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**Kaushik et al.**

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(54) **AGGREGATED BEACONS FOR PER STATION CONTROL OF MULTIPLE STATIONS ACROSS MULTIPLE ACCESS POINTS IN A WIRELESS COMMUNICATION NETWORK**

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(73) Assignee: **Fortinet, Inc.**, Sunnyvale, CA (US)

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(51) **Int. Cl.**
***H04W 4/00*** (2009.01)
***H04W 36/18*** (2009.01)
(Continued)

(52) **U.S. Cl.**
CPC ............. ***H04W 36/18*** (2013.01); ***H04W 4/06*** (2013.01); ***H04W 8/26*** (2013.01); ***H04W 48/12*** (2013.01); *H04W 48/20* (2013.01); *H04W 84/12* (2013.01)

(58) **Field of Classification Search**
CPC ........... H04W 4/06; H04W 8/02; H04W 8/26; H04W 28/08; H04W 36/18
See application file for complete search history.

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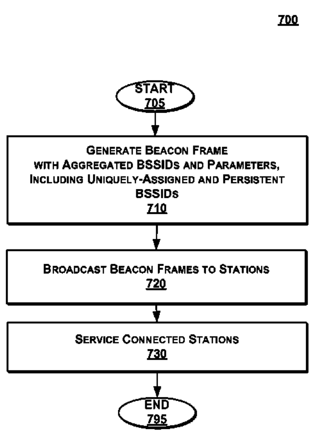
(57) **ABSTRACT**

A technique for providing per station control of multiple stations in a wireless network across multiple access points. A look-up table that assigns a station connected to the access point and at least one communication parameter to each of a plurality of persistent, uniquely-assigned BSSIDs (Basic Service Set Identifiers) is stored. An access point responds to messages addressed one of the plurality of persistent, uniquely-assigned BSSIDs and ignores messages addressed to other BSSIDs. Persistence of the BSSID allows the controller to maintain individual control over each station after moving to a second access point of the plurality of access points. A frame comprising the plurality of BSSIDs corresponding to each connected station aggregated into the frame is generated. The frame is transmitted to the plurality of stations. Responsive to a station of the plurality of stations being handed-off to a different access point, a uniquely-assigned BSSID corresponding to the station is deleted from the look-up table.

**19 Claims, 10 Drawing Sheets**



**Related U.S. Application Data**

application No. 12/913,584, filed on Oct. 27, 2010, now Pat. No. 8,787,309, which is a continuation of application No. 11/715,287, filed on Mar. 7, 2007, now Pat. No. 7,826,426, which is a continuation of application No. 11/298,864, filed on Dec. 9, 2005, now abandoned, which is a continuation-in-part of application No. 11/294,673, filed on Dec. 5, 2005, now Pat. No. 8,160,664.

(51) **Int. Cl.**

| | |
|---|---|
| ***H04W 8/26*** | (2009.01) |
| ***H04W 4/06*** | (2009.01) |
| ***H04W 48/12*** | (2009.01) |
| *H04W 48/20* | (2009.01) |
| *H04W 84/12* | (2009.01) |

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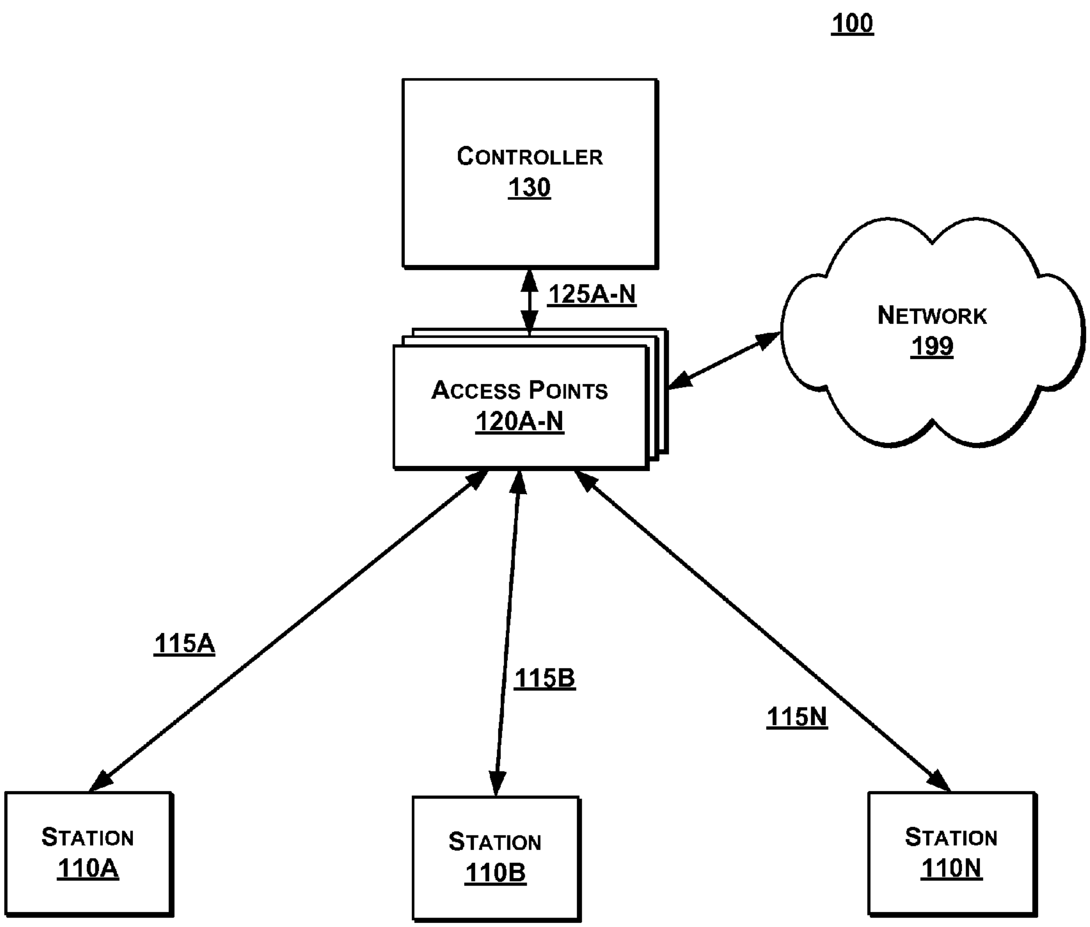

100
CONTROLLER
130
125A-N
NETWORK
199
ACCESS POINTS
120A-N
115A
115B
115N
STATION
110A
STATION
110B
STATION
110N

FIG. 1

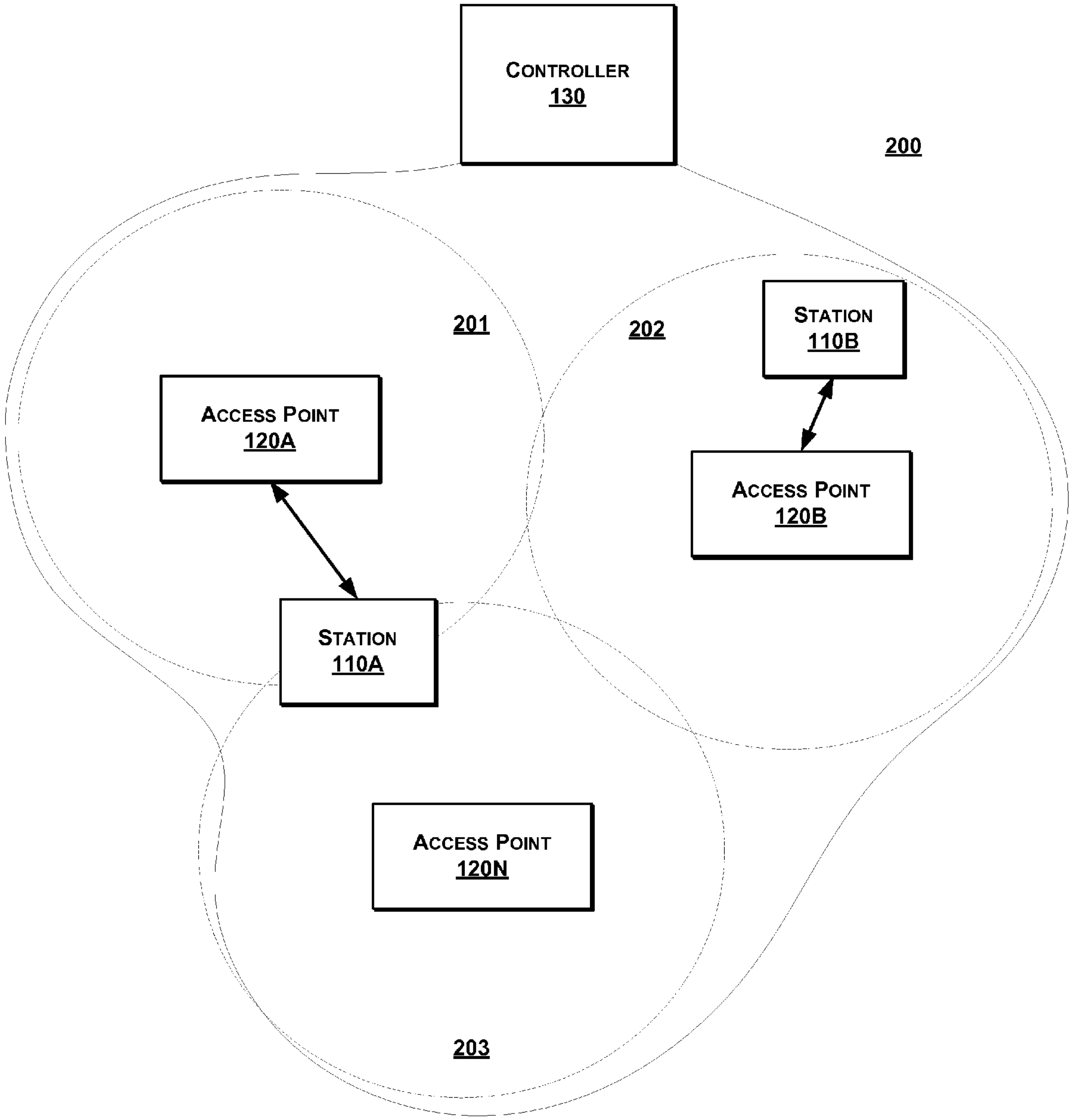
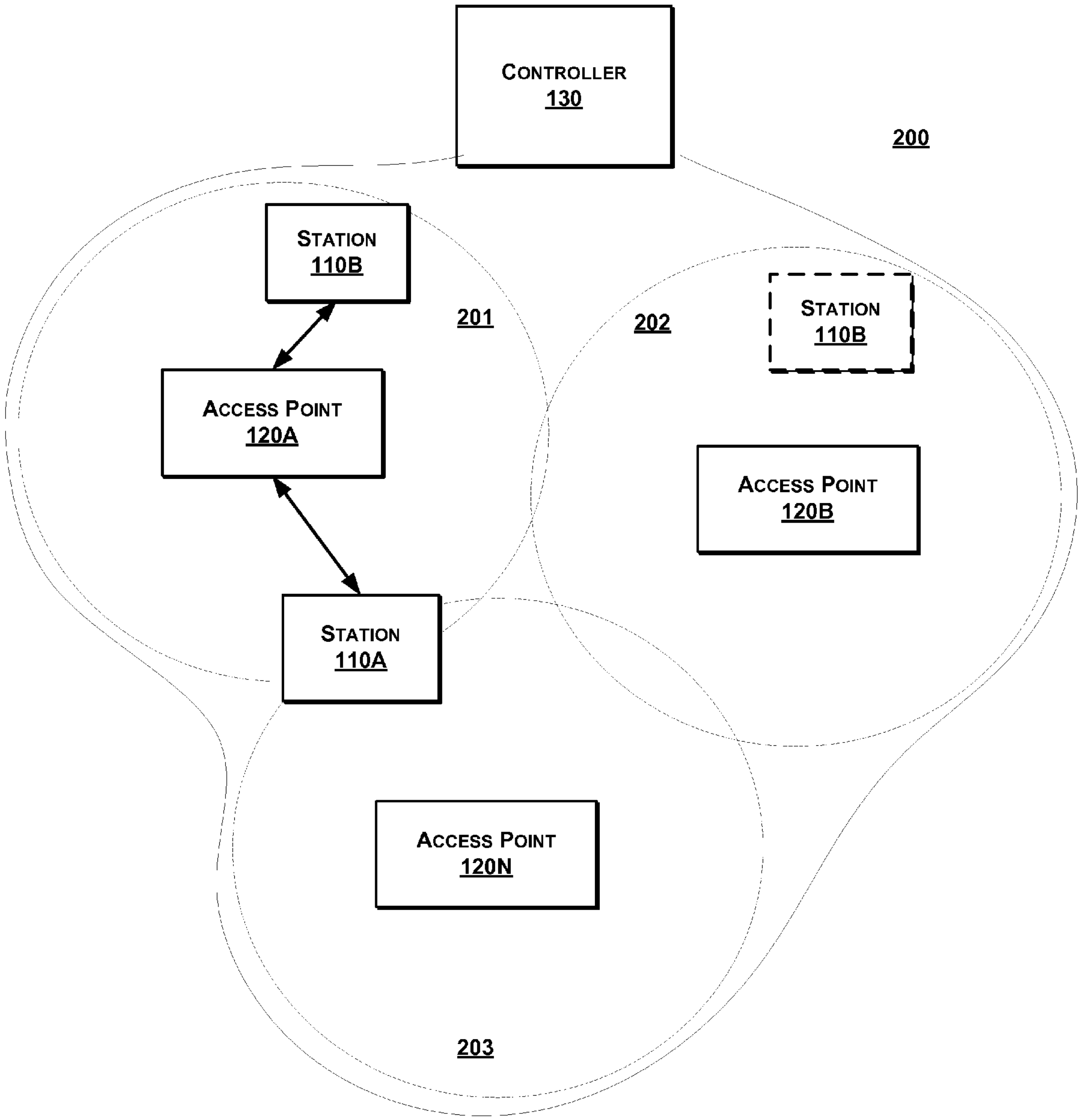

CONTROLLER
130
200
201
202
STATION
110B
ACCESS POINT
120A
ACCESS POINT
120B
STATION
110A
ACCESS POINT
120N
203

FIG. 2A



CONTROLLER
130
200
STATION
110B
201
202
STATION
110B
ACCESS POINT
120A
ACCESS POINT
120B
STATION
110A
ACCESS POINT
120N
203


FIG. 2B

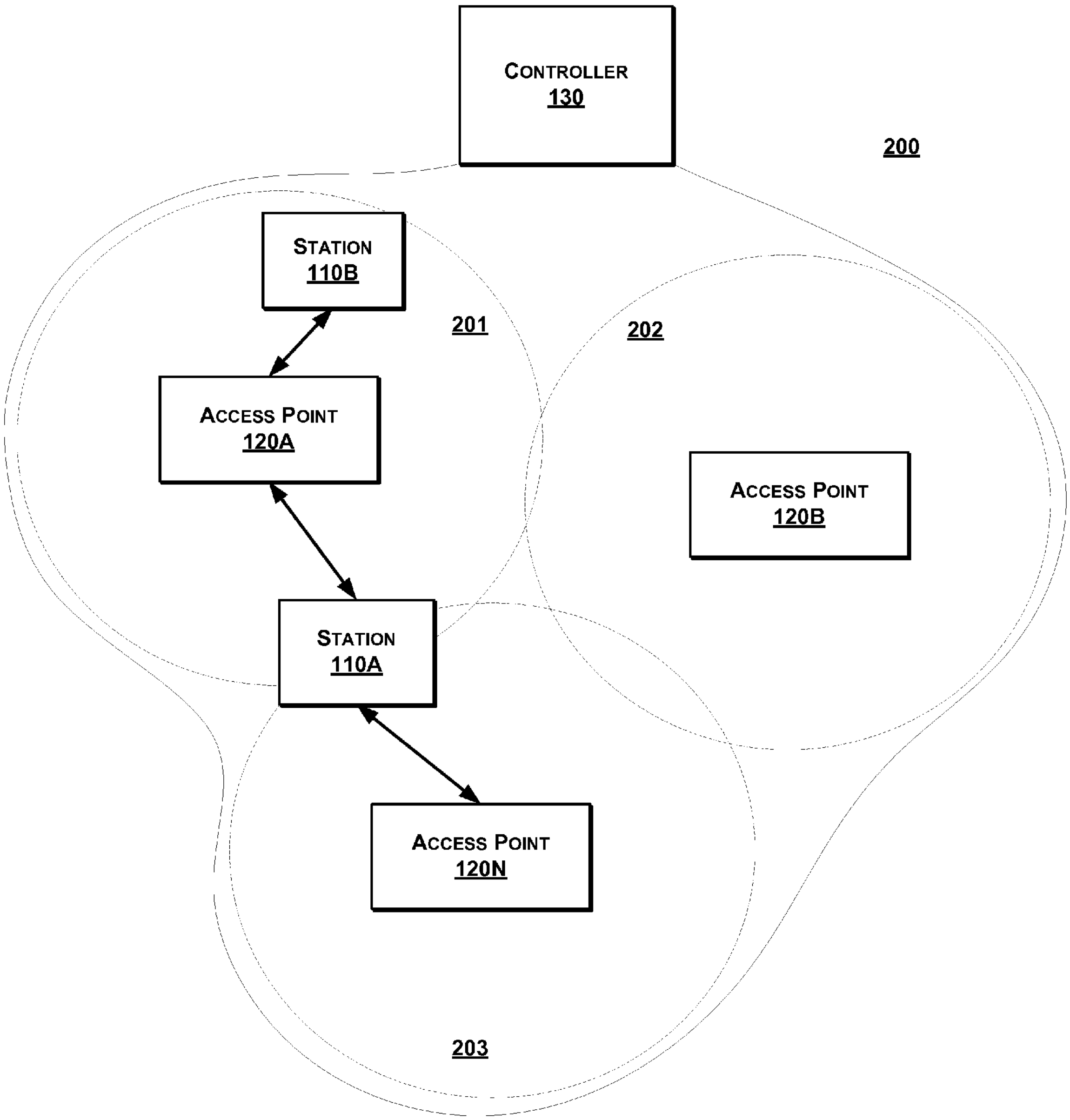

CONTROLLER
130
200
STATION
110B
201
202
ACCESS POINT
120A
ACCESS POINT
120B
STATION
110A
ACCESS POINT
120N
203

FIG. 2C

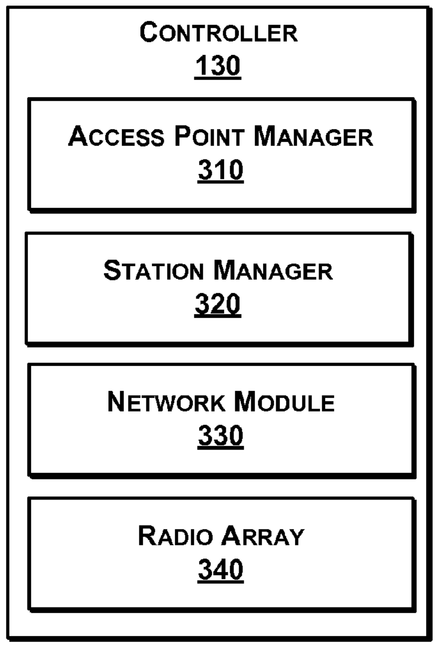

CONTROLLER
130
ACCESS POINT MANAGER
310
STATION MANAGER
320
NETWORK MODULE
330
RADIO ARRAY
340

FIG. 3

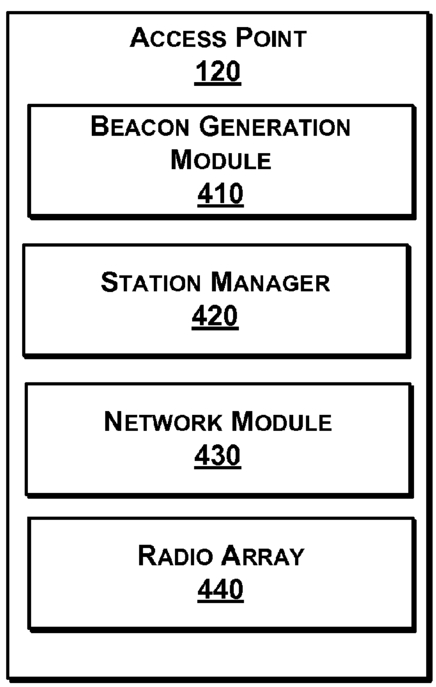

ACCESS POINT
120
BEACON GENERATION MODULE
410
STATION MANAGER
420
NETWORK MODULE
430
RADIO ARRAY
440

FIG. 4

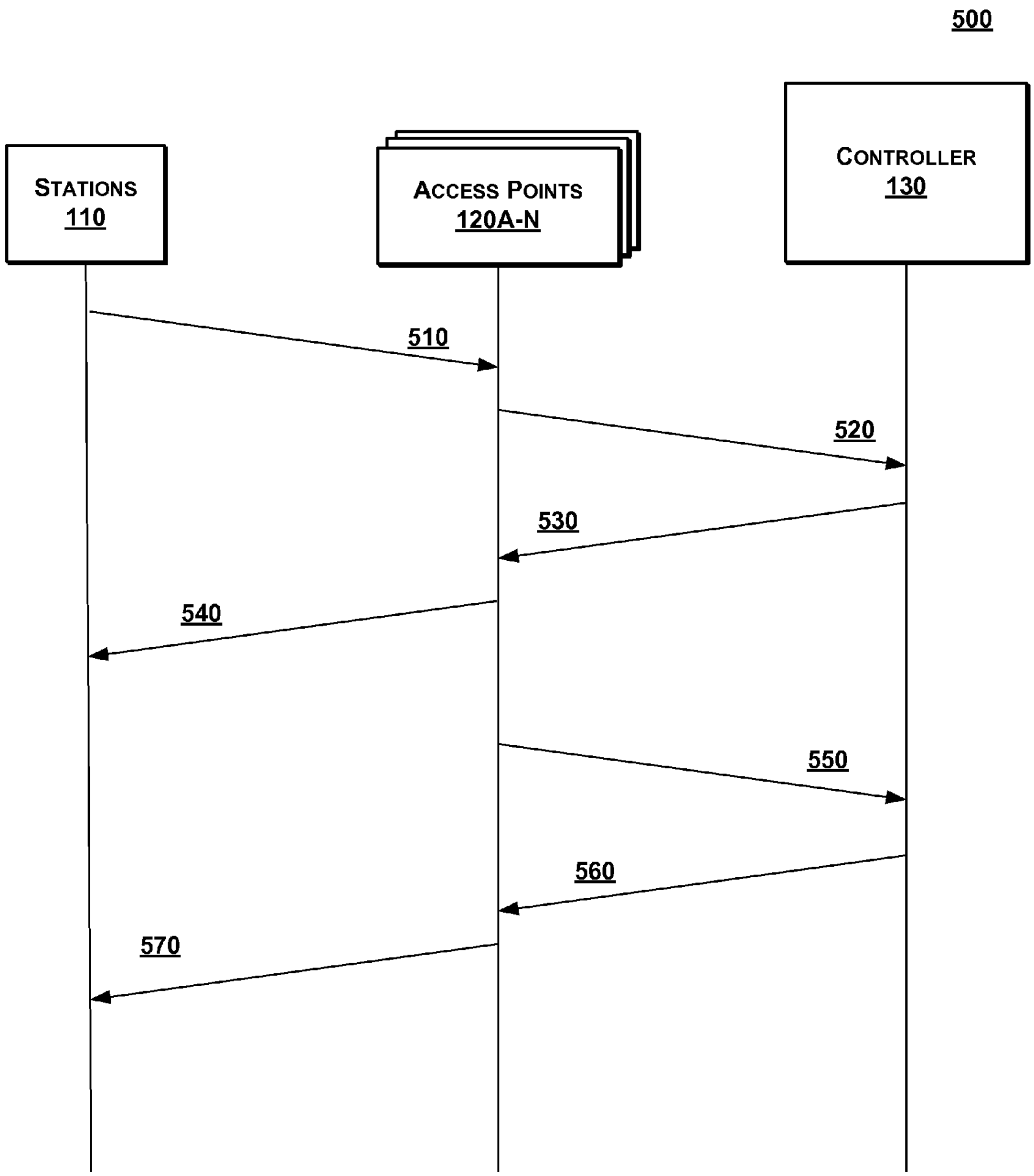

500
STATIONS
110
ACCESS POINTS
120A-N
CONTROLLER
130
510
520
530
540
550
560
570

FIG. 5

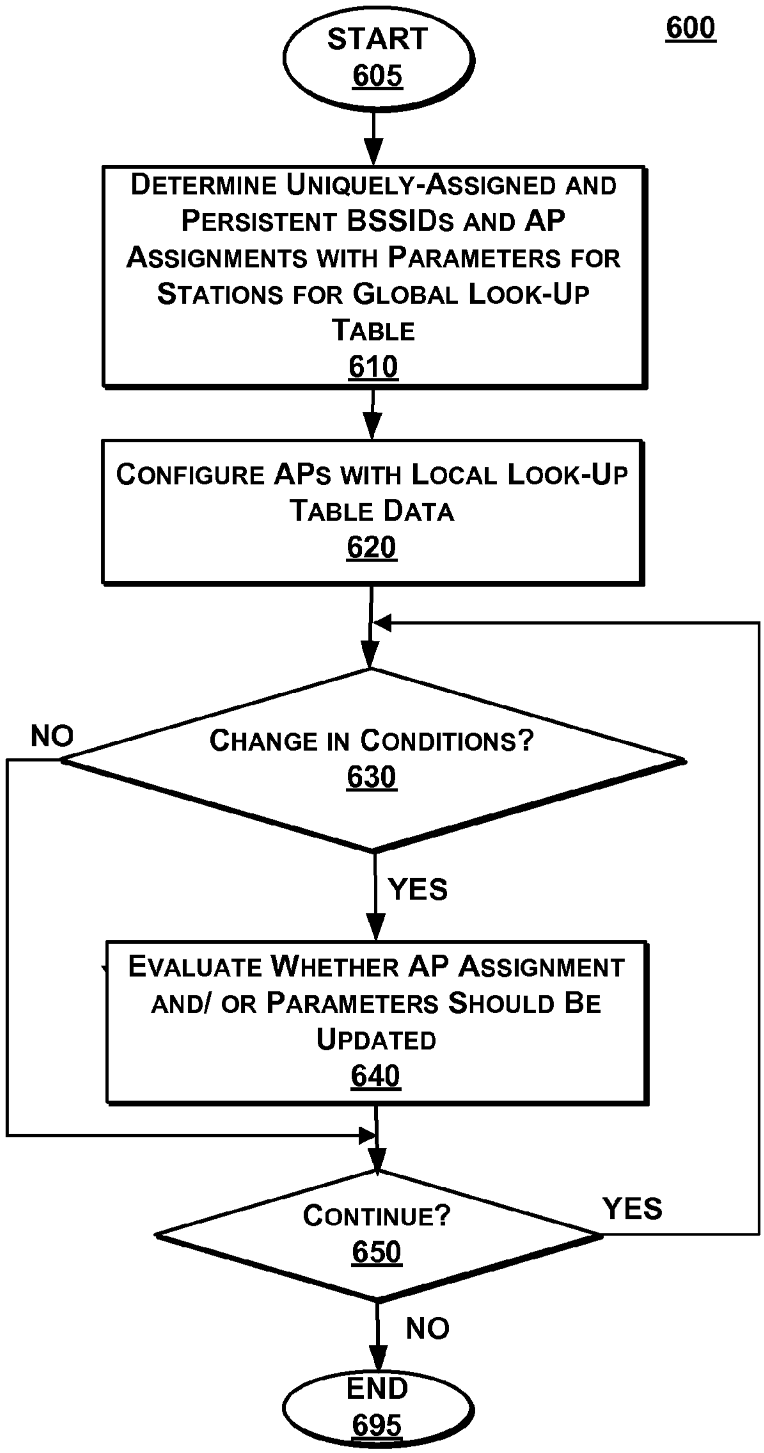

600
START
605
DETERMINE UNIQUELY-ASSIGNED AND PERSISTENT BSSIDS AND AP ASSIGNMENTS WITH PARAMETERS FOR STATIONS FOR GLOBAL LOOK-UP TABLE
610
CONFIGURE APS WITH LOCAL LOOK-UP TABLE DATA
620
CHANGE IN CONDITIONS?
630
NO
YES
EVALUATE WHETHER AP ASSIGNMENT AND/ OR PARAMETERS SHOULD BE UPDATED
640
CONTINUE?
650
YES
NO
END
695

*FIG. 6*

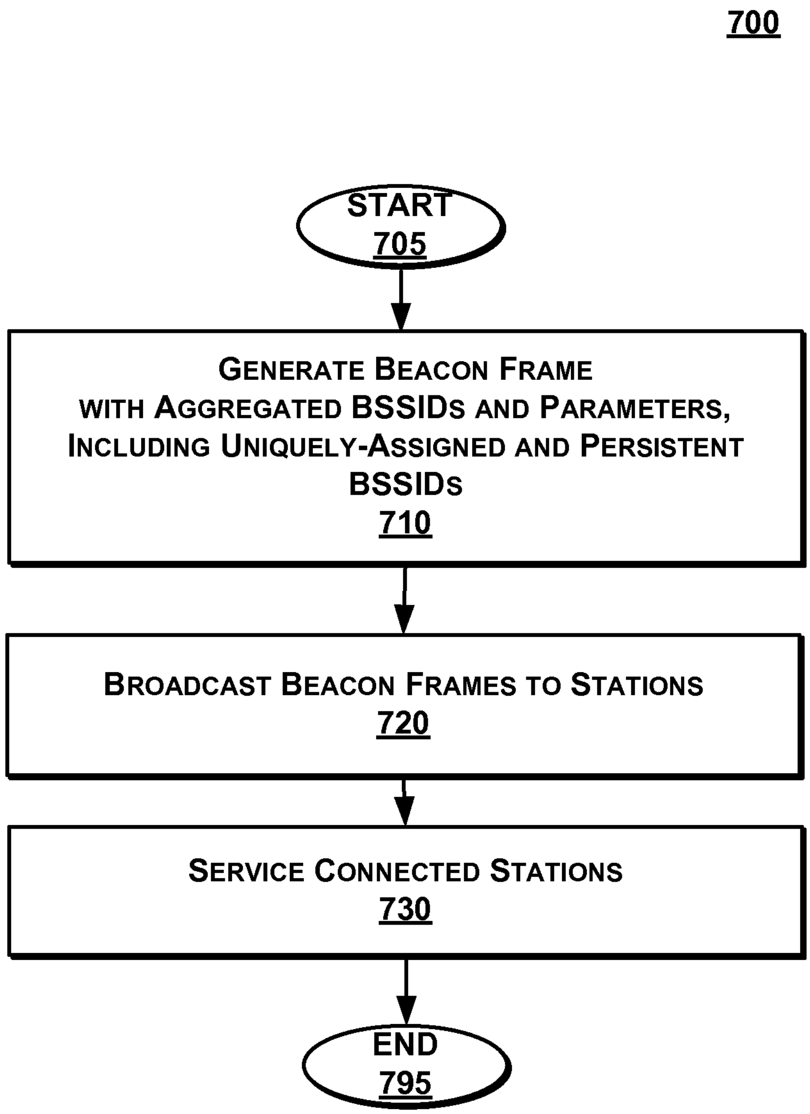

700
START
705
GENERATE BEACON FRAME
WITH AGGREGATED BSSIDS AND PARAMETERS,
INCLUDING UNIQUELY-ASSIGNED AND PERSISTENT
BSSIDS
710
BROADCAST BEACON FRAMES TO STATIONS
720
SERVICE CONNECTED STATIONS
730
END
795

*FIG. 7*

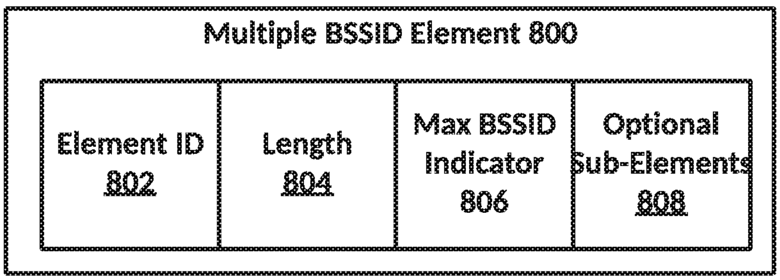

Multiple BSSID Element 800
Element ID 802
Length 804
Max BSSID Indicator 806
Optional Sub-Elements 808

FIG. 8

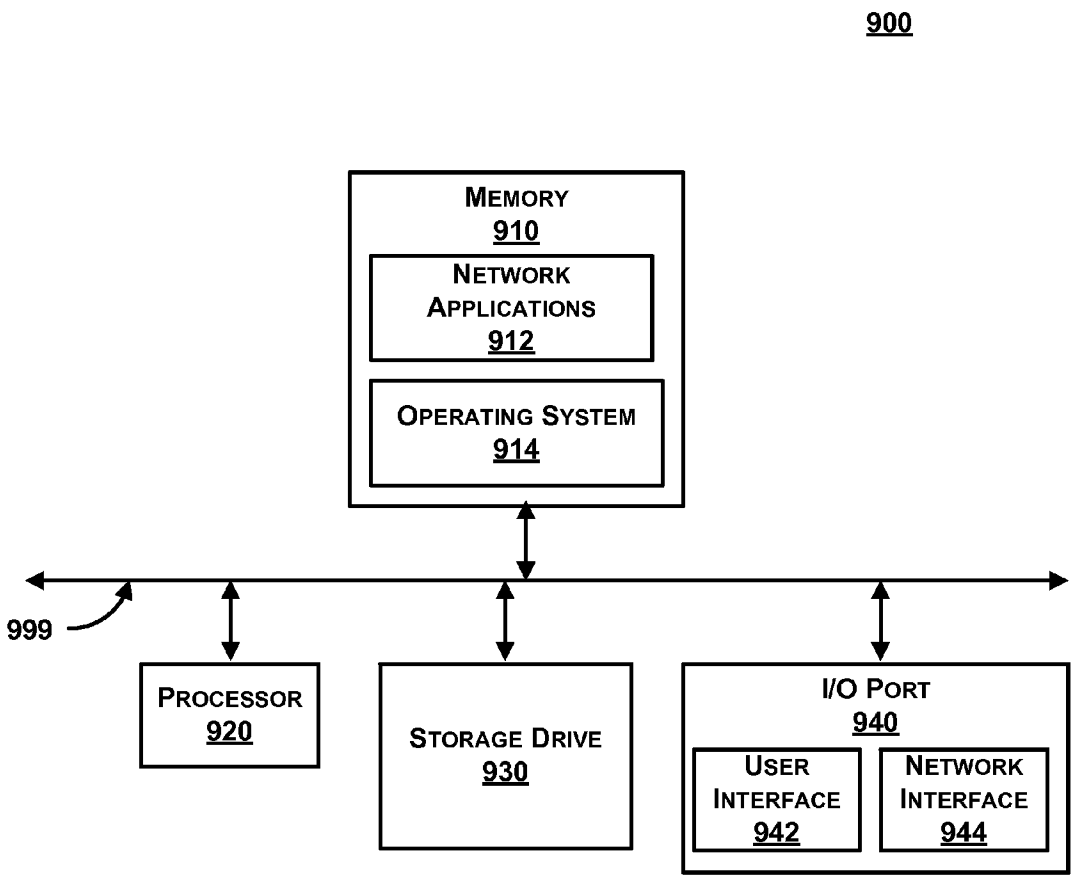

900
Memory
910
Network Applications
912
Operating System
914
999
Processor
920
Storage Drive
930
I/O Port
940
User Interface
942
Network Interface
944

FIG. 9

# AGGREGATED BEACONS FOR PER STATION CONTROL OF MULTIPLE STATIONS ACROSS MULTIPLE ACCESS POINTS IN A WIRELESS COMMUNICATION NETWORK

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 14/337,184, filed Jul. 21, 2014, which is a continuation of U.S. patent application Ser. No. 12/913,584 filed Oct. 27, 2010, now issued U.S. Pat. No. 8,787,309, which is a continuation of U.S. patent application Ser. No. 11/715,287 filed Mar. 7, 2007, now issued U.S. Pat. No. 7,826,426, claims priority of the following document(s), collectively sometimes referred to herein as the "Incorporated Disclosure". Each of these documents forms a part of this disclosure, and is hereby incorporated by reference as if fully set forth herein. U.S. patent application Ser. No. 11/298,864, filed Dec. 9, 2005, in the name of inventors Vaduvur Bharghavan, Sung-Wook Han, Joseph Epstein, Berend Dunsbergen, and Saravanan Balasubramanian, and assigned to the same assignee, titled "Seamless Mobility in Wireless Networks," now abandoned. U.S. patent application Ser. No. 11/294,673, filed Dec. 5, 2005, in the name of inventors Rajendran Venugopalachary, Senthil Palanisamy, Srinith Sarang, and Vaduvur Bharghavan, and assigned to the same assignee, titled "Omni-Directional Antenna Supporting Simultaneous Transmission and Reception of Multiple Radios with Narrow Frequency Separation", now issued U.S. Pat. No. 8,160,664, the content of which is incorporated herein by reference in its entirety.

## FIELD OF THE INVENTION

The invention relates generally to wireless computer networking, and more specifically, to providing per station control of multiple stations across multiple access points.

## BACKGROUND

Wireless computing technologies provide untethered access to the Internet and other networks. One of the most critical technologies for wireless networking (or Wi-Fi) is the IEEE 802.11 family of protocols promulgated by the Institute of Electrical and Electronics Engineers. Currently, the protocols are widely adopted in stations such as laptop computers, tablet computers, smart phones, and network appliances.

Stations complying with standards such as IEEE 802.11 have control over how a connection to wireless network is made. Namely, a station selects an access point among a number of access points that have sent out beacons advertising a presence. The beacon includes a BSSID (Basic Service Set Identifier) as an identifier of the access point. In turn, the station sends data packets which include the BSSID of the intended access point. Unintended access points receiving a transmission merely ignore the data packets.

One technique to address this issue is to download customized software to a station. But reconfiguration of stations running on a station is not always desirable. For instance, guests connecting to a public hot spot for only one time would be burdened with the process of downloading and installing a client during a short connection. Furthermore, many computer users are weary about malicious applications downloaded from the Internet.



Another technique to address this issue, known as virtual port, assigns a BSSID to each station in order to set uplink parameters. Unfortunately, the overhead of virtual port is prohibitive for scaling because regular beacons are sent out for each BSSID to maintain synchronization with an access point. In larger deployments, the occurrence of still beacons increase as the requirement for individual beacons required over each period cannot be met. Consequentially, degradation of station connectivity can occur, for instance, when 20 or more wireless stations are connected to the access point.

What is needed is a robust technique to provide a more scalable solution for per station control of multiple stations across multiple access points in a wireless communication network.

## SUMMARY

These shortcomings are addressed by the present disclosure of methods, computer program products, and systems for providing per station control of multiple stations across multiple access points in a wireless communication network. Aggregated beacons with multiple BSSIDs (Basic Service Set Identifiers) can maintain connections for multiple stations without requiring separate beacons, for example, according to protocols such as IEEE 802.11k, IEEE 802.11v and IEEE 802.11r (collectively referred to herein as "IEEE 802.11 kvr").

In an embodiment, a look-up table that assigns a station connected to the access point and at least one communication parameter to each of a plurality of persistent, uniquely-assigned BSSIDs is stored. An access point responds to messages addressed to one of the plurality of persistent, uniquely-assigned BSSIDs and ignores messages addressed to other BSSIDs of other access points. Uniqueness of BSSIDs allows the controller to individualize communication parameters for specific stations. Persistence of the BSSIDs allows the controller to maintain individual control over each station moving across different access point of the plurality of access points.

In one embodiment, the plurality of BSSIDs corresponding to each connected station is aggregated into the frame when generated. For example, the frame can be compliant with a Multiple BSSID element of the IEEE 802.11 standards. The frame is then transmitted to the plurality of stations connected to an access point in order to connect, or maintain connections with an access point. Alternatively, BSSIDs can be sent in responses to probes received from a station. Responsive to a station of the plurality of stations being handed-off to a different access point, a uniquely-assigned BSSID corresponding to the station is deleted from the look-up table.

Advantageously, virtual port control is scalable for large deployments, and without the overhead of sending individual beacons for each station of a deployment.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the following drawings, like reference numbers are used to refer to like elements. Although the following figures depict various examples of the invention, the invention is not limited to the examples depicted in the figures.

FIG. **1** is a high-level block diagram illustrating a system to provide per station control of multiple stations across multiple access points, according to one embodiment.

FIGS. **2**A-C are high-level block diagrams illustrating a spatial layout of the system of FIG. **1**, according to one embodiment.

FIG. **3** is a more detailed block diagram illustrating a controller of the system of FIG. **1**, according to one embodiment.

FIG. **4** is a more detailed block diagram illustrating an access point of the system of FIG. **1**, according to one embodiment.

FIG. **5** is a sequence diagram illustrating interactions between components of the system of FIG. **1**, according to one embodiment.

FIG. **6** is a flow diagram illustrating a method for providing per station control of multiple stations across multiple access points from a controller, according to one embodiment.

FIG. **7** is a flow diagram illustrating a method for providing per station control of multiple stations across multiple access points from an access point, according to one embodiment.

FIG. **8** is a schematic diagram illustrating an exemplary IEEE 802.11 network packet with multiple BSSIDs (Basic Service Set Identifiers), according to one embodiment.

FIG. **9** is a block diagram illustrating an exemplary computing device, according to one embodiment.

## DETAILED DESCRIPTION

The present invention provides methods, computer program products, and systems for providing per station control of multiple stations across multiple access points in a wireless communication network. For example, uniquely-assigned and persistent BSSIDs (Basic Service Set Identifiers) can be aggregated into a Multiple BSSID element according to IEEE 802.11 specifications. Additionally, one of ordinary skill in the art will recognize that many other scenarios are possible, as discussed in more detail below.

Systems to Provide Per Station Control of Multiple Stations Across Multiple Access Points (FIGS. **1-5**)

FIG. **1** is a high-level block diagram illustrating a system **100** to provide per station control of multiple stations across multiple access points, according to one embodiment. The system **100** comprises stations **110**A-N, access points **120**A-N, and a controller **130**. The components can be coupled to a network **199**, such as the Internet, a local network or a cellular network, through any suitable wired (e.g., Ethernet) or wireless (e.g., Wi-Fi or 4G) medium, or combination. In a preferred embodiment, the stations **110**A-N are coupled to the access points **120**A-N through a wireless communication channel **115**A-N while the access points **120**A-N can be coupled to the controller **130** through a wired network **125** (e.g., Ethernet network). Other embodiments of communication channels are possible, including a cloud-based controller, and hybrid networks. Additional network components can also be part of the system **100**, such as firewalls, virus scanners, routers, switches, application servers, databases, and the like. In general, the stations **110**A-N use communication channels **115**A-N for uplink (and downlink) access to local and/or external networks.

The controller **130** can be implemented in any of the computing devices discussed herein (e.g., see FIG. **9**). For example, the controller **130** can be an MC1500 or MC6000 device by Meru Networks of Sunnyvale, Calif. In operation, the controller **130** communicates with each of the access point **120** to direct parameters for each of the stations **110**A-N. Moreover, the controller **130** determines, in one embodiment, which access point of many should communicate with a particular one of the stations **110**A-N, among other things. The controller **130** can also solely or jointly determine parameters for each station. In one example, the controller **130** varies the parameters based on a top-level network view of traffic and congestion (i.e., provide less access during heavy traffic and more during light traffic). The controller **130** can also track the stations **110**A-N through connections to different access points and enforce the same parameters after hand-offs. Additional embodiments of the controller **130** are discussed with respect to FIG. **3**.

To implement virtual port functionality for per station control of the stations **110**A-C, in an embodiment, the controller **130** can maintain a global look-up table or database with a global view (e.g., network-wide view) of connected stations and other devices. The global look-up table stores a uniquely-assigned BSSID for each station configured for virtual port. All or some stations can be so configured. Additionally, the global look-up table stores parameters, for each BSSID, shared or not. Alternatively, a list of BSSIDs can be stored and stations are associated and de-associated therewith. In one embodiment, a BSSID is generated to be unique by incorporating a device-unique identification, such as a MAC address of a station. The controller **130** sends a BSSID to a selected access point to initiate the association. In one example, a BSSID is a 48-bit field of the same format as an IEEE 802 MAC address that uniquely identifies a BSS (Blind Service Set).

The controller **130** provides seamless mobility functionality for hand-offs between access points while maintaining the same BSSID, in one embodiment. In further detail, a station can be handed-off from one access point to another access point by the controller **130** de-associating the former access point and associating the new access points. The hand-off can be substantially transparent to the affected station because although a different access point is responding to communications, the BSSID persists.

Accordingly, the full-featured virtual port functionality with seamless mobility is enabled with BSSIDs that are both uniquely-assigned across all devices on the system **100** and persistent through hand-offs between the access points **120**A-N.

Algorithms to initially set parameters, to adjust the parameters, and to determine which access point is assigned to a particular station are all implementation-specific. In one example, the controller **130** discriminates parameters for particular users or groups of users (e.g., CEO, network administrator, authenticated user, guest, suspicious station, etc.), for particular types of computers (e.g., critical data server, rarely-accessed archival data storage, etc.), for particular types of traffic (streaming high-definition (HD) video, low bandwidth video, secure data, voice, best effort, background, etc.), and the like. Initial default parameters can be uniform and adjusted once the access point **120** gathers more information about a particular station such as traffic patterns. For instance, over use by a particular station can be controlled. More detailed embodiments of the controller **130** are set forth below with regards to FIG. **3**.

The access points **120**A-N include one or more individual access points implemented in any of the computing devices discussed herein (e.g., see FIG. **9**). For example, the access points **120**A-C can be an AP **110** or AP **433** (modified as discussed herein) by Meru Networks of Sunnyvale, Calif. A network administrator can strategically place the access points **120**A-N for optimal coverage area over a locale. The access points **120**A-N can, in turn, be connected to a wired hub, switch or router connected to the network **199**. In another embodiment, the functionality is incorporated into a switch or router.

In operation, the access points **120**A-N can maintain a local look-up table with an local view (e.g., access point-wide) of connected stations and other devices. The local look-up table stores BSSIDs assigned by the controller **130**. All or some of the BSSIDs can be uniquely-assigned and/or persistent BSSIDs. For virtual port and seamless mobility functionality, the access points **120**A-N can receive real-time associations and de-associations for the stations **110**A-N. Periodic beacons are transmitted by the access points **120**A-N to advertise availability and maintain connections. As such, the access points **120**A-N can respond to messages addressed to BSSIDs for the local look-up table and ignore messages addressed to other BSSIDs.

In one embodiment, the access points **120**A-N aggregate multiple BSSIDs into a single beacon. For example, protocols such as IEEE 802.11 kvr inherently support a multiple BSSID element in beacon and probe response. In some cases, aggregated BSSIDs belong to the same class, channel and antennae connector. Optionally, BSSID aggregation can be toggled on and off automatically based on a number of connected stations. Example frame structures are shown in FIG. **7**. More detailed embodiments of the access points **120**A-N are discussed below with respect to FIG. **4**.

The stations **110**A-N can be, for example, a personal computer, a laptop computer, a tablet computer, a smart phone, a mobile computing device, a server, a cloud-based device, a virtual device, an Internet appliance, or the like (e.g., see FIG. **9**). No special client is needed for this particular technique, although other aspects of the network may require downloads to the stations **110**A-N. The stations **110**A-N connect to the access points **120**A-N for access to, for example, a LAN or external networks. In one embodiment, a child plays video games on a wireless game console as a station in communication with streaming applications from a cloud-based application server. In a different embodiment, an employee authenticates from a laptop as a station over a secure channel of an enterprise network to modify remotely stored secure files. In another embodiment, a guest at a coffee shop uses a smart phone as a station to access a public hot spot to watch stream videos stored on a public web site.

Using the current technique, the stations **110**A-N receive beacons from one or more of the access points **120**A-N with multiple BSSIDs, including a persistent, uniquely-assigned BSSD used for configuration. Each of the stations **110**A-N interacts with a corresponding one of the access points **120**A-N under parameters associated a uniquely-assigned, persistent BSSID to which a station is configured.

FIGS. **2**A-C are diagrams illustrating reconfigurations of stations responsive to changes in conditions, according to some embodiments. Changes can be initiated by the controller **130** or the access points **120**A-N. The controller **130** has a network-wide view **200**C and the access points **120**A, **120**B and **120**N, have access point-wide views **201**, **202** and **203**, respectfully. The access point-wide views **201**, **202**, **203** can be defined by a wireless radio range of respective access points while the network-wide view is not so constrained due to a wired back-end. In operation, the station **110**A is within range of both access points **120**A and **120**N which may both report to the controller **130** that frames from the station **110**A have been received. The controller **130** uses an internal algorithm, with factors such as shortest flight time, to select the access point **120**A for servicing the station **110**A. Various conditions discussed herein can affect the decision.

At a later point in time, in FIG. **2**B, station **110**B has changed locations such that it is within range of the access point **120**A. The controller **130**, having a network-wide view **200** is able to identify the station **110**B at its new location and continue communication with the same BSSID assigned when connected to the access point **120**B, in a manner that is transparent to the station **110**B. Separately, and in response to the change in conditions caused by the station **110**B also being serviced by the access point **120**A, the controller **130** can reduce uplink configurations specifically for the station **110**A. The two updates to the access point **120**A can be affected by updating the global look-up table and sending changes to the access point **120**A.

At an even later point in time, in FIG. **2**C, the station **110**A has been reassigned to access point **120**N by the controller **130**. The flight time for data packets may still be less when sent to the access point **110**A, but other conditions have triggered the change. For example, a controller can redistribute the processing load from the access point **120**A to be partially absorbed by the access point **120**N. Moreover, the access point **120**N can handle the larger demand for uplink access demand by the station **110**A, resulting in an update in uplink configurations that increases the amount of uplink access allowed by the controller **130**. Countless additional scenarios are possible.

FIG. **3** is a more detailed block diagram illustrating a controller **130** of the system **100**, according to one embodiment. The controller **130** comprises an access point manager **310**, a station manager **320**, a network module **330**, and radio array **340**. The components can be implemented in hardware, software, or a combination of both.

The access point manager **310** logs and directs activities of access points under the controller **130**, such as BSSID assignments. In one embodiment, the access point manager **310** determines global conditions that affect BSSID assignments and parameters. The station manager **320** can store and update a global look-up table that associates stations with BSSIDs, and designates some or all as virtual port BSSIDs. The network module **330** can manage higher layer network communications with external network resources. The radio array **340** represents radio frequency (RF) hardware necessary for physical channel access.

FIG. **4** is a more detailed block diagram illustrating an access point **120** of the system **100**, according to one embodiment. The access point **120** comprises a beacon generation module **410**, a station manager **420**, a network module **430**, and a radio array **440**. The components can be implemented in hardware, software, or a combination of both.

The beacon generation module **410** generates beacons with aggregated BSSIDs, including virtual port BSSIDs. The station manager **420** stores globally and/or locally-influenced parameter values, policy-based parameter values, manually configured parameter values, or the like. Parameter values for historical and predictive stations can be stored in one option. The network module **430** and the radio array **440** can all be similar to the components of the controller **130** of FIG. **3**.

FIG. **5** is a sequence diagram illustrating interactions **500** between components of the system **100** of FIG. **1**, according to one embodiment. The interactions represent wireless communications in accordance with IEEE 802.11 standards, and the like. An example of an 802.11 network packet configured for implementation herein is illustrated in FIG. **8**. In between the interactions, methods performed within the components of FIG. **5** are illustrated in FIGS. **6** and **7**. The illustrated interactions **500** are not intended to be limiting. As such, the interactions **510** to **570** can be a portion of steps from a longer process.

Initially, at interaction **510**, the station **110** a probe request to the access point **120**, which in turn reports the request to the controller **130**, at interaction **520**. At interaction **530**, the controller **130** configures a particular one of the access point **120** to respond to the probe request at interaction **540** by sending a BSSID. The order of interactions herein can be varied, for example, interaction **530** can occur prior to interaction **510** and without the need for interaction **520**.

At a later point in time, at interaction **550**, one or more of the access points **120**A-N send the controller **130** local condition information. In response, at interaction **560**, the controller **130** transfer or updates parameters for the station **110** by sending information to relevant ones of the access points **120**A-N, that implement the change to the station in interaction **570** in beacons.

Methods for Providing Per Station Control of Multiple Stations Across Multiple Access Points (FIG. **6-8**)

FIG. **6** is a flow diagram illustrating a method **600** for providing per station control of multiple stations across multiple access points from a controller (e.g., the controller **130** of FIG. **1**), according to one embodiment.

The method **600** starts at step **610**, when uniquely-assigned and/or persistent BSSIDs and access point assignments with parameters for stations are determined. A type of BSSID can be conditioned on whether virtual port is manually or automatically enabled for a system, for a particular station, and/or for a particular station. The data can be stored in a global look-up table, or alternatively, an external database or fast response cache.

At step **620**, access points are configured with local look-up table data. The local look-up data can be limited to include stations that are connected, attempting to connect, were formerly connected, or are predicted to connect, to a particular access point. In other embodiments, access points retrieve or receive information as needed from a controller or other resource.

At step **630**, responsive to a change in conditions, a controller evaluates whether AP assignments and/or parameters should be updated. As discussed above, global information relating to network load, predicted loads, bandwidth usage, and more can be taken into consideration for updates. Consequently, in an embodiment, changes to one station can occur in response to changes in another station connected to a different access point across the network. The process continues **650** until ended **695** by, for example, a reboot, shut down, or disabling of virtual port.

FIG. **7** is a flow diagram illustrating a method **700** for providing per station control of multiple stations across multiple access points from an access point (e.g., the access points **120**A-N of FIG. **1**), according to one embodiment.

The method **700** starts **705**, at step **710**, when a beacon frame with aggregated BSSIDs and parameters is generated. Some or all of the BSSIDs are uniquely-assigned and/or persistent BSSIDs. Some BSSIDs may be supported by a different access point. BSSIDs preferably belong to a same class, channel and antenna connector. One example of a Multiple BSSID element **800** for beacon or probe response frames under IEEE 802.11 kvr is illustrated in FIG. **8**. Element ID field **802** identifies the multiple BSSID value. Length **804** has a value of 1 plus the length of the extensions in units of octets. MaxBSSID Indicator **806** indicates the maximum number of BSSIDs supported, although an access point can operate with fewer. A value of n translates to 2^n stations supported, so a value of 3 indicates that 8 BSSIs are supported. The value can be manually configured by a network administrator or automatically, for example, by a controller-based or access-point based algorithm. Optional Sub-elements **808** contains zero or more sub-elements. Each of fields **802**, **804** and **806** is one octet in size except the Optional Sub-elements **808** which can be of variable size. Other formats are possible.

At step **720**, beacon frames are broadcast to stations. Beacon frames advertise a presence of an access point and keeps connected stations synchronized with parameter information. The beacon frames include the aggregated BSSIDs. Each station can retrieve updated information associated with its BSSID from beacons.

At step **730**, connected stations are serviced. Data is sent to and received from stations according to individualized parameters set for a station, such as uplink parameters, and other custom parameters. The process ends **795**.

According to some IEEE 802.11 standards, EDCA provides a probabilistic-based, quality of service by grouping traffic into four access classes: voice, video, beset effort and background in respective order of priority. Frames are passed to the MAC layer from upper protocol layers with a priority value set between 0 and 7, which are used for mapping into one of the four access classes. Each class can have a separate transmission queue and medium access parameters. The values of AIFS **752**, CW **754** and others ensure priority to the medium.

Generic Computing Device (FIG. **9**)

FIG. **9** is a block diagram illustrating an exemplary computing device **900** for use in the system **100** of FIG. **1**, according to one embodiment. The computing device **900** is an exemplary device that is implementable for each of the components of the system **100**, including the stations **110**A-N, the access points **120**A-N, and the controller **130**. The computing device **900** can be a mobile computing device, a laptop device, a smartphone, a tablet device, a phablet device, a video game console, a personal computing device, a stationary computing device, a server blade, an Internet appliance, a virtual computing device, a distributed computing device, a cloud-based computing device, or any appropriate processor-driven device.

The computing device **900**, of the present embodiment, includes a memory **910**, a processor **920**, a storage device **930**, and an I/O port **940**. Each of the components is coupled for electronic communication via a bus **999**. Communication can be digital and/or analog, and use any suitable protocol.

The memory **910** further comprises network applications **912** and an operating system **914**. The network applications **912** can include the modules of controllers or access points as illustrated in FIGS. **3** and **4**. Other network applications **912** can include a web browser, a mobile application, an application that uses networking, a remote application executing locally, a network protocol application, a network management application, a network routing application, or the like.

The operating system **914** can be one of the Microsoft Windows® family of operating systems (e.g., Windows 95, 98, Me, Windows NT, Windows 2000, Windows XP, Windows XP x64 Edition, Windows Vista, Windows CE, Windows Mobile, Windows 7 or Windows 8), Linux, HP-UX, UNIX, Sun OS, Solaris, Mac OS X, Alpha OS, AIX, IRIX32, or IRIX64. Other operating systems may be used. Microsoft Windows is a trademark of Microsoft Corporation.

The processor **920** can be a network processor (e.g., optimized for IEEE 802.11), a general purpose processor, an application-specific integrated circuit (ASIC), a field programmable gate array (FPGA), a reduced instruction set controller (RISC) processor, an integrated circuit, or the like. Qualcomm Atheros, Broadcom Corporation, and Marvell

Semiconductors manufacture processors that are optimized for IEEE 802.11 devices. The processor **920** can be single core, multiple core, or include more than one processing elements. The processor **920** can be disposed on silicon or any other suitable material. The processor **920** can receive and execute instructions and data stored in the memory **910** or the storage device **930**.

The storage device **930** can be any non-volatile type of storage such as a magnetic disc, electrically erasable programmable read-only memory (EEPROM), Flash, or the like. The storage device **930** stores code and data for applications.

The I/O port **940** further comprises a user interface **942** and a network interface **944**. The user interface **942** can output to a display device and receive input from, for example, a keyboard. The network interface **944** (e.g. RF antennae) connects to a medium such as Ethernet or Wi-Fi for data input and output.

Many of the functionalities described herein can be implemented with computer software, computer hardware, or a combination.

Computer software products (e.g., non-transitory computer products storing source code) may be written in any of various suitable programming languages, such as C, C++, C#, Oracle® Java, JavaScript, PHP, Python, Perl, Ruby, AJAX, and Adobe® Flash®. The computer software product may be an independent application with data input and data display modules. Alternatively, the computer software products may be classes that are instantiated as distributed objects. The computer software products may also be component software such as Java Beans (from Sun Microsystems) or Enterprise Java Beans (EJB from Sun Microsystems).

Furthermore, the computer that is running the previously mentioned computer software may be connected to a network and may interface to other computers using this network. The network may be on an intranet or the Internet, among others. The network may be a wired network (e.g., using copper), telephone network, packet network, an optical network (e.g., using optical fiber), or a wireless network, or any combination of these. For example, data and other information may be passed between the computer and components (or steps) of a system of the invention using a wireless network using a protocol such as Wi-Fi (IEEE standards 802.11, 802.11a, 802.11b, 802.11e, 802.11g, 802.11i, 802.11n, and 802.11 ac, just to name a few examples). For example, signals from a computer may be transferred, at least in part, wirelessly to components or other computers.

In an embodiment, with a Web browser executing on a computer workstation system, a user accesses a system on the World Wide Web (WWW) through a network such as the Internet. The Web browser is used to download web pages or other content in various formats including HTML, XML, text, PDF, and postscript, and may be used to upload information to other parts of the system. The Web browser may use uniform resource identifiers (URLs) to identify resources on the Web and hypertext transfer protocol (HTTP) in transferring files on the Web.

This description of the invention has been presented for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form described, and many modifications and variations are possible in light of the teaching above. The embodiments were chosen and described in order to best explain the principles of the invention and its practical applications. This description will enable others skilled in the art to best utilize and practice the invention in various embodiments and with various modifications as are suited to a particular use. The scope of the invention is defined by the following claims.

We claim:

**1**. A computer-implemented method in an access point of a plurality of access points managed by a controller of a wireless communication network, the method for providing seamless mobility to the plurality of stations in a while maintaining per-station control each station in the plurality of stations, the method comprising:

storing a look-up table that assigns one or more station connected to the access point and at least one communication parameter to each of a plurality of persistent, uniquely-assigned BSSIDs (Basic Service Set Identifiers), the access point responding to messages addressed one of the plurality of persistent, uniquely-assigned BSSIDs and ignoring messages addressed to other BSSIDs, wherein uniqueness of the BSSID allows individual control over each of the one or more stations and persistence of the BSSID allows the controller to maintain individual control over each of the one or more stations after moving to a second access point of the plurality of access points;

generating a frame comprising the plurality of BSSIDs corresponding to each of the one or more connected stations aggregated into the frame;

transmitting the frame to the one or more connected stations;

responsive to a station of the one or more of stations being handed-off to a different access point, deleting a uniquely-assigned BSSID corresponding to the station from the look-up table; and

toggling the access point from a first mode to a second mode responsive to surpassing a threshold number of connected stations, wherein the first mode enables aggregated BSSIDs in the frames when generated and the second mode disables aggregated BSSIDs in the frames when generated.

**2**. The method of claim **1**, wherein the frame comprises a beacon broadcast to the plurality of stations.

**3**. The method of claim **1**, wherein the frame comprises a probe response transmitted to a station that sent a probe.

**4**. The method of claim **1**, wherein the frame is compliant with one or more of the IEEE 802.11k protocol, the IEEE 802.11v protocol, and the IEEE 802.11r protocol.

**5**. The method of claim **1**, wherein generating the frame comprises:

generating the frame to comprise BSSIDs that are persistent and uniquely-assigned, and BSSIDs that are not persistent and uniquely-assigned.

**6**. The method of claim **1**, generating the frame comprises:

generating the frame to comprise BSSIDs that are serviced by a different access point.

**7**. The method of claim **1**, wherein generating the frame comprises:

generating the frame to include at least one communication parameter corresponding to each BSSID for each connected station.

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

toggling the access point from a first mode to a second mode, wherein the first mode enables virtual port functionality and the second mode disables virtual port functionality.

**9**. The method of claim **1**, wherein the uniquely-assigned BSSID from a plurality of persistent, uniquely-assigned BSSIDs to associate with the mobile station based on one or more communication parameters of the uniquely-assigned BSSID selected from the group of:

access control parameters, backoff or retry parameters, channel selection parameters, QoS (Quality of Service) parameters, and transit power parameters.

**10**. A computer-implemented method in a controller managing a plurality of access points of a wireless communication network, the method for providing seamless mobility to the plurality of stations in a while maintaining per-station control each station in the plurality of stations, the method comprising:

storing a look-up table that assigns one or more station connected to the plurality of access points and at least one communication parameter to each of a plurality of persistent, uniquely-assigned BSSIDs (Basic Service Set Identifiers), the plurality of access points responding to messages addressed one of the plurality of persistent, uniquely-assigned BSSIDs and ignoring messages addressed to other BSSIDs, wherein uniqueness of the BSSID allows individual control over each of the one or more stations and persistence of the BSSID allows the controller to maintain individual control over each of the one or more stations after moving to a second access point of the plurality of access points; and

transmitting at least a portion of the look-up table to one of the plurality of access points to allow generation of a frame comprising the plurality of BSSIDs corresponding to each of the one or more connected stations aggregated into the frame,

wherein at least one of the plurality of access points toggles from a first mode to a second mode responsive to surpassing a threshold number of connected stations, wherein the first mode enables aggregated BSSIDs in the frames when generated and the second mode disables aggregated BSSIDs in the frames when generated.

**11**. The method of claim **10**, wherein the frame comprises a beacon broadcast to the plurality of stations.

**12**. The method of claim **10**, wherein the frame comprises a probe response transmitted to a station that sent a probe.

**13**. The method of claim **10**, wherein the frame is compliant with one or more of the IEEE 802.11k protocol, the IEEE 802.11v protocol, and the IEEE 802.11r protocol.

**14**. The method of claim **10**, wherein generation of the frame comprises:

generating the frame to comprise BSSIDs that are persistent and uniquely-assigned, and BSSIDs that are not persistent and uniquely-assigned.

**15**. The method of claim **10**, generation of the frame comprises:

generating the frame to comprise BSSIDs that are serviced by a different access point.

**16**. The method of claim **10**, wherein generating the frame comprises:

generating the frame to include at least one communication parameter corresponding to each BSSID for each connected station.

**17**. The method of claim **10**, further comprising:

receiving updated information from various points around the wireless communication network;

compiling an updated global condition from the updated information; and

updating a parameter for at least one of the plurality of persistent, uniquely-assigned BSSIDs of one or the plurality of stations responsive to the updated global condition, wherein the global condition concerns updated information at an access point other than the access point serving the one of the plurality of stations.

**18**. The method of claim **10**, wherein the uniquely-assigned BSSID from a plurality of persistent, uniquely-assigned BSSIDs to associate with the mobile station based on one or more communication parameters of the uniquely-assigned BSSID selected from the group of:

access control parameters, backoff or retry parameters, channel selection parameters, QoS (Quality of Service) parameters, and transit power parameters.

**19**. An access point of a plurality of access points managed by a controller of a wireless communication network, to provide seamless mobility to the plurality of stations in a while maintaining per-station control each station in the plurality of stations, the access point comprising:

a processor; and

a memory, comprising:

a first module to store a look-up table that assigns one or more stations connected to the access point and at least one communication parameter to each of a plurality of persistent, uniquely-assigned BSSIDs (Basic Service Set Identifiers), the access point responding to messages addressed one of the plurality of persistent, uniquely-assigned BSSIDs and ignoring messages addressed to other BSSIDs, wherein uniqueness of the BSSID allows individual control over each of the one or more stations and persistence of the BSSID allows the controller to maintain individual control over each of the one or more stations after moving to a second access point of the plurality of access points;

a second module to generate a frame comprising the plurality of BSSIDs corresponding to each of the one or more connected stations;

a third module to transmit the frame to the one or more stations; and

a fourth module to, responsive to a station of the one or more stations being handed-off to a different access point, delete a uniquely-assigned BSSID corresponding to the station from the look-up table,

wherein at least one of the plurality of access points toggles from a first mode to a second mode responsive to surpassing a threshold number of connected stations, wherein the first mode enables aggregated BSSIDs in the frames when generated and the second mode disables.

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