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Optimize Wireless Local Area Networks for Voice and Video Call

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Abstract:

When a user is making a voice or video call on a user device over a wireless local area network (WLAN), the characteristics of a WLAN call can cause high power consumption on the user device, latency, and poor transmission which leads to an unfavorable quality of service. The user device can optimize the WLAN for voice and video calls by detecting timing information of a WLAN call and then optimizing the device's software and hardware during the WLAN call. The device may use a target wakeup time (TWT) protocol to reduce power consumption. The device may reduce the number of antennas, the channel bandwidth, or the power mode of one or more radios to reduce power consumption. To reduce latency, the device may adjust power save parameters, scanning and roaming operations, and cap the number of retries to send packets. The device may improve transmission reliability by using a medium physical layer (PHY) rate and by enabling request to send/clear to send (RTS/CTS) when communicating with a WLAN access point (AP).

Keywords:

WLAN calling, voice over WLAN, VoIP, voice call, video call, wireless network, target wakeup time (TWT) protocol, power consumption, power save mode, battery loss, transmission reliability, antenna, channel bandwidth, power mode, DFS channel, periodic band scan, RSSI threshold values, Tx/Rx statistics thresholds, hysteresis threshold, Tx PHY rate, RTS/CTS, smartphone

Background:

Wireless local area networks (WLAN) (*e.g.*, Wi-Fi®) are commonly used for wireless network communications with a variety of electronic devices. WLAN has become popular in real-time multimedia communication such as voice and video calls. For example, WLAN is often used for a WLAN phone call, which could be a voice call and/or a video call. The call could be native voice/video call (also known as WLAN calling) or non-native voice/video call over mobile applications (voice-over WLAN, VoIP, video conference). Voice and video calls are sensitive to latency, which would cause callers to notice delay and echo on their calls. Voice and video calls have a required data bit rate that is low to medium (*e.g.*, tens of Kbps for voice to a few Mbps for video) and the data is typically sent over short packets. For example, the typical packet size of WLAN calling is a few hundred bytes per packet. However, although the packet size is small, these applications tend to have high packet rates. For example, WLAN calling may send tens to hundreds of packets every second.

Description:

To optimize WLAN calling, an electronic device completing the call, such as a smartphone, needs to detect timing information for a voice/video call and then optimize the underlying hardware and software.

To find and detect timing information, such as start and end time information of a WLAN voice/video call, the user device determines whether the voice/ video call is a native call. A native call is native to the device and is not a third-party application. A native call can transition from WLAN to cellular and back again without any interruption in service. If the call is a native call, a software module on the device, such as an IP multimedia subsystem (IMS) stack, can transmit the timing information of a voice or video call directly to a WLAN layer, the software supporting the device's wireless local area network (WLAN) capability.

A non-native voice/video call, such as those made by a third-party application are not controlled by the IMS stack. The timing information for these calls can be detected by the device or by an access point (AP) that creates a wireless local area network by:

- checking the type of service (ToS) field in IPv4 packets or traffic class bytes used for a voice/video call. For voice/video calls, ToS field or traffic class byte is typically marked as a high priority level.
- checking the access category (AC) type of packet queued in WLAN data path. For voice or video calls, the packets are normally queued in AC_VO or AC_VI, respectively.
- utilizing a dedicated operating system or framework level application interface (API) to indicate the presence of non-native voice/video calls. The API can be set by a non-native call application when WLAN call sessions start and end.
- detecting the traffic pattern of voice and video calls from network layer statistics. Detection can be done based on the unique traffic characteristics of small packet size and close-to-constant Transmit/Receive (Tx/Rx) packet rates.

Additionally, an AP for a native WLAN call may use the above methods to detect a WLAN call since the access point typically doesn't have information about IMS protocol.

After a voice/video call is detected, the device can take steps to optimize power usage during a WLAN call using software that utilizes target wakeup time (TWT) protocol. TWT protocol schedules packet transmission and receipt with an AP allowing the device to go into a power save mode (*e.g.*, doze mode or sleep mode) during unscheduled time slots. The device estimates the required TWT timing parameters based on latency, recent WLAN speed, and throughput required by the voice/video call. The device sends a TWT request (including target wake time, TWT wake interval, minimum TWT wake duration, etc.) to the AP. The access point decides TWT agreement parameters, including timing parameters and TWT group information based on the device's request, network load, and channel congestion. Multiple devices can schedule TWT agreements with the AP. The device's TWT agreement with the AP may be an individual TWT agreement or a broadcast TWT agreement. The device's WLAN can wake up during scheduled wake-up time slots and use power save mode during other unscheduled times. This results in significant power savings.

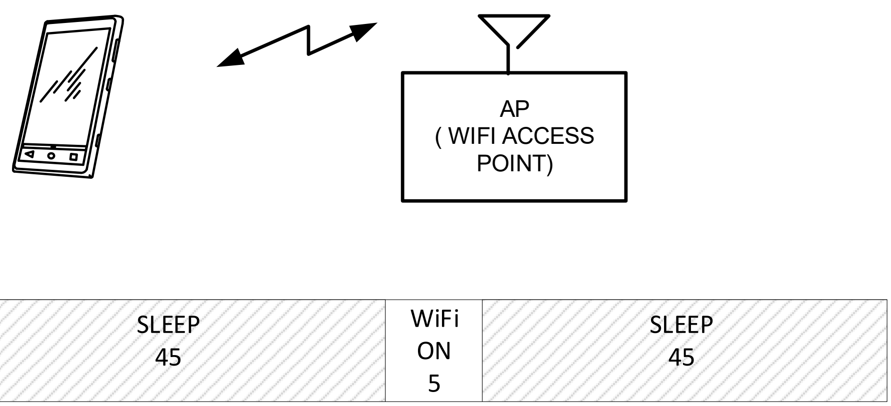
Consider an example implementation with a WLAN data link rate of 20Mz/MCS7/1S able to send and receive a total of 100 data packets per second (equivalent to 15 KB/s data rate). The device has a data packet size of 60 microseconds including 40 microseconds in the preamble and 20 microseconds of data. Additionally, the device must allow for spacing and other features according to the 802.11 family of standards including short interframe space (SIFS), DCF interframe space (DIFS), acknowledgment (ACK), and contention window (CWIN). Example values for these are illustrated in Fig. 1.

Data packet	SIFS	ACK	SIFS	DIFS	CWIN
60	16	28	16	34	45

Example data transmission stream
(in microseconds)

Figure 1

Given a rate of one hundred data packets per second, the sum of the above microseconds computes to requiring roughly twenty milliseconds of airtime every second. Using TWT protocol for this connection with a max TWT interval of fifty microseconds and a 50% overhead (due to TWT signaling and extra allocated time slot), the device would require two milliseconds TWT slot every fifty milliseconds to transmit to the AP. In addition to the two milliseconds TWT slot, the WLAN hardware on the device requires some time to power up/power down in each transmission. With an estimated power up/power downtime of three milliseconds, the total time that the WLAN is on is five milliseconds every fifty milliseconds, illustrated in Figure 2. This is a 90% power savings compared to typical WLAN calling in which the power save is normally disabled.



Example Device WiFi TWT schedule in milliseconds

Figure 2

After a voice/video call is detected, the device can take steps to optimize power usage during a WLAN call using hardware. Options for hardware power savings on the device during a voice/video call, illustrated in Figure 3, may be implemented individually or in combination.

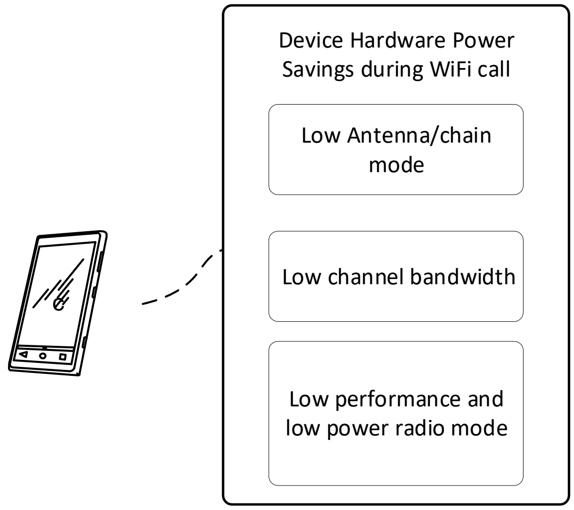


Figure 3

To implement low antenna/chain mode, the device can periodically check the network received signal strength indicator (RSSI) and other link layer metrics. When these metrics are above acceptable threshold values, the device can be configured to use low antenna/chain mode where the number of used antennas or chains is less than the maximum number of antennas or chains supported by hardware. At high and medium RSSI, when the device has a quality signal, there is minimal network throughput or performance improvement with higher data rates due to the fixed and large Physical Layer (PHY)/Media Access Control Layer (MAC) overhead in small packets. This overhead is independent of packet PHY rates. Using a few antennas/chains results in reduced power consumption.

Additionally or alternatively for hardware power savings, the device may use low channel bandwidth mode, which reduces the power consumption in both the digital and analog hardware blocks. As with above, there is little network throughput improvement with higher bandwidth modes when small packets are used due to PHY/MAC overhead. The PHY/MAC overhead is independent of channel or packet bandwidth. The device can use a signal such as an operation mode notification (OMN) frame or similar signaling method to notify the AP of the device's change of channel bandwidth mode.

In another embodiment of hardware power savings, the device can switch to low performance and low power radio mode for optimization. The low performance and low power radio mode can be implemented as a low power radio frequency (RF) synthesizer and/or low power transmit/receive (Tx/Rx) radios. There is minimal network throughput improvement with higher bandwidth modes when small packets are used due to a fixed and large PHY/MAC overhead. The device can use a signal such as an OMN frame or similar signaling method to notify the AP of the device's change of peak rate capability. After the AP receives an OMN frame from the device, the AP may not send frames with high Quadrature Amplitude Modulation (QAM) modulations to the device when low-performance radio is enabled on the device.

Voice/video calls are sensitive to latency, which gives a user an unsatisfactory call experience. Latency may be reduced by adjusting power save parameters, reducing scanning and roaming latency, and limiting excessive retries to send packets. Figure 4 illustrates an overview of addressing device latency during a WLAN call.

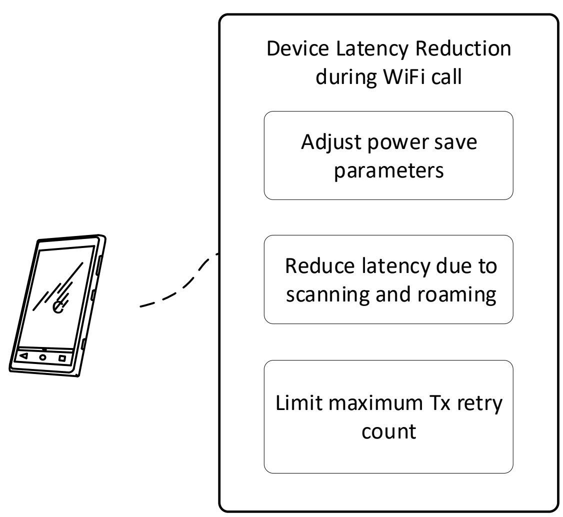


Figure 4

To reduce latency associated with power saving, WLAN software on a device can adjust power save related operation parameters. For example, the WLAN software can increase inactivity timeout time, which is used to detect the inactivity of a WLAN network layer and decide when the WLAN system goes to a power-saving mode such as doze mode. To further ensure low latency, the WLAN software may disable power save completely during WLAN voice or video calls.

There is latency due to scanning and roaming with WLAN when a device changes location because the WLAN client software and hardware on the device need to perform periodic band scan operations to look for a better AP. If a current connection quality drops below a certain threshold, the device may disconnect from the current AP and connect to the better AP, otherwise known as roaming. When the WLAN software on a device performs a scan operation during a voice/video WLAN call, there are several ways to reduce latency. The device can reduce the scan dwell time in non-dynamic frequency selection (DFS) channels. The device can avoid performing passive scans in DFS channels that implement a Wi-Fi® Protected Access (WPA) security profile (*e.g.*, WPA/WPA2/WPA3) on a personal network because DFS channels are typically not used in these networks.

When a device is making a voice/video call, the roaming parameters can be adjusted to reduce the frequency of WLAN roaming as long as the call quality is within acceptable values. Roaming parameters can comprise RSSI threshold values, Tx/Rx statistics thresholds, timing parameters, hysteresis threshold, and other link layer quality metrics. As an example, the roaming RSSI threshold can be reduced during WLAN calling as long as the Tx and Rx link speed are above minimum threshold values.

To further address call latency, the AP and a device can limit the maximum transmit (Tx) retry count. Latency can occur with too many retries to send packets. Latency is particularly large when the packets queued in the voice queue (AC_VO) and/or video queue (AC_VI) are above a certain threshold.

To improve transmission reliability, an AP and a device making a WLAN voice/video call can limit the transmitter physical layer (Tx PHY) rate to a medium value. There is a minimal benefit to using high PHY rates with WLAN calls due to calling requiring low to medium data rates using short packets, as discussed previously. Additionally or alternatively, the AP and the device can enable Request to Send/Clear to Send (RTS/CTS) before a data frame when the WLAN channel is congested. The device can determine whether the AP is idle or not by monitoring the channel utilization factor based on various channel clear assessment (CCA) indication signals.

As WLAN voice and video calling become more popular, there is a need to optimize hardware and software on the device, to create a positive user experience. A device or AP detects timing information for a WLAN call and then optimizes the hardware and software on the device to reduce power consumption, reduce latency, and improve transmission reliability while keeping a seamless network connection.

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