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DEVELOPMENT OF THE NETWORK ARCHITECTURE OF THE CANADIAN MSAT SYSTEM

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ABSTRACT

This paper provides a description of the present concept for the Canadian Mobile Satellite (MSAT) System and the development of the network architecture which will accommodate the planned family of three categories of service; namely, a Mobile Radio Service (MRS), a Mobile Telephone Service (MTS), and a Mobile Data Service (MDS).

The MSAT satellite will have cross-strapped L-band and Ku-band transponders to provide communications services between L-band mobile terminals and fixed base stations supporting dispatcher-type MRS, gateway stations supporting MTS interconnections to the public telephone network, data hub stations supporting the MDS, and the network control centre. This paper briefly discusses the currently perceived centralized architecture with demand assignment multiple access for the circuit switched MRS, MTS and permanently assigned channels for the packet switched MDS.

INTRODUCTION

The technology to provide commercial mobile satellite communications services, and the market need in North America, have been explored for more than ten years. The lack of frequency spectrum to accommodate land mobile satellite communications, which has been a major impediment to the implementation of the service, was finally overcome at WARC 87. Bands of frequencies between 1530 and 1559 MHz and between 1626.5 and 1660.5 MHz were allocated, respectively, for space-to-earth and earth-to-space links for the land mobile satellite service (LMSS) on a primary, shared primary and secondary basis.

While the allocation is not generous, analyses show that the frequency re-use that can be provided with multi-beam satellites can accommodate the anticipated market demand, at least for the first generation systems. Operational experience and advances in technology are expected to increase the capacity of the present allocation and to provide evidence to support the allocation of additional spectrum to meet the requirements.

Telesat Canada anticipates that very soon the design of satellites, to be launched in the early 1990s, will be determined. Procurement action for the space segment should begin in late 1988. Shortly thereafter, the design of the basic MSAT communications systems will be frozen in order that procurement of the ground segment may proceed. While much of the work in the past has focussed on technological development, this must now be integrated into the design for an operational system.

MSAT COMMUNICATIONS SERVICES

The Canadian MSAT system will provide services to L-band mobile terminals under three main service categories, namely:

- Mobile Radio Service (MRS)
- Mobile Telephone Service (MTS)
- Mobile Data Service (MDS)

Mobile Radio Service (MRS)

The MRS will provide two-way voice and optional voice-band data communications between a base station and user terminals belonging to the same private network. This service is primarily targeted to meet customers' needs for voice dispatch operations. The MRS will be a circuit switched service and subscribers will be charged for the air time used. The service will be provided through privately owned or shared base stations.

Mobile Telephone Service (MTS)

The MTS is intended to provide an extension of the public switched telephone service (PSTN) mainly to mobile terminals, but also to some portable and fixed terminals. The service will be provided through a number of gateway stations interconnected with the PSTN. The service will operate on a circuit-switched basis and subscribers will be charged for air time.

Mobile Data Service (MDS)

The packet-switched MDS will provide data communication capabilities between mobile terminals and a subscriber's office through an MDS data hub station. Subscribers will be charged for each packet of data transmitted. Most of the MDS applications will be supported through a Data Hub owned by Telesat Canada, located at the Network Control Centre (NCC), and interconnected with user headquarters and dispatch centres by means of a Ku-Band VSAT network or via public packet data networks. If it is required, there will be more data hubs located in other locations. These data hubs can be connected to the NCC through the SHF link or by terrestrial means.

Some applications, such as an Aeronautical Mobile Data service, will require facilities which are compatible with international standards and therefore require their own unique capability. The special purpose data hub could be located at the NCC or at the location of the service provider.

The MDS will be capable of bearer and value-added data communications, including:

- Interactive Digital Messaging
- Vehicle Dispatch/Location
- Paging
- Data Acquisition and Control
- Data Collection
- Data Broadcast
- Bulk Data Transfer (Data/Image/Text)

POTENTIAL MARKET FOR MSAT SERVICES

The potential market, or need, for MSAT services in Canada is presently (1986) estimated at 660,000 mobile units, growing to close to a million units by the year 2000. Ninety-two percent of the market is for land mobile, 5% for marine and 3% for aeronautical services.

The demand for MSAT voice services is anticipated to grow to 80,000 mobile units some 10 years after the introduction of MSAT service. It is estimated that 75% of MSAT voice terminals will be used to provide an MRS and 25% to provide an MTS. It is expected that 70% of this demand will be generated by six major industry sectors: transportation, minerals, services, forestry, government and construction.

The demand for MDS has not yet been investigated as thoroughly as that for MRS and MTS but it is expected to exceed that for the MRS and MTS terminals.

MSAT SYSTEM DESCRIPTION

The communications payload of the geostationary MSAT satellites will be cross-strapped L-Band and Ku-band transponders. These transponders will provide communications paths between mobile terminals, which will operate at L-band in portions of the 1.5 GHz and 1.6 GHz frequency bands (as will be coordinated by Telesat Canada) and fixed Ku-band (14/12 GHz or 13/11 GHz) earth stations. SHF - SHF communications between the network control centre and the other SHF stations in the system will also be supported.

Telesat Canada plans to cooperate with the U.S. MSS Consortium to implement the first generation system with one Canadian and one American satellite, each of which will have the capability to provide back-up services to the other country, as well as to provide services to mobile users who move from one country to the other.

In the present baseline design of the Canadian system [1], each satellite will have two large (a minimum of 5 m in diameter) L-Band deployable parabolic reflectors which will generate nine 2.7° beams covering Canada and the United States. Another pair of beams may cover Mexico.

One or more transponders may transmit into each beam, probably in specific sub-bands of the L-band allocations, as coordinated for each beam. There will be re-use of frequencies in beams that are separated by at least two beamwidths.

The nominal channel spacing will be 5 kHz for both voice and data signals. Some services may require a multiple or one half of a basic channel. Initial planning is to have paired L-band downlink (forward) and uplink (reverse) 5 kHz channels. However, the number of reverse channels may not be so severely limited as the forward channels. Within an overall bandwidth limit, it may be possible to associate more than one return channel with an L-band downlink channel and thereby improve the message handling capability of channels, particularly for the MDS and perhaps for the signalling channels.

The SHF transponder will operate with an antenna that provides coverage of North America. As there are far fewer design constraints on the SHF links, there is considerable flexibility in the implementation of the back-haul links to the base, gateway and the NCC.

Demand assignment multiple access (DAMA) techniques will be employed to provide MRS and MTS voice subscribers with access to a satellite channel. Over 60,000 voice terminals in Canada can be served by the Canadian satellite in the first generation system.

The capacity of the satellite system, expressed as the number of mobile subscribers that can be offered service, is determined through the application of statistical utilization factors (e.g. a 40% activity factor for a voice conversation) and estimate of the traffic generated by an average subscriber. Studies have indicated that the average MRS voice subscriber will use a channel for approximately 150 minutes/month (the average busy hour traffic is 0.0106 erlang). The tolerable probability of all channels being busy, the probability of a call blockage, has been assumed to be 15 percent. Under these conditions, for the initial system, an average of approximately 95 voice users can share each 5 kHz channel.

Packet switching techniques will be used to provide data transmission services. It is anticipated that 2,000 - 5,000, perhaps somewhat more, MDS subscribers can be accommodated within a 5 kHz channel. The number of subscribers that can be accommodated will depend upon the particular user application and implementation of the packet switched links. The MDS will likely use permanently assigned multiple access (PAMA) channels with the capability to augment capacity for certain data applications with DAMA channels.

The allocation of PAMA channels for the MDS will reduce the capacity available for the MRS and MTS services. At any one time, there will be an optimum balance between the capacities allocated for the respective services (optimization based on maximizing revenue, service capacity, or other criteria).

The signalling to communicate the DAMA control functions and to provide for requests to access the network will be implemented through specific DAMA signalling channels within each satellite antenna beam. Mobile terminals will use L-band DAMA access signalling channels to request capacity and to receive instructions on the channels to be used for communications. Correspondingly, SHF DAMA signalling channels will be used to communicate DAMA control functions to the base, gateway and possibly the data hub stations.

The use of the SHF bands and North American coverage for back-haul to the NCC, base, gateway and data hub earth stations economizes on the use of scarce L-Band frequencies, and provides for economical assignment of channel capacity from one location (rather than from within each beam). In addition, it allows access by a mobile terminal in any beam to any designated base, gateway or data hub station in the system, permits monitoring and control of L-Band access to the system and allows precise control of the signal levels transmitted via the L-Band transponders to the mobile terminals.

Studies have indicated that there is a very limited requirement for mobile-to-mobile communications. Such communications will be double-hopped through the Network Control Centre.

MSAT NETWORK ARCHITECTURE

Figure 1 illustrates the concept for the MSAT network architecture. The network is controlled from one Central Control Station (CCS) which embodies the coordinated functions of a Network Control Centre (NCC) to manage the communications network, and a Spacecraft Control Centre (SCC) to manage the satellite.

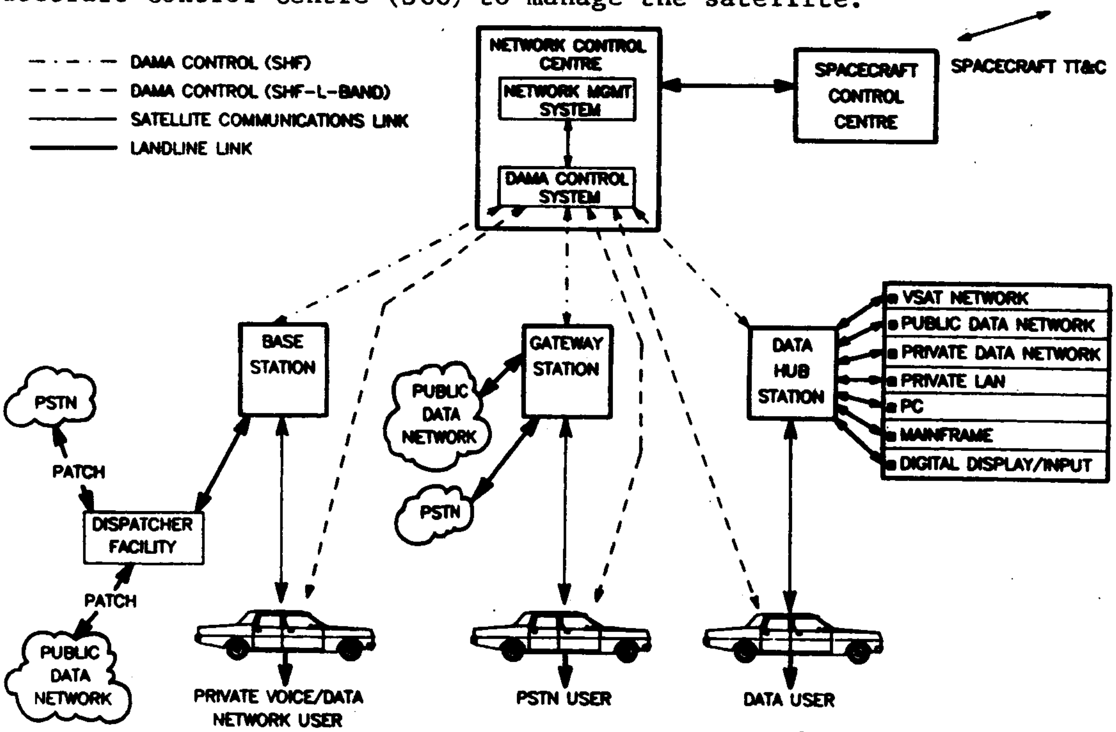

Figure 1: MSAT Network Architecture and Interconnections

The NCC maintains control of the communications network through DAMA signalling channels which use SHF - SHF links to interconnect the NCC with the SHF base, gateway and data hub stations and SHF - L-band links to interconnect the NCC with the mobile terminals. The signalling controls the allocation of L-band - SHF communications links between the mobile terminals and designated base, gateway and data hub stations.

The NCC incorporates a Network Management System (NMS) and a DAMA Control System (DCS). The major functions of these two systems in the management of all aspects of the communications network are as follows:

Network Management System

- Network Operation
  - Initialization and re-initialization of the network
  - Generation of call routing algorithms
  - Maintenance of a database of logged-on subscribers
  - Optimum transponder partitioning
  - Management of resources to meet service priority objectives

- Network Monitoring and Maintenance
  - Monitor power levels of transponder access
  - Gather alarms, monitor and control activation of redundant network elements
  - Report on network status and performance
  - Run network diagnostic tests

- Network Administration
  - Collect call records
  - Compile traffic, network performance and maintenance history statistics
  - Control security of subscriber access
  - Generate billing records

DAMA Control System

- Call Processing (Call Handling)
  - Respond to call requests, assign resources and set up the call, if possible, or otherwise signal calling party and take down call
  - Inform subscribers of the status of the network
  - Generate alarms for unusual conditions

- Call Administration
  - Manage orderly subscriber log-on and log-off
  - Establish and maintain DAMA assignment and request channels in each beam of the system
  - Respond to individual terminal status reporting
  - Record call data
  - Generate polls of network elements
  - Command changes to mobile terminal transmit power under control of NMS
  - Monitor emergency channels

The other elements of the network architecture are:

- L-Band mobile and transportable terminals
- SHF Base Stations which support the MRS
- SHF Gateway Stations which support the MTS
- SHF Data Hub Stations which support the MDS, which have been discussed earlier, and
- the signalling channels

The protocols and access techniques that will be used on the signalling channels are a critical aspect of the network architecture. A number of protocols have been explored [2]. Considerable simulation and testing will be required to confirm the performance and ensure that all the problems have been addressed and overcome. The performance of the whole MSAT system will depend upon the performance of these signalling channels.

SUMMARY

Telesat Canada anticipates cooperating closely with the U.S. MSS Consortium to develop a common system concept and architecture in order to reap the benefits of providing a "standard" service throughout North America. This approach will result in large scale production of lower cost units built to a common functional specification. Action during the next year will determine whether the system will be a common coordinated design, perhaps along the lines described in this report, or be a more fragmented collection of services.

More investigative, analytical, simulation, and experimental work must be done to improve the understanding of the user requirements and to optimize the technical approaches and the system design.

Very little of the hardware or software necessary for the implementation of a mobile satellite system exists as a manufactured product at this time. For this reason, the design, specification and procurement of the first generation MSAT system to serve over 100,000 mobiles in Canada and over three times that number in the United States will challenge the technical and management capabilities of the Canadian and U.S. organizations.

REFERENCES

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[2] Razi, M., Shoamanesh, A., and Azarbar, B. 1988. L-Band and SHF Multiple Access Schemes for the MSAT System, NASA JPL Mobile Satellite Conference, Pasadena, U.S.A.