ARCHITECTING THE HOME GATEWAY TO DELIVER BUNDLED SERVICES AT THE LOWEST COST AND HIGHEST PERFORMANCE

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Abstract

This paper provides an overview of the various home-networking technologies, along with their associated advantages and disadvantages. An in-depth analysis of the rollout of 802.11 (a,b,g) is performed

A cable and 802.11 gateway architecture is examined, analyzing the trends in component technology, integration and power consumption, relative to system cost.

INTRODUCTION

Broadband to the home and office has become a reality. With any technology introduction there are two factors for its mass success, and thus economic benefit to both the technology developers/providers and end users: (1) Ease and cost of installation and operation; and (2) worthwhile applications that compel the subscriber/purchaser to use the technology.

With the introduction of home installation kits and the retail market for hardware and software, the technical barriers to setting up broadband services have been greatly reduced. Receiving broadband to the home is becoming as easy as ordering cable television or local telephone service. The "killer application" for this technology is high-speed Internet service, which alone could most likely drive next-generation technology. Applications such as telephony, digital video, and Video On Demand (VOD) are all reaching points of maturity where they will also become prime drivers. Once the enabling technology is installed and subscribers become familiar with one or two basic applications, the technology becomes almost "infectious", with subscribers using more and more of the technology.

In recent years, technology has focused on the "last mile". As broadband to the home has reached the masses, and upgraded cable plants can provide the required bandwidth for new and desired subscriber applications, the early adopters of this technology are now ready for the next generation of broadband technology to the home – the Home Gateway. For the purposes of this paper, a Home Gateway is a unit that can distribute data/services to multiple sources for multi-service applications. Users want the flexibility to take this large "bandwidth pipe" and its applications and seamlessly distribute it to computers, entertainment units and appliances in the home. The primary drivers for this technology are to minimize costs in hardware/systems, ease installation, and allow portability within the home/office. This technology offers a multi-service operator (MSO) the opportunity to increase revenue per subscriber, either by (1) supplying more applications; (2) enhancing the subscriber experience; and (3) offering networking services to the subscriber.

This paper will discuss the trends in the architecture of the Home Gateway, with an emphasis on semiconductors required to provide these services. Specific emphasis will be given to the requirements of semiconductors in the Home Gateway.

Standard	Technology	Approximate Max Data Rate	Advantages	Disadvantages
Ethernet (802.3)	Wired (Cat 5 Cabling)	100 (Mbps)	• Fast • Inexpensive hardware	• Requires new wiring • Not portable
WLAN	Wireless	54 (Mbps)	• Portable • Reducing in cost quickly • Relatively quick	• "Coverage" problems. • Interference • Range
HPNA	Wired (Twisted Pair Telephone lines)	32 (Mbps)	• Some existing wiring in place	• Not portable • Dependent on quality of phone line • Limited number of phone lines in homes
HomePlug	AC/Mains Wires	14 (Mbps)	• Pseudo-portable – plugs are relatively convenient but still require connection	• Data rates are not high enough for multi-media applications. • Dependent on quality of phone line • As most equipment is AC powered, NIC built already built in.

Table 1: Last 100 Feet Technologies

"LAST 100 FEET" TECHNOLOGIES

There are many technologies and standards available for implementing the "Last 100 Feet", as shown in Table 1. These include wireless LAN (WLAN) technologies, Electrical distribution standards such as HomePlug and twisted pair standards, such as Home PNA (HPNA) and Ethernet.

Although all networking technologies have their advantages and disadvantages, it is believed that wireless, and specifically the 802.11 (a,b,g) wireless standards, will provide the major technology thrust for the last 100 feet. Features such as "no cables", ease of portability, available bandwidth and the historical quick adoption of wireless devices such as pagers, cell phones, and PDAs, show that wireless will be the major technology in this market. With respect to bandwidth alone, few of the technologies can support multimedia applications simultaneously delivering multiple sessions of Internet connections at 3Mbps and video/audio applications at 10Mbps.

Table 2 gives an overview of the wireless networking standards. IEEE 802.11 has become the dominant wireless networking technology. In fact, companies promoting other wireless technologies are including support for 802.11 into their product lines to track this market transition. The shaded areas represent the three relevant 802.11 standards.

The rollout of the 802.11 (a,b,g) standards began with 802.11 (b), providing basic data connectivity within the home and office. The 11Mbits/s data rate, approximately the same as 10Mbps Ethernet, was satisfactory to meet subscribers' early data networking requirements. The access rate was similar to the service they received by being attached to a wired Ethernet network solution.

	Infrared	Bluetooth	DECT	HomeRF	HiperLan2	802.11 (a)	802.11 (b)	802.11 (g)
Speed(Mbits/s)	4	1	0.032	1-10	54	54	11	22/54
Launch	-	1997	1988	1998	1999	1999	1999	July/2002
Range (ft)	15	30	1,000	150	400	400	300	300
Modulation	N/A	FHSS	FHSS	FHSS	OFDM	OFDM	DSSS	DSSS/OFDM
Frequency(GHz)	IR Band	2.4	2.4	2.4	5	5	2.4	2.4

Table 2: Wireless Networking Standards

802.11 (a) was intended to rollout next, providing a much higher data rate for advanced services (video, VOD, telephone) and larger networks. However, this rollout strategy has changed over the last year. 802.11 (g), expected to be ratified in the summer of 2002, will rollout simultaneously, as shown in Figure 1, bridging the 802.11 (a) and (b) standards. According to Cahner's In-Stat, 802.11 (g) (or a combination of 802.11 (a) and 802.11 (b)) will capture 63% of the market by 2005, compared to 802.11 (a) at 33%.

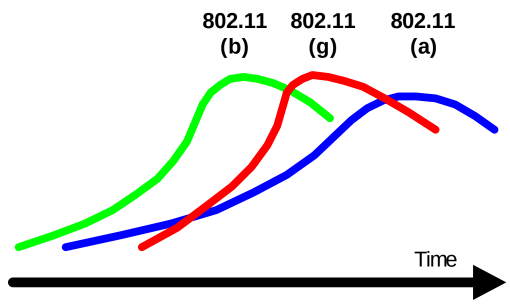

Figure 1: 802.11 Technology Implementation Roadmap

802.11 (g) provides many advantages over 802.11 (a) while transitioning from 802.11 (b). Because the operating frequency is at 2.4GHz, in the Instrument, Scientific and Medical (ISM) Band, 802.11 (g) leverages the technology that has been developed for 802.11 (b), Bluetooth and the cellular market. This includes backward compatibility of the standard 802.11 (g) to 802.11 (b) standards, as well as components on the reference design. This minimizes technical risk and component costs due to large volumes provided by these other markets, as shown in Figure 2.

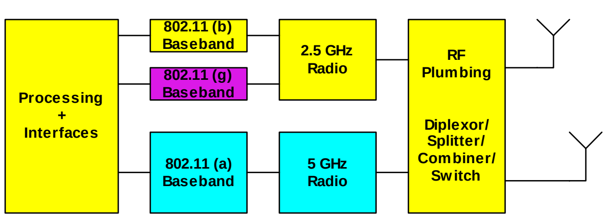

Figure 2: 802.11 (a,b,g) System Diagram

Another advantage of operating at 2.4GHz is to minimize propagation issues that have been a major cause of concern for using the 5GHz 802.11 (a) standard. 5GHz operation has had problems reaching the entire network footprint. Operation at 2.4GHz has had much empirical analysis, trials and customer feedback. If an MSO is going to promote the use of a wireless network technology, its operation will reflect on their total service offering, so issues such as this must be bulletproof before being released. The 2.4GHz ISM band, used by 802.11 (b) and (g) is also recognized around the world, so equipment does not have to be customized according to geography. Portions of the 5GHz spectrum used by 802.11 (a) has been allocated to other services, and although work is in process to make it usable worldwide by a 802.11 (a) variant called 802.11 (h), this will take time. At the access point level, total system costs can be reduced as components can be shared between the 802.11 (b) and (g) systems. Microsoft has previously stated that any new wireless LAN standard including the 5GHz 802.11 (a) and (h) should be backwards compatible with 802.11 (b) in order to have the software drivers incorporated within the Windows XP software package. So, access points and nodes can be sold with 802.11 (g) compatibility at a small price increase. This makes the transition to the higher data rate services much easier as subscribers do not have to replace their equipment.

Concerns with 802.11 (b) and (g) largely center around potential "interference" issues because the 2.4GHz ISM band is used by other wireless network technologies such as Bluetooth, HomeRF and DECT. Microwave operation has also been known to cause interference issues but these issues have been largely resolved.

In the end, the 2.4GHz technologies, 802.11 (b) and (g), will be pushed as far as possible until capacity begins to drop due to over usage. At this point, wireless access devices will have had the opportunity to begin offering 802.11 (a) compliance in their 802.11 (g) product lines, minimizing the switch over costs when the transition begins to occur.

LOCATION OF THE HOME GATEWAY

Figure 3 represents the opportunities for the Home Gateway to provide access to the last 100 feet. Each system has advantages and benefits to the subscriber and MSO, so there will be no one winner in the Home Gateway market. Technology selection will depend on the maturity of the subscriber base, and the goals and core competence of the individual MSOs.

(1) *Pole Side Network Access Point.* Although a novel Home Gateway solution, this solution has the advantage that it allows the MSO to maintain control of configuration, provisioning, operation and upgrades of the network access point. This relates directly to the solution cost with respect to maintenance and support. Other advantages related to revenue and costs include: (i) minimizes the technical competence required by a subscriber, increasing the total overall subscriber base, (ii) requires subscribers to contact the MSO to add features and additional nodes, so the MSO can more easily charge for these additions and (iii) hardware costs can be minimized by sharing access points among multiple subscribers depending on their consolidated bandwidth requirements. Security issues can be solved via encryption.

(2) *Outdoor Wall Mounted Access Point.* This solution is similar to (1) above with the added benefit that it is commonly used for cable telephony solutions today,

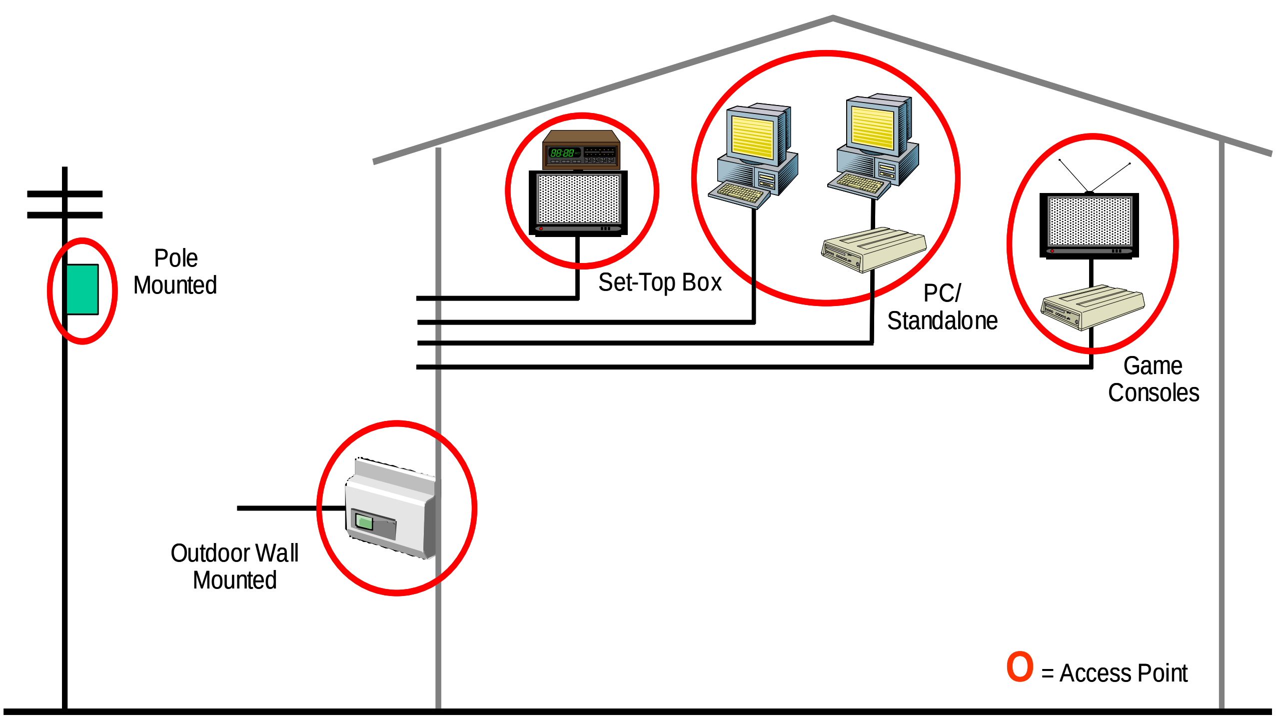

Figure 3: Home Gateway Opportunities

minimizing technical risk in the rollout. The advantages and disadvantages are similar to (1) above with an additional advantage being that the MSO has the ability to select from multiple access solutions such as Wireless, HPNA and HomePlug.

(3) *PC/Standalone Access Points.* These products can be commonly found in the retail market today and require a computer with connected access point. Benefits to the MSO of these access points are that the user must purchase the hardware and is responsible for maintaining their own network. Disadvantages with this model is that (a) it is difficult for the MSO to collect additional revenue for this service and additional nodes and (b) the customer will not have the skill to properly setup their network.

(4) *Set Top Box (STB) Access Points.* These products can already be found on the market, with STBs containing both traditional video and cordless telephone service. The advantages of this access point are that (a) subscribers are already familiar with the STB product in the home, minimizing the "new technology" scare that may limit penetration; and (b) subscribers purchase/rent their individual equipment, minimizing MSO costs. With entertainment typically being the primary driver for new applications within the home, the STB is well positioned to be a strong winner.

(5) *Game Console Access Point.* Although another novel Home Gateway product, who best to drive the next generation broadband technology than the "next generation" of subscribers. New networking technology can be driven into the home via gaming features.

SYSTEM ARCHITECTURE

Figure 4 shows a typical architecture, and major components, of a Home Gateway using broadband cable connection as the front-end and 802.11 for the back-end, in-home distribution. The cable front-end architecture requires multiple tuners to receive all the available applications. Semiconductor manufactures have been under pressure to lower the total solution cost of the system. This translates not only to lower IC prices, but also to the ability to offer application-specific semiconductors that contain higher integration, thereby absorbing more of the discrete solution, and minimizing board/product size. In the end, the solution cost must be minimized. Increasing integration is occurring with both digital and radio frequency (RF) technologies. With digital technology, the functionality of the MAC, PHY, processor and back-end chipsets are constantly being integrated on one IC. With RF technology, IC tuner and amplifiers are increasing integration. This minimizes the RF solution to a two IC solution with minimal discrete component support.

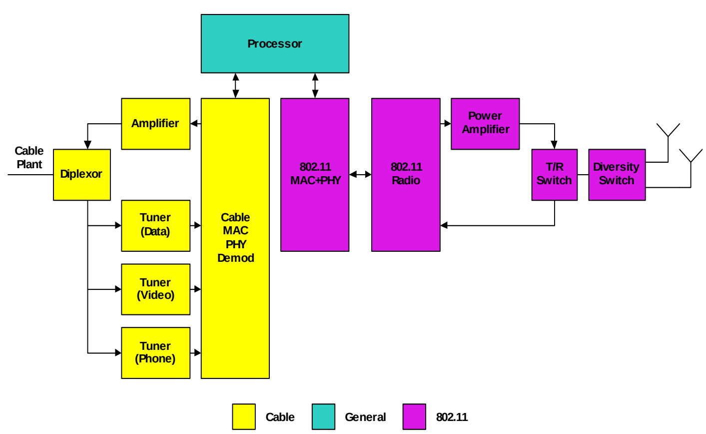

Figure 4: Cable-802.11 Home Gateway Architecture

SYSTEM DESIGN CONSIDERATIONS

Outdoor verse Indoor

Outdoor products have cost and revenue advantages over indoor, subscriber purchased units. However, there are two primary concerns with producing equipment for outdoor operation: (1) operation over a wide temperature range; and (2) powering the equipment. Product offerings marketed to outdoor applications typically have to perform over a temperature range of –40 to +85 Celsius. Developing a product to work at one particular temperature extreme is not difficult. However, designing one product to work at both extremes requires creative and robust designs. Historically, RF designers needed to choose components specifically designed for this wide temperature range or choose components with very low variation. This shortens the list of available components. These components were typically more expensive. In addition, due to the lack of options, they could cause supply problems during times of high demand, requiring excess inventory costs to be incurred. Designers are also required to add increased performance margin for these harsher requirements.

The second major concern, powering equipment, comes from the fact that MSOs must economically power remote equipment. Local AC/main powering raises safety issues that must be addressed, and increases the cost of the equipment as well as liability concerns. If the gateway is supporting primary telephony, the MSO is required to ensure that the gateway remains operational during a local power failure. Battery powering is not a preferred solution due to equipment costs and requirements to eventually replace batteries. Remote powering, via the cable, has been selected as the preferred solution, with battery operation in lower density subscriber situations. However, this makes lowering the power consumption of the equipment critical to minimizing the remote powering infrastructure costs. Lowering the power consumption of a Home Gateway allows the MSO to deploy more gateways for a given infrastructure cost.

For the cable front-end, these two issues have largely been solved due to the aggressive push by some MSOs to deploy cable telephony, where the preferred deployment is outdoor, remote powered customer premise equipment. Gateway manufacturers and component manufacturers have years of experience developing products meeting these requirements. The outdoor component design issues have been minimized by the development of integrated circuit process technologies, such as silicon germanium (SiGe), and increased integration by IC manufacturers. The downstream portion that historically was composed of 300 components has now been integrated onto one IC tuner, with some of these new IC tuners operating over –40 to 85 Celsius. An added benefit of these process technologies is that their power consumption is quite low, facilitating the use of efficient remote powering over the cable. With the tuner now integrated onto one IC, sourcing issues for wide temperature range components is minimized, and design issues relative to matching components is easier. Baseband vendors have also developed products for the cable telephony market, offering lower power consumption.

802.11 (a,b,g) products have been following a similar trend as cable products, with semiconductor manufacturers supporting extreme temperature ranges and low power.

Power Consumption

Both the cable and wireless markets have individually been driving for low-power solutions. Cable applications must have low-power operation for lifeline cable telephony, remote indoor power, USB powered cable modems, smaller form factors and increased applications without the requirement for an internal fan. 802.11 technologies have been driving for lower power because of PC peripheral power supply constraints, and longer battery life for portable applications. Both industries have lowered power consumption by leveraging new silicon processes, largely driven by the cell phone market, increased integration and better design.

Apart from the low power consumption required for outdoor, remote powering applications, as mentioned above, there is also the requirement for low power consumption for indoor applications. In applications where multiple access points may be connected to a central unit, Remote powering, over the indoor data connection, can be used to minimize deployment time and costs for access points in indoor applications. As no AC re-wiring is required, installation can be done by the corporate IT group, technician or subscriber. An electrician is not required saving time and cost. Secondly, portable in-home/business solutions, such as PDAs, laptop and portable tablets, require battery operation and usage time must be maximized to ensure subscriber satisfaction. This puts a constraint on the wireless standard and its available chip-sets to offer extremely low power consumption.

The current generation of cable modem applications requires approximately 4-5 Watts. The 802.11 (b) wireless backend currently requires approximately 2 Watts to operate with the power budget currently dominated by the power amplifier, which consumes about 1 Watt.

Now, the market is beginning to see components that will allow cable modem functionality to approach a power consumption of 2.5-3 Watts. This drop in power consumption is largely based on the drop in power consumption of the major cable components, with some components dropping their power consumption by 50% over the last year. Current power budgets for the major components, in sampling, of the cable front end are: Downstream Tuner = 600 mW, Upstream Amplifier = 500 mW, Processor/Mac/Phy = 500-600 mW.

New 802.11 (b) solutions have been able to achieve operation at under 1 Watt, largely driven by more power efficient designs and new power amplifier technology, which reduces the power amplifier current consumption, the most power intensive portion of the design, to 45% over current generation solutions.

So, combining the 3-Watt cable and 1-Watt Wireless sub-systems a basic access point could draw under 4 Watts. This can be powered, using today's technology, by a remote source over the data cable.

Bills of Materials

Both cable and wireless industries have been moving towards higher integration and thus a reduction in components. IC manufacturers have been racing to increasingly integrate more of the total solution into one IC. This is most evident in the cable modem industry, wherein (1) silicon tuner manufacturers integrate the complete receiver on one IC; and (2) baseband manufacturers integrate support for the complete range of back-end distribution standards including, PCI, Ethernet, 802.11, and HPNA. Some baseband vendors have even attempted to integrate the cable upstream amplifier into their IC. For 802.11 (a,b,g), the radio, which was typically two separate ICs, has been integrated onto one radio IC, making it a three chip set solution. New power amplifiers have also been designed, which eliminate the output filter by integrating it within the matching circuitry.

This can be most dramatically seen in the cost of basic cable modems, which have dropped in price from $179 to $89 dollars within a year. 802.11 (a,b,g) devices are expected to follow similar aggressive pricing as they enter the consumer market.

CONCLUSION

An overview of Home Gateways technologies was given, with the most favorable architecture being a broadband cable front-end, with multiple tuners for multi-media applications, and an 802.11 (a,b,g) back-end, for the in-home distribution. Power consumption, standards, integration and operational environments were all examined with respect to cost and performance.

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