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White Paper

Low Power Advantage of 802.11a/g vs. 802.11b

Wireless LAN Business Unit
Texas Instruments

Introduction

802.11 Wireless Local Area Networking (WLAN) or Wireless Fidelity (Wi-Fi®) technology is being deployed successfully in enterprises and homes worldwide. As the implementation of Wi-Fi has grown, so has the number of new applications running on it. Initially, Wi-Fi was conceived as a simple Ethernet replacement for home and business networks and for industrial mobile computing, but over the last 12 months a new trend has emerged. Cost reductions and expanded capabilities have made WLAN technology a compelling solution for a wide range of devices that were previously unconnected to any WLAN. Some of these devices and new applications include the following:

- Cell phones/smart phones including cell phones with Voice over Internet Protocol (VoIP) capabilities for the enterprise
- Personal digital assistants (PDAs)
- Cordless phones with Wi-Fi VoIP capabilities
- Video game controllers, wireless audio speakers, video tuners for displaying MPEG videos on wall-mounted, flat-screen monitors
- Sensors and cameras for security and other purposes

Power consumption and battery life are critical for most of these new Wi-Fi-enabled devices but especially for cell phones and PDAs. Most Wi-Fi applications typically spend 90 to 95 percent of the time in a standby mode rather than actively transmitting or receiving data. Clearly, very low power consumption during standby operations is a requirement for long battery life. In response to this situation, TI has developed Enhanced Low Power (ELP™) technology to achieve best-in-class standby power consumption.

This white paper addresses the following question:

Which Wi-Fi (802.11) physical layer (PHY) technology best extends the battery life of portable Wi-Fi-enabled devices?

The PHY options are:

- 802.11b
- 802.11g or 802.11a/g

In theory, it would appear that the simpler, lower throughput 802.11b modulation scheme would result in lower battery power consumption. If one only examines the power consumed to transmit or receive a byte of data, for example, then an 802.11b device would consume approximately 30 percent less power than an equivalent 802.11a/g device for that same amount of data. But it can be very deceptive if the analysis is limited to an examination of solely the per bit or per byte power consumption when the device is in an active mode transmitting or receiving data.

Another critical factor in the overall power consumption of an 802.11 device is how long the device must remain in an active mode to transmit or receive a certain amount of data. Battery life is not just a function of the power consumed per bit of data in an active mode but also how much time the device must remain in an active mode to transmit or receive a meaningful amount of application data.

For example, while an 802.11b device may consume 30 percent less power than an 802.11a/g device to perform a single transmit or receive operation, that same 802.11b device must remain in an active state three to four times longer than an 802.11a/g device to transmit or receive the same amount of data. As a result, an analysis based on real-world usage patterns finds that on the average, an 802.11b mobile device shortens the life of a battery by consuming approximately two to three times more power during typical operations than would an 802.11a/g device.

The remainder of this white paper provides research, analysis and examples that support this conclusion. VoIP is used as an example application because it consumes more battery power than simple web browsing or several other applications.

802.11 Packet Structure

Because the time spent in an active mode plays such a critical role in the power consumption of a mobile device, a review of packet structures will elucidate why 802.11 modulation schemes differ in this regard.

During 802.11 packet assembly, payload data from the IP layer, or the data that is being communicated, is encapsulated with MAC (media access controller) data and another four-byte segment of data that functions as a check sum and is also referred to as CRC or FCS. All of this data is assembled into an MPDU (MAC Packet Data Unit). When the packet is transmitted, the PHY layer appends a synchronization header. A complete 802.11 packet is illustrated in the following diagram.

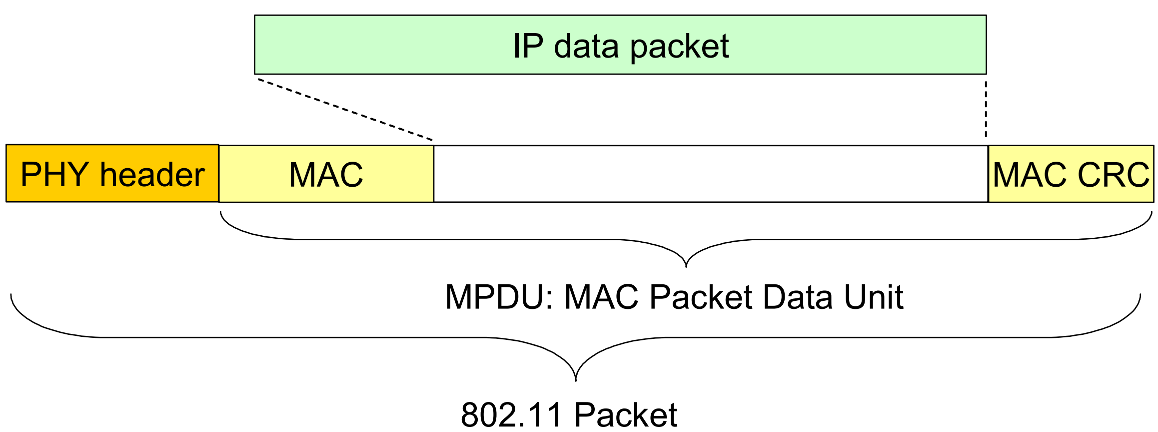

Figure 1 – 802.11 packet encapsulation

Research has shown that network traffic is dominated by short bursts of data. The graph on the next page illustrates a study by the IEEE which substantiates this point.

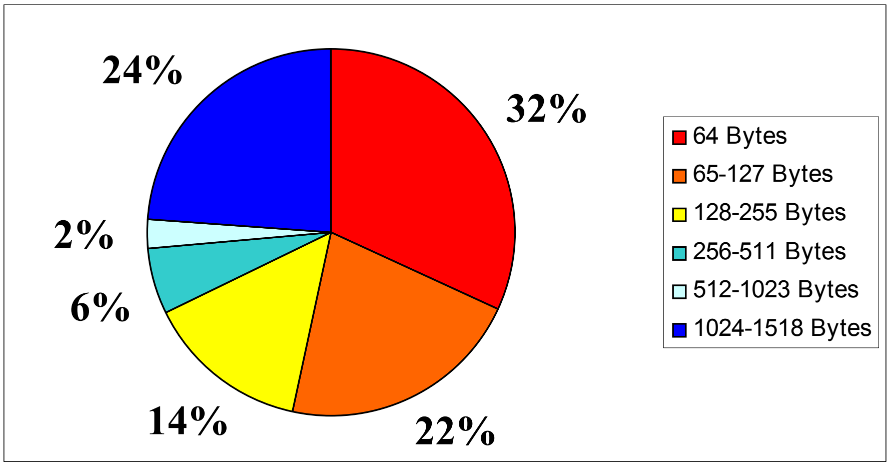

Figure 2 – IEEE network traffic packet size model

This study showed that 54 percent of IP traffic is made up of packets which are less than 127 bytes long. And 68 percent of network traffic is composed of packets that are less than 256 bytes long. Based on these research results, one can conclude that analyzing the effects of short packets on power consumption will provide an accurate indication of how power will be consumed in a real-world WLAN application.

A VoIP application provides a good example of the packet size encountered in the typical 802.11 network. For instance, the application could be configured to encapsulate 20 msec of coded voice. Differing by the type of voice codec implemented, the size of the voice data payload in a packet is shown in Table 1 below.

CODEC	Duration (bytes)
G.711	160
G.726 (16 kbps)	40
G.729 (8 kbps)	20

Table 1: Size or duration of a voice data payload according to different codecs in a VoIP application

The payloads shown above are then encapsulated in an IP packet. An RSVP protocol header to support QoS within the IP network is appended first. Then, a UDP header is attached. Finally, the packet is completed according to the dictates of either the IPv4 or IPv6 protocols. The total overhead for the entire IP packet is then:

- 44 bytes for IPv4
- 64 bytes for IPv6

In addition to the IP overhead, 802.11 MAC overhead must be added to it to form the MPDU. In this case, the latest 802.11e WME MAC header and FCS have been appended to the packet, adding another 32 bytes to its length.

Finally, the 802.11 PHY header must be concatenated to the MPDU. The length of the PHY header varies greatly by the 802.11 modulation method. The fixed header lengths for the several 802.11 modulation schemes are:

- 802.11b short 96 usec
- 802.11b long 192 usec
- 802.11a/g 20 usec

These figures show that 802.11b requires that the header appended to every data packet is five to 10 times longer than the header on an 802.11a/g packet.

The following figure illustrates the entire encapsulation process and the associated overhead:

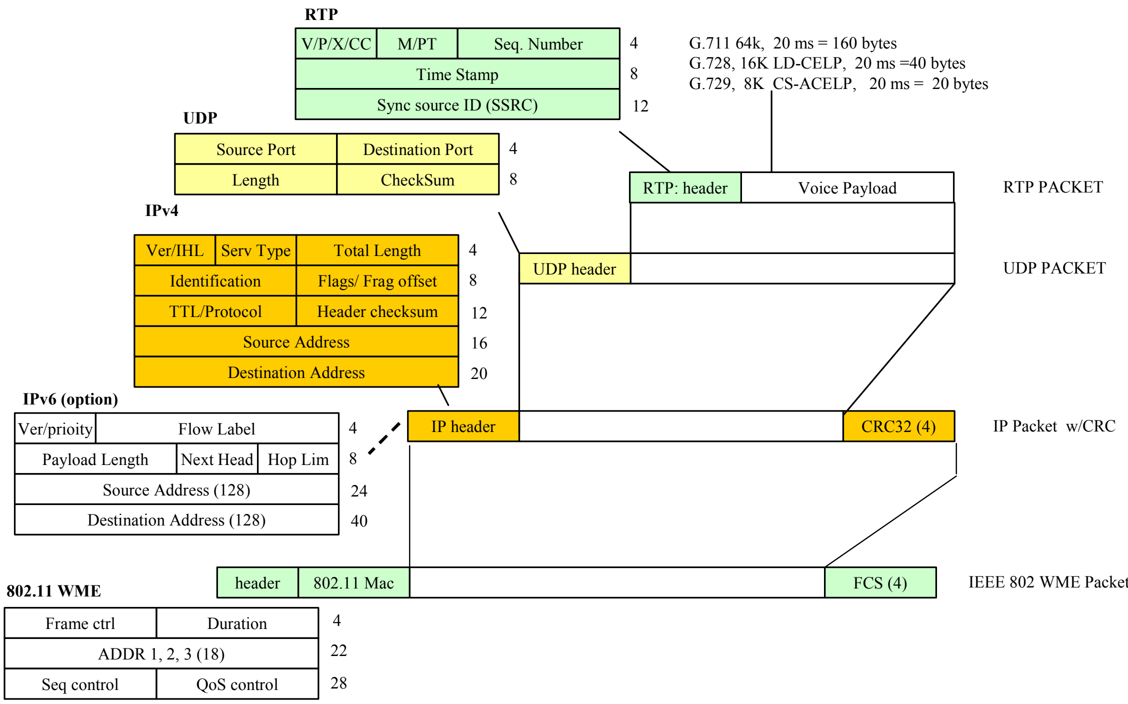

Figure 3 - IP and 802.11 encapsulation of VoIP packets

Conclusions on Overhead

Especially when 802.11 packets are short, overhead can dominate 802.11 traffic. When the standard IPv4 protocol is implemented, roughly 45 percent of the WLAN's traffic can be attributed to 802.11 MAC encapsulation overhead. Furthermore, 802.11b has a header that is strictly overhead and it is, at a minimum, five times longer than the 802.11a/g header.

The following section shows that lower data rates and longer headers cause grossly high power consumption for 802.11b WLANs relative to the power consumption of 802.11a/g networks.

The Duration of 802.11 Packets by Modulation Scheme

The following example illustrates the extreme dichotomy in active transmit or receiver time between the 802.11b and the 802.11g modulation schemes. A 20 msec G.729 VoIP voice packet was used in this analysis. To be as fair as possible to legacy 802.11b systems, the analysis assumes that the shorter 96 usec PHY header has been implemented.

Based on these assumptions, the following diagram illustrates the distinct advantages that 802.11a/g has over 802.11b with respect to the time required to transmit or receive VoIP packets.

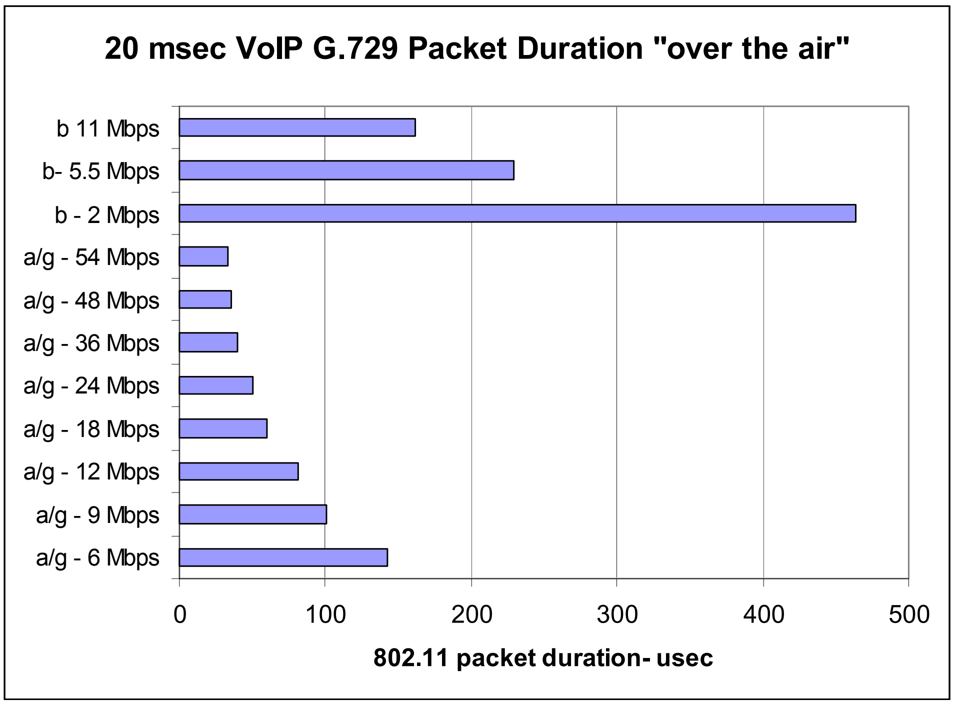

Figure 4 – Duration of 802.11b and 802.11a/g G.729 voice packets by modulation

Not only does this information apply to traffic with short data packets, but it also can be applied to all TCP/IP data traffic, as shown in the following figure for traffic with 512-byte packets.

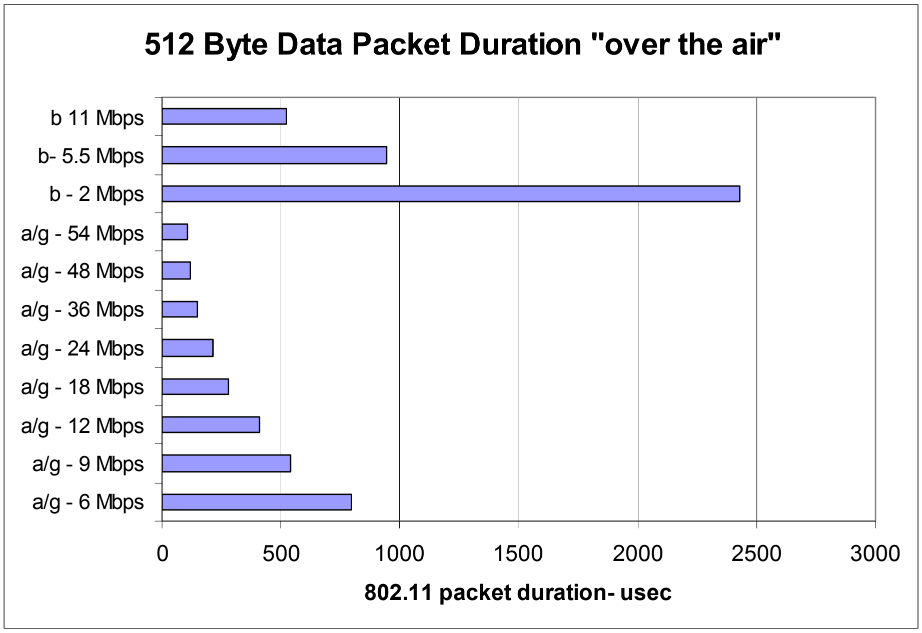

Figure 5 - Duration of 802.11b and 802.11a/g data packets by modulation

The analysis has shown that an 802.11b packet can be as much as five times longer than 802.11a/g packets and that most typical 802.11b packets are at least three to four times longer than 802.11a/g packets. Furthermore, if the 802.11 PHY header is included in the analysis, shorter packets, such as those that are typical of VoIP applications, have a significant advantage over longer packets regardless of the 802.11a/g modulation rate.

Table 2 below summarizes the number of times longer an 802.11b packet is when it is compared to an equivalent packet at a certain 802.11a/g modulation rate. In this example, the VoIP packet has a 20-byte payload while the data packet has a 512-byte payload.

Modulation	Data Packet	VoIP Packet
a/g - 6 Mbps	0.652	1.141
a/g - 9 Mbps	0.965	1.604
a/g - 12 Mbps	1.271	2.000
a/g - 18 Mbps	1.864	2.700
a/g - 24 Mbps	2.430	3.240
a/g - 36 Mbps	3.490	4.050
a/g - 48 Mbps	4.444	4.629
a/g - 54 Mbps	4.906	4.909

Table 2: Number of times larger (xN) 802.11b packets are when compared to 802.11a/g packets at different 802.11a/g modulations

Once there is an understanding of the significant difference in duration of packets between 802.11b and 802.11a/g, the power savings advantages of 802.11a/g can be addressed.

Comparing the Power Consumption of 802.11b and 802.11a/g

In a real-world Wi-Fi network, several characteristics must be taken into consideration, including the decreasing modulation rate as a user device moves away from the access point. In addition, the difference in power consumption between 802.11a/g and 802.11b is a critical factor in user satisfaction.

The following graph plots the range of a subscriber from an access point, the modulation rate at various distances from the access point, and the power consumption of an active station measured as energy consumed per bit transmitted. A typical office environment's propagation model with losses proportional to R^3.3 was assumed instead of the ideal propagation model with losses proportional to R^2. Modulation complexity and peak-to-average rates also were included in the analysis.

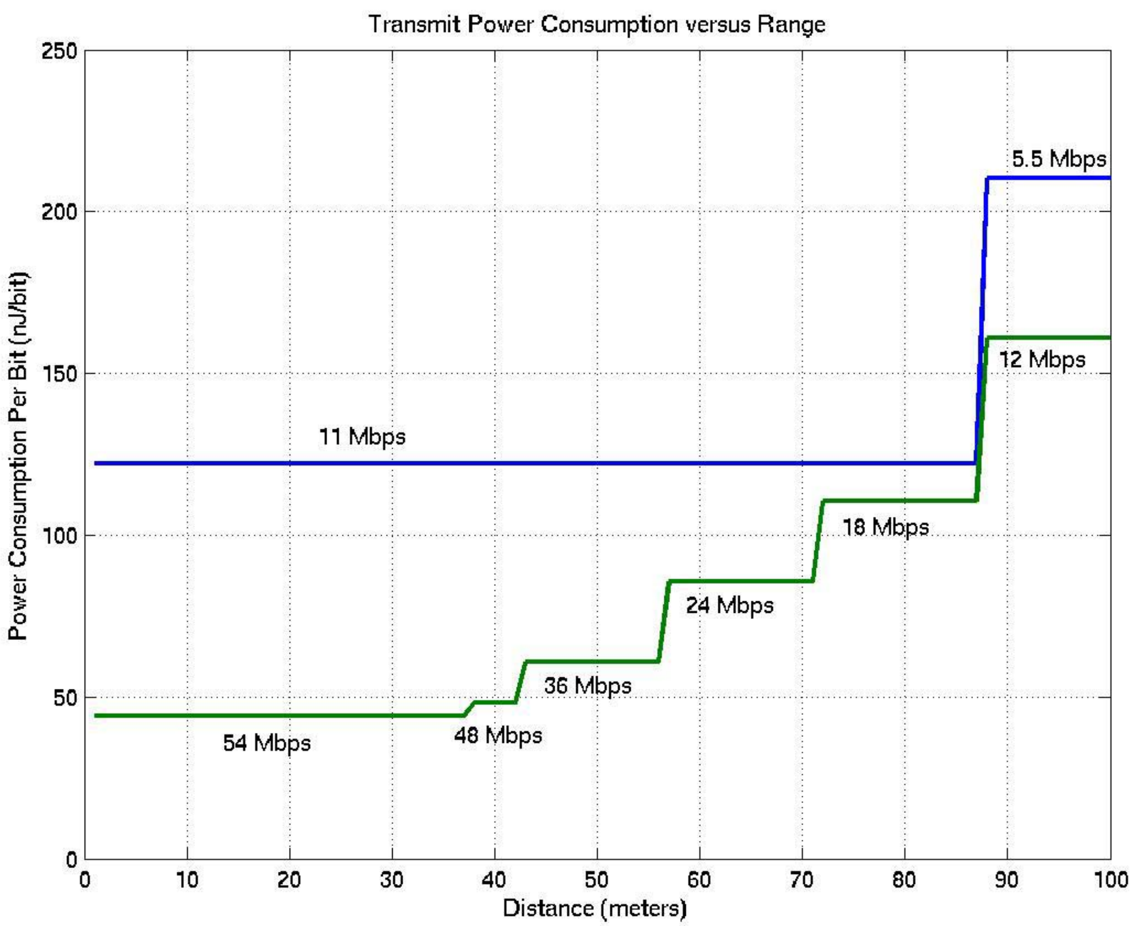

Figure 6 – Worst case energy consumed per transmitted bit (802.11b vs. 802.11a/g) (blue line = 802.11b and green line = 802.11a/g)

The data used in the graph on the previous page shows that the better power efficiency of 802.11a/g over 802.11b leads to a significant advantage of at least 2.5-times (2.5x) less power consumed per bit transmitted. And this power efficiency advantage has been derived from a worst case scenario using 802.11a/g packets that were longer than typical. In a typical WLAN with shorter 802.11a/g packets, the power consumption advantage of 802.11a/g over 802.11b increases to more than three times (3x).

Conclusions and Other Considerations

It may seem counterintuitive, but the fact remains that 802.11a/g modulation is two to three times more power efficient than 802.11b. This results in a significant improvement in battery life for mobile devices operating on a WLAN.

While 802.11b may consume less power at any instant in time, the length of time needed to transmit/receive a meaningful amount of application data can be five times longer on an 802.11b network than on an 802.11a/g WLAN. The power needed to support these longer transmit/receive times makes 802.11b much less power efficient than 802.11a/g.

To take full advantage of the power efficiencies of 802.11a/g, chipsets must be optimized for battery operation. These chipsets should provide:

1. Very low power under idle conditions. TI's solutions have the lowest idle power consumption of any chipsets available today.
2. Rapid wake-up cycle from idle to active state.
3. Ability to intelligently process 802.11 beacons. (TI's ELP operational mode is an example of this.)
4. Transmit power control.
5. Ability to support 802.11e WME and WSM QoS modes.

TI's TNETW1130 and TNETW1230 MAC controller/baseband processors as well as the Auto-Band™ family of radio frequency front ends (RFFE) include all of the requirements listed above in addition to many others. TI's Wi-Fi chipsets have become the chipsets of choice for next-generation Wi-Fi-enabled VoIP and data services in PDAs, smartphones, multimedia phones and devices, and Wi-Fi peripherals.

This white paper focused narrowly on improving the battery life of 802.11 mobile devices, but additional benefits can also be derived from 802.11a/b/g "world band" chipsets. These benefits include the following:

1. Over 30 Wi-Fi channels are available for 802.11a/b/g world band WLANs as compared to only three channels for 802.11b deployments.
    a. As a result of the greater number of channels, 802.11a/b/g Wi-Fi networks can more effectively avoid interference than WLANs with just three channels.
2. 802.11a/b/g Wi-Fi networks have over four times the throughput and capacity of 802.11b-only WLANs.
    a. A WLAN with higher throughput and capacity can support a more extensive set of applications which have greater performance requirements as well as a greater number of user devices.

Elaborating the issues is beyond the scope of this white paper, but they will be the subject of additional white papers that TI will be releasing over the next several months.

For more information, visit the Texas Instruments Web site:
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