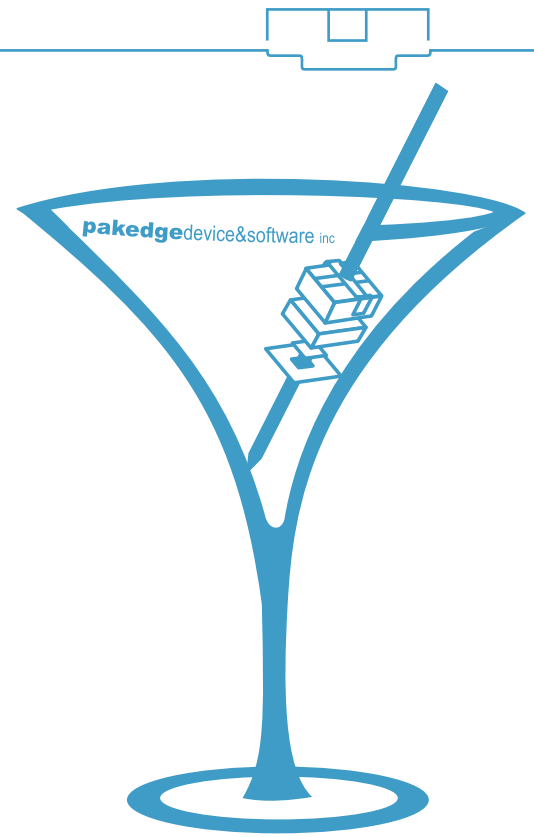


802.11n – Know its Limits

Pakedge Device & Software creates innovative networking products for people who demand performance, features and reliability. Our products use the most advanced wireless and networking technology and are designed for professionals to install and consumers to enjoy. You'll find our products are easy to use, productive and aesthetically pleasing.



NETWORK RESPONSIBLY.

The upcoming 802.11n standard is sweeping the wireless world like a prairie fire. Before we know what we're dealing with, however, we need to clear the smoke.

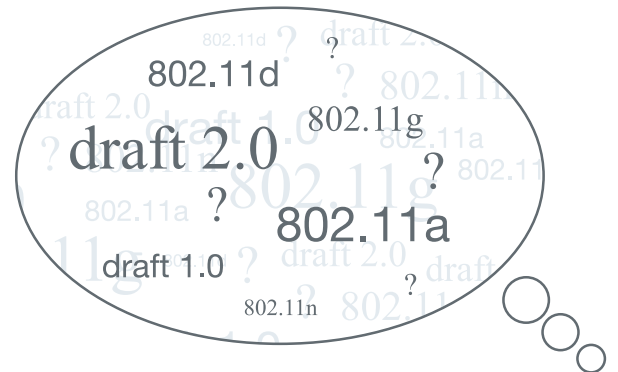
Explosive growth in Wi-Fi devices means that every one of us now depends on a wireless network. From home controls to public service systems, business operations to educational and entertainment endeavors, a switch to new wireless standards means putting a lot at risk. So much is riding on wireless technologies now that a new standard will have to promise to be just as predictable and compatible as it is fast.

Along with astounding claims, there are a lot of unanswered questions being asked by manufacturers, industry media, dealers, and consumers.

In the Wi-Fi wireless arena, the 802.11b standard gave us a quality level we came to expect. Then the 802.11g standard helped spark the expansion of wireless devices into every corner of our lives.

Enter the new 802.11n standard. It promises a throughput increase from 400% up to 1000% greater than the standards in use today. This translates into expanded capabilities in range and data transfer to Wi-Fi devices. Currently, there's an 802.11n Draft 2.0 that most manufacturers have adopted. They are so sure of this new Draft 2.0

that they've been aggressively pushing wireless gear with the new capabilities. Most have dropped the "Draft 2.0" from their product descriptions so these devices are known as 802.11n. Along with astounding claims, there are a lot of unanswered questions being asked by manufacturers, industry media, dealers, and consumers. What can 802.11n Draft 2.0 actually deliver in terms of performance, compatibility, and future upgrades?



With all the talk, it's important to take a moment and separate the hype from the facts. Only when the technologies behind 802.11n are laid out, can purchasers make informed decisions to determine if 802.11n Draft 2.0 will get them where they need to go.



802.11N ON THE HORIZON

A fully-functional 802.11n Draft 2.0 network with all the promised benefits is not as straight forward as it may seem. It's not a matter of buying an 802.11n wireless access point and 802.11n clients and you're "off to the races" with faster throughput and expanded range. There are a lot of issues to consider in addition to buying the right gear that support the right features.

Understand that 802.11n is still a draft. The current version is Draft 2.0, and the IEEE Standards Board approval of the final draft is scheduled for March 2009. There are a significant number of technical issues to be addressed and resolution of most of those issues is not planned until July 2008. Only after final approval will there be an 802.11n product for which everyone's implementation can be the same. Until this standard is approved, any product with 802.11n is a manufacturer's interpretation of the current draft. The key point to understand is that every manufacturer is attempting to interpret the standard its own way. Also, in the slew of 802.11n Draft 2.0 products on the market today we see not all manufacturers are choosing to implement all aspects of Draft 2.0. Finally, since the ratification of Draft 2.0, there has been a lot more discussion. Many changes have already been made.

In addition, the Wi-Fi Alliance, an industry organization run by manufacturers, started providing interoperability certification for 802.11n Draft 2.0 devices starting in June 2007. For a wireless access point to receive certification, it only needs to be tested against five different 802.11n Draft 2.0 clients, and only one of them needs to be commercially available for sale.

Beyond interoperability, another goal of the Wi-Fi Alliance certification is to ensure that all Draft 2.0 hardware can be fully upgraded to the final 802.11n standard when completed. This is a fine goal; whether it can be achieved remains to be seen. As stated earlier, there have already been many changes to Draft 2.0. If history is any indication, by the time the new standard is finalized, some 802.11n devices will be obsolete. Proof? No Pre 802.11g was upgraded to the final standard and even last year's 802.11n Draft 1.0 could not be upgraded to Draft 2.0.

Another way to think of SNR is like cash in hand. The more you have, the more you can spend on increasing your data throughput, or increasing your range, or a little of both.

THE TECH & THE SPECS

The main goal of 802.11n is to dramatically increase data throughput from the current 802.11a and 802.11g standards of 54 Mbps. The current 802.11n Draft 2.0 has increased the benchmark throughput to 300 Mbps with a path to 600 Mbps. However, as with any claim, "your mileage may vary" depending on interference, equipment, and the environment. For real world performance, as a rule of thumb cut the manufacturer's stated speeds in half. Take 802.11b's stated speed of 11 Mbps. The realistic throughput speed is going to be 5 to 6 Mbps. For 802.11g's speed of 54 Mbps, an average of 25 Mbps is realistic. Similarly, with a speed of 54 Mbps for 802.11a, you can expect an average of 29 Mbps. These data points will occur when client and wireless access point are at relatively close range. As the distance between the access point and client card increases, these throughput numbers drop off dramatically. Also, note the throughput for 802.11a is better than half because there is generally less interference in the 5.0GHz spectrum.

Now let's look at 802.11n Draft 2.0 and see how it compares. Take any manufacturer's new 802.11n Draft 2.0 equipment, apply our rule of half, and you can expect throughput speeds of 100 to 150 Mbps. Sounds great! But before you get too excited about these actual throughput speeds, take a look at testing results in October's PC World magazine article on 802.11n*. They were only able to achieve throughputs of 5 to 28 Mbps! The article attributed the significantly lower speeds to testing with client cards unmatched by manufacturer to the wireless access point. However, even with clients and access points from the same manufacturer, the best throughput speed was 28 Mbps.

From our tests with realistic environmental conditions, we were able to do somewhat better than PC World. However, we are far from meeting the target with 802.11n Draft 2.0, especially in the 2.4GHz spectrum.

To achieve the new standard's stated promises, many factors were required to change between 802.11n, on the one hand, and 802.11g and 802.11a on the other. For example, the radio was enhanced, frame formats tweaked, MAC layer protocol reduced, and power saving logic changed.



The key to understanding how 802.11n is going to improve network performance is to understand Signal-to-Noise ratio, or SNR. SNR is a basic measure of the quality of radio signal relative to the noise, or disturbance in a particular environment. The higher the SNR value, the more data you can receive and transmit or the further the range your client can be from the access point. Another way to think of SNR is like cash in hand. The more you have, the more you can spend on increasing your data throughput, or increasing your range, or a little of both.

handheld gaming devices, and laptops, transmit beamforming's utility will mostly be limited.

Multipath describes a phenomenon in which radio waves rarely take a direct path from access point to client. Radio waves always reflect off surfaces and take different paths, reaching the destination at different times. (See Figure 2.) With single radio configurations, multipath will degrade the SNR because copies of the same information will arrive at different times. However, with multiple radios on both the wireless access point and client,

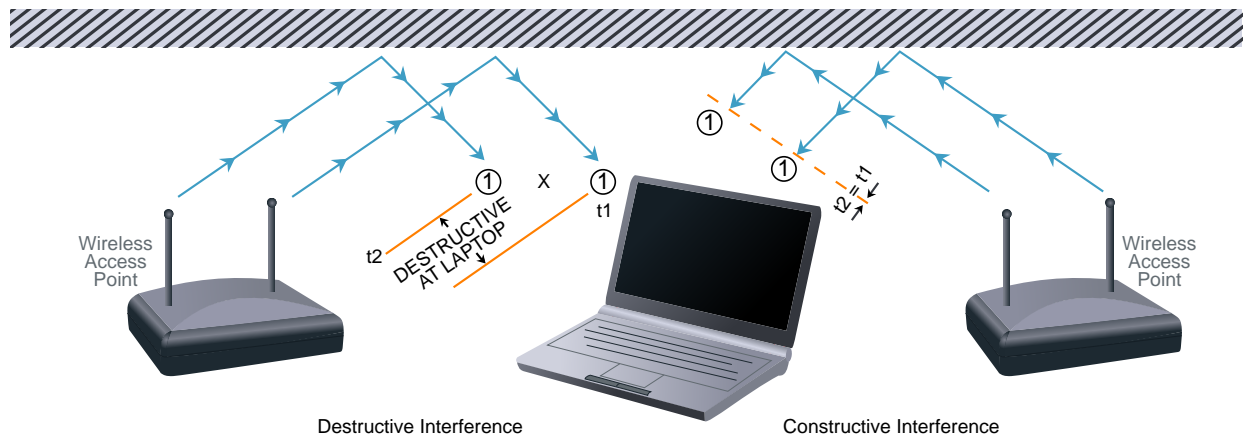


Figure 1

802.11N & MIMO

The center of 802.11n technology is called MIMO— Multiple-in multiple-out. MIMO varies the technique of radio transmission by using multiple antennas and multiple radio signals to improve the SNR value. There are two key parts of MIMO that are used in 802.11n: Transmit Beamforming, and Multipath/Spatial Diversity.

To improve the SNR, transmit beamforming uses at least two radio signals at the wireless access point end and carefully adjusts the timing of client radio waves reception. Basically, the wireless access point receives feedback and “tunes itself” for best reception by the client. The access point adjusts its transmission from its two radios so that the two radio wave phases are constructive at the client side and complement each other. (See Figure 1) The feedback can take time to receive and the “tuned transmission” is valid only momentarily because the environment is constantly changing. In addition, because the wavelength of 2.4GHz is so small and the 5.0GHz even smaller the slightest movement on the client side will invalidate any tuning efforts by the wireless access point. Given that most client devices are mobile devices such as touch panels,

multipath can dramatically increase the SNR value. In a MIMO scenario, multiple radios will broadcast signals at the same time; each of these signals is called a spatial stream. Since each spatial stream will follow a different path to the target (spatial diversity), and each spatial stream is received and decoded at independent radios at the other end, the combined SNR is dramatically improved by applying a complex mathematical algorithm.

From these examples we find that spatial diversity is much more effective than transmit beamforming. The benefit of spatial diversity increases in large steps from one radio to one radio (1x1) to a two radio to one radio (2x1) scenario, or even more so with a 2x2, or 2x3 and finally 3x3 radio scenarios. Benefits beyond a 3x3 radio scenario are relatively small.

POWER SAVING OR FEEDING THE BEAST?

The main method 802.11n uses to boost its SNR, as we just discussed, is by the use of multiple radios or MIMO. However, radios are very power hungry and adding multiple radios causes a client to thirst for more power. On the other side, mobility and

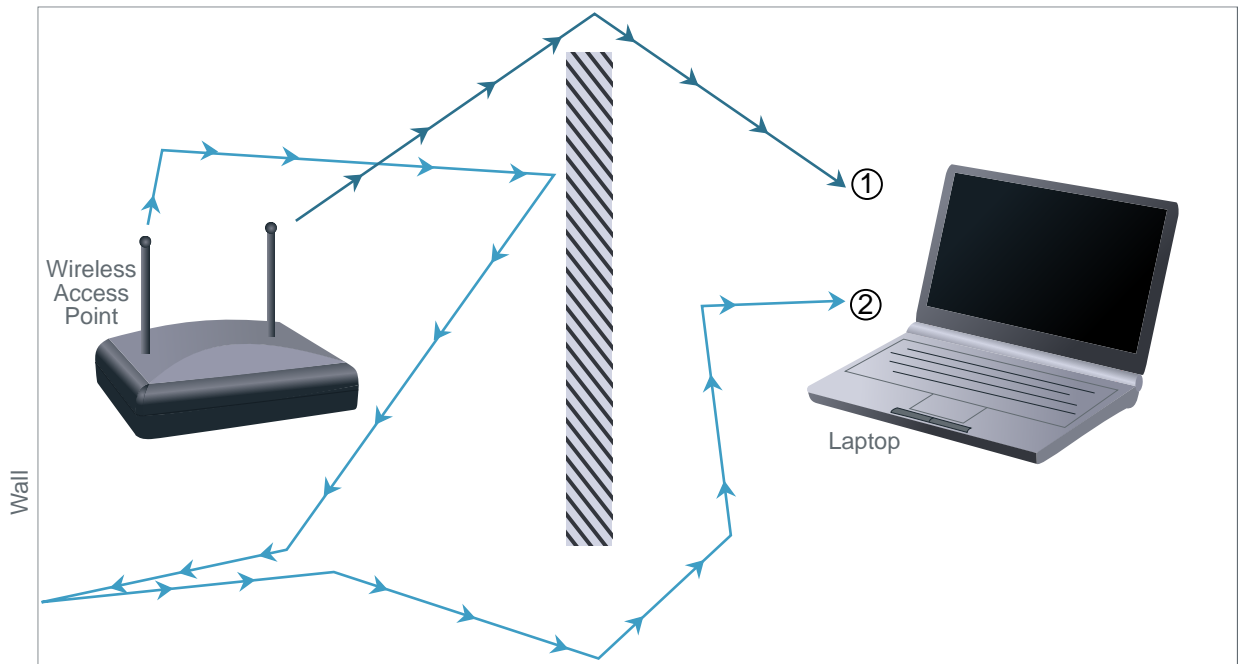


Figure 2

freedom from wires are wireless' greatest appeal. Unfortunately, mobility and power hunger are not a good combination. Current mobile devices such as laptops, touch panels, and even cell phones- (e.g. Apple iPhone) and portable gaming devices (e.g. Sony PSP) with 802.11 capabilities are somewhat handicapped by their relatively short battery life compared to devices without 802.11 WiFi capabilities. Adding more radios to 802.11 devices will make the battery situation worst.

In the 802.11n Draft 2.0, the power saving logic was changed to take into account multiple radios. Simply put, if a device does not have a continuous supply of power (i.e. powered by a battery), the power saving scheme will turn off all but one radio and make essentially make the device an 802.11a or 802.11g device. Time will only tell if 802.11n will be adopted in highly mobile devices such as touch panels, cell phones, and gaming devices. Manufacturers reluctant to produce a new portable device with 802.11n Draft 2.0 standards, for the time being, side with battery life over increased wireless range or throughput.

RADIO ENHANCEMENT

In addition to MIMO, the 802.11n radio has been enhanced to increase the SNR. The important changes center around two elements: higher modulation rates and channel size.

802.11n will continue to use Orthogonal Frequency

Division Multiplexing, or OFDM, as in 802.11a and 802.11g. In OFDM, each radio channel is divided into smaller channels, or sub-carriers. Each sub-carrier acts as its own radio and carries information independently. 802.11n will increase the number of sub-carriers to achieve more data throughput for each radio it uses. As more radios are used simultaneously, data throughput multiplies. In the current 802.11n draft form, each sub-carrier uses the same modulation scheme or "equal modulation." However the 802.11n committee is discussing instituting different modulation methods for each spatial stream, a change that could dramatically increase throughput. As of this writing, there are more than a dozen possible data rates using "unequal modulation methods" being discussed for their feasibility and practicality. Note that any significant change to a radio's modulation method will make 802.11n Draft 2.0 radios difficult to upgrade.

The other significant alteration to increase data throughput is channel size. In 802.11a and 802.11g, the radio channel size is 20 MHz wide. One channel is used for each data stream. A simple approach to double data throughput is to use two 20 MHz channels or 40 MHz at the same time. This technique is known as channel bonding. A good analogy is to picture cars going down the highway. By adding another lane to a single lane highway, twice as many cars can travel. 802.11n uses both 20 MHz and 40 MHz channels, or channel bonding to increase data throughput.



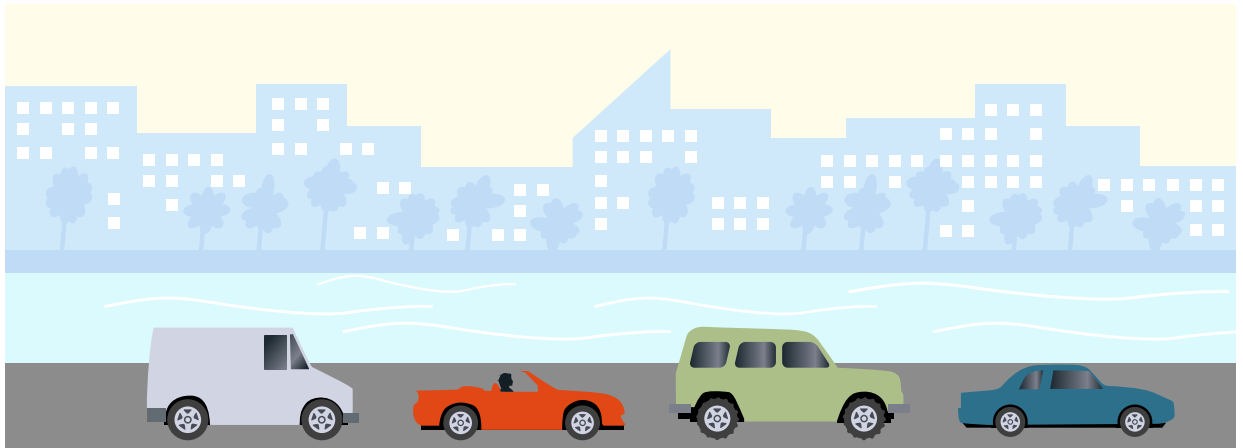
INTERFERENCE IN THE 2.4GHZ AND 5.0GHZ SPECTRUMS

Sticking with the highway analogy, to increase traffic, where do you get the extra lane if there is no room to add a lane? You would have to take away a lane from another current use. The same is true for wireless. The 2.4GHz spectrum has a fixed overall bandwidth of about 100 MHz, and with 802.11g, you have three channels that don't overlap or interfere with each other. What is nice about having three non-interfering channels is you can have three wireless networks serving different users. No network is hurt by the presence of the others. With 802.11n and a 40 MHz channel stream, you will effectively have one channel.

devices in the same area, their performance will be hurt as well. 802.11n is still in the draft form and thus flexible, therefore some manufacturers have chosen not to implement channel bonding in the 2.4GHz spectrum. Others only allow channel bonding in the 5.0GHz spectrum where there is no danger of hurting existing wireless networks.

There is preventative logic in 802.11n Draft 2.0 that disables this feature if it senses any 2.4GHz network, however only time (and the final 802.11n standard) will tell how it plays out. Most likely, the use of the 40 MHz mode in 802.11n will not be feasible because a significant portion of the band will suffer from interference from a single 40MHz transmission.

By adding another lane to a single lane highway, twice as many cars can travel. Likewise, 802.11n uses both 20 MHz and 40 MHz channels, or channel bonding to increase data throughput.



This means if you have more than one wireless network in the same area, they will be interfering with each other, thus reducing the overall performance for everyone. Worse yet, if there are legacy 802.11

CLEAR SKIES ON THE 5.0GHZ

We are swimming in stormy waters everyday. Because the troubled seas are, in fact, radio waves – 2.4GHz more precisely – we can't see



them. People scratch their heads and wonder why their devices are not performing as they should or why performance varies throughout the day. The answer is the popularity of 802.11 Wi-Fi networks and a lot of other formats, standards, and devices all using the 2.4GHz spectrum. This has created a tumultuous ocean of congestion, interference, and unreliable performance in a lot of areas, especially metropolitan areas. Wi-Fi laptops surf the internet, Bluetooth headsets connect with cell phones, wireless keyboards/mice chatter with PC's, cordless telephones, microwave ovens, wireless lighting controls, wireless music/audio streaming speakers are all humming away at the same time. All of these devices compete for room on the 2.4 GHz spectrum.

Although the FCC set aside the 1.9 GHz band for cordless phones and voice-only applications, there's little relief for the 2.4GHz spectrum in the

a significant number of channels worldwide. We don't see any issues using 40 MHz transmission with 802.11n and existing side by side with current 802.11a networks, both on 5.0 GHz. The current 802.11a uses the 5.0 GHz spectrum and has been around for quite a while. However, it has never been popular, given the lack of availability of 802.11a clients and a range lower than that of 802.11g. However, this limitation can be compensated for by using a wireless access point with higher power and better receiver sensitivity.

Because of the crowded 2.4GHz spectrum, a dual band 5.0GHz and 2.4GHz wireless access point will be important for 802.11n. However, this type of wireless access point presents its own set of problems, not easily solved with today's available technology and standards. A dual band 802.11n wireless access point will need even more radios and thus a very powerful processor to support all

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near future. While 802.11n might broadcast a 40 MHz data stream in hopes of an improved SNR, real benefits seem unlikely due to congestion in the 2.4GHz spectrum.

The 5.0GHz spectrum, however, could provide a much more feasible home for 40MHz transmissions. Regulatory agencies have recently opened up

the radios and calculations, especially for a high use residential or commercial environment. Current Power-Over-Ethernet, PoE only supports up to 15 Watts over Cat 5e cable using the IEEE 802.3af standard. With a dual radio configuration, power requirements will be well above 15 watts unless a strong main board processor gets sacrificed for a weaker one.



802.11N & THE FUTURE OF WIRELESS

Despite all the hurdles, we can't wait to utilize the 802.11n standard. It's a great technology that will, among other things, significantly increase SNR in Wi-Fi networks. Unfortunately, the unresolved issues regarding both the final standard and the type of devices that will actually benefit from the increased SNR must be overcome and the ramifications must be studied and debated for the current draft 2.0 to move forward. The need for a firm standard is evident. 802.11n must solve the power supply issue, choose the best strategy for increased SNR, and find a clear road to travel on. When all the kinks get worked out the possibilities are endless.

REFERENCE:

* PC World, October 2007, "Wi-Fi Draft 2 Ensures Compatibility,"
Becky Waring

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Company Background

Founded in 2003, Pakedge Device & Software was created to fill the voids in high performance home computer networking products. Before our company was founded, computer networking products for the home were too compromised, unreliable and lack the "right" features. Pakedge Device & Software delivers the ultimate wireless and networking products for the uncompromising home owner. Our products speak for themselves.

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