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Implementation of a System to Provide Mobile Satellite Services in North America

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ABSTRACT

This paper describes the implementation of the ground network to support Mobile Satellite Services (MSS). The system is designed to take advantage of a powerful new satellite series and provides significant improvements in capacity and throughput over systems in service today. The system is described in terms of the services provided and the system architecture being implemented to deliver those services. The system operation is described including examples of a circuit switched and packet switched call placement. The physical architecture is presented showing the major hardware components and software functionality placement within the hardware.

SYSTEM DESCRIPTION

Services Provided

The technically compatible systems which AMSC and TMI are implementing, and which will enter service in mid-1994, will provide a full range of user services to subscribers throughout the continental United States and Canada, Alaska, Hawaii, the Caribbean Basin, plus offshore territorial waters to at least 200 n. miles. These services will be provided primarily to land vehicular mobile terminals (MTs), but the system will also accommodate transportable, maritime and aeronautical terminals.

The mobile telephone service terminal will support:

- Basic voice service interconnected to either public (PSTN) or private networks. Services will include a variety of advanced calling features.
- Circuit switched asynchronous data service at rates of 1200, 2400 and 4800 b/s.
- CCITT Group 3 facsimile service.

Multi-mode variants of mobile terminals will provide full interoperability with terrestrial cellular networks.

The Net Radio variant of the MT will support network broadcast and dispatch services in private systems.

The Mobile Data variant will provide packet-switched data service at 2250 to 5000 b/s interconnected with public (PSDN) and private data network applications.

Network Architecture

Overall System Architecture

The MSS System is comprised of five principal components:

- The MSS Satellite
- The Network Operations Center/Network Communications Controller (NOC/NCC)
- The Feederlink Earth Station (FES)
- The Mobile Terminal (MT)
- The Data Hub (DH)

The identical large geostationary MSS satellites [1] [2], one each owned by AMSC and TMI, will be described only briefly in this paper. The satellites provide the radio links between MTs which operate exclusively in the L-band, and the various fixed control and gateway stations, which utilize Ku-band. The satellite transponders provide the necessary frequency translation. The coverage area is served by six L-band beams and a single Ku-band beam. The current frequency plan supports division of the available L-band spectrum into approximately 1800 full duplex 6 KHz channels. The channels are aggregated in circuit pools from which they are demand assigned to support communication to individual subscribers. Frequency reuse is possible between the east and west beams.

The Communications Ground Segment [3], which is being developed by Westinghouse Electric Corporation under joint contract to AMSC and TMI, is logically divided into two primary parts: the Network Control System (NCS) and the Communications System (CS). This is shown in Figure 1.

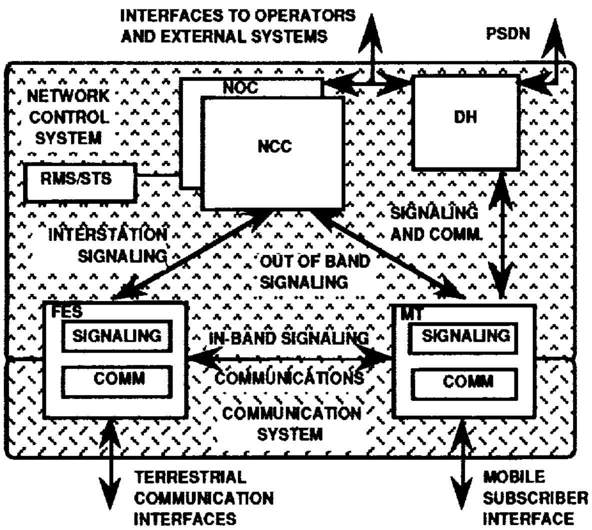

Figure 1. Logical Structure of the CGS

The NCS is comprised of the NOC/NCC, and parts of the FES(s) and MT(s), and performs the functions of system management and control. This includes commissioning and authentication of MTs, paging, call setup/teardown, initial signaling between system elements, channel assignment and congestion control. The NCS utilizes less than five percent of the satellite bandwidth for control/signaling channels, which function in a combination of random access, TDM and TDMA formats. The NCS span is designed to include all ground segment elements, all beams, and, in the future, multiple satellites.

The CS is comprised of elements of the FES(s) and MT(s), and provides connections between the MTs and other MTs or destinations in private networks or the PSTN/PSDN.

The signaling and communications links are digital, and the voice communications links employ voice activation.

Network Elements

The NOC provides the principal interfaces to the CGS for operators. It is designed to perform the functions of fault, accounting, configuration, performance and security management for the CGS. It accumulates information related to individual calls from other network elements to generate call billing and performance records for each call. The NOC has important interfaces with providers of Aeronautical Mobile Satellite (Route) Services (who have priority use of some portions of the L-band spectrum), with other independent users of the satellite, with AMSC and TMI counterpart NOCs, with Customer Management Information Systems, and with the Satellite Operations Center. Its operations are largely non-real-time.

The NCC provides real-time control of the CGS system for circuit switched operations. It manages the access of users to the CGS and assigns satellite channels on a demand basis to provide communications links between FESs and MTs. The NCC manages out-of-band signaling channels which the MTs access to request communications channels and is capable of performing periodic performance verification tests of MTs using the CGS. The NCC is designed to establish a call connection within approximately three seconds and to support a maximum call establishment rate of 70 call attempts per second.

The FESs provide the interface between the CGS and terrestrial communications networks to permit communication between MTs and the PSTN, private networks and cellular systems. A FES consists of a number (up to 1500) of frequency agile channel units which are interconnected to a Ku-band earth station to support two-way communications with individual MTs. The FES interfaces to the PSTN through a Mobile Telephone Switch which implements various calling features and provides the capability to support roaming between the CGS and cellular systems by multi-mode MTs. Individual FESs will support up to 20 call attempts per second.

The CGS design supports inclusion of the NOC/NCC and FES function in a single integrated installation. Multiple FESs are also possible and may be remotely located.

The Mobile Terminals, which operate at L-band frequencies, are small, low cost units which can be easily installed on land vehicles. The MTs may also be adapted for the maritime and aeronautical environment. They are capable of accessing the signaling channels to the NCC and support single channel two-way communications with the FESs. MTs have an antenna with a gain of approximately 8 dB to provide a G/T of -16 dB/K and an EIRP of 12.5 dBW.

The Data Hub provides packet switched data services to mobile terminals by managing a number of packet data channels in each beam and the allocation of capacity to individual data MTs. The DH supports interactive data sessions, efficient query-response sessions, and data broadcast. The interface to the DH from terrestrial networks uses the X.25 protocol via a commercial packet switch. The user interface at the MT may be either via the X.25 or an asynchronous protocol. The DH supports a maximum data throughput rate of 6,000 32-byte packets per second and a call placement rate of up to 130 calls/second. A MT operating in the packet data network may interrupt the packet service to receive or place circuit switched calls.

Remote Monitoring Stations in each beam of the CGS monitor the use of the L-band spectrum and the quality and performance of the signaling channels. A System Test Station, located at the NOC/NCC, provides for testing of FES channel unit performance.

A simplified block diagram of the CGS system, including a non-collocated FES, is shown in Figure 2.

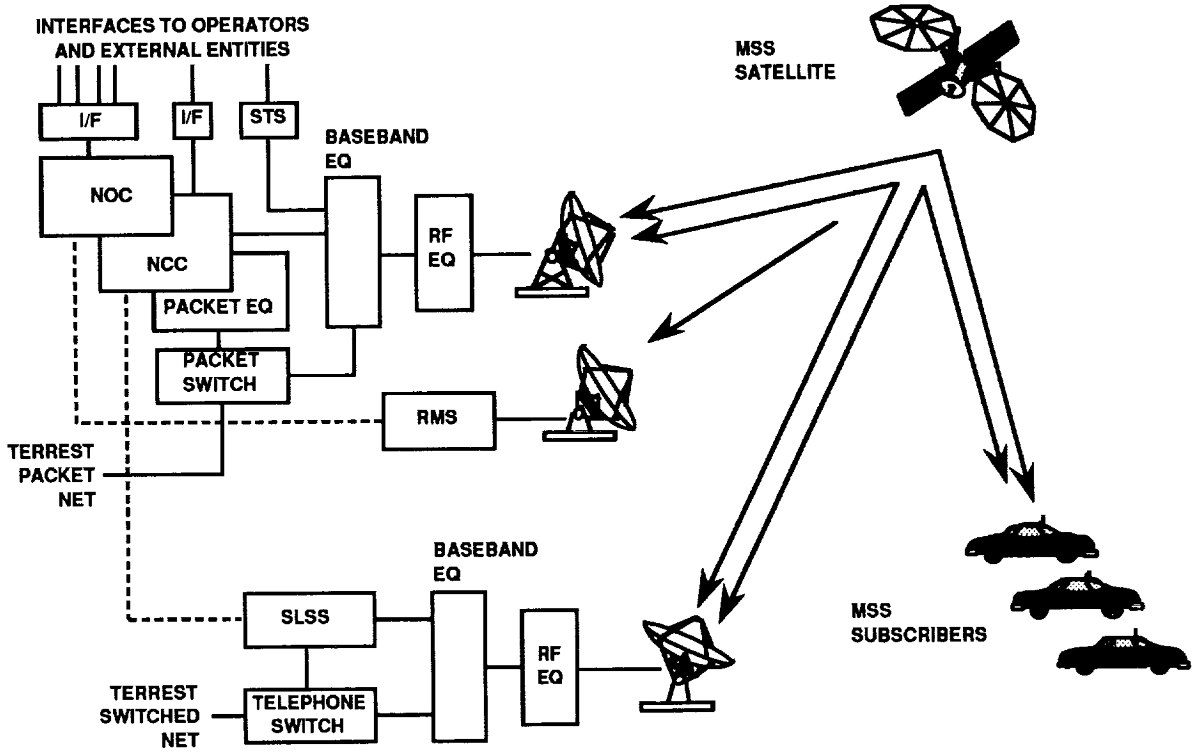

Figure 2. CGS System Architecture

SYSTEM OPERATION

Provision of Services

At the time of commissioning (the time at which a MT electronically "enters" the system) the MT is assigned a "set" of control channels [4]. These channels comprise the primary outbound (NCC or DH to MT) TDM channel, one or more inbound random access channels, and one or more inbound TDMA channels.

Following commissioning, all idle MTs continuously monitor the outbound TDM channel. This channel carries commands, pages, and responses to signals from individual mobiles by specific address, plus "bulletin board" information, which may be of significance to all mobiles.

The bulletin board consists of several numbered and time-stamped pages. A MT cannot operate within the system until it has acquired the latest update of the complete bulletin board.

The inbound random access (slotted aloha) channels are used only for MT initiated functions, such as requests for call placement, or network specific functions such as control channel changes. All subsequent MT signaling is transmitted on one of the inbound TDMA channels.

A variety of error detection and retransmission schemes are used to insure the integrity of signaling.

Circuit Switched Call Placement Scenarios

To place a mobile to land circuit switched call, the MT subscriber will enter the destination telephone number at his terminal and push a SEND key, in a manner similar to that used in cellular telephony today.

The MT will then transmit its electronic serial number (ESN) and the first 10 digits of the destination in a Signaling Unit in a single burst on a random access channel. On receipt, the NCC will check the validity of the information, and will respond to the MT with transmit and receive frequency channel assignments. The same information will also be sent to the serving FES. Both the MT and the FES will tune to these channels, and, through an exchange of protocol, establish communication. Concurrent with this process, the FES will instruct the Gateway Switch to establish the necessary terrestrial connection. The call will then be cut through to the switch, which will provide standard call progress tones. Subsequent signaling (for example that required to perform tandem dialing or to activate advanced calling features) will be handled by 96-bit Signaling Units inserted into the communication stream.

Land-to-mobile calls are established in essentially the same manner. When the FES receives the MT bound call from the terrestrial network, it signals the NCC with the MT identification, and the NCC subsequently pages the mobile to establish the radio link.

Packet Switched Call Placement Scenarios

To place a mobile-to-land packet switched call, the MT subscriber will generate an X.25 call request using a PC or specialized interface unit. The call request message containing the X.121 address of the called party is transmitted to the DH via a random access data channel. The DH then attempts to complete the call via the interconnected Public Switched Data Network (PSDN). When the host on the PSDN responds with a call accept message, this is transmitted to the calling MT via TDM data channels. When a block of data is to be sent from the MT, the MT formulates a capacity request message and transmits this to the DH via a random access data channel. The DH responds by allocating a unit of capacity on the TDMA channel which can be extended by requests form the MT, piggy-backed on the data message, until the transmission of the block of data is completed. A block of data sent from the host on the PSDN is transferred to the MT by the DH in packets via the TDM channel. Reliable information transmission over the mobile satellite link takes place in packets of up to 64 data bytes under an ARQ protocol.

Land-to-mobile calls are placed as a result of a call request received by the DH from a host on the PSDN. The DH sends an X.25 call request to the MT and allocates capacity on the TDMA channels for its response. Once a connection is established, data messages are exchanged as described above.

Network Management

Architecture

Figure 2 shows the overall Network Architecture. The components that form the Network Management Architecture are primarily the Network Management System (NMS), the NOC, and the MDS Network Management System (MNMS). The NMS is the administrative system management function that is responsible for setting management policy and procedures. The NMS consists of three separate functional areas: System Engineering (SE), Network Engineering (NE), and the Customer Management Information System (CMIS). SE is responsible for long range planning functions. Traffic analysis techniques are used to predict when the network should be expanded or reconfigured to meet long term growth requirements or changes in system utilization. NE is responsible for carrying out the decisions made within the SE organization and as such formulates tactical plans for meeting the daily needs of the Network. These tactical plans, such as the definition of circuit pools, satellite resource planning, frequency allocation usage, and network configuration, are electronically communicated to the NOC and the MNMS for implementation. The CMIS is the interface to the users of the communications services, the mobile terminal subscribers. Through this system, new customers are entered into the network or their user profiles are updated. It is also through the CMIS interface that the NOC and MNMS provide the billing data for call placed by subscribers.

The NOC is the heart of the network management process for circuit switched operations as is the MNMS for packet switched operations. The NOC and MNMS each have a director which controls and keeps status on the remainder of the elements. The director obtains status and alarms and provides control through the use of agents. An agent is located at each physically separate site and provides local control for all of the managed objects at that site. Each agent is responsible to the director for all alarming, event recognition, and the execution of network control or configuration commands. Standard network management protocols are used, although all objects are not required to use the same protocol. An example would be the concurrent use of Simple Network Management Protocol (SNMP) and Common Management Information Protocol (CMIP) at the same site to manage different objets. The NOC and MNMS provide centralized network management for Configuration, Accounting, Security, Faults, and Performance.

Call Billing

Each network element involved in processing real time call information collects information about that call. Two types of information are collected: billing information and performance information. Billing information is transferred to the NOC after each circuit switched call completion and to the MNMS after each packet switched call completion. The NOC and MNMS will hold that information in local storage until requested by CMIS. The data will then be transferred in batch mode. The CMIS may request individual call records at any time from the NOC or MNMS. That data is transferred immediately. Performance data is also transferred to the NOC or MNMS after each call. This data is transferred daily for analysis by the NE and SE functions. The results of this analysis are used to plan future operations, short term or long term.

Resource Management

The NOC and MNMS are responsible for the overall management of network resources. However, these elements do not manage the most important resources, satellite bandwidth and power, on a real time basis. That task is accomplished by the NCC for circuit switched calls and by the Data Hub for packet switched calls. These elements manage the real time assignment of satellite channels at the appropriate power to or between Mobile Terminals and from the terrestrial networks. Other network resources, not required for call assignment on a real time basis, are managed by the NOC and MNMS.

SYSTEM IMPLEMENTATION

Physical Architecture

A simplified block diagram of the physical implementation of the Communications Ground Segment Architecture is shown in Figure 3. This is a generalized architecture that would accomplish all system functions. At this time, the implementations for the initial TMI and AMSC sites are different in that they do not both support all of the possible system functions. The differences between the two site configurations will be explained after the general architecture is described.

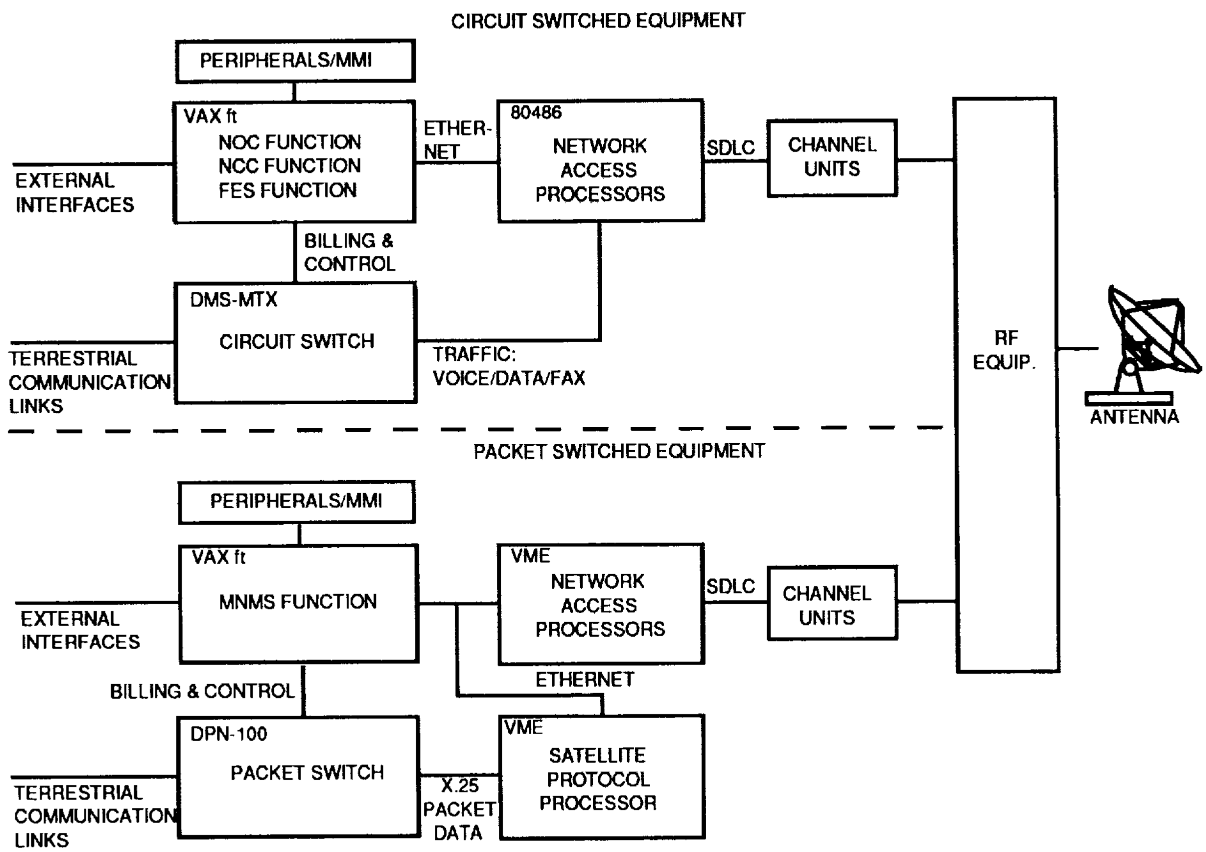

Figure 3. Hardware Implementation Diagram

The typical site may be divided into a circuit switched configuration comprising a NOC, NCC, and FES and a packet switched configuration containing a Data Hub. At a typical combined site installation, a single Radio Frequency (RF) subsystem, provided by Satellite Transmission Systems, is used.

The NOC, NCC, and FES functions are combined into a single fault tolerant computer platform, a Digital Equipment Corporation VAXft 810, plus several peripherals and communications devices. All functions utilize operator terminals and mass storage. In addition, the NCC and FES make use of channel units from EF Data Corporation, that provide the conversion to/from digital baseband signals to modulated Intermediate Frequency (IF) signals. These signals are used to communicate to Mobile Terminals via the RF equipment which provides the conversion from IF to Ku-band. The FES element contains a switching element, a Northern Telecom DMS-MTX cellular switch. This switch provides the connection between the Mobile terminals and the terrestrial network for all circuit switched calls.

Communication between the VAX and its peripherals is via dual rail Ethernets while communications traffic to the terrestrial network is carried via T-1 telecommunication links.

The data hub architecture is implemented using a number of computing technologies. The Terrestrial interface is accomplished utilizing a Northern Telecom DPN-100 packet switch carrying X.25 traffic. The Satellite Protocol Processor and Network Access Processor are implemented via redundant VME based processing elements. The channel units and RF equipment are the same as in the circuit switched architecture (the channel units being defined for packet operation via a different software load). The MNMS function is implemented using a VAXft 810 as in the circuit switched architecture allowing both hardware and software commonality for the MNMS and NOC functions.

Non-collocated system elements and external interfaces are connected via the MSS Internetwork. This network employs various communications technologies depending on the amount and frequency of data traffic. Connectivity spans from low speed dialup modems to high speed dedicated circuits. As the system is expanded, the most time critical data transmissions will be to keep the off-line elements in hot standby mode, ready to take over operations in case of on-line element failure. Other Internetwork transactions include the addition of new customers, the resulting billing data, and transfer or control of resource information.

AMSC Site

The AMSC site incorporates full capability for Cellular Interoperability as well as Networked Radio operations. The installation will not initially include a data hub, so that support of packet data services will be a future capability.

TMI Site

The TMI site will contain a data hub and thus will directly support packet data services, as well as integrated voice/data services to Mobile Terminals capable of both packet and circuit switched operations. The TMI Site will also support Networked Radio Operations. Cellular Interoperability will be incorporated at a future time.

Mobile Terminal

Operational Modes and Configurations

MTs can be configured as circuit switched, packet switched, or both for integrated voice/data operation. When packet switched operation is one of the selections, all communications will be initiated through the data hub. Circuit switched calls will then be processed to the selected FES for termination to the terrestrial network.

Cellular Interoperability may be added as an option to circuit switched MTs. In addition, Networked Radio operation may be added. MTs that are required to provide position location information may be outfitted with a GPS option. Facsimile and circuit switched data communications may also be configured.

In addition to the mode selection available, various configurations may be provided depending on the vehicle type. Land Mobile, Fixed Site, Maritime, and Aeronautical configurations are available.

Cost and Availability

The initial production Mobile Terminals are scheduled to be available by mid-1994 in time for planned service introduction which is in late 1994 for AMSC and early 1995 for TMI. Two MT providers are planning on introducing MTs, Westinghouse and Mitsubishi.

The retail price for a circuit switched, land mobile, cellular interoperable MT with voice and circuit switched data capability is expected to be under US$2,000. A similar price is anticipated for a land mobile, packet switched MT with Global Positioning System position location capability.

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