



11 October 2006

Home Networking

One remote to rule them all

FITT Research

Fundamental, Industry, Thematic, Thought-Leading

Deutsche Bank Company Research's Research Product Committee has deemed this work F.I.T.T for our clients seeking differentiated ideas. Our wireless technology team captures the key dynamics and emerging trends of home networking to enable deeper understanding of this long-awaited area.

Fundamental: home networking could lead growth in consumer electronics

Industry: a comprehensive industry view from standards to chips to gear

Thematic: it takes a village of standards to raise an industry

Thought-leading: we view the industry from a consumer's viewpoint

Favor chip vendors and complete solution providers



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DISCLOSURES AND ANALYST CERTIFICATIONS ARE LOCATED IN APPENDIX 1

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Fundamental: home networking could lead growth in consumer electronics

We believe the field is poised for rapid growth. The proliferation of consumer electronics devices in the home is a key driver of this demand as consumers seek to connect their multiple home computers, media players, cameras, game consoles, etc to the Internet and to each other. We think this will accelerate as new technologies such as 802.11n and BPL mature and consumers become aware of their greatly increased capacity.

Industry: a comprehensive industry view from standards to chips to gear

The home networking industry has grown considerably in recent years. Since the adoption of 802.11b Wi-Fi in 1999, companies such as Apple have pioneered new ways for consumers to connect their home electronics devices with each other and shared Internet connections. The supply chain comprises chip vendors, network gear vendors and an emerging class of complete solution vendors, including Apple, with the potential to greatly change some fundamental consumer usage patterns.

Thematic: it takes a village of standards to raise an industry

In this report we track the numerous standards proposed for filling various gaps in the home network puzzle. This includes Wi-Fi 802.11 in all its various extensions including a, b, g, n, i, e, s, r etc. We consider the prospects of Broadband over Power Lines (BPL). We review several proposed solutions for linking home controls and sensors through low-cost/low-power standards such as Z-Wave. We also consider several competing solutions for integrating all these pieces.

Thought-leading: we view the industry from a consumer's viewpoint

We approach the industry from a consumer's perspective, evaluating several distinct 'islands' of demand. In our view, a major obstacle for home networking will be improving ease-of-use for consumers. Today's products are far from plug and play. Companies that can securely solve the user-interface issue will lead the way while others risk the commoditization that comes from open standards.

Favor chip vendors and complete solution providers

We see the best exposure for investors to the home networking sector through Wi-Fi chip vendors such as Atheros (ATHR, Buy, \$20.77), Marvell (MRVL, Buy*, \$17.27) and Broadcom (BRCM, Buy*, \$28.77). Equipment vendors face lower barriers to entry, which risks commoditization for companies such as Netgear (NTGR, Hold, \$20.88), although Motorola's (MOT, Buy, \$25.28) set-top boxes have a stronger position. We would also favor companies which can provide end-to-end consumer or consumer software solutions, including Apple (AAPL, Buy*, \$73.71). Microsoft is another potential beneficiary, though our analysts do not have earnings estimates or an investment opinion (MSFT, not rated, \$27.65).

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Top picks

Motorola (MOT.N),USD19.32 Buy
Atheros Communications (ATHR.OQ),USD20.29Buy

Companies featured

Atheros Communications (ATHR.OQ),USD20.29Buy

	2005A	2006E	2007E
EPS (USD)	0.21	0.69	0.94
P/E (x)	48.4	29.5	21.6
EV/EBITDA (x)	33.7	16.1	9.6

Motorola (MOT.N),USD19.32 Buy

	2005A	2006E	2007E
EPS (USD)	1.12	1.39	1.54
P/E (x)	17.1	13.9	12.6
EV/EBITDA (x)	6.6	6.0	5.2

Netgear, Inc. (NTGR.OQ),USD20.89 Hold

	2005A	2006E	2007E
EPS (USD)	1.02	1.26	1.42
P/E (x)	18.3	16.7	14.6
EV/EBITDA (x)	-	-	-

Note on coverage

* MRVL and BRCM: lead analyst is Ross Seymore.
AAPL: lead analyst is Chris Whitmore.

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Executive summary

Outlook

The number of digital devices in the home has increased

If you are like the average consumer, your house has many more digital devices than it did three years ago. In the U.S. and other markets, the number of PCs, digital cameras, DVRs, DVD players, camcorders, VoIP phones and game consoles, has exploded in recent years. At the same time, broadband Internet penetration rates have increased as well. The next step in the evolution of the consumer electronics industry will be connecting this constellation of devices to each other and to the Internet.

Home networking technologies are now in place

We believe that the Home Networking industry is poised for very robust growth as several key enabling technologies reach maturity and begin to see consumer adoption. In this report we examine the industry from a consumer demand viewpoint, by identifying major applications for networking in the home including Internet access, entertainment, cable replacement, and home automation. We then take a look at the array of standards, solutions and technologies that companies are developing to address these demands.

802.11n is a major milestone

In our view, the pending adoption of the 802.11n standard could mark a major milestone for the industry. The new Wi-Fi standard offers the ability to stream multiple channels of HD TV. This could enable the wireless installation of home media servers and a new way to think about TV. Outside of these headline-grabbing items, we also think there is a sizable market attached to peripherals such as digital cameras, particularly for the technology that replaces the miles of cables hidden behind the average home's entertainment console. Finally, one of the largest opportunities lies in automating home controls and sensors from light switches and thermostats to webcams. Here low-cost technologies have emerged which can drive the costs of automation down to affordable price points.

The industry now needs something to knit all the pieces together

While the opportunity remains large, we caution investors that the industry's ecosystem is still missing an important piece. As the boundary between computers and televisions blur, consumers will not adopt new technologies that lack TV's simplicity. In our view, the ultimate success or failure of home networking will depend on the industry coming up with a user interface and software layer that makes connecting the legion of devices as effortless as turning on a TV. Industry trends could also benefit companies that offer comprehensive, easy-to-use systems including Apple and Microsoft. Other potentially influential industry participants are the telecom and cable operators, set-top box makers such as Motorola, and companies with exposure to the leading technologies in the space such as Atheros, Broadcom and Marvell through their 802.11n products.

Valuation

Among the leading beneficiaries of developments in this field will be Motorola through its cable set-top box business. We also think Atheros will benefit from the spread of 802.11 technologies into a wider array of consumer electronics. While Netgear also has exposure to the field, we think their current product line-up offers lower barriers to entry. We believe they are headed in the right direction with their moves to develop software interfaces, but it could be some time before this is felt in the market.

We have valued the companies in this sector using a discounted cash flow analysis. For Netgear, of which we are initiating coverage, we used an 11% discount rate and 3% growth rate. Our price . Our \$30 price target for Motorola is based on DCF analysis using a 10% discount rate and 4.5% growth rate, and our \$22 price target on Atheros is derived using a 13% discount rate and a 4% growth rate.

Risks

The primary risk associated with this industry is the pace of consumer adoption. Companies operating in this field are also subject to rapid technological change, and to the ability of several large companies such as cable MSOs to determine market timing and direction. Companies operating in the sector are exposed to macro-economic trends, particularly consumer demand and retail spending. Most companies are also subject to competitive risk with the ever-present possibility of new entrants. The industry is also exposed to changes in technology and companies operating here remain under pressure to continually keep up with a highly dynamic environment.

Home networking today

Home networking is poised to become one of the fastest growing segments of the consumer electronics industry in coming years. The average household contains an increasing number of digital devices – digital cameras, VoIP phones, digital video recorders, game consoles, webcams and a growing number of computers and many more. At the same time networking technologies are improving, raising consumer expectations over their ability to link these devices together.

Innovation does not equal success; the industry could still fail

In the following pages you will find technical detail displaying the immense amount of innovation coming from this industry. Be forewarned, however, that innovation does not always equal success. In our view, all this promise could come tumbling down if the industry does not resolve a major issue. The industry is tangling with the ultimate in simplicity – the TV, indolence's lowest common denominator. We do not believe mass market adoption will occur until home networking is truly effortless.

New technologies must be as easy to use as existing products

Home networking vendors are betting their future that their products will become as pervasive as televisions and stereos in the home. In doing so, they risk overlooking the basic simplicity that has made these devices so universally popular. Home networking today is not simple and the average user experience is prohibitively complex.

The hardware works, but issues remain

In recent months we have tested out several of the devices we detail later in this report. Almost without exception we have encountered difficulty in building reliable networks and we have the benefit of access to RF and network engineers. In general we find that the technology offered works as promised – bandwidth and range met our expectations. Areas where these devices fail include the following

- Security
- Network management, particularly adding a device
- User interface
- Interoperability
- Reliability

Problems increase with the number of access points

As a rule of thumb we have found that these devices work well when networks are confined to a single access point. When additional access points or range extenders are needed, the systems break down.

Attaching new devices to Wi-Fi is not as seamless as promised

As we detail below, Wi-Fi has become the most widespread of the network technologies. A key criticism of the 802.11 standard has been its perceived security. While Wi-Fi actually offers a viable security protocol (64- and 128-bit WEP), it is surprisingly difficult to actually enable that security and attach new devices when it is activated. The standard employs 32-digit hexadecimal keys. Some operating systems allow users to type in their own passwords and then fill in the extra digits behind the scenes. However, when complications arise (and they always arise) users have to revert to the hex-key.

The issues of security and network management are closely related. The key to solving this issue, and several others, is the need for a better user interface. We will return to this in a moment.

Inter-operability needs improvement...

It should come as no surprise that Wi-Fi lacks a compelling software layer. The original standard focuses only on OSI Layers 1 & 2, leaving higher order (i.e. application layer) implementation to individual vendors. (We should point out that WiMAX suffers from the same shortcoming.) For Wi-Fi, this is evident in the difficulty in inter-operating equipment from different vendors. This is true of other technologies as well including BPL, and in Zigbee, the standards body deliberately left some very basic implementation choices to vendors thereby ensuring no interoperability.

...as does reliability

Finally, we remain concerned about the reliability of this gear. Consumers have come to take for granted the six-sigma, always-on dial-tone of wireline carriers. Today's home networking technologies are far closer to the Internet's 'best efforts' approach. While this may be appropriate for gaming or in-house data transfer, it becomes a more serious issue when considering 911 calls over VoIP phones.

The quest for simplicity has important financial implications. In our view, companies that provide reliable, end-to-end connectivity will succeed. We would take it a step further and say that if such solutions do not emerge, the industry will not be able to achieve its promise.

We favor companies with software solutions

So far only a few companies have demonstrated that they are capable of bridging the gap between the ease of the remote and the promise of digital media. We caution, however, that none have fully achieved the required simplicity. As it stands now, industry trends could benefit companies which are at least heading in the right direction. These include, but are not limited to, the following:

- Apple
- AT&T
- Comcast
- Microsoft
- Netgear
- Sony
- Time Warner

These companies have a reputation for understanding the needs of consumers either through intuitive user interfaces or a relatively sophisticated customer service operation.

Carriers & home networking

As highlighted in this report, the home networking market is highly segmented. With so many vendors offering incompatible products, it is not surprising that consumers are finding adopting these technologies quite difficult. Perhaps, the only common thing among home networking products is the end market – ‘the home’. Every company hopes to capture some share of this lucrative market and create an ecosystem around their solutions. The eventual goal for these companies is to create a level of stickiness with their products.

All technologies mentioned in this report relate to home networking aimed at solving one important thing – how can the consumer’s life be made easier by making content and services available on any device and anywhere at home? Whether this is based on wireless technologies such as 802.11n or wireline technologies, such as MoCA or HPNA, consumers would like a ‘plug-and-play’ approach in networking different devices within their home.

Based on our experience, not only is interoperability of devices across vendors impossible, but products from the same company are far from being seamless. We therefore believe, at least in the short run, some of the success of home networking will depend on the involvement of an intermediate entity that will perform the function of a system integrator. We also believe that this entity will likely involve a service provider such as AT&T, Comcast, or Verizon. These service providers will be able to extend their relationship with the customer in the home networking arena.

Customer ownership – The key to success in home networking

If we step back and take a bigger picture look at the home, there are three fundamental areas where the customer may be owned. The first one is the PC at home, the second one is the residential gateway, and the final one is the set-top box.

Home PC: Many vendors think the Home PC is going to be the anchor point for in-home content distribution and home networking needs. Leading the way with this approach are companies like Intel and Microsoft. According to Intel, the Home PC will not only serve the normal needs of a home computer, but also perform the role of a media server. By integrating wireless technologies within the Home PC, content may be easily moved around the house. Companies supporting this philosophy believe that every device (TVs, stereos, etc.) will incorporate wireless radios and can receive and transmit information. Some of the stronger advocates of this model believe that there is no need for service operators like AT&T and Verizon for content delivery since the internet will be the primary source for voice and video content services.

Wi-Fi residential gateway: Over the past five years, there has been a proliferation of Wi-Fi access points within the home. Generally speaking, a residential gateway is a broadband modem that incorporates basic router and firewall functionality. Some of the leading gateway providers include 2-Wire, Netgear, and D-Link. Although today most of the use of these gateways has been for wireless internet connectivity, these elements may have additional functionality to support home networking needs. Examples of these include incorporating a SIP server to convert into a VoIP gateway, a web server to download video content from the internet, or incorporating different flavors of Wi-Fi to transmit content within the home. Based on our assessment of the industry, however, the residential gateway providers do not want to get into the managed services business and prefer to stick to selling their devices rather than offering managed services.

Figure 1: 2-Wire residential gateway

Source: 2Wire

Figure 2: Westall residential gateway

Source: Westall

Set-top box: Traditionally, a set-top box has been a device for delivering cable television. However, over the past couple of years, with the entry of satellite and IPTV providers, the set-top box has evolved in functionality. Some of the newer features that these boxes include DVR, DRM, VoIP, residential gateway, and Wi-Fi. This market continues to be dominated by two players – Scientific Atlanta (now part of Cisco) and Motorola.

Set-top boxes typically incorporate greater functionality than a residential gateway. The set-top box providers, in conjunction with service operators, hope to exploit the set-top box as an anchor point for home networking needs. By incorporating interfaces for home networking (such as 802.11n, MoCA, HPNA), content may be moved around the house.

Figure 3: Motorola Set-Top Box

Source: Motorola

Figure 4: 2-Wire HomeZone

Source: 2Wire

With their existing relationship with the customer and their ability to deliver content, these operators can offer managed services for home networking needs. Companies like AT&T, Comcast and Verizon can take the lead in delivering reliable home networking solutions across a set of pre-approved devices. With it, customers will be prevented from going through the painstaking process of troubleshooting and integrating devices within their homes. As an example, AT&T with its IPTV and DSL offering may incorporate technologies for distribution of content from the IPTV set-top box to other parts of the home.

We think that the service providers recognize the importance of home networking, but are taking a cautious approach. One contact told us that up to 70%-80% of calls to cable MSO customer care 800-numbers are about home networking. That is, in most cases their customers are turning to them for help with equipment that they did not provide. This suggests not only cost savings, but an important demand that needs to be served. Carriers, however, do not want to have to foot the capex bill that would come with supplying everyone with a working network. The cost of a technician's visit alone may be prohibitive. Moreover, the carriers themselves do not yet know which standards will win and they do not want to become captive to the 'wrong' standard.

Understanding a networked home and user's needs

Today, a typical household has a myriad of consumer electronic devices and these connect to each other in different ways utilizing different interconnect technologies. Some of the networked scenarios that are commonly found in households today are:

- A camera, printer, or an MP3 player connected to a PC via USB.
- A DVD player/DVR connected with a set-top box, TV, and Audio Video Receiver via a complex set of digital and analog interfaces carrying audio and video signals.
- Smart phone connected to a computer using Bluetooth/IRDA.

Each of the above scenarios is like a "sub-network" in a home and the devices attached to one sub-network are not visible to devices outside that sub-network. Home networking promises to combine these sub-networks into one so that these devices are "visible" to each other, although this is only a small part of what home networking promises to achieve.

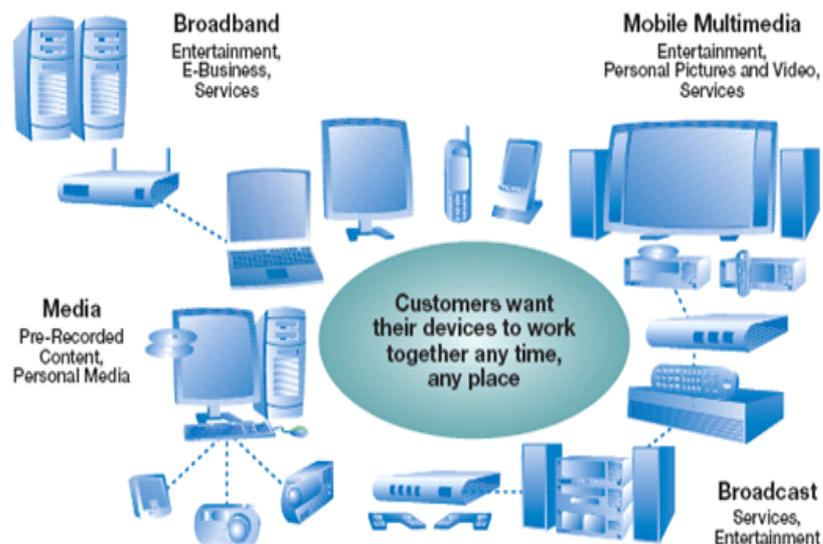
Home networking is more than sharing broadband Internet

Home Networking is more than sharing broadband Internet

A networked home allows users to connect various devices like desktop computers, laptops, game consoles, and cameras to the Internet and each other. It also enables users to share digital media across various devices, share a single printer, and share a broadband Internet connection. In an ideal scenario all devices should be able to interconnect seamlessly. For example, viewing images from a single digital camera on several home computers.

Many service providers are also eager to make inroads into this untapped market. Many companies are developing digital programming, which will be delivered to households through broadband. Home networking could enable a user to share this service among TVs, DVRs, and PCs. One such company, Akimbo, has partnered with producers and distributors of movies and videos and already delivers it to homes via the broadband Internet connection. Applications like Akimbo have potential to create a huge market for home networking gears as these services gain more adoption. Figure 5 illustrates various consumer electronic (CE) devices in a typical household and connectivity scenarios.

Figure 5: Connectivity scenarios in a typical home network



Source: www.dlna.org

Not all the scenarios shown in Figure 5 are widely used today and, additionally, some scenarios may be overly complex to set up with currently available products in the market today. For example, wired or wireless connectivity between a media center PC and TV or other display and audio devices is missing. As more and more digital media content is made available online, many people will look to connect their PCs to TV preferably via a wireless network. For this interconnecting technology to penetrate beyond early adopters, it must be compatible, simple, reliable and above all affordable.

We believe sharing broadband Internet and digital multi-media across various devices would be the most typical application of home networking in the early phases of evolution of home networking.

Home control and automation too are part of home networking

Home Control and Automation too are part of home networking

Home automation includes applications like controlling temperature, real-time remote monitoring, and operating appliances at home remotely via a computer or mobile device. Figure 6 shows several possible home automation applications which are a part of the home network.

Figure 6: Typical home control and automation applications



Source: Forrester Research

The current state of home networking lacks integration of all applications on one platform and hence these applications exist as isolated clusters of devices and applications. While the situation is far from ideal, recent developments in relevant standards give new momentum to the industry.

Understanding a users' needs

A user's home networking requirements are as diverse as the number and variety of devices one has in the home.

A typical household today could easily have several of the following capabilities:

- Ability to share digital media in cameras, PDAs, camcorders, etc across multiple devices like desktops, laptops, and TV.
- Ability to stream videos and songs from iPod, MP3 players, DVRs, TV, to/from a home audio system. Many consumers like to stream audio directly from the internet and listen to it on their AV systems. There is also a growing interest in streaming multiple channels of audio/video from a PC to different devices in different rooms in a home.
- Ability to share a single broadband Internet connection across all devices in the home.
- Ability to operate and control appliances remotely using Internet or via a remote control device or laptop. Some of the applications of interest are: controlling temperature, lighting, and monitoring security using network cameras at home.
- Finally, the ability to control, configure, manage and enroll new devices in the home network in a secure and simple way is the ultimate goal of home networking.

The uncertainty over the choice of technology remains

Figure 7 illustrates various scenarios in a home network. You will note that there are many connection technologies used. As we will see below, Ethernet cabling is giving way to Wi-Fi as the backbone used for accessing broadband in the home network.

Figure 7: Typical devices in a home network



Source: www.digitime.com

The evolving landscape of applications and devices for home networks are pushing the industry towards the most robust and specialized technologies in the home network making it a "hybrid network". We will analyze the potential technologies in each application space and how convergence can be achieved in a "hybrid home network".

Home networking evolution

Sharing Internet connectivity among multiple PCs at home has evolved from its infancy as 10/100 Mbps Ethernet hubs into a more versatile form. Now, broadband Internet can be shared among different computing devices at home via 802.11a/b/g/n wireless connectivity. Interconnectivity between portable consumer devices and PCs was mostly achieved via data cables and later via infrared (IRDA) interfaces. This connectivity has been replaced by Bluetooth, which has greater speeds and range. There are several other technologies that are in play at homes and we discuss them in separate sections in this document.

30% of PC owners in the US are interested in home networking

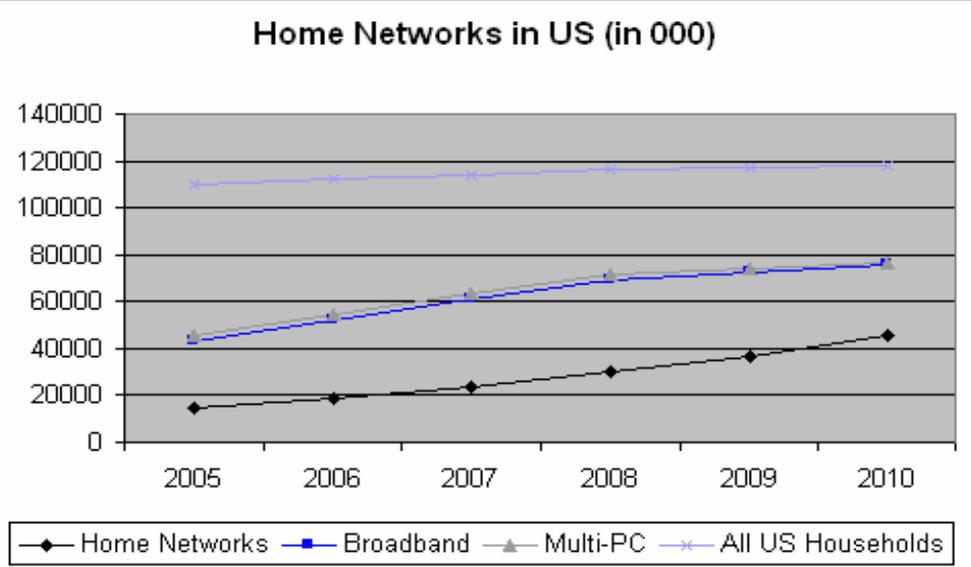
There are several drivers for the growing demand and need for home networking. Yankee group estimates that about 30% of PC owners in the US are interested in home networking. And we believe this figure will grow in coming years as users learn of new capabilities being offered. The key drivers for the growth and need of home networking solutions are:

PCs everywhere and the increasing number of smart devices at home

According to Forrester Research, there are currently about 50 million households in the US with more than one PC and this number is projected to rise to 75 million by 2010. With declining PC prices, more and more households are acquiring their second and third PC or laptop, which is creating a growing need for home networking solutions.

Another trend has been the deluge of smart devices that can connect to the Internet. A need for devices like smart phones, MP3 players, and game consoles to connect to the Internet simultaneously has also pushed the demand for home networking solutions.

Figure 8: Home networks and broadband connections in US



Source: Forrester Research

Forrester Research predicts more than 45 million networked homes by 2010 more than doubling the current usage of home networks in the US households.

Increasing amount of digital media and smart devices

Today, consumers are acquiring an increasing amount of digital media in the form of pictures, movies, MP3s, and other content and managing a wide array of consumer electronic devices like digital cameras, iPods, computing devices, and smart phones. Seamless integration and interoperability of these devices and ability to access and play this digital content anywhere at home and on any device would be crucial in delivering this experience to the consumers.

Rapid Increase of Broadband subs and advent of Wi-Fi (IEEE 802.11a/b/g)

Broadband once was a channel for only delivering high-speed Internet access. As the role of broadband evolved into delivering more services to the home, the need for home networking has grown. Today, many service providers are eager to provide home entertainment services like IPTV and Video-on-Demand (VOD) via broadband necessitating the need for home networking products.

Another development, which familiarized common households with the benefits of home networking, was the advent of Wi-Fi. Wi-Fi access points and wireless enabled laptops and PCs gave users mobility to move around the house and outdoors without losing Internet connectivity.

These two developments together spurred the demand for home networking products. The widespread adoption of Wi-Fi is attributed to its ease of use and affordability, which is the key to penetrate the home networking market.

Support for applications like Media Center on Windows and MAC OS

Many people bought their wireless router for the first time when they wanted to go live on Xbox 360. We believe that native support of applications like audio/video streaming, photo sharing, device management etc on Windows and Apple Macintosh will further fuel the need for home networking going forward. Additionally, native support for these features and integration of device management in the operating system will make it easier for typical users to try out these applications.

“Islands” in home networks

A comment on our approach

The inability to adopt standards is hindering adoption

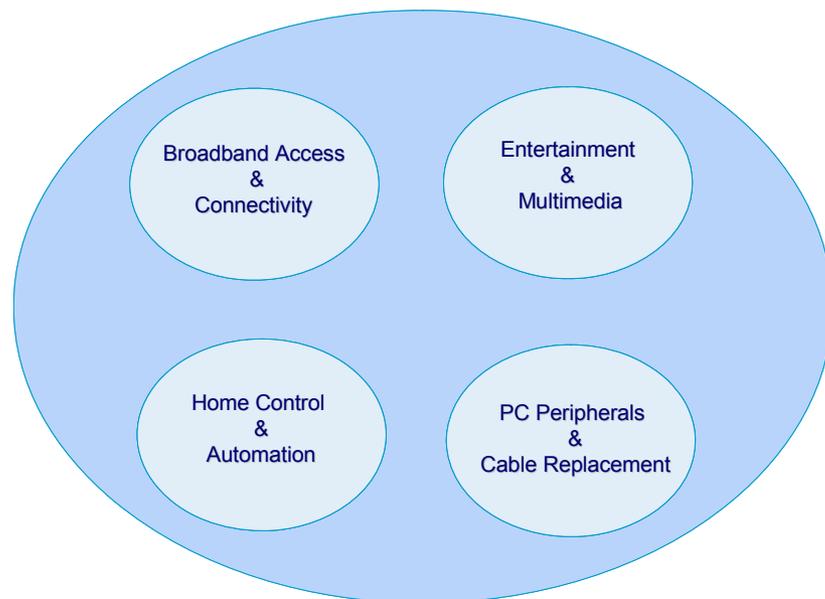
Currently, there are many technologies and standards that are already a part of the home network, but there are many more intended to play a role in the future. In the absence of any approval body, there are today many competing standards, each of which promises to solve the same problem in some better or more efficient way. These standards are backed by different industry players for different reasons like geographic scope, legacy products, and future impact on the position of these players. We feel that the inability to drive common standards is hindering adoption of products based on these technologies. Letting the marketplace decide on the final outcome has been slow and inconclusive in many cases.

Over the years many technologies have surfaced on the home networking front and unlike a “winner-takes-all” scenario, these technologies have so far coexisted. One such example is Bluetooth, which many thought was set to be replaced by Wi-Fi. Contrary to this prediction, Bluetooth has not only survived but also found solid footing in several home applications and is unlikely to disappear in the foreseeable future. Like Bluetooth there are many other technologies which exist in our homes today and have found a sweet spot in specific applications such as infrared, 802.11a/b/g/n, UWB, etc with each being used in a separate set of applications.

We look at the industry from a usage viewpoint

Accordingly, we are taking a different approach in segmenting the various technologies and standards that are or are likely to be a part of home networking in future. If we look at the many different applications in a typical home network today, we find that they belong to one of four “islands”: Broadband Access and Connectivity, PC Peripherals and Cable replacement, Entertainment and Multimedia, and Home Control Automation.

Figure 9: Islands in a home network



Source: Deutsche Bank

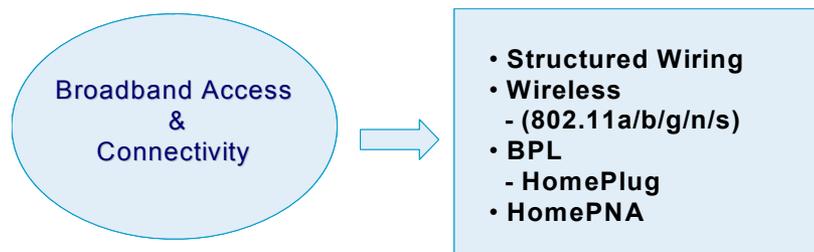
We will analyze the most promising technologies and standards in each island and explore the holy grail of home networking: achieving device and application manageability and framework convergence among all four islands. We will also analyze technologies that could potentially bridge these islands to form a virtual, seamless, and converged home network.

Broadband access and connectivity

Although there are many different technologies available for broadband access today, we have restricted the scope to technologies applicable in a home network. Technologies used in delivering the broadband connection to home could be different, viz., DSL, Cable, Satellite, and even WiMAX, but the scope of our discussion here is limited to technologies that are used for sharing the broadband connection among different devices at home.

Figure 10 shows the broadband access technologies that will be the focus of our analysis in this section.

Figure 10: Broadband access technologies in home networking



Source: Deutsche Bank

Structured wiring

Before the availability of wireless and BPL (Broadband over Power Lines) routers and adapters, structured cabling was the primary means to achieve connectivity in different rooms. Though structured cabling is expensive and time-consuming to install, it is a more reliable and secure media.

Originally designed for office wiring, structured cabling based on "Category 5" later also found its way in home networks in the form of pulling CAT5 cables from one central point (or a wiring closet) to each room, sometimes also known as "Home Run" cabling.

Consumers are now looking to stream audio and video and connect the output of set-top boxes to many rooms. The home run cabling approach is clearly going to be messy, inflexible, and expensive to install.

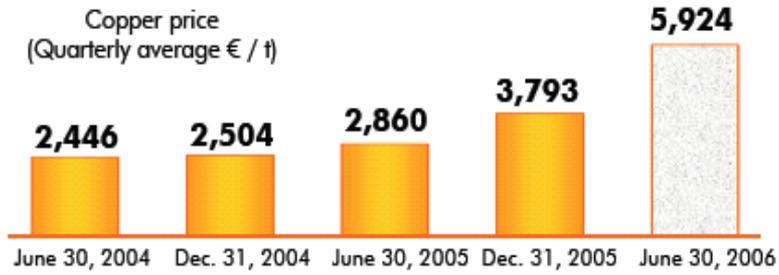
As Wi-Fi and BPL rise, we will see cables disappear from the home

As wireless technologies, like Wi-Fi and related standards, and BPL technologies, like HomePlug AV and HomePNA provide a wireless solution to these problems, we will see cables disappearing from many homes. Structured cabling, however, will continue to exist in enterprise segments where security issues take precedence over mobility of office workers.

Main players in this segment

In 2003, the largest suppliers of cable in the US market were: Avaya, Nexans, Mohawk, Belden, CommScope and General Cable.

Figure 11: Average quarterly copper prices



Source: www.nexans.com

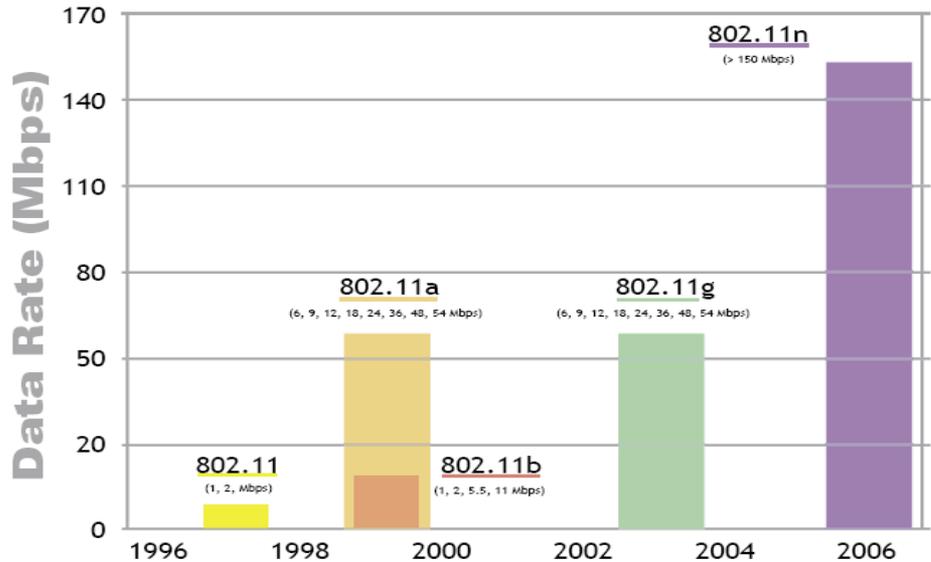
With rising copper prices and availability of more flexible wireless technologies, we expect to see a decline in the use of UTP and CAT5 cable components in structured cabling in homes.

Wireless broadband access

Wi-Fi (IEEE 802.11 a/b/g/n)

IEEE 802.11a/b/g WLAN standards are most commonly known as Wi-Fi. These standards are described in more detail under the “Technologies” section later in this document. The a/b/g/n extensions of the base WLAN IEEE 802.11 standard have different data rates and characteristics. Figure 12 summarizes the key features of each of these extensions.

Figure 12: Data rates of Wi-Fi technologies



Source: www.tropos.com

Figure 13: Comparison of IEEE 802.11 extensions

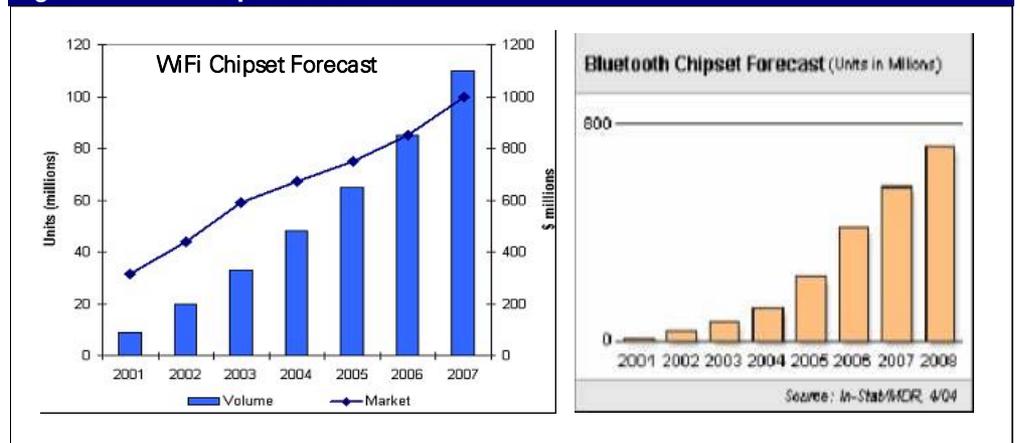
Parameters	802.11	802.11a	802.11b	802.11g	802.11n
Speed	1-2 Mbps	25-54 Mbps	6.5-11 Mbps	25-54 Mbps	200-540 Mbps
Spectrum	2.4 GHz	5.0 GHz	2.4 GHz	2.4 GHz	2.4 GHz
Modulation	DSSS, FHSS, IR	OFDM	DSSS (CCK)	OFDM (and reverts to CCK and DSSS)	MIMO OFDM
Channels	14	12	14	14	14 (with channel bonding)
Range	-	upto 50 m	upto 100 m	Upto 100 m	Upto 400 m
QoS Support	None	None	None	None	WME and WSM based
Compatibility	None	None	802.11	802.11/802.11b	802.11a/b/g
Other		Smallest range of all 802.11x at comparable data rates, higher bit rate in less crowded spectrum	Low bit rate for emerging applications, widely deployed higher range	Limited number of co-located WLANs, higher bit rate than 802.11a, higher bit rate in 2.4 GHz spectrum	Higher bit rate, longer range, 2 competing proposals TGn Sync and WWiSE

Source: Deutsche Bank

Market opportunity

Wi-Fi has been a huge success since the approval of IEEE 802.11b standard in 1999. Figure 14 shows the rapid growth of Wi-Fi over the last five years. This growth has largely been attributed to success in the consumer and home-office markets and a simultaneous drop in the Wi-Fi chip prices from \$35 in 2001 to about \$4-\$8 currently.

Figure 14: Wi-Fi Chipset forecast



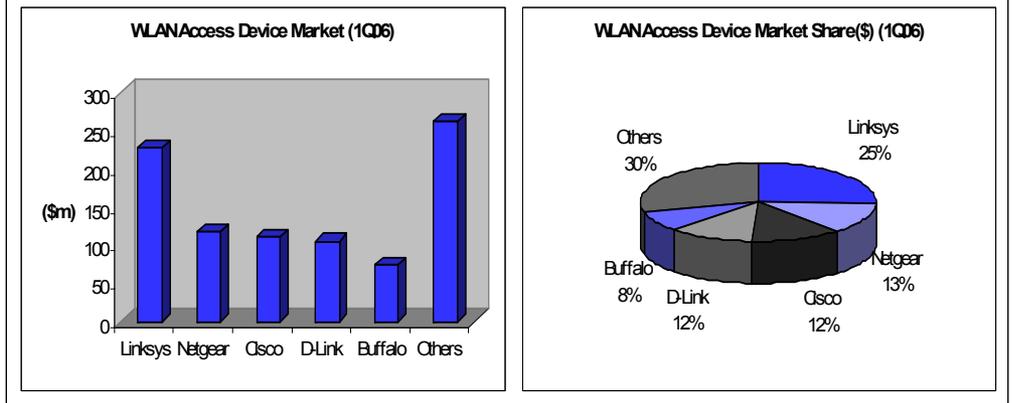
Source: In-Stat/MDR

Use of Wi-Fi in mobile devices will drive chip prices below those of Bluetooth

Use of Wi-Fi adapters in mobile device, cell phones, cameras, and other CE devices will drive prices downwards, further making it cheaper, we believe, than Bluetooth, which is currently at \$3-\$5 per unit. We expect Wi-Fi chipset sales growth to mimic the trajectory of Bluetooth devices down the line as shown in Figure 14. Over the next five years we expect the total market for Wi-Fi chips to reach \$2-\$3 billion annually.

In 1Q06, top 5 players in the Wi-Fi Access device market, which includes AP, Routers, Controller/Switch/Gateways and all radio technologies a/b/g/a+g, were Belkin, Buffalo, Cisco, D-Link, Linksys (now a part of Cisco), and Netgear as shown in Figure 15.

Figure 15: WLAN access device market size and share

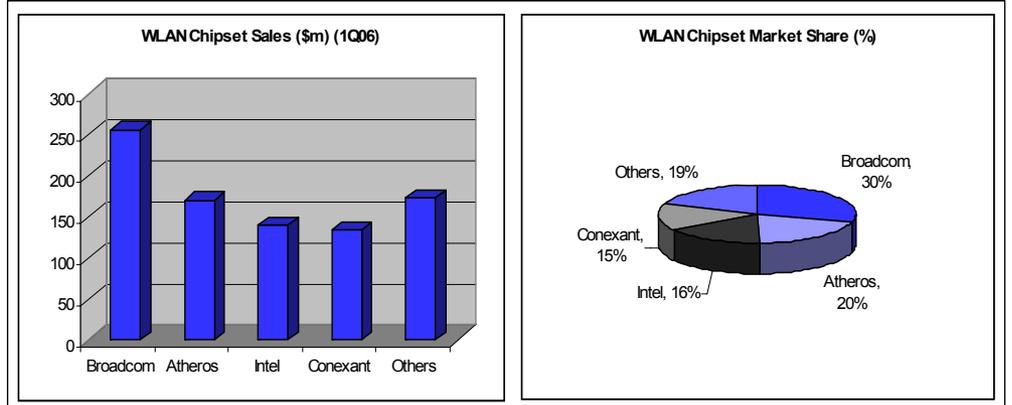


Source: IDC

In Wi-Fi chipset market, the top players are Broadcom, Atheros, Intel, Conexant, TI, and Marvell.

In Wi-Fi chipset market, the top players are Broadcom, Atheros, Intel, Conexant, TI, and Marvell. Figure 16 shows the market share and revenue of the top players in 1Q06.

Figure 16: WLAN chipset sales and market share



Source: IDC

Wi-Fi has become the key technology for enabling devices to share broadband connectivity in home and enterprise markets. We believe that this will continue to play a dominant role as scale economies have started to favor its deployment. The existing IEEE 802.11 a/b/g-based wireless standards lack both throughput and range to support digital home entertainment applications.

IEEE 802.11n (MIMO)

New multimedia applications like distribution of audio streams and high-quality video and HDTV streams from a central location and need for better coverage are driving the demand for wireless standards with higher throughput with QoS support.

MIMO is the key to 802.11n

MIMO (Multiple Input and Multiple Output) is the key underlying technology in the IEEE 802.11n draft specification and its performance can be further extended through channel bonding.

In early 2006, there were two competing version of MIMO implementation vying to become IEEE 802.11n standard TGn Sync and WWiSE. WWiSE backers included Texas Instruments, Broadcom, Conexant, STMicro, Airgo, Bermai, Motorola and Nokia (which switched sides in March). TGn Sync's supporters included Intel, Atheros, Agere, Infineon, Cisco, Qualcomm, Nortel, Mitsubishi, Sony, Panasonic, Philips, Samsung, Sanyo and Toshiba.

A final unified version of IEEE 802.11n is expected to be approved by IEEE in November 2006.

Earlier this year, the two factions in the race to develop the standard for the next generation of Wi-Fi, 802.11n, agreed to submit a unified proposal to the IEEE. That draft is now going through the customary review process, while it is taking longer than expected to complete, most industry participants expect a finalized standard in early 2007.

There was a technical dispute between the companies. The main difference between WWISE and TGn Sync products was the use of spatial multiplexing, which is the underlying technology for higher throughput using the MIMO scheme. These differences are listed in Figure 17.

The leading proponent of WWise was Airgo. They claim that spatial multiplexing is a crucial element for MIMO, and Airgo's CEO backs that up with several patents in MIMO. MIMO generally requires the use of multiple antennas on both sides of a communications link to simultaneously transmit several data streams through the same channel. According to Airgo the key to MIMO is its ability to do spatial multiplexing - which allows for the transmission of multiple distinct data streams over multiple radios in the same frequency at the same time.

Other companies in the standards body do not offer 'true' spatial multiplexing yet and believe MIMO (and thus 802.11n) can be successful without the significant processing burden that it would require. For instance, Atheros offers a chipset that uses four antennas and two radios that send data over two transceivers simultaneously. The difference is that the two radios transmit the same data stream simultaneously to extend the range of a signal but not the throughput speed. This beam-forming technique is being proposed as an optional element to the 802.11n standard.

One problem in MIMO products using only channel bonding is that the speed attained isn't stable. This opens the system to interference from nearby 802.11 b/g access points.

While companies like Airgo and Metalink will persist in their usage of spatial multiplexing, it seems that the rest of the industry is ready to move on, settle the dispute and begin commercial production of 802.11n products.

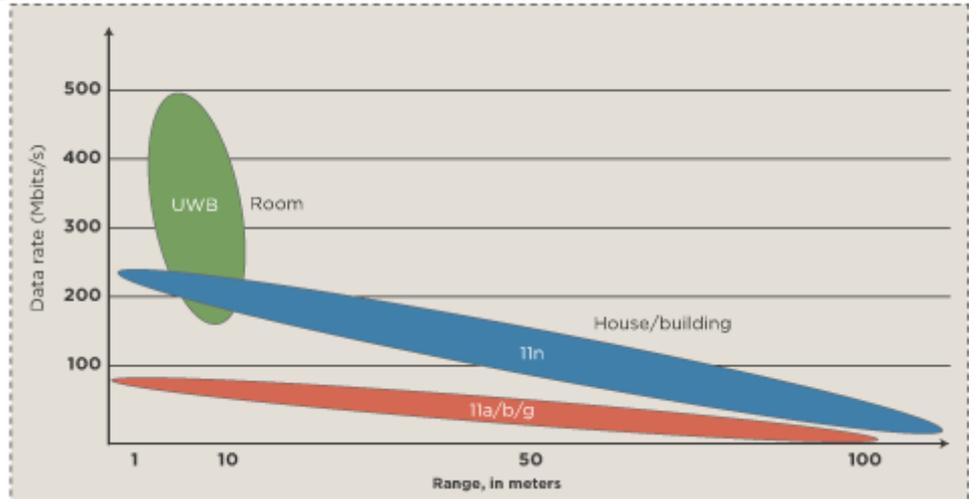
Figure 17: Comparison of Atheros and Airgo MIMO implementation

MIMO Features /Implementation	<u>Airgo</u>	<u>Atheros</u>
Spatial Multiplexing	Yes	No (in true sense)
Channel Bonding	Yes	Yes
Chipset Complexity	High	Medium
Cost	High	Medium
Other	<ul style="list-style-type: none"> - Requires a new chipset to get advantages of MIMO's improved range and throughput - Airgo's solution is not susceptible to interference as it uses the same channel to transmit multiple streams 	<ul style="list-style-type: none"> - Does not require chipset upgrade. Changes can be made in the software to achieve higher range and throughput - Cannot sustain higher throughput when other 802.11 b/g devices are present

Source: Deutsche Bank

Ultimately, the market will decide which solution to use. So far, the major equipment vendors (Netgear, Belkin, Linksys, etc.) have preferred the simpler, cheaper solutions that have industry backing.

Figure 18: Comparison of IEEE 802.11n data rate and range



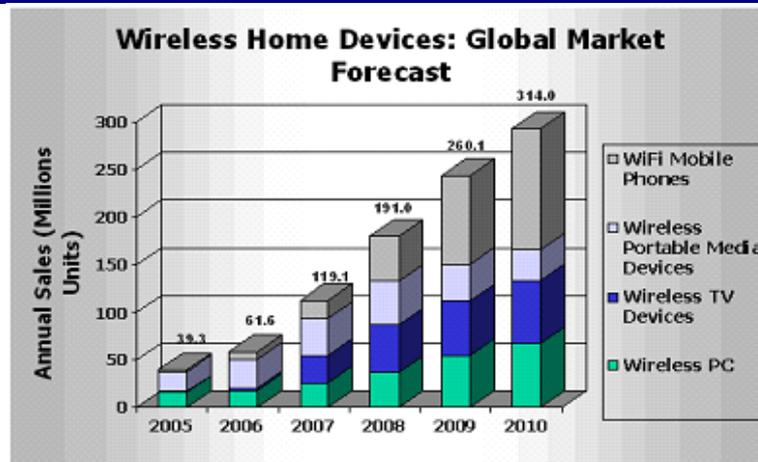
Source: Texas Instruments

IEEE 802.11n market is expected to take off soon after the approval of the draft-n standard which is now expected to be approved in 1H07. Although both camps have combined their proposals and submitted a unified draft, we believe the final approval of this standard will be anything but smooth. There are already Pre-N and draft-n products out in the market from many manufacturers like Netgear, Linksys, Cisco, D-Link, etc. Broadcom, which launched its chipset early this year, has already shipped more than a million chips and Atheros' 2Q06 revenues from draft-n chips were 13% of the total revenues. The Wi-Fi Forum has actually taken the drastic step of certifying "Pre-N" devices, bowing to reality.

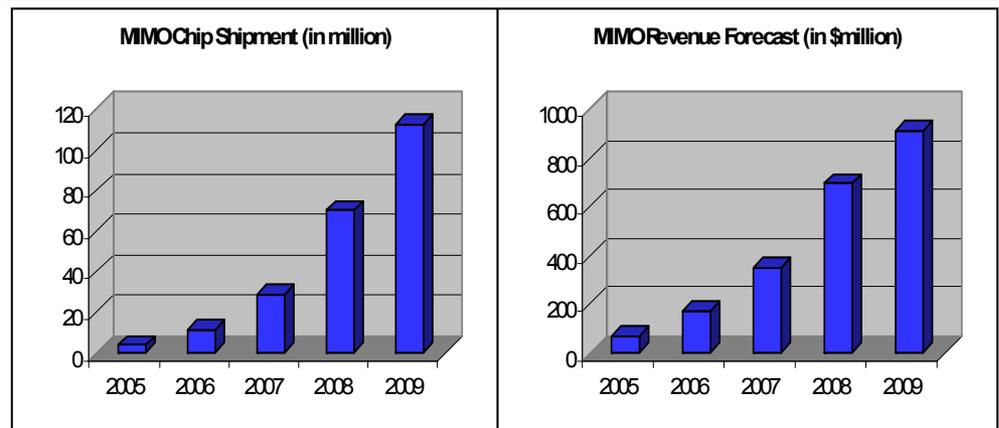
Audio/video devices with 802.11n will reach 70 million units in 2007.

As Figure 19 illustrates, many believe that most of the wireless TV and media devices in the future will have integrated 802.11n chipsets. According to Philips, consumer audio/video devices with integrated 802.11n will reach up to 70 million units in 2007. We also expect a significant number of existing 802.11b/g will be replaced by the faster IEEE 802.11n devices just like 802.11g devices replaced 802.11b devices.

Figure 19: Wireless global home devices market



Source: Strategy Analytics

Figure 20: MIMO unit shipment and revenue projections

Source: IDC

IDC predicts that annual demand for MIMO and 802.11n devices will reach 110 million units by 2009 from 2-3 million in 2006 and revenue will reach close to the \$1 billion mark. Unit sales are projected to grow at a CAGR of 234% from 2005 to 2009.

IEEE 802.11s (Wireless Mesh)

Wireless mesh networking, which is based on the yet-to-be approved IEEE 802.11s standard, is used to extend the range of a wireless network and create ad-hoc networks. Wireless meshes can also be used in home networks to extend the range of the Wi-Fi network without installing any wires and remove any dead zones. Although it makes sense in principle, we think it may prove overkill to use mesh routers in a typical home. There are other cost effective ways to extend the range like using MIMO techniques in Wi-Fi (Pre-N and draft-n), BPL (broadband power lines) bridges with wireless range extenders, and even by home-running a cable near a second Wi-Fi router.

We do not expect IEEE 802.11s to play a significant role in the home networking arena directly. However, the standard itself may become important in deployment of enterprise and municipal networks.

Broadband over Power Lines (BPL)

BPL takes advantage of well-established infrastructure

Broadband over Power Lines (BPL), also known as power-line Internet, is the use of PLC (Power Line Communications) technology to provide broadband Internet access through ordinary power lines. A computer (or any other device) would need only to plug a BPL "modem" into any outlet in an equipped building to have high-speed Internet access.

When talking about BPL, it is important to distinguish between BPL used for 'last mile' solutions which deliver Internet to a home, and BPL used to extend the network throughout a house. In this report we focus on the in-house solution only.

Variations in electricity networks and the absence of IEEE mean BPL is not fully standardized

BPL offers obvious benefits: chiefly, its well-established availability in the home already, making it easier for all electronics to be within easy reach of the BPL AP. However, variations in the physical characteristics of the electricity network and the current lack of an IEEE standard mean that provisioning of the service is far from being a standard, repeatable process. For instance, we were warned that certain BPL gear does not work with house wiring greater than 20 years old, and few BPL OEMs have gotten their equipment to work with competing OEMs' gear. Further, the bandwidth a BPL system can provide remains an open question.

Differences in the electrical systems in North America and Europe affect the implementation of BPL

Differences in the electrical distribution systems of North America and Europe also affect the implementation of BPL. In North America relatively few homes are connected to each distribution transformer, whereas European practice may have hundreds of homes connected to each substation. Since the BPL signals do not propagate through the distribution transformers, extra equipment is needed in North America.

Some of the industry organizations and forum that promote BPL technologies are:

- HomePlug (HomePlug 1.0, HomePlug BPL, HomePlug AV)
- UPA (Universal Powerline Association)
- PLCforum (Power Line Communications Forum)
- OPERA (Open PLC European Research Alliance)

Here we will focus on the most prominent of BPL technologies - HomePlug.

HomePlug BPL

Although power line communication systems could technically transfer data in the 1970s and 1980s, improvements in the power line data transfer rates necessary for home data networking did not occur until the early 2000s.

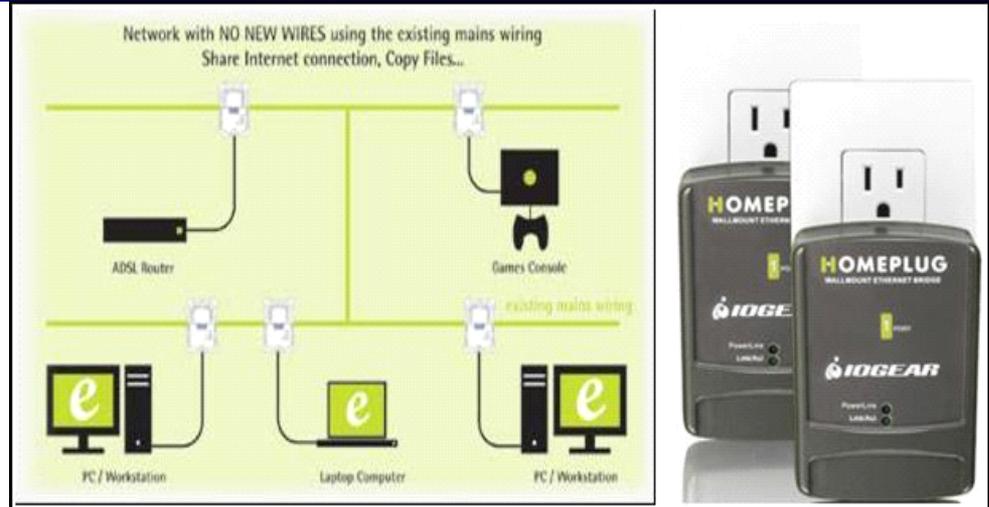
PLC systems operate in a harsh environment

One of the significant challenges for power line communication (PLC) systems is the "sources and effects" of interference signals that can distort power line communication signals. Interference sources include motor noise, signal reflections, radio interference, changes in electrical circuit characteristics, and stray transmission.

Another common challenge with PLC is the dynamic change that can occur in the electrical circuit characteristics as users use light switches and plugs in or removes electrical devices from outlets. Although both these challenges have been tackled by HomePlug, there are still issues of variability in the data rates achieved in different homes because of the level of interference and the topology of electrical wires.

Millions of HomePlug devices have already sold**Market opportunity and updates**

Over the last few years millions of HomePlug and HomePlug 1.0 products have been sold. There are HomePlug-enabled devices, such as set-top boxes from Echostar, home monitoring cameras from WiLife and GigaFast, digital media adapters from Digital 5 and speakers from Radio Shack. Non-HomePlug-enabled products can be connected to the HomePlug network using adapters. Other companies which make HomePlug-based products include: Intellon, Conexant, devolo and Netgear. According to ABI Research, MoCA and HomePlug markets will grow to a combined value of \$464 million from \$100 million in 2006.

Figure 21: HomePlug network topology and available adapters in market

Source: www.homeplug.org

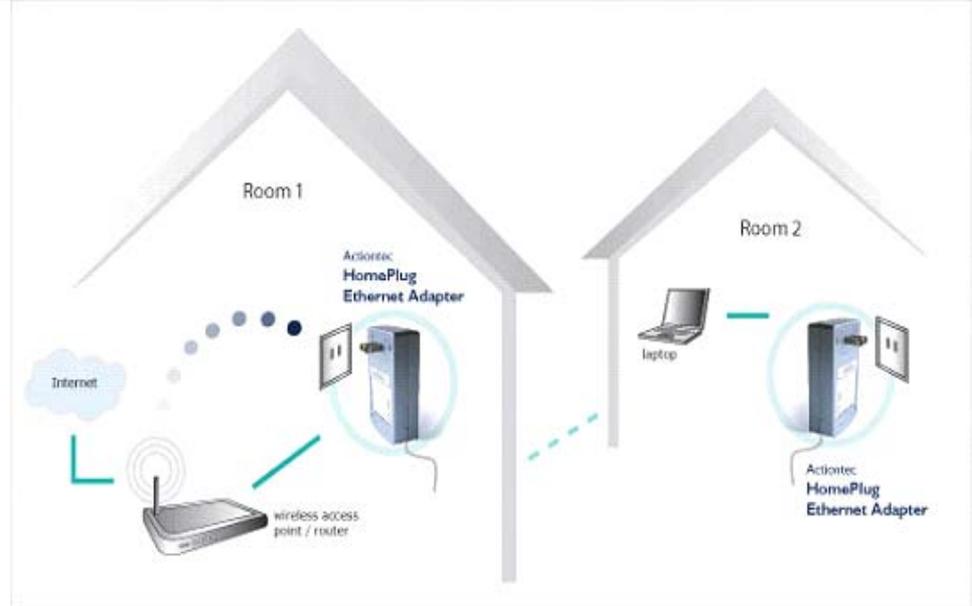
Some of the recent developments in HomePlug 1.0 suggest that this technology is gaining traction with service providers (both utility and Telco). Although our focus is only on the home networking aspect of various technologies, we do intend to recognize some of the positive developments pushing the HomePlug BPL technology to provide an alternative way of delivering broadband Internet.

Some of the key recent developments in this regard have been:

- FCC voted to promote Broadband over Power Lines
- Current Communications Services LLC, a startup pushing BPL based on HomePlug, received \$130 million in funding from investors like Google and Liberty Media
- BPL has been gaining momentum in Hong Kong, Australia, Germany, and many other countries with many utility services providers announcing commercial BPL launches

Coming back to our focus on home networking, we believe IEEE 802.11n, which is expected to be approved some time in early to mid 2007, will be a strong competitor for the primary technology of choice in the home network. We expect the industry and consumer interest in wireless technologies will continue to favor IEEE 802.11-based technologies as the primary technology in the home network for broadband connectivity.

We do, however, expect that HomePlug-based products will be used to extend the range of the home network as shown in Figure 22. We foresee a world in which BPL and WiFi technologies co-exist.

Figure 22: Application of HomePlug adapter as range extender

Source: www.atontec.com

In Figure 22, Room 2 is not in range of the wireless router placed in Room 1. To provide broadband connectivity in Room 2, a typical subscriber can:

- Run cable from Room 1 to Room 2, and install a second wireless AP there
- Install a wireless mesh router which can extend the coverage area
- Plug in HomePlug BPL adapters in both rooms

The first two options are possible, but not practical when the third option is available. The average consumer will not want to drill holes in a wall and will lack the patience to configure a mesh network. In these kinds of applications we expect that HomePlug will have a big advantage and a significant role to play in a home network.

In 2005, Comcast and Bell South both announced business deals with networking gear manufacturers like Asoka USA Corp to provide HomePlug adapters to extend the range and fill the dead spots in a typical home served by a primary Wi-Fi router.

HomePNA

The Home Phoneline Networking Alliance, or HomePNA, is an in-home networking technology that works over existing home telephone or coax wiring and also provides QoS mechanisms for supporting voice and video. The Home Phoneline Networking Alliance finalized its most recent version, HomePNA 3.0, in June 2003. HomePNA 3.0 specification supports data rates of up to 240 Mbps with guaranteed QoS for “triple play” services such as VoIP, video, and HDTV.

The popularity of Wi-Fi has been a challenge for HomePNA

Surging popularity and penetration of Wi-Fi has been a challenge for technologies like HomePNA. Over the last few years, HomePNA seems to have strengthened its focus on service providers from an in-home network technology. Reliability is a key issue with service providers and Wi-Fi, although appropriate for in-home networking needs, is yet not a suitable technology for service providers because of interference and coverage issues.

HomePlug enjoys several advantages over HPNA.

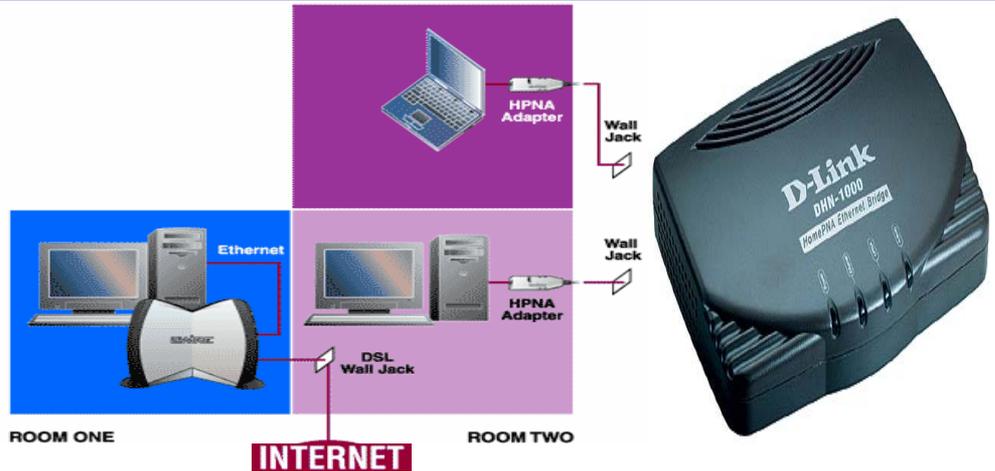
When compared with HPNA, one thing that stands in favor of HomePlug is that homes have far fewer phone jacks than they do electrical outlets. Reportedly, a major U.S. telecom operator conducted a comparison between HPNA and HomePlug in 20 homes. They were able to get connections in 100% of the electrical jacks with HomePlug, but only 80% of phone jacks worked with HPNA.

Although it would seem that the DSL Forum might be pushing HPNA, given that both DSL and HPNA use existing telephone wiring; the DSL Forum is not backing any particular home network technology. Instead, they intend to provide capability to interface with multiple technologies (HomePlug, HomePNA, and MoCA) in a home network using Universal Plug and Play (UPnP).

Market opportunity

D-Link, 2Wire, Corinex Communications Corp., OSI Systems Inc. and a few other vendors are currently developing home networking products based on HPNA technology. In the HPNA chipset market, CopperGate Communications holds a leading position.

Figure 23: HomePNA connectivity scenario (left) and a Bridge from D-Link (right)



Source: www.sbc.com

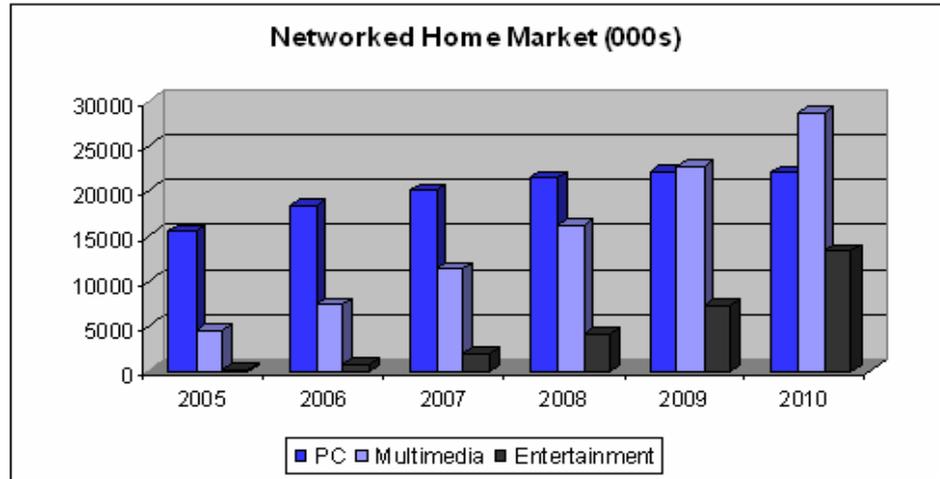
We believe HomePNA has lost momentum

In the last couple of years we believe HomePNA has lost momentum in the in-home networking market. We have not seen many product launches from vendors in quite some time. The HPNA forum (www.homepna.org) has noted the occasional win, for instance with AT&T's U-Verse, but we think HomePlug has the edge going forward.

Digital home entertainment

There is an ever-increasing amount of digital content – digital photos, movies, MP3s as well as user-generated content on websites like myspace, YouTube, etc. The early stages of online media availability (e.g. movies on iTunes) further increase the need for some way to easily access all these forms of digital media. Figure 24 shows the market projections of various categories in home networking market.

Figure 24: Networked home market projections



Source: IDC

Figure 25 illustrates the ecosystem of a digital home. In this section we will analyze potential technologies in this island of the home network and examine its prospects for actually achieving the vision of a digital home.

Figure 25: The digital home ecosystem



Source: www.intel.com

Before analyzing the potential technologies in the digital home, we first take a look at the bandwidth and QoS requirements of various multimedia applications. Figure 26 summarizes the requirements of typical multimedia applications in a home network.

Figure 26: Bandwidth and latency requirements for various applications

Application	Bandwidth	Latency	Frame Loss
Audio	64 Kbs - 1.5 Mbps	Higher tolerance to latency	Higher tolerance to frame loss
Video streaming	Higher requirement: 2 Mbps for SD and 20 Mbps for HD	Low	Higher tolerance to frame loss
Voice and Video conferencing	Lower requirement: voice < 32 Kbps; 128 Kbps for videoconferencing	Low (<50 ms)	Higher tolerance to frame loss
Gaming	Lower requirement: 32 Kbps - 128 Kbps	Lowest (< 10 ms)	Low tolerance to frame loss

Source: www.intel.com

Figure 27: Throughput and latency requirements for various multimedia applications

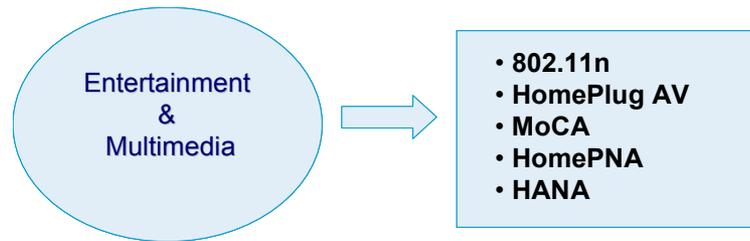
Service / Application	Payload Rate (Mbps)	Latency (ms)	QoS Needed	Jitter (ms)
HDTV	12 - 20	90	Yes	±10
HQ MPEG 2	4 - 8	90	Yes	±10
Home Theatre Audio	5 - 6	100	Yes	±10
Video Conference	1.5 - 3	10	Yes	±5
SDTV	3	90	Yes	±10
Online Games	1	<10	Yes	±5
VOIP	0.1	10	Yes	±10
CD Quality Audio	0.256	100	Yes	±10
Data (Internet Browsing)	0.5	>100	No	>100

Source: Deutsche Bank

The industry 60/60 rule of thumb is 60Mbps at 60 feet

Assuming there will be more than one HDTV stream, total throughput in a home network must be more than 60 Mbps with reliable QoS to support different multimedia applications expected to be used in a typical home network. Service providers are also looking at technologies that can deliver more than 60 Mbps in a home network enabling them to provide multimedia services at homes like IPTV, Video-on-Demand (VOD), etc.

Figure 28 shows some of the technologies that can provide capabilities to enable a digital home. We will also discuss some of the recent developments in each technology to understand the evolving ecosystem and the market shifts towards one technology over others.

Figure 28: Home entertainment and multimedia technologies

Source: Deutsche Bank

IEEE 802.11n

IEEE 802.11n, which is yet to be approved, is already gaining momentum among CE manufacturers, consumers, and networking gear companies.

Wireless is emerging as the preferred solution....

Existing wireless technologies IEEE 802.11b and g have limitations in terms of range, interference, coverage, and throughput, which make them unsuitable for multimedia applications in a home network. The 802.11n standard has the potential to improve performance on all these fronts. For more details on the throughput and QoS support on 802.11n, please refer to the analysis in the first section. Initial baseline throughput is expected to be closer to 100 Mbps.

Some of the recent industry developments look promising for IEEE 802.11n:

- Philips recently announced an agreement with Metalink to use its 802.11 Draft-n technologies in its consumer electronics products for in-home use. In the deal, Philips will integrate 802.11 technologies into devices such as set-top PVRs, receivers, HDTV and other home theater devices.
- Hai'er also announced a similar agreement with Metalink to integrate its Draft-n technology into its HDTV and other home appliance. It is interesting to note that Hai'er had originally planned to integrate UWB, but shifted its strategy after seeing the early success of 802.11n.

...but some wrinkles still need to be ironed out

Although wireless technologies seem to be gaining momentum, there are a few limitations which need to be addressed to ensure more reliability, security, and throughput. Since IEEE 802.11b/g/n all operate in the unlicensed 2.4 GHz band, interference from neighboring nodes will remain a concern in deploying these services over wireless (IEEE 802.11 based) technologies.

HomePlug AV

HomePlug AV represents the next generation of technology from the HomePlug Powerline Alliance. Its purpose is to provide high quality, multi-stream, entertainment-oriented networking over existing AC wiring within the home. It can reportedly provide up to a 200 Mbps data rate for video, audio, and data applications. QoS support in HomePlug AV provides guaranteed bandwidth reservation, reliability, and tight control of latency and jitter.

The future of BPL is still open to debate, of course, but some market estimates reach \$2.5 billion by 2010. In-house BPL is interesting and certainly has a market niche to exploit where buildings cannot be easily rewired. The promise of HomePlug AV at 200 Mbps is impressive, but 802.11 continues to evolve. Given the size of the market, we may not see a winner take

all, but see HomePlugAV continue to exist with other technologies or become the preferred solution in certain geographies. For instance, some believe that HomePlug could prove more popular in densely populated parts of Asia where interference is a greater issue for wireless.

Intellon leads the HomePlug chip market

Intellon holds a leading share of the HomePlug chipset market. Other players in the market include Spidcom, Panasonic, Conexant, and Barcelona-based DS2 (which has been more focused on access market).

The players in the HomePlug AV based product market include Netgear, Aztec (which uses the Intellon chipset), Texas Instruments (residential gateways which use Intellon, for now), Arkados, and devolo among others.

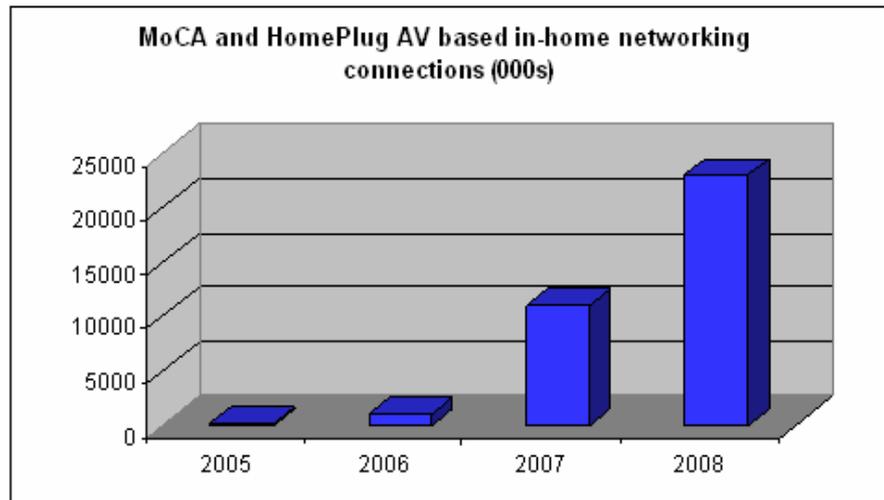
MoCA (Multimedia over Coax Alliance)

MoCA technology is primarily geared toward distributing multiple streams of high-definition video from one room to another. It also provides sufficient bandwidth to accommodate remote control of the video streams, such as with a DVR, as well as telephony service and computer data networking on the same coax cable. In the recently completed field test MoCA technology was found to have a net throughput of more than 100 Mbps in 95% of the homes tested, with at least 80Mbps in all the homes.

The need for high-speed multimedia networking links in the home is driving growth for both MoCA and HomePlug AV silicon. Increased demand for both no-new-wires media networking technologies across both service providers and consumer-installable home networks will result in the combined value of MoCA and HomePlug IC shipments reaching \$100 million in 2006 and growing to \$464 million by 2011, according to ABI Research.

Whole-home DVR installations are expected to grow at a CAGR of more than 100% from 2006 to 2008, reports In-Stat. This is driving the market for home networking-over-coax (MoCA, HPNA, Coaxsys, and HomePlug AV) chipsets, which is expected to grow by more than 150% from 2005 to 2010.

Figure 29: Growth of MoCA and HomePlug AV-based networks



Source: In-Stat/MDR

Market Update

- MoCA has seen some design wins and rollouts in the IPTV space during 2006.
- Vendors such as Motorola, ActionTec, and 2Wire have all integrated MoCA silicon into selected set-top box and gateway products. Verizon is currently using MoCA based set-top boxes from Motorola in its FiOS TV deployment.
- In May 2006, leading set-top box chip makers Conexant and STMicroelectronics announced that they would develop MoCA-compliant chips. Another recent addition is Broadcom. In total, there are now seven chip suppliers in the consortium including Entropic.

At this point, MoCA has definitely built more momentum behind it than rival technologies.

Despite these positive developments for MoCA, it still faces stiff competition from competing technologies like Wi-Fi, HPNA, Coaxsys, and DS2 (in Europe). Wireless technologies have not been considered very reliable for multimedia transmission. (but this could change with 11n). We believe both service providers and home-installable equipment manufacturers are interested in coax technologies as about 70% of homes in US are pre-wired with coax. At this point, MoCA has some momentum behind but still has issues to resolve and lacks a standard.

HomePNA

HomePNA is developed by Home Phoneline Networking Alliance, an industry consortium, whose members originally included 2Wire, Motorola, CooperGate Communications, Scientific Atlanta, AT&T Labs, etc.

The recently adopted HomePNA 3.0 specification supports maximum data rates of up to 240 Mbps with guaranteed QoS for "triple play".

Although HomePNA 3.0 offers impressive performance for multimedia applications at home, its implementation has a few drawbacks.

- Lack of availability of RJ-11 plugs near networked or AV equipment
- HomePNA 3.0 devices cannot share the same telephone line with advanced DSL technologies like VDSL
- Suffers from occasional interference when used in proximity to other devices based on current Wi-Fi standards
- Throughput varies from home to home based on the condition of the phone lines

For more details on HomePNA, please refer to the HomePNA section in the appendix.

Although MoCA seems to be the strongest of the three main wired contenders, Wi-Fi continues to be the dominant home networking technology. This is especially true among consumers, but less so among service providers for in-home pay-TV distribution, particularly in North America. Vendors such as Ruckus Wireless have had some success in Europe, but overall, service providers are waiting for the completion of the 802.11n standard as well as more testing to prove whether the technology offers sufficient reliability needed for video distribution. Figures 30 and 31 compare competing wired technologies in home multimedia networking.

Figure 30: Comparison of home multimedia technologies

TECHNOLOGY	CURRENT COSTS	FUTURE COST TARGETS	NOTES
IP over Coax (MoCA)	\$15-\$20 chipsets; additional RF component and software costs	<\$10 for integrated solution in home gateways and IP STBs	Additional required RF components increase solution cost; additional processor may be required for IP STB to support MoCA
IP over Coax/ Phoneline (HPNAv3)	Chipsets circa \$8-\$10; two required (analog front-end, digital) for a total cost of \$16-\$20	<\$10 combo chip-set for integration with home gateways and IP STBs	Multiple chipsets required (analog front-end, digital)
IP over Powerline (HomePlug AV)	\$80-\$100 per adapter (2 per connection: 1 at HG, 1 at IP STB)	<\$10 chipset for integration with home gateways and IP STBs	HomePlug AV chipset availability lags MoCA and HPNAv3; chipsets from Intellon will be generally available around May/June 2006

Source: www.heavyreading.com

Figure 31: Comparison of various multimedia technologies

	MoCA	HPNAv3	HomePlug AV	802.11x (NG WiFi)
Physical Medium	Coax cabling (RG6 & RG59)	Coax and phoneline (RG6 & RG59 coax)	Electrical Powerline	Air
Data Rate	270Mbps max; 140Mbps realistic; 100+Mbps proven in field. NG chipsets targeting 160-200Mbps.	140Mbps max; 128Mbps initial chipsets; 80-100Mbps proven in field. v3.1 max PHY rate 340Mbps.	200Mbps max; 120Mbps realistic; observed testing 50-80Mbps max (98% outlet coverage may drop significantly)	802.11g max 54Mbps; video-optimized consistent throughput 15-30Mbps range; 802.1n promising 100+Mbps.
Capex	\$\$	\$	\$	\$\$\$
Opex	\$	\$	\$	\$ (lowest opex)
Security	DES	AES	128-bit AES	802.11i, WEP, WPA2
Interference	Limited	Limited	Surge protectors, electrical motors, switching power supplies, dimmers, etc.	2.4GHz cordless phones, microwaves, etc.
QoS	RF/IP bandwidth separation; challenges with standard IP priority markings	MAC-level QoS with unlimited priority levels	TDM/CSMA-CA-based MAC	802.11e, WMM, proprietary techniques for optimized 802.11g
Additional Notes	Verizon deploying as part of FIOS. MSO market may be larger opp. Moto & others integrating today.	AT&T deploying as part of Lightspeed. Emerging as preferred NA telco choice. SA, 2Wire, etc., integrating today.	AV standard chipsets not readily available, lags MoCA, HPNAv3. DS2 (UPA) leads powerline deployments internationally to date. Expect more action 2H06 and 2007.	Initial deployments of video-optimized 802.11g are promising. Ruckus Wireless leading market. Carriers worldwide will continue to drive NG WiFi.

Source: Heavy Reading

HANA (High-Definition Audio-Visual Networking Alliance)

HANA stands for the High-Definition Audio-Video Network Alliance. HANA includes members from IT, content providers, service carriers and consumer electronics makers. HANA's mission is to utilize existing standards and technologies to create a design guideline for secure High Definition AV networks that will advance commercial deployment of products and services and will enhance the consumer HD entertainment experience.

HANA was incorporated in October 2005 by Charter Communications, Mitsubishi Digital Electronics America, NBC Universal, Samsung and Sun Microsystems. ARM, Freescale and Pulse-LINK later joined the Alliance at the contributor level.

HANA was created to solve the two basic problems:

- Consumers are confronted with an increasingly confusing set of connections, remote controls and set-up options as new digital products and services are introduced
- Increasingly, content is being delivered to the home over broadband connections that today terminate at the PC; however, most consumers do not want to watch movies and TV programs or listen to music on their PCs

The alliance chose IEEE 1394 as the underlying connectivity technology because IEEE 1394 is the only digital interface that has an FCC mandate to be included in Digital Cable Set-Top Boxes.

A common consumer complaint – too many remotes

HANA believes that there are two problems with the current paradigm that cause the vast majority of complaints consumers have with their entertainment products - confusing connections (component, composite, S-Video, DVI, and the resulting problem of selecting AV1, AV2, channel 3 or 4, etc.) and too many remote controls or 'universal' remotes that are not 'universal' and that must be programmed.

HANA proposes to solve the problem of connector confusion through the use of 1394 or FireWire. Any device can be connected to any other device with a single cable, common across all HANA devices.

HANA solves many, but not all, problems

This approach definitely sounds a lot simpler if you have ever patched connections behind a TV, AVR, or a DVD player. We, however, are not sure how HANA intends to solve the problem of streaming multimedia from a PC to any TV in a home. It would need an extra device to bridge wireless (Wi-Fi) and HANA to achieve this interconnection. Also, though it is a better approach for eliminating connection confusion, it lacks the flexibility of wireless technologies.

Market update

HANA-based products like HDTV and DVR are slated to be launched late this year. The Alliance plans to showcase the benefits of this technology in CES 2007. HANA currently does not enjoy participation from the most prominent industry players, but since the alliance was formed only in October 2005, it is still too early to predict how things will shape up for this alliance in the future.

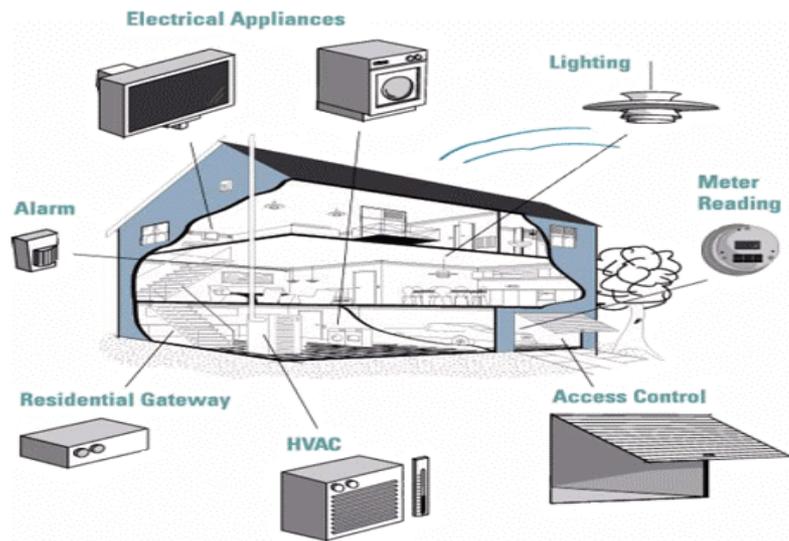
HANA also plans to address compliance and certification testing in the second half of 2006. The alliance plans to work with a third party to conduct interoperability testing for HANA products.

Home control & automation

Home control and automation applications are now coming out of the realm of hobbyists. For many years home control and automation applications have struggled their way into homes because of a lack of standards, a lack of network-ready appliances in the market, and cost of installation. Penetration of wireless broadband technology and a more evolved ecosystem of appliances and applications are turning this market into more than just an enthusiast's dream.

In our experience, the topic of home automation sends even the most jaded industry observer into flighty realms of fantasy. No one likes housework, and the Jetson-ian idea of the coffee pot that senses its master's need for caffeine holds near universal appeal. The list of applications is endless, and we note a few in Figure 32.

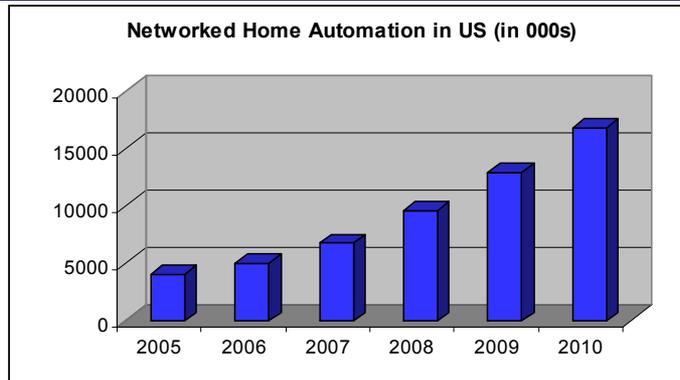
Figure 32: Typical home control and automation applications



Source: www.hekta.org

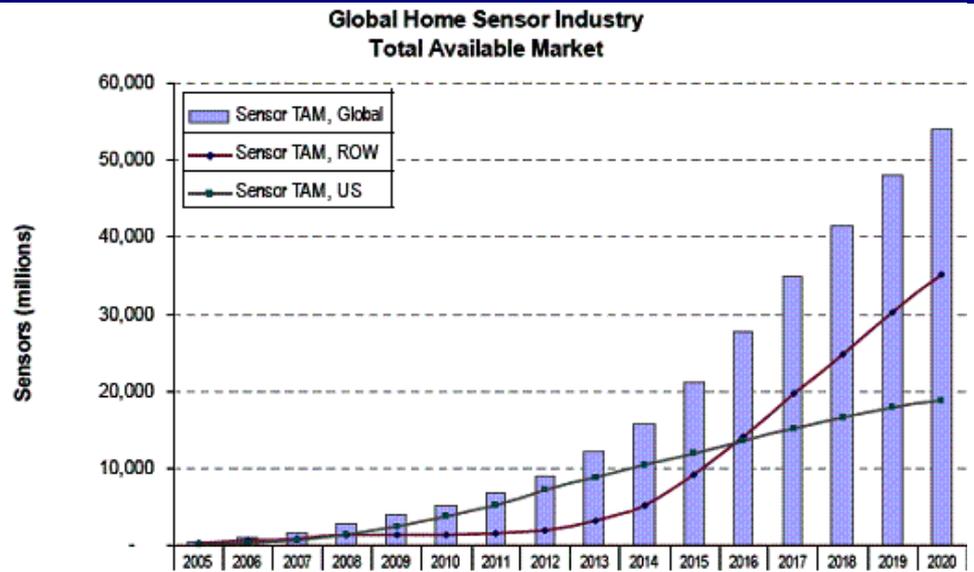
IDC has put out estimates for the size of the home automation market, which we depict in Figure 33. In our view, it is too early for forecasting given the variation in the costs of solutions now on the market. The typical custom installation, all that has been available until recently, can easily cost \$100,000. At the same time, low-cost, standardized products from companies like Zensys offer a simpler form of automation for as little as \$5,000.

Figure 33: Projection of networked homes in US



Source: Deutsche Bank

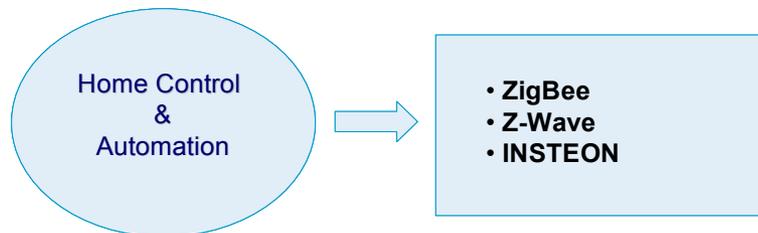
Figure 34: Global home sensor market



Source: WTRS, Jan 2006

Several products are already available in the market for installation by either a professional or self, but the key to success in this market will be simplicity, ease of installation, interoperability, and the emergence of a clear, winning standard. There are three main technologies in the home control and automation market vying for dominance.

Figure 35: Home control and automation technologies



Source: Deutsche Bank

ZigBee

ZigBee (built on top of IEEE 802.15.4) has gained significant attention in the past year or so in the home control and automation market. The ZigBee Alliance lists Motorola, Cisco, Texas Instruments, Eaton and Legrand as some of its backers and has more than doubled its membership to over 120. The alliance estimates that more than 700,000 radio systems shipped last year, primarily in the industrial and building automation space. While these numbers appear strong, most of these chips were sold for 802.15.4 and very few of the chips are used in Zigbee applications. Currently, ZigBee chipset cost under \$5 and we are starting to see speedier rollout of products for residential home applications. ZigBee development and evaluation kits are also available in the market.

Some of the advantages of ZigBee are:

- Standards-based and hence can be used throughout the world without royalties
- Operates in 2.4 GHz band which is available for unlicensed use in most of the countries
- Battery life is good
- Disadvantages
 - Fewer products available today in the retail channels
 - The flip side of this, however, is that it could be subject to interference from 802.11, also operating in this band
 - Few products have been deployed with interoperability due to lack of device profiles and a lack of adherence to those profiles that do exist
 - ZigBee's initial focus has been industrial automation market

ZigBee technology is intended to be simpler and cheaper than other WPANs such as Bluetooth. The most capable ZigBee node is said to require only about 10% of the software of a typical Bluetooth node. As of 2006, the estimated cost of the radio for a ZigBee node is about \$1 and is expected to fall even lower as manufacturers hit higher volumes.

In March 2006, Texas Instruments acquired Chipcon, a leading developer of ZigBee technology, for \$200 million. The announcement demonstrates that after a slow start, momentum is building behind ZigBee technology.

Z-Wave

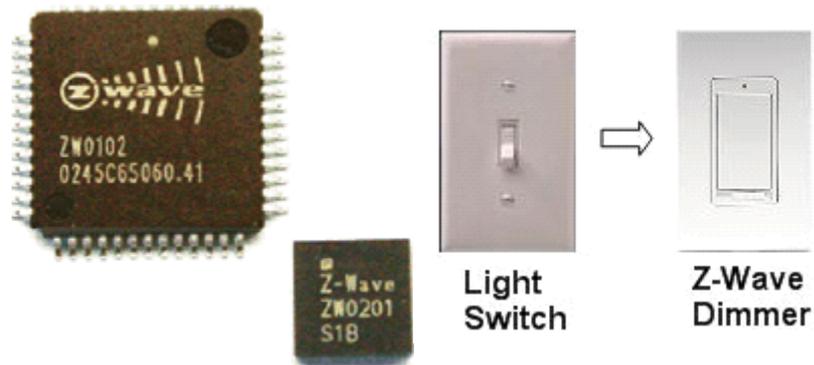
Z-Wave technology developed by Zensys (received \$40 million in VC funding) is another technology which competes with ZigBee and INSTEON. While ZigBee is making inroads in the industrial space, Z-wave has a leading position in residential market applications. It shipped its first single-chip mesh node in 2002, and is now delivering its third generation of mesh-node chips. Z-wave is currently embedded in domestic devices (such as light switches) and has a roadmap over the next 24 months that will get the cost to around \$1 in volume, enabling partners to deliver products such as a wireless controlled dimmer switch for around \$10. Z-wave is a proprietary wireless protocol developed by Zensys, which is working towards making Z-Wave the de facto standard for home control.

Z-Wave is backed by companies such as Intel, Cisco, Leviton, Intermatic, Cooper Wiring Devices, Logitech and Panasonic. Zensys has more than 125 customers with development contracts for Z-Wave, which uses a mixed signal ASIC that combines both a processor and a transceiver.

Market update

Z-Wave products have been available in the market for three years now compared with the other two technologies that only recently started shipping products. Currently there are more than 100 Z-Wave based products in the market and more are in the offing. Intel has recently made a strategic investment in Zensys.

Currently, more than 125 companies are developing products that incorporate the Z-Wave technology. These products fall into many areas like lighting, temperature control, home theatres, pool and spa control, garage door openers, automated meter reading and many more.

Figure 36: Z-Wave single chip solution (left) and a Z-Wave dimmer (right)

Source: Deutsche Bank and Zen-Sys

Recently, a wave of events has put Z-Wave in the forefront of the home networking technologies. Most notable of these events are:

- CNET award at the Consumer Electronics Show in January 2006
- A successful demo of a package of Z-Wave products at the International Builders' Show
- An investment in Z-Wave by Cisco of an undisclosed amount

Another big reason for this push behind Z-Wave is that most of the leading Z-Wave companies are well known among homebuilders and have established sales channels to them.

Zensys and Z-Wave still face a few challenges. All three technologies will have to bolster the limited consumer awareness of automated home applications. Z-Wave not only has to struggle with building consumer awareness, but also IT industry awareness. While backed by Intel and Cisco, among others Z-Wave still does not have the high level of awareness that ZigBee does.

In a round of recent channel checks, we confirmed with several industry contacts that Z-Wave has tangible traction that the other standards lack. In our view, this is in large part due to its focus on supplying low-cost solutions and working closely with suppliers of home-building materials. Competition from older technologies, such as X10 power-line networking, is waning as this is outdated technology. ZigBee, which has multiple chip manufacturers and multiple software stack creators, is struggling to deploy interoperability and is having problems getting adherence to its standard, is less mature and less well optimized for home automation mesh network applications. The relative maturity of Z-Wave, combined with the strength of the Z-Wave alliance and solid deployment of interoperability makes this a technology to watch.

INSTEON

INSTEON offers a simple and reliable solution for managing home control and automation. INSTEON is fully compatible to X-10, which is a powerline-based networking technology. X-10 currently has an installed base of about 10 million homes, which gives INSTEON a solid footing vis-à-vis competing technologies.

Though X10 backward compatibility is not an inherent part of the Z-Wave or ZigBee wireless systems, both technologies have interfacing products available that allow interoperability.

The signal transmission method used by INSTEON is simulcasting, as opposed to the routing method used by Z-Wave and ZigBee. With routing, the transmitter looks for the shortest or least noisy path to the receiver, but with simulcasting, the signal is broadcast to all receivers (or nodes) within range, then those nodes retransmit the signal to all nodes within their range until the message is received by the correct device. Competitors claim that INSTEON's simulcasting has the potential of flooding the network with too many signals and consequently slowing down the response time of its devices or causing it to crash if 50 or more devices are used in a single network.

The 904 MHz ISM band is not available in Europe and Asia and, thus, INSTEON must find a way to make it work in other countries for a broader adoption of the standard. INSTEON is aware of this issue and is actively looking for solutions and partnership to make it work in Europe and Asia. INSTEON currently plans to develop products using the 868 MHz band for Europe and Asia and is also open to developing products for 2.4 GHz band if demand arises.

In spite of these unclear scenarios, INSTEON boasts a 350+ strong alliance of industry members and participants. Also, history tells us that a technology doesn't need to be the best to win in the market. Figure 37 details comparisons among each technology.

Figure 37: Comparison of home automation technologies

	INSTEON	ZigBee	Z-Wave	X10
Standard Based	No	Yes	No	Yes
Retail Pricing	\$20+	\$20+	\$40+	\$10+
Chipset Cost	\$1-\$2	<\$5	\$2-\$4	-
Product Availability	Low	Low	High	-
Physical Media	RF + Powerline	RF Only	RF Only	Powerline Only
Frequency Band	904 MHz - US	915 MHz - US 868 MHz - Europe 2.4 GHz - ROW	908 MHz - US 868 MHz - Europe	-
Bandwidth (kbps)	38.4 - RF 2.8 - Powerline	20 - 250	40-100	0.06
# Nodes per Network	16,777,216	2 ⁶⁴	232	256
Range (meters)	1 - 45	1 - 100	30 - 100	-
Network Type	Mesh, Peer-to-peer with no controller	Star, Peer-to-peer, or mesh	Mesh	-
X10 Compatible	Yes	No	No	-

Source: Deutsche Bank

Although each technology has its strength and weaknesses, key success in this market will come through interoperability, wide acceptance, and cost.

Other issues to be tackled are the development of retail channels for home automation products, bridges to other elements of a home network, and consumer education - not trivial tasks, to be sure, but reachable enough that those looking for home networking applications beyond data and entertainment networking need to start paying attention to the home automation market.

PC peripherals and cable replacement

In this section we will focus on short-range wireless technologies which can replace the cables for devices which we usually connect to a PC or laptop as shown in Figure 38.

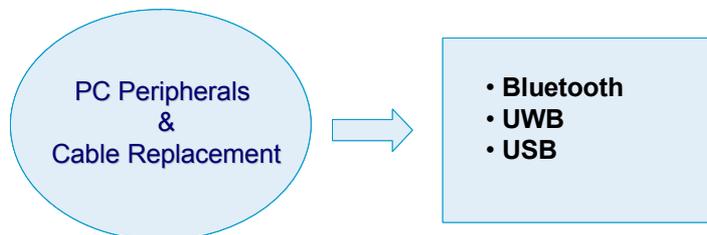
Figure 38: Typical PC peripherals and CEs connected to a PC or laptop



Source: Deutsche Bank

Although some of the technologies under focus here could be used in other applications as well, we will analyze them based on their traction and market position in the cable replacement applications only.

Figure 39: PC peripheral and cable replacement technologies



Source: Deutsche Bank

Bluetooth

Bluetooth has become a de facto technology for cable replacement for mobile handsets, synchronization of portable devices with PCs, and other PC peripherals requiring short distance wireless connectivity. Bluetooth technology is now also playing a role in the voice and data applications like headsets for music players, and file transfer between portables devices and laptops. As the VoIP becomes more popular, Bluetooth could also find applications in cordless phones connecting the cradle and the computer.

Figure 40: Worldwide Bluetooth unit shipment forecast

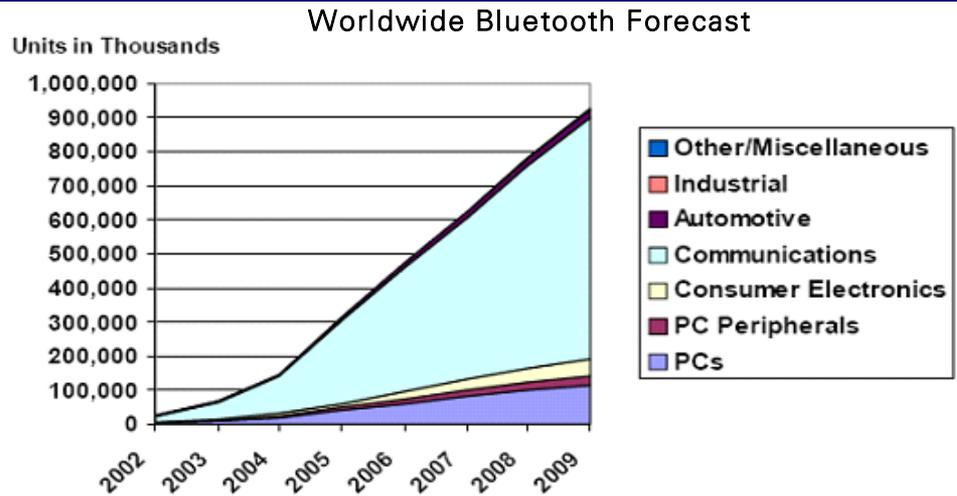
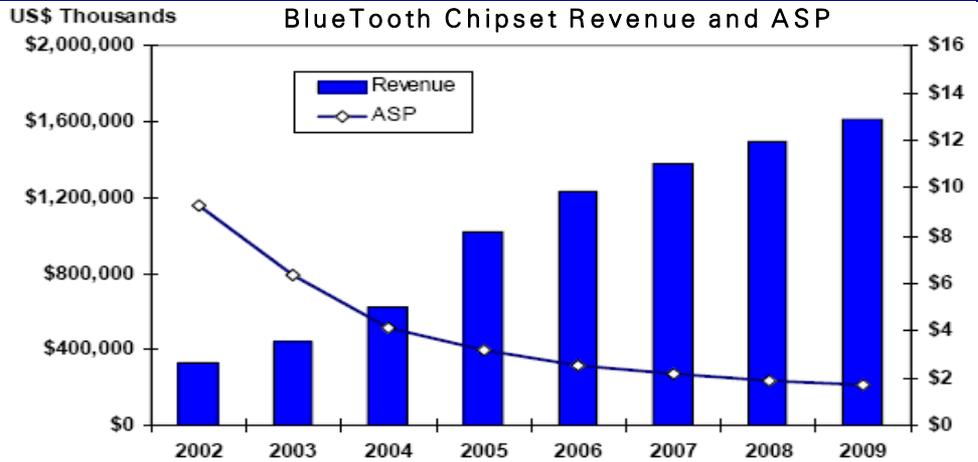
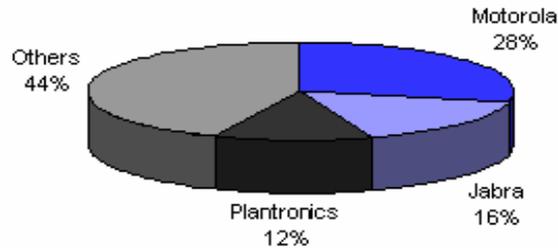


Figure 41: Worldwide Bluetooth chipset revenue and ASP



Figures 40 and 41 show the worldwide market size and dropping price points of Bluetooth chips which was instrumental in its mass adoption in various products.

Top players in the Bluetooth accessory market are Motorola, Jabra, and Plantronics with their respective market share shown in Figure 42. According to a report from Strategy Analytics, the Bluetooth headsets market will rise by 70% in a couple of years.

Figure 42: Bluetooth market share**Bluetooth Market: Top Players**

Source: Strategy Analytics

In March 2006, the Bluetooth Special Interest Group announced its selection of multi-band OFDM version of UWB for integration with the current Bluetooth wireless technology. This new version of Bluetooth technology would be appropriate to meet the high-speed demands of synchronizing and transferring large amount of data as well as enabling high quality video and audio applications for portable devices, multi-media projectors, and TVs, and wireless VoIP. In this version the data rates would jump to 480 Mbps from the 3 Mbps specified in the fastest version of the Bluetooth.

Unlike USB, Bluetooth does not require a host PC to connect two devices

Bluetooth has found its place in the digital home as a viable technology to interconnect and synchronize plethora of portable, mobile devices with the Home PC. Unlike USB, Bluetooth does not require a host PC to connect two devices and hence two Bluetooth devices can form an ad hoc peer-to-peer network. Bluetooth has also become a popular technology to integrate mobile phones into automobile in-dash navigation systems.

Although mobile phone accessories are the main driver of Bluetooth growth right now, there are a few other markets where Bluetooth is gaining traction:

- Integration of mobile phones and navigation capabilities for automotive systems
- Cordless and VoIP phones
- Integration of Bluetooth capability in stereos and TVs for headset and in other CE devices like cameras, portable media players, and printing and imaging devices.

UWB (Ultra-Wideband)

UWB proponents claim it to be a likely contender for the backbone of a home network. The advantages of UWB are its high data rates of up to 480 Mbps and low power consumption.

Currently, there are two competing flavors of UWB: Direct Sequence-UWB proponent Forum (Freescale Semiconductor), and the Multiband group WiMedia Alliance (Intel, Microsoft, HP).

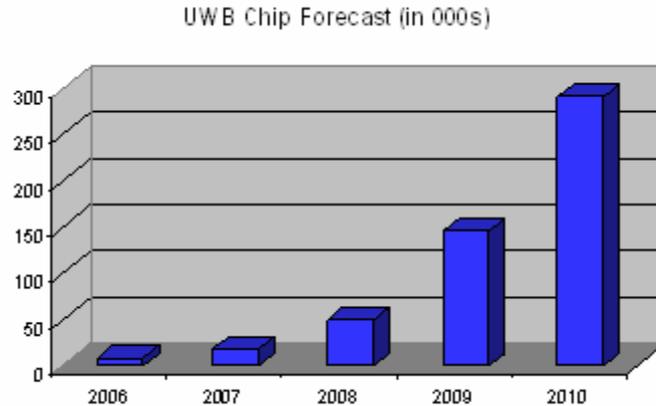
The WiMedia flavor of UWB got a boost when in March 2006 Bluetooth SIG selected the WiMedia Alliance version of UWB for integration with the Bluetooth wireless technology. The Freescale-backed UWB forum points to the fact that products are already in the market as a key indicator of its technology's proven readiness, while also pointing to the weakness in the WiMedia proposition arising from its lack of products.

Although this situation is being compared with the classic Betamax and VHS showdown on market traction front, we do not think that UWB's market traction is of any significance even to this point.

In Jan 2006, IEEE abandoned its effort to create a UWB standard.

In Jan 2006, IEEE abandoned its effort to create a UWB standard. The collapse of the IEEE 802.15.3a standard group is definitely a setback to the UWB forum and would make it an unlikely candidate for inclusion in other super-set standards. The lack of a clear winner is also holding up development of UWB products.

Figure 43: UWB unit shipment projections



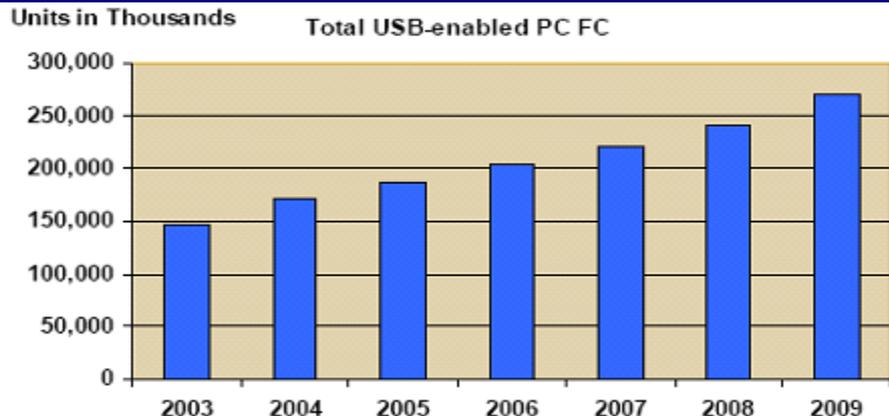
Source: In-Stat

We however believe that the WiMedia version of the UWB combined with Bluetooth technology could further augment Bluetooth's position and create a powerful Personal Area Network (PAN) capable of multi-channel streaming of high quality videos. As it stands now, the UWB/Bluetooth combination remains in its infancy.

USB and Wireless USB (Universal Serial Bus)

USB ports are now found in almost every PC worldwide. It has also gained some traction in mobile phones using a miniaturized connector.

Figure 44: Total worldwide USB-enabled PC forecast



Source: In-Stat

Since USB needs a host PC to function, its application space is limited to devices which need connectivity with a PC for synchronization or file transfers.

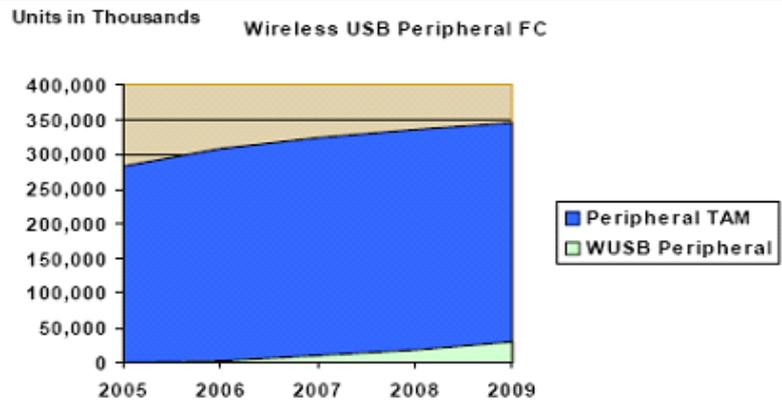
Flash drives have been a big success for USB

On the CE side, USB can be found in cameras, printers, scanners, flash drives, and external memory storage media. Flash drives have been a big success for USB and the 100 millionth device with USB shipped in less than 5 years.

The USB Forum recently announced a wireless version of the same technology with improved security and throughput, Wireless USB (WUSB). WUSB is a new short-ranged, high-bandwidth wireless extension to USB intended to combine the speed and security of wired technology with the ease-of-use of wireless technology. WUSB is based on Ultra-Wideband (UWB) wireless technology defined by the WiMedia Alliance, capable of sending 480 Mbps at distances up to 3 meters, and 110 Mbps at up to 10 meters. It operates in the 3.1–10.6 GHz band-range and spreads communication over an ultra-wideband of frequencies.

Just like UWB, there are two versions of WUSB each associated with one of the UWB factions. WiMedia WUSB has an advantage as there are more industry backers including Intel and Microsoft. The future of WUSB is tied to the outcome of the standards war in UWB to a certain extent, which may lead to confusion and delay in product development.

Figure 45: Forecast for wireless USB based peripherals

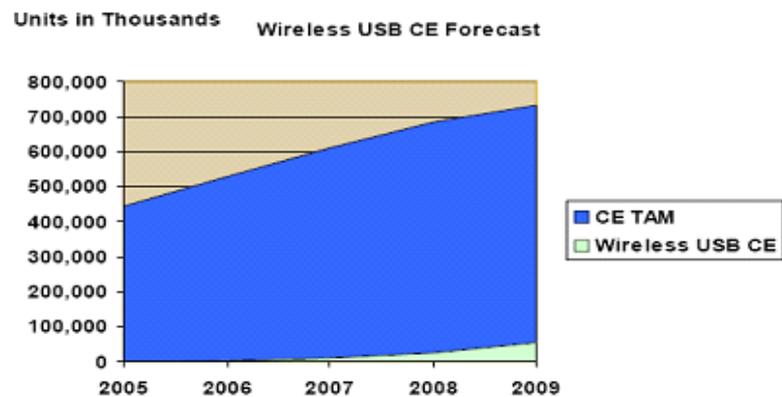


Source: In-Stat

We believe WUSB will find a narrow, but deep niche

Due to increasing dominance of Bluetooth and announcement of integration of Bluetooth with WiMedia UWB, we do not expect WUSB to make significant inroads in the cable replacement market. However, we do believe that the wired USB market will remain steady for a while due to the cost advantages from scale economies WUSB lends itself to certain applications such as build data transfer that will favor its simplicity and low-cost profile.

Figure 46: Projection of wireless USB in consumer devices

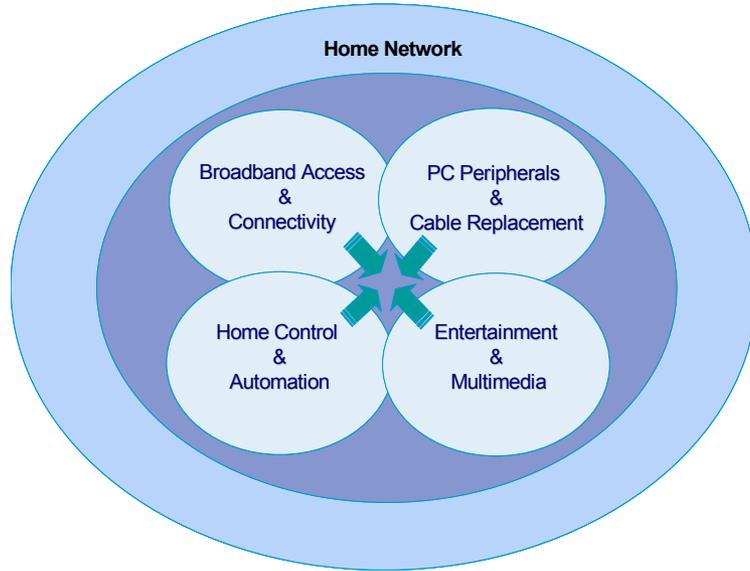


Source: In-Stat

Integrating the islands

The concept of home networking has been around for decades, but the marketplace has yet to see any commercially successful technology that can integrate all the diverse applications and devices in a home network.

Figure 47: Convergence of islands in the home network

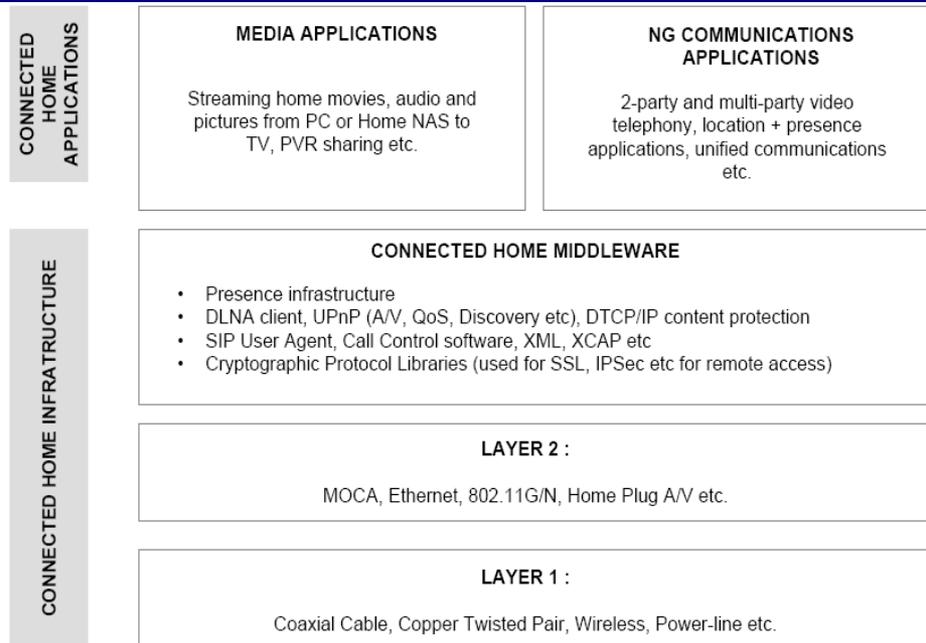


Source: Deutsche Bank

Ideally middleware should be technology, device, OS, and application agnostic

Ideally the integrating middleware should be technology, device, OS, and application agnostic to deliver the vision of a fully integrated and connected home network. In this section, we review recent developments in this regard and analyze potential middleware technologies which could integrate the home network islands as depicted in Figure 48.

Figure 48: Components of a connected home



Source: www.cisco.com

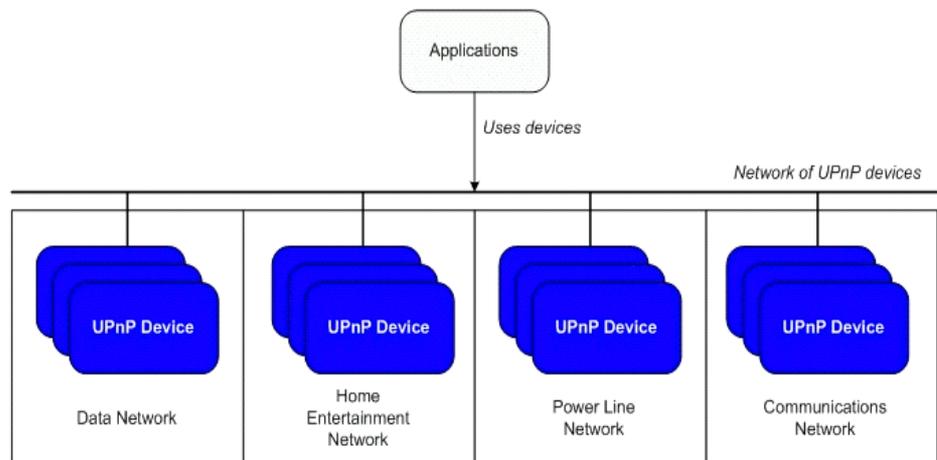
UPnP (Universal Plug n Play)

UPnP – Universal Plug and Play – is a technology intended for smart homes, small offices and other types of local area networks. It was originally created by Microsoft in 1999. UPnP is now led by the UPnP forum (<http://www.upnp.org>), an independent organization with over 800-member vendors, including industry leaders in consumer electronics, computing, home automation, home security, appliances, printing, photography, computer networking, and mobile products.

In July 2006, the UPnP Forum announced the release of version 2 of the UPnP Audio Video specifications (UPnP AV v2), which enable the next progression of the AV-oriented home network. The UPnP AV specifications use the UPnP Device Architecture– the core interoperability technology for all UPnP-enabled devices - allowing different companies to build home network products that automatically locate and identify each other without any end-user configuration.

Figure 49 shows how various different devices on the home network are connected to one UPnP network.

Figure 49: UPnP devices in a home network



Source: Deutsche Bank

UPnP is agnostic to the technology being used underneath the devices at layer 2 as shown in figure 48 above. Several UPnP device and service profiles have been defined including:

- Internet Gateway Device (IGD)
- Media Server and Media Renderer
- Quality of Service
- Printer Device and Print Basic Service
- WLAN Access Point Device
- Digital Security Camera
- Device Security and Security Console
- HVAC
- Lighting Controls and Remote UI Client and Server
- Scanner

A UPnP compliant appliance can offer a number of important advantages, including:

- *Open standards:* Because UPnP is based on standard Internet protocols; it can work with a broad range of information appliances, from large PCs to small consumer electronics information appliances.
- *Scalability:* UPnP normally functions in small network environments; however, it is possible to scale upwards to larger networks.
- *Plug and Play:* Most home users want to just plug it in and have it work immediately with no hassles. UPnP is based on straight forward, innovative mechanisms for discovery and connectivity that provide a basis for enabling information appliance services.
- *Low footprint:* Unlike traditional PC-based solutions, consumer electronic appliances have radically less systems resources at hand. Typically, they are based on a low-cost microcontroller and 200-1000 Kbytes of RAM and flash memory. Implementing Universal Plug and Play requires very little development work and requires only a very small amount of system resources and footprint.
- *Multi-vendor and mixed media environment:* UPnP has been explicitly designed to accommodate these mixed environments including home automation and control devices.
- *Smooth integration with legacy systems and non-IP information appliances:* Although IP inter-networking is a strong choice for Universal Plug and Play, it also accommodates home networks that run non-IP protocols such as IEEE 1394-based entertainment networks. The home network, for example, could use a Windows PC to host several different types of legacy information appliances and use the UPnP mechanism to make these information appliances discoverable to other peers on the network.
- *Non-PC-centric architecture:* The configuration of a UPnP based network can be based on a peer-to-peer network architecture, which means that the home network can function without a PC. This doesn't, however, mean that the PC has no role in a UPnP based network. The PCs general-purpose nature and substantial resources will make it a valuable part of any network where it is present.

Market update and recent developments

In January 2006, DIRECTV announced plans to implement DLNA and UPnP interoperability into its next generation of set-top boxes.

DLNA (Digital Living Network Alliance)

DLNA specifications are based primarily on UPnP

The Digital Living Network Alliance (DLNA) is a consortium of over 280 consumer electronics companies whose goal is to develop guidelines needed for interoperable networked products for Digital Homes. DLNA specifications are based primarily on UPnP.

DLNA has published a common set of industry design guidelines that allow vendors to participate in a growing marketplace, leading to more innovation, simplicity and value for consumers. The DLNA Interoperability Guidelines specify the interoperable building blocks that are available to build platforms and software infrastructure.

DLNA published the first edition of the Home Networked Device Interoperability Guidelines in June 2004 and subsequently released (in January 2005) an addendum of additional support for 11 more media formats. The guidelines dictate that networks must be based on an IP foundation; connected through Ethernet or Wi-Fi; utilize HTTP for media transport, and feature Universal Plug and Play (UPnP) for device discovery, control, and media management. In September 2005, DLNA also launched its DLNA Certified certification and logo program.

Jini

Jini was developed by Sun Microsystems as a home networking software solution. It is a layer of Java software that allows information appliances to plug directly into a home network without the hassle of installing drivers and configuring operating systems.

In a Jini-enabled home network there is no central repository of drivers. The Java programming language is the key to making Jini technology work. Information appliances in a network employing Jini technology are tied together using Java Remote Method Invocation (RMI). RMI is best described as a set of protocols being developed by Sun's JavaSoft division that enables Java objects to communicate remotely with other Java objects.

Along with Sun Microsystems, Jini's fortunes have changed a lot. Jini was initially proposed as a device-centric technology. However, its latest definition positions it as a technology to create network-centric services that can be used to build adaptive networks that are scalable, evolvable, and flexible as typically required in dynamic computing environments.

it is difficult to run JVM on each mobile device which is a major impediment for Jini

One issue with Jini is its use of RMI, which requires a Java Virtual Machine (JVM) to run on each mobile device. Since these mobile devices are scarce on computing resources, it is difficult to run JVM on every device, which is an impediment for Jini. Although we expect Jini to serve other markets as a protocol agnostic technology for distributed, network-centric, scalable software services, we do not expect Jini to take a front seat in the race of technologies promising to integrate diverse set of applications in a home network.

Summary

We expect UPnP and DLNA to lead the market towards ultimate interoperability and seamless integration of different devices in a home network. Built on IP protocol and leveraging the strengths and popularity of Ethernet, we believe UPnP will be the core of device management and control in a home network.

Conclusion

So now we have an integrated home network with various devices and technologies from all four islands as we described above. But, how do we control it? What does this device look like? Could this device be a PC or a handheld or a tablet or even a mobile phone?

Here is one product announcement from Sanyo to give you a hint of what these devices for ultimate control of the home network may look like.

“Sanyo Electric announced on January 7, 2006 that it has developed a technology to control Net appliances which can be connected to cell phones and the Internet. Called DarWIN, the new technology can control white goods, such as refrigerators and washing machines, audiovisual equipment, and security devices on a single controller.

Implemented on a home server and a remote controller with a touch panel, DarWIN supports ECHONET, a communications standard for white goods, as well as Universal Plug and Play (UPnP), an AV device communications system. The touch panel displays the layout of a house, and the user can turn on and off home electric appliances from the panel. Also embedded is a voice recognition system, which can accept instructions to switch on and off the appliances.”

Extending the thought, this ultimate device would allow you to control, enroll, and monitor all your devices on the home network irrespective of underneath technology, OS and application. You can also take your networked home wherever you go, in the sense that you can remotely monitor your home network and all appliances over Internet.

The challenge for home networking remains recreating the ease of use which most home appliances now boast. In our view the company that can replace the five remote controls most homes now feature with a single truly universal device will emerge as the winner in the field. At this point, however, this remains in the realm of science fiction. However, we think the key hardware elements are now in place, and the last remaining obstacle is a software solution that can knit these disparate elements together.

Appendices

Appendix A: Technologies and standards

In the following sections we will analyze each of these technologies on their outlook and target applications. We have organized the analysis of various home-networking technologies based on the set of applications they are most appropriate for (broadband access, home automation, entertainment and multimedia, and PC peripheral).

IEEE 802.11 (Wi-Fi)

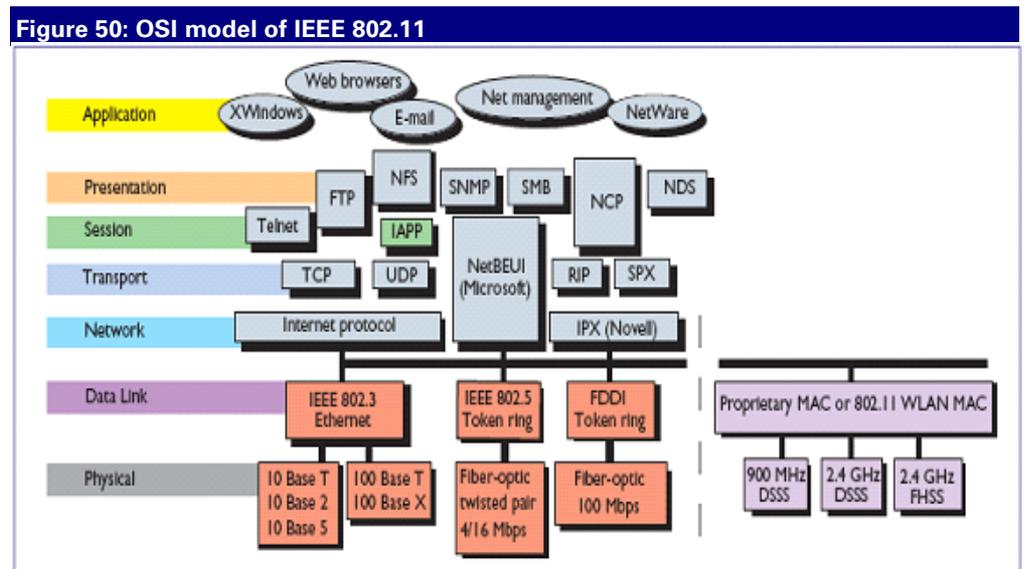
In 1997 the IEEE released 802.11, the first wireless LAN (WLAN) standard which defines medium access control (MAC), physical layer (PHY), and procedures to provide security for user information being transferred for wireless connectivity for fixed, portable, and moving stations within a local area.

The physical layers used in the IEEE 802.11 are different from its wired media counterpart 802.3. The 802.11 PHYs are different in following ways:

- Use a medium that does not have readily observable boundaries
- Have dynamic topologies
- Lack full connectivity and are unprotected from outside signals

Protocol Basics

Figure 50 illustrates the relationship between wireless and wired protocols in the ISO model. The IEEE 802.11 standard allows unconnected client devices to communicate with the Ethernet network through an RF transmitter that is physically connected to the wired network. This technology works like an Ethernet hub, and as long as a client remains within the transmitter's range, the client is connected to the network and can send and receive data.

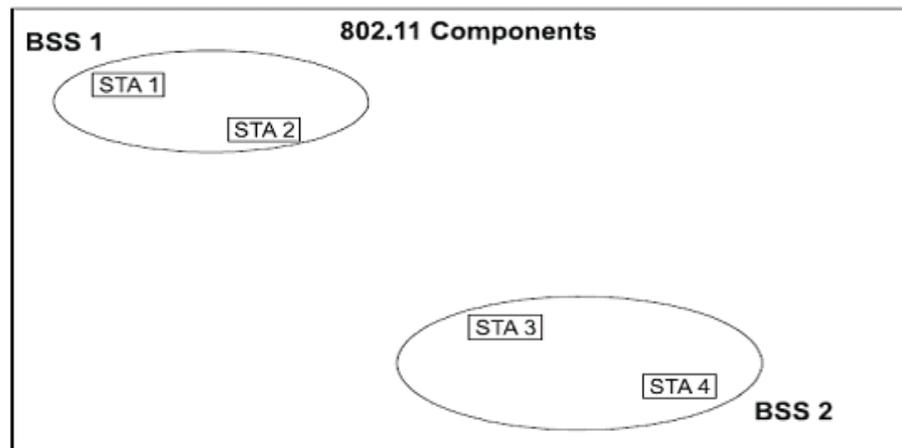


Source: www.computer.org

Architecture of IEEE 802.11

The main components of 802.11 architecture are: basic service set (BSS), station (STA), access point (AP), independent basic service set (IBSS), distribution system (DS), and extended service set (ESS).

Figure 51: Basic service sets in IEEE 802.11



Source: IEEE 802.11-1999

The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 51 shows two BSSs, each of which has two stations that are members of the BSS. If a station (STA) moves out of its BSS, it can no longer directly communicate with other members of the BSS.

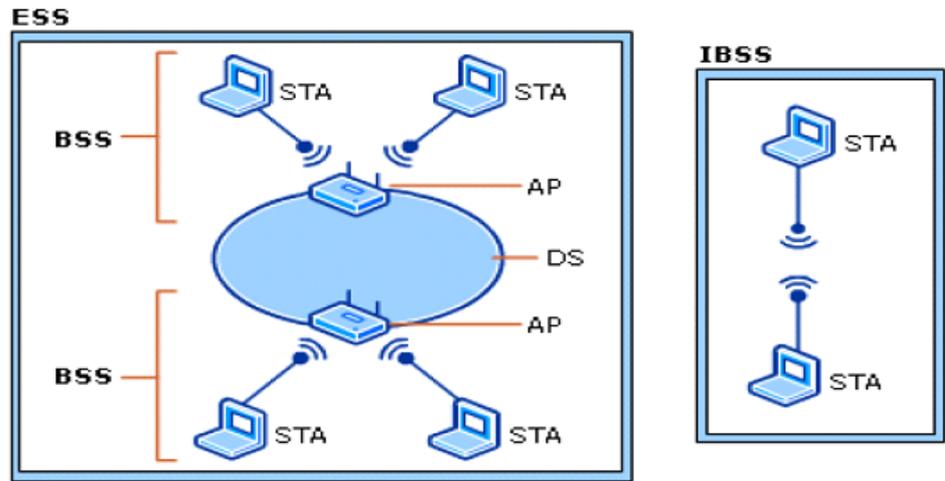
The independent BSS (IBSS) is the most basic type of IEEE 802.11 LAN. A minimum IEEE 802.11 LAN may consist of only two stations. Figure 51 shows two IBSSs. This mode of operation is possible when 802.11 stations are able to communicate directly. Because this type of LAN is often formed without pre-planning, for only as long as the LAN is needed, this mode of operation is referred to as an ad hoc network.

The architectural component used to interconnect BSSs is the distribution system (DS). The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.

The standard does not place any restrictions on how the DS is implemented, but it does specify the services it must provide. Figure 52 shows the topology of DS and APs where data moves between a BSS and the DS via an AP. Since all APs are also STAs, they are addressable entities. The addresses used by an AP for communication on the WM (wireless medium) and on the DSM (distribution system medium) are not necessarily the same.

The DS and BSSs allow IEEE 802.11 to create a wireless network of arbitrary size and complexity, which is referred to as the extended service set (ESS) network. An ESS is a set of infrastructure BSSs, where the APs communicate amongst themselves to forward traffic from one BSS to another to facilitate movement of stations between BSSs.

Figure 52: DS and Access Points in IEEE 802.11 architecture



Source: Microsoft TechNet

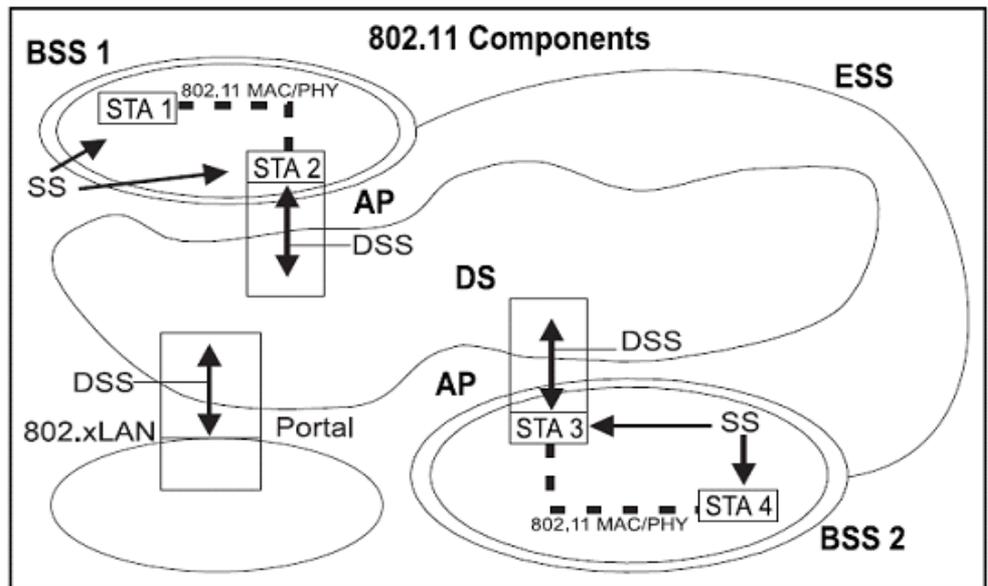
The APs of multiple BSSs are connected via DS. This extends mobility to STAs as they can now move from one BSS to another. APs can be interconnected with or without wires.

Services specified in the 802.11 are divided into two categories: Stations Service (SS) and Distribution System Service (DSS).

The SS is present in every IEEE 802.11 station (including APs as they include station functionality). The SS specified for use by MAC sublayer entities are: authentication, deauthentication, privacy, and MAC service data units (MSDU) delivery.

Figure 53 combines the components from previous Figures 52 and 51 with both types of services to show the complete IEEE 802.11 architecture.

Figure 53: Complete IEEE 802.11 architecture



Source: IEEE 802.11-1999

802.11 Media Access Control

The 802.11 MAC layer provides functionality to allow reliable data delivery for the upper layers over the wireless media. The data delivery itself is based on an asynchronous, best-effort, connectionless delivery of MAC layer data.

CSMA/CD

The fundamental access method of the IEEE 802.11 MAC is known as Carrier Sense Multiple Access with Collision Detection (CSMA/CD). This is implemented in all STAs, for use within both IBSS and infrastructure network configurations.

Before transmitting, an STA senses the medium to determine if another STA is transmitting. If the medium is not determined to be busy, the STA may transmit. If the medium is determined to be busy, the STA should defer until the end of the current transmission. After deferral, the STA selects a random back-off interval and waits for that period before attempting to transmit again.

The CSMA/CD is designed to reduce the collision probability when multiple STAs are accessing a medium. Just after the medium becomes idle following a busy medium is when the highest probability of a collision exists. This situation is resolved using a random back-off procedure to eliminate contentions for the medium.

IEEE 802.11 Physical layer (PHY)

The IEEE 802.11 physical layer is the interface between the MAC and the wireless media where frames are transmitted and received. The IEEE 802.11 PHY provides three functions: an interface to exchange frames with the upper MAC layer for transmission and reception of data, an interface to transmit data frames over the media, and provides a carrier sense indication back to the MAC to status activity on the media.

The IEEE 802.11 provides three different PHY definitions: Frequency Hopping Spread Spectrum (FHSS), Direct Sequence Spread Spectrum (DSSS), and Infrared (IR).

Frequency Hopping Spread Spectrum (FHSS)

FHSS radio uses frequencies from 2.4 GHz to 2.4835 GHz, a total bandwidth of 83.5 MHz. It uses 2 and 4 level Frequency Shift Keying (FSK) and divides the total bandwidth into 79 channels of 1 MHz each. It then hops among all of these channels in one of the 78 orthogonal (non-colliding) patterns.

This makes it possible to have approximately 15 access points in an area before interference occurs. Compared to DSSS, FHSS has low throughput and shorter range. The standard specifies 2 Mbps maximum but there are proprietary products capable of up to 3 Mbps.

Direct Sequence Spread Spectrum (DSSS)

DSSS uses radio frequencies ranging from 2.4 to 2.4835 GHz. It uses a Differential Binary Phase Shift Keying (DBPSK) and Quadruple Phase Shift Keying (DQPSK) modulation and divides the total bandwidth into 13 channels (11 channels in USA and other countries, 14 channels in Japan). When configured, the radio stays on the selected channel. The term "spread spectrum" refers to the fact that the radio uses several frequencies simultaneously.

DSSS has somewhat longer range than FHSS and opens for a potential higher throughput than the 2 Mbps that the standard defines.

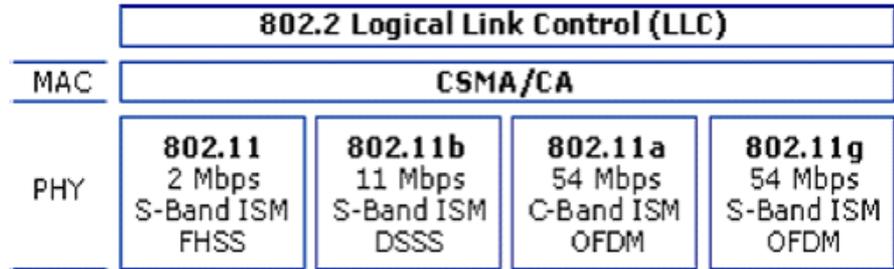
FHSS vs. DSSS

Both techniques are designed to handle interference in the wireless medium. FHSS achieves this by hopping between the channels across the entire bandwidth. DSSS uses a broad channel and expects that the interference will not span the entire channel. A narrow band interference occurring across the used channel will disrupt DSSS communications. These techniques are not compatible with each other.

The Infrared (IR) PHY was never commercially implemented and still there are no products in the market which use 802.11 IR PHY.

The IEEE later released variations of DSSS and FHSS via extensions to the original specifications as shown in Figure 54.

Figure 54: PHY MAC in IEEE 802.11



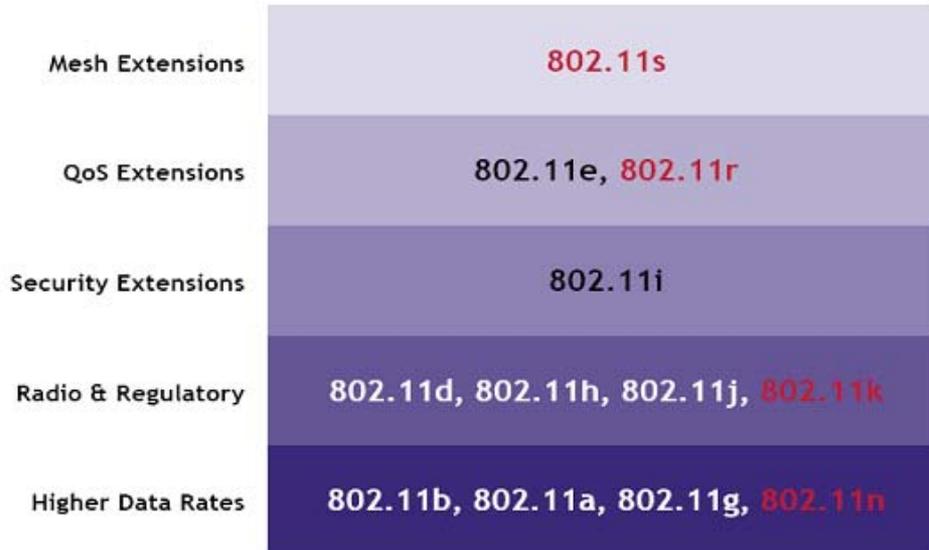
Source: Microsoft TechNet

IEEE 802.11 Wireless LAN (Wi-Fi)

IEEE 802.11, the Wi-Fi standard, denotes a set of wireless LAN standards developed by working group 11 of the IEEE Standards Committee. The 802.11 family currently includes six over-the-air modulation techniques that use the same protocol. The most popular techniques are those defined by the b, a, and g amendments to the original standard, which was launched in 1997. Other amendments to the standard (c-f, h, j, n) are service enhancements and extensions to the previous specifications. Security in the original specification was enhanced via 802.11i amendment.

802.11b was the first widely adopted wireless networking standard, followed by 802.11a and 802.11g. The various extensions of the base 802.11 standard are shown in Figure 55.

Figure 55: Extensions of the base IEEE 802.11



Source: Tropos Networks

Wi-Fi Interoperability

The Wireless Ethernet Compatibility Alliance (WECA) includes Cisco, 3Com, Enterasys, Lucent, and many other networking companies. WECA member companies have collaborated to foster IEEE 802.11 interoperability and the consortium's "wireless fidelity" (Wi-Fi) certification has been a key factor in the standard's widespread acceptance.

IEEE 802.11 Legacy

The original version of the standard IEEE 802.11 released in 1997 is sometimes called the 802.11 legacy as there is no extension after the specification number.

Since the original version specified too many implementation options, interoperability of products using this standard was never achieved. IEEE 802.11 legacy was later supplemented in 1999 by IEEE 802.11b, which is one of the most popular standards in the IEEE 802.11 family currently.

IEEE 802.11b

The IEEE 802.11b amendment to the original standard was ratified in 1999. 802.11b has a maximum data rate of 11 Mbps and uses the same error-correction, security, power-management, CSMA/CD media access method defined in the original standard.

This extension of the DSSS system provides 5.5 Mbps and 11 Mbps data rates in addition to the 1 and 2 Mbps rates supported by the original standard. To provide the higher rates, 8-chip complementary code keying (CCK) is used as the modulation scheme. CCK does not work with FHSS or Infrared.

In addition to providing higher-speed extensions to the DSSS system, IEEE 802.11b also specifies a few optional features to improve performance of the radio frequency LAN system.

IEEE 802.11b products appeared on the market very quickly soon after the approval of the draft in 1999. The dramatic increase in the throughput along with the gradual price reductions led to the widespread adoption of IEEE 802.11b as the key wireless LAN technology.

Products based on this standard are usually used in a point-to-multipoint configuration, wherein an access point communicated via an omni-directional antenna with one or more clients that are located in a coverage area accessible to the access point. Typical indoor range is 30m at 11 Mbps and 90m at 1 Mbps. With high gain antennas, the protocol can be used in fixed point-to-point communication with ranges up to 8 km.

Several companies have developed extensions for the IEEE 802.11b protocol (e.g., channel bonding and burst transmission techniques) to increase the data rates, but these are proprietary and are not endorsed by IEEE. These extensions have been largely rendered redundant by the development of IEEE 802.11g, which has data rates up to 54 Mbps and is backward compatible with IEEE 802.11b.

IEEE 802.11a

In 2001, 802.11a, a faster version of the original protocol came to market even though the standard was released in 1999. Instead of 2.4 GHz, 802.11a uses the 5 GHz band and operates at a maximum data rate of 54 Mbps. The data rates are reduced to 48, 36, 34, 18, 12, 9 and 6 Mbps depending upon the distance from the AP.

IEEE 802.11a extension specifies the PHY for Orthogonal Frequency Division Multiplexing (OFDM) and additions have been made in the original standard to accommodate the OFDM PHY. 802.11a uses OFDM instead of DSSS, which is used in 802.11b, and hence these standards are incompatible with each other.

The radio frequency LAN system is initially aimed for the 5.15-5.25, 5.25-5.35, and 5.725-5.825 GHz unlicensed national information structure (UNII).

The 5 GHz had faced regulatory hurdles in European countries initially, after being approved by the US and Japan. After some delay, however, it was approved by European Union, which was also considering the HiperLAN standard at that time.

IEEE 802.11a-based products have not seen wide adoption because of already installed base of IEEE 802.11b products and hence the network effect. Its range is shorter than IEEE 802.11b because it uses the 5GHz band which is absorbed more readily. Most manufacturers are now shipping dual/tri-mode cards that can automatically handle IEEE 802.11a, b or g as available. Access Points that can support all these standards simultaneously are also available in the market nowadays.

IEEE 802.11g

In June 2003, a third standard was released, IEEE 802.11g. 802.11g specifies further rate extensions of the DSSS PHY known as Extended Rate PHY (ERP), which operates in the 2.4 GHz ISM band. 802.11g operates at 54 Mbps raw like 802.11a. It is fully backward compatible with IEEE 802.11b and uses the same frequencies. The modulation scheme used in IEEE 802.11g is OFDM for the data rates of 6, 9, 12, 18, 24, 36, 48, and 54 Mbps, and reverts to CCK for 11 Mbps for 802.11b and to DBPSK/DQPSK for 1-2 Mbps for 802.11 legacy.

The maximum range of 802.11g devices is slightly greater than that of IEEE 802.11b devices, but the range in which full 54 Mbps can be achieved is much shorter than that of IEEE 802.11b.

IEEE 802.11n

In response to growing demand for higher throughput WLANs, IEEE approved creation of the IEEE 802.11 Task Force n (TGn) in 2003. The purpose of the task force is to modify specifications of PHY and MAC to support at least 100 Mbps throughput.

This minimum throughput requirement represents an approximate 4x leap in performance compared to IEEE 802.11a/g networks. TGn expects a smooth adoption transition by requiring backward compatibility with the existing IEEE 802.11b/g solutions.

IEEE 802.11n builds upon the previous 802.11 standards by adding Multiple-input Multiple-output (MIMO). MIMO uses multiple transmitter and receiver antennas to allow for increases in data throughput through spatial multiplexing and increased range by exploiting spatial diversity via improved coding schemes.

The existing 802.11 protocols primarily use the distributed coordination function (DCF) access method to the wireless medium. The DCF provides an equal chance to each device to access the wireless medium. When dealing with video, gaming and other applications that are intolerant to bandwidth fluctuations, the fairness access provided by DCF is inadequate.

IEEE 802.11n uses HCCA mode of IEEE 802.11e QoS extension, which guarantees reserved bandwidth for packets classified based on EDCA by using a central arbiter for the bandwidth usage. HCCA is a schedule-based access and therefore it is able to guarantee bandwidth, jitter, and latency.

When the IEEE 802.11 Task Force "n" began, there were four competing proposals for it, which were reduced to two: TGn Sync and WWiSE (World Wide Spectrum Efficiency).

TGn Sync is backed by Intel, Atheros, Qualcomm, and Sony among other companies, while WWiSE is backed by Airgo, Motorola, Conexant, Broadcom, etc.

Both sides proposed the use of MIMO architecture, but there were subtle differences in the proposals. TGn Sync wanted a mandatory channel width of 40 MHz with only two antennas needed at minimum, while WWiSE is proposing 20 MHz mandatory width with four antennas (with 40 MHz as an option). WWiSE believes this will make 802.11n standard more backward compatible and regulation friendly as a 40 MHz channel is not permitted in Japan and in some areas in Europe.

In February 2006, both camps agreed to combine their proposals and submitted a consensus draft to the IEEE. This is obviously an important step towards reaching a consensus and should lead to a speedier approval of the IEEE 802.11n standard.

Figure 56 summarizes the key features and differences in both proposals.

Figure 56: PHY comparison of two competing proposals

Features	TGnSync	WWiSE
Bandwidth extension 20MHz → 40MHz mode	(M) 20 MHz mode (O) 40 MHz mode	(M) 20 MHz mode (O) 40 MHz mode
MIMO OFDM; SDM	(M) 2 spatial streams @ 20MHz mode (max 144 Mbps)	(M) 2 spatial streams @ 20MHz mode (max 135 Mbps)
Support for higher rates	(O) 3 or 4 spatial streams	(O) 3 or 4 spatial streams
Higher coding rate	(M) 1/2, 2/3, 3/4, 5/6	(M) 1/2, 2/3, 3/4, 5/6
Guard Interval	(M) 800 ns (M) 400 ns	(M) 800 ns
Transmit beamforming	(O) Basic (SVD beamforming) (O) Advanced; bit loading, 256QAM	(O) Supported
“STBC”	(O) Spatial Spreading (Walsh) + CS	(O) $N_t \times 1$ and $N_t \times 2$ STBC
Number of subcarriers	(M) 52 (4 pilots) @ 20 MHz (O) 108 (6 pilots) @ 40 MHz	(M) 54 (2 pilots) @ 20 MHz (O) 108 (4 pilots) @ 40 MHz
Advanced coding	(O) LDPC (max block: 1728 bits)	(O) LDPC (max block: 1944 bits)

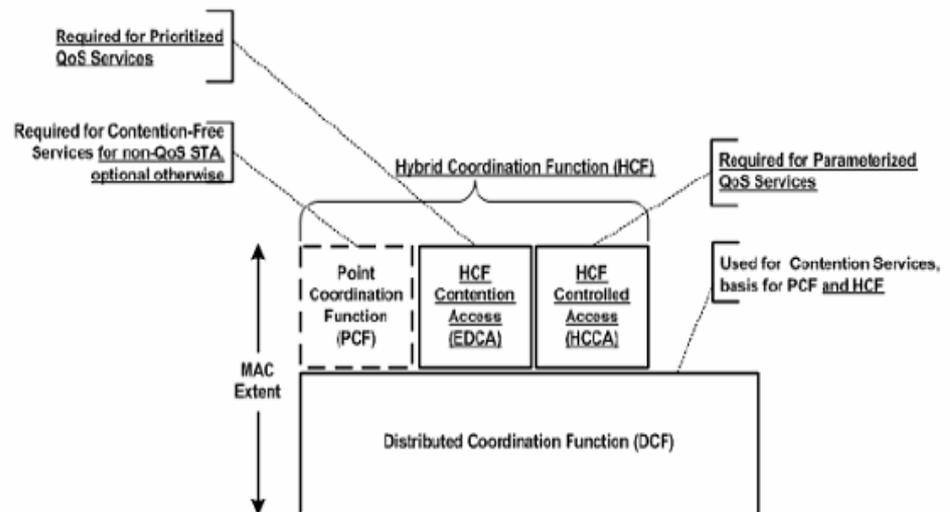
Source: Airgo Networks

(M)=Mandatory, (O)=Optional

According to the IEEE working group project timelines, the 802.11n standard is not due for formal approval until July 2007; however, we expect the standard to be effectively completed sooner.

IEEE 802.11e - Quality of Service enhancements

IEEE 802.11e standard was approved in 2005 and it defines Quality of Service (QoS) enhancements for LAN applications especially for 802.11 Wi-Fi standard. The standard is considered critical for delay-sensitive applications, such as Voice over Wireless IP (VoIP) and streaming multimedia. This amendment provides two mechanisms to support applications with QoS requirement, Enhanced Distributed Channel Access (EDCA) and Hybrid Coordination Function (HCF) Controlled Channel Access (HCCA). Figure 57 shows the extension to the original IEEE 802.11 MAC.

Figure 57: IEEE 802.11e MAC architecture

Source: IEEE 802.11e-2005

Enhanced Distributed Channel Access (EDCA)

Also called HCF Contention based Channel Access, this mechanism provides differentiated, distributed access to the wireless media (WM) for QSTA (QoS enabled STAs) using eight different User Priorities (UPs). This differentiation is achieved by varying the following for different UP values:

- Amount of time an STA senses the channel to be idle before back-off or transmission, or
- The length of the contention window to be used for the back-off, or
- The duration an STA may transmit for after it acquires the channel.

HCF Controlled Channel Access (HCCA)

The second mechanism, HCCA, uses a QoS-aware centralized coordinator, called a hybrid coordinator (HC), to manage the wireless medium access to provide parameterized QoS. Parameterized QoS refers to the capability of providing QoS flows from applications with specific QoS parameters – such as data rate and latency.

The HC has the highest priority over all QSTAs in gaining access to the WM with the shortest waiting time compared to QSTAs. The HC provides contention-free frame exchange with short delays, thereby providing tighter controlled latency.

Need for QoS

Multimedia applications in a Wi-Fi network require QoS functionality. QoS enables Wi-Fi Access Points to prioritize traffic and optimizes the way shared network resources are allocated among different applications. Without QoS, all applications running on different devices have equal opportunity to transmit data frames. This works well for data applications like email and file transfer. Multimedia applications like VoIP, video streaming, and interactive gaming are highly sensitive to latency and throughput, and thus require QoS.

Wi-Fi Multimedia (WMM) and Wi-Fi Alliance

Wi-Fi Multimedia (WMM) is a subset of the draft 802.11e standard and is motivated by the need to provide an early QoS implementation. WMM is also known as Wireless Multimedia Enhancements (WME). The key focus of WMM is the EDCA portion of the 802.11e standard.

The Wi-Fi Alliance started the interoperability certification for WMM compliance to IEEE 802.11e, EDCA extension in December 2005. WMM defines four access categories: voice,

video, background, and best effort. WMM-enabled devices concurrently support legacy devices that lack WMM functionality. The WMM “best effort” category and legacy devices are given the same priority.

WMM-Scheduled Access, also known as Wi-Fi Scheduled Multimedia (WSM), is also a subset of the 802.11e standard. The key feature of WMM-Scheduled Access is HCCA. WSM certification is expected to begin in 2006.

Figure 58 summarizes the key differences between WMM (EDCA based QoS) and WMM-Scheduled Access (HCCA based QoS). Until a proper infrastructure for WMM-Scheduled Access is in place, WMM is expected to play a key role in providing QoS in WLAN.

Figure 58: WMM vs. WMM-Scheduled Access

Parameters		WMM	WMM-Scheduled Access
Channel Access Mode		<ul style="list-style-type: none"> • Contention based • Distributed control 	<ul style="list-style-type: none"> • Poll based • Central reservation scheme
Key Technical Benefits		QSTAs and QAPs can provide prioritization among wireless data streams to distinguish between high and low priority traffic	Provides QAP the mechanism to centrally reserve bandwidth; <ul style="list-style-type: none"> • QAP can refuse a connection when not sufficient bandwidth is available • QAP can ensure that subscribed % of media access will be given to the subscribers.
Applications Dependency		Current applications support WMM as WMM uses 802.1D priority and the applications can be agnostic	Current applications do not support WMM-Scheduled Access as the applications have to be wireless aware
OS Dependency		Current OS support provided for WMM	No current support for WMM-Scheduled Access
Fast Roaming Support Requirements		No requirements	Traffic flow schedule coordination between QAPs required and it is not supported in 802.11e
Usefulness	Environment	More appropriate to provide QoS in environments where: <ul style="list-style-type: none"> • Other WLANs are within range (e.g. in the neighbor's house) 	More appropriate to provide QoS in environments where: <ul style="list-style-type: none"> • There are lots of devices • There are no other WLANs within range contending for the same bandwidth.
	Applications	More suitable for applications that require variable bit rate (e.g. video)	More suitable for applications that require constant bit rate (e.g. VoIP)
User intervention		No user intervention required	User intervention will be required for configuration—no standardized API

Source: Intel.com

IEEE 802.11i - MAC Security Enhancements

The original IEEE 802.11 standard provided the following set of security features:

- Two different authentication methods: Open system and shared key
- The Wired Equivalent Privacy (WEP) encryption algorithm, and
- An integrity Check Value (ICV), encrypted with WEP, which provided data integrity

To address the security issues of the original IEEE 802.11 standard, the following technologies have been used:

- The IEEE 802.1X Port-based Network Access Control standard.
- Wi-Fi Protected Access (WPA), an interim standard adopted by the Wi-Fi Alliance to provide secure encryption while the IEEE 802.11i standard was being ratified. WPA is a subset of the IEEE 802.11i specification.

The IEEE 802.11i formally replaces the WEP and other security features of the original 802.11 standard. Wi-Fi Alliance started the WPA2 certification process in September 2004 for products compliant to the IEEE 802.11i standard.

The IEEE 802.11i amendment defines two classes of security algorithms for IEEE 802.11 networks:

- Algorithms for creating and using a Robust Security Network Association (RSNA) algorithms
- Pre-RSNA algorithms

Pre-RSNA comprises of the following algorithms:

- Wired Equivalent Privacy (WEP)
- IEEE 802.11 Open System Authentication

RSNA security comprises the following algorithms:

- TKIP (Temporal Key Integrity Protocol)
- AES-CCMP (Advanced Encryption Standard - CTR (counter mode) with CBC (cipher block chaining) MAC Protocol. CCMP provides confidentiality, authentication, integrity, and replay protection. CCMP is mandatory for RSN compliance.

Figure 59 summarizes the key difference in TKIP and AES-CCMP algorithms.

Figure 59: Differences in TKIP and AES-CCMP

TKIP	AES-CCMP
Temporal Keys	
Data Encryption Key (128 bits)	Data Encryption/Integrity key (128 bits)
Data Integrity Key (128 bits)	
EAPOL-Key Encryption Key (128 bits)	EAPOL-Key Encryption Key (128 bits)
EAPOL-Key Integrity Key (128 bits)	EAPOL-Key Integrity Key (128 bits)
Group Keys	
Group Encryption Key (128 bits)	Group Encryption/Integrity key (128 bits)
Group Integrity Key (128 bits)	
Total key sizes	
768 bits	512 bits

Source: SANS Institute

Like WPA, WPA2 offers both a Personal and Enterprise mode of operation. In the personal mode of operation, a pre-shared key is used for authentication; while in the Enterprise mode of operation authentication is achieved via 802.1X and the EAP (extensible authentication protocol, used for identifying network devices). Personal mode requires only an access point and a client device, while Enterprise mode typically requires a RADIUS or other authentication server on the network.

IEEE 802.11s - Wireless Mesh Networks

An IEEE technical group is working to develop the 802.11s standard for wireless LAN mesh networking. In March 2006, the group announced the baseline document for the standard. They expect to have an initial draft by July 2006 and a ratified 802.11s standard by early 2008.

The group is defining capabilities in several areas, including topology discovery, path selection and forwarding, channel allocation, security, traffic management, and network management.

Wireless Mesh Network

In wireless mesh networks, nodes are comprised of routers and clients. Each node operates not only as a host but also as a router, forwarding packets on behalf of other nodes that may not be within the direct wireless transmission range of their destinations. A wireless mesh network can configure itself dynamically, with the nodes in the network automatically establishing and maintaining mesh connectivity among themselves. This feature brings many advantages to mesh networks such as low up-front cost, easier network management, robustness, and reliable service coverage.

Wireless mesh networking is a promising wireless technology for applications in broadband home-networking, enterprise networking, municipal city-wide internet access, education, warehousing, healthcare, public safety, video surveillance, etc. Since these nodes can be deployed incrementally and require significantly less up-front investment, wireless mesh networking has been getting a fair amount of attention from ISPs and other service providers.

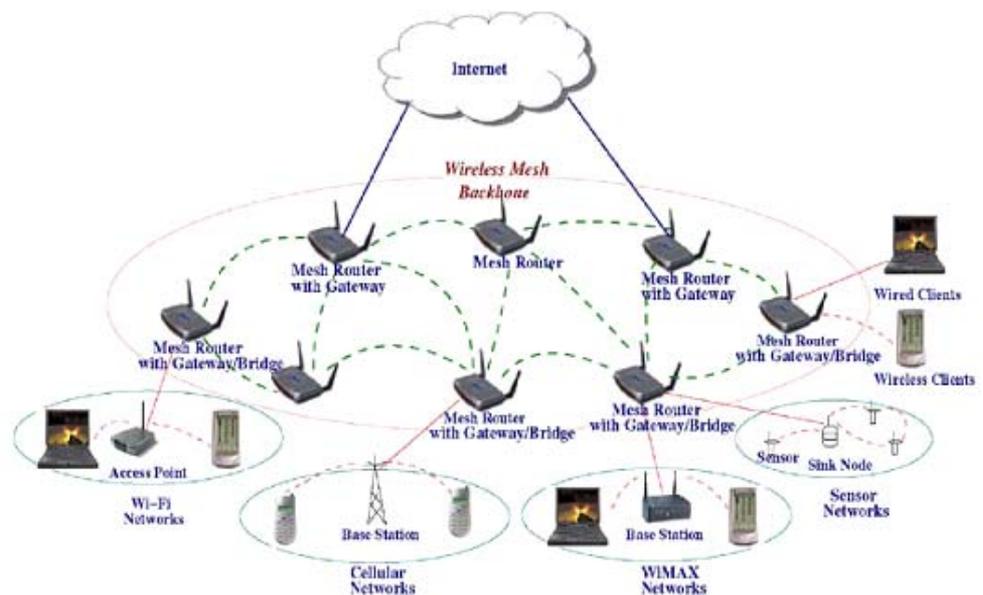
Wireless Mesh Network Architecture

A wireless mesh network contains two types of nodes: mesh routers and mesh clients. In addition to routing functionalities, a wireless mesh router is equipped with contains additional routing functions to support mesh topologies.

Figure 60 shows the architecture of infrastructure/backbone wireless mesh networks. In this type of network the mesh routers form an infrastructure for clients that connect to them. Since mesh routers have gateway functionality, they can be connected to the Internet (also referred to as a drop-off point). Typically, two types of radios are used in the routers for backbone/backhaul connectivity and another for client communication. Mesh backbone communication can be established using long-range communication techniques such as directional antennas.

To extend the coverage without sacrificing the channel capacity, the wireless mesh networks must provide meshed multiple-hops. This allows the clients to connect to other clients in the network without direct line-of-sight links. Mesh routers are equipped with multiple radios to separate the access and backhaul parts of the network. The backhaul itself may utilize more than one radio to separate its transmit and receive functions to improve network capacity.

Figure 60: Architecture of infrastructure mesh network



Source: Computer Networks (2005)

Applications of Mesh Networking

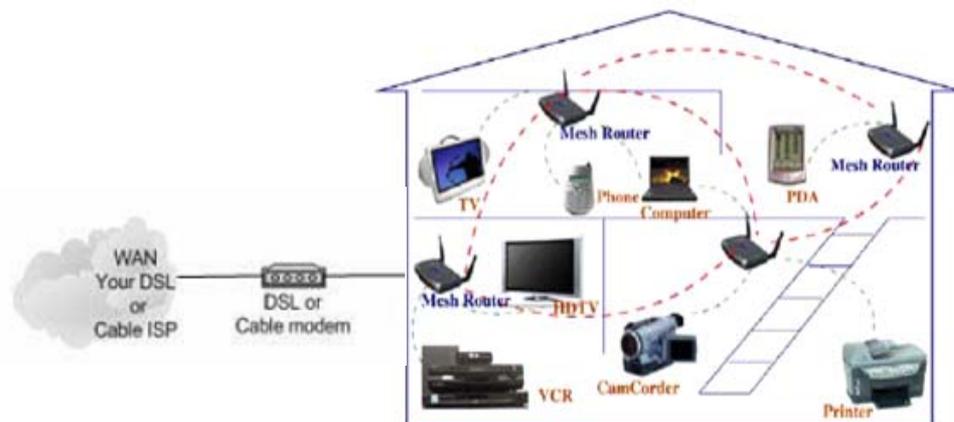
Some applications are uniquely suited to wireless mesh networks and cannot be supported by existing technologies like cellular, IEEE 802.11, etc.

- Home Networking

Currently, broadband wireless home networking is achieved via IEEE 802.11 Wi-Fi networks. Finding an appropriate location for the access points and dealing with dead zones is an still unresolved problem with in-home networking. Installation of multiple access points is expensive and needs wired connections to each access point. Mesh networking in a home network could solve all these issues.

Figure 61 shows implementation of mesh routers in a home network. The access points are replaced by wireless mesh routers. By using mesh routers, the communication among these nodes becomes much more flexible. Dead zones can be eliminated by adding mesh routers, which do not need additional cabling, changing location of the mesh routers, or by automatically adjusting the power levels of the mesh routers.

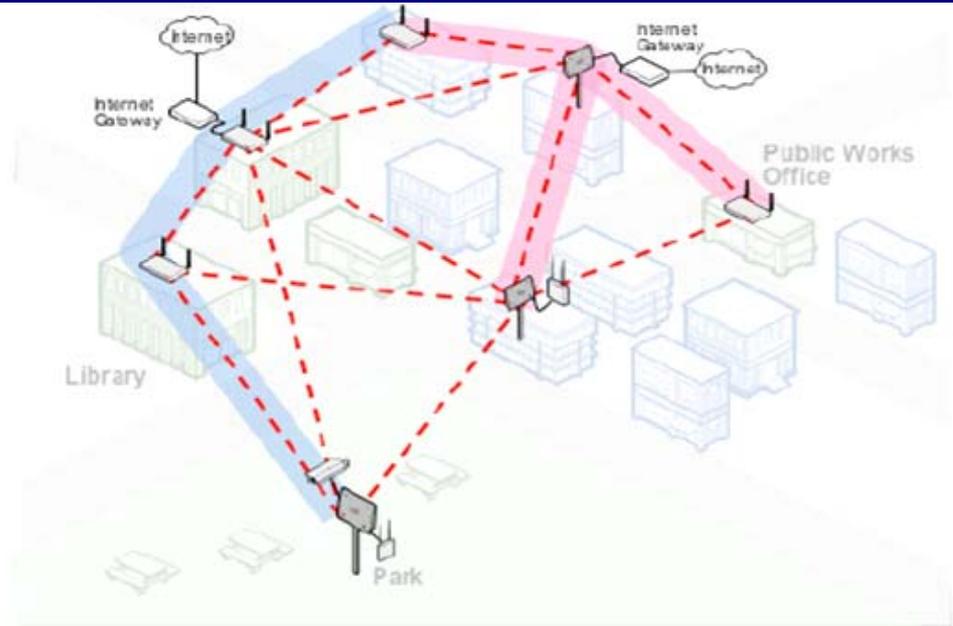
Figure 61: Wireless mesh in home networking



Source: Deutsche Bank

- Metropolitan and Community Networks

Another appealing application of wireless mesh networking is providing broadband Internet access to large geographical areas such as cities and extended communities like school campuses. Flexibility of remotely managing the network and incrementally increasing or decreasing nodes and capacity is crucial in such applications. Figure 62 shows the topology of such citywide network.

Figure 62: Wireless mesh network in metropolitan area

Source: FireTide.com

- Public Safety and Defense Establishment

Wireless mesh networks are easy to deploy with low upfront costs and can be quickly scaled to extend coverage area. They are also well suited for use by first responders, and defense establishments for establishing ad hoc networks. For example, city police and First responders can use the network to monitor surveillance cameras in real time and can effectively respond to any crisis situation.

- Warehousing and Manufacturing

Increasing use of RFID tags to track packages and manufactured units makes wireless mesh networking an ideal technology for this application. A wireless mesh-covered warehouse or manufacturing facility can greatly reduce costs associated with inventory management, tracking of units, and could also boost productivity.

Few companies like Symbol Technologies and Intermec Technologies are incorporating Wi-Fi mesh networks to read RFID tags.

- Enterprise Networking

Currently, IEEE 802.11 wireless networks are widely used in the office environment, but most of these networks are isolated and are not connected with each other. Connection between them is currently achieved through wired connection which increases the cost of deployment. If access points can be replaced by mesh routers, the Ethernet wires can be eliminated. Multiple backhaul access modems can be shared by all nodes in the entire network, and, thus, can improve the robustness and resource utilization of enterprise networks.

The service model of enterprise networking can be applied to many other applications like hospitality services in hotels and convention centers, shopping malls, and airports.

- Transportation Systems

Wireless mesh networking can be extended to buses, trains, and other mass transit systems. This can facilitate cost-effective in-vehicle monitoring and information access inside a moving vehicle. To enable such mesh networking for a transportation system, two key techniques are needed: mobile backhaul from a vehicle to Internet and mobile mesh networks within the vehicle. Currently, there are multiple solutions for both the mesh Wi-Fi access network and the backhaul network. We think Wi-Fi beats all available technologies for the access network; however, the backhaul picture is not that clear as there are multiple solutions for it, ranging from satellite links to linear wireless backhaul network deployment along the tracks of the train. These are very different solutions to achieve mobility in trains; which solution would become a clear winner is uncertain at this time. We believe low up-front cost and ease of scalability (upward and downward) and deployment would be the key to a winning solution.

- Ad Hoc Networks

Mesh networks can also be used in creating ad hoc networks quickly and without upfront infrastructure cost. The applications include rescue and disaster zones and military operations. Few companies like PacketHop Communications are developing software to enable ad hoc networks.

There are many other applications like VoIP etc which require the network to be scalable, readily deployable, reliable, and cost effective and are well suited to wireless mesh networking.

- Issues/Critical factors in Wireless Mesh Networking

- Radio Technology

Currently, many approaches have been proposed to increase the capacity and flexibility of wireless systems. Typical examples include directional and smart antennas, MIMO systems, and multi-radio/multi-channel systems. MIMO has already become a key technology for its role in IEEE 802.11n. Multi-radio chipsets and their development platforms are already available in the market.

Further improvements in the performance of wireless networks would come from advanced radio technologies such as reconfigurable radios and SDRs (software defined radios). These technologies also require sophisticated higher layer protocols. For example, an advanced routing protocol is needed to make use of directional antennas to appropriately select the sectors. Directional antennas help reduce exposed nodes, but they also generate hidden nodes. To resolve this would require significant changes in the current IEEE 802.11 MAC.

- Scalability

Multi-hop communication, which is crucial in wireless mesh networking, suffers from scalability issues. The performance degrades significantly as the size of the network increases. Current IEEE 802.11 MAC protocol and its derivative cannot achieve a reasonable throughput as the number of hops increases to 4 or higher. With CSMA/CD being the main technology for the multi-hop networks, the network suffers from low frequency spatial-reuse efficiency which significantly limits the scalability of such networks. We believe the ongoing research work on this topic could pave the way for more appropriate technologies to be used in a mesh network.

- Centralized Network Management

Deploying a mesh network with hundreds of nodes requires a comprehensive and centralized network management. Managing network capacity, QoS, and efficient network planning are crucial in any successful deployment of a mesh network. Due to its dynamic nature, real time network monitoring and correction are needed to sustain a mesh network. There are already a few companies which are involved in tackling these challenges.

HomePlug

HomePlug is a standard body for powerline communication. This organization, board of directors is comprised of members from Comcast, EarthLink, Intel, GE, Linksys, Motorola, and Sony:

- HomePlug 1.0 – specification for connecting devices via power lines in the home
- HomePlug AV – designed for transmitting HDTV and VoIP around the home
- HomePlug BPL – broadband over powerline (BPL), a working group to develop a specification for providing broadband connectivity to homes
- HomePlug CC – command and control (CC) is designed to be used as a home appliance control standard and is intended to complement the alliance's higher-speed powerline communications technologies

HomePlug 1.0 is the specification for a technology that connects devices to each other through the existing electrical powerlines in the home. Current HomePlug certified products connect PCs and other devices that use Ethernet, USB, and IEEE 802.11.

Operation

The HomePlug 1.0 PHY uses OFDM at 2-28 MHz frequency band as the basic transmission technique. The current HomePlug standard allows for speeds up to 14 Mbps. The MAC protocol in the HomePlug technology is a variant of the CSMA/CA protocol. Several features have been added on top of CSMA/CA to support priority classes and allow control of latency.

To provide security, HomePlug allows users to set a password for encryption. To simplify the process of configuring passwords on a HomePlug network, each device has a built-in master password hard-wired into each device by the manufacturer.

In August 2005, the HomePlug Powerline Alliance announced approval of HomePlug AV (HPAV) specifications that has a raw data rate of up to 200 Mbps with actual throughput rates around 100 Mbps. Its purpose is to provide high-quality, multi-stream, entertainment-oriented networking over existing AC wiring within the home, while addressing interoperability with HomePlug 1.0. HPAV employs advanced PHY and MAC technologies that provide a 200 Mbps (raw data rate) powerline network for video, audio, and data. The PHY supports both CSMA and TDMA (Time Division Multiple Access) based access. The TDMA access provides guaranteed QoS bandwidth reservation, high reliability and tight control of latency and jitter. HomePlug currently offers a range of as much as 300 meters without repeaters, which is well more than the 100 meters supported by 10/100BaseT – and without the need for running Cat 5 data-grade cable.

HomePlug AV also provides advanced capabilities consistent with the new networking standards. It supports plug-and-play configurations as well as the service provider and set-up configuration. HPAV supports tight security based on 128-bit AES and makes provision for a dynamic change in the configuration and for admitting stations to the network.

Applications

HomePlug 1.0 devices typically function as transparent Ethernet bridges connecting one device to another using a powerline. This standard never became the mainstream standard for networking devices at home and Wi-Fi based wireless networking has become the technology of choice for network devices at home.

HPAV aims to be the network of choice for the distribution of data and multi-stream entertainment including HDTV, SDTV, and high quality audio throughout the home. It is designed to provide best connectivity at the highest QoS of the home networking technologies competing for these applications. HPAV enables all devices with a power plug to have network access through HPAV.

Figure 63 compares various HomePlug standards.

Figure 63: Comparison of HomePlug standards			
	HomePlug 1.0	HomePlug 1.0 with Turbo	HomePlug AV
Applications	Home/SOHO data, audio, and VoIP networking and WiFi bridging	Data, SD video, audio and VoIP sharing - cable, xDSL and WiFi bridging - IPTV and VoD	HD and SD video and data networking - cable, xDSL, Wi-Fi and UWB bridging - HD, IPTV and VoD
PHY Rate	14 Mbps	85 Mbps	200 Mbps
Max. Rate	8 Mbps	30 Mbps	120 Mbps
MAC Type	Hard	Soft	Soft
Supports Firmware Update	No	Yes (customizable)	Yes
Frequency Bandwidth	4-21 MHz	4-21 MHz	2-30 MHz
Host Interfaces	MIII, USB, Ethernet	MIII, Ethernet	MIII, Ethernet, PCI, MBI, MPEG
Channel Access (QoS)	CSMA/CA	CSMA/CA	TDMA, CSMA.CA
Modulation	DQPSK	256-QAM	1024-QAM
Security	56 DES	56 DES	128 AES
Compatibility	HomePlug 1.0	HomePlug 1.0	HomePlug 1.0 Coexistent

Source: Intellon.com

MoCA (Multimedia over Coax Alliance)

The Multimedia over Coax Alliance (MoCA) was formed to develop and promote specifications for the transport of digital entertainment and information content over in-home coaxial cable.

More than 70% of homes in the United States have coax already installed into the home infrastructure. MoCA technology allows homeowners to utilize this infrastructure as a networking system and to deliver other entertainment and information programming with high QoS. Some of the prominent members of this alliance include Cisco, Comcast, Linksys, Panasonic, Motorola, Verizon, Siemens, and 2Wire.

In the 2005 National Cable TV Association show, MoCA announced that the technology can consistently deliver 100 Mbps of usable Ethernet data throughput over existing in-home coaxial cable.

A recent test conducted by MoCA yielded following results for its technology:

- >100 Mbps net usable throughput in more than 95% of home
- >80 Mbps net usable throughput 100% of serviceable coax outlets with reasonable remediation such as replacing low bandwidth splitters.

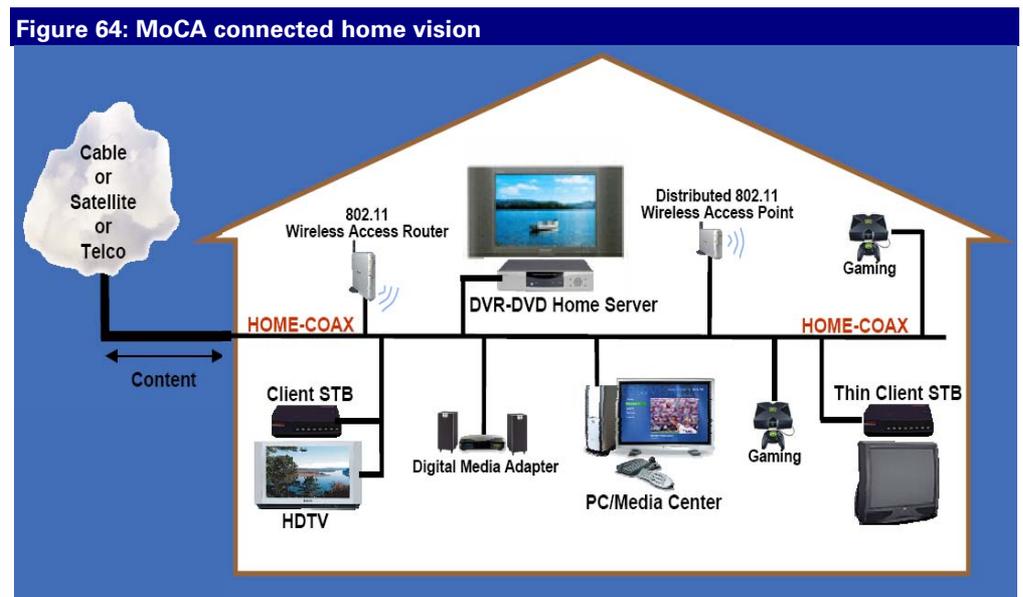
MoCA standards also requires the devices running its technology to:

- Support eight 802.1p priority queues
- Latency shall not increase 10 ms for the highest priority asynchronous traffic up to the maximum aggregate throughput

- Packet error rate shall not exceed 10 per million packets transferred
- Support tree-branch, loop, and home run in-house coax topologies
- Self-adaptive to time and location varying characteristics of coaxial networks
- Plug and Play at the majority of serviceable coax outlets in homes with no need to access or change splitters, or run new cables
- Compatible with existing devices and services on the coax with no interference

Applications

Figure 64 illustrates various applications which MoCA can support over existing coaxial wiring in a home.



Source: www.mocalliance.com

Application of MoCA can be categorized into four areas:

- Cable/Satellite Operators: whole-home DVR and triple play
- Telcos: Triple play – voice, video, data
- Retail: Home server (multimedia client)

HomePNA

HomePNA, also known as Home Phoneline Networking Alliance, is an alliance of more than 150 companies including 3Com, AMD, IBM, Intel, 2Wire, Motorola, and Samsung. HomePNA aims to establish standards among telecom, computer and network products such that they are compatible for HomePNA.

The current version of Home Phoneline standard is 3.0 and is known as HomePNA 3.0. Its earlier version, HomePNA 1.0, was developed by Tut Systems, and HomePNA 2.0 was developed by Epigram, Inc and it continues to play a lead role in developing the standard further. The current version HomePNA 3.0 was developed by Broadcom and Coppergate solutions.

Operation

HomePNA allows us to network our home computers much like a LAN using the existing telephone wiring. Internet access can be shared among several computers with or without a router. Using HomePNA, computers can access each other's peripherals like printers and storage devices. Its initial versions HomePNA 1.0 and HomePNA 2.0 were similar to Ethernet providing 1 Mbps and 10 Mbps of data rates capability respectively.

HomePNA 3.0 which was approved in 2003 was significantly enhanced to support interoperability among many different networking scenarios.

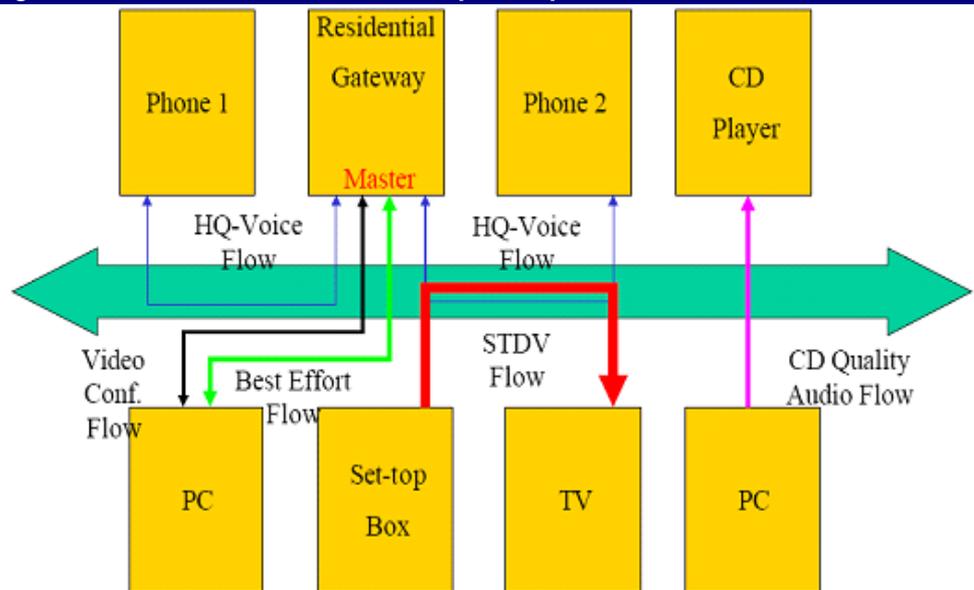
HomePNA 3.0 is based on 2.0 PHY and is backward compatible to 2.0 standard. The 3.0 version is capable of reaching speeds in excess of 100 Mbps while offering QoS capabilities. HomePNA 3.0-based products like network interface cards, multimedia devices, Internet appliances, residential gateways, broadband modems can be easily found in the market. In addition, the HomePNA 3.0 offers extensions that will enable it to reach speeds of up to 240 Mbps.

This technology is designed to complement wireless networking technologies by providing a hi-speed backbone for a home multimedia network throughout the home. Users can connect multiple PCs to a high-speed Internet connection without interfering with standard telephone/fax service.

HomePNA 3.0 offers deterministic QoS capabilities for enhancing the specification's multimedia handling capabilities. This expanded QoS capability is expected to enable service providers to offer "triple play" service of POTS, high-speed Internet access, broadcast and on-demand video over the home network. In addition, it will allow HomePNA 3.0 to transport data with inherent QoS requirements such as IEEE1394.

HomePNA 3.0 network consists of a master device which usually resides in a residential home-gateway. This master device facilitates peer-to-peer connection between various devices as shown in Figure 65:

Figure 65: HomePNA: Master controlled peer-to-peer transfer



Source: Coppergate Communications, Inc

IEEE P1901

In June 2005, IEEE formed a group to start working on a standard for MAC and PHY for Broadband over Power Line (BPL) Networks. This project will develop a standard for high speed (>100 Mbps at the physical layer) communication devices via alternating current electric power lines, so called Broadband over Power Line devices. The standard will define detailed mechanisms for coexistence and interoperability between different BPL devices. This standard will also address the necessary security issues to ensure the privacy of data communication between two devices. This standard will only focus on the PHY and MAC part of the OSI reference model.

Coexistence of the BPL devices on the same power lines is a basic need of the BPL market. Devices from different vendors should continue to operate properly while using the same power lines. Interoperability will support the growth of the emerging BPL market and will also enable consumers to use devices from different vendors.

Currently, UPA (Universal Powerline Association), DS2 and HomePlug are members of this standard and expect to improve the interoperability of their standards by using IEEE P1901-based MAC and PHY.

About UPA

The Universal Powerline Association (UPA) is an international not-for-profit trade association working to promote global standards and regulations in the fast developing powerline communications market. The UPA aims to catalyze the growth of PLC/BPL technology by delivering UPA-certified products that comply with these specified standards and regulations. All products and applications designed around UPA guidelines will communicate, from simple coexistence to full interoperability. The UPA provides all PLC/BPL players the opportunity to respond to key customer expectations with open standards, based on interoperability, security and coexistence and supported by exclusive and independent certifications, the only global guarantee of quality and confidence for high-speed power line technology available today.

Members of the UPA include AcBel Polytech Inc., Ambient Corporation, Commax, Corinex Communications, Current Technologies International, DS2, EDF, Duke Energy, Itochu Corporation, Ilevo (Schneider Electric Powerline Communications), PCN Technology, ST&T, Sumitomo Electric Industries, Tecnom, Telekom Research and Development SDN BHD, Toshiba Electronics Europe GmbH and TOYO Network Systems.

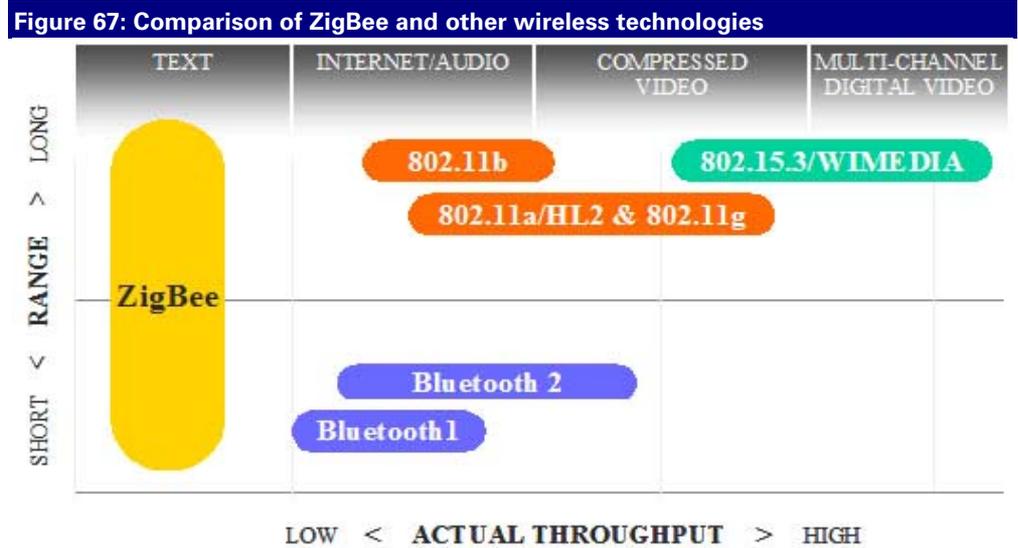
About DS2

DS2 is the world's leading supplier of the 200 Mbps technology that enables home networking and broadband access over powerline, coaxial cable, and telephone wire. DS2 was a pioneer in the industry with the introduction of its 200 Mbps chipsets, creating the fastest and highest performance solution for simultaneous data, digital audio and high-definition video transmission over any wire. Two preeminent industry groups, the Universal Powerline Association (UPA) and the European Union consortium OPERA (Open PLC European Research Alliance), have adopted DS2 technology in support of multi-vendor standard certified product. Both groups develop and support open standards based on interoperability, security and coexistence. DS2 is headquartered in Valencia, Spain, with a U.S. operations base in Santa Clara, Calif., and an Asian operations base in Tokyo, Japan.

ZigBee (IEEE 802.15.4)

IEEE 802.15.4, which was approved in May 2003, specifies the MAC and PHY for Low-Rate Wireless Personal Area Networks (LR-WPANs). Unlike wireless local area networks (WLANs), connections effected via WPANs involve little or no infrastructure. This feature allows small, power-efficient, inexpensive solutions to be implemented for a wide range of devices.

Figure 70 compares the relative position it occupies in the application space among other wireless technologies.



Source: www.vitelec.nl

ZigBee is the name of a specification based on IEEE 802.15.4 for wireless personal area networks (WPANs) being developed by member companies of the ZigBee Alliance. It is a low-cost, low power consumption, two-way, wireless communications standard. Solutions adopting the ZigBee standard can be embedded in consumer electronics, home and building automation, industrial controls, PC peripherals, medical sensor applications, toys and games.

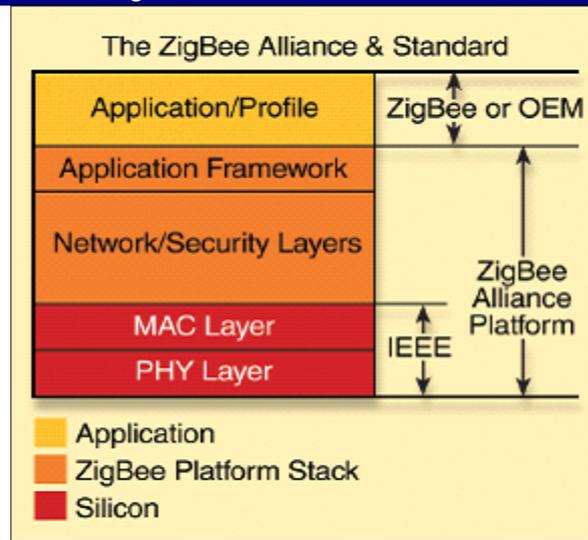
ZigBee Alliance

ZigBee Alliance, whose members include Texas Instruments, Motorola, Samsung, Phillips and many other participating companies, was created to address the market need for a cost-effective, standards-based wireless networking solution that supports low data rates, low power consumption, security, and reliability.

The relationship between IEEE 802.15.4 and ZigBee is similar to that between IEEE 802.11 and the Wi-Fi Alliance.

ZigBee Architecture

The ZigBee Alliance is responsible for the following components of the ZigBee architecture, shown in Figure 68.

Figure 68: Architecture of ZigBee

Source: www.rfdesign.com

The PHY and MAC layers

The physical and MAC layers are based on IEEE 802.15.4 specifications. ZigBee uses the same data rates, channelization, and modulation techniques as defined in the IEEE 802.15.4 specifications.

ZigBee Platform Stack

The ZigBee Alliance specifies the network, security, and application framework for the firmware stack. It is this stack which provides capability to create a wireless mesh network. Each device requires its own ZigBee stack and is configured differently to support different device modes.

ZigBee Application Layer

There are two types of profiles defined in the application layer: public profiles, which are certified by the ZigBee Alliance for interoperability purpose, and private profiles which are used in closed systems.

ZigBee certification is currently available for public profiles. Private profiles need not interoperate with other devices and hence are not certified. At this time, there seems to be only one public profile for lighting applications. Some chipmakers have also created private profiles that are integrated into their stacks. Developing a public profile is a very tedious process at this time and may take multiple rounds of negotiations with the stakeholders.

ZigBee operates in the ISM radio bands: 868 MHz in Europe, 915 MHz in the USA and 2.4 GHz in other countries as shown in Figure 69.

Figure 69: ZigBee frequency and data rates

PHY (MHz)	Frequency band (MHz)	Spreading parameters		Data parameters		
		Chip rate (kchip/s)	Modulation	Bit rate (kb/s)	Symbol rate (ksymbol/s)	Symbols
868/915	868–868.6	300	BPSK	20	20	Binary
	902–928	600	BPSK	40	40	Binary
2450	2400–2483.5	2000	O-QPSK	250	62.5	16-ary Orthogonal

Source: IEEE 802.15.4-2003

Target applications for ZigBee are:

- Home Automation – security, remote control of domestic appliance
- Customer Electronics – TV, DVD, CD, games, etc
- PC peripherals – mouse, keyboard, joystick, etc
- Personal healthcare – monitors, diagnostics, sensors, etc
- Industrial and Commercial – monitors, sensors, automation, control, etc.

ZigBee supports data rates of 250, 40, 20 kbps @2.4 GHz, 915 MHz, 868 MHz respectively. It has a battery life of 6 months to 2 years on 2 AA batteries and approximately 30 m range.

ZigBee protocols are intended for use in embedded applications requiring low data rates and low power consumption. ZigBee's current focus is to define a general-purpose, inexpensive, self-organizing, mesh network that can be used for industrial control, embedded sensing, medical data collection, smoke and intruder warning, building automation, home automation, etc.

There are currently three types of ZigBee devices defined in the specifications:

- ZigBee Coordinator (ZC)

It is the most capable device and forms the root of the network tree and bridges other networks. There is exactly one ZC in each ZigBee network. It is able to store information about the network, including acting as the repository for security keys. The coordinator also manages the Key Value Pair (KVP) service and maintains a master look-up table, known as a binding table, that lists which nodes are interested in a particular KVP. ZC is referred to as Full Function Device (FFD) in IEEE 802.15.4 standard.

- ZigBee Router (ZR)

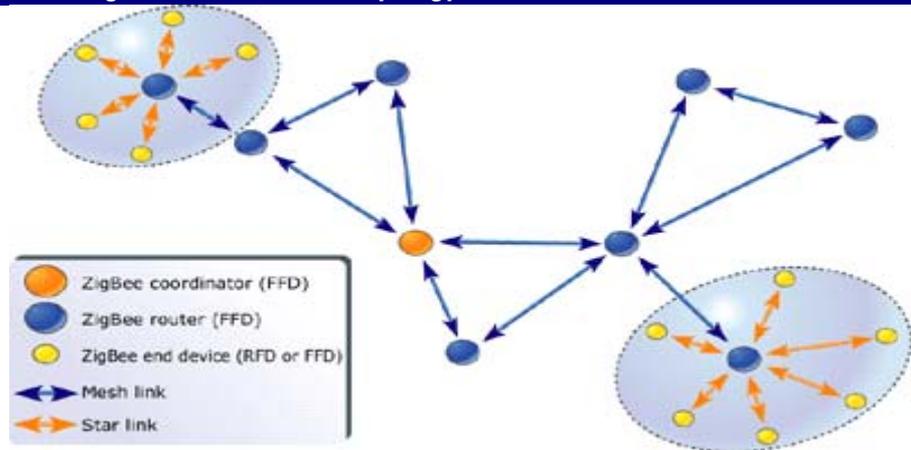
Routers can act as an intermediate router, passing data from other devices. ZR is an FFD device.

- ZigBee End Device (ZED)

The end device contains just enough functionality to talk to its parent node (either a coordinator or router); it cannot relay data from other devices like a ZR. It requires the least amount of memory and therefore can be less expensive to manufacture than a ZR or ZC. ZED is referred to as Reduced Function Device (RFD) in IEEE 802.15.4 standard.

ZigBee devices can form both star and cluster topology as shown in Figure 70.

Figure 70: ZigBee star and cluster topology



Source: www.uab.edu

ZigBee operates in two main modes: non-beacon and beacon mode. Beacon mode is a fully coordinated mode in that all the devices know when to coordinate with one another. In this mode, the network coordinator will periodically “wake-up” and send out a beacon to the devices within its network. This beacon subsequently wakes up each device, which must determine if it has any messages to receive. If not, the device returns to sleep, as will the network coordinator, once its job is done. The non-beacon mode, on the other hand, is less coordinated and any device can communicate to it at will. However, in this operation various devices can interfere and the coordinator must be awake all the time, making it more power expensive. Nonetheless, ZigBee operates at a very low power as most of the devices in the network can remain inactive for long periods of time.

Figure 71 shows a quick comparison of competing wireless technologies.

Figure 71: Comparison of ZigBee with other wireless technologies

Market Name	ZigBee	Cellular	Wi-Fi	Bluetooth
Standard	IEEE 802.15.4	GSM/GPRS CDMA/1xRTT	802.11b	IEEE 802.15.1
Application Focus	Monitoring and Control	Wide Area Voice & Data	Web, email, Video	Cable Replacement
System Resources	4kB-32kB	16MB+	1MB+	250kB+
Battery Life (days)	100 - 1000+	1 - 7	.5 - 5	1 - 7
Network Size	32+	1	32	8
Bandwidth (kbps)	20 - 250	64 - 128+	11,000+	720
Range (meters)	1 - 100+	1000+	1 - 100	1 - 10+
Success Metrics	Reliability, Power, Cost	Reach, Quality	Speed, Flexibility	Cost, Convenience

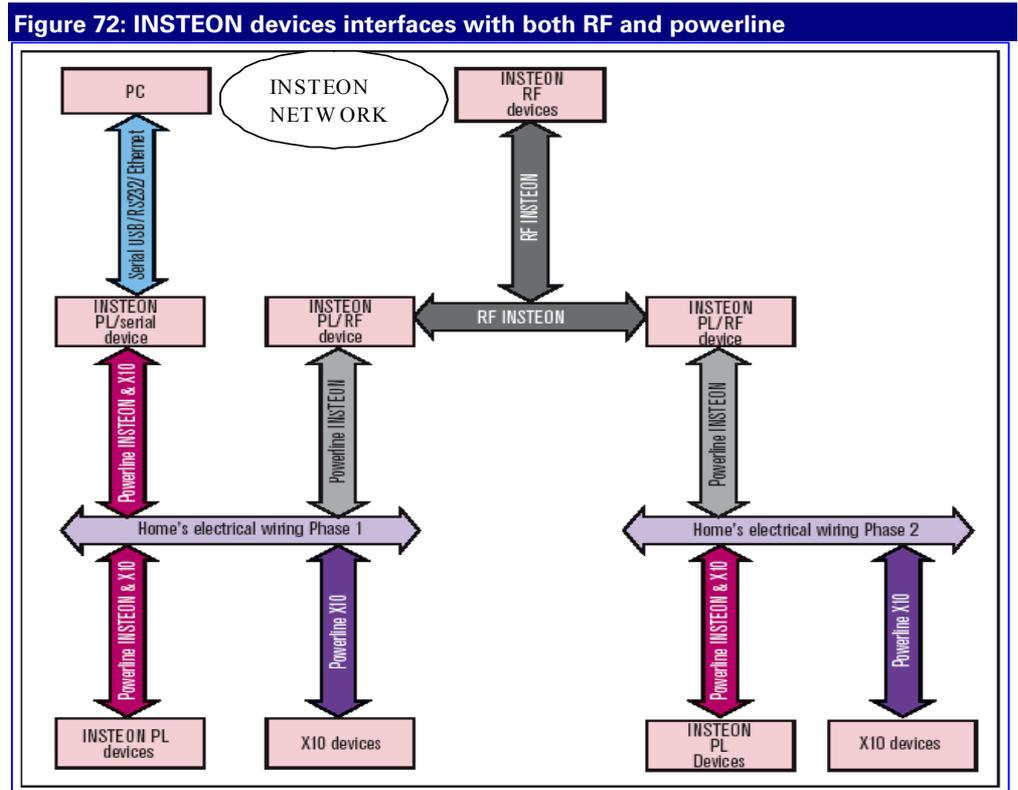
Source: ZigBee Alliance

INSTEON

INSTEON is a proprietary, hybrid dual-band (RF and powerline) home-control networking technology invented by SmartLabs Technology. INSTEON enables simple, low-cost devices to be networked together using the powerline, radio frequency (RF), or both. This technology is backwards compatible with X10 and provides secure, highly available, robust home control and automation network for home innovations.

All INSTEON devices are peers, meaning that any device can transmit, receive, or repeat other messages, without requiring a master controller or complex routing software. There is no need for routing tables, each device in the network receives messages simultaneously, independent of whether the message originated via a wireless or powerline device.

INSTEON solves the interference and reliability issues by using a dual-mesh network. As shown in Figure 72, INSTEON devices can communicate with each other using both radio and the powerline.



Source: www.eepn.com

All INSTEON devices that are plugged into the powerline communicate with each other using the INSTEON Powerline protocol. INSTEON devices with radios, whether they are plugged into the powerline or handheld, use the INSTEON RF protocol to communicate with other INSTEON devices that have radios. Not all INSTEON devices are required to have radios.

Devices on the INSTEON network can also interface with the larger world. When suitably equipped with a dedicated serial interface, such as USB, RS232 or Ethernet, an INSTEON device can also interface with computers and other electronic equipment. INSTEON, with an emphasis on simplicity, reliability, and low cost, is optimized as an infrastructure network for home integration and control.

INSTEON Operation

With a unique ID number assigned to every device, INSTEON devices automatically join an INSTEON network and help with simulcasting repeated messages as soon as they are powered up. With no need for a separate network enrollment step, users only need to push buttons on the new controller device to link them. This straightforward method is simple to use and can optionally be done using software on a PC.

INSTEON uses Frequency Shift Keying (FSK) at 904 MHz ISM band. Some of the key characteristics of INSTEON are captured in Figure 73.

Figure 73: INSTEON specifications

INSTEON Specifications	
Powerline Frequency:	131.65 kHz, devices auto switch to X10 band at 120 kHz
Radio Frequency:	902- 924 MHz (ISM Band) (900 MHz is ideal for penetrating the structure of a home. INSTEON does not interfere with other devices)
RF Sensitivity:	103dbm
RF Modulation:	FSK
RF Range:	150 feet, line of sight
Speed:	10 messages per second, maximum
Supported Devices:	16,777,216 (no limit on nodes per network)
Possible Commands:	Over 65,000 (On, Off, Dim, Lock, Open, etc.)
Battery Power Consumption:	Extremely low

Source: www.smarthome.com

The INSTEON Alliance

The INSTEON Alliance, founded in May 2005, has currently more than 350 members and influences the development of INSTEON solutions within the growing electronic home improvement industry.

Applications

There are two basic kinds of applications that developers can create for INSTEON networks: External Applications and Internal Applications.

External Applications run on a computing device such as a PC or PDA. An INSTEON Bridge connects the computing device to an INSTEON network. INSTEON also provides a simple scripting language and an application development platform to help embed INSTEON in various applications.

Internal Applications run on INSTEON devices themselves. SmartLabs has also developed a SmartLabs Integrated Development Environment (sIDE) which makes it easy for programmers to create and debug applications using a PC.

Some of the home control applications where INSTEON could play a role are:

- Scene and remote control lighting
- Security alarm interfaces and sensors
- HVAC control and management, and energy saving
- Audio/Video control and appliance management

There are already a couple of products with INSTEON technology in the market. Some of the available products are: on/off switch modules, light dimmers, home appliance management solutions, etc.

Installation and Activation

INSTEON devices are set up using a Plug and Tap™ method. Each device has its own unique ID, eliminating the need to set addresses or manipulate code wheels. The procedure to link two INSTEON devices involves pressing and holding the ON button on the first controller for 10 seconds, and then doing the same for the second device. Though a basic system can be deployed without a PC, such a device may be later added for advanced home management.

Z-Wave

Z-Wave is a wireless communications standard developed by privately-held Zensys and the Z-Wave Alliance. It is designed for low-power and low-bandwidth appliances, such as home automation and sensor networks.

Z-Wave radios operate in the unlicensed frequency band of 908.42 MHz in the US and 868.42 in Europe. Data is modulated at 9.6-100 kbps using the BFSK (binary frequency shift keying) method. In Europe, the 868 MHz band has a 1% duty cycle limitation, meaning that a Z-Wave device can only transmit 1% of the time. This limitation is not present in the US, but there is a 1mW transmit power limitation (as opposed to 25 mW in Europe).

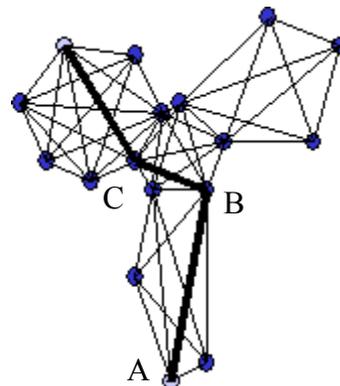
Operation

Z-Wave uses an intelligent mesh topology and has no master node. Just like ZigBee, Z-Wave also has three kinds of nodes: Controller, Routing Slaves, and Slaves.

- *Controller:* These nodes initiate communication with other nodes and it uses controller-protocol stack.
- *Routing Slave:* Z-Wave nodes with routing functionality initiate communication with a well-defined subset of nodes and run the Z-Wave routing protocol stack in them.
- *Slaves:* These nodes do not initiate communication, but rather respond to requests from other nodes and are based on a slave protocol stack.

A message from node A to node C can be successfully delivered even if the two nodes are not within range providing that a third node B can communicate with nodes A and C. If the preferred router is unavailable, the message originator will attempt another router until a path is found to C node. In Figure 74 nodes on the solid line are beyond the reach of each other's range.

Figure 74: Nodes in a Z-Wave network



Source: Deutsche Bank

Z-Wave routes its messages through the network using a Source Routing Algorithm (SRA). The SRA requires the initiator device to know the topology of other devices in the network so that it can compute the next route for messages to route through.

The Z-Wave nodes that are involved in routing the messages cannot be in sleep mode. The mesh network also serves as the basis for the self-healing functionalities. RF communication links vary over time due to their strong correlation to the physical environment. The strength of the RF signals may change with the changing physical environment. In these situations, the self-healing mechanism in Z-Wave network automatically reroutes the messages through other nodes until the message reaches the destination node.

Z-Wave Alliance

Z-Wave Alliance is an open consortium of more than one hundred independent manufacturers who build products based on the Z-Wave standard. Principal members include Danfoss, Intel, Intermatic, Leviton, Monster Cable, and Zensys.

Activation and Installation

The Z-Wave supports two types of installation: local and central installation.

The local installation is ideal for small low-cost systems (up to 30 nodes). In this type of installation, the user activates both the node and the controller to install the new product. The installation can be simultaneous or skewed and it can be initiated once or for all the new products. The new product sends out a request to join the network, which is acknowledged by a controller by assigning an ID to the node. Finally, the new node reports back its neighbor list to the controller enabling it to have full network topology information.

The central installation is used for more complex home control systems with many different products and appliances. In this installation, the Z-Wave enables any controller in the system to include new products to the system in coordination with the Z-Wave SIS (Static update controller ID server). The SIS is typically implemented in a PC or equivalent intelligent device.

Applications

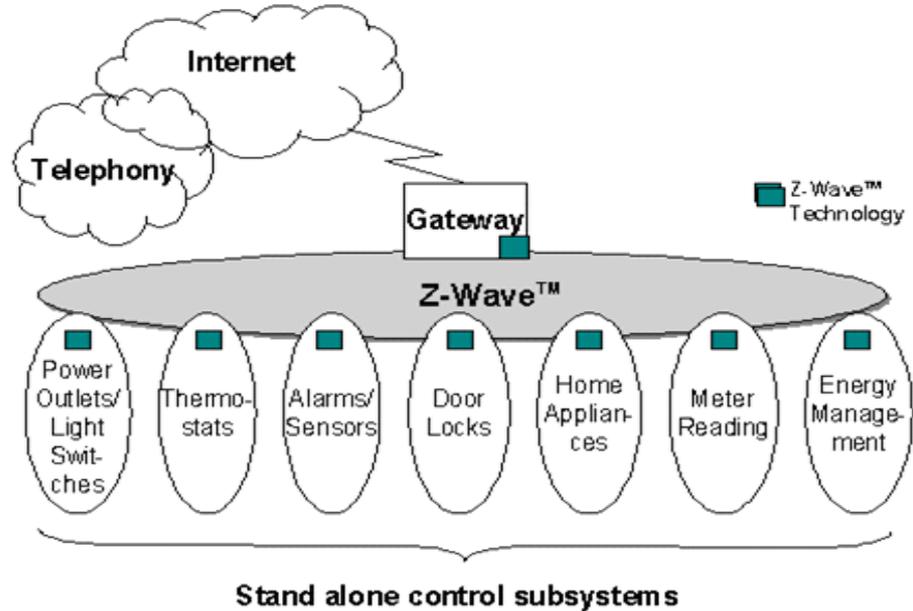
The Z-Wave technology supports the full range of AC-powered, battery-powered, fixed position nodes, moving nodes, and potentially, bridging nodes to other technologies, with a range of Z-Wave protocol stacks. Z-Wave also supports moving battery-powered devices such as a handheld remotes and moving sensors with each type of node position. Z-Wave has support for re-discovery of the moving nodes within the overall network topology.

Z-Wave is interoperable across a range of devices and is guaranteed by the Z-Wave certification program. Product interoperability is ensured by two levels of standardization:

- **Command Level:** All commands can be transferred between the nodes and are standardized.
- **Device Level:** All devices are members of a Device Class that defines mandatory, recommended, and optional commands.

An example of the total interoperability scope of Z-Wave is shown in Figure 75.

Figure 75: Interoperability scope of Z-Wave devices



Source: Zensys.com

Bluetooth

The Bluetooth Special Interest Group (Bluetooth SIG) was established by Sony Ericsson, IBM, Intel, Nokia, and Toshiba, and later many other companies joined it as associate or adopter members. Currently, it has more than 1800 members.

Bluetooth wireless technology is a short-range communications technology intended to replace the cables connecting portable and/or fixed devices while maintaining high levels of security. The key features of this technology are robustness, low power, and low cost. Bluetooth was initially conceived by Ericsson.

Bluetooth operates in the unlicensed industrial, scientific and medical (ISM) band at 2.4 to 2.485 GHz, using FHSS. Its adaptive frequency hopping (AFH) capability was designed to reduce interference between wireless technologies sharing the 2.4 GHz spectrum. AFH works within the spectrum to take advantage of the available frequency. This is done by detecting other devices in the spectrum and avoiding the frequencies they are using. Bluetooth technology is omni-directional and does not require line-of-sight positioning of connected devices.

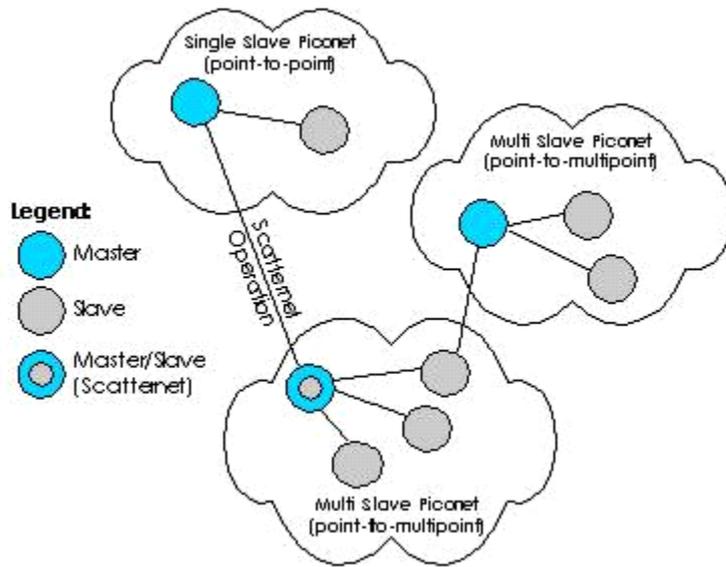
Operation

Bluetooth technology has achieved global acceptance and any Bluetooth-enabled device anywhere in the world can connect to other Bluetooth device. Bluetooth-enabled electronic devices connect and communicate wirelessly through short-range, ad-hoc networks known as piconets. Each device can simultaneously connect with up to seven other devices within a single piconet.

Each device can also belong to several piconets simultaneously. Piconets are established dynamically and automatically as Bluetooth-enabled devices enter and leave radio proximity.

The network topology of Bluetooth devices is shown in Figure 76. Each Bluetooth device can operate in more than one mode at a time. For example, a Bluetooth device can be a master in one piconet and a slave device in another.

Figure 76: Piconets in Bluetooth



Source: www.wipro.int

The key strength of Bluetooth technology is its ability to simultaneously handle both data and voice transmissions. This enables users to enjoy a variety of innovative solutions such as a hands-free headset for voice calls, printing and fax capabilities, synchronizing PDA, wireless keyboard and mouse, and mobile phone applications to name a few. Bluetooth does not have native IP support and hence cannot support the TCP/IP protocol suite which makes it unsuitable for WLAN applications.

Unlike many other wireless standards, the Bluetooth wireless specification gives product developers both link layer and application layer definitions, which support data and voice applications. This has led to faster interoperability among Bluetooth products from different vendors.

Bluetooth differs from Wi-Fi in that the latter provides higher throughput and covers greater range, but requires expensive hardware and has higher power consumption. Bluetooth can be a cable replacement solution for many applications, while Wi-Fi only provides solutions for local area network access.

The operating range depends on the device class: Figure 77 shows the range and permitted power levels for each class of Bluetooth devices.

Figure 77: Range and power of Bluetooth devices

Class	Max. Permitted Power	Max. Permitted Power	Range
Class 1	100 mW	20 dBm	100 m
Class 2	25 mW	4 dBm	10 m
Class 3	1 mW	0 dBm	1 m

Source: Deutsche Bank

The most commonly used radio is Class 2, which uses 2.5 mW of power. Class 2 device is commonly used in mobile phones and devices, headsets, keyboards, mice, etc. Bluetooth supports up to 1 Mbps of data rate for version 1.2 and up to 3 Mbps for version 2.0 +EDR (enhanced data rate).

Bluetooth supports three modes of security for access between two devices. The three modes are non-secure, service-level enforced security, and link-level enforced security.

Current cost of Bluetooth chips is under \$3.

UWB

UWB (Ultra-Wide Bandwidth) is a short range radio technology and is used for transmitting information spread over a large bandwidth from a host device to other devices in the range of about 10 m (30 ft). UWB makes an efficient use of scarce radio bandwidth while enabling both high data rate personal area network (PAN) wireless connectivity as well as longer range.

Currently, there are two competing flavors of UWB: direct sequence-UWB proponent Forum (Freescale Semiconductor), and the Multiband group WiMedia Alliance (Intel, Microsoft, HP).

On one side is UWB Forum, backed by Freescale Semiconductor and Motorola that has a classic view of UWB and uses full 7.5 GHz in one long stretch with a filter that notches out the fragile unlicensed 5 GHz band used for 802.11a, which could be adversely affected by UWB. Motorola, Freescale's parent company, also backs this view. On the other side is the WiMedia Alliance, which merged with Multiband OFDM Alliance (MBOA) in 2005. MBOA was formed during the IEEE standard setting process and backs a PHY based on IEEE 802.15.3a standard. WiMedia later came into existence to work on the top layers (MAC layer up to applications) of the IEEE 802.15.3a standard.

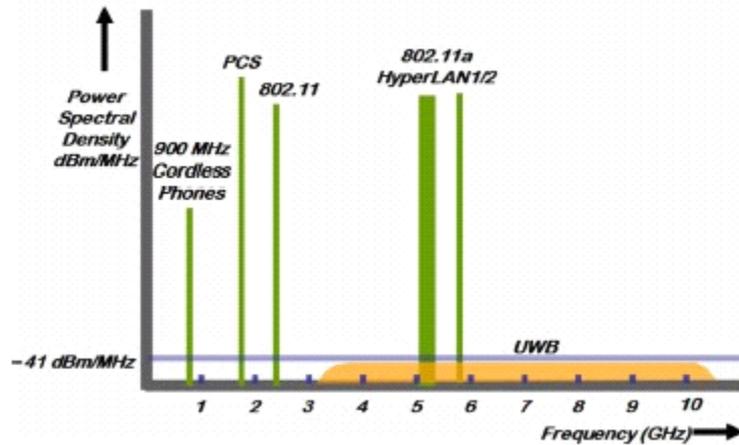
In January 2006, IEEE voted to disband the 802.15.3a task group as no consensus could be reached between the opposing camps. Both groups pledged to continue to develop their own approaches and let the market forces determine the final outcome. UWB Forum members are pursuing a personal-computer-centered approach which is touted to be the replacement for USB cables.

Operation

Unlike many other wireless standards, UWB transmits very narrow and low-power pulses over a wide spectrum. This combination of broader spectrum and lower power improves speed

UWB systems use Orthogonal Frequency Division Multiplexing (OFDM) to occupy a very wide spectrum. UWB's combination of broader spectrum and lower power improves speed and reduces interference with other wireless spectra. In the US, the FCC has mandated that UWB can operate in the range from 3.1 GHz up to 10.6 GHz, at a limited power of -41dBm.

Figure 78: UWB Operating Frequency Spectrum

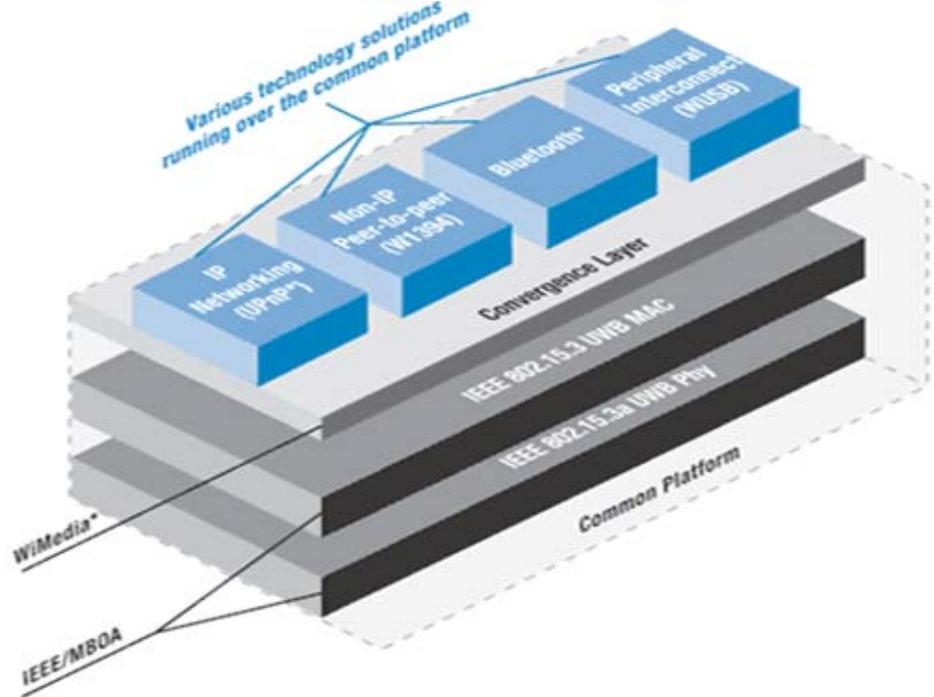


Source: www.dailywireless.com

WiMedia Alliance and UWB

WiMedia Alliance’s vision of UWB is of a common platform spanning many different applications. Figure 79 shows the evolution of WiMedia UWB and applications to be supported in future.

Figure 79: UWB MAC and Application layers



Source: www.intel.com/technology

Thus, UWB along with the convergence layer becomes the underlying transport mechanism for different applications. Bluetooth SIG has already agreed to integrate its technology on top of WiMedia UWB. We expect USB and UPnP will soon be willing to integrate their technologies with the WiMedia UWB. This integration of popular technologies on a proven UWB platform makes WiMedia UWB a much more attractive proposition than the UWB Forum flavor of the UWB. ABI Research put a statement that this choice by the Bluetooth SIG puts WiMedia UWB makers in a superb position for unit volumes and could open up a vast market for products. It forecasts over one billion Bluetooth radio shipments per annum by the end of the decade.

Applications

Ultra-Wideband allows consumers the hope of eliminating the maze of wires connecting electronic products in their homes, including large screen displays, set-top boxes, speakers, televisions, digital video recorders, PC/laptops, digital cameras, smart phones, and more. Products that include UWB are expected to:

- Build a home theatre environment without cables
- Share live multimedia content between televisions
- Transfer images from a digital camera to other products
- Share wireless video between a computer and a separate monitor

More than in anything else, we think WiMedia UWB is expected to play a big role in replacing the cables around the computer and home audio-video equipment.

Universal Plug and Play (UPnP)

The UPnP Forum is an industry initiative designed to enable simple and robust connectivity among stand-alone devices and PCs from many different vendors. The UPnP technology enables data communication between any two devices under the command of any control device on the network. It is an extension to the plug-and-play initiative that was introduced by Intel, Compaq, and Microsoft back in 1992. Currently, UPnP Forum has about 800 member companies.

UPnP can run on any medium including phone lines (HomePNA), power lines (INSTEON, Z-Wave, and ZigBee), Ethernet, IR (IrDA), and RF (Wi-Fi, Bluetooth). Since UPnP is based on common base protocols, it does not require any device drivers. UPnP is also operating system and programming language independent. UPnP supports zero-configuration, invisible networking and automatic discovery for a breadth of device categories from a wide range of vendors, whereby a device can dynamically join a network, obtain an IP address, and learn about the presence and capabilities of other devices.

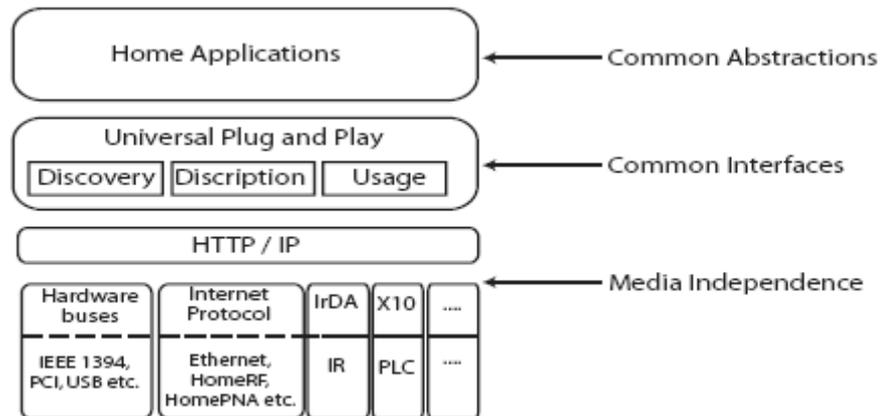
UPnP leverages Internet components, including IP, TCP, UDP, HTTP, and XML. UPnP uses IP networking because of its proven ability to span different media to enable multi-vendor interoperation, and seamlessly connect to different devices running IP protocol. UPnP can accommodate non-IP devices via bridging.

Some of the key features of UPnP are:

- Standards-based architecture: The UPnP architecture is based on open standards such as IP, TCP, UDP, HTTP, XML, etc.
- Device connectivity: UPnP devices can join and leave the network transparently, advertise their services, discover other devices and services, and control other devices.
- Ad-hoc networking: Devices participating in a UPnP network can join networks in a dynamic manner.
- Media and Device independence: UPnP protocol can run on any medium for which there is an IP stack, including phonelines, powerlines, Ethernet, RF and IEEE 1394.

Operation

The UPnP-enabled devices initiate a sequence of steps to enroll in the UPnP network, advertise services, and connect to other devices in the network. A high-level architectural view of UPnP is shown in Figure 80.

Figure 80: High-level architecture of UPnP

Source: Xilinx.com

UPnP provides developers with a common set of interfaces for accessing services on a home network. UPnP interconnects all types of information appliances in the home, including PCs, smart home appliances, residential gateways, and home control systems.

When a device is connected to the UPnP network, the device initiates a discovery process. During the discovery process, a control point queries the network using Simple Service Discovery Protocol (SSDP) and identifies devices that are hosting various services. Upon query by the control point, the device offering a particular service responds to the control point by offering a URL of the device description and services offered by the device. The control point can interrogate the XML-based device description document to identify the make, model and services offered by the device. A detailed description of various services – input and output parameters will be contained in the XML-based service description document. By having access to the various services offered by the device, the control point can invoke actions on one or more services using SOAP protocol.

UPnP AV

The AV Architecture defines, in general, interaction between UPnP device Control Points and UPnP AV devices. It is independent of any particular device type, content format, and transfer protocol. It supports a variety of devices such as TVs, VCRs, CD/DVD players/jukeboxes, set-top boxes, stereo systems, MP3 players, cameras, and the PC. The AV architecture allows devices to support different types of formats for entertainment content (such as MP3, MPEG2, MPEG3, JPEG, WMA, BMP, etc) and multiple types of transfer protocols.

Benefits of UPnP

- **Plug and Play:** UPnP allows for discovery and connectivity among a diverse set of devices on the network.
- **Low footprint:** UPnP requires very small amount of system resources and is a good fit for integration with consumer electronics devices.

Issues with UPnP

There are a couple of issues with UPnP as well. First, it uses HTTP over UDP, which is an Internet draft only and expired in 2001. Second, it does not have a light-weight authentication protocol. As a result, many UPnP devices whip with UPnP turned off by default.

DLNA (Digital Living Network Alliance)

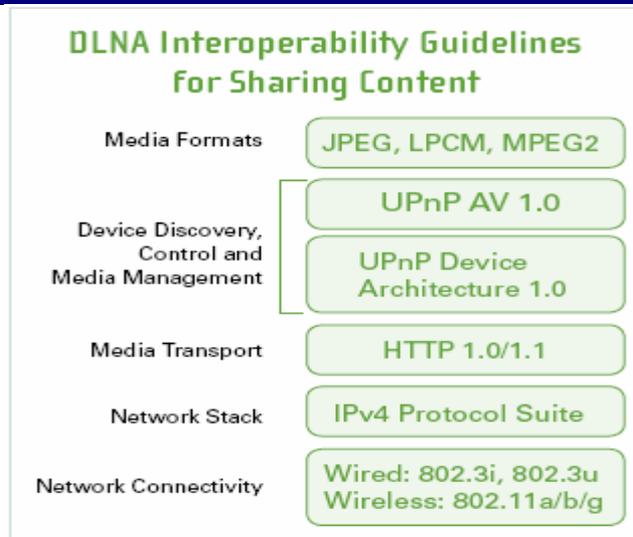
The Digital Living Network Alliance (DLNA) is a cross-industry organization of leading consumer electronics, computing industry and mobile devices companies. It aims to create an interoperable network of wired and wireless PCs, CEs, and mobile devices in the home. DLNA has currently more than 280 members from the industry including Intel, Nokia, Samsung, Motorola, TI, etc.

DLNA has published a common set of industry design guidelines that allow vendors to participate in a growing marketplace of networked entertainment and mobile devices.

Scope and Operation

The DLNA interoperability guidelines specify the interoperable building blocks that are available to build platforms and software infrastructure. They have so far focused on interoperability between networked entertainment and media devices. As the new technologies and standards become available, the guidelines may broaden to cover other areas, such as home control, communications and advanced entertainment scenarios. Figure 81 shows the standards-driven components of the DLNA architecture.

Figure 81: Architecture of DLNA



Source: www.dlna.org

Figure 82 shows the specific functional components and technology ingredients covered by the DLNA interoperability guidelines. The basic criteria for specific technology ingredients selected for the DLNA Interoperability guidelines for 2006 and beyond include: standards-based technologies, should be interoperable, should be possible to bridge or translate as required between any two technologies.

Figure 82: Functional Components of DLNA

Functional Components	Technology Ingredients
Connectivity	Ethernet, 802.11, and Bluetooth
Networking	IPv4 Suite
Device Discovery and Control	UPnP Device Architecture v1.0
Media Management and Control	UPnP AV v1 and UPnP Printer:1
Media Formats	Required and Optional Format Profiles
Media Transport	HTTP (Mandatory) and RTP (Optional)

Source: www.dlna.org

DLNA is currently certifying products which meet all the compliance and interoperability criteria set forth in the DLNA Interoperability Guidelines by the member companies.

DLNA architecture comprises the following key technology components:

- **Networking and Connectivity:** IPv4 is the foundation of the networking and connectivity in the DLNA architecture. There are several advantages of using IP in the digital home: 1) Applications running IP over different media can communicate transparently; 2) IP can connect every device in the home to the Internet; and 3) IP connectivity is inexpensive.
- **Device Discovery and Control:** Device discovery and control enables devices on the home network to automatically configure the networking properties, and discover the presence and capabilities of other devices on the home network. DLNA uses UPnP to address these needs.
- **Media Format and Transport Model:** The DLNA media format is intended to achieve a baseline of networking interoperability. Figure 83 summarizes the media format supported in the DLNA. These are continuously updated and new formats are added as the ecosystem evolves.

Figure 83: Supported formats in DLNA

Media Class	Required Format Set (must implement all)	Optional Format Set (must implement 1 or more)
Image	JPEG	PNG, GIF, TIFF
Audio	LPCM	AAC, AC-3, ATRAC 3plus, MP3, WMA9
AV	MPEG2	MPEG-1, MPEG-4*, AVC, WMV9

Source: www.dlna.org

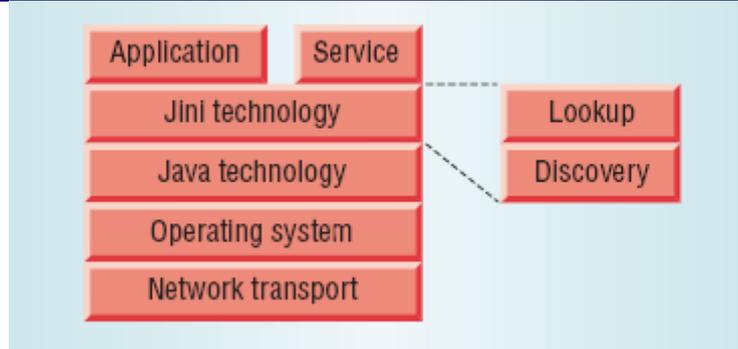
- **Media Management, Distribution and Control:** This function enables devices and applications to identify, manage, and distribute media across the devices on the home network. DLNA uses UPnP Audio/Video (AV) technology to achieve these aims.
- **Digital Rights Management (DRM):** Today, there are several DRM technologies available to device manufacturers and content providers. DLNA uses few of these technologies to protect, administer, and distribute stored content.

DLNA and UPnP

DLNA is built upon the UPnP standard and hence is a superset standard of UPnP. DLNA goes beyond the basic UPnP architecture specification to include media formats and other issues such as Digital Rights Management (DRM) to ensure a higher degree of device interoperability.

Jini

Jini was developed by Sun Microsystems. It is a layer of Java software that allows devices to plug directly into a home network without the hassle of installing drivers and configuring operating systems. Jini was initially designed at Sun, hidden from public eyes, until 1999 when the technology was officially made available to the public with a host of licensees already on board.

Figure 84: Architecture of Jini

Source: IEEE Computer, 2002

As shown in Figure 84, the Jini software runs on top of a Java platform to create a federation of virtual machines. The technology accepts all sorts of devices, including electronic home appliances, musical instruments, and other devices that are not part of the conventional computer network. Each device can act as a client or server depending on whether it is requesting a service or providing one. A service in a home network might be as small as requesting the room temperature from an air conditioner or as big as transferring a file from a laptop to a printer.

Figure 84 also shows Jini's two basic services: lookup and discovery. These services manage the processes of making a network service available to devices and subsequently using it.

The Jini architecture allows for non-Jini capable devices to join the service federation, even if they lack enough memory and processing power to implement a Java virtual machine.

The main distinction between Jini and UPnP lies in the API strategy. Jini uses its APIs as a contract between the vendors. UPnP allows vendors to build their own APIs, modeled on protocol standards and targeted for specific features of the operating system. Also, Jini follows a code download model, which connects devices through a common application that developers must use to test their device's operation.

Appendix B: Glossary

Access Point (AP). A wireless hardware device that attaches to a wired network and transmits data to and receives data from your wireless network cards or adapters. Sometimes also called a base station.

Ad-hoc mode. A networking arrangement in which wireless devices communicate directly with one another, rather than through an access point. Also known as peer-to-peer networking.

Advanced Encryption Standard (AES). A standard for encryption which is intended to replace the DES. AES supports key lengths ranging from 128 to 256 bits.

Backhaul. In the context of wireless communications, refers to taking data beyond its original destination and back. For example, WLANs within an enterprise can be backhauled to a LAN or a WAN, whereby communication is established first via the LAN or WAN and then routed back to the WLAN.

Basic Service Set (BSS). A set of 802.11-compliant stations that operate as a fully connected wireless network.

BPSK. Binary Phase Shift Keying. A modulation scheme.

Broadband over Power Line (BPL). BPL is also called Power Line Telecommunications (PLT), Broadband Powerline Carrier, or Powerline Communications (PLC). BPL is a system mostly still in beta mode, but the technology's aim is to provide broadband Internet service via electric power lines.

Cat 5. Category 5 unshielded twisted pair (UTP) cabling. The Cat 5 cable contains eight conductors, arranged in four twisted pairs, and terminated with an RJ45 type connector. In addition, there are restrictions on maximum cable length for both 10 and 100 Mbps networks.

CCK. Complementary Code Keying.

CE. Consumer Electronics.

Cell. The span of physical space covered by an access point.

Collision. An event that occurs when two nodes on a network both attempt to send data at the same time, disrupting network traffic.

Collision Detection Protocol. A protocol that enables a network to detect simultaneous transmissions or collisions between communication mediums. Carrier-Sense Multiple Access/Collision Avoidance (CSMA/CA) and Carrier-Sense Multiple Access/Collision Detection (CSMA/CD) are two common approaches to handling data collisions on a network segment.

DBPSK. Differential Binary Phase Shift Keying. A modulation scheme used in DSSS.

DCF. Distributed Coordination Function.

DES. Data Encryption Standard.

DQPSK. Differential Quadrature Phase Shift Keying. A modulation scheme used in DSSS.

Direct Sequence Spread Spectrum (DSSS). A method of wireless transmission that splits each byte of data into several parts (chips) and sends them concurrently and continuously on different frequencies over a wide frequency band.

DVR (Digital Video Recorder). A device which stores multimedia in digital format.

Ethernet. An industry-standard network hardware specification (IEEE 802.3) developed by IEEE that offers dedicated network (and Internet) access.

FCC. The Federal Communications System is the government agency responsible for regulation of the communications industry.

Frequency Hopping Spread Spectrum (FHSS). A method of wireless transmission in which a transmitter and receiver hop together from one frequency to another in an arranged pattern.

Frequency-Shift Keying (FSK). A method of transmitting digital signals that uses two different frequencies to represent the binary states of 0 and 1.

Gateway. A hardware or software device that provides access to the Internet for multiple computers or networks. Sometimes called a gateway router.

HPNA. Home Phoneline Networking Alliance.

Independent Basic Service Set Network (IBSS Network). An IEEE 802.11-based wireless network that has no backbone infrastructure and consists of at least two wireless stations. This type of network is often referred to as an ad hoc network because it can be constructed quickly without much planning.

Internet Key Exchange (IKE). An automated method for exchanging and managing encryption keys between two VPN devices.

Infrastructure Mode. A wireless network arrangement in which network cards or adapters communicate with a central transmitter/receiver called an access point, which functions as a sort of wireless hub.

Institute of Electrical and Electronics Engineers (IEEE). A professional organization that develops standards for the computer industry, including the commonly used IEEE 802.11b wireless networking standard. Usually called by its acronym, pronounced "Eye-triple-E." (See the IEEE Web site.)

Internet Protocol (IP). The established standard protocol for transmitting and receiving data in packets over the Internet. IP is a fundamental part of the TCP/IP protocol suite.

IPTV (Internet Protocol Television). IPTV delivers a digital television service to subscribers via the Internet Protocol over a broadband connection.

Local Area Network (LAN). A network of computers typically housed in the same office, building, or campus. Computers on a LAN are connected together via cables or wireless access points for the purpose of sharing applications, data, peripherals, or other resources.

Media Access Control (MAC). Specific protocols that govern client access to a network and perform authentication, privacy, and data integrity services.

Mbps. Megabits per second, a rate of data transfer.

MIMO (Multiple Input Multiple Output). It is the use of multiple transmitters and receivers (multiple antennas) on wireless devices for improved performance.

MoCA. Multimedia over Coax Alliance.

Network. A group of computers and devices that are connected to one another and can communicate.

Node. Any point on a network. May be a computer, router, printer, or any other device connected to the network.

Orthogonal Frequency Division Multiplexing (OFDM). It is a communications technique that divides a communications channel into a number of equally spaced frequency bands. A subcarrier carrying a portion of the user information is transmitted in each band. Each subcarrier is orthogonal (independent of each other) with every other subcarrier, differentiating OFDM from the commonly used frequency division multiplexing (FDM).

Point coordination function (PCF). An IEEE 802.11 mode that enables contention-free frame transfer based on a priority mechanism. Enables time-bound services that support the transmission of voice and video.

Private Area Network (PAN). A very small network, usually within the space of a few feet or the size of a room. Also known as a piconet. A good example of a PAN is a cell phone and a personal digital assistant with a Bluetooth adapter. The adapter links with the cell phone, allowing the PDA to access the Internet.

Peer-to-Peer. A network architecture in which computers on the network share resources on an equal basis, and stations can initiate direct communication with one another. Also known as ad-hoc networking.

Piconet. Another term for a personal-area network (PAN).

QPSK. Quadrature Phase Shift Keying. A modulation scheme.

QSTA. QoS-enabled station (STA).

Quality of Service (QoS). QoS is a networking term that specifies a guaranteed level of throughput. Throughput is the amount of data transferred from one device to another or processed in a specified amount of time.

Shared key authentication. A type of authentication that assumes each station has received a secret shared key through a secure channel independent from an 802.11 network. Stations authenticate through shared knowledge of the secret key. Use of Shared Key authentication requires implementation of the 802.11 Wireless Equivalent Privacy algorithm.

Spread Spectrum. A method of wireless transmission in which data is sent in small pieces over a number of the discrete frequencies available for use at any time in the specified range, and then collected back to the original frequency at the receiving point.

STB. Set-Top Boxes.

TDM. Time-division multiplexing (TDM), a method for sending multiple digital signals along a single telecommunications transmission path.

Triple-play. In telecom refers to bundling Internet data services, television (IPTV) and phone service (VoIP).

UPnP (Universal Plug and Play). A discovery and management protocol developed by Microsoft.

USB (Universal Serial Bus). A widely used hardware interface used for connecting peripherals to a PC.

VOD (Video on Demand). VOD systems allow users to request and select video content over a network as part of an interactive television system.

Wireless Ethernet Compatibility Alliance (WECA). An industry organization dedicated to certifying wireless products for interoperability and promoting issues (such as security) that are important to wireless network developers, manufacturers, and users.

Wide Area Network (WAN). A network or system of networks that connects computers and computer users over a wide geographical area, usually encompassing different metropolitan areas. A good example of a WAN is the University's System Network.

WiMax. A wireless technology based on the IEEE 802.16 standard providing metropolitan area network connectivity for fixed wireless access at broadband speeds.

Wired Equivalent Privacy (WEP). A common way of securing wireless networks and part of the Wi-Fi specification's built-in encryption scheme. Known to be vulnerable to hackers.

Wireless Fidelity (Wi-Fi). The standard used by wireless component manufacturers to make their products compatible with other wireless products (similar to how "Hi-Fi" stands for "High Fidelity" in audio equipment). The IEEE 802.11b wireless standard is also known as Wi-Fi.

Wireless LAN (WLAN). A derivative of a traditional LAN that uses radio waves instead of cables to transmit data.

Wi-Fi Protected Access (WPA). is a specification of standards-based, interoperable security enhancements that increase the level of data protection and access controls for existing and future wireless LAN systems.

WMM (Wi-Fi Multimedia). Wireless Multimedia Extensions (WME), also known as Wi-Fi Multimedia (WMM) is a Wi-Fi Alliance interoperability certification, based on the IEEE 802.11e draft standard.

WPA2. IEEE 802.11i, also known as WPA2, is an amendment to the 802.11 standard specifying security mechanisms for wireless networks.

WUSB. Acronym for Wireless USB (Universal Serial Bus).

WWiSE. Acronym for World Wide Spectrum Efficiency.

X-10. The standard for automatic, remote control lighting for homes and offices from X10, Hong Kong (www.x10.com).

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Appendix 1

Important Disclosures

Additional information available upon request

Disclosure checklist			
Company	Ticker	Recent price*	Disclosure
Motorola	MOT.N	19.36 (USD) 10 Jul 06	1,2,6,7,8,14,15,SD11
Qualcomm	QCOM.OQ	37.80 (USD) 10 Jul 06	2,6,14,15
Nortel Networks	NT.N	2.53 (USD) 10 Jul 06	1,2,6,7,8,14,15,17

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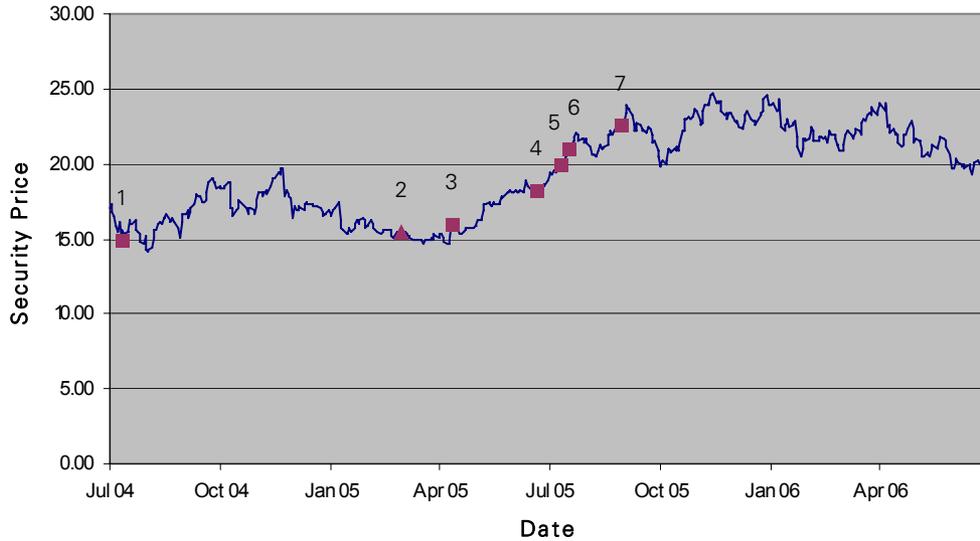
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Historical recommendations and target price: Motorola (MOT.N)

(as of 7/11/2006)



Previous Recommendations

- Strong Buy
- Buy
- Market Perform
- Underperform
- Not Rated
- Suspended Rating

Current Recommendations

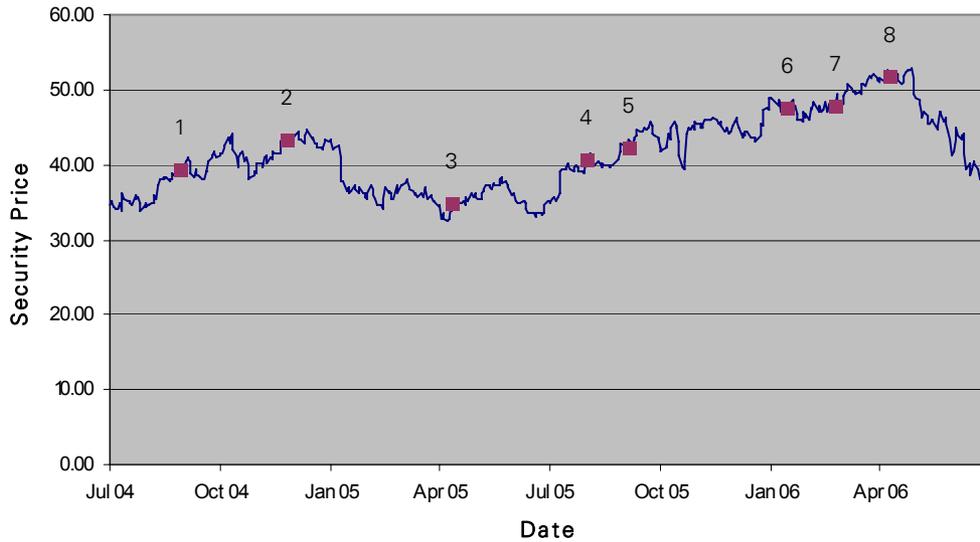
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(as of 7/11/2006)



Previous Recommendations

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- Buy
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- Underperform
- Not Rated
- Suspended Rating

Current Recommendations

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- Hold
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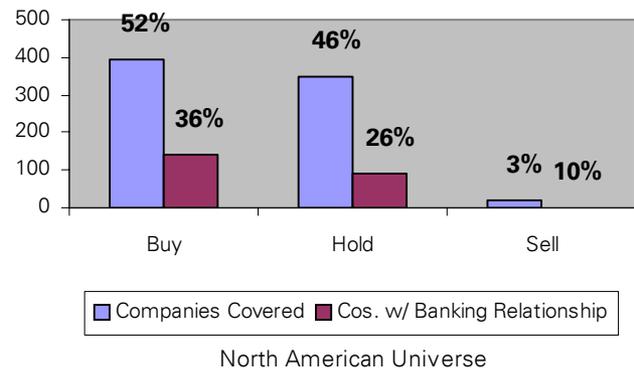
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