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MSAT Network Architecture

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ABSTRACT

Telesat Mobile Inc. will provide Mobile Satellite Services (MSS) in Canada starting in 1993 using a geostationary MSAT satellite. The communications system, which is being developed in close cooperation with the American Mobile Satellite Corporation, will support mobile voice and data services using circuit switched and packet switched facilities with interconnection to the public switched telephone network and private networks.

Control of the satellite network will reside in a Network Control System (NCS) which is being designed to be extremely flexible to provide for the operation of the system initially with one multi-beam satellite, but with the capability to add additional satellites which may have other beam configurations. The architecture of the NCS is described. The signalling system must be capable of supporting the protocols for the assignment of circuits for mobile public telephone and private network calls as well as identifying packet data networks. The structure of a straw-man signalling system is discussed.

INTRODUCTION

Telesat Mobile Inc. (TMI), which is authorized to provide mobile satellite services (MSS) in Canada, will launch a dedicated MSAT satellite in late 1993 to provide mobile telephone, mobile radio and mobile data services to customers on the move in any part of Canada. The American Mobile Satellite Corp. (AMSC), the licensed MSS operator in the U.S.A., will procure a similar satellite. The satellites of the two organizations will provide mutual back-up. TMI is cooperating closely with AMSC to define and to procure the necessary satellites and ground segment equipment. Contract negotiations are under way with satellite suppliers with the objective to enter into a contract in the second quarter of 1990. The design and procurement of ground segment equipment will proceed in parallel. The satellites and the ground system are to be ready for full operation by 1994.

This paper describes the baseline planning of the infrastructure for the ground segment. Through close cooperation with AMSC, it is planned that a common communications infrastructure be designed, such that customers will be able use their mobile terminals anywhere in North America and will have a choice of suppliers for mobile terminals.

MSAT SERVICE REQUIREMENTS

TMI estimates the potential demand for MSS at 300,000 to 450,000 mobile terminals in Canada by the year 2000. Studies of the requirements for the mobile data services indicate that the requirements for mobile data terminals could reach 50% to 60% of the total demand. Assumptions regarding this market penetration rate indicate that TMI's system should support 75,000 to 130,000 mobile voice terminals by the year 2000. In comparison, it is anticipated that the market in the U.S.A. could be three to ten times greater.

The penetration of the market will depend critically upon the cost of the mobile terminals and the charge for air time, which should not be too much greater than the equivalent costs and charges for cellular services. The MSAT communications network must be designed to provide as much satellite circuit capacity as possible with a given satellite using mobile terminals that are cheap, very reliable and are appropriate to the land, sea and air mobile environments. The network design should permit many services to be provided through mobile transceivers which are manufactured to a common standard.

To aid the design of the communications network, the service requirements in Canada have been aggregated into the following four categories.

Mobile Radio Service (MRS) - a circuit switched voice and data private network service.

Mobile Telephone Service (MTS) - a circuit switched voice and data service with interconnection to the public switched telephone network.

Mobile Data Service (MDS) - a packet switched data service with interconnection to private and public data networks.

Aeronautical Services - services which are compatible with international standards for mobile satellite communications with aircraft.

The first three categories of service will support land and marine mobile services as well as aeronautical services to private and small commercial aircraft. A separate category has been defined for the provision of aeronautical mobile satellite services to large commercial aircraft which will most likely adhere to international standards which are defined by the International Civil Aviation Organization (ICAO). Other categories may be added as experience is gained.

THE BASELINE SYSTEM

The MSAT system will use the L-band frequencies 1530.0 - 1559.0 MHz (downlink) and 1631.5 - 1660.5 MHz (uplink) for communication with mobile earth terminals (METs). The service area is the whole of North America and the islands of Puerto Rico and Hawaii with an option for coverage of Mexico and the Canadian and U.S.A. controlled international flight information regions. This coverage has been defined for the satellites of both systems in order that in-orbit back-up of each system can be provided. The baseline design for the first generation system [1] has envisaged five to nine beams with re-use of the limited frequency spectrum up to 1.3 times. Ku-band frequencies in the 11/13 GHz allotment bands, in a single continental beam, will be used for feeder-links to fixed feeder-link earth stations (FESs).

The frequency translating satellite communications transponder will relay signals between Ku-band feeder-link earth stations and L-band mobile terminals. The satellite transponders will not constrain the choice of communications signals. The baseline system design is for FDMA/SCPC multiple access narrow-bandwidth SCPC channels, nominally 5 kHz in bandwidth. The conceptual design of the satellite transponder has considerable flexibility to reallocate power and bandwidth to the different beams or service areas of the system.

A wide variety of mobile terminal types will be able to operate with the MSAT satellite. While the detailed parameters of many of these terminals are not yet firmly established, the parameters for voice communications terminals have been extensively explored. It is anticipated that these terminals will have an antenna gain of 10 to 13 dBic (circularly polarized) and a corresponding G/T of -15 to -12 dB/K. MET EIRP will be below 16 dBW.

Both analog and digital forms of speech modulation are being considered. Amplitude companded single sideband (ACSSB) modulation is assessed to be a very rugged form of modulation for use under the severe multipath and blocking anticipated in the land mobile environment. 4.8 kbps digital speech with trellis coded modulation is also becoming very attractive. The latter form of modulation may permit satisfactory operation at lower values of C/No, permitting more channels to be assigned through a given satellite, but has a sharper threshold and hence may not be so satisfactory in a highly shadowed environment.

The range of communications capacity of the baseline L-band satellite transponder and the two types of speech modulation is some 1,000 to 2,000 assignable voice channels which can support 100,000 to 200,000 METs for voice or the equivalent in data traffic [2].

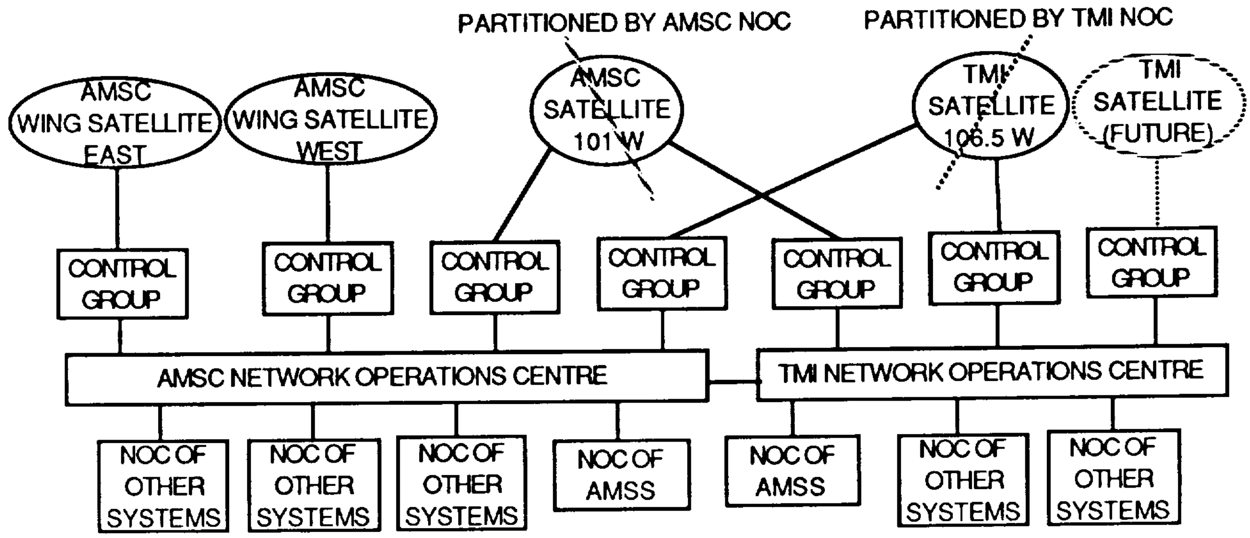

Figure 1. General Architecture of a System to Provide MSS in North America

The bandwidth and power available in a satellite transponder will be subdivided into one-way channels of various bandwidths and power levels. Generally, forward and return link channels will be paired to support two-way communication. A symmetrical channel pair forms a circuit. Pairings may be asymmetric for provisioning of asymmetric services such as packet switched data and to support signalling. Circuits may be used for DEMAND PERIOD or for FULL PERIOD circuit switched service. DEMAND PERIOD circuits are used on a call-by-call, as needed, basis; FULL PERIOD circuits are devoted to a long term particular use.

NETWORK ARCHITECTURE

The general architecture of the systems to provide MSS in North America is illustrated in Figure 1. The satellites owned respectively by TMI and AMSC are located at several different orbital positions. Communications services provided through any of these satellites, or a portion of a satellite, is managed within a Control Group, to be described in more detail later. For business reasons or for network restoral in the event of satellite failure, capacity on the two central satellites may be allocated to both a TMI and an AMSC Control Group.

A TMI and a AMSC Network Operations Centre will manage and control all the resources of the respective systems. A NOC will coordinate the frequencies to be used in each beam and will allocate blocks of satellite bandwidth and power within beams as satellite circuits to a Control Group. The NOC also allocates blocks of satellite bandwidth and power to customers such as the commercial aviation community, who may wish to operate their own mobile satellite system. The NOC receives and acts upon requests for pre-emption of frequencies if required for aeronautical safety services. In responding to the flight safety requirements, the NOC may need to reconfigure the frequency bands to be used by each satellite in each beam and so advise the GCs.

The NOCs will carry out the administrative functions associated with management of the total MSS system. This includes the registering of METs with their attributes, setting up conditions so that properly authorized METs may access the system, the recording of system usage for billing purposes and the accumulation of network performance records to aid in long-term system planning.

This architecture clearly has provision to accommodate growth through the addition of new satellites (which may have a different transponder and beam configuration), and the addition of Control Groups. It also provides needed flexibility in the allocation of resources to different Control Groups.

Within this overall architecture, the provision of DEMAND PERIOD circuits to and from METs is managed by a Network Control System (NCS). The structure of the NCS is shown diagrammatically in Figure 2. The elements of a NCS are a Network Operations Centre (NOC), a Network Control Centre (NCC) and the portions of the FESs and METs that are associated with the signalling channels through which the assignment of circuits and other network control functions are exercised. A Group controller (GC) within the NCC assigns satellite circuits to meet customer requirements. All interfaces within the NCS will be in accordance with a specified network standard. The operator interface at the MET and the terrestrial network interface at the FES will not be standardized in order to maintain flexibility to meet the needs of specific end-user customers or service provider organizations.

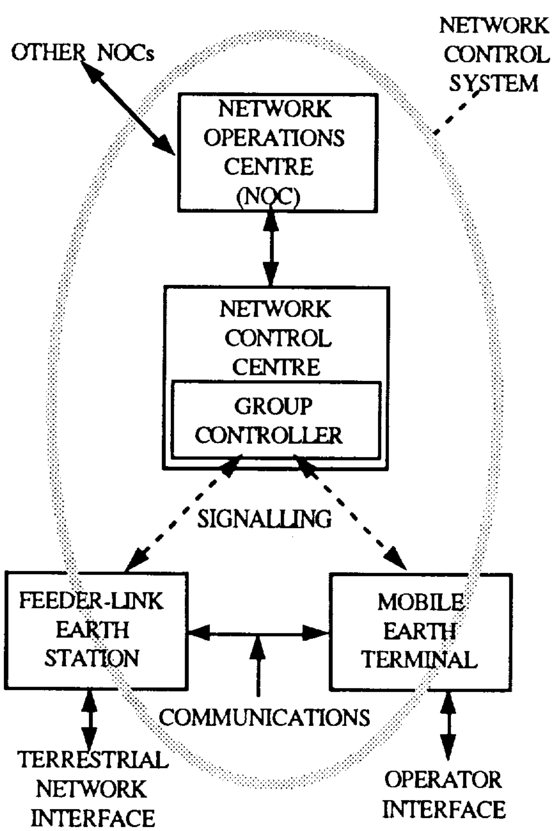

Figure 2. Architecture of the NCS

Because bandwidth and power are valuable and limited, the available satellite circuits are formed into pools large enough to ensure high circuit usage efficiency. The various customer networks within the NCS will use circuits from circuit pools on an as-needed basis.

METs located within the various beams of the system access the GC through L-band signalling channels to request a satellite circuit for communication involving requirements for an interconnection through a FES to the PSTN or to a private network. The necessary instructions from a GC to a FES to set up a communications channel with a MET are provided through Ku-band signalling channels. Calls between METs, which are not expected to be a large part of the total service, are established by double hopping through a FES which is suitably equipped to support such calls.

Two examples of virtual networks will illustrate the application of these features of the NCS. For the first example, a single FES serves a group of METs to form a private network. Call connections are made between the METs and a PBX attached to the FES. The FES is provisioned with several voice channel units of a single type. The interface between the PBX and channel units provides the necessary protocol conversion. Virtual network managers within the GC set up the pre-assigned routing option for this closed user group. The second example involves a virtual network configured for providing PSTN access by subscribing METs. FESs are strategically located throughout the country and interconnected to the PSTN. Each FES is equipped with a number of channel units and PSTN connections based on traffic engineering forecasts and the routing method selected. A virtual network manager within the GC sets up call routing through a FES which is closest to the called party in the PSTN. Appropriate routing is also provided for calls to METs originating from the PSTN.

The network architecture provides for the incorporation of packet switched services, as a separate network, which will likely operate using FULL PERIOD channels administered by a Data Hub [3].

SIGNALLING

The signalling system provides a method for mobile terminals to access the NCS for the exchange of channel assignment and network management information among all the elements of the NCS. The signalling system must serve the anticipated number of mobile terminals and provide the required response time for setting up calls. One or more signalling channels will be needed in each beam of each satellite.

The signalling system must provide for positive and continuous control of all METs in the system. For this reason and because of the need for a continuous signal for MET antenna tracking and the benefits of a common frequency reference, consideration is being given to requiring all METs to receive a signalling channel at all times, even when a call is in progress.

The strawman concept for the signalling system described here supports the circuit switched services for MSAT. The packet switched data services, the MDS, operate on separate channels. This signalling will be used to set up calls between an FES and a MET. Call take-down will be managed by the FES via some form of signalling on the traffic channel with appropriate notification to the GC.

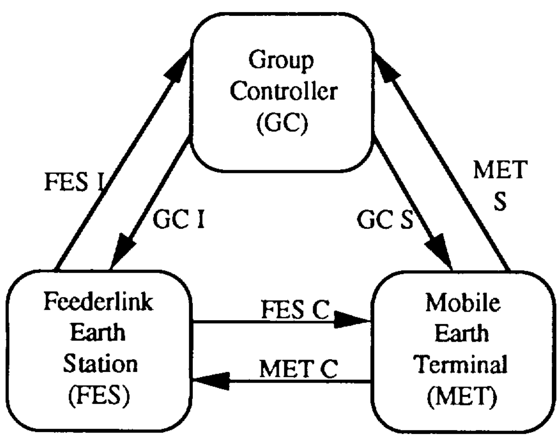

Figure 3. Signalling Channel Configuration

Figure 3 shows the channel configuration between a GC, an FES, and a MET. Six different channel types have been defined as shown in Table 1 [4].

The interstation signalling channels (GC-I and FES-I) will be a simplified form of many existing VSAT systems and will not be described further here.

The communications channels (FES-C and MET-C) are demand-assigned circuit switched channels. The type of traffic to be carried on the channel will be negotiated during the call set-up and may include the type of modulation to be used. Thus the same signalling infrastructure will be able to set up calls for ACSSB, 4.8 kbps CELP, stream data, etc.

Channel	Description	Characteristics
GC-I	Interstation sig. ch. from GC to an FES	TDM
FES-I	Interstation sig. ch. from an FES to GC	TDMA
GC-S	Outbound sig. ch. from GC to a MET	TDM
MET-S	Inbound random access sig. ch. from a MET to the GC	Sloppy Slotted Aloha
FES-C	Outbound com. ch. from an FES to a MET	Traffic
MET-C	Inbound com. ch. from a MET to an FES	Traffic

Table 1. Channel Descriptions

Due to the nature of the signalling channels, it is necessary to have a fixed packet size for the exchange of information. These packets are referred to as signalling units (SU) and are 96 bits long. This size was deemed to be adequate for most applications and is also the size that other MSS operators have chosen [5,6].

The signalling channels may use A-BPSK transmitted at 2400 sps. Rate 1/2 coding may be used thus giving an information rate of 1200 bps. The use of higher rate block codes is being investigated, especially for the inbound channel (MET-S) in order to improve throughput.

The outbound GS-S channel uses time division multiplexing and channel could be interleaved over a one second frame. Each frame could handle 12 SUs. Periodic bulletin boards would be transmitted on this channel in order to relay vital network information (i.e. congestion information, alternate signalling channels, etc.).

The inbound signalling channel (MET-S) could use Sloppy Slotted Aloha (SSA) [7]. This scheme permits the use of small guard times.

However METs do not necessarily have to have correct timing on their first access. The MET-S channel will be able to support 10 slots per second.

In addition to the SSA approach, various reservation schemes are being investigated which may lead to greater throughput. The ratio of inbound to outbound channels will depend upon which reservation scheme is selected.

The connect time is defined as the time from which the MET or FES initiates a call to the time an end-to-end connection is established between a MET and FES. The performance objectives are as follows:

Connect Time (seconds)				
Performance	Degree of Shadowing			
Objective	None	Light	Moderate	Heavy
Mean	2.5	3.0	4.0	5.0
90%	5.0	6.0	8.0	10.0

Given one GC-S channel as described above and as many inbound channels as are necessary, it is desired to estimate how many users could be supported. The following assumptions are made: three outbound packets needed to set up a call; an average busy hour usage of 0.01 erlangs per user; and an average call duration of 60 seconds.

Working with these averages, and ignoring queuing problems, this leads to one GC-S channel being able to support or 240 calls in progress (approximately 24,000 users). This number would be lower in actual practice, so that the queues could be minimized. The number of inbound channels required per outbound channel will depend upon the reservation scheme adopted, but will be in the range of one to five.

CONCLUSION

This paper has described the concept for the ground segment infrastructure that will be needed to support the mobile voice and data services that will be provided by MSAT. The design of the ground segment will be developed further during 1990 and procurement of hardware will commence at the beginning of 1991.

The design process will be pursued in cooperation with the AMSC with the intention that systems to be operated by the two companies should provide a fully compatible service.

The detailed design and implementation of the systems will be a major and exciting challenge.

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