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System Services and Architecture of the TMI Satellite Mobile Data System

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ABSTRACT

The North American Mobile Satellite Service (MSS) system being developed by AMSC/TMI and scheduled to go into service in early 1995, will include the provision for real time packet switched services (Mobile Data Service - MDS) and circuit switched services (Mobile Telephony Service - MTS). These services will utilize geostationary satellites which provide access to Mobile Terminals (MTs) through L-band beams. The MDS system utilizes a star topology with a centralized Data Hub (DH), and will support a large number of mobile terminals. The DH, which accesses the satellite via a single Ku band beam, is responsible for satellite resource management, for providing mobile users with access to public and private data networks, and for comprehensive network management of the system. This paper describes the various MDS services available to the users, the ground segment elements involved in the provisioning of these services, and a summary description of the channel types , protocol architecture and network management capabilities provided within the system.

INTRODUCTION

The North American Mobile Satellite Service (MSS) system [1] being developed by AMSC/TMI and scheduled to go into service in early 1995, will include the provision for real time packet switched services (Mobile Data Service - MDS) and circuit switched services (Mobile Telephony Service - MTS) The MDS system uses packet switching techniques to provide for the dynamic sharing of satellite resources between a large number of mobile users. The architecture of the MDS system is similar to packet switched VSAT systems, wherein a centralized Data Hub (DH) communicates with a large number of remote units. In contrast to currently deployed land mobile data systems such as INMARSAT Standard C, which primarily support store and forward messaging, the MDS system provides a flexible architecture which is capable of supporting a wide variety of application types. Potential applications which can be supported via this system include Remote Data Base Access and Entry, Fleet Management, Supervisory Control and Data Access (SCADA), and multicast data, as well as messaging. Potential customers of this system include transportation (trucking, taxicab) companies, field sales, field services, public services agencies (police, ambulance, fire), oil companies, utilities, as well as the general category of mobile professionals.

MDS GROUND SEGMENT ARCHITECTURE

The ground segment architecture of the MDS system is shown in Figure 1. The MDS ground segment elements consist of a Data Hub (DH), Mobile Terminals, and Remote Monitoring Stations. The MDS system can be configured to operate either in an integrated manner within the MSS system, or as a standalone system. In an integrated system, the DH interfaces with the MSS Network Operations Center (NOC) for allocation of system resources, and with the Network Control Center (NCC) for supporting circuit switched services to integrated voice data MTs. In an integrated system, the DH RF Equipment may be shared with the NCC or FeederLink Earth Station (FES) RF Equipment. In a standalone configuration, the MDS system operates with a pre-allocated set of resources from the NOC operated by the MSS service provider. A brief description of the MDS ground segment elements is provided next:

Data Hub Terminal Equipment (DH - TE) - The DH-TE provides packet switched communication services to MTs. On the terrestrial side the DH interfaces to public and private data networks as well as customer host computers. It provides for the dynamic assignment of MDS capacity to MTs on a demand basis. It also provides for the overall management and control of the MDS network. The DH interfaces with the Network Management System (NMS), which includes the Customer Management Information System (CMIS), to obtain customer configuration information and to provide network usage information. Network status and configuration information are also communicated between the DH and Network/Systems Engineering functions within the NMS.

Mobile Terminal (MT) - The MT provides user access to the packet switched services provided by the MDS system. Four MT types are supported by the MDS: full duplex, half duplex, receive only, and integrated voice/data. The half duplex MT, which does not require an RF diplexer provides a low cost, limited feature, alternative to the basic full duplex MT. The receive only MT supports only unicast services and can be used for applications such as paging and multicast data reception. The integrated voice data MT (IVDM) combines the capabilities of a full duplex MDS MT, and a circuit switched MT.

Remote Monitor Station (RMS) - The RMS provides the capability to monitor the L Band RF spectrum and transmission performance in a specific L-band beam. An RMS is located in each L band beam and interfaces with the DH via a satellite or terrestrial link.

MDS SERVICES

In designing MDS services, two key requirements were taken into account - a) emphasis was placed on providing application independent core networking services and b) supporting service offerings that are compliant with international standards. Emphasis on the core networking services, which provide for basic packet switched circuit setup, data transfer and circuit takedown, allows the system to support user specific applications in a very flexible manner. Adherence to international standards makes it possible to use commercial off-the-shelf communications software for providing value added services and also reduces the cost associated with implementing the MDS ground segment. The standards compatible core networking services category is referred to as Basic Services in the MDS system. Since some MDS capabilities (such as multicast data, and TDMA bandwidth reservation) could not be optimally accessed via the core networking services, an additional service category referred to Specialized services is also supported by the MDS system.

As described earlier, the Basic services category provide for transparent communications services between data terminal equipment (DTE) connected to the mobile terminal and DTEs connected to the data hub. Two types of Basic Services are provided within the MDS system: X.25 and Asynchronous. The X.25 Service provides for the establishment of virtual circuits between an X.25 DTE attached to the MT and a fixed X.25 DTE connected to the DH. Figure 2 shows the X.25 Service architecture. As shown in the figure, the DH can directly interface with the fixed DTE, or the interconnection can be via an intermediate public or private data network. This service is compliant with the 1988 and 1984 versions of the CCITT Recommendations X.25. The X.25 service provides a flexible mechanism for the deployment of value added services. An MDS service provider can easily provide such services by integrating off-the-shelf hardware and/or software such as protocol gateways (e.g SNA packet assemblers/disassemblers). A number of such X.25 gateway products are commercially available on the market from a large number of vendors. Applications such as store and forward messaging can also be easily supported via off-the-shelf communications software packages on personal computers and workstations.

The second service in the Basic Services category is the Asynchronous Service which provides for the interconnection of an asynchronous DTE connected to the MT with a packet mode DTE connected to the DH. The Asynchronous Service uses procedures compliant with the 1988 and 1984 versions of the CCITT recommendations X.3, X.28 and X.29 protocols. Figure 3 shows the Asynchronous Service architecture. As shown in the figure, the Asynchronous Service also provides the capability for the asynchronous DTE attached to the MT to communicate with a fixed asynchronous DTE through the use of an external Packet Assembler/Disassembler.

The primary advantage associated with the basic services: X.25 and Asynchronous is that they provide the flexibility to support value added services without any impact on the core MDS network. However a number of attributes associated with a landmobile system cannot be fully utilized by these services. To provide a mechanism for utilizing these attributes, the MDS system also supports two Specialized Service categories: Reliable Transaction Service (RTS) and Unacknowledged Data delivery Service (UDS). RTS provides the capability to efficiently complete a short transaction (request/response) between mobile and fixed users. This service is especially efficient when the fixed user connected to the DH originates the transaction request, since the DH can allocate space on the inbound reservation channel for the response. For applications (e.g cargo monitoring, location tracking) which require periodic polling, this service is much more efficient than using the X.25 service, since a) fewer messages are generated and b) a prioiri capacity can be assigned on the inbound channel.

The second specialized service is the Unacknowledged Data delivery Service (UDS) which provides the capability to transmit non-assured data. More importantly, UDS provides the capability of multicasting data to MT User Groups. Both the RTS and UDS services are offered to end users via a specialized services access function within the DH and the MT. Message primitives and formats for applications to communicate with the specialized service access function have also been standardized in the MDS system.

In addition to packet data services, MDS also supports the provisioning of an integrated voice/data Service to MTs. This service allows a class of MTs termed Integrated Voice/Data MTs (IVDMs) to use the circuit switched system (MTS) for voice, stream data, and facsimile, and the packet switched system (MDS) for packet data services. The circuit switched service provisioning is supported via co-ordination between the DH and the Network Control Center (NCC) which allocates the satellite circuit resources for the mobile telephony service. The call setup signalling between the NCC and the telephony call control function at the MT is done over the MDS channels by utilizing the RTS Services. A FES selected by the NCC for completing the call provides the interconnection of the circuit with the public switched telephony network (PSTN).

MDS CHANNEL ARCHITECTURE

Four channel types (one outbound, three inbound) are defined at the physical layer to provide the connectivity between the MTs and the DH. The outbound (DH to MT direction) channel termed DH-D, operates as a Time Division Multiplex (TDM) channel with a data rate of 6750 bps using differentially encoded QPSK modulation and rate 3/4 convolutional coding. The frame structure utilized over the DH-D channel is shown in Figure 4. Fixed size frames which carry variable data segments are transmitted over this channel which operates at a nominal information rate of 5062 bps. The DH-D frame structure provides the common timing reference for the synchronization of inbound channel frames.

Three types of inbound channels: MT-DRr, MT-DRd, and MT-DT are used in the MDS system. These channels employ differentially encoded QPSK modulation at a transmission rate of 6750 bps. Data is coded using rate 1/3, constraint length K = 7 convolutional coding. The MT-DRd is a contention type channel (slotted aloha) which is used to transmit short packets for interactive applications. The MT-DRr is also a contention type channel, except that it is only used for making capacity requests for the MT-DT channel. The MT-DT channel is a reservation (assigned) channel, the access to which is controlled by the DH.

The frame structures for the three channels are shown in Figure 4. The MT-DRd and MT-DRr channel framing consist of fixed size slots (108.15 msec, and 42.88 msec respectively). The transmission of data packets into these slots is done in accordance with the slotted Aloha scheme. The MT-DT channel uses variable length framing. The access to the MT-DT channel is done in a Time Division Multiple Access (TDMA) manner under the coordination of the DH. Two types of MT-DT frames (types A & B) are used. Type A frames which provide for two information fields, are used to support the piggybacking of requests for additional capacity on the TDMA channel. This technique enables the MT to pipeline data requests and have the capability to transfer data at rates close to the inbound channel information rate.

MDS PROTOCOL ARCHITECTURE

The internal protocols designed for the MDS system are required to provide sufficient functionality for supporting the Basic and Specialized service categories, while taking into account the unique characteristics associated with the land mobile environment,. Efficiency was an extremely important criteria in designing these protocols, given the high cost associated with the MSS satellite resources. Efficient recovery of errored packets due to the fading and shadowing conditions was another important requirement. Unlike typical VSAT systems, where the remote nodes are designed to be operational at all times, the design of the MDS protocols also needed to take into account the requirements for frequent resynchronization of the protocol state machines given the operational nature of the MTs.

The internal protocol architecture used within the MDS network is shown in figure 5. A layered protocol architecture consistent with the Open System Interconnect (OSI) model is used in designing the MDS protocols. The access to the MDS physical channels (DH-D, MT-DRd, MT-DRr, and MT-DT) is controlled by the Channel Access and Control (CAC) protocol. The CAC protocol provides different functionality at the MT and the DH. At the DH, the CAC protocol is responsible for formatting of packets within the DH-D frames, and for allocating TDMA capacity on the MET-DT channel, in response to requests from the MT or upper layer protocols at the DH. At the MT, the CAC controls access to the inbound channels. It implements the retransmission backoff algorithm for accessing the slotted Aloha (MT-DRr, and MT-DRd) channels. It is also responsible for monitoring the inbound packet queues and for requesting MT-DT channel capacity. The CAC provides for the prioritized processing of packets within the MDS network. It also implements algorithms for congestion control of the MT-DRd, MT-DRr, and MT-DT channels.

The Basic Service Categories (X.25 and Asynchronous) in the MDS system are supported by the MDS Packet Layer Protocol (MPLP) and MDS Data Link Protocol (MDLP). The MDS Packet Layer Protocol (MPLP) provides procedures for the setup, data transfer, and clearing of multiple virtual circuits between the MT and the DH. ISO 8208 which supports symmetric X.25 packet interconnection is used as the baseline protocol for MPLP. MPLP incorporates small enhancements to ISO 8208 for more efficient operation in the MDS environment. For instance, a strategy which reduces the number of Receiver Ready (RR) packets is incorporated into MPLP.

The MDS Data Link Protocol (MDLP) provides for the reliable sequenced delivery of packets. In terms of functionality, the MDLP is similar to the Link Access Protocol - Balanced (LAP-B) defined in CCITT Recommendation X.25. However, unlike LAP-B, MDLP incorporates a number of features that provide for efficient operation in the landmobile environment. These include a selective repeat error recovery scheme to recover from lost packets, and a rapid synchronization of the protocol state machine in response to frequent MT on/off conditions.

The MDS Specialized Services Protocol (MSSP) provide for the multiplexing of application messages over the reliable transaction and unacknowledged data delivery services provided by MDS Transaction Protocol (MTP) and MDS Unacknowledged Link Protocol (MULP), respectively. MTP supports transactions involving short messages between the MT and the DH and vice versa. MTP is especially efficient when the transactions are originated by fixed users, since capacity for the response can be allocated over the reservation channel (MT-DT). MULP provides for the transmission and reception of unacknowledged data packets to and from MTs. More importantly it provides for the multicasting of data from the DH to MT user groups.

Finally the Bulletin Board protocol (BBP) provides for the dissemination of system information from the DH to all MTs. The bulletin board pages are organized in a manner that reduces the system overhead, while providing for significant flexibility in making incremental changes and incorporation of additional system parameters.

MDS NETWORK MANAGEMENT ARCHITECTURE

The MDS system provides for a comprehensive set of network management procedures. All five functional areas specified within the OSI network management framework: Configuration, Fault, Performance, Security, and Accounting are covered within the system. Key items within each of these functional areas are briefly summarized below:

Configuration Management - Procedures are provided for automated commissioning of new MTs, performance verification of MTs, updating of MT parameters, system parameter distribution, and maintenance of several databases that contain network configuration information. Keeping in mind the mobility of the users as well as the evolving nature of the service, MDS provides for the dynamic reconfiguration of all system and MT specific parameters via automated system procedures (MT parameter update and bulletin board distribution).

Fault Management - The DH incorporates several procedures to detect network failures and implement appropriate restoral actions. Failure modes that are detected include malfunctioning channel units, failure of terrestrial links, failure of RF link, rain fade, and lack of connectivity with the NOC. The DH is also required to implement procedures for the detection of malfunctioning MTs.

Performance Management - The DH maintains, and makes available to the network operator, management information variables related to overall MDS performance. These include traffic loads, congestion indicators, error indicators, and protocol statistics. The MT is also required to maintain performance statistics for each internal MDS protocol layer (MPLP, MDLP, MTP, CAC, Physical). Messages have also been defined to transfer these statistics back to the DH and make them available to network and systems engineering personnel.

Security Management - Given the large potential for fraudulent access in a mobile environment, a number of access authentication procedures have been incorporated into the MDS system. At the simplest level, two separate terminal identification numbers are used when communicating with the MT. A Forward Terminal Identification Number (FTIN) is used for outbound messages from the DH to the MT, while a Reverse Terminal Identification Number (RTIN) is used for inbound messages. More sophisticated security mechanisms are also provided for access authentication, during virtual circuit setup, and via a periodic polled challenge issued by the DH. An additional user facility has been defined within the X.25 call request and call accepted packets to carry the authentication information.

Accounting Management - The DH maintains accounting records for both the basic, as well as specialized services. The Basic Services records are collected by the off-the-shelf packet switch (Terrestrial Interface Subsystem). The accounting records are made available to the CMIS operated by the service provider, which is responsible for customer billing.

REFERENCES

[1] J. Lunsford, R. Thorne, D. Gokhale, W. Garner, G. Davies, "The AMSC/TMI Mobile Satellite Services (MSS) System Ground Segment Architecture", AIAA 14th International Communications Satellite Conference, Washington, D.C. March 1992

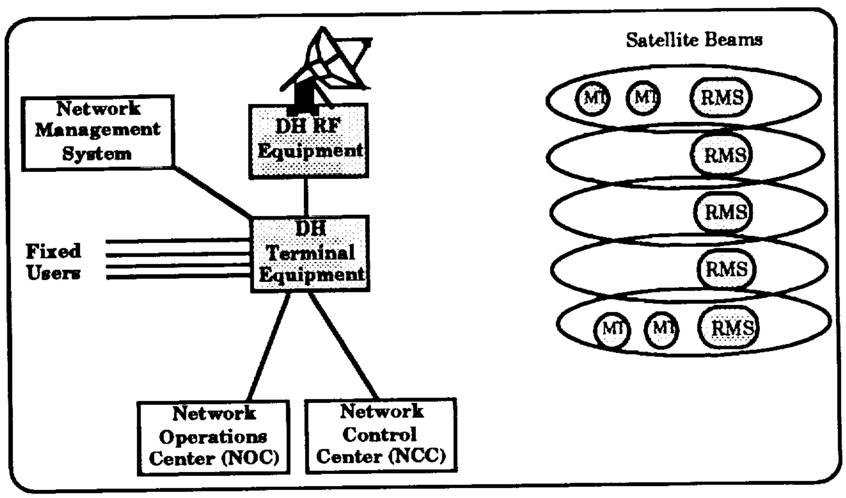

Figure 1. MDS Ground Segment Architecture

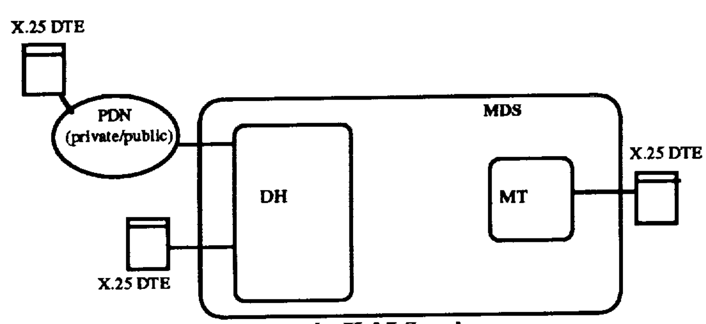

Figure 2. X.25 Service

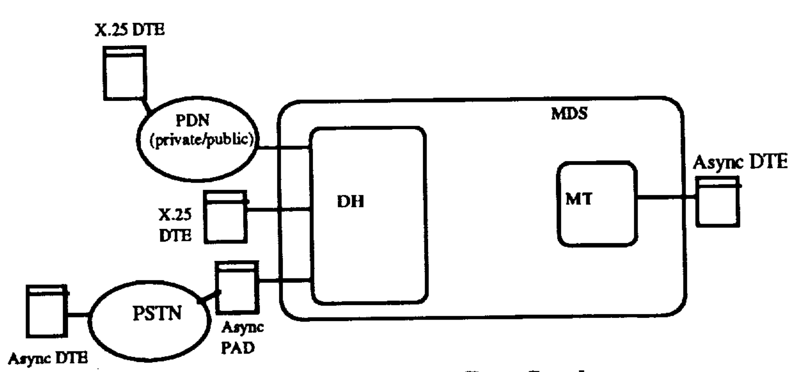

Figure 3. Asynchronous Data Service

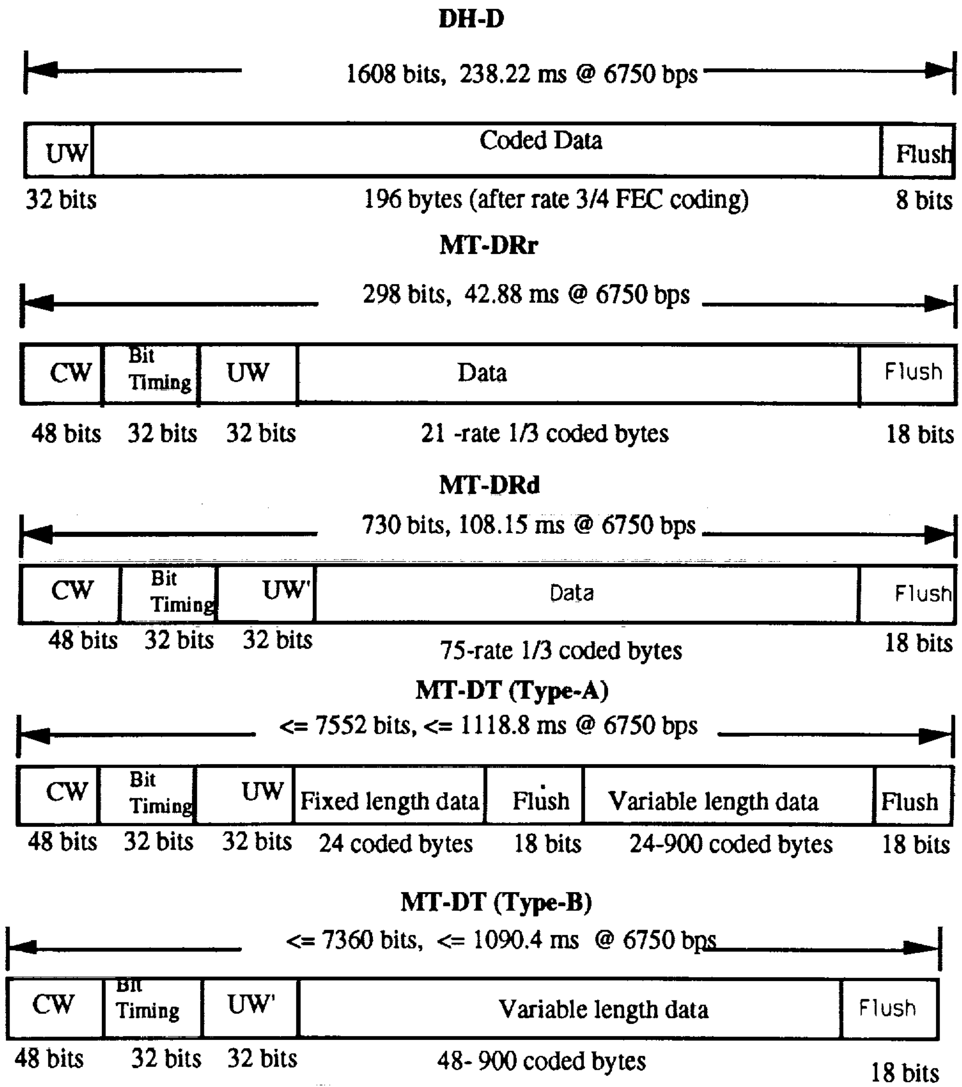

Figure 4. MDS Channel Frame Formats

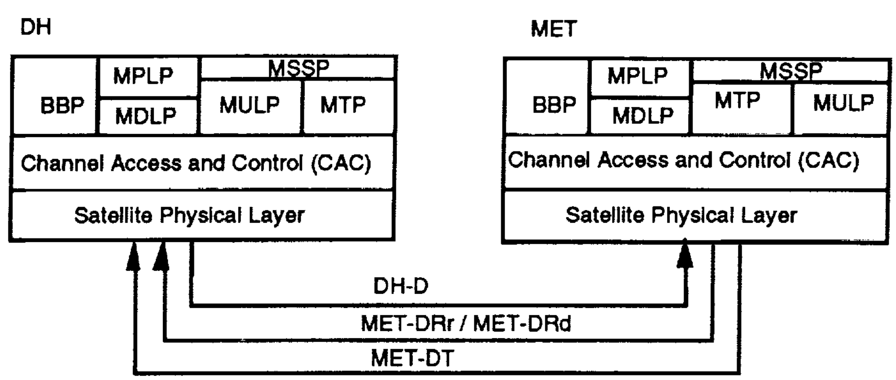

Figure 5. MDS Protocol Architecture