The Connected Home

Release November 2002

4th Infocomm Technology Roadmap Report 2002 - 2007

iDA INFOCOMM DEVELOPMENT AUTHORITY OF SINGAPORE

Dear Reader,

Welcome to the newest revision of our Infocomm Technology Roadmap Reports.

The "Infocomm Technology Roadmap" programme serves to anticipate the macro infocomm technology trends globally and identify potential strategic technologies for adoption in Singapore. Facilitated by IDA, each "Infocomm Technology Roadmap" report is conceived and written via a collaborative effort between many parties, namely from the industry, research & academic community, as well as from government agencies.

It has been slightly over two years since we inaugurated the "Infocomm Technology Roadmap" programme via the first report on "Broadband Access and Mobile Wireless". To date, we have together travelled through four cycles of technology roadmap exercises with the support from our participants on different but strategic technology areas to Singapore.

In embarking on this intimate journey with the local infocomm community, the Technology Group in IDA is guided by the motto 'to bring technologies to better our lives' to build up Singapore's competitiveness via the infocomm cluster.

We hope that you will find our published reports useful and take your time to enjoy reading this latest version. You too can be part of the local infocomm community, if not already, just by being part of the knowledge, even as an informed user with a sophisticated demand.

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The roadmap process entails a continual updating exercise. This ITR4 Release November 2002 has combined, revised, added new emerging interests and will supersede the following:

- ITR1 Release July 2000 *("Broadband Access and Mobile Wireless")*;
- ITR2 Release March 2001 *("Broadband Access and Mobile Wireless Updates", "The Connected Home", "Infocomm Security in e-commerce")*;

  ITR3 Release February 2002 *("Next Generation Optical Networks and Photonics", "Next Generation Internet Applications")* remains valid and current.

Objective of Roadmap Reports

Summary of Worldwide Technologies, Standards and Applications. A key objective of this roadmap report is to provide a good overview of past and future developments worldwide, the efforts of key standardisation bodies and industrial forums for interoperability. The report also aims to promote a good understanding of the market and technology undercurrents which are constantly evolving.

Collective Vision for Alignment of Resources. The fast changing landscapes, the multidisciplinary nature of emerging technologies, competing and converging technology standards, and heightened user expectations call for a more collaborative and managed approach to technology development. For this, the report aims to derive a common vision and directions for future work, reflective of the joint work effort between the industry, government, research community and academia. Where possible and appropriate, we would include strategic gaps and opportunities for collaborative exploitation. The roadmap exercise aims to identify synergies and complementary expertise so that we can pool our resources, leverage on each other's strengths to seize technology opportunities.

Your Feedback

Lastly and very importantly, your feedback will be deeply appreciated on either the report itself, or on collaborative proposals for technology development via the survey form attached at the end of this report. We thank you in advance for your time and effort in doing so and this will help us produce better future roadmap reports.

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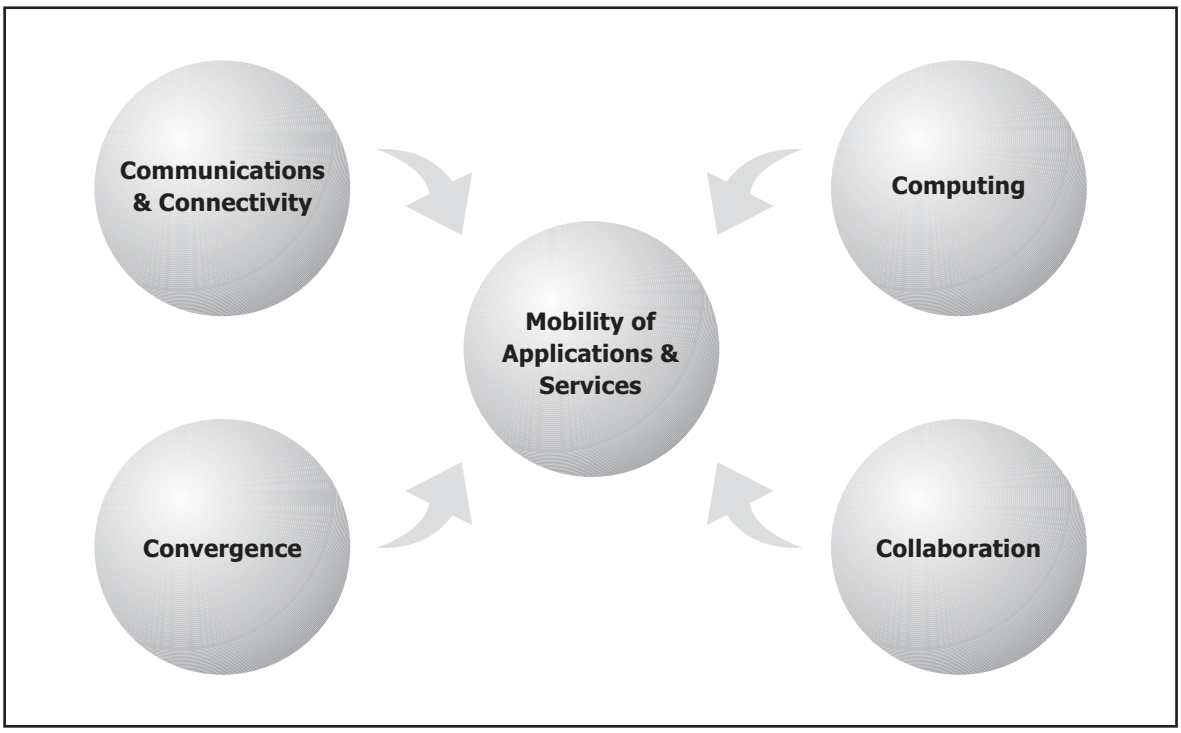
In moving towards 2007 and beyond, this ITR4 report weaves through emerging modern communication technologies for an integrated broadband infrastructure. An integrated broadband infrastructure is a multi-pronged combination of heterogeneous networks (last-mile access, mobile wireless or in-home networks), technologies and end devices closely integrated to allow the key concept of *application mobility and access* anytime, anywhere. Secured payment and authentication mechanisms, non-repudiation of services, communication between trusted parties and access management to information and services will also be an enabler of this integrated infrastructure.



The global trend towards an integrated infrastructure will facilitate three basic human needs for "communication and connectivity", "computing" and "collaboration". The "convergence" of technologies, open standards & platforms, and contents will lend to the ease of mobility of applications and services encapsulated in this infrastructure. Ultimately, working towards the mobility of applications and services regardless of the technology, network and platform used is to enable a convenient and consistent user experience. It is all about users, both consumer and corporate.

We shall now elaborate more on what we see today and the milestones ahead. Some of the technologies or applications to be described below can satisfy more than one of the three basic human needs mentioned above, hence some overlapping is to be understood.

Communication and Connectivity. Communication is a human basic need to contact each other anywhere, anytime and via various platforms and devices, and a means to stay connected. In the area of mobile wireless, we will see new varieties of services apart from simple voice calls such as rich multi-party multimedia communications, instant messaging and presence services, location based services, as well as one-to-many multimedia broadcast and mobile webcasting. This will enhance individual communication features but also open up enterprise opportunities such as in the areas of mobile e-learning, mobile seminars, corporate teleworking and marketing. Emerging 3G mobile networks could offer in Singapore average data rates of around 100 to 200Kbps while in the longer term, 4G networks could reach peak rates of 100Mbps targeting average data rates of 20Mbps at least. In fact, certain 3G standards such as HSDPA (high speed downlink packet access) for WCDMA in 3GPP Release 5 today is exploring downlink rates of up to 10Mbps, with up to 20Mbps downlink for Release 6 (but deployments are expected around 2005). This development coupled with the decreasing computational power differences between hand-held devices and desktops would facilitate the mobility of applications from wireline to wireless domain.

In the area of Broadband Access, it is about creating the necessary connectivity for communication, computing and collaboration. In our vision of 2007, we expect ADSL and cable to replace dial-up as the dominant means for accessing Internet. However, these two access technologies may no longer be considered "broadband". We believe that the access speeds offered by VDSL and fibre will set the stage for the new definition of "broadband". Lifestyle changes like teleworking will become common, resulting in increase use of applications like video-conferencing, workgroup collaboration, and productivity tools. "Always-on" broadband access characteristic is not sufficient and needs to be enhanced by QoS and symmetric downstream/upstream access speed.

Bandwidth for home area networks will even be less of an issue compared to access networks. By 2007, we could expect a home network to support applications with data rate in excess of 100Mbps, made possible by a wide choice of networking technologies, such as Ethernet, Phoneline networking and Ultra-Wideband. The preference for mobility and "no new wire" advantage will make WLAN (802.11a and beyond) and UWB the dominant choices in most homes, enabling applications with speed of 54Mbps or more. Wireline technologies such as structured wiring will be increasingly used as the high-speed backbone for in-home wireless networks. Powerline communication technology may find its niche in smart home kitchen appliances. However, for home technologies to take off, these technologies must become embedded into devices to the point that they become transparent to the users, and that the deployment of IPv6 is critical to meet the demand for addresses, QoS and security. At the same time, the plug and play ease of use is to be enabled by efforts in automatic service deployment and discovery of enabled appliances.

Security will take precedent to address a myriad of issues in diverse communication paths occurring between one-to-one, one-to-many and many-to-many in an open dynamic network. Adding to the complexity is the variety of participants in this network, from humans to machines and software agents. At the base of secured communication channels is encryption. By 2007, DES will be completely phased out and AES will be dominant over Triple-DES.

Computing. Pervasive or anywhere computing advances communications and its success pivots on the creation of more sophisticated user demand. In mobile wireless, computing applications will migrate from simplistic mobile games, rudimentary calculator functions to mobile web services, multi-party role play coloured gaming, Java enabled applications, packet based multimedia applications and mobile VPN solutions. The introduction and more widespread use of feature-rich handsets and smartphones will facilitate this migration. In addition, the development of open specifications (e.g. OSA/Parlay APIs) and IP Multimedia Subsystem specifications will work towards the vision of interoperable roaming of these services across both CDMA and GSM networks across the world.

Computing applications like web services are predicted to change the nature of computing to service based models. But regardless of the setting, in working towards end-to-end security for open and heterogeneous web services, the industry targets by 2007 to have a rather complete stack of security standards to support for dynamic and federated networks of web services. This will be the layer of security infrastructure bridging silo-computing systems.

For computing inside the Connected Home, we see today the first wave of development under the guise of data networking for sharing of resources. A second wave of development will revolve around home information and entertainment space. Towards 2007, many entertainment equipment will transit from analogue to smart digital network-ready appliances, examples are multi-services residential gateway, advanced set-top box, digital/interactive television, home media servers, and to a lesser extent, smart kitchen appliances. Most of these appliances will be integrated with one or more in-home networking technologies and adopting open standard device connectivity, with features such as easy plug and play, zero administration, automatic service delivery and discovery, quality of service and device discovery. Security and a flexible billing mechanism will be built-in to support a variety of home applications.

Collaboration. Collaboration extends communication, connectivity and computing to group interaction and team sharing. It widens the interaction scope to groups of individuals in proximity or geographically disparate around the globe. Ad-hoc networking is an important feature to allow the impromptu set up of local networking for collaborative work or resource sharing in meetings or even for multi-party entertainment and gaming.

Collaboration can also be between trusted or non-trusted parties. To enable more sophisticated user demand by 2007, we need to move towards using appropriate security mechanisms to allow communication and collaboration between trusted parties. As such, in addition to PIN and passwords, we will see the emergence of related security authentication and non repudiation technologies and services such as trust service providers, 3D Secure, PKI, biometrics and smart random tokens and chip cards.

Convergence. Convergence can occur at several levels. At the industry cluster level, it can mean working towards integrating contents across different clusters such as the media, arts and entertainment, home automation, finance, IT & communication, broadcasting, telematics, telemedicine, education or e-learning, and e-government.

At the network level, we already see the convergence of voice, text, data, multimedia video that can be delivered with a single IP based network. At the technology and standards level, convergence can mean the confluence of hardware packaging techniques (e.g. BGA, CSP, stacked packaging), movement towards globally standardised architecture, platforms, open APIs (e.g. OMA, OSA). In services, convergence can happen with aggregated contents with 3G portals, or with IP based bundled multimedia services. At home, the OSGI residential gateway represents a tool for convergence towards a multi-service model and whereby service providers can enter to make headway into the smart home via remote provisioning of new services.

Similarly, at the security level, we see efforts towards identity management, federations and single sign on. If we converge under a federated umbrella model, each partner then agrees to trust user identities issued or authenticated by other organisations, while maintaining control of the identity and preference information of its own users. This will not be easily achieved. Sharing session and authentication information across networks and across disparate application is not only difficult, but resource-intensive as well. The level of trust placed over a given client request might vary across different services. By 2007, management console to talk to any security server or client regardless of device type, brand, OS, application or location will however lend itself to support this convergence.

Mobility of Applications and Services. There can be many different networks, access devices, technology platforms but we should have only one convenient, consistent and connected lifestyle. By this, we mean that we should not need to worry about which network we are connected to, how to access different networks or be preoccupied with end to end security of applications. Increasing online applications from fixed sites mainly confined to environments such as corporate LANs or PC internet access networks (in-home or at public internet access sites) are now ported to mobile devices, leading to ubiquitous connectivity.

Security will also need to interoperate over heterogeneous environments from LAN to public, from wireline to wireless to provide the user with uninterrupted connection to the various forms of services. By 2007, single sign on solutions and portable security such as biometrics (key ones being fingerprint, iris and facial) and smart cards will gain momentum.

The above spells our vision for this report. In gearing up to this vision, the many network and enabling technologies covered in this timeframe of 2002-2007 should take a backseat when compared to the more critical issue of understanding and creating sophisticated user demand, as well as to factor in business perspectives and operational challenges. However, it is a highly volatile task for anyone to anticipate accurately trends in market factors like future user demand and business sentiments. Hence, we can at best provide a technical roadmap of technology vision and trends, and a best-effort attempt to position technology milestones in this timeframe as we collectively judged with the help of industry participants, which the reader should moderate according to prevailing market sentiments.

List of Figures and Tables

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The Connected Home

This roadmap report examines the trends and development in home networking as the global broadband wave takes off. We envision homes in Singapore to experience a "digital elevation" through the connectivity of broadband services and emergence of home networks and smart consumer electronics products. Hence, the concept of the "Connected Home."

We explore in this report the different home networking technologies, applications, their growth paths, challenges and the plausible convergence and integration of various digital home platforms for the next five years over the period 2002-2007. We also provide a current status report on the Singapore landscape and revisit our directions for this timeline. This release reviews, updates and supersedes the previous version of the Infocomm Technology Roadmap (ITR) on The Connected Home, Release March 2001.

Drivers for Connected Homes

Increasing Broadband Subscribers and the Desire to Share Broadband Connection. As more households get accustomed to the benefits of high-speed Internet access, there is also greater need for multiple users to share the broadband connection simultaneously from different PCs. Everyone on the home network can be online, sharing a single xDSL or cable modem via a phone line or cable connection respectively, and an ISP connection.

Rise of Household PCs, the Trend Towards Multiple PC Ownership and the Desire to Share Resources. With the rising popularity of desktop PCs, notebooks PCs, PDAs, mobile phones, printers, scanners, external storage devices and other LAN peripherals in the home, homeowners will want to be able to connect these equipment together to share data and resources, saving cost and maximise resources.

Emergence of Smart Home Platforms with Built-in Standard Connectivity for Ease of Sharing Digitised Information Within the Home. The recent years saw an increase of smart digital platforms in conception. They range from entertainment equipment to information devices to kitchen appliances with added intelligence and network connectivity to enable them to function in a smart manner.

Trends In Connected Homes

The pervasive adoption of the Connected Home in 2002 to 2007 will rest on the socio-technical development in two areas, namely data networking and entertainment networking. The rapid emergence of the *IP-based networks* within the home will eventually allow these networks to

co-exist seamlessly with each other and enjoy greater collaboration between them. In the longer term, we will see the development of an integrated smart home management system, with more control-oriented applications extending to these networks.

Declining prices and availability of more home network products such wireless LAN, coupled with the rising ownership of multiple PCs per household are compelling reasons for installing home networks for these applications. Future direction of these data networking technologies is aimed to deliver greater speed, higher security and better interoperability among them.

The emergence of smart digital platforms would further raise consumer interest in home networking as these devices bring better infotainment experience and e-lifestyle through greater connectivity between them and the home network. These platforms include digital televisions, advanced set-top boxes, home media servers, digital video recorders, wireless tablets, mobile phones and PDAs. We foresee continual research and development towards "network-readiness" in smart home platforms in the next five years propelled by the commensurable growth of Internet and improved bandwidth availability to the home. Further collaboration between consumer electronics and data networking companies are expected. Vendors would need to focus on delivering services that the consumers deem useful. In the long run, home users' e-lifestyles will be enriched as zero-administration and easy plug and play will be the key requirement for these products.

Ultimately, applications and services delivered through the home area networks that would enhance homeowners' lifestyle and bring about greater convenience and time saving will spell opportunities for service providers. The intelligent home would also encompass home automation technologies. While the intelligent home would take a much longer time to see mass adoption, it will eventually become an important element for a connected home.

Home automation systems started many years ago as individual vendor efforts to add intelligent interfaces to their mechanical and electrical (M&E) solutions. These systems were designed to enable building/home users to easily control devices like the heating/ventilation/ air-conditioning (HVAC), lighting and security etc. There are currently no common standards and interoperability among the competing vendors. Control of these M&E solutions over the Internet still needs further customisation from third party integrators. However this fragmented situation is starting to change in Europe and Japan. Konnex is leading a project (called Convergence) with the aim to standardise the home and building electronics system in Europe while the EchoNet consortium in Japan is developing a cost-effective in-home communications infrastructure specification for applications such as energy conservation, security and home healthcare.

Home Networking Technologies. There are many choices of home networking technologies available for consumers today. Each has its strengths and weaknesses. A common trait in each of these technologies is that they are moving towards higher data rates and with better features such as security, support for voice and power management. HomePNA (using phone line for communication) and powerline communication such as HomePlug & CEA are wired line technologies that use the existing wiring in the home. These technologies are able to support data rate of about 10Mbps. HomePNA is planning its next specification for 100Mbps. For powerline, there are still many standards with no clear winner. For structured wiring, it is more popular for newly built homes.

In the wireless LAN space, IEEE 802.11b is clearly dominant at this time for data networking. This technology is gaining popularity in the home due to its benefit of office/home mobility, eroding price point and ability to support data rate of up to 11Mbps in the 2.4GHz ISM band. In the 5GHz band, the IEEE 802.11a technology can provide data rate of 54Mbps. Products based on 802.11a have just started to be available in 2002. Dual-mode chipset based on a & b will be critical to facilitate the transition from existing 2.4GHz, 802.11b networks to future deployments of the 802.11a 5GHz system. By 2003, IEEE 802.11g standard will be ready, offering a data rate of up to 54Mbps in the crowded 2.4GHz ISM band.

In the wireless personal area network technology, Bluetooth is moving from its 1Mbps toward a high data rate version of 12Mbps by end 2003. Compliant products based on Ultra-Wideband (UWB) technology will emerge to deliver data rate in excess of 100Mbps when the standard completes in 2004. Currently, there is a lot of interest in UWB from the consumer electronics industry as it is envisaged that UWB will be implemented for high-speed wireless communication for future multimedia platforms.

Residential Gateway. Defined as a device that connects an in-home network to an external broadband network, the residential gateway (RG) has been evolving in functionality. With the trend of bundled service plans offered by broadband service providers, some degree of functionality convergence such as voice and data is expected at the RG. The RG will play an important role in our future home. The completion of the Open Gateway Service Initiative (OSGI) specification can also enhance platforms like the RG to be a service gateway that enables delivery of end-to-end and multiple services over wide area networks to the home area network. Many platforms such as RG, game console, PC, media server, devices with intelligent processing capability can be incorporated with OSGI to deliver bundled services.

Market Outlook. The worldwide connected home market, consisting of home networking equipment and software, residential gateways and home control and automation products is projected to grow from US$1.4 billion in 2001 to US$9.2 billion by 2006 according to In-Stat/

MDR. This market has been spurred by the popularity of wireless networking technology and basic routers to enable broadband sharing at home.

The information appliances market is projected to impact many sectors of the consumer electronics industry. These sectors include TV makers, set-top makers, PC makers, game console makers, traditional home appliance makers and mobile device makers in hardware and software markets. Market research firm eTForecasts predicts that worldwide information appliance shipments which includes web-enabled cell phones, PDAs, handheld computers, entertainment appliances and personal access devices, will reach 830 million units in 2007, with a market value of more than US$167 billion.

Singapore Landscape

The home networking market in Singapore is in the stage of early-adopters with increasing tech-savvy household owners investing in it. One local service provider, StarHub has begun to offer wireless Internet access for consumers by bundling home networking hardware with the subscription plans. The initial marketing hype reflective of a revolutionary change in lifestyle is beginning to give way to one that is more evolutionary in the implementation of connected homes. The future growth of home networks in Singapore is expected to be fuelled by the need for broadband sharing, increasing number of household having multiple PCs, and teleworkers working from home. According to the 6th Infocomm usage household survey carried out by IDA for 2001, there was a trend that more homes were now having more than one computer. The proportion of homes with more than one computer rose by 3.3% to reach 26.7% in 2001. In total, there were about 900,000 computers in the homes, an increase from the estimated 808,000 in 2000.

A trigger point for the mass market penetration of home networks in Singapore will be a complete and affordable bundled service offer by service providers, providing practical solutions and applications that are useful for consumers. Ultimately, the arrival of multi-service RG products that interconnect across the different home-networking platforms and service provider networks will pave the way for more diverse and attractive applications for Singaporeans.

In line with this roadmap direction, IDA has begun to promote the development of Connected Homes early this year. For example, the Connected Homes Programme for connecting the homes and communities and the RG reference design and OSGI initiatives are aimed to spur industries in Singapore to identify and develop integrated end-to-end solutions so as to deliver user-friendly and hassle-free services for home users. By leveraging on these initiatives, the industries could gain critical understanding of consumer behaviour, develop capabilities and establish viable business models through trials, test-bedding and in collaboration with strategic partners.

Structure of the Report

The report begins with an overview of the connected home roadmap. This chapter provides an overview of the trends and drivers shaping the development of our future home.

Chapter 2 delineates the development of home networking technologies and related standards, challenges and future evolutions for the connected home.

In Chapter 3, we describe the residential gateway which will play a pivotal role in connecting devices between in-house and outside the home.

Chapter 4 provides some important device connectivity technologies within the home. The middleware and the physical layer of each technology and their challenges are discussed.

Chapter 5 proceeds to highlight a few compelling home applications such as digital home platforms and smart home management. This chapter also talks on Convergence.

The Singapore landscape is covered in Chapter 6.

The final chapter summarises the report and concludes with some observations on possible ways ahead for the local community and areas of strategic developments.

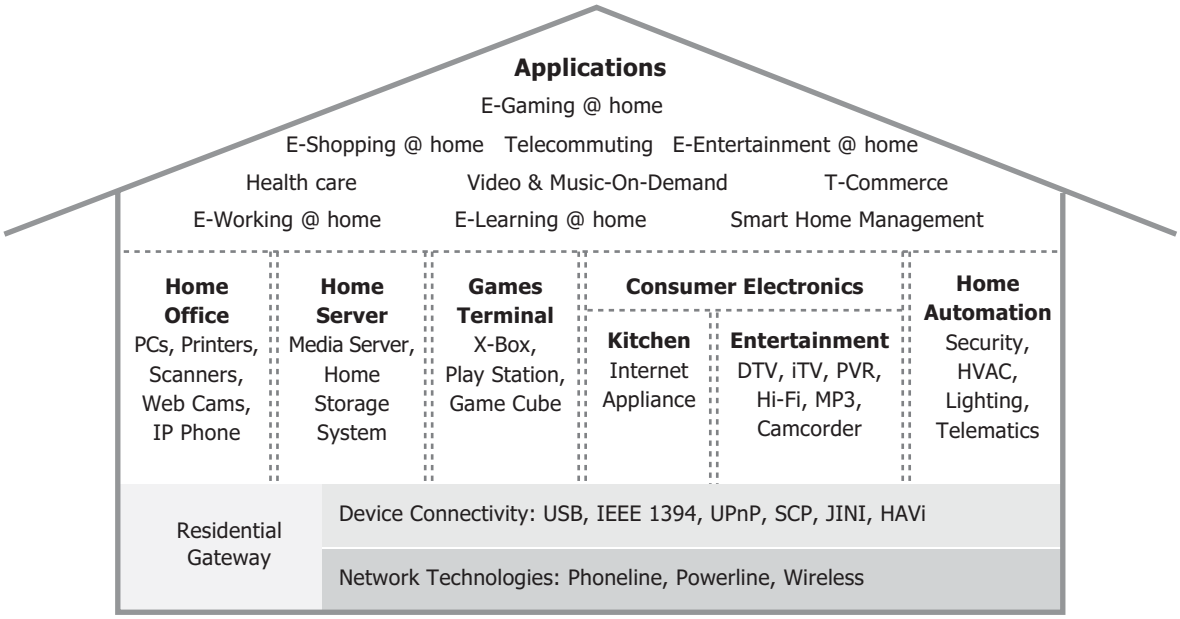


Figure 1. Overview of "The Connected Home"

1 Introduction

1.1 Overview

A "Connected Home" is a living environment that empowers the consumer to tap the potential of technology to satisfy personal lifestyle needs. It gives the homeowner control to integrate two or more home systems to realise the benefits most desirable for their lifestyles. Those systems could include home data networking, home entertainment, home automation, home security, healthcare and energy management services.

There are two key trends currently shaping the development of the connected home. They are data networking and entertainment networking, enabled by smart digital home platforms. We defined them as follows:

Data Networking refers to the networking of PCs, notebook computers, mobile communication devices, web cams, scanners, printers and other data processing devices that commonly figure in the office LAN. File transfers, network resource sharing and Internet/ intranet access are some of the most common motivations. Declining price points, proliferation of LAN technologies and ownership of multiple PCs and peripherals have prompted demand for home data networks that are able to offer similar speeds to the office LAN. Data networking in the home/SOHO environment requires the use of physical networking technologies such as HomePNA (via phoneline), HomeRF (wireless), Cat-5 unshielded twisted pair, 802.11 WLAN (wireless LAN) and HomePlug (via power line) to realise the above-mentioned data-centric applications. Emerging short-range wireless technologies such as Bluetooth and Ultra-Wideband (UWB) technologies will eventually bring greater connectivity and more bandwidth in personal area networks.

Home Entertainment. Another observable trend in the home environment is the emergence of smart networked devices and home platforms for audio-visual entertainment and information services. These include digital televisions, set-top boxes, home media servers, digital radio, and other home audio/video equipments, web-enabled cellular phones, PDAs, handheld computers and web tablets. Simplicity, auto or zero configuration and maintenance are keys to the deployment success of these platforms and consumer acceptance. Key to these platforms are some prominent network connectivity technologies that enable automatic network insertion, service lookup and discovery. This includes Universal Plug-and-Play (UPnP) and Jini. Central to the connectivity of consumer audio and video equipment is the Home Audio Video Interoperability (HAVI) technology, and the related IEEE 1394 recommendation, commonly called i.LINK or Firewire. These are, in our opinion, the more significant players in the home platform domain.

Eventually, homeowners would want an integrated home management system that could automate most of the daily activities in the home. Home automation aims to provide the intelligence to support most of these applications. Home automation started many years ago as individual vendor efforts to add intelligent interfaces to their mechanical and electrical (M&E) solutions. However, it has not achieved meaningful penetration into mainstream households. These systems were designed to enable home users to easily control the air conditioning/heating, lighting, security and other basic building M&E solutions. M&E control systems designed for simple office environments like conference rooms and auditoriums enjoy popularity among the bigger corporations. These solutions integrate the control onto a common touch pad for users to conveniently "set the mood" for the occasion. As vendors compete, standards were given little attention. This has resulted in many proprietary technologies, namely X-10, LonTalk, BatiBus, EIB, etc. Therefore interoperability between products remains a major issue, which is viewed as a barrier to bring home systems into critical mass deployment.

In recent years, home automation is gathering more attention from residential property developers. More new condominium projects are offering some forms of home automation as part of their efforts to differentiate their projects as high-tech home. The convenience of automation, simplicity coupled with the lower price point has resulted in greater acceptance among homeowners. In line with this trend, we are beginning to see more impetus from the industry and standards bodies joining effort to develop a common home systems platform. The Konnex Association in Europe is an example. However, home automation systems as a mature industry will not be further discussed in this track.

1.2 Drivers

We see three main drivers for networking the home:

Driver 1: Increasing Broadband Subscribers and the Desire to Share Broadband Connection. The number of world broadband subscribers is expected to rise steadily over the next five years as more applications and services will be developed with multimedia-rich contents which narrowband access would not be able to support. Based on a recent report[1] from In-Stat/MDR, the number of broadband subscribers will rise 53% worldwide this year to 46 million from the 30 million at the beginning of 2002. People who have migrated over to broadband access will find it unacceptable to revert back to narrowband access. Instead, they would demand for even higher speed for Internet activities. As more users migrate from their dial-up 56kbps-modem service to cable modem and ADSL technologies, chances are that these users would want to have all the desktops and laptop PCs sharing the same connection. We believe that there is

1 In-Stat/MDR report: Broadband 2002: DSL & Cable Modem Services Fuel Worldwide Subscriber Growth, June 2002

greater need to share the broadband access as duplicating connections through separate modems to the Internet makes no economic sense for consumers.

Driver 2: Rise of Household PCs, the Trend Towards Multiple PC Ownership and the Desire to Share Resources. With the rising popularity of desktop PCs, notebook PCs, PDAs, mobile phones, printers, scanners, external storage devices and other LAN peripherals in the home, homeowners will want to be able to interconnect these equipment to share data and resources, saving them on cost and improving convenience. This will inevitably drive the need for greater connectivity between these devices and the home network. A market research report from eTForecasts indicated that the PC industry will continue to see long term growth potential, despite the short-term uncertainty. In 2001, the worldwide number of PCs-in-use has surpassed 535 million units, and will reach 1.1 billion units in 2007 with home PCs accounts more than half of them. Teleworking has also contributed to the rise in the number of PCs at home, as an increasing population of infocomm workforce using office notebook PCs at home continue to rise. A recent survey by AC Nielsen showed that almost 25% of the Singaporean households have two or more PCs and 20% of the households have two to three PDAs or handheld PCs.

Driver 3: Emergence of Smart Home Platforms with Built-in Standard Connectivity for Ease of Sharing Digitised Information Within the Home. The recent years saw an increase of smart digital platforms in conception. They range from entertainment equipment to mobile handheld information devices with added intelligence and network connectivity to enable them to function in a smart manner. The ubiquity of Internet has provided home users with greater accessibility to digitised media through the use of these platforms such as PCs, digital TV, set-top boxes, digital video recorders, home servers, game consoles, PDAs, MP3 players and wireless tablets. Analysts projected the arrival en masse of these networked devices in homes in the coming years.

We envisage the emergence of smart digital platforms/devices will further generate consumers' interest in home networking. Through home networking, users could enjoy better management and control of personal activities through greater collaboration of these equipment. For instance, a user can simply download digitised photos or video clips from a digital camera or camcorder directly into a home central server via the wired or wireless technologies. The user could later retrieve the stored information from any networked PCs/TVs within the home for editing/captioning and sharing the "home production" with other members of the home. Nonetheless, digital rights management, personal and/or third party intellectual property protection remain key challenges.

2 Home Networking Technologies

In this chapter, we will present the technology and standard development trends, highlight the challenges and issues, the market outlook and opportunities of some of the more prominent home network technologies. There are several approaches to home networking, which can be grouped into three distinct classifications, namely:

- Wireline home networking with no new wiring needed (i.e. those that use existing wires)
- Wireless home networking
- Wireline home networking using new wiring (i.e. structured cabling)

2.1 "No-New-Wiring" Wireline Technologies

2.1.1 HomePNA

Phoneline networking uses the existing telephone wiring in the home as physical medium for data communication, without disrupting the operation of the telephone, fax and ADSL services. The Home Phoneline Networking Alliance[2] (HomePNA) is an organisation driving the development and adoption of this technology. It was formed in 1999 to develop a specification based on this technology. To-date, HomePNA has defined a 1.0 specification for data rate of up to 1Mbps and a 2.0 specification with data rate up to 10Mbps. Products are readily available in the market.

Technology & Standard Development. Release 1.0 of the HomePNA standard, published in 1998, was based on Tut Systems' 1Mbps technology. Tut's solution makes use of the passband frequency range between 5.5MHz and 9.5MHz to transmit and receive data over normal phonelines. The choice of frequency was such as to ensure non-interference with existing systems (e.g., POTS, ISDN and ADSL) common in the home/SOHO environment.

Like traditional Ethernet, the IEEE 802.3 access method based on carrier sense multiple access with collision detection (CSMA/CD) was chosen to mediate between contending access from multiple stations on the same LAN. HomePNA thinks that the "Ethernet pedigree" allows it to leverage on the tremendous amount of Ethernet compatible software, applications and hardware in the market. Another feature of Tut's technology is its ability to adapt to the topology of home phonelines, some of which are unterminated bridge taps. To achieve the

2 Home Phoneline Network Alliance is a home networking standardisation organisation that was established in June 1998, by 11 companies such as 3Com, AMD, Lucent Technologies, IBM, Compaq, AT&T, Hewlett Packard, Intel, Conexant, Epigram, and Tut Systems.

1Mbps rate on normal phonelines, the Time Modulation Line Coding Method developed by Tut, was adopted as well.

Following the completion of 1.0 specification, Release 2.0 (10Mbps version) of the HomePNA specification was issued in December 1999. This release, based on Epigram's proprietary technology, offers backward compatibility, QoS support to better enable streaming applications. In line with the specification, ITU has approved a first set of Recommendation G.989.1 (Phoneline Networking Transceivers - Foundation) on home phoneline networking in February 2001. This recommendation specifies characteristics for home-networking devices to operate over existing telephone wiring. G.989.2, (Phoneline Networking Transceivers - Payload Format and Link Layer Requirements) was later approved in November 2001. G.989.2 assumes the use of Medium Access Control (MAC) and encapsulation procedures defined in G.989.1. The requirements in G.989.2 are intended to ensure compatibility between devices.

In September 2002, the alliance approved a joint technology proposal for the next specification, HomePNA 3.0 by Broadcom and CopperGate Communication, capable of achieving a data throughput of 128Mbps. The specification is in finalisation and is scheduled for completion in November 2002. Silicon chipsets supporting adapters and bridges can be expected from multiple vendors in 2003. Products based on this specification will be able to support a variety of high-speed devices for advanced digital multimedia applications, such as multiple HDTV streaming within the home, etc.

Challenges. *Coexistence with Very high bit-rate Digital Subscriber Line (VDSL).* It is understood that HomePNA and VDSL are spectrally incompatible. There is, to date, little sign of co-ordination between both technologies. The interference issue will come into play once VDSL standards are completed and operators start to roll out services. This will become an issue that requires attention from regulators although some prefer to claim that VDSL services target corporate customers who will not implement HomePNA. This argument is unlikely to hold water given that SMEs with installed HomePNA solutions may still want to upgrade their ADSL connection to VDSL in future.

Unspecified wiring topology, attenuation, cross-talk & other interference issues. As with all technologies that run over twisted pairs copper wires, the issue with randomly varying line conditions is a major technical challenge to overcome for phoneline networking. The technology must be able to work on random, unspecified wiring topology, including unterminated phonelines. As telephone wires are not shielded, ingress noise and egress interferences to neighbouring systems must be taken into consideration during implementation.

Different home profile. Technical issues aside, market profile also determines the success of HomePNA. Naturally, phoneline networking appeals more to users with multiple well-located

telephone outlets at home. This is the case of the larger-sized US households with telephone outlets already installed in every room, and even the kitchen. However in Europe, many homes could still have only one telephone outlet located near the door entrance, not an ideal location to connect a PC. In such a market, the "no-additional wires" benefit of HomePNA will not be a selling point.

Market Trends. The market dynamics have changed dramatically since 2001, when phoneline technology was then perceived as front-runner. With decreasing prices, wireless solutions are now positioned as the leading transmission medium in home networking, and will remain so for the foreseeable future. HomePNA is also rivalling another strong contender, HomePlug, which is making inroad into the home networking space. According to Allied Business Intelligence (ABI), though HomePNA 2.0 specification has met and exceeded most cost and performance goals, it has not achieved the strong market penetration once predicted, primarily resulting from a lack of consumer awareness. However, ABI does believe that phoneline remains well positioned in the North American market, especially as a home networking backbone technology that may complement wireless networks. The emerging HomePNA 3.0 specification is envisaged to position phoneline communication as an important home networking technology in the future.

2.1.2 Powerline Communication

Powerline Communication (PLC) is a technology that sends data through existing electric cables alongside the electric current. PLC technology has been around for a long time, with very limited success. The major applications of PLC technology have remained within the boundaries of low-speed data communication[3] for simple home automation control, monitoring & load control and remote metering system. However, little information on the specification is made available by the vendors. In general, most are proposing spread spectrum techniques to modulate the data onto a harsh environment, believing that this approach promises higher resilience against ingress interference and other noises.

In-home PLC technology has inherent appeal in its simplicity and the low investment infrastructure cost as it uses existing electrical wiring within homes/offices as the physical transmission medium. Data connectivity with other devices is achieved by just connecting the data equipment to a powerline adapter. Ease of use will be a major strength of powerline networking solutions, especially for people demanding simple requirements from networked devices. The benefit of "no-new-wiring", coupled with the ubiquity of power sockets in every

3 Popular low speed PLC technologies include X-10 (max. 60bps), Intellon's CEBus (10kbps), Smart House (50kbps), and Echelon's LonWorks (610bps to 1.25Mbps).

room, denser than the existing telephony infrastructure constitute strong selling points for vendors and consumers.

In the following section, we will look at the development on some of the more promising PLC initiatives for the homes.

Technology & Standard Development. Energy Conservation and Homecare Network (ECHONET). This consortium[4] was formed to provide a cost-effective in-home communications infrastructure utilising power lines, radio frequency and infrared to provide a low-cost implementation of data transmission without requiring additional wiring. The ECHONET Consortium has developed key software, middleware and hardware to support applications such as energy conservation, security, home healthcare, etc.

The ECHONET specifications Version 1.0 were available to the public on 26 July 2000. Version 2.1 specifications are currently available to the members, paving the way for ECHONET products to be available in 2003. Currently, work is in progress to develop Version 3.0 and to further expand the specifications to incorporate IP capability and Bluetooth as a new transmission media.

HomePlug Powerline Alliance (www.homeplug.org). This is an independent alliance formed to promote powerline home connectivity and drive the creation of industry standard based on powerline technology. The alliance members include Intellon, Enikia, Adaptive Networks and Itran, among others. The focus of HomePlug is to provide an "Ethernet-class" solution, with an emphasis on speed and PC connectivity.

HomePlug technology is based on Intellon's high-speed powerline networking technology as the baseline to build its specification. HomePlug uses orthogonal frequency division multiplexing (OFDM) implementation capable of delivering 14Mbps at the PHY layer. The effective data rate is about 10Mbps.

HomePlug 1.0 specification was completed in June 2001. Since then, about a dozen products have been certified. To date, there is no information available in the future development of this specification. The HomePlug Alliance has concurrently established formal liaisons with two Europeans groups working on powerline home networking. They are European Telecommunication Standards Institute (ETSI) and the International Powerline Communications Forum (IPCF).

According to the Alliance, it would be possible for the European to adopt the same technology as the HomePlug Alliance, even though the European powerline access technology is different

4 ECHONET (www.echonet.gr.jp/english/index.htm) was founded by leading Japanese home appliance manufacturers to standardise PLC control for home appliances.

than in the US. The European power line delivers 220 volts at 50Hz whereas in the US, the voltage is 110 volts at 60Hz. Therefore, if the Europeans choose to follow the HomePlug Alliance specification, it would have to be a variant of the US.

Power Line Communications Forum (PLCforum) (www.plcforum.com). Moving on to power line scene in Europe, we are seeing a more concerted effort of standardisation by the powerline industries. The PLCforum is a merger between IPCF (International Powerline Communications Forum) and IPF (International Powerline Forum) and was established with the aim of uniting and representing the interests of players engaged in powerline communication. It was set up in Switzerland by 51 founding members from 17 countries, mainly from Europe. PLCforum is responsible for making recommendations on PLC technology to the two European standards organisations, ETSI and Cenelec.

Consumer Electronics Association (CEA) R7.3 Data Networks Subcommittee. (www.ce.org). This group is made up primarily of consumer electronic companies as well as various powerline proponents. The goal of the group is to develop and maintain the standardisation necessary to facilitate communication and interoperability among consumer products on the data network using powerline carrier for home networking. Standards developed will also address communication, interoperability, and coexistence between other residential networks within the home and communication and interoperability with other networks entering the home. The group has approved a PLC test plan on 11 October 2001 with the objective to establish a set of test & measurement parameters as a requirement for actual home deployment. The group is also considering for the standard to support up to 20Mbps.

PLC-related Companies. In addition to the various powerline organisations, a growing number of silicon developers continue to promote proprietary alternatives PLC technologies, including Adaptive Networks, Enikia, Inari, Itran, nSine and PolyTrax among others.

Future Development. *Many technologies, many standards.* There are many PLC solutions with different and conflicting technologies and standards in the market today. Given the huge market potential of consumer electronics and home networking technologies, it is not surprising that PLC companies, standards bodies and special interest groups are taking different technical approaches to develop products for their own target market and address localised standards. For this technology to enter mass-market deployment, we see that interoperability between various home appliances using different PLC technologies will be one of the biggest challenges to overcome as multi-vendors products which is typical in a home, need to coexist. We believe that to realise economies of scale, future PLC development will be toward a more interoperable protocol.

Interference on power line communication will be a challenge for future development of this technology. We can broadly classify interference into the following:

- Susceptibility – how signals from other equipment/appliances interfere with the PLC system. Interference from these devices (both conducted through power cables and radiation through unintentional antennas) are governed by existing EMC regulation. Hence emission would pose less of a problem to PLC systems.

- Emission – how interference emitted from PLC systems would interfere with other devices or existing radio services operating in the Low Frequency (LF), Medium Frequency (MF), High Frequency (HF) and even the Very High Frequency (VHF) bands. The emissions, both conducted directly through power lines and radiated through the power lines acting as an array of antennas are also governed by existing EMC regulations.

  If these EMC regulations are significantly relaxed, the higher emissions could potentially interfere with various existing services operating today like communications, broadcasting and other sensitive mission critical system. There are now new medium and short wave digital broadcast services proposed which could also be affected. There are already agreed emission standards for emissions up to approximately 200kHz (LF band) for low bandwidth PLC systems. PLC systems with bandwidths of several MHz, now being tested would emit higher frequency signals that could affect more services.

Market Trend. With advances in digital signal processing capabilities and robust modulation techniques, PLC has emerged to support high bit rate in the data networking space. PLC products of more than 10Mbps are beginning to be available in the market. However, PLC is still not widely adopted for data networking in homes and small businesses, particularly due to conflicting standards, higher cost and other operational barriers such as security concern. According to In-Stat/MDR report, the powerline home networking market is expected to improve over time, from under 0.2 million home nodes in 2002 to about 1.9 million home nodes in 2006.

2.2 Wireless Technologies

Wireless Local Area Network (WLAN). A wireless local area network (WLAN) is a flexible data communications system implemented as an extension to, or as an alternative for, a wired LAN. Using radio frequency (RF) technology, WLANs transmit and receive data over the air, minimising the need for wired connections. Thus, WLANs combine data connectivity with user mobility. WLAN essentially comprises of several competing technologies, each with different operating characteristics such as frequency band, modulation technique, data throughput, and

transmitting power. Each has its unique appeal suitable for specific applications. In this section, we discuss the following technologies under WLAN:

- IEEE 802.11
- HiperLAN/2
- HomeRF

2.2.1 IEEE 802.11 Technologies

The 802.11 family (a, b, g, etc.) can be regarded as "Wireless Ethernet" as the specifications differ only in the physical and Media Access Control (MAC) layer characteristics to the basic 802.3 Ethernet protocol. Without delving too deeply into the details, it suffices to say that 802.11 network consists of at least two wireless nodes (or stations, STA) implemented with the 802.11 stack. In this setup, both stations communicate on a peer-to-peer basis. Where an Access Point (AP) is present, it serves as a bridge between the 802.11 and a wired network. In this scenario, all communication goes via the AP, even if the traffic is intended solely between two stations. In yet another mode of operation, two or more WLANs are overlapped and are connected to an Ethernet LAN (or any other wired network). This provides roaming for stations from one WLAN to another, thus overcoming the problem of range.

IEEE 802.11 standard adopted the Distributed Co-ordinated Function (DCF) that uses CSMA/CA as media access method. As in the case of the 802.3 Ethernet, all STAs listen to the channel before transmission. If the channel is busy, the STA executes a random back-off procedure to prevent multiple STAs from seizing the channel at the same time after the end of the preceding transmission.

Technology & Standard Development. The IEEE 802.11 specification defines the air interface between wireless clients and the network's Access Points, as well as among wireless clients operating in the 2.402GHz–2.4835GHz ISM band. Completed in June 1997, the final specification defines only the media access control (MAC) and physical (PHY) layers for a WLAN. This early head start in standardisation effort benefited WLAN in terms of technology maturity, installation base and expertise build-up. However, the initial 2Mbps specification was hardly enough bandwidth for sharing among users in a typical business environment. To rectify this weakness, the IEEE 802.11 working group approved a higher bit-rate standard on September 1999, known as 802.11b (or Wi-Fi[5]) that is capable of up to 11Mbps. This brought transmission capability on par with wired Ethernet but on a shared basis. Notwithstanding the "shared" limitation, 802.11b products enjoy much better market acceptance than the predecessor does. One key difference with the original 802.11 standard

5 The Wireless Ethernet Compatibility Alliance (WECA) has taken the IEEE 802.11b specification and generated a suite of interoperability tests for these products. WLAN products that pass the WECA tests are given a "Wi-Fi" (Wireless Fidelity) logo.

is that 802.11b defines only one PHY specification based on DSSS, whereas the predecessor allowed for both DSSS and FHSS (*see insert 1*).

Insert 1:
Frequency Hopping Spread Spectrum (FHSS) techniques allow for a relatively simple radio design, but are limited to speeds of no higher than 2Mbps. This limitation is driven primarily by FCC regulations that restrict sub-channel bandwidth to 1MHz. These regulations force FHSS systems to spread their usage across the entire 2.4GHz band, meaning they must hop often, which leads to a high amount of hopping overhead.

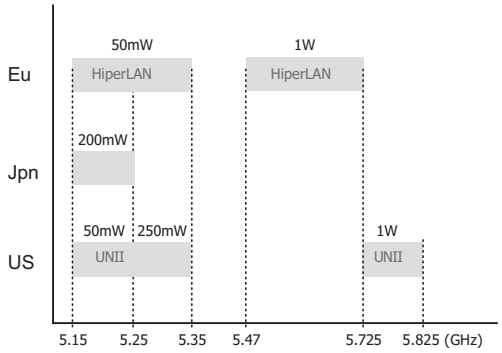
Direct Sequence Spread Spectrum (DSSS) achieves the spreading of the signal by modulating the data with a key sequence known as chipping code. The result of this operation is a signal spread across the desired frequency band. DSSS can generally support higher data rates than FHSS and is more tolerant to many types of interference.

Orthogonal Frequency Division Multiplexing (OFDM) split the input data into several parallel streams, modulating each stream onto a separate carrier frequency, then demodulating all the carriers at the distance end and recombine the data to construct the original signal. Because OFDM is inherently resistant to multipath, it is ideal for cluttered environments with high signal reflection.

The 802.11b also added two new speeds, 5.5Mps and 11Mbps, to the original 802.11 standard. The higher speeds are achievable only on DSSS systems, meaning no backward compatibility is envisaged for 802.11 networks based on FHSS.

Towards end 1999, IEEE concurrently approved 802.11a, a new specification to support the next generation of enterprise-class WLAN. Among the advantages it has over current technologies are greater scalability, better interference immunity, and significantly higher speed. The 802.11a standard is designed to operate in the 5GHz UNII (Unlicensed National Information Infrastructure) band, supporting data rates of up to 54Mbps. *(see insert 2)* Unlike 802.11b, the 802.11a standard differs from the traditional spread spectrum technology, using orthogonal frequency division multiplexing (OFDM).

Insert 2:
In the USA, the FCC has allocated 300MHz of spectrum for unlicensed operation in the 5GHz block, 200MHz of which is at 5.15GHz to 5.35GHz, with the other 100MHz at 5.725 GHz to 5.825GHz. The spectrum is split into three groups. The first 100MHz in the lower section is restricted to a maximum power output of 50mW. The second 100MHz has a more generous 250mW power budget, while the top 100MHz is dedicated for outdoor applications, with a maximum of 1 watt power output. In Europe, the entire band from 5.15GHz to 5.825GHz is available. This is not the case for US and Japan, where only portions of this spectrum are assigned to UNII. Figure below shows the band allocation and power level assignments.



In November 2001, the IEEE passed a proposal for 802.11g that will boost data rates in the 2.4GHz spectrum from the 11Mbps with 802.11b to a maximum rate of 54Mbps. As 802.11g operate in the 2.4GHz ISM band, it is not compatible with 802.11a in the 5GHz band. It is designed to be backward compatibility with existing 802.11b equipment. The draft specification mandates the use of OFDM[6] for higher data rates (greater than 20Mbps) and requires support for complementary code keying (CCK) to ensure backward compatibility with existing 802.11b radios. The draft specification also includes two optional elements, called CCK/OFDM and packet binary convolutional coding (PBCC). Currently, 802.11g is still undergoing development and it is expected to be ratified in early 2003.

Future Development. Further specification work is ongoing in IEEE task groups. For instance, Task Group E is working on 802.11e to enhance the current 802.11 MAC to expand support for applications with Quality of Service (QoS) requirements. This development aims to improve the overall usability and adoption of existing 802.11b and 802.11a standards. The IEEE has also introduced a new variant of 802.11a, called 802.11h, which adds transmit power control

6 Prior to 2001, the use of OFDM in the 2.4GHz ISM band where Wi-Fi operates was not legal in the US. The change with FCC granting permission for this technology to be used in this band has spurred the development of 802.11g, extending the data rates for 2.4GHz wireless LAN systems to 54Mbps and provides backward compatibility with existing 802.11b (Wi-Fi) equipment.

(TPC) and dynamic frequency selection (DFS) to the 802.11a standard. This specification is aim to deal with interference issues between 802.11 and the military radar and satellites installations in the Europe.

Another development is harmonisation effort of 802.11 5GHz standards with HiperLAN/2. The IEEE and ETSI have started the 802.11j or 5UP (for ETSI) working group with task to permit both standards to interoperate in the 5GHz band. It will be a step closer to global 802.11 wireless LAN roaming if this effort succeed. Table 1 summaries a few key 802.11 technologies and their expected date of completion in standardisation.

IEEE 802.11 still has security problems yet to resolve. One of the critical security vulnerabilities is eavesdropping. In 802.11, data is broadcast in all directions to Access Points and other listening devices in the vicinity. 802.11 includes the use of encryption, called Wired Equivalent Privacy (WEP), to protect the data from eavesdroppers. Unfortunately, WEP uses a static key that is highly insecure and can be easily broken within a few tens of minutes by hackers. The IEEE 802.11i is aim to address this issue.

IEEE 802.11i encompasses 802.1x standard to provide a framework that enables centralised authentication and dynamic key distribution. It introduces the Extensible Authentication Protocol (EAP) and the concept of the Authentication Server. EAP allows wireless client network interface cards, which may support different authentication types, to communicate with back-end services such as the Remote Authentication Dial-In User Service (RADIUS). The Authentication Server co-ordinates with the access point to derive a per-user per-session WEP key to be used by the client. Dynamic key derivation ensures that the WEP key varies from session to session, making attacks much more difficult.

An interim solution for security is TKIP (Temporal Key Integrity Protocol) and 802.1x. However, moving ahead, implementing 802.11i with AES (Advanced Encryption System) and 802.1x incorporated would improve user confidence in the security of WLAN.

Standard	Frequency	Modulation	Data Rate	Remark
IEEE 802.11	2.4GHz ISM	FHSS DSSS	1 & 2Mbps	Original standard of the series first published in July 1997 Both standards involve spreading a radio signal to improve performance, but FH and DS are incompatible.
IEEE 802.11a	5GHz UNII	OFDM	Up to 54Mbps	**OFDM in the 5GHz Band** - An emerging standard. Not backward compatible with 802.11b.
IEEE 802.11b	2.4GHz ISM	DSSS	5.5 & 11Mbps	**High Rate DSSS in the 2.4GHz band** - Standard was completed in 1999. Most popular standard. A wide range of products has been available since 2001.
IEEE 802.11e	5GHz UNII	OFDM	Up to 54Mbps	**MAC Enhancements for Quality of Service (QoS)** - Enhance the current 802.11 MAC to expand support for applications with QoS requirements, and in the capabilities and efficiency of the protocol. (Expect to complete in 2003)
IEEE 802.11g	2.4GHz ISM	CCK & OFDM	Up to 54Mbps	**Standard for Higher Rate (20+ Mbps) Extensions in the 2.4GHz Band** - A higher speed extension to the 802.11b PHY. Intended to maintain backward compatibility with 802.11b. Supports CCK and PBCC modulation. (Expect to complete in mid 2003)
IEEE 802.11h	5GHz UNII	OFDM	Up to 54Mbps	**Spectrum Managed 802.11a** - Add transmit power control and dynamic freq. selection to 802.11a to address requirements from European regulatory bodies regarding issues on Satcom interference. (Expect to complete in end 2003)
IEEE 802.11i	5GHz UNII	OFDM	54Mbps or beyond	**MAC Enhancements for Enhanced Security** - Security and authentication enhancement in the MAC to counter issues related to WEP. Incorporate 802.1x and stronger encryption techniques, such as AES. (Expected to complete by 2004)
IEEE, ETSI 802.11j	5GHz UNII	OFDM, GMSK	54Mbps or beyond	**Global Harmonisation** - Globalisation among 802.11 and HiperLAN standard to permit interoperation in the 5GHz band. (committee forming)
ETSI HiperLAN/2	5.15-5.30GHz or 17.1-17.3GHz	OFDM	54Mbps	European Community developed standard (product expected in 2002)

Table 1. Related 802.11 Standards

Market Trend & Forecast. *Dual-mode chipset.* A growing list of wireless chip vendors is vying to deliver IEEE 802.11a and 802.11b combo solutions in 2003. Those already developing dual chip solutions include Atheros, Envara, LinCom Wireless, Resonext Communications and Systemonic. It is unclear whether the 802.11a and 802.11b combo will prove a popular solution. It is possible that a dual-mode chip set pairing the 802.11a and upcoming 802.11g standards will end up dominating the market. Companies with a combined 802.11g and 802.11a solution on the roadmap include Atheros, Intersil and Texas Instruments are major proponents of 802.11g.

A recent forecast from Synergy Research Group indicated that the home/SOHO 802.11-based WLAN market would reach more than US$1.2 billion with shipment of 16 million units by end 2002 and expected to reach US$3.5 billion with shipment approaching 50 million units by 2006. A separate report from Gartner indicated that there would be more than 10 million new WLAN PC users during 2002. Although most will be using the 802.11b physical layer standard, sales of 802.11a products are expected to increase rapidly in North America during the second half of 2002.

2.2.2 HiperLAN/2

HiperLAN/2 is a flexible Radio LAN standard designed to provide high speed access of up to 54Mbps to a variety of networks including 3G mobile core networks, ATM networks and IP based networks, and also for private use as a WLAN system. Basic applications include data, voice and video, with specific QoS parameters taken into account. HiperLAN/2 systems can be deployed in offices, classrooms, homes, factories, hotspots and more generally where radio transmission is an efficient alternative or a complement to wired technology.

HiperLAN/2 relies on cellular networking topology combined with an ad-hoc networking capability. It supports two basic modes of operation: centralised mode and direct mode. The centralised mode is used in the cellular networking topology where each radio cell is controlled by an access point covering a certain geographical area. In this mode, a mobile terminal communicates with other mobile terminals or with the core network via an access point. This mode of operation is mainly used in business applications, both indoors and outdoors, where an area much larger than a radio cell has to be covered. The direct mode is used in the ad-hoc networking topology, mainly in typical private home environments, where a radio cell covers the whole serving area. In this mode, mobile terminals in a single-cell home "network" can directly exchange data.

HiperLAN/2 signal modulation is based on the OFDM with several sub-carrier modulation and forward error correction combinations that allow to cope with various channel configurations. The Convergence Layers (CL) has two main functions: Adapting service requests from higher

layers to the services offered by the DLC and converting the higher layer packets with fixed or variable size into fixed-size DLC Service Data Units that is used within the DLC. Convergence layers have been developed for Ethernet (IP-based) applications, cell based core networks as ATM and for IEEE1394 protocols and applications. In addition, it is scheduled to define access interface to the 3G mobile in cooperation with ETSI and 3GPP.

The first release of the HiperLAN/2 standard was published in April 2000 with conformance test specifications approved later in January 2001 by ETSI BRAN (Broadband Radio Access Networks). In July 2002, ETSI held an interoperability test, Plugtests, to demonstrate their implementations of HiperLAN2. An IEEE 1394 audio-visual stream over HiperLAN/2 was demonstrated on large screens via live satellite broadcast. The next HiperLAN2 Plugtests event is scheduled for January 2003 in Sophia Antipolis, France.

In order to facilitate convergence among WLAN standards designed to operate in 5 GHz frequency band, a joint task force called 5GARG "5 GHz Alignment Rapporteur Group" was formed aiming to:

- prepare a solution for co-existence and inter-working between the solutions developed in the different IEEE 802.11 groups and ETSI BRAN's HiperLAN/2 in close cooperation with the relevant IEEE802.11 groups;
- facilitate the alignment activities of the HiperLAN/2 and the Japanese MMAC-HiSWANa standard (*High Speed Wireless Access Network type a*), based on an initiative of the HiperLAN/2 Global Forum;
- coordinate the activities on global 5GHz spectrum allocation and harmonisation.

2.2.3 HomeRF

HomeRF is an open industry specification that defines how devices share and communicate voice, data and streaming media in and around the home. HomeRF-compliant products operate in the unlicensed 2.4GHz ISM band, utilising frequency hopping spread spectrum RF technology for secure and robust wireless communications. An industry consortium, the Home Radio Frequency Work Group[7], was formed in early 1998 to promote a specification known as Shared Wireless Access Protocol (SWAP).

HomeRF networks provide a range of up to 50m, sufficient to cover the typical home environment. HomeRF blends technologies from several worldwide standards. For instance, data networking

7 More information on this group can be obtained from: http://www.homerf.org/

technology based on CSMA/CA protocols were derived from the OpenAir and IEEE 802.11 standards, and voice technology based on TDMA/TDD (*see insert 3*) are adapted from DECT.

> *Insert 3:*
> *Unlike Ethernet, HomeRF uses two separate medium access protocols for its two primary services, voice and data. Voice packets are sent using a guaranteed access TDMA/TDD protocol. TDD allows for a full duplex communication, and TDMA provides guaranteed access to the medium once per frame for each voice connection. Data packets are sent using a wireless version of Ethernet. Like Ethernet, the data service is built on the CSMA/CA protocol. This is known within HomeRF as the Asynchronous Data Service. For streaming audio or video sessions, HomeRF implemented a Priority Asynchronous Data Service, in which selected data packets gain priority access to the channel while using the CSMA protocol.*

Technology & Standard Development. HomeRF products first hit the market in 2000 with 1.6Mbps performance, which is a great match for DSL and cable modems. Nearly all of the early products were PC related and supported data applications.

In 2001, the HomeRF working group releases HomeRF 2.0 that boosts the data throughput to 10Mbps. This came after FCC new ruling allowing wideband frequency hopping. This specification, offering backward compatibility to its predecessor, enables the introduction of high-speed applications such as CD quality audio distribution to wireless speakers and streaming video possible within the home. HomeRF 2.0 supports up to 8 phone lines, 8 registered handsets, and 4 active handsets.

The work on the next specification of HomeRF 2.1 continues in 2002. This specification will add features designed to reinforce HomeRF voice advantages, improve video support on set-top box, extend its range for larger homes and businesses, and allow roaming with soft hand-off between repeaters. Other enhancement includes complementing other WLAN standards such as 802.11a. The work group is also evaluating the need to increase its data capacity to 20Mbps (to support streaming video of DVD quality at 2.4GHz) in light of its planned support of 5GHz.

Future Development. HomeRF WG will embrace 5GHz using 802.11a for its extension. The working group believed in the coexistence of 2.4GHz and 5GHz since each frequency band has specific strengths that can complement each other. The group plans to write application briefs describing how to bridge between the two frequency bands. This information will include how to handle differences in QoS and can also be applied to HiperLAN/2 and proprietary 802.11a extensions that extend performance from 54Mbps to 100Mbps or more.

Wireless Personal Area Network (WPAN). This short-range wireless is a complementary class of emerging technologies meant primarily for indoor use over very short distances. Except for Ultra-Wideband, their operational range is typically allocated in the ISM frequency band. The WPAN networking cover the area that corresponds to the human natural interactive environment, and support the applications that range from several kbps to more than 100Mbps in data capacity. In this section, we provide the development trend of three emerging technologies, namely;

- Bluetooth
- Ultra-Wideband (UWB)
- ZigBee

2.2.4 Bluetooth

Bluetooth is a short-range wireless technology that operates in the unlicensed 2.4GHz ISM band. This band includes the spectrum between 2.402 and 2.4835GHz, and is currently used for many applications, including cordless phone, remote control and other WLAN systems. Bluetooth allows for the replacement of the many propriety cables that connect one device to another with one universal radio link. Its key features are robustness, low complexity, low power and low cost. Bluetooth radio supports both point-to-point and point-to-multipoint connections. These radios use a spread spectrum, frequency hopping, full-duplex signal at up to 1600 hops/sec. The signal hops among 79 frequencies at 1MHz intervals to give a high degree of interference immunity.

The Bluetooth radio interface is based on a nominal antenna power of 0dBm. Each device is classified into 3 power classes as defined in the following table.

Power Class	Maximum Output Power	Expected Range
Class 1	100m W / 20dBm	Long range ~ 100 metres
Class 2	2.5m W / 4dBm	Ordinary range ~ 10 metres
Class 3	1mW / 0dBm	Short range ~ 10 centimetres

Table 2. Bluetooth Power Classes
(Source: Bluetooth 1.0b specification)

The Bluetooth baseband manages physical channels and links apart from other services like error correction, data whitening, hop selection and Bluetooth security. The baseband layer lies on top of the Bluetooth radio layer in the Bluetooth stack. Bluetooth baseband channel is based on both packet and circuit switching. Synchronous and asynchronous traffic can be supported. On each voice channel, 64kbps synchronous (voice) channels are supported in both directions. For an

asynchronous (data) channel, up to 723.2kbps (with still another 57.6kbps on the return link) or 433.9kbps (symmetric) are possible. The protocol also includes specific support for "high quality" voice transmissions at 64kbps.

Two types of links are specified in Bluetooth baseband physical links: the Synchronous Connection-Oriented (SCO) link and the Asynchronous Connection-less link (ACL). The SCO link is a symmetric point-to-point link between a master and a single slave in the piconet. The master maintains the SCO link by using reserved slots at regular intervals (circuit switched type). The SCO link mainly carries voice information. The master can support up to three simultaneous SCO links while slaves can support two or three SCO links. SCO packets are never retransmitted. SCO packets are used for 64kbps speech transmission. The ACL link is a point-to-multipoint link between the master and all the slaves participating on the piconet. In the slots not reserved for the SCO links, the master can establish an ACL link on a per-slot basis to any slave, including the slave already engaged in an SCO link (packet switched type). Only a single ACL link can exist. For most ACL packets, packet retransmission is applied.

Each radio transceiver is allocated a unique 6-bytes address that is IEEE 802 standard-based. Link connection between Bluetooth devices are made using this address. Once a link is established, one device in the piconet is elected as the master with others becoming slaves. A piconet can accommodate up to 8 devices. Multiple piconets can exist across an area known as a scatternet. Each piconet is recognised by a different frequency hopping sequence, which is also used to synchronise all users within the same piconet. Up to 10 piconets within range can form a scatternet. When a new device is detected by the piconet, that device must respond to an interrogation that provides access-level security.

Technology & Standard Development. The Bluetooth 1.0 specification was first released by the Bluetooth Special Interest Group[8] (SIG) in July 1999. The specification consists of two documents: the Foundation Core, which provides design specifications, and the Foundation Profile, which provides interoperability guidelines. The Bluetooth 1.0b technology was the global release anticipated to bring Bluetooth to the public, offering business users the promise of personal area networking. However this release was not sufficiently reliable to support the expectations of the industry; interoperability was an issue and security concerns raised.

In March 2001, the Bluetooth 1.1 specification was released to correct the deficiencies of the 1.0b specification. The specification also rectified errors and bugs that were surfaced during testing. The most important fixes are key exchange (resolution of master & slave

8 The Bluetooth SIG comprised of companies such as 3Com Corp., Ericsson Technology Licensing AB, IBM Corp, Intel Corp., Agere Systems, Inc, Microsoft Corp., Motorola Inc., Nokia Corp., Toshiba Corp., as well as hundreds of Associate and Adopter member companies. For more information on the Bluetooth SIG, refer to www.bluetooth.com.

race condition), harmonisation of frequencies (all countries will utilise 79 hop-pattern instead of 23 hop specified in 1.0b for certain countries such as France, Japan and Spain) and incompatible data formatting with regards to handling variable data slots sizes as not all Bluetooth devices support five-slot packets.

Standardisation work on Bluetooth was also undertaken by the WPAN Task Group 1 (TG1) of IEEE 802.15 Working Group for WPANs. In April 2002, the IEEE Standards Association (IEEE-SA) standard board approved the IEEE Standard 802.15.1 "Wireless MAC and PHY Specifications for Wireless Personal Area Networks (WPANs)" which is adapted from portions of the Bluetooth 1.1 foundation specifications developed by the Bluetooth SIG. This standard was published on 14 June 2002 and has become an additional resource for those who implement Bluetooth devices.

A high-rate specification, Bluetooth 2.0 is currently in development. This version not only adds new profiles but also specifies a change in the radio frequency in two key areas: the peak data transfer rate will be boosted from the current 1Mbps to 2-12Mbps. To address security concern, Bluetooth 2.0 might employ more complex encryption methods, or advanced user ID recognition to support m-commerce applications. Bluetooth 2.0 might also extend the range further, while also improving the power efficiency.

In recognition of the growing significance of the unlicensed wireless band used by 802.11 and Bluetooth, the FCC has modified the rules that govern the unlicensed 2.4GHz ISM spectrum (*see insert 4*). The most significant changes to FCC rule Part 15.247 will allow for coexistence of WLAN devices with devices using Bluetooth.

Insert 4:
The Federal Communications Commission (FCC) has amended the rules governing spread spectrum technologies used by fixed wireless operators in May 2002. The amended rules will provide manufacturers flexibility to design and market a diverse set of products, such as devices with both Bluetooth and 802.11 capabilities.

FHSS systems in the 2.4GHz band have been granted more flexibility in design and operation. FCC now permits the use of as few as 15 hopping channels for FHSS in the 2.4GHz band. These systems will be able to use channel bandwidth up to 5MHz wide, but must reduce their output power to 125mW if fewer than 75 hopping channels are used. FCC believes that this will allow new FHSS systems to better avoid interference than today's systems by enabling them to avoid occupied channels.

Future Development. The Bluetooth Special Interest Group is currently concentrating on expanding the types of products that the technology support. Work is progressing in several SIG working groups to create new profiles that adapt the specification to new markets, including imaging, audio and video, and high-speed file transfer. In particular, the high-rate radio group is working on a faster Bluetooth radio 2.0 specification, which is expected to complete in 2003.

Some of the challenges that need to overcome are listed below;

Coexistence issues with WLAN. Radio interference is a potential issue for Bluetooth and a radio hazard to other technologies, since it coexists with other devices, including WLAN in the same 2.4GHz ISM band. It is not yet clear how serious this could be if Bluetooth enters the mass market. Currently, IEEE and the industry are addressing this issue. A Coexistence Task Group 2 (TG2) known as IEEE 802.15 was formed to develop a coexistence model to quantify the mutual interference of WLAN and WPAN. The Task Group is also developing a set of coexistence mechanisms to facilitate coexistence of WLAN and WPAN devices. We see this as a biggest challenge for Bluetooth in the coming years.

Security concerns. As Bluetooth is fundamentally an ad-hoc networking protocol, a device can be called on to communicate at any moment with another previously unknown to it. While Bluetooth link encryption is robust, the challenge is in the initial authentication of a new device, where there is a reliance on a possibly insecure initial exchange of secret keys via a side-band channel. Although not all Bluetooth links require security, many do (e.g. data from a voice headset), and the omission of a stronger secret key exchange mechanism is a weakness of the current Bluetooth 1.1 specification.

Interoperability and certification. Bluetooth needs to be certified at three levels; baseband, protocol level, and profile. Successful performance at the first two levels results in products being included on the Bluetooth qualification list. However, the 13 profiles that have been developed so far do not appear on the list. As a result, vendors are conducting their own interoperability verification with selected products that they then recommend. This lack of a formal interoperability testing and certification process is a growing problem for end users, who have no control over which devices and protocols they encounter. There were many stories of incompatibilities between different Bluetooth-certified devices in 2001. Similarly, problems with different vendors' interpretations of profile terminology have caused interoperability problems. The Bluetooth industry urgently requires an independent interoperability, profile-testing and certification body along the lines of the Wireless Ethernet Compatibility Alliance.

Market Outlook. The continual improvement of Bluetooth product in design, development and integration has resulted in Bluetooth achieving a steady market growth in 2002. As of July

2002, there are over 650 qualified Bluetooth products. The majority of these products includes mobile phone, computing and other consumer electronics. Other products qualified were the critical chips, software and development tools from which equipment manufacturers can develop their own Bluetooth wireless products. According to ABI[9], Bluetooth chipset shipments will increase from 11.2 million in 2001 to 33.8 million in 2002. By 2007, the Bluetooth IC market is forecast to generate US$2.54 billion in revenues. Though the mobile handsets market will still lead all other applications, headsets and PDAs, computing devices and automotive market will make a substantial market for Bluetooth. Gartner expects Bluetooth-enabled product shipments to approach 40 million units in 2002 and to reach more than 125 million units in 2003.

2.2.5 Ultra-Wideband (UWB)

Wireless networking is beginning to gain popularity in the home environment, especially due to the growing demand of 802.11b from mobile users. However, WLAN technology, including variants such as 802.11a, g, etc. will have limited capabilities for streaming multiple audio & high bandwidth video applications in a congested environment. To support future high-bandwidth wireless applications, such as multiple stream of high definition TV in the home, a disruptive communication technology known as Ultra Wideband, or UWB in short, is fast entering the arena of consumer electronics.

UWB is seen as one of the most suitable candidates to achieve the vision of a truly mobile broadband wireless interconnection between computing devices. Many UWB products already exist in the government and military sector, the by-product being more than 100 patents being issued between 1960 and 2000. Today, UWB is only at the beginning of its development for the consumer market, which appears to be one of the main segments for UWB. Applications such as multiple high-speed multimedia streaming in an in-door wireless environment would become possible using UWB technology. From a technical perspective, UWB can deliver extremely high-speed data transfer (between 50Mbps and 1Gbps) at low power levels. At such, it is ideal for consumer electronics applications such as camcorders, laptops, DVDs, digital cameras, etc.

Fundamentally, in all UWB systems, a transmitter emits pico-second impulses that are detected by a corresponding receiver. Information that is to be sent is modulated onto certain parameters of the transmitted impulse such as pulse position, amplitude or pulse orientation. The receiver detects these pulses and extracts the modulation information. If the amplitude of the transmitted impulses is kept sufficiently low, it may be possible to keep its spectra

9 ABI report: The Global Outlook for Bluetooth Component and Equipment Markets, September 2002

below the noise floor and thus operate the system without disruption to others using the same spectra on a primary basis.

UWB uses the concept of time and/or code discrimination instead of frequency discrimination. The complexity of an UWB device will be very close to the one of a today's GPS device where front-end hardware carry weight for about 20% of the development effort versus the remaining 80% for the software development. UWB will push this sharing out even further and will make future radio device implementations to finally depart from the concept of "dedicated radio" to reach the concept of "software-defined radios" (SDR). SDR will bring the flexibility in radio device design, allowing by software changes to develop short-range/ high data rate or long-range/low data rate applications with decimetre location abilities, or all at the same time. This ability of an UWB device to know its location towards other devices could bring interesting solutions in managing mobile ad-hoc wireless area networks.

Technology & Standard Development. UWB technology for short-range wireless communications is still in its earliest days. It is not standardised, has its own multiple competing variations, and has not received necessary regulatory approvals, besides FCC in the United States. Nonetheless, as a long-term target, UWB appears to have enormous potential, especially in WPAN applications.

To bring UWB into the mainstream, FCC issued a notice of proposed rule making in May 2000. The FCC later adopted a First Report and Order[10] on 22 April 2002 that permits the marketing and operation of certain types of new products incorporating UWB technology, making available 7500MHz of spectrum from 3.1GHz to 10.6GHz. The equipment must be designed to ensure that operation can only occur indoors or it must consist of hand-held devices that may be employed for such activities as peer-to-peer operation. The power spectral density (PSD) is limited to -41.3 dBm/MHz (same as current FCC Part 15). The FCC defined UWB device as fractional bandwidth greater than 0.2 and occupies more than 500MHz.

The IEEE 802.15 High Rate Alternative PHY Study Group[11] (SG3a) for WPAN is currently defining a high-speed PHY enhancement amendment to the existing IEEE 802.15.3 WPAN standard. This standard, IEEE 802.15.3a, is expected to be completed in 2004 and will support applications such as digital imaging for faster & better resolution, multimedia for video, VoIP, HDTV, home theatre, surround sound audio and pervasive gaming. It is anticipated that future applications will go beyond the currently defined PHY capabilities, for example very high data rates and location awareness. The PHY layer requirement must, amongst others, co-exist with all IEEE 802 wireless

10 FCC 02-48, UWB Report & Order, released April 22, 2002

11 IEEE 802.15 WPAN High Rate Alternative PHY Study Group 3a (SG3a) (www.ieee802.org/15/pub/SG3a.html). Members in this group currently include companies from Motorola, Time Domain, XtremeSpectrum, Intel, TI and Sony.

PHYs, with data rate in excess of 100Mbps. Representatives of this study group also proposed to use 802.15.3 MAC as a requirement.

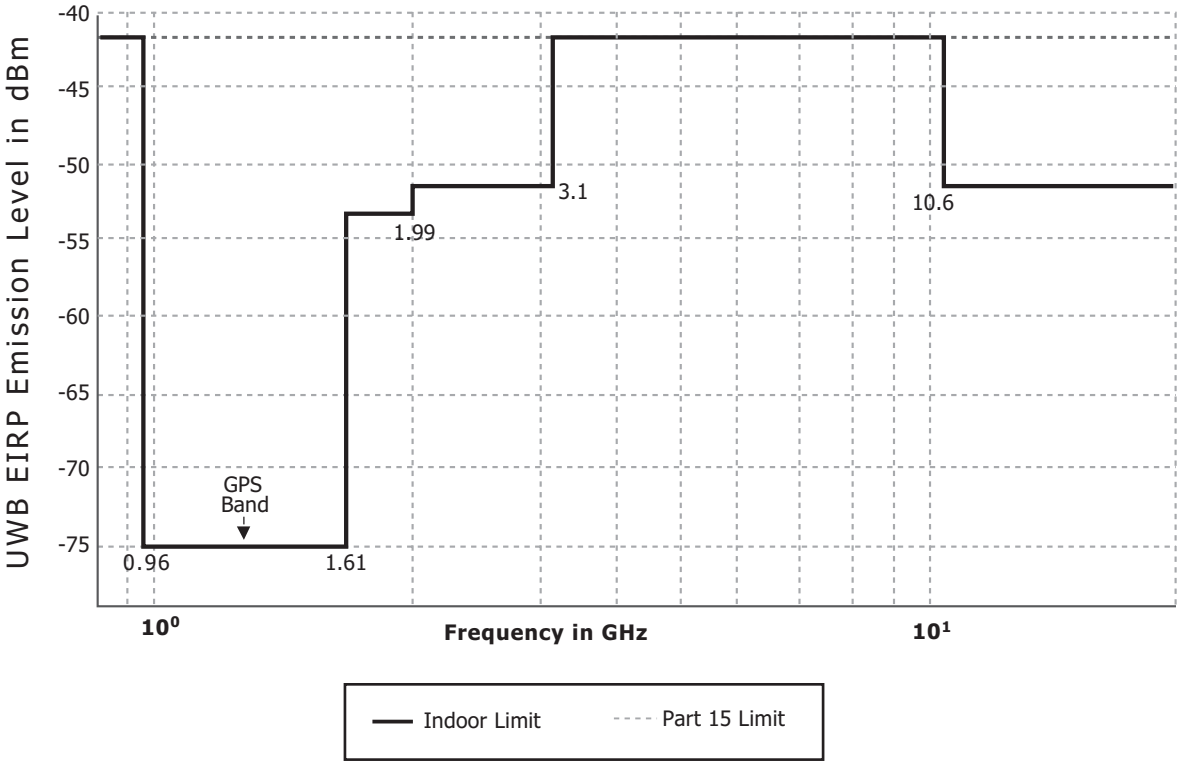


Figure 2. UWB Emission Limit for Indoor Systems

In September 2002, a WiMedia Alliance[12] was formed to develop and adopt standards-based specifications for connecting personal area range, wireless multimedia devices. The WiMedia Alliance will establish a certification program to accelerate widespread consumer adoption of "wire-free" imaging and multimedia solutions. Initial Alliance activity will be based on the high data-rate IEEE 802.15.3 draft standard with amendments and enhancements planned for future wireless systems such as UWB. The WiMedia brand mark will certify the interoperability of multimedia devices that use personal area wireless technologies. The brand will also let consumers know which personal devices are WiMedia-compatible and interoperable in a consumer-electronics-based networked environment. The Alliance will manage the WiMedia brand and license its use to organisations whose products pass certification tests.

12 The WiMedia Alliance (www.wimedia.org) was founded by nine leading technology companies from Appairent Technologies, Eastman Kodak Company, HP, Motorola, Philips, Samsung, Sharp Laboratories, Time Domain, and XtremeSpectrum.

Separately, an informal association of companies, individuals, governing officials and regulators known as the UWB Working Group[13] is promoting the development and acceptance of ultra wideband technology to be used as a candidate technology for this new PAN standard.

Future Development. UWB will have significant impact on the future development of infocomm, especially in the field of communications. There is still a lot to be done to make this technology attractive. Technology requirements on UWB systems are drastically different. Silicon and hardware improvements, challenges in software and algorithms for efficient data transmission and network management are the technical challenges that should be taken up by this new technology. Other work areas around the standardisation and the regulation are to be done in order to make UWB widespread and popular.

UWB can potentially cause noise pollution over large span of frequency spectrum, in particular, to the Global Positioning System (GPS) bands used by airlines and military system. Therefore more field tests and data gathering of UWB to prove that critical installations are not compromised is important to its future. Although FCC has given limited approval for UWB transmissions, proponents are petitioning the FCC to loosen these restrictions in the near future. However, the airline industry is strongly against any intrusion into the unshared spectrum. According to the Air Transport Association (ATA), a new round of studies proved that the proliferation of UWB devices will interfere with GPS signals, as well as sensitive avionics systems.

From a technical point of view, the mechanisms and techniques whereby a signal resides below the noise floor can be detected and decoded in the presence of multipath reflections and increasing data rates have yet to be clearly defined and understood. While the anti-UWB camp is trying to prove that UWB does cause interference, UWB proponents face a far more challenging task of proving that it does not. Technical and standards issues aside, the sheer impossibility of proving a negative, combined with the influence of the military has over all thing governmental, still hang like a cloud over UWB's progression.

The FCC thinking and decision is critical to the future of UWB. We could expect further notice of proposed rulemaking on UWB from FCC in the near term (*see insert 5*). In line with this, the FCC has started a test program for UWB devices and the results will be made available for public comments. Laboratory and field measurements will also be conducted to analyse the effect of UWB emission limits.

13 Ultra-Wideband website: www.uwb.org

Insert 5.
FCC: "We are concerned, however, that the standards we are adopting may be overprotective and could unnecessarily constrain the development of UWB technology. Accordingly, within the next six to twelve months we intend to review the standards for UWB devices and issue a further rule making to explore more flexible technical standards and to address the operation of additional types of UWB operations and technology"

Paragraph 1, First Report and Order
Adopted by the Commission, February 14, 2002

Market Trend. It is likely that any standard for UWB will not be in place until at least in mid-2004. That implies that standards-based products could only begin to rollout in 2005. However, we can still expect to see a ramp-up of pre-standard UWB products available in 2004. A market report from In-Stat/MDR on UWB indicated that there will be 0.36 million UWB nodes shipped in 2004 and is expected to reach 1.8 million by 2006, bringing in US$41 million of revenue. The number of UWB nodes is expected to grow strongly from 2007 and beyond, as it will become the technology of choice to be integrated in many consumer electronics products.

ABI[14] forecasts that global shipment of UWB-enabled electronics and chipsets could reach 45.1 million units by end 2007, producing revenues of US$1.39 billion.

Most UWB component vendors are currently working with the consumer electronics industry to incorporate their chipsets into home entertainment systems. Table 3 provides information of some component companies that are working in this area.

14 ABI report: Ultra Wideband (UWB) Wireless - An Evaluation of Technology Prospects and Potential Market Applications

Company	UWB Technology type/modulation	Speed & Range	Applications	Status
Æther Wire and Location (www.aetherwire.com) Military contracts (primarily DARPA)	PPM/Time hopping	1cm accuracy over km distances	Precision location	Prototype demonstrated
General Atomics (web.gat.com/photonics/uwb)	Propriety Spectral Keying, not PPM or PAM	High bit rate: hundreds of Mbps less than 10m; Medium bit rate: compatible to WLAN, greater than 10m; Low bit rate: sensory applications for range greater than 100m	Military & consumer electronics, sensors, and short range computer and data communication	Beta, pre-production of products ready by Q2, 2003
MultiSpectral Solutions (MSSI) (www. multispectral.com) Funding from military contracts (DARPA, air force and navy)	On-off Keying OOK)	20+Mbps WLANs	Voice communications; data transfer; precision location; radar	Military systems in use; civilian applications under development
Pulse-Link (www.pulse-link.net)	Pulse Position Multiple Access (PPMA)	1st gen: 80Mbps, 150m 2nd gen: 100Mbps, 300m 3rd gen: 100Mbps, km	Data transfer; precision location	Chips scheduled for release 2003
Pulsicom (www.pulsicom.com) Investors include Intel Capital	Pseudo-UWB technology	Up to 1cm	Precision location	Chips scheduled for release late 2003
Time Domain (www.timedomain com) funding from Sony and Siemens.	Pulse Position Modulation (PPM) and other mod. techniques	Home apps: 40Mbps, 10m Location cap: 10-20cm	Data transfer; precision location; radar	Radar products on the market; first communications chips to be released this year
XtremeSpectrum (www.xtremespectrum.com) Investors include Cisco Systems, Motorola and Texas Instruments	Patented pseudo -noise-encoded bi-phase modulated wavelet	100Mbps, 10m 20Mbps, 20m	Multimedia data transfer	First chips released this year
Intel	Unknown		Data transfer	Prototype demonstrated
IBM Research	Unknown		Networking	Long-range R&D
AT&T	Unknown		Multimedia data transfer	Long-range R&D

Table 3. UWB Component Companies
(Source: Compiled from open sources, Technology Review:
An Ultra Wideband Who's Who, and In-Stat/MDR, 5/02, The Promise of UWB)

2.2.6 ZigBee

The ZigBee technology is a low data rate, low power consumption, low cost, wireless personal area networking protocol targeted towards automation and remote control applications. This wireless communications solution is targeted for embedding into consumer electronics, home and building automation, industrial controls, PC peripherals, medical sensor applications, toys and games products. ZigBee was created to address a market need for an industry standard to support these applications, as opposed to proprietary solutions. Philips, Honeywell and Invensys joined forces to draft a Market Requirements Definition for ZigBee. The specification originates from the Firefly Working Group in March 2000, and changes its name to RF-EasyLink in August 2000. The IEEE 802.15 Task Group 4[15] started working on a low data rate and low complexity standard a short while later. The scope of the group is to define the physical (PHY) and media access control (MAC) layer specifications. In August 2001, the Alliance was renamed as ZigBee. Both IEEE and ZigBee Alliance are now jointly working toward defining a common standard. The IEEE 802.15.4 standard is expected to complete in early 2003.

ZigBee technology can operate at data rate of 250kbps at 2.4GHz and 20 to 40kbps at 868/915MHz. The range is 10 to 75 meters nominally, which is dependent on the power output (consumption) required for a given application and can be increased by various methods. ZigBee air interface is based on DSSS, with 11 chip/symbols, 62.5 k symbols/sec and 4 bits/symbol. The average peak information rate is approximately 128kbps.

ZigBee greatest advantage against Bluetooth is low power consumption (multi-month to multi-year battery life) and low cost (expect chipset price to be US$6 in 2003 when produced, Bluetooth is US$10 now, by 2005, ZigBee expects its price to be around US$1.5 to US$2.5, whereas Bluetooth is US$5). It also has faster connectivity time compare with Bluetooth. However, there is interference issue with 802.11 and need to work under the co-existence mechanism. IEEE 802.15.4 is expected to complete by 2003.

2.3 "New-Wiring" Technologies

Structured wiring requires installing new cabling in the walls. The cabling technologies generally include unshielded twisted pair (UTP) wires and coaxial cables. Structured wiring provides high bandwidth and excellent security. To handle the full range of current applications, a complete installation today requires several types of cabling, including UTP for telephone and data, and coaxial for video. Fast Ethernet at 100Mbps over UTP is widely used for data applications. While it has sufficient bandwidth for video, it presently does not include QoS support. As high definition video

15 IEEE WPAN Task Group 4: www.ieee802.org/15/pub/TG4.html16 In-Stat/MDR 09/2002 report: Wi-Fi Rules: 1H2002 Home Networking Market Shares

moves into homes, many believe that a "home backbone" network based on structured wiring will be required to interconnect sections of the home. The Electronics Industry Association (EIA) and CEA are developing the R-7.4 VHN Home Network Standard for this purpose.

Though "no- new-wiring" home networking technologies are promising, it is important to note that structured wiring systems provide a comprehensive "wired" home networking solution, particularly in new home builds. Structured wiring is a method of providing the communications infrastructure for non-electrical requirements, such as broadband Internet, home automation and telecommunications. With structured wiring, all phones, cable and data communication cables terminate at a central distribution hub. Structured wiring also entails using high performance grade wiring to decrease the problems associated with noise from external sources.

2.4 Home Networking Summary

The worldwide connected home market, consisting of home networking hardware equipment and software, residential gateways and home control & automation products is projected to grow from US$1.4 billion in 2001 to US$9.2 billion by 2006, according to In-Stat/MDR. The home networking hardware market remains dominated by WLAN (802.11x) and Ethernet technologies. While the future of the home networking market will see an increasing number of entertainment centric network connections, today's market is primarily focused on data sharing.

In-Stat/MDR[16] finds that Ethernet products, which include NICs, routers and switches/hubs, are the leading technology in this market today, enjoying the momentum of being the dominant business LAN technology. However, WLANs are emerging as the fastest growing category, with 802.11b products currently accounting for the vast majority of all wireless LAN products sold. As of mid-2002, WLAN accounted for about 38% of all home networking hardware, while Ethernet accounted for about 60%. This is up from the end of 2001 when wireless accounted for a third of all home networking hardware and Ethernet about two thirds. The leading vendor in the wireless home networking market is Linksys with a 24.1% of the market. Other vendors such as Netgear, D-Link and Buffalo also have seen strong market shares. The HomePNA and HomePlug markets account for a very small percentage of the overall home networking equipment market. HomePlug products, which just started shipping in the first quarter of 2002, will continue to ramp up, but will need greater awareness among retailers and consumers. Linksys, Netgear and Phonex account for the majority of this nascent market.

The evolution of the various home networking technologies in term of their standard development is presented in Figure 3. A quick reference of the home networking technologies and their technical characteristics is also summarised in Table 4.

16 In-Stat/MDR 09/2002 report: Wi-Fi Rules: 1H2002 Home Networking Market Shares

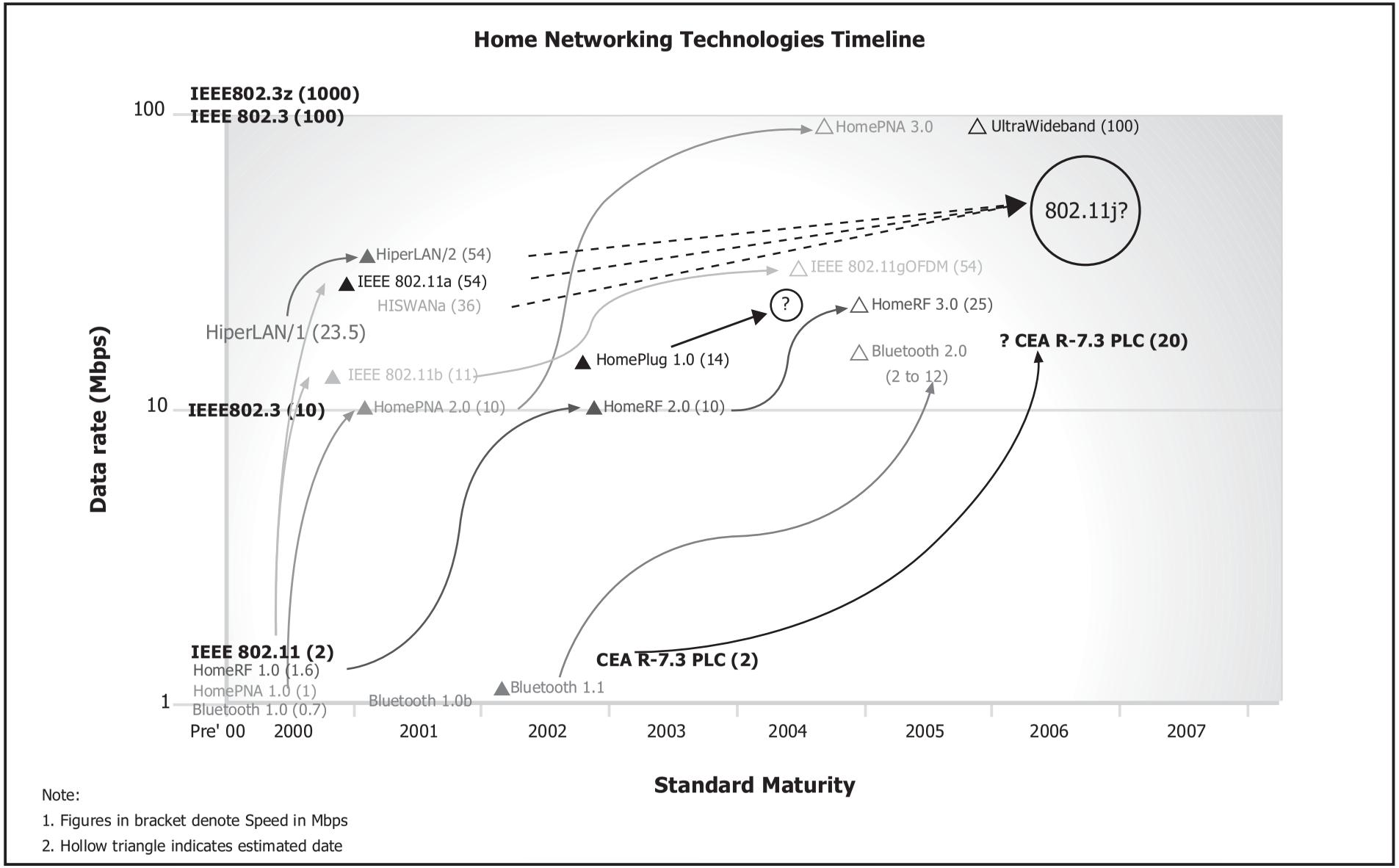


Figure 3. Home Networking Technologies Summary

Technology / Characteristic	Wireline Communication			Wireless Communication[1]				
	Ethernet	**HomePNA**	**Powerline**	**IEEE 802.11**	**HiperLan2**	**HomeRF**	**Bluetooth**	**UWB**
Transmission Medium	Uses Cat-5 UTP wiring	Uses existing phone lines and FDM	Uses existing power lines in home	Uses RF at 2.4GHz ISM band and 5GHz in UNII	Uses 5GHz	Uses RF at 2.4GHz ISM band	Uses RF at 2.4GHz ISM band	Currently uses FCC approved 3.1GHz to 10.6GHz
Association/ Alliance/ Standard Organisation	IEEE	Home Phoneline Networking Association	HomePlug Poweline Alliance, CEA, PLCforum	IEEE WLAN WG	ETSI	HomeRF Working Group	Bluetooth SIG	IEEE WPAN WG UWB Working Group
Specification	IEEE 802.3	HomePNA 1.0 HomePNA 2.0 HomePNA 3.0	HomePlug 1.0	IEEE 802.11 IEEE 802.11b IEEE 802.11a Other variant e, g, h, i, j	HiperLAN/2	SWAP 1.0, 1.1, 1.2, 1.3 SWAP 2.0 (WIP)	Bluetooth 1.1 Bluetooth 2.0 (WIP)	IEEE 802.15 High Rate Alternative PHY
Data Rate	10Mbps to 100Mbps	HPNA 1.0: <1Mbps HPNA 2.0: <10Mbps HPNA 3.0: <100Mbps	HomePlug 1.0 <14Mbps CEA 2 to 20Mbps	802.11: <2Mbps 802.11b: <11Mbps 802.11a <54Mbps	54Mbps	1.6Mbps Future up to 10Mbps	Bluetooth 1.1: 721.2kbps (asymmetric) 433.9kbps (symmetric) Bluetooth 2.0: 2 to 12Mbps	>100Mbps
Range (Maximum)	100m	300m	400m	100m	<50m	50m	10m to 100m	10m
Privacy of Physical Medium	Good	Good	Poor	Poor	Good	Poor	Poor	Good
Reliability	High	High	Moderate	High to moderate	High to moderate	High to moderate	High to moderate	High to moderate

Table 4. Home Networking Technologies Summary

Technology / Characteristic	Wireline Communication			Wireless Communication[1]				
	Ethernet	**HomePNA**	**Powerline**	**IEEE 802.11**	**HiperLan2**	**HomeRF**	**Bluetooth**	**UWB**
Cost	Moderate (Low hardware cost, but higher cost when installing new wiring)	Low	Low	Moderate	High	Moderate	BOM moderate (US$25. Target US$5 in future)	BOM moderate (US$20 initially) to low
Applications	Enterprise and home data network apps, Home controls, Entertainment & information apps.	Home data network app, Home controls, Entertainment & information apps.	Home data network & information applications, Home controls, Limited video steaming	Enterprise and progressively home data network app., Home controls, Entertainment & information apps.	Enterprise and progressively home data network app., Home controls, Entertainment & information apps.	Voice, and less bandwidth intensive applications	Cable replacement & voice communications. Low bandwidth apps.	Very high bandwidth apps, such as multiple HDTV streaming, multimedia apps.
Pro	Secure, reliable and fast One industry standard	Supported by many key OEM	Power outlets are ubiquitous	Widely adopted by many enterprises Price still high	More reliable	Lower cost, Quality voice	Good for small form factor mobile devices	Very high data rate, very lower consumption
Con	Require New Wiring	Although no new wiring is required, phone outlets are not ubiquitous, especially in Europe	Security concerns, A harsh medium may limit upward potential	Security weakness in WEP	High cost	Mainly for Voice only, but future version could support data	Low data rate Bluetooth integration on client is still high.	Technology could potentially interfere with critical systems

Cont'd: Table 4. Home Networking Technologies Summary

Notes:

1 Several competing systems are under development and proposed for the unlicensed 2.4GHz band (Bluetooth, HomeRF, IEEE 802.11b). This band has multiple sources of interference such as DECT standard phones, and microwave ovens. The 5GHz spectrum may also be used for home networking, using IEEE 802.11a or some other standard. Other standards and frequencies are proposed for systems to be used in Europe and Japan

3 Residential Gateway

3.1 Technology Overview

The Residential Gateway (RG) concept is not new. Initially conceived by the Residential Gateway Group (RG Group) in 1995 as a centralised physical device between an in-home network and wide area network (WAN), the forms of RG has now been construed differently by different people and industries. For the RG Group, it envisioned the RG as a centralised, intelligent, generic and whole-house gateway i.e. a unit that terminates all external access networks and connects to all in-home networks. In terms of implementation, RG can be a simple network equipment such as a hub/router, a broadband modem, a set-top box, or simply a gateway switch.

Since 1999, RG has been gaining popularity due largely to the tremendous growth in the Internet and the broadband evolution. Work on RG is now currently pursued by the ISO/IEC working group and the Open Services Gateway Initiative (OSGI) alliance to define a multi-service RG that is open, platform independent, and provide a framework and APIs that allow for dynamic delivery of managed services to consumers.

Figure 4 depicts a RG implementation. Conceptually, the RG allows communication between devices within the premises and systems, service providers, operators and users in the external environment outside the premise. It enables service providers to deliver home management services such as tele-care, home appliance control and preventive maintenance, remote metering and security monitoring. Other service providers may provide energy management, entertainment, information and a variety of other community-based services to the info appliances within the home.

The RG essentially provides the hardware and software necessary to allow data between one kind of WAN to be sent and/or received by another LAN. Inter-LAN communication might also be possible. Figure 5 below shows the hardware architecture of a typical RG.

Some design principles such as modularity, robustness, usability and performance are critical for successful implementation of RG. The hardware and software architectures need to be modular i.e. specific hardware interfaces and software APIs should be designed to facilitate customisation such as adding or removing of components. As the RG should be "always on" to provide instantaneous information access from both inside and outside the home, the RG should be based on a low-power and high-performance integrated processor. Users should be able to quickly install the RG and get it up-and-running in a "plug-and-play" fashion with the necessary processing power to perform all required functionality. The RG should also provide

capabilities such as network address translation (NAT), dynamic host configuration protocol (DHCP), domain name service (DNS), firewall, support for VPNs and audit features to maintain a trail of system activities as part of the architecture requirements.

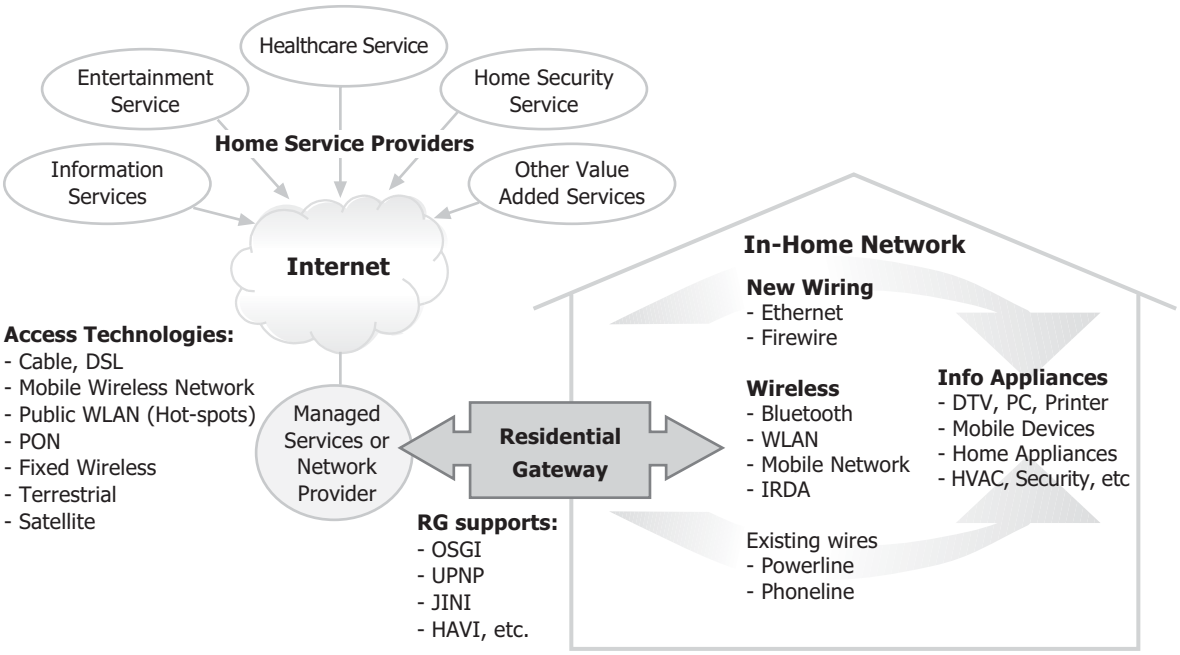


Figure 4. An Overview of a Residential Gateway Services & Applications Delivery

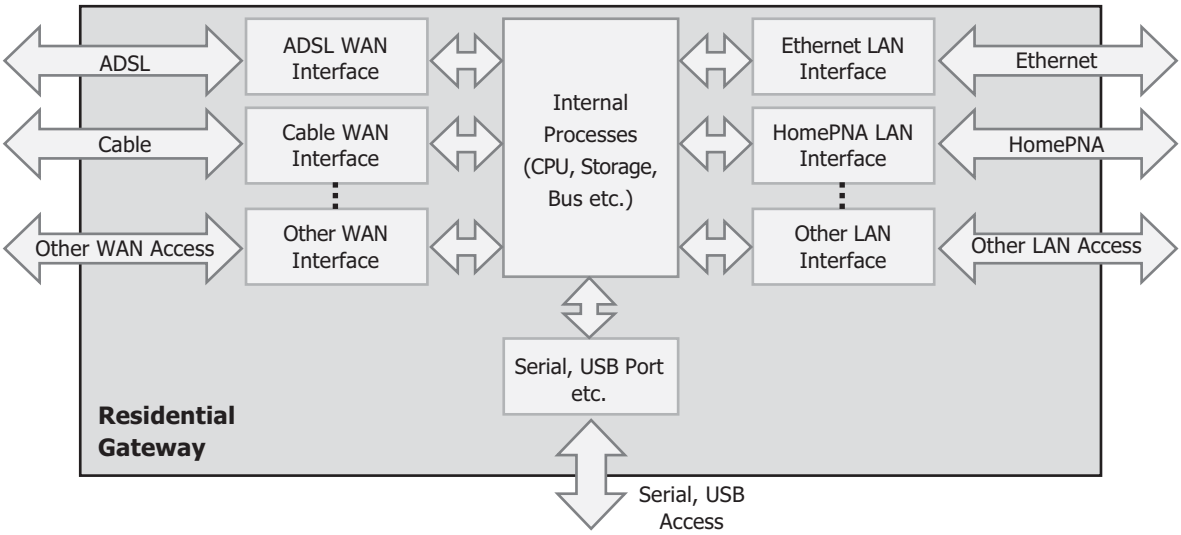


Figure 5. Typical Hardware Architecture of a RG

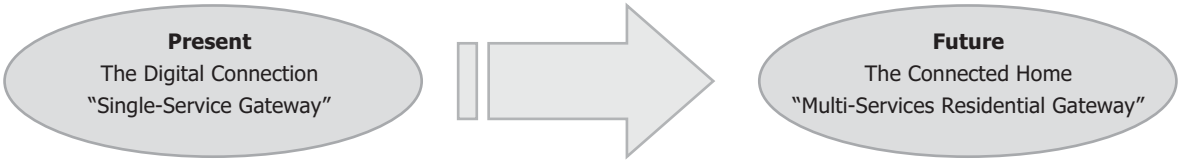
3.2 Evolution of The Residential Gateway

3.2.1 Single-Service RG

Single-service RGs are basically data-centric. They contain router functionality and provide support for LANs within the home. Single-service RGs may be tied to either a specific access technology (such as ADSL or cable modem) or multiple access technologies. In the former, a broadband modem is typically integrated into the RG. Another single-service RG is the digital STB. We will see the proliferation of these boxes as more cable operators upgrade to digital headend in 2003. This box delivers high quality digital TV programmes to home, either via satellite or cable. The digital set-top box is also capable of connecting to the home area network using Bluetooth, 802.11b or HomeRF technology.

3.2.2 Multi-Service RG

There is a trend towards multi-service RGs. These RGs can be differentiated from their single-service counterparts by their inclusion of voice, data and/or telemetry support and an intelligent service framework. Like single-service RGs, multi-service RGs can also provide support for either single (e.g. advanced set-top boxes, media servers) or multiple access technologies (e.g. a whole-house gateway). In some cases, RGs may primarily take the form of telemetry devices, such as an automatic energy metering for example. The connected home will eventually see a converge gateway that could deliver more than one service to consumers. This will provide a good revenue for service providers who could bundle value-added services using an open end-to-end multi-service gateway. However, it is likely that we will not see mass market deployment of these gateways before 2004.



2001 to 2003
Providing high-speed 2-way data access to home
- Cable modem
- ADSL modem

Providing digital TV program
- Digital Set-Top Box
- Digital Video Recorder

2004 to 2007
A Converged Gateway enabling multiple services around the home
- Advanced STB,
- Home Media Servers
- Entertainment Gateway
- Telemetry Gateway
- Home Gateway integrated with Voice, Video & Data

Figure 6. Evolution of the Residential Gateway

3.3 Standard Development

3.3.1 Open Services Gateway Initiative (OSGI)

OSGI (www.osgi.org) is an alliance formed in March 1999 to establish a specification for an open service gateway. The alliance includes companies such as Sun Microsystems, IBM, Ericsson, Lucent and Motorola.

The OSGi specification is a Java-based application layer framework that provides service providers, network operators, device makers and appliance manufacturers vendor-neutral application and device layer APIs and functions to deploy a variety of services. Its key goal is to enable the delivery of multiple services over wide area networks to LAN, and then from the client/gateway to a device on the home network or a local network such as a telematics-enabled automobile. The idea is to focus on a complete end-to-end solution architecture from remote service provider to local devices.

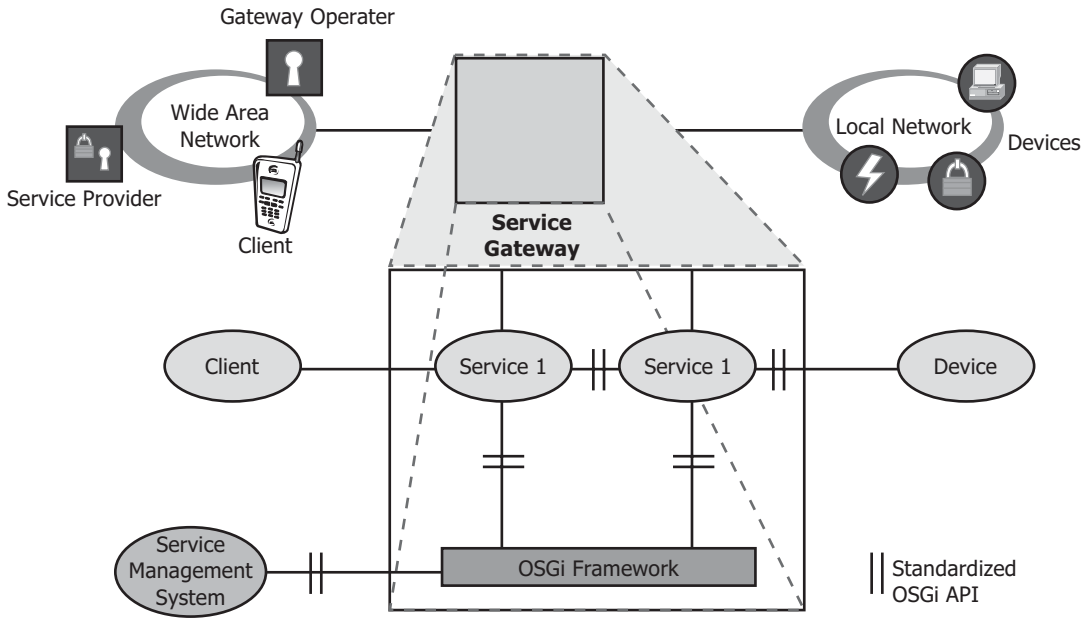


Figure 7. OSGI Service Delivery Framework
(Source: OSGI)

The central component of OSGi specification is the Services Gateway (SG) that functions as the platform for many communication-based services. The SG will enable, consolidate and manage voice, data, Internet and multimedia communications to and from the home and small

office. The SG will also function as an application server for a range of other high value services such as energy measurement and control, safety and security services, healthcare monitoring services, device control and maintenance, electronic commerce services and more. The OSGi specification focuses on service implementation and is designed to be compatible with the various networking technologies such as Bluetooth, CAL, CEBus, Convergence, emNET, HAVI, HomePNA, HomePlug, HomeRF, Jini technology, LonWorks, UPnP and VESA.

Technically, the SG may be integrated in whole or part in existing product categories such as set-top boxes, cable modems, routers, residential gateways, energy management systems, consumer electronics, PCs and more. Services are delivered from trusted Service Providers on the external network and are delivered to the SG or internal clients. The SG is targeted to be a zero-admin device.

The first specification was released in May 2000. Three specific services were defined. The first is the "log service", which is where service bundles can send events through the gateway. The second is the device access, which defines how a device on the network can be incorporated into the service framework. The third part of the specification is the HTTP server, which allows the embedded OSGI server to create web pages for those devices connected to the platform. In October 2001, OSGI released Service Platform Release 2[17], which improves upon the service delivery by both clarifying and simplifying the service bundles defined in OSGI 1.0. OSGI has also been actively promoting the availability of development toolkits through third party vendors as part of the effort to accelerate new service offerings. Six companies have announced the availability of developer toolkits: Acunia, Espial, GateSpace, IBM, ProSyst and Sun Microsystems.

OSGI prospects appear bright for now. There are more than 11 products implemented based on OSGI and 22 OSGI Service Platform Release 2 deployment as of May 2002[18]. The alliance has a good mix of participants from many different market segments such as service providers, networking companies, STB suppliers, consumer electronics vendors, device vendors and software application vendors. More RG products are anticipated to be incorporated with OSGI. We believe service providers such as utility companies, telephone companies, and broadband providers would be interested in deploying systems based around OSGI technology for applications such as home surveillance, energy management and personal healthcare applications. OSGI will also further its specifications to support the automobile industry for telematics applications.

17 Organisations that have worked together to deploy Release 2 products in the residential space include HomeDirector, Echelon, ProSyst, Telia, Sun, Gatespace, MetaVector, P&S, Ciaolab, Electricité de France, France Telecom and Ericsson.

18 OSGi Implementation & Deployment Fact Sheet, May 2002

3.3.2 HomeGate

ISO (International Organisation for Standardisation) and IEC (International Electrotechnical Commission) have proposed a residential gateway model for home electronic system. This model is called HomeGate, defined as the connection between a WAN and an in-home LAN. HomeGate's functions include WAN termination, protocol translation, resource arbitration, firewall security, and privacy assurance. Working Group 1 of ISO/IEC JTC1/SC25 developed the first specification of HomeGate in October 1998. The working group has been seeking comments by developers of residential and commercial gateways. The HomeGate specification will eventually become part of a new standard under development, entitled 'Interconnection of Information Technology Equipment.'

The HomeGate standard is designed to interoperate with the OSGI specification (see following section). The proposed HomeGate standard will be circulated among the participating member nations of ISO/IEC JTC1/SC25 for comment and ballot in Q3 2002. Barring any serious objections, HomeGate should become a standard in 2003.

3.3.3 CableHome

CableHome is an initiative that was set up in 2000 by Cable Television Laboratories Inc (CableLabs[19]) in the U.S. This organisation aims to create an open, interoperable interfaces that will enable users to extend the features of DOCSIS, PacketCable and OpenCable standard across the home network.

CableHome addresses cable Multi-Service Operators (MSOs) need to provide broadband services from their cable plant into the home area network, using wireline and wireless technologies. The CableHome technical specification is summarised in Table 5.

CableLabs has completed and published the first CableHome 1.0 specifications in April 2002. Compliance Test Plan (CTP) development is currently in development and the first CableHome Certification Wave is expected to begin Q4, 2002.

19 CableLabs (www.cablelabs.com) – An industry organisation comprises of cable operators from North and South America

Functionality	Existing Product Features	CableHome 1.0 Feature	Value
Network Management	Console, Telnet, Web- based, UPnP	SNMPv3	• Remote configuration and management • Proactive event reporting
Device Provisioning	Unmanaged DHCP	SNMPv3, Managed DHCP	• Zero config for residential gateway
Address Translation	Unmanaged NAPT	SNMPv3, Managed NAPT & NAT	• MSO manageability and visibility • Support for popular apps • Eliminate unnecessary traffic on HFC
Secure Software Download	None or Firmware	Secure Software Download (DOCSIS 1.1)	• Remote device functionality upgrade • Upgrade to firewall policies
Security/ Firewall	None or weak/No Firewall	Medium Security/Policy file Download	• Secure Management & Firewall
QoS	None	Supports PacketCable Telephony	• Ensures Packetcable QoS Signaling

Table 5. Summary of CableHome Technical Specification
(Source: CableLabs)

3.3.4 TIA/EIA/TSB-110

The TIA (Telecommunications Industry Association) TR-41.5 committee has attempted to create specifications for a centralised gateway device that includes the following features:

- The physical interface to terminate all external access networks to the home, with multiple sresidential services being delivered over each type of access network

- The enabling platform for residential services to be delivered to the consumer, for example, telephone, television, and data networking, or the termination point of internal home networks

The proposed standard is called TIA/EIA/TSB-110. It was originally referred to as a multimedia premises reference architecture. The RG standard is still in development and has been slow. TIA TR41.5 defines the residential gateway as a device that resides in the home and architecturally sits between the home network and the service provider. The standard is meant to interoperate with the Open Services Gateway Initiative specification (see following section).

There have been no updates to this standard since Dec 1999, and no further updates are expected as well.

3.4 Worldwide Activities on RG

The following are examples of some trials and showcases where the RG plays a key role:

- **E2 Home** (www.e2-home.com). E2 Home is a project involving a condominium estate (Ringblomman 1) in Stockholm, Sweden. It consists of 59 apartments built by Skanska. Residents have access to e-mail, the control of electricity, water and heat consumption, the front door security camera, online booking of common amenities, ordering of food that can be easily delivered in the smart delivery boxes next to the outer door. These services accessible from a touch screen home terminal in kitchen. The IT services and interfaces are based on OSGI specification. The e2Home solution focuses on security, simplicity and the ability to add new applications as family needs grow. Occupation of the E2 Home began moving in on February 2002.

- **Telia Connected Home**[20] (www.telia.com). This trial started in November 2001 in Stockholm. In this trial, no RG is placed in the home – it is instead placed within the telco's (i.e. Telia's) network. The OSGI RG is currently being used to enhance connection-oriented services, such as the measurement of service usage. It is claimed that this approach of situating the RG within the network provides both security and scaling advantages. This trial is a collaboration between Skanova and Telia Research. The RG is built using Sun and Gatespace technologies.

- **OpenPLANET.** (www.openplanet.co.jp) OpenPLANET technology by Shikoku Electric Power Company of Japan enables the remote control and monitoring of any device in the home. The RG consists of a typical electric meter embedded with OpenPLANET server software. With embedded microchips, devices/white goods in the home can be monitored or controlled. Existing devices/white goods can be integrated with the system using an external adapter. Java Virtual Machines duplicate the features and functions of actual devices/white goods, and can be transferred to any controlling device for remote control. At the backend, a Service Centre maintains the system and ensures system security (e.g. operates firewall). Field test scenarios include elder care, grocery delivery and energy management. Trials of the system began in October 2000; it is slated for system performance review in 2002.

20 Press release, 23 November 2001 - Delivering Services via a Gateway in the Network. More information can be obtained from IEEE Communications magazine, April 2002 Vol. 40 No. 4, Telia's Service Delivery Solution for the Home.

3.5 Challenges

From the implementation perspective, one of the biggest hurdles to deploy the residential gateway is the cost of installation and maintenance. It is also unclear how the RG will initially be installed at a consumer's home. Consequently, who bears the installation cost is yet to be determined. From the technology perspective, the RG may seem like a complex device to manage within the home. Although the RG concept is based on a seamless integration of the access networks with the in-home network, the details as to how this would be accomplished are still being developed. This transparency will be critical in gaining consumer acceptance of the RG.

Another major obstacle is the lack of consumer awareness of the residential gateway concept. It is in a technology push phase and not a market pull phase. To successfully market this concept will require consumer education on the benefits and needs for a RG. An impediment that impacts service providers and equipment manufacturers is the lack of standardisation. Interoperability and QoS issues are the main challenge to successfully deploy multi-service RG with features such as PKI for security, pay-per-use charging etc. There are multiple ongoing standards efforts, and discussions on integrating these efforts are still not addressed. Other issues include digital rights management (DRM) in the distribution of digital contents via RG. The lack of innovative services that come bundled with the multi-service RG could also dampen demand for the RG.

4 Device Connectivity

Smart platform in the home enhances its value and functionality through interconnection on the network. As homes are beginning to be populated with a wide array of networked-ready consumer electronic (CE) devices and platforms, there is a growing impetus for multi-device connectivity. We will highlight two important technologies that have gained widespread acceptance by the CE industry, namely, Universal Serial Bus (USB) and IEEE-1394 (commonly known as Firewire). HAVI has also emerged as an important middleware in ensuring interoperability between multiple entertainment equipment from different manufacturers. A critical requirement of network devices is to ensure ease of installation and usage for consumers. Plug and Play feature is therefore critical for user acceptance and adoption. One of the key developments in network plug and play is the service and device discovery technology such as Universal Plug and Play (UPnP), Simple Control Protocol (SCP) and JINI. DVB-MHP has also evolved to become an open middleware standard for interactivity. We will discuss each of them in the following sections.

4.1.1 Universal Serial Bus (USB)

USB was developed by Compaq, DEC, IBM, Intel, Microsoft and NEC, to provide an intelligent serial bus for low to mid-speed peripherals. It provides an expandable, plug and play serial interface that ensures a standard, low-cost connection for peripheral devices such as keyboards, mice, joysticks, printers, scanners, storage devices, modems, and video conferencing cameras, allowing up to 127 devices to run simultaneously on a computer.

USB eliminates the need to install new cards to the internal bus and reconfigure the system. It is host-centric, which allows the host PC to detect when a USB device is added or removed allowing new peripherals to be configured automatically upon attachment without the need to reboot or run setup. The bus will automatically determine what host resource (including driver software and bus bandwidth) each peripheral requires; those resources are made available without user intervention. This will eliminate much of the confusion encountered when installing new devices, along with providing a universal bus for connecting most peripherals to a system.

USB 1.0 was first released in 1996 and it was followed by USB 1.1 in 1998. Today, USB connections conforming to both version 1.0 and 1.1 can be found in a range of devices, from PC cameras to scanners, printers, digital camcorders and digital modems. In 2000, the USB 2.0 specification was released and is poised to continue the success of the USB standard as it offers 40 times the speed of USB 1.1 and backward compatibility with USB 1.1.

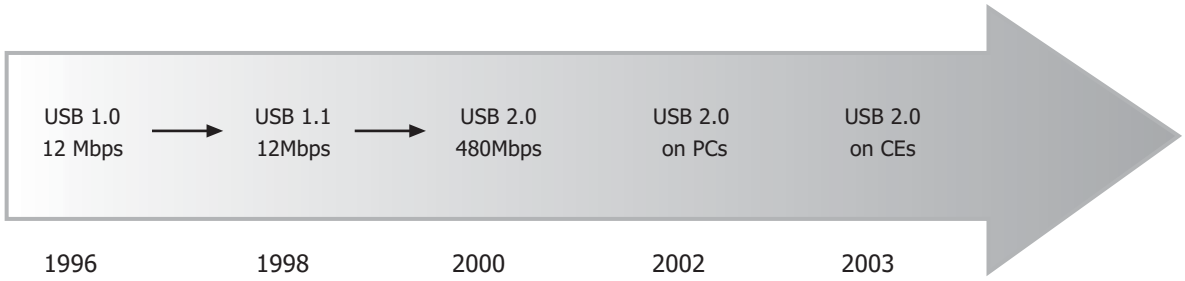


Figure 8. USB Evolution

USB 2.0 extends the speed of the connection from 12Mbps (on USB 1.1) up to 480Mbps, providing an attachment point for next-generation peripherals which complement higher performance PCs and user applications. Leading the development of USB 2.0 are four members of the original USB core team (Compaq, Intel, Microsoft, and NEC), and three new members (Hewlett Packard, Lucent and Philips). To date, USB 2.0 is the latest standard and there has been no announcements of new USB standards.

USB has been the most successful interface for the PCs. It has effectively achieved universal support in the PC market, and is gaining a growing share of the PC peripheral and consumer electronic device markets. In-Stat/MDR has predicted that by 2004, there will be 750 million USB equipped PCs and peripherals in use. USB 2.0 is only available in a limited range of home products and we expect PC and peripheral devices to be the first to adopt it, followed by consumer electronics such as digital camera and camcorder. PC manufacturer such as Gateway has already released many of its products with this new standard in 2002. Dataquest expects that 95% of all new desktop and notebook PCs will support USB 2.0 by 2003.

4.1.2 IEEE 1394

IEEE 1394 is an affordable, scalable, flexible and easy to use digital interface standard that can integrate the consumer electronics devices and personal computers. The IEEE 1394 standard defines a backplane physical layer and a point-to-point cable-connected virtual bus implementations. The backplane version operates at 12.5, 25 or 50Mbps, while the cable version supports data rates of 100, 200 and 400Mbps. These two versions are compatible at the link layer and above in the OSI model. Because of IEEE 1394's high bandwidth and the fact that it has "hot plug-and-play" capability, it is the preferred interface for external hard drives, digital audio and video devices, home theatre system and other high-speed peripherals.

The average Audio Video setup, especially the home theatre, entails complex cabling as it usually requires each component to be physically connected to a range of components leading to a complex array of cabling behind such components lying around in the home. Moreover, such conventional cabling systems are prone to error due to their complexity and they are thus very effort intensive. The advantage of IEEE 1394 in the home network here is obvious especially when each component need only be daisy chained or connected to the next in a linear manner.

IEEE 1394 specification was first conceived by Apple Computer (known as Firewire[21]) in 1986 and later developed by the 1394 TA (Trade Association) in 1994. It was eventually standardised by the IEEE 1394 Working Group as High Performance Serial Bus (IEEE 1394-1995) in 1995. An examination of the IEEE 1394-1995 standard by members of the personal computer industry later concluded IEEE 1394-1995 does not provide adequate guidance for how power is to be provided, used, or managed. This has led to further revisions of this standard with IEEE 1394a-2000 being released in 2000, operating at speeds of up to 400Mbps and supporting both isochronous and asynchronous data transfers.

A new specification IEEE 1394b was introduced in 2001 to extend the current standard's specification. IEEE 1394b maximum throughput is expected to double to 800Mbps with capabilities to go to 1.6Gbps. In the next few years, with the use of optical fibre, the IEEE 1394b standard would extend its throughput to 3.2Gbps. The transmission range is further extended from 4.5m to 100m for longer reach. The specification also improves the overall manageability of the network, with features such as the ability to work correctly even if the user accidentally creates a loop in the bus. IEEE 1394b is backward compatible with the current IEEE 1394a-2000 and as such, is expected to replace the current standard soon.

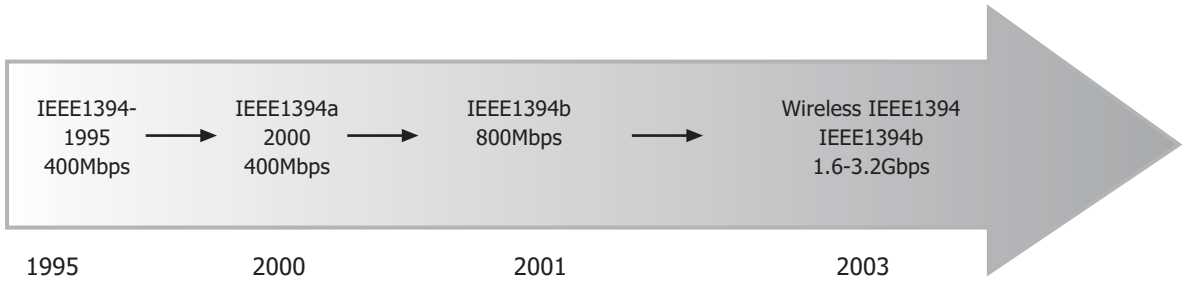


Figure 9. IEEE 1394 Evolution

21 Firewire has since been synonymous with IEEE 1394 and can be used interchangeably.

The IEEE 1394 market can be divided into CE and PC sectors. IEEE 1394 is poised to play a key role in CE device connectivity as industry leaders such as Sony, Cannon, Kodak, and JVC have adopted it as the preferred interconnect between digital consumer devices. Industry analysts are predicting a huge surge in IEEE 1394 adoption in the next few years. According to In-Stat/MDR, the total number of CE devices using IEEE 1394 interface will reach 200 million units by 2003. We expect IEEE 1394 to be implemented in all advanced digital CE products such as digital television, digital video recorders and home media servers in the near future. This can be seen from the OpenCable specification (from US-based CableLabs) that requires IEEE 1394 connector on all new digital set-top boxes.

IEEE 1394 is also beginning to emerge as a standard in PCs connectivity, along with the USB. This is especially evident in notebook computers compared to PCs because the overheads for notebook computers are higher, allowing them to be able to absorb the higher cost of these interfaces. The current trend is that USB and high speed serial ports are the standard for slower devices on PCs and that IEEE 1394 is slowing becoming the preferred standard for more multimedia applications. Since 2001, the PCs have increasingly been shipped with IEEE 1394. In-Stat/MDR projected that there will be 112 million IEEE 1394 equipped PCs and peripherals in use by 2004.

IEEE 1394 is also making inroads in the wireless space. There are currently three prominent wireless 1394-based efforts: 1394 Trade Association WWG (Wireless Working Group), MMAC-PC (Multimedia Mobile Access Communication Promotion Council) in Japan and the ETSI/BRAN HiperLAN/2. Each is engaged in addressing issues associated with implementing 1394 over a wireless transport. For example, the 1394 WWG operates under the procedures of the 1394 TA is currently developing implementation guidelines for Wireless 1394. This is done by implementing IEEE 1394 as a Protocol Adaptation Layer (PAL) on top of the IEEE 802.11 radio hardware and Ethernet protocols. To achieve this, the WWG will develop a Common Architecture Layer (CAL) specification that enables the creation of a PAL specification and its associated Protocol Interface Layer (PIL). The PAL and PIL define a standard method for implementing 1394 over 802.11. The CAL establishes a specific set of 1394 requirements that must be met in the PAL and PIL. The WWG PAL project will produce a standard specification where OEMs can refer when implementing a 1394 wireless bridge to a PC Ethernet 802.11 WLAN.

In Japan, Wireless 1394 is now being standardised by the Telecommunications Advancement Organisation (TAO) and the MMAC-PC, for which the name of Wireless Homelink is given. Wireless Homelink can transmit from 30 to 100Mbps using 5/25/40/60GHz radio frequency bands .It is targeted for PCs and Audio/Video equipments to support multimedia applications. On the other hand, HiperLAN/2 has being studied in the ETSI project – BRAN, including its extension for home-oriented services. Physical layers of the Wireless 1394 and HiperLAN/2 are compatible so that the coexistence becomes possible (refer to section 2.2.2 for more information on HiperLAN/2).

4.1.3 Home Audio-Video Interoperability (HAVI)

HAVI[22] is a digital Audio/Video networking initiative set up to provide a standard open architecture to allow intelligent audio and video devices to work with one another, regardless of the fact that these devices may come from different manufacturers and have different hardware and software. The purpose of HAVI is to coordinate technical development and ensure compatibility of Audio/Video IEEE 1394 applications of different vendors. On top of defining the device architecture, the HAVI specification also defines APIs and device type definitions for IEEE 1394 products. These APIs are platform independent and even describe specific products such as modems, amplifiers, tuners and clocks among others. HAVI is language neutral and it can be implemented in devices using any programming language, CPU or Operating System. This means that developers can write Java applications for devices, using the APIs provided by HAVI.

HAVI is essentially a networking middleware that focuses on the control and content of digital Audio/Video streams while providing support for digital copy protection. HAVI software takes advantage of the powerful resources of chips built into modern audio and video appliances to provide management function of a dedicated audio-video networking system. The HAVI specification allows IEEE 1394 devices to share information and interoperate within a Plug and Play environment without the need for a PC. Each appliance added to the network automatically installs its own application and interface software. The complexity and sophistication has been built into the products and its power is harnessed to work behind the scenes, so that control is simple for the user. HAVI has standardised the APIs of the most common AV functions.

The specifications for HAVI version 1.0 were published in December 1998. In 2000, HAVI made available an amended version of 1.0 specifications to include IEEE 1394 as its underlying digital interface. Since then, HAVI version 1.0 has been the accepted standard and is adopted by a number of manufacturers. Probably the most important aspect of the amendment is the added security to protect itself against viruses and rouge applications. The Java bytecode has been selected as the standard format and connectivity with external networks incorporated. Other features that have been added are event scheduling, which allowed for programmed recording and standard programming interfaces that are used to control device functions. In May 2001, HAVI released specifications for version 1.1, which was built on the specifications of version 1.0 network applications and further defining the applications' behaviour.

The next phase of HAVI development is to connect HAVI to other networks, especially the Internet. This would allow HAVI-enabled appliances to be remotely controlled by any Internet

22 HAVI (www.havi.org) was formed in 1999 by 8 major electronics manufacturers, Grundig, Hitachi, Matsushita Electric (Panasonic), Philips, Sharp, Sony, Thomson multimedia and Toshiba.

enabled device such as the PDA, through its Internet browser. Research is being conducted in this area whereby, a Messaging System Proxy encodes HAVI messages into Extensible Markup Language (XML) and SOAP (Simple Object Access Protocol) and these messages are then sent through the Internet using HTTP. On receiving these XML and SOAP messages, they are then converted to HAVI messages.

4.1.4 Universal Plug and Play (UPnP)

The Universal Plug and Play Forum (www.upnp.org) is an industry initiative set up in June 1999 to accelerate the development of distributed networks for PCs of all form factors, Internet-centric computing devices and other standalone devices. The goals of the forum are to enable pervasive and easy peer-to-peer device connectivity and to simplify the implementation of networks in the home and corporate environments. To achieve this, the Forum defines and publishes UPnP device control protocols built upon Internet-based communication standards.

UPnP is a distributed, open networking architecture that uses TCP/IP and HTTP to enable peer-to-peer networks to allow for control and data transfer among networked digital devices in the home and office. Based on the Microsoft's defined common device architecture, it emerged as a counter to Sun's JINI, as a way to let devices find and operate with one another on the network.

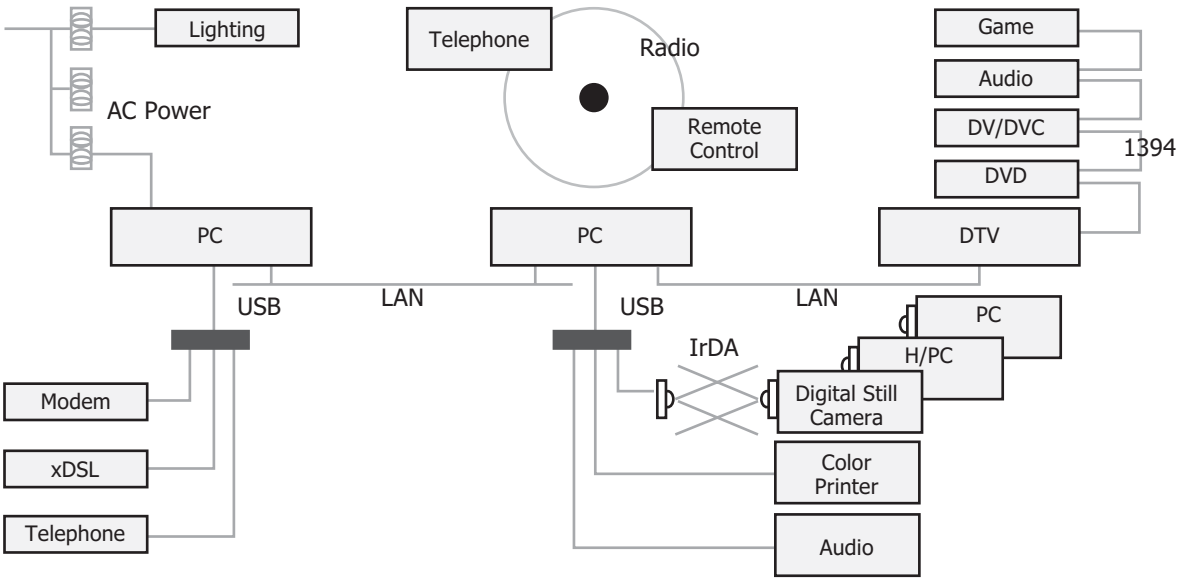


Figure 10. A Mixed Media Multiple Vendor Network
(Source: Microsoft)

The UPnP Device Architecture defines a schema or template for creating device and service descriptions for any device or service type. Individual working committees subsequently standardise on various device and service types and create a template for each individual device or service type. Finally, a vendor fills in this template with information specific to the device or service, such as the device name, model number, manufacturer name and URL to the service description. This data is then encapsulated in the UPnP-specific protocols defined in the UPnP Device Architecture document (such as the XML device description template). The required UPnP specific information is inserted into all messages before they are formatted using Simple Service Discovery Protocol (SSDP), General Event Notification Architecture (GENA), and SOAP and delivered via HTTP, HTTPU, or HTTPMU.

The architecture defines a set of common interfaces that allows a user to plug a device directly into the in-home network. In other words, a user can begin using a new device without worrying about configuration settings and installing new drivers. UPnP was developed within the context of existing industry standards. For instance, UPnP provides developers with a common set of interfaces for accessing services on a home network. Another advantage is that UPnP does not depend on any particular operating system, programming language, or physical medium. UPnP interconnects all types of devices in the home, including PCs, PC peripherals, new smart home appliances, gateway devices, home control systems, and web-connected devices.

Other features of UPnP include zero-configuration networking and automatic discovery. With such features, devices can dynamically join networks, obtain their IP addresses, announce their names, convey their capabilities upon request, and learn about the presence and capabilities of other devices. Furthermore, devices can leave a network smoothly and automatically without leaving any unwanted state behind. UPnP leverages on standard Internet components such as IP, TCP, UDP, HTTP, and XML, enabling it to fit seamlessly into existing networks.

UPnP discovers devices on the IP network using SSDP and device control is possible through XML. The UPnP architecture allows non-UPnP devices to utilise proxies to expose these devices to non-IP based networks. UPnP provides support for communication between control points and devices. The network media, the TCP/IP protocol suite and HTTP provide basic network connectivity and addressing needed. On top of these open, standard, Internet based protocols, UPnP defines a set of HTTP servers to handle discovery, description, control, events, and presentation.

The current version of UPnP is version 1.0, which was based on the original specification that was completed in 1999. In its efforts to go web services, Microsoft has introduced version 2.0, which would allow it to work with its .Net services. UPnP 2.0 has additional features such as:

- Scalability improvements to reduce traffic;
- Addition of data types such as structures and arrays;
- Improvement in the handling of options and extensions;
- Named events with arbitrary data returned;
- Supports IPv6.

Architecturally, UPnP 2.0 has taken on the following directions:

- Addressing. Optional support for IPv6 with rules for selecting between IPv4 and IPv6;
- Discovery. Scalability is improved and simplified with use of standard features and a more enterprise friendly environment;
- Description. UPnP Template Language is replace with WSDL (Web Services Description Language) and XDR (XML Data Reduced, an XML schema language) is replaced with XSD (XML Software Description);
- Control. New argument types to match data types;
- Eventing. GENA is replaced with SOAP-based mechanism;
- Presentation. Few changes were made here.

The inclusion of these features is substantial and would require changes to the architecture of version 2.0 to such a point whereby version 2.0 is no longer backward compatible with version 1.0. However, this new standard is considered to be at least 2 to 3 years away.

A number of companies, including Intel, Linksys and NetGear have indicated that they will support UPnP in their future family of home networking devices such as home gateways. Microsoft is shipping their XP and Windows Me with UPnP. The first UPnP devices have already been certified and already hitting the shelves. However, although there is some initial movement in the UPnP space, the industry is still slow in adopting the standard, with not many hardware vendors implementing UPnP specification into their products. Furthermore, there appears to be confusion in the marketplace, with the new version 2.0 being promoted even before version 1.0 has been fully adopted by vendors.

4.1.5 Simple Control Protocol (SCP)

Simple Control Protocol (SCP) is a lightweight networking protocol that is used for devices with low memory and processing power and for networks with low bandwidth. It was announced in June 2000 by Microsoft. SCP extends the capabilities of UPnP into small devices with very low processing power and limited memory. SCP devices interact with one another in a peer-to-peer manner, without the need for a PC. However, SCP differs from UPnP in that it does not operate with TCP/IP. Thus the SCP network of devices will need a PC to interoperate with UPnP devices.

SCP basically manages communication and control. Being a simple protocol which lets a server and client have multiple conversations over a single TCP connection, the key feature of SCP is dialogue control, which allows either end of the connection to establish a virtual session over a single transport connection. Other features of SCP include indicating message boundaries and rejecting incoming sessions. SCP, when used with UPnP, will allow consumers to control the devices of their entire home from one network. These devices can be of any type, from the simplest smart devices, to the most sophisticated consumer electronic devices. This can be done, for instance, by having a PC that connects to both UPnP and SCP networks that runs software connecting these different environments together. Additionally, SCP devices will use standard UPnP device models, giving seamless interoperability between UPnP and SCP devices and this leads to seamless services on networks of any media type. Due to this close relationship between SCP and UPnP any SCP device is assured to be Internet ready.

SCP is considered a major breakthrough for the home control industry as it can be used in conjunction with existing CEBus-based standards, allowing for a smooth technology transition. Devices that can benefit from SCP include lighting, home security and automation devices, and other small appliances that cannot support TCP/IP networking. As existing standards gets converged into SCP, confusion in the marketplace could be resolved.

Itran, Mitsubishi, and Domosys are currently actively developing SCP-enabled power line carrier networking chips. For instance, Domosys is providing tools and support services to developers and manufacturers intent on integrating SCP and UPnP into their devices. Mitsubishi is involved in a project, which aims at integrating SCP/PLC technologies with Mitsubishi M16C processor to develop a chip that can be supplied to device manufacturers at a very low cost. Itran, in partnership with Microsoft, has unveiled its first SCP based chipset for carrying control and networking signals over household electrical wiring. In conjunction with Microsoft, Itran will release an SCP developer kit by end 2002. Microsoft is shipping SCP with Windows Me and XP.

4.1.6 JINI

The Jini technology[23] was introduced by Sun Microsystems in 1999 as an architecture for a distributed network system of autonomous devices to be aware of one another and cooperate if necessary. The overall goal is to turn the network into a flexible and easily administered tool on which resources can be discovered and looked up by other devices on the network.

The Jini technology provides mechanisms for devices, services and users to join and detach from a network in an automatic and dynamic manner. It uses the term "federation" to refer to

23 More information of Jini technology can be obtained from www.jini.org and www.sun.com/jini/index.html

the concept of a group of devices, services and software components (i.e. members of a Jini system) co-operating in a single and dynamic distributed system.

The Jini architecture centres on the concept of services. A service is a functional entity that can be used by a person, a program or another service. A service may be a computation, storage, a communication channel to another user or service or a hardware device. Members of a Jini system federate in order to share access to services. There are defined mechanisms for service construction, lookup, communication and use. Examples of services include devices such as printers, displays or disks; software such as applications or utilities; information such as databases and files; and users of the systems.

Jini attracted early partners such as Whirlpool, but has not been adopted by many industry players since 1999 and has not been experiencing much success in Jini-embedded device adoption. Sun has made Jini open source, allowing other manufacturers to implement Jini licence free, thus enabling manufacturers to freely use the technology. Sun is currently not actively pursuing Jini within the Connected Home space.

4.1.7 DVB-MHP

MHP defines a generic interface between interactive digital applications and the terminals which those applications are executed. The standard enables the digital content providers to address all types of terminals ranging from low to high-end set-top boxes, interactive digital TVs and multimedia PCs. With MHP, DVB extends its successful open standard for broadcast and interactive services in all transmission networks including satellite, cable, terrestrial and wireless systems.

The MHP platform is based on Java Virtual Machine, an Application Manager (or Navigator), for navigating through the system and applications, and a set of Transport Protocols that enable the reception of the DVB video and audio broadcast.

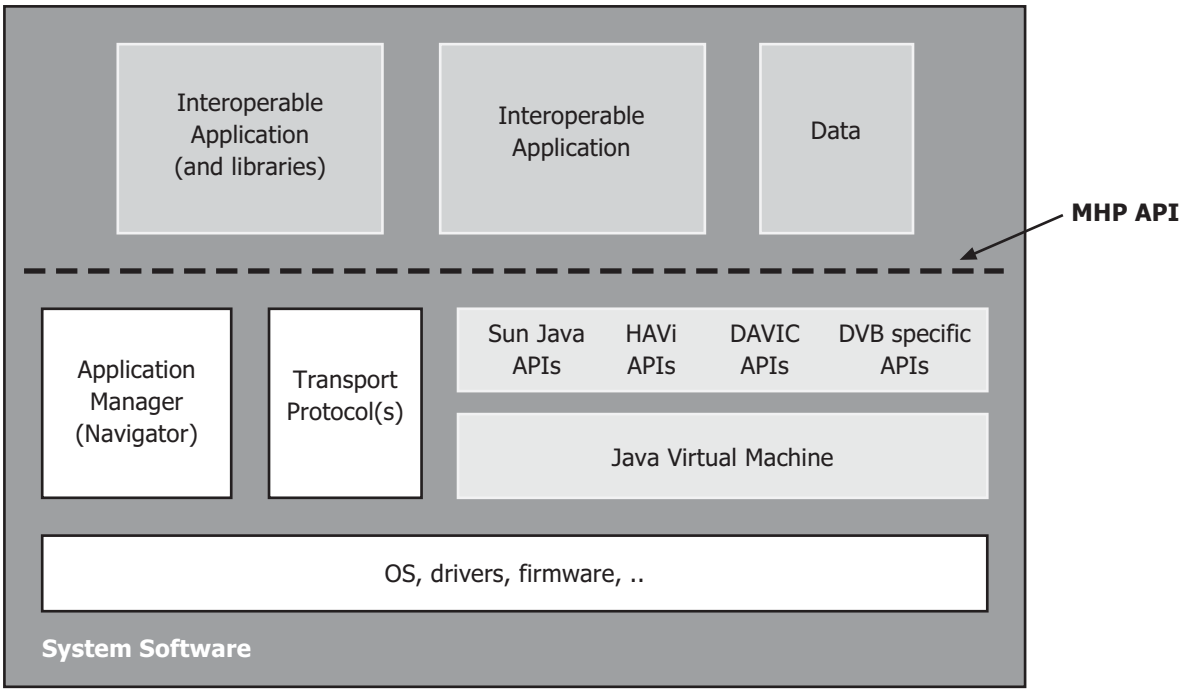


Figure 11. MHP Architecture
(Source: Nokia)

On top of the Java Virtual Machine a combination of several Application Programming Interfaces (APIs) forms the combined MHP API. These APIs include the Sun Java APIs (including JavaTV), the HAVI APIs for the graphical user interface, the DAVIC APIs and the DVB specific APIs that allow the access to audio and video. On top of the MHP API it is then easy to develop multimedia applications independently from each other and independently from the target hardware in the equipment. This allows wider flexibility in the content creation. Also, as the Java Virtual Machine, and the Internet with HTML, is so well known software platform it is much easier to find capable software developers for MHP than for the existing proprietary platforms.

The completion of the MHP test suite (version 1.0.2a) in July 2002 allows MHP conformance testing to begin and the first DVB-MHP receiver is expected to launch in Germany and Scandinavia in Q4 2002. For MHP 1.1 the specification has been defined and released as an ETSI standard. However, interoperability tests are currently unavailable. MHP 1.1 includes the Internet Access profile, which essentially states that an Internet Access MHP should include a Web browser and e-mail client, along with ways to go to and from interactive TV. The next generation of MHP technology, MHP 2.0, is under discussion and definition by the DVB Consortium. This specification is intended to include intelligent personal video recorder (PVR), home networking, mobility and broadband content capabilities.

5 Home Applications & Platforms

Infotainment, which includes technologies for computing, communication, information and entertainment promises to transform our lifestyles. Increasingly, smarter infotainment-related products are permeating into households, delivering better performances and functionalities.

- Entertainment platforms such as digital television, home media server, personal video recorder are getting smarter with software/middleware enhancement to manage user contents. Home platforms and appliances have also improved significantly in computing power, as well as in network connectivity to allow the sharing of resources;

- Mobile devices are also alternative smart devices for the home space. User interface for these devices will improve significantly with PAN and Internet connectivity, better display, hand and voice recognition capabilities;

- Wireless home networking technologies are also decreasing in cost and their chipsets are increasingly miniaturised for embedded applications in the smart home;

- There will be increasing challenges to ensure end-to-end connectivity for applications, as not only networking technologies need to be standardised for interconnectivity, but also down to the different types of open and proprietary operating systems in home platforms and devices.

Simply put, the next stage of home platforms and devices will extend the delivery of information to end-users in a smart, organised, real-time manner that enables new kinds of applications more suited to users' time-sensitive needs.

Also, many home applications such as those examples in Table 6 are becoming more bandwidth hungry. We will discuss some emerging applications and their supporting platforms in the following sections.

Application	Min. Speed	Ideal Speed
Near Video on Demand	1 Mbps	7 Mbps
Movies on Demand	1 Mbps	7 Mbps
Digital Television	1 Mbps	7 Mbps
Teleworking	110 kbps	6 Mbps
E-Learning	110 kbps	6 Mbps
Telemedicine	110 kbps	6 Mbps
Videoconferencing	110 kbps	650 kbps
Audio on Demand	110 kbps	650 kbps
Video Telephony	64 kbps	200 kbps
Home Shopping	28 kbps	6 Mbps
Electronic Newspapers	28 kbps	2 Mbps
Telegaming	28 kbps	550 kbps
Electronic Banking	28 kbps	320 kbps

Table 6. Bandwidth Requirements for Selected Applications
(Source: Adapted from Planned Approach Inc & Canada National Broadband Task Force)

5.1 Home Entertainment

The cluster of home entertainment appliances is familiar to most consumers. Traditionally, this group consists of equipment such as television, VCR, Set-top box (STB), CD/VCD/DVD player, hi-fi sets, radio tuners and home theatre system. As technology advances, these appliances are beginning to evolve into digital entertainment platforms, combining IP for internetworking. With broadband at home, more home users are using PCs to download music files from Internet into MP3 players, and sharing with other members of the family and friends. This application has enjoyed much popularity among the internet-savvy users. These users generally keep titles of CDs/VCDs/DVDs and personal/family photos with other information in hard disks for storage and convenience of sharing with friends and relatives.

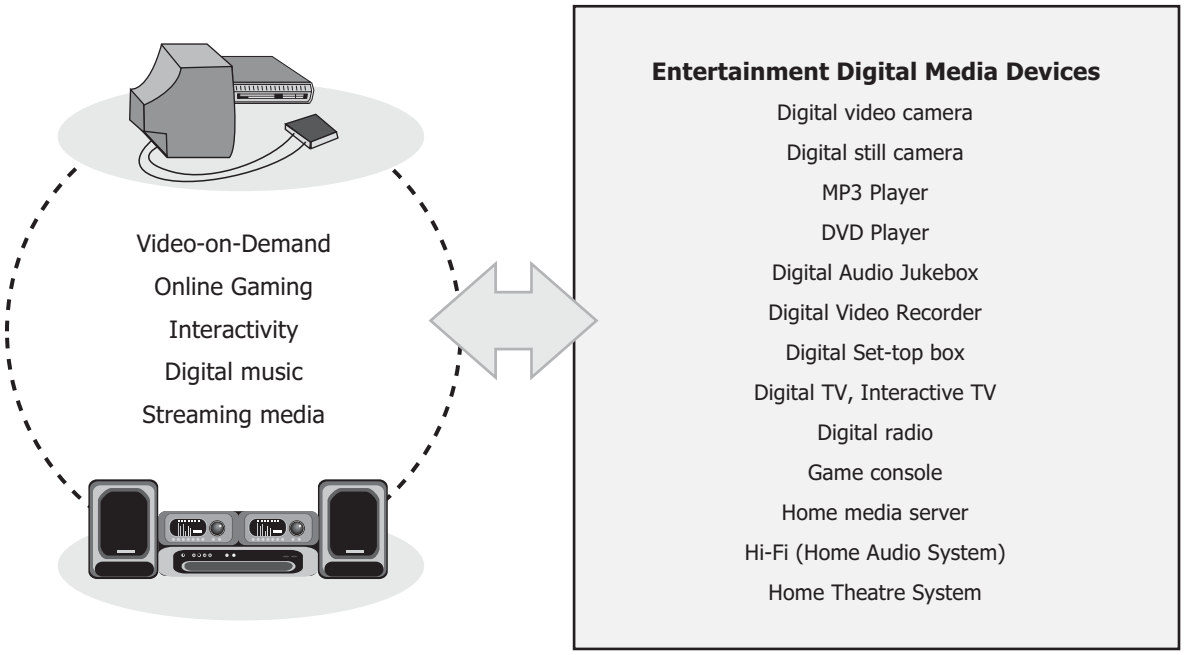


Figure 12. Home Entertainment Cluster

5.1.1 Digital Television (DTV), Set-Top Box (STB) & Interactive TV (ITV)

Digital TV (DTV) can generally fall into three main categories: integrated high definition sets that include a digital receiver and display; digital set-top boxes designed to work with high definition (HD) and standard definition (SD) digital displays (and, in some cases, with current analogue sets); and DTV-capable displays that, with the addition of a digital set-top box, offer a complete DTV system.

Given the huge installed base of analogue TV, the initial development of the digital TV market will focus on the use of set-top boxes to prolong the life of these TV sets. The digital set-top market is expected to reach a plateau by 2010, as the cost of integrated digital TV falls to a point where a replacement set is more attractive to consumers than buying a set-top box.

The launch of digital television services has a profound effect on the market for set-top boxes. In many countries, service providers are retrofitting subscribers' analogue set-top boxes with new digital set-top boxes. Already many set-top boxes deployed today are sophisticated computing devices capable of supporting rich multimedia applications. Today the installed base of set-top boxes can be broadly classified into the following categories:

- Analogue set-top boxes;
- Digital set-top boxes;
- Advanced digital set-top boxes.

Analogue set-top boxes perform the functions of receiving, tuning and decoding the incoming television signals. These appliances have changed very little over the past twenty years. In the recent years, some of these boxes have included dial-up modem that allows subscribers to access the Internet through the television.

A basic digital set-top box is capable of receiving broadcast digital television and provides support for interactive TV services with navigation tool known as Electronic Program Guide (EPG). Characteristics of this type of box include low cost, limited quantities of memory, interface ports and processing power. Typically, digital set-top box contains one or more microprocessors for running the operating system, possibly Linux or Windows CE, and for parsing the MPEG transport stream. A set-top box also includes RAM, an MPEG decoder chip, and more chips for audio decoding and processing. The contents of a set-top box depend on the DTV standard used. European DVB-compliant set-top boxes contain parts to decode COFDM transmissions while ATSC-compliant set-top boxes contain parts to decode VSB transmissions.

As digital technology advances, these boxes have doubled the processing power and storage capabilities of the first generation boxes. For example, while a basic set-top box needs approximately 1 to 2MB of flash memory for software code, mid range set-top boxes normally include between 4MB and 8MB of flash memory for code and data storage.

Major set-top box chipsets vendors are currently developing high functionality chipsets for advanced digital set-top boxes. These boxes bear close resemblance to a multimedia desktop PC. They have more than ten times the processing power of a low-level broadcast TV set top box with storage capabilities of between 16MB and 32MB of flash memory. Most of these boxes come with a high-speed return path such as cable modem or ADSL to run a variety of advanced services such as video teleconferencing, home networking, IP telephony, VOD and high-speed Internet TV services. Additionally, subscribers are able to use enhanced graphical capabilities within these types of boxes to receive high definition TV signals.

The idea of putting a hard disk drive (HDD) into the advanced digital set top box in order to provide PVR functionality is drawing interest from MSOs and manufacturers alike. Such receivers may come with a choice of home networking ports, allowing them to function as residential gateways.

Set-Top Box Software. There are three layers of software required to operate a digital set-top box, namely, the operating system and device drivers layer, the middleware layer and the user

applications layer. The operating system and device drivers layer keep all parts of the set-top box operating together. Vendors addressing this space include Microsoft, Wind River, various Linux vendors, Microware Systems and PowerTV. The middleware is a layer of software programs that operates below the interactive TV applications and above the operating system and provides set-top box programmers with a common API to which they may write applications. Key vendors and technologies that compete in this market include OpenTV, Liberate Technologies, Canal+ Technologies, PowerTV and Microsoft. Subscribers use the application software layer to watch TV and use interactive features.

Set-Top Box Hardware. Advanced digital set-top boxes are comprised of three separate subsystems: TV, conditional access (CA) and PC components. The TV subsystem includes a number of tuners and video decoders that are responsible for processing streams of digital information. Another important subsystem in a digital set-top box is the CA system. This subsystem provides MSOs control over what their subscribers watch and when. The PC subsystem provides set-top designers to add PC functionalities such as hard disk drive. Smart chip card reader in set-top boxes will also facilitate CA and payment applications.

According to a forecast from Strategy Analytics' Broadband Entertainment Strategies service, digital television is set to reach 103 million homes this year. Viewers continue to upgrade to digital satellite and cable services in large numbers. By 2007, about 324 million homes around the world will be watching digital television. Strategy Analytics predicts that the year 2003 will be the first time that cable TV becomes the world's fastest growing digital TV platform: 15.9 million homes will sign up to digital cable, compared to 15.4 million for digital satellite. The worldwide shipments of integrated digital TV sets, according to Ovum, is expected to rise from 10 million units in 2002 to over 140 million units in 2007.

5.1.2 Personal Video Recorder (PVR)

The Personal Video Recorder (PVR) can be considered a revolutionary technology to appear in the home recording market since the VCR. It is basically a computer hard disk, either operated manually or tied to an interactive electronic programme guide for "intelligent recording", that provides the function of digital record and playback of television programmes. It has the ability to record content whilst simultaneously rewinding and playing back, allowing live television to be paused, and in some implementations skipping advertisement during recording.

PVR can be generally categorised into two types, namely, network-based PVR and standalone PVR. Network-based PVRs provide significant advantages over standalone PVRs. Most standalone PVRs can record only one program at a time, whereas network-based PVR programming is virtually unlimited. Standalone PVRs also have fixed storage limitations based upon the size of

the disk in the unit. Network-based PVR will provide the consumer with virtually unlimited storage capacity since thousands of subscribers will be able to view a single stored program simultaneously.

While PVRs have yet to ship in large numbers, PVR functions are being integrated into Direct Broadcast Satellite (DBS) set-top boxes at a fast pace. According to In-Stat/MDR, the total worldwide PVR unit shipment is forecasted to surpass 28 million by 2004. The following table provides information on some PVR products available in the markets.

Vendor Products	Basic Specification/ Features
Sony's Cocoon gateway- **C**onnected **c**ommunity **o**n **n**etwork	A set-top box concept that uses a MIPS RISC processor and Linux operating system for AV entertainment and broadband connectivity. It contains a 160GB (expandable to 320GB) hard disk capable of recording 15 hours high definition programs.
Panasonic's DMR-HS2 DVD recorder	The DMR-HS2 can record a maximum of 52 hours of video on its 40 GB hard disk drive, 12 hours on a 9.4GB double-sided DVD-RAM disc, and 6 hours on a DVD-R disc.
Thomson's RCA Scenium Digital Media Recorder	Combination of DVD player and PVR. Consists of 40GB hard disk storage for 30 hours of recording. Capable of creating a personal video, photo album and audio juke box.
Nokia's Mediamaster 9902S PAD Personal Active Disc	This is a digital satellite receiver based on DVB standards. Capable of storing 15 hours of programs on a 40GB hard disk. Key specifications include a 32-bit RISC processor and using OpenTV API. RAM/SRAM/Flash memories are all 4MB in size.

Table 7. Examples of PVR Products

5.1.3 Home Media Server (HMS)

The term Home Media Server (HMS) has been used in recent times to refer to advanced networked devices offering PVR functionality. The PVR can be seen as the first generation of home media servers to some extent. By 2002, however, the characteristics of the HMS were becoming clearer as distinct from that of a networked PVR. The HMS is a single networked device equipped with a hard disk drive and interfaces that can manage television programming (delivered by cable, satellite or the Internet), DVD playback/recording (via built-in DVD drive), music (delivered by Internet or transferred from CDs), and probably other media. It can also handle more computer-like functions, such as email, instant messaging, Web browsing, and online entertainment services. The HMS will be able to perform its various functions simultaneously, connecting to television sets, stereos and personal computers in other rooms of a household. The HMS is effectively the hub of a home entertainment network, bringing TV/

PC convergence, offering all the functions currently carried out by a number of boxes - a device that will store and/or playback digital media and communicates with to a number of devices throughout the home over a network.

Table 8 lists a few examples of some leading CE vendors launching the first wave of home media server products into the consumer market.

Home Server	Vendors	Description
Moxi Media Centre	Digeo (Digeo and Moxi merged on 29 March 02)	The Moxi Media Center has a DVD drive and 80GB hard drive. It functions as a cable or satellite receiver, digital video recorder, music jukebox and computer hub. Video, music and other data can be sent to other devices via coaxial cable, Ethernet wires and through wireless.
Digital Media Library	Pioneer Electronics	Pioneer Digital Library has a music CD drive and a 60GB hard disk, connecting to as many as three household TV sets and a home computer network. It is able to rip CD into MP3 format and play back through TV and stereos connected directly to it. With network capabilities, it can store files, and distributing audio and video throughout the house.
Home Media Centre	Samsung Electronics	A prototype home media centre, one of the first products based on the Freestyle extension to the Windows XP operating system. Freestyle includes applications for DVD and digital-music playback and for processing and recording live television, allowing the PC to become an entertainment command centre.
Broadband Media Center (BMC)	Motorola	Broadband media centers are new classes of advanced set-top devices. The BMC8000 is a companion device for DCT2000 digital set-top; and the BMC9000 is an integrated system. The BMC8000 includes a hard drive and DOCSIS cable modem for broadband connectivity and digital video recorder capability. It can support web access, email, Internet messaging and a digital media jukebox for music, photos, animations and games. It also features wireless or wired home networking and telephony capabilities. Charter Communications plans to begin initial deployment of this advanced media center platform in early 2003.
Explorer MC Home Media Center	Scientific-Atlanta	This advanced set-top, slated to ship under the product name Explorer MC home media center, will enable cable operators to offer consumers wide range of digital entertainment services, including personal video a recording, digital music, games, and photos all through one easy-to-use platform. Charter Communications plans to deploy the new Explorer MC set-top in 2003.
Media Center PCs (Freestyle)	Microsoft	Windows XP Media Center Edition (Freestyle) is a new generation of TV-based PCs, or PCs used in smaller living areas such as dorm rooms and apartments where its main purpose is to provide digital media experiences such as music, photos, and movies to anywhere in the living room. Freestyle builds on the foundational digital media technology in Windows XP and enables a simple user interface through a remote control, rather than a keyboard and mouse.

Table 8. Examples of Home Media Servers

5.1.4 Television Commerce (T-Commerce)

One significant global trend to expect is the emergence of TV-based e-commerce. By 2007, the TV in particular will become a much more important platform and will take away some of the emphasis from PC. We can expect transactions like travel booking and more impulse-type purchases done via the TV. In a B2C study by Ovum in 2002, it estimated T-commerce transactions to increase from US$1.8 billion in 2002 to approximately US$69 billion by 2007. The use of digital television for e-commerce transactions has not reached significant levels yet. Mobile phones (e.g. SMS) have also help to enhance the interactivity of TV teletext. According to the study, e-commerce transactions over digital TV and mobile devices represent only 2% and 7% respectively of total e-commerce revenues. Ovum, however, noted that T-commerce has "significant potential" as alternative to PC-based e-commerce.

In a research[24] on interactive TV commissioned by UK OFTEL in Q3, 2001, many consumers felt that home shopping applications have limited scope, as the use of TV for shopping is viewed as "selfish" in multi-person households. Online TV banking was almost universally rejected. Those who wanted to bank remotely already did so (via the telephone and/or Internet), and those who did not were extremely uncomfortable with the idea of managing their account on a large screen TV in the middle of their living room. E-mail also has very limited appeal, the lack of compatibility with PCs, particularly in relation to the management of attached documents.

Games are viewed as "light-hearted" and "exciting." Many households used the games as a 'short break' activity. Digital text services such as receiving news, weather, information updates on the TV is found to be attractive to TV viewers. Electronic Program Guide (EPG) is also crucial in helping viewers make sense of channels.

5.2 Gaming Applications

Gaming is fast becoming a key home application as the gaming industry has experienced strong growth over the past few years, and today, we have seen a plethora of gaming and game-related services in this market.

Gaming Platform. Today, there are various options of hardware platform used to access online games. These platforms include:

24 OFTEL research — Digital Television: Consumer's Use and Perceptions

Personal Computer. The PC remains as the single most popular gaming platform for most gamers as almost all the top ranking games are played on the PC. It also supports game titles on other gaming platforms. The quality of graphics, sound cards and accessories available on the PC also contribute to its popularity. The PC gaming platform also boasts the most customisable gaming environment available where gamers can create shortcuts, design game play environments (e.g. preferences, play settings, appearances, and frequently visited sites), build websites to host their own games, and even modify the overall game. However, the increasing demands of 3D intensive graphics and sound system and professional game controllers are beginning to compete with other PC resources. This has given rise to specialised gaming consoles market.

Gaming Console. The popularity of game consoles are rapidly growing to become a gaming platform of choice for many gamers. Gaming consoles consist of a hardware platform specifically designed from the ground up for gaming. These consoles support high-end graphics capability, theatre sound, high performance game controllers, HDTV outputs, and a growing list of popular games. Most of the major gaming consoles vendors are now designing their platform to be Internet capable. The games available on these consoles tend to be high-end sports/action, first person shooter, role playing, community-based, and social interaction games. Other games like board games and card games have not been in high demand for this platform. This platform is also one of the most protected platforms and does not boast significant flexibility or customisation from the subscriber – no where near that of PC games. The market leaders in this area include Sony (which controls 70% of the market), Nintendo (which controls 28% of the market), and new comer Microsoft which controls a meagre 2% of the market.

Set-Top Box (STB). There is growing interest from service providers to provide games via cable and satellite set-top boxes to PC and television. This interest has spurred leading STB manufacturers including Motorola, Pace, Philips, Scientific Atlanta, and Sony to develop next generation STBs that will be equipped with 3D graphics capabilities, faster processors, more memory, and hard disk drives to provide better entertainment experience. Gaming content providers look at this initiative as just another platform to support and will port their gaming content over to run on these platforms once demand and capability is there. The main challenges with regards to these STBs is whether they have enough processing power to support multiple applications (e.g. digital video, HDTV, Video-on-Demand, and gaming) while keeping cost affordable. Also almost all existing STBs deployed have insufficient resources (processors, memory, graphics, etc.) to support the demands of graphic intensive games and would need to be upgraded. The cost of upgrading these STBs could be significantly huge.

Mobile Handheld Devices. The dawn of gaming into wireless devices has the potential to become a major market for online gaming. A wireless games report from Ovum indicated that

the market will be worth US$4.3 billion worldwide by 2006, with a consumer base of 53 million gamers. However, the capabilities of wireless devices such as PDAs and wireless phones are not yet equipped to handle sophisticated games. Further work is needed to improve media displays, application management, and wireless data transmission bandwidth before these games will be possible. Until then, subscribers can play games by using simple text messaging applications, but these games will be limited in scope and more costly as the subscriber would need to pay for airtime. Wireless games are where PC games were many years back. However, as more bandwidth and better portable electronics become available this gaming sector will close the gap quickly. Many believe that wireless is the technology earmarked for the gaming console to connect to the Internet, as broadband interconnections are typically not located near the television.

The following section reviewed three platforms that are likely to be a major indicator of the future of console online gaming technology. These platforms are namely PlayStation 2, GameCube and Xbox.

PlayStation 2 (PS2). The 300MHz 128-bit Emotion Engine, developed jointly by Sony and Toshiba serves as the core CPU for Sony's Playstation2, allowing the advanced game system to handle 6.2 GFLOPS at peak floating performance and able to transform 66 million polygons per second. Beside gaming capabilities, Sony's PS2 supports both audio CD and DVD video formats, using Dolby Digital AC-3 and digital theatre system sound capabilities to further enhance entertainment experience. Currently Sony leads the game console market, owning about 45% for both of its PSs. As of September, PS2 has already achieved critical mass of more than 40 million units' sales worldwide. Going forward, Sony is preparing its PS2 game console into a home entertainment gateway that could offer interactive applications and capability to tap into Internet connections via a network adapter interface. The network adapter, available in August 2002, combines a 10/100 Ethernet connection with a 56kbps V.90 analogue modem.

Xbox. Xbox is an entertainment hub that provides users with high quality video games, Internet support for online gaming, web surfing, email, etc. The Xbox houses an Intel Pentium III CPU, running at a clock speed of 733MHz and a 233MHz custom-designed graphic chip, developed by Microsoft and NVIDIA that could deliver more than 150 million micropolygons per second. It contains a 8GB hard disk, 64MB RAM, a DVD player and audio/video system that can create soundtracks and supports for HDTV & TV resolutions up to 1920 x 1080 pixels. The Xbox utilizes DirectX API for game development. Microsoft next phase for Xbox is to support online gaming. Beta testing of the online service is expected to start in October 2002. The Xbox online service, dubbed Xbox Live will be a closed subscription service run by Microsoft. Microsoft

will manage the network and individual publishers will need to work through the Xbox Live service if they want their games to go online. Xbox Live will also allow subscribers to download new game levels, characters and sports statistics to their Xbox hard drive.

GameCube. The GameCube contains a Custom IBM Power PC "Gekko" running at a clock speed of 485MHz. GameCube can handle up to 10.5 GFLOPS of floating-point arithmetic capability and able to transform 6 to 12 million polygons/second. It also houses a 1.5GB hard disk drive inside the box. Nintendo revealed in its plan to release the broadband adapter for the GameCube in October 02 in Japan. Inserted using the underside of the console, the adapter will allow high speed Internet connectivity for future games. A 56kbps-dialup modem for the GameCube will also be available in September.

We believe that PC would be the main platform for online gaming for at least the next five years. Console systems will have online capabilities, but for the short-term it is unlikely that many users will take advantage of those capabilities. Instead, the short-term is likely to witness limited roll out. By 2006 DFC Intelligence[25] forecasts that there will be 23.4 million online console gamers worldwide. As pointed out by DFI, there is a big difference between the positioning of Microsoft, Sony and Nintendo. Microsoft is making a big bet that the future of console online gaming is now. They have built-in online support and are spending a great deal of money building a proprietary online service. On the other hand, Sony and Nintendo seem to be of the belief that, in the short term, online gaming will be something for the hard-core. Their current systems require separate add-ons to play online games. Even more telling, neither Sony nor Nintendo will launch their own proprietary online game service in the short term.

Market Forecast. Based on IDATE projection, the combined video game market for USA, Europe and Japan is estimated to be worth US$30.5 billion in 2002. The turnover generated by the sale of home console games represents 43% of the total market. In 2003, the market will drop to about US$27.5 billion. This decrease is largely due to a drop in the hardware market.

As these new game consoles are beginning to support online gaming, we believe that in future, gaming will occur on multiple devices in the home where gamers sit in his living room, playing online against people from all over the world. A buddy list can be used to initiate gaming sessions between players while at the same time communicate with each other. According to Microsoft, online technology is the next revolution in video games, and it will fundamentally transform gaming into a new form of social entertainment. However, studies by game makers and independent researchers conclude that most game console owners have no clear business case for online gaming. So it will take some time just to find out what works for the mainstream consumer that the console audience typifies.

25 Online Gaming on the Video Game Systems, by David Cole, DFC Intelligence, 29 Aug 02

5.3 Telecommuting & Information Services

We have said that the sharing of broadband Internet and office resources for telecommuter represents one key driver for home network. Enabled by broadband, these users can perform activities such as video conferencing, VPN connection to corporate network, and web surfing at home.

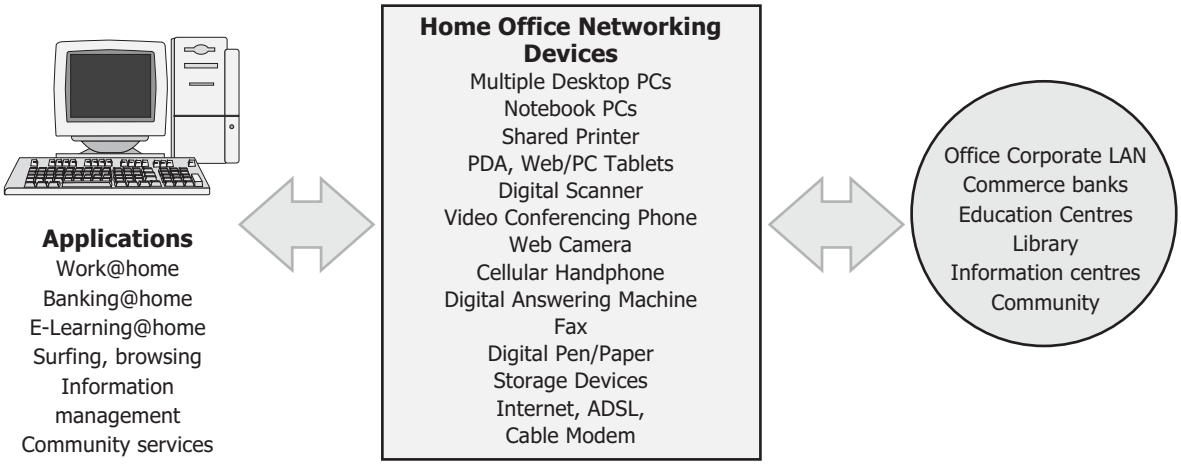


Figure 13. Home Office Networking

Information Service Organiser. A home information delivery service represents many opportunities for applications to be developed. These services could be, for instance:

- Calendar services;
- Memo list to inform them of children's school activities and weekend programmes;
- Personalised payment schedules and records for bills and taxes;
- Shopping lists, including daily essential such as newspapers;
- Checking nearby amenities;
- Reservation of tickets, restaurants, taxi, etc;
- Latest weekend interest planner;
- Family's member medical schedule;
- Medication reminder for the aged;
- Fast retrieval of financial & stock markets information;,
- Information about the road condition, weather forecasts;
- Schedule for car maintenance with mechanics;
- and other tasks.

Rather than hardware and embedded device focus, intelligent home connectivity moderating among many devices could be performed with an open software architecture. Semantically, home services can be composed and chained together that abstract above networking and hardware layers. For example, "*Display the nearest primary school within ten km range on my home theatre system*", then "*Choose the top five cheapest means of private transport for my kid to these schools with service ratings*" and finally from the input device of my home theatre, "*Select mode of secured electronic payment scheme for transport payment*". At this level of coarse-grained business services, where each service is provided by different providers and needs to be chained dynamically into a single meaningful service, abstraction to a service-based architecture is essential. The language that enables this infrastructure is Web Services.

Information devices could allow family members to have access to the above services at a touch of a button, scribbling over the screen, or even voice input while allowing mobility. The devices could also let users access to television programmes, surf the Internet, do transaction online, control home appliances and play games. The different types of information devices are discussed below.

Web-based Wireless Tablets. Traditional hardwired home control interface usually commonly come in the form of wall-mounted keypads or tabletop infra-red remote control, through which a user can synchronise, modify and adjust the settings of lights, security devices, thermostats and audio/video gear, etc. tied to a network. This user interface is beginning to take a new form as wireless technologies such as Bluetooth and 802.11b are integrated into the product. Wireless tablet is typically larger than a PDA, more mobile than a notebook computer and provides an always-on connection with the Internet. It is ideally suited as a portable home control and info device.

Smart Display & PC Tablets. Media pad is an ultra-mobile laptop computer with convertible screens that can be used in normal laptop mode, or flipped around and used like a tablet, with stylus and on-screen keyboard input. Microsoft has unveiled its media pad known as the Mira in the Consumer Electronics Show in early 2002. Mira is a wireless handheld device and contain a large screen. In conjunction with a TV or a PC, Mira will deliver Internet content, serve as a portable game player in conjunction with the Xbox video game console, and allow consumers to shop online, view program listings and perform other tasks. The Mira-enabled screen can be picked up and carried around the house where the user interacts with the PC back in the home office using 802.11b. Microsoft sees homes being built with multiple smart screens, including fold-down units for under kitchen cabinets and portable tablets with smart display functionality in the future. The Mira is expected to be available in early 2003.

Cellular Handphone, PDA and Other Handheld Devices. The home user could also choose to select cellular phones, PDAs and handheld devices as the home connectivity to the above

mentioned services. These devices may start first as a tool to monitor and control a home network from office and then eventually as an interface to also be used inside the home. With the right price point, users are more likely to select the same type of wireless solution to be used for both office and the home, as user does not need to change or carry two network access devices. Still, home control and networking manufacturers believe that PDA and smartphone solutions will not become a predominant means of controlling a home network. They are likely to be used at a moment of convenience, and it will remain as only tertiary interfaces as their screens are simply too small to display all the information a home network needs.

5.4 e-Learning at Home

E-learning can be defined as what occurs when education and training are delivered and supported by networks, in particular by the Internet. Effective e-learning should have the following characteristics:

- an expert-rich content and curriculum;
- flexibility and convenience;
- real-time feedback and tracking;
- multimedia simulations, rich case studies and threaded discussions; and
- a dynamic engaging environment for learning.

A rich multimedia (video, audio, data; interaction among remote parties) content will definitely make the learning more effective and enjoyable, and the lessons are more interesting and memorable. It can be a reality that one is participating a live class discussion for MBA program in a foreign university using his/her PC at home (with camera, microphone; plus TV if he likes) while his/her son is reading a story book in the same room. Interactive modes are needed so that "whiteboard display" can be shared and "hands-up" for questions are notified among remote parties. Content-based retrieval technology (MPEG-7 or others) may help learners to locate or summarise the relevant/interested multimedia material (remote lectures, tutorial, etc.).

E-learning standards has gained its importance with the commonality of technology-based learning, which embraces a range of electronic media. These standards are essential to encourage healthy growth of the E-learning industry.

Among the international E-learning initiatives are example such as AICC (Aviation Industry CBT Committee), IMS (Instructional Management Systems), ARIADNE (Alliance of Remote Instructional Authoring and Distribution Networks for Europe), ISSS (Information Society Standardisation System), ADL (Advanced Distributed Learning) and JTC1/SC36 on Learning Technology.

In Singapore, the Learning Standards Technical Committee (LSTC) under the National IT Standards Council aims to establish a local E-learning framework and develop an integrated set of standards necessary to support the requirements and implementation of online distributed learning. The LSTC represents Singapore as an "Observer" member in ISO/IEC JTC1/SC36 on Learning Technology and is an active participant of IMS activities.

5.5 Digital Kitchen

Several consumer electronics giants have already launched smart kitchen appliances that are Internet-ready. For example, LG multimedia fridge could allow user to watch the morning news, download MP3, listen to music, download recipes, send and receive e-mail, web surfing, or leave video messages for family members. The fridge runs on a 100MHz Pentium processor with 64MB RAM, houses a 10 GB hard drive and a 15-inch LCD touch screen. Its Internet-enabled microwave oven could even allow owners to search for recipes, download cooking related information such as cooking time and microwave power level, for automatic cooking.

The digital network refrigerator from Samsung is also Internet capable. The fridge could function as a videophone, a TV and DVD for entertainment purposes. Toshiba also revealed its product roadmap for a range of smart appliances to be available in 2003. Its smart Internet fridge include a camera that allow owner to check stocks while at work. Its air-con system is capable of connecting to the wireless network and its microwave oven could download recipes from the Internet. All these appliances will be able to access via PDA, mobile phone and headsets using speech recognition technology. What follows is more consumer research and market testing to ascertain the services that are useful, practical and have a sufficiently big market.

For information to smoothly converge with consumer durable in the kitchen, there needs to be top-quality design (ease of use, usefulness of features, rugged build etc.) and consumer education (on proper use, maintenance etc.). Massive marketing effort must go hand in hand with in-depth user studies to grow this emerging market. Users are very much accustomed to extremely simple user interfaces on devices in the kitchen. Users need to be convinced to access the new services using new interfaces. It would be tremendously difficult, however, to modify entrenched usage patterns. This is especially for most users and those who do not fancy spending more time and money in the kitchen.

To-date, there is sufficient reason to believe that the average home/SOHO user does not look forward to populating the kitchen with Internet home appliances. We see that there is no cost saving and meaningful services to be derived from such appliances by the mass to justify the

price of the Internet fridge. Besides, the system and Internet components to build, deliver, and operate such services are not available or ready. e.g. a low cost RG, web services technology, readiness of supply chain to exploit the technology are not sufficient, lack of knowledge of how to leverage Internet for brick to mortar businesses. Despite these challenges, Consumer electronics vendors appear serious in the smart appliance market. We expect further collaboration among these vendors and networking companies to work towards developing a more practical and cost-effective smart kitchen appliances market.

5.6 Smart Home Management

Smart home management represents another area shaping the development of our future connected home vision. This area includes advanced residential applications/services listed in Figure 14. The key drivers for smart home management services will depend on the technology (needs to be adaptive, intuitive, flexible, reliable and robust), coupled with low price point and ease of use. For instance, a patient at home will not tolerate an unreliable and sophisticated healthcare service during the full medical consultation period in the event of a power outage or a poor communications link. We believe that this segment will take more time to evolve or until consumers conceived of its true value and benefits.

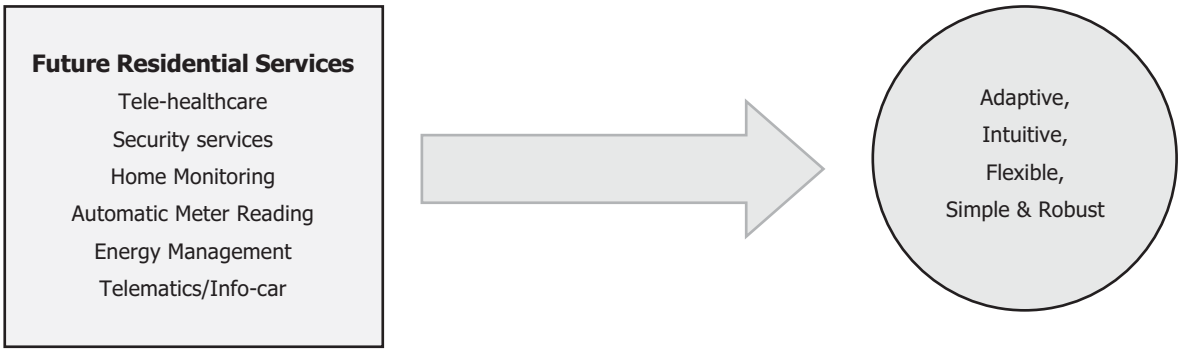


Figure 14. Future Home Management Applications

Technically, security system and healthcare system should continue to function during emergency in the event of a power failure. Most sensors and communication system linking to the remote monitoring centre are powered (via the communication bus) by the security alarm or healthcare system, which normally equipped with backup power system. Therefore, it is more likely that the networking bus for security and healthcare system is separated from the other control functions such as lighting control, HVAC system. Operationally, both of the systems required a remote 24-hour monitoring centre in most cases. These services are likely covered by the same group of service providers.

Security, Control & Automation. This includes developing applications for home security and surveillance purposes. For instance, the home security systems can be linked with PCs, motion detectors and monitoring devices for event-based video analysis of home activities. Segmented visual objects (to fit the limited bandwidth/storage) can be compressed for record and/or transmitted to homeowners through a wireless means once suspicious motion is detected. It could also automatically inform the community security providers when an alarm warning is triggered from the smart home system. The home management system could also provide energy management of high-energy consumption appliances. Homeowners can see where the energy is being used in order to pinpoint targets for change. It can automatically measure and adjust to meet maximum energy efficiently set by the user, such as setting the refrigerator to cycle instead of run continuously. Home automation also means to automatically alert homeowners when important appliances and devices malfunction. For example an alert can be sent to the user for decision to forward to equipment service centre when the water heater overheat or fails.

Tele-healthcare. Tele-healthcare involves the use of information and communications technology to deliver healthcare, health education and health information to individual in the home. The prime driver for this service is the ageing population. Tele-healthcare may become increasingly important as a means of reducing unnecessary visits to hospital, reducing unscheduled visits to doctor, teaching patients to manage early symptoms and gathering information on vital signs of poor medical conditions. An always on broadband connection that allow jitter-free examination of moving medical gauges, continuous patient monitoring and advanced assessments via video conferencing will be important to deliver this service. To support this application, the technology need to be robust if it involves life/death decision. Other application could also include security and monitoring services for elderly and disabled people, providing relatives a peace of mind while at work or travelling. The likely applications are monitoring and sensing devices, alarms systems, assistance tools for reminder of important activities such as taking medicines on time, doctor appointments, etc.

AMR is the collection of telemetry data such as water, electricity and gas consumption from customer premise meter to a remote central location using a communication medium, such as telephone, power line carrier, wireless, or HFC networks. AMR can provide significant operating advantages to providers as well as for consumers as it can reduce meter reading inaccuracy and billing costs. It will eliminate most estimated bills, cancel-and-rebills or callbacks and improve customer-provider relationship. The Enel's "Contatore Elettronico" remote metering management project in Italy is an example of AMR implementation. This project is significant in part because of the size of the deployment – replacing approximately 27 million electromechanical energy meters with remotely managed digital electronic meters, capable of being integrated into a complete home networking infrastructure.

Home management application could also include connecting information to an info-device enabled cars. Information on road conditions, best route to divert traffics, etc. before you start your journey to work, outing or visiting friends is one application that could bring technology to value. Ease of usage, simple and user-friendly human control intuitive interface are therefore crucial factors when developing applications for this cluster. Multimedia images coupled with sound effect will help a person to understand what he or she should (not) do to get a certain result. Also, interaction with domestic appliances in the household for viewing consumption values of each appliance, turning them on or off, or even automatically manages and optimise energy distribution within the house should be made simple enough for all members of the household.

5.7 Convergence

Home networking has entered a new era of growth. What started out as a way to connect home PCs and share an Internet connection has recently grown to encompass a wide range of network-enabled consumer electronics (CE) appliances including digital audio servers, video servers, and residential gateways. These enhancements present both opportunities and challenges to many. To the consumers, the advent of new technologies has gradually changed the way people interact with information at home. Consumers are looking for simpler ways to manage time and money in these wide choices of products. On one hand, the new features add value and functionality to a home network. At the same time, the network becomes increasingly complicated for consumers to manage. It has called for new requirements in design and packaging to entice them to embrace these technologies.

Market and competitive dynamics suggest that the long anticipated convergence of the CE and PC markets is eventually in progress, driving manufacturers to produce a new breed of digital appliances – an "intelligent home platform" that could support multiple applications in a single box. There are three main industries heading in this direction of convergence; the set-top box CE makers, the PC makers, and the game console makers. Companies in these industries are stepping outside of their traditional markets boundaries to grab as much market share as possible.

Set-top box makers are moving in the direction of developing boxes to enable Internet access, voice telephony, e-commerce and gaming on television. For examples, Sony has unveiled a Net-connected video recorder that can seek out and record TV programmes it thinks its owner would like. The device, which uses a hard drive instead of optical discs or magnetic tapes, will be the first "Cocoon" line of products that aim to become an alternative to the PC for accessing Internet content. The computer industry has developed PC to become a platform for playing collaborative games, making VoIP call, watching streaming media, and listening/exchanging

MP3 music files. The game hardware manufacturers are also developing a new generation of PC-like game consoles, adding DVD functions and MP3 audio features, with enhanced graphics and immersive sound features into the box. Most importantly, the console will have Internet connectivity. This connectivity will not only enable gamers to play against one another, thereby adding significant value to the gaming experience, but it will also usher in new opportunities for service providers and advertisers.

The convergence of technologies and linkages between the difference platforms is depicted in Figure 15.

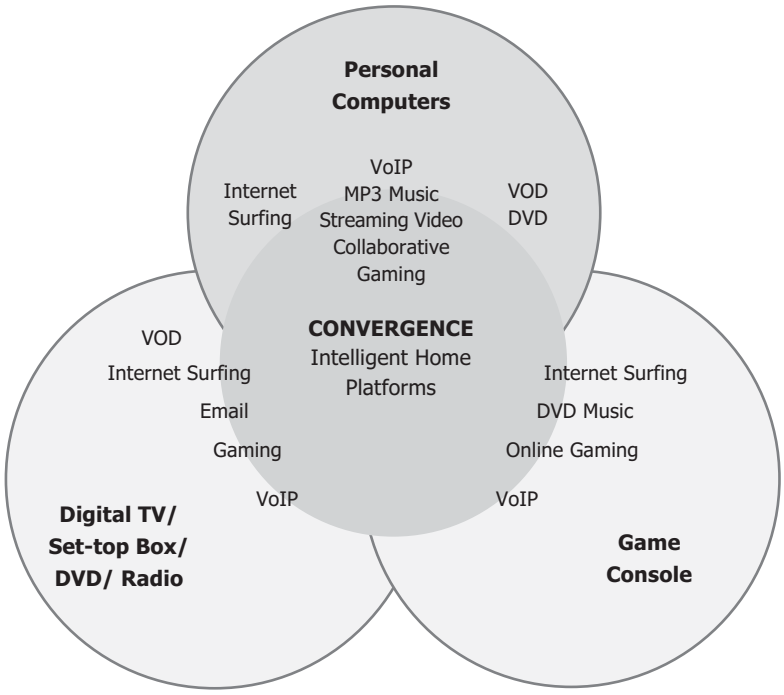


Figure 15. Convergence Sphere

Figure 16 illustrates the various IP-based home platforms in the future connected home. Intelligent centres such as game console, PC, or any access platforms would enable digital information and media contents to be shared from any source devices/platforms (such camcorders, digital cameras, DVDs,) to any output devices/platforms (digital monitors, PDAs, smart phones, tablets) using the in-home networks.

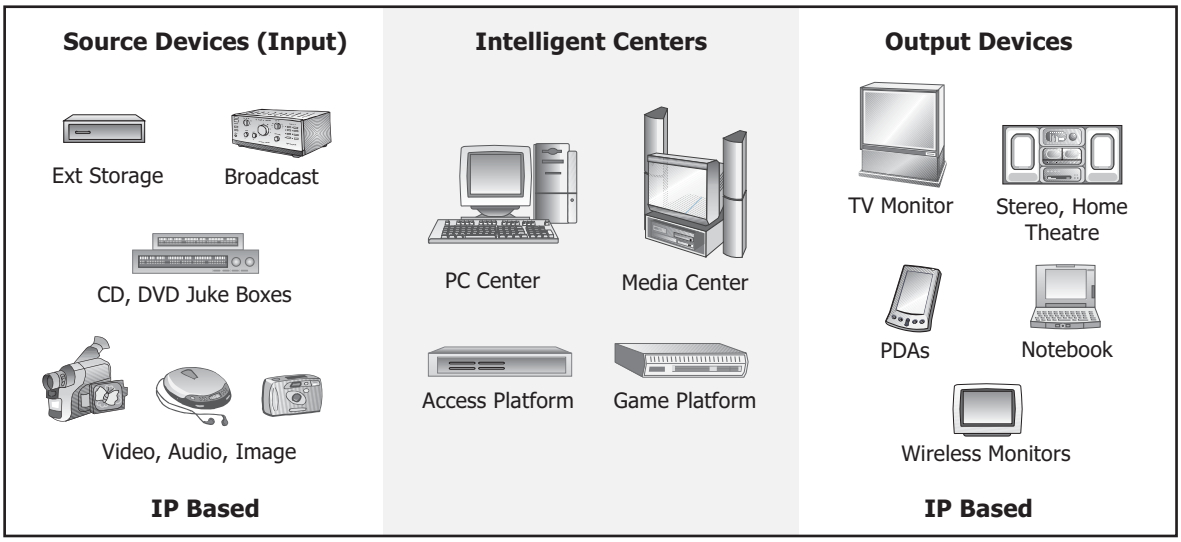


Figure 16. Home Platforms & Devices
(Source: Intel – Digital Home Product Categories)

The rapid growth of digital media and IP networking is driving a need for a common industry framework for interoperability of computing and consumer electronics devices throughout the home. A cross-industry initiative on home networking technologies, known as The Extended Wireless PC Initiative, composing of PC and CE manufacturers was formed in September 2002 to create and review a common architecture for Digital Home framework and guidelines. The working group, led by Intel, will facilitate industry marketing and promotion of this new home network architecture. It will be the first step in delivering on the Digital Home vision, providing key building blocks and toolkits to the developer community, allowing them to easily and seamlessly distribute PC digital media to TVs and stereos throughout the consumer's home. It will also encourage development, interoperability, and support of digital home technologies through this effort. Draft guideline is expected to be ready in Q2, 2003. Follow by prototype demonstration in Q3, 2003. Compliant products are expected in 2004 and beyond.

Technology Evolution. We summarised this chapter with an evolution chart of the various home platforms (see Figure 17). The diagram broadly organised the home platforms in clusters of technologies that are more likely to collaborate with each other. Many of these platforms such as digital TV set, advanced STB, home media servers, digital video recorders, wireless web tablets are expected to be widely adopted in most homes in 2007. The technology convergence to the MPEG-2 format, interoperable home area networks technologies, and the use of open interfaces such as IEEE 1394 and USB will be key enablers in networking these devices.

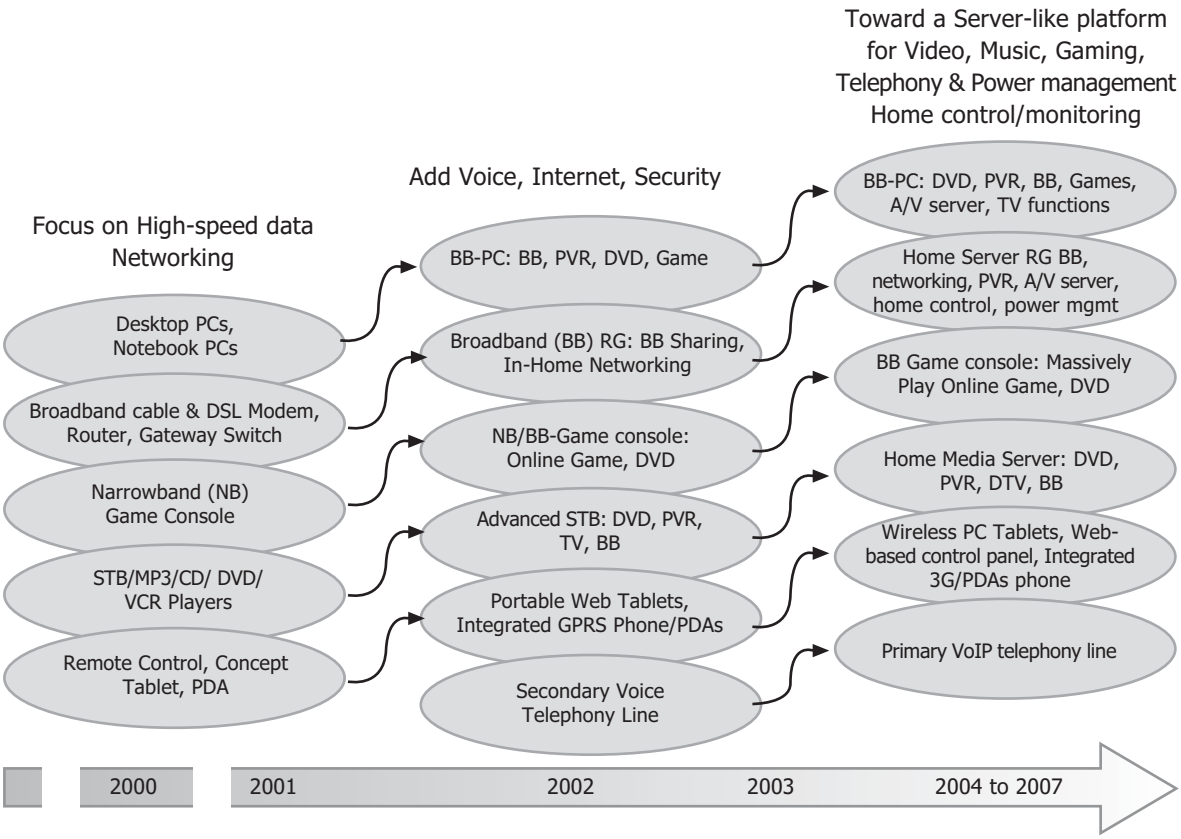


Figure 17. Home Platform Evolution

Ensuing Issues. As these digital home platforms become commonplace, with more applications and services flow into the homes, and devices remotely accessed via public networks, the consumers will not want to be exposed to unauthorised access to their home networks from a non-trusted source. Thus, an important issue that needs to be addressed is to understand what security is required to be implemented (whether centralised at residential gateway or implemented in individual devices). To build consumer confidence, we should work toward end-to-end security services that reach out to home networks.

6 Singapore Landscape

In Singapore today, there are more than 950,000 broadband users who can access to more than 250 broadband content and services on Singapore ONE. Singapore has one of the highest IT literacy rates in the world and more than 74.8% mobile phone penetration (as of September 2002). In 2001, more than half (56.8%) of the Singapore households had access to the Internet (including Broadband). Broadband access in the Singapore households has risen to 17.7% from 8% in 2000. According to IDC, total broadband subscribers in Singapore will grow at a CAGR of 55% (2001- 2006) from 144,000 in 2001 to 1.289 million in 2006. The residential sector will experience a CAGR of 48%. Penetration rates will increase dramatically to 28% of the total population or 69% of households in 2006. On the other hand, broadband access service revenue is expected to grow from US$48 million to US$343 million (2001- 2006) for the residential market.

According to the 6th Infocomm usage household survey conducted by IDA for 2001, there were about 63.9% home computer ownership as of end 2001. The rapid increase in ownership over the last 5 years was mainly due to the government's efforts in promoting IT through Internet ownership and usage among the general public, as well as the emphasis on IT usage in the school curriculum. There was also a trend that more homes were now having more than one computer. The proportion of homes with more than one computer rose by 3.3% to reach 26.7% in 2001. 23% of these multiple PC households had set-up some form of home networking technologies. This translates to about 6% of homes with networking capabilities.

Although home networking is still in the early-adopter stage with some tech-savvy household implemented it, we expect more pervasive home networks in households in the next few years as more service providers started to provide value added services with home networking technology for consumers. The focus in the initial phase will be to hook up multiple PCs to shareresources and to share broadband Internet connections.

In term of home applications, there is an increasing demand for more sophisticated applications and content such as multimedia content sharing, multi-players network gaming, peer-to-peer applications and community services. There is a growing trend of multiple household users that demand connected applications and devices in a home networking environment. The household survey found that 92% of all broadband users went online at least 2 days a week. Amongst home users, 52% use broadband to get the latest news, 45% to download music and about 33% play online games. Figure 18 shows the type of broadband applications and services more commonly used by Singaporean.

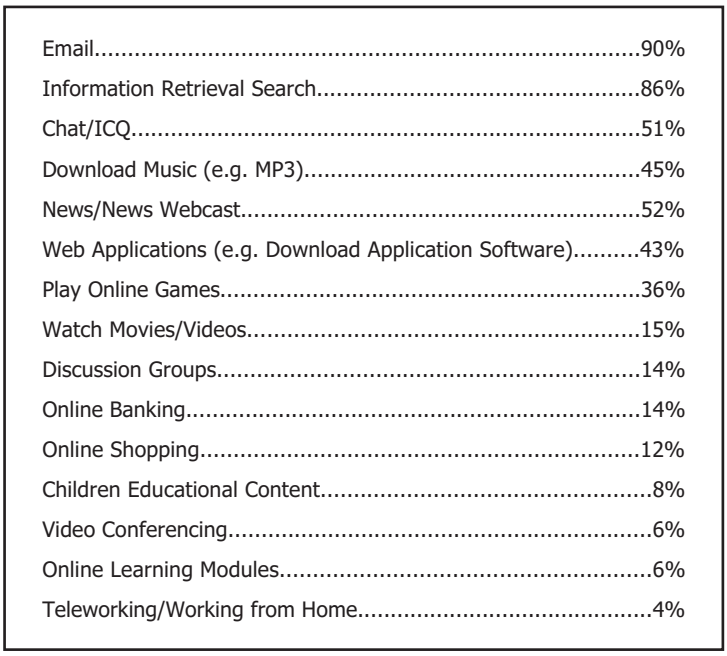


Figure 18. Types of Frequently Used Broadband Applications/Services
(Source: IDA. Survey on Broadband Usage in Singapore 2001)

The survey results have shown that data and communications-related services (such as e-mail, information retrieval/search, chat/ICQ) are the most popular category of broadband services used here in Singapore. Infotainment services (e.g. downloading of MP3 files, news, gaming) comes in second. Home banking and shopping represents the third more popular broadband applications used by Singaporeans.

While online learning interest is still relatively low at the moment, we believe that it will eventually become an important application in connected homes. This is especially so in Singapore as parents tend to invest heavily into educational needs for their children. Emerging technologies that would bring convenience and timely information access to MOE, Libraries, and other service providers to automate knowledge transactional access to provide a well rounded education for their children would be beneficial. Examples of such connected home services could be structure recommended reading list for different educational levels, tracked student learning progress, etc.

We see consumers' acceptance of home networking technologies, applications and services remain as the biggest challenges for service providers. As long as this remains unanswered, service providers will remain unsure of the wide spectrum of consumers' needs. It is therefore important to set up an environment for the design, development and packaging of home

networking technologies and information platforms to test the market. This will help service providers understand mass consumer requirements and deliver innovative and integrated end-to-end solutions.

The ability to quickly integrate new innovative applications and technologies through open source technologies such as Linux will also present opportunity for our local industry. Open source fosters creativity and encourages innovation in product design. In China, for example, many companies have adopted Linux in building their next generation products. If the Connected Homes project can quickly incorporate new technologies, its framework will be more adaptable with a reduced time-to-market latency.

The following initiatives from the various government agencies and property developers will help to pave the path for industry to develop, pilot and trial innovative products and services to link up homes and the community. Industry players can leverage on this environment to improve their products. We believe that those who participate in these initiatives will be able to gain early foothold in this potentially huge market.

The **Housing and Development Board, HDB** (www.hdb.gov.sg) is the public housing authority in Singapore. Established more than 40 years ago, its mission is to build affordable homes of high quality, in integrated environments that meet modern lifestyle needs. Today, about 85 percent of Singaporeans live in HDB flats as a result of its sustained public housing programme.

With a world-class broadband infrastructure in place and a growing infocomm-savvy population, HDB has initiated a few experimental building contracts for network-ready HDB flats, wired with structured cabling. These flats are installed with a flexible telephone/data cabling system sing Category 5 cabling systems from a central location to every room as well as essential places. Residents of these flats no longer have to seek specialist home installers to wire up their homes, saving them a huge cost. These flats come pre-installed with 11 UTP outlets that can be configured either as a data or telephone point. In addition, there are also 5 cable TV outlets. With these, residents will be able to set-up a home network plugged into the Internet using broadband connections such as cable modem or DSL modem.

Currently, two building contracts in Sengkang, with provision for the telephone/data cabling system within the residential units, will be completed soon. Two more contracts in Sengkang and another in Sembawang are under construction with this provision. HDB also has plans to implement telephone/data cabling systems for all future HDB Build-to-Order flats.

The **Infocomm Development Authority of Singapore, IDA** (www.ida.gov.sg) is an organisation with an integrated perspective to developing, promoting and regulating info-communications in Singapore. We shall now take a look at some IDA initiatives in the Connected Home.

- **Connected Homes Programme.** IDA envisions realising an e-lifestyle where ordinary Singaporeans can access a wide range of products and services via the Internet from the convenience of their home. In order to realise this vision, IDA initiated a Connected Homes Programme on 11 April 2002 with the aim to provide a test-bed environment for the industry to develop, pilot and deploy innovative and integrated end-to-end solutions for the homes. This programme leverages on the existing Singapore ONE infrastructure and services to promote the development and trial of innovative products and services to homes and communities. This will enable consumers and communities to realise the benefits of an e-lifestyle. A call for collaboration (CFC) was also made in the same month for industry members. To date, proposals from 10 consortia have been shortlisted for evaluation by a committee setup by IDA.

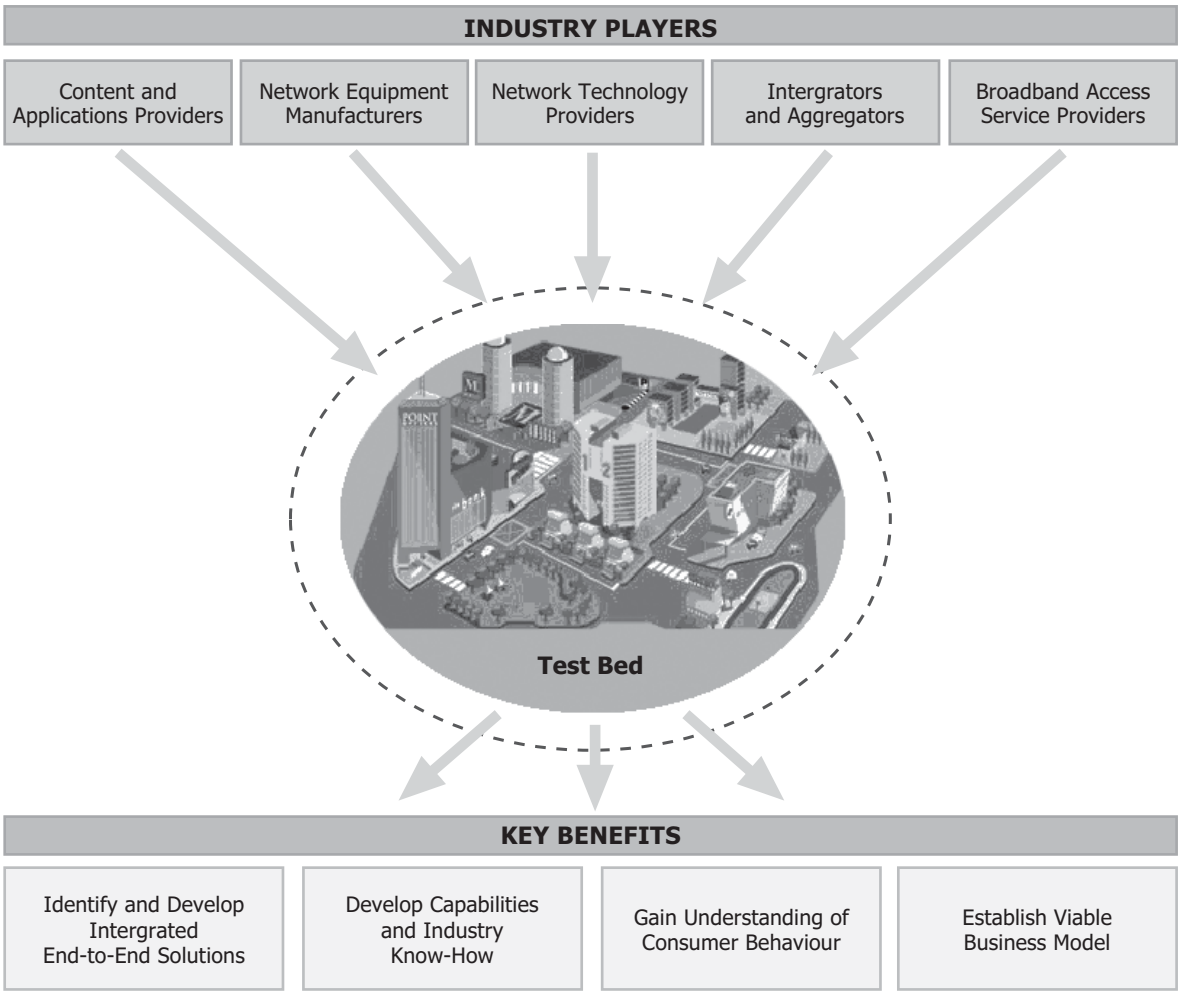


Figure 19. The IDA Connected Home Programme

- **Local Working Groups.** IDA has also formed several industry-led groups, each consisting of a mix of local companies, MNCs and research institutes in response to the strategic importance of the RG and the challenges that need to be overcome. For instance, the *Broadband Homes Working Group (BHWG)* was formed to facilitate pre-competitive industry/ academia collaboration for the development of new products and services for homes. The BHWG works closely with IDA to identify areas for collaboration and to ensure the successful delivery of initiated programmes. Several focus areas have also been identified for the further development of broadband in Singapore. A *Residential Gateway Task Force (RGTF)*[26] is assisting with the development of a reference design of a multi-service RG based on the OSGI specification. We should expect to see a handful of companies launching OSGI-based RGs by the end of 2003. Concurrently, a *Broadband Applications Task Force (BATF)*[27] has been working towards the identification of innovative services to be delivered via such a RG.

- **Other IDA Activities: Improving Infocomm Accessibility for All.** To increase PC ownership and access, IDA engaged multinational corporations, local enterprises and the community to assist in initiatives such as the PC Reuse Scheme and IT Resource Centres for self-help groups. These initiatives reach out to needy households and late adopters of infocomm products and services. To date, more than 5,000 needy households and 82 IT Resource Centres have benefited. The EasyPC Plan has benefited many Singaporeans. It is championed by the National Trades Union Congress and enables union members to own a PC with Internet connectivity for less than S$1 a day. This scheme has helped more than 4,000 union members to date. As of May 2002, more than 1,200 people have volunteered for IDA's e-Ambassador programme. These volunteers, early adopters of infocomm products and services, inspire late adopters to embrace an e-lifestyle by introducing them to infocomm services and applications.

The **Singapore Broadcasting Authority, SBA** (www.sba.gov.sg) was set up on 1 October 1994 as a statutory board under the Ministry of Information, Communications and the Arts to oversee and facilitate the growth of the broadcasting scene in Singapore. SBA plays a principal role in supporting the development of the local TV industry and in upholding the quality and standard of broadcast content. SBA sees digital TV as offering great potential and has adopted the European DVB-T standard for digital TV and the MHP (Multimedia Home Platform) standard for interactive TV. Both standards are widely adopted among many countries around the world. The early introduction of DTV in Singapore seeks to improve the standard of broadcasting here and enable Singapore to maintain its competitive edge. We will take a look at some of SBA initiatives to support the development in this area:

26 RGTF (Residential Gateway Task Force) was formed in November 2001 and is currently chaired by ST (Singapore Technologies) Electronics

27 Broadband Applications Task Force (BATF) was formed in March 2002 and is currently chaired by CISCO Security Technology

- **Digital Broadcasting Development Fund.** SBA has established a Digital Broadcasting Development Fund (DBDF) in 2000 to support the development of new digital content and services. Through this funding, SBA hopes to encourage the development of original, innovative and high quality content and services for digital radio and digital television.

  For digital radio, SBA has funded projects ranging from the development of multimedia applications to measurements of transmission and coverage. For digital TV, the projects have ranged from the development of new content to the development of monitoring standards. Some of the products developed from SBA's funding have been exhibited at trade shows, such as BroadcastAsia and International Broadcasting Convention (IBC). In addition, articles about the products have been published in trade magazines, such as Envision and Asia Pacific Broadcasting. These efforts on the part of the successful companies funded by SBA have helped placed Singapore at the forefront for innovative R&D projects in digital broadcasting technology.

- **National Digital TV Committee.** This is an industry-led group formed in September 1999. It spearheads and co-ordinates the implementation and growth of digital TV in Singapore. It is a platform where industry members meet, share information, exchange ideas and identify areas that need to be strengthened for digital TV. The Committee plays an important role in advising SBA on issues related to the developments and early adoption of digital TV in Singapore. To address the implementation of interactive digital TV services in Singapore, a MHP (Multimedia Home Platform) Task Force was formed in June 2001. The MHP Task Force also keeps track of MHP implementation experiences outside of Singapore, and identifies and advises on the application of available solutions on MHP implementation.

In August 2001, SBA issued the Singapore Telecommunications Ltd (SingTel) an Interactive Television Trial Service Licence to conduct a consumer and technical trial on the level of acceptance of interactive TV (iTV) services in Singapore, and to gather public feedback on this novel service. This trial includes a whole suite of services such as VOD, walled garden Internet access, T-commerce and e-banking services. The past year also saw the entry of two new players in the VOD market. Cathay Organisations Holdings Pte Ltd and Intertainer (Asia) Pte Ltd, who were issued VOD Service Licences, valid for five years, to offer entertainment-on-demand services.

SBA also issued DTV trial service licences to MediaCorp T&T Pte Ltd (mtt) and Advent TV Ltd in 2001 to explore new frontiers in DTV R&D, such as the implementation of a back channel, interactive content and datacasting. Since December 2001, MediaCorp TV's DTV service, Mdigital, has been simulcasting Channel NewsAsia, and new enhanced and interactive services such as digital teletext, food guide, games, and a T-banking prototype. Mdigital also conducted a multiple camera angles demonstration.

Private Property Developers. Developers of several new private condominiums are also incorporating home networking and broadband access to the new homes as part of the smart home features. Most of them would install a data point in each room, including kitchen using structured wiring. Home automation, security and surveillance systems are also implemented in some condo. Some even provide WLAN access at external areas such as pool side and gardens. One common feature is a dedicated information and service web portal that provides the condo residents access to online services such as news bulletin, community news, classified advertisements, chat room, updates on condo events and booking of facilities.

Example of some of the smart condominiums include:

- Caribbean At Keppel Bay — Smart Home by Keppel Land
- Freesia Woods — Smart Home by Keppel Land
- The Linc — Smart Home by Keppel Land
- Edgewater — Smart Home by Keppel Land
- Butterworth 8 — Smart Home by Keppel Land
- The Loft — Intelligent and e-lifestyle homes by CapitaLand
- Sunhaven — e-enabled Home by CapitaLand
- The Equatorial — i-Home by City Developments

Service Provider. The future growth of home networks in Singapore is expected to be fuelled by the need for broadband sharing, increasing number of household having multiple PCs, and teleworkers working from home. A trigger point for the mass market penetration of home networks in Singapore will be a complete and affordable bundled service offer by service providers, providing practical solutions and applications that are useful for consumers. One local service provider, StarHub has begun to offer wireless Internet access for consumers by bundling home networking hardware with the subscription plans, MaxOnline. The wireless home networking hardware will have the options of using wireless PC card (Linksys Wireless Access Point & PCMCIA card) or the wireless USB external card (Linksys Wireless Access Point & USB network adapter).

Research Institution. The research institutes in Singapore also conduct research in technologies that are applicable for the connected home. We will list some of the projects that are ongoing at the various institutions.

Laboratories for Information Technology (LIT). LIT, (www.lit.a-star.edu.sg) a research institute of the Agency of Science & Technology (A*STAR), undertakes research in information science and technology, in particular, on enabling technologies and processes that would drive new and enhanced services in a knowledge-based economy. LIT focuses its research efforts in

the areas of Ubiquitous Computing, Distributed Systems, Media Engineering, Signal Processing, Knowledge & Discovery and New Initiatives. One of the project related to the connected home is the *Full Service Residential Gateway*. The project targets at designing the full service residential gateway (RG) which provides a common, secure and intelligent interface between Wide Area Network (WAN) and Home Area Networks (HAN) as well as home devices. The RG is designed not only to provide internal and external communication capability, but also provide the framework for the delivery of applications and services such as digital TV, automated meter reading, security, healthcare, home automation etc. to home users. The project addresses a wide spectrum of technologies and research areas such as broadband access (DSL/Cable), home networking (Ethernet/HPNA/Bluetooth/WLAN), device access (HAVI, UPnP, Jini, LonWorks, CEBus, X10 etc.), service discovery and delivery (OSGI) etc. The team has already developed the first prototype of OSGi and Jini compliant home automation services using the X-10 technology and intends to provide an infrastructure solution to the future home services.

Institute for Communications Research (ICR). ICR (www.icr.a-star.edu.sg) was established on 2 January 2002 as a national R&D institute with complementary research capabilities in wireless and optical communications technologies. It is a merger between Centre for Wireless Communications (CWC), a leading research centre in wireless technology, and Network Technology Research Centre (NTRC), another leading research centre in optical communications. CWC itself was a department under the National University of Singapore (NUS) while NTRC was under Nanyang Technological University of Singapore (NTU). In part, this merger lends itself to the convergence between wireless and optical technologies, as well as the need to closely integrate the two for the deployment of telecommunication networks. There are at present seven core research programmes and PBAN (Pico and Broadband Access Networks) is one among them related to wireless area networking. Some of projects related to the connected home are highlighted below:

IEEE802.11a compliant WLAN Chipset R&D. This project focuses on the design and development of a complete 5GHz WLAN chipset solution compliant with the IEEE 802.11a standard specifications. The chipset adopts zero IF (Intermediate Frequency) architecture and consists of a radio frequency integrated circuit (RFIC) and mixed signal baseband integrated circuit (IC) with embedded MAC. The objective is to provide a low cost chipset with high performance supporting a peak data rate of 54Mbps with QoS and Security features.

Advanced Research on OFDM Algorithms and WLAN Data Rate Extension (WLAN Next Generation). This project concentrates on the research and development of transmission technologies and enhanced baseband receiver algorithms for the high-speed nomadic wireless access system based on OFDM. The objective is to provide high spectral efficiency i.e., to achieve data rates of 100 to 155Mbps within the same 20MHz channel

allocation as in 5GHz WLAN systems. These targeted data rates, which are about 10~15 times higher than that is offered by current IEEE 802.11b wireless LAN, will satisfy the home/office networking needs in future.

Bluetooth Access Point. This completed project focused on the PAN environment. The project developed a low cost embedded appliance: Bluetooth Wireless Access Point that acts as a gateway for connecting personal wireless devices to the LAN/Internet.

7 Conclusion

In this report, we have examined the global trends and future development of home networking technologies, standards development, home applications and platforms, and industry development programmes. We have also discussed the key drivers that will enable the enlargement of this industry. In our views, home networking will remain as an important market with high growth potential in the coming years.

In envisioning the Connected Home in 2007, we see the convergence of "infotainment" technologies in the new digital era, where information, communications and entertainment can be easily and conveniently accessed around the house through a variety of home networking and high-speed broadband access technologies, supported by a wide variety of smart digital platforms and mobile handheld devices. Smart devices and platforms will communicate with each other based on a common language, IP protocol, to simply share resources and computing power. The home will also become smarter and more energy efficient with the eventual integration of intelligent home automation & control system into a common logical network. This greater convergence at home will invariably help home dwellers save time and improve their overall quality of life.

Bandwidth will not be an issue for the in-home network. By 2007, we can expect a home network to support applications with data rate in excess of 100Mbps, made possible by a wide choice of networking technologies, from Ethernet, Phoneline networking to Ultra-Wideband technologies. Applications such as streaming of rich multimedia contents, e-learning, video conferencing and multi-parties online gaming will reach critical mass. The preference for mobility and "no new wire" advantage will make WLAN (802.11a & beyond) and UWB the dominant choices in most homes, enabling applications with speed of 54Mbps or more. In connected homes, more will see the use of structured wiring as the high-speed backbone of the in-home wireless networks. Powerline communication technology may find its niche in smart home kitchen appliances.

More services will arrive at the residential gateway (RG) in 2007. Whether the RG will eventually evolve to a multi-service model will depend on the pace and extent of convergence and market demand. Home networks will be an industry for telcos, cable operators, Internet service providers, utility companies, etc. The RG enables these service providers to deliver a range of new and value-added services that leverage on the home network. This gateway will be an important entity for service providers to make headway into the home networking market. The remote provisioning of new services via the RG will mean that truck rolls will no longer be required. Besides providing better services, broadband providers must embrace the RG as a channel for value-added services before exciting new home applications can take off. We believe that more and more RG will incorporate OSGI functions as it provides a good service

platform to deliver just-in-time and end-to-end services. Once the necessary infrastructure is in place, we expect to see more widespread deployment of OSGI service gateways offering services such as remote monitoring, home security, maintenance and automatic metering services.

We envision a range of digitised information ranging from MP3 music files, digital photo collections, e-learning course material and assignments, video files, to home financial spreadsheets and archives of family documents within the home in 2007. At least four platforms will assume the central role of managing and distributing these information to the users – PC, TV/set-top box, home media server and game console — depending on lifestyles and preferences. Many of these equipment are in the process of migrating towards "network-readiness". Ultimately, these appliances will be integrated with one or more in-home networking technologies and adopting open standard device connectivity for sharing of resources. Platforms will includes functions and features such as easy plug & play, zero administration, automatic service delivery & discovery, device discovery, quality of service, security and a flexible billing mechanism built-in to support a varieties of home applications and services.

We see affordable broadband subscription as essential for home networks to take off. Many home device applications, such as audio and video, require broadband. Certainly, more consumer education and service promotion is required before home networks reach the mass market. Non-tech-savvy consumers are unlikely to walk in a retail shop to purchase the necessary products and accessories to install their home network. PC sellers, broadband service providers, ISPs, home automation vendors can potentially bundle their services with the installation of home networks for customers who want that option.

Broadband access in the Singapore households has risen to 17.7% from 8% in 2000, with home computer ownership reaching more than 63.9% in 2001. Telecommuters are on the rise, pushing for more demand in wireless connectivity, thus creating the initial impetus to set-up a home area network. The future HDB flats will be networked ready where homeowners can easily deploy residential gateway at a central distribution location to extend network services to all the rooms. For existing homes, there is no shortage of home networking solutions. "No-new-wire" and wireless solutions are matured and stable for easy deployment. Various initiatives from the government agencies are also geared toward developing a connected home, bringing better services and applications to the residents.

3G	Third Generation
3GPP	Third Generation Partnership Project
5GAGR	5 GHz Alignment Rapporteur Group
ACL	Asynchronous Connection-less Link
ADSL	Asymmetric Digital Subscriber Line
AES	Advanced Encryption Standard
AMR	Automated Meter Reading
ANSI	American National Standards Institute
AP	Access Point
API	Application Programming Interface
ATM	Asynchronous Transfer Mode
ATSC	Advanced Television Systems Committee
AV	Audio Video
B2C	Business-to-consumer
BAV	Base Audio Video
BB	Broadband
BRAN	Broadband Radio Access Networks
CA	Conditional Access
CCK	Complementary Code Keying
CE	Consumer Electronics
CEA	Consumer Electronics Association
CEBus	Consumer Electronics Bus
CFC	Call for Collaboration
COFDM	Coded Orthogonal Frequency Division Multiplexing
CPU	Central Processing Unit
CRT	Cathode Ray Tube
CSMA/CD	Carrier Sense Multiple Access/Collision Detect
CTP	Compliance Test Plan
DARPA	Defense Advanced Research Projects Agency
DAVIC	Digital Audio Video Council
DBS	Direct Broadcast Satellite
DCF	Distributed Co-ordinated Function
DCM	Device Control Module
DECT	Digital Enhanced Cordless Telecommunications
DES	Data Encryption Standard
DFS	Dynamic Frequency Selection
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Server
DOCSIS	Data Over Cable Service Interface Specification
DSL	Digital Subscriber Line

DSSS	Direct Sequence Spread Spectrum
DTV	Digital Television
DVB	Digital Video Broadcasting
DVB-T	Digital Video Broadcasting-Terrestrial
DVR	Digital Video Recorder
EAP	Extensible Authentication Protocol
EchoNet	Energy Conservation & Homecare Network
EHS	European Home System
EIA	Electronic Industries Alliance
EIB	European Installation Bus
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EPG	Electronic Programme Guide
ETSI	European Telecommunications Standards Institute
FAV	Full Audio/Video
FCC	Federal Communications Commission
FHSS	Frequency Hopping Spread Spectrum
GFLOP	Gigaflop (floating-point operations per second)
GMSK	Gaussian minimum shift keying
GPRS	General Packet Radio Service
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HANA	Home Automation & Networking Association
HAVI	Home Audio-Video Interoperability
HCS	Home Cinema System
HDD	Hard Disk Drive
HDTV	High Definition Television
HF	High Frequency
HFC	Hybrid Fibre Coax
HiSWANa	High Speed Wireless Access Network type a (Japan Standard for WLAN)
HMS	Home Media Server
HomePlug	HomePlug Powerline Alliance
HomePNA	Home Phoneline Networking Alliance
HomeRF	Home Radio Frequency Working Group
HRb SG	High Rate 802.11b Study Group
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
HVAC	Heating, Ventilation & Air-Conditioning
IA	Internet Appliance
IAAP	Inter-Access Point Protocol

IAV	Intermediate Audio Video
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
IPCF	International Powerline Communications Forum
IPF	International Powerline Forum
IPR	Intellectual Property Rights
IPSec	Internet Protocol Security
ISDN	Integrated Services Digital Network
ISM	Industrial, Scientific and Medical
ISO	International Standards Organisation
ISP	Internet Service Provider
ITU	International Telecommunication Union
ITV	Interactive Television
JES	Java Enabled Server
JINI	Java Intelligent Network Infrastructure
JTC	Joint Technical Committee
JVM	Java Virtual Machine
LAN	Local Area Network
LAV	Legacy Audio Video
LCD	Liquid Crystal Display
LF	Low Frequency
M&E	Mechanical and Electrical
MAC	Media Access Control
MF	Medium Frequency
MHP	Multimedia Home Platform
MIPS	Million Instructions Per Second
MOE	Ministry of Education (Singapore)
MP3	MPEG 1 Layer 3
MPEG	Moving Pictures Expert Group
MSO	Multiple System Operator
NAT	Network Address Translation
NAPT	Network Address Protocol Translator
NIC	Network Interface Card
OFDM	Orthogonal Frequency Division Multiplexing
OFTEL	OFfice of TELecommunications (UK)
OS	Operating System
OSGI	Open Services Gateway initiative
OSI	Open Systems Interconnection

PAL	Protocol Adaptation Layer
PAN	Personal Area Network
PBCC	Packet Binary Convolutional Coding
PCI	Peripheral Component Interface
PCMCIA	Personal Computer Memory Card International Association
PHY	Physical Layer
PLC	Power Line Communications
PLCforum	Power Line Communications Forum
POTS	Plain Old Telephone Service
PPV	Pay-Per-View
PSTN	Public Switched Telephone Network
PVR	Personal Video Recorder
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RADIUS	Remote Authentication Dial-In User Service
RAM	Random Access Memory
RF	Radio Frequency
RG	Residential Gateway
RISC	Reduced Instruction Set Computer
SCO	Synchronous Connection-Oriented
SCP	Simple Control Protocol
SDR	Software Defined Radio
SG	Service Gateway
SME	Small and Medium Enterprises
SMS	Short Message Service (GSM)
SNMP	Simple Network Management Protocol
SOAP	Simple Object Access Protocol
SOHO	Small Office Home Office
SRAM	Static Random Access Memory
SSDP	Simple Service Discovery Protocol
SSL	Secure Socket Layer
STB	Set-Top Box
SWAP	Shared Wireless Access Protocol
T-Commerce	Television Commerce
TDMA/TDD	Time Division Multiple Access/Time Division Duplex
TG	Task Group
TIA	Telecommunications Industry Association
TKIP	Temporal Key Integrity Protocol
TPC	Transmit Power Control
UDP	User Datagram Protocol

UHF	Ultra High Frequency
UMTS	Universal Mobile Telecommunications System
UNII	Unlicensed National Information Infrastructure
UPnP	Universal Plug-and-Play
USB	Universal Serial Bus
UTP	Unshielded Twisted Pair
UWB	Ultra Wideband
VCR	Video Cassette Player/Recorder
VDSL	Very High data rate Digital Subscriber Line
VESA	Video Electronics Standards Association
VHF	Very High Frequency
VOD	Video-on-demand
VoIP	Voice over IP
VPN	Virtual Private Network
VSB	Vestigial Side Band
WAN	Wide Area Network
WAP	Wireless Application Protocol
WSDL	Web Services Description Language
WECA	Wireless Ethernet Compatibility Alliance
WEP	Wired Equivalent Privacy
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WPAN	Wireless Personal Area Network
xDSL	Variation of Digital Subscriber Line
XML	eXtensible Markup Language

IDA Technology Roadmap November 2002

The Connected Home

With active contribution from the industry and research community, IDA has launched the *Infocomm Technology Roadmap Release November 2002*. You have either attended the Roadmap Symposium or downloaded a copy of the Technology Roadmap document from our website. Your feedback is valuable to us to better our future services for you. We appreciate if you could spare a few minutes to fill up the following survey.

Please return the completed questionnaire to IDA:
via Fax: **+(65) 6211 2211 (Attention to Ms Saliza Mohd)**
or via Mail to the address on the previous page.

Company Name : _____

Your Name : _____

Designation/
Area of Expertise : _____

Email Address : _____

Contact Number : _____

Q1. With regards to "The Connected Home" Roadmap Report Release November 2002, please rate the following on a scale of 1 to 6.

Factors	Excellent					Poor
Usefulness of the roadmap	6	5	4	3	2	1
Completeness of coverage and contents	6	5	4	3	2	1
Ease of understanding	6	5	4	3	2	1
Usefulness of the Roadmap Chart 2002-2007	6	5	4	3	2	1
Relevance to you or to your business strategy/planning	6	5	4	3	2	1

Comments (if any):

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Q2. Please indicate the accuracy (in terms of trend & development) of each chapter in "The Connected Home" Roadmap Report. Please rate them on a scale of 1 to 6.

Chapter	Accurate			Inaccurate		
Home Networking Technologies	6	5	4	3	2	1
Residential Gateway	6	5	4	3	2	1
Device Connectivity	6	5	4	3	2	1
Home Applications & Platforms	6	5	4	3	2	1
Singapore Landscape	6	5	4	3	2	1
Roadmap Chart 2002-2007	6	5	4	3	2	1

Comments (if any):

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Q3. Do you have any suggestions for improvement on the Technology Roadmap?

_____

_____

_____

Q4. If you are an industry player in Connected Home, what are the strategic business areas and recommendations for future development that you deem appropriate for and unique to Singapore's competitiveness?

_____

_____

_____

Q5. Would you like to be informed of our future Infocomm Technology Roadmap Seminars/ Reports? Yes / No

…. Thank You ….

THE CONNECTED HOME ROADMAP 2002 TO 2007

Technology & Market Trends

	2002	2003	2004	2005	2006	2007
Smart Home Platforms, Device Connectivity & Applications	• Popularity of MP3 music files download, web surfing, email and other data networking applications • PCs play a pivotal role in managing information at home • Game console starts to include networking capability • Digital television receiver with DVB-MHP launch in Germany and Scandinavia • Adoption of Internet-enabled kitchen appliances remains insignificant • More widespread trials/deployment of OSGi service platform. Extend spec. for future automotive services • IEEE 1394 poises to play a key role in CE platforms & devices • First wave of PCs with USB 2.0	• Mobile gaming applications emerges • Increase of CE devices with networking capability • Digital video recorders gaining popularity • Emergence of smart display and tablet PCs • Singapore launches first wave OSGi residential gateway by end 2003 • ISO/IEC/JTC1 SC25 HomeGate standard ratified for residential gateway • More telcos and cable operators expand DSL and cable services to home via digital set-top box platforms • IEEE 1394 begins to emerge as a standard in PCs connectivity • First wave of CEs with USB 2.0	• More T-commerce transaction • Entertainment-on-demand popular • Online gaming gaining popularity • Cluster of CE devices/platforms forming an entertainment network in the home • Home media servers enable easier management of information and digital entertainment contents • Digital tuners integrated into TV sets for 36" and larger by July 2004 (in U.S.) • IEEE 1394b supporting 1.6 to 3.2Gbps available • UPnP 2.0 ready	• Online gaming proliferate • Mobile gaming becomes pervasive • Home security services popular • RG functionality improvement such as service delivery and discovery, better security & flexible billing mechanism • Emergence of multi-service gateway • Proliferation of wireless tablets	• Telemetry services such as automatic meter reading deployed by more utility providers • E-Learning gains dominance • Proliferation of digital TV as US broadcasters transit to digital broadcasting	• Tele-Healthcare applications popularise • Digital tuners integrated into all TV sets, including 13 to 24" by July 2007 (in U.S.) • Digital kitchen appliances gain consumer acceptance in high-end market
Home Networking Technologies (Wireline, Wireless LAN & PAN)	• Data networking via WLAN 802.11b dominant at home • HomePNA Alliance approved proposal based on Broadcom & CopperGate to become HomePNA 3.0 (100Mbps) spec • HomePlug 1.0 gains greater acceptance as certification process begin • First wave of IEEE 802.11a products appears • Effort to globalise 802.11, HiSWANa and HiperLAN/2 standard begin to permit interoperability in 5GHz band • UWB approved for limited commercial applications by FCC • IEEE 802.15 High Rate Alternative PHY Study Group (SG3a) for WPAN to define a high speed PHY enhancement • WiMedia Alliance formed to establish a certification program to accelerate widespread adoption of wireless multimedia product based on the high data-rate IEEE 802.15.3	• HomePNA version 3.0 spec. completed • Bluetooth 2.0 spec. completed • IEEE 802.11e standard ready in Q1, adds QoS enhancement in the MAC • IEEE 802.11g standard completed, enabling 54Mbps in 2.4GHz ISM band • IEEE 802.11h ratified with transmit power control and dynamic freq. selection • Dual-mode IEEE 802.11 a and b chipset available • Pre-standard UWB products available from limited vendors • IEEE802.15.4 for LR-WPAN expected to complete, enabling 20kbps to 250kbps low data rate automation and remote control applications	• HomePNA products with 100Mbps data rate • Powerline communication technology attains critical mass • Rise in households with structured wiring • Dual-mode IEEE 802.11 a and g chipset available • IEEE 802.11i ratified, enhancing security in the MAC • UWB standard for WPAN based on IEEE 802.15.3a completed	• 802.11j standard complete for global harmonisation of HiperLAN/2, HiSWANa & IEEE802.11a • First wave of standard-based UWB technology in CE appliances • Convergence of IP-based entertainment and data network allow devices/home platforms ability to share resources	• UWB technology gains critical mass • Heterogeneous in-home networks with IEEE 802.11 WLAN and Ethernet dominating the home • Seamless connectivity of in-home network with cars for telematics application	• Widespread deployment of 802.11-based WLAN in home • Ethernet and Phoneline become technologies of choice as backbone to the in-home wireless networks • Widespread integration of UWB into CE appliances and mobile devices • Bluetooth dominant standard for local connectivity with other options such as USB interface
Market Figures	• Phoneline networking home nodes approach 0.38 million [In-Stat/MDR] • HomePlug to garner US$190 million in revenue [In-Stat/MDR] • Bluetooth chipset price typically US$10. Bluetooth gain popularity with 40 million shipped [Gartner] • Worldwide broadband subscribers: 46 million [In-Stat/MDR] • Video game market for USA, Europe and Japan worth US$30.5b [IDATE] • IDA launched CFC for its Connected Homes Programme • IDA released residential gateway reference design blueprint	• Bluetooth gains widespread adoption with more than 125 million units shipped [Gartner] • First ZigBee compliant product available. ZigBee chipset price typically US$6 [ZigBee Alliance] • US home networking market grows to US$1.4 billion [In-Stat/MDR] • Total number of CE devices using IEEE 1394 interface will reach 200 million units [In-Stat/MDR] • 95% of all new desktop and notebook PCs will support USB 2.0 [Dataquest]	• Information appliance shipments reach 89 million [IDC] • There will be 750 million USB equipped PCs and peripherals in use [In-Stat/MDR] • 112 million IEEE 1394 equipped PCs and peripherals in use [In-Stat/MDR] • PVR unit shipment is forecasted to surpass 28 million [In-Stat/MDR]	• Shipment of UWB nodes reaches 0.9 million [In-Stat/MDR] • Bluetooth chipset price at US$5 [ZigBee Alliance] • ZigBee chipset price typically US$1.5 to US$2.5 [ZigBee Alliance] • Net-based home automation and control systems will grow to US$3 billion [ABI] • Residential gateway market will grow to 25 million installed units at a value of US$5 billion [Park Associates]	• The connected home market, (equipment, software, RGs and home control products) grows to US$9.2 billion [In-Stat/MDR] • Shipment of UWB nodes reaches 1.8 million, bringing in US$41 million of revenue [In-Stat/MDR] • Powerline home networking equipment market reaches US$706 million [In-Stat/MDR] • Wireless LAN equipment markets grow to US$3.72 billion [In-Stat/MDR] • Online console gamers reach 23.4 million [DFI Intelligence] • 80% of new vehicles have built-in telematics capabilities [Forrester Research]	• Bluetooth IC market is forecasted to generate US$2.54 billion in revenues [ABI] • UWB-enabled electronics and chipsets reach 45.1 million units, producing revenues of US$1.39 billion [ABI] • Asia Pacific Wireless LAN market reaches US$882.7 million, with 5.3 million wireless LAN adapter cards and access points [Frost & Sullivan] • Information appliance shipments reach 830 million units, with a market value of more than US$167 billion [eTForecasts] • Shipment of integrated digital TV sets is expected to rise to over 140 million units [Ovum] • Europe iDTV penetration will reach 44% of European households [Forrester Research]