the performance of the first handover when the second signal level meets the first signal level criteria during the predetermined time period.

14. The method of claim 13, further comprising:

permitting the wireless device to request the performance of the first handover after the predetermined time period expires when the second signal level meets the first signal level criteria.

15. The method of claim 14, further comprising:

permitting the wireless device to request the performance of the first handover after the predetermined time period expires when the second signal level is greater than or equal to the first signal level plus a first signal level offset.

16. The method of claim 14, wherein instructing the wireless device further comprises instructing the wireless device to not request the performance of the first handover during the predetermined time period unless the first signal level of the first access node is greater than or equal to a signal level threshold minimum and the second signal level of the second access node is less than a signal level threshold.

17. The method of claim 16, wherein the signal level threshold is a minimum receive sensitivity of the wireless device.

18. The method of claim 13, wherein preventing the performance of the first handover further comprises preventing the performance of the first handover when the wireless device requests the performance of the first handover during the predetermined time period.

19. The method of claim 18, wherein preventing the performance of the first handover further comprises setting an indicator at a network element indicating that the wireless device has been instructed to change from communicating with the first access node to the second access node, to prevent the performance of the first handover during the predetermined time period.

20. The method of claim 19, further comprising:

setting a second indicator at the network element after the predetermined period of time expires to permit the performance of the first handover.

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