IEEE 802.11n Wireless LANs: Opportunity and Challenges

Executive Summary

The next generation of wireless local area network standards is nearing final approval in the IEEE standards process. The standard, known as IEEE 802.11n, is close enough to final approval that interoperable products incorporating this standard are being delivered to market today in anticipation of compatibility with the fully approved standard that comes later. This paper examines the standard, its position in the standards process, and the implications for the key markets where Wi-Fi is the dominant wireless networking standard today.

IEEE 802 Standards

The Institute of Electrical and Electronic Engineers (IEEE) is a professional organization of electrical engineers that has organized a highly successful and unique standards making activity. Arguably the most successful of these standards making activities has been under the auspices of the IEEE's 802 Committee which is responsible for networking standards at the data link (the Media Access Control or MAC) and physical (the PHYsical) network layers. Subcommittees of the 802 Committee have been responsible for the major networking standards that we use every day:

802.3	The entire family of Ethernet standards, defining both local and wide area communication on coaxial cable, twisted pair copper and optical fiber.
802.5	The legacy standards of Token Ring for network communication over coaxial cable and twisted pair copper and optical fiber..
802.11	The entire family of wireless local area network standards. Commercially known as Wi-Fi.
802.16	The entire family of wireless metropolitan area network standards. Commercially known as WiMAX.

In particular, the IEEE 802.11 Subcommittee is responsible for the family of evolving wireless local area network (WLAN) standards:

802.11	The original WLAN standard in 1997 using 1 and 2 Mbps PHY in the 2.4 GHz band.
802.11b	The enhanced standard for the 2.4 GHz band in 1999 providing 11 Mbps PHY.
802.11a	The enhanced PHY standard for the 5 GHz band providing 54 Mbps using OFDM (Orthogonal Frequency Division Multiplexing) modulation in 1999.
802.11g	The enhanced PHY standard for the 2.4 GHz band providing 54 Mbps using OFDM with backwards compatibility to 802.11b in 2003.

The variants of 802.11 all use a common MAC protocol. Other auxiliary standards in the family (c–f, h, I, j) are service enhancements and extensions or corrections to previous specifications.

The IEEE 802.11n subcommittee was chartered by its parent IEEE 802.11 committee in 2003 to develop high performance enhancements to these standards.

Wi-Fi is a brand of the Wi-Fi Alliance - a commercial organization that certifies interoperability of products implementing the 802.11 IEEE standard and promotes the standard though market education.

What's New About 802.11n?

IEEE 802.11n is the most significant change in the wireless LAN world since the adoption of the original standard in 1997. 802.11n defines enhancements for both the MAC and the PHY. The greatest impact of 802.11n is in the technology used for the PHY. The ability to create low-cost radios in CMOS now allows the simultaneous use of multiple radios and antennas in every client. Advanced signal processing enables 802.11n to integrate multiple radios and a number of other PHY improvements to effectively increase the burst transmission speed and the total system capacity by a factor of ten when all of the new enhancements are used.

802.11n PHY Improvements

Improved coding and modulation

802.11n updates the OFDM methods pioneered by 802.11a for bit and frame encoding. The more efficient OFDM used in 802.11n produces a maximum data rate of 65 Mbps per stream compared to 54 Mbps for 802.11a and 802.11g systems. These changes result in 20% more burst transmission speed.

MIMO and Spatial Multiplexing

802.11n introduces smart radio technology to dramatically increase the quality and speed of the PHY by creating multiple simultaneous data streams. Previous wireless systems have modestly used multiple antennas at the receiver to take advantage of the fact that a transmission from a source to a destination may take multiple paths based on reflections from obstructions in the direct path between source and destination. Historically, multipath has been viewed as a signal impairment that degrades the quality of the radio transmission. 802.11n exploits multipath to enhance the delivery of multiple spatial streams.

802.11n systems employ MIMO (multiple input, multiple output) which defines multiple transmit and receive radios – each with its own antenna – that combine to deliver multiple streams of data between stations on the same channel. By digitally controlling simultaneous transmissions and reception, 802.11n stations can effectively multiply the data rate by the number of simultaneous spatial streams they support. 802.11n defines up to 4 spatial streams. The Wi-Fi Alliance 802.11n Draft 2 certification requires that systems support at least 2 spatial streams. Spatial multiplexing can increase the burst transmission rate up to 4 times.

Channel Bonding

802.11n allows channel aggregation that bonds two adjacent 20 MHz channels into a single 40 MHz channel in both the 2.4 GHz and 5 GHz bands. Channel bonding doubles the burst transmission rate. The overall system capacity for large systems with many access points will not increase, since more spectrum is consumed. However, for smaller networks with one or two access points, it can increase total capacity as well. Channel bonding is supported in both the 2.4 GHz and 5 GHz bands. Only one independent 40 MHz channel is possible in the 2.4 GHz band. Channel bonding will be most useful in the 5 GHz band for green field 802.11n networks.

Beamforming

Beamforming is an optional feature of 802.11n. It is a natural extension of the physical layer that has multiple radios and antennas in each station. By controlling the transmit power and phase of the collection of transmission antennas, it is possible to shape the effective gain of the antennas to create a pattern that points towards the receiving station - a beam. Beamforming will be used to extend the effective range and create more robust coverage with 802.11n systems.

Shorter Guard Interval

802.11n reduces the Guard Interval (GI) from 800 nanoseconds to 400 nanoseconds. This small change increases the symbol rate by 10 percent.

More Available Spectrum

802.11n supports both 2.4 GHz and 5 GHz bands. It has a single MAC that operates with a multiple frequency physical layers. This is really a configuration benefit rather than a PHY feature.

Frequency Band (GHz)	Independent 20 MHz Channels	Possible 40 MHz Channels	
2.40-2.485	3	1	Indoor/outdoor
5.15-5.25	4	2	Indoor only
5.25-5.35	4	2	Indoor/outdoor
5.47-5.75	10	5	Indoor/outdoor, dynamic frequency selection and power control
5.75-5.85	4	2	Outdoor
Total	25	12	

802.11n makes use of the legacy 2.4 GHz band and constructs three (3) largely non-interfering 20 MHz channels or 1 20 MHz channel and 1 40 MHz channel. It is backward compatible with 802.11b/g stations and channelization. 802.11n makes use of the existing 802.11a channel set in the 5 GHz band at (5.15-5.25, 5.25-5.35, and 5.75-5.85 GHz) to construct 12 non-overlapping 20 MHz channels or as many as 6 non-overlapping 40 MHz channels.

802.11n also takes advantage of new worldwide regulatory changes making the 5.47-5.75 GHz band available for unlicensed WLAN use. Existing primary users of this band (largely radars) have heretofore limited its use, but the Dynamic Frequency Selection and power control features defined by the companion standard 802.11h and new regulations open up this band to use.

802.11n MAC Layer Enhancements

The 802.11n MAC protocol is more efficient than the 802.11 legacy MAC protocol.

Frame Aggregation

The 802.11n MAC allows successive frames to be combined and supports frames up to 64 k bytes with the Aggregated MAC Protocol Data Unit.

Block ACK

Block ACK enables multiple frames to be transmitted and then acknowledged with a single ACK frame.

These and other MAC improvements reduce protocol overhead and improve the efficiency of the MAC protocol resulting in higher throughput. The new mechanisms also allow new 802.11n equipment and legacy 802.11 a/b/g equipment to share the airwaves more fairly in a mixed network.

The impact of MAC performance improvements will be more subtle than the PHY improvements. The amount of performance gain will vary according to the type of application traffic and the mix of legacy and new stations in the network. With all of the enhancements and the most optimistic set of conditions, these improvements could double the effective throughput.

Benefits of 802.11n

Irresistible Performance and Range

The greatly enhanced 802.11n PHY introduces a very large number of options for communications between stations based on number of antennas, number of spatial MIMO streams, optional beam forming, modulation method and forward error correction (FEC) coding options. However, the standard is silent on algorithms to guide the choice between these options. It is expected that more mature 802.11n implementations and experience in the field will be required in order to learn how best to employ all these options.

802.11n certainly fulfills its charter of higher performance. In particular, it delivers a substantial step forward from the legacy 802.11 standards to provide:

Increased Range - By two times or more with improved robustness to fading. This increased range will be particularly important for networks utilizing the 5 GHz channels. 802.11n makes 5 GHz far more usable and thereby substantially increases the effective capacity of system.

Increased Data Rate - By up to ten times the burst data rate of legacy 802.11 a/b/g systems. For advanced stations using maximum MIMO techniques to deliver 4 spatial streams, channel bonding, and short GI; burst data rates of up to 600 Mbps are possible.

Improved Quality of Service - In addition to modest 802.11n MAC protocol improvements that improve efficiency, most implementations of 802.11n will include the Quality of Service enhancements of 802.11e to further improve streaming media performance.

Compelling Capacity

After throughput and range, the greatest improvement of 802.11n is dramatically increased wireless capacity. The improved physical layer of 802.11n will modestly improve system capacity in the 2.4 GHz band, but the existence of legacy equipment will minimize that improvement. The extended range provided by 802.11n overcomes many of the real world deployment challenges of 5 GHz 802.11a networks. Novarum testing of Draft 802.11n products shows that 802.11n operating at 5 GHz will have similar range to legacy 802.11g networks in the 2.4 GHz band – at the maximum data rates. The combined performance benefits of 802.11n enable more practical enterprise deployments at 5 GHz. The result is that 802.11n will be able to operate effectively across many more channels and therefore deliver much higher capacity in a given area. With 3 channels in the 2.4 GHz band and 22 channels in the 5 GHz band, advanced 802.11n systems will be able to deliver as much as 7.5 gigabits of raw capacity at any given location.

No Network Left Behind

As with any network standard, 802.11n is compatible with previous generations of the standard. The amazing thing about 802.11n is that it makes legacy networks better. 802.11n clients work with legacy infrastructure at the highest possible performance, and adding 802.11n access points makes legacy clients work better. 802.11n includes backward compatibility for 802.11a/b/g. It anticipates an 802.11n station participating in three types of networks:

Legacy - A network in which all stations use PHY and MAC features of legacy networks - 802.11a/b/g.

Mixed - A network in which stations use a mixture of legacy 802.11a/b/g as well as native 802.11n MAC and PHY features. Special care is taken to insure effective sharing of the channel and interoperation of the all stations.

Greenfield - Stations are all 802.11n, communicating solely to other 802.11n stations.

Our testing suggests that 802.11n clients will allow legacy 802.11a/b/g access points to deliver more consistent performance and range and in turn, 802.11n access points will deliver more consistent performance and greater range to legacy 802.11 a/b/g clients. This improvement is not large enough to motivate replacement of a working legacy 802.11 b/g network with 802.11n for most enterprises. However, upgrading to an 802.11n Wi-Fi router in a home Wi-Fi network will act as a range booster for all of the wireless devices.

Challenges of 802.11n

Enterprise Deployment Challenges

The additional capacity of 802.11n exacts its own price on the wired network infrastructure that supports Wi-Fi. Large-scale Wi-Fi deployments in particular are usually based on a wired Ethernet network that supplies both backbone trunking between Wi-Fi access points and power over the network wiring through Power Over Ethernet (POE).

Moving the Network Bottleneck

Enterprise class 802.11n access points will often be capable of delivering more than 100 Mbps of useful capacity each. The first wave of Draft 2 802.11n APs will support at least two spatial streams with a short GI. That yields 145 Mbps of raw capacity. With the new MAC enhancements, 100 Mbps of IP throughput per AP is possible. Channel bonding and more spatial streams will increase capacity per AP even further. Hundreds of APs with these capabilities will strain the wired infrastructure of many enterprises. In some networks, the wired core network will become the bottleneck rather than the wireless LAN at the edge. When deploying an 802.11n wireless LAN, enterprises will have to consider upgrading their wired infrastructure as well.

Newer 802.11n multi-radio access points will consume more electrical power than legacy 802.11a/b/g access points and more than the current POE standard delivers. This will require an upgrade of the wired infrastructure to the next generation POE standard or provisioning two Ethernet drops per AP location.

System Architecture Choices

The dominant Wireless LAN architecture for enterprises has been a central Wireless LAN controller that manages and secures a set of “thin” APs. The WLAN controller provides management, security and deployment tools for the entire wireless network. All of the wireless traffic passes through the WLAN Controller. The improvements of 802.11n can be difficult for a centralized WLAN Controller architecture to handle and have prompted a new round of innovation at the system level. 802.11n APs are getting “fatter” anyway – they have more radios and are more complex than legacy a/b/g APs. The significant increase in data rate and capacity brought by 802.11n challenges the wisdom of aggregating all of the wireless traffic back through a single node in the network.

New system level architectures are being proposed for 802.11n in the enterprise.

Scaled up WLAN controllers – 802.11n APs deliver ten times the capacity, so create a new bigger WLAN controller that can handle that increase and leave the network architecture the same.

Distributed clusters of controllers – each WLAN controller is smaller and manages a subset of APs. The clusters communicate with each other to manage system wide functions.

Hierarchical network of controllers – define the notion of edge controllers and master controller. Data and management traffic are split and routed directly from the edge controllers. Only management traffic flows to the master controller.

No controller at all – back to the future. New APs are "fat APs" capable of independent operation without a controller. For large deployments there is a management appliance

Co-channel Interference

One of the biggest and least appreciated challenges of large-scale enterprise Wi-Fi deployments is the problem of interference. In particular, the self-interference between nearby Wi-Fi cells served by different access points in the same system. The vast majority of enterprise Wi-Fi networks today are constructed using only the three non-overlapping channels of the 2.4 GHz band to create a microcellular architecture. Three channels are not sufficient for adequate isolation between micro-cells on the same channel. The interference range of Wi-Fi is much greater than the effective communication range. A substantial amount of system capacity is lost to interference from micro-cells operating on the same channel – often quite some physical distance away.

802.11n improves this situation by opening up the additional channels in the 5 GHz band thus introducing many more new channels that can mitigate this self-interference challenge. However, while more channels help – they do not eliminate the problem entirely. The use of smart antennas in 802.11n, particularly with beam forming, dramatically increases range but not necessarily in predictable or manageable patterns. While the range increase is welcome, it also brings with it increased interference at distance. These issues suggest that though the problem of interference is reduced with the advances of 802.11n; it will continue to be a key challenge in the design of large scale, high performance 802.11n Wi-Fi networks.

New Coverage Patterns

The range of 802.11n networks is much better that its predecessors, but the way that range is achieved is very different and much more sensitive to the physical environment. Local multi-path conditions allow greater range in some directions preferentially to others resulting in unpredictable coverage. These new coverage patterns will interact with "adjacent" access points in ways that existing network planning and site survey tools do not anticipate. New versions of these tools will be required to help manage the deployment of 802.11n networks in the enterprise. Conventional wisdom about how to deploy wireless LANs in an office environment

Variety of Client Devices

Coverage and range will also vary depending on the type of client using the 802.11n infrastructure. Like any 802 standard, 802.11n includes the provision of supporting earlier version of the standard. So there will be 802.11b, 802.11g and 802.11a clients operating on 802.11n infrastructure. These devices will have very different range than 802.11n clients. 802.11n introduces the possibility of a wider variety for client devices – from low-power single radio, single antenna clients to multi-radio clients supporting up to four spatial streams and beam forming. The different client capabilities will make designing 802.11n networks for coverage much more complicated. Do you optimize the system design for the 802.11g Voice over Wi-Fi handsets or the dual band 802.11n notebook computers with intelligent antenna systems that support 3 spatial streams?

MAC Protocol Challenges

The original 802.11, just like its wired inspiration 802.3 Ethernet, was designed as a best effort network delivery system. And just like Ethernet, Wi-Fi is now supporting applications that require more than best effort delivery in order to function properly. Even though 802.11n delivers much higher throughput and capacity, high-density mixed voice, video and data applications will continue to put a strain on enterprise Wi-Fi systems. For streaming applications, managing delay and delay variance is often more important than throughput. IEEE 802.11e combined with the raw throughput improvements of a 802.11n network will offer some relief, but best performance at scale will require end-to-end delay and jitter management of these services on a per application basis.

Even with the channel capacity enhancements of 802.11n, large network configurations with many stations allocated to a single channel will occasionally be offered more load than the channel can effectively handle. The underlying access Listen Before Talk MAC protocol of 802.11 offers each station on a channel served by an access point, including the access point, an equal opportunity to transmit. Conventional Wi-Fi APs serving N stations will be granted 1/(N+1) th of the opportunities to transmit even though the AP participates in all of the communication to its associated stations and therefore has roughly half of the traffic to transmit.

In a small or lightly loaded network this effect is not noticed. But under conditions of stress, the access point may be starved for airtime and overall performance will decrease. Under high load and marginal radio conditions, the 802.11 protocol is less efficient in sharing the channel. Too much of the airtime is spent with retransmissions. It may be more effective to have higher layer protocol mechanisms throttle client applications in order to match load to capacity, and thereby avoid the negative channel overload behavior.

Is it Soup Yet?

The current Draft 2 802.11n Standard was approved in March 2007 by over 81% of the voting membership of the IEEE 802.11 working group. The current IEEE 802.11 schedule shows that the standard will not be completely ratified until late 2008. However, there are no substantive technical issues remaining. 802.11n chipsets are available today and some vendors are already shipping second or third generation 802.11n products.

Though the standard is not officially completed, the Wi-Fi Alliance is now certifying 802.11n Draft 2 products. Some vendors are cautiously guaranteeing that their products will comply with the final standard through a future firmware upgrade.

We believe that enough work and implementations have been done to demonstrate the stability and effectiveness of current designs. We expect that tweaking of 802.11n implementations at the system will continue for some time as the industry builds experience with this new type of wireless LAN. More capable 802.11n products supporting additional spatial streams will be coming in the future. However, current products are really quite usable and in most cases will be compatible with the final, official standard.

Consumer and Small Business Already Moving

The consumer and small business markets are the first to adopt 802.11n, and will ultimately speed the process for other markets – just as consumer adoption of 802.11g did in 2003. As early as 2006, so-called "pre-N" non-standard products have been sold to this market. These early products delivered many of the benefits (increased range and performance) of 802.11n in non-standard products. But the lack of interoperability across different vendors stalled wide-scale deployment of these early products. With the adoption of a firm draft 802.11n standard, and Wi-Fi certification for Draft 2 802.11n products, this limitation is effectively removed.

Apple quietly converted all of its wireless products to be native 802.11n in early 2007. We expect to see most other computer and consumer electronic manufacturers move to 802.11n in their next product cycle – Lenovo, Dell and HP have already done so in recent notebook products incorporating dual-band 802.11n capability. Consumer products featuring wireless distribution of high definition video streams through 802.11n will be coming soon.

The low-cost availability of built-in dual band 802.11n clients in a variety of mobile devices will accelerate the deployment of 802.11n in the enterprise and metropolitan networks.

Recommendations

There is no reason for consumers to hold back on purchases of 802.11n. The Wi-Fi Alliance has addressed the interoperability issue by certifying Draft 2 802.11n products. A computer with an 802.11n client will function as the best possible client on legacy Wi-Fi networks in the home or office. When the Wi-Fi infrastructure is upgraded to support 802.11n, those clients will be able to deliver the additional performance promised by 802.1n.

Upgrading the infrastructure in a home network to 802.11n will act as range booster for legacy Wi-Fi products in the home.

Possibilities for Metro Wi-Fi

The universal inclusion of Wi-Fi as part of the standard laptop and increasingly other consumer electronic devices has created the opportunity to use Wi-Fi as an access network for metropolitan scale wireless networks.

Now, many such metro Wi-Fi networks are being deployed and many more are under consideration. The inevitable migration of almost all Wi-Fi clients to 802.11n technology will have a strong influence on the success of these Metro Wi-Fi networks.

The conventional architecture for a Metro Wi-Fi network consists of access nodes offering Wi-Fi service (802.11b or g) mounted on light poles throughput a city. The Metro Wi-Fi nodes are usually interconnected through a wireless mesh or a fixed wireless point to multi point network. Today Metro Wi-Fi networks are deployed at 40 nodes per square mile in suburban areas and up to 100 nodes per square mile in urban centers.

Novarum's measurements of Metro Wi-Fi networks shows that the primary performance limitation of these networks is from the poor radio performance of the low power client devices typically accessing the network. The Metro Wi-Fi infrastructure APs are operating at the highest possible to the access node. Better quality in that link would permit better coverage at the same node density or (less likely) lower density coverage and hence reduced cost.

Client stations will be migrating to 802.11n very quickly for the reasons outlined in our analysis of the consumer market. This client upgrade alone will have a positive impact on Metro Wi-Fi networks using 802.11g infrastructure. The coverage of these networks will appear to be more solid for a client using 802.11n technology.

Although 802.11n is considered primarily an indoor technology because of the way it leverages multipath to improve performance, it will eventually be used in outdoor Metro Wi-Fi network infrastructure as well. The better quality radio and antenna systems will have a positive impact on Metro Wi-Fi deployments. Even though these networks will be in legacy mode for many years to come and primarily operate in the 2.4 GHz band; 802.11n infrastructure will improve the economics of Metro Wi-Fi networks by providing superior coverage.

Recommendations

Cities and service providers should encourage Metro Wi-Fi customers to use 802.11n technology in their PC clients and home routers. They will have a better experience using Metro Wi-Fi networks.

Enterprise Adoption Incremental and Inevitable

802.11n will deliver substantial long-term value to the enterprise. It will help enable the delivery of all enterprise applications wirelessly with performance similar to 100 megabit Ethernet and will deliver enough capacity to serve a completely wireless enterprise and will occur over time. However, 802.11n is not an instant panacea for the enterprise.

There are many perfectly good 802.11a/b/g networks in operation today. Deployment of 802.11n within enterprises will be incremental and will occur over time.

There are four principal advantages of 802.11n for medium and large enterprise:

Performance	With net station throughput approaching 100 Mbps, 802.11n based networks will have the speed to support all enterprise class applications including converged voice/data/video at performance levels similar to what is delivered by 100 Base T Ethernet systems today – but with the added cost savings and operational advantages of wireless deployment.
Capacity	The coverage increase, particularly in the 5 GHz band, means that the largely unused 5 GHz band becomes truly useable for enterprise class deployments. Effectively this means that almost 7 gigabits of raw throughput is available at any given location.
Security	The default security for 802.11n networks will be high-grade WPA2 (which includes 802.11i), further decreasing the perceived security risk of Wi-Fi and building on the end to end enterprise class security infrastructure built around Ethernet networks.
Value	The wide scale adoption of 802.11n in the consumer and small business markets will enable the wide spread adoption of client side 802.11n interfaces in most mobile platforms and drive volume pricing of 802.11n semiconductors for the infrastructure as well.

Applications Performance

Simple high performance data throughput will thrive with the deployment of 802.11n, but many enterprise class applications require more.

The uncertainty of the precise coverage area of this generation of 802.11n likely means that roaming from access point to access point in a micro-cellular Wi-Fi infrastructure may not be as seamless as it has been with legacy enterprise Wi-Fi networks. Current algorithms for roaming and association may not work well with 802.11n initially and will need to be adjusted to account for the nuances of 802.11n. Since it is the Wi-Fi client that controls roaming, these changes may take a while to propagate.

Migration and Compatibility

802.11n will support legacy 802.11b/g/a stations and access points. The security and QoS parts of the standard, 802.11i and 802.11e, will apply to 802.11n as well.

Network channel planning will become more complex, with over 25 channels available for 802.11n systems in both 2.4 and 5 GHz. New channel plans must deal with existing Wi-Fi as well as plan for new 802.11n capabilities. New tools will be required to manage this greatly enlarged and complex spectrum model.

Both clients and infrastructure must change in order to get full benefit of 802.11n. Replacing an existing well-engineered 2.4 GHz 802.11 b/g network with a 802.11n network is unlikely. The new infrastructure will incrementally improve the existing service to 802.11b/g clients but the constraints of the existing channel structure in 2.4 GHz will not allow full performance of 2.4 GHz 802.11n stations.

Incremental deployment of new 802.11n stations under a new 802.11n infrastructure operating as a greenfield network at 5 GHz is the more likely deployment scenario.

Infrastructure

The performance capacity of an enterprise class 802.11n access point will likely exceed the throughput of the typical 100 megabit Ethernet backbone connection. The power requirements of multi-radio 802.11n access points will exceed the limits of existing 802.3af Power Over Ethernet.

Both of these issues will mandate that enterprise class 802.11n infrastructures will require an upgrade of the wired network to gigabit Ethernet backbone connections and a high capacity switching backbone. Existing wireless security and management systems may indeed require upgrade to handle new higher traffic levels.

Security

802.11n requires the highest level wireless security standard and is fully compatible with 802.11i. Existing network security systems should straightforwardly migrate to incorporate a 802.11n subnetwork.

However, the wide availability of 802.11n exacerbates at least one aspect of enterprise security - rogue APs. It becomes straightforward to add a 802.11n high performance 5 GHz access point (such as the newer Apple Airport Extreme) that will be undetectable by most existing Wi-Fi security tools.

Almost all enterprise networks will have to invest in upgraded 802.11n dual band intrusion detection and prevention security tools even in advance of their own widespread 802.11n deployment.

Enterprise Deployment Expectations

Enterprises adopting wireless LANs will inevitably migrate to 802.11n for superior range, performance and capacity.

Well-engineered existing Wi-Fi networks are likely to be retained and operated as legacy Wi-Fi networks.

The new standard for enterprise computer wireless clients should be dual-band 802.11n capable as procured on natural equipment replacement cycles or for particular projects with special performance requirements. These clients will perform as well as the best 802.11g clients on existing 802.11 legacy networks, and should be available at no price premium. Enterprises can purchase these now and get the benefit of 802.1n performance as they upgrade their infrastructure.

Beginning in early 2008, as sufficient installed base of 802.11n capable clients are available, enterprises will consider the deployment of a parallel 5 GHz 802.11n greenfield networks to support these more capable 802.11n clients. Support for 802.11n will require matching changes in the design of the wired backbone for the 802.11n infrastructure.

Large scale deployments of 802.11n will require debugging of such issues as coverage planning, interference and roaming that are not yet well understood for 802.11n. We expect that these issues will be much better understood in 2008 as the entire Wi-Fi ecosystem builds more 802.11n deployment experience.

Recommendations

New client computers should be purchased with dual-band 802.11n Wi-Fi interfaces. 802.11n clients should be purchased now regardless of when an enterprise anticipates upgrading its infrastructure to 802.11n. These new computers will offer improved performance with legacy Wi-Fi networks as well as providing all of the benefits of 802.11n when operating on greenfield 802.11n networks. Wi-Fi Certified Draft N products should work well for the enterprise.

Wireless network infrastructure such as WLAN controllers and security tools should be purchased with support for 802.11n in mind. Early acquisition of 802.11n capable intrusion detection and security tools will be required for every enterprise network whether deploying 802.11n or not.

When designing a network for 802.11n, assume 100 to 200 Mbps of useful capacity delivered by each access point. Evaluate the wired network infrastructure to determine if it can support this additional load.

Every enterprise wireless network has unique requirements based on the environment in the buildings, the wired network supporting it, the number of users, and the types of applications supported. The design of a new 802.11n network will vary depending on these requirements. There are some general guidelines that apply:

Use the multi band capability of 802.11n. Deploy networks that leverage both the 2.4 GHz band and the 5 GHz band.

Leave legacy Wi-Fi products in the 2.4 GHz band. The network infrastructure for this can be a mix of legacy 802.11 b/g access points and new 802.11n access points operating in legacy mode. The 2.4 GHz subnetwork can be used to support legacy 802.11 b/g clients and also guest access to the enterprise network.

Develop a 5 GHz network to support new, more capable 802.11n client devices. Implement strict security policies and control the capabilities of clients accessing the 5 GHz subnetwork. Use the newer capabilities of 802.11n in the 5 GHz band including channel bonding if that is required. Force less capable clients (legacy a/b/g or new 802.11n clients with only one radio) to use the 2.4 GHz subnetwork. This will insure that the 5 GHz subnetwork operates at maximum performance and can deliver all of the promise of 802.11n.

Conclusions

It's All Good

802.11n will substantially increase the performance and ubiquitous wireless access of laptops, desktops, smart phones and entertainment devices over the next several years.

Without cost increase, just like the migration from 802.11 cousin 10 Mbps Ethernet to gigabit Ethernet, 802.11n will first appear in client devices and begin to be pervasively deployed in enterprises, homes and eventually metro networks.

While their will be teething problems with this new technology, there is no doubt of its pervasive and inevitable deployment.