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Cable Industry Considerations in Choosing Wireless Home Networking Technology

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Abstract

Home networking evolved over the last few years into an affordable technology that can be applied to cable customers. Many home networking alternatives were proposed over the last few years. Wireless home networking emerged as the most promising solution in terms of consumer and operator benefits.

We will compare the wireless home networking variants to other alternative home networking technologies and discuss the wireless home networking options. We will focus especially on IEEE 802.11 and its various extensions, and discuss what features are important for addressing the Cable industry needs and their importance to enable new revenue opportunities.

Home Networking Overview

Home networking has rapidly emerged in the last three years and is considered today as an important element for home connectivity.

Many home networking alternatives exist to date with each alternative further divided into flavors, which makes it very confusing for the consumer and operator. The main home networking alternatives are:

- *Wireless home networking:* Utilizing RF technology to create a wireless local area network. This category includes IEEE 802.11[1], HomeRF[2], and HiperLAN2.
- *Home phone line networking:* Using phone lines to create a home network. This category includes HPNA1.0[3] and HPNA2.0.
- *Power line home networking:* Utilizing AC power line network as the home network media. This category includes HomePlug[4] and X-10 technologies.
- *Ethernet:* This good and mature technology can be used for networking the home, however unlike the previous technologies, requires addition of CAT5 wires across the home.

Table 1 details the technical attributes of the key alternatives

Table 1 – Home Networking Standards

Standard	PHY Rate	QoS	Wiring
802.11	11-54 Mbps	Full (11e)	No
HPNA2.0	16-32 Mbps	Weak	Phoneline
HomePlug	14 Mbps	Weak	Powerline
100 BaseT	100 Mbps	No	CAT5

Among the various technologies, wireless LAN (WLAN) is gaining momentum as the consumer's technology of choice. Its most important feature is avoiding the need to install new wires, while still having the freedom to roam throughout the house and use a computer where desired. In addition, many laptops are already equipped with WLAN cards used in the office environment. This drives higher availability of WLAN stations. Powerline networking may become attractive depending on the ability to overcome the Powerline noise issues and the availability of very low cost Network Interface Cards (NIC) that connect to the power line network. Phoneline networking was attractive in the past as the only 10 Mbps technology available but is losing momentum, as users prefer using wireless technologies.

Among the various wireless technologies, IEEE 802.11 is emerging as the technology of choice mainly for its wide industry support and higher rate compared to HomeRF. Compared to HiperLAN2, 802.11 is more suitable for North America and can provide equivalent rate and range depending on the chosen 802.11 extension.

IEEE 802.11 Flavors and Advanced Technologies

Most people are well familiar with IEEE 802.11b, or Wi-Fi, as the standard for WLAN. There are, however, many extensions to IEEE 802.11 aiming to improve rate, range, QoS and security compared to the 802.11 baseline.

Table 2 summarizes the relevant IEEE 802.11 standards and draft standards (*italicized*).

Table 2 – IEEE 802.11 Standards

Standard	Layer	Features
802.11b	PHY	Baseline, 2.4 GHz
802.11a	PHY	5 GHz OFDM modulation up to 54 Mbps
802.11e	MAC	QoS features
802.11g	PHY	Up to 54 Mbps in 2.4 GHz
802.11i	MAC	Improved security

802.11b provides up to 11Mbps physical layer rate with carrier frequency at 2.4 GHz range. The modulation is based on Direct Sequence Spread Spectrum (DSSS) using Complementary Code Keying (CCK) and optional Packet Binary Convolutional Code (PBCC) single-carrier technologies. IEEE 802.11b standard defines PBCC at 5.5 and 11 Mbps. There is an additional 22 Mbps extension supported by current generation silicon solutions. A receiver that implements a PBCC convolutional decoder properly provides 3dB-coding gain (over CCK), which translates into either 70 percent extended coverage or into a higher rate at a given range (e.g. 5.5 to 11 Mbps).

The effective TCP/IP [5] throughput of 802.11b at 11Mbps rate is reduced from the theoretical 11Mbps to 5-6 Mbps when considering the MAC layer overhead (see figure 1). Each transmission of a 1460-byte IP packet (1060 µsec) is preceded by inter-frame spacing (60 µsec), 300 µsec back-off time on average, 72 or 144 preamble bits transmitted in 1Mbps (72/144 µsec), MAC header (24/48 µsec) and 10 MAC overhead bytes (55 µsec). An 802.11 acknowledge follows each data packet in addition to IP acknowledge packet adding more overhead. The overall overhead accounts for 50 percent of the total time and reduces the effective IP throughput of 802.11b to 5-6 Mbps.

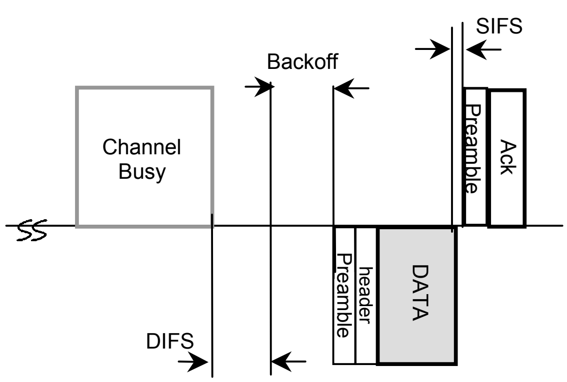

Figure 1 - 802.11 Distributed Access Control

IEEE 802.11a provides a PHY layer based on 5.2-GHz RF frequency and high rate modulations from 6 to 54 Mbps. IEEE 802.11a is based on multi-carrier OFDM technology where each individual tone can support up to 64 QAM modulation, allowing very high rates. A tradeoff exists between range and rate at 5.2-GHz RF such that the rate falls back rapidly as the distance between the station and the access point increases. A disadvantage of IEEE 802.11a is the use of 5.2 GHz frequency and OFDM modulation, which are not interoperable with the widespread 2.4 GHz 802.11b technology.

The new IEEE 802.11g draft specification defines two technologies that can increase bit rates at 2.4 GHz while keeping backward compatibility to the widespread 802.11b technology. One technology is CCK/PBCC-11, used in 802.11b, while the other is OFDM, similar to 802.11a OFDM. IEEE 802.11g allows a mixed mode called CCK-OFDM and another mode called PBCC-22/33. PBCC-22/33 allows coexistence with legacy 802.11b stations while providing higher rates of 22 and 33 Mbps for new stations. This 22 Mbps mode is already supported in Texas Instruments 802.11b-only silicon solutions (e.g. ACX100) and WLAN access points and NIC solutions.

IEEE 802.11e working group focuses on enhancing the MAC layer QoS capabilities in order to support multimedia applications such as video, audio and voice. The MAC scheme used in 802.11 is a contention-based carrier-sense multiple-access with collision avoidance (CSMA/CA) mechanism with binary exponential backoff (BEB) called Distributed Coordination Function (DCF). In DCF, there is no need for a central coordinator, and each station can attempt accessing the network based on some DCF rules. In low network loads, most access attempts are successful on first attempt and stations are able to send packets over the network with low latency. In some cases, the channel is occupied by another station for a few milliseconds and the station needs to defer until the channel is idle again. Since the access method is based on "First-come-First-serve" a very high latency in the order of tens of milliseconds can be created, especially in very high network load scenarios. A well-known example would be a file transfer between two PCs or between a PC and a printer that would block QoS-sensitive traffic. Another drawback of a contention based access mechanism is the low efficiency usage of available channel bandwidth due to collisions and backoff mechanisms. Results attained over Ethernet networks using a similar contention based access mechanism show that for multiple device networks the effective throughput can go as low as 10 percent of the actual payload data-rate.

IEEE 802.11e offers improved mechanisms to solve the above issues. The change from legacy 802.11 MAC to 802.11e can be compared to the change made in the DOCSIS [5] MAC when moving from DOCSIS 1.0 to DOCSIS 1.1. The most relevant mechanism is Hybrid Coordination Function (HCF), which supports a mix of contention based as well as centrally coordinated access. In HCF mode, a central coordinator (called hybrid coordinator, HC) is defined. HCF supports both prioritized QoS as well as parameterized (sometimes referred to as guaranteed) QoS. This is done through the support of prioritized traffic categories (TCs) as well as parameterized traffic streams (TSs), which are similar to service flows in DOCSIS 1.1. Stations can request bandwidth reservation from the HC, and a scheduler that resides in the HC controls the admission into the channel and may support QoS-critical applications such as voice, audio and video using the parameterized QoS mechanisms. Other types of traffic can be supported using the prioritized contention based mechanism. The centrally controlled channel access also makes the channel usage much more efficient, allowing for much higher effective data rates. This is achieved by eliminating contention intervals and ACK overhead or by using burst acknowledges mechanism. In an HCF centrally controlled scenario of streaming video for example, 80 percent efficiency can be easily achieved.

IEEE 802.11i introduces additional security features beyond the 802.11 baseline. IEEE 802.11i supports 40-bit Wireline Equivalent Privacy (WEP), 128-bit WEP and Advanced Encryption Standard (AES) algorithms as well as improved mechanisms for authentication, significantly reducing the risk for hacker attack on private data.

There are other IEEE 802.11 extensions offering additional improvements over the baseline 802.11, however, they are less relevant for the Cable industry.

IEEE 802.11 Application to Cable Requirements

IEEE 802.11 is a generic technology that can be applied to enterprise, consumer and even access environments. When considering IEEE 802.11 for Cable, one needs to consider the specific requirements relevant to the Cable operators and end-users:

- *Installation:* This is one of the most important factors affecting both the end users and the Cable operators. Obviously, WLAN does not require installation of new wires, which makes it appealing as a technology. However, the issues of installing drivers and configuring the network need to be addressed. Robust installation software is key to smooth installation process. Provisioning of network addresses can be resolved by CableHome[7] and smooth installation can be resolved by utilizing plug and play technologies[8].

- *Supporting multimedia applications:* Unlike enterprise environments, home environments are expected to have richer multimedia traffic including audio, video and multi-player gaming. Supporting video is critical for Cable operators as this is traditionally their key business and value proposition over competing access providers. Initially it is expected that supporting low rate, streaming IP video traffic will be required. Rates will vary starting from 100 kbps up to 750 kbps per stream, with moderate requirements for QoS. At a later stage, operators and service providers would like to offer broadcast quality video with MPEG rates between 4-6 Mbps. Video conferencing also could be offered either using PC Web cameras or special device. Ultimately, multiple video streams mixed with data, gaming and music could be envisioned, requiring very high rate and QoS performance of the wireless network.

- *Voice support:* As many cable operators would like to offer voice as an additional service, Cable Gateways will include PacketCable [9] functionality as a standard feature. PacketCable phones will be connected to RJ11 jacks at the Cable Gateway. Another possibility is using 802.11-based cordless phones that will provide both normal cordless phone functionality and smart terminal functionality, enabling additional service revenue.

In order to support the requirements above, the Cable industry will need to utilize WLAN technologies beyond the basic 802.11b. This could happen in phases as services offered evolve (see figure 2):

- *Phase I (today):* Support basic data connectivity with streaming IP video at low-moderate rates. IEEE 802.11b is sufficient to support this level of service

- *Phase II:* In addition to basic data connectivity service, phase II will support broadcast quality video distribution from residential gateways or set-top-boxes to remote TVs and PCs. This level of service requires higher physical rate going from 11 Mbps to 22/24 Mbps (with 12-16 Mbps effective payload rate) and IEEE 802.11e for QoS support and higher payload efficiency. This combination of high effective throughput and QoS support will enable reliable distribution of broadcast quality video even when the network is loaded with other traffic. For backward compatibility with phase I solutions, 802.11 networks need to use 2.4 GHz and thus 802.11g is preferred over 802.11a as it will support backwards compatibility with legacy equipment.

- *Phase III:* In addition to Phase II, Phase III will support multiple video streams between PCs, DVD player and TVs, few voice and audio streams and data traffic. This level of service will require the highest rate, as in IEEE 802.11g 54 Mbps mode, and full usage of 802.11e HCF in order to provide guaranteed bit rate service to the end user.

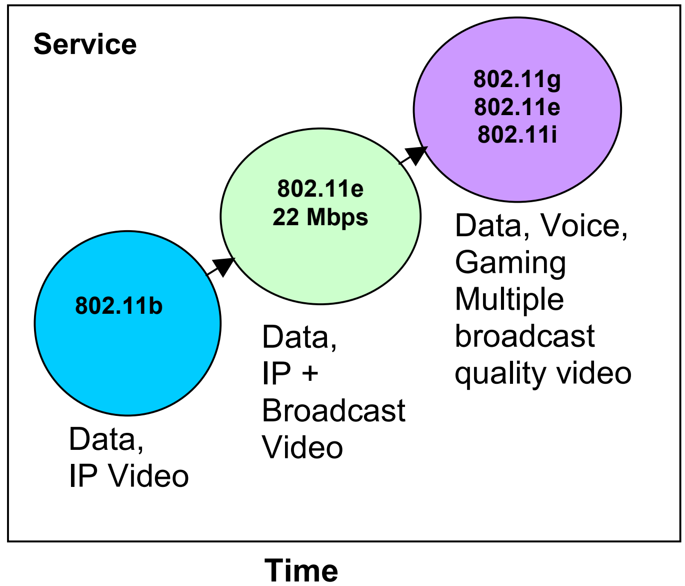

Figure 2 - Evolution of WLAN for Cable Applications

<u>Conclusion</u>

From the multiple home networking technologies that can be applied to the Cable environment IEEE 802.11 seems to provide the best solution to the Cable industry needs. IEEE 802.11 different extensions were analyzed in the context of Cable industry requirements. An evolution of features is expected, starting with IEEE 802.11b for basic service, continuing through 22 Mbps rate for providing broadcast quality video and finally onto IEEE 802.11g and IEEE 802.11e to provide ultimate rate and QoS features supporting multiple broadcast quality video streams, voice, audio, gaming and data services.

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