Discussion of Wireless Issues

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Introduction

This document is written as a general introduction to the area of wireless data communications. It describes the environments that wireless computers will need to serve and the various technologies that may be used to fulfill that need. As an introduction, some of the terms and concepts included in this document have been overly simplified.

Wireless computing has many system implications that require a different paradigm for computer networks. It is not simply replacing the last few feet of wiring with the air media. Since computers are now free to roam, they may appear anywhere in a network randomly. Security also becomes a major concern for our customers.

There are four environments for wireless products that should be consider in it a long-term strategy. They are in-building, campus, metropolitan area and inter-city. Within each environment, there are a number of products and services that need to be provided to serve the needs of the customers.

The wireless in-building environment can be classified into two applications, tethered and non-tethered. For the computer that is primarily used in a desktop application, wireless communications provides the services of a coax link. The non-tethered application allows the user of a notebook/laptop computer to wander the building and still maintain active sessions.

The campus environment allows users to roam between buildings or within a limited geographic area and still maintain the same services which are available at their desktops. These services include connections to a host, departmental computers, printers, and database servers. In the future, customers may wish to have multimedia applications running while attending meetings located some distance from their desk.

There are several major professions that use mobile communications while moving around the metropolitan area. Sales representatives, commuting office professionals, and expediters would find this service an aid in their activities.

As professionals travel between cities, they would still like to have access to services at their home site. This inter-city environment broadens the scope of the architectures and provides the mechanism to serve a broad class of users in their normal activities.

By providing a seamless architecture across all of these environments, users can perform their tasks without worrying about how to establish connections with their computers in different geographical situations. The current state of wireless architectures is designed for a subset of each the situations mentioned. Our competitive advantage then is to provide a total solution to the needs of a user in a transparent manner.

Current Wireless Architectures and Activities.

Classification by Geographic Coverage

Wireless In-Building

The wireless in-building market can be defined as tethered, where the computer moves infrequently; and non-tethered, where the computer can roam throughout the building. The devices providing the connection may attach to Ethernet or Token Ring LANs and be transparent or they may be new architectures.

Tethered

The tethered environment is one where the location of the computer changes infrequently. The market segment that requires this service is in old buildings, where it is difficult to install new cables, or the time to provide the connection is too long.

In some firms, work groups are created for a specific mission with a work duration of several weeks. Providing computer links is best done by using a flexible, coax replacement wireless connection. There are several venders who provide products for this market and they employ different underlying technologies.

Vendor	Frequency	Data Rate	Range	Cost $ Hub / User
Carrier Current (CarrieNet)	Power line	38 Kb/s	Building	199
BICC (InfraLAN)	Infra-red	4 Mb/s	80 ft.	2995
Photonics (Photolink)	Infra-red	230 Kb/s	70 ft.	1195
Cal. Microwave (RadioLAN)	2.4-2.5 GHz	1 Mb/s	300-000 ft.	
NCR (WaveLAN)	902-928 MHz	2 Mb/s	100-800 ft.	1390
Apple	1850-1990 MHz	10 Mb/s	150-450 ft.	
Motorola (Altair)	18.8-19.2 GHz	10 Mb/s	50 ft.	3995/1195
Proxim (RangeLAN)	902-928 MHz	242 Kb/s	300-800 ft.	
Windata (FreePort)	2.4/4.8 GHz	10 Mb/s	285 ft	4695/995

Figure 1. Representative Wireless LAN products

Motorola's Altair product is designed as an Ethernet smart bridge. The command module attaches to the wired LAN and accepts traffic for up to 32 end stations. Up to 6 end stations are connected to a receiver module located within a 50 foot radius of the command module. The command module is priced at $3995 and each receiver module is $1195. The total 10 Mb/s is available to any station. The technology is standard RF radio.

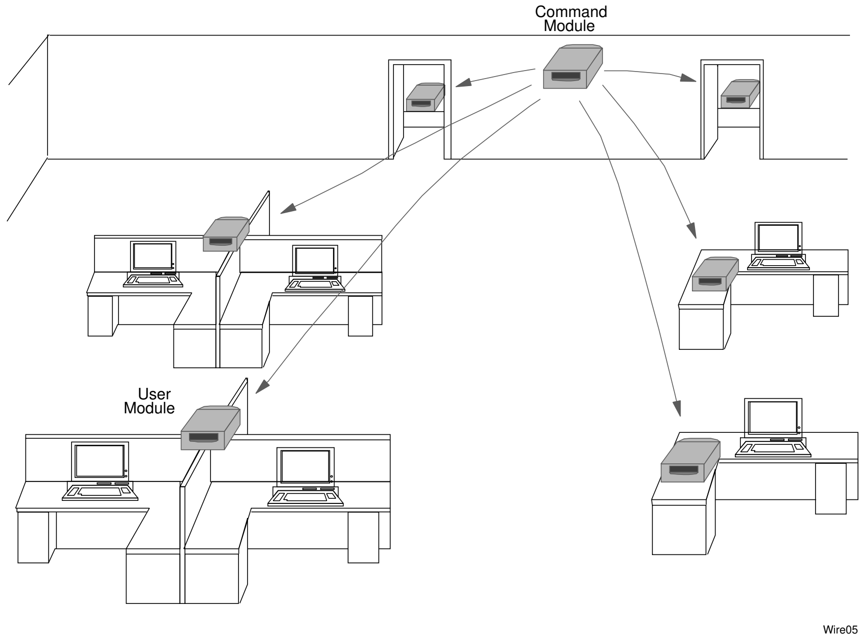


Figure 2. Operational environment for the Altair product

Adaptive Networks provides a product operating over the powerlines using a spread spectrum technique. For $665 a station, it provides 19.2 Kb/s thruput without any modifications to existing networks or cabling.

NCR's WaveLAN product, priced at $1395/station, provides 2 Mb/s of thruput. Apple has a product called LocalTalk to provide wireless interconnections for its stations. It has also applied for FCC approval for a 49 Mhz frequency which would provide very inexpensive connectivity if approved.

The IEEE 802.11 is in the process of creating a wireless standard to address this in-building market. The range of products covered by this standard will employ frequencies between 1 and 3 GHz and have a bandwidth covering 1 to 20 Mb/s.

Non-Tethered

The non-tethered environment provides a connection between a notebook or laptop computer and host or LAN services as the user roams around the building.

In a manufacturing application computers could be used at the site of incoming packages to read and process labels, on pallets to tell other computers destination or processing steps to perform.

For professionals, the freedom to carry their computers with them into meetings to record information directly, to retrieve information from other computers or in providing computations on the spot, would be a major segment of this market. Having a high speed link to perform interactive computing equivalent to their desk links and allowing multimedia applications to run remotely is a goal for the market.

Campus Environment

Many companies have more than one building in a geographic area. As employees move between these buildings, they would like to be able to have communications similar to that provided in their office. The issues of security are more complex because unlike a traditional LAN that is protected within a building. The wireless nature allows people outside the company to receive and potentially transmit information into the corporate network.

Metropolitan Area

There are many companies currently providing services that allow a user to receive information while traversing an urban area. The technologies used may be a single frequency transmitter or cellular.

There are two cellular approaches, analog and digital. Analog networks need to charge for time-of-use since a user reserves a frequency for his own use while in a cell. Digital networks allow many users to share a single frequency, and thus they can charge on usage basis. Both types of networks need to then connect to local RBOC to provide terrestrial transmission of the voice data traffic.

ARDIS is a company jointly owned by Motorola and IBM to provide transmission facilities for digital information across the country. A single transmitter, covering a 15-20 mile radius, transmits and receives information in an area. A user can be within buildings and still receive the signal.

The service operates at 800 MHz and includes 400 metropolitan areas consisting of 1250 base stations. It is digital radio transmitting packets that have a maximum length of 240 characters. They charge $.08/packet + $.004/character with a minimum monthly charge of $32.

There are companies that provide cellular digital radio services. In the U.S., RAM Data Systems has networks to provide metropolitan area coverage. Their base stations use Ericsson switches and many of the portable transceivers are provided by a GE/Ericsson arrangement.

Vendor	Frequency	Data Rate
IBM (CDPD)	826-849 860-894 MHz	19.2 Kb/s
RAM Data Systems	896 - 902 MHz	2.4 Kb/s
Proxim (RangeLAN)	800 MHz	9.6 Kb/s
ARDIS	855 - 865 MHz	4.8 Kb/s

Figure 3. Representative Wireless MAN Providers

Inter-city

There are limited activities to link cities together to provide the connectivity required in the future. The IBM Information Network is one way in which the connection can be accomplished. Other services such as SMDS or interconnection of cellular digital networks may also be offered.

Terminals

An interesting workstation has been created by IBM called the PC Radio (9075). The terminal can use ARDIS, RAM Data, or analog cellular module to connect into different environments.

NEC recently announced a terminal called the RC-9801 which will allow a user to roam around a building.

Defining the Underlying Technologies

In-Building

Some of the technologies used by the wireless in-building products are radio, infrared, and powerlines. Each technology has advantages and disadvantages. All the wireless technologies have as an inherent function the ability to broadcast to all stations simultaneously. Generally, our architectures assume a single point-point connection and could not make use of the intrinsic multicast capabilities of the media.

Powerline

The powerline technologies use the standard power wires in a building to transmit the signal. As long as there are no transformers between two stations, a communications path can be established. Because of the large amount of noise on the wire and the type of media used to carry the conventional power, speeds are generally low, 1.2 Kb/s to 38.4 Kb/s. Their attractive feature is that connectivity is achieved using existing wire, and they are relatively inexpensive.

Optical

The optical wireless- or more precisely, fiberless- technologies employ the infrared frequencies to transmit the information. Generally, the signal bounces off the ceiling, wall, and floor to provide the path between sending and receiving stations. The signal is usually stopped by going around a corner, and it will not penetrate through closed doors. The upper bound on the transmission speed is limited by the interference caused by the signal being received from multiple paths simultaneously (multipath).

RF

The RF (radio frequency) technologies use three dominant techniques: single frequency, frequency hopping and spread spectrum. The cost of the units increases as the power and number of frequencies handled increases. There are also many regulatory considerations associated with the use of this technology.

The Federal Communication Commission controls the allocation of the frequencies available for commercial use in the United States. Many countries have an equivalent body to our FCC to control the usage of the RF spectrum. The frequencies available for the different applications are generally not the same in most countries. For example, there are differing numbers of channels available for television usage and the positions in the RF spectrum also vary.

The two parameters that define RF are the frequency of the transmission and the bandwidth. Bandwidth is defined as the amount of shift from the center frequency of the carrier. For example, AM radio can be 1310 KHz with a bandwidth of +/- 5 KHz (10 KHz bandwidth). This means that a 5 KHz audio signal applied to the 1310 KHz carrier will produce frequencies from 1305-1315 KHz.

The higher the carrier frequency, the higher the cost of the equipment and the more directional the signal. The higher the frequency, the higher the bandwidth theoretically available. For example, a 1 MHz carrier cannot be modulated by a 16 MHz signal. A 1 GHz carrier can easily carry the 16 MHz signal.

Since the radio spectrum has a limited number of channels available, and the bandwidth in each band is fixed, only a small number of licenses are available for use for the wireless computer application. Recently, 200 MHz of bandwidth across many frequencies has been taken away from the government and been made available for the FCC for reallocation. Some of these frequencies may be made available for computer usage.

Single Frequency

The simplest of the RF technologies uses a single frequency for transmission of the data. The carrier is turned on/off when data needs to be transmitted. For higher frequencies (> 800 MHz), the transmitter and/or receiver will use some type of directional technique to reduce the effect of multipath.

Spread Spectrum

The last major RF technology is spread spectrum. There are several forms of spread spectrum, among them are frequency hopping, direct sequence, and CDMA (Code Division / Multiple Access).

Frequency hopping is a technique in which the transmitter and receiver use a variety of available frequencies. The transmitter uses one frequency for a period of time and then choose another. The period of time can be as short as 1 ms.

This approach can offer security by having the transmitter and receiver algorithmically change frequencies rapidly. Unless the algorithm and duration for choosing the channels are known, interception becomes difficult.

Choosing from a variety of channels also provides a mechanism for many stations to share a limited number of frequencies, since a frequency does not have to be permanently assigned to a station. In cases of interference on one channel, another channel could be used thus providing a degree of fault tolerance.

CDMA uses many frequencies simultaneously to transmit a portion of the information. It uses a random number generator that changes the frequencies in the order of 1 million times/sec for LAN based environments.

Some stations use 10 to 500 simultaneous frequencies. The advantages of this technique are that it is very difficult to jam, can provide secure communications, avoids regulatory problems on power limits, and can offer higher thruput. Sharing of the airwaves is simpler because it only appears to be more background noise in a band.

The disadvantages of spread spectrum are its cost to implement the technique and unreliability when slow frequency hopping is used in the same band. To be effective, the control system is more complex. One form of that is dynamic power control of the transmitter.

In secure military communications, spread spectrum offers security by having a unique key for a sender and receiver. Since the message is appearing in fragments in so many different places, it is very difficult to intercept.

The FCC regulates the power and frequency of a transmitter in all frequencies available for commercial RF use. If a transmitter is under a prescribed power level, no license is required to use that transmitter. For spread spectrum, you can put out more total power on the combination of many different frequencies than you could on a single frequency.

Cellular

Since channels (frequencies) are a limited resource, it is best to reuse the channels as much as possible. The theory behind this is that a geographic area (a cell) uses a set of frequencies and that adjacent cells use a different set of frequencies. Cells not adjacent to these cells can then reuse those frequencies without interference.

As the geographical cell size gets smaller, the number of stations that can use those frequencies increases. Of course since there are more cells, there is more equipment cost associated with the network.

As a person roams through various cells, the frequency that is being used must change. The change must occur before there is a degradation in the signal, it must occur quickly and transparently to the user. There is a control mechanism to make this sequence happen, and it occurs via an out-band signaling channel.

For the cellular telephone system serving a metropolitan area, there are many cells each covering a several block area. The cells are connected and relay their traffic through a tree hierarchy. The company providing this service is called the Cellular Access Provider (CAP).

There are 56 channels available in each cell. A person wishing to make a call must get access to one of these frequencies. A special ID, unique for each cellular phone, is transmitted to the cell when service is requested. If the ID is authorized to use the system, one of the channels is assigned for usage while in that cell.

The CAP is connected into the regular RBOC servicing the area to provide the terrestrial lines. As the telephone number is dialed, the CAP forwards the number to the central office and the connection between the user and the destination number is then made.

As the user leaves the cell, his signal is switched automatically through a mechanism operating as a circuit switch which maintains the connection path. Since two cells overlap somewhat, the user's signal is received by multiple cells simultaneously. There is a mechanism based on signal strength and quality of signal that determines which cell will handle the call at any given instant in time.

The current systems use an analog RF-based technology. The cost to the user is based on the amount of connection time used.

There is a new technology under development which uses digital technology to carry information and also uses a cellular approach. Several companies are starting to market services for computers, charging on a per-packet basis. The raw data error rates are approximately 1 bit in 100. Forward error correction is usually employed to help obtain a lower error rate.

Satellite

A satellite transmission can be thought of as a wireless LAN which extends over a very large geographical area. A different way that this technology can be used is for a multicast distribution system. In this mode, the amount of traffic in each direction is asymmetrical with the uplink providing the majority of the information flow and the receiving stations having minimal back traffic.

The links are characterized by bandwidths of around 10 MHz and long delays (250 ms). The uplink transmits at around 14 GHz and downlink is around 11 GHz. The satellite contains receivers and transmitters. Many satellites contain multiple antennas that transmit different signals to separate parts of the country.

Related Standards

- EIA
  - TR45 Cellular Communications
    - TR45.2 Analog
    - TR45.3 Digital
- ANSI
  - T1P1 Personal Communications
    Voice oriented. This body works on the Universal Personal Telephony (UPT) that associates the phone number with a person and forwards calls to a person's location.
- CCITT
  - Study Group 11 working on UPT
  - Study Group 18 GSM (Cellular Telephony)
  - Study Group 1,7 performance and operations
- IEEE
  - 802.11 Wireless LANs
    This is designed for in-building applications.
- ETSI
  - RES10 (20 Mb/s LAN)
  - DECT (Digital European Cordless Telephone)
  - DCS 1800,
  - Universal Mobile Telecommunications Service (UMTS)
    Consortium of European PTT's addressing mobile communications.

Operational Characteristics of the Wireless Environment.

Corporate Environment

The desired goal of the user is to effectively perform his work whether he is at the desk, in a meeting, on the road or at home. The applications that he currently runs should be available as he switches to the wireless products. This implies that the applications run unaltered from today's wired computers. There are many challenges to performing this migration.

Many communication protocols today require awareness of the destination's path, and they do not adapt to rapidly changing between intermediate nodes. Adding this facility would greatly increase the host processing requirements to maintain a large number of roaming stations. Additionally many applications may have to be rewritten to function in this environment. The implication then is to provide a transparent path that allows the underling transport system to keep track of the end station and to provide the switching between intermediate notes rapidly and transparently.

To understand what needs to be accomplished, a discussion of the users working environment would be helpful. Refer to Figure 4 for an illustration of this packet flow.

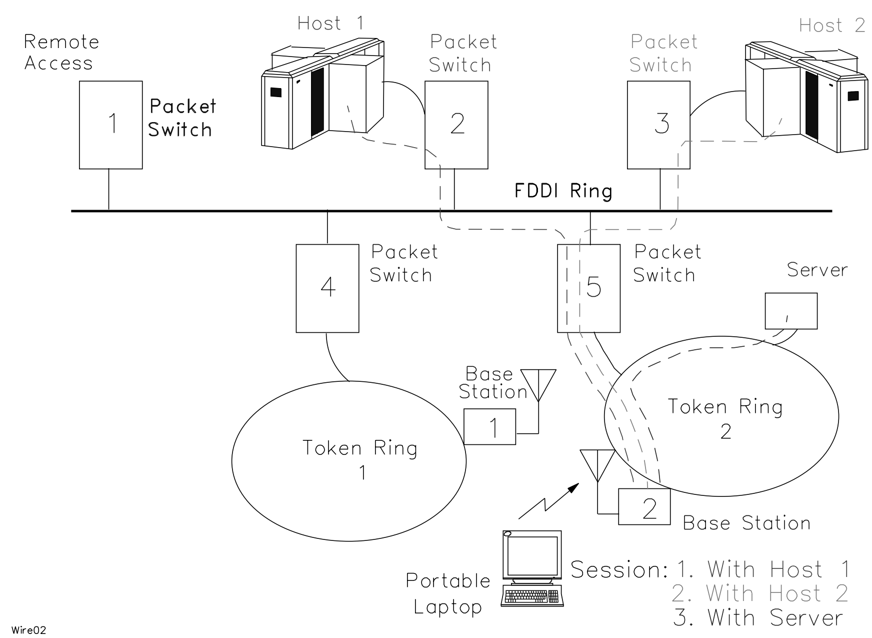


Figure 4. Wireless Laptop attached through a Token Ring LAN

A user has three sessions established using a laptop computer. One session is with host 1, an SNA session and is routed through packet switch 2, 5 and base station 2. The second session is connected to host 2 through packet switch 3,5 and base station 2. Session 3 is to a server located on token ring 2.

For some time the user is in the region serviced by base station 2. The user moves and his signal is simultaneously received by base stations 1 and 2. Eventually, the user goes out of range of base station 2, and base station 1 is required to carry the packets. The packet flow is now shown in Figure 5 on page 12.

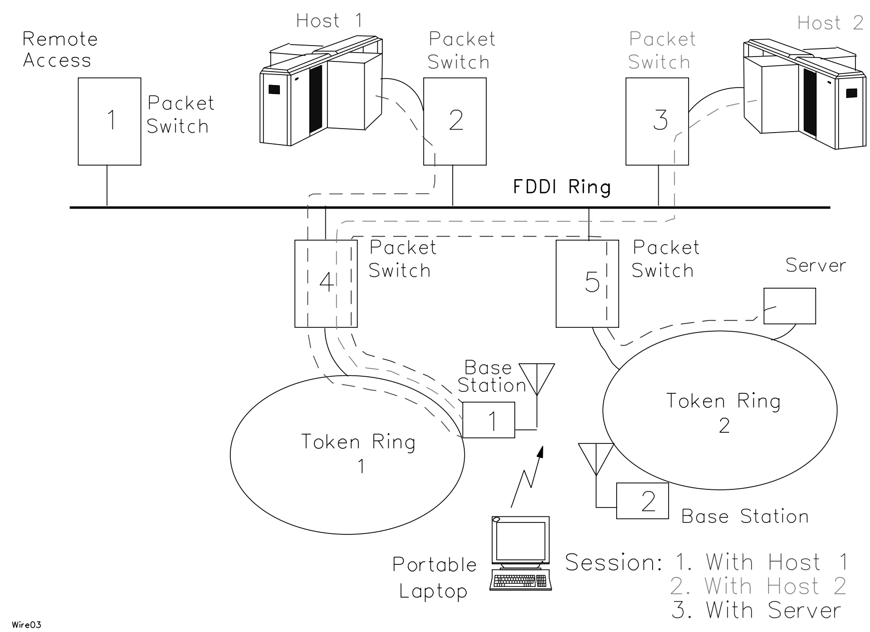


Figure 5. Laptop Computer roams to another area on campus

The packets for host 1 are rerouted through packet switch 2, 4 and base station 1. The packets for host 2 are rerouted through packet switch 3, 4 and base station 1. The packets to the server must flow through packet switch 4 and 5.

The user exits the building, gets into a car, and travels around the city. The packet flow moves as shown in Figure 6 on page 13.

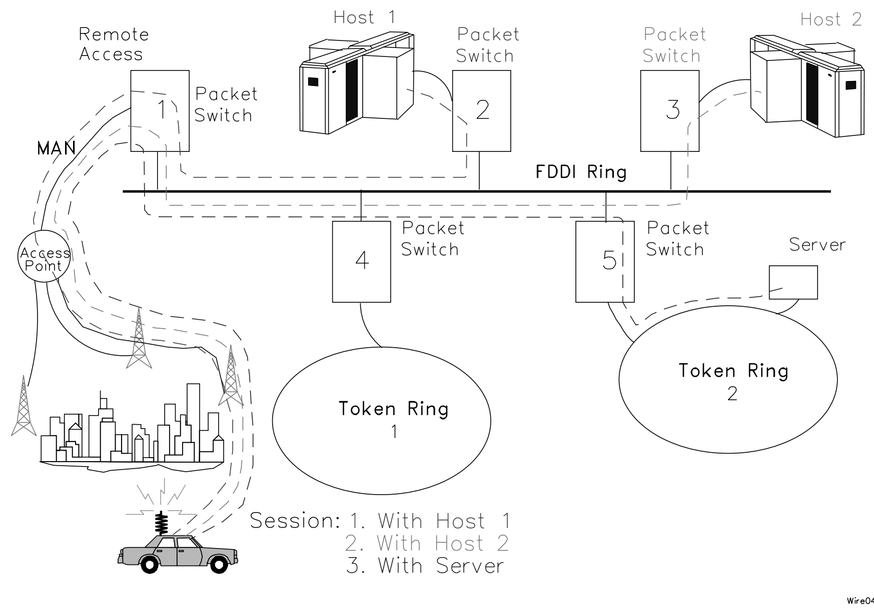


Figure 6. Computer wanders across the metropolitan area.

As the user travels around the city, the signal is picked up by different antenna sites. The signal is routed to the Cellular Access Provider where it is forwarded through a packet switch onto the Metropolitan Area Network (MAN), into the company's packet switch and onto the company's network.

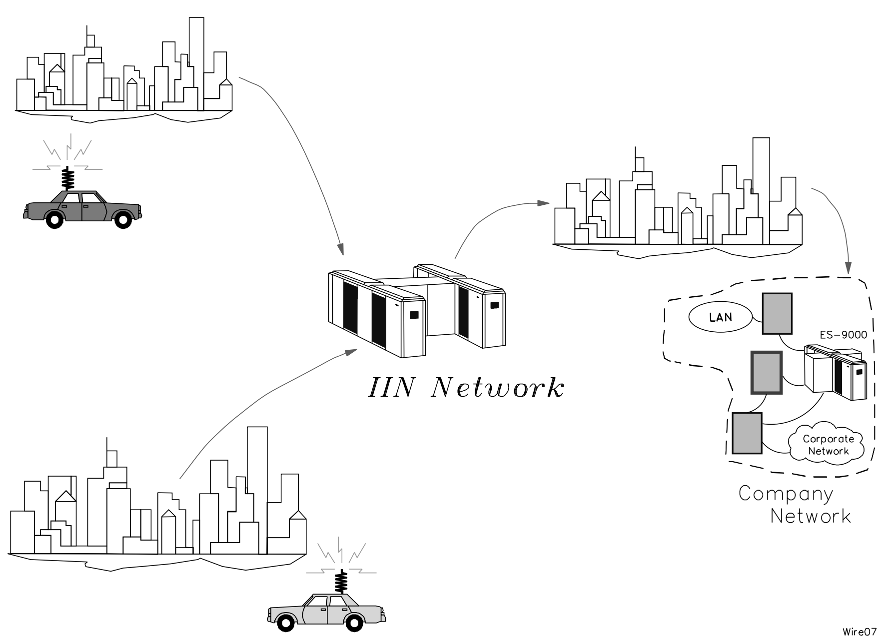


Figure 7. Computer wanders between metropolitan areas.

Users must also be allowed to work as they move between cities (see Figure 7). The IBM Information Network (IIN) is a candidate to provide this connection fabric.

Again, the user wishes to maintain their service and without overt action for each change. This seamless operation is not possible today.

Back to Figure 4 on page 11, for initialization there are several steps that must occur. The laptop must be allowed to pass its packet through base station 2. How does the base station know that this laptop is to be allowed into the network? Obviously some type of authorization for the laptop is required.

Additionally, how can the network ensure that the user of the laptop is the person registered for the laptop? This now requires authentication of the user's identity. Is this authorization/identification information available locally, or is it located at another node, another site within the city or across the country?

Since the session with host 1 will be using an SNA protocol, the application that is running requests a bind. Normally that would flow through to the end-station. The network can either provide a transparent path, or packet switch 2 must terminate the LU and establish an independent transport to the laptop. This action is required to shield the application from the routing problems that will occur as the user moves.

If the topology of the wireless receivers is structured correctly, there will be a time in which both base stations 1 and 2 are receiving the laptop's signal simultaneously. One problem that occurs in this situation is to have the network understand which receivers have the signal and ensuring that only one base station forwards the laptop's packets. How do these particular base stations know about each other? In a network of a hundred base stations and hundreds of laptops there would be a large number of inquiries about the determining the best path.

If an assumption was made that a centralized information source were available to provide the arbitration and directed the switch over, the network would then have a single point of failure. A decentralized/distributed architecture would be desirable to ensure a fault tolerant network.

As the user moves outside the confines of the company, information security becomes much more difficult to ensure. Communications access from outside the company into this backbone must be carefully controlled. Authorization and authentication are obviously still important, but additionally, the need to protect the data from eavesdropping will probably require encryption.

Cellular Access Provider Environment

The Cellular Access Provider and the company's IS area will require fast packet switches, controllers to handle the new architecture protocols, and software to run on the portable terminals, bridges, and servers.

In Figure 8, the user is traveling in a car and has both telephone and computer plugged into his cellular radio. This radio provides an electronic switch to provide access for either device to transmit.

The radio's signal is related to the CAP access point. There, another electronic switch provides the same switching function to route the voice traffic to the Central Office (CO) as is currently done today or over to a fast packet switch for the computer-generated traffic.

For some users, their packets would be placed on a Metropolitan Area Network (MAN) which will transport the packet to their company's computer system. Other users will be routed over a more secure route via a point-to-point T1 from the CAP's packet switch to the company's packet switch.

There are many architectural questions that need to be resolved for this scenario to work. Some of the issues include: security of the packets from interception, protection of the company's private network from unauthorized access, addressing, naming, and switching users from the internal to the CAP network.

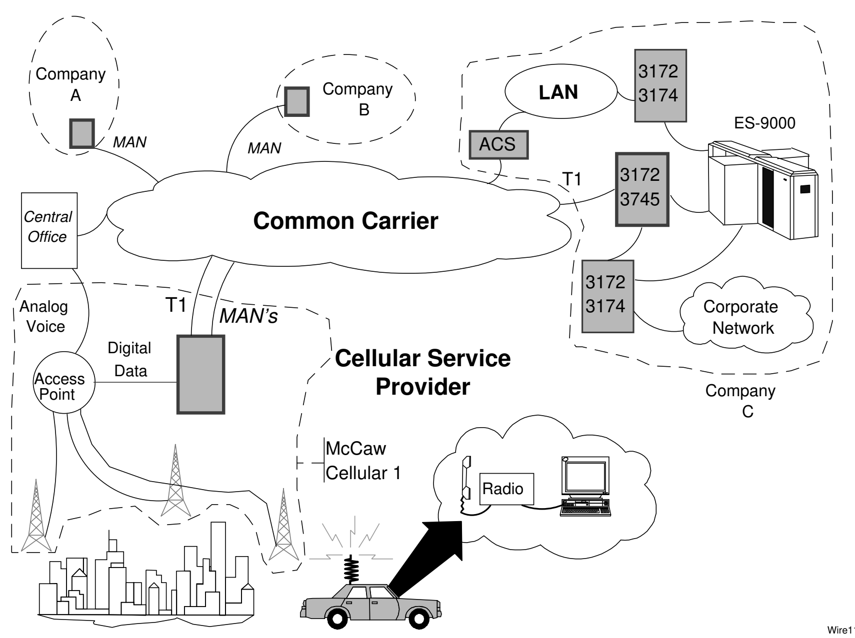


Figure 8. Networking support products.

Satellite Environment

Satellite communication for distribution of computerized information is an ideal utilization of this technology. The long distance (23,500 miles up / 23,500 miles down) between sender and receiver provides a significant delay for some applications, but is not a detriment for most computer applications.

The primary advantage this technology has over competing transmission technologies is that it can multicast to millions of computers without the need for additional distribution hubs, signal regeneration, or wired connection. This is also a good technique for providing transmission to roaming computers.

The publishing industry is a good example of how the technology could be exploited. Magazines and periodicals are currently printed, mailed, and take several days to arrive. The original computer-generated pages used in the printing process could be sent directly to millions of people for the same cost as transmitting to the printing plant.

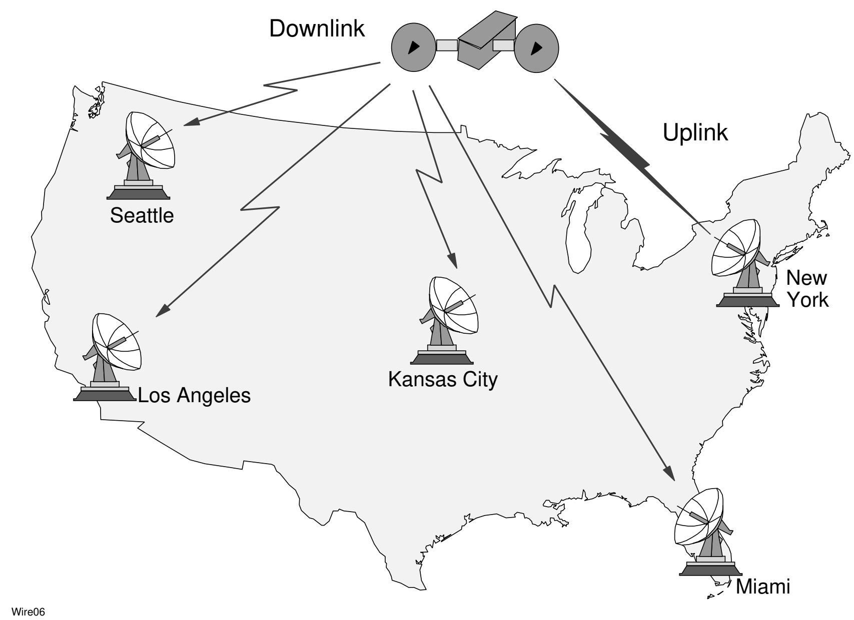


Figure 9. Multicast capabilities of satellite links.

There are other satellite services today that provide data relay services. Among them are Inmarsat, providing communications for maritime users, and SkyTel, which recently signed an agreement with Hewlett-Packard to offer a new SkyStream wireless message receiver. In the US, the FCC issued a license to American Mobile Satellite Corporation (AMSC), a consortium of seven companies providing mobile communications via satellite relay.

Motorola's Iridium project is planning to put 77 satellites into a polar synchronous orbit to provide continuous communications coverage. This is a cellular topology except both the user and the cell move. Enabling communications to remote areas that do not have a developed telecommunications industry is an excellent market for this form of Low Earth Orbit (LEO) systems.

LEO satellites circle the earth at an altitude of approximately 400-500 miles. They were recently given a giant push when the World Administrative Radio Conference (WARC'92) allocated a variety of frequencies for Mobile Satellite Service (MSS). The frequencies for the MSS were 1930-1970 MHz / 2120-2160 MHz (Up link / down link) for North and South America. The rest of the world will use 1610-1625 MHz / 2483-2520 MHz (Up link / down link). This world wide allocation will now allow common products to be built and used world wide.

Architectures Required to Serve the Wireless Environment.

- Transparency for route switching
- Mechanism for determining when/how to reroute
- Security Architectures
  - Registration
  - Authentication
  - Authorization
  - Encryption
- Network Management
- Naming and Directory Services

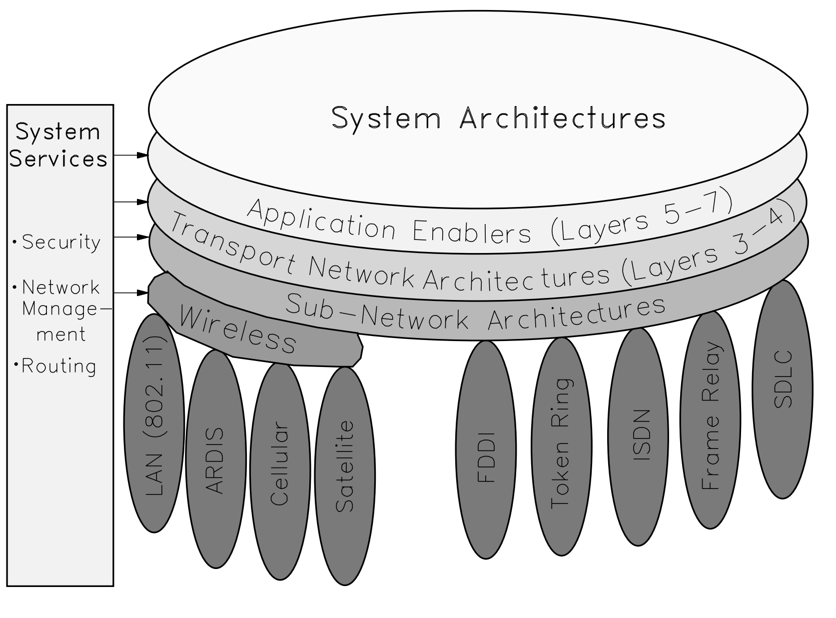
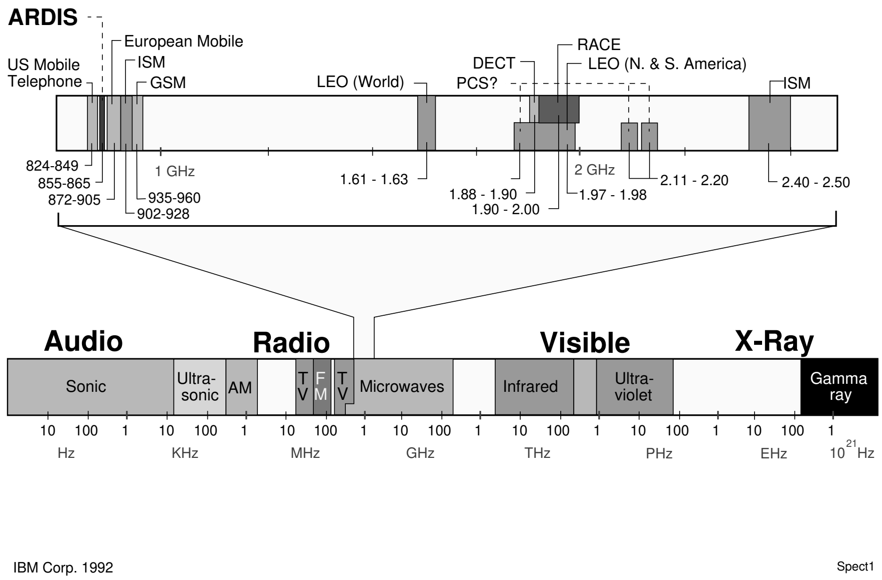


Figure 10. Positioning of Wireless Architectures.

Appendix A. Frequency Spectrum Charts

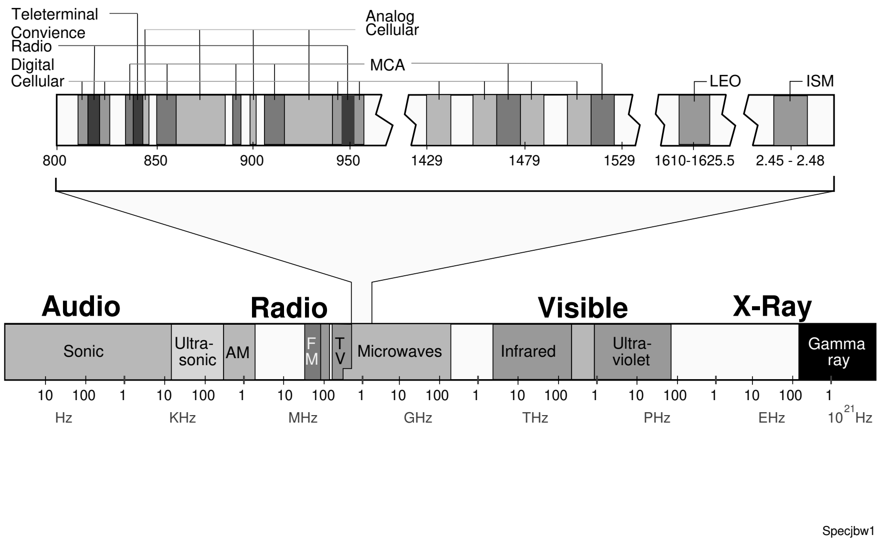
U.S.



Service	Frequency
AM Radio	535 - 1605 KHz
Cordless Telephone	46-47 48-49 MHz
FM Radio	88 - 108 MHz
TV (2-6)	54 - 88 MHz
(7-13)	174 - 216 MHz
(14-69)	470 - 806 MHz
ARDIS	855 - 865 MHz
US Mobile Telephone	826-849 860-894 MHz
European Mobile	872-905 917-950 MHz
RAM (MobiTex)	896 - 902 MHz
NCR (WaveLAN)	902 - 928 MHz
GSM (Digital Phone)	890-915 935-960 MHz
LEO (satellite)	1.97 - 1.98 GHz
ISM band	2.40 - 2.48 GHz
Cal. Microwave	2.40 - 2.48 GHz
Microwave Ovens	2.43 - 2.46 GHz
Motorola (Altair)	18.8 - 19.2 GHz

Figure 11. Selected RF Spectrum Usage

Japan



Service	Frequency
Cordless Telephone	253-255 380-382 MHz
FM Radio	76 - 90 MHz
TV (1-3)	91 - 104 MHz
(4-12)	171 - 218 MHz
(13-62)	471 - 766 MHz
MCA (Multi-Channel Access)	834-838 889-893 MHz
	850-860 905-915 MHz
	1465-1477 1513-1525 MHz
Teleterminal (packet)	838 - 843 MHz
Mobile Telephone (analog)	843-846 898-901 MHz
	860-885 915-940 MHz
Mobile Telephone (digital)	810-815 821-826 MHz
	940-945 951-956 MHz
	1429-1441 1453-1465 MHz
	1477-1489 1501-1513 MHz
Low Earth Orbit satellite	1.61 - 1.63 GHz
ISM band	2.45 - 2.48 GHz
Motorola (Altair)	17.7 - 19.7 GHz

Figure 12. Selected RF Spectrum Usage