Wireless Home Area Network Technologies

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Abstract—**One of the visionary concepts that home area network intends to achieve is the establishment of communication between home appliances such as computers, TVs, telephones, refrigerators, air conditioners etc. Wireless home area networks have an edge over their wired counterparts because features of wired networks such as flexibility and interoperability are coupled with those in the wireless domain, namely, simplicity of installation, and mobility. Yet despite this promising prospect, the market is evolving slowly because there are numerous industrial grouping and standardization bodies that continue their work on independent and often non-interoperable specifications for home networks; on the other hand, while there are multiple home PCs and multimedia network-enabled appliances, the majority of the houses can not support sophisticated interconnection, while most consumers are unwilling or cannot afford a large scale home rewiring. Wireless Networks can resolve the rewiring issue capturing, major share of home network market. In this paper, the author reviews the available technologies in the home network area, and provides a comparison of the in-home technologies.**

Keywords—**Wireless Networks, CSMA/CA, HomeRF, Bluetooth, WLAN, Zigbee.**

I. Introduction

The Home Area Network (HAN) provides an infrastructure to interconnect a variety of home computing appliances like PCs, communicating appliances like phone, entertainment and audiovisual appliances like TV, security systems like motion detectors etc. Appliance manufactures are working on smart appliances capable of communication. This intelligence allows eremite checking test for maintenance of appliances and remote control operations. Another wave of interest in home network stems from utility companies for distance utility metering for billing etc. One of the solutions is to communicate this information through the HAN and its access to the Internet.

The HAN must take care of application diversity, network requirement, building infrastructure of home and market size. In homes, number of users of network is less, diversity of devices and their bandwidth requirements vary. Homeowners are also reluctant to allow service workers to enter their homes and can't afford a network manager to operate their network. A HAN needs to be user friendly; must be low cost; power efficient; operating in license free band; can tolerate interference; safe; compatible with other technologies like Internet easy to install and relocate, upgrade; should be able to enable multimedia applications and be capable of accommodating voice and data services. It needs to be flexible and scalable to allow location independence and easy reconfigurabilily of networks without performance degradation. To avoid eavesdropping or session hijacking, it needs security and privacy provisions.

Until recently the major obstacle to *"digital networked house"* has been the inadequate network infrastructure and the huge cost of installations. Today, many technologies, working groups and standard specifications for home networking already exist, providing guidelines for interoperation between access and in-home networks, while increasing the entropy in the home network industry.

In this review, author analyzes and compares some of the most widely accepted current and future wireless home networking technologies. Section 2 presents the wireless technologies and section 3 compares them based on various characteristics. Conclusions are recapitulated in Section 4.

II. Wireless Network Technologies

The "no wires" RF technologies are considered the "Holy grail" of the home networking and are expected to play a key role in pushing forward the digital house concept. A detailed overview of the various wireless home network alternatives is given in the following subsections.

Home RF

HomeRF supported by the HomeRF Working Group (HRFWG), provides base for wireless digital communication between PCs and consumer electronic devices anywhere in and around the home. Specification defines a common Home RF MAC and Physical layers, which support wireless voice and data networking in the residential side [1][2].

Many companies are working with the HRFWG to develop the Shared Wireless Access Protocol (SWAP) [3] for radio-based home networks. The SWAP specification has been derived from IEEE 802.11 and European digitally enhanced cordless telephony (DECT) standards. As a result, the SWAP MAC layer can support both data oriented

services, such as TCP/IP, and the DECT/GAP protocols for voice. The SWAP system can operate either as an ad-hoc network or as infrastructure based network under the control of a Connection Point. In an ad-hoc network, where only data communication is supported, all stations are equal and control of the network is distributed between the stations. For time-critical communications, such as interactive voice, a Connection Point is required to coordinate the system. The Connection Point, can be connected to a PC via a standard interface (e.g. USB) enabling enhanced voice and data services. The SWAP system also can use the Connection Point to support power management for prolonged battery life by scheduling device wakeup and polling. The network can accommodate a maximum of 127 nodes of a mixture of four basic types:

- Connection Point that provides a gateway to Public Switched Telephone Network (PSTN), hence supporting voice and data services.
- Voice node that only uses TDMA service to communicate with a base station
- Asynchronous data node that uses the CSMA/CA service to communicate with a base station and other data nodes.
- Voice and Data Node which can use both types of services

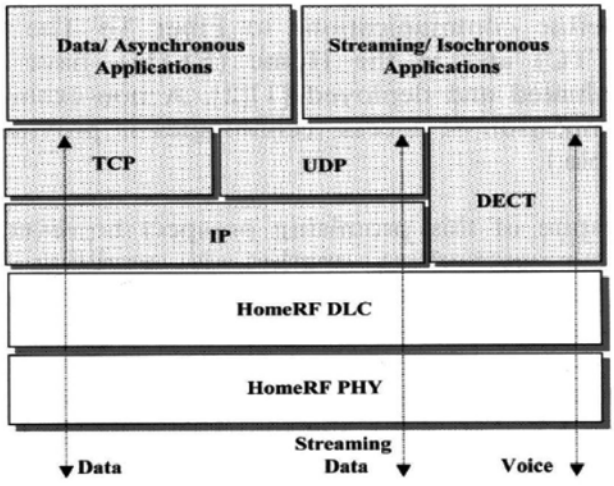

Fig. 1: Home RF Protocol Stack

Bluetooth

Bluetooth is a short- range frequency-hop wireless system for connecting personal devices. It supports both point-to-point and point-to-multipoint connections. Currently a piconet can have up to seven slave devices communicating with a master. Several piconets can be linked together in ad hoc networking mode [4]. The Bluetooth protocol stack architecture shown in Figure 2 is a layered stack that supports physical separation between the Link Manager and the higher layers at the Host Control Interface (HCI), which is required when layers above LM are implemented on the motherboard of a host device [5][6]. The Baseband layer provides the functionality required for air interface packet framing, establishment and maintenance of piconets and link control. The Link Manager is responsible for link set-up and control including authentication, encryption control, physical parameters control etc. The Logical Link Control Adaptation Layer Protocol (L2CAP) provides connection oriented and connectionless data services to higher layer protocols. Service Discovery Protocol (SDP) allows Bluetooth devices to discover what services are available on a device, RFCOMM provides an emulation of serial ports, and Telephony Control Specification (TCS) provides an adaptation layer that enables Q.931 call control services. Bluetooth is ideal for both mobile office workers and small office/home office (SOHO) environment [7]. For example, once VoIP is established, it can be used to automatically switch between a cellular and an in-door wireless phone, when one enters a house or an office.

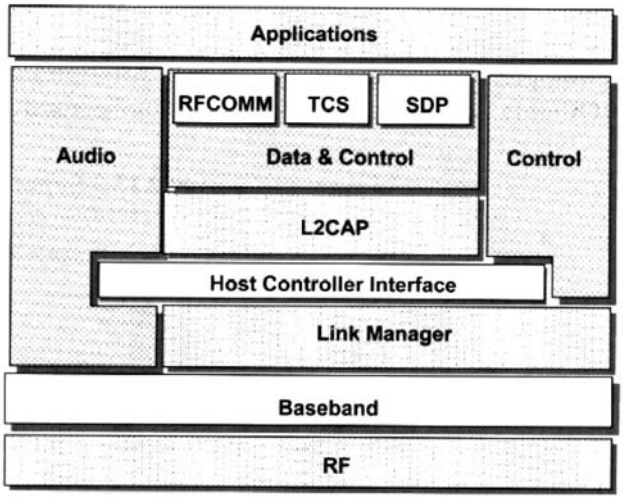

Fig. 2: Bluetooth Protocol Stack

IEEE 802.11

IEEE 802.11 is the most mature wireless protocol for wireless LAN communications, tested and deployed for years in corporate, enterprise, private and public environments. It is one of the favored technologies for home networking. The 1997 IEEE 802.11 standard [8] supports several wireless LAN technologies that share the same MAC over different PHY layer specifications: Direct-Sequence Spread Spectrum (DSSS); Frequency-Hopping Spread Spectrum (FHSS) technologies and infrared technology. In 1999, two new techniques OFDM and HR-DSSS were introduced to achieve higher bandwidth. In 2001, a second OFDM modulation was introduced, but in a different frequency band from the first one. To deal with hidden and exposed terminal problem [9], 802.11 supports two modes of operation. The first, called DCF (Distributed Coordination Function), does not use any kind of central control (in that respect, similar to Ethernet). The other, called PCF (Point

Coordination Function), uses the base station to control all activity in its cell [10][11]. All implementations must support DCF but PCF is optional. In order to ensure interoperability and compatibility across all market segments, IEEE 802.11 product manufactures have agreed on a compliance procedure called Wi-Fi (Wireless Fidelity standard). Moreover a Wireless Ethernet Compatibility Alliance (WECA) has been formed in order to certify Wi-Fi interoperability of new products [12][13].

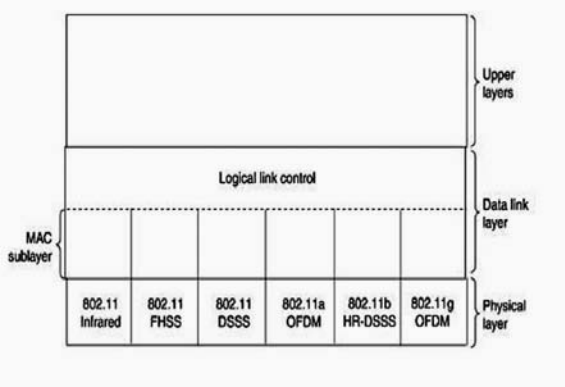

Fig. 3: Part of the 802.11 protocol stack

HiperLan 2

HIPERLAN/2 is the European proposition for a broadband Wireless LAN operating supported by the European Telecommunications Standards Institute (ETSI), and developed from the Broadband Radio Access Networks (BRAN) group [14][15][16]. It is a flexible Radio LAN standard, designed to provide high-speed access to a variety of networks, including 3G mobile core networks, ATM networks and IP based networks, as well as for private use or Wireless LAN system. HiperLAN/2 is a connection-oriented Time Division Multiplexed (TDM) protocol. Data is transmitted on connections that have been established prior to the transmission using signaling functions of the HiperLAN/2 control plane. This makes it straightforward to implement support for QoS. Each connection can be assigned a specific QoS, for instance in terms of bandwidth, delay, jitter, bit error rate, etc. It is also possible to use a more simplistic approach, where each connection can be assigned to a priority level compared to other connections. This QoS support, in combination with the high transmission rate, facilitates the simultaneous transmission of many different types of data streams, e.g. video, voice, and data [17]. The HiperLAN/2 protocol stack is shown in Figure 4. At the physical layer HiperLAN/2 uses OFDM to transmit the analogue signals. OFDM is very efficient in time-varying environments, where the transmitted radio signals are reflected from many points, leading to different propagation times before they eventually reach the receiver. Above the physical layer, the MAC protocol is built from scratch, implementing a type of dynamic TDMA/TDD scheme with centralized control. The MAC frame appears with a period of 2 ms. The Error Control is responsible for detection and recovery from transmission errors on the radio link. Moreover, it ensures in-sequence delivery of data packets. In the Control Plane, the Radio Link Control Sublayer (RLC) provides a transport service to the DLC User Connection Control, the Radio Resource Control and the Association Control Function. Finally a convergence sublayer is provided for each supported network.

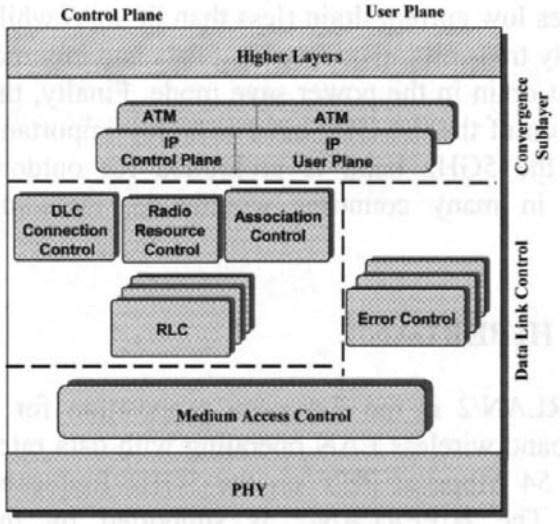

Fig. 4: HiperLAN/2 protocol stack

Zigbee

ZigBee is a low-cost, low-power Wireless standard for high level communication protocols using small, low-power digital radios. ZigBee builds upon the physical layer and Medium Access Control defined in IEEE standard 802.15.4 for low-rate WPAN's [18][19]. The specification goes on to complete the standard by adding four main components: Network layer, Application layer, ZigBee device objects (ZDO) and manufacturer-defined application objects which allow for customization and favor total integration as shown in the Figure 5. The main functions of the network layer are to enable the correct use of the MAC sublayer and provide a suitable interface for use by the next upper layer, namely the application layer. Its capabilities and structure are those typically associated to such network layers, including routing. The application layer is the highest-level layer defined by the specification, and is the effective interface of the ZigBee system to its end users. It comprises the majority of components added by the ZigBee specification: both ZDO and its management procedures, together with application objects defined by the manufacturer, are considered part of this layer.

III. TECHNOLOGIES COMPARISON

The Wireless technologies are expected to push forward the concept of the digital house. However, the selection among current and future technologies and standards is quite difficult. Table 1 gives the comparison of Home Wireless Technologies discussed in the previous sections.

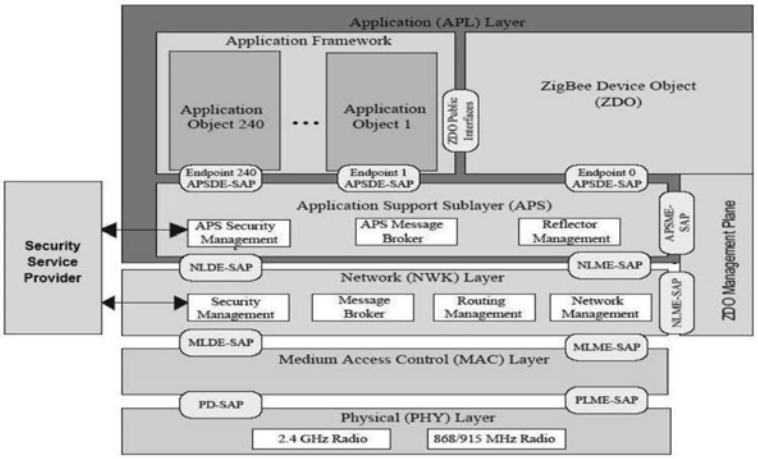

Fig. 5: HiperLAN/2 protocol stack

TABLE I: COMPARISON OF WIRELESS HOME AREA NETWORK TECHNOLOGIES

Feature	Home RF	Bluetooth	IEEE 802.11	HiperLan 2	Zigbee
Reference	[1]	[4]	[8]	[17]	[19]
Promoting Group	HomeRF Working Group	Bluetooth Special Interest Group	Wi-Fi Alliance	RES-10 group of ETSI	Zigbee Alliance
Architecture	Ad-hoc or infrastructure based network	Ad-hoc network	Ad-hoc or infrastructure based network	Ad-hoc or infrastructure based network	Ad-hoc
Frequency Band	2.4GHz	2.4GHz	2.4GHz	5 GHz	868 MHz in Europe, 915 MHz in USA and 2.4 GHz others
Physical Layer	FHSS	FHSS	FHSS/DSSS/Ir	OFDM	DSSS
Maximum Transmission Rate	10 Mbps	1 Mbps	54 Mbps (802.11a, 802.11g)	32 Mbps	250 kbps in 2.4 GHz, 40 kbps in 915 MHz, 20 kbps in 868 MHz
Maximum Throughput	-	<700 Kbps	32 Mbps (IEEE 802.11a)	32 Mbps	-
Maximum Range	50 m	10 cm – 10m extended upto 100m	150 m IEEE 802.11 g	80 m	10-75 m
Frequency Management	Dynamic Selection	Dynamic Selection	None	Dynamic Selection	None
Medium Access	CSMA/CA	Polling	CSMA/CA	TDMA/TDD	CSMA/CA
Authentication	Shared Key Encrption like DECT	E1 Challenge response scheme with 128-bit key	None	NAI/IEEE Add/X.509	-
Encryption	128-bit secret key	128-bit secret kev	40-bit RC4	DES,3DES	CCM with 128-bit Key
QoS support	TDMA	Polling	PCF	ATM 802.1d/RSVP	-
Voice/Data Support	Yes	Yes	Yes	Yes	Yes
Wired Backbone	Ethenet/PPP/WLL	Ethenet/PPP	Ethernet	Ethernet/ATM /UMTS/PPP	Ethernet/PPP
Connectivity	Both	Both	Connectionless	Connection oriented	-
Link Quality Control	None	None	None	Link Adaptation	None
Regional Support	US/Asia	World	World	Europe/Japan	Emerging
Product Promoters	<50	2000+	100+	<50	<50
Target Application	Wireless Voice/Data	Cable replacement for personal devices	Wireless Voice/Data	Wireless Data	Cable replacement for personal devices
Complexity	1.5 x	1 x	1.2 to 4 x	2.5 x	1 x
Strength	-	Accepted and simple	Widely accepted, proven and mature	High data rate with IP services	Simple and cheap
Weakness	Complex MAC and PHY increases cost	No handoff, routing support	Less Secure, Brute force method can break key	Popular in Europe	Yet to be accepted

IV. CONCLUSION

In this paper, author has reviewed the major available technologies and standardization efforts in the wireless home network area, and provided a comparison of the competing home networking technologies. It is the authors' opinion that multiple technologies will be finally used at the indoor side, however the *"no-wires"* technologies will dominate. Current deployed (e.g. IEEE 802.11) and emerging (e.g. Bluetooth) technologies may cover the main in-home networking requirements, while for short distance and low cost communication Zigbee is envisaged to be a major candidate. Success will be based on the effectiveness, usefulness and cost of the end-to-end network system as a whole. Digital Home will be a reality, when added value services will be able to attract customers, providing the appropriate functionality and flexibility, fulfilling user requests and agreed quality, have sufficient content, and be favorably compared to standalone systems.

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