5 Networking Protocol

5-1 WINDS Satellite Networking Protocol for Regenerative Mode

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The Wideband InterNetworking engineering test and Demonstration Satellite (WINDS), which is an experimental satellite and development by Japan Aerospace Exploration Agency (JAXA) and NICT, has two operating modes: a regenerative mode and a bent-pipe mode. The regenerative mode is realized using an on-board ATM switch subsystem (ABS) which was developed by NICT. In the regenerative mode, ABS demodulates, switches, and modulates the receiving data.

In this section, we introduce the networking protocol for the regenerative mode.

Keywords
WINDS, ABS, Regenerative mode, Networking protocol

1 Introduction

The Wideband InterNetworking engineering test and Demonstration Satellite (WINDS) is equipped with an onboard ATM baseband switch subsystem (referred to simply as the "ABS" below), which demodulates and switches data items on the satellite. Thus, the earth stations are required to use a specified networking protocol to connect to the WINDS network. In addition, as WINDS sets the connection between multiple beams on demand, the Network Management Center (NMC, or standard station) on the ground shares part of the switching function. Thus, the WINDS network uniquely specifies a networking protocol enabling the user stations to communicate via WINDS and a networking protocol between the satellite station and the NMC. This article describes the networking protocol enabling the user stations to join the WINDS regenerative network, to start communications, and to close the connection, as well as a discussion of compensation for attenuation due to rain.

2 Overview of regenerative network

2.1 Transmission rate and frequency allocation

The WINDS regenerative mode uses variable rates for the uplink communication, with four available transmission rates: 1.5 Mbps, 6 Mbps, 24 Mbps, and 51 Mbps. Using three 51-Mbps channels enables a maximum uplink rate of 155 Mbps. The downlink rate is fixed at 155 Mbps. Figure 1 shows the frequency allocation used in regenerative mode. Channels Fu-1 through Fu-9 can each be used at transmission rates of 1.5 Mbps, 6 Mbps, 24 Mbps, or 51 Mbps. Using Channels Fu-1 to Fu-3, Fu-4 to Fu-6, or Fu-7 to Fu-9 simultaneously at 51 Mbps can provide data transmission at 155 Mbps. The modulation method

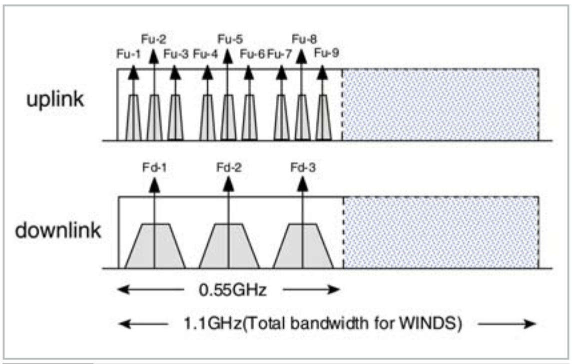

Fig.1 *Frequency allocation in regenerative mode*

used is Quadrature Phase Shift Keying (QPSK), and the RS (255, 223) error-correction method is employed.

2.2 TDMA format

The WINDS system uses the Time Division Multiple Access (TDMA) method to access the satellite. Figure 2 shows the TDMA format for WINDS. A super frame consists of 16 basic frames. A basic frame consists of 20 slots. This slot is the minimum unit for the physical connection between the user and the satellite. A slot corresponds to 2 ms. In regenerative mode, the first slot of each basic frame is used in uplink communication as the signaling slot for the association required for the user station to join the WINDS network, and in the downlink communication as the notification slot for transmitting the reference burst, which contains TDMA synchronization information, association response information, and notification of satellite status. The remaining slots (19 for each frame) are used as traffic slots.

2.3 Burst format

Figure 3 shows the burst format within a single slot. As the uplink communication employs variable transmission rates, the number of data blocks in a slot differs depending on the transmission rate. As the downlink communication employs a fixed rate, the number of data blocks in a downlink slot is constant. Basically, the reference burst and the remaining bursts (i.e., the traffic burst and the

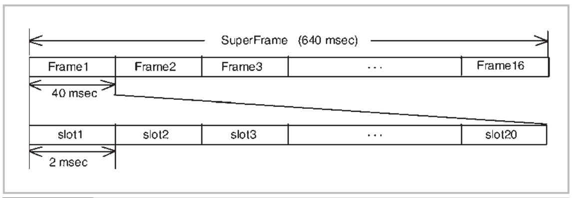

Fig.2 *TDMA format*

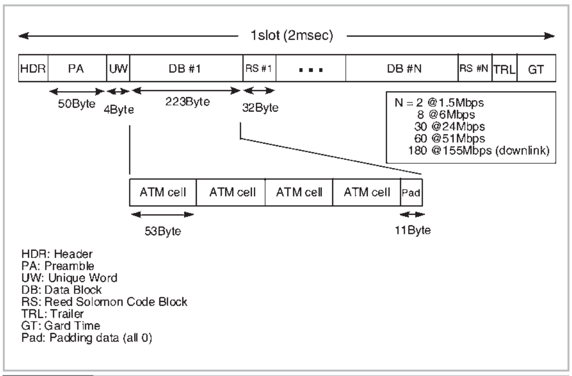

Fig.3 *Burst format*

signaling burst) feature the same structure. Nevertheless, the reference burst and other bursts can be identified by differences in the UW.

3 User station communication link settings

This section describes how the user station establishes synchronization with the satellite, how it joins the WINDS network, how it starts communication, and how it closes the connection.

3.1 Establishing synchronization

When the satellite regenerative mode is initiated, the reference burst provides corresponding notification to each area. The user station receives this burst and demodulates it to acquire the reception timing. The user station also calculates the transmission timing based on the reception timing, using the orbital information contained in the reference burst. As WINDS uses a super-frame structure, the user station needs to determine to which basic frame the received reference burst belongs in order to identify the head of the super frame. The reference burst contains a communication area number (corresponding to the basic frame number), and the user station uses this information to calculate the timing of the head of the super frame. Thus, generally only one reference burst is delivered to each experimental area per super frame.

3.2 Joining network and starting communication

After TDMA synchronization is established, the user station must perform the association procedures and to be assigned an uplink slot to join the WINDS network. Thus, the user station in a given area transmits an association request to the NMC through the onboard switch, using the signaling slot with the same basic frame number used by the reference burst sent to the user station's area. The traffic slot can employ variable transmission rates, but the signaling slot will transmit the data based on the Slotted Aloha method at a fixed transmission rate of 1.5 Mbps, which uses the bandwidths of Fu-n (n:1 to 9) divided into 14 channels.

The association request includes the ID of the user station, the transmission rate, the desired number of slots to be assigned, the service class, the destination ID, and an indication as to whether or not rain-attenuation compensation is required. The service classes provided essentially consist of two ATM service classes: CBR (Constant Bit Rate) and UBR (Unspecified Bit Rate). If congestion should occur in the onboard switch, the data designated UBR are disposed of first. Two classes are defined for CBR, according to the slot assignment method. One class maintains a constant interval of assigned slots (to maintain delay as constant as possible); the other class does not consider the slot assignment interval.

When the NMC receives an association request from a user station, the NMC accepts the request if the satellite resources (e.g., frequency, bandwidth, and slot) are available. The NMC then sets the communication table in the satellite station for the corresponding area, the demodulation rate, and the communication route for each slot, and notifies the calling user of the transmission slot position and other information, as an association response. The association-related messages from the NMC are combined in the reference burst for each area. Thus, the user station must always receive and demodulate the reference burst.

On the other hand, the NMC sends the association notification to the called station. The called user that has received this notification is assigned an uplink slot according to procedures similar to those applicable to the calling user, such that a full duplex communication link with the calling user is established. After the uplink slots are assigned for both the calling and called users, the user stations communicate directly, using the assigned traffic slots.

WINDS restricts the control range of the NMC to the physical and data link layer. In order for users to establish a full duplex communication link, the calling and called stations each need to perform the relevant association procedures separately. In addition, relating these separate connections as a pair is the responsibility of the upper-layer design of the user stations.

3.3 Terminating communication and closing connection

Communication termination processing between the user stations is performed through the assigned traffic slot. However, as the NMC cannot monitor the content of the traffic slot, the user stations need to transmit a release request to the NMC to release the assigned slot, in a manner similar to that employed when joining the network (although the transmission of the release request uses a traffic slot instead of a signaling slot). The association release request contains the identification number of the connection and the ID of the user station sending the request. When the NMC receives the release request, it releases the assigned uplink slot and prepares it for use with another association request. The NMC also sends a release notification to the called station in a manner similar to that employed when allowing the user station to join the net-

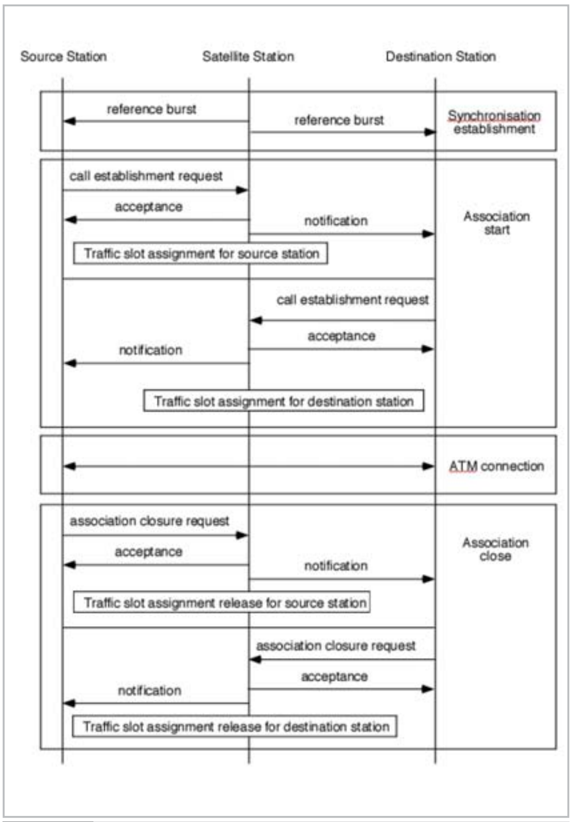

Fig.4 Communication link setting sequence of user stations

work, and prompts release of the assigned slot for the called station. These procedures thus release the full duplex network resource.

Figure 4 shows the communication link setting sequence of the user stations.

4 Rain-attenuation compensation method

Attenuation-compensation control of the traffic link in rain is performed both in the uplink and downlink in regenerative mode.

4.1 Uplink rain-attenuation compensation

In the uplink, the user station autonomously compensates for attenuation due to rain.

The reference burst includes the satellite reference burst transmission power information, and this information and the propagation distance calculated from satellite orbital information are used to calculate the reception level for clear sky. If the actual reception level of the reference burst is lower than the calculated reception level for clear sky, the user station estimates the attenuation in the uplink frequency based on the actual reference burst reception level, and adjusts transmission power accordingly.

4.2 Downlink rain-attenuation compensation

Compensation for attenuation due to rain is performed in the downlink based on statistical processing of the information provided by the user station and through control of the satellite transmission power.

The user station that indicates a need for rain-attenuation compensation receives the reference burst and calculates the C/N_0 from measured signal power and noise power. The user station notifies the NMC of the difference between this reception C/N_0 value and the reception limit C/N_0 value of the user station (i.e., the reception margin), using the assigned traffic slot. The NMC statistically processes the margin information sent from the user station requiring compensation, calculates the downlink compensation power value required for each area targeted for such compensation, generates power control information for each target area, and controls satellite transmission power.

Power for rain-attenuation compensation is distributed according to four priority levels: HIGH1, HIGH2, LOW1, and LOW2. HIGH1 compensates for such attenuation as fully as the satellite transmission allows. HIGH2 assumes power will be shared with other areas and compensates for rain within its range of surplus power. Here, even when sharing power, the power required in clear sky is always distributed. LOW1 and LOW2 assign constant power without satellite transmission power control. Different values can be set for LOW1 and LOW2.

The priority of compensation for attenuation due to rain is indicated to the NMC at the time of the association request.

5 Conclusions

This article describes the networking protocol of the WINDS regenerative mode used when the user station establishes synchronization with the WINDS system, joins the network, and closes the connection. It also describes an outline of the method of rain attenuation compensation.

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