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EFFICIENT WIRELESS NETWORK SCANS FOR COMPUTING DEVICES

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ABSTRACT

Computing devices increasingly provide wireless network connections rather than wired network connections. In order to support the wireless network connections, the computing devices scan for wireless access points (WAPs) in a number of different ways that may avoid needless consumption of power. For example, the computing devices may support periodic preferred network offload (PNO) scans that enable low-power wireless network scans for so-called “preferred networks” while the primary processor is in a low power (or, in other words, stand-by state). The computing devices may also separately enable roaming scans for switching between WAPs associated with the same wireless network (e.g., identified by the same service set identifier – SSID). When roaming scans do not return a WAP that meets various criteria (in terms of, e.g., signal strength), the computing device may perform a full scan in order to identify potential WAP candidates. Rather than periodically perform PNO scans according to a set schedule and regardless of the criteria, the computing devices may only perform PNO and/or roaming scans in certain instances (e.g., when the signal strength is low, the computing device is in motion, etc.). Moreover, rather than separately implement each of the various scans, the computing devices may reuse information obtained from one scan (such as a roaming scan or full scan) for another scan (such as the roaming scan or PNO scan). As such, the computing device may support more efficient wireless network scans (e.g., in terms of power consumed, number of scans, etc.).

DESCRIPTION

Techniques are described that enable a computing device 10 to more efficiently conduct wireless network scans when establishing a wireless connection with one or more networks 20A-20N ("networks 20"). Computing device 10 may include any type of computing device capable of exchanging data with another computing device over one or more of networks 20. Examples of computing device 10 include a smart phone, a desktop computer, a laptop computer, a tablet computer, a smart watch, a smart camera, a smart speaker (with or without a display), smart glasses, a smart thermostat, a smart television (including an add-on device to enable smart television experiences), a server, a vehicle infotainment system, or any other type of computing device or system capable of interfacing with networks 20.

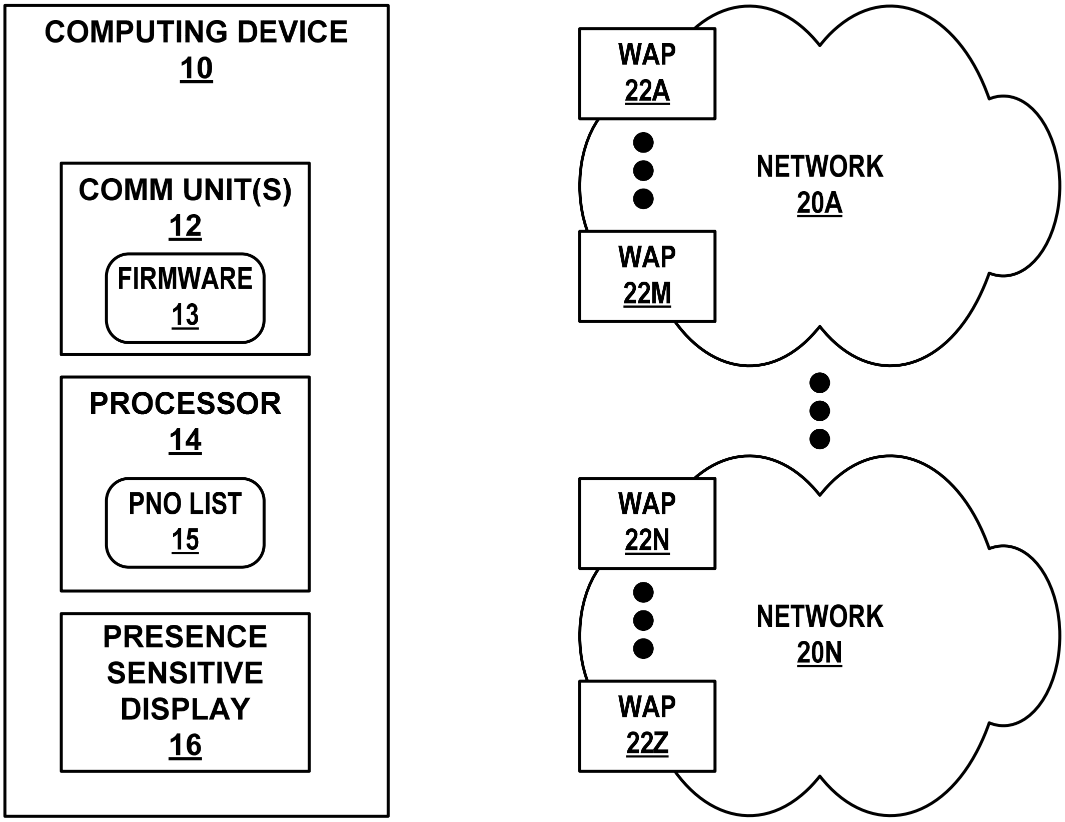

FIG. 1

As shown in the example of FIG. 1, computing device 10 may include communication (comm) unit 12. Examples of communication unit 12 include a cellular radio, a wireless network radio (e.g., WIFI™, BLUETOOTH ®, etc.), a network interface card (e.g. such as an Ethernet card), a cable modem, or any other type of device that can send and/or receive information. For example, communication unit 12 may communicate with other computing devices via networks 20.

Computing device 10 also includes a processor 14. Although a single processor 14 is shown, computing device 10 may include multiple processors 14. Examples of processor 14 include, but are not limited to, digital signal processors (DSPs), general purpose microprocessors (where multiple processor may be housed in the same package - whereupon each processor may represent a different processing core - or in separate packages), application specific integrated circuits (ASICs), field programmable logic arrays (FPGAs), or other equivalent integrated or discrete logic circuitry.

Computing device 10 further includes a presence-sensitive display (PSD) 16. PSD 16 may function as a respective input and/or output device for computing device 10. PSD 16 may be implemented using various technologies. For instance, PSD 16 may function as an input device using a presence-sensitive input screen, such as a resistive touchscreen, a surface acoustic wave touchscreen, a capacitive touchscreen, a projective capacitance touchscreen, a pressure sensitive screen, an acoustic pulse recognition touchscreen, or another presence-sensitive display technology. PSD 16 may also function as an output (e.g., display) device using a display device, such as a liquid crystal display (LCD), a dot matrix display, a light emitting diode (LED) display, an organic light-emitting diode (OLED) display, e-ink, or similar monochrome or color display capable of outputting visible information to a user of computing device 10.

Networks 20 may represent any type of network, such as a public network (including the "Internet"), a private network, an ad hoc network, a personal area network (PAN), or any other type of network capable of interfacing with computing device 10. Networks 20 may include one or more devices configured to route and/or switch data units (which may refer generally to discrete portions of data, where examples of data units include packets, cells, frames, etc.) between one another to enable communication of data units between a sending computing device and an identified recipient computing device. Networks 20 may include an Internet protocol (IP) network that communicates in accordance with an IP, which is an example of a layer three (L3) network protocol (where L3 may also be referred to as a network layer) as defined according to the Open Systems Interconnection (OSI) model. In IP networks, routers or other L3 devices may route data units referred to as "packets" via routes through the IP network from a sending or transmitting computing device to a recipient or destination computing device.

Network 20A may include wireless access points (WAPs) 22A-22M, while network 20N may include WAPs 22N-22Z. WAPs 22A-22Z ("WAPs 22") may represent a network device configured to support wireless access to each of networks 20A and 20N. Although multiple WAPs 22 are shown in each of networks 20A and 20N, networks 20A and/or 20N may include a single WAP. WAPs 22 may operate in accordance with WIFI™ series of standards, such as the Institute of Electrical and Electronics Engineers (IEEE) 802 protocol family. Although primarily described herein with respect to WAPs 22 that operate to facilitate wireless access to networks 20 via the IEEE 802 protocol family, the techniques may be performed with respect to other types of wireless communication, such as cellular, PANs, etc.

In instances where multiple WAPs 22 provide access to a respective one of networks 20, the multiple WAPs 22 for the respective one of networks 20 may be configured with the same name (which may be referred to as a service set identifier – SSID, but different basic SSIDs – BSSID) and operate collectively to provide access to the respective one of networks 20. However, sharing the same SSID is not a requirement for providing wireless access to the respective one of networks 20 using multiple WAPs 22, and the WAPs 22 may be configured to present different names for accessing the respective one of networks 20.

For mobile computing devices, which computing device 10 is assumed to represent for purposes of explanation, computing device 10 may move within wireless coverage provided by WAPs 22. As the location of computing device 10 changes, signal strength of wireless communications may change, particularly as the computing device 10 moves away from or toward WAPs 22 physical location. As such, communication unit 12 may routinely perform various types of scans for WAPs 22 to identify a best available one of WAPs 22 (in terms of signal strength, latency, bandwidth, or various other criteria).

Communication unit 12 may select one of the scans to perform based on a current state of computing device 10. When in use, as defined in some examples by whether or not presence sensitive display 16 is activated or otherwise powered on (with presence sensitive display 16 being active indicating that computing device 10 is in use), computing device 10 may perform either a roaming scan or a full scan. When communication unit 12 is already connected to one of WAPs 22, communication unit 12 may execute firmware 13, which may configure communication unit 12 to periodically perform the roaming scan.

A roaming scan refers to a scan for the same SSID as the one of WAPs to which communication unit 12 is already connected, but for a different BSSID, thereby scanning one or more channels (but possibly less than all of the channels) for a single SSID. As such, the roaming scan may apply in situations in which multiple WAPs 22 are configured to provide access to the same one of networks 20 using the same SSID but different BSSIDs. When the roaming scan returns results that differ from the SSID/BSSID combination of the one of WAPs 22 to which communication unit 12 is currently connected, firmware 13 provides the results to processor 14, which evaluates the results to identify the best available one of WAPs 22, switching to a different one of WAPs 22 when the signal strength, latency, bandwidth or other criteria (including user preference) indicates that a better wireless connection would be provided by way of the different one of WAPs 22.

When not connected to one of the WAPs 22, processor 14 may interface with communication unit 12 to perform a full scan. The full scan refers to a scan of channels across all SSIDs. The full scan may return a list of SSIDs to processor 14, whereupon processor 14 may perform a similar evaluation as that described above with respect to the roaming scan to potentially establish a wireless communication session with one of WAPs 22. The full scan may consume relatively more power than a roaming scan considering that all channels across all SSIDs are scanned and any results are processed by the host processor, which is represented by processor 14. As firmware 13 performs the roaming scan and only notifies the host processor (e.g., potentially without passing the actual scan results) should the scan result in one or more different ones of WAPs 22 (and firmware may already be switched to a different WAP), the roaming scan may further reduce power consumption compared to the full scan.

When not in use, as defined in some examples by presence sensitive display 16 being inactive, computing device 10 may perform the above described roaming scan and/or a preferred network offload (PNO) scan. Communication unit 12 may execute firmware 13 to perform the PNO scan. Depending on whether communication unit 12 is currently connected to one of WAPs 22, firmware 13 may perform a connected PNO scan or a disconnected PNO scan.

The connected PNO scan refers to a scan when communication unit 12 is already connected to one of WAPs 22, and scans across channels for SSIDs identified by a preferred network list (which may be defined by a user, a vendor, a manufacturer, or some combination of the foregoing). The preferred network list is shown as preferred network (PN) list 15 in the example of FIG. 1. In this respect, the connected PNO scan may provide a larger scan than the roaming scan, but again, as the connected PNO scan is implemented by firmware 13, the connected PNO scan may consume less power than a full scan. The connected PNO scan may return a list of SSIDs to processor 14 that match SSIDs specified in the PN list 15, whereupon processor 14 may perform a similar evaluation as that described above with respect to the roaming scan to potentially establish a new wireless communication session with one of WAPs 22.

The disconnected PNO scan refers to a scan when communication unit 12 is not already connected to one of WAPs 22. The disconnected PNO scan is the same as that discussed above with respect to the connected PNO, but may occur with greater or less frequency than the connected PNO scan and according to different conditions (e.g., the frequency may increase at different time thresholds than the connected PNO scan when moving, stationary, driving, etc. to provide a few examples).

Rather than periodically performing PNO scans according to a set schedule and regardless of the criteria, computing device 10 may only perform PNO and/or roaming scans in certain instances (e.g., when the signal strength is low, the computing device is in motion, etc.). Moreover, rather than separately implement each of the various scans, computing device 10 may reuse information obtained from one scan (such as a full scan or a roaming scan) for another scan (such as the roaming scan and/or the PNO scan). As such, the computing device may support more efficient wireless network scans (e.g., in terms of power consumed, number of scans, etc.).

In operation, firmware 13 may perform the connected PNO scan when signal strength (such as a signal strength indicated by a received signal strength indication – RSSI) is below a threshold signal strength (potentially defining a low signal strength). Firmware 13 may therefore refrain from performing the connected PNO scan when the RSSI of the existing wireless connection is equal to or above the threshold signal strength, thereby further reducing power consumption.

In some instances, processor 14 may schedule the connected PNO scan, defining a schedule by which firmware 13 is to perform the connected PNO scan. The schedule may include PN list 15 along with a minimum triggering threshold for current link quality (which is one example, although other metrics, such as bandwidth, dropped packets, latency, etc., may be used in addition or as an alternative to current link quality, such as RSSI). The schedule may indicate that firmware 13 is to perform the scan only when presence sensitive display 16 is inactive or regardless of whether presence sensitive display is active or not.

When RSSI is below the threshold signal strength (or possibly a different threshold signal strength indicative of a low signal strength), firmware 13 may perform a roaming scan. Should the roaming scan fail to identify a different one of WAPs 22, firmware 13 may perform a full scan but, rather than immediately provide any resulting SSIDs to processor 14, utilize the full scan results for comparison to the SSIDs specified in PN list 15. When the connected PNO scan is enabled, firmware 13 may perform the roaming scan or the full scan, but an additional connected PNO scan is not really needed considering that firmware 13 may apply PN list 15 to the full scan results. Firmware 13 may identify any preferred networks in the full scan results and interface with processor 14 to establish the wireless communication session with the one of WAPs 22 supporting the preferred one of networks 20.

In addition, firmware 13 may, when RSSI is below a roaming signal strength threshold (which may indicate a low signal strength), perform a roaming scan according to a fixed minimum time interval (e.g., once every 10 seconds). However, firmware 13 may determine whether computing device 10 is relatively stationary (via, as one example, global navigation satellite system – GNSS – coordinates being within some distance threshold of each other over time). When firmware 13 determines that the device is stationary, firmware 13 may increase the scan interval to reduce latency and power consumption. In some examples, processor 14 may provide the distance threshold and/or intervals to firmware 13.

As noted above, when the roaming scan fails, firmware 13 may perform a full scan. However, rather than provide the full scan results to processor 14, firmware 13 may first determine a current link quality associated with the current connection to one of WAPs 22 (e.g., RSSI of current WAP, and possibly transmission and/or receive speeds). When the current link quality is below a triggering threshold, firmware 13 may parse the full scan results against PN list 15 (which may define a network profile for each preferred network) and only return the scan results to processor 14 if there is a match against PN list 15 and the link quality exceeds the current link quality (or possibly a minimum requirement).

It is noted that the techniques of this disclosure may be combined with any other suitable technique or combination of techniques. As an example, the techniques of this disclosure may be combined with the techniques described in U.S. Patent Application Publication No. 2015/0341850A1, entitled “DYNAMIC AND ADAPTIVE CHANNEL SCANNING,” and/or PCT Application Publication No. WO 2015/148460A1, entitled “INITIAL SCAN

ENHANCEMENTS BASED ON A NEIGHBOR REPORT GENERATED BY AN ACCESS POINT FROM NEIGHBOR INFORMATION REPORTED BY ITS ASSOCIATED STATIONS."