IEEE 802.11n advantage

Most current embedded devices that integrate 802.11 WLAN use the legacy 802.11b or 802.11g standards. The data rates offered by these methods have been deemed to be sufficient for the relatively small amounts of data exchanged by these devices, and indeed, from the point of view of the embedded devices, the 802.11b/g data rates easily meet their transport requirements. But enterprises are increasingly moving towards the deployment of 802.11n based wireless networks. The IEEE 802.11n standard has defined the physical layer and MAC layer characteristics to significantly increase the end-user throughput that can be achieved in a given frequency channel. It has also defined the means to achieve high throughput over a much wider operational range than legacy WLAN. Because of this 'high throughput' thrust, the 802.11n standard is popularly associated with high speed communications between high performance computing platforms. Less known, but equally significant, is that it enables a much more efficient use of available spectrum. However, the benefits of 802.11n are realized fully only when all nodes on the wireless network are capable of communicating using 802.11n methods or are compatible with 11n. The presence of legacy 802.11a/b/g nodes in a network forces the other 802.11n nodes to resort to the use of protection mechanisms to preserve network integrity, thereby reducing overall network capacity by 30 percent or more. You may find a detailed description of this in http://www.embedded.com/columns/technicalinsights/209901733

Introduction

Most current embedded devices that integrate 802.11 WLAN use the legacy 802.11b or 802.11g standards. However, a significant evolutionary step has happened recently through the release of the 802.11n standard. The IEEE 802.11n standard has defined the physical layer and MAC layer characteristics to significantly increase the end-user throughput that can be achieved in a given frequency channel. It has also defined the means to achieve high throughput over a much wider operational range than legacy WLAN.

In this technical note, we describe the benefits of the standard and why all new designs that use WLAN connectivity, irrespective of what their individual throughput requirements are, should adopt 802.11n.

Throughput Enhancement in 802.11n

The IEEE 802.11n endeavor aimed at increasing user-level throughput – and this required it to address not only high PHY layer data rates but also the improvement of MAC layer efficiency through reduction of overhead.

Increase in PHY layer data rate is brought about by several means:

a) Increase in coding rate to reduce error correction overhead.

b) Use of a greater number of subcarriers to carry payload

c) Reduction of the guard interval

d) Use of higher bandwidths – a 40 MHz option in addition to the regular 20 MHz

e) Use of MIMO, or spatial multiplexing, with up to four streams transmitted on the same channel at the same time using four antennas

The table below summarizes the on-air data rates made available by the use of 802.11n PHY enhancements, with up to two streams, comparing them with legacy data rates.

Mode	Channel	Streams	Peak Data Rate (Mbps)
802.11b	22 MHz	One	11
802.11a,g	20 MHz	One	54
802.11n (800 ns GI)	20 MHz	One	65
	20 MHz	Two	130
	40 MHz	One	135
	40 MHz	Two	270
802.11n with short GI (400 ns)	20 MHz	One	72.2
	20 MHz	Two	144.4
	40 MHz	One	150
	40 MHz	Two	300

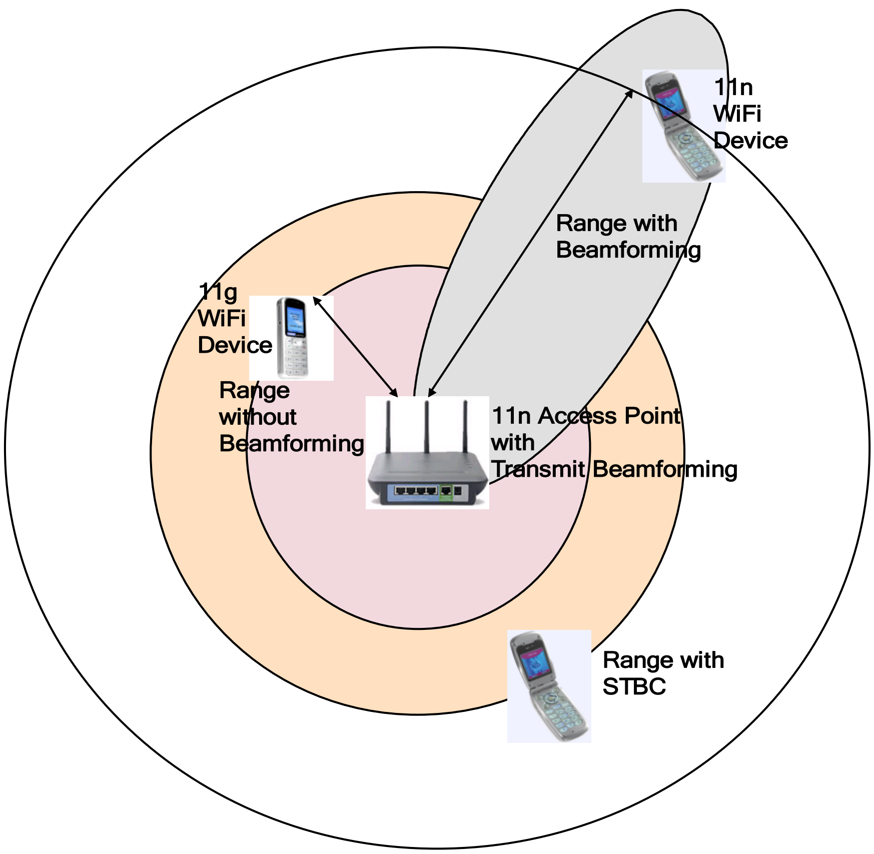
The primary objective of 802.11n being the provision of increased throughput to the user, there were several improvements made at the MAC layer. The fixed overhead in each frame, and including the interframe spaces, is considerable and at the higher physical layer rates afforded by the new standard, this overhead can often be longer than the data portion of the frame. And every attempt at transmission has a finite probability of ending in failure due to a collision. The 802.11n standard has defined packet aggregation methods to help mitigate these issues and to increase overall throughput. Aggregation is the concatenation of several frames into one large frame, with a sharing of overhead. Useful data payload forms a greater percentage of aggregated frames than they do in normal frames. Aggregation can be carried out on the Ethernet frames or on 802.11 format frames – in the latter case the individual frames of the aggregated superframe are acknowledged together through a block-ack.

MAC layer enhancements can contribute over a 50% increase in user throughput.

Antenna Diversity

Usable data rates in most indoor scenarios are usually limited by the nature of the signal degradation between the AP and the wireless node. 802.11n provides for antenna diversity to counter the effects of the multipath interference occurring in these cases. Multiple antenna techniques such as Space Time Block Codes (STBC), Advanced Beamforming (ABF) and Maximal Ratio Combining (MRC) increase usable data rates significantly.

The additional benefit to the network overall is that nodes in various locations in the network are serviced with higher data rates, thereby freeing up air time for greater network throughput across all users.



Network Capacity Advantage of 802.11n

When an 802.11n Access Point sees only 802.11n capable clients connected to its BSS, it is free to use all the 11n features it and the clients support. The 802.11n clients are guaranteed to support the decoding of frame length information from the PLCP header of each transmitted frame. The AP and clients therefore use 11n data rates and, if supported, Greenfield preambles and short GI options. The overall throughputs between the clients and the AP are therefore maximized.

In a network comprised of a mixed set of 802.11n nodes and legacy 802.11b/g nodes, the 802.11n AP and other 802.11n clients use RTS/CTS protection for 11n transmissions. They do this even if they detect legacy nodes in other BSS's in the same channel and vicinity.

A typical packet exchange in an all-11n network is shown below:

11n Network

9	100%	-42	58.0	98	0.677004	PING Req
9	100%	-36	24.0	14	0.000009	802.11 Ack
9	100%	-41	144.5	98	0.000378	PING Reply
9	100%	-38	24.0	14	0.000028	802.11 Ack
9	100%	-45	54.0	122	0.322195	PING Req
9	100%	-36	24.0	14	0.000008	802.11 Ack
9	100%	-42	65.0	122	0.000417	PING Reply
9	100%	-43	36.0	14	0.000007	802.11 Ack
9	100%	-44	58.0	98	0.676948	PING Req
9	100%	-39	24.0	14	0.000009	802.11 Ack
9	100%	-46	144.5	98	0.000365	PING Reply
9	100%	-40	24.0	14	0.000038	802.11 Ack

Let us compare this with a typical packet exchange in an 11n network in which there are one or more 11b or 11g clients associated:

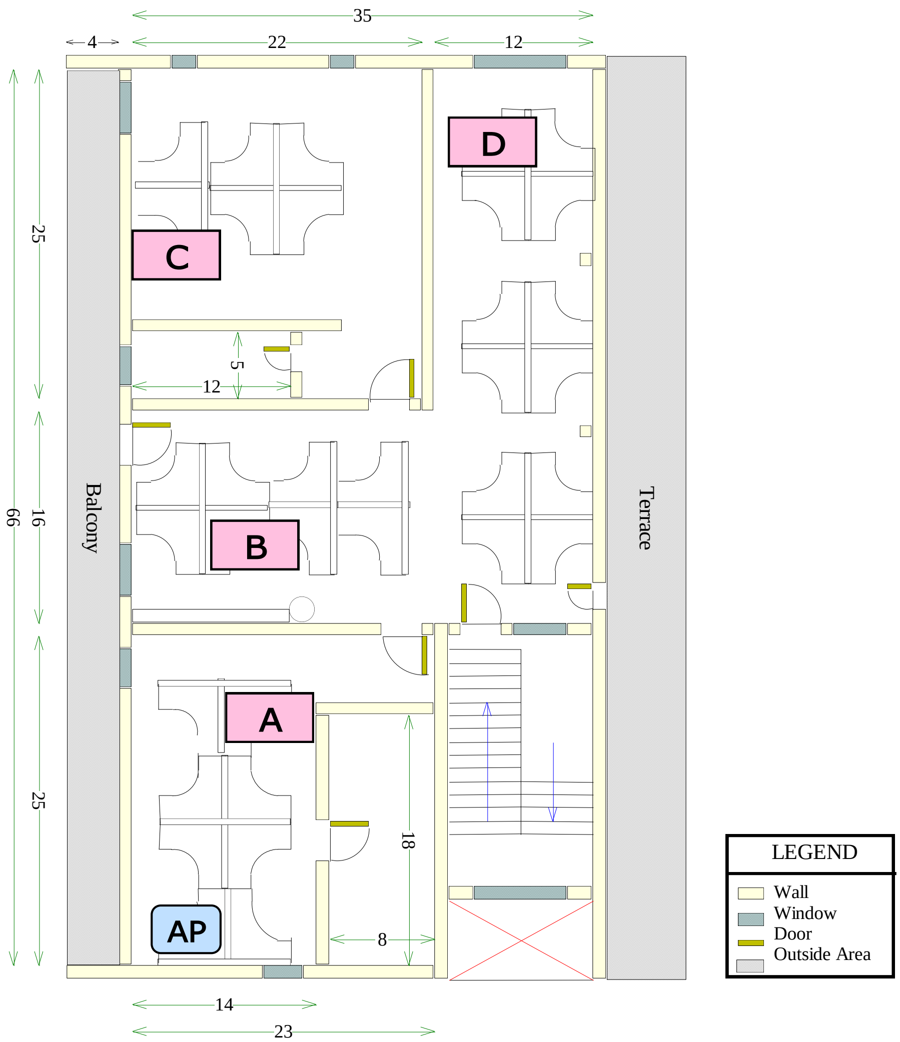
Mixed Network

9	100%	-36	6.0	20	0.000443	802.11 RTS
9	100%	-36	6.0	14	0.000012	802.11 CTS
9	100%	-43	144.5	1535	0.000003	UDP
9	100%	-36	24.0	14	0.000005	802.11 Ack
9	100%	-36	6.0	20	0.000407	802.11 RTS
9	100%	-35	6.0	14	0.000005	802.11 CTS
9	100%	-42	144.5	1535	0.000003	UDP
9	100%	-36	24.0	14	0.000004	802.11 Ack
9	100%	-36	6.0	20	0.000003	802.11 RTS
9	100%	-35	6.0	14	0.000331	802.11 CTS
9	100%	-41	[illegible]	[illegible]	[illegible].000004	UDP
9	100%	-38	24.0	14	0.000004	802.11 Ack
9	100%	-36	6.0	20	0.000386	802.11 RTS
9	100%	-37	6.0	14	0.000004	802.11 CTS
9	100%	-40	144.5	1535	0.000002	UDP
9	100%	-36	24.0	14	0.000005	802.11 Ack
9	100%	-36	6.0	20	0.000386	802.11 RTS
9	100%	-37	6.0	14	0.000004	802.11 CTS
9	100%	-44	144.5	1535	0.000003	UDP
9	100%	-36	24.0	14	0.000003	802.11 Ack
9	100%	-37	6.0	20	0.000414	802.11 RTS
9	100%	-38	6.0	14	0.000005	802.11 CTS
9	100%	-43	144.5	1535	0.000003	UDP

We can see that there are a lot of non-productive RTS/CTS exchanges. The loss in throughput because of the presence of the legacy node is a significant 30% or more.

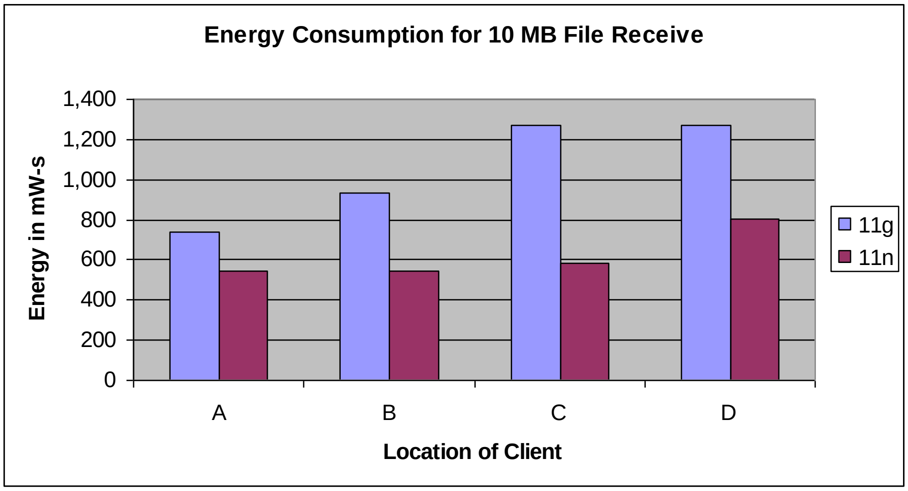
Battery Life Advantage of 802.11n

For battery operated devices, 11n provides greater energy efficiency. For example, let us consider a case where a user with a handheld device moves around in an office, and where he has the need to download data or files into his device via the access point positioned in the office. A plan of the office with the sample locations is shown below.



At each location the useable data rate of the device depends on the quality of the signal at that point. 11n, being capable of robust data transfer through techniques such as STBC and beamforming, would provide a higher useable data rate for a given condition. In this example we use STBC to provide the robustness. In addition to a higher useable data rate, we saw that 11n also helps reduce overhead to provide a greater efficiency of data transfer. These benefits together provide the ability to transfer data into an 11n handheld at greater energy efficiency than into an 11g device. Energy is saved mainly because the handheld device can enter into a low power standby state as soon as transfer is done – and this happens much sooner in an 11n environment.

The figure below summarizes the energy savings in this example.



Summary

In summary, the coming years will see billions of new devices getting connected to each other, and Wireless LAN based on the IEEE 802.11n standard will be a primary means of connectivity in these devices. For system designers today, choosing the right 802.11n wireless module is paramount to securing successful deployment in this promising market.