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(54) **SYSTEM AND METHOD FOR WIRELESS NETWORK OFFLOADING**

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See application file for complete search history.

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(57) **ABSTRACT**

Wireless offloading provides tools to a service provider to encourage or direct a subscriber to offload from a first network, e.g., a cellular network, to a second network, e.g., a Wi-Fi network. The cellular service provider can use network data to determine wireless offloading priorities for cellular subscribers on an individual or group basis. The cellular service provider may use wireless network data it has and/or wireless network data it learns about networks from the wireless devices (which may obtain Wi-Fi network data from beacon frames of Wi-Fi networks or active scanning and which may report to the cellular service provider). Each wireless device can be given scanning assignments to ensure that the reporting task is shared among subscribers or adjusted to fill in gaps in data. With the network data, the cellular service provider is capable of generating useful prioritized network lists for wireless devices, either individually or as a group. Preferences can be encouraged in the form of incentive offers to subscribers to, e.g., offload from
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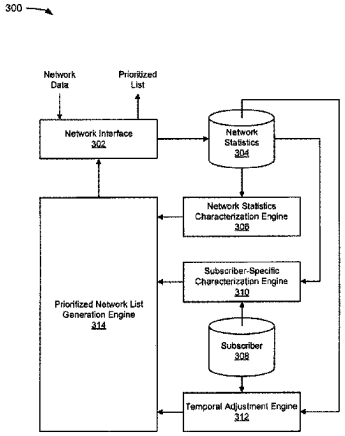

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the cellular network to a Wi-Fi network. Incentive offers can include offers to lower service costs or provide additional or improved services.

10 Claims, 15 Drawing Sheets

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division of application No. 13/134,005, filed on May 25, 2011, now Pat. No. 8,635,335, which is a continuation-in-part of application No. 12/380,778, filed on Mar. 2, 2009, now Pat. No. 8,321,526, which is a continuation-in-part of application No. 12/380,780, filed on Mar. 2, 2009, now Pat. No. 8,839,388.

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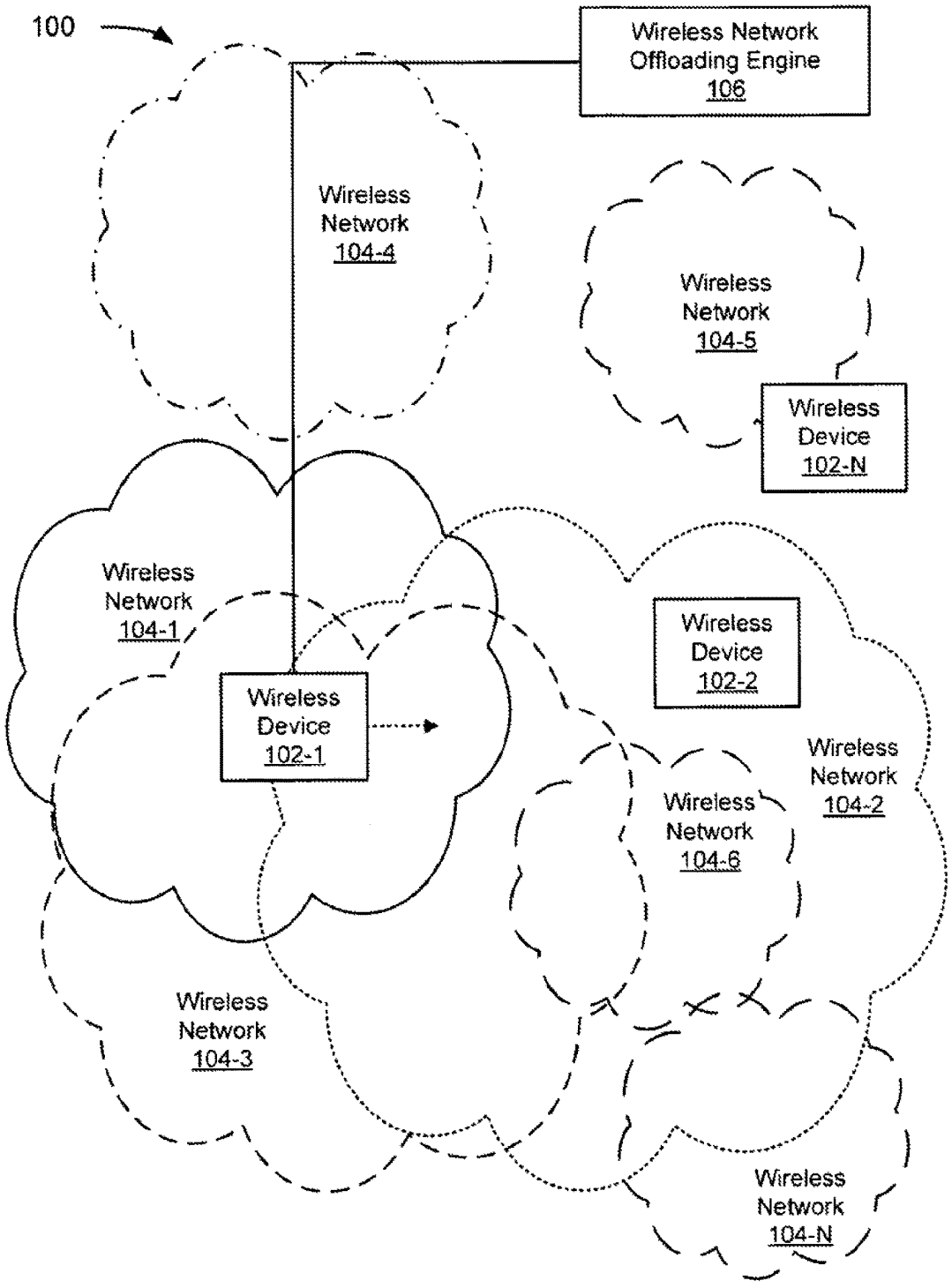
100
Wireless Network Offloading Engine 106
Wireless Network 104-4
Wireless Network 104-5
Wireless Device 102-N
Wireless Network 104-1
Wireless Device 102-1
Wireless Device 102-2
Wireless Network 104-2
Wireless Network 104-6
Wireless Network 104-3
Wireless Network 104-N

FIG. 1

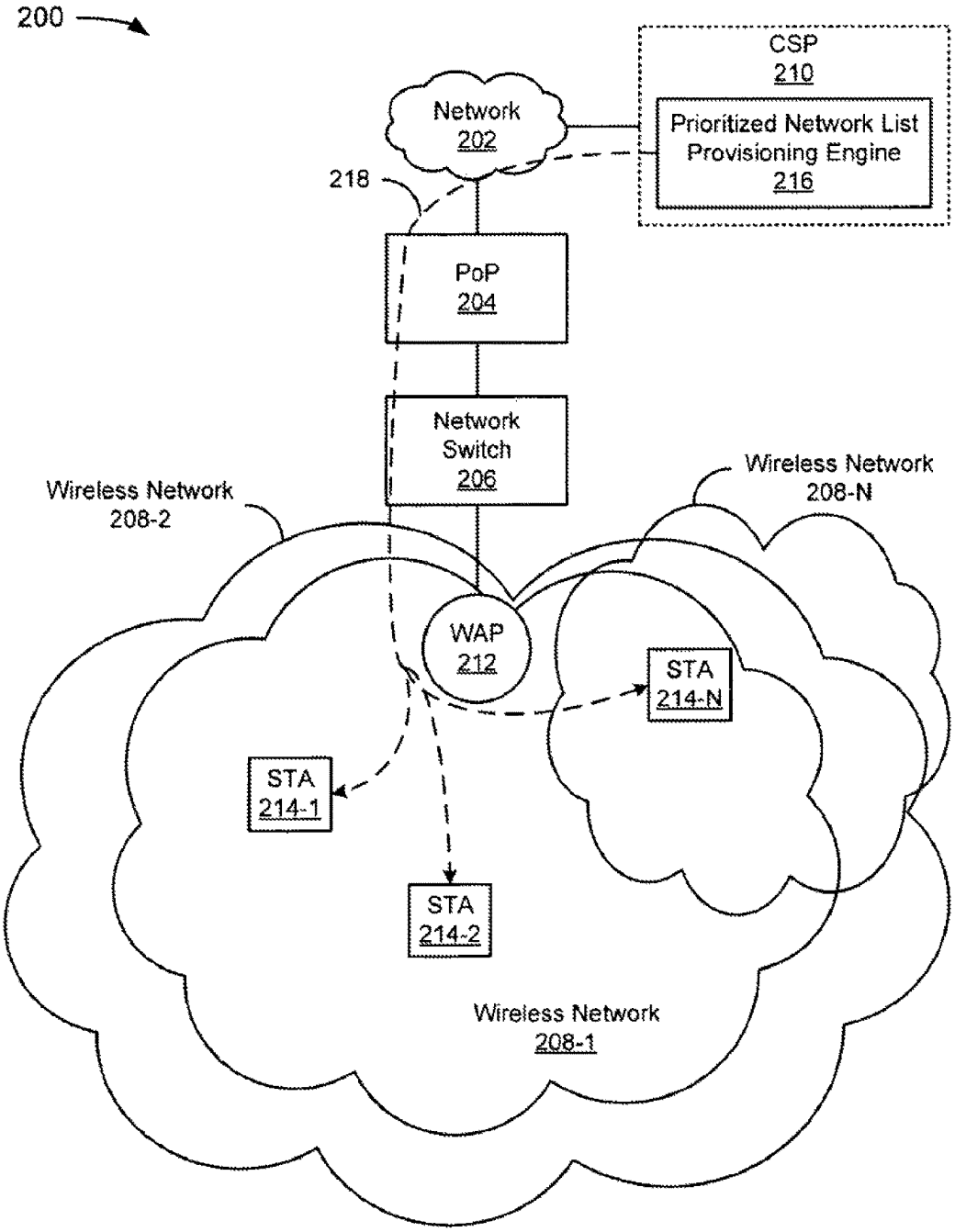
200
CSP
210
Prioritized Network List Provisioning Engine
216
Network
202
218
PoP
204
Network Switch
206
Wireless Network
208-2
Wireless Network
208-N
WAP
212
STA
214-N
STA
214-1
STA
214-2
Wireless Network
208-1

FIG. 2

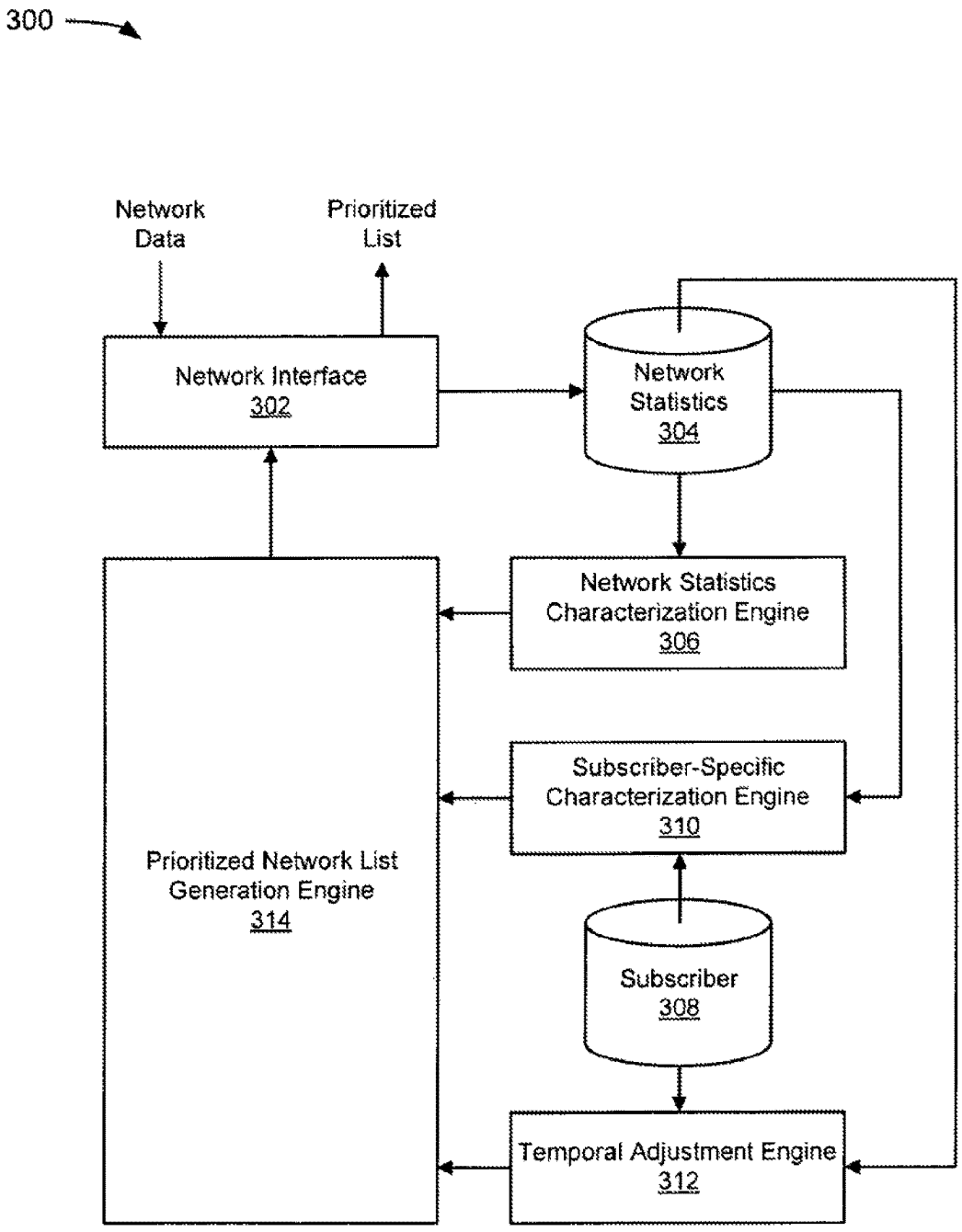
300
Network Data
Prioritized List
Network Interface 302
Network Statistics 304
Network Statistics Characterization Engine 306
Subscriber-Specific Characterization Engine 310
Prioritized Network List Generation Engine 314
Subscriber 308
Temporal Adjustment Engine 312

FIG. 3

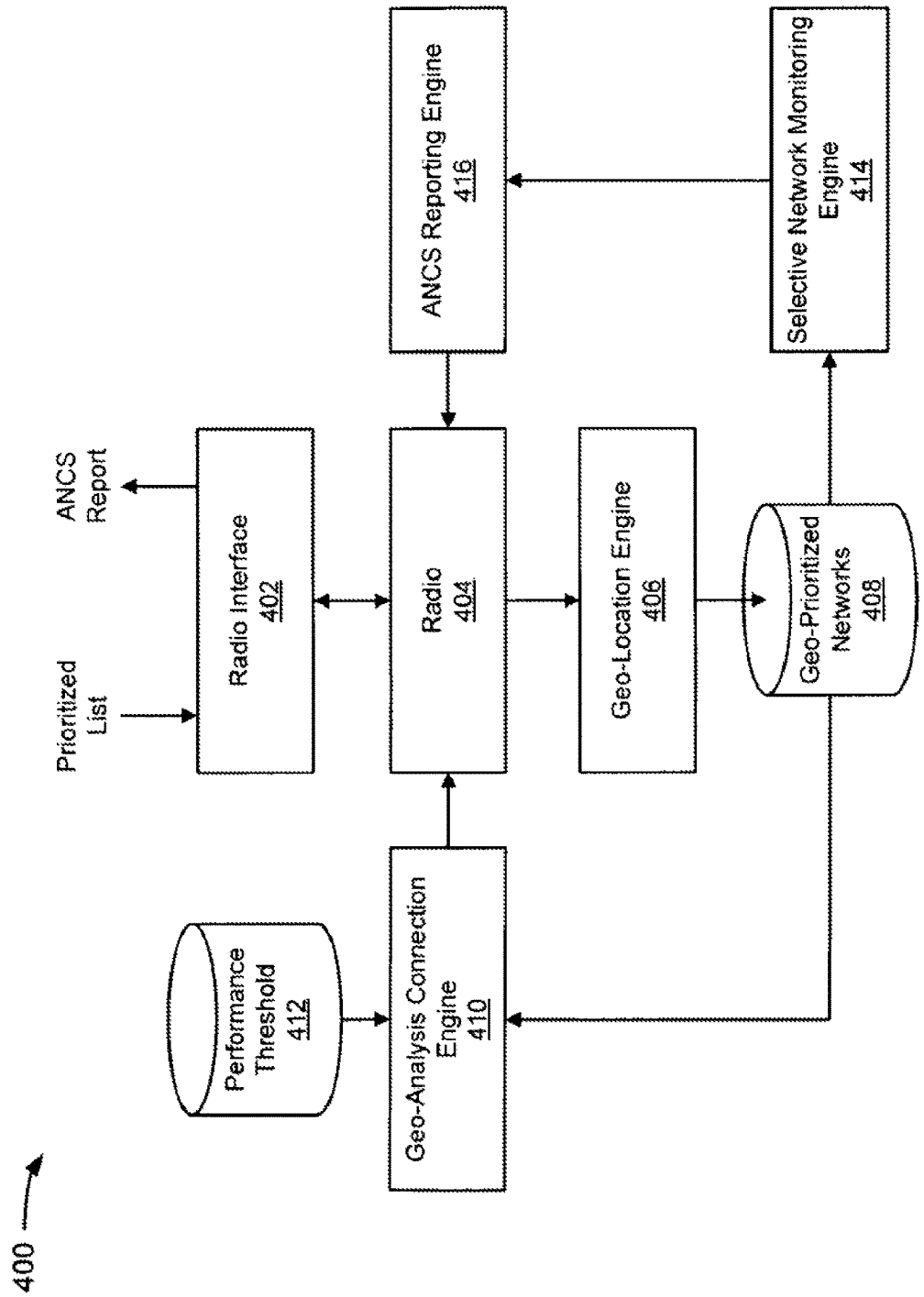
400
Performance Threshold 412
Geo-Analysis Connection Engine 410
Radio Interface 402
Radio 404
Geo-Location Engine 406
Geo-Prioritized Networks 408
ANCS Reporting Engine 416
Selective Network Monitoring Engine 414
Prioritized List
ANCS Report

FIG. 4

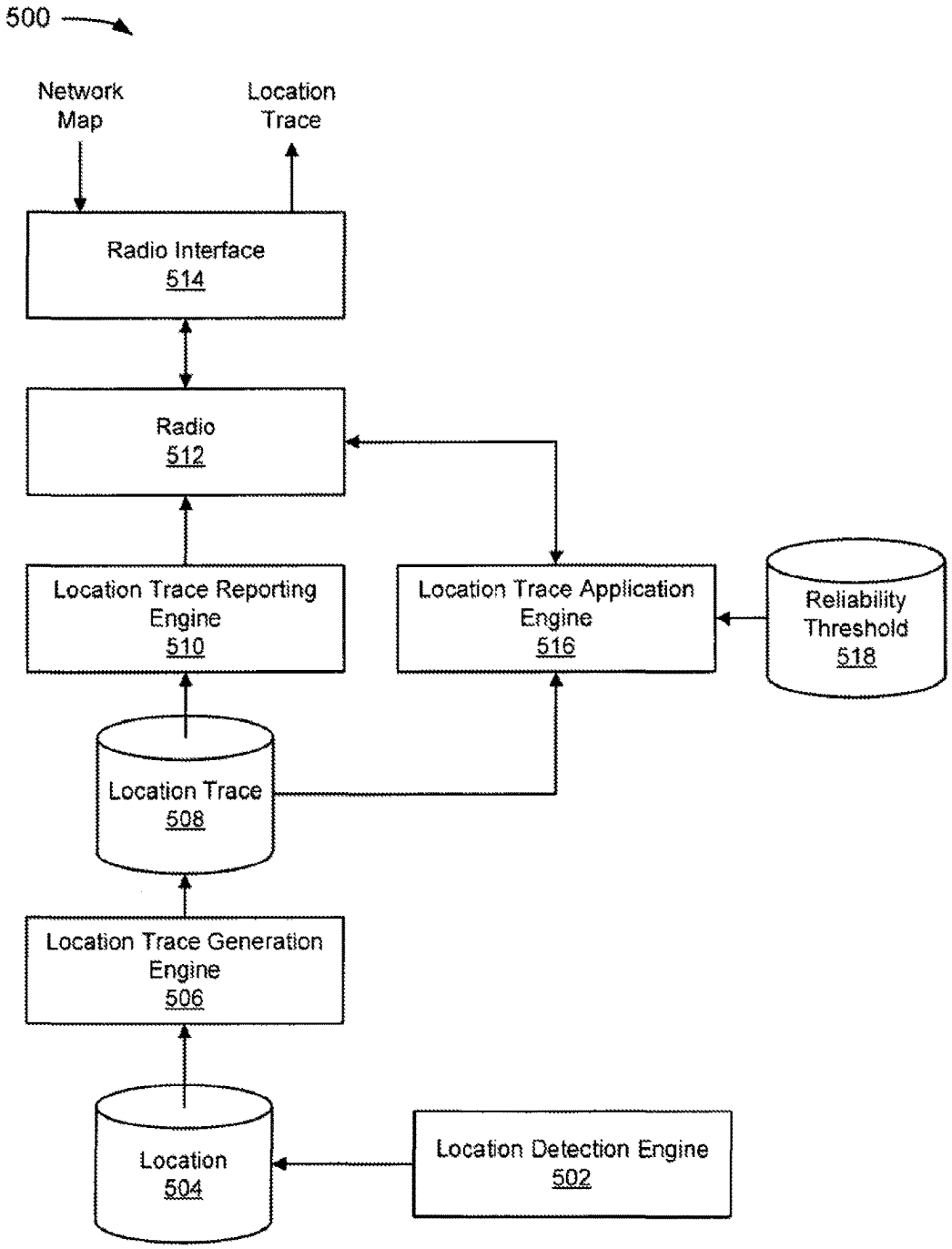
500
Network Map
Location Trace
Radio Interface 514
Radio 512
Location Trace Reporting Engine 510
Location Trace Application Engine 516
Reliability Threshold 518
Location Trace 508
Location Trace Generation Engine 506
Location 504
Location Detection Engine 502

FIG. 5

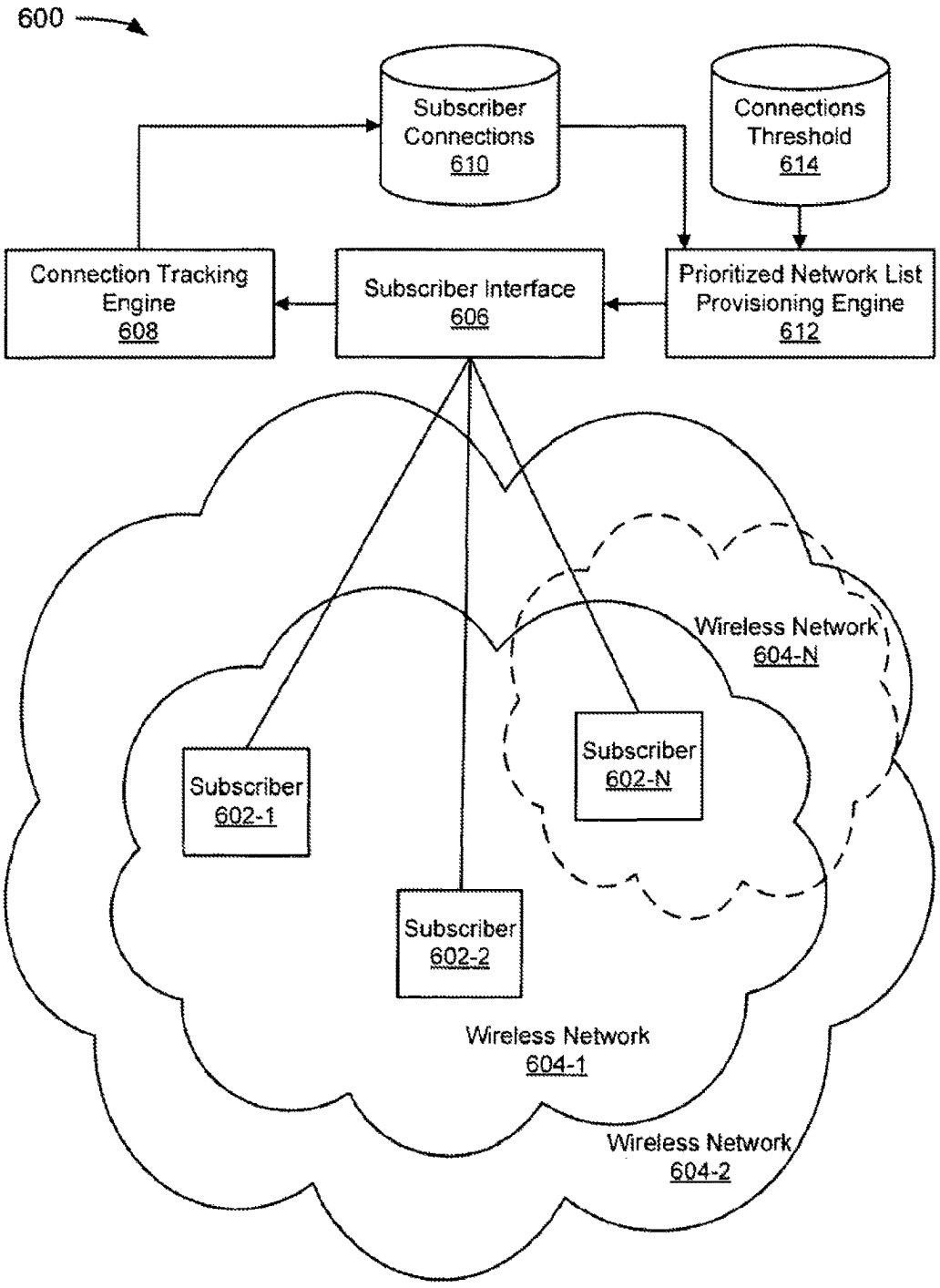
600
Subscriber Connections 610
Connections Threshold 614
Connection Tracking Engine 608
Subscriber Interface 606
Prioritized Network List Provisioning Engine 612
Wireless Network 604-N
Subscriber 602-N
Subscriber 602-1
Subscriber 602-2
Wireless Network 604-1
Wireless Network 604-2

FIG. 6

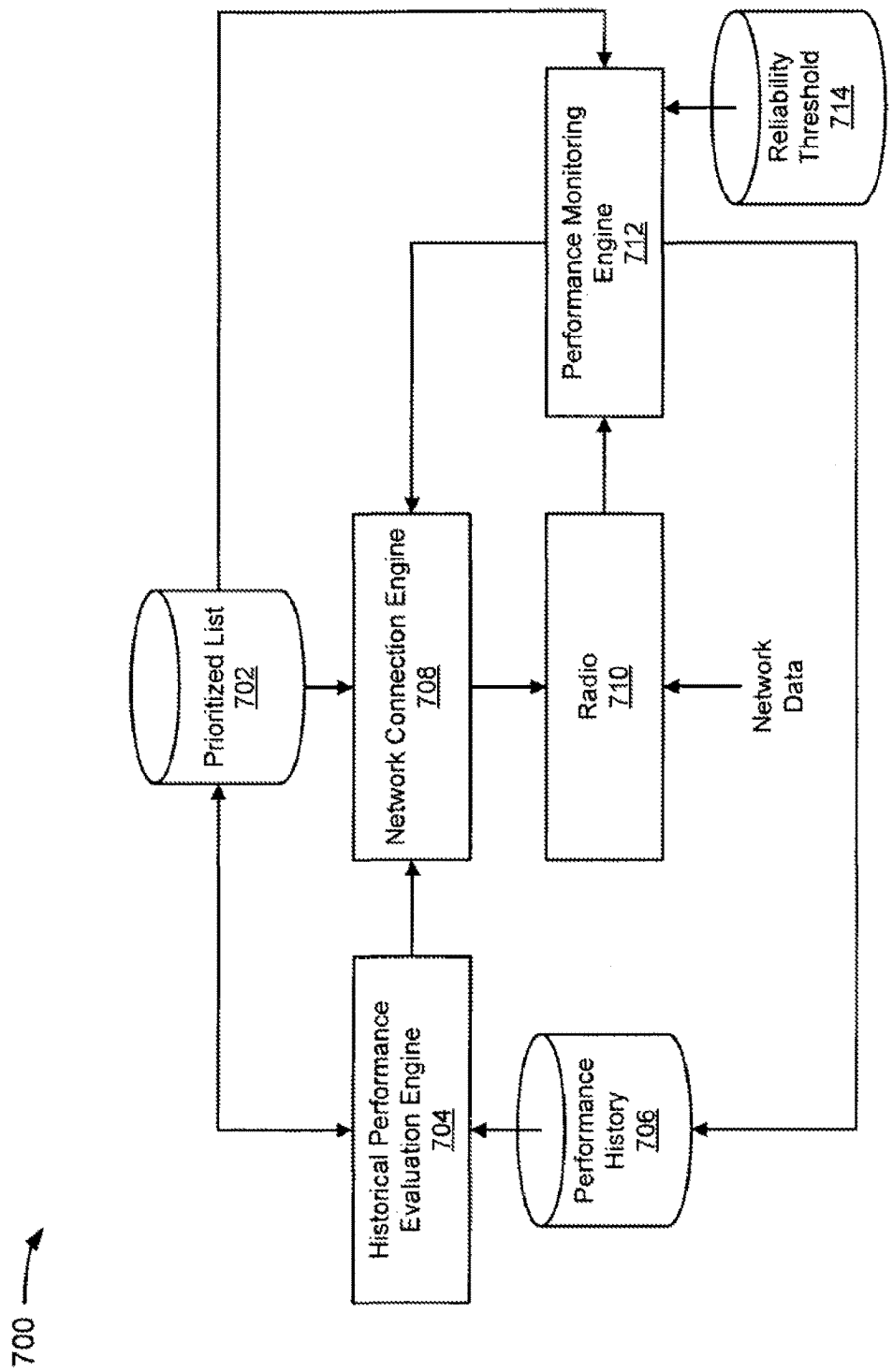
700
Prioritized List
702
Network Connection Engine
708
Radio
710
Network Data
Performance Monitoring Engine
712
Reliability Threshold
714
Historical Performance Evaluation Engine
704
Performance History
706

FIG. 7

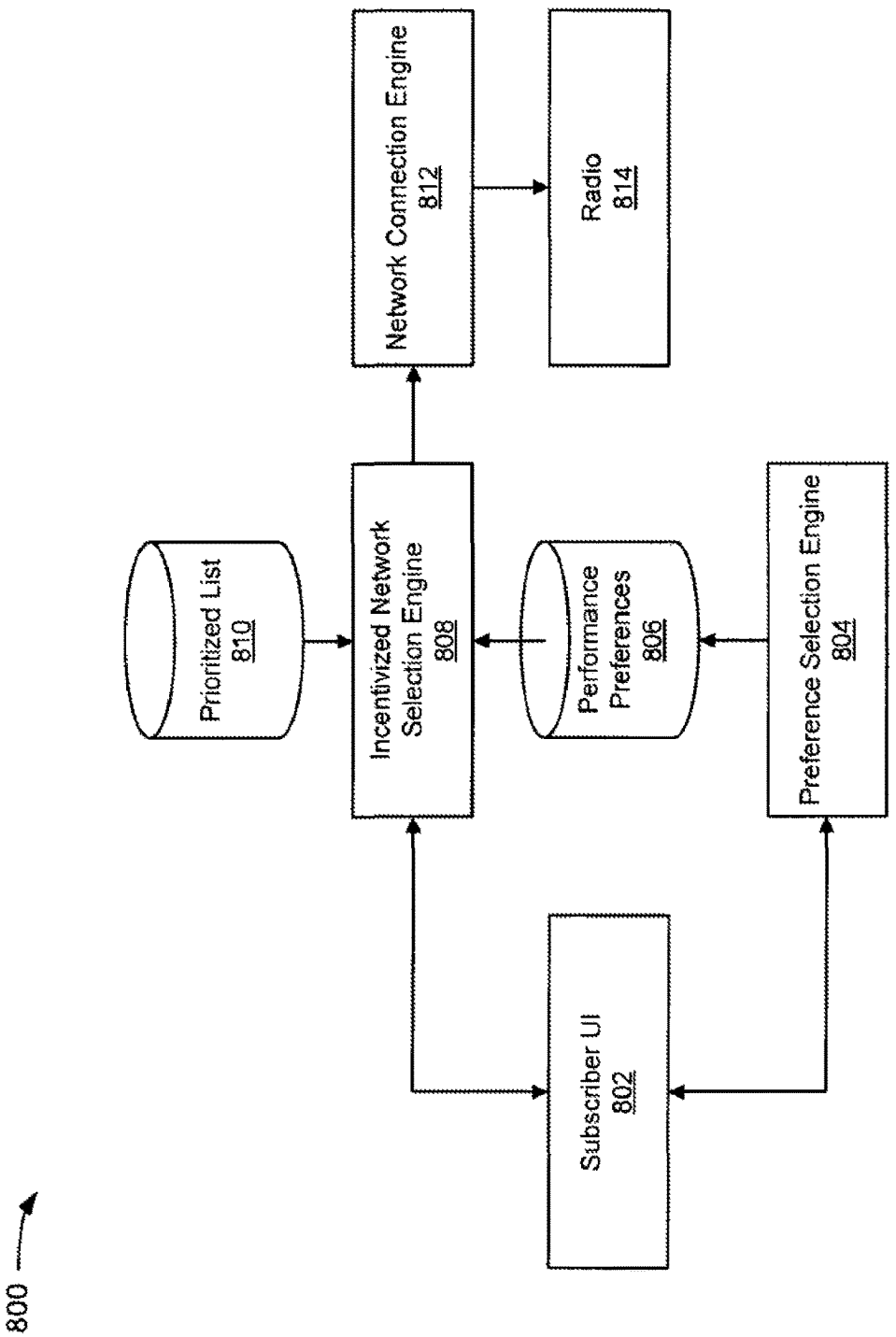
800
Subscriber UI
802
Prioritized List
810
Incentivized Network Selection Engine
808
Performance Preferences
806
Preference Selection Engine
804
Network Connection Engine
812
Radio
814

FIG. 8

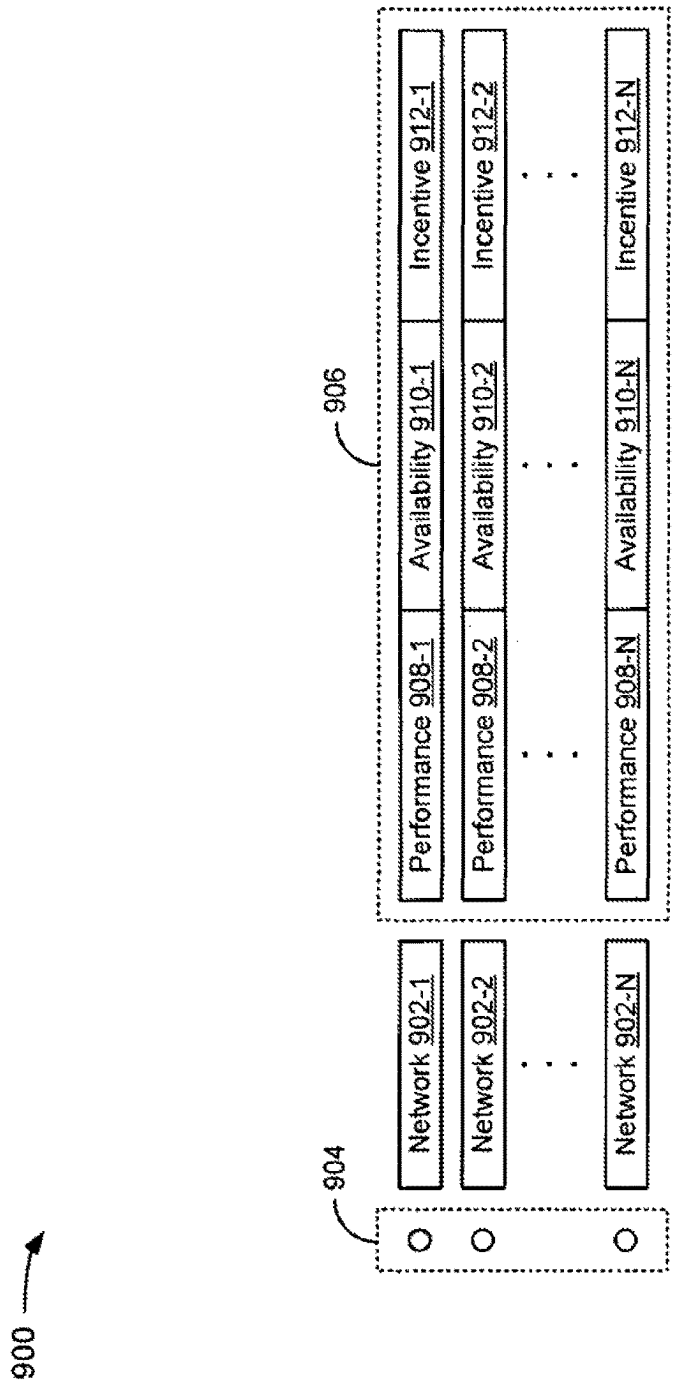
900
904
Network 902-1
Network 902-2
Network 902-N
906
Performance 908-1
Availability 910-1
Incentive 912-1
Performance 908-2
Availability 910-2
Incentive 912-2
Performance 908-N
Availability 910-N
Incentive 912-N

FIG. 9

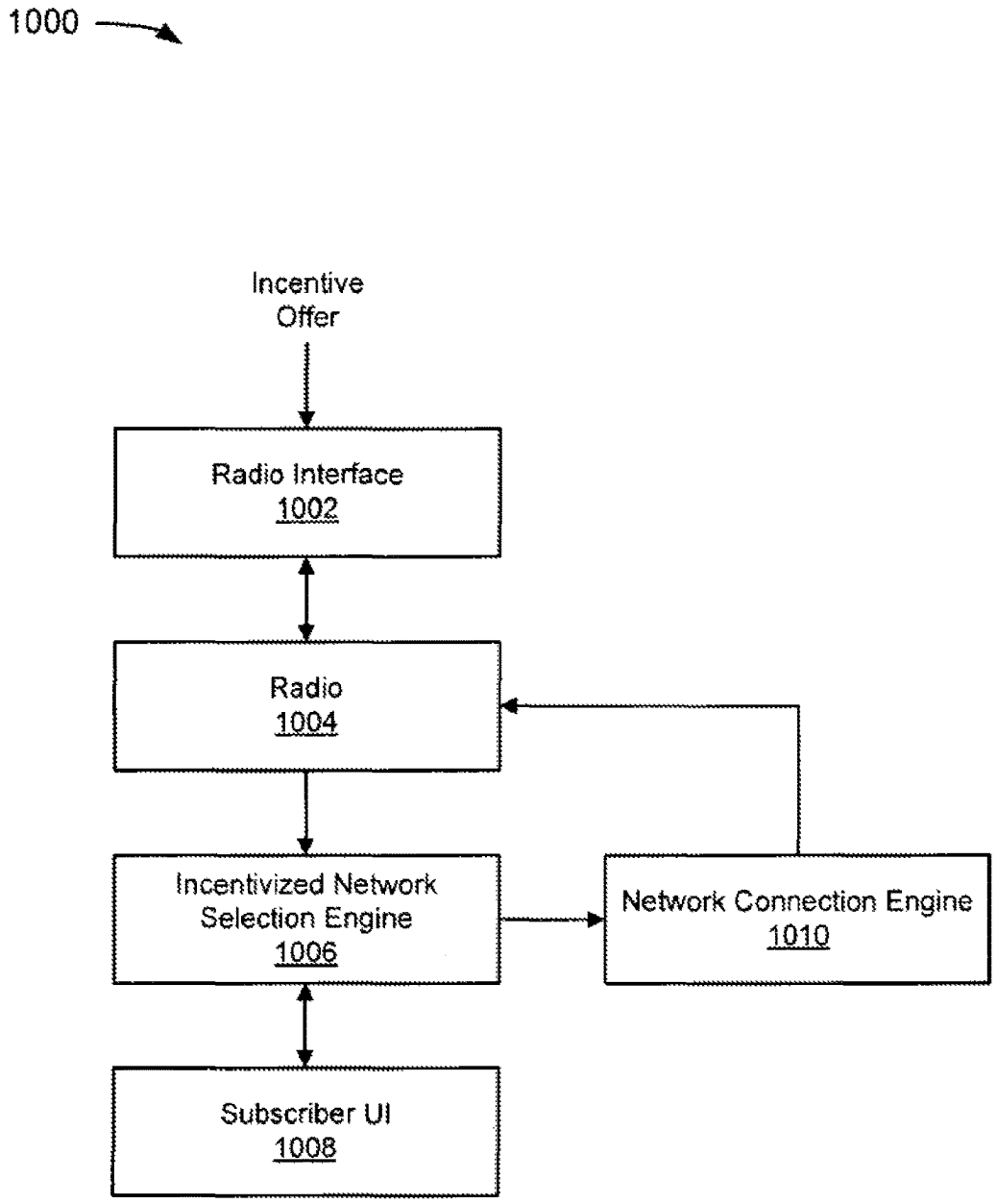
1000
Incentive Offer
Radio Interface 1002
Radio 1004
Incentivized Network Selection Engine 1006
Network Connection Engine 1010
Subscriber UI 1008

FIG. 10

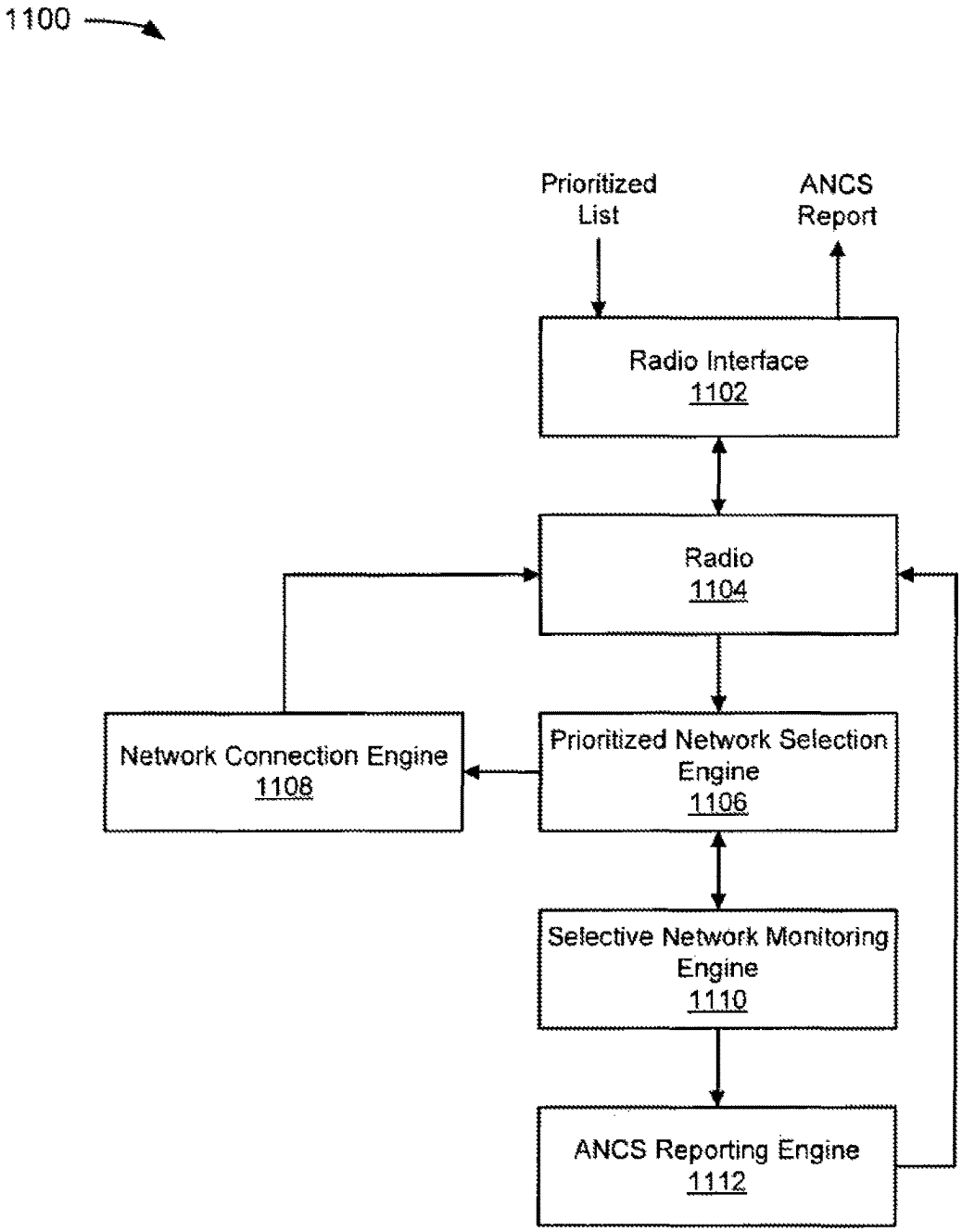
1100
Prioritized List
ANCS Report
Radio Interface 1102
Radio 1104
Network Connection Engine 1108
Prioritized Network Selection Engine 1106
Selective Network Monitoring Engine 1110
ANCS Reporting Engine 1112

FIG. 11

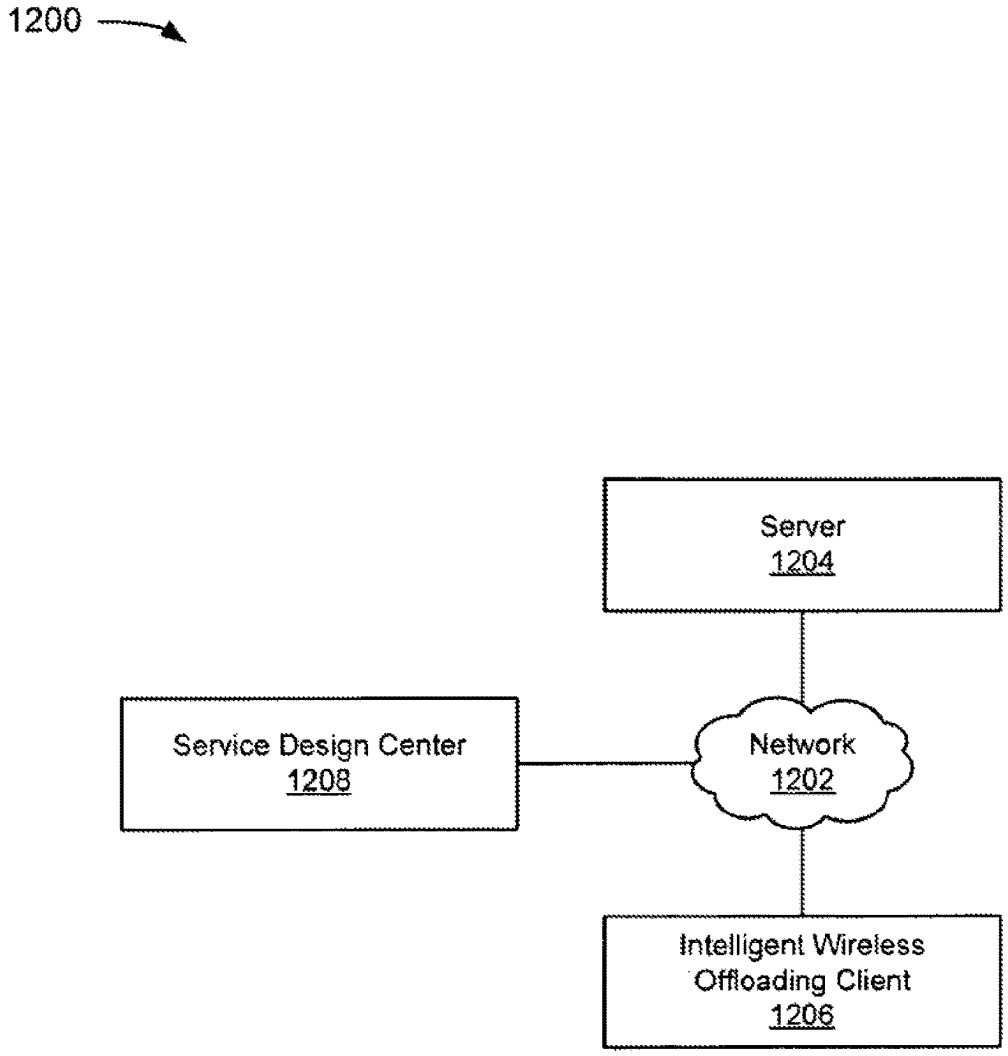
1200
Server
1204
Service Design Center
1208
Network
1202
Intelligent Wireless
Offloading Client
1206

FIG. 12

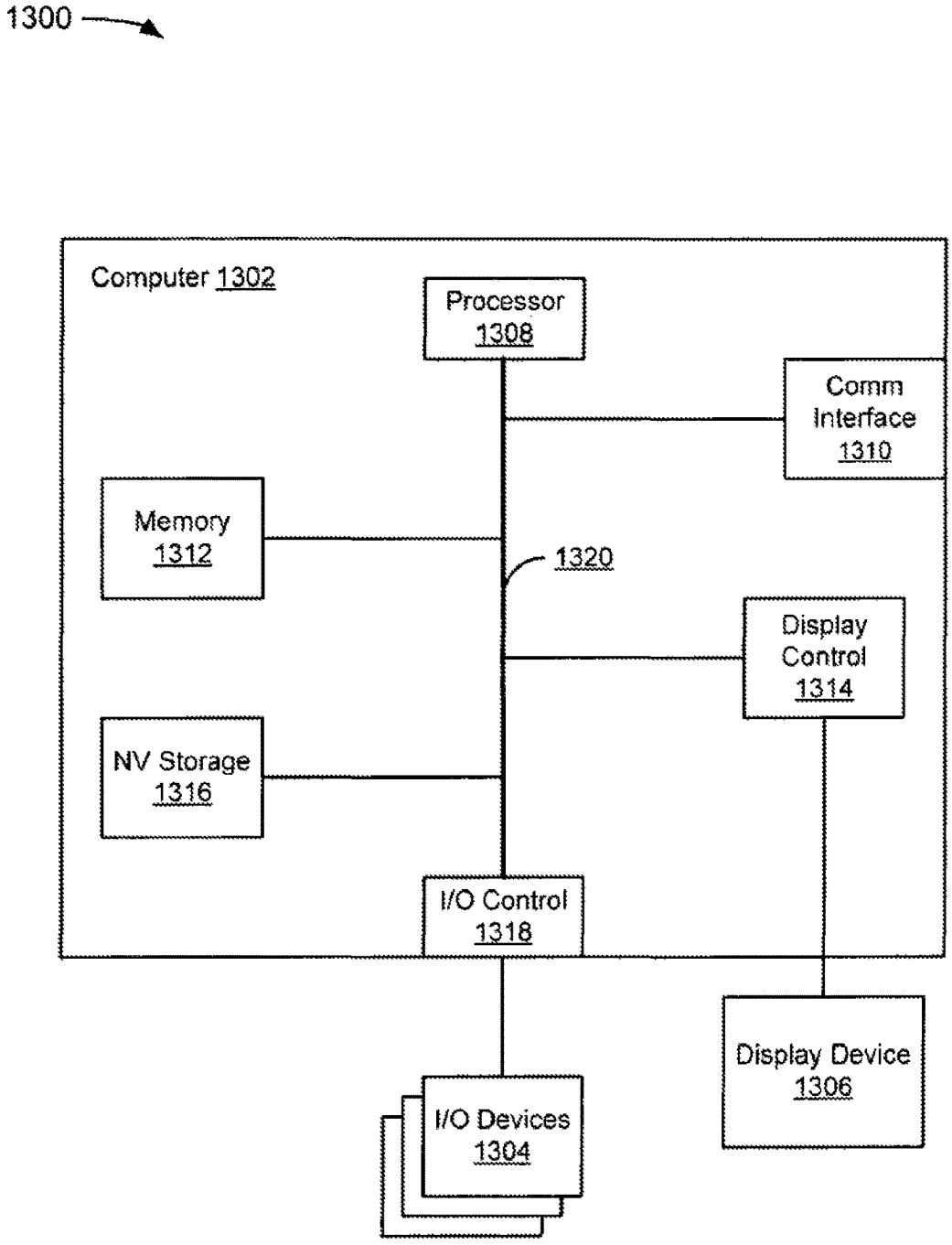
1300
Computer 1302
Processor 1308
Comm Interface 1310
Memory 1312
1320
Display Control 1314
NV Storage 1316
I/O Control 1318
Display Device 1306
I/O Devices 1304

FIG. 13

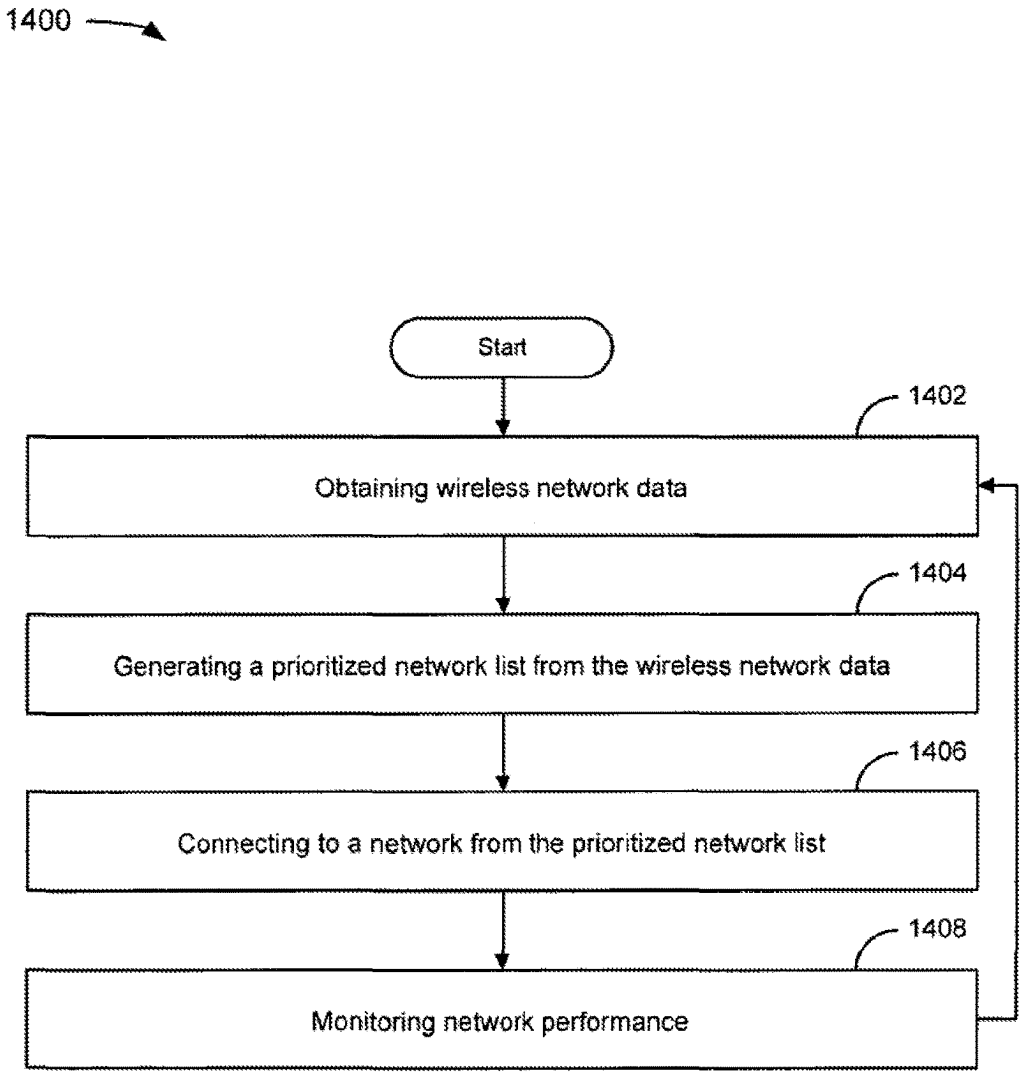
1400
Start
1402
Obtaining wireless network data
1404
Generating a prioritized network list from the wireless network data
1406
Connecting to a network from the prioritized network list
1408
Monitoring network performance

FIG. 14

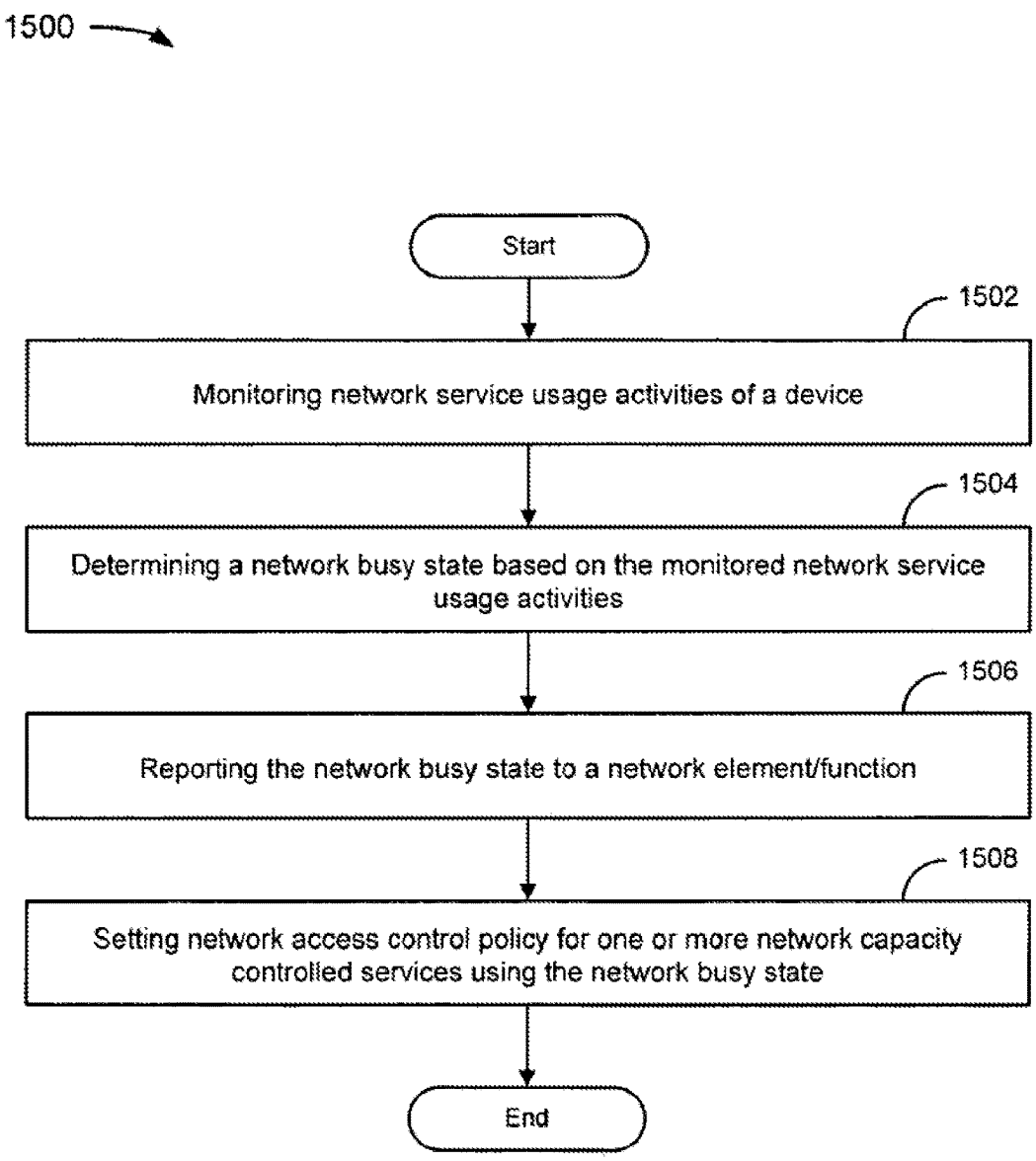
1500
Start
1502
Monitoring network service usage activities of a device
1504
Determining a network busy state based on the monitored network service usage activities
1506
Reporting the network busy state to a network element/function
1508
Setting network access control policy for one or more network capacity controlled services using the network busy state
End

FIG. 15

SYSTEM AND METHOD FOR WIRELESS NETWORK OFFLOADING

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BACKGROUND

Wireless networks, such as Wi-Fi, 2G, 3G, 4G and WiMAX, whether governed by standards or proprietary protocols, often overlap with one another. Multiple wireless networks of the same type, perhaps with configuration-specific differences, also often overlap with one another.

A wireless device chooses an available wireless network to associate with. The choice is generally made based on user selection, whether or not a better selection is available for a given situation.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a diagram of an example of a system including a wireless network offloading engine.

FIG. **2** depicts a diagram of an example of a system for providing a prioritized network list to stations on a wireless network.

FIG. **3** depicts a diagram of an example of a system for generating temporally adjusted prioritized network lists.

FIG. **4** depicts a diagram of an example of a system for monitoring performance of networks on a prioritized network list.

FIG. **5** depicts a diagram of an example of a system for using a motion trace to prioritize networks on a network map.

FIG. **6** depicts a diagram of an example of a system for using knowledge of subscriber network connections to prioritize network lists for subscribers.

FIG. **7** depicts a diagram of an example of a system for using performance history to customize a prioritized network list.

FIG. **8** depicts a diagram of an example of a system for selecting network connections based on network prioritization.

FIG. **9** depicts a conceptual display associated with incentivized network selection.

FIG. **10** depicts a diagram of an example of a system for offering incentives to a subscriber to connect to a network.

FIG. **11** depicts a diagram of an example of a system for repeatedly cycling through performance tests.

FIG. **12** depicts a diagram of an example of a system capable of wireless network offloading.

FIG. **13** depicts an example of a computer system on which techniques described in this paper can be implemented.

FIG. **14** depicts a flowchart of an example of a method for prioritized wireless offloading.

FIG. **15** depicts a flowchart of an example of a method for using device assisted services to facilitate wireless offloading.

DETAILED DESCRIPTION

In the following description, several specific details are presented to provide a thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that embodiments of the invention can be practiced without one or more of the specific details, or in combination with other components, etc. In other instances, well-known implementations or operations are not shown or described in detail to avoid obscuring aspects of various embodiments.

A technique for wireless offloading provides tools to a service provider to encourage or direct a subscriber to offload from a first network to a second network. For the purposes of this introductory example, the service provider may be referred to as a cellular service provider, the first network may be referred to as a cellular network, and the second network may be referred to as a Wi-Fi network.

The cellular service provider can use network data to determine wireless offloading priorities for cellular subscribers on an individual or group basis. In order to determine wireless offloading priorities, the cellular service provider may use wireless network data it has and/or wireless network data it learns about networks from the wireless devices (which may obtain Wi-Fi network data from beacon frames of Wi-Fi networks or active scanning and which may report to the cellular service provider). Each wireless device can be given scanning assignments to ensure that the reporting task is shared among subscribers or adjusted to fill in gaps in data. With the network data, the cellular service provider is capable of generating useful prioritized network lists for wireless devices, either individually or as a group. These prioritized network lists can be represented as a network map.

The cellular service provider can obtain more than just network data. For example, wireless devices can provide connection data, such as the probability that an authentication request will result in an eventual connection or the delay in the access grant. The wireless device can timestamp certain data to enable the service provider to determine how network or otherwise relevant characteristics can vary by, for example, time of day or day of the week. Other data can include the location of the wireless device, which can provide data useful for determining zones of coverage for a service area with different performance or other characteristics. Using a combination of the timestamp and location data, the server can derive a motion trace, or the motion trace can be explicitly provided by subscribers, that is representative of the velocity at which a subscriber is moving. All of this data can be useful for generating more useful prioritized lists for the wireless devices.

The cellular service provider can also obtain subscriber-specific data. Some such data may be available from a subscriber account or the parameters of a service plan. Other such data can be in the form of user preferences or performance history for a wireless device. Rules for adjusting network priorities can take into account a cost function with parameters that may vary by implementation, configuration, or preference. Preferences can be encouraged in the form of incentive offers to subscribers to, e.g., offload from the cellular network to a Wi-Fi network. Incentive offers can include offers to lower service costs or provide additional or improved services.

FIG. **1** depicts a diagram of a system **100** including a wireless network offloading engine **106**. The system **100** includes wireless devices **102-1** to **102-N** (referred to collectively as the wireless devices **102**), wireless networks **104-1** to **104-N** (referred to collectively as the wireless networks **104**), and a wireless network offloading engine **106**.

The wireless devices **102** will at a minimum include a processor, memory (though the memory could be implemented in the processor), a radio, and a radio interface (though the radio interface could be implemented as "part of" the radio). The wireless devices **102** will typically have at least one input device and at least one output device, including input and output interfaces, if applicable.

The wireless devices **102** can be implemented as stations. A station, as used herein, may be referred to as a device with a media access control (MAC) address and a physical layer (PHY) interface to the wireless medium that comply with, e.g., the IEEE 802.11 standard. A station can be described as "IEEE 802.11-compliant" when compliance with the IEEE 802.11 standard is intended to be explicit (i.e., a device acts as described in at least a portion of the IEEE 802.11 standard.) One of ordinary skill in the relevant art would understand what the IEEE 802.11 standard comprises today and that the IEEE 802.11 standard can change over time, and would be expected to apply techniques described in this paper in compliance with future versions of the IEEE 802.11 standard if an applicable change is made. IEEE Std. 802.11™-2007 (Revision of IEEE Std. 802.11-1999) is incorporated by reference. IEEE 802.11k-2008, IEEE 802.11n-2009, IEEE 802.11p-2010, IEEE 802.11r-2008, IEEE 802.11w-2009, and IEEE 802.11y-2008 are also incorporated by reference.

In alternative embodiments, one or more of the wireless devices **102** may comply with some other standard or no standard at all, and may have different interfaces to a wireless or other medium. It should be noted that not all standards refer to wireless devices as "stations," but where the term is used in this paper, it should be understood that an analogous unit will be present on all applicable wireless networks. Thus, use of the term "station" should not be construed as limiting the scope of an embodiment that describes wireless devices as stations to a standard that explicitly uses the term, unless such a limitation is appropriate in the context of the discussion.

The wireless networks **104** will typically include an internetworking unit (IWU) that interconnects wireless devices on the relevant one of the wireless networks **104** with another network, such as a wired LAN. The IWU is sometimes referred to as a wireless access point (WAP). In the IEEE 802.11 standard, a WAP is also defined as a station. Thus, a station can be a non-WAP station or a WAP station. In a cellular network, the WAP is often referred to as a base station.

The wireless networks **104** can be implemented using any applicable technology, which can differ by network type or in other ways. The wireless networks **104** can be of any appropriate size (e.g., metropolitan area network (MAN), personal area network (PAN), etc.). Broadband wireless MANs may or may not be compliant with IEEE 802.16, which is incorporated by reference. Wireless PANs may or may not be compliant with IEEE 802.15, which is incorporated by reference. The wireless networks **104** can be identifiable by network type (e.g., 2G, 3G, 4G, and Wi-Fi), service provider, WAP/base station identifier (e.g., Wi-Fi SSID, base station and sector ID), geographic location, or other identification criteria.

The wireless networks **104** may or may not be coupled together via an intermediate network. The intermediate network can include practically any type of communications network, such as, by way of example but not limitation, the Internet, a public switched telephone network (PSTN), or an infrastructure network (e.g., private LAN). The term "Internet" as used herein refers to a network of networks which uses certain protocols, such as the TCP/IP protocol, and possibly other protocols such as the hypertext transfer protocol (HTTP) for hypertext markup language (HTML) documents that make up the World Wide Web (the web).

In the example of FIG. **1**, the wireless network offloading engine **106** is coupled to the wireless device **102-1**. In a specific implementation, the wireless network offloading engine **106** is implemented on a server and is coupled to the wireless device **102-1** through the Internet. However, at least a portion of the wireless network offloading engine **106**, described in more detail later with reference to FIG. **2**, can alternatively be implemented on the wireless device **102-1**, with or without a connection to a server that includes another portion (e.g., a server portion) of the wireless network offloading engine **106**.

In an example of operation, periodically, occasionally, or when instructed, the wireless device **102-1** performs an available network characterization scan (ANCS) on one or more of the wireless networks **104**. Other devices, such as the wireless device **102-2** or some other station, may or may not also perform an ANCS. The ANCS can be used to characterize available performance for each network (e.g., data rate, bit rate variability, latency, latency jitter, quality of service (QoS), response time, etc.).

Some objective criteria for measuring performance exist (e.g., throughput). Intelligent network monitoring can enable real-time monitoring of network service usage (e.g., at the packet level/layer, network stack application interface level/layer, and/or application level/layer) of the wireless network (e.g., radio access networks and/or core networks) and to effectively manage the network service usage for protecting network capacity (e.g., while still maintaining an acceptable user experience). Using Device Assisted Services (DAS) techniques, and in some cases, network assisted/based techniques, to provide for network service usage monitoring of devices, network carriers/operators would be provided greater insight into what devices, which users and what applications, and when and where network congestion problems occur, enabling operators to intelligently add additional resources to certain areas when necessary (e.g., offloading data traffic onto femto cells or WiFi hotspots and adding more network resources), to differentially control network service usage, and/or to differentially charge for network service usage based on, for example, a network busy state, for protecting network capacity.

Performance need not be based on network performance alone. For example, a subscriber may be interested in economic performance (e.g., price). Accordingly, in this paper, performance is sometimes characterized using a cost function that can include various parameters, including network performance, economic performance, reliability, and/or other parameters that are indicative of preferences of a user or service provider. Where a particular type of performance is applicable, the meaning can be made explicit (e.g., by making reference to "network performance" as opposed to simply "performance") or can be derived from context.

The wireless device **102-1** generates an ANCS report using results of the ANCS in order to characterize available performance for each scanned network of the wireless networks **104**. The ANCS report can also include an identification of currently available networks for the wireless device **102-1**, location, time, and potentially some performance characterization. The wireless device **102-1** makes the ANCS report available to the wireless network offloading engine **106**. The wireless device **102-1** can also make device-specific information available, such as location, per-

formance thresholds, a motion trace, knowledge about other devices or interference, a performance history, applications (e.g., a VoIP or streaming media application), device-specific rules related to when the device will link to a network or offload (e.g., based on reliability, performance state, congestion state, QoS, incentive state, et al.), or a cost function (e.g., based on signal strength, channel strength, basic radio bit rate, network speed, network throughput, speed jitter, throughput jitter, network delay, delay jitter, network availability, network reliability in access grant percentage, network reliability in delay in access grant, variation in performance as a function of position, et al.). Alternatively, some device-specific information may or may not be shared with the wireless network offloading engine **106**, and used to customize a priority list or multi-dimensional network map that is generated or received at the wireless device **102-1**.

The wireless network offloading engine **106** generates a multi-dimensional network map from the ANCS report and/or other data that is known to the wireless network offloading engine **106**. The wireless network offloading engine **106** can provide the multi-dimensional network map to the wireless device **102-1**, from which the wireless device **102-1** can generate or modify a wireless operation instruction set. Alternatively, the wireless network offloading engine **106** can generate an instruction set from the multi-dimensional map, which it makes available to the wireless device **102**. The instruction set can be an implementation of a general algorithm that is customized by the wireless device **102-1** after it is received, or the instruction set can be generated specifically for the wireless device **102-1** or a set of devices that includes the wireless device **102-1**, to be executed on-device in accordance with device-specific parameters (e.g., power saving settings, location, time of day, etc.). Advantageously, the wireless device **102-1** is able to use the instruction set to enable intelligent offloading of the wireless device **102-1** from one of the wireless networks **104** to another. In some embodiments, the wireless device **102-1** is capable of modifying the multi-dimensional network map before making a network selection decision. The wireless network offloading engine may provide one or more parameters and/or algorithms to the wireless device **102-1** for making the network selection decision.

Differential network access control for protecting network capacity includes applying policies to determine which network a service activity should be connected to (e.g., 2G, 3G, 4G, home or roaming, WiFi, cable, DSL, fiber, wired WAN, and/or another wired or wireless or access network), and applying differential network access control rules (e.g., traffic control rules) depending on which network to which the service activity is connected. In some embodiments, differential network access control for protecting network capacity includes differentially controlling network service usage activities based on the service usage control policy and a user input (e.g., a user selection or user preference). Depending upon the implementation, network service usage control policy can consider availability of alternative networks, policy rules for selecting alternative networks, network busy state or availability state for alternative networks, specific network selection or preference policies for a given network service activity or set of network service activities, to name several.

In a specific implementation, the wireless device **102** aids in determining (e.g., measuring and/or characterizing) a network busy state experienced by the device (e.g., which can be used to determine the network access control policy for one or more network capacity controlled services). For example, the network busy state experienced by the device can be recorded by the device and included in a network busy state report that is sent to a network element/function (e.g., a wireless network offloading engine **106** as described herein). The network busy state report can include, for example, data rate, average throughput, minimum throughput, throughput jitter, latency, latency jitter, bit error rate, data error rate, packet error rate, packet drop rate, number of access attempts, number of access successes, number of access failures, QoS level availability, QoS level performance, variability in any of the preceding parameters, and/or the historic statistics of any of the preceding parameters, to name several by way of example. The network busy state report can include, for example, 2G, 3G, 4G or WiFi base station ID, SSID, cell sector ID, CDMA ID, FDMA channel ID, TDMA channel ID, GPS location, and/or physical location to identify the edge network element that is associated with the network busy state report to a network element, to name several by way of example. In a specific implementation, the network busy state is monitored by one or more network elements that can measure and/or report network busy state (e.g., wireless network offloading engine **106**, BTS, BTSC, access point, base station monitor, and/or airwave monitor).

As a clarifying example embodiment, the wireless device **102** (e.g. a network performance characterization software or hardware agent on the device) acts in conjunction with a network element (e.g. a wireless network offloading engine **106**) to characterize the network busy state of an alternative network access point or base station resource. In such embodiments the device can sense an available alternative network, connect to a network element (e.g. a wireless network offloading engine **106**) through the alternative network, conduct a download and/or upload sequence during which the network performance is monitored, and then cause the performance to be characterized and recorded. The performance can be characterized by the network element (e.g. a wireless network offloading engine **106**), by the wireless device **102** (e.g. a network performance characterization software or hardware agent) or by both.

As another clarifying embodiment, the wireless device **102** (e.g. a network performance characterization software or hardware agent on the device) can sense an available alternative network, connect to the alternative network, allow the user to use the network connection services, monitor the resulting network performance and record the performance results.

In a specific implementation, one or more of the wireless devices that use wireless services on the one or more main networks and/or alternative networks are used as described herein to collect alternative network performance, busy state and/or QoS state information.

In a specific implementation, the main networks and/or alternative networks can be monitored and characterized by devices that are permanently located in the vicinity of one or more alternative network base stations or access points and configured to communicate with a wireless network offloading engine **106**. A permanently located mobile terminal can provide network monitors for reporting, for example, network busy state, to a central network element, such as the wireless network offloading engine **106**, which can, for example, aggregate such network busy state information to determine network busy state for one or more network coverage areas.

For example, airwave monitors and/or base station monitors can be provided to facilitate a reliable characterization of network busy state in a coverage area of one or more base

stations and/or base station sectors and/or WiFi access points, such as affixed mobile terminals (e.g., trusted terminals that can include additional network busy state monitoring and/or reporting functionality) installed (e.g., temporarily or permanently) in the coverage area of one or more base stations and/or base station sectors (e.g., in which a sector is the combination of a directional antenna and a frequency channel) so that the mobile terminals perform network busy state monitoring and reporting to the wireless network offloading engine **106**, the local base station, and/or other network element(s)/function(s). In some embodiments, the permanently affixed mobile terminals provide network monitors for reporting, for example, network busy state (or performance, reliability or QoS), to a central network element, such as the wireless network offloading engine **106**, which can, for example, aggregate such network busy state information to determine network busy state for one or more network coverage areas. In some embodiments, the mobile terminals are always present in these locations where installed and always on (e.g., performing network monitoring), and can be trusted (e.g., the mobile terminals can be loaded with various hardware and/or software credentials). For example, using the mobile terminals, a reliable characterization of network busy state can be provided, which can then be reported to a central network element and aggregated for performing various network busy state related techniques as described herein with respect to various embodiments.

In a specific implementation, the wireless network offloading engine **106** uses the network busy state reports (or performance reports or QoS reports) from user devices and/or permanent mobile terminals connected to the same alternative network to determine the network busy state for an alternative network edge element connected to the device.

In some embodiments, a network element/function (e.g. a wireless access point or base station) sends a busy state report for the network edge element to the device (e.g., and to other devices connected to the same network edge element), which the device can then use to implement differential network access control policies (e.g., for network capacity controlled services) based on the network busy state. In some embodiments, a network busy state is provided by a network element (e.g., wireless network offloading engine **106** or service cloud) and broadcast to the device (e.g., securely communicated to the wireless device **102**).

In some embodiments, the wireless device **102** (e.g. a network performance characterization software or hardware agent) selects the access network connection in accordance with a network service profile setting that determines which network the device should choose between available alternative WWAN, WLAN, WPAN, Ethernet and/or DSL network connections. This choice can be based on the performance, reliability, busy state or QoS capability of one or more alternative networks. The characterization of the alternative networks can be based on an end to end performance, and not just the over the air or radio frequency performance. For example, service profile settings can be based on the performance of the actual access network (e.g., home DSL/cable, coffee shop, shopping center, public WiFi hot spot or work network) behind the Wi-Fi not the fact that it is Wi-Fi (e.g., or any other network, such as DSL/cable, satellite, or T-1), which is viewed as different than accessing a Wi-Fi network at the coffee shop. For example, in a Wi-Fi hotspot situation in which there are a significant number of users on a DSL or T-1 backhaul, the wireless network offloading engine **106** can sit in a service provider cloud or an MVNO cloud, the service controls can be provided by a VSP capability offered by the service provider or the wireless network offloading engine **106** can be owned by the hotspot service provider that uses the wireless network offloading engine **106** on their own without any association with an access network service provider.

FIG. **2** depicts a diagram an example of a system **200** for providing a prioritized network list to stations on a wireless network. In the example of FIG. **2**, the system **200** includes a network **202**, a point-of-presence (PoP) **204**, a network switch **206**, wireless networks **208-1** to **208**-N (collectively referred to as wireless networks **208**), and a communications service provider (CSP) **210**. The wireless network **208-1** includes a WAP **212** and, in operation, stations **214-1** to **214**-N (collectively referred to as stations **214**). The CSP **210** includes a prioritized network list provisioning engine **216**.

The network **202** can include any applicable network that is capable of coupling the station **214-1** to the CSP **210**. The PoP **204** is coupled to the network **202**. The term "PoP" is often used to refer to a PoP on the Internet. However, the term as used with reference to FIG. **2** is intended to mean a PoP on the network **202**, regardless of the type of network. The network switch **206** can be referred to as a wireless network switch because it couples the WAP **212** to a (typically) wired network, such as a LAN. The term "WAP" is often used with reference to AP stations in an IEEE 802.11-compatible network. However, the term should be construed to include the relevant node when the wireless network makes use of some other access technology (e.g., the term "base station" is often used to refer to the access node of a cellular network). In some cases, one or more of the PoP **204**, network switch **206**, and WAP **212** can be co-located.

The wireless networks **208** can be of an applicable known or convenient wireless network type. The basic service set (BSS) is a term used in IEEE 802.11 to refer to a group of stations that communicate with one another. The basic service area is defined by the propagation characteristics of the wireless medium. (Note: the term "area" is typically used to describe the three-dimensional space of a basic service area.) A station in the basic service area can communicate with other stations in the BSS. A BSS with a WAP, as is depicted in the example of FIG. **2** for the wireless network **208-1**, can be referred to as an infrastructure BSS. To avoid confusion with the acronym IBSS, which refers to an independent BSS (also known as an ad hoc BSS), an infrastructure BSS is not referred to as an IBSS. An infrastructure BSS is defined by the distance from the WAP; so the stations **214**, which are all on the wireless network **208-1**, are within reach of the WAP **212** (as illustrated by the stations **214** being depicted as inside the cloud associated with the wireless network **208-1**). In an infrastructure BSS, stations must associate with a WAP to obtain network services. The stations typically initiate the process and the WAP decides whether to grant or deny access based on the contents of an association request. Although this process is described in the context of IEEE 802.11 language, a similar description is applicable to other wireless network technologies.

The wireless network **208-1** is constrained in size by the range of the WAP **212**, though multiple WAPs (not shown) could be used to increase the size of the wireless network **208-1**. An extended service set (ESS) can comprise multiple BSSs, each connected to a backbone network. All of the WAPs in an ESS are given the same service set identifier (SSID), which is can be considered to be the "name" of the

wireless network. The degree to which basic service areas overlap in an extended service area is implementation- and/or technology-specific.

The WAP **212** may or may not support multiple wireless networks with the same radio. Within the WAP **212**, each SSID would be associated with a virtual LAN (VLAN). A relatively common implementation of this is when the WAP **212** supports a guest network (a first VLAN) and an internal network (a second VLAN). The stations **214** would likely see two separate networks in the radio domain. Thus, the wireless networks **208** may or may not have separate WAPs. A WAP that supports multiple networks may or may not have the same range for each network, particularly if the broadcast power or frequency bands are different (e.g., a WAP could be 802.11a and 802.11b/g-compatible).

In the example of FIG. **2**, the stations **214** are within a service area of the wireless networks **208**. As is shown by way of example, some of the stations, e.g., station **214**-N, can be within the service area of a different wireless network, e.g., wireless network **208**-N, than the other stations **214**. The stations **214** can send information about a subset of the wireless networks **208** if the stations **214** are in the respective service areas of the wireless networks **208**. By subset, it is intended that, depending upon the implementation or station capabilities, a station may or may not send information about all of the wireless networks **208** if in the respective service areas, and may or may not send information about any of the wireless networks **208**. Depending upon the implementation or station capabilities, a station may or may not send information about a network when no longer in a service area of the wireless network, such as, e.g., when a WAP fails or the station is moved out of the service area. As shown by way of example, the station **214-1** is in the service area of wireless networks **208-1** and **208-2**. So the station **214-1** can send information about the wireless networks **208-1** and **208-2**, either the wireless network **208-1** or the wireless network **208-2**, or neither of the wireless networks **208-1** and **208-2**; the station **214-1** may or may not also send information about the wireless network **208**-N, e.g., based on historical data, data received from station **214**-N, or data received from another source, even though the station **214-1** is not currently within the service area of the wireless network **208**-N.

The stations **214** are operationally connected to the CSP **210** through the WAP **212**. Where the CSP **210** is part of an enterprise network that includes the wireless network **208-1**, the stations **214** may or may not actually be coupled to the CSP **210** through the PoP **204** because the CSP **210** could be on the wired backbone network to which the WAP **212** is connected. However, this observation does not make an understanding of the example of FIG. **2** difficult to one of ordinary skill in the relevant art.

The CSP **210** can be part of a public or private entity in, e.g., telecom (landline or wireless), Internet, cable, satellite, and/or managed services businesses. CSPs often specialize in an industry, such as telecommunications, entertainment and media, and Internet/Web services, though service providers can operate in multiple areas. While it is likely that a CSP would be able to best implement the prioritized network list provisioning engine **216** due to the data available to the CSP, it is also possible to offer the prioritized network list provisioning engine **216** through an application service provider (ASP), if the ASP is given sufficient data either from stations or CSPs, or perhaps a managed service provider (MSP) providing services on behalf of the CSP or some other entity. Alternatively, the prioritized network list provisioning engine **216** could be implemented on a private network, or on some other server.

In the example of FIG. **2**, it is assumed that the stations **214** are known to the CSP **210**. If the CSP **210** provides services to each of the stations **214**, the CSP **210** can have account information associated with each of the stations **214**, can be made aware of device-specific data (e.g., roaming, bandwidth consumption, application use, etc.), and can receive additional information associated with the stations **214** and/or networks near the stations **214** over time. How the stations **214** are known and what information is made available to the CSP **210** can depend upon the implementation. For example, the CSP **210** could be controlled by a mobile wireless communication company that provides cellular services to the stations **214** on, e.g., a 4G network. (As was previously mentioned, some services could be provided through an ASP; so it should be borne in mind that this is simply one example and other applicable implementations should be understood to have appropriate variations.)

In the example of FIG. **2**, the prioritized network list provisioning engine **216** provides a prioritized network list to the stations **214**, which is represented in the example of FIG. **2** as a dashed line **218**. The list need not be identical for each of the stations **214**. For example, the prioritized network list provisioning engine **216** could customize the list sent to the station **214-1** based upon account parameters, current device-specific parameters, or historical device-specific parameters. Alternatively, the list sent to each of the stations **214** could be customized (or not) at the stations **214**.

The prioritized list can be provided through an applicable channel. For example, the prioritized network list provisioning engine **216** could push the prioritized list to a station through a cellular network provided by a company that controls the CSP **210**, through a public network out of the control of the company, through a private network, or through some other channel. The station could also pull the prioritized list from the prioritized network list provisioning engine **216**. While it is likely the prioritized list will be provided on a wireless network periodically or as needed, it is also possible to provide the prioritized list in advance, which means it could be, for example, provided when a wireless device is wire-connected to a computer that has been provided or can obtain the prioritized list.

Advantageously, the prioritized list can include information that is not available to the stations **214** at a given point in time. For example, the stations **214** can perform a passive scan of nearby network service areas. The stations **214** can sort the list of applicable wireless networks based on, for example, a received signal strength indicator (RSSI) for each of the wireless networks. This type of list is referred to in this paper as a "sorted list," which is intended to mean a list that has been sorted in accordance with a current key value. However, certain data is not used when sorting the list of wireless networks. The certain data can be categorized as "historical data," which is previously obtained data about characteristics of a subset of the wireless networks, and "remotely obtained data," which is data of which one or more of the stations **214** did not collect on their own. (Data collected by a station can be referred to as "locally obtained data.") A "prioritized list" is defined as a sorted list that is further sorted using historical and/or remotely obtained data. Where it is desirable to explicitly indicate the type of prioritized list, the prioritized list can be referred to as a historically and contemporaneously prioritized list, a remotely and locally prioritized list, or (where both types of data are used to create the prioritized list) a historically and contemporaneously, remotely and locally prioritized list. A

prioritized list that can include any of these types is referred to as a "prioritized list." Advantageously, the stations **214** can use a prioritized list that is provided from the prioritized network list provisioning engine **216** to guide network association behavior.

The stations **214** can obtain data by scanning. Passive scans can identify wireless networks that use beacon frames, which will include some information about the wireless network. Active scans can generally obtain more data than a passive scan. The data obtained can be used to modify the prioritized list. In an embodiment in which a station can generate its own prioritized list (in addition to or instead of receiving the prioritized list from the prioritized network list provisioning engine **216** on the CSP **210**, for example) the station will use historical data accumulated with scans, and additional historical and/or remotely obtained data could be provided from a server or other source.

In an example in which the stations **214** are serviced by the CSP **210** or other communication service provider, the CSP **210** can optimize capacity for the stations **214** as a group. Capacity for the stations **214** can be optimized for the stations as a group by the CSP **210** having information about the networks **208** and deciding a prioritized list for each of the stations **214** that results in the stations **214** choosing to associate with the networks **208** such that the stations **214** have, in the aggregate, greater performance. The CSP **210** can take into account network loading on the networks **208** when generating the prioritized lists provided by the prioritized network list provisioning engine **216** to the stations **214**. In this way, the CSP **210** can determine which of the networks **208** have more available bandwidth, and can optionally determine what the loading of the networks **208** will be after the stations **214** make use of the prioritized lists. Advantageously, the CSP **210** can use the current network load to predict load on the networks **208** based upon data provided by the stations, historical data, and prioritized lists that have not yet been sent. The CSP **210** can also consider station-specific data, such as applications that are being used, QoS requirements, historical bandwidth consumption, a cost function, etc., when determining how to generate the prioritized lists.

The stations **214** can have a network optimization engine (not shown) in which an algorithm is implemented to optimize capacity. The network optimization engine can reorganize a prioritized list based upon device-specific parameters and/or user preferences.

FIG. **3** depicts a diagram of an example of a system **300** for generating temporally adjusted prioritized network lists. In the example of FIG. **3**, the system **300** includes a network interface **302**, a network statistics datastore **304**, a network statistics characterization engine **306**, a subscriber datastore **308**, a subscriber-specific characterization engine **310**, a temporal adjustment engine **312**, and a prioritized network list generation engine **314**.

The network interface **302** is intended to include an applicable known or convenient interface to a network. The network interface **302** can have a variety of implementations, including a network interface card (NIC), a modem, or some other technology that facilitates interconnection with a network.

The network statistics datastore **304**, and other datastores described in this paper, can be implemented, for example, as software embodied in a physical computer-readable medium on a general-purpose or specific-purpose machine, in firmware, in hardware, in a combination thereof, or in an applicable known or convenient device or system. Datastores in this paper are intended to include any organization of data, including tables, comma-separated values (CSV) files, traditional databases (e.g., SQL), or other applicable known or convenient organizational formats. Datastore-associated components, such as database interfaces, can be considered "part of" a datastore, part of some other system component, or a combination thereof, though the physical location and other characteristics of datastore-associated components is not critical for an understanding of the techniques described in this paper.

The network statistics datastore **304** can store network statistics data structures. As used in this paper, a data structure is associated with a particular way of storing and organizing data in a computer so that it can be used efficiently within a given context. Data structures are generally based on the ability of a computer to fetch and store data at any place in its memory, specified by an address, a bit string that can be itself stored in memory and manipulated by the program. Thus some data structures are based on computing the addresses of data items with arithmetic operations; while other data structures are based on storing addresses of data items within the structure itself. Many data structures use both principles, sometimes combined in non-trivial ways. The implementation of a data structure usually entails writing a set of procedures that create and manipulate instances of that structure.

The network statistics datastore **304** can store data structures having data that is received or derived from stations on a network. The amount of data that a station can obtain and provide to the system **300** will depend upon the capabilities of the station, the type of network, device-specific settings (e.g., active scan settings), and other factors. Data can include such values as RSSI, channel strength, basic radio bit rate, loading, network speed, network throughput, speed jitter, throughput jitter, network delay, delay jitter, network availability, successful network access grant, delay in access grant, location, to name several. The network statistics datastore **304** can store data from a plurality of stations to create a store of remotely obtained data. Over time, the network statistics datastore **304** can obtain a large store of historical data.

The network statistics characterization engine **306** can use network statistics to characterize networks. For example, the network statistics characterization engine **306** can, e.g., analyze location and RSSI for stations to determine a variation in performance as a function of position, analyze access grant data to determine an access grant likelihood, analyze number of stations associated to a network, applications in use at the stations, and the capacity of a network to determine available capacity for the network, or the like. Thus, the network statistics characterization engine **306** can take standard network measurements, combine the network measurements with historical network data and network data that is remotely obtained relative to a particular station, and transform the network statistics into a more useful form. Characterized network statistic data structures can be stored in the network statistics datastore **304** (an arrow indicating such storage is not shown in the example of FIG. **3** in order to avoid disrupting the illustrative flow).

Where the system **300** is on a private network managed by a service provider (e.g., a mobile service provider), subscribers will typically have an account. The subscriber datastore **308** can store account data structures (or subscriber data structures). Advantageously, the account data structures can include data that is useful for generating prioritized lists. For example, an account could include cost function parameters that are indicative of when a subscriber would wish to offload from one network to another. Such data can be used

to customize a prioritized network list for a particular subscriber. As another example, an account could include performance or favored network preferences that enable prioritizing networks based upon subscriber preferences. As another example, the subscriber datastore **308** could include a motion trace useful to predict movement between coverage areas. It should be noted that some or all of the contents of the subscriber datastore **308** could instead be stored on a device, and a prioritized list could be customized based on the device-specific settings, movement (e.g., the motion trace), or the environment.

The subscriber-specific characterization engine **310** can use subscriber-specific data to modify network list priorities. For example, a subscriber can indicate what applications are used on a mobile device. The subscriber-specific characterization engine **310** can determine from the applications which networks are more desirable given the operational parameters of the application.

As another example, if a motion trace suggests that a subscriber is on a train because it is moving relatively fast, the subscriber-specific characterization engine **310** may strongly prioritize a cellular network over a shorter-range network (e.g., Wi-Fi). By "relatively fast," what is meant is that the subscriber is moving at a rate that suggests hand-off from one network to another will be required with relatively high probability due to the subscriber's motion. It is possible for a motion trace to show relatively high velocity, but relatively low risk of hand-off (e.g., if a subscriber is riding a carousel). Hand-off from one access point of a network to another access point of the same network is likely not as large a concern as hand-off from one network type (e.g., Wi-Fi) to another network type (e.g., cellular) or from two different networks of the same type (e.g., a first private Wi-Fi network and a second private Wi-Fi network). The motion trace itself can be considered a subscriber-specific characterization in the sense that the subscriber datastore **308** can receive location data from, e.g., a mobile device of the subscriber, and the subscriber-specific characterization engine **310** can determine velocity from the change in location over time to establish that a subscriber is moving relatively fast.

The temporal adjustment engine **312** can adjust network priorities based on, e.g., time of day. For example, if the networks statistics datastore **304** has historical data that shows certain networks have high loads at certain times of day, the temporal adjustment engine **312** can prioritize networks that have lower loads in the near future. The temporal adjustment engine **312** can also change priorities using data from the subscriber datastore **308**. For example, if a subscriber indicates they have a preference for not switching networks once associated, the temporal adjustment engine **312** can use subscriber historical activity to determine a likely amount of time the subscriber will be connected to a network and network historical data to determine likely loads on various networks during that time, and prioritize networks such that the subscriber can be connected to a network that will meet minimal performance preferences for the duration of the connection.

To the extent the subscriber datastore **308** is on a client device, the temporal adjustment engine **312** could provide priorities based upon time, and the client device could customize the prioritized network list. In an alternative implementation, the temporal adjustment engine **312** is on the client device and the client device receives prioritized lists that are different at different times, then the temporal adjustment engine **312** customizes (or picks the appropriate) prioritized list based upon the current time.

The prioritized network list generation engine **314** generates a network list in accordance with the network statistics characterization engine **306** and, if applicable, the subscriber-specific characterization engine **310** and temporal adjustment engine **312**. The prioritized network list can be provided to devices through the network interface **302**.

Advantageously, the system **300** can characterize the statistics of available capacity for a network and determine how much if any reliable capacity is typically available on that network. This is accomplished by having devices report network data, e.g., how many devices are connected to the network, and prioritizes the network such that one or more devices will connect to or disconnect from the network based on an algorithm to optimize the (e.g., average, worst case, median, etc.) capacity offered to a group of devices serviced by the system **300**. The algorithm can take into account loading of one or more alternative networks before sending the prioritized network list or otherwise communicating with a device to connect to or disconnect from the network. The system **300** can thereby characterize statistics of available capacity and provide prioritized network lists with reliable capacity as a function of time to adjust an available capacity factor. This technique is applicable to one or more devices optimized in the aggregate.

FIG. **4** depicts a diagram of an example of a system **400** for monitoring performance of prioritized network lists. In the example of FIG. **4**, the system **400** includes a radio interface **402**, a radio **404**, a geo-location engine **406**, a geo-prioritized networks datastore **408**, a geo-analysis connection engine **410**, a performance threshold datastore **412**, a selective network monitoring engine **414**, and an ANCS reporting engine **416**.

In the example of FIG. **4**, the radio interface **402** includes applicable known or convenient technology sufficient to enable a wireless device to use a radio to connect to a wireless network. Devices that use something other than a radio are theoretically possible; the term "radio interface" is used with the understanding that the communication device may or may not be limited to a specific subset of the electromagnetic (EM) spectrum, i.e., radio waves. The radio interface **402** can include multiple interfaces for use with multiple radios and/or different radio frequencies or wireless protocols.

In the example of FIG. **4**, the radio interface **402** is coupled to a radio **404**. The radio **404** can include multiple radios for use with different radio frequencies or wireless protocols. For illustrative simplicity, the radio **404** will generally be treated as if operating consistently over one channel (potentially with multiple subchannels). In an alternative, the radio **404** can send reports or scan on one frequency, and send/receive other communications on another frequency.

In the example of FIG. **4**, the geo-location engine **406** receives a prioritized list and modifies the list using device location. The geo-location engine **406** can use location to determine what networks should be included on the network list and what priorities of the networks should be. In a specific implementation, the geo-location engine **406** can be used in conjunction with a server that sends a geo-prioritized list that the geo-location engine **406** customizes at the device. For example, the server could send a geo-prioritized list for a geographical area that the geo-location engine **406** can adjust or use in accordance with current device location and/or a motion trace. Geo-prioritization can be in accordance with a cost function, where parameters of the cost function vary depending upon location (e.g., network performance can vary as a function of position).

In an alternative, the geo-location engine **406** could be implemented on a server, and used to generate geo-prioritized network lists for provisioning to subscribers. Using known locations of devices, the server can, depending upon the implementation, send a geo-prioritized network list for a local geographical area near the device or for geographical areas that have historically been frequented by the device.

In the example of FIG. **4**, the geo-prioritized networks datastore **408** includes network data structures that are organized by priority, where the determination of priority includes a consideration of device location. A prioritized list could be stored as data structures in the geo-prioritized networks datastore **408** initially, and the data structures transformed later in accordance with geo-location data, or the data structures could be generated with the relevant priority. In either case, when device location changes enough, the geo-priority will change, and the data structures can be transformed (or new data structures generated) to have the updated geo-priority.

In the example of FIG. **4**, the geo-analysis connection engine **410** uses the geo-prioritized network list stored in the geo-prioritized networks datastore **408** to instruct the radio **404** to connect to a highest priority network that is available. Alternatively, the geo-analysis connection engine **410** could form a connection using the prioritized list as received from a server and use the geo-prioritized network list for subsequent connection determinations. As was previously noted, it is also possible that the geo-location engine **406** could be at least partially located at a server, and the prioritized list could include device location when prioritizing the network list.

As device location changes, performance of network can also change. The geo-analysis connection engine **410** can determine whether performance has dropped below a performance threshold using the performance threshold datastore **412**. When performance drops below the performance threshold, the geo-analysis connection engine **410** can connect to a second network. The second network can be the next network on the geo-prioritized network list. It may be noted that the geo-location engine **406** can update the geo-prioritized networks datastore **408** so that network priorities change while a device is connected to a first network. So when performance drops below the performance threshold, the geo-analysis connection engine **410** can use the updated geo-prioritized network list to find a highest priority network that is available and instruct the radio **404** to connect to it. So the second network may or may not be the next highest priority network in the geo-prioritized list that was used when a connection to the first network was established.

Advantageously, the performance threshold setting can avoid frequent hopping between networks. Even if a second network has a higher geo-priority than a first network for which a device has a current connection, it may not be desirable to switch because of the risk of switching back and forth as performance fluctuates for the first and second (or other) networks. Thus, the performance threshold can be indicative of a performance that is "good enough" even if predicted performance of a second network exceeds the performance of the first network.

The performance threshold can be dynamically adjusted. While it is desirable to avoid frequent hopping between networks, a change in location can result in significantly higher performance on a second network. Even if the performance on the first network is "good enough," the predicted performance of the second network may be sufficiently superior that the desire to avoid frequent hopping is eclipsed by the potential improved performance of the second network. Thus, the performance threshold can be a function of current performance on a first network and a predicted performance of a second network in addition to or instead of a performance threshold network switching preference.

When the performance threshold takes into account the performance of a first network to which a device is connected and a performance of a second network, the performance parameters of the first network and the second network need not be the same. For example, performance of the second network could include an access grant reliability parameter and a predicted delay in access grant parameter, while no such parameters are used to characterize performance of the first network. Other parameters may or may not be considered for characterizing both networks (e.g., post-connection network performance parameters or economic performance parameters).

In the example of FIG. **4**, the selective network monitoring engine **414** can monitor networks other than a first network to which a subscriber is connected. Monitoring can include passive scans, which entail listening for beacon frames (or equivalent transmissions) from a WAP. The information available from beacon frames can vary depending upon network-specific variables. Active scanning typically produces more network information, but consumes more resources (e.g., wireless bandwidth, battery power, etc.).

The selective network monitoring engine **414** can monitor networks that are on the geo-prioritized networks list. Not all networks are necessarily treated equally when determining which to monitor, which is why the selective network monitoring engine **414** is called "selective." For example, a prioritized list could indicate a preference for monitoring certain networks (not necessarily based upon the priority of the network). The selective monitoring of certain networks can be in order to limit the number of networks scanned by each of a plurality of devices that are relatively close to one another, to check on a network that has been flagged as a poor performer to see if performance has changed, to keep the device aware of relatively high priority networks in case performance of a current network dips below a performance threshold, to obtain additional information about a network, or the like.

The selective network monitoring engine **414** can work in coordination with the geo-analysis connection engine **410**. For example, the selective monitoring can be of networks that are high on the geo-prioritized networks list in order to keep network priorities as up-to-date as possible. The selective network monitoring engine **414** can also ensure that a dynamic performance threshold is updated with the most current network data. Data from selective network monitoring can be used at the device or sent to a server and provided in the form of a prioritized list after processing at the server.

The ANCS reporting engine **416** generates reports from ANCS of the selective network monitoring engine **414**. The ANCS reporting engine **416** provides the ANCS reports to the radio **404** for transmission through the radio interface **402** to a server. The server can ensure that future prioritized lists are relatively current and, assuming an indication is provided by the server rather than derived from rules at the device, that selective network scanning indicators enable the device to scan networks in coordination with other devices or at least without wastefully consuming resources by providing less useful data regarding networks compared to more useful data that the server could use to more effectively prepare prioritized network lists for subscribers.

Advantageously, the system **400** provides location data and ANCS reports to a server to enable the server to generate prioritized network lists using the location and ANCS reports for the device sending the ANCS report and other subscribers (regardless of whether the other subscribers also send ANCS reports). The CSP **210** of FIG. **2** could, for example, include such a server.

Advantageously, the system **400** can customize prioritized network lists using a device's current location. For example, the geo-location engine **406** can customize prioritized network lists for a large geographic area in accordance with a device's current location, a motion trace (e.g., predictor of future location), or knowledge regarding historical network connection preferences. Alternatively, the geo-location engine **406** can receive a prioritized network list for a local geographic area dependent on a device's current location and/or historical network connection preferences. Alternatively, the geo-location engine **406** can choose between multiple local geographic area network maps in accordance with a device's current location and/or historical network connection preferences.

Advantageously, the system **400** enables selective monitoring of networks on a prioritized network list to identify networks for which it is most optimal for a device to connect in a given geographic area. A device can apply implemented rules to determine an optimal network using a prioritized network list. The device can also selectively scan other networks to update the prioritized network list in accordance with what is discovered. This can benefit both the device and other subscribers.

Advantageously, the system **400** can reduce the likelihood of frequent jumping from one network to another as the network priority list changes or the performance on a given network fluctuates over time. The geo-analysis connection engine **410** can ensure a device remains connected to a network until performance drops below a minimum performance threshold.

FIG. **5** depicts a diagram of an example of a system **500** for using a motion trace to prioritize networks on a network map. In the example of FIG. **5**, the system **500** a location detection engine **502**, a location datastore **504**, a location trace generation engine **506**, a location trace datastore **508**, a location trace reporting engine **510**, a radio **512**, a radio interface **514**, and a location trace application engine **516**.

In the example of FIG. **5**, the location detection engine **502** is capable of determining a current location of a device. Although in this paper the location of the device is treated as a known value, it should be understood that location detection is often an estimate of current location. For example, a GPS system is not always capable of pinpoint accuracy. As another example, three WAPs could detect three signals having three different signal strengths from the device and determine location based on the distance, e.g., RSSI seems to indicate, but this triangulation technique is typically fairly inaccurate. However, any applicable known or convenient location estimation technique, regardless of its accuracy, can be sufficient if it sufficiently accurate to enable application of techniques described in association with location detection in this paper.

In the example of FIG. **5**, the location detection engine **502** stores the detected location in the location datastore **504**. The data structures of the location datastore **504** can be as simple as coordinates in two-dimensional or three-dimensional space. It may be noted that while networks have ranges that extend into three-dimensional space, it may be useful to simplify to two-dimensional space (typically as an overlay over the ground or a floor of a building). More important than whether a z-axis component (altitude) is recorded is a timestamp for a given location. Thus, a minimalist location data structure will include an x-axis component (e.g., longitude), a y-axis component (e.g., latitude), and a timestamp, and a useful variant can include a z-axis component (e.g., altitude). The units of the axis components need not be the same. For example, the x- and y-axis components could be GPS coordinates and the x-axis component could be in feet (or meters) or a more abstract value, such as floors of a building.

In the example of FIG. **5**, the location trace generation engine **506** can use historical location data to determine changes in location over time. By comparing the location associated with a first timestamp to a location associated with a second timestamp, it is possible to determine velocity as well as distance.

Velocity can be recorded in a vector data structure in the location trace datastore **508**. As is true for datastores described in this paper in general, the location datastore **504** and the location trace datastore **508** can be implemented as the same datastore. For example, locations estimated by the location detection engine **502** could be stored as nodes and vectors calculated by the location trace generation engine **506** could be stored as edges between temporally adjacent nodes, in a single datastore. Alternatively, edges could be calculated on the fly such that only the nodes, with timestamps, are stored in non-volatile memory.

The location trace reporting engine **510** can generate a report for a server. The contents of the report can vary somewhat based upon implementation, but a minimal report will include at least the current location of the device and a timestamp. The server may or may not be capable of generating a location trace, which means in an alternative at least a portion of the location trace generation engine **506** can be located at a server.

The radio **512** can send the location trace report through the radio interface **514** to a server. In response to receiving the location trace report, the server can provide a network map. In an alternative, the server need not receive the location trace in order to provide the network map; so the network map is not provided in response to receiving the location trace. The network map can be generated using ANCS reports from the device or from other devices. The network map may or may not be customized at the server using the location trace of the device.

The network map is a multi-dimensional map of networks to which the device can connect. The dimensions can include two or three spatial dimensions, time, network continuity, station velocity, device-specific history, or other parameters. Advantageously, the network map can be combined with device-specific characteristics to enable intelligent and reliable switching to or from wireless networks represented in the network map.

In the example of FIG. **5**, the location trace application engine **516** can use the network map and location traces to choose a network for connection from the network map. Specifically, the location trace application engine **516** can use the motion trace to predict movement into or out of network service areas, and select networks that are appropriate for the predicted movement. Further processing of location traces beyond a determination of velocity can be useful. For example, high velocity followed by a short period of rest can be indicative of travel in a car, followed by stopping at a stoplight. In such a case, it may be desirable to avoid offloading even while the subscriber is stationary. As another example, a connection history could be used to show that some locations are typically passed through fairly

quickly (e.g., a subscriber might walk to work through certain areas, making certain networks unappealing targets for offloading due to the likelihood that the subscriber will continue through the network relatively soon).

In a specific implementation, the network map can include zones of reliable coverage, which may be contiguous or disjoint. Thus, the location trace application engine **516** can use a network map of reliable networks and the location (or location trace) of the device to remove networks that the device is likely to move in and out of coverage faster than a reliability threshold. The reliability threshold datastore **518** can store a data structure can include subscriber or service provider preferences for how quickly after a pause or slow movement to offload to another network. If the location trace velocity exceeds the reliability threshold, the device will not offload to certain networks (e.g., shorter-range networks).

As was mentioned previously, the location trace application engine **516** can make use of other information, such as connection history for a subscriber, activity that is indicative of being in a car or on public transportation, etc. to use a constructive velocity in the determination. Thus, even if the actual velocity of a subscriber is zero (e.g., when the subscriber is at a stop sign), the constructive velocity can have a higher value representative of the predicted future velocity. Constructive velocity can also be "net velocity" found by adding vectors over a period of time such that movement back-and forth (e.g., if a subscriber is pacing). That is absolute velocity, or speed, of a subscriber over a relatively short period of time may not be as significant as the net velocity for the purpose of comparison to the reliability threshold.

When the location trace is applied to the network map to find a highest priority network to which the device can connect, the radio **512** can be instructed to authenticate and associate with the chosen network. Thus, offloading from one network to another can be achieved using a location trace of the device and a multi-dimensional network map.

FIG. **6** depicts a diagram of an example of a system **600** for using knowledge of subscriber network connections to prioritize network lists for subscribers. In the example of FIG. **6**, the system **600** includes subscribers **602-1** to **602**-N (collectively, subscribers **602**), wireless networks **604-1** to **604**-N (collectively, wireless networks **604**), a subscriber interface **606**, a connection tracking engine **608**, a subscriber connections datastore **610**, and a prioritized network list provisioning engine **612**.

In the example of FIG. **6**, the subscribers **602** can include stations that are capable of connecting to wireless networks. Depending upon the context, a subscriber can refer to a device or a person using the device. It is occasionally expedient for illustrative purposes to refer to subscriber data, which can include data about the user of the device, and the existence of a subscriber record is not necessarily indicative of the existence of a device. However, the techniques described in this paper are generally applicable to a subscriber who can connect to a wireless network. Thus, the subscriber will, at least as used in the description of operation, always include a device.

In the example of FIG. **6**, the wireless networks **604** can include a variety of different types of networks. For example, the wireless network **604-1** could be a Wi-Fi network and the wireless network **604-2** could be a 3G (cellular) network.

In the example of FIG. **6**, the subscriber interface **606** is assumed to be on a server. It should be noted that details regarding how the subscribers **602** connect to the subscriber interface **606** are omitted. For example, the connection between the subscribers **602** can be through intervening networks including the Internet and/or a PSTN. In order for the subscribers **602** to connect to one of the wireless networks **604**, the subscribers **602** may also have to connect through a WAP or base station. In an alternative, the subscriber interface **606** could be on a peer device (e.g., a station in an IBSS).

In the example of FIG. **6**, the connection tracking engine **608** can receive data from the subscribers **602**. The data can include ANCS reports and authentication data, but for the purpose of this example, the data includes data sufficient to identify the wireless networks **604** to which the subscribers **602** are connected. For example, subscribers **602-1** and **602-2** may indicate that they are connected to the wireless network **604-1**, a Wi-Fi network in this example. Some of the subscribers **602** may not be connected with any of the wireless networks **604** at a given point in time, but are nevertheless known to the server due to authentication attempts, wireless transmissions, a wired connection, or for other applicable reasons.

In the example of FIG. **6**, the subscriber connections datastore **610** stores a data structure that includes data sufficient to identify the wireless networks **604** with which the subscribers **602** are connected. The connection tracking engine **608** can modify the relevant data structure when one of the subscribers **602** disconnects from or connects to one of the wireless networks **604**. The data structure may or may not also include data associated with networks for which the subscribers are within range, though this information could also be derived from knowledge of a subscriber's location and a network map.

In the example of FIG. **6**, the prioritized network list provisioning engine **612** can use data from the subscriber connections datastore **610** to determine, for example, how many of the subscribers **602** are connected to a given network, such as the wireless network **604-1**. When generating a prioritized network list the prioritized network list provisioning engine **612** can use this information to steer subscribers away from wireless networks that have a relatively large number of connections and/or toward wireless networks that have a relatively small number of connections. A technique of a similar type is often refereed as network load balancing.

For example, assume subscribers **602-1** to **602-2** are connected to the wireless network **604-1** (a Wi-Fi network in this example) and the subscriber **602**-N can be offloaded to the wireless network **604-1** from the wireless network **604-2** (a cellular network in this example). The prioritized network list provisioning engine **612** can use the knowledge of the number of devices **602-1** to **602-2** to prioritize the wireless network **604-1** in a prioritized network list that is to be provided to the subscriber **602**-N. For the purposes of this example, the subscriber **602**-N is in the service area of each of the wireless networks **604**; so the prioritized network list can potentially include any or all of the wireless networks **604**. If the prioritized network list provisioning engine **612** determines that the number of devices connected to the wireless network **604-1** exceeds an optimal number of connections threshold, the wireless network **604-1** can have a reduced priority in the prioritized list that is provided to the subscriber **602**-N (or the wireless network **604-1** could be omitted from the prioritized list). In this way, the server can effectively advise devices contemplating a connection to a first network based upon the number of devices connected to the first network.

In the example of FIG. **6**, the connections threshold **614** includes a data structure indicative of the number of connections that are acceptable. The number of connections that are acceptable may or may not vary by network. For example, some networks may be capable of supporting a larger number of connections. Also, some networks might be more predictably impacted by subscriber connections (e.g., a network that services a relatively large number of subscribers can improve predictability for a server that only receives connection information for the subscribers and not for other wireless devices on the network), making connection data more useful to the prioritized network list provisioning engine **612** when weighting the various factors used to determine priority for networks.

FIG. **7** depicts a diagram of an example of a system **700** for using performance history to customize a prioritized network list. In the example of FIG. **7**, the system **700** includes a prioritized list datastore **702**, a historical performance evaluation engine **704**, a performance history engine **706**, a network connection engine **708**, a radio **710**, a performance monitoring engine **712**, and a reliability threshold datastore **714**.

In the example of FIG. **7**, the prioritized list datastore **702** includes a prioritized network data structures. For the purposes of this example, the prioritized list datastore **702** is treated as including data structures with data sufficient to identify networks having service areas in which a device having the system **700** at least partially implemented is located and the priority of the networks. Of course, an actual implementation of the prioritized list datastore **702** could include additional data. The prioritized list datastore **702** can be populated by a server that sends a prioritized network list (not shown), the prioritized list could be generated at the device, or the prioritized list could be obtained in some other manner.

In the example of FIG. **7**, the historical performance evaluation engine **704** can customize the prioritized list in the prioritized list datastore **702**. In this way, in addition to using a prioritized list that has been prioritized based on reliability, location, time of day, or other factors that are described elsewhere in this paper, the device is capable of fine-tuning the prioritized list using on-device data.

In the example of FIG. **7**, the performance history datastore **706** includes a data structure that is instructive regarding past performance for a given network. To the extent a network data structure exists in both the prioritized list datastore **702** and the performance history datastore **706**, the historical performance evaluation engine **704** can compare the priority of the network to an actual performance history. Other networks in the prioritized list datastore **702** and the performance history datastore **706** can be similarly compared. Depending upon the implementation, the prioritized list datastore **702** can be updated with a customized prioritized list that adjusts networks in the prioritized list based upon past performance. It is not necessarily the case that a network having superior network performance will have the highest priority (e.g., superior economic performance could be more important), and depending on the implementation, the subscriber may be able to adjust performance preferences as it relates to changing prioritization of networks.

In the example of FIG. **7**, the network connection engine **708** can use the (now) customized prioritized list to select a network. The rules used to make the selection can be as simple as choosing the highest priority network from the customized prioritized network list. However, the network connection engine **708** could also have, e.g., an offload priority threshold that must be met in order to offload to, e.g., a Wi-Fi network from a cellular network. In other words, a cellular network could be a default and other networks would have to have, e.g., a performance advantage sufficient to merit offloading, regardless of prioritization. The network connection engine **708** could also be configured to connect to the highest priority network of the prioritized network list (prior to customization) and only use the customized prioritized list after some performance monitoring.

In the example of FIG. **7**, the radio **710** is instructed to connect to a network that is selected by the network connection engine. Over time, the radio **710** will receive at least some network data (e.g., from packets received over the wireless medium) that can be used to monitor performance on the selected network. The radio **710** can also be instructed to scan other networks, as is described elsewhere in this paper, and the data obtained can be used to monitor performance on the other networks.

In the example of FIG. **7**, the performance monitoring engine **712** at least monitors performance on the selected network, and may or may not also monitor performance on other networks. The data obtained can be stored in the performance history datastore **706** and used by the historical performance evaluation engine **704** to customize the prioritized list. The historical performance evaluation engine **704** and the performance monitoring engine **712** can operate in parallel or in some other fashion.

In the example of FIG. **7**, the reliability threshold datastore **714** includes a data structure indicative of when the performance monitoring engine **712** will trigger the network connection engine **708** to switch networks. When the performance monitoring engine **712** determines that a network is, for example, sufficiently reliable, the network connection engine **708** can offload from, e.g., a cellular network, to, e.g., a sufficiently reliable Wi-Fi network. What is meant by "sufficiently reliable" is that a reliability threshold is established based upon user preferences for reliability, network configurations, or other factors that, when met, are indicative of sufficient reliability for an offload target. The reliability threshold is described elsewhere in this paper.

Advantageously, the system **700** enables a device to perform a network performance evaluation before deciding to connect to a network. The system **700** can then offload from a first network to a sufficiently reliable second network. The device can then continue to evaluate performance and decide whether to switch to another network based on performance. FIG. **8** depicts a diagram of an example of a system **800** for selecting network connections based on network prioritization. In the example of FIG. **8**, the system **800** includes a subscriber user interface (UI) **802**, a preference selection engine **804**, a performance preferences datastore **806**, an incentivized network selection engine **808**, a prioritized list **810**, a network connection engine **812**, and a radio **814**.

The subscriber UI **802** enables a user to view information about networks, preferences, and incentives, and to input data for use by the device. As such, the UI is presumed to include a display device (with drivers, if applicable) and an input device (with drivers, if applicable). By way of example but not limitation, the subscriber UI **802** could include a touchscreen input/output (I/O) device, a liquid crystal display (LCD) and keypad, or some other applicable known or convenient combination or collection of I/O device(s).

The preference selection engine **804** displays options on the subscriber UI. The options can include, for example, rules that dictate when to switch to or from networks or network types. For example, the user could define reliability, congestion state, QoS, performance, or some other param-

eter value. The user can also define incentive states. These settings can be in association with a specific network (e.g., a subscriber may have a high preference for offloading to home or office Wi-Fi networks, which can be explicitly identified) or in association with a network type (e.g., a subscriber may have differing preferences for offloading to an 802.11a network or an 802.11b/g/n network).

The performance preferences datastore **806** stores data structures indicative of the performance and/or incentive settings selected at the preference selection engine **804**. In a specific implementation, a user can update preferences at any time by, for example, triggering the preference selection engine **804** with a menu selection. Performance preferences can also be dynamic settings that can change in accordance with operational changes. For example, preferences may be different when a device has a full battery relative to when the device is running out of power. Thus, the preferences can by used in conjunction with or stored as rules for controlling operation of the device, specifically in this example, network connection selections by the device.

The incentivized network selection engine **808** uses a prioritized network list, which can be stored in the prioritized list datastore **810**, and preferences and/or rules in the performance preferences datastore **806** to select a network and prompt the network connection engine **812** to control the radio **814** to connect to the selected network. In the example of FIG. **8**, the subscriber can be provided with options that are displayed at the subscriber UI **802** and the subscriber can input data associated with those options. The amount of information provided to the subscriber can vary with implementation, but can include a list of all available networks, all available reliable networks, one or more aspects of network performance for displayed networks, or the like.

FIG. **9** depicts a conceptual display **900** associated with incentivized network selection. The display **900** includes a list of prioritized networks **902-1** to **902**-N (collectively, prioritized network list **902**), radio buttons **904**, and state indicators **906**. The prioritized network list **902** may or may not include all available networks, depending upon implementation- or configuration-specific parameters. For example, the subscriber may or may not be able to limit the list only to networks that meet certain performance or incentive specifications, or a service provider may or may not have a similar ability to prune the list of available networks. In the example of FIG. **9**, the prioritized network list **902** is presumed to be ordered by priority, but a priority indicator other than order could be used instead (e.g., priority could be indicated by a number in a column, text or background color, etc.).

In the example of FIG. **9**, the radio buttons **904** are intended to illustrate a network selection mechanism. An applicable known or convenient mechanism for selecting one of the networks of the prioritized network list **902** could be used instead (e.g., the text of the prioritized network list **902** could be selectable such that if a user "clicked" on a network, that network would be selected). It should be noted that in a specific implementation the choice of network can be made by the device based upon a set of rules decided upon by a subscriber regarding when to connect to a network or switch to a new network.

In the example of FIG. **9**, the state indicators **906** are intended to illustrate information that could be provided in association with a prioritized network list display. In the example of FIG. **9**, the state indicators **906** include a column of performances **908-1** to **908**-N (collectively, performance states **908**), a column of availabilities **910-1** to **910**-N (collectively, network availability states **910**), and a column of incentives **912-1** to **912**-N (collectively, incentive states **912**). The state indicators **906** need not be displayed in a columnar or tabular form (e.g., data could be displayed by hovering over a network in the prioritized network list **902**). The data can also be represented by color-coding (e.g., networks in the prioritized network list **902** could be displayed with red text if a corresponding congestion state of the network is high and green text if a corresponding congestion state of the network is low), or using some other applicable known or convenient technique to convey information about the state of a network.

As was mentioned elsewhere in this paper, performance can have many different meanings (e.g., network performance, economic performance, access grant performance, etc.). Thus, although there is one column of performance states **908**, there could be several columns to indicate state or estimates for different types of performance. Within each type of performance, there may be additional subcategorizations (e.g., network performance can be measured in more than one way, including throughput, QoS, congestion, etc.) Performance can be summarized for a subscriber and presented as a single value (e.g., a number that is indicative of the relative performance of the network) or more explicit data can be provided (e.g., the basic radio bit rate of the network).

The network availability states **910** are related to performance, but are represented in a separate column due to some distinctions. Performance can be indicative of what can be expected if a connection is established with the corresponding network. Availability can be indicative of the likelihood with which a connection can be established. Reliability (not shown) can also be distinguished because it is indicative of the likelihood that performance will be consistent or a connection can be maintained over time (e.g., in consideration of a motion trace or zone of reliability based on time of day), which is somewhat different from both performance and availability. Reliability can be obviated as an indicator in an implementation in which only reliable networks are in the prioritized network list **902**.

The incentive states **912** can indicate to a subscriber an "incentive offer" that may entice the subscriber to choose one network over another, regardless of prioritization.

FIG. **10** depicts a diagram of an example of a system **1000** for offering incentives to a subscriber to connect to a network. In the example of FIG. **10**, the system **1000** includes a radio interface **1002**, a radio **1004**, an incentivized network selection engine **1006**, a subscriber UI **1008**, and a network connection engine **1010**.

The radio **1004** receives an incentive offer from or on behalf of a network through the radio interface **1002**. The incentive offer can be provided in a number of different ways, such as in beacon frames, in frames identifiable as "incentive frames," in the body or header of a message, etc. It will typically be more valuable to send incentives to devices that are in a service area of a network, but depending upon implementation, incentives could be sent based upon predicted movement, probably in the immediate future, based upon connection history or a motion trace. In an alternative, the incentive offer is not received over the radio interface **1002**, and is instead generated at the system **1000** in the incentivized network selection engine **1006** (or in an incentive offer generation engine, not shown).

The incentivized network selection engine **1006** enables a user to select the incentivized network through the subscriber UI **1008**. The selection could also be made based upon rules or preferences that were previously input by the

subscriber or a service provider. The network selection option could be presented as a pop-up window prompting a user to select whether to connect to the applicable network in exchange for the incentive offer. Alternatively, the incentive offer could trigger a display similar to the display depicted by way of example in FIG. **9**. Regardless of the mechanism used to provide the choice to the subscriber, the network connection engine **1010** can connect to the network in accordance with the subscriber's choice.

Advantageously, a service provider can identify one or more networks (e.g., Wi-Fi networks) that the service provider would like a subscriber to offload to. In the case of a cellular provider, this can enable the service provider to reduce load on the cellular network. By incentivizing the offloading, the service provider can expect a larger number of subscribers to offload than if no incentive was offered. The incentive offer can explain advantages of switching networks to the subscriber, which can include, for example, traffic charges are free or less expensive, one or more service capabilities or activities are available on, e.g., Wi-Fi that are not available or have a lower performance on, e.g., cellular, the subscriber gets a discount or credit for switching, etc.

FIG. **11** depicts a diagram of an example of a system **1100** for repeatedly cycling through performance tests. In the example of FIG. **11**, the system **1100** includes a radio interface **1102**, a radio **1104**, a prioritized network selection engine **1106**, a network connection engine **1108**, a selective network monitoring engine **1110**, and an ANCS reporting engine **1112**.

The radio **1104** receives a prioritized list from a server through the radio interface **1102**. The prioritized list could alternatively be generated at least in part at a device one which the system **1100** is implemented.

The prioritized network selection engine **1106** selects a priority network in accordance with any techniques described previously in this paper. The network connection engine **1108** controls the radio **1104** to connect to the applicable network. The network connection engine **1108** can perform a scan to determine available networks before or after obtaining the prioritized list.

The selective network monitoring engine **1110** can cycle through one or more network performance tests for a subset of the available networks. The ANCS reporting engine **1112** can report the results of the tests to a server through the radio **1104** and radio interface **1102**. The server could then perform a selection algorithm to select the network that best meets a network selection cost function and prioritize the network accordingly and provide another prioritized list. Alternatively, the device implementing the system **1100** can use the ANCS to customize the prioritized list. If the prioritized network selection engine **1106** selects a new network, the network connection engine **1108** can control the radio **1104** to connect to the selected network.

The selective network monitoring engine **1110** can repeatedly generate ANCS such that the prioritized list is continuously updated. In an alternative, the ANCS reports can be uploaded to a service controller function.

The embodiments illustrated in FIGS. **1-11** include components that can be selectively combined with one another. The cost functions of the various embodiments can include such parameters as signal strength, channel strength, basic radio bit rate, network speed, network throughput, speed jitter, throughput jitter, network delay, delay jitter, network availability, network reliability in successful network access grant percentage, delay in access grant, variation in performance as a function of performance, to name several.

FIG. **12** depicts a diagram of an example of a system **1200** capable of wireless network offloading and of enabling carriers to establish the wireless network offloading service. In the example of FIG. **12**, the system **1200** includes a network **1202**, a server **1204**, an intelligent wireless offloading client **1206**, and a service design center (SDC) **1208**. The network **1202** will include a wireless network to which the intelligent wireless offloading client **1206** is connected, but can otherwise include any applicable known or convenient network suitable for linking the components of the system **1200**. The server **1204** can be a server of a CSP or other service provider. The intelligent wireless offloading client **1206** can include capabilities of a wireless device and can include an implementation of any subset of the techniques described in this paper.

In one embodiment, the SDC **1208** acts as the portal to enable the service providers to set service plan parameters for the wireless networking offloading functionality. The SDC **1208** can enable the service providers to set charging rates for each of the different wireless network connections, such as a charging rate for Wi-Fi networks, a charging rate for 3G networks, a charging rate for 4G networks, etc. Each service provider may set different charging rates for the same or different network connections. Each service provider may establish different service plans, each having different charging rates for the different wireless connections. For example, a service provider may have a service plan that benefits the highly mobile user, charging less for cell connections. A service provider may have a service plan that benefits those who anticipate reduced usage of cell connections.

In one embodiment, the SDC **1208** acts as the portal to enable the service providers to set notification parameters. For example, each service provider can set different notifications to motivate users to switch between wireless connections. These notifications and incentives can be temporal, geo-specific, service plan specific, etc.

In one embodiment, the SDC **1208** acts as the portal to enable the service providers to set access parameters. For example, each service provider can enable the various devices to access only a subset of available network connections, to offload to only certain network connections, etc.

The SDC **1208** further can provide functionality that may not be provided by the server **1204** or the intelligent wireless offloading client **1206**. For example, the SDC **1208** can load algorithms for use at the client or server, set periodicity of scans by the client, set matrices, establish geographic boundaries of networks, set periodicity of reporting, etc.

Examples of the SDC **1208** can be found in the following related published applications, which are hereby incorporated by reference: U.S. publication No. 2010/0188975, filed Mar. 2, 2009, entitled "Verifiable Device Assisted Service Policy Implementation," U.S. publication No. 2010/0192170, filed Mar. 2, 2009, entitled "Device Assisted Service Profile Management with User Preference, Adaptive Policy, Network Neutrality, and User Privacy," U.S. publication No. 2010/0191612, filed Mar. 2, 2009, entitled "Verifiable Device Assisted Service Usage Monitoring with Reporting, Synchronization, and Notification," U.S. publication No. 2010/0191576, filed Mar. 2, 2009, entitled "Verifiable Device Assisted Service Usage Billing with Integrated Accounting, Mediation Accounting, and Multi-Account," U.S. publication No. 2010/0188991, filed Mar. 2, 2009, entitled "Network Based Service Policy Implementation with Network Neutrality and User Privacy," U.S. publication No. 2010/0188990, filed Mar. 2, 2009, entitled "Network Based Service Profile Management with User Prefer-

ence, Adaptive Policy, Network Neutrality and User Privacy," U.S. publication No. 2010/0192212, filed Mar. 2, 2009, entitled "Automated Device Provisioning and Activation," U.S. publication No. 2010/0191604, filed Mar. 2, 2009, entitled "Device Assisted Ambient Services," U.S. publication No. 2010/0191575, filed Mar. 2, 2009, entitled "Network Based Ambient Services," U.S. publication No. 2010/0188993, filed Mar. 2, 2009, entitled "Network Tools for Analysis, Design, Testing, and Production of Services," U.S. publication No. 2010/0190470, filed Mar. 2, 2009, entitled "Roaming Services Network and Overlay Networks," U.S. publication No. 2010/0192120, filed Mar. 2, 2009, entitled "Open Development System for Access Service Providers," U.S. publication No. 2010/0192207, filed Mar. 2, 2009, entitled "Virtual Service Provider Systems," U.S. publication No. 2010/0191613, filed Mar. 2, 2009, entitled "Open Transaction Central Billing System," U.S. publication No. 2010/0188995, filed Mar. 2, 2009, entitled "Verifiable and Accurate Service Usage Monitoring for Intermediate Networking Devices," U.S. publication No. 2010/0188994, filed Mar. 2, 2009, entitled "Verifiable Service Billing for Intermediate Networking Devices," U.S. publication No. 2010/0191846, filed Mar. 2, 2009, entitled "Verifiable Service Policy Implementation for Intermediate Networking Devices," U.S. publication No. 2010/0188992, filed Mar. 2, 2009, entitled "Service Profile Management with User Preference, Adaptive Policy, Network Neutrality and User Privacy for Intermediate Networking Devices," U.S. publication No. 2010/0191847, filed Mar. 2, 2009, entitled "Simplified Service Network Architecture," U.S. publication No. 2010/0197266, filed Jan. 27, 2010, entitled "Device Assisted CDR Creation, Aggregation, Mediation, and Billing," U.S. publication No. 2010/0198698, filed Jan. 27, 2010, entitled "Adaptive Ambient Services," U.S. publication No. 2010/0199325, filed Jan. 27, 2010, entitled "Security Techniques for Device Assisted Services," U.S. publication No. 2010/0197267, filed Jan. 27, 2010, entitled "Device Group Partitions and Settlement Platform," U.S. publication No. 2010/0198939, filed Jan. 27, 2010, entitled "Device Assisted Services Install," U.S. publication No. 2010/0195503, filed Jan. 27, 2010, entitled "Quality of Service for Device Assisted Services," and U.S. publication No. 2010/0197268, filed Jan. 28, 2010, entitled "Enhanced Roaming Services and Converged Carrier Networks with Device Assisted Services and a Proxy."

FIG. **13** depicts an example of a computer system **1300** on which techniques described in this paper can be implemented. The computer system **1300** may be a conventional computer system that can be used as a client computer system, such as a wireless client or a workstation, or a server computer system. The computer system **1300** includes a computer **1302**, I/O devices **1304**, and a display device **1306**. The computer **1302** includes a processor **1308**, a communications interface **1310**, memory **1312**, display controller **1314**, non-volatile storage **1316**, and I/O controller **1318**. The computer **1302** may be coupled to or include the I/O devices **1304** and display device **1306**.

The computer **1302** interfaces to external systems through the communications interface **1310**, which may include a modem or network interface. It will be appreciated that the communications interface **1310** can be considered to be part of the computer system **1300** or a part of the computer **1302**. The communications interface **1310** can be an analog modem, ISDN modem, cable modem, token ring interface, satellite transmission interface (e.g. "direct PC"), or other interfaces for coupling a computer system to other computer systems.

The processor **1308** may be, for example, a conventional microprocessor such as an Intel Pentium microprocessor or Motorola power PC microprocessor. The memory **1312** is coupled to the processor **1308** by a bus **1370**. The memory **1312** can be Dynamic Random Access Memory (DRAM) and can also include Static RAM (SRAM). The bus **1370** couples the processor **1308** to the memory **1312**, also to the non-volatile storage **1316**, to the display controller **1314**, and to the I/O controller **1318**.

The I/O devices **1304** can include a keyboard, disk drives, printers, a scanner, and other input and output devices, including a mouse or other pointing device. The display controller **1314** may control in the conventional manner a display on the display device **1306**, which can be, for example, a cathode ray tube (CRT) or liquid crystal display (LCD). The display controller **1314** and the I/O controller **1318** can be implemented with conventional well known technology.

The non-volatile storage **1316** is often a magnetic hard disk, an optical disk, or another form of storage for large amounts of data. Some of this data is often written, by a direct memory access process, into memory **1312** during execution of software in the computer **1302**. One of skill in the art will immediately recognize that the terms "machine-readable medium" or "computer-readable medium" includes any type of storage device that is accessible by the processor **1308** and also encompasses a carrier wave that encodes a data signal.

The computer system **1300** is one example of many possible computer systems which have different architectures. For example, personal computers based on an Intel microprocessor often have multiple buses, one of which can be an I/O bus for the peripherals and one that directly connects the processor **1308** and the memory **1312** (often referred to as a memory bus). The buses are connected together through bridge components that perform any necessary translation due to differing bus protocols.

Network computers are another type of computer system that can be used in conjunction with the teachings provided herein. Network computers do not usually include a hard disk or other mass storage, and the executable programs are loaded from a network connection into the memory **1312** for execution by the processor **1308**. A Web TV system, which is known in the art, is also considered to be a computer system, but it may lack some of the features shown in FIG. **13**, such as certain input or output devices. A typical computer system will usually include at least a processor, memory, and a bus coupling the memory to the processor.

In addition, the computer system **1300** is controlled by operating system software which includes a file management system, such as a disk operating system, which is part of the operating system software. One example of operating system software with its associated file management system software is the family of operating systems known as Windows® from Microsoft Corporation of Redmond, Wash., and their associated file management systems. Another example of operating system software with its associated file management system software is the Linux operating system and its associated file management system. The file management system is typically stored in the non-volatile storage **1316** and causes the processor **1308** to execute the various acts required by the operating system to input and output data and to store data in memory, including storing files on the non-volatile storage **1316**.

Some portions of the detailed description are presented in terms of algorithms and symbolic representations of operations on data bits within a computer memory. These algo-

rithmic descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. An algorithm is here, and generally, conceived to be a self-consistent sequence of operations leading to a desired result. The operations are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like.

One skilled in the art should recognize that terms used are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as "processing" or "computing" or "calculating" or "determining" or "displaying" or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or display devices.

The present invention, in some embodiments, also relates to apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, any type of disk including floppy disks, optical disks, CD-ROMs, and magnetic-optical disks, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

The algorithms and displays presented herein are not inherently related to any particular computer or other apparatus. Various general purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language, and various embodiments may thus be implemented using a variety of programming languages.

FIG. **14** depicts a flowchart **1400** of an example of a method for prioritized wireless offloading. The method is organized as a sequence of modules in the flowchart **1400**. However, it should be understood that these and other modules associated with other methods described herein may be reordered for parallel execution or into different sequences of modules.

In the example of FIG. **14**, the flowchart **1400** starts at module **1402** with obtaining wireless network data. The wireless network data can be obtained through ANCS at a wireless device. The ANCS can be used at the wireless device and/or can be provided to a server in an ANCS report. In an implementation that makes use of a server, the server can receive ANCS reports from multiple wireless devices. This can enable the server to generate prioritized lists for subscribers making use of network data that is remotely obtained relative to a subscriber.

In the example of FIG. **14**, the flowchart **1400** continues to module **1404** with generating a prioritized network list from the wireless network data. In an implementation that makes use of a server, the server can perform an algorithm in memory to optimize capacity to a group of subscribers of a service provider associated with the server. The optimization can take into account network loading, wireless device location, wireless device connections, performance history (including, e.g., a time of day associated with a particular performance for a network), a network map over a geographic area, motion traces of wireless devices, subscriber preferences, incentives, and cost functions to name several. The prioritized list can take the form of a network map, which can be treated as a subset of prioritized list (with an added geo-location component).

In the example of FIG. **14**, the flowchart **1400** continues to module **1406** with connecting to a network from the prioritized network list. A device may or may not customize a prioritized network list that is provided from a server in accordance with device-specific parameters. Where customization does not occur, the server may take into account the device-specific parameters (as well as, e.g., account-specific parameters) when generating the prioritized list. Where customization does occur, in an implementation that includes a server, the prioritized list can still be partially customized at the server. Customization can be in accordance with monitored performance of networks within range of the device, subscriber-specified rules, service provider-specified rules, a location trace, performance history, environmental conditions, cost function, or incentives, to name several.

In the example of FIG. **14**, the flowchart **1400** continues to module **1408** with monitoring network performance. The monitoring can be of the network to which the device is connected. The device can also monitor other networks, either passively or actively, in accordance with network monitoring rules. The rules can be provided by a service provider, SDC, or input directly.

In the example of FIG. **14**, the flowchart **1400** returns to module **1402** and continues as described previously. It is not necessary that the same elements perform the same tasks described. For example, a server could initially generate a prioritized network list (**1404**), but on a second iteration, a wireless device could generate a (customized) prioritized network list without receiving a new prioritized list from the server. Also, there may be additional or fewer actions or determinations on a second iteration. For example, when a device first connects to a network (**1406**), it may be unnecessary to compare performance or some other parameter of a network with a threshold value to determine whether to switch to another network, but when the device considers switching from one network to another, it may be desirable to compare current performance with a threshold value to ensure it is "worth it" to switch to a (currently) more highly prioritized network.

FIG. **15** depicts a flowchart **1500** of an example of a method for using device assisted services (DAS) to facilitate wireless offloading. In the example of FIG. **15**, the flowchart **1500** starts at module **1402** with monitoring network service usage activities of a device. The network service usage activities can be monitored with a verified/verifiable network performance characterization software (implemented in hardware) or hardware agent. The agent can be implemented on the device in question, on a different device, or can have components that are implemented on more than

one device. The monitoring can be accomplished using a radio and can be selective. An example of an agent that performs selective monitoring is the selective network monitoring engine **414** or the selective network monitoring engine **1110**, respectively described by way of example with reference to FIGS. **4** and **11**, or the performance monitoring engine **712** described by way of example with reference to FIG. **7**.

In the example of FIG. **15**, the flowchart **1500** continues to module **1504** with determining a network busy state based on the monitored network service usage activities. Network statistics can be stored in a network statistics datastore, such as the network statistics datastore **304** described by way of example with reference to FIG. **3**. The network busy state can also be stored in a network statistics datastore or can be derived from statistics that are stored in the network statistics datastore. The network busy state can include a measure of network capacity, availability, and/or performance, and can be derived using techniques described in this paper. The network busy state can be determined with a network performance characterization software (implemented in hardware) or hardware agent, which can measure and/or characterize a network busy state experienced by a device. An example of an agent that performs network busy state determination is the network statistics characterization engine **306**, such as is described by way of example with reference to FIG. **3** or the historical performance evaluation engine **704**, such as is described by way of example with reference to FIG. **7**.

In the example of FIG. **15**, the flowchart **1500** continues to module **1506** with reporting the network busy state to a network element/function. The network busy state can be included in any of the reports described in this paper (e.g., a network busy state report, ANCS report, etc.). Depending on the implementation, the network busy state can be used by a network element/function on a wireless device, such as the wireless device that at least in part monitored network service usage activities and/or determined a network busy state, on a server, or on some other applicable device. An example of such a network element/function includes the wireless network offloading engine **106**, such as is described by way of example with reference to FIG. **1**.

In the example of FIG. **15**, the flowchart **1500** continues to module **1508** with setting network access control policy for one or more network capacity controlled services using the network busy state. The network access control policy can be acted upon by the geo-analysis connection engine **410**, the network connection engine **708**, the incentivized network selection engine **808** and/or the network connection engine **812**, the incentivized network selection engine **1006** and/or the network connection engine **1010**, the prioritized network selection engine **1106** and/or the network connection engine **1108**, such as are respectively described by way of example with reference to FIGS. **4**, **7**, **8**, **10**, and **11**.

Data on a wireless network is often encrypted. However, data may also be sent in the clear, if desired. With encrypted data, a rogue device will have a very difficult time learning any information (such as passwords, etc.) from clients before countermeasures are taken to deal with the rogue. The rogue may be able to confuse the client, and perhaps obtain some encrypted data, but the risk is minimal (even less than for some wired networks).

The following example illustrates possible benefits of this system. In one embodiment, a subscriber turns on a smart phone, the smart phone notices that the subscriber's home network is available. Assuming that the subscriber is connected to the cellular network and not connected to the home network, the cellular service provider sends the subscriber an incentive offer: a reduction in service fees if the subscriber offloads from the cellular network to his home network.

Upon traveling to work, the smart phone recognizes that the subscriber is no longer in the service area of his home network, but is within the service area of three of his neighbors' home networks and the cellular network. The smart phone recognizes that his motion trace (velocity) indicates movement that will move the subscriber out of the range of all three of his neighbors' home networks quickly. Thus, the smart phone may be configured to connect to the cellular network. Upon recognizing that the smart phone is stationary, e.g., at a stoplight, the smart phone may be configured to wait a predetermined period of time before considering to offload to a Wi-Fi network (especially if the smart phone knows the subscriber was moving). Accordingly, the smart phone may be configured to remain connected to the cellular network.

Upon reaching a destination, the smart phone recognizes that the motion trace becomes stationary or relatively slow and that the smart phone is proximate to two local Wi-Fi networks. In one embodiment, the beacon frames of the first Wi-Fi network may have higher received signal strength indicators (RSSI). However, other subscribers may have provided network data about the first network that indicate the first network is typically severely congested at this time. Thus, the smart phone may be configured to indicate that the second network has a higher priority than the first network, despite the high RSSI.

In some embodiments, the smart phone receives a prioritized network list that indicates the second network as having a higher priority than the first network. In some embodiments, the smart phone is configured to connect to a wireless network in accordance with an incentive offer, to connect based on preferences set by the subscriber, or to wait for the subscriber to select a network from the prioritized network list.

To assist with information gathering, the smart phone may be configured to gather information about another local wireless network, e.g., about the first wireless network, and may report the information to the cellular service provider. While the smart phone is in range of the other local wireless network, the smart phone may passively or actively scan the other network. In some embodiments, the smart phone is configured to perform active scans only when the smart phone is plugged into a power source.

INCORPORATION BY REFERENCE

This application incorporates by reference the following U.S. Patent Applications for all purposes: U.S. Ser. No. 13/134,005, filed May 25, 2011, entitled "System and Method for Wireless Network Offloading"; U.S. Ser. No. 12/380,778 filed Mar. 2, 2009, entitled "Verifiable Device Assisted Service Usage Billing with Integrated Accounting, Mediation Accounting, and Multi-Account"; U.S. Ser. No. 12/380,780 filed Mar. 2, 2009, entitled "Automated Device Provisioning and Activation"; U.S. Ser. No. 12/695,019 filed Jan. 27, 2010, entitled "Device Assisted CDR Creation, Aggregation, Mediation and Billing"; U.S. Ser. No. 12/695,020 filed Jan. 27, 2010, entitled "Adaptive Ambient Services"; U.S. Ser. No. 12/694,445 filed Jan. 27, 2010, entitled "Security Techniques for Device Assisted Services"; U.S. Ser. No. 12/694,451 filed Jan. 27, 2010, entitled "Device Group Partitions and Settlement Platform"; U.S. Ser. No. 12/694,455 filed Jan. 27, 2010, entitled "Device Assisted

Services Install"; U.S. Ser. No. 12/695,021 filed Jan. 27, 2010, entitled "Quality of Service for Device Assisted Services"; and U.S. Ser. No. 12/695,980 filed Jan. 28, 2010, entitled "Enhanced Roaming Services and Converged Carrier Networks with Device Assisted Services and a Proxy".

This application also incorporates by reference the following U.S. provisional applications: U.S. provisional application Ser. No. 61/206,354, filed Jan. 28, 2009, entitled "Services Policy Communication System and Method"; U.S. provisional application Ser. No. 61/206,944, filed Feb. 4, 2009, entitled "Services Policy Communication System and Method"; U.S. provisional application Ser. No. 61/207,393, filed Feb. 10, 2009, entitled "Services Policy Communication System and Method"; U.S. provisional application Ser. No. 61/207,739, filed Feb. 13, 2009, entitled "Services Policy Communication System and Method"; U.S. provisional application Ser. No. 61/270,353, filed Jul. 6, 2009, entitled "Device Assisted CDR Creation, Aggregation, Mediation and Billing"; U.S. provisional application Ser. No. 61/275,208, filed Aug. 25, 2009, entitled "Adaptive Ambient Services"; U.S. provisional application Ser. No. 61/237,753, filed Aug. 28, 2009, entitled "Adaptive Ambient Services"; U.S. provisional application Ser. No. 61/252,151, filed Oct. 15, 2009, entitled "Security Techniques for Device Assisted Services"; U.S. provisional application Ser. No. 61/252,153, filed Oct. 15, 2009, entitled "Device Group Partitions and Settlement Platform"; U.S. provisional application Ser. No. 61/264,120, filed Nov. 24, 2009, entitled "Device Assisted Services Install," and U.S. provisional application Ser. No. 61/264,126, filed Nov. 24, 2009, entitled "Device Assisted Services Activity Map"; U.S. provisional application Ser. No. 61/348,022, filed May 25, 2010, entitled "Device Assisted Services for Protecting Network Capacity"; U.S. provisional application Ser. No. 61/381,159, filed Sep. 9, 2010, entitled "Device Assisted Services for Protecting Network Capacity"; U.S. provisional application Ser. No. 61/381,162, filed Sep. 9, 2010, entitled "Service Controller Interfaces and Workflows"; U.S. provisional application Ser. No. 61/384,456, filed Sep. 20, 2010, entitled "Securing Service Processor with Sponsored SIMs"; U.S. provisional application Ser. No. 61/389,547, filed Oct. 4, 2010, entitled "User Notifications for Device Assisted Services"; U.S. provisional application Ser. No. 61/385,020, filed Sep. 21, 2010, entitled "Service Usage Reconciliation System Overview"; U.S. provisional application Ser. No. 61/387,243, filed Sep. 28, 2010, entitled "Enterprise and Consumer Billing Allocation for Wireless Communication Device Service Usage Activities"; U.S. provisional application Ser. No. 61/387,247, filed Sep. 28, 2010, entitled "Secured Device Data Records"; U.S. provisional application Ser. No. 61/407,358, filed Oct. 27, 2010, entitled "Service Controller and Service Processor Architecture"; U.S. provisional application Ser. No. 61/418,507, filed Dec. 1, 2010, entitled "Application Service Provider Interface System"; U.S. provisional application Ser. No. 61/418,509, filed Dec. 1, 2010, entitled "Service Usage Reporting Reconciliation and Fraud Detection for Device Assisted Services"; U.S. provisional application Ser. No. 61/420,727, filed Dec. 7, 2010, entitled "Secure Device Data Records"; U.S. provisional application Ser. No. 61/422,565, filed Dec. 13, 2010, entitled "Service Design Center for Device Assisted Services"; U.S. provisional application Ser. No. 61/422,572, filed Dec. 13, 2010, entitled "System Interfaces and Workflows for Device Assisted Services"; U.S. provisional application Ser. No. 61/422,574, filed Dec. 13, 2010, entitled "Security and Fraud Detection for Device Assisted Services"; U.S. provisional application Ser. No. 61/435,564, filed Jan. 24, 2011, entitled "Framework for Device Assisted Services"; and U.S. provisional application Ser. No. 61/472,606, filed Apr. 6, 2011, entitled "Managing Service User Discovery and Service Launch Object Placement on a Device."

The invention claimed is:

1. A wireless end-user device comprising:

a radio configured to identify available wireless networks, the available wireless networks being different than a current wireless network to which the end user device is currently connected; and

a prioritized network selection engine configured to

select one of the available wireless networks based on a prioritized network list,

cause the wireless end-user device to connect through the selected available wireless network to a network element in a second network reachable through the selected available wireless network,

initiate an upload and/or download sequence between the wireless end-user device and the network element,

characterize performance of the selected available wireless network based on the conducted upload and/or download sequence, and

determine, based at least in part on the characterized performance, to communicate network data for the wireless end-user device through the selected available wireless network instead of the current wireless network.

2. The wireless end-user device of claim **1**, configured to receive the prioritized network list from a remote server.

3. The wireless end-user device of claim **1**, configured to supply information based on the characterized performance to an access network characterization server that collects such information from a plurality of wireless end-user devices.

4. The wireless end-user device of claim **1**, wherein the prioritized network selection engine configured to cause the wireless end-user device to connect through the selected available wireless network comprises configured to automatically cause the wireless end-user device to connect through the selected available wireless network.

5. The wireless end-user device of claim **1**, wherein the prioritized network selection engine configured to cause the wireless end-user device to connect through the selected available wireless network comprises configured to cause the wireless end-user device to connect through the selected available wireless network in response to a user selection.

6. The wireless end-user device of claim **1**, wherein the prioritized network selection engine configured to cause the wireless end-user device to connect through the selected available wireless network comprises configured to automatically cause the wireless end-user device to connect through the selected available wireless network based on one or more user preferences.

7. The wireless end-user device of claim **1**, the prioritized network selection engine further configured to provide a user of the wireless end-user device with a notification including an incentive offer to incent the user to connect to one of the available wireless networks.

8. The wireless end-user device of claim **7**, wherein the incentive offer includes a network-performance incentive.

9. The wireless end-user device of claim **1**, wherein the radio comprises a WiFi radio.

10. The wireless end-user device of claim **9**, further comprising a cellular radio, and wherein at a time that the

WiFi radio identifies available wireless networks, the current wireless network is a cellular wireless network.

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