EE506 - Introduction to Local and Wide Area Networks
Department of Electrical Engineering
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Wireless Networks
&
IBM Wireless Network Products

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Abstract

This project report describes the Wireless Network Types, which are Personal Area Networks (PAN), Local Area Networks (LAN) and Wide Area Networks (WAN). It concentrates more on LANs and explains the technologies, protocols and topologies used for them. A brief discussion about Bluetooth Technology Standard used in PANs is also included. A very short description of Wireless WANs is given and the IBM wireless products in the market are briefly described.

1. Introduction

Almost a century after one of the biggest and most important inventions of the human kind - telephone (1877) - mobile telephone was introduced in 1946. This was the beginning of a new and fascinating way of personal communication. Starting from these days together with the new inventions and improvements in the computing area, telecommunications entered into its gold age. With the development of reliable and small size radio frequency hardware in the 1970's, the wireless communication/computing era was born.

When we talk about wireless communications, we can separate it into three major categories that are Wide Area Networks (WAN), Local Area Networks (LAN), and Personal Area Networks (PAN). The reason behind this categorization is the difference in coverage area, necessary equipment and protocols for each of them. Figure 1 introduces all three in a geography/technology diagram.

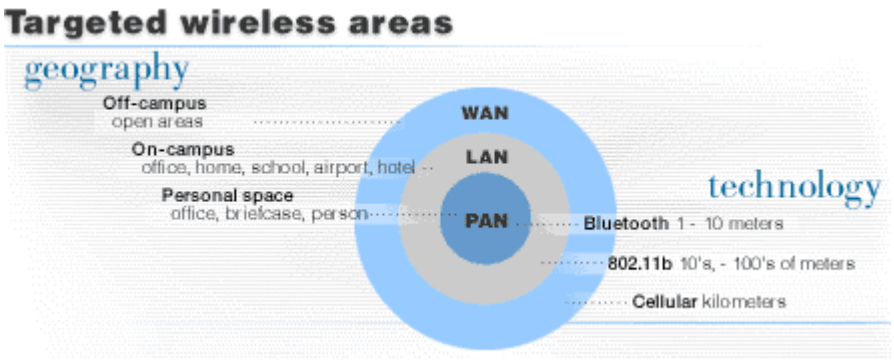

Figure 1 Targeted wireless areas shown in a diagram

In this project report, I will concentrate more on Wireless LANs and PANs or more specifically bluetooth technology.

The different forms of electromagnetic radiation are defined by their frequencies and include radio waves, infrared radiation, visible light, ultra violet light, X-rays and gamma

rays. All these different frequencies of electromagnetic radiation form the electromagnetic spectrum as shown in Figure 2.

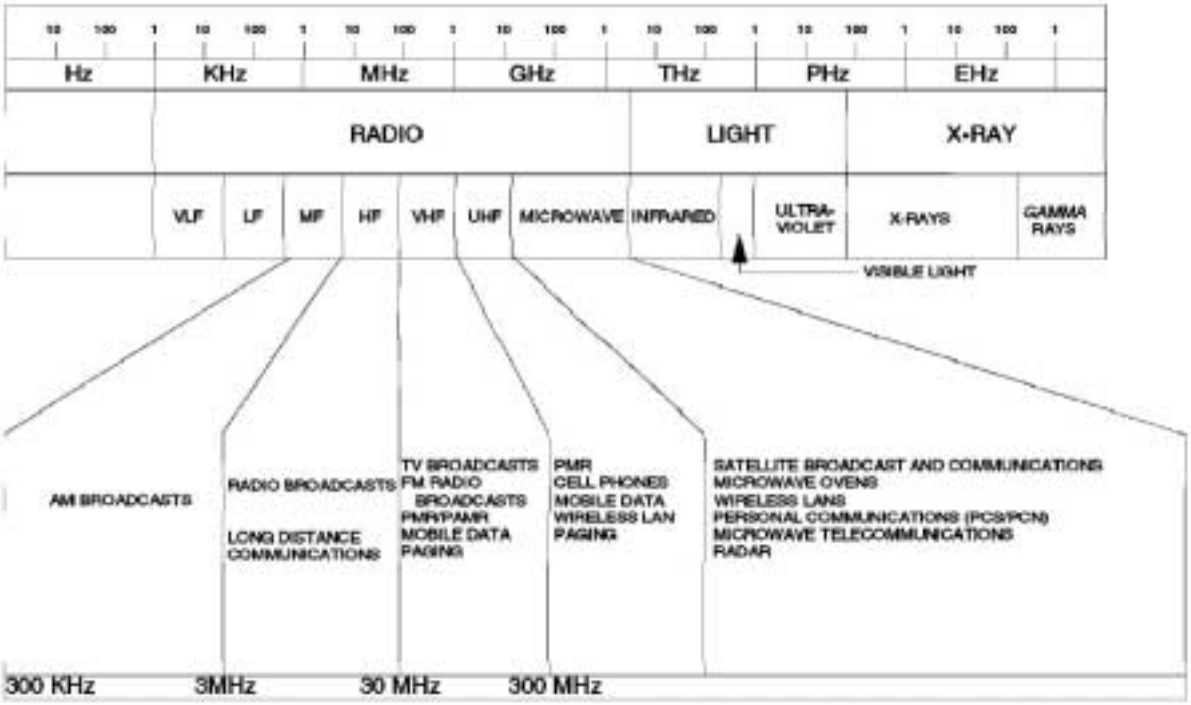

Figure 2. The Electromagnetic Spectrum

As radio frequencies increase and approach the frequency of light, they take on more of the propagation characteristics of light. The signals typically used by wireless LANs (900 MHz – 18 GHz) are not as limited as light but still do not pass through physical barriers as easily as typical radio broadcast band signals (1600 KHz - 100 MHz). Still closer to light signals, infrared signals have properties similar to light.

After this brief introduction, you can find the following subjects in this paper in the given order: Section 2 describes Wireless LANs, technologies used, protocols, topologies and introduces IBM Wireless LAN products. Section 3 talks about Bluetooth technology and Wireless Personal Area Networks (WPAN). Section 4 gives a brief description of Wireless Wide Area Networks (WWAN). And finally, Section 5 summarizes the report.

2. Wireless LANs

Local Area Networks cover an area around 10-100 meters wide and provide a high-speed connection between the hosts. It is usually set in a covered area like an office or a room. Wireless LANs give the flexibility of moving the computers without being wired to the network inside the LAN coverage area.

2.1. Wireless LAN Technologies

The two most common methods for wireless LAN usage are

- Infrared (IR) channels

- Radio Frequency (RF) channels

In this subsection we will investigate both of this wireless LAN technologies.

2.1.1. Infrared LANs

Diffuse infrared light produced by a Light Emitting Diode (LED) can be used for data communications. At the transmitter, an LED converts electrical signals into infrared signals. At the receiver, a photodiode convert the infrared signal back into electrical signals. If the transmitter and the receiver of a station are in the same enclosure, it is called *transceiver*.

Because most IR receivers detect the power (amplitude) of optical signals (not their frequency or phase), the systems that use them are simple in design, have no frequency conversions or precision components, and are cost efficient.

Since the infrared light is diffuse, the signal will bounce off ceilings, walls and floors before reaching the receiver. The transmitter and receiver need not be in direct line of sight. Typically, the area covered by an infrared transmitter is about 10 x 10 meters, with a line of sight range of up to 17 meters. IR LAN Topologies can be listed as follows:

- Place all transmitters and receivers higher than about 2.5 meters to avoid interference from most room furniture.
- Direct all signals directly at the ceiling using what is known as a diffuse link. Signals are send at a wide-aperture angle and after several reflections, they reach the receiver. See Figure 3.
- Aim all signals at a single point (satellite) on the ceiling. It is called quasi-diffuse transmission.

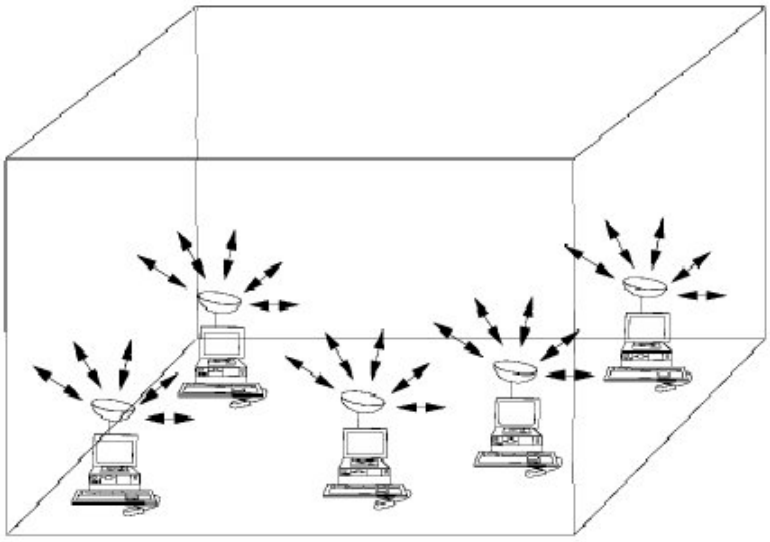

Figure 3. Diffuse Links

Modulation schemes used in IR networks are as follows:

- *On-Off Keying (OOK):* This method basically turns the carrier signal on for a one bit and off for a zero bit.
- *Multisubcarrier:* In this method, the data stream to be transmitted is divided up into series of fixed length blocks.
- *Frequency Shift Keying:* Frequency Shift Keying (FSK) is simply the use of two different frequencies to represent 1s and 0s.
- *Pulse Phase Modulation:* In this method, the position of the impulse in time varies depending on the amplitude of the input signal.

2.1.2. Radio Frequency LANs

The radio frequency LAN is different in many ways from wired one and these differences create unique problems. Ideally, a wireless LAN should appear to the user exactly same as other networks in all aspects.

In the indoor radio medium, radio frequency has the advantage of the multi-path effect. To some extent radio signal travels around the solid objects (if they are radio transparent through them). This is not the case for infrared light.

According to the multi-path effect the radio signals use different paths and this causes them to spread out in time (some paths are shorter than others) i.e. many copies of the signal will arrive at the receiver slightly shifted in time. (Typically 30ns to 250ns shift)

2.2. Wireless LAN Topologies

The widely used three radio LAN topologies are as follows:

- *Peer-to-peer:* Traffic is directly transmitted from user to user. There is no base station. This topology is shown in Figure 4.

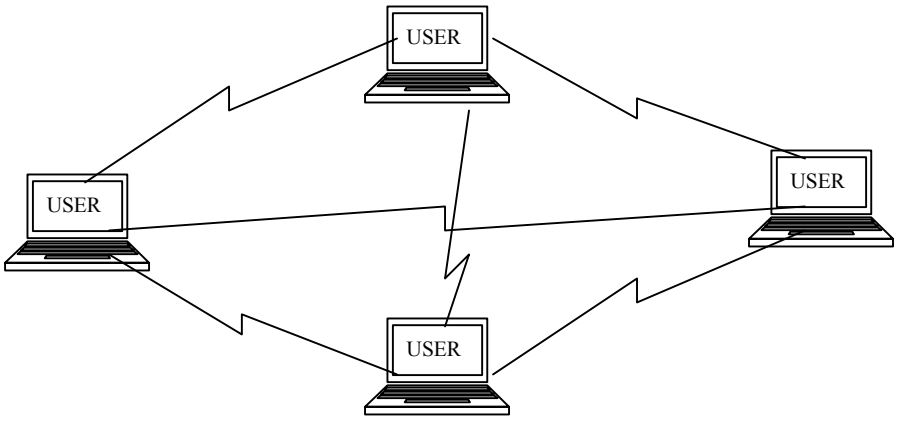

Figure 4. Peer-to-peer WLAN Topology

- *Base-to-remote:* In this topology, a base station is used to route all the transmissions from workstations. It is shown in Figure 5.

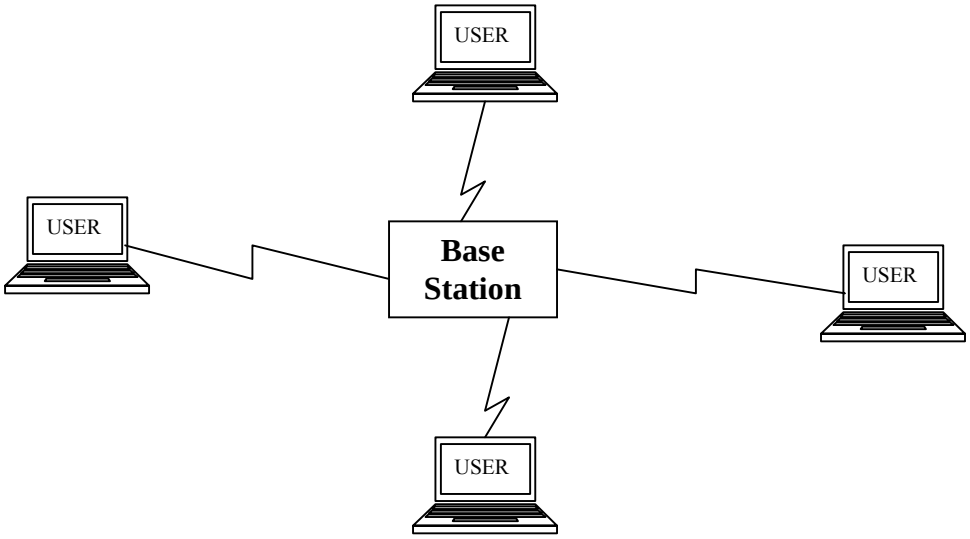

Figure 5. Base-to-remote WLAN Topology

- *Base-to-remote with wired LAN:* Most of the time, the WLAN needs a connection to the wired LAN. Base stations takes over the bridge responsibility in this case. This topology is shown in Figure 6.

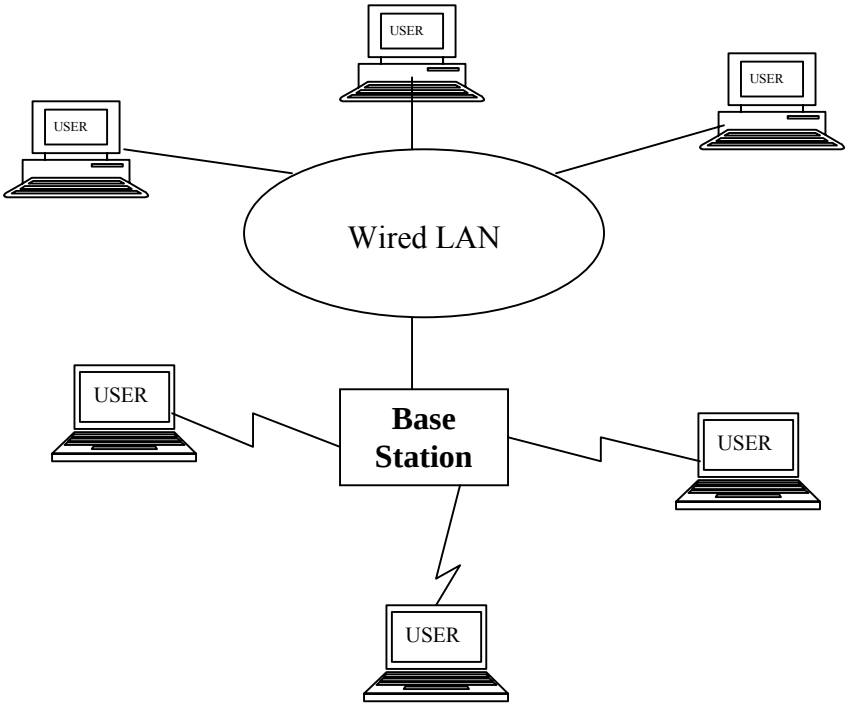

Figure 6. Base-to-remote WLAN Topology with wired LAN

The base-station approach allows a single radio LAN to be geographically much larger than the peer-to-peer approach. On the other hand, if the traffic pattern is genuinely peer-

to-peer and evenly distributed, the peer-to-peer approach offers much greater capacity and efficiency. If you go through a base station, the data must be transmitted over the air twice, reducing the system's capacity by half. However, peer-to-peer approach is not practical. Therefore, base station topology is preferred most of the time.

2.3. Bandwidth Sharing

When many computers want to communicate in the environment a method to share the bandwidth is needed. Those methods are described below:

- *Frequency Division Multiplexing (FDM):* A transceiver is allocated a range of frequencies; a signal may be sent and information may be encoded on that signal using a range of modulation techniques. The receiver must be able to receive that frequency and to decode the modulation technique used.
- *Time Division Multiplexing (TDM):* With TDM, many signals take turns at using the same high-speed transmission link. Each signal is allocated a time interval or a "frame" in which to transmit.
- *Polarization Division Multiplexing (PDM):* Provided that polarization can be maintained, the direction of it can be used as a multiplexing technique. In the presence of multiple reflections, however, polarization changes unpredictably. Thus, polarization is not usable as a multiplexing technique in the indoor radio environment.
- *Space Division Multiplexing (SDM):* Using directional antennae and reflectors can shape radio signals into beams. Signals can be beamed from one location to another and the same frequency can be used for many beams between different locations. A radio LAN system could be built with carefully selected frequencies and directional antenna such that the same frequency is reused for many connections.
- *Code Division Multiplexing (CDMA):* In a spread spectrum system (with some special techniques) it is possible to transmit multiple signals at the same frequency at the same time and still separate them in the receiver.

2.4. Wireless LAN Protocols

Wireless LANs have different properties than conventional LANs and require special Multiple Access (MAC) sublayer protocols. In the common configuration, base stations are placed and wired inside the LAN area (building, office) Each base station may have different effective range because of the walls and furniture inside the rooms. If we consider that the range of a base station is around 3-4 meters, than each room becomes a single cell and the entire building becomes a large cellular system. Unlike traditional cellular telephony system each cell has only one channel, covering the entire available bandwidth.

Major problems in wireless networks arise from multiple transmissions occurring simultaneously. In a wired network, all signals propagate to all stations, therefore; only one transmission takes place at once anywhere in the system. Hence, protocols like CSMA (listen for other transmissions and only transmit if no other station is transmitting) does not work for wireless.

In **MACA** (Multiple Access with Collision Avoidance), one of the first protocols, sender uses a short frame (RTS – Request to Send) to stimulate the receiver and waits for CTS (Clear to Send) frame from the receiver to start transmitting the actual data frame. Any station hearing RTS is close enough to the sender and must remain silent until CTS to be received by the sender. Also, any station hearing CTS is close enough to the receiver and must wait until the sender finishes sending its data. This protocol forms a basis to IEEE 802.11 wireless LAN standard.

MACAW, the improved version of MACA, included ACK frame after each successful data frame to overcome the lost data frame problem. It also included carrier sensing for multiple RTS send at the same time. Furthermore, it contained a mechanism for stations to exchange information about congestion.

2.4.1. IEEE 802.11 Wireless Standard

The main purpose of the 802.11 standard is to provide a minimum subset of standards to ensure that WLANs from different manufacturers can interoperate. This is to be achieved by developing a medium access control (MAC) and Physical Layer (PHY) specification for wireless connectivity for fixed, portable and moving stations.

IEEE 802.11, which has the layer reference model given in Figure 7;

- Describe the functions and services required by an 802.11 compliant device to operate within ad hoc and infrastructure networks as well as aspects of station mobility (transition) within those networks.
- Describe the medium access (MAC) procedures to support asynchronous and time-bounded MAC service data unit (MSDU) delivery services.
- Support the operation of an 802.11 compliant device within a wireless LAN that may coexist with multiple overlapping wireless LANs.
- Describe the requirements and services necessary to provide security, privacy and authentication of 802.11 compliant devices.

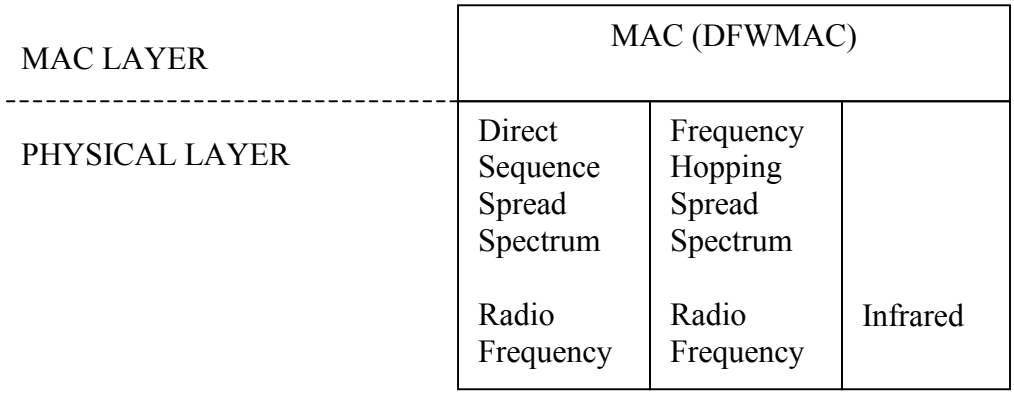

Figure 7. IEEE 802.11 Layers Reference Model

2.4.1.1. Physical Layer (PHY)

There are three different PHY environments that are studied:

- *Direct Sequence Spread Spectrum (DSSS) group:* The modulation methods used are Differential Binary Shift Keying (BSK) for 1 Mbps data rate and Differential Quaternary Phase Shift Keying (QPSK) for 2 Mbps.
- *Frequency Hopping Spread Spectrum (FHSS) group:* The modulation methods defined are two-level Gaussian Frequency Shift Keying (GFSK) for 1 Mbps and four-level GFSK for 2 Mbps.
- *Infrared (IR) group:* The baseband modulation definition specifies 1 Mbps and 2 Mbps transmission rates. The carrier modulation definition specifies data rates of 4 Mbps and 10 Mbps within a spectrum of 15 MHz to 30 MHz.

IEEE 802.11b presents "Higher-Speed Physical Layer Extension" in the 2.4 GHz band. It specifies a high rate that operates at 11Mps as opposed to 802.11 which is limited to 2Mbps.

2.4.1.2. MAC Layer

The definitions in this 802.11 layer are described by the Distributed Foundation Wireless Media Access Control (DFWMAC). The DFWMAC describes how wireless stations communicate and includes definitions of collision detection, frame size, frame priority and access control. It is independent of the underlying PHY specifications and should enable communications programs to be written independently of the PHY layer.

2.4.1.3. 802.11 Components

Figure 8 shows the complete 802.11 Architecture including all the 802.11 Components. They are defined as follows:

- *Station (STA):* Any device that contains an IEEE 802.11 conformant medium access control (MAC) and physical layer (PHY) interface to the wireless medium (WM).
- *Basic Service Set (BSS):* A set of stations controlled by a single coordination function.
- *Station Service (SS):* The set of services that support transport of medium access control (MAC) service data units (MSDUs) between stations within a basic service set (BSS).
- *Extended Service Set (ESS):* A set of one or more interconnected basic service sets (BSSs) and integrated local area networks (LANs) that appears as a single BSS to the logical link control layer at any station associated with one of those BSSs.
- *Distribution System Service (DSS):* The set of services provided by the distribution system (DS) that enable the medium access control (MAC) to transport MAC service data units (MSDUs) between stations that are not in direct communication with each other over a single instance of the wireless medium (WM).

- *Distribution system (DS):* A system used to interconnect a set of basic service sets (BSSs) and integrated local area networks (LANs) to create an extended service set (ESS).
- *Access Point (AP):* Any entity that has station functionality and provides access to the distribution ser-vices, via the wireless medium (WM) for associated stations.
- *Portal:* The logical point at which medium access control (MAC) service data units (MSDUs) from a non-IEEE 802.11 local area network (LAN) enter the distribution system (DS) of an extended service set (ESS).

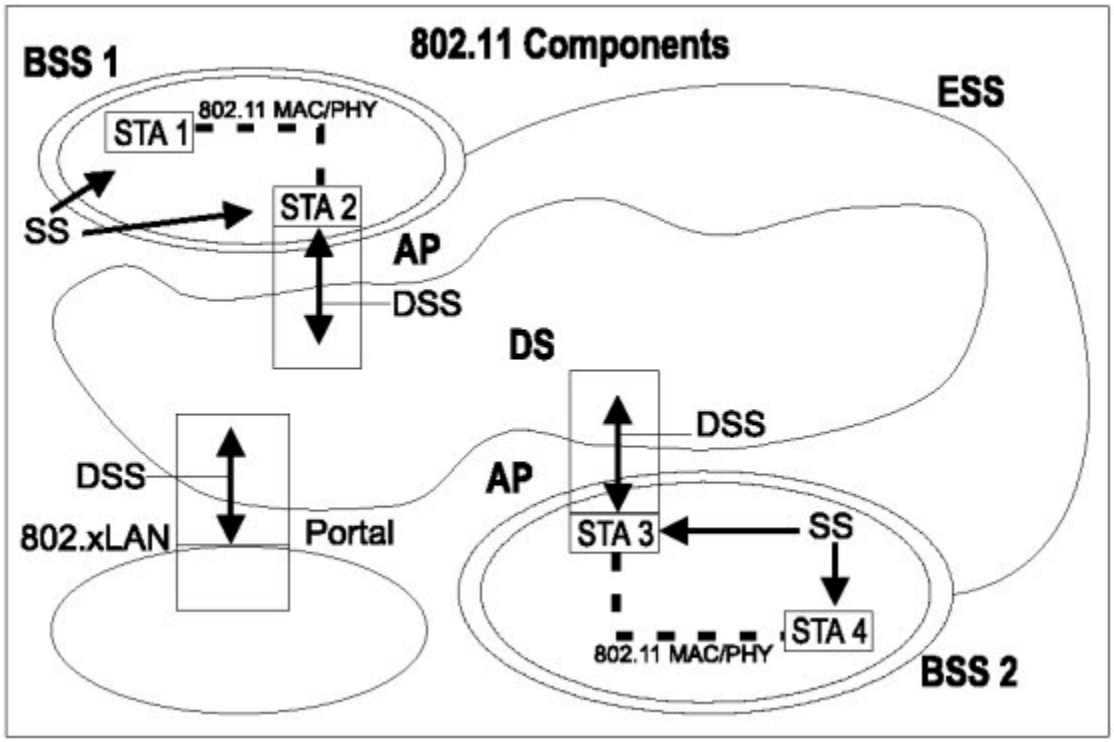

Figure 8. Complete IEEE 802.11 Architecture

2.5. IBM Wireless LAN Products

Currently IBM has two wireless LAN products in the market. These are:

- High Rate Wireless LAN Access Point-500
- High Rate Wireless LAN PC Card-128

When these IBM Wireless LAN Products used together, they provide a solution that combines the speed of IEEE 802.11b technology standard and the 128-bit security of Wired Equivalent Privacy (WEP) encryption.

2.5.1. High Rate Wireless LAN Access Point-500

Features:

- Compatible with 802.11 technology - - Allows the user to connect wire-free with speeds up to 11Mb per second.
- Provides 128-bit RC4 encryption - Protects your network from unauthorized access.
- Includes AP Manager configuration tool - software which enables administrators to manage Access Points from a wireless or a wired station.

Characteristics:

- Data rate(s): 1Mbps, 2Mbps, 5Mbps Kbps
- Supported standards: IEEE 802.3, IEEE 100Base-TX
- Connectors: RJ45 (for 10BASE-T)

2.5.2. High Rate Wireless LAN PC Card-128

Features:

- PC Card Type II - Utilizes the industry standard mobile PC form factor for ease of use.
- Supports 128-bit WEP encryption - Enables secure wireless transmissions
- Low power consumption - Provides for longer PC battery life
- Integrated diversity antenna - Eliminates the need for external dongles for attachments

Characteristics:

- Data rate(s): 1Mbps, 2Mbps, 5Mbps Kbps
- Interface bus: CardBus

3. Wireless Personal Area Networks (PAN) and Bluetooth™ Technology

Personal Area Networks (PAN) represents an area of 1-10 meters. The idea of Wireless PANs can be considered as started with the Bluetooth Industry Standard. Bluetooth introduced by Bluetooth Special Interest Group initially formed by IBM, Ericsson, Nokia, Intel and Toshiba in 1998.

By definition Bluetooth ™ wireless technology is an industry specification that eliminates the need for cables to connect mobile phones, portable computers and countless other devices.

Products with Bluetooth wireless technology (including portable computers, mobile phones, PC companions, and office equipment) will be able to communicate with each other over short ranges, without the burden of cables. Beyond convenience, Bluetooth wireless technology is designed to be inexpensive and fast (many times faster than a standard serial connection), and no line-of-sight is required between communicating devices. Bluetooth operates in the unlicensed ISM (industrial, medical, scientific) frequency band (2.4GHz), enabling devices to be used with no special radio license requirements.

A network is formed, when Bluetooth devices come within range of each other and detect one another's presence. This network, known as a piconet, is flexible and dynamic. As long as devices remain within range (1-10 meters) of one another, they are aware of each other and prepared to request and provide information. The piconets dynamically reconfigure themselves as devices enter or leave the network, so that the network is always up to date.

Bluetooth is a packet-based communications medium, and can accommodate both data and voice transmissions. For voice, it uses a connection-oriented service, and for data, the service is connectionless. In fact, Bluetooth packet transmissions can use TCP/IP as their transport protocol.

As for the data transmission and reception, the receiver may send an acknowledgment packet back when it receives a packet or not depending on the transmission software used. For example, if TCP/IP is specified as the transport protocol for both devices, they will use receipt acknowledgment packets.

3.1. IBM Bluetooth PC Card

Features:

- 2.45GHz RF wireless connectivity - Eliminates the need for expensive proprietary cables, and is supported in most countries
- Optimized wireless performance with max throughput up to 724Kbps and 10 meter (30 feet) range
- Supports both data and voice and certified Bluetooth interoperability by the Bluetooth Special Interest Group - Interoperable with other products with BLUETOOTH wireless technology such as mobile phones, PDAs and portable computers
- Secure Communications - Supports both authentication and encryption

- Low power consumption

Characteristics:

- Data Rate: 724 Kbps
- Interface bus: PC Card Type II

4. Wireless Communication in WANs

Wireless Wide Area Networks has similar characteristics to Wireless Local Area Networks. However, there are additional problems in WWANs, which might be result of the followings:

- Use of data communications on networks designed for voice
- Use of public access networks
- Effects of data transmission to/from moving vehicles
- Environmental considerations
- External interference
- Security

The selection of the type of wide area wireless network must be made by examining the application(s) to be used very carefully. Matching applications to networks is very important in the wireless arena and failure to do so may result in excessive costs, unacceptable delays, and in the worst case, total failure of the system.

5. Summary

Wireless Communications is in its fastest growing time. Most of the technology companies are introducing new products having wireless communication capabilities in different manners. All the software that is being developed has a target to enable the usage of wireless communications (e.g. synchronization of a PC program with a PDA)

Wireless LANs are providing flexibility and ease of use to the users. The capacity of the technology used is increasing very fast and becoming comparable to the wired network's speed.

In this project report I tried to introduce the different types of wireless networks, and technologies, topologies and protocols that are being used. I limited the details to

Wireless LANs and PANs and gave only a brief description of Wireless WANs. Wireless Wide Area Networks introduces many different technologies and techniques that should be studied separately and extensively.

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