# NXP Semiconductors puts the connected living in the fast track with 5Ghz broadband

*The proposed IEEE 802.11n standard provides the bandwidth and interference immunity needed to deliver high quality, HD video anywhere in the home*

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It is clear that if the availability of digital content is to take off quickly then the industry can not rely on consumers rewiring their homes with Ethernet or coax cables. The faster deployment, lower installation costs, configuration flexibility and other advantages of wireless networks have already been well established.

But there have always been doubts about the ability of home networks based on the IEEE 802.11a/b/g standards to distribute high-quality (especially HD) video in a home environment. Multipath interference, available data bandwidth, and interference from other devices using the same spectrum have been the primary causes for concern.

The developing IEEE 802.11n standard will change all that. Prototype systems based on the still-evolving standard have left no doubt that the data throughput, spectrum availability, immunity to multipath interference, and quality required by HD video can be achieved in properly implemented 802.11n Wi-Fi networks.

At the IFA show in Germany, Berlin 1-6 September 2006, NXP Semiconductors introduced its Connected Living concept with a demo working on the 802.11n standard. There, a multi-room PVR, a DMA/PC-server and a audio-hub were wirelessly connected in order to stream live and recorded HD content from either one of the devices to several Digital TV's and Portable Media Players. Connected Living is an NXP semiconductor concept in which server devices such as multi-room PVRs but also mobile and automotive devices easily connect allowing users to access stored or live content - information, entertainment and services - anytime, anywhere in the home and on the move.

**System-level considerations**

As previously mentioned, IEEE 802.11n is needed because the existing 802.11 a/b/g wireless networking standards have substantial limitations for consumer electronics applications. In addition, the PC-to-PC applications they were created to serve tended not to have exceptionally high data-rate requirements and are quite tolerant to intermittent interference.

For example, although 802.11g has a theoretical maximum data rate of 54 Mb/s, in practice it often struggles to deliver 20 Mb/s. In a difficult environment such as a home where the signal has to penetrate walls, the data rate will fall much below and this is not good enough.

Proprietary technology based systems are delivering in excess of 100 Mb/s but these systems will force consumers to buy equipment made with the same technology creating interoperability issues. One 802.11a/b/g's huge successes was the interoperability gained from Wi-Fi certification.

There are other changes in technology, which are having profound effects on the demands on a networking technology for the networked home. While advances in codec technology like

MPEG4, H.264 and WMV9 are reducing the required bandwidth to carry a given stream other trends are also driving to increase this demand. The trend to HD, further penetration of networked audio devices and VoIP all must be supported in a whole home network in parallel to the existing data traffic.

Significant technology integration is required and the integrator needs to know as much about devices such as TVs, set-top boxes, and cell phones and networked home standards such as Universal PnP (UPnP) and Digital Living Network Alliance (DLNA) as it needs to know about wireless networking. Networking video and audio is quite different from networking computers and overall systems expertise is critical to success.

It is against this background that 802.11n will deliver a step forward in the wirelessly networked home and that suppliers must work to realize this vision.

**MIMO technology**
Although other technologies contribute to the unprecedented performance of 802.11n-based systems, the core technology is antenna diversity, also known and MIMO (multiple-in, multiple out antennas).

Figure 1 shows a simple example of antenna diversity. Transmissions from the antenna on the left are received by the three antennas on the right. (There is, in fact, usually more than one transmitting antenna in a MIMO system.) The signal from each of the receiving antennas is adjusted in phase and amplitude and combined into a single output signal that achieves the best possible result.

In multipath environments -- and especially in the home where receiving equipment such as a set-top box may be moved from time to time -- MIMO's ability to sort out and combine the different multipath signals into one robust data stream is valuable. Further, this MIMO arrangement can actually take advantage of the multiple paths to enhance the robustness and performance.

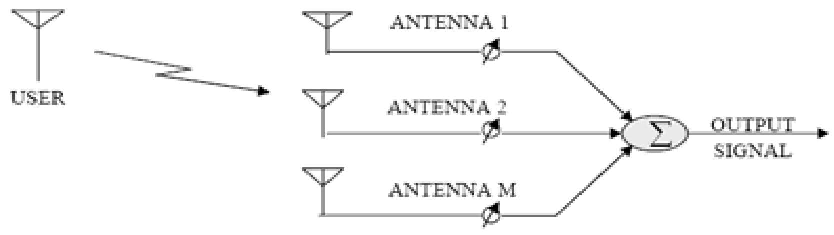


Figure 1. Multiple antennas create a more robust output signal.

Figure 1 illustrates a 1:3 MIMO configuration. But any number of transmit and receive antennas is theoretically possible. It is important to note that all the antennas transmit and receive at the same frequency. Decorrelating the multipath signals to synthesize a robust output signal is therefore compute intensive and configurations typically involve relatively few antennas (2:2 and 2:3 for example).

The goal of antenna diversity is to make each antenna's fading independent of the other antennas and to minimize the likelihood of all signals fading identically. There are three ways to achieve independent fading.

1. Space the antennas far enough apart. Generally, quarter-wavelength spacing is enough to achieve independent fading if the scattering environment produces signals arriving from all directions.
2. Point the antennas in different directions or use antennas with different dispersion patterns. Fading becomes independent because there is a different signal path to each antenna.
3. Use different polarizations.

A mixture of spatial, pattern and polarization diversity can be used. The practical limitation on the number of antennas is the cost/complexity/power of the RF circuitry needed for each antenna.

MIMO produces markedly superior results: A 2:2 configuration delivers double the physical layer (PHY) data rate of a conventional one-transmitter, one receiver system. Robustness is also improved. Doubling the data rate is often accompanied by an 8 dB improvement in receive sensitivity as well.

**Which frequency band to work in: 2.4GHz or 5GHz?**
By looking at the networked home from a whole-system perspective, for example, there are at least two reasons to take advantage of the option in the 802.11n specification to utilize the 5-GHz band instead of the more popular 2.4-GHz band.

The most important reason is that the 2.4-GHz band is already heavily utilized. When all of the Bluetooth, cordless phone and existing 802.11 a/b/g/ devices in the world are counted, there is probably well over a billion devices using the band and the majority are mobile. This interference is tolerable in a data centric application because the user cares little that part of the web page that is loading took a few hundred milliseconds more to arrive than it might have – in a video application this will lead to visible disturbance of the picture which is not acceptable.

The 5-GHz band, on the other hand, is relatively under-utilized. The primary reason is that designing 5-GHz equipment that can meet consumer price points is more difficult. As a result, only about 50 million devices operate in the 5-GHz band, and most of them are 802.11a equipment in use in Japan.

So a company with expertise on the consumer device side of the networked home requires a highly capable partner in the 802.11n space who can engineer solutions optimized for the 5-GHz band.

The other advantage of the 5-GHz band is that there is simply more spectrum available to use as an interference-avoidance strategy. Part of the performance improvement realized by 802.11n is channel bonding.

According to Shannon's capacity law, the theoretical data capacity limit of a communications system increases linearly with bandwidth availability. This means that the easiest way to increase the data rate is to expand its operating bandwidth, which is known as channel bonding.

**Channel bonding**
For wireless LAN systems additional bandwidth is achieved by bonding two adjacent 20 MHz channels into a single 40 MHz channel. The bandwidth increase is actually more than double since the guard band between the two bonded channels can also be removed.

Figure 2 illustrates the results of channel bonding.

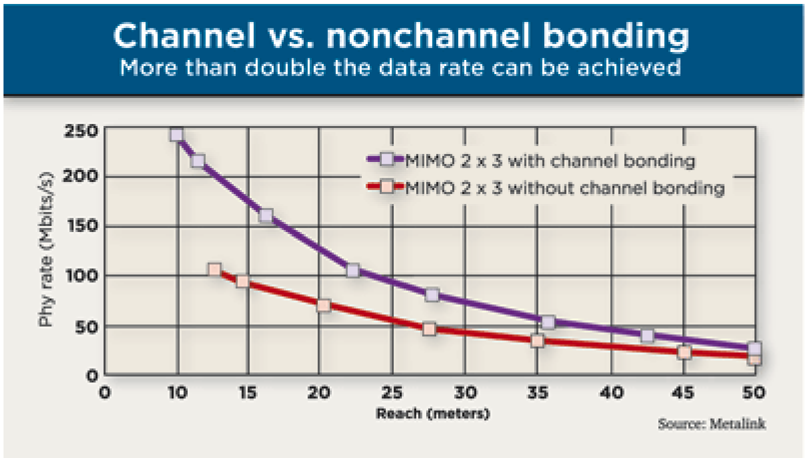


Figure 2. Channel bonding augments the performance boost of antenna diversity

The problem with the 2.4-GHz band is that it has only three non-overlapping 20 MHz bands, which makes channel bonding problematic at best. In most countries, on the other hand, the 5-GHz band has between 10 and 20 non-overlapping channels so there is an excellent chance of utilizing channel bonding to achieve the results shown in Figure 2.

For the designer of computer-to-computer networks, channel bonding and spectrum availability may not justify the added engineering time and cost to design a 5 GHz radio. For designer working in the networked home space, however, the trade-off is quite different. Use of the 5-GHz band and channel bonding are not mandatory requirements of the developing 802.11n standard – but they are included as options.

**Forward error correction**
Forward error correction is another critical technology for video delivery. Previous IEEE 802.11 versions (that is, a/b/g) intended for PC-to-PC communication used a convolution code for error detection that was, in turn, inherited from earlier IEEE standards.

But 802.11n provides another option: Low Density Parity Check (LDPC) provides a coding gain about 3 dB higher than the convolution code. Moreover, the coding benefit of LDPC is highest when low packet error rate (PER) and high data rates are required -- and this is exactly the conditions for demanding applications such as video distribution.

LDPC is not a new technology, however. It has been verified and adopted for the DVB-S2 satellite broadcast and 10 Gigabit Ethernet Over Copper standards.

An LDPC code is a linear block code specified by a very sparse parity-check matrix. The additional coding gain can be used to extend the reach for the same data rate. For example, 3 dB of LDPC coding gain translates into up to 30 percent improvement in range. It can also be used to increase the throughput or to increase the robustness and immunity to interference.

Forward error correction (FEC) is another example where systems A/V systems expertise leads to a different conclusion than PC expertise. FEC is best implemented at the chip level and most chip set suppliers appear not to have gone the LDPC route. Metalink's WLANPlus is one example of a product that uses LDPC instead of the legacy convolution code to great advantage.

The simulation results shown in Figure 3 are for a 2 x 3 MIMO system implemented with Metalink's WLANPlus chip set. The results include the effects of channel bonding and using the ETSI Channel A model, with output power of 13 dBm per antenna and an SNR difference of 3 dB between LDPC and non-LDPC modes of operation.

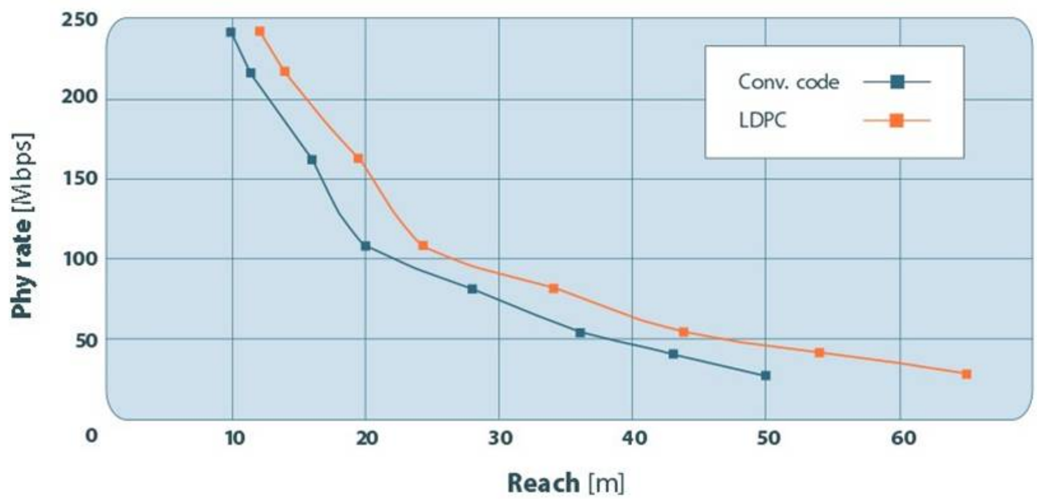


Figure 3. Benefits of LDPC forward error correction

The coding gain merits of LDPC enable higher throughput at a lower SNR. This SNR gain translates to reduced RF costs, increased rate or increased reach as described above.

**Quality of Service**

Video, gaming and similar data types are intolerant to bandwidth fluctuations and this creates a problem for the existing 802.11 protocols because they use the Distributed Coordination Function (DCF) access method to the wireless medium. Unfortunately, DCF was chosen for computer transfers. As such, it gives each device equal access the medium. Once again, from the perspective of someone with video system expertise, the fairness access provided by DCF must be considered inadequate. It will remain an option, however, and some chipmakers may implement it.

Settling on a QoS has been a hotly debated topic. The IEEE 802.11e standard provides two options: Enhanced Distributed Channel Access (EDCA) and Hybrid Coordination Function Controlled Channel Access (HCCA). But in May 2006, the Wi-Fi Alliance's Board of Directors terminated its HCCA task group, leaving WMM (EDCA) as the only scheme for QoS with certification plan in place.

EDCA has four priority levels, which are also known as Access Categories (ACs): Voice; Video; Best Effort; and Background. The EDCA parameter set for each AC defines the priority by setting individual inter-frame spaces, contention windows and other parameters. The mechanism for listening to the medium to determine the required transmission times is similar to the mechanism defined by DCF.

However, unlike DCF, the maximum back-off times differ for the various ACs. Higher-priority ACs have a shorter maximum back-off times to allow the higher-priority AC to gain access to the wireless medium more frequently than the lower-priority AC.

Once a device accesses the wireless medium, it can continue transmitting for a specified transmission opportunity (TXOP). Applications or packets that share the same AC also have the same maximum back-off time. This gives them the same opportunity to gain access to the wireless medium. EDCA is fairly simple to implement, but cannot guarantee latency, jitter or bandwidth and has no means to handles several applications with the same priority level. A combined approach is based on EDCA with the addition of admission control.

Admission control prevents other traffic from impairing the behavior of admitted traffic that has the same priority level. It assures that if system resources are not sufficient to support two high-priority services, the additional high-priority service will not degrade the performance of the existing service with the same priority.

For example, while EDCA assures higher priority for a video service over a data service, an attempt to deliver an additional video stream could crash both streams. Admission control evaluates the system's resources, and allows use of the additional stream only if resources are found to be sufficient.

EDCA admission control is mandatory at the AP and optional at the station. The AP may require stations to support admission control and explicitly request access rights if they wish to use an access category.

In a typical scenario, a station specifies its traffic flow requirements (data rate, delay bounds, packet size, and others) and requests the AP to approve. The AP calculates the existing load based on the current set of issued requests. Based on the current conditions, the AP may accept or deny the new request.

If the request is denied, the high priority access category inside the station is not permitted to use the high priority access parameters and must use lower priority parameters instead.
EDCA plus admission control network uses exactly the same mechanism as a legacy network and it uses the same distributed architecture were the decision about transmission time is left for the stations.

EDCA plus admission control takes advantage of EDCA's fairly simple implementation but still utilizes the benefits of admission control benefits (which was originally included in the recently abandoned HCCA). As such, EDCA plus admission control is now the preferred option for QoS implementation.

**IEEE 802.11n evolution**
The IEEE recently pushed its target date for 802.11n final approval out to 2008. (It had previously been the second half of 2007.) While the standard is progressing, most experts believe the interoperability of the pre-802.11n solutions will improve. In fact, the Wi-Fi Alliance has indicated that it will start certifying 802.11n products in 2007. This is not an unusual situation, in part because the standard is largely in place already. In addition, standards organizations and industry associations such as the Wi-Fi Alliance have somewhat differing interests. Industry groups want to move products into the market in a timely fashion and can accomplish this by working with a subset of the standard as it evolves.

Another important consideration for design engineers is the level of integration for the new 802.11n-based products. Here, it is best to look at past performance.

Most wireless solutions are now delivered as modules because the main markets are laptops and routers. In the short term, this will continue for 802.11n solutions. In the long term, the decision on when to integrate a complete 802.11n solution together with the consumer silicon will depend how stable and accepted the standard become. In other words, when it becomes evident that there will not be a follow on standard to fix whatever problems may have cropped up, then further solution integration is worth pursuing.

Past performance also provides a good guide on pricing of chip sets that conform to a new wireless standard. If the pricing of 802.11n follows the same trend as 802.11g, it will drop from its introductory level of around $20 to sub $10 in two years. Once 802.11g dropped below $10 the market really took off in volume moving from the early adopters with pre standard product to a mass market reality.

**Conclusion**

While the 802.11n standard may appear to be an evolutionary development from previous 802.11 variants, it really represents a discontinuity. Previous variants were created from the perspective of PC to PC link and by choosing the right options within the 802.11n standard it will become an enabler for video transport in the networked home.

This means that successful implementations depend not just on connectivity expertise but on consumer electronics expertise as well. Since this represents a convergence "at the chip level" of the PC world with consumer electronics world, the best solutions will come from wide ranging partnerships. NXP Semiconductors and Metalink, for example, have the same vision of the networked home so it is natural for them to work together with each other and other companies that share the same connected living vision where consumers can access digital content from all sources such as information, entertainment and services anytime, anywhere in the home and on the move.

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Paul Martin is the strategic marketing manager for the Home Business Unit of NXP Semiconductors. An expert on consumer electronics systems, he is responsible for the mid- to long-term market strategy of the business unit, forging strategic partnerships to deliver the NXP Connected Living vision. Paul holds a bachelor’s degree in Electronics Engineering from the University of Southampton (UK).