WIRELESS COMMUNICATION

Sakshi Jain, Snehal Dhote , Neha Gabhane

JD College of engg and management

Computer Science & Engg.

**Abstract**—Wireless systems are now popular worldwide to help people and machine to communicate with each other irrespective of their location. Wireless Communication is an application of science and technology that has come to be vital for modern existence. From the early radio and telephone to current devices such as mobile phones and laptops, accessing the global network has become the most essential and indispensable part of our lifestyle. One expectation for the future in this field is that, the devices can be developed to support communication with higher data rates and more security.Research in this area suggests that a dominant means of supporting such communication capabilities will be through the use of Wireless LANs. As the deployment of Wireless LAN increases well around the globe, it is increasingly important for us to understand different technologies and select the most appropriate one. This paper provides a detailed study of the available wireless LAN technologies and the concerned issues. This is followed by a discussion evaluating and suggesting a feasible standard for future.

**1. Introduction**

Many technical challenges must be addressed to enable the wireless applications of the future. Communication has enhanced to convey the information quickly to the consumers. Urgent situation can be alerted through wireless communication. The affected regions can be provided help and support with the help of these alerts through wireless communication. Wi-Fi, Bluetooth, Cellular, WiMAX these are the different types of wireless technologies. The increased demands for mobility and flexibility in our daily life are demands that lead the development from wired LANs to wireless LANs (WLANs).Today a wired LAN can offer users high bit rates to meet the requirements of bandwidth consuming services like video conferences, streaming video etc. With this in mind a user of a WLAN will have high demands on the system and will not accept too much degradation in performance to achieve mobility and flexibility. This will in turn put high demands on the design of WLANs of the future. In this paper, we first discuss the various Wireless LAN standards available for deployment. Secondly, a study on the challenging factors of these with a little overview on security issues in wireless LAN is discussed. Finally, an analysis of the available Wireless LAN standards and a feasible solution for future deployment is discussed. A wireless LAN is based on a cellular architecture where the system is subdivided into cells, where each cell (called Base Service Set or BSS\*) is controlled by a Base station (called Access point or AP). Wireless LAN standards that are currently being explored in the field of communications technology are:

1. IEEE 802.11.

a. 802.11a

b. 802.11b

c. 802.11g

2. HiperLAN/2.

3. Bluetooth.

4. HomeRF.

**1.1 Wireless LAN Standards:** There are several wireless LAN solutions available today, with varying levels of standardization and interoperability. Two solutions that currently lead the industry are, HomeRF and Wi-Fi\* (IEEE\*\* 802.11b). Of these two, 802.11technologies enjoy wider industry support and are targeted to solve Enterprise, Home and even public “hot spot” wireless LAN needs.

**a. IEEE 802.11:** The IEEE finalized the initial standard for wireless LANs, IEEE 802.11 [1] in June 1997. This initial standard specifies a 2.4 GHz operating frequency with data rates of 1 and 2 Mbps. With this standard, one could choose to use either frequency hopping or direct sequence (two non compatible forms of spread spectrum modulation).Because of relatively low data rates (as compared to Ethernet), products based on the initial standard did not flourish as many had hoped.

In late 1999, the IEEE published two supplements to the initial 802.11 standard: 802.11aand 802.11b (Wi-Fi\*). The 802.11a [3] standard (High Speed Physical Layer in the 5 GHzBand) specifies operation in the 5 GHz band with data rates up to 54 Mb/s. Theadvantages of this standard (compared to 802.11b.Higher Speed Physical LayerExtension in the 2.4 GHz Band) include having much higher capacity and less RF (radiofrequency) interference with other types of devices (e.g., Bluetooth), and products arejust now becoming available throughout 2002. However, 802.11a isn’t compatible with802.11b and 802.11g products. As with the initial standard, 802.11b operates in the 2.4GHz band, but it includes 5.5 and 11 Mb/s in addition to the initial 1 and 2 Mb/s. The802.11b standard only specifies direct sequence modulation, but it is backwardcompatible with the initial direct sequence wireless LANs. The IEEE 802.11b standard iswhat most companies choose today for deploying wireless LANs.

The 802.11 working group is currently working to extend the data rates in the 2.4 GHz band to 54 Mb/s using OFDM (orthogonal frequency division multiplexing), which is the 802.11g [7] standard. This standard will hopefully be ratified by the end of 2002. Companies should be able to easily scale their existing 802.11b products to become 802.11g-compliant through firmware upgrades. This enables companies having existing 802.11b infrastructures to scale up their network via relatively simple cost-effective changes.

**b.** **HiperLAN 1/2:** European Telecommunications Standards Institute, ETSI, ratified in 1996 with High Performance Radio LAN (HiperLAN1) [4] standard to provide high speed communications (20Mbps) between portable devices in the 5GHz range. Similarly to IEEE802.11, HiperLAN/1 adopts carrier sense multiple access protocol to connect end user devices together. On top of that, HiperLAN/1 supports isochronous traffic for different type of data such as video, voice, text, etc. Later, ETSI, rolled out in June 2000, a flexible Radio LAN standard called HiperLAN 2, designed to provide high speed access (up to 54 Mbps at PHY layer) to a variety of networks including 3G mobile core networks, ATM networks and IP based networks, and also for private use as a wireless

LAN system. Basic applications include data, voice and video, with specific QoS. parameters taken into account. HIPERLAN/2 [5] has a very high transmission rate up to 54 Mbps. This is achieved by making use of a modularization method called Orthogonal Frequency Digital Multiplexing (OFDM). OFDM is particularly efficient in time-dispersive environments, i.e. where the radio signals are reflected from many points, e.g. in offices.

**c.** **Bluetooth:** Bluetooth is an industry specification for short-range RF-based connectivity for portable personal devices with its functional specification released out in 1999 by Bluetooth Special Interest Group [6]. Bluetooth communicates on a frequency of 2.45 gigahertz, which has been set aside by international agreement for the use of industrial, scientific and medical devices (ISM). One of the ways Bluetooth devices avoid interfering with other systems is by sending out very weak signals of 1 milliwatt.

The low power limits the range of a Bluetooth device to about 10 meters, cutting the chances of interference between a computer system and a portable telephone or television. Bluetooth makes use of a technique called spread-spectrum frequency hopping. In this technique, a device will use 79 individual, randomly chosen frequencies within a designated range, changing from one to another on a regular basis. Bluetooth devices essentially come in two classes, both using point-to-point communication to speak. Class 3 devices operate at 0 dBm range and are capable of transmitting 30 feet, through walls or other objects and the other class is termed as class 1 products. These devices operate at 20 dBm, which allows for the signal to travel about 300 feet through walls or other solid objects. Both Bluetooth classes are rated at traveling at about 1 Mbps, with next generation products allowing anywhere from 2 to 12 Mbps, to be determined at a later date.

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| --- | --- | --- | --- | --- | --- |
| **Standard** | **IEEE802.11** | **802.11a/802.11b** | **HiperLAN/2** | **Bluetooth** | **HomeRF** |
| **Mobile Freq.**  **Range**  **(GHz)** | N.A/Europe  2.4 - 2.483  Japan  2.47 - 2.499 | **a** Aimed at  5.15 - 5.25  5.25 - 5.35  5.725 - 5.825  **b**  NA/Europe  2.4 - 2.483  Japan  2.47 - 2.499 | Aimed at  5.15 - 5.35  5.47 - 5.725 | NA/Europe  2.4 - 2.483  Japan  2.47 - 2.499 | NA/Europe  2.4 - 2.483  Japan  2.47 - 2.499 |
| **Multiple**  **Access**  **Method** | CSMA/CA | CSMA/CA | TDMA | TDMA | TDMA/CSMA |
| **Duplex**  **Method** | TDD | TDD | TDD | FDD | TDD |
| **Number of**  **Independent**  **Channels** | FHSS\*: 79  DSSS\*: 3-5 | **a** 12  **b** 3 to 5 | 12 | FHSS\*: 79 | FHSS\*: 79 |

**d.** **HomeRF:** HomeRF is an open industry specification developed by Home Radio Frequency Working Group [2] that defines how electronic devices such as PCs, cordless phones and other peripherals share and communicate voice, data and streaming media in and around the home. HomeRF-compliant products operate in the license-free 2.4 GHz frequency band and utilize frequency-hopping spread spectrum RF technology for secure and robust wireless communications with data rates of up to 1 Mbps (HomeRF 1). Unlike Wi-Fi, HomeRF already has quality-of-service support for streaming media and is the only wireless LAN to integrate voice. HomeRF may become the worldwide standard for cordless phones. In the year 2001, the Working group unveiled HomeRF 2.0 that supports 10 Mbps ( HomeRF 2.0) or more.

**2. Wireless automotive communications**

In this section three Personal Area Network (PAN) standardsfor in-vehicle communications are presented: Bluetooth(IEEE 802.15.1) [1, 5], ZigBee (IEEE 802.15.4)[8, 5], and Ultra Wide Band (UWB/IEEE 802.15.3a) [7, 5]. Also, one Wireless Local Area Network (WLAN) for inter-vehicle communications is presented: Wi-Fi (IEEE 802.11a/b/g) [4]. All these technologies are possible candidates for wireless real-time control systems found in automotive systems. Important issues not discussed in this paper are safety and security. In general, concerning safety, a wireless link is more sensitive to interference compared with a wired one. Also, from a security perspective, the wireless medium makes the system reachable from outside, possibly subject to intrusion. Moreover, it is still an open issue whether wireless networks introduce health risks for the driver of the vehicle.

**2.1 Bluetooth**

Bluetooth (IEEE 802.15.1) [1, 5] currently provides network speeds of up to 3 Mbps. Originally devised for PAN deployment for low-cost, low-power, short-range wireless ad hoc interconnection, Bluetooth technology has fast become very appealing also for the automotive environment, as a potential automotive wireless networking technology. In response to interest by the automotive industry, in December 1999 the Bluetooth Special Interest Group (SIG) formed the Car Working Group. The Hands-Free profile was the first of several application level specifications from the Car Working Group. Using the new Hands-Free profile, products that implement the Bluetooth specification can facilitate automatic establishment of a connection between the car’s hands-free system (typically part of its audio system) and a mobile phone. Bluetooth wireless products in corporating these new enhancements enable a seamless, virtually automatic interface between the car and wireless products. Today, Bluetooth allows hands-free use of a mobile phone either through the car’s audio system or wireless headsets, resulting in better sound and control, and a safe solution to legislation banning mobile phone use while driving. The Bluetooth SIG, in November 2004, laid out a three year roadmap for future improvements to Bluetooth. Prioritised targets include Quality of Service (QoS), security, power consumption, multicast capabilities, privacy enhancements. Long-range performance improvements are expected to increase the range of very low power Bluetooth enabled sensors to approximately 100 meters.

**2.2 ZigBee**

ZigBee (IEEE 802.15.4) [8, 5] is a new low-cost and low-power wireless PAN standard, intended to meet the needs of sensors and control devices. Typical ZigBee applications do not require high bandwidth, but do impose severe requirements on latency and energy consumption. Despite the number of low data rates proprietary systems designed to fulfil the above mentioned requirements, there were no standards that met them. Moreover, the usage of such legacy systems raised significant interoperability problems which ZigBee technology solves, providing a standardized base set of solutions for sensor and control systems. The Zig-Bee Alliance (with over 120 company members) ratified the first ZigBee specification for wireless data communication sin December 2004.ZigBee provides network speed of up to 250 Kbps, and is expected to be largely used in home and building automation(e.g., for fire detection, security and access monitoring, heating, lighting and environment control), and in industrial process monitoring and control systems (e.g., for use in monitoring and control of industrial processes and equipments, especially in hazardous environments inaccessible to normal wired systems).

**2.3 Wi-Fi**

Wi-Fi (*wireless fidelity*) is the general term for any type of IEEE 802.11 network [4]. Examples of 802.11 networks are the 802.11a (up to 54 Mbps), 802.11b (up to 11 Mbps), and 802.11g (up to 54 Mbps). These networks are used as WLANs. The three 802.11 standards differ for the offered bandwidth, coverage, security support and, therefore, the kind of applications supported. 802.11a is better suited for multimedia voice, video and large-image applications in densely populated user environments. However, it provides relatively shorter range than 802.11b, which consequently requires fewer access points for coverage of large areas. The 802.11g standard is compatible with and may replace 802.11b, partly due to its higher bandwidth and improved security.

**3. Discussion**

A summarizing comparison of the wireless technologies discussed in this paper is presented in Table1.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Standard** | **Bluetooth**  IEEE 802.15.1 | **ZigBee**  IEEE 802.15.4 | **UWB**  IEEE 802.15.3a | **Wi-Fi**  IEEE 802.11a/b/g |
| **Freq. band** | *•* 2.4 Ghz & 2.5 Ghz (ver 1.2) | *•* 2.4 Ghz | *•* 3.1-10.6 Ghz | *•* 2.4 Ghz (b/g) & 5 Ghz (a) |
| **Network** | *•* P2P | *•* Mesh | *•* P2P | *•* P2P |
| **Modulation**  **technique** | *•* Frequency Hopping Spread Spectrum (FHSS) | *•* Direct Sequence Spread Spectrum (DSSS) | *•*Orthogona lFrequency Division  Multiplexing (OFDM) or  Direct-Sequence UWB (DSUWB) | *•* OFDM or DSSS with Complementary  Code Keying  (CCK) |
| **Maximum**  **network**  **speed** | *•* 1 Mbps (ver 1.0)  *•* 3 Mbps (ver 1.2)  *•* 12 Mbps (ver 2.0) | *•* 250 Kbps | *•* 50-100 Mbps (480 Mbps  within short ranges expected). | *•* 54 Mbps (802.11a)  *•* 11 Mbps (802.11b)  *•* 54 Mbps (802.11g) |
| **Network**  **range** | *•* Up to 100 meters, depending  on radio class (effective 10 meters). | *•* Up to 70 meters (effective 20  meters). | *•* Up to 20 meters (effective 10  meters). | *•* Up to 100 meters (effective  50 meters). |
| **Main**  **usage** | *•* Voice applications.  *•* Eliminating short-distance  cabling. | *•* Sensors/control applications.  *•* Grand-scale automation.  *•* Remote control. | *•* Multimedia applications.  *•* Healthcare applications | *•* Office and home networks.  *•* WLAN.  *•* Replace Ethernet cables. |
| **Strong**  **points** | *•* Dominating PAN tech.  *•* In vehicles today.  *•* Easy synchronization of mobile  devices.  *•* Frequency hopping tolerant  to harsh environments. | *•* Static network.  *•* Control/sensor.  *•* Many devices/nodes.  *•* Small data packets.  *•* Low duty cycle.  *•* Low power. | *•* Easy and cheap to build.  *•* Consume very little power.  *•* Provides high bandwidth.  *•* Broad spectrum of frequencies (robustness). | *•* Dominating WLAN tech.  *•* Know-how. |
| **Weak**  **points** | *•* Interference with WiFi.  *•* Consume medium power. | *•* Low bandwidth | . *•* Short range.  *•* Interference | *•* Traditionally consume high  power. |
| **Automotive**  **usage**  **(potential)** | *•* Portable devices.  *•* Diagnostics tools.  *•* Real-time communications.  *•* Device connectivity. | *•* In-vehicle communications.  *•* Mobile/static sensor networks. | *•* Robust vehicle communications.  *•* High bandwidth communications. | *•* Inter-vehicle communications.  *•* Vehicle-to-vehicle.  *•* Vehicle-to-roadside. |

**3.1 Technology comparison**

From a general perspective, the main differences between the wireless technologies considered originates from the different target applications they were optimized for. Bluetooth addresses voice applications, eliminating short distance cabling, is suitable for hands-free audio but also for synchronization of cell phones to PDAs, file transfer, adhoc networking between capable devices. For these applications a network range of a few tens of meters is sufficient together with network speeds of a few (1-2) Mbps. This is what Bluetooth provides. ZigBee, on the other hand, addresses sensors and control, and other short message applications. ZigBee applications are consisting of lots of devices typically requiring small data packets with a lightweight protocol and a small protocol stack. Network speed here is not as important as for the other technologies presented in this paper, and currently only 250 Kbps is provided. Nodes can be scattered around in a slightly larger area compared with Bluetooth. UWB is the upcomer (although historically it has its roots in the sixties), providing interestingly high network speeds together with a robust communications using a broad spectrum of frequencies. This technology is best suited at very short range (a few meters), compared with the others, but the bandwidth it provides (up to 480 MBps) is magnitudes higher compared to the other technologies. WiFi is developed as a replacing technology for wired Ethernet used mainly in home and office environments. To provide mobility, network speeds and range should be as high as possible. 54 Mbps is provided and the network is still effective around 50 meters. Considering power usage, both ZigBee and UWB require very low power for operation. On the other hand, although much better than WiFi, which is not built with low power as the prime target, Bluetooth requires about 50 times more energy to transfer a single bit compared to UWB.

**3.2 Automotive applications**

Looking at the automotive context, Bluetooth is built into many vehicles today. Hence, it is currently the most widely used automotive wireless technology. The frequency hopping modulation technique is also suitable in harsh environments often found in automotive applications. The availability of Bluetooth in vehicles and cell phones, means that it already today provides a technology for telematics applications. In a Bluetooth-enabled vehicle, the car audio system takes over the phone function. In addition, other Bluetooth devices can easily interconnect within a Bluetooth enabled car: for example, portable devices, such as DVD, CD, MP3 players, can be connected to speakers. More-over, hand-held computers and diagnostic equipments can interface to the car and access services provided by the onboard diagnostic and control systems through Bluetooth interfaces. Beyond entertainment and phone calls there are other emerging possibilities, including remote starting to warm-up the car in the winter or start the air conditioning in summer, iPod or MP3 players streaming to the audio system, a remote parking garage or home garage door controller, and payment for gas at the pump and toll road payments. ZigBee on the other hand, fills a gap not provided by the other technologies, namely the interconnection of wireless sensors for control. ZigBee is expected to be used in monitoring and control applications, related to temperature and humidity measurement as well as heating, ventilation, air conditioning and lighting control. There are also quite novel and original ways of using ZigBee for the driver’s benefit. One of them is rental car monitoring. A ZigBee-enabled monitoring system could allow customers to quickly drop off a rental car without waiting for the attendant to check gas or mileage. Other interesting automotive applications are tire-pressure monitoring and remote keyless entry. Further proposals involve attaching a ZigBee device to anything which should not be lost (e.g., car keys), so that, whenever the device goes out of range, an alert signal is generated from a ZigBee-equipped phone. UWB is the newcomer in this area, possibly providing robust communications thanks to its usage of a broad spectrum of frequencies. We are likely to see UWB in applications requiring high bandwidth, such as interconnection of multimedia devices. Other automotive applications are collision-detection systems and suspension systems that respond to road conditions [7]. However, UWB being a young technology, no such applications are available to date. For inter-vehicle communications, WiFi is the most interesting technology today, partly due to its extensive usage in office and home networks, but also due to its availability.

Hence, it is often used in pilot research projects. Wi-Fi is used for inter-vehicle communications by, e.g., the Car2Car Consortium [2], a non-profit organization initiated by European vehicle manufacturers. Applications here are advanced drive assistance reducing the number of accidents, decentralized floating car data improving local traffic flow and efficiency, and user communications and information services for comfort and business applications to driver and passengers. Research projects working in this area are, e.g., the European Network-on-Wheels (Now) project [6].

**3.3 Real-time issues**

From a real-time point of view, most telematics applications do not feature real-time requirements in the strict sense. Navigation and traffic information systems require position and Internet-like communications, providing traffic information and directions. Voice applications have slightly higher requirements on QoS, e.g., real-time voice processing and recognition. However, some safety-systems do have real-time requirements, e.g., communications between the vehicle and other vehicles or roadside objects, implementing collision detection/avoidance systems or active suspension systems that respond to road conditions. Moreover, diagnostics and service tools could make real-time data available during operation of the vehicle. Also, real-time requirements are put by the usage of wireless technologies as a redundant link between nodes linked with wired type of networks. None of the wireless technologies presented in this paper provide hardreal-time guarantees, since they are not as deterministic as wired technologies and messages are more likely to be corrupted. However, they can make use of real time dependability concepts to provide as good service as possible in the area of wireless automotive real-time communications.

**4. Summary and way forward**

This paper has presented existing and upcoming automotive wireless networking technologies, and identified basic wireless applications relying on these technologies. There are several open issues to be addressed. First, which wireless automotive applications rely on real-time systems and how existing research on wireless real-time communications can provide support for these applications. Other important points are related with the integration of wireless networking technologies and with the interoperability problems which could be expected in the automotive domain. Finally, it should be discussed how these wireless technologies should be integrated in the existing communications architecture comprising several network protocols, e.g., CAN, LIN and MOST, and if such an architecture should be extended with a wireless infrastructure.

**5.** **References**

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