Recent Advances in Wireless Data Networking

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Abstract

This paper discusses the various standards that have come up in the area of Wireless Networks in the last few years. First I talk about the IEEE standard and after that I move on to other standards namely., IrDA, Bluetooth, SWAP, WAP and OpticAir. OpticAir technology just came out in 1999 and has huge bandwidth advantage over the other competing technologies.

See Also: Wireless Data Networking (Lecture by Dr Jain) | In-building Wireless LANs | Wireless Local Area Networks | Home Networking | Books on Wireless Networking | References on Wireless Networking
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1. INTRODUCTION

Wired Local Area Network (LAN) have been tremedously successful in the past few years and the market now is moving towards another alternative technology - developing Wireless LAN (WLAN) which match the speed of the current wired LAN. WLAN is a flexible data communication system, which can be used for applications in which mobility is necessary or desirable. Till a year back, the speed of the WLAN was limited to 2 Mbps but with the introduction of new standards, we are seeing WLANs which can support upto 11 Mbps in the ISM band. Wireless LANs have typically been operating in the Instrumentation, Scientific and Medical (ISM) radio band but Lucent's OpticAir uses lasers for transmitting data and thus doesn't use the ISM radio bands. To compete with the traditional wired LANs, the wireless LANs should be powerful, simple, economical, secure and and have efficient Power Management. In the following sections, various wireless standards are discussed.

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2. IEEE STANDARD

2.1 IEEE 802.11

The IEEE 802.11 standard was approved in 1997 and it defines the physical layer options for wireless transmission and MAC layer protocol. The IEEE 802.11 standard defines the protocol for two types of networks: Adhoc networks and client/server networks. An adhoc network is a simple network where communications are established between multiple stations in a given coverage area wihout the use of an access point or server. All the nodes are assumed to be peers with no master station. The client/server network uses an access point that controls the allocation of transmit time for all stations and allows mobile stations to roam from cell to cell. The access point is used to handle traffic from the mobile radio to the wired or wireless backbone of the client/server network.[80211] [Bing99]

The following figure shows the basic topology of an 802.11 network. A Basic Service Set (BSS) consists of two or more wireless nodes, or stations (STAs), which have recognized each other and have established communications. In most instances, the BSS contains an Access Point (AP). The main function of an AP is to form a bridge between wireless and wired LANs. The AP is analogous to a base station used in cellular phone networks. [Breezecom]

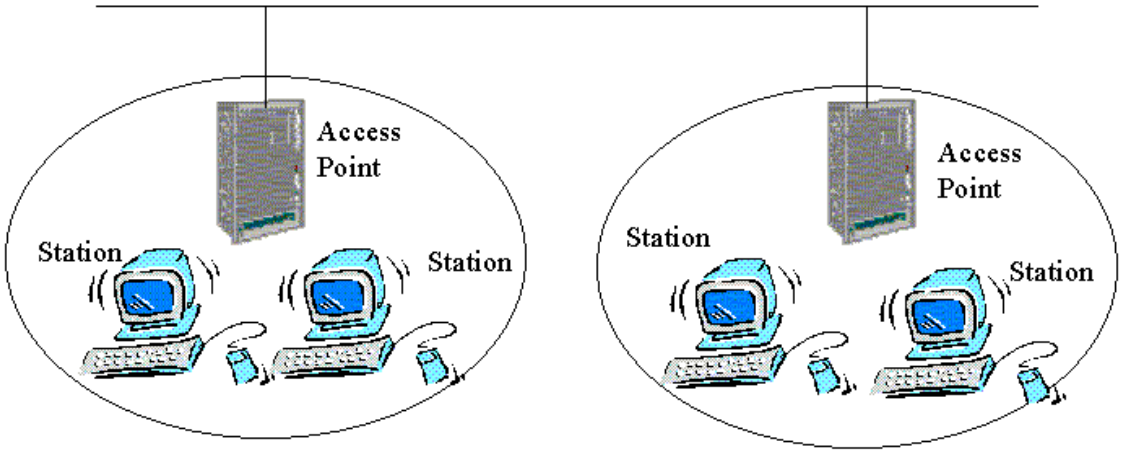

Fig 1. A sample IEEE 802.11 topology

IEEE 802.11 provides for two variations for the physical layer. These include two Radio Frequency (RF) technologies namely Direct Sequence Spread Spectrum (DSSS), and Frequency Hopped Spread Spectrum (FHSS). Both the DSSS and FHSS work in the 2.4 GHz of Industrial, Scientific and Medical (ISM) band. This was chosen because you don't need a license from the Federal Communications Committee (FCC) to operate on it. With direct sequence spread spectrum the transmission signal is spread over an allowed band and a random binary string is used to modulate the transmitted signal. This random string is called the spreading code. The data bits are mapped to into a pattern of "chips" and mapped back into a bit at the destination. The number of chips that represent a bit is the spreading ratio. The higher the spreading ratio, the more the signal is resistant to interference. Recovery is faster in DSSS systems because of the ability to spread the signal over a wider band. The DSSS system provides a wireless LAN with both a 1 Mbps and a 2 Mbps data payload communication capability. According to the FCC regulations, the DSSS system shall provide a processing gain of at least 10 dB. The DSSS system uses baseband modulations of Differentail Binary Phase Shift Keying (DBPSK) and Differential Quadrature Phase Shift Keying (DQPSK) to provide the 1 Mbps and 2 Mbps respectively. [Steinkuhler] [Prem97] [Jain00]

FHSS splits the band into many small subchannels (1MHz). The signal then hops from subchannel to subchannel transmitting short bursts of data on each channel for a set period of time, called dwell time. The hopping sequence must be synchronzied at the sender and the receiver or information is lost. The FCC requires that the band is split into at least 75 subchannels and that the dwell time is no longer than 400ms. Frequency hopping is less suceptible to interference because the frequency is constantly shifting. This makes frequency hopping systems extremely difficult to intercept. This feature gives FH systems a high degree of security. In order to jam a frequency hopping system the whole band must be jammed. These features are very attractive to agencies involved with law enforcement or the military. [Zuo99]

Recently, the IEEE 802.11 Working Group came up with a new set of standards for high speed Wireless Local Area Networks (WLAN). The IEEE 802.11 standard allows a maximum speed of 2 Mbps. The new standards viz., IEEE 802.11a and IEEE 802.11b allows speeds upto 54 Mbps. The modulation scheme used in IEEE 802.11 is normally Binary Phase Shift Keying (BPSK) or Quadrature Phase Shift Keying (QPSK). They are sufficient in 1 and 2 Mbps systems, but they

do not meet the demands of higher data rate transmission schemes. To achieve the higher speeds, different modulation techniques should be implemented.

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2.2 IEEE 802.11a

It uses the 5 GHz unlicensed ISM band and provides support for data, voice and images. Instead of using BPSK or QBPSK, this uses Orthogonal Frequency Division Multiplexing (OFDM). This proposal was set forth by NTT and Lucent which the IETF standard body accepted. The OFDM system provides a wireless LAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48 and 54 Mbps. The support of transmitting and receiving at data rates of 6, 12 and 24 Mbps is mandatory. The system uses 52 sub carriers that are modulated using binary or quadrature phase shift keying (BPSK/QPSK), 16-quadrature amplitude modulation (QAM) or 64-QAM. [80211a]

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2.3 IEEE 802.11b

This standard also came out in 1999 and is actually more popular than the IEEE 802.11a. It uses the 2.4 GHz ISM band and can support data rates upto 11 Mbps. The data rates that it supports are 1, 2, 5.5 and 11 Mbps. Complementary Code Keying (CCK) is used as the modulation scheme to provide the higher rates. CCK modulation was proposed by Harris and Lucent Technologies and allows a maximum throughput of 11 Mbps. The chipping rate is 11 MHz which happens to be the same as that of the DSSS system, thus providing the same occupied channel bandwidth. CCK allows upto 8 bits to be packed in a symbol and the symbol rate is increased to 1.375 Million Symbols/sec. Thus speeds of 11 Mbps can be achieved using CCK. In addition to providing higher speed extensions to the DSSS system, a number of optional features allow the performance of the radio frequency LAN system to be improved as technology allows the implementation of these options to be cost effective. A key benefit of CCK is its resistance to multi-path interference. This allows CCK based devices to be less susceptible to multi-path interference thereby allowing the wireless LANs to provide system performance. In addition to the CCK modulation, another technique that is available is Packet Binary Convolutional Coding (HR/DSSS/PBCC). Another optional capability is Channel Agility. This option provides for IEEE 802.11 FH PHY interoperability with High Rate PHY of IEEE 802.11b. [80211b] [Lucent98] [Drewry00] [Frank00] [Andren98]

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3. INFRARED DATA ASSOCIATION(IrDA)

IrDA is an international organization that creates and promotes interoperable, low-cost infrared

data interconnection standards. IrDA has a set of protocols covering all layers of data transfer and in addition has some network management and interoperability designs. IrDA protocols have IrDA DATA as the vehicle for data delivery and IrDA CONTROL for sending the control information. [Feng99] [Williams00]

3.1 IrDA DATA

IrDA DATA defines a standard for an interoperable universal two way cordless infrared light transmission data port. Adapters now include the traditional upgrades to serial and parallel ports, Universal Serial Bus (USB) and Ethernet/Token Ring LAN point to point access. IrDA Data Protocols consist of a mandatory set of protocols and a set of optional protocols. The mandatory protocols are listed below.[Irda1] [Irda2]

- PHY (Physical Signaling Layer)
- IrLAP (Link Access Protocol)
- IrLMP (Link Management Protocol and Information Access Service (IAS))

And for each of these protocols, an outline of their characteristics is given in below:
1) Physical IrDA Data Signaling,

- Range: Continuous operation from contact to at least 1 meter (typically 2 meters can be reached). A low power version relaxes the range objective for operation from contact through at least 20 cm between low power devices and 30 cm between low power and standard power devices. This implementation affords 10 times less power consumption. These parameters are termed the required maximum ranges by certain classes of IrDA featured devices and sets the end user expectation for discovery, recognition and performance.
- Bi-directional communication is the basis of all specifications
- Data transmission from 9600 b/s with primary speed/cost steps of 115 kb/s and maximum speed up to 4 Mb/s
- Data packets are protected using a CRC (CRC-16 for speeds up to 1.152Mb/s and CRC-32 at 4 Mb/s).

2) IrDA Link Access Protocol (IrLAP)

- Provides a device-to-device connection for the reliable, ordered transfer of data.
- Device discover procedures.
- Handles hidden nodes.

3) IrDA Link Management Protocol (IrLMP)

- Provides multiplexing of the IrLAP layer. Multiple channels above an IrLAP connection.
- Provides protocol and service discovery via the Information Access Service (IAS).

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3.2 IrDA CONTROL

IrDA Control is an infrared communication standard that allows cordless peripherals to interact with many types of intelligent host devices. Host devices include PC's, home appliances, game machines and television/web set top boxes. IrDA Control is well suited to deal with devices that leverage the USB HID class of device controls and home appliances, while traditional remote controls will sophisticated implementation guideline for bi-directional remote control with MAC enumeration and binding and with LLC transactions. [Feng99] [Microsoft98] [Irda1]

IrDA Control Protocols consist of a mandatory set of protocols.

- PHY (Physical layer)
- MAC (Media Access Control)
- LLC (Logical Link Control)

For these protocols, their characteristics can be described as below:
1) IrDA Control Physical Signaling

- Distance and range equivalent current uni-directional infrared remote control units (minimum 5 meter range).
- Bi-directional communication is the basis of all specs.
- Data transmission at 75 kb/s at the top end
- The data is coded using a 16-Pulse Sequence multiplied by a 1.5 MHz subcarrier which is allocated for high speed remote control in IEC 1603-1 although this base band scheme has harmonics which can intrude upon other IEC bands.
- Data packets are protected with a CRC (CRC-8 for short packets and CRC-16 for long packets). The physical layer is optimized for low power usage and can be implemented with low-cost hardware.

2) IrDA Control MAC

- Enables a host device to communicate with multiple peripheral devices (1:n) and up to 8 peripherals simultaneously.
- Ensures fast response time (13.8 ms basic polling rate) and low latency.
  Provides for dynamic assignment and re-use of peripheral addresses for asymmetric MAC

3) IrDA Control LLC:

- Provides reliability features that provides data sequencing and retransmission when errors

are detected.

- Works with an HID-IrDA Control Bridge to enable the link control functions of USB-HID.

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4. BLUETOOTH

BlueTooth is a new standard that came up in 1998 and it uses a short range radio link to exchange information thereby enabling effortless wireless connectivity between mobile phones, handheld computers etc. The standard describes how mobile phones, hand-held computers, etc can interconnect among themselves using a short range wireless connection. It aims to replace the InfraRed Data Association (IrDA) spec of InfraRed in mobile and computing devices. The Bluetooth Special Interest Group (SIG) was formed in 1998 as a result of efforts by 5 leading companies. Currently, it boosts of over 600 member companies. Some of the features of Bluetooth are listed below: [Haartsen00] [Softtooth99]

- Operates in the 2.56 GHZ ISM band which is globally available
- Uses FHSS
- Can support upto 8 devices in a piconet
- Omni-directional, non line of sight transmission through walls
- 10m to 100m range
- Low cost, $20
- 1mW power
- Extended range with external power ampilifier (100 meters)

Each bluetooth device has a microchip transceiver that transmits and receives in the 2.45 GHz ISM band and has a unique 48-bit address. The spread spectrum technique used by Bluetooth is FHSS and it allows devices to communicate even in areas with lots of electromagnetic interference. Bluetooth can operate in noisy RF environment and uses a fast acknowledgement and FHSS to make the link robust. Bluetooth radio modules avoid interference from the other signals by hopping to a new frequency after receiving or transmitting a packet. The connections can be either asynchronous or synchronous as well as either point to point or multipoint. The asynchronous bands carry data at a speed of about 700 kbps while the synchronous bands support voice. FHSS allows many bluetooth networks to coexist in the same neighborhood even though each Bluetooth network can support only eight devices. It currently has a range of 10m but that range can be increased to 100m by increasing the transmission power. One of the advantages of Bluetooth over IrDA is the security mechanism supported by Bluetooth. It uses a 128 bit encryption technique as well as some authentication mechanisms which permits the

device to identify itself before starting to transmit information. Another big advantage of bluetooth is the fact that it doesn't use either cables or Line of sight and this is the single most important thing that is going to cause a revolution in the mobile office environment. Bluetooth will find usage in ecommerce applications like electronic payments for parking meters, movie tickets, shopping etc. Smart offices will exist where the employee carrying a Bluetooth device would be automatically checked into the building and his arrival would trigger a series of actions like Computers being turned on, lights being switch on, answering machines start playing etc. The key factor leading to the above situation is that it does not need to be set up. Bluetooth essentially runs in the background and the line of sight is not required for the machines to automatically initiate and trigger processes. Such intelligence is going to be useful in most cases but can also be a nuisance at some times. To avoid it from being a nuisance, some control mechanisms have been provided which includes assigning a unique 12 byte address. So in order to connect to a device, you have to know its address. Enquiry features will also be provided so as to allow searching for other Bluetooth enabled devices with a particular range. [Seybold98] [Rawcon99] [Countersys]

Bluetooth provides a nominal rate of 1 Mbps for a piconet. One piconet consists of one master and a maximum of seven slaves. The master is responsible for synchronizing the frequency hop pattern in its piconet. One bluetooth unit can send a maximum of 721 kbps of data or 3 voice channels. Within the same bluetooth radio range, several independent piconets may exist. These piconets can form scatternets to allow for a higher number of bluetooth devices to be active or possibly allow higher aggregate bandwidth. The usage scenarios for Bluetooth can be classified as

- Use in the office environment: Bluetooth will bridge the gap between the portable devices and the wired backbone of the office.
- Use in the home environment: Bluetooth will allow cordless phones, remote control, vacuum cleaner etc to be connected.
- Use in the public environment: Bluetooth will allow PDAs to have access to local information services in public areas (subway, airport etc)
- Use in Adhoc networks: Bluetooth will be used to connect devices independently and out of range of any fixed networking equipment.

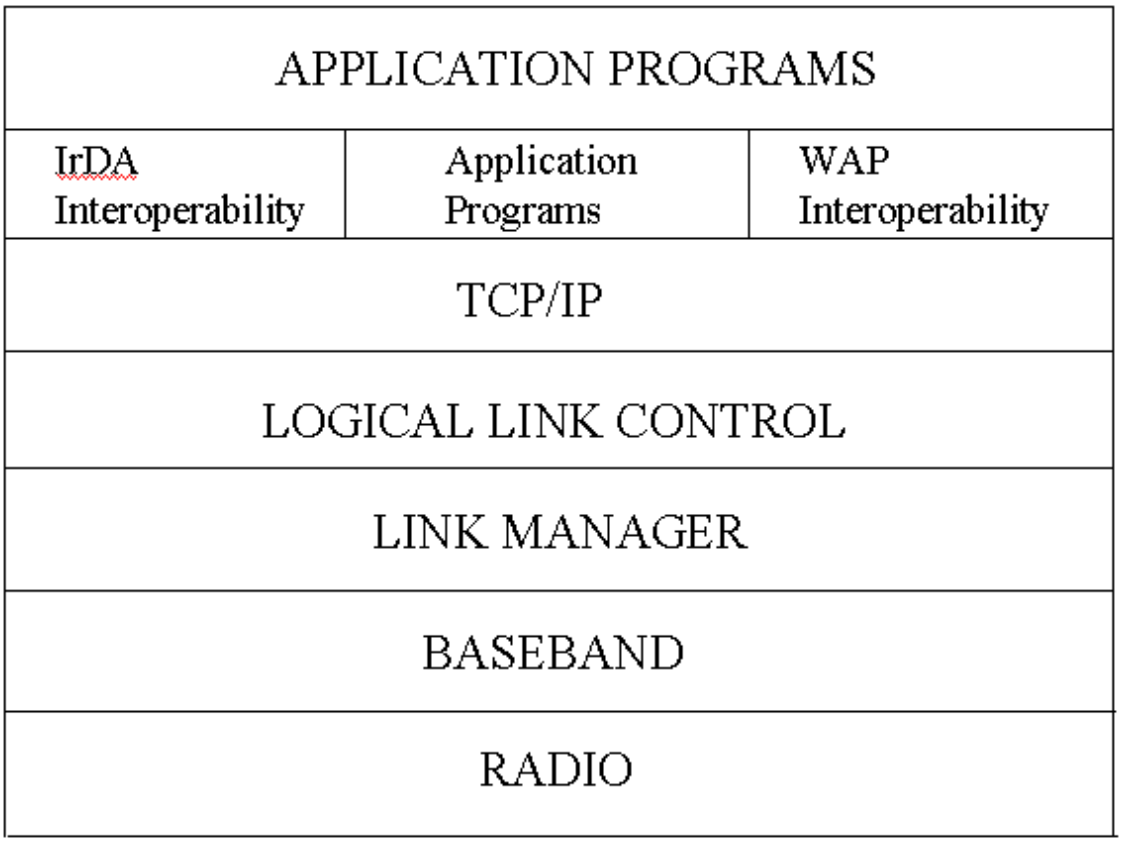

Fig 2. The application framework for Bluetooth [Albrecht99]

The Bluetooth standard defines the layers 1 and 2 of the OSI model. The application framework of Bluetooth is aimed to achieve interoperability with IrDA and WAP. In adddition, a host of other applications will be able to use the Bluetooth technology and protocols.

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5. HOMERF

The HomeRF Working Group was established in March 1998 and currently boosts of around 100 member companies. It is a subset of the International Telecommunication Union (ITU) and specially works on the development of a standard for inexpensive RF voice and data communication. Currently, the HomeRF Working Group specification provides for wireless Ethernet transmission at data rates of 1.2 Mbps for as far as 40 meters. The HomeRF Working Group has also developed the Shared Wireless Access Protocol (SWAP), which operates in the 2.45 GHz range of the unlicensed ISM band and employs frequency hopping at 50 hops per second. SWAP is a industry specification that permits PCs, peripherals, cordless telephones and other devices to communicate voice and data without the usage of cables. It supports both a TDMA service to provide delivery of interactive voice and CSMA/CA service for delivery of high speed data packets. SWAP is similar to the CSMA/CA protocol of IEEE 802.11 but with an extension to voice traffic. Just like IEEE 802.11, the SWAP system can either operate as an

adhoc network or as a infrastructure network under the control of a connection point. In an adhoc network, all stations are peers and control is distributed between the stations and supports only data. In an infrastructure network, a connection Point is required so as to coordinate the system and it provides the gateway to the PSTN (Public Switched Telephone Network). Infrastructure networks support multi-user voice capabilities. The Connection Point can also support power management for prolonged battery life by scheduling device wakeup and polling. The network is capable of supporting upto 127 nodes and these nodes can be a mixture of the following 4 basic types: [Negus00] [Csdmag00]

- Connection Point that supports both voice and data services
- Voice terminal that only uses TDMA service to communicate with a Base Station
- Data Node that uses the CSMA/CA service to communicate with a base station and vice versa
- Voice and Data Node that support both services

The main features of SWAP are:

- Frequency hopping network : 50 hops/sec
- Frequency range : 2.4 GHz ISM band
- Transmission Power : 100mW
- Data Rate : 1Mbps using 2FSK modulation and 2 Mbps using 4 FSK modulation
- Voice connections : upto 6 full duplex conversations
- Data Security : Blowfish encryption algorithm (over 1 trillion codes)
- Data Compression : LZRW3-A algorithm

SWAP allows a range of upto 150 feet and can work with dial-up, DSL or cable modems. Walls and floors don't cause any problem in its functionality and some security is also provided through the use of unique network IDs. It is robust, reliable and minimizes the impact of radio interference.

In the previous section, Bluetooth was discussed. Currently SWAP has more installed base compared to Bluetooth but according to the pundits Bluetooth is eventually going to prevail. Below I compare both these technologies.

Bluetooth is a technology to connect devices without cables. The intended use is to provide short-range connections between mobile devices and to the Internet via bridging devices to different networks (wired and wireless) that provide Internet capability. HomeRF SWAP is a wireless technology optimized for the home environment. Its primary use is to provide data networking and dial tones between devices such as PCs, cordless phones, Web Tablets and a broadband cable or DSL modem. Both technologies share the same frequency spectrum but do not interfere when operating in the same space. [Derfler00]

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6. WIRELESS APPLICATION PROTOCOL(WAP)

WAP is a set of standards designed to extend Internet services to the mobile telephony environment. The basic aim of WAP is to provide a web like experience on small portable devices such as PDAs, pagers, mobile phones etc. WAP allows mobile users to easily access live interactive information from the screens of mobile phones. This information could be emails, weather alerts, traffic updates, stock market trends, sports news etc. The WAP Forum is the primary body for discussing issues related to WAP and is an open body. The main benefits of WAP are: [Apion]

- An Internet based programming model
- A protocol stack that is optimized for the wireless environment
- Endorsement of over 90% of all handset manufacturers
- License free usage

The WML's user interface components map well onto the existing mobile phone user interfaces which implies that end users can start using WAP enabled mobile phones and services without any difficulty. WAP is based on Internet protocols like UDP, HTTP, HTML, JavaScript and so the the programming concepts behind it are similar. There is however one main difference between the WAP transport model and the Internet model and this is the presence of a gateway between the wireless network and the client. The gateway acts as a proxy between the Internet and the wireless network. In addition, it also encodes the WAP data into bytecodes so as to conserve bandwidth in the narrowband environment of wireless communications. WAP specifications enable products which employ standard Internet technology to optimize content and airlink protocols to better suit the characteristics and limitations of existing and future wireless networks and devices.

The standards define a protocol stack (WAP suite) that will run in the terminal and WML and WMLScript in the WAP gateway. The languages are used to program applications that are loaded from a WAP server over the network and run by the WML microbrowser. The goals of the WAP standard are: [Smith00] [WapForum]

- To bring Internet contents and advanced data services to digital cellular phones and other wireless terminals
- To create a wireless global protocol specification that will work across differing wireless network technologies
- To enable the creation of content and applications that scale across a very wide range of bearer networks and device types
- To embrace and extend existing standards and technologies wherever appropriate

Vertically, the architecture consists of a protocol stack that is supposed to run at mobile terminals, Internet gateways and WAP capable WWW servers. The bottom layer in the stack contains the bearers such as GSM data, IS-36, CDMA etc. Above this layer is the actual WAP stack consisting of the Transport Layer (WDP), Security Layer (WTLS), Transaction Layer (WTP), Session Layer (WSP) and Application Layer (WAE). The horizontal architecture consists of a server, a gateway and the mobile client. Two protocol stacks run on the gateway (TCP/IP + HTTP and WAP stack). The gateway translates the WAP requests to WWW requests confirming to HTTP specification. In the reverse direction, the gateway converts the results from HTML to WML. WML and WMLScript are the languages that are used to program the applications. Microbrowsers run in the WAP terminals and is capable of interpreting and displaying WML contents. The WML contents and WMLScript applications are compiled into WML bytecode before interpretation. [Ojanen00]

WAP was designed to address three main issues related to wireless networks:Low bandwidth, high latency and connection availability. It has been pretty successful in addressing all these three issues. Another factor which was essential to the design of the WAP was the size of the wireless devices. Since most mobile devices have small screens and keypads, so the form factor could not be sidelined.

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7. OPTICAIR

Fat pipes don’t come cheap. Fiber optic lines must either be leased or laid and then maintained, a costly prospect usually involving contractors and earth-moving machines. Lucent’s WaveStar OpticAir technology comes to the rescue since it employs laser light to bridge physical gaps of several miles in optical networks while keeping the dataflow steady and quick.

Using light beams instead of radio waves, a new wireless technology makes it easier to handle growing Internet traffic without digging up city streets to add fiber optic cables. OpticAir can transmit data 65 times faster than wireless systems that rely on radio waves to carry a signal between roof tops or windows.
OpticAir converts data, voice and video information into a laser beam, shooting it through a two inch wide lens. The signal travels between roof tops or office windows and is then passed back to a fiber-optic cable for the rest of the distance. The system can simultaneously transmit at different wavelengths or colors of light, each carrying distinct streams of information. Each laser can handle 2.5 Gbps going both ways. The initial OpticAir system promises 2.5 Gbps of information through the air over distances ranging from 4.4 to 5 km The second version should be able to deliver 10 Gbps (2.5 Gbps over four wavelengths). The microwave link as well as all RF links require spectrum allocation and regulatory permits but optical links are license free. Further, an optical link supports much greater bandwidth than do conventional microwave links and it does not suffer from potential interference as microwave signals do. The line-of-sight, free space optical link is an attractive alternative when you need communications in temporary situations, such as a natural disaster; to get around ruptured or blocked paths; or to connect an array of TV cameras back to a control van at a sporting event or a convention. You can use it to meet vertical challenges, for eg to send data between the floors of a single building.

[Lindstrom99] [Lucent99]

The WaveStar OpticAir system includes an amplifier and 1550 nm laser for each wavelength, interfaces by which to connect the OpticAir data streams to metropolitan SONET and an autotracking beam designed to keep lasers aligned as buildings, ships at sea or other sites shift from natural forces. Like RF systems, OpticAir throughput will be subject to interference and attenuation from fog and other atmospheric conditions. However users will be able to achieve 99.99 percent or greater network availability through manipulation of power, capacity, distance, alternate paths and other factors. The purpose of the technology is not only to boost capacity of local data networks dramatically but also to extend the reach of today's high capacity fiber-optic systems further towards the desktop by using beams of light to transmit information through the air.

The lasers used are "expanded-beam" lasers instead of the harmful, high density streams typically found in laser pointers. These spread the light over a wider surface area thereby lowering intensity while broadening the potential reception area. It also utilizes a modular structure that allows the network to grow as needs change and an open interface to support equipment from a variety of vendors. Airborne photonics can signal instant market entry for new service providers. They need invest only a small amount in infrastructure before rolling out service to customers and their networks can grow in step with their subscriber bases. The equipment is much smaller and easier to transport than satellite or microwave systems. Also they are extremely secure making them useful for military and financial purposes as well. [Maney00]

Because OpticAir has a per-wavelength capacity of 2.5 Gbps, cable operators and network broadcasters can transmit uncompressed HDTV signals through the air. Potential applications for WaveStar OpticAir system include transmitting data between high rise office buildings, enabling naval ships to share huge amounts of information while in port, and establishing temporary, high capacity data links for special events. Like other open air transmission systems such as wireless, the WaveStar OpticAir system will meet industry standards for performance and reliability. Implementing OpticAir requires no spectrum licenses and the system is easily upgradeable. Its modular design will enable carriers to grow their networks as capacity requirements rise and open interfaces supporting equipment from a variety of vendors will help carriers protect the investment of their embedded infrastructures.

Some of the features of this technology are: [Pescovitz99]

- Break through Open Air technology – offers fast and easy deployment opportunities with fast time to service
- High Capacity – upto 10 Gbps on a single wavelength
- Easy upgrade – modular design and plug-in components promote graceful network growth, easy integration with existing network infrastructure and effective interworking
- Safety – complies with eye safety requirements
- Security Protection – the system is designed such that it can not be overtly intercepted

Some people think using laser for wireless communications is a temporary technology. Others

have high hopes for the laser gear. Mr Szelag, VP of the Lucent's optical group is reported to have said the following:
"OpticAir is not a fiber replacement. It's a temporary vehicle until fiber can be placed".

Well only time will tell whether OpticAir is a temporary technology or a replacement for fibers.

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Summary

Wireless LAN is currently a hot topic and lot of research and standardization is taking place. IETF very recently came up with a pair of new standards that allow much higher rates for enterprise networks. For home networks, the competing technologies are Bluetooth, HomeRF, IrDA etc. Presently IrDA has a big customer base in US but Bluetooth is trying to snatch a part of IrDA's share. It is believed that in the next few years, Bluetooth will be the technology of choice for the handheld equipments of the users. Lucent very recently (1999) came up with a technology that allows communication without the usage of either fiber or radio waves. Data is transmitted between the systems using different wavelengths of light. A table is provided below which compares some of the technologies discussed in this paper.

	Peak Data Rate	Range	Relative Cost	Voice network support	Data network support
IEEE 802.11	2 Mbps	50m	Medium	Via IP	TCP/IP
IrDA	16 Mbps	< 2m	Low	Via IP	Via PPP
Bluetooth	1 Mbps	< 10m	Medium	Via IP and cellular	Via PPP
HomeRF	1.6 Mbps	50m	Medium	Via IP and PSTN	TCP/IP

Table 1. Compares the different technologies [Derfler00]

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References

[80211] IEEE, "Wireless LAN MAC and PHY Specifications", 1999, 450 pages
This describes the IEEE 802.11 standard in great detail

[80211a] IEEE, "Wireless LAN MAC and PHY Specifications: High Speed PHY in the 5 GHz Band", 1999, 82 pages
This is a supplement to the 802.11 standard and explains the modifications that have been made to the PHY layer

[80211b] IEEE, "Wireless LAN MAC and PHY Specifications: Higher Speed PHY Extension in the 2.4 GHz Band", 1999, 89 pages
This again is a supplement to the original 802.11 standards and gives the modifications made to the PHY layer that enables higher data rates

[Negus00] K Negus, A Stephens and J Lansford, "HomeRF: Wireless Networking for the Connected Home", IEEE Personal Communications, Feb 2000, pp. 20-27
This paper describes the SWAP protocol of the HomeRF working Group.

[Williams00] S Williams, "IrDA: Past, Present and Future", IEEE Personal Communications, Feb 2000, pp. 11-19
This paper briefs you about the IrDA and what are the future prospects for it

[Haartsen00] J Haartsen, "The Bluetooth Radio System", IEEE Personal Communications, Feb 2000, pp. 28-36
This paper describes the Bluetooth standard

[Albrecht99] M Arbrecht, M Frank, P Martini, M Schetelig, A Vilavaara, A Wenzel, "IP Services over Bluetooth: Leading the Way to a New Mobility", LCN'99, Oct 1999, pp. 2-11
This paper provides protocol concepts for extending IP for mobility issues in Bluetooth networks

[Ojanen00] E Ojanen, J Veijalainen, "Compressibility of WML and WMLScript byte code: Initial results", RIDE 2000, pp. 55-62
This paper explains how the byte codes used in the WAP environment can be compressed.

[Bing99] B Bing, "Measured Performance of the IEEE 802.11 Wireless LAN", LCN'99, Oct 1999 pp. 34-42
This paper measures the network performance of the IEEE 802.11 LANs at the MAC layer

[Lough97] D Lough, T Blankenship, K Krizman, "A Short Tutorial on Wireless LANs and IEEE 802.11", 5 pages, http://www.computer.org/students/looking/summer97/ieee802.htm
This paper gives a very short tutorial on IEEE 802.11

[Steinkuhler] "Understanding the benefits of IEEE 802.11", 10 pages,http://www.steinkuehler.de/wavelan_802_11_Benefits.htm
This white papers gives you the pros and cons of the IEEE 802.11 standard

[Csdmag00] Csdmag, "HomeRF: Wireless Networking for the Connected Home", Feb 2000, 6 pages, http://www.csdmag.com/main/2000/02/0002home.htm
This paper a short introduction to the SWAP standard

[Andren98] "CCK Modulation Delivers 11 Mbps for High Rate", 1998, 11 pages, http://www.intersil.com/prism/papers/CCK_Mod_Delivers_11Mbps.htm
This paper describes the CCK modulation technique that was adopted by IETF for Task Group b

[Intersil98] "11 Mbps Modulation Techniques", 1998, 9 pages,
http://www.intersil.com/prism/papers/modtech.asp
This paper explains the various potential modulation techniques that were in consideration for IEEE 802.11b

[Apion] "Wireless Application Protocol", 20 pages,http://www.webproforum.com/wap/
This is a short tutorial on WAP

[Derfler00] "Crossed Signals: 802.11b, Bluetooth and HomeRF", March 2000, 4 pages,
http://www.zdnet.com/pcmag/stories/reviews/0,6755,2470132,00.html
This paper discusses the three main competing standards viz., 802.11, Bluetooth and HomeRF

[Rawcon99] Rawcon, "Workshop on Wireless Personal Area Networks", Rawcon 1999
This tutorial was presented by a group of experts in their area of expertise. It discussed the need for wireless, the current competing standards IEEE 802.11, IrDA, Bluetooth and HomeRF

[Softtooth99] Softtooth, "Bluetooth Tutorial" 20 pages,
http://www.softtooth.com/tech/tutorial/bluetooth/intro.html
This is a good introductory tutorial on bluetooth

[Seybold98] A Seybold, "Bluetooth Technology: The convergence of Communications and Computing", May 1998, 5 pages, http://www.gsmdata.com/artblue.htm
This paper praises the Bluetooth technology and says that it is a much awaited standard for the computer industry.

[Countersys] Countersys, "IrDA versus Bluetooth: A Complementary Comparison", 5 pages,
http://www.countersys.com/tech/bluetooth.html
This paper compares the two competing technologies IrDA and Bluetooth

[Smith00] Josh Smith, "The WAP Vision" Feb 2000, 8 pages,
http://webreview.com/pub/2000/02/11/feature/index2.html
This paper discusses the vision that WAP has envisaged

[WapForum] WapForum, "What is WAP and WAP FORUM", 8 pages,
http://www.wapforum.org
This discussed how the WAP Forum was formed and what are their key objectives

[Feng99] X Feng, "Home Networking", Dec1999, 16 pages, http://www.cis.ohio-state.edu/~jain/cis788-99/home_nets/index.html
This survey paper explains the IEEE 802.11, Bluetooth, HomeRF and IrDA standards

[Zuo99] Z Zuo, "In-building Wireless LANs" , Dec 1999, 16 pages, http://www.cis.ohio-state.edu/~jain/cis788-99/wireless_lans/index.html
This survey paper discussed the two enterprise standards IEEE 802.11 and HIPERLAN

[Jain00] R Jain, "Wireless Data Networking", May 2000, 14 pages, http://www.cis.ohio-state.edu/~jain/cis777-00/g_ewir.htm
This discusses the key concepts of the IEEE 802.11 standard

[Prem97] E Prem, "Wireless Local Area Networks", Dec 1997, 14 pages, http://www.cis.ohio-

state.edu/~jain/cis788-97/wireless_lans/index.htm
This survey paper discusses the PHY and MAC layer of the IEEE 802.11 standard

[Lindstrom99] A Lindstrom "The Big Bang of Bandwidth", Nov 1999, 10 pages, http://www.americasnetwork.com/issues/99issues/991115/991115_bigbang.htm
This paper discusses how the use of Optics for wireless is revolutionizing the wireless industry

[Pescovitz99] D Pescovitz, "Fiberless Future", Oct 1999, 3 pages, http://www.business2.com/articles/1999/10/content/break.html
This article talks about the latest Lucent's technology, OpticAir, that is going to remove the fiber in the future

[Microsoft98] Microsoft, "IrDA: Background and Overview", Derc 1998, 18 pages, http://msdn.microsoft.com/library/backgrnd/html/IrDAwp.htm
This is a good tutorial on the IrDA technology.

[Lucent99] Lucent, "Lucent Unveils WaveStar OpticAir Free DWDM System", July 1999, 4 pages, http://www.bell-labs.com/news/1999/july/14/1.html
This paper explains the WaveStar OpticAir technology that Lucent has come up with.

[Maney00] K Maney, "Video Transmission without the fiber", Jan 2000, 3 pages, http://www.usatoday.com/life/cyber/ccarch/cckev002.htm
This talks of how video can be transmitted through the air using Lucent's latest technology

[Raytheon97] Raytheon, "The IEEE 802.11 Wireless LAN Standard", 1997, 9 pages, http://www.standards.nhsia.nhs.uk/its/wlan/Wlanstan.htm
This paper discusses the Physical and MAC layers of the IEEE 802.11 standard

[Flood99] K Flood, "Staging a Comeback: Emerging standards position wireless networks for broad appeal, Oct 1999, 7 pages, http://www.tolly.com/Archives/Articles/199910WirelessComeback.htm
This paper discusses the different competing standards viz., IEEE 802.11b, OpenAir, HIPERLAN, SWAP, Bluetooth.

[Breezecom] Breezecom, "IEEE 802.11 Technical Tutorial", 18 pages,http://www.breezecom.com/TechSupport/bnpro-ad.htm

[Lucent98] Lucent, "IEEE Selects Lucent/Harris proposal for new high speed wireless LAN", July 1998, 3 pages, http://www.lucent.com/press/0798/980713.nsb.html
This is an article about the modulation scheme proposed by Lucent and Harris being accepted by IEEE

[Frank00] A Frank, "Wireless LANs up-shift to 11 Mbps", 2000, 5 pages, http://www.data.com/issue/000301/wlan.html
This article primarily deals with IEEE 802.11b with some portions provided for Bluetooth and HomeRF as well

[Drewry00] J Drewry, "Wireless LAN speeds get a boost", Feb 2000, 3 pages, http://www.nwfusion.com/news/tech/0214tech.html?nf

This discusses the IEEE 802.11b standard

[Irda1] Infra-read Data Association , 'Technical Summary of IrDA DATA and IrDA CONTROL, http://www.irda.org/standards/standards.asp
This discusses the Irda DATA and Irda CONTROL protocol stacks

[Irda2] Infra-read Data Association , "LAN Access Extensions for Link Management Protocol (IrLAN)", http://www.irda.org
This discusses the extensions for link management protocol

[Irda3] Infra-read Data Association ,"Tiny TP: A Flow-Control Mechanism for use with IrLMP", http://www.irda.org
This discusses a flow control mechanism used with IrLMP

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List of Acronyms

BPSK	Binary Phase Shift Keying
CCK	Complementary Code keying
CSMA	Carrier Sense Multiple Access
DPSK	Differential Phase Shift Keying
DSSS	Direct Sequence Spread Spectrum
DWDM	Dense Wavelength Division Multiplexing
FHSS	Frequency Hopping Spread Spectrum
HomeRF	Home Radio Frequency
HR/DSSS	High Rate Direct Sequence Spread Spectrum
ITU	International Telecommunications Union
IETF	Internet Engineering Task Force
IrDA	Infra-red Data Association
ISM	Industrial, Scientific and Medical
IP	Internet Protocol
LAN	Local Area Network
MAC	Media Access Control
OFDM	Orthogonal Frequency Division Multiplexing
PHY	Physical
PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
SWAP	Shared Wireless Access Protocol
TDMA	Time Division Multiple Access
USB	Universal Serial Bus
WLAN	Wireless Local Area Network

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Last Modified: May 28,2000.

Note: This paper is available on-line at
http://www.cis.ohio-state.edu/~jain/cis788-99/wireless_data/index.html