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Digital Data System:

System Overview

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This paper presents an overview of the Digital Data System. The services to be provided are described and the premises for establishing both service and system objectives are discussed. The network concept, planning for its growth and administration, and a description of the network elements are presented as an introduction to the detailed papers which follow.

I. INTRODUCTION

The Digital Data System (DDS) is a new data communications network that is integrated into the nationwide telecommunications system. With this network, *Dataphone®* digital services are available. Point-to-point and multipoint private line services are provided. The first allows digital communication between two subscriber terminals, while the latter allows several terminals at different locations to share a common transmission channel. Data rates of 2.4, 4.8, 9.6, and 56.0 kb/s are offered. These services are similar to those which have been available for the past decade using analog telephone channels of various bandwidths. The new system, however, utilizes station-to-station digital transmission techniques as contrasted to modulation and demodulation of digital signals to and from analog form for transmission over telephone channels.

Existing business machine terminals are directly usable on the system through industry standard interfaces or, if the customers prefer, connection may be made at a four-wire channel service interface. Data transmission is synchronous; timing signals are always supplied from the network.

The DDS has become practical and desirable through the large-scale deployment of digital transmission systems in metropolitan areas, the development of long-haul digital transmission systems, progress in technology, and the development of a sufficient market for the services. It offers economies in the cost of transmission and, by taking advantage of the regeneration, monitoring, and protection approaches applicable to digital signals, it promises a higher-quality service than has been realized in using analog telephone systems for data communication.

The system is complex in that it comprises many elements of hardware, planning, operation, and administration. A unique set of abbreviations and acronyms has naturally developed. The appendix is a glossary of those used in this and the accompanying papers.

II. A DDS SERVICE

A point-to-point *Dataphone*® digital service in which a customer's channel interconnects two stations located in different cities is shown in Fig. 1. Three main parts of the DDS are readily identifiable: a local distribution system that makes use of readily available telephone distribution cable pairs to reach the subscriber, a metropolitan area network of digital lines for collecting customer channels from many serving central offices into one "hub" office which acts as the serving test and administration center, and the intercity network of long-haul digital transmission facilities.

From a station, the customer's channel is carried to a local serving office by a newly designed loop transmission system which includes station equipment, a four-wire loop (cable pairs), and an office channel unit which processes the data signals into a format for entry into the network. The local serving office serves as a collection point for individual channels.

The channel is then combined with other channels terminating in the same serving office by a time-division multiplexer into one high-speed signal for efficient transmission over a digital line to a hub office. A hub office acts as a collection point for channels coming from numerous serving offices in the metropolitan area. In the hub office, the channel is separated from other channels by demultiplexing it from the incoming high-speed bit stream to provide maintenance test access and to allow it to be connected to the desired long-haul transmission system.

The channel is then combined with other channels destined for the same distant city by a time-division multiplexer into a single high-

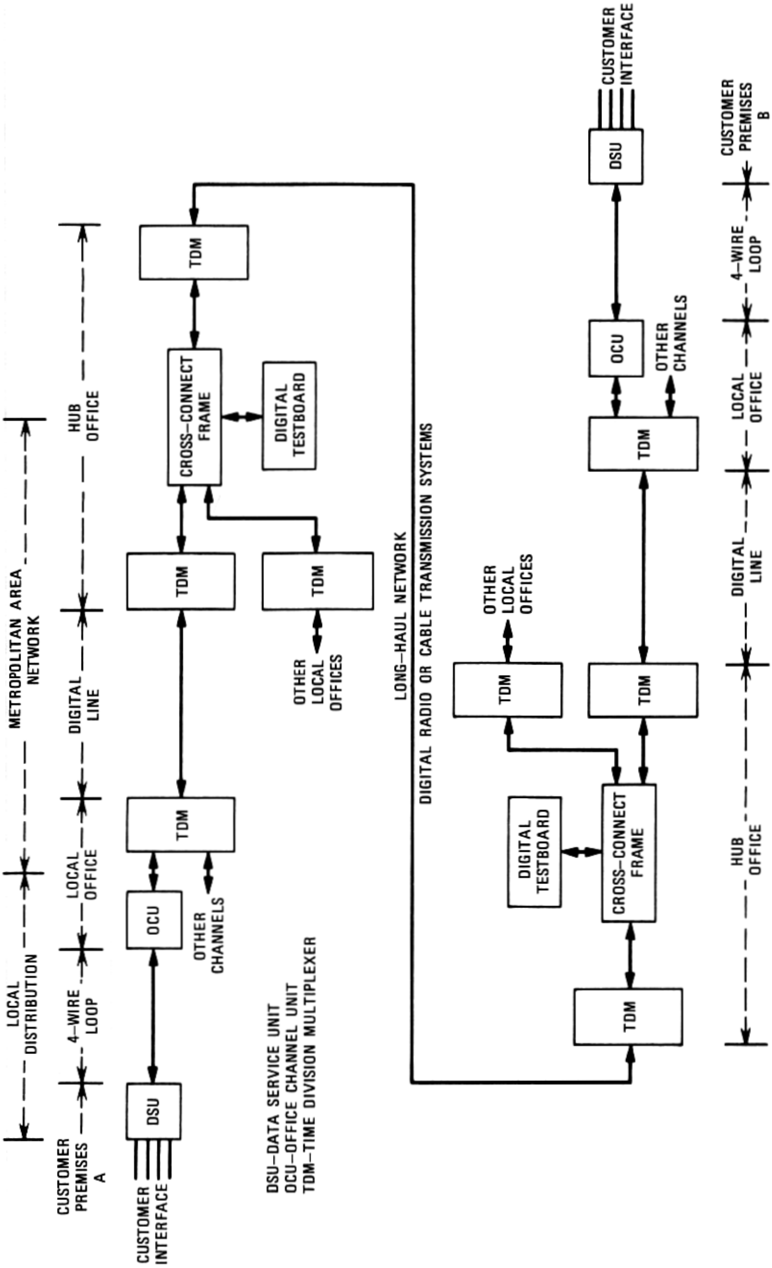

Fig. 1—A point-to-point DDS service.

speed signal for long-haul transmission through the intercity network to the distant hub office. The high-speed signal may be carried over radio or cable systems of several types.

When the high-speed signal reaches the hub office in the destination city, the individual channels are again separated and each is made available for maintenance test access. The customer's channel is then routed to the desired serving office via multiplexers and digital lines in the metropolitan area network and finally to the second station by means of a local loop-transmission system.

This example shows the most simple point-to-point channel including a single link in the long-haul intercity network between hub offices and one local office in each of the two cities involved. In reality, a customer's channel may pass through several local and hub offices of different kinds while traversing the network and may be demultiplexed and remultiplexed several times to efficiently load each link encountered.

III. NETWORK CONCEPT

It is planned that the DDS will rapidly grow into a nationwide network arranged in a three-level facility hierarchy. The highest-level regional hub offices are interconnected by large cross-section transmission facilities and are located along major existing radio and cable transmission routes. Second-level sectional hub offices home on and have transmission links to only one regional hub. Third-level metro hub offices, in turn, home on only one sectional hub office. Within this three-level framework, the geographical area surrounding a hub office is designated either a class I, class II, or class III digital serving area (DSA) corresponding, respectively, to the level of hub office. Facility engineering rules have been developed to provide the required digital transmission capacity between any DSAs in the network in a manner that realizes efficient loading of the facilities.

Each hub office contains time-division digital multiplexers, timing supplies, digital testboards, cross-connect arrangements for flexible channel interconnection, and customer loop terminations for the immediate geographical area. Transmission throughout the network is synchronous. One regional hub office will ultimately contain the timing supply that acts as the master source for the entire network. This supply will be locked to the Bell System reference frequency standard. Timing is derived in each office from selected incoming communication bit streams and is successively passed to equal or lower-level offices in the same manner. This approach synchronizes the entire network by creating a tree-structured timing network.

Homing on the hub offices of the three-level intercity network are the metropolitan networks of serving central offices. An example is shown in Fig. 2. Local serving offices are designated either as intermediate offices or end offices. They are at the end branches of the tree-structured timing network and derive timing information, in the same manner as higher-level hub offices, from selected incoming bit streams. The manner in which local offices are engineered and designated is determined by the characteristics of a particular metropolitan area and the network configuration best suited to the existing central office locations and subscriber distribution. As in the hub offices, local offices contain digital multiplexers, timing supplies, and subscriber loop terminations.

Standard telephone loop plant is used from the nearest DDS central office, local or hub, to reach the subscriber premises. Station terminal equipment is provided to operate at the service data rate and with the appropriate interface.

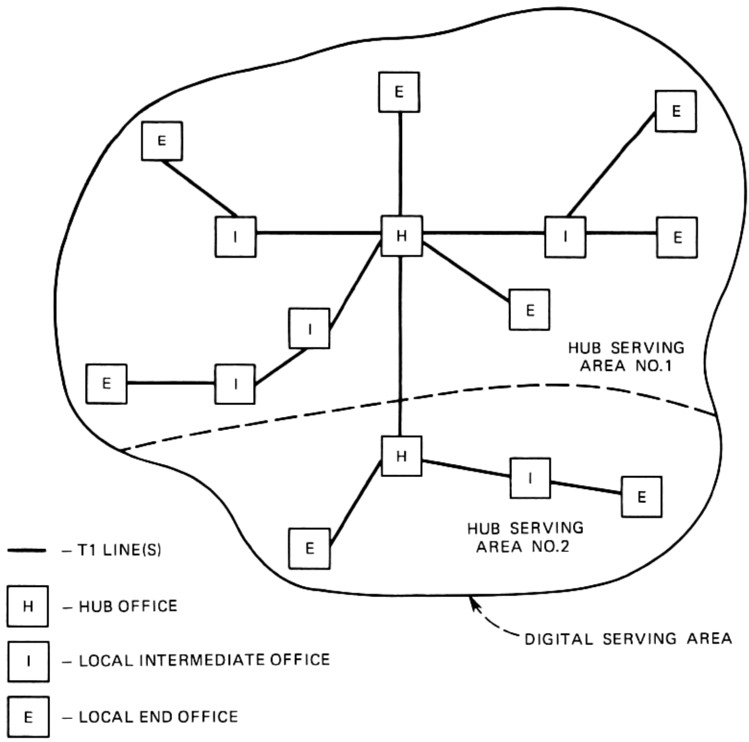

Fig. 2—Example of DDS metropolitan network.

All long-haul facilities in the network are protected by the normal radio or cable protection-switching systems. Digital line facilities in the metropolitan area plant are continuously monitored and protected by standby lines. Time-division multiplexer terminals are continuously monitored and, if a failure occurs, protection equipment automatically takes over. Service-affecting failures result in major alarms, while failures covered by protection equipment result in minor alarms calling for maintenance effort.

Transmission testing for installation or maintenance of subscriber channels is carried out primarily from testboard positions located in hub offices where each channel may be accessed with digital test equipment. Remotely controlled loop-around features activated by digital control code signals make it possible for a testboard operator to isolate trouble to the station, loop, or network without aid from either the subscriber or another testboard operator. Most troubles in or between offices are detected and appropriate personnel informed by alarms before the customer has reported a trouble.

Facility assignment, monitoring, and restoration activities are carried out by the same centralized approaches as have been recently evolving for voice telephone facilities. Within metropolitan areas, this is primarily through T-carrier restoration control centers, and, in the long-haul plant, by regional operating control centers.

IV. OBJECTIVES

New approaches have been taken in establishing both service and system objectives for the DDS.[1] It is recognized that the long-term average bit error rate is not a complete characterization of the performance of a data communication service. For the user to plan effective communication systems, a more useful characterization of performance includes (*i*) the expected amount of the time the service will be available for use, and (*ii*) knowledge of how error events are distributed in time while the service is available. These are the terms in which the objectives for the DDS have been established. Equipment designs, maintenance approaches, and administrative procedures have been directed toward achieving the objectives.

In establishing error performance objectives, the causes of errors were considered. These include such events as protection switches of terminals or transmission links and radio transmission fades. From past experience, it is known that errors usually occur in bursts that can cause considerable variation in the measured average bit error rate but have little effect on the efficiency of the communication. An objective has been established to provide transmission which is error-free in 99.5 percent of all one-second intervals. This objective now offers guidance, for example, in the design of terminals that use block retransmission for error correction and places a bound on the overall throughput efficiency that can be expected.

In establishing service-availability objectives, the kinds of failures that can occur as well as experience in restoring such failures have been considered. An objective has been established that a customer's service will be available for his use an average of 99.96 percent of the time. Allowable outage time is allotted to the various parts of a customer channel. After realistic experience values of repair or restoration time are applied to the transmission systems, subscribers' loops, etc., the remaining time within the objective is allotted to new parts of the system. Where necessary, automatic protection features have been included in terminal or transmission system designs to eliminate most causes of system outage. Maintenance alarm and testing features with appropriate procedures are designed into the system for isolation of trouble conditions and initiation of repair based upon allocations within the objectives.

Planning the system design and operation, while based upon new approaches to establishing objectives, has followed the concepts of centralized administration and restoration control that have been introduced into the telephone network. DDS signal transmission formats are identical to those of PCM voice systems, so they require no special treatment or recognition for either maintenance or administrative activities.

V. NETWORK PLANNING

Communities of interest requiring data communication services are geographically widespread. For the DDS to provide effective communication systems, the network must grow to reach almost every part of the country. Growth must be simultaneous in two dimensions: the interconnection of many metropolitan areas by long-haul digital routes and the penetration of each area to a large number of serving central offices.

Developing a viable growth plan[2] requires the determination of not only a facility network but also the rate of growth in each dimension if the available resources are to be properly used. Estimates of the potential market and location, and information on available or planned transmission routes, have been the basic inputs to the planning studies. Computer aids have been developed to assist in optimizing the initial and growth configurations of the intercity and metropolitan area portions of the network. The output of these aids is directly usable in engineering the system, in forecasting, and ultimately in programming equipment manufacture.

Many objectives and features of the network have led to new areas of planning. For example, maintaining the network synchronization plan requires long-term centralized control of the plan and rapid availability of information to permit connection of new offices or routine rearrangements. New forms of circuit-layout cards specifically designed for digital channels must be available quickly at numerous locations so that tests may be conducted and trouble isolated within objective time limits. Time-shared computer approaches are being utilized where possible for these and other areas of network planning and administration.

VI. NETWORK ELEMENTS

Development of the DDS network concept required the formulation of a plan to use the digital transmission systems already available, or planned for various other services, and definition of the required equipment or systems specific to data services and their unique objectives. The T1 carrier DS-1 digital signal rate (1.544 Mb/s) offered a basic digital capacity available in both short-haul and long-haul transmission plant. Subscriber loop cable plant offered the practical way of reaching the subscriber premises. The additional systems requiring design and development effort to implement the network were the loop and station transmission system, time-division multiplexers and protection equipment, channel interconnection arrangements, test access and test equipment, and timing supplies for signal synchronization.

Figure 3 shows the relationship of network elements below the 1.544-Mb/s (DS-1) digital transmission level.

6.1 Loop transmission system

The subscriber loop transmission system[3] utilizes twisted-pair cable facilities to provide full-duplex four-wire transmission between the subscriber's premises and his serving DDS office. The loop is terminated in either a data service unit (DSU) or a channel service unit (CSU) at the subscriber's location and in an office channel unit (OCU) at the central office. A DSU interfaces a business machine terminal with industry standard control, timing, and data leads and performs all the signal shaping, encoding, and decoding necessary to communicate with the network. A CSU provides only the necessary circuitry to properly terminate the loop with a well-defined interface and allow it to be tested from a central office location. Where a CSU unit is provided, the timing recovery and signal encoding and decoding is incorporated into the business machine terminal. Transmission on the loop is bi-

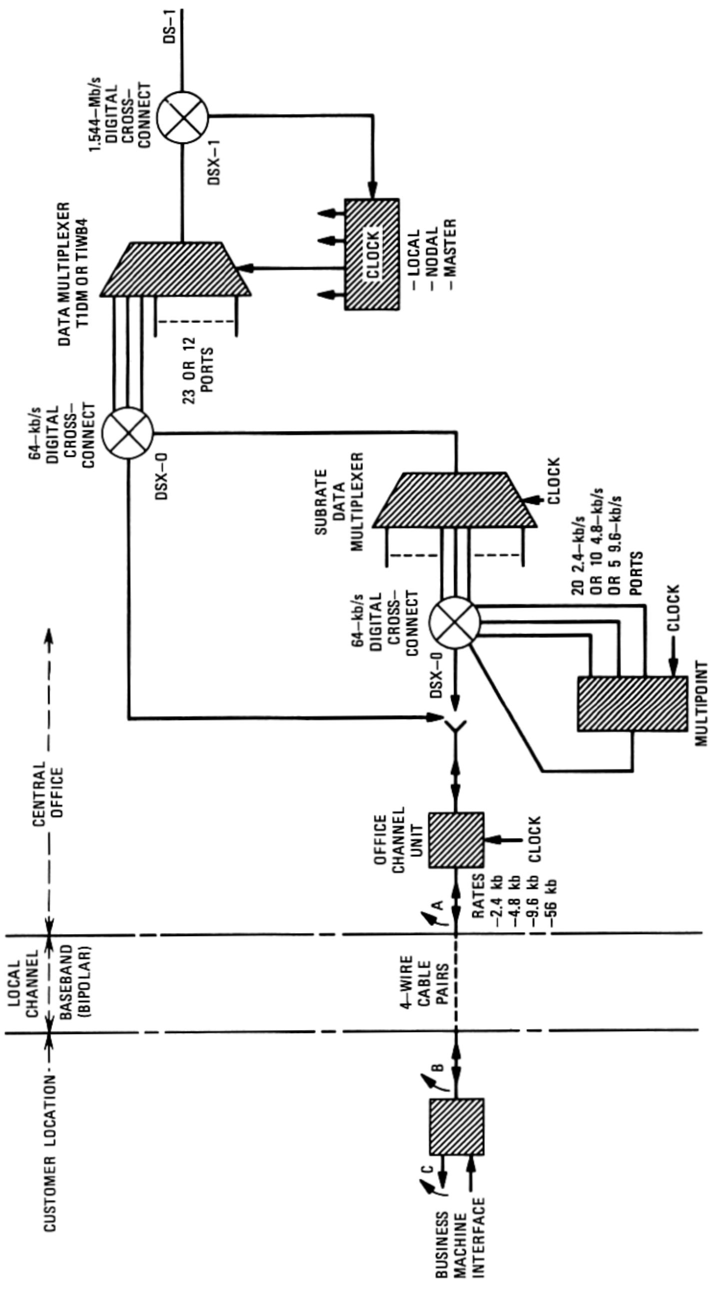

Fig. 3—DDS network elements below DS-1 level.

polar baseband with specific violation patterns to encode test and supervisory control information into the bit stream. Pulse rates are at the service data rate. Transmitting power levels are chosen to minimize the problems of pair selection and coordination with other services in the same cable sheath. The OCU performs similar functions to those of the DSU toward its loop side. On the central office side, it forms the data signals into a "byte" format, adds the necessary control information, and, regardless of the service data rate, builds the signal up to a universal 64-kb/s interconnection rate that has been designated as a "DS-0" signal. This prepares the signal for interconnection to multiplex ports, junction units, or other subscriber loop terminations.

6.2 Time-division multiplexers

A two-stage synchronous multiplexer organization has been developed.[4] The first stage is available in arrangements that accept either twenty 2.4-, ten 4.8-, or five 9.6-kb/s service rate channels, each having been converted to the DS-0 format by the office channel unit, and deliver a single DS-0 signal. Since the multiplexing organization is synchronous, the required rate-changing is a simple process of "byte" repetition or deletion. Two types of second-stage multiplexers are provided: the T1DM which combines up to 23 data channels into a DS-1 signal format, and the T1WB4 which, in conjunction with a D-type channel bank, combines a flexible mixture of up to 24 data and voice channels into the same format. The latter type provides less equipment redundancy and is more economically suited to central offices serving a small number of DDS subscribers. The channels derived by either will accept the DS-0 signal from office channel units, first-stage multiplexers, a 56-kb/s service rate channel, or other multiplexer ports. Modular hardware design of the multiplexer terminals allows complete freedom to equip only the channel capacity required, and to change capacity by addition or removal of plug-in circuit modules without service interruption. Performance-monitor equipment continuously scans the multiplexers in an office and, if a persistent failure is detected, causes protection circuitry to be switched into operation.

By application of the two stages of multiplexing, a flexible mix of customer channels may be derived from a 1.544-Mb/s DS-1 signal which ranges from 23 operating at 56.0 kb/s to 460 operating at 2.4 kb/s. The economics are evident when a comparison is made to the 24 voice-frequency analog channels normally derived by a D-type channel bank from a DS-1 signal, which could be used as 24 data channels operating at 2.4 kb/s.

6.3 Channel interconnection

Interconnection between loops or channels in an office is always accomplished at the 64-kb/s (DS-0) signal rate. In local offices, this may be through jack and connector panels, while in hub offices the interconnection is by plug-ended jumpers on a DSX-0 cross-connect frame. The former provides test access and limited cross-connect flexibility, while the latter provides total flexibility of equipment assignment, channel interconnection, and introduction of jack field appearances for test access.

Since all signals at the DSX-0 cross-connect are in the universal 64-kb/s format, any channel may be cross-connected to any multiplex port of equal or higher rate designation. For example, a 4.8-kb/s channel can be connected to a 4.8-, 9.6-, or 56-kb/s port, but not to a 2.4-kb/s port. This feature makes it possible to minimize or eliminate the installation of first-stage multiplexers until the number of channels required is large enough to necessitate efficient use of the line capacity.

6.4 Multipoint channel arrangements

Multipoint junction units, interconnected at the DSX-0 cross-connect, permit a number of channels and/or loops to be associated with one multipoint communication system. This arrangement is similar to a full-duplex telegraph hub in concept. The maintenance testing features, however, allow remote selection of "legs," which facilitate one-man testing of a multipoint service.

6.5 Synchronization timing supplies

All multiplexers, channel units, junction units, and test equipment within an office operate synchronously from one timing supply which derives its frequency information from a selected incoming DS-1 facility.[5]

The timing supply in a hub office is designated a "nodal timing supply." The frequency of this supply is inherently contained in transmitted DS-1 signals, and is therefore passed on to other offices of equal or lower level in the transmission hierarchy. The hardware is totally redundant, since failure would disable all communication through the office. Occupying so strategic a position in the network demands that the nodal timing supplies employ highly stable oscillators with memory so that loss of incoming frequency information does not disrupt or degrade performance on other facilities and channels through the office before restoration or repair can be effected.

While the network is growing geographically, a nodal timing supply will act as the master timing supply. Its location in the network will change from time to time. Ultimately, one such supply will be connected to the Bell System reference frequency standard and become the "master timing supply."

The timing supply in local offices is designated a "local timing supply." It is, in principle, identical to a nodal timing supply with the exception that lower-cost, less stable oscillators are used. Redundancy is again employed to insure reliability and, since local offices are likely to be unattended for relatively large periods of time, automatic switching to a secondary source of incoming frequency information is provided if such a source exists. A local timing supply may pass frequency information to other local offices, but never back to a higher-level office in the network.

6.6 Maintenance testing

A new digital testboard that will be located in facility hub offices is provided for installation and maintenance testing of DDS channels.[6] A 450-channel-capacity testboard position provides a six-jack (four transmission and two monitor) appearance for each channel. The full duplex channels may be monitored in either direction of transmission, or the channel may be opened and test signals transmitted and received in either direction. Remote loopback tests may be conducted around the loops shown as A, B, or C in Fig. 3. The loopback connections are activated and maintained by control signals and test data generated by a digital transmitter test set. Return signals are observed by a digital receiver test set. The test sets are an integral part of the testboard design and are also available as portable test sets.

The testboard has a number of additional features suited to its serving test center (STC) functions. These include the ability to generate unique test codes which may be connected to a channel for extended periods of time when required in tracing a channel through the network to locate a problem condition. A multipoint signaling unit (MSU) provides a method of selecting a route through remote multipoint junction unit (MJU) branches until a particular station is reached. Loopback tests may then be conducted as with one end of a point-to-point channel. Responses from each MJU encountered along the way verify its identity and the selected branch by means of a numeric display on the MSU. A telephone circuit with key equipment is provided to pick up a number of order wire or dial lines for voice communication. All connections of test equipment to channel appearances are made by means of retracting cord reel circuits. Display of status and test results is by a combination of light-emitting-diode lamps and light-emitting-diode numeric displays.

Use is made of the portable test set versions of the digital transmitter and digital receivers in office equipment areas away from the testboard. Access is provided by test points on channel, junction, and multiplexer units where individual customer channels or selected channels from a multiplexed bit stream may be observed. In local offices, jack and connector panels in the equipment bays provide access to individual channels where loopback tests may be conducted in the same manner as from a testboard.

The one-man testing capabilities designed into the system will enable craftspeople to quickly isolate trouble in a customer's channel and will, in conjunction with the many equipment alarms, aid in identifying the type of maintenance required.

6.7 Facilities

Figure 4 depicts the digital transmission facilities that will be used in the DDS network. The hierarchy of facilities begins with the DS-1 (1.544-Mb/s) signal rate of the T1 carrier line. Within metropolitan areas, the T1 line will actually be the primary facility used to interconnect local end offices and local intermediate offices to the hub office.

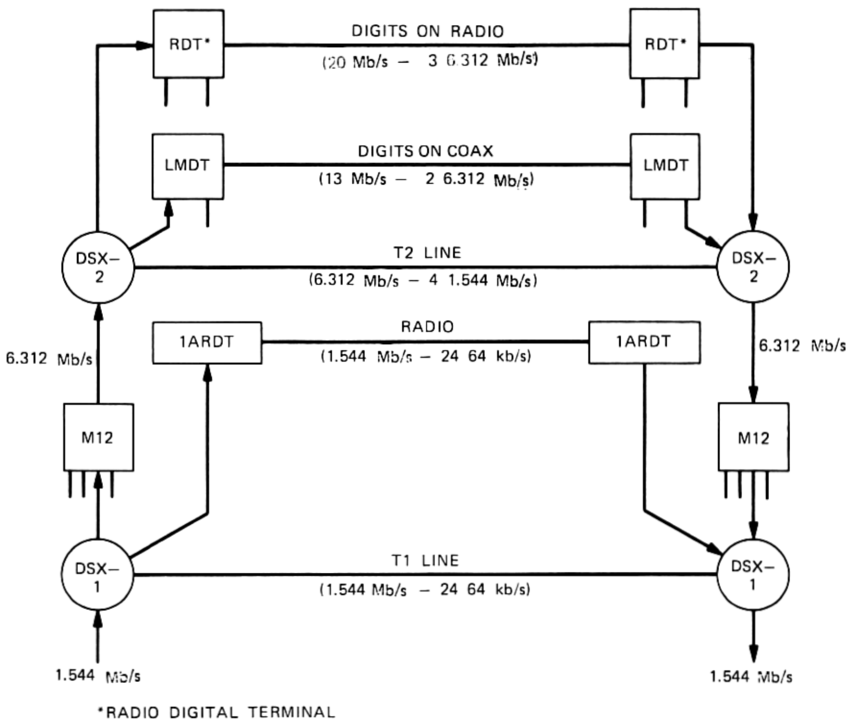

Fig. 4—Digital transmission hierarchy.

Hub offices at all levels will ultimately be interconnected with a variety of long-haul digital systems. During the early years of network growth, the system most used will be the 1A radio digital system (1ARDS) which operates at the DS-1 signal rate. This system, also referred to as DUV (data under voice), employs multilevel signal encoding and shaping to compress the baseband spectrum to a bandwidth that occupies the bottom 500 kHz of the radio baseband. In this manner, a 1.544-Mb/s digital capacity may be derived from each radio system in a route without reducing the message channel capacity of the system.

As the network route cross-section requirements grow beyond the capacity available by application of 1ARDS, it will be necessary to utilize higher-capacity systems. Several have been developed, although not yet deployed. Up to four DS-1 signals may be combined by the M12 multiplexer to form a DS-2 signal of approximately 6.3 Mb/s. In some cable routes, this signal will be directly applicable to the T2 digital line. Further combination of two DS-2 signals (comprising eight DS-1 signals) by the M2L multiplexer produces a signal that will, by use of the L-mastergroup digital terminal (LMDT), occupy one mastergroup band of either the L4 or L5 coaxial cable carrier system.

Another alternative that has been successfully demonstrated for large cross-section digital capacity occupies a full radio channel and has a capacity of approximately 20 Mb/s. By use of M12 multiplexers, this system can provide up to 12 DS-1 facilities.

The range in digital capacity of the available transmission systems and those currently being developed will allow selection to fit the needs of the DDS network during its early years of growth and to meet the needs for the future.

All multiplexing above the DS-1 signal level is asynchronous, using bit-stuffing techniques for rate synchronization. The DDS utilizes hub-to-hub synchronization at the DS-1 rate; therefore, it is not necessary to tie the DDS synchronization network to any of the higher-level multiplexers or transmission systems.

VII. PHYSICAL DESIGN

A key consideration in the physical design[7] of DDS central office equipment is flexibility: (*i*) to permit engineering, ordering, and installation to meet service needs, (*ii*) to grow easily with short installation intervals, and (*iii*) to allow rearrangements for changing service needs with little or no downtime.

Initial and growth installations are greatly simplified by the use of factory-supplied connectorized cables to interconnect bays of equipment or assemblies within a bay. Installation time and chance of installer wiring error are greatly reduced.

Considerable flexibility has been realized within unit designs and the total number of circuit pack codes held as low as possible by devoting special attention to the physical partitioning of circuit functions. For example, the office channel unit (OCU) assembly can function at any of the four data rates or mixes thereof by inserting appropriate plug-in circuit packs. Similarily, the subrate data multiplexer (SRDM) assembly may be equipped with a flexible mix of 5, 10, or 20 port multiplexers for 9.6, 4.8, or 2.4 kb/s channels by selecting the proper circuit packs and the connectors into which they are plugged. Where different channel operating rates are involved within the same equipment assembly, color coding of circuit-pack face-plate labels is used for identification.

Care has been taken to ensure reliability of channel connections at the DSX-0 cross-connect where the interconnection of 64-kb/s signals among channel units, multiplex ports, etc., is accomplished as a continuing activity. The cross-connect panels mount on duct-type bays that can be located in the same lineup with other equipment bays. Within the panels, four-wire plug-ended jumpers engage four recessed pins in a plastic cell structure. Seated jumper plugs are automatically locked in place to avoid accidental disconnections. Removal of a jumper can be accomplished only with a special tool that is secured to the bay.

Precautions have been exercised in developing cabling, shielding, and grounding arrangements to ensure performance in the wide range of operating environments to be encountered. Designs have been realized that make it easy to introduce the required service capacity into existing telephone central offices. While fixed equipment configurations have been coded for convenience in engineering and ordering, the connectorized assemblies may be mounted on a miscellaneous basis if special arrangements are desired by an operating company.

VIII. SUMMARY

The services, the objectives, and the elements for realization of the Digital Data System have been outlined. The papers that follow describe in more depth the systems that have been developed, the strategies for their use, and the planning being carried out to provide the features of a specialized digital data communications network, while utilizing to a maximum the existing Bell System network and its established operating methods.

IX. ACKNOWLEDGMENTS

Many individuals have contributed to the planning and realization of the Digital Data System. Special recognition is due T. H. Thompson and R. L. Wagner who in the course of the development program provided the project organization and leadership, and to C. R. Moster, L. R. Pamm, J. T. Bangert, and U. S. Berger in whose laboratories or engineering centers the major planning and system development efforts were pursued.

APPENDIX

Glossary of Acronyms and Abbreviations

Throughout this series of papers, certain terms, abbreviations, and acronyms are used to simplify and shorten the presentation of ideas. A listing of some more commonly used terms relating to the Digital Data System is presented here with brief descriptions.

ALBO Automatic line-build-out network.

AVAILABILITY Percentage of time that satisfactory data communication service is available. The term "satisfactory" implies that terminal equipment and cables are in working order.

BASEBAND In the Digital Data System, a digital stream designated to contain data for only one customer station. For example, data on a customer's loop or at the DS-0A level are at baseband, while data at the DS-0B level are not at baseband.

BASEBAND OFFICE An office in a DDS digital serving area that contains no DDS multiplexing gear, but acts as a link-up point between the four-wire connection to a customer's station and an interoffice cable.

BCPA (bay clock, power, and alarms shelf) A DDS equipment shelf used in conjunction with office timing supplies to supply timing to equipment bays. It also supplies power to equipment in the bays and combines alarms.

BIPOLAR RZ (BPRZ) (bipolar return to zero) A three-level code in which alternate 1s change in sign (for example, 1011 becomes +1, 0, −1, +1) and transitions between adjacent 1s pause at the zero voltage level.

BIPOLAR NRZ (BPNRZ) (bipolar nonreturn to zero) The same as bipolar RZ, except that transitions between adjacent 1s do not stop at zero level.

BPV (bipolar violation) A violation of the alternating +1, −1 pattern in a three-level code.

B6ZS (bipolar with 6 zero substitution) A coding scheme, implemented by the M12 multiplex, whereby any group of six consecutive zeros is converted into a known bipolar violation pattern at the DS-2 level.

BYPASS CIRCUIT A DDS circuit that is routed directly from DSX-0B in the local access multiplexing section of a hub office to DSX-0B in the long-haul access multiplexing section without appearing at DSX-0A.

BYTE In the Digital Data System, a group of eight consecutive binary digits associated with a single user.

BYTE STUFFING In the Digital Data System, the technique by which the bit rate of a digital stream is increased by repeating bytes and transmitting them at a faster rate. The information content of the stream is not increased.

CHAIN OFFICE A local end office having a T1WB4 at one of the intermediate points connecting two links in a T1WB4 chain.

CHAIN See *T1WB4 chain.*

CONTROL SIGNALS Signals in byte format used for synchronization, status, and remote testing.

CROSS-CONNECT A piece of hardware used to interconnect multiplexers with line-terminating equipment and other multiplexers. Access to signals is often available through jacks associated with a testboard located near the cross-connect.

CP (circuit pack) A unit that contains part of the DDS circuitry and can be inserted into equipment shelves where required.

CSU (channel service unit) A unit located on the customer's premises that terminates a DDS channel and is used with the customer's logic and timing recovery circuitry.

DATA MODE A condition of the DSU with respect to the transmitter in which its data-set-ready and request-to-send circuits are ON and it is presumably sending data.

DDS Digital Data System.

DDS LOOP That portion of an individual customer's channel between the station and its associated office channel unit (OCU).

DMC (data-message combiner) Combines analog multiplexed voice signals with a DS-1 level data signal.

DOWN TIME Time during which data communication is not available or is unsatisfactory (see *Availability*) because of malfunction. Time required for preventive maintenance is not included.

DSA (digital serving area) The combined geographical serving areas of a set of DDS serving offices, as specified in the appropriate tariff(s). The DDS office serving areas making up a DSA are not necessarily contiguous, and a DSA may overlap state and associated company boundaries; however, a typical DSA might encompass one urban area of a single associated company.

DSU (Data Service Unit) A terminal located on the customer's premises for the purpose of accessing the Digital Data System through a standard Electronic Industries Association (EIA) or Comité Consultatif International Télégraphique et Téléphonique (CCITT) interface.

DS-0 (digital signal at the 0th level of the DDS TDM hierarchy, the DS-0 level) A signal at the 64-kb/s rate (the DS-0 rate).

DS-0A A DS-0 signal designated to carry data for only one station. For subrate speeds, successive bytes are repeated as necessary to match the customer's data speed. Only DS-0A data signals appear at the DSX-0A cross-connect.

DS-1 (digital signal at the first level of the DDS TDM hierarchy, the DS-1 level) A biopolar return-to-zero signal at a 1.544-Mb/s rate (the DS-1 rate).

DS-2 (digital signal at the second level of the DDS TDM hierarchy, the DS-2 level) A bipolar return-to-zero signal at a 6.312-Mb/s rate (the DS-2 rate).

DSX-0 (hub X-conn) Digital cross-connect used to interconnect equipment at the DS-0 level. Note that no cross-connects are used in DDS local offices.

DSX-0A (STC X-conn) The DSX-0 digital cross-connect at a DDS hub office where individual customer circuits are properly routed.

DSX-0B (multiplex X-conn) The DSX-0 digital cross-connect at a DDS hub office used to connect T1DM and T1WB4 ports with SRDMs and to connect T1DM and/or T1WB4 ports together for through or bypass circuits.

DSX-1,2,3 Digital cross-connect used to interconnect equipment, provide patch capability, and provide test access at the DS-1, DS-2, or DS-3 level respectively.

DUPLEX A communication mode in which transmission can occur in both directions simultaneously (sometimes referred to as full duplex).

DUTY CYCLE The percent of a single pulse period (for a 1) during which the voltage is nonzero.

DUV See *1ARDS*.

EFFICIENCY OF DATA COMMUNICATIONS Percentage of one-second intervals in which data are delivered free of error.

EFS Error-free seconds.

END OFFICE In a digital serving area, a local office that passes on toward the hub-only circuits that entered the office over local loops. The main function of an end office is to combine several individual customer channels, by means of DDS multiplexers, and to transmit the combined bit stream toward the STC hub.

FMT/FMR (FM transmitter and FM receiver) Used with broadband radio systems.

FOUR-WIRE CIRCUIT A facility that provides two full-time, independent channels for transmission in opposite directions. It is historically associated with two wires for transmission and two wires for reception.

FRAME On a T1 line, 193 binary dibits, that is, 24 bytes plus one framing bit.

HALF DUPLEX A facility that permits transmission in both directions, but only one direction at a time.

HIT Any disruption of service that persists for less than one second.

HUB An office in the Digital Data System that combines the DS-1 data streams from a number of local offices into signals suitable for transmission over DDS facilities at the DS-1 level or above. Cross-connects at a hub are made via DSX-0. Also see *STC hub*, *Collection Hub*, *Regional Hub*, *Sectional Hub*, and *Metro Hub*.

HUB CROSS-CONNECT See *DSX-0*.

IDLE CODE A bipolar violation sequence transmitted by the DSU to indicate no data are being sent over the line.

IDLE MODE A condition of the DSU with respect to the transmitter in which its data-set-ready circuit is ON, but its request-to-send circuit is OFF, and it is sending idle code.

INTERMEDIATE OFFICE In a DDS digital serving area, a local office that passes on toward the hub circuits that entered the office over a T1 line, in addition to those that entered over local loops.

ISMX (integral subrate multiplexer) A subrate multiplexer arrangement used only in local offices, in which the subrate multiplexing function is contained within the OCU shelves.

JCP (jack and connector panel) A unit used in a local office to connect the various equipment pieces and to provide test access with portable test sets. See *M-JCP* and *SM-JCP*.

kb/s Kilobits (10^3 bits) per second.

LDFMC (long-distance facilities maintenance center) A long-lines toll test room concerned with maintenance of long-haul digital systems.

LMDS (L-mastergroup digital system) A system that provides for the transmission of two DS-2 signals in one of the mastergroup bands of the L4 or L5 coaxial cable systems.

LMDT L-mastergroup digital terminal.

LOCAL ACCESS MULTIPLEXING The multiplexing equipment in a DDS hub office dedicated to combining circuits for transmission to local offices or another hub office in the same digital serving area.

LOCAL LOOP The cable pairs between a DDS office and customer premises.

LOCAL OFFICE A DDS office that concentrates "on-net" customer circuits into T1 streams which can be transmitted to a hub office. Cross-connects at a local office are made via JCPs.

LTS (local timing supply) Common timing source for a DDS local office. In the absence of input timing information, this unit is less stable than the NTS.

LONG-HAUL Transmission distances typically beyond 50 miles utilizing, for example, TD, T2, L1, or L5 facilities.

LONG-HAUL ACCESS MULTIPLEXING The multiplexing equipment in a DDS hub office dedicated to combining circuits for efficient transmission to *other* local serving areas.

LOOPING (LOOPBACK) A testing procedure that causes a received signal to be transmitted (i.e., returned to the source).

Mb/s Megabits (10^6 bits) per second.

M12 A multiplexer that combines four DS-1 signals into a DS-2 signal.

METRO (CLASS III) HUB A hub office in the lowest of three levels in the interhub routing hierarchy.

MTS (master timing supply) The modified nodal timing supply that receives input timing information from the Bell System reference frequency standard and provides this timing information to the rest of the system.

METROPOLITAN AREA See *Digital Serving Area.*

M-JCP A jack and connector panel that gives access to the ports of a T1DM or a T1WB4.

MJU (multipoint junction unit) A unit employed at a DDS hub office to link together three or more segments of a multipoint circuit.

MULTIPLEX CROSS-CONNECT See *DSX-0B.*

MULTIPOINT A customer circuit with more than two end points. One end point is designated the "control" station.

MSU (multipoint signaling unit) A device used in conjunction with the DDS test equipment to isolate and test various segments of a DDS multipoint circuit.

MUX Multiplexer.

NTS (nodal timing supply) Common timing source for a DDS office. This unit is highly stable in the absence of input timing information, and is only used at hub offices.

OCU (office channel unit) A terminal located in the central office which terminates the customer's loop and provides signal and format conversions between the two types of baseband signals (DS-CS and DS-0A).

OFF-NET A location beyond the primary serving area of the Digital Data System.

ON-NET A location within the primary serving area of the Digital Data System.

1ARDS (1A radio digital system) A system that provides for the transmission of one DS-1 signal over a microwave radio link. This system is also known as data under voice (DUV).

1ARDT (1A radio digital terminal) A digital terminal used in the 1ARDS which converts a T1 line signal to a seven-level partial response format. The resultant signal has a bandwidth of 0 to 500 kHz, and it can be transmitted below the message on a radio facility.

OUTAGE Any disruption of service that persists for more than one second.

PCM (pulse code modulation) The process in which analog signals are sampled, quantized, and coded into a digital bit stream.

PLL (phase locked loop) A circuit containing a variable frequency oscillator whose phase is compared with a reference signal. By a suitable feedback mechanism, both signals are forced to agree in frequency and possibly in phase.

Q (quad) A group of four wires that carry a four-wire circuit.

ROCC (regional operations control center) Coordinates the restoration of failed L4, L5 carrier, or TD/TH radio routes.

SLIP A defect in timing that causes a single bit or a sequence of bits to be omitted or read twice.

SHORT-HAUL Transmission distances typically less than 50 miles.

SM-JCP A jack and connector panel that gives access to the ports of a subrate data multiplexer.

STC SERVING AREA The geographical area for which an STC has maintenance responsibilities.

STC (serving test center) A test location established to control and maintain circuit layout records (CLR), receive customer trouble reports, assist in the checkout of newly installed stations, perform trouble localization, and coordinate service restorals.

STC CROSS-CONNECT See DSX-0A.

STC HUB A hub office that has an STC.

STC HUB SERVING AREA The geographic area covered by all DDS customer stations that home on a single STC hub office.

STRAIGHTAWAY TEST A test procedure in which a test signal is transmitted from one point to a receiver at a different point.

SRDM (substrate data multiplexer) A unit that combines a number of data streams at or below some basic rate (2.4, 4.8, 9.6 kb/s) into a single DS-0B 64-kb/s time-division multiplexed signal.

SUBRATE In the Digital Data System, a data bit rate that is either 2.4, 4.8, or 9.6 kb/s.

TCAC (T-carrier administration center) A center with responsibility for the maintenance and restoration of the T-carrier facilities on an automated basis.

TD-2, -3, etc. A point-to-point microwave radio transmission system.

TDM (time division multiplexing) The process of combining a number of digital signals into a single digital stream by an orderly assignment of time slots.

TEST MODE A condition of the DSU in which its transmitter and receiver are inoperative because of a test in progress on the line.

TRCC (T1-carrier restoration and control center) Performs the same functions as the TCAC, but on a manual basis.

T1 AUTOMATIC STANDBY UNIT (T1ASU) A unit that monitors a regular T1 line and its standby T1 line, and automatically switches to the standby, based on the bipolar violation rate of the regular line.

T1 LINE A digital transmission line that carries data at the 1.544-Mb/s rate (DS-1 level); in DDS, it is used primarily for short-haul links.

T1DM (T1 data multiplexer) A multiplexer that is capable of time-division multiplexing up to twenty-three 64-kb/s channels and synchronizing information into a DS-1 signal.

T1WB4 A voice-data multiplexer capable of combining up to twelve 64-kb/s DS-0B data channels with PCM-encoded voice channels from a D3 or D1D channel bank. The resultant TDM format is a DS-1 signal. Development is under way to permit up to 24 DS-0B data channels, instead of up to 12.

T1WB4 CHAIN An arrangement using T1WB4s to allow a local end office and up to two chain offices to share usage of a single T1 line, which is routed to an STC hub.

T2 LINE A digital transmission line that carries data at the 6.312 mb/s rate (DS-2 level) for distances up to 500 miles.

VOICE MMX (voice mastergroup multiplex) Used to combine 600 voice channels into a spectrum suitable for transmission via broadband radio systems.

X-CONN Cross-connect.

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