Mobile Computer Networking Feasibility For Field Research in a University Environment

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Abstract

The University of Wisconsin – Eau Claire is presently engaged in numerous field-oriented research projects. This study is taking a look at the feasibility of extending the University's technology with the intent of allowing these field projects to remain in constant contact with the University and the University's servers. The study will explore the technological opportunities presently available to commercial and educational environments. This information will be evaluated by comparing the cost and effectiveness of today's technology. This information will be used to build one or more plausible scenarios. These scenarios could be taken inder consideration and used to update or replace the equipment presently owned by the University in the hopes of improving contact between future trips and the University. Ideally, in the near future, classes at the University will be able to remain in contact with these trips for the purpose of extending the learning opportunities available to University of Wisconsin – Eau Claire students.

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1.0 Introduction

Universities from around the world are presently embracing a technological revolution. Information is accessible in forms and amounts as it has never before. This is largely the responsibility of the advent of computer networks, notably, the Internet. The next step in this revolution is the extension of intra-campus networks to completely cover the university's campus and beyond. The technology making this notion into a reality is called mobile networking. The goal of this study was to determine whether a mobile network was possible in today's university environment. The study first looked at what a network was and what it was comprised of. Second, the study researched the mobile networking technology publicly available today. Comparing the seemingly most useful technologies, the study attempted to determine which, if any, technology could help to achieve the goal of a campus which was mobile-network capable.

2.0 Computer Networks

2.1 What Is A Computer Network?

A computer network is commonly recognized as a group of computers that are connected together and display a certain set of characteristics. The primary example of a computer network in existence today would be the Internet. The Internet is only one example, though. There are tens of thousands of smaller networks in existence in workplaces and universities all over the world.

2.1.1 Characteristics Of A Computer Network

Most computer networks are defined under a basic set of four rules. These four rules or characteristics must be exhibited by a system in order for it to be labeled a network. These rules are: one, information must be delivered reliably without corruption of data; two, information must be delivered consistently – the network should be capable of determining where its information is going; three, multiple computers must be able to identify each other across the network; four, there must be a standard way of naming and identifying the parts of the network (Hayden, 1998).

The first of these characteristics should explain itself. If information is routinely lost or damaged during transfer, the system is largely without value. Would anyone use a service such as the United States Postal Service if they were unsure their package would, not only arrive undamaged, but also arrive at all? This characteristic of a network exists as a clause to safeguard against systems that are unreliable, making them unlikely to be incorrectly labeled as a network.

The network must also be required to know where it is sending its information. Without this stipulation, a network could be allowed to save a copy of a file a person is working on somewhere on the network. The problem being, the network isn't quite sure where the file was saved, only that is was saved to the network. Like the first rule, this rule is a safety clause.

The third characteristic of a network is that everything connected to the network must be able to identify everything else on the network. This is a protection to keep a user from saving a file to what is thought to be a file server but is, in reality, a printer.

The final of the four characteristics is a simple method that forces the consistent identification of the components of their network. This allows enough consistency that multiple networks can connect to each other.

2.1.2 Components Of A Computer Network

Now that the characteristics of what classifies something as a network have been established, it is time to define what components are linked to create a computer network. There are four main groups of components (excluding the cables and wires used to connect the components to each other and peripherals such as printers). They are clients, servers, multi-station access units, and routers. The combination of these units comprises a network.

2.1.2.1 Clients

The most recognizable component of a network is called the client. A client is normally defined as a computer on which a user does his or her work. They are more commonly known as personal computers (PCs), or workstations. The majority of work done on a network is performed on these machines.

2.1.2.2 Servers

A server is a catchall term for a large number of powerful computers that fit a certain definition. The definition of a server is a computer whose resources are shared with other computers. Examples of servers on a typical network would be file servers, computers with large amounts of memory which can be used as a remote directory for saving files, email servers, computers responsible for sending and receiving all email for a network, and web servers, computers on which web pages are stored which can be viewed via the internet. While all these computers are most likely very different and perform different tasks, they all fulfill the definition of a server. All three of these examples are computers that have a certain task performed for the benefit of the entire network.

2.1.2.3 Multi-station Access Units

A multi-station access unit (MAUs), also known as a hub, is one of the most important pieces of hardware *within* a network. A MAU is a device that provides the network with a single point of contact for all other devices.

2.1.2.4 Routers

Routers, also called bridges, are the most important piece of hardware *outside* a network. Without routers, the internet would not be possible. A router is a device that moves data between networks. An example of a "real-world" router would be a post office. Mail enters the office and is directed towards its final destination in much the same way data is redirected by routers towards its destination.

2.2 Remote Connection To A Computer Network

2.2.1 Modems

Remote access to a network is typically accomplished through a device called a modem. According to SHELDON (1998):

> Modems (modulators/demodulators) are data communication devices that allow two end systems to communicate over the public-switched telephone network. A modem at the sending device converts computer digital signals into analog signals that can be transmitted over telephone lines. A modem at the other end of the link reconverts the analog signals back into digital pulses. Digital-to-analog conversion is called modulation and analog-to-digital conversion is called demodulation; thus, the name modems.

2.2.2 Bandwidth

One of the most important terms to understand in a network environment is bandwidth. The term bandwidth describes the maximum speed at which a given device (such as a network card or a modem) can transfer data over a network. It is measured in kilobits per second and megabits per second. The higher the bandwidth, the faster data can be transferred. To give you an idea of bandwidth in present technologies, a high-end modem will transfer data at a maximum speed of 56.6 kilobits per second over conventional telephone lines. On the other end of the spectrum, the high-speed phone lines used by phone companies transfer data at 155 to 622 megabits per second.

2.2.3 Packet-Switched Data

Packet-switched data is one of the more important aspects of network data communication. To understand it, a person must first understand what a packet is. According to SHELDON (1998) a packet is:

> …a package of data exchanged between devices over a data communications link. Information in the packet may include messages and commands, such as a request for service, connection management controls, or data. Large transmissions are divided into packets instead of being transmitted as one long string. If a packet is corrupted during its transmission, only the corrupted packet needs to be re-sent, not the entire transmission.

There are three reasons that packet-switched data is important. The first is that packet-switched data allows more than one stream of data to travel over a wire or connection at a time. Second, packet-switched data inherently ensures error-correction, that is, that data transmitted over a wire or connection is free of errors. Finally, packet-switched data allows data to be sent from one computer to another over multiple routes, depending on which routes are currently open.

2.2.4 Open Systems Interconnect (OSI) Model

The Open Systems Interconnect (OSI) model was based on a proposal by the International Standards Organization. It was created with seven layers. The principles that were applied to arrive at the seven layers are as follows: one, a layer should be created where a different layer of abstraction is needed; two, each layer should perform a well-defined function; three, the function of each layer should be chosen with an eye towards defining internationally standardized protocols; four, the layer boundaries should be chosen to minimize the information flow across the interfaces; five, the number of layers should be large enough that distinct functions need not be thrown together in the same layer out of necessity, and small enough that the architecture does not become unwieldy. This model is the model from which the majority of network protocols are presently derived.

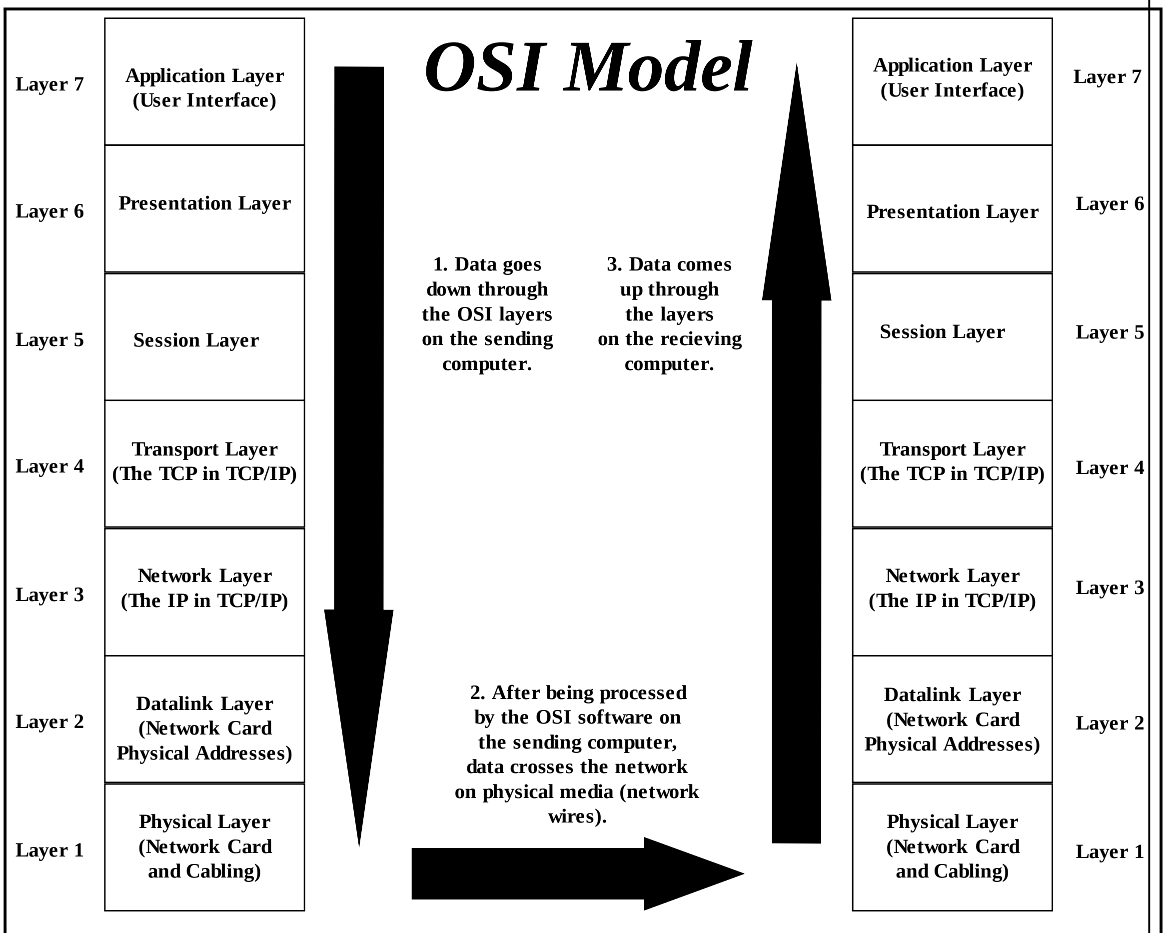

Figure 1: A visual representation of the OSI model.

2.2.5 Transmission Control Protocol/Internet Protocol (TCP/IP)

Transmission Control Protocol/Internet Protocol (TCP/IP) is the name given to the collection of networking protocols that have been used to construct the global internet. It originated as a set of standards created by a body called the Internet Engineering Task Force. IP

Transmission Control Protocol/Internet Protocol
TCP/IP

TCP	Transmission Control Protocol. Ensures that connections are made and maintained between computers.
IP	Internet Protocol. Handles software computer addresses.
ARP	Address Resolution Protocol. Relates IP addresses with hardware addresses.
RIP	Routing Information Protocol. Finds the quickest route between computers.
OSPF	Open Shortest Path First. A descendant of RIP that increases speed and reliability.
ICMP	Internet Control Message Protocol. Handles errors and sends error messages for TCP/IP.
BGP/EGP	Border Gateway Protocol/Exterior Gateway Protocol. Handles how data is passed between networks.
SNMP	Simple Network Management Protocol. Allows network managers to connect to and manage network devices.
PPP	Point-to-Point Protocol. Provides for dial-up networked connections to networks. PPP is commonly used by Internet Service Providers to allow customers to connect to their servers.
SMTP	Simple Mail Transfer Protocol. How email is passed between servers on a TCP/IP network.
POP3/IMAP4	Post Office Protocol version 3/Internet Message Advertising Protocol version 4. Both set up ways for clients to connect to servers and collect email.

Table 2: A table displaying members of the TCP/IP protocol package. TCP/IP is the most widely used netowrk protocol package because it is an open standard.

is the central protocol for the TCP/IP package. It provides the basic delivery method for packets of data sent between all systems on a network, regardless of whether the systems are in the same room or on opposite sides of the world. TCP provides a reliable byte-stream transfer between two endpoints on a network. TCP relies on IP to move packets around the network on its behalf.

IP is inherently unreliable, so TCP protects against data loss, data corruption, packet reordering, and data duplication by adding checksums and sequence numbers to transmitted data and, on the receiving side, sending back packets that acknowledge the receipt of the data. What makes TCP/IP so valuable is the fact that it is an open standard. That is to say, no one company controls it. This allows any company, government, organization, or individual to use it without a cost.

2.2.6 OSI Model Compared To TCP/IP

The OSI model and TCP/IP are similar due to the fact that TCP/IP was created using the OSI model. There are differences between the two, though. The primary difference being that

OSI vs. TCP/IP

OSI Layer	***TCP/IP Layer***	***TCP/IP Applications and Protocol Running At This Level***
Layer 7	**TCP Layer 4 *(Application)***	**FTP (File Transfer Protocol)** **Telnet (Terminal Program)** **SMTP (Mail Transfer)** **POP3 and IMAP4 (Mail Clients)**
Layer 6		
Layer 5		
Layer 4	**TCP Layer 3 *(Also called host-to-host; a host is any system running TCP/IP)***	**TCP (Transmission Control Protocol)** **UDP (User Diagram Protocol)**
Layer 3	**TCP Layer 2 *(Internet)***	**IP (Internet Protocol)**
Layer 2	**TCP Layer 1 *(Network Interface)***	**Hardware**
Layer 1		

Figure 3: A comparison of the OSI model and TCP/IP. The figure also shows examples of TCP/IP applications and protocols which could be running on each level.

TCP/IP contains only four layers, whereas the OSI model contains seven. This and other differences are only minor, as both the OSI model and the TCP/IP protocol function in much the same way.

3.0 Mobile Networking

3.1 What Is Mobile Networking?

Mobile networking has been cited by many to be the possible future of computer networks. Mobile networking allows a computer to remain attached to a network without being restricted by a physical connection. The network takes advantage of other technologies which can be extensive enough to allow clients on the network near limitless mobility.

3.2 Methods Of Mobile Network Connection

There are presently multiple different types of devices offering mobile network connections presently on the market. The three options that show the most promise are the PCS style cellular telephone, the Iridium satellite cellular telephone, and the T1 wide area wireless.

3.2.1 PCS Cellular Telephone

PCS cellular technology is presently being spear-headed in the United States by Sprint PCS. Sprint PCS operates the "largest 100 percent digital, 100 percent PCS nationwide wireless network in the United States" (Sprint-PCS 1998) The company also boasts the United States only nationwide all-digital, fiber optic network. PCS is built upon a technology called code division multiple access (CDMA). CDMA is a digital cellular system. It is superior to normal cellular in four main ways. These are sound quality, reliability, security, and capacity.

The sound quality of PCS phones is comparable to a landline telephone due to its digital signal as opposed to the normal analog signal. Digital also allows for clear signals inside of buildings where analog phones cannot even operate.

PCS also tends to be more reliable due to a system it calls a "soft handoff." A handoff occurs when a phone moves from one cell to another during a transmission. Analog cellular phones handle this occurrence by sending a message to the new cell directing it to pick up the call. If for some reason the call is not picked up, the call abruptly terminates. This is referred to as a "dropped" call. To solve this problem, PCS does not use the traditional concept of channels. It uses a CDMA digital group. When the signal is moving, it can be picked up by any station within its range. The system then does not have to decide which channel to keep, it can use them both. When the signal moves out of range of one station, the second station, which has been receiving the signal for some time, continues to broadcast without interruption. This greatly reduces the number of "dropped" phone calls.

The security of PCS greatly reduces both eavesdropping and number cloning. It accomplishes this by assigning each call with a special code. This forces a person attempting to crack a single call to sort through 64,000 different codes.

Finally, the capacity of PCS is far greater than present analog cellular technology. CDMA offers capacities from 6-14 times higher than analog technology. This occurs because as a CDMA cell begins to become overloaded, the cell shrinks its own size. While this could conceivably result in dead spots in coverage, carriers can actually use this flexibility to place more coverage in the exact places where it is needed (Sprint, 1998).

3.2.2 Iridium Cellular Telephone

Iridium was developed in response to a concept of the wife of a Motorola executive. The woman, Karen Bertiger, convinced her husband of the necessity of a mobile wireless system which allowed people to place a telephone call from anywhere in the world. Two years later in 1987, the Iridium concept is proposed by a group of Motorola engineers. Their vision consists of a constellation of low-orbit communications satellites which provide seamless coverage of the planet. The original design for the system called for 77 communication satellites (77 is the atomic number of the element iridium, hence, the name Iridium) to be launched into orbit. These satellites would serve as a link to current terrestrial telephone networks. The satellites were to be positioned at an altitude of 750 kilometers in circular polar orbits (Iridium. They would be arranged in north-south "necklaces," with one satellite positioned every 32º latitude. The system was revised to only necessitate 66 satellites and remove the need for calls to pass through terrestrial telephone networks. From 1997 to 1998, all 66 satellites were launched into orbit with a 100% success rate. The system officially came online on November 1, 1998. In addition to the satellite coverage, Iridium has signed agreements with cellular providers which allow the phones access to present cellular networks. This allows users to use less-expensive cellular communication whenever possible. Currently the Iridium network covers the entire globe, but is not allowed in certain countries such as Iraq and Cuba. The system not only provides seamless global coverage, but also displays incredible versatility. On August 27, 1999 at 10:41 am, a call was placed from an F-16 flying at a speed of mach 1.6 and an altitude of 42,000 feet. What makes this all the more impressive is that the call was placed using an off-the-shelf Iridium-compatible phone (Iridium LLC, 1998).

3.2.3 T1 Wide Area Wireless (WAW)

Wide area wireless (WAW) technology is a blossoming technology. It is an example of the opinion voiced by many that "data has become too important to the way we live for it to only be available at the end of a wire" (Angel, 1999). WAW is an example of the type of wireless mobile networking which appears to be right around the corner. Other wireless networks currently being researched and developed are the local area network (LAW) and the personal area network (PAW). Although a directly public-accessible method does not presently exist, some experts believe that such a network could be poised for release by the year 2000 (Angel, 1999). Presently, T1 WAWs exist which can transmit data over distances of up to 50 miles. This technology is still in its infancy, though, and is not yet widely available.

3.2.4 Comparisons Between The Methods

PCS digital cellular, Iridium satellite cellular, and T1 WAWs are all technically feasible in a University environment. The large issues to be tackled in deciding the optimal method to be used are cost and effectiveness.

The operating cost for the PCS and Iridium systems is still relatively high. Both charge about $0.30 per minute for calls placed in a users home area (Rysavy, 1999). PCS prices rise to about $1.00 when outside of local coverage (roaming) and Iridium prices jump to anywhere from $1.00 to $3.00 per minute when roaming (Rysavy, 1999). T1 WAW is not billed by the minute as the user owns all equipment being used.

	PCS Cellular	Iridium Satellite Cellular	T1 WAW
Startup Cost	$100	$300	$7000
Cost Per Minute (Local)	$0.30	$0.30	$0
Cost Per Minute (Roaming)	$1.00	$2.00	$0

Table 4: A table documenting the costs of three mobile networking alternatives. All prices are approximate costs taken from commercial averages in November 1999.

The systems are not inexpensive, though, with basic systems starting at approximately $5000.00 (Molta and Irshad, 1999). This is a large startup cost compared to PCS and satellite cellular, but over an extended periods of time T1 WAW ends up being comparable in price.

The measures of effectiveness in terms of this study are being identified as the achievable bandwidth and the reliability of the connection. In this category, the three options are remarkably different in respect to their characteristics. All three options have high levels of reliability, but the T1 WAW has incredibly high bandwidth in respect to the other two options.

	PCS Cellular	Iridium Satellite Cellular	T1 WAW
Maximum Achievable Bandwidth	9.6 Kbps	9.6 Kbps	≈15000 Kbps

Table 5: A table documenting the maximum achievable bandwidth of the three options. Maximum bandwidth is not necessarily an effective measurement of average bandwidth. In this case, the T1 WAW's bandwidth is so much higher, the averages are similarly incomparable.

The maximum achievable bandwidth on the T1 WAW is about 1500 times greater than the other two options. The average bandwidths for the three are similarly incomparable. While the drop-off for the average T1 WAW bandwidth is much larger than the drop-off for the average cellular modem, the T1 WAW is still an order of magnitude faster than the other options.

5.0 Conclusion

This study has looked at the possibility of bringing mobile networking into a university environment. The three options which were explored were the PCS cellular telephone (using Sprint PCS as an example), Iridium satellite cellular telephones, and T1 wide area wireless (WAW) technology. The conclusions which were drawn were relatively inconclusive. On one hand, T1 WAW technology, for a one time cost, presents a very fast connection over a relatively large area. One thing that the study did not originally take into consideration was how user-friendly the system was. Both cellular technologies are very user friendly as both behave in the same way as a normal phone. The T1 WAW is very difficult to set up. The system must have its antennae pointed towards each other. The main problem inherent in this is that positioning the antennae over a distance of 50 mile is very difficult. The antennae must also be repositioned with respect to movement from either antenna. Taking this into consideration, the study found that, while technologies which solve the problem of mobile networking do exist, the technology used does not sufficiently solve the problem presented by the study. It should be noted, though, that the technology that could solve this problem would most likely be mainstream within the next ten years.

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