Mobile Satellite Communications System | High-speed Data Communication | All-IP Network

Technology Reports

Special Articles on WIDESTAR II High-speed Mobile Satellite Communications Service for Diverse Satellite Communications

Overview of WIDESTAR II Mobile Satellite Communications Scheme

WIDESTAR II is a mobile satellite communications service that covers the landmass of Japan and the surrounding maritime area by using the N-STAR c/d geostationary satellites, which are positioned approximately 36,000 km above the equator. The design of the system requires high reliability during disasters and the ability to provide diverse satellite communication services over the coming ten years or more. The mobile satellite communications system based on accumulated experience with radio technology, we have increased transmission speed through increased channel utilization efficiency and other such improvements in the WIDESTAR II system. Also, by adopting the necessary and sufficient control technology for the satellite and conducting compact development, we are implementing diverse satellite services for the NTT DOCOMO wide area mobile communication system.

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1. Introduction

In the more than ten years since beginning operation with the voice service in 1996, the NTT DOCOMO mobile satellite communications service, WIDESTAR, has provided services based on the Second-Generation mobile communication system PDC [1][2]. Over that time, the mobile phone system underwent a generation change in response to richer services and content and the increased traffic that came with them. The new generation featured higher communication speed, and progress is now being made toward an All-IP core network [3]. WIDESTAR II was developed to cope with those advances in mobile communication and expand the use of the mobile satellite communications service.

In this article, we describe an overview of the WIDESTAR II mobile satellite communications system, compare it to the conventional WIDESTAR system, and explain some of the design challenge.

2. Development Requirements and Policy

The purpose of the development of WIDESTAR II is to promote the utilization of data communication by continuing to provide the conventional services at higher speeds and to simplify development and operation by adopting IP and other general purpose technology [4]. To satisfy these service and facility requirements, the design policy for WIDESTAR II included the following two points.

1) Selection of the Necessary and Sufficient Functions to Reduce the Overall System Development and Operation Scale

WIDESTAR was used for maritime, isolated islands, and for disasters. Use over a long term once the mobile station was installed was expected, so replacement of mobile stations is difficult. Accordingly, the system design aims to allow use of diverse forms of communication by centralizing many functions in the main mobile station unit and assuming the connection of various peripheral equipment and solution devices. Taking this form of use into consideration, WIDESTAR II is designed for a simpler system configuration and control procedure and allocation of necessary and sufficient functions to reduce the scale of development and operation while maintaining the established reliability of the conventional system.

2) Improving Channel Utilization Efficiency for Higher Transmission Speed in Satellite Communication

The satellite and frequency bands used by WIDESTAR II are the same as used by WIDESTAR, and the migration plan is to increase speed in the new system while the new and old systems co-exist. Higher radio transmission speed requires greater spectral efficiency[*1]. However, WIDESTAR II is a mobile communication system that covers all of Japan via geostationary satellites positioned approximately 36,000 km above the equator, and so uses radio signals that are greatly weaker than mobile phone signals and wide antenna beams that have a radius of approximately 600 km. Therefore, repeated reuse of frequencies is not possible, and there can be no dramatic increase in spectral efficiency from taking that approach. Therefore, a design that increases channel utilization efficiency by controlling radio frequency resource occupancy time is important to achieving high-speed data transmission by many users.

3. System Design

The system design involves selection of the necessary and sufficient functions as well as centralization of the radio node, integration of communication control and re-organization of function allocation compared to the conventional system.

3.1 Integration of the Radio Node

The radio access node configurations are compared in **Figure 1**. WIDESTAR II integrates the radio controller and the modulator and demodulator into the Satellite-Access Point (S-AP). This integration makes the interface for interworking between the radio control and modulation and demodulation processing internal to the equipment, and thus reduces the load of implementing radio resource allocation and communication state assignation and equipment monitoring.

3.2 Integration and Simplification of Communication Control to IP

An overview of the voice communication scheme is shown in **Figure 2**. Based on the experience with WIDESTAR, the upper layer of the voice communication processing of the radio processing unit is based on the FOMA packet switching protocol General Packet Radio Service (GPRS)[*2], but features IP use for the voice communication control. In other words, the core network and mobile station manage voice calls and other communication with the Packet Data Protocol (PDP) context[*3] for handling packet data virtual path connection information. Voice call control is handled by Session Initiation Protocol (SIP)[*4]. Communication is simplified by using a single PDP context, regardless of whether it is voice or text, regardless of whether it is voice or

*1 **Spectral efficiency**: The number of data bits that can be transmitted per unit time and unit frequency band.

*2 **GPRS**: A packet-switching service available on GSM and W-CDMA networks.

*3 **PDP context**: Communication control information relevant to packet communication stored by mobile stations and core nodes.

*4 **SIP**: A call control protocol defined by the Internet Engineering Task Force (IETF) and used for IP telephony with VoIP, etc.

data, and suppressing the number of communication control states by not implementing multi-domain[*5] or multi-call[*6] functions. A service switching control is introduced to reset the PDP context when a voice call arrives during data communication.

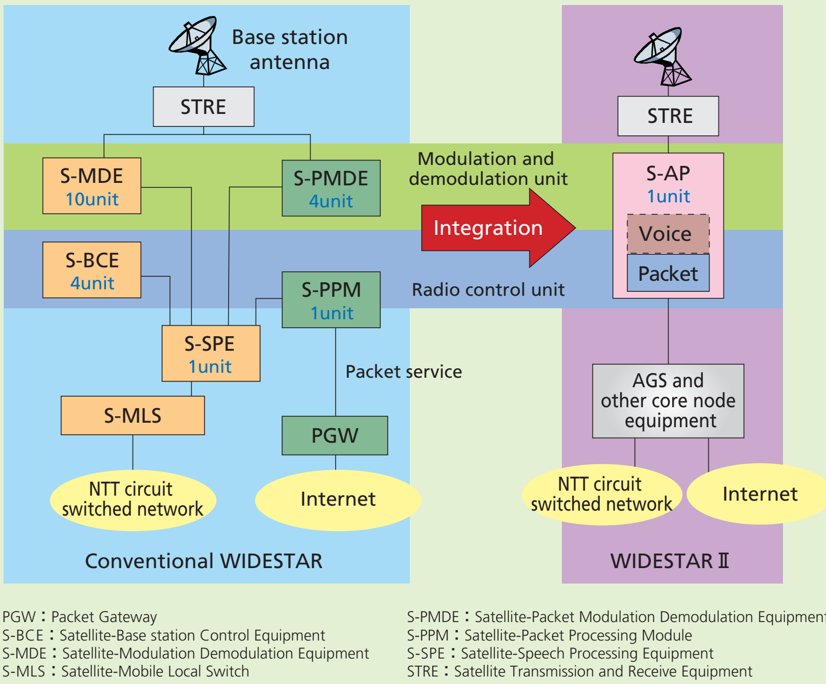

Figure 1 Radio access node configuration

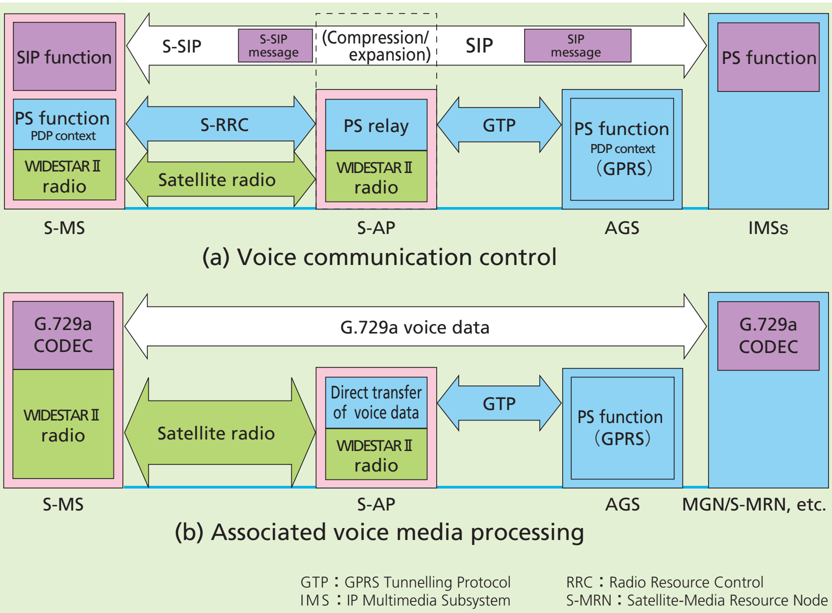

Figure 2 Overview of voice communication processing

3.3 Allocation of the Necessary and Sufficient Functions

1) S-AP Interface

The satellites cover a wide area, so the probability of moving between beams during a call is low and the delay for hand-over is long. There is therefore no need to deal with high-speed hand-over or redirecting as a subscriber line extension method[*7], and hand-over can be dealt with by relocation[*8] at reconnection. In that way, the processing for hand-over between S-AP can be reduced and the interface between S-AP can be greatly simplified.

2) CODEC Processing

The general purpose G.729a[*9] voice CODEC, which is used for IP telephony, was adopted to replace the conventionally-used Pitch Synchronous Innovation Code Excited Linear Prediction (PSI-CELP)[*10] (Fig. 2(b)). For voice calls between Satellite-Mobile Stations (S-MSs), the intermediate nodes are bypassed and CODEC processing is done only by the terminal. In the case of calls with other networks, CODEC conversion is done by the core node Media Gateway Node (MGN). This lightens the load and reduces the functions implemented on the radio access equipment, which conventionally performed the conversion. It also contributes to the improvement of voice

*5 **Multi-domain**: Performing the communication processing for both the packet and the circuit switching domain.

*6 **Multi-call**: The processing of multiple calls, such as when a voice call arrives during packet communication.

*7 **Subscriber line extension method**: A method for control by the subscriber system Mobile Communication Control Center (MCC) that was set at the time a call is originated or terminated, even if the mobile terminal moves during communication.

*8 **Relocation**: Hand-off of communication processing between nodes due to movement of the mobile station.

*9 **G.729a**: A voice coding method widely used in IP telephony.

quality of calls between mobile stations.

4. Radio Communication Scheme

The radio channels used for WIDESTAR II are shown in **Figure 3**. The two types of physical channels for data transmission are the fixed-speed 64-k Physical User Packet Channel for Guarantee type (PUPCH-GR) and the best-effort Physical User Packet Channel for Best Effort (PUPCH-BE) . An information broadcast channel was added to the function channels as a control channel. The radio frame uses the same 40-ms units as conventional, Forwardlink PUPCH (FPUPCH)-BE only, and a time slot configuration that uses units of 5 ms (**Figure 4**). The radio specifications are shown in **Table 1**. Inheriting from the conventional system [5], the modulation and demodulation scheme is $\pi/4$ shift Quadrature Phase Shift Keying (QPSK), the access method is Frequency Division Multiple Access (FDMA) for the uplink and Frequency Division Multiplexing (FDM) and Time Division Multiplexing (TDM) for the downlink. The carrier configuration for the packet communication channels is shown in **Figure 5**. For the bandwidth of each channel, WIDESTAR II obtains a higher spectral efficiency and higher speed by varying the roll-off rate and the coding rate, with turbo coding applied for error correction.

4.1 Improving Channel Utilization Efficiency

In FDMA, where mobile stations have exclusive use of a radio channel, the occupied channel cannot be used by other mobile stations even if the occu-

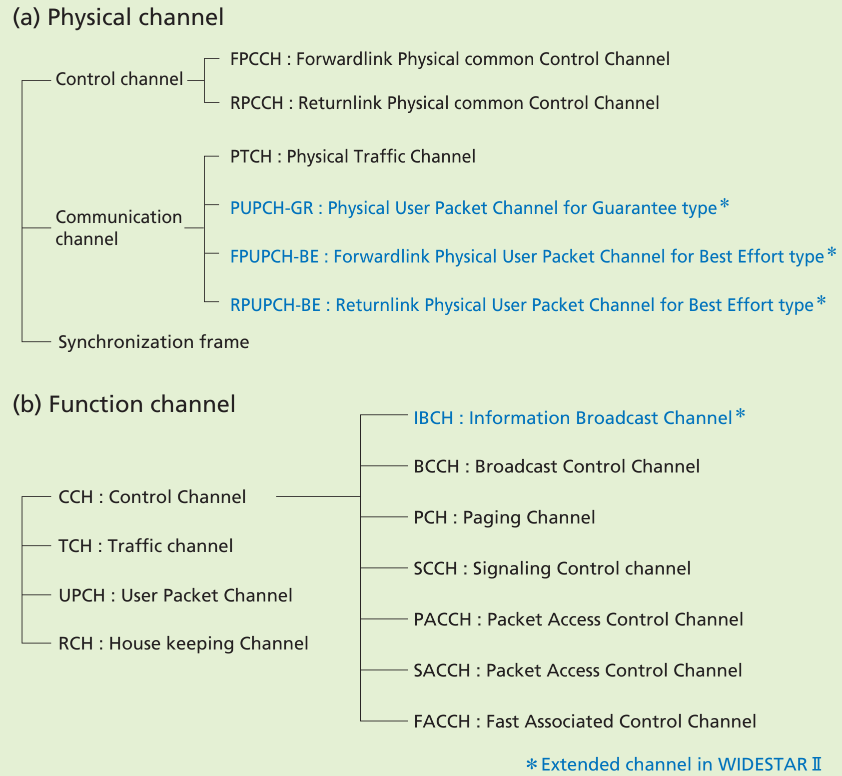

Figure 3 Types of radio channels

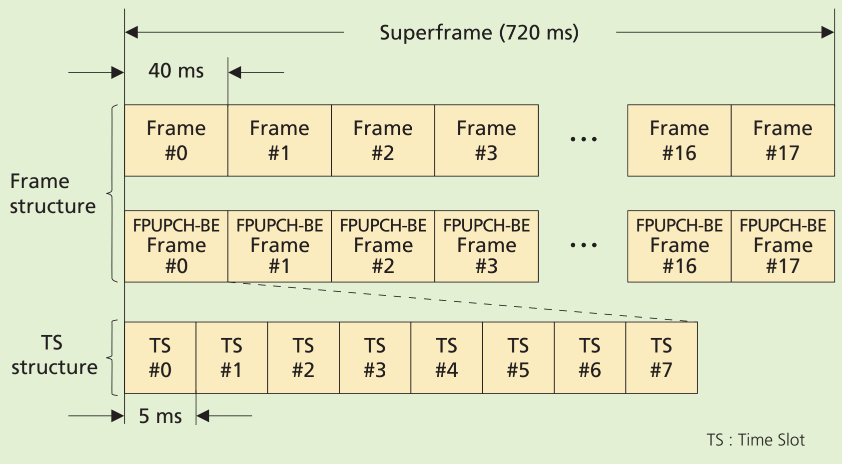

Figure 4 Radio frame structure

*10 **PSI-CELP**: A half-rate voice coding method used by PDC.

Table 1 Comparison of radio specifications

Item	WIDESTAR Ⅱ	Conventional WIDESTAR
Frequency band	Service link: 2.6/2.5 GHz band (2,660 to 2,690 MHz/2,505 to 2,535 MHz) Feeder link: 6/4 GHz (6,345 to 6,425 MHz/4,120 to 4,200 MHz)	
Modulation and demodulation scheme	π /4 shift QPSK	
Symbol rate	11 ksps 60.5 ksps (64 k data communication) 30.25/60.5/121 ksps (packet communication uplink channel) 242 ksps (packet communication downlink channel)	7 ksps 77 ksps (packet communication downlink channel)
Roll-off ratio	0.2	0.5
Carrier frequency interval	15 kHz 75 kHz (64 k data communication) 37.5/75/150 kHz (packet communication uplink channel) 300 kHz (packet communication downlink channel)	12.5 kHz 150 kHz (packet communication downlink channel)
Error correction	Convolution encoding/Viterbi decoding Turbo encoding/decoding (64 k data communication, packet communication channel)	Convolution encoding/Viterbi decoding
Voice encoding method	8 kbit/s G.729a	5.6 kbit/s PSI-CELP

sps : symbol/s

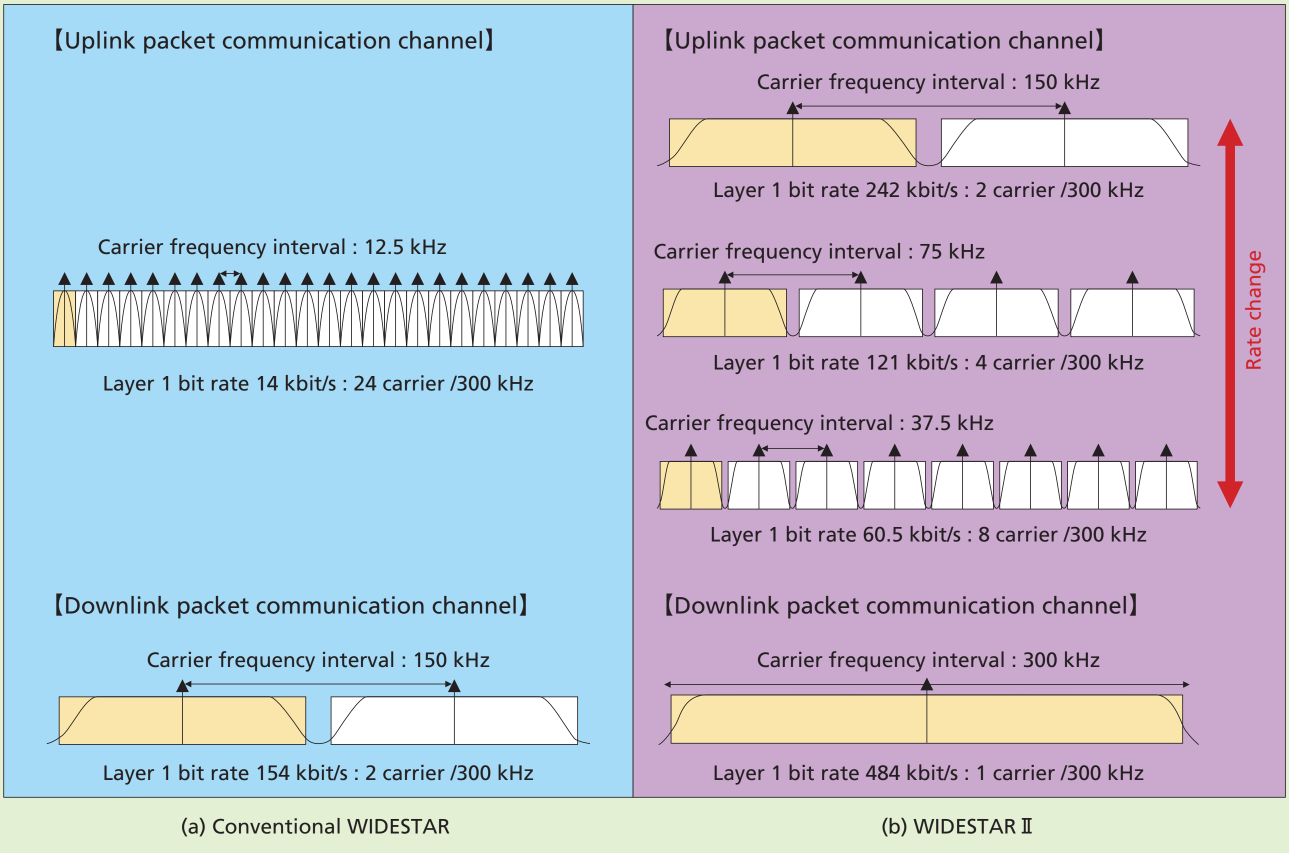

Figure 5 Carrier arrangement

pying station is not sending or receiving data. Many mobile station communicate at higher speeds than before, so it is necessary to increase the channel utilization efficiency.

1) Packet Data Communication Status

For higher channel utilization efficiency, the communication channel is released as frequently as possible in states where no data is being sent or received.

First, if there is no data for transmission for a specified period of time while in the state of communication, the mobile station releases the return link channel. For receiving, the system is designed to transition to the stand-by state, in which the status changes from constant receiving to intermittent receiving state[*11] in the stand-by state or intermittent receiving operation in the communication state, thus contributing to power consumption. Furthermore, final disconnection is done by the non-communication monitoring function via the control channel stand-by preservation state[*12].

2) Handling Voice Data and SIP on the Satellite Channel

IP headers and other such redundant data is removed from the Realtime Transport Protocol (RTP) packets and SIP signals for sending voice data in the radio circuit; only the respective voice media data and SIP messages are transferred to the radio frame. Furthermore, SIP processing is done by the base station equipment with message compression to increase transmission efficiency [6].

3) BE Channel Assignment Method

This is the same as the conventional WIDESTAR packet in that the FPUPCH-BE sent by the base station is shared between mobile stations, but either 384 kbit/s or 256 kbit/s is specified for each time slot based on the demand of each mobile station and according to the Carrier to Noise Ratio (CNR)[*13]. The RPUPCH-BE sent by the mobile station is variable speed, but high-speed variable control is not adopted and the speed is set when RPUPCH-BE is allocated. That is because the wait due to satellite propagation delay, inconsistency of channel status between the mobile stations and base stations, etc. can lead to an increase in communication state complexity and circuit scale. In setting the speed, the fastest available channel is assigned according to the CNR, the number of simultaneously communicating mobile stations and the efficiency-of-use ratio. An occupied band use service channel allocation and scheduler management that differ from the ordinary are used for each contract.

4.2 Reduction of Communication Control Delay

One issue with using geostationary satellites in a mobile communication system is the 500 ms round-trip propagation delay. If multiple round-trip control signals precede use of the communication channel, there is excessive occupancy of the high-speed channel and use efficiency decreases. Therefore, communication control delay must be reduced.

1) Voice Stand-by in the Preserved State

In the power on state, the PDP context is always preserved, and in the stand-by state in particular, the voice PDP context is made the preserved state and SIP registration[*14] is executed in that PDP context [7]. For a voice connection, SIP call control can begin by simply transitioning from the preserved state to the activated state rather than from the time-consuming PDP context generation. In that way, the same voice connection delay quality as provided by the conventional circuit switching method can be achieved.

2) Radio Bearer Setup

In the layer 3 radio bearer[*15] setup procedure, the base station equipment immediately assigns a radio channel to the mobile station in parallel with the setup procedure for radio access bearer to the core node.

3) Message Pooling

In layer 3, wait delay is reduced by pooling of messages for transmission between the S-AP and the S-MS and between the core node and the S-MS.

In layer 2, multiple connection message are pooled for efficient use of radio circuit resources and to suppress delay as well.

*11 **Intermittent receiving state**: A receiving state in which reception is done intermittently at a pre-set constant radio frame timing to reduce power consumption.

*12 **Preservation state**: A control channel stand-by state in which the communication channel is released.

*13 **CNR**: The noise power ratio to the carrier wave.

*14 **Registration**: On an IP-Phone network, when a mobile terminal uses SIP to register its current location information with a Home Subscriber Server (HSS).

*15 **Bearer**: In this article, a virtual packet transmission path set up between the AGS (see *17) and S-AP, etc.

4) Layer 1 Control Messages

Based on the conventional WIDESTAR packet communication system to simplify execution of the procedure for RPUPCH-BE channel assignment and rate changing during communication, the effects of the propagation delay associated with round-trip control messages are minimized by fast execution of resource allocation control and setting the speed at the same time in the layer 1 control frame.

5) Self-balancing

The mobile station stand-by common channel selection and call group selection are performed on the mobile station side with the International Mobile Subscriber Identity (IMSI)[*16] in the same way as the priority satellite or priority Access Gateway for Satellite (AGS)[*17] selection. This suppresses delay by averting collision and accumulation of messages through self-balancing and aggregation to certain channels and call groups under the direction of the mobile station.

5. Conclusion

The design of the WIDESTAR II mobile satellite communications service aims for simplification by adopting the radio and communication procedures and functions required for a mobile satellite communications system while emphasizing higher circuit use efficiency and less delay to realize diversity in satellite communication. In future work, we will continue to introduce new satellite solutions in WIDESTAR II with a communication system designed for higher speed.

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*16 **IMSI**: A number used in mobile communications that is unique to each user and stored on a User Identity Module (UIM) card.

*17 **AGS**: The access gateway node developed for WIDESTAR II.