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White Paper:
Wi-Fi CERTIFIED™ for WMM™ - Support for Multimedia Applications with Quality of Service in Wi-Fi® Networks

Introduction

Interest and demand for Wi-Fi multimedia applications and advanced capabilities are growing quickly, spurred by new devices and by the desire of Wi-Fi users to extend the functionality of their networks. In the residential market, Voice over Internet Protocol (VoIP), video streaming, music streaming, and interactive gaming are among the most anticipated applications. In enterprise and public networks, support for VoIP, real-time streaming of audio and video content, as well as traffic management, allows network owners to leverage the Wi-Fi infrastructure to offer a richer and more diverse set of services.

Quality of Service (QoS) is required to support multimedia applications and advanced traffic management. WMM adds prioritized QoS capabilities to Wi-Fi networks and optimizes their performance when multiple concurring applications, each with different latency and throughput requirements, compete for network resources. By using WMM, end-user satisfaction is maintained in a wider variety of environments and traffic conditions. WMM makes it possible for home network owners and enterprise network managers to decide which data streams are most important and assign them a higher traffic priority.

The Wi-Fi Alliance defined WMM as a profile of the upcoming IEEE 802.11e standard and started a program for Wi-Fi CERTIFIED for WMM to satisfy the most urgent needs of the industry for a QoS solution for Wi-Fi networks. An addendum to the IEEE 802.11 standard, 802.11e, is currently being developed and it will include support for QoS in Wi-Fi networks. The 802.11e project began in 1999, and ratification for 802.11e is projected for the end of 2004 or early 2005.
The proactive approach taken by the Wi-Fi Alliance with WMM is similar to that followed for WPA™ (Wi-Fi Protected Access™). Wi-Fi CERTIFIED for WPA has allowed manufacturers to offer an interoperable, robust security solution based on 802.11i, a year and a half ahead of the ratification of the standard.

Wi-Fi CERTIFIED for WMM is optional for Wi-Fi products since not all applications need QoS, but Wi-Fi CERTIFIED products that do offer QoS are required to be Wi-Fi CERTIFIED for WMM. Wi-Fi CERTIFIED for WMM ensures that products interoperate with each other and are able to coexist with legacy devices that lack WMM functionality. In a Wi-Fi network, WMM functionality requires that both the access point (AP) and the clients running applications that require QoS are Wi-Fi CERTIFIED for WMM and have WMM enabled.

At the same time, it is important to realize that WMM-enabled devices can take advantage of their QoS functionality only when using applications that support
WMM and can assign the appropriate priority level to the traffic streams they generate. WMM provides prioritized media access and is based on the Enhanced Distributed Channel Access (EDCA) method. It defines four priority classes (voice, video, best effort, and background) to manage traffic from different applications. The rest of the white paper discusses in more detail how Wi-Fi networks benefit from QoS and how WMM will encourage the growth of multimedia applications and advanced network management capabilities, explains how WMM works, and provides additional inform ation about the Wi-Fi Alliance testing program.

The Need for QoS in Wi-Fi Networks
QoS functionality in Wi-Fi networks is emerging as a key requirement to support multimedia applications and advanced network traffic management in the residential, enterprise, and public access market segments.

Residential market. In the residential market, demand for Wi-Fi multimedia applications is growing rapidly as four key trends emerge:

- Wi-Fi home networking is spreading rapidly among broadband households (In a recent report (IDC #31762, August 2004), IDC forecasts that by 2008, 36.7 million US households will have either a data-centric or a media-centric home network), and Wi-Fi has emerged as the clear favorite among wireless technologies for home networks.
- Residential broadband penetration has taken off (in Korea, 79% of households have broadband according to PointTopic (World Broadband Statistics Q3 2003, January 2004); the FCC estimates broadband penetration in the US at 26% and growing at an impressive rate of 42% in 2003).
- New services, digital content, and new applications (e.g. VoIP, gaming, music streaming) are becoming more widely available, and consumer demand is growing.
- A wide range of products addressing digital entertainment connectivity – a substantial market for potential Wi-Fi onnectivity – are rapidly entering the market. Annual shipments of such products are expected to grow at a fast pace over the next few years and to reach 120 million units by 2008, according to Parks Associates (Multimedia Networks in the Home - Analysis and Forecasts, January 2004).

Enterprise market. Enterprises urgently need QoS to be able to support wireless VoIP, which can provide significant cost savings and wireless voice connectivity throughout the campus by leveraging the Wi-Fi infrastructure while avoiding the higher costs of cellular voice services. Another application that benefits from WMM is prioritized traffic management, which allows the IT administrator to assign different priority levels to different users. For instance, network administrators may wish to assign a lower priority to visitors sharing the network, or to provide more resources to employees working on critical tasks, or to applications like video streaming or teleconferencing.

Public market. Prioritized traffic management is also a key capability for Wi-Fi public access. Use of Wi-Fi ZONEs™ is growing rapidly with the number of active hotspot locations expected to grow to 135,000 by the end of 2006, according to Datamonitor (Public wireless LANs: hotspots - finally heating up - #DMTC0921). Users are increasingly accustomed to VoIP and multimedia applications such as streaming and gaming, and they will expect to be able to use them in Wi-Fi ZONEs as well, putting additional pressure on shared network resources. WMM may be used both to ensure that specific applications (e.g., voice or gaming) have access to the required network resources or that specific users (e.g., those paying higher fees) receive priority access. This will enable service providers to offer premium services and provide support for multimedia applications.

Why is QoS Necessary?

Traditional Wi-Fi networks give equal access to all connected devices. When traffic demands exceed the available bandwidth, throughput for all data streams is similarly reduced, regardless of the type of data. The impact on user experience, however, is strongly affected by the type of data and by the type of application. A one-second delay in sending a print job from a laptop to a printer is unlikely to be noticed by the user. However, a much smaller increase in latency or a reduction in throughput may disrupt the conversation in a VoIP call, or may result in dropped in frames or a frozen image on the screen in a streamed video application.

Non-prioritized, best effort access effectively deals with contention from data applications such as file transfers, email, and Internet and intranet access. Applications such as voice, video and music streaming, and interactive gaming generate data streams that have strict latency and throughput requirements. To ensure a good user experience, traffic from different applications has to be managed and prioritized using QoS.

In the residential market, the increasing complexity and functionality of Wi-Fi networks that multimedia applications bring create a more acute need for QoS. CE manufacturers are marketing a wider array of Wi-Fi-enabled devices, such as VoIP phones, TV, VCRs, PVRs, MP3 players, game consoles, and other multimedia players, in addition to Wi-Fi media adapters that enable legacy devices. Network owners are exploring new ways to use their Wi-Fi networks that go beyond connecting a DSL or cable router to one or more laptops or PDAs and possibly a printer (Figure 1). Potential new uses include:

Figure 1. Wi-Fi multimedia home network

- Providing wireless voice connectivity within the house through VoIP Wi-Fi phones, either using a VoIP service or through a traditional phone line connection
- Using the Wi-Fi network to distribute content from a media server, PC, or an external broadband connection to any device in the home (TVs, MP3 players, or game consoles)
- Establishing wireless connectivity between devices in the home (e.g. a DVD player and speakers in different rooms)
- supporting peer-to-peer networks for telephony or gaming.

Across all the markets, more Wi-Fi-enabled devices in the same network mean more concurrent applications competing with each other, increased traffic demands and, at the same time, higher expectations from users who expect Wi-Fi to match the performance of a wired Ethernet network.

WMM Offers QoS for Wi-Fi Networks

The Wi-Fi Alliance has taken an active approach to promote the development of multimedia and advanced applications by developing the WMM specification and certification program that offers QoS functionality for Wi-Fi networks. Key WMM advantages are:

Interoperability. WMM was developed with a strong commitment to interoperability. It works across device types and manufacturers, and can be implemented by any application that uses Wi-Fi.

Availability. The WMM specification and test plans have been finalized, and Wi-Fi CERTIFIED for WMM is available beginning September 2004. Manufacturers have already started to incorporate support for WMM in new multimedia Wi-Fi devices. Availability of WMM is crucial to support the rapid growth of QoS-based applications because the IEEE draft 802.11e, which will provide QoS support for Wi-Fi networks, has not yet been ratified.

Relationship with IEEE 802.11e. Wi-Fi Alliance members have worked closely with the 802.11e TG to develop QoS for Wi-Fi networks. WMM is a profile of the upcoming IEEE 802.11e QoS extensions for 802.11 networks. The 802.11e draft includes additional capabilities and features that may be included later in the Wi-Fi CERTIFIED for WMM program as optional capabilities. For example, the Wi-Fi Alliance is already developing a test plan for the scheduled access capability.

Wide industry support. As with previous certification efforts, the Wi-Fi Alliance has worked in close collaboration with industry players to facilitate WMM adoption in the market.

Wide appeal. WMM meets the requirement of the residential, SOHO, enterprise, and public access market segments.

User confidence. Through the Wi-Fi Alliance certification program and education efforts, users see the Wi-Fi logo as an assurance of interoperability. Similarly, users will rely on the WMM mark to identify Wi-Fi devices that support QoS and to guide their purchasing decisions.

Global reach. Wi-Fi CERTIFIED for WMM is set to have worldwide recognition, thus
making Wi-Fi CERTIFIED for WMM products appealing to customers who need to
deploy interoperable solutions across several countries, and capable to meet public
agencies and private companies requirements globally.

Coexists with devices that do not support WMM. Most Wi-Fi devices deployed or in the market do not support QoS. This is not likely to change, as many devices and applications do not need QoS capabilities. WMM allows Wi-Fi clients with and without WMM capabilities to coexist in the same network. The APs are, however, required to have WMM functionality to support WMM-enabled clients. The network owner can either buy a Wi-Fi CERTIFIED for WMM AP or apply a Wi-Fi CERTIFIED for WMM software upgrade to deployed APs.

Adapts well to dynamic data rates. This is a key requirement for a technology like Wi-Fi that operates in the license-exempt spectrum and therefore cannot guarantee a constant throughput level.

IETF Differentiated Services (DiffServ). WMM is based on the IETF DiffServ architecture, which is well suited for providing QoS on shared media technologies like Wi-Fi, as it enables effective traffic prioritization without imposing an onerous overhead. Individual data packets are labeled with either IETF DSCP headers or IEEE 802.1d tags.

Compatible with Universal Plug and Play (UPnP) QoS. The common DiffServ foundation enables UPnP QoS to manage WMM, and allows network owners to develop and enforce network-wide policies that apply to the wired and wireless infrastructure.

The success of WMM, as well as other Wi-Fi CERTIFIED technologies, depends on manufacturers' support in new products, which will lead to a constellation of interoperable products that users will be able to combine as desired in their networks.

To take advantage of QoS functionality, however, it is equally necessary that multimedia applications support WMM, as they are responsible for assigning the appropriate priority level to data packets. Applications or operating systems that do not support WMM do not have access to the network QoS capabilities. The traffic they generate is treated as best effort, and receives a priority lower than voice and video.

Users and CE manufacturers alike will demand WMM functionality in new applications, as this will enable them to work as expected over a Wi-Fi network. Applications developers should add WMM support in new applications that require QoS if they want to reach Wi-Fi users. Resources for application developers are listed in the Appendix.

Access Categories (AC)

WMM defines four access categories derived from 802.1d, which correspond to priority levels (Table 1). While the four ACs were designed with specific types of traffic (voice, video, best effort, low priority data) and associated priorities in mind, WMM leaves the network owner free to choose the most appropriate network-wide policy and to decide which ACs have priority. For instance, a network owner may prefer to give priority to video streaming over voice. A customized policy for the ACs can be set through an interface in which default priority levels for ACs can be modified. WMM specifies a protocol used by the AP to communicate the policy to QoS-enabled clients and by the clients to send transmit requests.

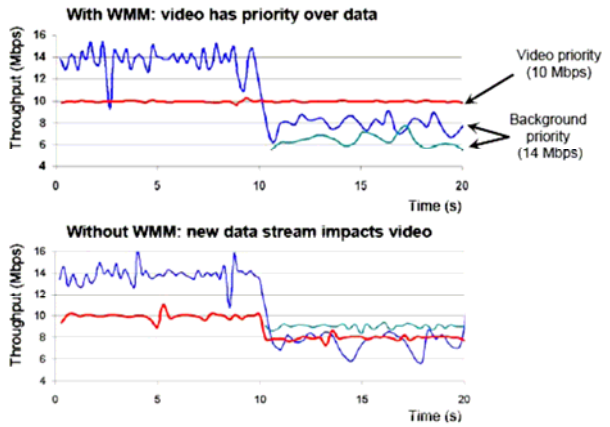

Figure 2. Example of effect of WMM on a video stream

Figure 2 shows an example of how WMM affects throughput for competing data streams. In the top graph, WMM gives a higher priority to the video application than to the other data streams. During the first 10 seconds, both the video and the low priority data stream have sufficient resources. The introduction of a third data stream creates transmission demands that exceed network capacity. WMM gives the video stream a higher priority to ensure that it has sufficient resources. In the bottom graph, WMM is not enabled and, therefore, all traffic streams are given the same access to the wireless medium. In this case, the introduction of the third data stream penalizes all data streams equally.

Overview of WMM Operation

WMM is an enhancement to the MAC sublayer to add QoS functionality to Wi-Fi networks. WMM is an extension to the legacy CSMA/CA-based DCF mechanism that gives all devices the same priority and that is based on a best effort, "listen-before-talk" algorithm. Each client waits for a random backoff time, and then it transmits only if no other device is transmitting at that time. This collision avoidance method gives all the devices the opportunity to transmit, but, under high traffic demand conditions, networks get overloaded and performance of all devices is equally affected.

WMM introduces traffic prioritization capabilities based on the four ACs listed in Table 1 (the higher the AC, the higher the probability to transmit) that address Distributed Coordination Function's (DCF) inadequacy to support multimedia applications. The Acs were designed to correspond to 802.1d priorities to facilitate interoperability with QoS policy management mechanisms, such as UPnP. WMM APs coexist with legacy devices (or devices that are not WMM-enabled): packets not assigned to a specific AC are categorized by default as having best effort priority.

WMM prioritization works as shown in Figure 3 and Figure 4. Applications assign each data packet to a given AC (Figure 3). Packets are then added to one of four independent transmit queues (one per AC; i.e., voice, video, best effort, or background) in the client. The client has an internal collision resolution mechanism to address collision among different queues, which selects the frames with the highest priority to transmit. The same mechanism deals with external collision, to determine which client should be granted the Opportunity to Transmit (TXOP).

The collision resolution algorithm that is responsible for traffic prioritization is probabilistic and depends on two timing parameters that vary for each AC (Figure 4):

- the minimum interframe space, or Arbitrary Inter-Frame Space Number (AIFSN)
- the Contention Window (CW), sometimes referred to as the Random Backoff Wait.

Both values are smaller for high-priority traffic. For each AC, a backoff value is calculated as the sum of the AIFSN and a random value from zero to the CW. The value of the CW varies through time. Initially the CW is set to a value that depends on the AC. © 2004 Wi-Fi Alliance. All rights reserved. 8 After each collision the CW is doubled until a maximum value (also dependent on the AC) is reached. After successful transmission, the CW is reset to its initial, AC dependant value. The AC with the lowest backoff value gets the TXOP. As frames with the highest AC tend to have the lowest backoff values, they are more likely to get a TXOP.

Once a client gains a TXOP, it is allowed to transmit for a given time that depends on the AC and the PHY rate. For instance, the TXOP limit ranges from 0.2 ms (background priority) to 3 ms (video priority) in an 802.11a/g network, and from 1.2 ms to 6 ms in an 802.11b network. This bursting capability greatly enhances the efficiency for high data rate traffic, such as AV streaming. In addition, devices operating at higher PHY rates are not penalized when devices that support only lower PHY rates (e.g. because of distance) contend for medium access.

WMM has been drafted in coordination with the 802.11e TG, and it is a subset of the QoS capabilities included in the 802.11e draft. WMM is based on the Enhanced Distributed Channel Access (EDCA) as defined by the 802.11e TG. The 802.11e draft includes additional features that may be added to WMM as optional modules, which include Scheduled Access, Direct Link Setup (DLS), Block Acknowledgement, and Power Save. While no timeline has been set yet, the Wi-Fi Alliance expects Scheduled Access to be the first WMM optional capability to be available.

Scheduled Access

Scheduled access allows applications to reserve network resources based on their traffic characteristics through requests sent by the client to the AP. It supports parameterized, planned access and corresponds to the HCF Controlled Channel Access (HCCA) in 802.11e. Because the impact of backoff delays is lower, scheduled access can reduce on average the network latency by using a centralized scheduling control mechanism.

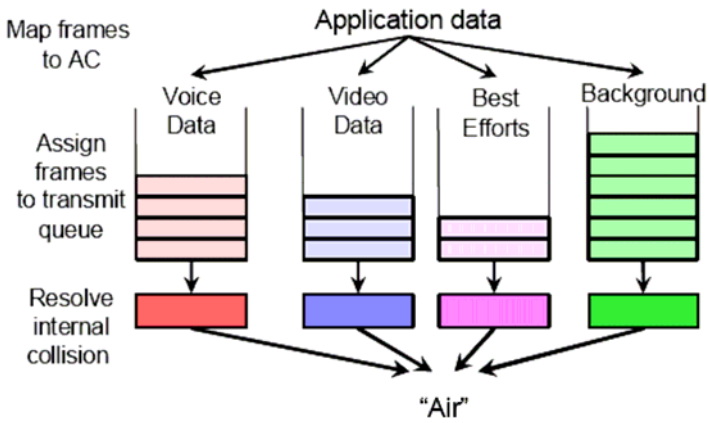

Figure 3. Transmit queues within a WMM client

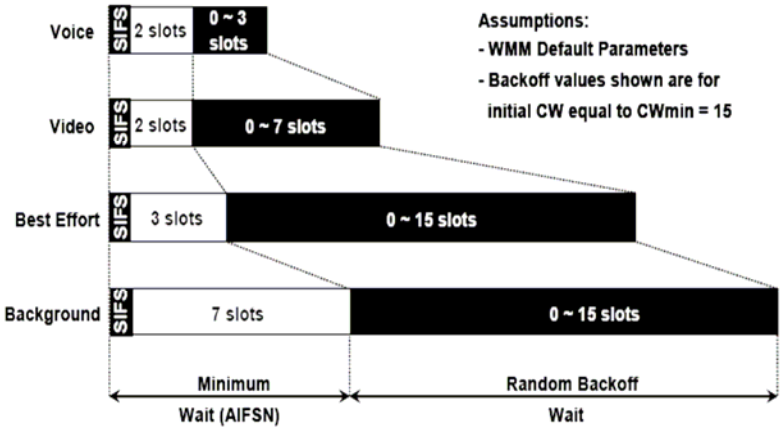

Figure 4. WMM AC Timing

The polling schedule for scheduled access is designed to meet applications' requirements for throughput and latency by assigning times when applications can transmit. The client sends a reservation request to the AP, which in turn assigns TXOPs to the appropriate traffic streams. The AP assignment depends on several Transmission Specification (TSPEC) parameters, such as data rate, PHY rate, packet sizes, service interval, and burst size.

Unlike baseline WMM, scheduled access requires that the client knows in advance what resources it needs and that the AP makes assumptions (e.g. minimum vs. maximum packet size, minimum vs. maximum PHY rate, service start time, surplus bandwidth reserved for re-tries) to schedule concurrent traffic effectively.

Conclusions

WMM extends Wi-Fi networks' functionality to include QoS, and to support a wide range of multimedia application and advanced capabilities, which include:

- VoIP
- Video and music streaming
- Interactive gaming
- Prioritized traffic management.

WMM is a QoS solution with industry-wide support that offers strong interoperability, meets the requirements of all market segments, and has global reach. It is available now and will be interoperable with 802.11e. The Wi-Fi Alliance has launched a WMM certification program that establishes a solid foundation for the growth of the Wi-Fi multimedia market, and that facilitates the development of interoperable devices and applications with QoS capabilities. At the same time, WMM greatly improves the enduser experience and enables a wider, more efficient use of Wi-Fi networks everywhere.