Appendix 2: Technical Fundamentals and Terminology

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Newcomers to the information age are frequently confused by the concepts and jargon of modern telecommunications. An advanced knowledge of these subjects is not necessary to use technology effectively any more than an advanced understanding of automobile mechanics is needed to operate a car. However, since many readers will be responsible for maintaining and troubleshooting their site, and may be interested in the principles on which it is based, the following information may be useful.

People who regard the concept of the ***information highway*** as intimidating or difficult to understand may be surprised to learn that it is simply a modern evolution of three familiar technologies that have been around for more than a century: the telegraph, the telephone, and the motion picture. In modern terms, these technologies are known as ***data***, ***voice***, and ***video***. In recent years, the principles on which they are based have steadily converged, redefining old concepts in productive new ways.

1. Data Principles. Many of the basic discoveries of the information age were made by Americans. In the 1840s, Samuel F. B. Morse demonstrated that electrical signals could be sent over copper wire. In a development that was almost as important as this invention, he also devised a system of alternating pulses called Morse Code to represent letters and numbers. Morse Code is the direct ancestor of ***digital*** or ***binary code***, which has only two values, on or off (represented visually by 1 or 0). It can now be transmitted by cable or wireless signalling at rates unheard of in the 19th century.

The telegraph dominated nationwide communication until the introduction of the telephone. Both systems continued into the 20th century. At first, trained operators translated messages into Morse Code and interpreted them by ear. Later, typewriters were integrated into the system, creating the teletype machines whose sound still conjures up the image of news broadcasting to millions of Americans. Binary code was developed to make these machines work. Still later, video display terminals replaced typewriters. When AT&T absorbed Western Union, an era in communications ended.

Contemporary computer networks may be visualized as updated versions of the old-time telegraph network, using the same principles to transfer digital information or ***data.*** Like its 19th-century predecessor, the modern data network encodes information at one end, then decodes it at the other. Strictly speaking, data is defined as any form of digital signalling, including the kinds used in voice and video services. However, the word is most often associated with computers and with the information they generate.

The two most familiar personal computer systems are the Macintosh, produced by Apple, and the PC (for Personal Computer), based on standards first developed by IBM. The physical mechanism, or ***hardware***, employs ***software*** packages to perform

applications such as word processing and spreadsheets. Hardware ***peripherals*** such as speakers or printers may be added. Programs that incorporate sound or visual imaging are called ***multi-media*** applications. Software is purchased on ***CD-ROMs*** (short for computer discs, read-only memory) or ***diskettes*** that are ***downloaded*** or programmed into the permanent memory, known as the ***hard drive.*** Diskettes are also used for copying and storing files. Some software programs, such as Windows by Microsoft, are integrative and allow the user to manage several applications at once.

2. Networking. Whether stationary (desktop) or portable (laptop), the computer is an instrument of awesome power. But even this power is expanded when computers are networked. A system operating within a single locale is known as a ***local area network (LAN)***. It requires ***protocols***, or technical procedures, and different kinds of hardware to make it function. The most common LAN protocol is Ethernet. ***Servers*** direct information and support shared packages such as electronic mail (e-mail). ***Bridges*** segment LANS to improve internal efficiency. ***Routers*** provide the interface (connection) to the outside world.

With the information age, computer networks have grown prodigiously in both size and complexity. A ***wide-area network (WAN)*** links separate LANs together through ***hubs*** at strategic points and can be regional to international in scope. The ***Internet*** is the best-known component of the ***national information infrastructure*** and ***world wide web (www)***. The NCIH provides connectivity to this ever-expanding global community.

The Internet began in the 1960s as a Defense Department initiative to link computers nationwide. For many years, it was known only to computer buffs trained in a complex programming language called Unix. In the early 1990s, new “user-friendly” software packages such as Netscape increased its accessibility and produced explosive growth. To many people, the Internet symbolizes the information highway. Individuals can access it through subscriber services that provide ***dial-up access*** using a ***modem*** (modulator-demodulator), which connects a computer to a telephone line. When a long-distance “call” is required for this service, “surfing the Net” can become an expensive pastime. Most agencies prefer to link up computers through their own LANs.

3. Voice Principles. In the 1870s, Alexander Graham Bell found that analogue voice signals also can be transmitted electrically. An ***analogue signal*** is “analogous” to its source and thus varies in intensity and duration. Telephone conversations, faxes, the grooves in phonograph records, videotapes, oscilloscope images, and the “Sound Track” representation in Walt Disney’s *Fantasia* are all examples of analogue signals.

Much digital and analogue signalling still takes place over copper wire, just as it did a century ago. The two principal kinds of copper cable are ***twisted pair*** (the ordinary telephone line, with one outgoing and one incoming wire) and ***coaxial,*** which has greater capacity and consists of copper strands interwoven around a central core. Electric signals traveling over copper must be boosted at intervals to prevent them from attenuating. Over long distances, they acquire extra noise and deteriorate in quality.

4. Cabling. Modern ***optical fiber*** is a significant improvement over copper. Fiber is made of thin glass strands smaller than a hair. It uses laser-quality light pulses rather than electric ones to transmit digital signals. Analogue signals cannot be carried over fiber. They must be digitized by coding and decoding devices called ***codecs***. A codec translates the outgoing analogue signal and reconverts the incoming digital one. The NCIH employs several codec systems utilizing proprietary hardware and software.

Fiber eliminates distance sensitivity and produces clean signal reproduction. At the network level, most telephone service is now fiber-based, though the final leg to the subscriber is usually still copper. When communications companies boast about "your true voice" or the ability to hear a pin drop, they are referring to fiber-optic quality.

Other advantages of fiber are greater volume and quicker transmission. In binary code, each individual value (1 or 0) is called a ***bit***. Eight bits constitute a ***byte***. The terms ***kilobit*** (kb, one thousand bits), ***megabit*** (mb, one million bits), and ***gigabit*** (gb, one billion bits) are frequently used. What is commonly referred to as the "speed" of a cable is properly known as ***bandwidth*** and is a function of its capacity as measured in kilobits, megabits, or gigabits per second. The transmission rate of fiber – the speed of light – is always the same. Smaller bandwidth channels are often embedded in larger cables, allowing them to support multiple signals simultaneously.

At the network level, the NCIH uses a standard called Optical Carrier Level 3, concatenated, or ***OC-3c***. This term can refer either to the cables themselves, which have 24 strands of optical fiber, or to their speed of 155mb (155,000,000 bits of information per second). Put in terms of a simple analogy, this bandwidth could transmit the equivalent of all the material in the *Encyclopædia Britannica* in 18 seconds.

The cable that furnishes video and data service to an individual NCIH site operates at a standard called Digital Signal Level 1 or ***DS-1*** (1.5mb). Continuing the analogy in the previous paragraph, DS-1 could transmit the *Britannica* in half an hour. Video and data signals are "merged" into the network at this speed. The term ***T-1*** is also used in references to this signal hierarchy. Originally, "DS" meant the protocol and "T" referred to the cable, but the terminology has become interchangeable.

Within an institution, there are probably a variety of smaller cables that transmit information at slower speeds. Many LANs still operate at 64kb, the standard of an ordinary telephone line. It would take 14 hours to transmit the *Brittanica* at this speed. For small data networks and local applications, this may be perfectly adequate. However, as the size of an institutional network grows and its applications become more sophisticated, such cabling may be too slow.

Bandwidth below DS-1 is usually described as ***narrowband*** or ***low bandwidth***. DS-1 or higher is ***broadband*** or ***high bandwidth***. Two terms used in this context, ***single-***

mode and ***multi-mode*****,** refer to the path or paths the signal travels along the cable. Single-mode fiber is more expensive but is preferable for broadband functions.

5. Video Principles. Motion pictures, associated with Thomas Edison, were invented at the beginning of the 20th century. Sound pictures originated in the 1920s when analogue sound tracks were added to film. Wireless video (television) technology also appeared in the 1920s, although it was not commercially viable for another three decades. Videotape, a modern descendant of film, first became available in the 1970s. All moving pictures are based on recording and projecting individual images at a speed fast enough to produce the effect of motion. These images are called frames. A projection speed of 30 frames per second is the industry standard.

Like other analogue signals, video can be transmitted directly over copper lines. This is the principle on which the typical cable television system is based. Cable TV provides signal reproduction superior to a wireless broadcast, but traditionally has been engineered to provide one-way signalling only. Cable companies now compete with other service providers to offer a full range of interactive capabilities to their customers.

Visual images can also be digitized. This technology first came to public attention during the early years of the space program, when black-and-white still pictures taken by weather satellites and space probes such as Ranger, Mariner, and Voyager were broadcast back to earth at the then-amazing speed of 85kb. Color, black-and-white, still and motion pictures can all be stored or transmitted in digital form. High-definition television, scheduled to replace standard systems within the decade, is digitally based. DVDs (digital video discs), which store images on CD-ROMs, also utilize this concept. Digital video can be transmitted either by cable or by wireless.

Because of the enormous amounts of information being transmitted, digital video requires ***compression*****,** in which redundant or nonessential information is eliminated, such as a background that does not change from frame to frame. Lower bandwidth requires greater compression. As compression increases, movement will eventually be affected and will appear jerky rather than smooth. Primitive computer teleconferencing can be done over ordinary telephone lines, though the rate may be as slow as a single frame per minute. Extreme compression is unsuitable for most practical applications.

The NCIH began as a service for full-motion interactive video conferencing that required 45mb of bandwidth. Since then, technical advances have enabled the speed of the application to be reduced to 384kb at considerable savings in cost. The multi-media communications protocol on which the network now operates is known as ***H.320***. This is an international technical platform on which many kinds of video conferencing equipment are built. H.320 supports speeds both higher and lower than 384kb over bandwidth that is ***dedicated***, or guaranteed.

6. Network Architecture. In an overworked but relevant analogy, the information highway is often compared to a conventional road system. Traffic volume varies by time and location. Vehicles travel at different speeds and must be able to find their destinations. Local traffic is slower than long-distance traffic. As vehicles approach the highway on-ramp, they must increase speed and merge without crashing. To keep traffic running smoothly, enough lanes must exist to handle anticipated volume, while interchanges must be available to let vehicles transfer from one route to another.

Like a regular roadway, the information highway must have mechanisms to organize data, the “traffic” of the network, and direct it successfully to its destination. Traffic must be “merged” or ***synchronized*** to prevent individual bits of information from colliding with one another. There must be a sufficient number of “traffic lanes” (bandwidth) to handle the “rush hour,” a sudden burst of data during a peak period.

The NCIH employs two principles called ***asynchronous transfer mode (ATM)*** and the ***synchronous optical network (SONET)***, chosen because of their suitability for interactive communication. The NCIH was the first state network to employ them.

The ATM protocol organizes data into 53-byte packets called ***cells***. These are the “vehicles” of the information highway, equipped with the “street addresses” that direct them properly. The first five bytes of each cell constitute the ***address***, which identifies the destination. The remaining 48 bytes are the ***payload*** or information field.

At an NCIH video site, cameras and audio equipment generate analogue signals that are digitized by the codec. The codec sends data to a router that functions as the “on-ramp” to the NCIH. The router creates ATM cells and feeds or ***multiplexes*** them into the network bitstream through the DS-1 pipeline. Regional network switches at central locations around the state, the “cloverleaves,” route the cells to their destinations. At the receiving end, a second router recaptures each cell by identifying its address, then sends it to another codec for translation back into an analogue signal.

Put another way, ATM is the *process* that makes it possible to handle enormous volumes of asynchronous (unsynchronized) video traffic simultaneously. SONET is the *result,* a broadband fiber network in which this information has been properly routed.

ATM/SONET principles allow your NCIH pipeline to carry up to three video and data signals at the same time. This concept is called ***dynamic bandwidth allocation***. When an NCIH video session is taking place, it employs 384kb or approximately one quarter of the capacity of the DS-1 cable. The remainder of the bandwidth can be used simultaneously and independently for a second video channel or for data transmission. When video session(s) are not taking place, the entire capacity of the cable is available for data. The Cisco router has three ports that function independently of one another and can be used for these purposes. Many NCIH sites use their network connection to provide a gateway to the outside world for their LANs with up to 1.5mb of data capacity.

The ***backbone*** or infrastructure of the information highway is a component of the public-switched network of North Carolina and is owned, installed, and maintained by the telephone companies. The NCIH is a partnership between the state and private enterprise. The state establishes technical standards, determines policy, and leases service. It does not own the network, as this would be a less cost-effective approach.

For decades, the public-switched network in this nation was an integrated whole. But with deregulation of the telecommunications industry, which promoted competition among service providers, local and long-distance services were separated. Local service is provided by a ***local exchange carrier (LEC)*** within a legally defined geographic region known as a ***local access transit area (LATA)***. LATAs do not correspond to political jurisdictions. For example, Robeson County is divided between BellSouth and Sprint service areas. Your telephone company (telco) can provide you with a statewide LATA map. There are more than 20 local telcos in North Carolina, some of which are owned by larger corporations or are members of cooperatives.

When LEC signals cross a LATA boundary, an ***interexchange carrier (IXC)*** is responsible for carrying them. The IXCs most recognizable to the public are AT&T, Sprint, and MCI. IXC cables are called ***trunk lines***, a term familiar to visitors to England, where long-distance telephone calls are known as “trunk calls.”

Like most WANs, the NCIH is based on a ***star configuration***, a central hub with radiating regional spokes. The hub is a switch in Raleigh and the regional spokes are switches in different LATAs around the state. BellSouth provisions the switches in Raleigh, Asheville, Charlotte, Winston-Salem, Greensboro, and Wilmington. Sprint switches are located in Hickory, Fayetteville, and Greenville. Two Verizon switches are situated in Durham. NCIH sites are connected to the nearest regional switch. Sites within the same LATA communicate through that switch. When connected across LATA lines, signals are relayed through Raleigh to other regional switches.

Regulation of intrastate telecommunications is the responsibility of the North Carolina Utilities Commission. The Federal Communications Commission (FCC) enters the picture when interstate usage is involved. Traditional parameters of protection and competition have changed substantially in the past decade. The Telecommunications Act of 1996 follows a trend of allowing more competition at the local and long-distance levels in all areas of telecommunications, thereby increasing options for the client.

7. The NCIH and Other Video Technologies. The NCIH has chosen H.320 technology for its network because of its versatility and the emergence of the protocol as an international standard. However, there are many other platforms and protocols available for teleconferencing. The NC Research and Education Network (NCREN) uses combined ***microwave*** and cable technology operating on the ***MPEG-2*** protocol. ***ISDN***, another standard often encountered, is prevalent in many areas, though not universally available in this state. Video conferencing over the Internet uses the ***H.323*** protocol, which covers transmission where bandwidth is not dedicated or guaranteed.

Microwave is an alternative term for the familiar wireless technology used in ordinary radio and television broadcasts, cellular telephones, and satellite uplinks and downlinks. Both digital and analogue signals can be transmitted. Since commercial wireless networks compete vigorously and often successfully in the market place with hard-wired systems, it is helpful to review their relative advantages and disadvantages. All wireless technology is based on line-of-sight transmission. In mountainous regions – a substantial portion of North Carolina – coverage is difficult and unreliable. Signals decay rapidly as distance from the transmitter increases. They are subject to interference from weather and other energy sources and will be interrupted if any solid object blocks the path between the transmitter and receiver even momentarily.

Some of the most important issues concerning wireless transmission involve privacy and unauthorized access. As the term implies, a "broadcast" transmits signals indiscriminately throughout the region in which it originates. With the right receiving or unscrambling equipment, anyone in this area can pick up these signals, as some users of cellular telephones have discovered to their dismay. In large metropolitan areas, millions of people may possess the potential to eavesdrop on confidential information. Often, a complex level of security must be added to the signal to guarantee its integrity.

The expense of wireless technology includes capital costs such as the construction of transmitting towers and dishes. Maintenance is correspondingly high-priced. The cost of access to a frequency or satellite uplink can make applications prohibitively expensive. Wireless technology is no longer used in the development of the state network, though such services are readily available from the private sector.

The ***MPEG-2*** protocol is a standard for the transmission of full-motion video. The acronym derives from the Motion Picture Experts Group, a committee of the International Standards Organization (ISO). NCREN video sites, which operate at a speed of approximately 11mb, use this standard. Although video quality is excellent, it is an expensive alternative to the NCIH because of the high bandwidth it requires. NCIH and NCREN sites can be bridged together at MCNC network control in Raleigh.

Integrated Services Digital Network (ISDN) technology bundles regular twisted pair telephone cables to create enough bandwidth for video transport. Each line has two 64kb channels for a total bandwidth of 128k. The addition of more lines increases the speed (2 lines = 384kb, 3 lines = 512kb, etc.) Like long-distance telephone service, the recurring costs are usage-sensitive: the amount that the client pays is determined by the number and duration of video "calls" that are made. In much of the United States, ISDN has become a *de facto* standard because of its widespread availability. However, its price can mount quickly. It is available in many regions of North Carolina from commercial vendors but is not offered as a state service.

Use of the ***H.323*** protocol for teleconferencing is steadily growing, but at present it offers insufficient ***quality of service*** (usually abbreviated QOS) to support a statewide network. Nationwide, the capacity of the Internet is not great enough to allow video conferencing on a substantial scale. The bandwidth that this application consumes may delay or even crash data transmission across LANs and WANs that have not been constructed for this purpose. The Internet is also vulnerable to hacking and cyber-sabotage, producing significant security concerns. As the Internet expands over time and its quality improves, the NCIH may eventually migrate to this standard.

All of these platforms have relative strengths and weaknesses. They will co-exist indefinitely. Interoperability among them requires the use of ***gateways,*** back-to-back codecs that bridge otherwise incompatible systems together. While it is not universally interoperable, the NCIH can interface with most common technologies, including the ones described here. Interconnectivity is a complex issue and the state is developing strategies to allow as many platforms as possible to communicate transparently.