CONCEPTUAL DESIGN ANALYSIS OF SWITCHED MULTIMEGABIT DATA SERVICE AS A TELECOMMUNICATIONS STRATEGY FOR USA TODAY NEWSPAPER

by

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(ABSTRACT)

The systems engineering process is applied to determine the feasibility of employing Switched Multimegabit Data Service (SMDS) to suport USA Today newspaper's current data communications needs. The terrestrial service must support current operations at a cost comparable to the current satellite based system while providing significantly greater bandwidth. Strategic modernization of USA Today's digital pagination operation requires the increased bandwidth.

The analysis indicates that SMDS simultaneously meets USA Today's needs for an economically feasible alternative for the near term while providing a more capable platform for the future.

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Chapter 1: Introduction

Analysis Objective

This project report presents the results of a systems engineering effort to evaluate Switched Multimegabit Data Service (SMDS) as an alternative for the transmission of USA Today newspaper's remote site digital pagination instructions. USA Today uses ten year old facsimile technology laser scanners to sample pictures of its newspaper pages, which are formatted at the Arlington, Virginia headquarters. These digital samples are then transmitted from the headquarters, via geosynchronous satellite, to 32 domestic remote printing locations, where the paper is produced and distributed.

The satellite link provides a data capacity of only 150 kilobits per second, which will not support the file transfer applications required for a strategic upgrade of USA Today's operation. Eventually, USA Today wants to upgrade both the headquarters and remote sites to exploit the speed and flexibility of current and future data applications. Before the end points of USA Today's network can take advantage of newer technologies, the network connecting the endpoints must be in place to support the high bandwidth demanded by the file transfer applications. This report includes a conceptual design for the SMDS approach to upgrading USA Today's data capacity. The project analysis generally follows the systems engineering approach presented in Blanchard (11).

Chapter 1 of this report presents an introduction to USA Today. Chapter 2 introduces the sytems engineering process and its relevance to this effort. Chapter 3 provides an analysis of the company's current need for an improved pagination instruction transmission method. Based on the needs analysis, a feasibility study, presented in Chapter 4, examines alternative solutions to USA Today's requirements. SMDS emerges as a promising method of meeting USA Today's needs. Operational requirements for an SMDS system are described in Chapter 5. Chapter 6 presents the conceptual SMDS design, including high level operational and maintenance functions. Chapter 7 includes an economic analysis of the proposed SMDS design. The economic analysis is accomplished by comparing the SMDS system to the current USA Today system, thereby determining the conceptual system's economic feasibility.

A Brief Introduction to USA Today

The upper left corner of every USA Today newspaper informs its reader that the paper comes via satellite. All of us are comfortable with the concept of television transmissions via satellite, but somehow a newspaper's use of a satellite seems like a foreign idea. However, at the most basic level the two media have much in common. Pixels creating an image on the television screen or pixels representing a page of newsprint are merely data on the satellite link. USA Today has taken advantage of the near real time capability of satellite technology to transmit its printing instructions from its Arlington, Virginia headquarters to 32 domestic and 2 foreign remote printing and distribution plants. Some of the specifics of the newspaper's technology were introduced as part of the final examination for the ISE 5984 Information Technology class offered at Virginia Tech in April 1992. The examination required recommendations for an improved telecommunications strategy for USA Today considering the state of Local Area Network (LAN) and Wide Area Network (WAN) technology. Research indicated that USA Today's ten year old satellite solution leaves room for improvement based on today's technologies and services. This project is a follow up on what appeared to be a very promising solution, proposed in answering that examination question.

USA Today as a Unique Media Player

USA Today newspaper enjoys world-wide readership with a circulation of over 2 million copies. The paper is printed and delivered daily to all US and many European and Asian locations. Readers receive same day service of a newspaper with identical format regardless of their location. Unlike other widely distributed media products, USA Today does not abridge its paper or print a special international edition. Readers in the Swiss Alps receive the same news in the same format on the same day as readers in USA Today's Arlington, Virginia headquarters (USATHQ) location.

To achieve same day printing and distribution objectives, USA Today has strategically located 32 domestic and 2 oversesas printing and distribution plants. Table 1.1 lists these locations. The plants receive digital printing instructions via satellite broadcast network from USATHQ.

Table 1.1. USA Today Headquarters and Remote Site Locations Worldwide

USA TODAY NETWORK OPERATIONS SERVICE NETWORK			
1.	Arlington, Virginia (HQ)	2.	Springfield,VA (Backup HQ)
3.	Atlanta, Georgia	4.	Batvia, New York
5.	Boston, Masssachussetts	6.	Brevard, Florida
7.	Bridgewater, New Jersey	8.	Chicago, Illinois
9.	Columbia, South Carolina	10.	Dallas, Texas
11.	Fort Collins, Colorado	12.	Fort Myers, Florida
13	Gainseville, Georgia	14.	Greensboro,North Carolina
15.	Harrison, New York	16.	Hattiesburg, Mississippi
17.	Kankakee, Illinois	18.	Lansdale, Pennsylvania
19.	Lawrence, Kansas	20.	Mansfield, Ohio
21.	Marin County, California	22.	Miami, Florida
23.	Nashville, Tennessee	24.	Olympia, Washington
25.	Pasadena, Texas	26.	Phoenix, Arizona
27.	Port Huron, Michigan	28.	Richmond, Indiana
29.	Rockland, New York	30.	Salt Lake City, Utah
31.	San Bernadino, California	32.	St. Cloud, Minnesota
33.	St. Louis, Missouri	34.	Tarentum, Pennsylvania
35.	Hong Kong, China	36.	Zurich, Switzerland

Source: Fello (22)

The digital equipment required to perform the data compression, formatting and transmission of the instructions is timing sensitive and dependent upon very reliable communications links. When the system was designed and implemented over ten years ago, the satellite configuration provided the only economically feasible solution to the timing and reliability requirements.

The specific purpose of this analysis is to determine whether a terrestrial network service can provide a competitive telecommunications strategy for USA Today's domestic remote sites compared to their current satellite based system. USA Today treats its domestic operations as a separate business component from its overseas operations. In order to perform an accurate analysis, only the domestic business is considered in this project. In order to be considered, the terrestrial system must compare favorably in the areas of cost, transmission capability, geographic access, and maintainability.

Chapter 2: The Systems Engineering Process

Introduction

The goal of this project is to determine whether a different telecommunications strategy will benefit USA Today more than their current system. The systems engineering process will be exercised to provide a top down approach to making the final determination. USA Today's data communications system is not a trivial engineering problem. Complex and finely calibrated electronic equipment, power sources, multiple system interfaces, and personnel interaction all contribute to the system's success. Any attempt to modify the system must address all facets and be carefully planned and executed. The systems engineering process provides a tool for thoughtful planning. This process considers the data communications system itself, as well as the support, maintenance, operations and retirement costs over the life of the system to arrive at the most economically competitive solution. The life-cycle approach prevents buying into a system that appears competitive in one or more of the life-cycle cost phases but performs so poorly in others that the apparent benefits do not outweigh the overall costs.

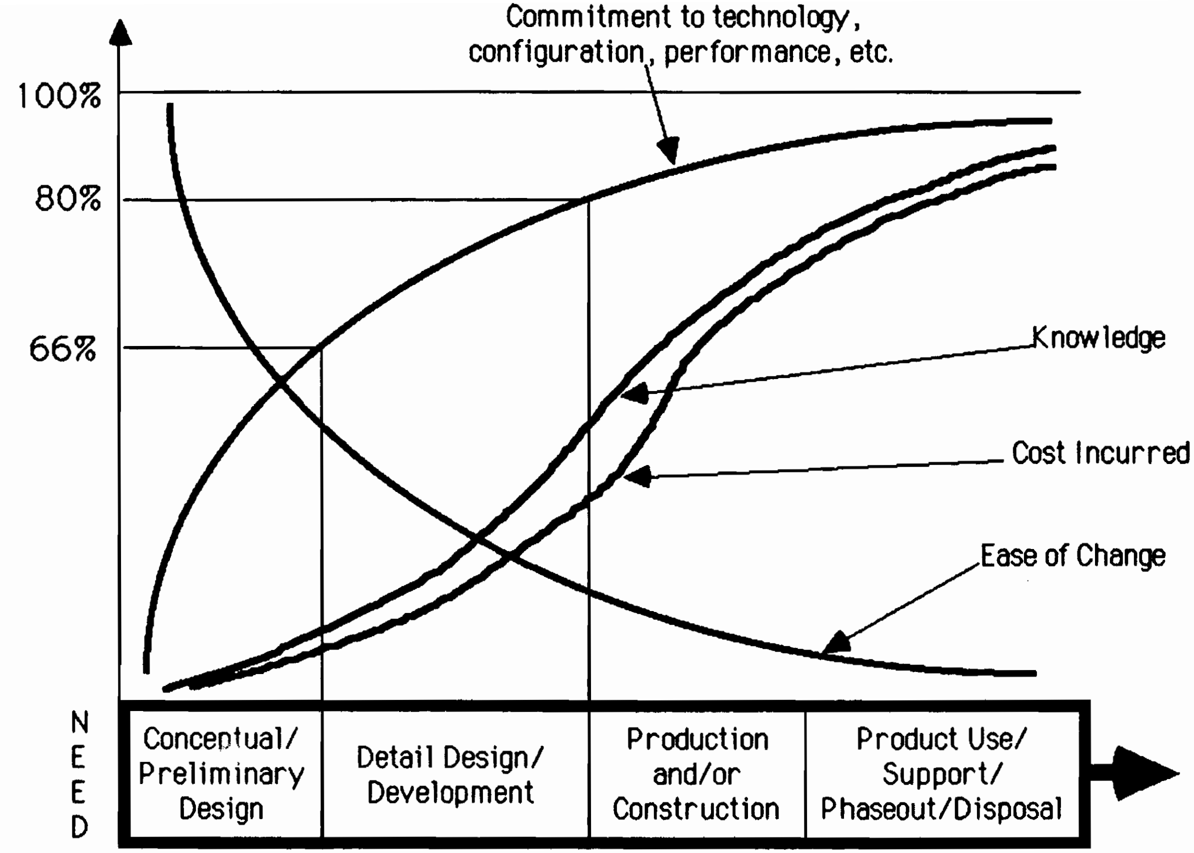
The systems engineering process transforms legitimate operational needs into a final system "through an iterative process of functional analysis, synthesis, optimization, definition, design, test, and evaluation." [Blanchard (11), pg. 21]. Systems engineering coordinates efforts of many specialized engineering disciplines to deliver competitive and economically sound solutions to the customer, in this case USA Today.

Project Methodology

In this project, the systems engineering process provides the context for system evaluation and conceptual design. The systems engineering process begins with the identification of USA Today's need and evolves through development to a fully defined, operational configuration. The conceptual design phase, the first design phase of the systems engineering process, is where ideas or models are developed to design a system which is functional and economically competitive over the life of the system. The conceptual design takes the definition of USA Today's needs and applies feasibility studies to determine acceptable technologies to address those needs.

System operational requirements are developed during this phase, as are the systems maintenance concept and preliminary system analysis. During the conceptual design, advanced system planning also takes place, where appropriate, to specifically identify the system components absolutely required for success. Although this advanced planning seems out of step with the top down approach advocated by the systems engineering process, certain critical configuration items may be identified even at this early stage.

Figure 2.1 illustrates the importance of the systems engineering process. As Figure 2.1 indicates, the ease of change decreases, while commitment increases, as the phases of the system life-cycle progress. Early in the life-cycle the ease of change is high, commitment is low, and cost incurred is minimal. This is where proper design effort is required. Applying the iterative systems engineering process helps produce more effective, cost competitive systems. Without the systems engineering process, the result is more likely a system that is less effective and continues to increase in cost as corrective actions are taken to fix the system during production or use.



Source: Fabrycky (21)

Figure 2.1. Commitment, Knowledge, and Ease of Change During a Project's Life-cycle

Chapter 3: Needs Analysis

Needs Analysis

USA Today gathers, prints, and distributes hardcopy format news. The more current that news, the more valuable it is to USA Today's customers. In order to present the most current news available, the paper's print deadline must be as late as possible. USA Today's current telecommunications strategy dictates that transmission of its formatted print instructions begin at 1530, Eastern Time, the day before the paper gets to the newsstand. The last transmission completes at 0430 the day of printing.

One of USA Today's goals is to decrease the time it takes to transmit its print instructions. Less time spent transmitting increases the time available to gather more current news, which adds value to USA Today's product. At the same time, USA Today's current technology has exceeded ten years of service. Within a few years, the equipment used to perform its operations will require replacement. The company hopes to change its process from manually formatted pages and facsimile data transmission to complete data file and image transfers.

The desired shorter transmission window and the move to file transfer technology indicate that USA Today needs faster data transmission rates, or bandwidth, to accomodate its telecommunications requirements. Bandwidth represents the amount of data a transmission facility can accomodate per unit time. If USA Today can transmit more data in the same amount of time, it can apply any time saved toward gathering more current news. Additionally, file transfer applications transmit entire data files, which are already stored in computer memory. In an existing file, the data is all present and ready to move, unlike a facsimile arrangement where the data is transmitted as it is sampled. Therefore, maximum bandwith, or capacity, of the transmission facility is used until the file transfer is complete.

USA Today cannot afford to make the desired changes immediately. The transition should occur over time as necessary equipment is replaced and improved. It is known that the file transfer technology will require data rates exceeding the current satellite capacity. Since all future upgrades depend on the data links being able to provide greater bandwidth, a logical first step in the transition includes designing the telecommunications system. The improved system equipment will operate at less than full capacity while the newer technology, which requires the increased capacity, is brought on line. USA Today needs a system that will provide a logical transition to their future operating strategy. The system selection has both short term and long term implications. The short term need is for a system that allows USA Today to continue with its current formatting process, with no greater cost than the current system. The long term need is for a system that provides greater bandwidth to accomodate file transfer and image transfer technology, and decreases data transmission time. By decreasing the data transmission time, USA Today can move its news deadlines closer to the time the paper gets to the consumer and increase its product's value.

Supplemental Information Impacting Need

The basic problem requiring resolution is how USA Today can increase its effective data rate while leaving both ends of the existing data transmission system intact. The remote and headquarters locations will not relocate. Rather, the method by which data is issued from USATHQ and arrives at the remote reconstructors may be fundamentally different. Instead of a satellite link and the necessary ground equipment to access that link, the system may revolve around a terrestrial network and the necessary equipment to access the service.

The satellite network is a ten year old strategy and is operating at 100 percent of its leased bandwidth capacity. Currently available data services that operate over telephone lines, including Frame Relay and SMDS, provide bandwidths at an effective capacity eight times that possible using the satellite. Although the available bandwidth on these terrestrial systems seems underutilized for the printing instructions relay application using USA Today's current data preparation process, it will be compared to the satellite network for that express purpose. The reasoning here is that the proposed system must not upset the way the company performs its basic procedures. The nodes of the network must be able to continue formatting and preparing the paper as in the past. The fact that the instructions may no longer pass through a geosynchronous satellite should be transparent to everyone involved except the operator responsible for the network interfaces. If this can be accomplished without raising the operating cost of USA Today's business, then the company can begin to experiment with other strategic enhancements that exploit the capabilities of the new service's technology and increase their competitive advantage. It is emphasized that this engineering effort is aimed at providing USA Today with a strategy that allows for future growth in the area of applications requiring more bandwidth; but the insertion of higher capactity should not conflict with current applications.

USA Today Economic History

Despite its innovative approach and obvious product differentiation, USA Today has not had a profitable year in its ten year history. The company has enjoyed several profitable quarters over the years, but never a profitable year. Although the cost savings made possible by a new telecommunications strategy cannot hope to make the difference between profitability and deficit, any cost savings possible are beneficial. According to Fello (22), the main cause of USA Today's poor profitability record is a lack of sustained advertising. However, any cost savings will decrease the losses the company incurs in its operation, strengthening USA Today's financial position.

USA Today's Need for Bandwidth: Basic Calculations

Each page of 14 inch by 22 inch newsprint is digitally sampled 1200 times per inch horizontally and 1400 times per inch vertically using facsimile technology. Each horizontal scan contains

$$1200 \text{ samples/inch} * 14 \text{ inches} = 16{,}800 \text{ samples.} \qquad (3.1)$$

Each vertical scan contains

$$1400 \text{ samples/inch} * 22 \text{ inches} = 30{,}800 \text{ samples.} \qquad (3.2)$$

Each page then contains

$$16{,}800 * 30{,}800 = 517.44 \text{ million samples.} \qquad (3.3)$$

If each page is transmitted in full at the current satellite based system rate of 150 kilobits per second, it would take

$$517.44\text{Mbits}/150\text{Kbps} = 3449.6\text{seconds,} \qquad (3.4)$$

or nearly an hour per page to transmit. A run length encoding compression algorithm reduces the per page transmission time to about four minutes. The compression ratio is from between 10:1 and 150:1, with an average of about 14.5:1. This means the actual number of samples transmitted is about 35.7Mbits per page. Color pages require four separate transmissions, one for each color (cyan, magenta, yellow, black). Other system limitations impact USA Today's processing speed. For example, the sampling rate and reconstruction rate limit the system. These limitations are covered in more detail in the explanation of the current configuration. The fact remains, the sheer amount of data requiring transmission indicates a need for bandwidth as well as the equipment necessary to keep up with high data rates.

The volume of data that USA Today transmits makes the operation an ideal candidate for "burst" transmissions. Using this method, data is buffered in a holding area until transmitted at very high data rates, or "bursts," to take maximum advantage of available bandwidth while minimizing transmission time. In a scenario where transmission costs are based on system use, such as the telephone system, short, bursty transmissions at high data rates can save money. Currently, USA Today leases a dedicated satellite link 100 percent of the time, pays for the service whether it is used or not, and uses the link to transmit data only a fraction of the time.

Current System Transmission Time Constraints

The current system operates from 1100 through 0430 each day. System startup occurs from 1100 through 1130. A system net test and laser scanner sample tone calibration runs from 1200 through 1300. Maintenance required to bring the half-tone dot sampling and transmitting equipment to within a three percent color and intensity tolerance is scheduled between 1300 and 1530. Transmission of printing instructions begins at 1530 and continues through 0430. The time from 0430 through 1100 is reserved for maintenance. Each page transmission requires between three and six minutes. The system averages 15 pages per hour, with a theoretical maximum of 22 pages per hour. Color pages require four times as long in order to register the correct combination of cyan, magenta, gold and black required to print all colors.

Relative Inefficiency of Current System

USA Today's current data rate, of 150 kilobits per second, is slow compared to available rates of over 1.5 megabits per second. With an effective data rate eight times faster than its current system, USA Today could transmit print instructions faster and conceivably go to press later, with more current news. The current satellite system has evolved over the past ten years. Different parts of the process have been modified, scrapped, and reworked to take maximum advantage of the bandwidth available on the satellite links. The system is optimized for the technology it relies on and little room is available for future improvement. The satellite system operates at 100 percent capacity. The only way to increase bandwidth is to lease more transponders on the satellite and configure the ground equipment to perform more complex tasks to take advantage of the newly available capacity. Both the transponder lease and ground re-configuration would increase the operating cost of USA Today with incremental capacity, rather than the orders of magnitude increase in capacity using other available services.

Maintaining Competitive Advantage

USA Today relies upon accurate, reliable data transfer to make its product available in a timely manner. Increased speed and lower cost, with the potential to support future applications not yet realized, would enhance the company's strategic market position and increase its competitive advantage. Considering today's economic circumstances, it is imperative that USA Today take advantage of solutions that strengthen its position. The current system has worked well for ten years, but appears to be optimized with little hope of further improvement. Before the current system requires replacement, as it inevitably will, USA has time to research newly available technologies and services that will position the company for success in the next ten years.

Trends in Computing and Data Communications

The current and forseeable trend in computing and data communications is toward client-server computing. This architecture basically involves a file server managing the use of data by its clients. USA Today's naturally existing organization exemplifies the ideal setting for a client server network. The headquarters provides the logical location for the powerful server unit while the remote sites logically represent the clients accessing that server. Until recently, it would have been prohibitively expensive to connect the clients to the server in a terrestrial wide area network. Expensive leased lines, or dial-up telephone networks with poor data rates, previously offered the only terrestrial solutions. With currently available data rates, inexpensive computer memory, and data services coming on line, this concept is now feasible for USA Today and deserves another look.

Current Satellite Configuration Explained

In order to effect an orderly change in a system as complex and critical as the data communication system at USA Today, the current configuration must be understood. System changes must occur within boundaries established by the engineer. The existing configuration impacts the definition of need, since system changes will need to interface with some portion of the present configuration.

Figure 3.1 shows USA Today's current configuration.

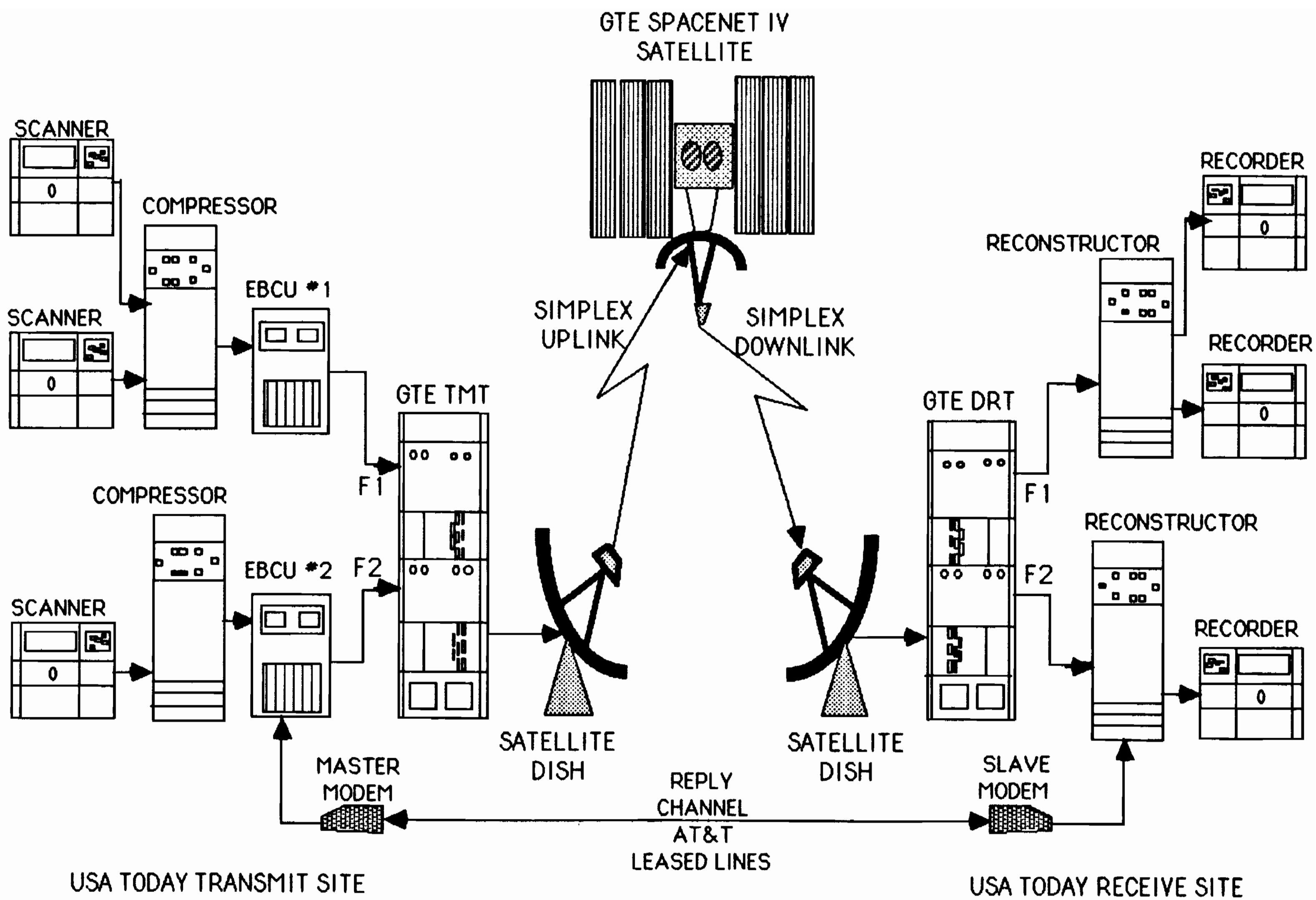


Figure 3.1. Current USA Today Configuration

USA Today manually formats its pages on pasteboards. The pasteboards are then photographed. The film positives of the photographed pages becomes the starting point for the data transmission system. The system's laser scanners sample the film positives, which are strapped to a drum rotating at 3600 RPM, and convert them into V.35 standard digital data. This digital data represents pixels, or samples, of the photographed page's content, whether it be blank space, color pictures, or other print. From the scanners the data is passed through a data compressor which samples the data and compresses it at a ratio of between 10:1 to 150:1. The compression algorithm determines how far the data can be compressed without sacrificing minimum data representation quality and recoverability after transmission.

The compressed data passes through the Expanded Broadcast Control Unit (EBCU). The EBCU is an Intel 80286 microprocessor based control unit which regulates the data flow and timing of the system. From the EBCU the data enters the Transmit Monitor Terminal (TMT). Here it is modulated onto one of two carrier frequencies, F1 or F2, for transmission via the GTE Spacenet IV satellite at 153.6 kilobits per second (Kbps). The first 150Kbps is the actual data rate, while 3.6Kbps are used for diagnostics and overhead. Although two channels are used, the process is still effectively limited to one channel in use at a time since the drums holding the film require reloading after completing the scanning process. Both could transmit at the same time, but then both would be off line simultaneously while the drums were being changed. The effective transmission rate is that of one drum constantly on line.

At the receiving end, the data enters the Digital Receive Terminal (DRT), where the original compressed data stream is demodulated. The data then passes to one of two reconstructors which recapture the original format and content of the uncompressed bit stream by reversing the compression algorithm. The reconstructors then feed three recorders which reproduce the page photograph for use by the printers at each remote site.

Data receipt acknowledgement comes via 4.8 Kbps landline. The EBCU has eight master modems that poll four slave modems each. The slave modems are connected to the landline in a multi-drop configuration, which allows four geographically clustered remote sites to access the same line. Eight master modems polling four slave modems each accounts for the 32 remote sites in the current USA Today configuration.

System timing is critical to the acknowledgment process. The 32 remote sites send acknowledgments (ACK's) when they receive good transmissions. The ACK data coming into the EBCU is timed so that if a site does not respond at its designated time division, the EBCU assumes that the data requires retransmission. Timing corruption causes data flow interruption from the compressor while the retransmission occurs, which prohibits progress toward transmitting the remainder of the data required to print the paper.

Past record of current system

USA Today has been transmitting its printing instructions via satellite since September 1982. In those ten years the system has experienced only one hard failure that kept any of the 32 remote locations from printing. The system includes total redundancy of critical components (dual feed Low Noise Amplifiers (LNA's), hot spares, switchable digital receive terminals, redundant data compressors, reconstructors, and recorders, multiple scanners and recorders). In the event of a total system failure at any of the remote sites, a contingency plan calls for designated print locations to output more copies and a contingency delivery plan to distribute the papers to the failed site's area. USA Today admits that the contingency plan is logistically infeasible and economically unacceptable. This makes the requirement for accurate and reliable data transfer all the more important.

System Boundaries

USA Today's current system will remain in place except for the transmission network required to move the data from the headquarters locations and receive acknowledgments. Table 3.1 lists the equipment USA Today currently uses and shows which pieces of equipment are subject to change if a different data transmission system is put in place. The transmission system boundaries are established at the compressors at the transmitting site, and at the reconstructors at the receiving sites.

Table 3.1. USA Today Existing Equipment Compared to that Required for an Alternative System

Existing Equipment used in Satellite Configuration	Required for New Configuration?
USATHQ:	
Scanners	YES
Compressors	YES
Expanded broadcast control units	NO
Transmit monitor terminals	NO
Satellite dish	NO
Remote Sites:	
Satellite dish	NO
Reconstructors	YES
Recorders	YES
Slave Modems	NO
Digital Receive Terminal	NO

Chapter 4: Feasibility Analysis

Alternative Solutions

The systems engineering process uses feasibility analysis to evaluate various technical solutions to the identified need. There are many ways to address a given problem. The feasibility analysis identifies the most promising technologies that can successfully solve identified problems. The goal of the feasibility analysis is "to propose feasible technology applications and to integrate these into the system requirements definition process." [Blanchard (11), pg. 36]. Several terrestrial based technologies, as well as the further use of satellite technology, are evaluated according to the attributes described below.

Desirable Attributes

The following attributes are considered in the feasibility analysis for the USA Today communications network:

1. Transmission Speed
2. Call Setup Time
3. Switching Capability
4. Connectionless Design
5. Cost Effectiveness for Bursty Traffic
6. Protocol Insensitivity
7. Alternate Routing Capability
8. ATM/SONET Compatibility

Each of the attributes is described in more detail below.

Transmission Speed and Call Setup Time

Any solution will necessarily have to meet the minimum requirements for transmission speed and call setup time. These parameters determine if the technology can physically send a transmission and receive an acknowledgment before the network software assumes the transmission was not received. Transmission speed is the rate at which data physically traverses the network medium, whether it be fiber optic cable, or standard twisted pair telephone wire. Call setup time is the time required to make the logical and physical connection between the transmission site and the desired receiving site. Many applications are delay, or data latency, insensitive. In other words, if the delay transmission and acknowledgment is too long, the application's timing is corrupted and the data exchange session fails. A simple example of data latency would be where a person places a telephone call to a long distance number. Due to overloaded circuits the call takes an inordinate amount of time to go through. The system logic is still trying to make the connection, but the frustrated caller assumes that the call did not go through and hangs up. The same type of "misunderstanding" occurs in data transfer between computer applications.

Switching Capability

Other desireable features include switching capability, which indicates whether any point in the network can communicate with any other point in the network. For example, leased lines are point to point links and are not able to communicate with any other points beside the direct connect point at the end of the leased line. Conversely, the public switched telephone system is a switched network based on the idea of dialing a number and connecting to another telephone anywhere in the world.

Connectionless Service

For economic reasons the solution chosen should be connectionless. Data transmissions do not require full time connections like callers on a telephone network. Once data is transmitted the network nodes should be able to rout the data to its destination by inspecting the destination address in the data header. Therefore, once the data is transmitted, the sending station should be able to break the logical connection to the network. Once the data is received at the desired station, that station sends a short acknowledgment transmission back to the sending station. Data handled this way is known as datagram traffic. Datagrams are analogous to telegrams or voicemail messages whereby the message originator quickly transmits the desired information and then waits for a reply, or acknowledgment. The cost of a telephone call to leave a message is generally less than the cost of a call where the other party picks up and a conversation ensues. This principal applies to data traffic as well. Costs rise if the connection is maintained for the duration of the two way transmission and acknowledgment process.

Bursty Traffic

The discussion of connectionless service above leads into another cost area: that of cost effectiveness for bursty traffic. Bursty traffic is characterized by short, sporadic transmissions. Computer to computer transmissions are generally bursty in nature. For reasoning similar to that used for connectionless service, the customer should consider whether a service that is billed on usage or set fees will be used. Leased lines between two pre-determined points are based on set fees, so the customer pays whether the line is used or not. The telephone system provides an excellent example for low speed bursty traffic uses. The caller dials the destination required, passes the message (or other data - facsimile is an example), and then terminates the circuit. The cost of the call depends on the duration. The customer does not pay for the service when it is not used.

Protocol Insensitivity

Another desirable characteristic for a communications network is that of protocol insensitivity. This feature indicates the network's ability to handle a variety of communications protocols, which are sets of rules governing the formatting of data for transmission. A protocol insensitve network generally uses intelligent end points, meaning that logic at all of the network's nodes is capable of making sense of the data it receives. An example of protocol insensitivity is the use of facsimile technology over the public telephone lines. The telephone network treats all the data traversing it the same way, regardless of whether it is voice traffic or data from a fax machine. The end points in this example are intelligent to the extent that the facsimile machines at the transmitting and receiving stations provide the logic to communicate with each other.

In the cases where the system logic resides at the relay nodes throughout the network, the network requires the use of a protocol that matches the logic residing at the nodes. All data traversing this type of network must already be formatted according to the network protocol before transmission. This limits customers to the choices of equipment and software configurations available to perform a given mission.

Alternate Routing

Ideally, when a portion of a data communications network fails, the system will provide a means for passing the data around the failed portion of the system. Usually, the customer does not care which path the data traverses, as long as it arrives at the desired receiving station within a specified period of time.

ATM/SONET Compatibility

The future of networking technology is headed toward Asynchronous Transfer Mode (ATM) and Synchronous Optical Network (SONET), which are competing methods of high speed data transmission. Some technologies are incompatible with either ATM or SONET, or both, due to the data rate alone. SONET rates will be up to 155 megabits per second. ATM will also require that systems interfacing with it assemble their data into packets. ATM will be compatible with Broadband Integrated Services Digital Network (B-ISDN), a technology and service slated for widespread availability later this decade, which will provide a way of allocating bandwidth for both voice and digital data applications over the same link. ISDN seeks to provide multiple digital services over the telephone lines already installed in nearly every home. A system designed for success in the future should comply with obvious trends indicating the direction of future technology and services.

Alternative Solutions

The following alternative solutions are evaluated for feasibility in the USA Today communications network:

1. Increased Capacity on the Satellite Link
2. Direct Dial Disconnect (DDD)
3. Leased Lines
4. T1 Multiplexer Network
5. X.25 Network
6. Frame Relay
7. Switched Multimegabit Data Service

Each of the alternatives is discussed in more detail below.

Increased Capacity on Satellite Link

The satellite solution has worked for USA Today for over ten years. By leasing more transponders and acquiring federal licensing to operate on the corresponding uplink and downlink frequencies, USA Today could achieve higher data rates and more bandwidth. Unfortunately, more capacity on the satellite system is sure to cost more than the current capacity on the same system. If none of the other alternatives seems feasible, increased data capacity at increased cost via the satellite is an option.

Direct Dial Disconnect (DDD)

Direct dial disconnect networks involve dialing the desired destination and connecting via the public switched telephone network using modems. This technology has many limitations. Alternate routing capability, if available at all, requires disconnecting from the current circuit and redialing. Service is interrupted in the interrim. A single call only accesses a single destination, and other callers are prohibited from accessing either the transmitting or receiving stations for the duration of the connected call. Call setup time is anywhere from a few seconds to more than ten seconds, which is fine for normal voice transmissions, but is far too long for computer data communications that may only be a few milliseconds in duration. Furthermore, the current data rates achieved over the public switched telephone network are extremely slow, achieving data rates only up to 19.2Kbps. For the purposes of USA Today's needs DDD is totally unacceptable. Figure 4.1c illustrates the DDD concept.

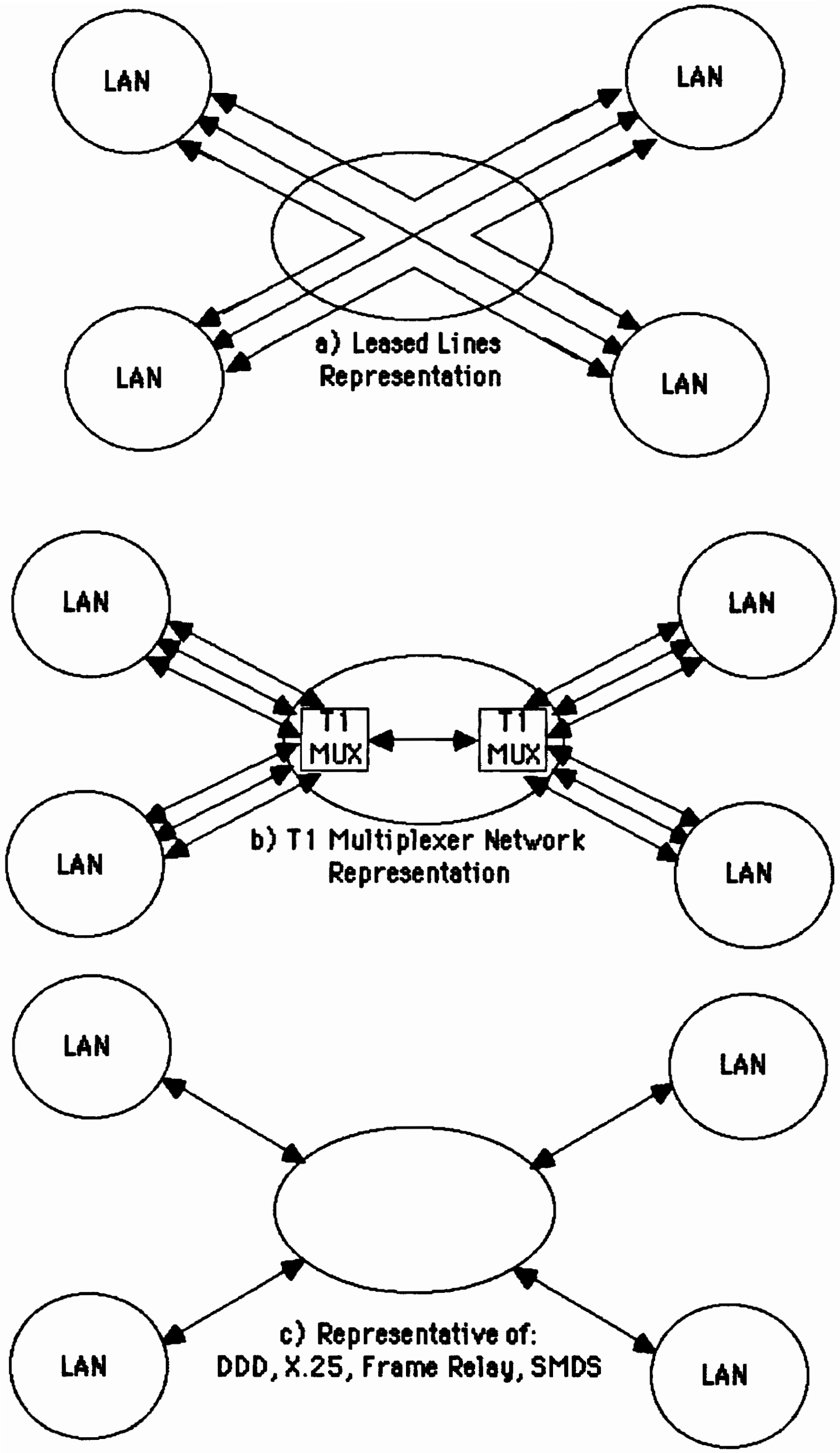


Figure 4.1. Network Characteristics

Leased Lines

Leased lines are a common method for achieving point to point connectivity. However, they offer no alternate routing and the user must install one line for each station requiring connectivity to another point. In the case of USA Today, the headquarters would require 35 lines for single connectivity to its remote sites. In fact, USA Today already employs leased lines in a multi-drop configuration to receive acknowledgments from the remote sites after each satellite transmission. With only eight lines, each passing through four sites party-line style, the monthly cost is $45,000 for 4.8 kilobits of bandwidth. Furthermore, the user pays for the leased line 100 percent of the time, whether or not the line is actually used. As discussed earlier, leased lines are cost inefficient for bursty traffic and network non-use times, both of which describe USA Today's needs. The number of remote sites requiring connectivity and the lack of economies of scale and cost effectiveness inherent in leased lines makes this a costly and undesirable option. Figure 4.1a illustrates a leased line configuration. Note that for point to point connectivity, each site must have a dedicated line to each of the other sites. USA

Today's headquarters would require 32 separate lines.

T1 Multiplexer Network

The T1 multiplexer network essentially models the leased line network concept, except there is no point to point connectivity. T1 multiplexers are strategically arranged, as shown in Figure 4.1b, to reduce the distance the leased lines would need to connect the same endpoints. The data rates achieved using the T1 multiplexer are up to 1.544Mbps. However, the same number of access lines are required at the user location. The T1 multiplexer merely selects the active line and provides connectivity to the desired endpoint once a transmission begins. USA Today's transmissions go to all 32 remote sites, so multiplexing offers no advantages for the purposes of this analysis.

X.25 Network

The International Telegraph and Telephone Consultative Committee (CCITT) is a United Nations Treaty organization working to standardize "techniques and operations in telecommunications to achieve end-to-end compatibility of international telecommunications connections, regardless of the countries of origin and destination." [Stallings (47), pg. 24]. The CCITT developed the X.25 standard for network interoperability. X.25 networks became popular because they addressed the needs of the time when they were developed for error detection and correction over transmission facilities that were unreliable. The standard was developed in Geneva in 1976 and amended in 1980, which makes it 12 years old at best according to Folts (23). The standard works, but it is dated. Personal computers did not exist when X.25 was developed.

During the routing of an X.25 packet, every node that handles the packet stores the data in the packet, examines the packet information for errors, repackages the data, and either forwards good packets to the nest node, or requests a re-transmission of packets that are determined to be in error. The intelligence in an X.25 network lies in the switching nodes, rather than at the endpoints of the network. The X.25 solution is effective but relatively slow, at up to 64Kbps, and inefficient compared to newer technologies based on extremely reliable transmission facilities and networks employing intelligent endpoints. The intelligent endpoints and reliable facilities remove the need for error detection and correction, packet buffering, and smart switching nodes. The reduced burden on the switching nodes creates less overhead and remarkably faster data rates than those possible with X.25 networks. For these reasons X.25 technology is less desirable than either Frame Relay or SMDS, which are discussed below, for future applications seeking to maximize speed and simplicity, and reduce overhead. Figure 4.1c illustrates the X.25 concept.

Frame Relay

Frame relay is a switched technology, meaning that connectivity between any desired points can be established without additional access lines. Frame relay also relies on intelligent endpoints, allowing for reduced overhead and faster data rates over the network than those available using X.25. Frame relay relies on extremely reliable transmission facilities. Bit error rates are no more than 1 in 10 billion bits. Transmission speeds are up to T1, which is a communications industry designation for a transmission facility capable of carrying 1.544 megabits per second. One of the drawbacks to frame relay service is the connection orientation of the service. In other words, frame relay sets up a permanent virtual circuit, or permanent connection, from the transmitting station to the receiving station for each transmission. Even at the fast data rates frame relay achieves, the call setup and teardown process detracts from the potential speed and simplicity that could be achieved if frame relay was a connectionless service. Connectionless services require no circuit set up between sending and receiving locations. Each packet, or datagram, is individually addressed to the receiving location. Furthermore, frame relay protocols do not appear positioned for a future based on Synchronous Optical Network (SONET), which is an international standard, fiber optic transmission concept promising data rates up to 155 megabits per second.

To its credit, Frame Relay is an immediately available option for USA Today's needs. However, USA Today's data communications upgrade does not need to occur immediately. The company has the time to explore other services that may better meet their requirements and position the company for the long run. Most of the equipment and modifications required to implement Frame Relay are also required for Switched Multimegabit Data Service (SMDS), which is discussed below. Figure 4.1c illustrates the Frame Relay concept.

Switched Multimegabit Data Service (SMDS)

SMDS is a connectionless fast packet data mover. A connectionless service allows for sending and receiving datagrams, or packets, with no form of acknowledgment to indicate successful delivery. At first glance, this seems contrary to what the user would like. However, since no connection or acknowledgment exists, the service data rate is extremely high.

SMDS is a public access service based on the existing 802.6 Metropolitan Area Network (MAN) standard. It delivers a minimum effective data rate of 1.17 megabits per second. SMDS uses special high speed switching technology and extremely reliable wire and fiber optic transmission facilities, which ensure lost packet ratios of less than one in 10,000 packets. [Bellcore (8)]. SMDS specifies extremely tight restrictions on data latency, which is the time it takes data to reach a receiving station after it is transmitted. This feature makes SMDS ideal for latency intolerant user applications, such as those previously available only to small local networks and individual machines. The public access nature and 802.6 standard base make SMDS attractive. A recognized standard increases the likelihood of widespread support and logical evolution and upgrade. Public access seems to indicate a method for spreading costs over more users to reduce individual user expense.

SMDS is billed on usage, rather than on the customary leased line concept, where the customer pays for the full bandwidth of a dedicated transmission facility whether or not the link is actually used. Furthermore, SMDS is a public network with bandwidth on demand up to the capacity of the customer's access facility, which is typically either a T1 (1.544 megabits per second) or T3 (45 megabits per second) trunk installed by the nearest serving central office of the local telephone company. SMDS's call setup time is even faster than that of Frame Relay since it is a connectionless service. The intelligent endpoints required for SMDS make it protocol insensitve. Since the service operates via the public telephone network and is a packet service, alternate routing is available based on speed and availability of access lines. Furthermore, SMDS has been specifically designed to be upwardly compatible to both ATM and SONET networks to come in the future. SMDS excels in all attribute areas considered for this analysis.

Comparison of Alternatives

Table 4.1 displays how each of the alternatives performed relative to the desirable attributes chosen for this analysis. As the table shows, each of the alternatives adequately addressed one or more of the attributes. Only one of the alternatives, SMDS, addressed all of the desirable attributes. Based on this comparison, SMDS deserves more detailed investigation.

Table 4.1. Comparison of Feasible Alternative Attributes

Attribute	DDD	LL	T1	X.25	FR	SMDS
Switching	Yes	No	No	Yes	Yes	Yes
Connectionless	No	No	No	Yes	No	Yes
Transmission Speed	Slow	S-F	S-F	S-M	Fast	Fast
Cost Effective (bursty traffic)	Yes	No	No	Yes	Yes	Yes
Protocol Insensitive	Yes	Yes	Yes	No	Yes	Yes
Alternate Routing	No	No	No	Yes	Yes	Yes
Call Setup Time	Slow	Fast	Fast	Fast	Fast	Fast
ATM/SONET Compatible	No	No	No	No	No	Yes

[Adapted from Sprint (41) pp. 28-33]

S = Slow = 2.4 - 19.2Kbps

M = Medium = 19.2 - 64Kbps/1.544Mpbs

F = Fast ≥ 1.544Mbps

The Feasible Choice for Conceptual Design: SMDS

The systems engineering process has helped provide a method for comparing several approaches to solving USA Today's problem. Based on the outcome of the comparisons made in the feasibility study, the most promising solutions should be more fully investigated. Realistically, each of the alternative solutions that display merit ought to be investigated. This analysis provides a more detailed investigation of SMDS, which apparently addresses all of the attributes considered desirable for USA Today's system success.

To review: USA Today's current satellite configuration, shown earlier in Figure 3.1, includes laser scanners, data compressors, and 80286 microprocessor based EBCU's which pass data into a TMT. The TMT modulates the data stream from the compressors onto a carrier signal which is upconverted to a Federal Communications Commission (FCC) approved satellite frequency and then sent to a high gain antenna and transmitted to the GTE Spacenet IV satellite. Onboard the satellite the signal is converted to a second frequency and downlinked to the remote printing locations. Here it is downconverted to a frequency acceptable to the ground equipment and demodulated in the DRT. From the DRT the data is passed to the data reconstructors, and finally to the recorders, which register the data on film for use by the printers.

The capability to transfer data such as USA Today's printing instructions via terrestrial system is not new. However, doing so at a cost comparable to that of the current system has not been possible using past technologies and services. Essentially, the terrestrial system replaces the satellite link and the hardware associated with generating and receiving the carrier signal, modulating the instructions onto the carrier, and receiving and recovering the instructions at the remote printing sites. Figure 4.2 compares the satellite system equipment to an SMDS configuration that could replace it to achieve USA Today's data transmission goals. Later sections of this project address specific components shown in the SMDS configuration.

SMDS promises bandwidth on demand with favorable prices tariffed on either a usage or standard monthly charge basis.

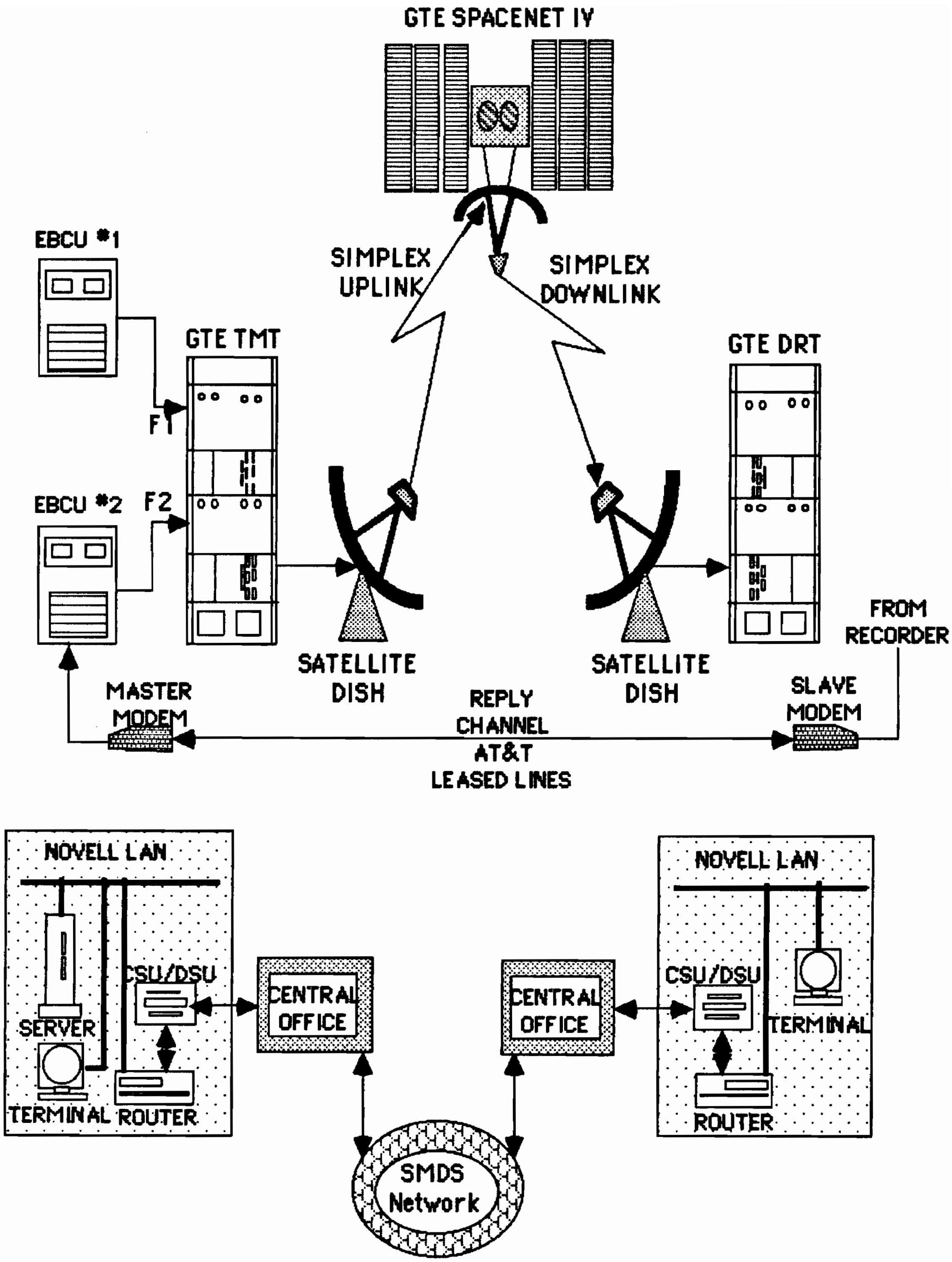


Figure 4.2. Direct Comparison of USA Today Satellite Configuration and Proposed SMDS Configuration

At the minimum SMDS speed of 1.17Mbps, each compressed page would take 30.5 seconds to transmit, which is nearly eight times faster than the current system.

Currently, SMDS is not fully available. Completed and ongoing trials have proven that the service works as advertised. However, tariff filing for customer billing purposes, long distance inter-operability issues, and widespread vendor support issues are still being finalized. The technology is not the cause of delays in service availability. Intercompany squabbles between regional carriers and long-haul carriers, as well as international deployment and control are political in nature. Nonetheless, these issues are at the heart of successful service delivery. SMDS deployment schedules are available for most domestic locations; and the European communications standards organization, ETSI, is currently reconciling its adopted standards with the Institute of Electronics and Electrical Engineers (IEEE) 802.6 specifications governing SMDS.

Clearly, SMDS is not an immediately available option for USA Today's needs. However, with the information available, the decision regarding such a strategic move can be made well before the service is publicly available. USA Today is not in a position where it has to make a decision now. As a matter of fact, their position is one of having the luxury to examine future technologies with the potential to change the strategic direction of their operations and increase their competitive position. Other terrestrial systems have been examined in the past and all have proven to cost about twice as much as the current satellite configuration. [ISE 5984 Case Study (45)]. USA Today states flatly that the company is always looking for better ways to do business. SMDS may prove to be one such business improvement. The systems engineering process will be used to further examine and develop the SMDS concept and determine whether it has merit for USA Today's identified needs.

Chapter 5: System Operational Requirements

Introduction

The system's operational requirements stem from the identified need, together with the feasibility of the technical approach used to address the need. Different technolological solutions dictate different operational requirements. The operational requirements address questions including equipment location, quantity required, operational environment, and use requirements. USA Today's mission is to print a daily newspaper. The SMDS system will facilitate this mission by relaying data crucial to each domestic remote printing site. The SMDS system will accept data from the USA Today compressors, format the data so it is acceptable to the network, and transmit the data to the remote sites via the publicly available SMDS network.

Remote site access

The SMDS system must provide access to all domestic remote site locations as listed in Table 1.1. Overseas locations are considered a completely different business entity by USA Today and are not considered in this analysis. SMDS network access comes via the nearest serving central office through a T1 (1.544 megabits per second) access line installed by the responsible local telephone traffic carrier. The serving central office will be responsible for providing connectivity to the nearest SMDS switch.

Data Rate

The minimum acceptable operational data rate necessary to support USA Today's requirements remains 153.6 kilobits per second, which is the current satellite link data rate. This data rate will ensure that the data preparation requirements prior to the EBCU and after the DRT, which are the system boundaries identified in the existing configuration, will not require alteration to accomodate the new system. A goal of any new USA Today system remains implementation with no impact on the existing operation.

SMDS operates at a minimum data rate of 1.544 megabits per second. This data rate is applicable across the SMDS network from the transmitting router to the receiving router. After the data traverses the network, it will need to be buffered at the receiving location and passed to the receiving station's equipment at a data rate acceptable to the receiving equipment. The data rate into the SMDS network is irrelevant because SMDS will deliver whatever the station connected to it forwards for transmission, up to the capacity of the access line. Therefore, SMDS will accomodate data rates of 0 to 1.544 megabits per second over the proposed T1 access line. Software at the intelligent end points of the SMDS network in USA Today's facilities will be required to control the data rate to the recorders.

Site Considerations

All equipment needed for implementation at the USA Today sites must require no more space than the current configuration equipment. The new system must fit within the space vacated by the TMT, DRT, and associated cables and installation equipment. Aside from the necessary electrical hookups and cosmetic facility reconfigurations, USA Today will not be required to modify its current work spaces to accomodate the new system equipment. The new configuration should require no more structural loading than the current system and there should be no restrictions on which floor of the USA Today facilities the new system may inhabit. If practicable, the new system should be human engineered to be "user friendly" for easy troubleshooting, and ergonomically designed for comfortable operation. USA Today's facilities are located at geographically diverse locations, but it is assumed that all of the locations maintain the minimum required operating conditions necessary to support the SMDS equipment. Individual site surveys can be performed to verify this assumption.

Each of the remote sites will require a T1 access line to be run from the nearest serving central office of the local telephone company. For system redundancy, two separate T1 access lines should be run. There is an important distinction here between bringing in two T1 lines and two separate T1 lines. Usually, when the phone company pulls a T1 line to a facility, it provides what is known as a fractional T3 line. This means that the phone company divides the resources of a 45Mbps T3 line into 1.544Mbps T1 lines for lower rate access. If a customer requests two T1 access lines, they will probably get two fractions of the same T3 line. This will not provide the required redundancy if the main line goes down since all of the fractions of the main line go down with it. USA Today needs T1 access off two separate main trunks, so that if one main fails the operation may continue.

Use Requirements

The system use is assumed to be at least as much as the current configuration, which is 1100 through 0430 daily. The system must function properly for at least 17.5 hours daily. It is assumed that the system will be able to function at peak performance for this period each day.

The system must function regardless of weather conditions. The design should include considerations required to allow the system to function without regard to outside influences, including "seasonal" telephone system busy periods. Since SMDS operates via the public telephone networks, arrangements for continued use and contingency plans in the event of service failure must be addressed. Service maintenance arrangements are addressed in the maintenance concept portion of this project.

Operational Deployment

The System will be deployed at each of the 34 sites, including the headquarters and backup headquarters locations. Each site will require sufficient equipment to meet minimum reliablility requirements (anticipate total system redundancy). Each site will be self-sufficient for maintenance and system operation. In other words, transmission of data from each remote site is that site's responsibility. Headquarters will transmit instruction data. Remote sites will transmit acknowledgment data. The sites are not solely responsible for SMDS service maintenance since the regional telephone companies provide and monitor the service. Each site will, however, be responsible for coordinating with the service provider in the event of service problems.

USA Today will need to decide upon a deployment schedule. For the puposes of this analysis, it is assumed that a local network services vendor will be subcontracted to perform all equipment and cable installation. If local vendors are used, each of the sites may be installed concurrently and the system will be ready for operation much sooner than if a team is dispatched to each site sequentially.

Operational Life Cycle

The system life-cycle is assumed to be eight years, including one year for design and development and seven years of on-line performance. This life-cycle is a conservative estimate of the SMDS system's longevity. This estimate represents how long computer hardware should be expected to perform. The estimate is conservative considering the successful past history of USA Today's current system. It is expected that the proposed system will work as designed for at least seven years. The system will take one year to design and field in addition to its operational life. Once the sytem is installed it will be operated and maintained by on-site and designated maintenance personnel.

System disposal is not addressed in detail in the life-cycle. It is assumed that all SMDS equipment that fails will be removed and disposed of by contracted maintenance personnel. As the system ages, components no longer useful will be reduced and sold for parts. When this option is exhausted, the components will be sold to recyclers or diposed of in accordance with existing regulations. None of the SMDS system components are hazardous or large enough to require any special handling. Disposal for most of the components is as simple as taking out the trash. As newer capabilities and business strategies evolve, USA Today will need to re-assess where the system fits in their overall plans. It is assumed that system equipment will be of negligible value at the end of its lifecycle.

Effectiveness Factors and Reliability

The system must be available 365 days per year for the minimum operational period identified as 1100 through 0430 daily. The daily system operational period is driven by the time required to scan each photo representation of each page of the newspaper. System operators should be able to bring redundant equipment on line in the event of hardware failure. SMDS service failures are the responsibility of the service provider, but USA Today's operators must know when to coordinate with the service provider in the event of failures. The system will provide alternate routing to at least two SMDS switch locations to preclude the possibility of single point failure impacting the mission of printing the daily newspaper.

System reliability will be not less than the current system's reliability. The satellite channel's bit error rate is 10E-10. This bit error rate is achieved by Sprint's Frame Relay service, and there is no reason to believe that long distance SMDS service will be of lesser quality. [Sprint (41)] The system must remain operational long enough to accurately transmit the required data to the remote sites and meet established daily printing deadlines. If one of the remote sites becomes unable to receive data, the headquarters site should be able to buffer one edition's worth of data, or about 200Mbytes based on a 40 page paper. Once the remote station recovers, the headquarters can transmit the required data.

Interfaces with External Data Handlers

In order for the SMDS solution to work, USA Today must hand its data off to the nearest serving central office providing SMDS service. Any data addressed for transmission outside of the local access and transport area must be passed over an interconnect carrier network. Both the local and long distance carriers tariff their transmission services. These tariffs directly impact the cost USA Today will incur by moving to an SMDS system. Tariffs for the Local Access and Transport Area (LATA) are controlled by the regional carriers, but regulated by the government. USA Today would be responsible for packaging its data in a format acceptable to the SMDS network. To this end USA Today is responsible for choosing appropriate hardware and software to format its data and successfully connect to the network.

If the transmission is bound for a destination not in the carrier's LATA, it is handed off once again to a long distance carrier. Since the breakup of AT&T some years ago, the rules of long distance telephone service have changed somewhat. The local companies sell the rights to transport calls to the long distance carriers, and the customer has a choice as to which long distance company is used. The SMDS data handoff at the long distance boundary, or interconnect carrier interface, is critical. The chosen carrier dictates tariffs and service reliability. So far, the long distance tariff issue has not been resolved. For the purposes of this analysis, Sprint's Frame Relay tariff is assumed to be a good, conservative estimate of the SMDS tariff. Sprint's service data rate ends where SMDS begins, but Frame Relay's high end data rate tariff should compare with SMDS's low end data rate tariff, which is the assumed data rate in this analysis.

As stated earlier, the technology already exists to make the physical data transfers. The resolution of the tariff issues remains in limbo. Bellcore designed SMDS to be an inexpensive, bandwidth on demand, public access system. It is assumed that the developer will not tariff the service such that potential customers are steered toward other data services, including Frame Relay. Bellcore knows what the competition is charging and should be able to price its offering to its own advantage. It should be noted that Sprint has no intention of carrying SMDS as such. According to DelRocco (19), Sprint will "ride SMDS on top of Frame Relay." So, as a worst case estimate, Frame Relay tariffs seem to be on the mark. Even if SMDS tariffs are not approved by the government, the service will work over Frame Relay links. This will add more overhead and require slightly different configurations, but technically it will work. This solution reduces the effectiveness of a pure SMDS system, but it does illustrate that the assumption on tariffs is valid.

Chapter 6: Conceptual Design

Introduction

Thus far, the analysis has covered the definition of system requirements, and the evaluation of alternatives to meet those requirements. At this point the actual design work begins. The data communication system development follows the operational functional flow shown in Figure 6.1. Figures 6.2 through 6.5 depict the first sub-level operational functional flows based on the top level flow presented in Figure 6.1. Figure 6.6 shows the second sub-level functional flow representing the SMDS data transmission and acknowledgement receipt process. At this early stage of system develpment the first sub-level flows provide adequate detail.

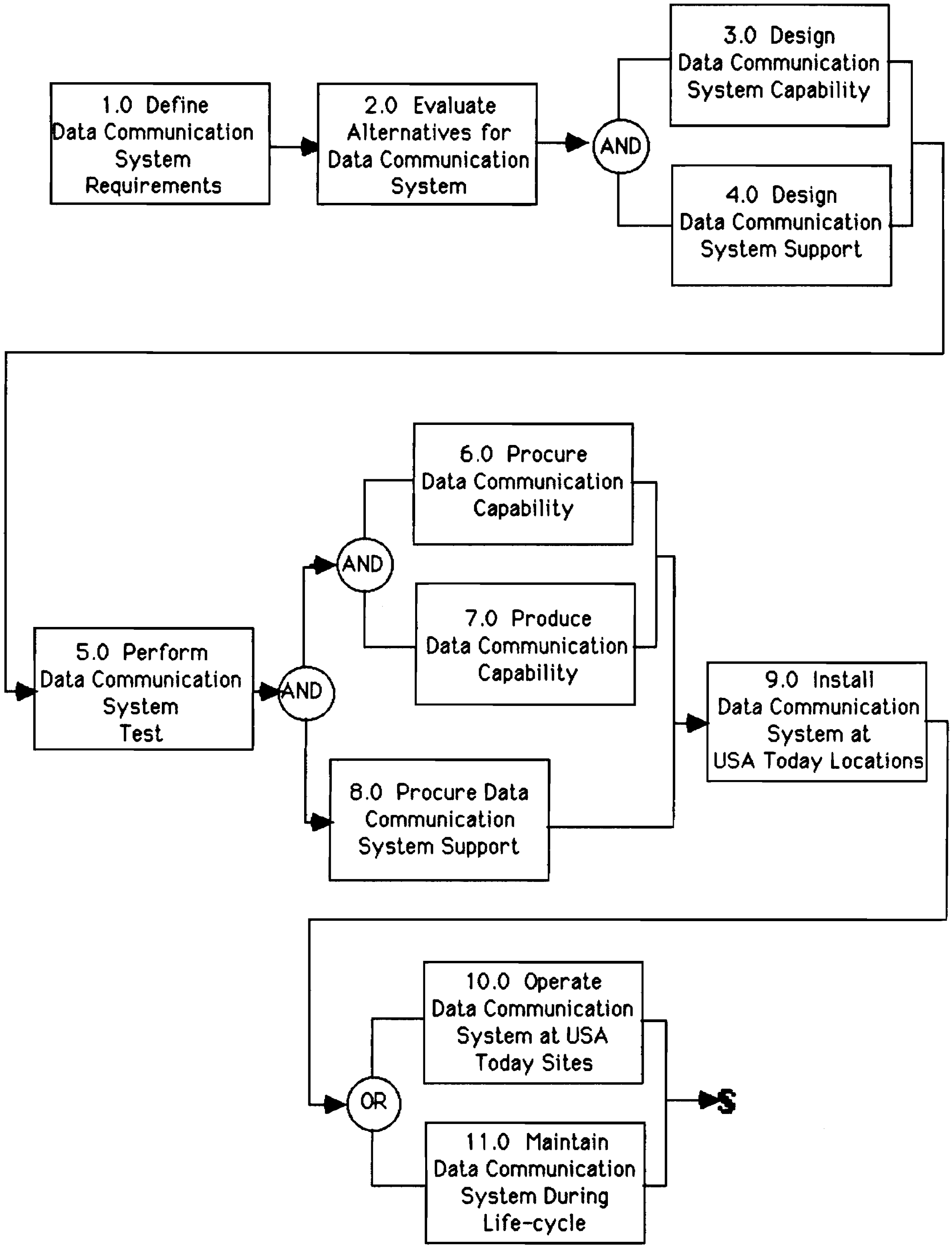


Figure 6.1. Top Level Operational Flow

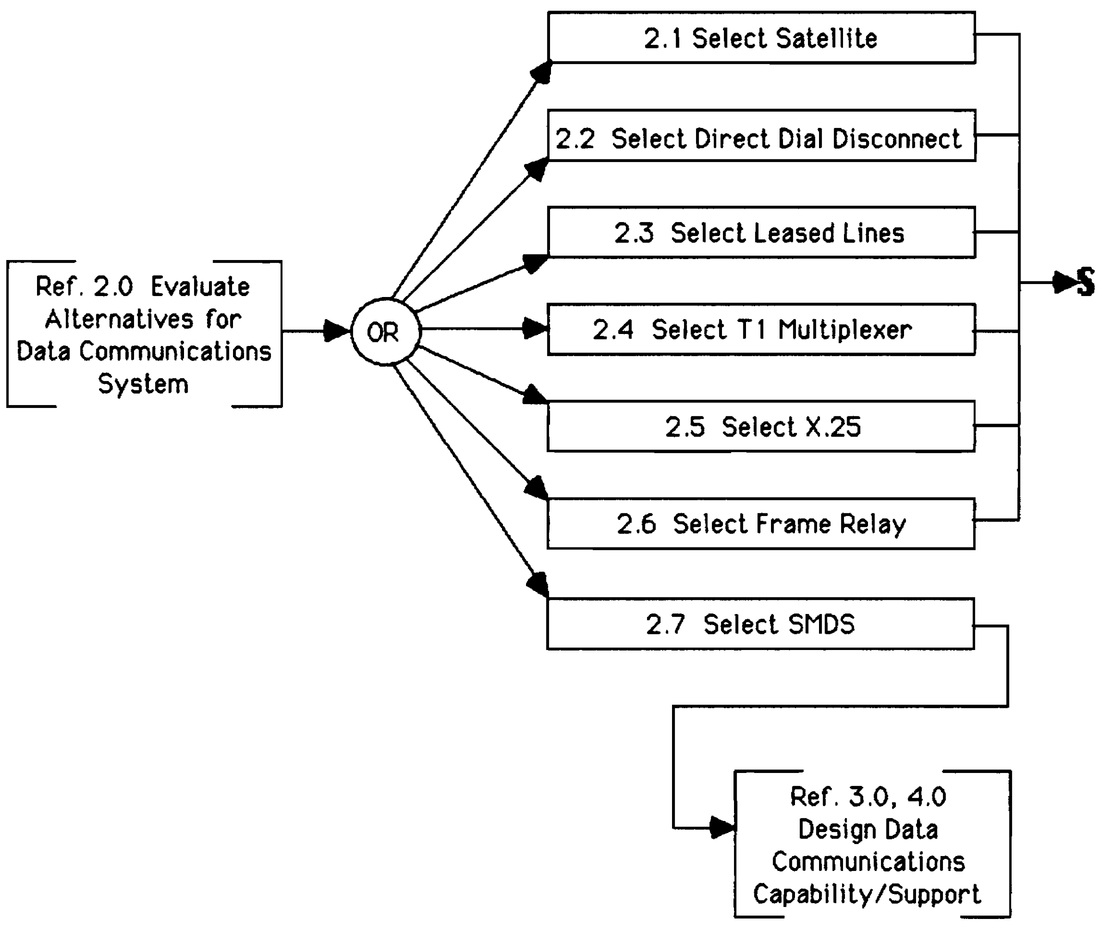


Figure 6.2. First Sub-level Operational Flow

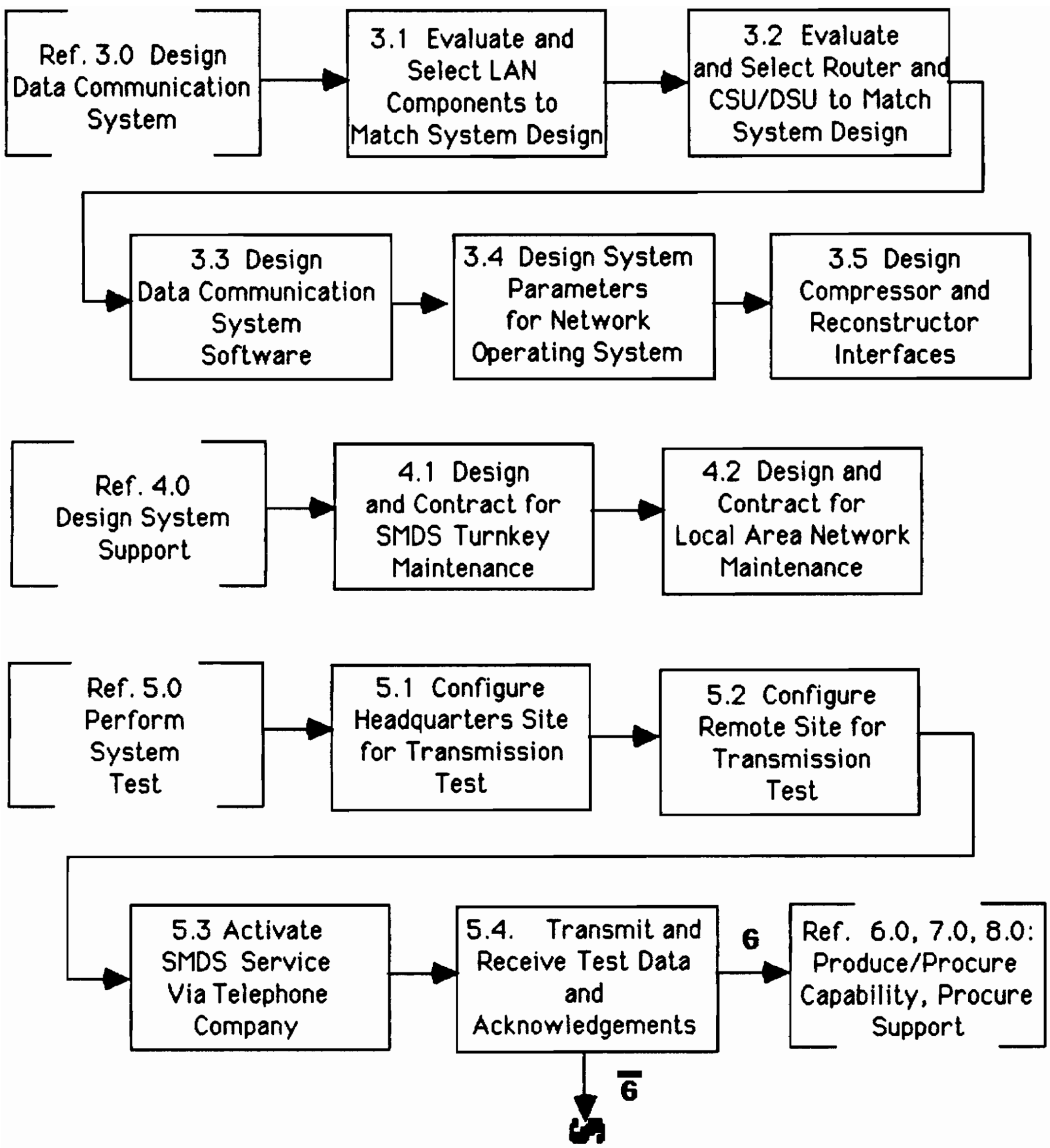


Figure 6.3. First Sub-level Operational Flow

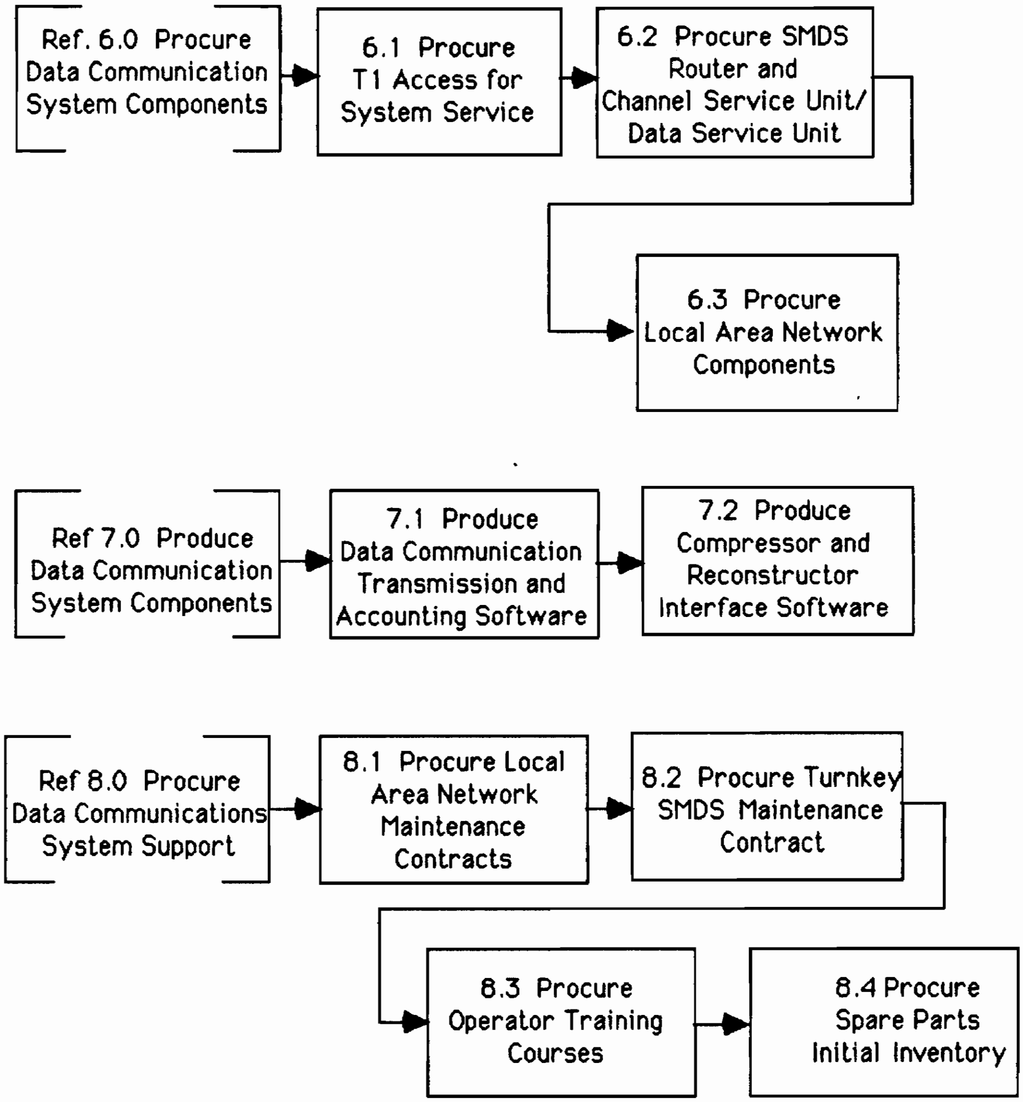


Figure 6.4. First Sub-level Operational Flow

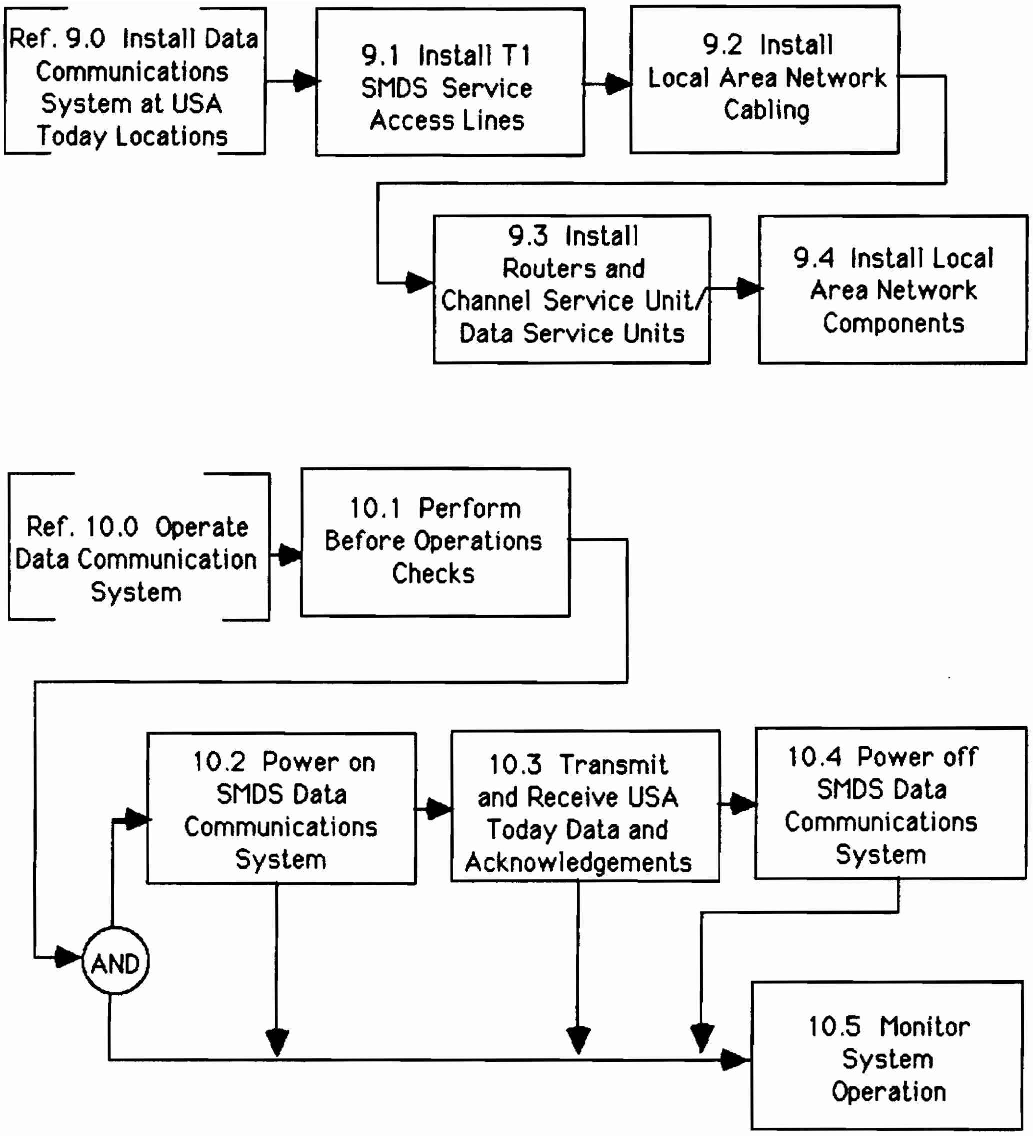


Figure 6.5. First Sub-level Operational Flow

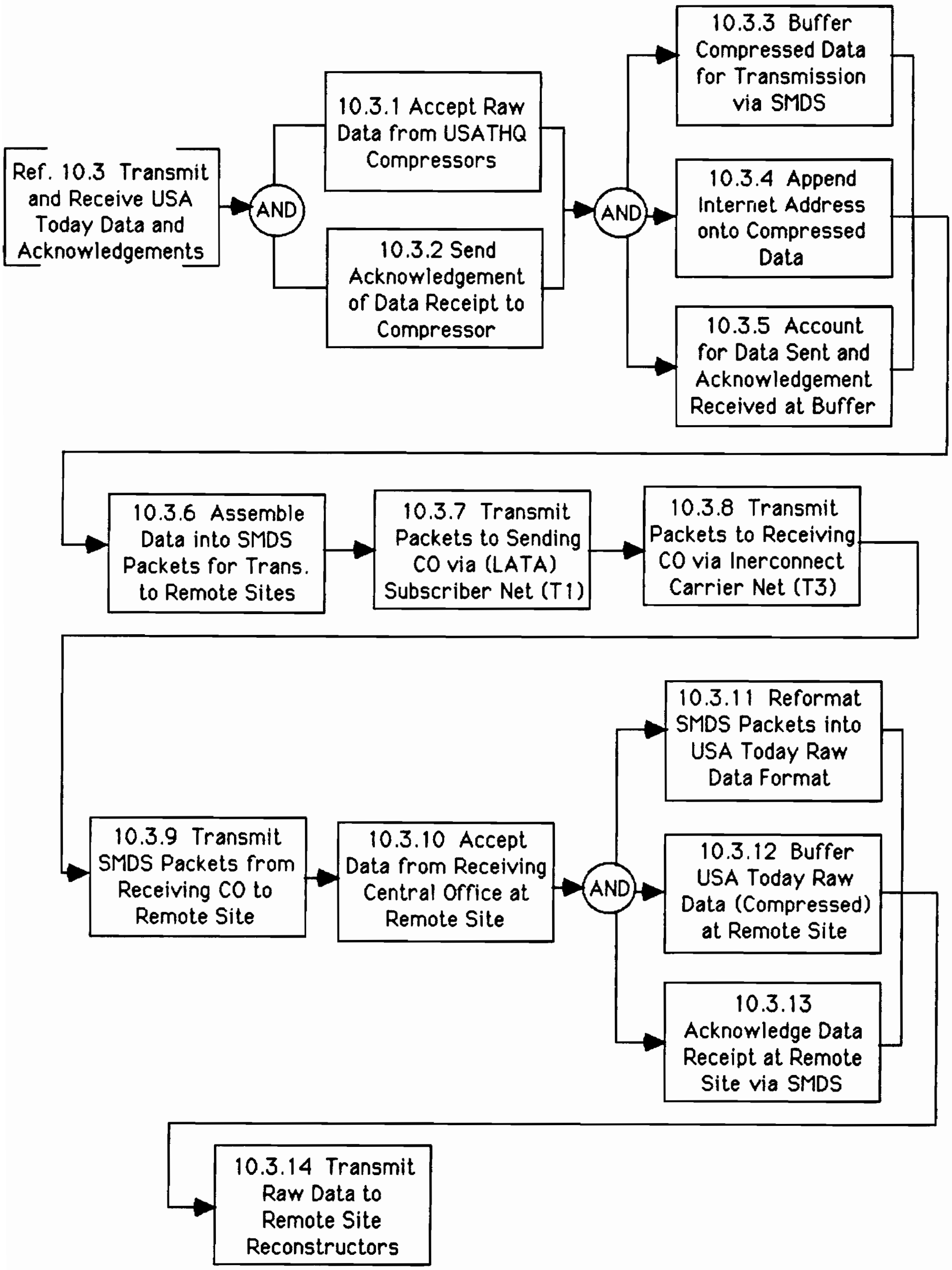


Figure 6.6. Second Sub-level Operational Flow

Conceptual Design: Proposed Configuration

At this point in the conceptual design, some of the specifics required for successful implementation of the SMDS solution selected during the feasibility analysis may be identified. In this instance, the equipment required to connect the remote and headquarters sites to the SMDS network is identified by type, along with potential vendors. Once the vendors are identified, cost data can be developed for use later in the analysis.

SMDS Overview and Review

SMDS is designated as a fast packet, connectionless, switched data service. As such, the service is responsible for moving customer data in cells, or fixed length packets, from one location to another at specified speeds at pre-determined cost. SMDS provides transmission at four different access speeds ranging from 1.544Mbps to 155Mbps. For the purpose of this analysis the slowest SMDS access speed, which is 1.544Mbps, is examined.

USA Today must provide the hardware and software required to connect into the nearest local telephone exchange carrier office. Figure 6.7 shows this arrangement, where the local office is known as the serving central office. USA Today must connect each of its headquarters and remote locations. This hardware and software, or customer premises equipment (CPE), consists of a router and channel service unit/data service unit (CSU/DSU). USA Today also provides the networking and SMDS software that enables each location to communicate with the others. SMDS delivers information to each destination, but it is USA Today's reponsibility to ensure that the data is formatted so that the receiving locations interpret it properly. As discussed in the desirable attributes section of this project, SMDS provides the transmission path, but USA Today's sites are intelligent end points providing system logic.

The serving central office provides the required access trunk to each USA Today location. This trunk is either a T1 or T3 access line. A T1 line, with a capacity of 1.544Mbps, is used in this analysis.

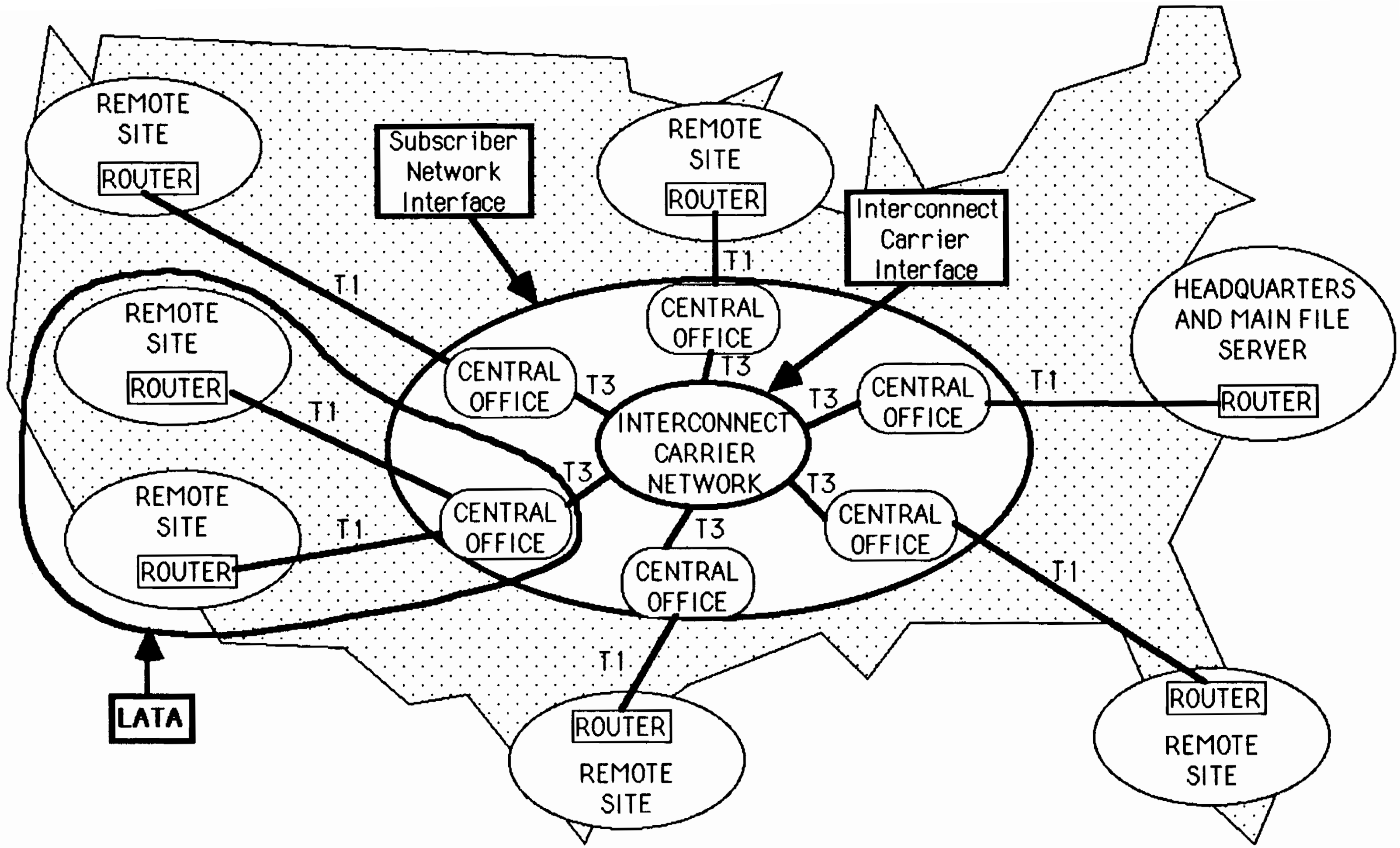


Figure 6.7. The SMDS Concept

The connection between the CPE and serving central office access trunk is known as the subscriber network interface (SNI). Data passes from the CPE, through the SNI and access trunk, to the serving central office. If the serving central office includes a fast packet cell relay SMDS switch, it routes the SMDS traffic. If the serving central office does not have an SMDS switch, it forwards the SMDS traffic via a 45Mbps trunk to the nearest central office (CO) with an SMDS switch.

The CO then routes the SMDS traffic either within the Local Access and Transport Area (LATA), or to an interconnect carrier (long distance) network. The connection between the CO, with its associated local exchange network, and the interconnect carrier network is the interconnect carrier interface (ICI). The interconnect carrier network provides the long distance transmission of the SMDS cells. The SMDS cell traverses the interconnect carrier network until it reaches the CO nearest its destination. At this point, the handoff from interconnect carrier network to local exchange network to CO to CPE is repeated in the reverse order of the transmission sequence.

Once the receiving site receives the transmission it sends back an acknowledgment (ACK) to the sending site to inform the sender that the error-free data was received. If the sending site receives an acknowledgment, it continues with the next sequential transmission. If the receiving site detects an error in the transmission, it sends back a negative acknowledgment (NAK) to the sending site. If the sending site receives a NAK, or does not receive any indication of data receipt, ACK or NAK within a programmed amount of time, it retransmits the data.

Equipment Required to Access SMDS

Each USA Today site will require a CSU/DSU, a router with SMDS capability, and an access line provided by the local telephone company before it can access the SMDS network. Routers are intelligent devices that receive data in one form and prepare it for transmission to a distant device by formatting the data appropriately for acceptance by the medium and protocol logic associated with the network. Two prominent vendors, Cisco Systems and Wellfleet Communications, offer routers that have been tested and found acceptable by Bellcore, the developers of SMDS. In order to divide the problem of accessing SMDS into more manageable pieces, and bring the needed equipment to market sooner, the connectivity functions were formally divided between routers and Channel Service Unit/Data Service Units (CSU/DSU's). Wellfleet and Cisco developed their products in concert with two other vendors. Wellfleet's routers operate best with Data Link CSU/DSU's, while Cisco's routers operate best with ADC Kentrox CSU/DSU's. Either pair of equipment is acceptable and both offer competitive pricing, which is addressed in the economic analysis.

Equipment Required for Data Transition Between USA Today and SMDS

Between the SMDS access equipment and USA Today's compressors and reconstructors lies a void. Without reformatting by an intermediate device, there will be data incompatibility and system failure is assured. The fundamental problem is that USA Today's data currently passes over a broadcast network. This requires no internetwork addressing scheme. Furthermore, the TMT and DRT communicate in a data format incompatible with terrestrial network operations. Essentially, USA Today must create Local Area Networks (LAN's) at each of its sites where none existed before. Figure 6.8 shows a conceptual SMDS LAN configuration replacing USA Today's satellite system.

The LAN's will connect the scanner/compressor and reconstructor/recorder equipment, which communicates according to the V.35 standard, to the SMDS CPE, which accepts data formatted according to AppleTalk, TCP/IP, or Novell IPX protocols. Folts (23) lists V.35 as an Open Systems Interconnection (OSI) layer 1 electrical standard for data transmissions at 48 kilobits per second. Appendix A includes information regarding the OSI protocol stack layers.

A LAN can consist of any combination of interconnected devices needed to perform a required data function. For USA Today's purposes, the required functions are data buffering, internet protocol addressing, transmission and acknowledgment accounting, and LAN administration. A convenient package for accomplishing all of the required functions is offered by Novell, Inc. in the form of their Netware 386 network operating system software.

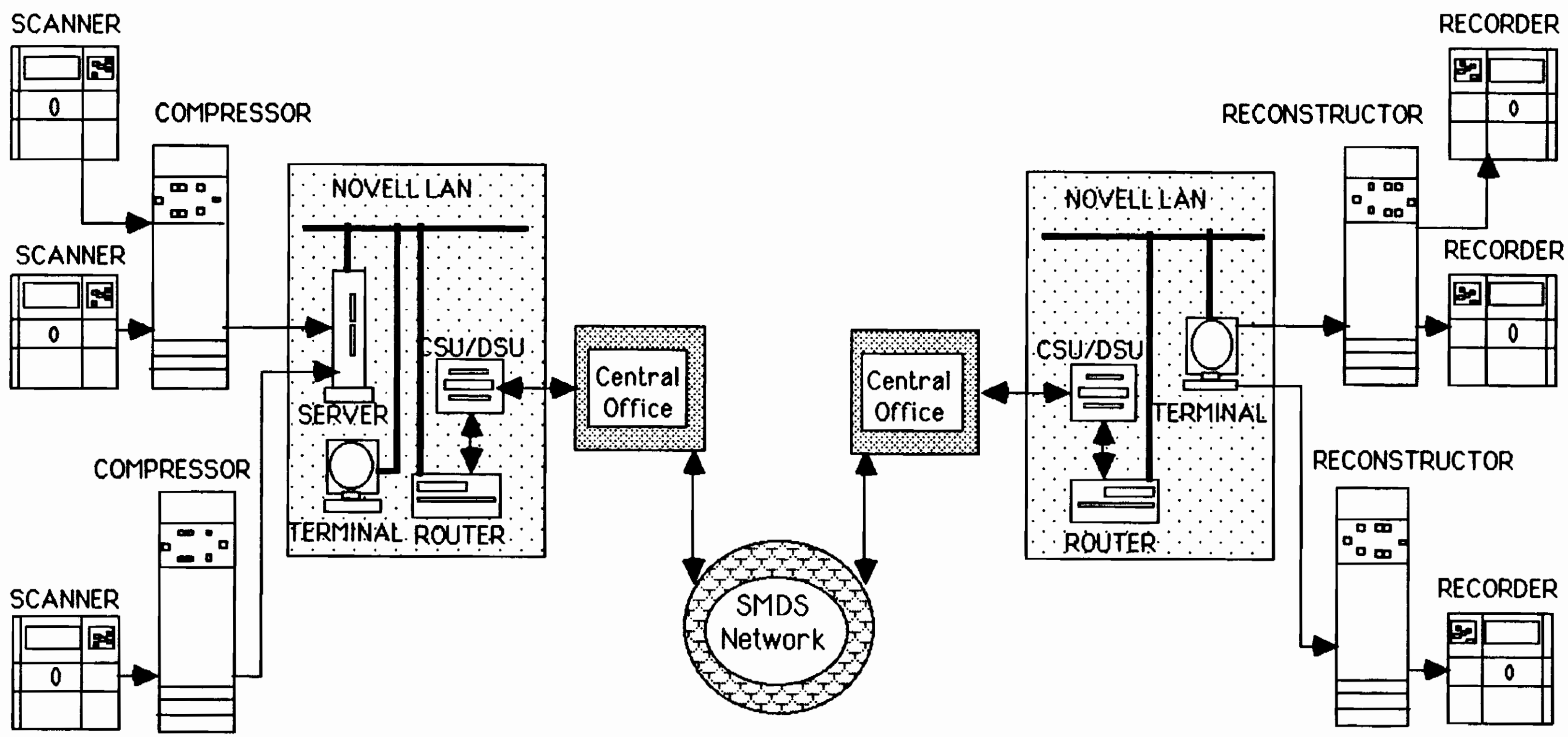


Figure 6.8. Conceptual SMDS Configuration

Novell's Netware performs all required functions, as well as providing interoperability with other systems that use any other SMDS acceptable protocols. Netware comprises 54 percent of the network operating system market and has an excellent reputation for support, upgrade, and maintenance. Other products are available, but this analysis will assume Netware is used due to its strong supportability and inter-operability, as well as the fact that it offers all required functions in a widely available, comprehensive, fairly priced package. The Netware solution requires a dedicated server unit, which is a computer, to operate the network software. Another computer with significant data storage capacity is required to provide the required data buffering capacity.

Finally, all of this equipment must be connected in an acceptable topology, or physical and logical configuration, to accomodate proper functioning. Perhaps the simplest, and least expensive method that meets USA Today's requirements, of LAN connection is an Ethernet configuration. Appendix B provides information on Ethernet. With only the server, workstation, and router on the network there should be little problem with Ethernet's carrier sensed multiple access - with collision detection (CSMA/CD) medium access protocol. The only cabling requirements for such a configuration are the backbone cable, and drop lines to the connected equipment, along with necessary repeaters to connect multiple devices to the backbone. Each site will have two redundant equipment strings to meet USA Today's stringent reliability requirements.

In summary, the USA Today equipment will connect directly to a LAN workstation, which will communicate via the LAN with the SMDS router and CSU/DSU. The LAN topology will be a variation of Ethernet. The network operating system will be Novell Netware 386.

Once the SMDS configuration is operational, the obsolete satellite equipment will need to be removed. This will entail removal of the TMT, satellite dishes, and DRT's. This equipment is leased from GTE Spacenet and it is assumed that they will remove their equipment for a nominal charge.

System Test and Evaluation and Conversion to the SMDS System

USA Today has a functioning, sensitive system operating about 17 hours each day to produce its newspaper. Putting a new transmission system in place while the existing system is running is not a trivial task. It would probably be easier to start from scratch than modify the existing configuration, but this is not an option since the daily business will continue while the upgrade takes place. The conversion will probably need to be a parallel conversersion, whereby both the old and new system operate side by side until the new system's proper functioning can be determined.

A system test involving the headquarters site and a remote site can be performed for about $100,000 to determine if the SMDS system design works properly. System redundancy would not be required for the test, and only one remote site and one headquarters site would require configuration. It is assumed that the data compressor and reconstructor can be configured to provide the required data to a splitter port so the data will go to both the new and old systems during the test. The SMDS configuration could then be directly compared to the existing configuration. The cost data summary provides the figures for outfitting a headquarters and remote site for non-redundant configuration. This test would be performed to validate the system design and ensure proper functioning prior to proceeding with a full scale transition of all of USA Today's sites.

Maintenance Concept

The system maintenance concept evolves directly from the system operational requirements and addresses how the system is to be supported throughout its design life. Maintenance costs are a major factor in the system life-cycle cost. Failure to address maintenance aspects could lead to implementing a system that is initially less expensive to install, but requires significantly more maintenance effort later. This results in unanticipated costs throughout the system's life that negate the apparent initial savings. Now that a general idea of the SMDS configuration is available, the maintenance concept can be developed.

The conceptually designed system maintenance functional flows stem from the operational functional flows shown in Figures 6.1 through 6.6. The SMDS data communication system's top level maintenance functional flow is shown in Figure 6.9. The first sub-level flows, which are detailed enough for this level of analysis, are shown in Figures 6.10 and 6.11.

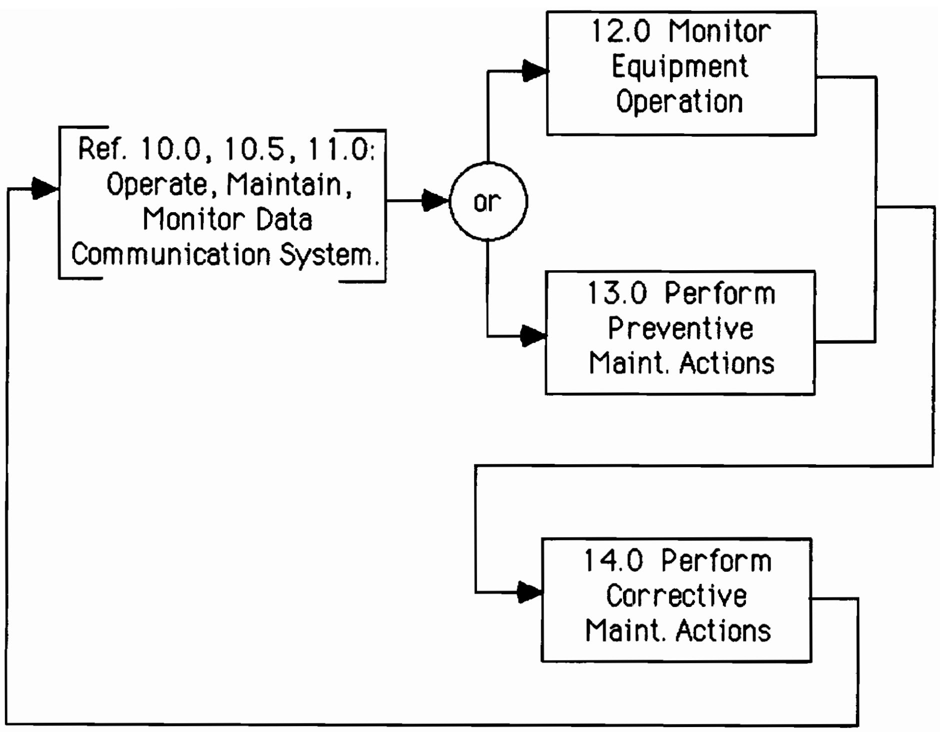


Figure 6.9. Top Level Maintenance Flow

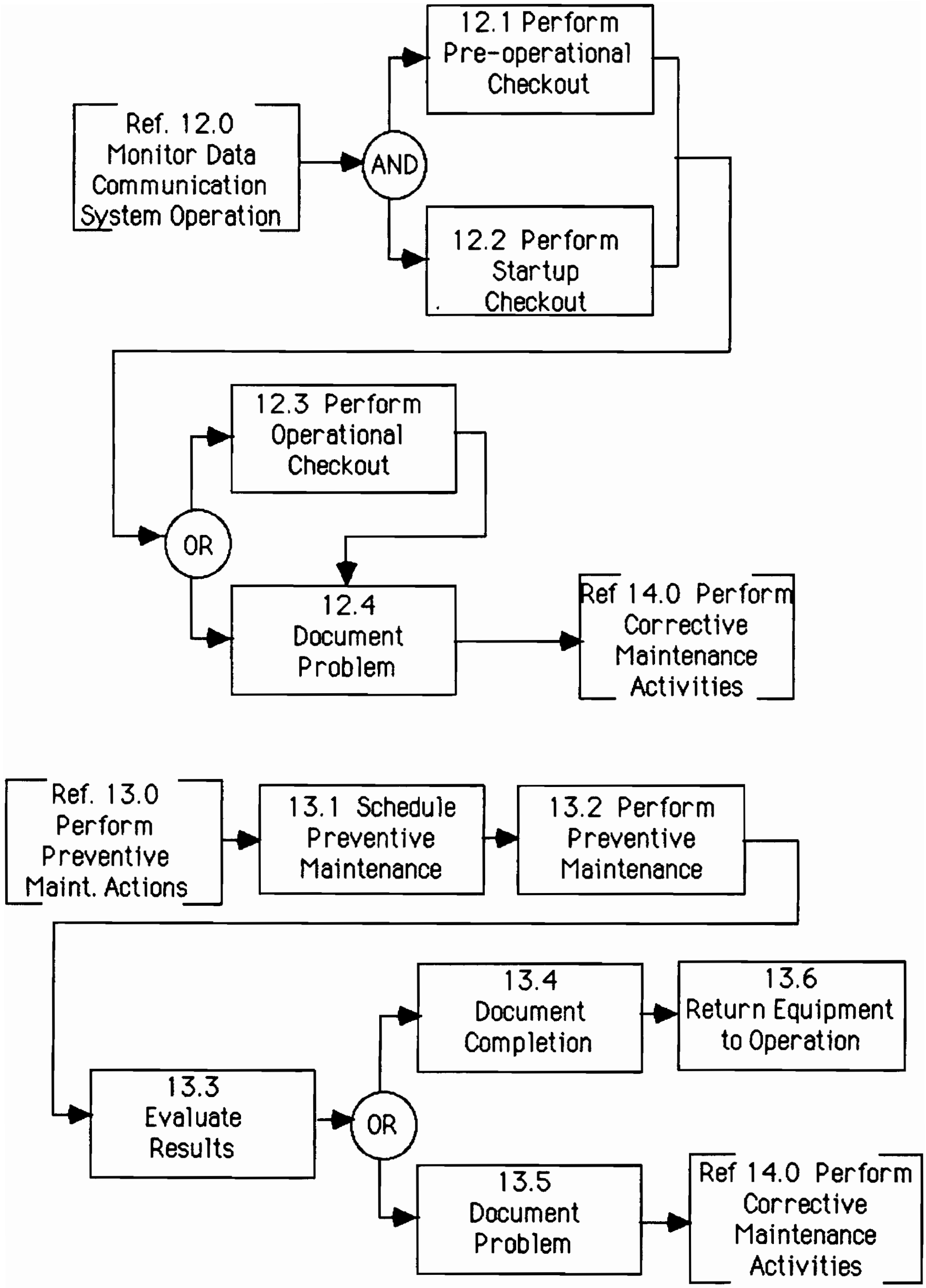


Figure 6.10. First Sub-level Maintenance Flow

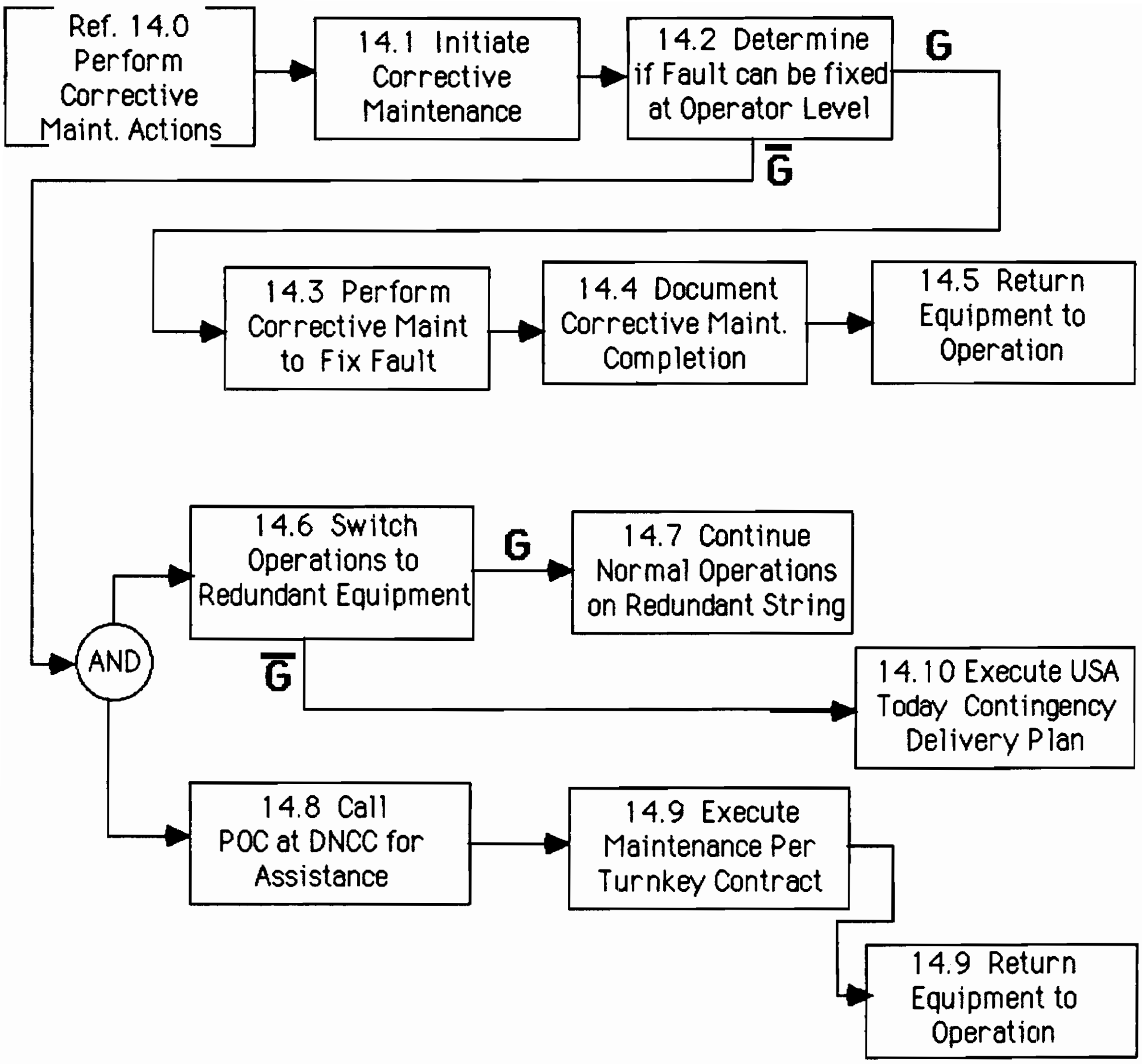


Figure 6.11. First Sub-level Maintenance Flow

Overall Plan

USA Today's maintenance concept will remain intact with the specific modifications noted in Figures 6.9 through 6.11. Since the SMDS system requires data handoff to the telephone companies, the interface points between customer premises equipment and the SMDS service provider equipment must be addressed. The simplest way to handle this situation is to contract for a single point-of-contact (POC) maintenance agreement. When a system failure occurs, the operations team simply calls the POC to begin troubleshooting the problem.

USA Today will have a single POC in the event of SMDS failure anywhere between its LAN, to which the SMDS CPE are attached, and the service provider's facilites. Once a problem is identified, the site crew calls the installation and maintenace POC at the Data Network Control Center (DNCC), who performs initial problem identification. If the POC has no indication of where the problem lies, he first dispatches a technician to the customer location and then contacts the DNCC to begin troubleshooting the network systems and transmission facilities. The DNCC is responsible for configuration functions, monitoring functions and fault isolation within the service and transmission facilities. The POC location and DNCC are manned 24 hours a day. The Bellcore advertised MTTR for any failure is 3.5 hours.

This maintenance concept assumes that USA Today does not have skilled router and CSU/DSU technicians available at each site, which is expected since the sites do not currently have this equipment. This concept is unique since USA Today's equipment will connect directly to equipment belonging to the telephone companies. The identification of whose equipment is responsible for any system problems provides the potential for confusion and delay. As a result, it seems prudent to use the single POC arrangement and make that POC responsible for the interfaces and CPE connecting into the SMDS network. USA Today may wish to change this arrangement as it gains experience with the equipment and technology involved. At this point in the analysis, although it is a worst case scenario economically, USA Today will contract for the required maintenance support for the routers, CSU/DSU's, access lines, and SMDS service as a single package.

Operator Maintenance

USA Today's current maintenance concept includes operator, intermediate, and depot levels. Since USA Today's operation is so dispersed, each site has three personnel: a technical supervisor, a technician, and an operator dedicated to operator maintenance. Each site is autonomous and its operators are somewhat more skilled than usually expected at this level of maintenance. The three man crew is responsible for all maintenance and repair of on-site equipment.

The operator level of maintenance requires the crew to identify problems associated with USA Today's SMDS related Customer Premises Equipment (CPE), including the router and channel service unit/data services unit, and SMDS service. Since the SMDS service is under control of the telephone companies, the crew will not be able to perform maintenance operations on the access lines or on the service itself. Furthermore, to avoid "boundary" related problems that could slow contingency response time, the SMDS maintenance concept will include a single POC at the telephone company's DNCC. If a problem arises involving any of the CPE or the service itself, the site crew informs the POC. This will avoid one party thinking the other is working on the problem and slowing problem response.

Once a problem is detected, the crew at the USA Today site will evaluate the severity of the problem and determine if the system is providing the necessary functionality to continue operations on the primary string of equipment. If the crew determines that the primary equipment is not functioning properly, they will bring the redundant equipment string on line and determine whether the mission can resume on the backup equipment. If neither equipment string works properly the crew will stand down. USA Today's in-place contingency plans for site failure will be followed until the problem is resolved.

Intermediate Maintenance

USA Today's SMDS specific CPE falls under a maintenance agreement with the local telephone DNCC. If a problem with the SMDS CPE or access lines is suspected, the DNCC will need to dispatch its intermediate maintenance assets. From the DNCC, a central POC can trouble-shoot transmission facilities and service functions. The POC will also dispatch a technician to the remote site to inspect and repair access lines and CPE under the maintenance contract.

Depot Maintenance

The single POC maintenance agreement between the remote sites and the local telephone company will cover all instances of SMDS CPE failure. If the technician dispatched to the remote site detects a failure that is unrepairable at the customer site, he will replace the component and evacuate the affected CPE to the DNCC for further maintenance actions.

System Implementation Schedule

Table 6.1 provides a sample SMDS system implementation schedule. The tasks identified in Table 6.1 represent the minimum tasks required to implement the conceptual design. Task durations, and start and end dates are estimates based on the level of effort required to complete the tasks and begin system operation within one year after the conceptual design review.

Table 6.1. Sample SMDS System Implementation Schedule

Task	Months After Conceptual Design Review												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Define Software Requirements	•	•											
Remote Site Surveys	•	•											
Define Network Operating System Requirements	•	•											
Software Engineering/Coding		•	•	•	•	•	•	•					
Local Area and Interconnect Carrier Service Negotiation/Contracting			•	•									
Maintenance Contract Negotiation/ Contracting			•	•									
Redundant T1 Access Line Vendor Negotiation/Contracting			•	•									
Network Operating System Selection/Procurement			•	•									
Network Operating System Engineering/ Coding USA Today Specific Tasks				•	•	•							
Hardware Selection/Procurement				•	•	•							
T1 Access Installation						•	•	•					
Local Area Network Installation								•	•				
System Test and Evaluation									•	•	•	•	
Redundant T1 Access Installation (Route Diversity)									•	•	•	•	
System Operation/Maintenace/Support Start Date													•

Chapter 7: Economic Analysis

Cost Goal

Ideally, the SMDS solution will provide the benefits of greater bandwidth at a cost less than or equal to the existing satellite configuration. Since the remainder of USA Today's operation will initially remain as it is today, the SMDS system should not impose any more of a financial burden than the existing satellite system over the eight year life-cycle. The cost of producing the pasteboards for photographing and conversion into digital format will remain. SMDS will provide the link between the headquarters compressors and the remote reconstructors.

Cost of Current System

The cost of the current system is provided as a benchmark against which to measure the SMDS system. USA Today's system relies on three main groups of equipment: Ricoh designed facsimile equipment, owned by USA Today samples and compresses data prior to transmission from USATHQ. Similar equipment reconstructs and records the data after reception at the remote sites. GTE owned satellite transponders and ground equipment, leased by USA Today provides the means by which the data is formatted for transmission over the satellite link and stripped off at the receiving site. AT&T owned multi-drop leased lines provide a terrestrial acknowledgment path for USA Today's transmissions via the GTE satellite.

The satellite uplink and downlink, including Federal Communications Commission (FCC) licensing, satellite transponder and ground equipment lease cost is $4 million per year, according to Pinyot (28). The multidrop acknowledgment leased lines cost $45,000 per month. USA Today spends $4.54 million annually, or about $379,000 per month to lease the necessary equipment to support its current telecommunications strategy.

Analysis

The SMDS system economic analysis presents all of the expected costs during the life-cycle of the system. As Figure 2.1 shows, about 60 percent of the life-cycle costs are commited by the end of the conceptual design phase. Blanchard (11) states that "a major portion of the projected life cycle cost for a given system or product stems from decisions made during early planning and as part of system conceptual design." [Blanchard (11), pg 505] Costs are estimated and projected for the life-cycle. Therefore, cost estimation during the early stages of design must be as accurate and comprehensive as possible to avoid economic disaster later in the system's life-cycle.

Assumptions

The following assumptions are made to simplify analysis calculations, establish initial conditions, and determine the SMDS system's economic feasibility.

1. SMDS monthly long distance tariff is comparable to that of Sprint's frame relay tariff.

2. USA Today's estimated domestic monthly operating costs are accurate enough for this analysis.

3. Overseas deployment of SMDS is not considered as part of this analysis.

4. System retirement and disposal costs are negligible.

5. USA Today will retain its current data preparation process up to the point of printer instruction transmission. For the purpose of this analysis the system boundary is drawn at USA Today's compressors at the transmission site and at the reconstructors at the receiving site.

6. USA Today does not require absolute control of the SMDS network.

7. The value of all hardware at the end of the eight year life-cycle is negligible.

8. Bell Atlantic's LATA access and service tariffs are representative of all local carrier tariffs.

9. Route diversity equipment installation is required at each remote site.

10. Novell Netware 386 is an acceptable network operating system for USA Today's needs.

11. USA Today's current level of spending for system management meets SMDS system management requirements.

Cost Data Development

The cost data for each portion of the SMDS system conceptual design is derived from existing data in industry literature, personal interviews with knowledgeable industry representatives, and applicable public documents. Where no literature or personal experience was available, reasonable and conservative cost estimates are based on level of effort required to achieve a given requirement.

System costs are incurred in the design and development of the system, during system implemetation, and during system operation. Normally, system management costs would also play a part in the life-cycle cost. However, USA Today already has a management team in place overseeing its current operation. All costs applicable to this analysis are changes from USA Today's current cost structure. It is assumed that USA Today's current spending for system management will suffice for the new system.

Systems engineering is an iterative process. Any changes made during the process can impact the cost data and the conclusions based on the cost data. The cost data that follows is reasonably accurate for the conceptual design presented.

The analysis seeks to be conservative, or "worst case" with all cost estimates. Economic feasibility of the proposed conceptual design can be determined based on the cost data gathered.

System Design and Development Cost

Blanchard (11) indicates that the system design and development cost category encompasses initial planning, product research, software, test and evaluation, engineering design, and feasibility studies. The costs associated with designing and testing USA Today's SMDS system are addressed in this section.

Engineering Design - Specific tasks include:

1. Designing the LAN interface between USA Today's compressors and reconstructors.
2. Programming the network operating system to account for transmissions and acknowledgements.
3. Designing the site layouts for each site to accomodate the SMDS system.
4. Designing and performing the SMDS system test.

USA Today's data compressor is a key component in the current configuration. The system timing must be programmed properly to allow the compressor to function. The EBCU currently performs the timing and interface function. In the SMDS configuration, the data server and workstation terminal will take over the compressor interface function. Pinyot (30) indicates that the compressor is very sensitive. The current transmission and acknowledgement scheme is very detailed to accomodate the compressor's sensitivity.

The SMDS configuration will include a large buffer area so that the compressor can simply send its data to the buffer, regardless of acknowledgement from the receiving location. The design engineers must write the software that will perform the interface functions. Once the data is buffered, the network operating system will account for transmissions and acknowledgements.

The design engineers must program the Novell 386 operating system with the timing and transmission accounting parameters. System administration functions must also be designed within the network operating system. The design engineers will also be responsible for designing site layouts for the SMDS system.

The engineering effort will also include the system test. The system test will include the headquarters site and one remote site to validate the System's design. System test costs are negligible since all equipment used in the test will be included and accounted for in the operational configuration.

Based on conversations with Saunders (35) and Singleton (36), one year appears to be a reasonable amount of time to design and implement the SMDS solution with two qualified engineers. Two qualified engineers, at $50,000 each, for one year makes the engineering design effort cost $100,000.

System Implementation Cost

The implementation cost category accounts for industrial engineering and all costs associated with constructing and integrating the system. The system's intial components and spares to maintain the system throughout the life-cycle are included in the system implementation cost. The system implementation costs presented in the analysis are those costs required to change USA Today's current configuration to the

SMDS conceptual design configuration. USA Today's costs which are not associated specifically with the SMDS transition are not addressed.

System Components

The SMDS system will require certain specific hardware, as determined in the conceptual design, to meet USA Today's needs. The required system components and their associated cost are listed below.

Router - A router is a customer premises equipment device serving the specific purpose of routing SMDS packets from one destination to another. Wellfleet Communications produces SMDS compliant routers that meet USA Today's needs for approximately $8,000. According to Ricci (34) the router itself will cost about $7,000, while the software that allows the router to perform SMDS functions is an additional $1,000.

Channel Sevice Unit/Data Service Unit (CSU/DSU) - The CSU/DSU acts as a functional extension to the router and provides the specific interface to SMDS transmission facility. Wellfleet routers are designed to operate most effectively with Digital Link CSU/DSU's. The companies entered into a joint development agreement to help bring SMDS technology to market sooner. The Digital Link CSU/DSU will cost about $6,500 according to Sharma (36).

Access Line Installation and Configuration - This is a one time $1000 charge to install the T1 trunk. The charge is per site, per access line and includes the effort to configure switches at the nearest central office, provide network addressing, and install the T1 trunk to the nearest serving central office. The one time charge appears in several documents, including Bell Atlantic (3).

Local Area Network Development - The assumption is made that Novell Netware 386 on an Ethernet LAN will be used. These are both highly tested, easily installed, universally accepted methods of addressing and accessing networks. Cost for these implementations includes hardware, software, installation and maintenance. A LAN is made up of several independent components:

a. Central Processor Unit

b. Novell Netware 386 Network Operating System

c. Network Cabling and associated Hardware

Central Processor Unit (CPU) - A CPU will be required to transform each site into a LAN. A 386 or 486 series machine is required to run the Novell Netware network operating sytem software. As advertised in the Washington Post (46), a 486 series machine with a 345 megabyte (MB) hard disk, 16 MB of random access memory, a 1.44 MB floppy disk drive, and 256 kilobytes of cache memory is available from Intellicom USA, which is a Novell authorized dealer, for about $3,000. Netware 386 requires at least 4MB RAM and a 1.2 or 1.44MB FD to load software. This high capability machine is capable of running Netware at the headquarters location. A second CPU is required at the headquarters to buffer data from the compressors. Each remote site LAN will only require one CPU to manage the LAN, since the Netware will only run at the headquarters site.

Novell Netware 386 - Netware cost is $12,495 for the 250 user version according to Sauders (35). Initially, USA Today will only have two stations, the CPU and the router, per remote site LAN. The headquarters locations will have three stations, the Netware CPU, the buffering CPU, and the router, per LAN. This solution allows for significant future expansion.

Network Cabling and Hardware Installation - According to Singleton (37), total cost is $2600 per site. This includes pulling the T1 access line from the facility's wiring closet to the CSU/DSU ($200 each), a patch cable from the CSU/DSU to the router ($175 each), a 12 port 10BaseT repeater ($800), 10BaseT adapter cards for each piece of hardware attached to the LAN ($100 each), drop lines to the 10BaseT cable from each machine ($75 each), and the labor of two technicians for two days to install and hook up the hardware ($1,040).

Redundant T1 Access (Route Diversity) - USA Today's remote sites are located in areas where real estate is inexpensive. Some of the sites are not located where it is likely that more than one T1 access cable would be available. In order to provide the redundancy required for USA Today's business, two separate T1 accesses are needed. Since a pre-existing T1 cable will only provide single access, some other form of access is required. The route diversity cost budgeted is more than the cost of all other system equipment combined. In the event the remote site cannot access two separate T1 trunks from the same serving central office, a second T1 will need to come into the site from another office. If a second office cannot provide the necessary service, the redundant T1 access will have to be installed. Installation cost is estimated at $3 per meter plus an additional $3 per meter for the fiber optic cable. A conservative estimate for this service is $50,000 per site. According to Cornbrooks (14), $50,000 is a high estimate of cost to provide the necessary access. The various sites will require individual estimation. The more expensive site estimates will be compensated by sites in areas such as Miami, Atlanta, and Boston, which should require no special work since they are metropolitan areas with abundant resources.

System Operation Cost

System operation costs are those that are required to operate the system. Sustaining maintenance support, logistics, operator training, local and long distance SMDS switching all fall under the system operation cost category. The system operation costs detailed in this analysis are those that are currently not a part of USA Today's operations.

Training - Router and CSU/DSU operations are not currently supported under USA Today's training plan. Router operation and immediate actions in case of failure require special training. Vendor supplied courses cost $2,500 per student according to product literature supplied by Wellfleet Communications (47).

Maintenance - SMDS service maintenance costs are built-in to the cost of the service. The additional cost to service the router and CSU/DSU will need to be worked out between USA Today and the vendor supplying these devices. Alternatively, Bell Atlantic Network Integration can contract a service arrangement so there is a single point of contact for all SMDS related equipment. This entails purchasing Bell Atlantic recommended equipment so that a minimum level of performance from the CPE is present before Bell will assume maintenance responsibilities. Gill (24) states that past contracts have used Cisco routers, which are common, fairly priced and SMDS compatible. Dubendorf (20) states that the cost of such a turnkey maintenance arrangement is generally ten percent of the cost of all hardware involved.

The hardware identified for the SMDS solution includes the network server, CPU at each site, router at each site, CSU/DSU at each site, redundant T1 hardware, and LAN cabling. The average per site cost of all hardware is about $60,000, which makes the average maintenance cost per site around $6,000. Novell Netware comes with its own maintenance and support package.

Spare Parts - Spare parts inventory is required to keep the system functioning as required. Pinyot (30) indicates that USA Today currently stocks ten percent spares for all of its equipment at each site. This figure seems reasonable and spares cost is estimated as ten percent of hardware cost. The maintenance cost derivation above details the hardware cost on which the spare parts estimate is based.

Local Tariffs - Unlimited monthly usage of local SMDS service incurs a service charge of $550 per month according to Chesapeake and Potomac Telephone, a division of Bell Atlantic (33). This analysis assumes that SMDS will be tariffed nationwide according to the highest current cost, that of Washington, DC, which is $650 per month. The higher figure provides a more conservative cost estimate for this analysis.

Long Distance Tariffs - SMDS long distance tariff is assumed to be the same as that for Frame Relay service. The current frame relay tariff available from Sprint is $5,860 monthly per site, including port fees and unlimited usage of reserved permanent logical links. These costs are listed in Table 7.1. Sprint's Frame Relay service rate schedule (39) provides these figures. This is probably a high estimate since SMDS does not require virtual connections like those needed for frame relay.

Table 7.1. Sprint's Frame Relay Tariff Structure

Port Fees		Reserved PVC (PLL)	
Size	Cost	Size	Cost
(bit/sec)	($/month)	(bit/sec)	($/month)
64K	175	128K	480
128K	325	192K	700
256K	600	256K	920
384K	875	348K	1,356
512K	1,125	448K	1,580
768K	1,475	512K	1,800
1.024M	1,750	768K	2,680
***1.544M**	**2,300**	***1.024M**	**3,560**

Source: Sprint (39)

* = minimum required for SMDS compatibility
PVC = Permanent Virtual Circuit
PLL = Sprint's name for a PVC

Cost Summary

The cost to design, implement, operate, and maintain the SMDS system are presented in Tables 7.2 through 7.7 and Figures 7.1 through 7.5. Each of the tables and figures presents the cost data from a different perspective. Tables 7.2 and 7.3 show constant dollar non-recurring and annually recurring costs. Figure 7.1 offers a visual representation of the system cost profiles derived from Tables 7.2 and 7.3. Table 7.4 presents the constant dollar life-cycle cost of both systems for direct comparison. Table 7.5 shows the constant dollar satellite and SMDS system year-by-year costs to demonstrate the point at which the SMDS system becomes a superior alternative. Table 7.6 performs a sensitivity analysis of the satellite and SMDS system present value costs to determine whether the engineer's decision would change based on various interest rates. Inflation is not considered in this analysis. Figures 7.2 through 7.5 show the crossover points where the SMDS system becomes preferable to the satellite system at each of the interest rates shown in Table 7.6. Table 7.7 performs a sensitivity analysis similar to Table 7.6, except the future value costs are determined.

Table 7.2. Summary of Non-recurring Cost

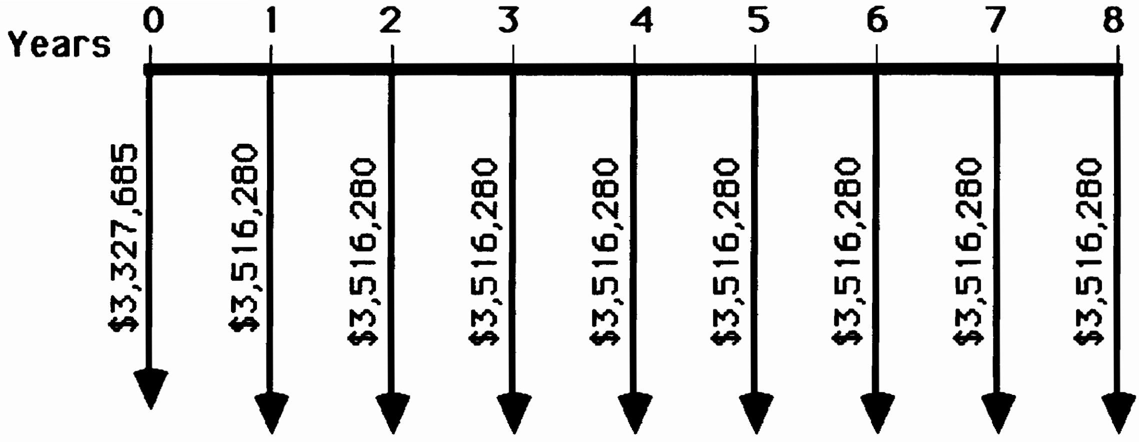
Non-recurring Costs

System Design	
System Design (per engineer per year)	$50,000.00
Two Engineers	**$100,000.00**
Headquarters Site (2 Sites: HQ and Backup HQ)	
Netware Server (based on Intellicom USA pricing)	$3,000.00
Netware 386 V3.11 (Novell quote for 250 users)	$12,495.00
CPU with Hard Disk (based on Intellicom USA pricing)	$3,000.00
Router (based on Wellfleet or Cisco)	$7,000.00
SMDS Router Software (based on Wellfleet or Cisco)	$1,000.00
CSU/DSU (based on ADC Kentrox or Data Link)	$6,500.00
Cabling/Installation (based on est. from CSI.)	$2,600.00
SMDS Access Line Charge (Bell Atlantic)	$1,000.00
Operator Training (Wellfleet product guide)	$2,500.00
Subtotal	**$39,095.00**
Redundancy at HQ site and single string at backup HQ:	**$117,285.00**
Remote Sites (32 remote sites)	
CPU with Hard Disk (based on Intellicom USA pricing)	$3,000.00
Router (based on Wellfleet or Cisco)	$7,000.00
SMDS Router Software (based on Wellfleet or Cisco)	$1,000.00
CSU/DSU (based on ADC Kentrox or Data Link)	$6,500.00
Cabling/Installation (based on est. from CSI)	$2,600.00
SMDS Access Line Charge (Bell Atlantic)	$1,000.00
Operator Training (Wellfleet product guide)	$2,500.00
Subtotal per site cost for single equipment string:	**$23,600.00**
Redundancy at each site gives per site cost:	**$47,200.00**
Route Diversity (based on TCI verification of estimate)	**$50,000.00**
Total for redundancy at all 32 domestic sites:	**$3,110,400.00**
Total Non-recurring Cost:	**$3,327,685.00**

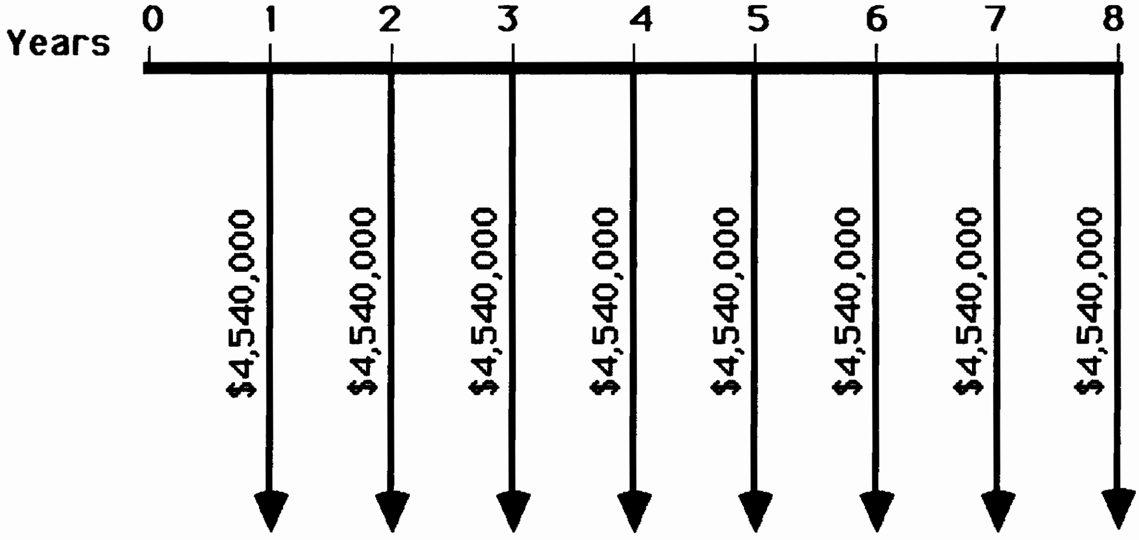
Table 7.3. Summary of Annually Recurring Cost

Recurring Costs (annual)

Headquarters (HQ and Backup HQ total)	
Software Engineering and Maintenance (2 engineers)	$100,000.00
Netware Upgrades and Maintenance (2 sites)	$2,000.00
	$102,000.00
All sites (HQ, Backup HQ, and 32 remote sites)	
Spares (based on 10% of total)	$6,000.00
Maintenance Contract (10% estimate from BANI)	$6,000.00
Local Tariffs (based on $650 per month per access)	$15,600.00
Long Distance Tariffs (based on $5860 per month)	$70,320.00
Operator Training (assume 1 per year)	$2,500.00
	$100,420.00
For 32 remote and both HQ Sites:	**$3,414,280.00**
Total Annual Recurring Cost:	**$3,516,280.00**



(a) Conceptual SMDS System



(b) Current Satellite System

Figure 7.1. System Cost Profiles

Table 7.4. Life-cycle Cost Analysis

<u>SMDS Alternative</u>	
First Year Total:	$6,843,965.00
Each Additional Year:	$3,516,280.00
Eight Year Life-Cycle Total for **SMDS**:	**<u>$31,457,925.00</u>**
<u>Satellite System Alternative</u>	
Annual Total:	$4,540,000.00
Eight Year Life-Cycle for **Satellite:**	**<u>$36,320,000.00</u>**

Table 7.5. Year-by-year Cost Comparison of Satellite and SMDS Alternatives

Running Total Cost Comparison (constant $)	Satellite	SMDS
Year 1 Cost (cumulative)	$4,540,000.00	$6,843,965.00
Year 2 Cost (cumulative)	$9,080,000.00	$10,360,245.00
Year 3 Cost (cumulative)	$13,620,000.00	$13,876,525.00
Year 4 Cost (cumulative)	$18,160,000.00	$17,392,805.00
Year 5 Cost (cumulative)	$22,700,000.00	$20,909,085.00
Year 6 Cost (cumulative)	$27,240,000.00	$24,425,365.00
Year 7 Cost (cumulative)	$31,780,000.00	$27,941,645.00
Year 8 Cost (cumulative)	$36,320,000.00	$31,457,925.00

Table 7.6. Comparison of Present Cost at Various Interest Rates

Comparing Present Cost:	Satellite ($) [$4.54M*(P/A)]	SMDS ($) [$3.52M*(P/A) +$3.3M]
Present Cost 8 year Life-cycle at 5% Interest: Present Worth Factor: P/A=6.4632	**$29,342,928.00**	**$26,054,105.90**
Present Cost 8 year Life-cycle at 10% Interest: Present Worth Factor: P/A=5.3349	**$24,220,446.00**	**$22,086,687.17**
Present Cost 8 year Life-cycle at 15% Interest: Present Worth Factor: P/A=4.4873	**$20,372,342.00**	**$19,106,288.24**
Present Cost 8 year Life-cycle at 30% Interest: Present Worth Factor: P/A=2.9247	**$13,278,138.00**	**$13,611,749.12**

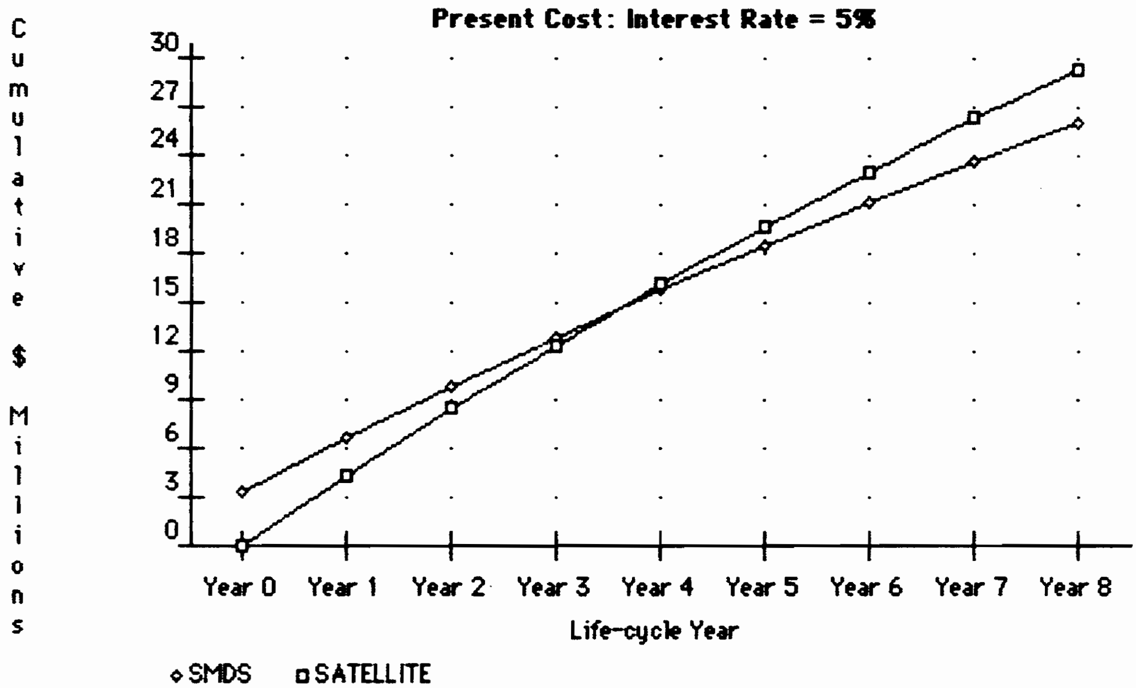


Figure 7.2. Break-even Analysis of Cumulative System Costs at 5% Interest Rate

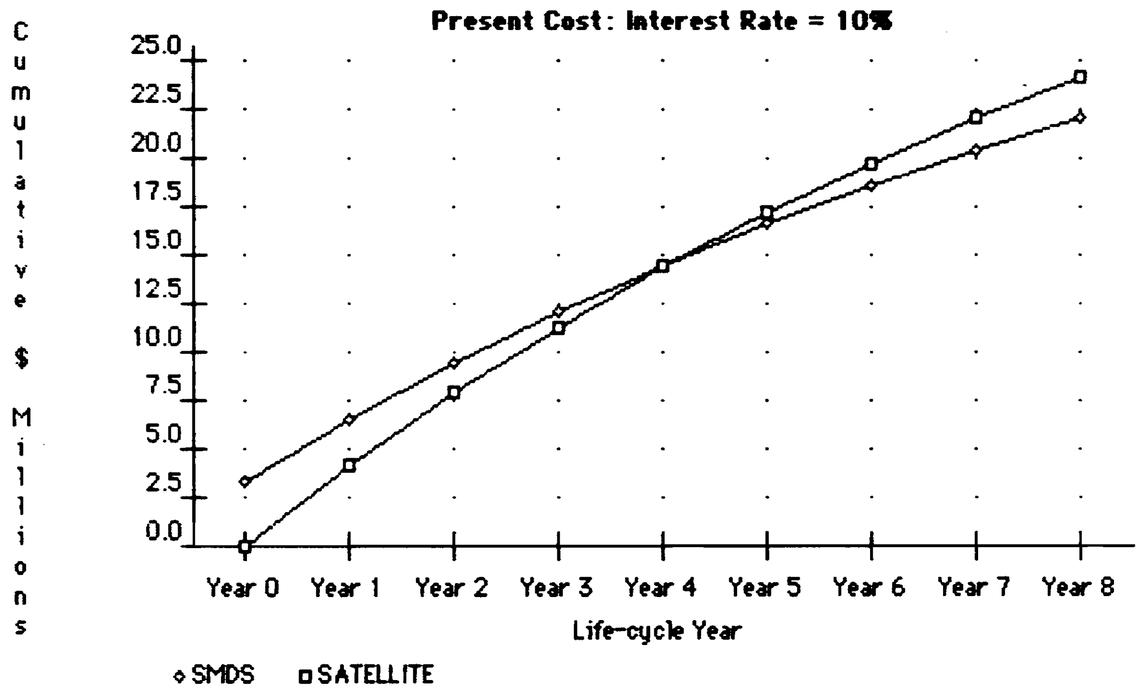


Figure 7.3. Break-even Analysis of Cumulative System Costs at 10% Interest Rate

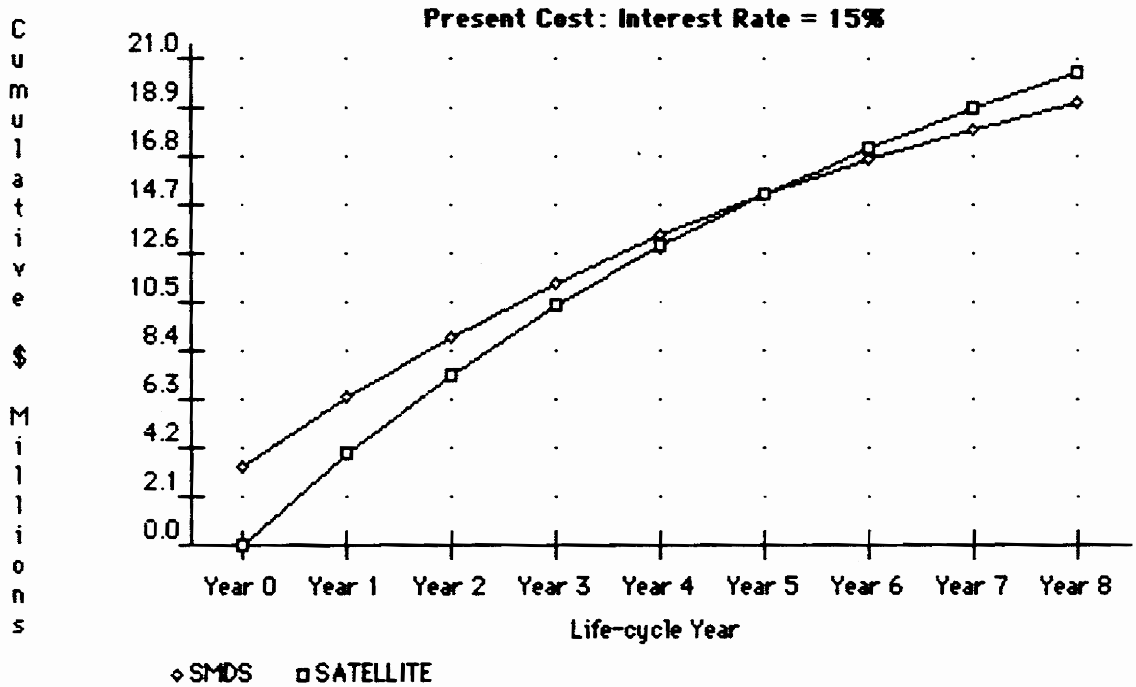


Figure 7.4. Break-even Analysis of Cumulative System Costs at 15% Interest Rate

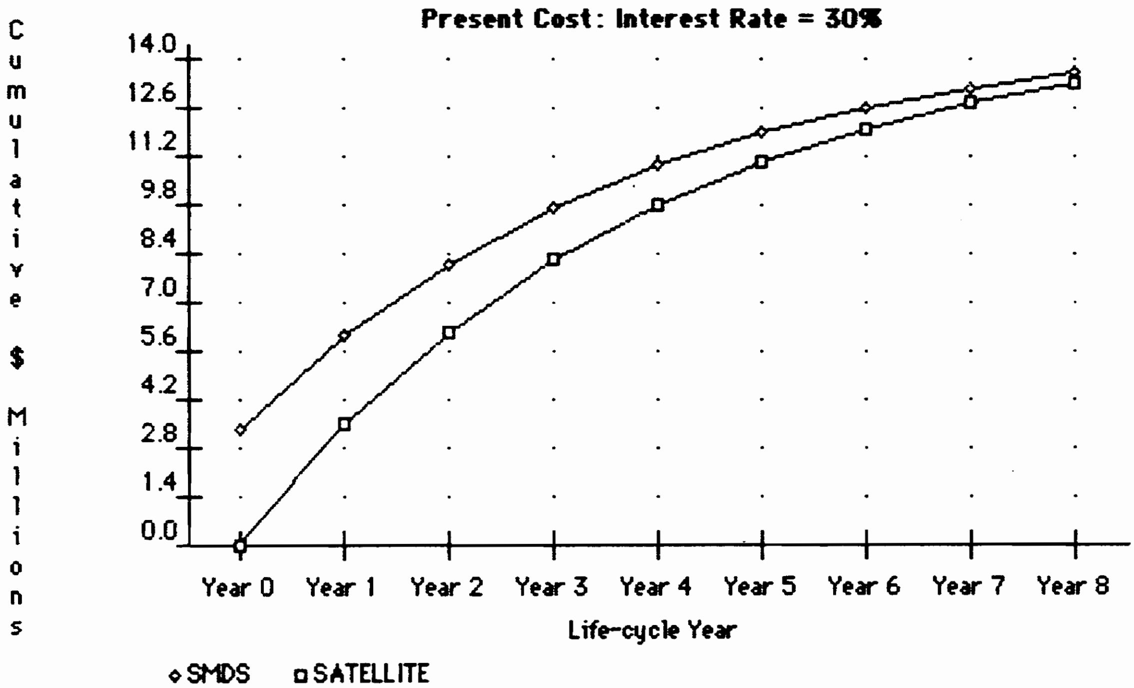


Figure 7.5. Break-even Analysis of Cumulative System Costs at 30% Interest Rate

Table 7.7. Comparison of Future Cost at Various Interest Rates

Comparing Future Cost:	Satellite ($) [$4.54M*(F/A)]	SMDS ($) [$3.52M*(F/A)+ $3.3M*(F/P)]
Future Cost 8 year Life-cycle at 5% Interest: Compound Amount Factor: F/P=1.477, F/A=9.549	**$43,352,460.00**	**$38,491,948.47**
Future Cost 8 year Life-cycle at 10% Interest: Compound Amount Factor: F/P=2.144, F/A=11.436	**$51,919,440.00**	**$47,346,734.72**
Future Cost 8 year Life-cycle at 15% Interest: Compound Amount Factor: F/P=3.059, F/A=13.727	**$62,320,580.00**	**$58,447,363.98**
Future Cost 8 year Life-cycle at 30% Interest: Compound Amount Factor: F/P=8.157, F/A=23.858	**$108,315,320.00**	**$111,035,334.79**

Conclusion

Based on the factors considered in this analysis SMDS performs well enough to be considered as an alternative telecommunications strategy for USA Today. Even when the additional cost of route diversity for each remote site is considered, the SMDS alternative surpasses the satellite alternative in economic performance within the first four years of the project's life-cycle. Only under the unlikely economic scenario of 30 percent interest does the current satellite alternative become more economically sound than the SMDS solution.

The SMDS solution will allow USA Today to continue its current format preparation and printing processes at lower cost than the current satellite configuration. Simultaneously, the SMDS system will allow USA Today to migrate from its obsolete facsimile technology to modern publishing applications that require significantly greater bandwidth than the satellite system provides. USA Today achieves both short and long term business objectives by implementing the SMDS solution.

Next Steps

If USA Today finds merit in this conceptual design analysis, the next logical step includes continuing the iterative systems analysis process and moving forward with preliminary design. Questions raised by this conceptual design analysis should be researched until USA Today is satisfied that the analysis addresses all of their concerns.

It should be noted that all risk cannot be engineered away. A major part of a working system involves writing enforcable contracts. This analysis does not address the specific workings of the maintenance or vendor support contracts. However, USA Today will need to ensure that the cost of vendor services, and liability for non-performance, are detailed in legal contracts. USA Today's business success depends upon reliable SMDS service. If that service fails at the headquarters site, a credit for the $650 monthly SMDS service charge will not replace the revenue consumer confidence lost when no papers are delivered. USA Today must somehow convince the service provider to contractually stand behind its product, and pay for the losses caused by product failure.

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Appendix A: The International Organization for Standards (ISO) Seven Layer Open Systems Interconnection (OSI) Reference Model

Introduction

This appendix provides a very brief discussion on the OSI reference model. The information presented gives a basic introduction to the layer concept for dividing up the task of inter-device communications. A more thorough discussion of the ISO reference model is found in Stallings (42 and 43).

OSI Reference Model

Transferring data between computers is not a trivial task. Communications between different machines frequently involves protocols that are incompatible. In other words, the different machines cannot interpret each other's way of communicating. IBM product incompatibility with Apple products provides a classic example of protocol incompatibility, but the problem occurs in virtually every area of computer communications. The following information is paraphrased from Datapro (16).

The International Organization for Standards (ISO) developed the seven layer Open Systems Interconnection (OSI)

Model in an attempt to simplify inter-device, or machine to machine, communications. The model calls for cooperation between systems of different vendors and designs. The model uses a layering concept to establish functional boundaries within the model hierarchy. There are seven layers working to achieve the goals of two distinct functional groups. The first functional group is the Application Platform, which interprets data and presents it to the system user in usable form. The Application Platform comprises layers 5, 6, and 7 of the OSI model. The application platform is concerned with what the user sees on the monitor. Interactive programs operate at the highest level of the OSI model.

The second functional group is the Transport Platform, which has the function of getting data from one system to the other without errors. The Transport Platform is made up of layers 1 through 4 of the model. The Transport Platform handles the rudimentary communications details, such as how long each electrical pulse over a computer cable must be to represent a particular character. The transport platform also handles error detection and recovery in the event of failed data transfers, and sets up and terminates inter-device connections.

The workings of the OSI model are transparent to the computer user. The data translation and manipulation takes place inside the system logic so that the user only sees interpretable information displayed on the computer screen. Each communication made between different devices must negotiate each of the seven layers of the model to ensure no portion of the data translation is missed. Table A1 lists the seven layers and provides a brief description of the purpose of each layer.

SMDS requires the use of a router and CSU/DSU to access the service network. Figure A1 illustrates where the router and CSU/DSU (considered one piece of equipment in the figure) fit in the seven layer hierarchy of the OSI model. Figure A1 also shows the SMDS interface protocol (SIP), which operates across layers 1 and 2 of the OSI model. Appendix C explains the functions of the SIP in greater detail.

Table A1. The OSI Layers

Layer	Purpose
7 - Application	Provides services to the users of the OSI environment; examples: transaction server, file transfer protocol, network management.
6- Presentation	Performs generally useful transformations on data to provide a standardized application interface and to provide common communication services;examples: encryption, text compression,reformatting.
5 - Session	Provides the control structure for communications between applications; establishes, manages, and terminates connections (sessions) between cooperating applications.
4 - Transport	Provides reliable, transparent transfer of data between end points; provides end-to- end error recovery and flow control.
3 - Network	Provides upper layers with independence from the data transmission and switching technologies used to connect systems; responsible for establishing, maintaining, and terminating connections; (X.25, layer 3).
2 - Data Link	Provides for the reliable transfer of data across the physical link; sends blocks of data (frames) with necessary synchronization, error control, and flow control (HDLC, SDLC, BiSync).
1 - Physical	Concerned with transmission of unstructured bit stream over phsical link;involves such parameters as signal voltage swing and bit duration; deals with the mechanical, electrical, and procedural characteristics to establish, maintain, and deactivate the physical link; examples: (RS-232-C, RS-449, X.21).

Source: Stallings (41) pg. 48

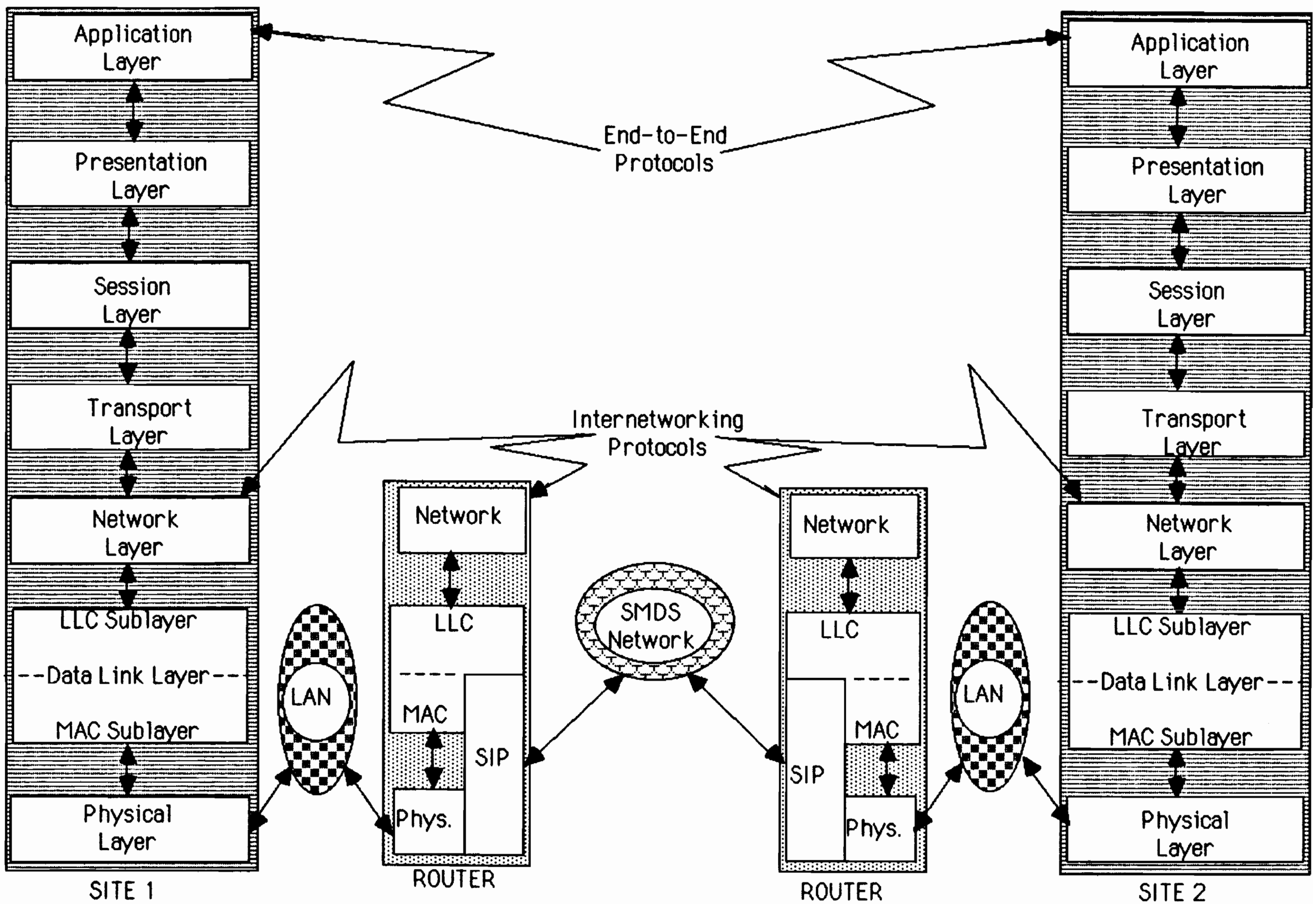

Figure A1. Router Function in an SMDS Network

Appendix B: Ethernet

Introduction

Ethernet was originally designed by a consortium of vendors led by Xerox. During the technology's evolution, the Institute of Electrical and Electronics Engineers (IEEE) and Xerox produced follow-on versions of the standard that were nearly identical. IEEE decided to adopt its own standard, so Xerox was never able to approach the financial gain envisioned when it began developing Ethernet. The following discussion presents some of the basic principals governing how Ethernet works and how it is physically connected. A more thorough presentation on Ethernet is available in Harris (25).

Basic Description of Ethernet

Ethernet is a very common designation for carrier sensed multiple access with collision detection (CSMA/CD) networks. Ethernet is a baseband technology, meaning that binary one's and zero's appear as electrical voltage pulses over the wires connecting the network. For instance +5 volts might represent a one, while 0 volts might represent a zero. The wiring scheme used to connect the Ethernet network is described as a bus topology, which is nothing more than a linear piece of wire or cable to which all of the devices sharing the network are attached. Ethernet operates at layers 1 and 2 of the OSI model. It handles the synchronization, flow control, error control, and transmission of the bit stream over the physical cables connecting the network. The basic operating principal behind Ethernet is that only one device on the network can transmit at any given time. If more than one device transmits at the same time, data "collisions" occur which corrupt the data from the colliding transmitting devices. A simple example of this type of collision occurs when two people engaged in a telephone conversation attempt to speak at the same time.

Ethernet logic uses statistical methods to ensure that no two devices attempt to transmit at the same time. The Ethernet technology has proven reliable, simple to install and maintain, and very inexpensive. Current versions of Ethernet, including 10BaseT (10 megabits per second/baseband/twisted pair), operate over simple twisted pair telephone wire. Each device connecting to an Ethernet network must have an Ethernet logic card, which governs access to the physical wire, or medium. If a collision between two transmitting devices is detected, the logic card will statistically determine how long to wait before attempting a retransmission. Ethernet is the network of choice for many applications, including the SMDS system described in this project.

Appendix C: SMDS Specific Information

SMDS Specifics

SMDS has been presented as a "black box" that magically trransports data at incredibly high speeds. This appendix provides more specific information to aid the reader in understanding the intricate processes involved in the SMDS service.

Creation of the SMDS Cell

The router and CSU/DSU, which are part of the SMDS CPE and will reside at each USA Today location, work together to produce the SMDS network formatted data cell. The SMDS cell is the key to the high bandwidth achieved using SMDS. By breaking the data into small cells, the network can effectively put all available data paths to work transporting data. Figure C1 shows the evolution of the data packet received from the USA Today LAN to the creation of the SMDS interface protocol cell. The cell is formatted according to the SMDS Interface Protocol (SIP) prior to leaving the CPE and entering the switching system comprised of local exchange and interconnect

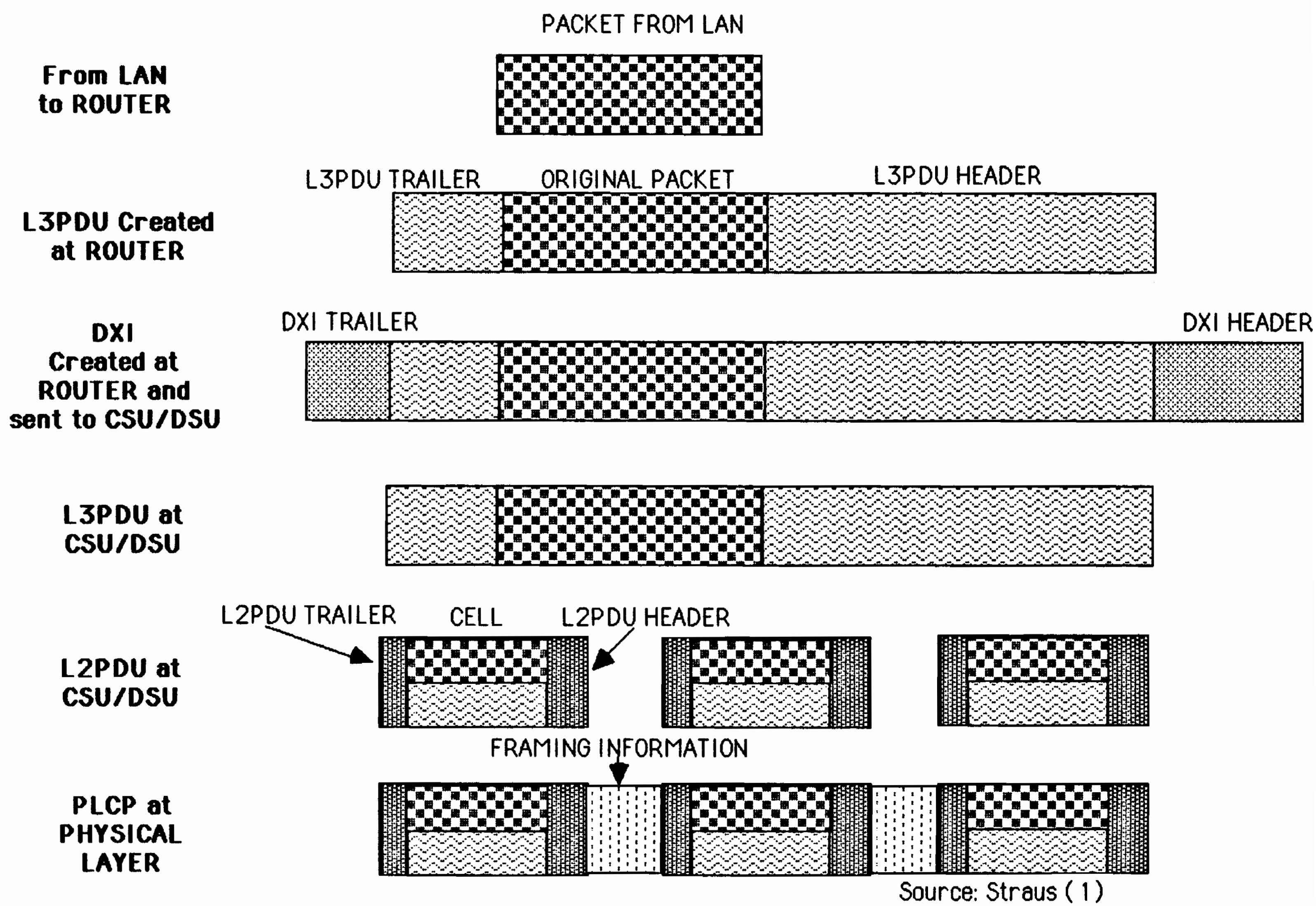

Figure C1. Local Area Network to SMDS Network Data Transition carrier networks. The three levels of the SIP correspond to the data link and physical layers of the OSI protocol stack referenced in Appendix A. Accordingly, the SIP receives customer formatted blocks, or packets, of data and prepares them for transmission over a physical medium. The SIP will receive USA Today's Netware IPX data, which is formatted by the Netware 386 network operating system, and transform it into SMDS compatible data.

The SIP contains three levels. The router at level 3 receives an addressed packet, or SMDS data unit (SDU), from the transmitting equipment. The SDU contains up to 9,188 bytes of customer data. The router appends a 36 byte header and four byte trailer, transforming the encapsulated SDU into what is known as a level 3 protocol data unit (L3PDU).

At this point the L3PDU is passed to SIP level 2, where an additional four byte data exchange interface (DXI) header and two byte DXI trailer are appended. The customer's router then passes the encapsulated L3PDU to the CSU/DSU, which identifies the data by the DXI header and trailer then strips off and discards this intermediate identification information.

At this point the CSU/DSU has the original L3PDU, which is 9,228 bytes long. The CSU/DSU first reads the addressing information contained in the L3PDU. The CSU/DSU then breaks the L3PDU into 44 byte cells called segmentation units (SU) and appends a seven byte level 2 protocol data unit (L2PDU) header and two byte L2PDU trailer to each cell. This header and trailer information is used to pass the cell across the SMDS network to the receiving router/CSU/DSU. The cell is passed to SIP level 1 where the CSU/DSU inserts four bytes of framing information between each 53 byte L2PDU and forwards the bit stream to the network via the physical layer convergence protocol (PLCP), which defines the rules for SMDS physical connectivity at layer one of the OSI protocol stack.

The SMDS network forwards the SMDS cells via available routes to the identified receiving CSU/DSU and router. At the receiving location, the cells are reassembled in the reverse order of the segmentation process. The receiving station sends a Novell IPX acknowledgment to the sender indicating that the data was received. If an intermediate hop is required to traverse the entire wide area network, the intermediate node is identified as the receiving station for SMDS purposes. At the intermediate node the entire L3PDU is reconstructed so that the true destination address can be determined, and the cell formation occurs all over again. This reconstruction and reformation occurs in only a few milliseconds within the superfast SMDS switches.

Appendix D: For The Future

Overseas Issues

USA Today treats its overseas operation as a completely separate business entity from its domestic business. The current satellite configuration addresses overseas locations differently than the US sites (different frequencies and transmission strategies). Overseas issues are not addressed in this analysis, but the technology to transmit SMDS data overseas is available. Regardless of whether a satellite hop is required to achieve overseas connectivity, the system can still work since long haul carriers provide bandwidths greater than T1 over satellite links. According to Stallings (47), they do so by using single sideband frequency division multiplexing to achieve mastergroups (combined voice channel equivalent groups) capable of carrying 600 voice channels. This equates to a data rate of 2.52 megahertz, or roughly 2.5 megabits per second.

If bandwidth is not a problem then the only issue left for resolution is that of data latency (delay) tolerance in the network operating system. If the network operating system can tolerate data latency to the extent required to allow a signal to traverse a satellite hop to Hong Kong or Zurich and back again, for the purposes of transmission and acknowledgment, then the service will work. Selection of the network operating system is addressed in Chapter 5. For now, it is sufficient to understand that such a network operating system (Novell's Netware 386, which allows the user to program the acceptable delay) is available at a very reasonable price. This is an example of advanced system planning. Since it is known that the system requires a component capable of a certain function, the analysis may be sidetracked until it is proven that such a component is available. The technology is not the issue. The overseas installation of SMDS is currently held up by the government controlled telephone companies of foreign countries. Only time will tell when the inter-country squabbling will allow world-wide access to SMDS services.

Appendix E: List of Acronyms

ACK	Acknowledgement of transmission receipt
AppleTalk	Apple Computer's network protocol
AT&T	American Telephone & Telegraph
ATM	Asynchronous Transfer Mode
BANI	Bell Atlantic Network Integration
Bellcore	Bell Communications Research (funded by ex-AT&T consortium)
CCITT	International Telephone and Telegraph Consultative Committee
CO	Central Office (Telephone company office serving the LATA)
CPE	Customer Premises Equipment
CPU	Central Processor Unit
CSI	Communications Services International (now called A-COM)
CSMA/CD	Carrier Sensed Multiple Access with Collision Detection
CSU/DSU	Channel Service Unit/Data Service Unit
DDD	Direct Dial Disconnect (Type of Network)
DNCC	Data Network Control Center
DOD	Department of Defense
DRT	Digital Receive Terminal (GTE hardware)
DXI	Data Exchange Interface

EBCU	Expanded Broadcast Control Unit
ETSI	The European Communications Standards Organization
F/A	Future cost given annual payment
F/P	Future cost given present value
F1, F2	Frequency 1, Frequency 2
FCC	Federal Communications Commission
FD	Floppy Disk Drive
GTE	Telecommunications vendor providing USA Today's satellite service
ICI	Interconnect Carrier Interface (local/long distance carrier boundary)
IEEE	Institute of Electrical and Electronic Engineers
IEEE 802.6	IEEE MAN standard governing SMDS
IPX	Novell, Inc.'s Internetwork Packet Exchange
ISO	International Organization for Standards
Kbps	Kilobit per second (thousands of bits per second)
L2PDU	Layer 2 Protocol Data Unit
L3PDU	Layer 3 Protocol Data Unit
LAN	Local Area Network
LATA	Local Access and Transport Area (local telephone area)
LNA	Low Noise Amplifier (Antenna hardware)

MAN	Metropolitan Area Network
MB	Megabyte
Mbps	Megabit per second (millions of bits per second)
MODEM	Modulator/Demodulator (communication hardware)
MTTR	Mean Time To Repair
NAK	Negative acknowledgement of transmission receipt
OSI	Open Systems Interconnect
P/A	Present value given annual payments
PLCP	Physical Layer Convergence Protocol
PLL	Permanent Logical Link
POC	Point Of Contact
PVC	Permanent Virtual Circuit
RAM	Random Access Memory
SIP	SMDS Interface Protocol
SMDS	Switched Multimegabit Data Service
SNI	Subscriber Network Interface (customer/phone service boundary)
SONET	Synchronous Optical Network
SU	Segmentation Unit
T1	Industry designation for a trunk with 1.544Mbps capacity

T3	Industry designation for a trunk with 45Mbps capacity
TCI	Telecommunications Concepts, Incorporated
TCP/IP	Transmission Control Protocol/Internet Protocol (DOD standard)
TMT	Transmission Monitor Terminal (GTE hardware)
USATHQ	USA Today Headquarters in Arlington, VA
V.35	OSI layer 1 electrical standard for data transmissions at 48Kbps
WAN	Wide Area Network
X.25	CCITT standard for packet network
10BaseT	One Variation of Ethernet configuration