

# The evolution of wireless home networking

Sergey Gerasimenko  
Helsinki University of Technology  
sgerasim@cc.hut.fi

## Abstract

The home networking market is growing rapidly and wireless technologies play an important role in the most home networks. This paper identifies and describes the main areas of networking. Using a service-oriented approach, we determine the main goals of the home networking. Several wireless technologies of varying bandwidth, operating range, and form factor currently exist or are emerging for the home networking (e.g. Wi-Fi, Bluetooth, Certified Wireless USB, Wibree, ZigBee, HSDPA cellular data, WiMAX etc.). The main scope of the paper is to examine and compare capabilities of such technologies and identify their current and future application. In the conclusion, we analyze future of the wireless home networking and possibility of success or fail of the discussed technologies.

**KEYWORDS:** Wireless home network, PAN, WLAN, Bluetooth, Ultra-Wideband, Wibree, ZigBee, Wireless USB, HSDPA, Wi-Fi, WiMAX.

## 1 Introduction

Each year home networking becomes more and more important in everyday life. Until recently, the home networking only provided home computers with shared access to the Internet. But nowadays, home networks support a multitude of applications running on the different devices, including personal computers, laptops, peripherals devices (printers, scanners etc.), Internet access devices, home entertainment systems, digital video recorders and smart household appliances. We can broadly divide home networking into two categories - *wired* and *wireless*. Competition of technologies in the *wired* area is not strong. Recently, relatively slow replacing of 100 Mbit/s Ethernet technology in the home networking area with its 1 Gbit/s successor (10 Gbit/s Ethernet is also available, but not popularized in the home use yet) can be seen. But at the same time, the market for the wireless technologies is full of competitors [1]. And it makes sense, because both technical and market factors are driving growth of the wireless home networks. Consumers who choose to install home network will prefer not to tear up walls, but to use new wireless solution instead [3]. Here we should also mention that tearing up walls can be avoided by using technologies which operate with the existing home wiring (landline telephone or power lines) such as HomePNA and HomePlug, but the networking adapters for such technologies are more expensive and the data rates are considerably lower than for wireless ones. Also, home networks rarely are

not connected to any other networks nor have subnetworks.

The remainder of the paper is divided as follows: we first review the main networking areas and current application of the home networking. Then we detail the current wireless technologies which can be used for the home networking. After that, we compare their technical characteristic and analyze advantages and disadvantages. Finally, we discuss the possible home network of the future and then conclude.

## 2 Networking areas

We can group the networking areas into four categories: Personal Area Network (PAN), Local Area Network (LAN), Metropolitan Area Network (MAN) and Wide Area Network (WAN) [1]. Typical modern home network is a conjunction of PAN and both wired and wireless LANs with a broadband access to the Internet. In the future, we suppose, home networks will be connected to the one big metropolitan area network, but we also should not omit WAN influence.

A personal Area Network (PAN) is a computer network which unites devices, such as cell phones, portable gaming consoles and personal digital assistants, close to one person. Contrary to its name, the devices may not belong to one person. PAN is widely used for interconnections between mobile devices of different persons.

Personal Area Networks may use wired connections, for instance USB and FireWire. But in the most cases such wireless technologies as infrared (IrDA) and Bluetooth are used. Nevertheless, we can state that nowadays IrDA is a redundant technology which is almost replaced with Bluetooth [6]. Since the main aim of PANs is to provide users with ability to synchronize data on their personal devices, high bandwidth capacity is not required. But energy consumption is a vital issue.

Also, PANs can be used for connecting to a higher level network and the Internet. One recent development in PAN area employs electrical conductivity of the human body as a data network in order to establish connection between wearable computer devices and other nearby computers. For example, two persons wearing business card-size transmitters and receivers could exchange information by shaking hands. State-of-the-art Skinplex technology can detect and communicate up to one meter from a human body. It is already used for the door locks access control and for protection against jamming convertible car roofs [6].

A Local Area Network is a computer network which covers a small geographic area, like a home, an office, or group of buildings and provides high transmission rate. Nowadays, wired LANs are based on the switched IEEE 802.3 Ethernet

technology, running at 10, 100 or 1000 Mbit/s. Based on the IEEE 802.11 Wi-Fi technology, Wireless LANs quickly replacing wired home networks [7].

Metropolitan Area Network is a large computer network which usually covers a city. The infrastructure of such networks is usually based on a wireless technology or optical fiber connections. Also, several LANs can be connected with each other and become a metropolitan area network. According to the IEEE 802-2001 standard [20], "*A MAN is optimized for a larger geographical area than is a LAN, ranging from several blocks of buildings to entire cities. As with local networks, MANs can also depend on communications channels of moderate-to-high data rates*".

The largest networking area is a Wide Area Network. Typically communications links of such networks cross metropolitan, regional, or national boundaries [9]. All current (and future) cellular technologies such as GSM, 3G/WCDMA, CDMA2000, etc. belong to the WAN category.

### 3 Current application

All possible applications of a home network can be divided into four groups: computing, entertainment, communications and automation [8].

*Computing* for home networks means sharing of the computing resources across multiple PCs and devices in the home. For instance, sharing of the data, files, peripherals (such as printers and scanners), mobile devices, home video recorders and digital cameras [7]. Also, sharing of a broadband Internet access is considered part of this category.

Usually, modern home network connects entertainment devices all around home. Also, home networks are used for applications that combine entertainment and computing functionality, for instance interactive TV and streaming media. Typically, home network includes digital video recorder. The market for entertainment applications such as gaming and audio/video is expected to be the killer application for home networking. And, in the last couple of years, we can see a tendency to creation of a centralized home entertainment network. All current generation gaming consoles - Microsoft Xbox 360, Nintendo Wii and Sony PlayStation 3 support wireless networking as well as streaming of multimedia content. PlayStation 3 and Wii even provide user with ability to surf Internet, while sitting on their sofas. In the last year Microsoft started to sell video content over the Internet which can be showed using video console. Also, recently Apple released Apple TV product - a wireless TV extension device which can stream media from home PCs and displays it on the TV [4].

Communications applications such as telephony are by definition network applications. Home users can use voice over IP (VoIP) applications to make calls from their computers within the area of a home network. Already now we can see that commonly used DECT telephones merging into new VoIP enabled devices, or VoIP companies developing phones with support of the landline telephone connection. Unfortunately, video based communication applications are evolving very slowly, mostly due to the lack of the market

drivers. Nevertheless, we suppose, as soon as broadband Internet access becomes de-facto standard for the each home network, there will be some significant changes.

Another important issue for the home users is interconnections between personal devices and the home network. Unfortunately, most of the devices require different types of cables in order to be connected to the computer. The situation can be very problematical if each family member has several personal devices. Also, such cables have tendency to be lost, thus, wireless technologies can really become a panacea. Nowadays, it is hard to find new model of a mobile phone or PDA without Bluetooth support, even some digital cameras support Wi-Fi.

Automation home networks are still only a draft of the future usability. It is supposed that automation home networks will connect security, lighting, and heating systems together for the purposes of the user's convenience and energy management [8]. Additionally, automation networks connect smart devices like Internet-enabled kitchen appliances together [7]. All those concepts are still in development and discussed in the terms of so-called *Smart home* project.

It goes without saying, using of the wireless technologies for computing home networks provides users with great mobility and comfort to use resources of the network anywhere in the home. Also, high bandwidth requirement is fully covered by current wireless technologies capabilities. However, there is a variety of the wireless networking technologies available on the market and sometimes there are significant technical differences between them. Thus, for us it is unclear which of the emerging technologies will become successors of so popular nowadays Wi-Fi and Bluetooth. The next section examines and compares capabilities of wireless technologies which can be used for the home networking. [4]

## 4 Technologies

Several years ago wireless technologies had been considered as the silver bullet which may push home networking to the new level. Unfortunately, the *Smart home* concept is still remaining a concept in most cases. Nevertheless, we can state with all confidence that wireless home networking market seriously improved over the last 5 year. Bluetooth became de-facto standard, which caused emerging of several competitive technologies. Wi-Fi also had been proved and matured. A detailed overview of the modern wireless home network technologies is given in the following subsections.

### 4.1 Bluetooth

Bluetooth was the first wireless interface for the mobile personal devices, and since the moment of unveiling, standard was ahead of the time. Researches in the wireless area, started by Ericsson in 90s, ended in 1998 with specification of Bluetooth 1.0. At the first place, new standard was intended to replace proprietary cables for mobile phones. However, it is important to notice that at that time not all mobile phone users understood why they even need cables. There were only two types of devices to which mobile phone

could be connected. First of all, there were *hands-free* headsets and speakerphones which required slow duplex connection at a short distance. Besides that, the mobile phone could be connected to a PC as an external modem. In such case, new standard replaced serial interface RS-232. [13]

For such tasks nobody required Bluetooth to have neither high bandwidth, nor wide range. Standard, developed for mobile devices, has to have low energy consumption and, in order to compete with wired solutions, it has to be very cheap in implementation.

Unfortunately, by that time there were no market demands and standard published in 1998 was highly adopted only after 2001 [13]. However, the idea of Bluetooth evolved very fast. New interface has not been approached only as mobile phone cable replacement, it turned into universal wireless personal area network interface, which supports variety of different devices such as mobile phones, PDAs, PCs, digital cameras, printers, keyboards and computer mice.

Accordingly to the specification [21], Bluetooth is a short-range (10cm - 100m) system with bandwidth less than 1 Mbit/s. However, released in November 2004 second version of Bluetooth increased bandwidth limit up to 2.1 Mbit/s. It is also interesting to notice, the first device with Bluetooth 2.0 support was not a mobile phone but an Apple's laptop. The previous version of the standard is still used in mobile phones, however, it is slowly replaced with the new one.

Bluetooth protocol operates in the license-free 2.4 GHz band. In order to avoid interfering with other protocols which use the same frequency (for example Wi-Fi), Bluetooth uses frequency-hopping technique. It divides the band into 79 channels (each 1 MHz wide) and changes channels up to 1600 times per second [10]. It is also possible to build small wireless network using Bluetooth technology, since it supports not only point-to-point but also point-to-multipoint connections. Currently, up to 7 slave devices can communicate with a master one [10]. Such networks are also very easy to build - users do not need to worry about network addresses, permissions and all other considerations that go with typical networks.

Until the recent time, Bluetooth had no rivals among the wireless interfaces for the personal area networks. However, bandwidth requirements of the home networking increase dramatically in the last couple of years. For example, modern printer can operate data faster than Bluetooth enabled device sends it. Increased number of personal devices in the home networks also made some impact. Thus, driven by the market and consumer demands new standards were developed. They are discussed in the following sections. [21]

## 4.2 Wibree

Wibree is a new developing digital radio technology (intended to become an open standard) unveiled by Nokia in October of 2006. It is designed for applications which require extremely low power consumption, small size and low cost, e.g. wrist watches, toys, wellness devices, wireless keyboards and mice.

Nevertheless, one can hardly name Wibree as a competitor of Bluetooth. In fact, Wibree and Bluetooth are complementary technologies. Wibree operates in 2.4 GHz band

and provides 1 Mbit/s throughput at the range about 10 meters. Wibree has two implementation alternatives. Wibree stand-alone chip can be very cost-effective for small simple devices. Bluetooth-Wibree dual-mode chip will probably be used in the future mobile phones and laptops. The idea here is to keep using Bluetooth for streaming and data-intensive applications (for instance, file transfers) and to use Wibree with devices for which throughput of Bluetooth is redundant (which means energy is not used efficiently). Bob Iannucci, head of Nokia Research Centre, claims the technology is up to ten times more efficient than Bluetooth [14]. However, energy consumption of Wibree strongly depends on the data rate, as it increases, the power consumption increases as well. The first sample Wibree chips is scheduled to be released by Nordic Semiconductor during the second half of 2007. [22]

## 4.3 ZigBee

ZigBee project started as an attempt to build self-organizing ad-hoc digital radio network, for which both Bluetooth and Wi-Fi technologies are unsuitable. Ratified in December of 2004, ZigBee is a suite of high level communication protocols for wireless personal area networks. It uses small, low-power digital radios based on the IEEE 802.15.4 standard. ZigBee protocol is intended to be used by home embedded appliances which require low throughput and very low power consumption.

ZigBee operates in the unlicensed 2.4 GHz, 915 MHz and 868 MHz bands. Theoretical data rate is 250 Kbit/s, 40 Kbit/s and 20 Kbit/s respectively. Transmission range is heavily depends on the environment and varies from 10 to 75 meters [15].

ZigBee self-organizing mesh networks can be cost effective replacement of a wired networks for industrial systems, home automation, building automation, smoke and intruder warning system. Since the main aim of ZigBee networks is the low energy consumption, theoretically, ZigBee enabled network device can run for a year or two using the originally installed battery. [23]

## 4.4 WirelessHD

Started in October 2006 by several leading electronics companies, WirelessHD is an initiative which is aimed to define a network interface specification of a wireless high-definition signal transmission for consumer electronics products (e.g. between video devices and high-definition displays).

Accordingly to the WirelessHD press release [16], new standard will be used for uncompressed digital transmission of high definition video and audio signals. It is also intended as a wireless analog of HDMI technology. Initial specification will support data rates from 2 Gbit/s to 5 Gbit/s. However, theoretical data rate doubles HDMI throughput and is about 20 Gbit/s. The signal will operate in the 60GHz frequency band. The goal range for the first specification is 10 meters with point-to-point non line-of-sight propagation. Finalized specification of the WirelessHD is scheduled to be presented in spring of 2007. [16]

## 4.5 Ultra-Wideband

Ultra-Wideband (UWB) technology designed for low-power, short-range, high-speed, wireless personal area networks. Operational range for UWB is up to 10 meters, and original specification is based on IEEE 802.15.3 standard (follow-on standard, 802.15.3a, is still in the formative stage) which uses carrier-based 2.4 GHz radio. However, at a limited transmit power, UWB radio transmissions can legally (authorized by FCC at 2002) operate in the range from 3.1 GHz to 10.6 GHz. Considering power consumption, UWB has an improvement over Wi-Fi from 10 to 30 times; it also has a smaller form factor for device implementations. UWB bandwidth strongly depends on distance between operating devices and varies from 53.3 Mbit/s (110 Mbit/s for successor) at a 10m distance to 480 Mbit/s at 2m [17].

One of the main advantages of UWB technology is an elimination of many analog and mixed signal components of the traditional carrier wave based radios. Considering the data rates it can support, UWB is a very low cost solution. Ultra-Wideband is mainly positioned as a high data rate cable replacement technology for streaming of high-definition video over the home network. Also, it ideally suits portable consumer devices such as digital cameras and music players which require large file transfers and long battery life. Nevertheless, this technology may be useful in the office network also, providing computers with connectivity to printers, scanners and Voice over IP headsets. An additional feature of UWB is a distance measurement. This feature can be used for tracking devices, ground penetrating radars and location identification applications. Another advantage of Ultra-Wideband is an absence of any interference issues with the existing wireless technologies such as Wi-Fi, WiMAX, and cellular communications.

However, for the end users, Ultra-Wideband name will stay unnoticed, since Certified Wireless USB name had been chosen for marketing of the new technology. The Wireless USB Promoter Group (mostly driven by Intel) was formed in February 2004 in order to define Certified Wireless USB specification, heavily based on the UWB common radio platform [1]. In the beginning of March 2007, Intel stated that key technical specifications are completed.

One of the main changes (comparative to the USB technology) is that Certified Wireless USB specification does not support hubs. At the same time Certified Wireless USB host supports up to 127 devices. Technology also supports so-called dual-role devices, which in addition to being a client device, can function as a host with limited capabilities. For example, a digital camera connected to a computer could act as a client, and at the same time it can act as a host while transferring pictures directly to a printer.

Unfortunately, consumer confusion cannot be avoided, since Cypress Semiconductor registered trademark *WirelessUSB*, doesn't relate to the *Certified Wireless USB* at all. Cypress's WirelessUSB is a protocol that uses the 2.4 GHz band with a range from 10 meters to 50 meters and bandwidth from 1 Mbit/s to 62.5 Kbit/s respectively. Its main application area is Human Interface Devices such as wireless keyboards and mice. WirelessUSB is currently supported by several major manufacturers to include Belkin and Logitech. [17]

## 4.6 Wi-Fi

Wi-Fi (short for wireless fidelity) is the brand name licensed by the Wi-Fi Alliance for wireless local area networks technology based on the IEEE 802.11 specifications. Initially conceived in 1990's, nowadays Wi-Fi became the most mature and widely used standard for wireless home networking as well as for wide public networks (e.g. at airports, libraries, coffee-shops etc.). The protocol evolved in the recent years and now includes several standards: IEEE 802.11a, 802.11b, 802.11g and recently unveiled 802.11n.

The bandwidth of Wi-Fi has always been one of the main factors and it highly improved over the several years. Ratified in 1999, 802.11b standard reached a maximum data transfer rate of 11 Mbit/s; 802.11g, ratified in 2003, has bandwidth up to of 54 Mbit/s [6]. The new version, which is still in development - 802.11n will support up to 540 Mbit/s. However, it is already possible to buy devices powered by new technology. For example, in February 2007 Apple released AirPort Extreme product - home access point based on 802.11n draft specification.

The range of Wi-Fi can exceed 100 meters in some outdoor conditions. The latest specification increased it up to 125 meters, while indoor range is about 50 meters (signals can partially penetrate the walls in a typical building). Except for 802.11a, which operates in 5 GHz band, Wi-Fi uses license-free spectrum near 2.4 GHz. One of the main Wi-Fi disadvantages is the high energy consumption. Wi-Fi is also relatively expensive and has higher latency than some of the other wireless technologies [6].

Despite the fact that Wi-Fi originally was developed as a wireless solution for the local area networks but not for PANs, today *Wi-Fi certified* sticker easily can be found on personal devices. Although the using of Wi-Fi by PDAs, modern mobile phones and portable gaming consoles is becoming very common, another Wi-Fi enabled devices only starting to appear on the market. For example, there are only a few digital cameras with Wi-Fi support available.

On the other hand, until recent time it was hard to find any Wi-Fi competitors on the wireless networking market. One may say the success is mostly defined by the high scalability of a Wi-Fi network. Although it typically covers an entire house, the data rate is reduced to 1 Mbit/s and below at the far distances. But, whereas high bandwidth and greater coverage is required, additional Wi-Fi access points can be installed. In context of the home networking, Wi-Fi is mainly used for interconnecting different devices and for Internet access provisioning. In the last few years Wi-Fi is also used for the data streaming by home media center devices such as Apple TV. Current generation gaming consoles also support Wi-Fi. [24]

## 4.7 WiMAX

WiMAX is an acronym for Worldwide Interoperability for Microwave Access. Technology is in development by WiMAX Forum since June of 2001 and is aimed at wireless broadband access provisioning as an alternative to the cable connections. WiMAX is based on IEEE 802.16 standard, also known as WirelessMAN. Transmission range up to 10 km makes this technology almost perfect for the build-

ing of wireless metropolitan area networks. However, we cannot state that WiMAX is a rival of Wi-Fi or 3G cellular networks. It is positioned more like a link between home or office local networks and global cellular networks, providing high bandwidth while users travel from one LAN to another. WiMAX is expected to deliver capacity of up to 40 Mbit/s which will be shared among all users of WiMAX network, at the distances up to 10 kilometers from the access point [18]. Direct line of sight with access point for WiMAX enabled devices is not required and presented as an important feature. Nevertheless, the data rate will decrease as distance from the access point increases.

Currently 3.5 GHz and 5.8 GHz bands are in the process to be certified for the WiMAX usage. However, WiMAX can operate in a big variety of spectrum bands, allowing operators to deploy services in either licensed or unlicensed spectrum [1]. Now WiMAX Forum is working with service providers and equipment manufacturers to expand the frequency allocation [18].

As for today, there are two versions of WiMAX standard. The fixed WiMAX or IEEE 802.16-2004 requires user to remain stationary, and thus, it is a wireless competitor of xDSL as a broadband access technology. In the areas with low population, for example at the country site, fixed WiMAX is often the only broadband access option, since xDSL is not available at all. Mobile WiMAX or 802.16e version provides user mobility within the range of the network, and seems to be a strong rival to HSDPA due to its better cost efficiency and possibly higher data rates. Many suppliers have already introduced equipment based on the mobile WiMAX specification. Intel is also promoting new technology and integrating mobile WiMAX support into the laptop chipsets. [5]

## 4.8 3G cellular

As an alternative to the modern wireless home networks, we should also consider implementation of the third-generation (3G) wireless cellular technologies for the home users needs. For example, deployment of a 3G cell for each home network. Thus, wireless connectivity for many devices will be provided as well as interconnections between different households.

For those purposes using of High Speed Downlink Packet Access (HSDPA) technology can be quite efficient. HSDPA is an upgrade of WCDMA/UMTS technology. Accordingly to its initial specification [19], supported bandwidth is limited to 1.8 Mbit/s. Current version of HSDPA supports up to 14.4 Mbit/s in downlink, however, theoretical maximum is 42 Mbit/s. Typical bandwidth available for users will be closer to 1 Mbit/s with a maximum of 2 Mbit/s. The range of an HSDPA-based network is roughly 5 kilometer in diameter, but in the urban settings range will be approximately twice smaller - from 1 to 3 kilometers[1]. HSDPA data cards and cell phones have been available since 2005 and 2006 respectively, and the vast variety of HSDPA enabled devices is announced to be release in the second quarter of 2007. In the near future, High Speed Uplink Packet Access (HSUPA) will also make its way into terminals and infrastructure, offering uplink data rates up to 5.76 Mbit/s.

## 5 Comparison

The modern market for the wireless technologies is full of Bluetooth rivals and without serious improvements even Bluetooth 2.0 may have very hard times in the nearest future. In our opinion, the most possible successor of Bluetooth is Certified Wireless USB. On the one hand, Bluetooth is cheaper and has relatively low energy consumption; on the other hand, Certified Wireless USB provides much higher bandwidth (up to 480 Mbit/s). The main disadvantage of the new standard - it is not ready yet. A vast variety of supported devices probably will not help Bluetooth much in the future rival. But acceptance by industry majors, marketing and promotion of the Certified Wireless USB will definitely help new standard to gain market share. Besides that, USB brand is widely adopted and the new standard, from the end user point of view, differs from usual USB only by absence of wires. However, the fast win of any of those standards in the nearest future is impossible. It is likely that Bluetooth will evolve in the direction of data rate increase, while next version of Certified Wireless USB will consume less energy.

Area of the sensor systems and home automation networks is the only area where Bluetooth energy consumption not only nonoptimal, but also does not even meet minimal requirements. For such applications, long life time is not less vital than energy consumption. Thus, ZigBee can be ideal solution for this area, because ZigBee enabled devices can work for a couple of years with one battery.

Since Nokia positioning Wibree as a Bluetooth complementary technology, we assume its closest competition might be ZigBee. In exchange for relatively low throughput (0.25 Mbit/s for ZigBee and 1 Mbit/s for Wibree) both technologies offer long battery life. As for the data transmission range, ZigBee area is three times wider than Wibree's 10 meters. However, it would not be correct to compare those technologies by the transmission range, since they have relatively different areas of usage. ZigBee is purposed for the home appliance and smart home technologies such as lighting and heating controls. While Wibree is designed for mobile phones, watches, and input devices. Thus, it is quite possible that both technologies will coexist side by side over next several years.

WirelessHD also can't be clearly called Bluetooth's rival, since it is mainly positioned as a wireless replacement of HDMI for the home TVs and projectors. It provides great data rate, but consumes lots of energy, which makes this technology unreasonable to implement in a small portable devices.

Theoretically, Bluetooth and Wi-Fi are purposed for the completely different tasks. Nevertheless, evolution of the wireless home networking made those standards to compete in the several areas. First of all, it is relatively small networks of the mobile devices intended for the multimedia and gaming tasks. Transmission range and data rate is a secondary goal for such applications, while energy consumption is the first one. Bandwidth increase in the latest specification of Bluetooth will definitely help this technology to consolidate its grip on such area. Wi-Fi is well suited for the wireless data networking in terms of range and data rates. Besides that, Wi-Fi is very competitive in the area of broadband In-

Technology	Bandwidth	Range	Power consumption	Frequency band
Bluetooth 2.0	2.1 Mbit/s	10 cm - 100 m	low	2.4 GHz
Wibree	1 Mbit/s	10 m	very low	2.4 GHz
ZigBee	250, 40, 20 Kbit/s	10 - 75 m	extremely low	2400, 915, 868 MHz
WirelessHD	2 - 20 Gbit/s	10 m	very high	60 GHz
Certified Wireless USB	480 Mbit/s	10 m	medium	3.1 - 10.6 GHz
Cypress's WirelessUSB	1 Mbit/s - 62.5 Kbit/s	10 - 50 m	low	2.4 GHz
Wi-Fi IEEE 802.11n	540 Mbit/s	50 m	high	2.4 GHz or 5 GHz
Fixed WiMAX	75 Mbit/s	1 - 50 km	medium	3.5, 5 GHz (in Europe)
Mobile WiMAX	30 Mbit/s	2 - 5 km	medium	3.5, 5 GHz (in Europe)
HSDPA	14.4 - 1.8 Mbit/s	0.1 - 20 km	medium	1900-1920 and 2010-2025 MHz

Table 1: Characteristics of the wireless technologies [5], [16], [17], [21], [22], [23], [24]

ternet access provisioning. New mobile phones, PDAs and gaming consoles use Wi-Fi in order to connect to the Internet, while Bluetooth is used for interconnections.

At the same time, WiMAX should not become Wi-Fi rival in the area of home networking, but it will compete and even may replace Wi-Fi in the case of public or private municipal wireless Internet access since it offers true seamless mobility. Also, it is very likely WiMAX will compete with 3G technologies, providing a higher bandwidth for a lower price. As for 3G and even 4G mobile technologies, in our opinion, it is very unlikely they will be used for the wireless home networking. Table 1 presents characteristics of the wireless technologies. In the next section we illustrate how, most probably, technologies discussed previously in this paper will be used for the home networking. [1], [4], [12]

## 6 Wireless home network of the future

The main part of any home network is a home media server [7]. Its main purpose is not only to store audio and video information, but also to provide other devices in the network with broadband access to the Internet. Typical home network also includes several PCs over a house, those we will call *room-server* [7]. Room-servers are connected over the home network to each other and to the media center. In order to organize LAN one may use widely adopted Ethernet with 1 Gbit/s data rate. Thus, one will have to drill holes and snake cables through the walls. Definitely, it is not a preferred solution. At the same time, such technologies as HomePNA and HomePlug which does not require new wiring, as well as wireless solutions of the previous generation can be used in such case, but relatively low bandwidth (54Mbit/s for IEEE 802.11g) will be provided. However, with the upcoming high-throughput Wi-Fi standard (802.11n), wireless connections up to 540 Mbit/s will become possible. Thus, wireless solution will be just twice slower than Gigabit Ethernet and at the same no wiring will be required.

For the connection of the various personal devices to the room-servers, one can use cable in order to achieve high bandwidth. But, from the consumers' point of view this is very undesirable due to the lack of simplicity and flexibility. Hopefully, new emerging standards will provide very high data rates for the personal devices. Thus, Certified Wireless

USB will be used to connect digital cameras and music players to PCs instead of USB 2.0 or FireWire. Also, new standard can be used in order to provide *smart home* services such as location-awareness. For the home automation services which require very low energy consumption, ZigBee will be used. WirelessHD will be used by the home media center to broadcast data to the TVs in different rooms. [4], [7]

## 7 Conclusion

In this paper, we overviewed current technologies which can be used in the wireless home networking area. We discussed their advantages, disadvantages and the most possible application area. Considering results of the analysis, discussed in the *Comparison* section, we may state that using some of the current wireless technologies as a home network backbone is not enough to cover whole area of a home (e.g. Bluetooth and Certified Wireless USB), while others (e.g. WiMAX and 3G cellular) are better suited for the networks which area exceeds typical home network, and some of them (e.g. Wibree and ZigBee) does not meet bandwidth requirement, but have serious advantages in the energy consumption. Thus, several of the discussed technologies, probably will be used in conjunction, amplifying each other. Nevertheless, it is the author's opinion that emerging wireless technologies can fully replace wired home network solutions in the next 5 years.

What should be also underlined, is that success of the particular technology will be based not only on the effectiveness, usefulness and cost, but also on the marketing and brand advertising. However, over the next five years, the wireless home networking landscape may change considerably.

## 8 Acknowledgement

I would like to thank Juha Winter for the guidance, valuable advices and support while writing this paper.

## References

- [1] David Fisher and Michael Stich. *Home Wireless Networks Evolve to Include Bluetooth, Wi-Fi, UWB*,

- WiMAX, HSDPA. In *Converge! Network Digest*. May 2006.
- [2] Kate Greene. *The Evolution of Wireless*. In *MIT's Technology Review*, September 2006.
- [3] Sohil N. Parekh. *The Evolution of Wireless. The Role of Policy-Makers in a Standards-based Market*. Massachusetts Institute of Technology. June 2001.
- [4] David Haskin. *Take a look at the home network of the future*. In *Computerworld*, January 2007.
- [5] Samiseppo Aarnikoivu, Juha Winter. *Mobile broadband wireless access*. HUT Telecommunications Software and Multimedia Laboratory, 2006.
- [6] Theodore Zahariadis. *Evolution of the Wireless PAN and LAN standards*. In *Computer Standards And Interfaces*, May 2004.
- [7] Chiu Ngo. *A Service-Oriented Wireless Home Network*. Consumer Communications and Networking Conference. January 2004.
- [8] Sohil N. Parekh. *Wireless home networks. User Applications mapped to Networking Technologies*. Massachusetts Institute of Technology. May 2000.
- [9] David Groth, Toby Skandier. *Network+ Study Guide, Fourth Edition*. Sybex, Inc. 2005.
- [10] K. Vaxevanakis, Th. Zahariadis, N. Vogiatzis. *A Review on Wireless Home Network Technologies*. In *ACM Mobile Computing and Communications Review*, April 2003.
- [11] Roberto Battiti, Renato Lo Cigno et al. *Wireless LANs: From WarChalking to Open Access Networks*. In *Mobile Networks and Applications*, June 2005.
- [12] Alben Mihovska, Fanny Platbrood et al. *Towards the Wireless 2010 Vision: A Technology Roadmap*. In *Wireless Personal Communications*, September 2006.
- [13] Alexey Kozlov. *Bluetooth EDR*. At [www.3dnews.ru](http://www.3dnews.ru), September 2005.
- [14] Iddo Genuth. *Nokia's Wibree and the Wireless Zoo*. In *The Future of Things online magazine*, November 2006.
- [15] Patrick Kinney. *ZigBee Technology: Wireless Control that Simply Works*. Kinney Consulting LLC, December 2003.
- [16] *WirelessHD press release*. At [www.wirelesshd.org](http://www.wirelesshd.org), October 2006.
- [17] *UWB technical FAQ*. At [www.uwbforum.org](http://www.uwbforum.org). 2006.
- [18] *WiMAX Forum technology FAQ*. At [www.wimaxforum.org](http://www.wimaxforum.org), October 2006.
- [19] *HSDPA and beyond*. Whitepaper by Nortel Networks, January 2005.
- [20] *IEEE 802-2001. Standard for Local and Metropolitan Area Networks: Overview and Architecture*. IEEE, 2002.
- [21] *Specification of the Bluetooth System*. Bluetooth Special Interest Group, 2004.
- [22] *Wibree Press Release*. At [www.wibree.com](http://www.wibree.com), 2006.
- [23] *ZigBee Wireless Networks for Industrial Systems*. Whitepaper by Andy Wheeler, Ember Corporation, June 2006.
- [24] *Wi-Fi White Papers*. At [www.wi-fi.org](http://www.wi-fi.org), 2007.