AN OPERATIONAL CONCEPT FOR A DEMAND ASSIGNMENT MULTIPLE ACCESS SYSTEM FOR THE SPACE NETWORK

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ABSTRACT

An operational concept for how a Demand Access Multiple Assignment (DAMA) system could be configured for the NASA Space network is examined. Unique aspects of this concept definition are the use of the Multiple Access system within the Space Network to define an order wire channel that continuously scans the Low Earth Orbit space for potential users and the use of advanced digital signal processing technology to look for the Doppler-shifted carrier signal from the requesting satellite. After the reception of the signal, validation and processing of the request is completed. This paper outlines the concept and the ways in which the system could work.

KEY WORDS

Satellite communications, satellite scheduling, space communications

INTRODUCTION

As part of an overall study to increase access to NASA's Space Network (SN), we have been considering options for a Demand Assignment Multiple Access (DAMA) system as an additional capability to the existing SN usage modes. This DAMA system would be used to request communications services on the Tracking and Data Relay Satellites (TDRS) within the SN. Currently, nominal user services are pre-scheduled to allocate service type and required equipment to a user of the SN. The availability of a resource for a given user is then communicated back to the user prior to the requested service time. The current system does not easily allow real-time changes to add new users to the service schedule. This is particularly important as spacecraft become more autonomous and will have the capability, with on-board error detection logic, to request interactions with their controlling ground station. The goals of this project are to improve the current operational modes as follows:

1. To reduce the support overhead required to maintain the overall scheduling requirements in this area,
2. To allow for more users to access the system, especially those who traditionally have not considered SN access available to them, and
3. To provide additional scheduling flexibility.

These goals can be met in the following ways:

1. Use of a DAMA processor will convert those parts of the schedule activity to a computer-controlled algorithm which will require less human intervention,
2. The development of a DAMA capability will provide small users with the perception that the process is easier to work and that schedule availability will be provided, and
3. The DAMA process will, by definition, provide scheduling flexibility over the current schedule-driven system.

The remained of this document presents a baseline concept for how this DAMA structure might be accomplished. When realized, the DAMA concept would allow scheduling of communications services on the TDRS spacecraft utilizing both the Single Access (SA) antennas at Ku-Band and S-Band and the S-Band Multiple Access (SMA) antenna system.

ASSUMED ENVIRONMENT

The baseline concept for the DAMA system is to restrict nominal usage to small projects without continuous or nearly-continuous coverage and not to have every user of the Space Network utilizing the DAMA system. For example, large projects with known schedules, e.g., Shuttle or HST, would continue with normal project scheduling because they know well in advance what their usage requirements are and have well-defined project schedules. Rather, we would expect the majority of the DAMA users to be from the small satellite community or non-traditional users having relatively low-rate command and data requirements, and are not in a permanent or full-time operational mode for their project. This does not mean that large projects could not utilize the DAMA scheme for emergency services. In effect, the DAMA users would primarily “fill the gaps” between contacts scheduled by projects. In the DAMA mode, we expect to treat the user spacecraft and the user Payload Operations Control Center (POCC) to be equal players in requesting services. This will allow for both normal operations and contingency or emergency operations. In this mode, the DAMA request can come to the scheduling office via either a space channel or from a land-based channel.

We also anticipate that the DAMA users would like to see an "Internet-type" access to data or to send commands. This would mean that the scheduling requests from either the user POCC or the user spacecraft could look like an electronic mail to the service scheduler. The service requests would be entered using a standard format and service request acknowledgment or request negative acknowledgment would return to the originator by the same route. If the user spacecraft is the service request originator, then the user POCC would be brought into the loop for verifying and approving the service request. It is anticipated that the user would receive spacecraft data from the SN using either direct routing or an anonymous ftp-type of service. The DAMA system is envisioned to utilize the TDRS SMA communications channel to establish services and the SA or SMA antenna systems to actually support forward and return data flow. The DAMA system would require the establishment of a new type of data service but would not change the spacecraft antenna configurations in any manner. The DAMA system being investigated here would require minimal modifications to the ground station at the White Sands Complex (WSC).

BASELINE CONCEPT

The proposed DAMA system will utilize both the S-band Multiple Access (SMA) capabilities and the Single Access (SA) capabilities of the Space Network. The SMA services are provided by an array of helical antennas mounted on the body of the TDRS spacecraft and operated as an electronically-steered phased array. The SA services are provided through one of the two gimballed dish antennas on the TDRS. The DAMA system will utilize the SMA system to transmit requests to a service scheduler for forward and or return communications services on either the SMA or SA antenna systems. In this concept, we allow for the user spacecraft as well as the user POCC to be the initiator of a service request. The DAMA service request would be initiated by the sending of a standardized service request packet from either the user spacecraft or the spacecraft control center. A conceptual sketch of such a packet is shown in Figure 1. The packet could be encapsulated inside of another Protocol Data Unit (PDU), for example, a TCP/IP packet, for channel transport. It could also be issued by the user spacecraft over a radio link or encapsulated an part of a Consultative Committee for Space Data Standards (CCSDS) virtual channel data stream where the virtual channel identifier is set to signal a DAMA request for service. This is illustrated in Figure 2.

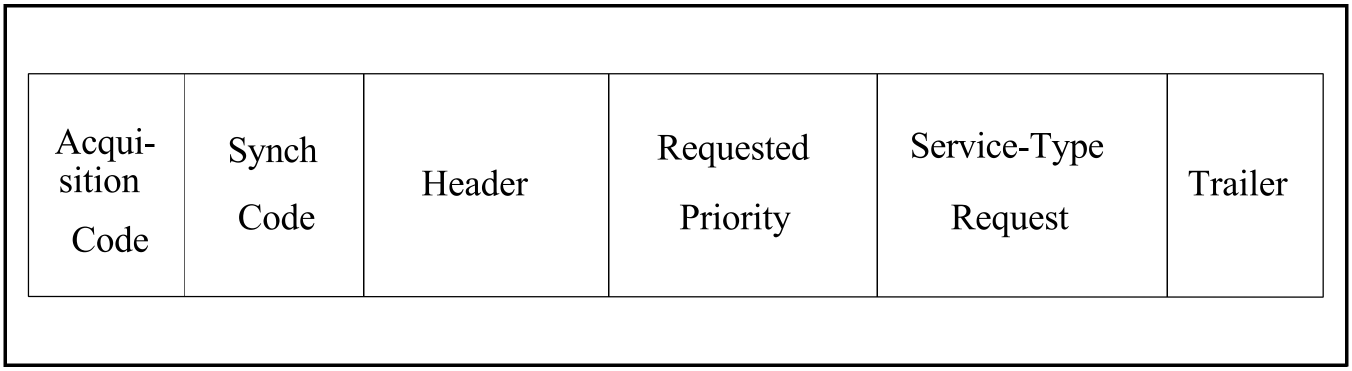

Figure 1 - DAMA Packet Structure

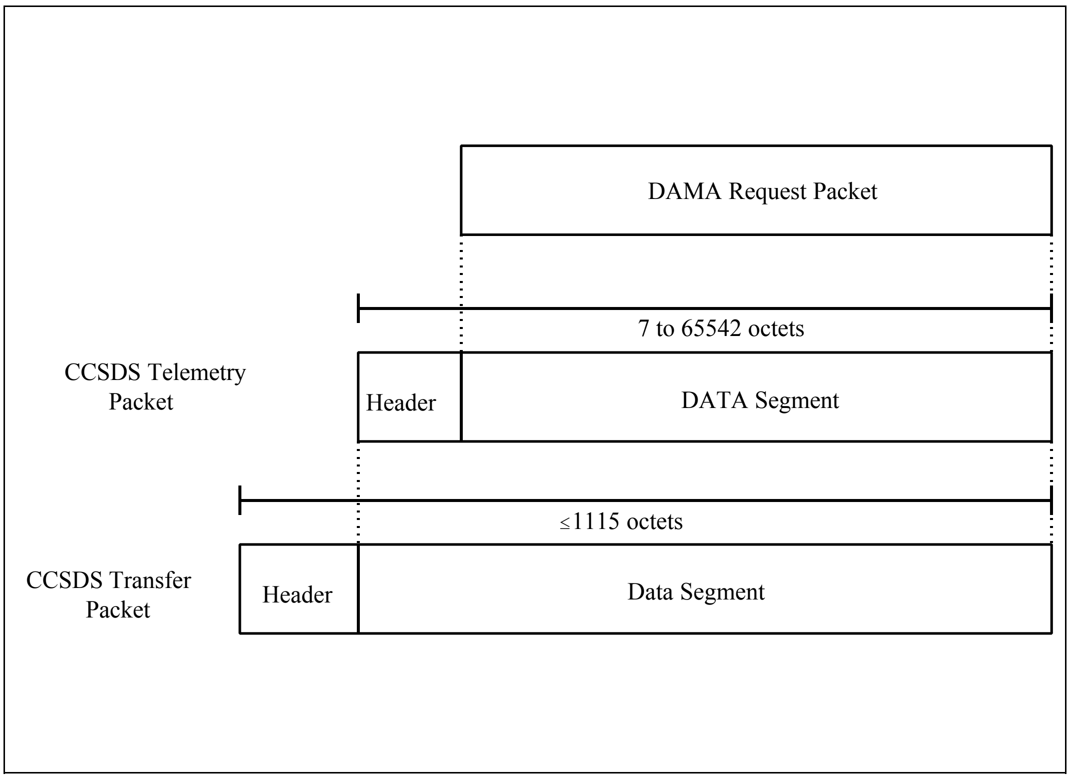

Figure 2 - CCSDS Telemetry Packet Structure

The field in the packet would be an follows:

1. Acquisition Sequence (optional) - used to synchronize to the packet when transmitted as part of a radio-frequency broadcast with the length to be determined by the receive specifications;
2. Synchronization Code (optional) - used to synchronized to the request packet if the packet is not encapsulated in a transport PDU of some type;
3. Header - used to identify payload needing DAMA service plus other DAMA accounting information which may be of the form of packet length, version number, etc.;

4. Requested Priority - encoding of the request priority and/or the desired grade of service;
5. Service-Type Request - would contain the necessary parameters to configure the service request and would contain such information an desired transmission band (S-band or K-band), access mode (Single Access or Multiple Access), standard SN configuration parameters that might be variable for this spacecraft, etc.; and
6. Trailer - end-of-request designator plus any required error detection and correction code.

It is expected that the data and trailer fields in such a packet could be kept to well under 1000 bits. The length of the synchronization code will need to be determined based on the receiver acquisition characteristics.

The on-orbit DAMA request would be received via the SMA link which we will term as an "orderwire channel". The current configuration for the return MA service is to use it in a spot beacon mode as shown in the left half of Figure 3. The spot beacon is formed electronically using the 30 array elements on the TDRS spacecraft. The user ephemeris is used by the ground station processing equipment to predict the position of the spot beacon and to track the movement of the user spacecraft. In the return service signal processing electronics at the WSC ground station, weighting factors are added to the return signal from each SMA antenna element to provide the correct phase addition to form the spot beacon. One set of weighting factors and associated signal processing equipment is required for each user being serviced by a TDRS within the SN. For the DAMA system, we propose configuring the SMA phased array to provide a global beacon from each TDRS in the SN an shown in the right half of Figure 3. This would be accomplished by utilizing the output from just one element of the phased array before it is processed through the beam-forming hardware at the WSC. This implies that no additional beam forming hardware would need to be dedicated to the DAMA system and taken from supporting normal SN users. Instead, a special receiver will be used to process the DAMA signals as they are stripped from the normal SMA processing system. Extensive simulation [1] of the resulting antenna patterns generated from a single array element shows that

1. A single element can cover the entirety of the LEO orbital range on the hemisphere facing the TDRS,
2. Using multiple array elements will give a smaller coverage pattern than that desired
3. Using all 30 array elements cannot produce the desired coverage.

Therefore, we believe that the single element approach will be capable of providing the necessary antenna pattern for the establishment of the orderwire channel. One element from each TDRS (East and West) will then cover the whole earth for LEO spacecraft except for the SN zone of exclusion over the Indian Ocean.

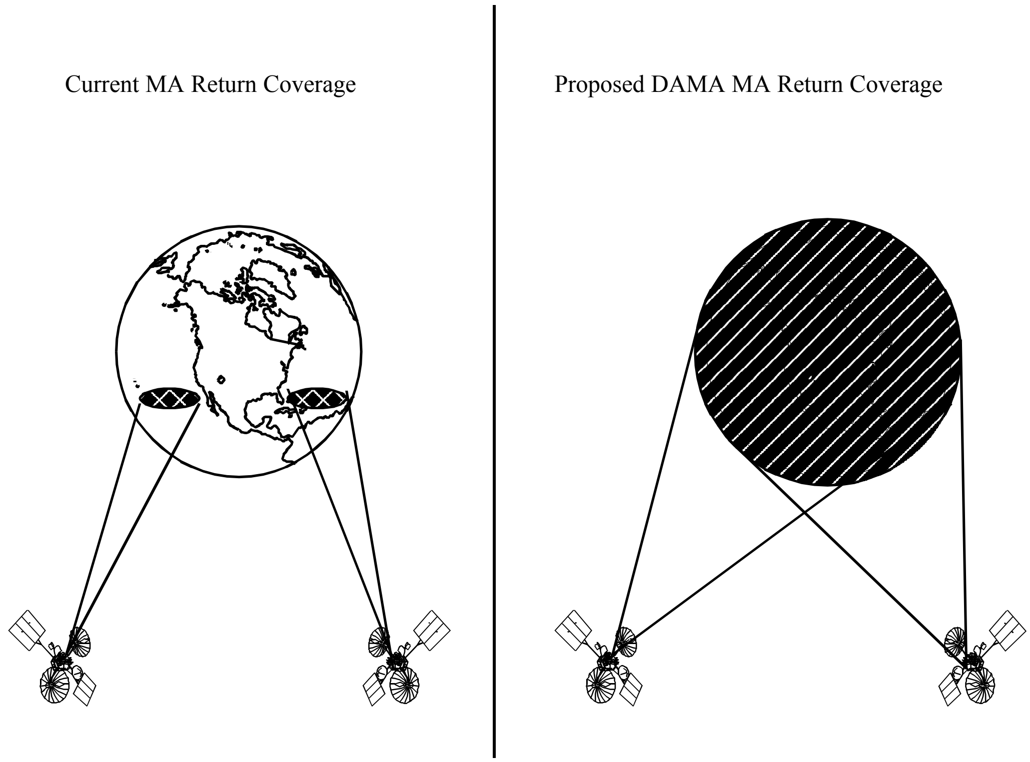

Figure 3 - MA Spot Beacons for MA Services (left) and DAMA orderwire channel (right).

The MA service channel operating as an orderwire would operate with an Aloha protocol and all users having a common PN code for the orderwire and a different PN code for data transfers. This latter code would follow the normal code assignment as in the current scheduled system. The orderwire PN code would require the reservation of a standard user PN code in the system for all DAMA users to utilize. The reason that an Aloha protocol and a single PN code can be used on the orderwire channel is that the users of the orderwire will be accessing it only during the short duration of the reservation requests thereby making the probability of reservation packets colliding low. The PN code will make the reservation packets orthogonal to the normal SMA data traffic and the orthogonality properties of the code will make each reservation packet orthogonal to all other reservation packets except for a short duration of a few chip times each code period. It is assumed that these short durations of vulnerability to collisions will not result in a meaningful number of request packet collisions due to the low probability of multiple request packets arriving at exactly the same moment. The SMA forward link would be used to answer service requests over the orderwire using a time-division multiplexing as is done in the system under scheduled service. The user of the DAMA orderwire channel would need to have a time-out programmed so that if a service scheduling message either confirming or denying the request is not received within a specified time, for example, five minutes, then a new service request packet would be issued.

The DAMA request packet from any source would flow into a DAMA service computer an shown in Figure 4. This computer would contain a data base for each legitimate user satellite with the following types of information:

1. Orbital ephemeris so that service window prediction possibilities can be computed,
2. Parameters for communications service configuration (nominal EIRP, transmission frequency, modulation and coding parameters, etc.),
3. User priority information, and
4. Routing information for command and telemetry data flow.

Some form of authentication service would need to be incorporated to prevent unauthorized DAMA request packets from being processed by the system. However, digital signal verification type of technology is readily available to support this function [2].

The DAMA processor will check for requested-service availability based on the pre-scheduled services, the service request type, and the user's priority in the system. If the service request can be honored, as requested, the WSC configuration is established via the normal scheduling mechanism requesting the services. A copy of the service request information is made available to the spacecraft POCC for concurrence and any necessary SN management entities.

The POCC is expected to be remote from the WSC and will need to communicate with the WSC via a commercial-grade communications network. This communication network would be used for transmitting service requests to the DAMA processor at the WSC. It is expected that this configuration will require the installation of a firewall to provide insulation between ground communication network and the WSC. The functions of this firewall are expected to be an follows:

1. Access verification and validation for terrestrial network users,
2. Access control for data types (command, telemetry, system inquiries),
3. Spacecraft command source and destination verification probably based on some form of digital signature,
4. DAMA request and status source and destination verification probably based on some form of digital signature, and
5. Destination flow control for telemetry data.

It is expected that commercially-available products will be able to supply these functions.

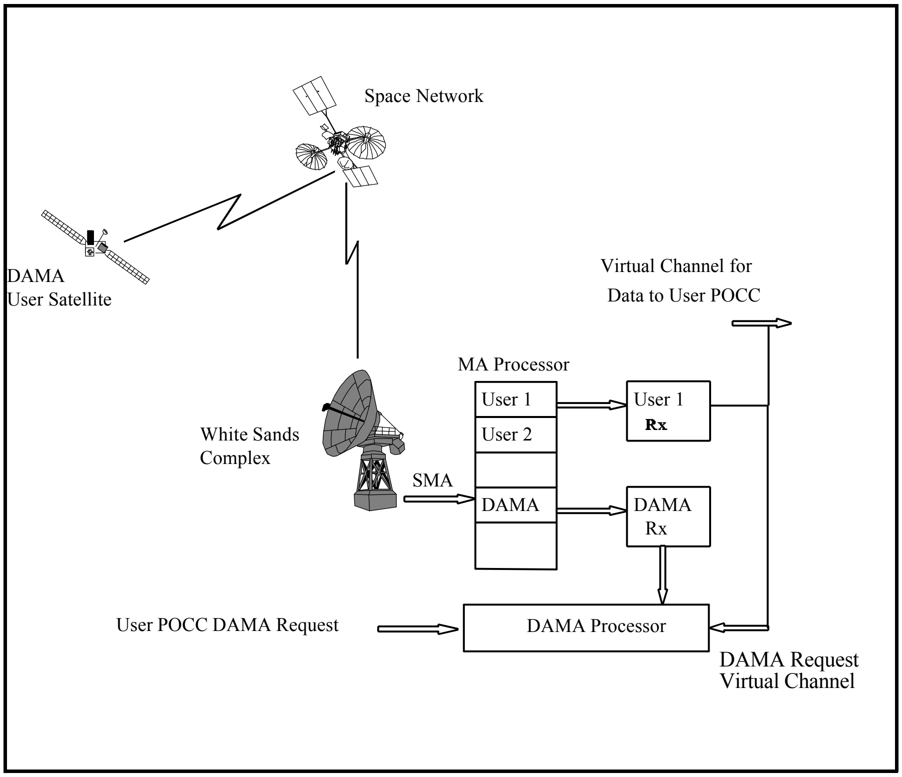

Figure 4 - DAMA Request Packet Flow

The largest technology development issue associated with this concept is the tracking of the user carrier frequency in the WSC signal processing equipment when the SMA orderwire channel is used. The current system utilizes the spacecraft ephemeris to predict the Doppler offset to the carrier frequency induced by the spacecraft. The offset is known to a small error margin and can be tracked as long as the user spacecraft stays within the TDRS spot beacon. The DAMA user will have an unknown Doppler offset at the start of the service. We are presently investigating designs for the receiver structure ([3] and [4]) that will scan the frequency domain for DAMA user signals and then determine the Doppler offset in real-time. With the real-time offset determined, the carrier and PN code can be tracked and request packet demodulated and processed.

Conclusion

We have presented a concept for the development of a DAMA system for use with the NASA Space Network. Innovative parts of this concept include using the S-Band Multiple Access system on the Tracking and Data Relay Satellite as an orderwire channel for service requests. To minimize the impact to the ground station beam forming hardware and to provide hemispherical coverage, only one element of the phased array is used to acquire the DAMA request. Advanced signal processing hardware in the ground station will be utilized to determine the user Doppler offset to the carrier frequency in real-time.

Acknowledgment

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