WMM™ Power Save
for Mobile and Portable Wi-Fi® CERTIFIED Devices

Wi-Fi Alliance
December 2005

Executive Summary

Wi-Fi mobile devices require advanced power-save mechanisms to offer a rich user experience for voice, audio, and video applications. WMM (Wi-Fi Multimedia) Power Save extends the battery life of Wi-Fi devices by increasing the efficiency and flexibility of data transmission. It is an addition to WMM, the technology that enables Quality of Service (QoS) functionality in Wi-Fi networks by prioritizing traffic from different applications. WMM Power Save has been optimized for mobile devices running latency-sensitive applications such as voice, audio, or video, but can benefit any Wi-Fi device. WMM Power Save uses mechanisms included in the Institute of Electrical and Electronics Engineers (IEEE) 802.11e amendment and is an enhancement of IEEE 802.11 legacy power save, which was designed for data applications. With WMM Power Save, the same amount of data can be transmitted in a shorter time and using fewer frames, while allowing the Wi-Fi device to remain longer in a low-power, “dozing” state.

The Wi-Fi Alliance has announced a new certification program for WMM Power Save driven by the market demand for converged Wi-Fi mobile devices that support voice applications. Certification started in December 2005 and is open to any Wi-Fi device certified for WMM. WMM Power Save certification indicates interoperability across vendors. Furthermore, Wi-Fi CERTIFIED for WMM Power Save devices will be able to operate in any Wi-Fi network and coexist with 802.11 legacy power-save mechanisms.

To take advantage of WMM Power Save functionality, both the Wi-Fi client and the access point need to be Wi-Fi CERTIFIED for WMM Power Save. In addition, applications need to support WMM Power Save to inform the client of the requirements of the traffic they generate. This provides additional flexibility and efficiency in managing network and power resources.

The battery life enhancements that WMM Power Save brings pave the way to a wide-scale adoption of Wi-Fi in mobile devices. To take advantage of this market opportunity, it is crucial for mobile device manufacturers, access point manufacturers and developers of latency-sensitive applications to understand the functionality that WMM Power Save offers and to support it in their products.

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Introduction

Wi-Fi is rapidly expanding its role in home, enterprise and public networks by moving beyond laptops and desktop PCs, into Personal Digital Assistants (PDA), phones, cameras, and other Consumer Electronics (CE) devices. Many of the new battery-operated devices have even stricter power management requirements than laptops and typically run applications like Voice over IP (VoIP), or video and audio streaming that do not tolerate long latencies.

These new devices and applications represent a great opportunity for Wi-Fi, a technology designed to operate within a license-exempt spectrum in a dynamic environment with a large number of client devices. The Wi-Fi Alliance has taken a proactive stance to enable a wider range of devices to benefit from Wi-Fi functionality through the Wi-Fi CERTIFIED for WMM and Wi-Fi CERTIFIED for WMM Power Save programs. WMM adds Quality of Service (QoS) capabilities to Wi-Fi networks. WMM Power Save is an improvement on the Institute of Electrical and Electronics Engineers (IEEE) 802.11e amendment that adds advanced power management functionality to WMM. WMM Power Save certification is optional for products that are submitted for WMM certification, and it was launched in December 2005.

The new WMM Power Save is ideally suited to mobile devices that require advanced power-save mechanisms for extended battery life, and for applications like VoIP where the user experience rapidly degrades as latency increases. WMM Power Save was designed for mobile and cordless phones that support VoIP. In addition, laptops, PDAs, game consoles, audio players, peripheral devices like keyboards and mice, headsets, sensors and controllers also stand to benefit from it.

WMM Power Save is an enhancement over the legacy power-save mechanisms supported by Wi-Fi networks. It allows devices to spend more time in a “dozing” state, which consumes less power, while improving performance by minimizing transmission latency (Figure 1). Furthermore, WMM Power Save promotes more efficient and flexible over-the-air transmission and power management by enabling individual applications to control capacity and latency requirements.

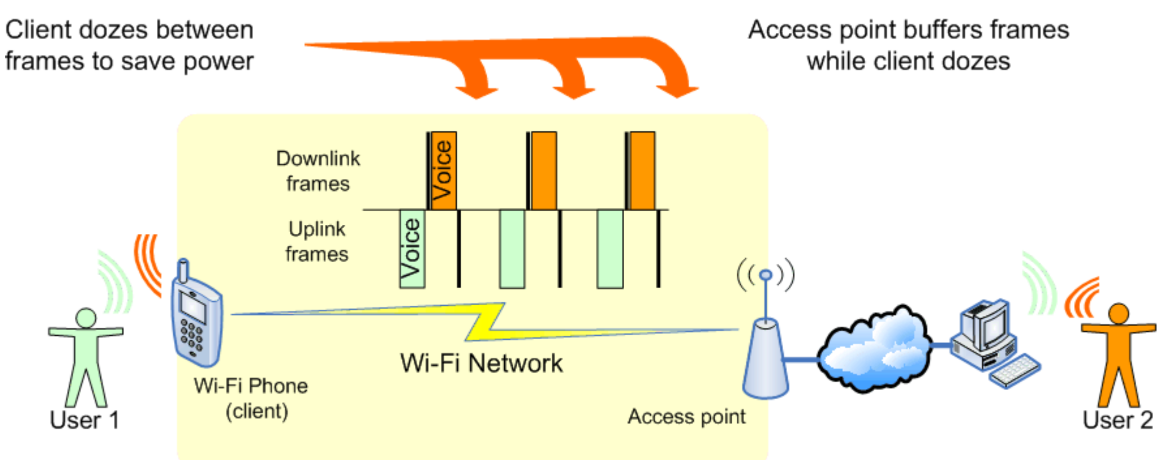


Figure 1. WMM Power Save in a Wi-Fi network

Three conditions have to be met for a Wi-Fi client to take advantage of WMM Power Save:

1. The client is Wi-Fi CERTIFIED for WMM Power Save
2. The access point is Wi-Fi CERTIFIED for WMM Power Save
3. Latency-sensitive applications support WMM Power Save.

As a result, vendors of access points and mobile clients need to be aware of the demand for WMM Power Save and of the advantages it brings to mobile clients, and must plan for WMM Power Save certification for new and existing products. It is equally important for application developers to understand how WMM Power Save can enhance application performance and to add support for it in the new versions of products.

The rest of this white paper provides an overview of the market drivers and technology behind WMM Power Save. It initially discusses the market needs for enhanced power-save mechanisms for Wi-Fi, and the applications and devices that stand to benefit the most from its adoption. The paper then outlines the relationship of WMM Power Save with the IEEE 802.11 standard and presents the Wi-Fi CERTIFIED for WMM Power Save program. The second half of the white paper focuses on how WMM Power Save works, on how it compares to Wi-Fi legacy power save, on the additional functionality it brings to Wi-Fi networks, and on how application developers can add support for WMM Power Save. A case study on how WMM Power Save enhances the experience of VoIP over Wi-Fi concludes the paper.

Market Need for More Efficient Power-Save Technologies

The initial success of Wi-Fi was largely tied to its ability to provide wireless data connectivity to laptops, which had a remarkable impact on usage models: the laptop user was no longer tethered to an Ethernet plug on the wall and instead could choose freely where to work, check email or surf the Internet. Mobile devices like mobile phones, smartphones or PDAs also provide a similar experience of freedom from a specific location, but in most cases functionality is limited to offline applications (e.g. calendar, contact information, games stored on the device), limited Internet access, or cellular voice services.

Both users and manufacturers see a great potential in the convergence of these two device types: a mobile device that supports both portability and mobility, while allowing broadband Internet access. Wi-Fi makes this possible, as long as the user is located within the coverage area of a Wi-Fi network. With the rapid spread of Wi-Fi networks in the home, enterprise and public areas, users are increasingly likely to be within range of a Wi-Fi network.

A major challenge to integrating Wi-Fi in mobile devices is its impact on battery life. WMM Power Save addresses the challenge by offering advanced power management mechanisms that are optimized for mobile devices. It was introduced in answer to demand from manufacturers, application developers and service providers who want to take advantage of the opportunity that Wi-Fi offers for new capabilities and services.

In particular, the growing popularity of VoIP and the ease with which it can be used over Wi-Fi networks has been instrumental in driving the Wi-Fi CERTIFIED for WMM Power Save program. The requirements of VoIP applications differ sharply from those of data applications such as Internet surfing, email or file sharing that Wi-Fi initially targeted. A VoIP application does not need high throughput, but it is extremely sensitive to delays. An increase in latency in a data application may result in an additional few seconds needed to download large emails or files, or a longer time to load a web page, while in a VoIP application it can make the speech flow fragmented or the call altogether unintelligible. Increased latency is typically the side effect of power-save mechanisms that work well on data but that can be disruptive for VoIP applications. WMM Power Save takes a different approach that gives individual applications the ability to tailor network transmissions to specific requirements, without a significant impact on network latency.

Benefits of WMM Power Save on Applications and Devices

WMM Power Save has been optimized for mobile devices and applications that have strict latency requirements, but it will benefit a wider range of devices and applications, because it offers a more efficient and flexible way to manage the transmission between an access point and a client. As a result, not only is the battery life extended, but performance may improve.

The application-based approach used in WMM Power Save enables individual applications to decide how often the client needs to communicate with the access point and how long it can remain in a dozing state. In legacy power save, the Wi-Fi driver in the client sets the dozing intervals, regardless of which applications are active. To save more power, the client may choose a longer dozing period, but in so doing it can degrade the performance of some applications. To improve performance, the client may poll the access point more frequently, but this will consume more power.

The tighter control over the transmission timing with the access point and the management of dozing versus active (receiving and transmitting) states gives battery-operated devices more flexibility in managing power consumption and a longer battery life. Mobile phones, smartphones, cordless phones and PDAs are expected to benefit the most from WMM Power Save.

Laptops will increasingly be able to take advantage of this mechanism as VoIP, and video and audio streaming becomes more widely used. In particular, the success of Skype and other VoIP providers like Vonage has greatly promoted the use of VoIP both from the home or office, and while traveling to avoid hefty roaming charges.

General purpose devices like laptops can enjoy the benefits of WMM Power Save even if only some applications support it. This is a very likely scenario for devices that in addition to VoIP or streaming applications run applications like email or Internet access that only require best-effort transmissions. Applications that do not initiate power save can still coexist with WMM Power Save enabled applications on the same device. In this case, data from the other applications will be delivered with legacy power save, while WMM Power Save applications will still enjoy its additional functionality as long as the access point also supports WMM Power Save.

Application Specific Devices (ASDs) and CE equipment like audio players, game consoles, or cameras, as well as peripherals (mice, keyboards, handsets), sensors and controllers also stand to benefit from WMM Power Save. This is because the device can regulate data access using a more efficient transmission schedule designed on application-specific requirements, while prolonging battery life. For instance, the traffic flow in a game console highly irregular and difficult to anticipate: there may be periods during which the user becomes more active, or periods where more data needs to be downloaded because other online players are active. A WMM Power Save game console would be able to minimize latency by requesting a data download from the access point as frequently as required by the game. The benefits of WMM Power Save application-based approach are apparent here as the frequency of downloads clearly depends on the game type: a chess or poker player will tolerate a much longer latency than a player of Doom or a car racing game.

Applications that need more than best-effort connectivity gain the most from WMM Power Save. VoIP is one of the most compelling applications, but video and audio streaming are also key target applications, as performance imposes a significant drain on battery life in mobile or portable devices. The application-initiated requests for transmission will prove an effective way to improve performance without suffering from a reduction in battery life for gaming and other real-time applications.

WMM Power Save and the IEEE 802.11 Standard

The core technology used by WMM and WMM Power Save depend on enhancements to the 802.11 Media Access Control (MAC) layer. The enhancements, designed to support QoS, were contributed by members of the IEEE 802.11e task group.

In September 2004, the Wi-Fi Alliance introduced the Wi-Fi CERTIFIED for WMM program based on the Enhanced Distributed Channel Access (EDCA) method. This enabled Wi-Fi products to have interoperable QoS mechanisms ahead of the final ratification of the 802.11e amendment in October 2005. With WMM, Wi-Fi networks can prioritize media access based on four Access Categories (AC) which define different priority levels:

- Voice (highest priority)
- Video
- Best effort (including legacy traffic)
- Background (lowest priority).

For example, in a Wi-Fi network with WMM, voice receives priority over all other types of traffic, thus improving the performance of voice applications. Other traffic that is less dependent on latency is often briefly delayed to accommodate higher-priority voice and video, without a significant impact on perceived performance.

WMM Power Save is based on Unscheduled Automatic Power Save Delivery (U-APSD), which, like WMM, is based on EDCA. U-APSD is a solution well suited to the dynamic environments where Wi-Fi is typically deployed and allows the client to download all or some of the frames buffered by the access point during unscheduled Service Periods.

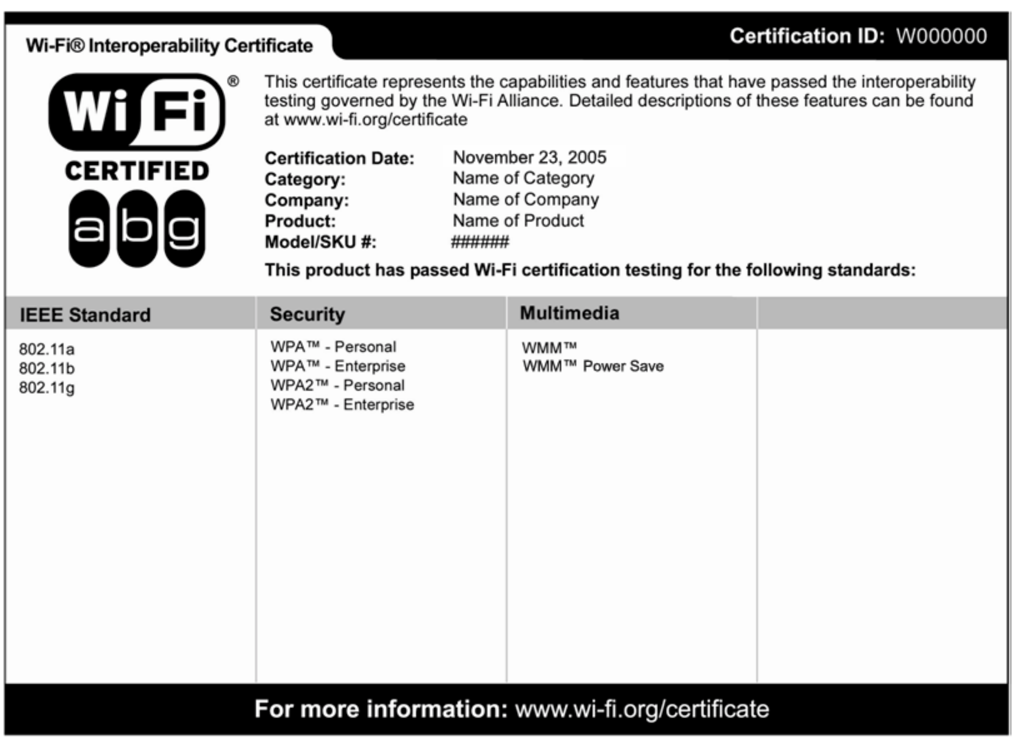
The Wi-Fi Alliance Wi-Fi CERTIFIED for WMM Power Save Program

The Wi-Fi Alliance is committed to improving the functionality of Wi-Fi networks and to expanding the variety of devices and applications that can benefit from Wi-Fi. Motivated by a strong market demand for mobile devices, such as cellular telephones, to support Wi-Fi, the Wi-Fi Alliance has focused on advanced power-save functionality, as the feasibility of Wi-Fi in mobile devices depends on good battery life.

Certification is available for both access points and clients that are Wi-Fi CERTIFIED for WMM. Wi-Fi CERTIFIED for WMM products typically only require a software upgrade to support WMM Power Save. The WMM Power Save certification is optional, although it is recommended for all access points, as this will enable them to support any client with WMM Power Save. Among clients, mobile devices are the most likely to incorporate WMM Power Save, but several portable terminals and ASDs will also increasingly include support for WMM Power Save.

As with other certification programs offered by the Wi-Fi Alliance (802.11a/b/g, WPA™, WPA2™, and WMM), certification tests are conducted in independent Authorized Test Labs of the Wi-Fi Alliance. Certification indicates that the product interoperates with all Wi-Fi CERTIFIED products, including other WMM Power Save and legacy power-save equipment. This will make it possible to have Wi-Fi networks with a mix of WMM Power Save and legacy power-save clients, where WMM Power Save devices can benefit from its increased functionality without penalizing legacy clients.

Manufacturers receive a Wi-Fi Interoperability Certificate (Figure 2) that indicates WMM Power Save. Additional information about the Wi-Fi Alliance certification program and a database of Wi-Fi CERTIFIED products can be accessed at www.wi-fi.org.


Wi-Fi® Interoperability Certificate

Certification ID: W000000

Wi Fi® CERTIFIED abg

This certificate represents the capabilities and features that have passed the interoperability testing governed by the Wi-Fi Alliance. Detailed descriptions of these features can be found at www.wi-fi.org/certificate

Certification Date: November 23, 2005
Category: Name of Category
Company: Name of Company
Product: Name of Product
Model/SKU #: ######

This product has passed Wi-Fi certification testing for the following standards:

IEEE Standard	Security	Multimedia	
802.11a 802.11b 802.11g	WPA™ - Personal WPA™ - Enterprise WPA2™ - Personal WPA2™ - Enterprise	WMM™ WMM™ Power Save	

For more information: www.wi-fi.org/certificate

Figure 2. The Wi-Fi Interoperability Certificate for WMM™ Power Save products

A Comparison with Legacy Power Save

Power save is not new to Wi-Fi networks. The initial IEEE 802.11 standard defines power-save mechanisms, referred to in this paper as legacy power save, that allow the client to become inactive, or doze, when there is no traffic. To extend battery life, the client tries to minimize the amount of time spent transmitting and receiving, states that consume more power. The access point supports power save by buffering the data frames for each client and delivering them when the client is awake.

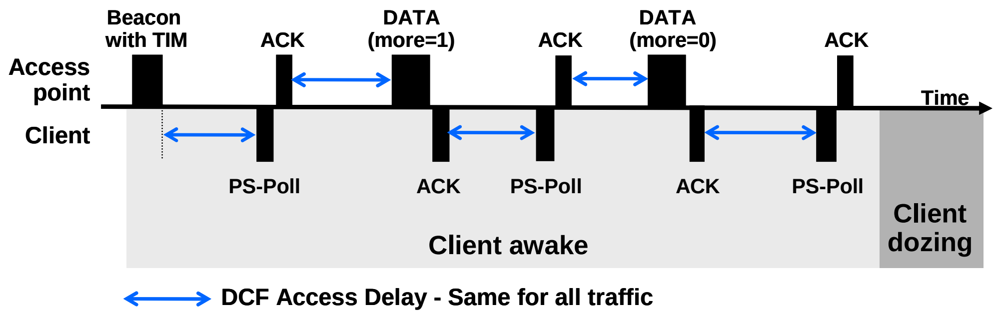


Figure 3. Wi-Fi legacy power save

Figure 3 shows how this is achieved. The client waits in receiving mode for a beacon frame from the base station. The beacon frame includes Traffic Indication Map (TIM) information that tells the client whether there is any data available for download. If there is no data to download, the client can doze until the next beacon frame. If there is data available, the client sends a PS-Poll (Power Save–Polling) frame to request a download of the data. After sending an acknowledgement frame, the access point starts transmitting frames with the data.

For each frame, the client sends a PS-Poll frame and an acknowledgement frame after the data has been received and receive an acknowledgement of its download request. When the access point has downloaded the data to the client, it sends a bit in the last data frame that indicates it is the last. Upon receiving this, the client goes back to dozing mode.

A DCF (Distributed Coordination Function) delay is imposed between any two frames sent by the access point or the client, regardless of the type of traffic (e.g., voice, email downloading, or Internet browsing). As a result, for each data frame sent from the access point, two data frames are sent from the access point and from the client, and two DCF access delays are interleaved.

Legacy power save operates in a ping-pong fashion that increases the latency for applications that require frequent data exchanges between the client and the access point, like VoIP, or voice and audio streaming. This is for several reasons:

- The client has to wait for the beacon frame and cannot initiate transmission at shorter intervals.
- Only one data frame is sent at a time and the client has to transmit and receive additional signaling frames for each data frame received.

- The dozing time is set by the client Wi-Fi driver regardless of which applications it runs, thus limiting the opportunity to tailor the client behavior to the requirements of specific applications.

How Does WMM Power Save Work?

WMM Power Save improves the efficiency of legacy power save by increasing the amount of time the client is allowed to doze and by decreasing the number of frames that a client needs to send and receive, in order to download the same number of frames buffered by the access point as before. It consists of a signaling mechanism added to WMM that enables the access point to buffer data frames and send them to the client upon its request.

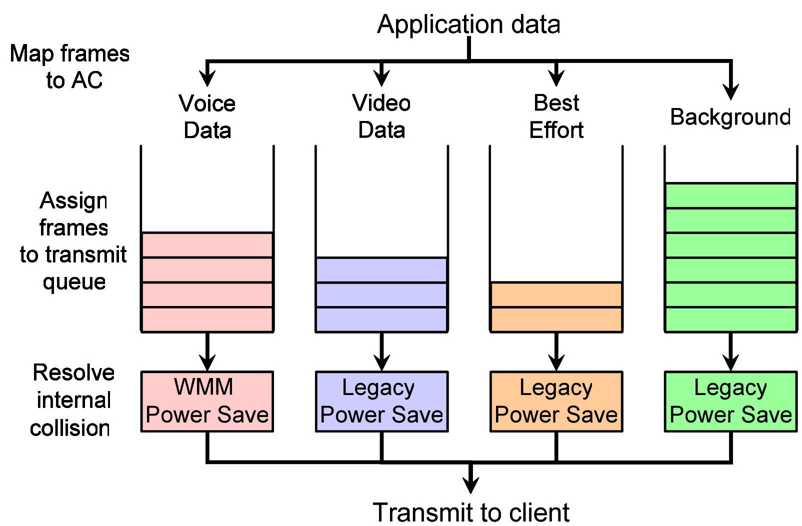


Figure 4. Example of a setup for WMM Power Save, with only voice traffic using WMM Power Save

Power save behavior is negotiated during the association of a client with an access point. WMM Power Save or legacy power save is set for each WMM AC (voice, video, best effort, background) transmit queue separately[1]. For each AC queue, the access point will transmit all the data using either WMM Power Save or legacy power save (Figure 4), using the WMM QoS mechanism.

While clients using legacy power save need to wait for the beacon frame to initiate a data download, WMM Power Save clients can initiate the download at any time, thus allowing more frequent data transmission for applications that require them.

There are two ways in which the access point may send the buffered data frames to the client. If the data belongs to a legacy power-save queue, transmission follows legacy power save (Figure 3). If the data belongs to a WMM Power Save queue, data frames are downloaded according to a trigger-and-delivery mechanism as shown in Figure 5.

[1] For WMM Power Save to be set, both the access point and the client need to be WMM Power Save certified, and applications that are active on the client need to support WMM Power Save.

The client sends a trigger frame on any of the ACs using WMM Power Save to indicate that it is awake and ready to download any data frame that the access point may have buffered. Unlike with legacy power save, the trigger frame can be any data frame, thus eliminating the need for a separate PS-poll frame which contains only signaling data.

After the client has sent a trigger frame, the access point acknowledges it is ready to send the data. Data frames are sent during an EDCA Transmit Opportunity (TXOP) burst, with each data frame interleaved with an acknowledgement frame from the client. On the last data frame, the access point indicates that no more data frames are available and the client can revert to its dozing state.

To ensure backward compatibility, the beacon frame contains TIM information for WMM Power Save frames only if all transmit queues are trigger-and-delivery enabled. If one or more transmit queues uses legacy power save, the beacon frame only contains legacy power-save TIM information.

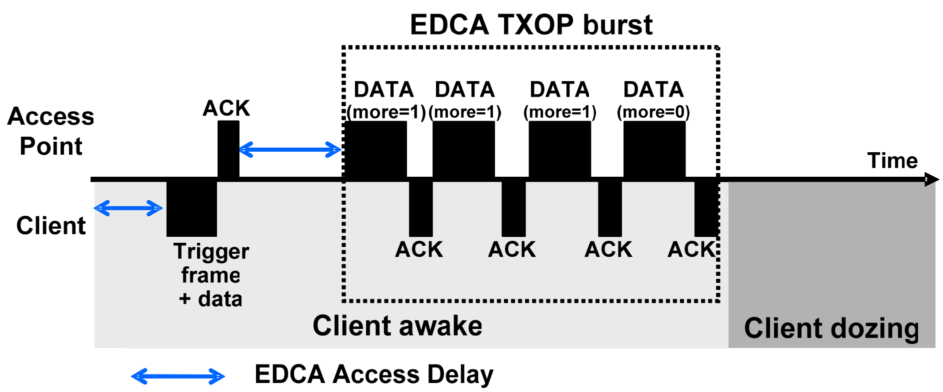


Figure 5. WMM Power Save

New Functionality Introduced by WMM Power Save

WMM Power Save offers additional functionality with respect to both WMM and legacy power save.

Wi-Fi networks that implement WMM optimize the allocation of shared network resources among competing applications by prioritizing media access depending on the traffic type. WMM relies on applications to determine the AC of the traffic they generate, which brings in additional flexibility in networks that have concurrent applications (e.g., voice, gaming and background data) with different latency and bandwidth requirements.

WMM Power Save brings WMM a step further. WMM Power Save improves the battery life of mobile devices while retaining the improved user experience that WMM brings. For instance, a VoIP application using WMM Power Save may save anywhere from 15 to 40% while keeping the impact on latency low. In WMM Power Save, QoS mechanisms are used to optimize power consumption based on the specific requirements of individual applications. WMM Power Save provides a mechanism for the access point to buffer data frames within each AC transmit queue while the client is dozing and to transmit the data quickly when the client wakes up.

Like WMM Power Save, legacy power save allows data frame buffering while the client is dozing, but it does so in a way that is better suited to data access and to applications that do not have tight latency requirements. WMM Power Save is more efficient in its use of the air link and in power consumption and brings a better user experience for some applications like VoIP, or audio and video streaming. Several changes over legacy power save make these improvements possible:

- The client can request a data download without having to wait for a beacon frame. This reduces latency for applications like VoIP that require low latencies and enables more efficient dozing periods when the client does not need to receive or transmit data (e.g. during the time intervals between sent or received frames in a voice call).
- All downlink data frames are sent together in a fast sequence, thus reducing the number of frames required to receive the same amount of data.
- The trigger frame in WMM Power Save is effectively a data frame, while the legacy PS-poll frame only includes signaling information. This effectively further reduces the number of frames sent by the client and it is particularly advantageous in applications like VoIP that need to send data frames and poll the access point very frequently.
- Applications specify the power-save behavior, thus increasing the flexibility in setting dozing periods and in sending trigger frames. As a result, applications like VoIP will poll the access point frequently during voice calls, while a data application may have longer dozing periods because it can better tolerate longer latencies.

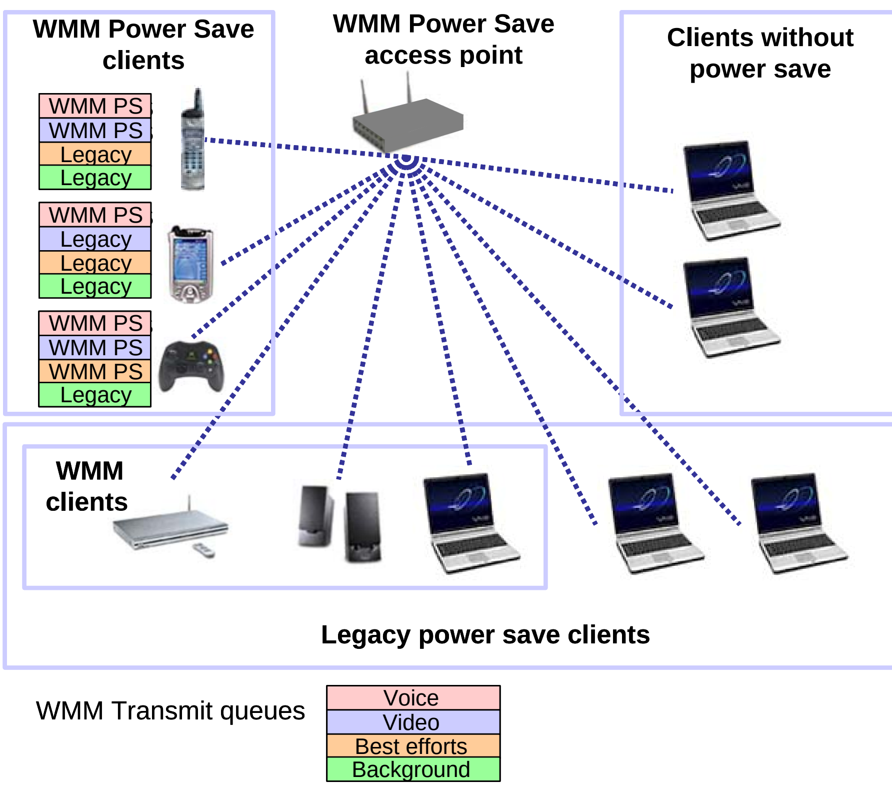


Figure 6. Coexistence of different Wi-Fi clients in a WMM Power Save network

WMM Power Save can coexist with legacy power save. A WMM Power Save client will still work within a legacy network and run applications that do not support WMM Power Save. As a result, no upgrade is needed to accommodate WMM Power Save devices in existing networks, if WMM Power Save functionality is not required.

However to take advantage of the benefits of WMM Power Save, both the client and the access point need to be Wi-Fi CERTIFIED for WMM Power Save. This enables the client and the access point to negotiate power-save behavior upon association. The presence of other clients in the network that are not Wi-Fi CERTIFIED for WMM Power Save does not affect the use of WMM Power Save for those devices that support it (Figure 6).

Application Support for WMM Power Save

To take advantage of its functionality, applications also need to support WMM Power Save. One of the key advantages of WMM Power Save over the legacy mechanisms is that the dozing behavior of the client is determined by applications. An application sends uplink data frames, acting as trigger frames, more or less frequently to change the dozing pattern. Not all applications on a client need to support WMM Power Save, however. Traffic generated by applications that do not support WMM Power Save uses legacy power save.

The selection of the appropriate uplink trigger data timing corresponding to the expected downlink data availability timing is the key task for application developers. They should check with chipset and driver vendors if they have recommendations for specific application types.

For applications with frequent and regular upstream and downstream frames, lsynchronization of the upstream and downstream data transmission contributes to a reduction of latency. This can be achieved by timing the upstream trigger-frame transmission with the expected availability of downlink frames. Triggering the delivery of a downlink data frame without having it buffered too long improves latency. For example, in a game application, the client may send an uplink frame every video refresh (e.g. 16 ms) and, to minimize latency, it should do so in the interval just after a new frame is expected to be available to download.

Applications that natively generate irregular uplink traffic should either use legacy power save or generate trigger frames to verify whether buffered data to download is available. Alternatively, the application can rely on trigger frames from other applications to check whether new buffered data is available for download.

VoIP: A Case Study

VoIP is the application that best exemplifies the advantages that WMM Power Save brings over legacy power save. Figure 7 shows how a Wi-Fi network transports a VoIP call. Voice traffic is greatly affected by latency. Typically a 20 ms delay between frames is acceptable, as speech is digitized into frames at 20 ms intervals, but beyond that the voice quality gradually decreases. Long delays will make a voice conversation difficult or impossible to understand.

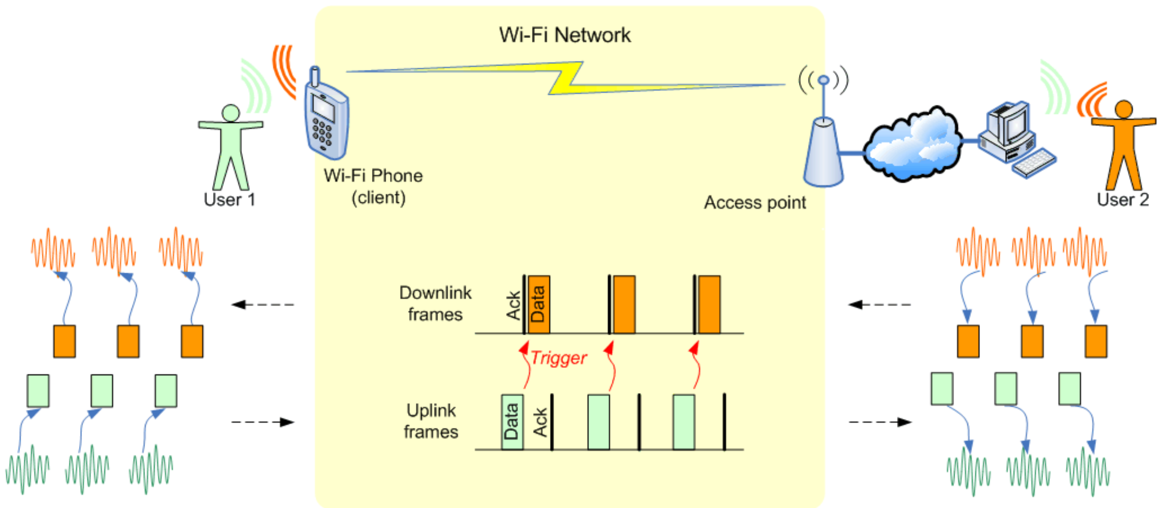


Figure 7. A VoIP call in a Wi-Fi network

WMM gives voice priority over other types of traffic, which greatly improves latency. WMM Power Save retains the prioritization mechanism, but also allows the client to download data only when it is in an active state (transmitting or receiving). The benefits of WMM Power Save are more notable during a voice call, with better voice quality (due to lower latency) and lower power consumption (due to longer dozing time).

In a legacy power-save configuration, the client waits for the beacon frame before it initiates the downlink data transmission. This may result in a delay in the downlink traffic of up to 100 or 300 ms, a typical interval between beacon frames, which is too long for VoIP calls. To support VoIP, the access point may send beacon frames more frequently, but that will reduce the dozing time, especially when there is no call in progress.

With WMM Power Save, the client does not need to wait for the beacon frame to request a data download from the access point (Figure 8). The access point buffers all the voice frames to be delivered until it receives a trigger frame from the client. At this point, all the frames are transmitted to the client and converted back to analog speech.

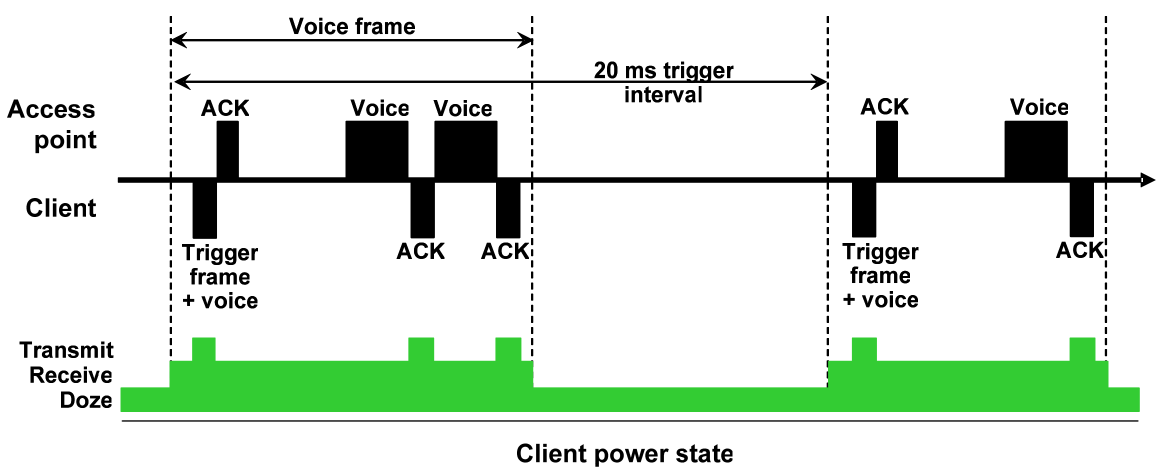


Figure 8. VoIP in a WMM Power Save network

During a VoIP call, the client typically transmits an uplink frame that acts as a trigger frame every 20 ms and rapidly downloads all the frames buffered in the access point. Once the download is completed, the client reverts into its dozing mode until the next uplink trigger frame is due. When no call is in progress, the client does not need to poll the access point as frequently, thus increasing the percentage of time spent dozing and reducing further overall power consumption. Individual VoIP applications can further refine the power consumption and the user experience by using settings that are application-specific.

The user may be checking email or watching a movie while making a phone call. In this case, the voice traffic has priority thanks to WMM and it is not greatly affected by data and streaming traffic. This is not the case in a legacy power-save network without WMM, where all traffic is treated equally and as a result, voice may experience substantial delays when the overall level of traffic is high.

Conclusions

WMM Power Save gives Wi-Fi networks advanced power-save capabilities that are designed for mobile devices and for applications that require low latencies, but that can also improve the power consumption of a wider range of Wi-Fi devices. WMM Power Save is a powerful addition to WMM and offers a substantial enhancement over 802.11 legacy power save:

- Lower power consumption, as the client spends more time in a dozing state and less overhead for transmitting or receiving data.
- Improved user experience, as the client's power-save behavior is driven by the requirements of specific applications, rather than by the client Wi-Fi driver. This approach is more flexible and promotes a more efficient use of the air link resources.
- Coexistence within existing Wi-Fi devices using legacy power save.

The Wi-Fi Alliance offers a Wi-Fi CERTIFIED for WMM Power Save program that indicates interoperability across vendors. The program was introduced in December 2005 and it is offered as an optional extension to products that are Wi-Fi CERTIFIED for WMM. The Wi-Fi CERTIFIED for WMM Power Save program was driven by market demand for converged devices that support VoIP and video and audio streaming, and will further promote the extension of Wi-Fi functionality to new devices, including mobile and cordless phones, CE devices, and peripherals.

Ultimately the success of WMM Power Save depends on the synergy among mobile device manufacturers, access point manufacturers and application developers as they design products that deliver multiple services, a great user experience and reduced power consumption.

Additional Resources

[1] Chen, Ye; Smavatkul, Natt; Emeott, Steve (2004) Power Management for VoIP over 802.11 WLAN. IEEE (http://www.comsoc.org/tech_focus/pdfs/2005/jan/1642chen.pdf)

[2] Palm, Stephen (2004) Delivering QoS in Home IP Networks. CommsDesign (http://www.commsdesign.com/showArticle.jhtml?articleID=18100157 **)**

[3] Wi-Fi Alliance (2004) Wi-Fi CERTIFIED™ for WMM™ - Support for Multimedia Applications with Quality of Service in Wi-Fi® Networks (http://www.wi-fi.org/getfile.asp?f=WMM_QoS_whitepaper.pdf)

[4] Wi-Fi Alliance (2005) WMM™ Power Save System Interoperability Test Plan (http://www.wi-fi.org/membersonly/testing_information.asp)

Note: Application developers can determine whether an access point supports WMM Power Save by looking at bit 7 in the QoS Information field of the WMM Information Element in the beacon frame sent from the access point.

List of Acronyms

AC	Access Category
ACK	ACKnowledgement [frame]
ASD	Application Specific Devices
CE	Consumer Electronics
DCF	Distributed Coordination Function
EDCA	Enhanced Distributed Channel Access
IEEE	Institute of Electrical and Electronics Engineers
MAC	Media Access Control
PDA	Personal Digital Assistant
PS	Power Save
PS-Poll	Power Save Polling [frame]
QoS	Quality of Service
U-APSD	Unscheduled Automatic Power Save Delivery
TIM	Traffic Indication Map
TXOP	Transmission Opportunity
VoIP	Voice over Internet Protocol
WLAN	Wireless Local Area Networks
WMM™	Wi-Fi Multimedia™
WPA™	Wi-Fi Protected Access™
WPA2™	Wi-Fi Protected Access 2™