

Mobile Computing Seminar

Technologies and standards in wireless communication

Summary

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Abstract

Recently there has been a growing interest in wireless communication in small devices. Although Infrared is already widely implemented in small low-cost devices, there is rapid movement towards wireless communication in the Giga Hertz spectrum, which allows for new concepts such as “hidden computing”.

The presentation first describes some of the techniques used in transmitting information wirelessly. It then presents various standards that are going to play an important role in wireless communication, distinguishing them between infrastructure networks and ad hoc networks.

Finally, an attempt is made at evaluating how well these standards are suited for the implementation in small devices.

1 Radio Transmission Techniques

We first have a look at techniques for transmitting information reliably over radio waves in the GHz spectrum.

Three techniques in radio transmission are presented: Frequency Hopping Spread Spectrum, Direct Sequence Spread Spectrum and Orthogonal Frequency-Division Multiplexing. They all try to achieve resistance against narrow-band interference caused by other radio sources.

1.1 Frequency Hopping Spread Spectrum (FHSS)

In Frequency Hopping, the transmission band is divided into different frequency channels, typically 79, and a logical channel, i.e. a channel on which two or more devices communicate, hops periodically from one frequency channel to another with a pseudo-random hopping sequence.

1.2 Direct Sequence Spread Spectrum (DSSS)

Also in Direct Sequence, the frequency band is divided into (fewer but larger) channels, but no hopping is used. To compensate for noise on a channel, a technique called *chipping* is implemented: each bit is converted into a redundant bit pattern called *chip sequence*, whereby an n-chip code spreads the signal by a factor of n. If some interference destroys part of the chip sequence, the original bit may still be recovered from the remaining chips.

1.3 Orthogonal Frequency-Division Multiplexing (OFDM)

The general idea of OFDM is to split a high-rate data stream into lower-rate streams which are transmitted simultaneously over a number of subcarriers. These subcarriers are orthogonal to each other in the sense that — when listening to one subcarrier — the others don't interfere, hence the name *Orthogonal* Frequency-Division Multiplexing. By using this technique, multipath delay spread and inter-symbol interference are considerably decreased because only low bit rate streams are employed.

2 Infrastructure Networks

In this section, two wireless network standards are presented: IEEE 802.11 and ETSI HiperLAN/2. They are usually intended for use as Wireless LANs (WLAN). Table 1 summarises the characteristics of these two standards.

Table 1: 802.11 and HiperLAN/2

	IEEE 802.11			ETSI HiperLAN/2
	802.11	802.11b	802.11a	
Frequency Range (GHz)	2.4 – 2.4835 (ISM), (also IR at 850nm–950nm)		5.150 – 5.350 5.725 – 5.825	5.150 – 5.350 5.470 – 5.725
Band Width (MHz)	83.5		300	455
Data Rate (Mbit/s)	1, 2	1 – 11	6 – 54	6 – 54
PHY (no. of channels)	FSSS (79) DSSS ¹ (11 N.America, 13 Europe)	DSSS ¹ (11 N. America, 13 Europe)	OFDM (12)	OFDM (19)
MAC	Mainly CSMA/CA (limited QoS)			Based on Wireless ATM (high QoS support)
Comparison	<ul style="list-style-type: none"> • Simple MAC (low processing power) • Low performance (channel throughput), decreasing at higher data rates • Good for low quality applications • 802.11 and 802.11b already widely available, 802.11a coming soon (late 2001 / early 2002) 			<ul style="list-style-type: none"> • Complex MAC (high processing power required) • High performance at any data rate • Good for high end applications • Standard not yet complete, no products available yet

¹In DSSS, the channels are 22MHz wide, but spaced 5MHz and therefore they overlap. Two overlapping channels used in one place interfere with each other, decreasing each other's data rate. Only 3 non-overlapping channels are available in one place.

3 Ad hoc Networks

Ad hoc networks have no infrastructure, e.g. no access points (AP). We consider the case of small devices, with low transmit power and typically short range. Also, the network is highly dynamic, i.e. devices can come and go at any time. 802.11 and HiperLAN/2 provide Ad hoc modes where devices can communicate without an AP. However, these standards are not intended for very small devices, such as PDAs and headphones. Instead, Bluetooth and IEEE 802.15 are specifically designed for small devices.

3.1 802.11 Ad hoc mode

Provides direct communication of stations in the absence of an AP. Because many features of 802.11 such as QoS or power saving rely on the AP, they are not available in ad hoc mode, making this a very limited ad hoc standard, nevertheless with high data rates.

3.2 HiperLAN/2

In the HiperLAN/2 ad hoc mode, called the *Home Network*, a wireless terminal (WT) serves as the central controller (CC), which is the equivalent of an AP in infrastructure mode. The CC coordinates the medium, and provides all the QoS features of infrastructure mode. Furthermore, unlike 802.11 ad hoc mode, it is possible for a WT located in two overlapping cells (called subnets) to become a bridging node between these two subnets, allowing WTs from one subnet to communicate with those of the other subnet.

3.3 Bluetooth

Bluetooth uses FSSS with 79 frequency channels in the 2.4 GHz ISM Band, which means it will interfere with 802.11b. The maximum data rate is 723kbit/s asymmetric, or 433kbit/s symmetric. Bluetooth units communicating on a common frequency-hopping channel form a *piconet*. In a piconet there is 1 master and up to 7 slaves, with 255 more in parked mode. Slaves never communicate directly with each other, but only from slave to master and vice versa. There can be up to 10 piconets per coverage area. A device can participate in more than one piconet (but only be a master in one), thereby forming a *scatternet*. However, a common unit must periodically switch between piconets. Furthermore, hopping times and frequencies are not synchronized.

Interesting applications of Bluetooth are: cable replacement (serial port emulation), wireless headphone, file transfer, automatic synchroniser. In particular, this last application implements the concept of *hidden spontaneous networking*. For some applications, most notably multimedia ones such as digital imaging, Bluetooth is not suitable because of the low data rate. Here, a more specialized standard such as IEEE 802.15 is necessary.

3.4 IEEE 802.15

802.15 is still in an early stage of development. It should provide different standards specialised in different applications within Wireless Personal Area Networks (WPAN), which are small, short-range networks of low power and low cost devices communicating within a Personal Operating Space (POS), which is the space extending in all directions from a person to a distance of 10m. Currently, there are four task groups (TG) working on 802.15:

- TG1: WPAN based on Bluetooth ($\sim 1\text{Mbit/s}$), with some improvements.
- TG2: Recommended Practices for coexistence of WPAN (802.15) and WLAN (802.11).
- TG3: High rate WPAN ($20+\text{Mbit/s}$, at 2.4GHz). Unlike WLANs, focus on low power and low cost. Typical applications: digital imaging and multimedia.
- TG4: Low rate WPAN (10kbit/s up to 200kbit/s). Here, focus is on “ultra low” complexity, cost, and power consumption (multi-month/multi-year battery life). Should be ideal for sensors, interactive

toys, smart badges, remote controls. Typical applications: location tracking for smart tags and badges, medical monitoring of patients in and outside hospitals.

4 Suitability of standards for small devices and mobile computing

In this section, an attempt is made at evaluating how suitable the presented standards are for implementation and use in small devices. We consider problems and issues that are relevant to small devices. 802.11 and HiperLAN/2 are grouped in WLANs, Bluetooth and 802.15 are grouped in WPANs, although for this evaluation, 802.15 is mostly not considered, because too little is known about the standard at this time.

Small Batteries

Small devices have very little battery power available. Furthermore, wireless transmission of information is very power-intensive compared to information processing.

WLANs typically operate at transmit powers that are ideal for notebooks (30-100mW), but not adequate for very small devices, e.g. PDAs and headphones. WPANs on the other hand concentrate on small devices (typically 1mW).

Spontaneous networking

Devices should be able to, at any time, discover other devices in range, and automatically establish networks with them, and transmit data.

Both WPANs and WLANs are able to implement this concept, to a greater or lesser extent.

Scalability

Because a person is likely to carry more than one small device with wireless connectivity, high concentration of small devices should be supported.

Here, the author believes that 802.11b scales badly, because only 3 non-overlapping channels are available in one place. Instead, 802.11a and HiperLAN/2 have many non-overlapping channels and the author believes that they scale well. Bluetooth has small cells (piconets), therefore it should scale well, although there can be only 10 piconets per coverage area, which could perhaps limit scalability.

Topology changes

In infrastructure networks, we consider the problem of roaming between different APs. The presented standards support roaming within a logical network, i.e. a subnet in TCP/IP. Roaming between subnets usually has to be implemented by higher protocol layers, such as Mobile IP. However, the standards provide the tools for implementing roaming, such as active/passive scanning of APs and reassociation requests.

In ad hoc networks, we must support the fact that any device may come and go at any time. Therefore, in Bluetooth, also the master may disappear and it must be possible to reassign the role of master without compromising the operation of the network.

Data rates

A look at the data rates clearly shows different approaches in the case of WLANs and WPANs. In the former case, the goal is to achieve the highest data rates possible, so as to make WLAN standards an attractive alternative to wired networks when the advantages of wireless networks are desired but one does not wish to compromise speed too much.

In the latter case, one optimises the standards for small devices, and there is a trade off between data rates (and range) and power consumption. Furthermore, WPANs show a wide range of data rates depending on how important these two aspects are. On one side we have sensors, which only require low data rates but should have minimal power consumption. On the other side we have multimedia applications, where high data rates are crucial.

Prices

Although one has to be careful when trying to compare prices, it is possible to say that commercial

implementations of WPAN standards will generally be cheaper than those of WLAN standards. This should be the case since, while we will usually only need WLAN standards implemented in one or two devices, we want WPAN standards to be implemented in all sorts of small devices that we may possess, thus enabling the concept of *ubiquitous computing*. It is therefore essential that these technologies be cheap.

5 Conclusion: Future of WLANs & WPANs

In the near future, we are probably going to see the coexistence of WLAN and WPAN standards. WLAN standards are ideal for connecting to high-speed infrastructure networks but — as they do not fit well into most small devices — we are likely to have only a couple of devices that connect to an infrastructure. Instead, WPAN can be implemented in all sorts of devices, and they can still access the infrastructure through WLAN-WPAN devices that serve as access points.

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