HIGH SPEED INTERNETWORKING TECHNOLOGY UTILIZING SATELLITE ON-BOARD SWITCH

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ABSTRACT

Communications Research Laboratory has been involved in the development of very high data rate satellite communications technology. One of the key technologies which CRL has developed is satellite on-board ATM switch and the application of the technology is very effective to facilitate high speed Internet with satellite communications systems. CRL completed to develop the breadboard model of on-board ATM switch and this technology is employed to newly planned Japan's experimental satellite to demonstrate effectiveness of satellite-based high speed Internet. This paper describes the networking architecture of high speed satellite Internet with on-board switch, and functions and performances of developed on-board ATM switch.

INTRODUCTION

The Communications Research Laboratory (CRL) is conducting research and development of on-board processing technology for future high-data-rate (HDR) satellite networks for multimedia services as a very important part of the "Gigabit Satellite Project"[1]. Considering the very rapid expansion of the Internet in, we have recognized the importance of developing more Internet-friendly technology for HDR satellite communications networks.

Concurrently, The Ministry of Public Management, Home Affairs, Post and Telecommunications (MPHPT) has been advocating pursuit of "Space Internet" technology since 2000. The aim of this technology is the development of a space-based Internet infrastructure. On the other hand, National Space Development Agency (NASDA) of Japan proposed "i-Space" initiative in order to utilize space infrastructure for realizing high speed Internetworking as a social infrastructure [2].

With these background, NASDA plans to launch Wideband InterNetworking engineering test and Demonstrations Satellite (WINDS) in 2005, and the CRL is in charge of the development of satellite on-board high throughput switch / router as a part of mission payload of the WINDS.

This paper describes the high speed Internetworking architecture utilizing satellite on-board switch / router, measured performance of the on-board switch and the design concept of the layer-3 routing processor.

BASIC CONCEPT OF INTERNETWORKING WITH ON-BOARD PROCESSOR

Networking Concept

An on-board IP routing function is one of the most effective schemes for highly efficient internetworking. The networking concept is shown in Fig. 1. All terminals and routers have at least one physical link to the satellite link and the satellite itself behaves as a router. In order to interconnect to other autonomous systems (AS), satellite on-board router can be a border gateway router with this architecture. Therefore, ground-based border gateway is not always necessary and the linking topology can be simple though the connection control link should be prepared independently.

Considering the on-board processing technology currently available, developing an on-board high throughout IP router or layer-3 switch involves several difficulties. One is that such a function should be implemented in combination with a high-speed processor and large-scale software, but it is hard to devise a high-speed processor for on-board applications. Another is that the layer-3 switching technology is changing rapidly and this means that any on-board subsystem built with the current technology may soon be obsolete. Regarding layer-2 switching technology, an on-board ATM (Asynchronous Transfer Mode) switch has been developed in Japan's Gigabit Satellite Project and Gen*Star Project by TRW [3], then it seems feasible that it may be ready for application around 2005.

Signaling Concept

In order to provide services to enormous amount users scattered in a satellite coverage, wireless circuits must be shared and therefore, switching technology is necessary. Out-band signaling scheme and in-band signaling scheme can be applied according to how physical circuit is provided.

In case which all users are covered by fixed beams, continuously accessible physical signaling circuit can be prepared independently from traffic circuit. The out-band signaling can be easily applied in this case. Out-band signaling scheme has advantages which signaling network can be designed independently from traffic networks. When it is applied to high data rate (HDR) satellite networks, signaling circuit can be realized at lower data rate than traffic channels, but each earth terminal should have dedicated modem for it.

In case which users are covered by scanning or hopping beams, signaling circuit should be shared with time-division-bases schemes. In-band signaling scheme is feasible to be applied in this case. An earth terminal can share modem and RF equipment with traffic channel for signaling channel, but careful channel assignment and appropriate access method should be designed in order to avoid interferences between signaling channels and traffic channels.

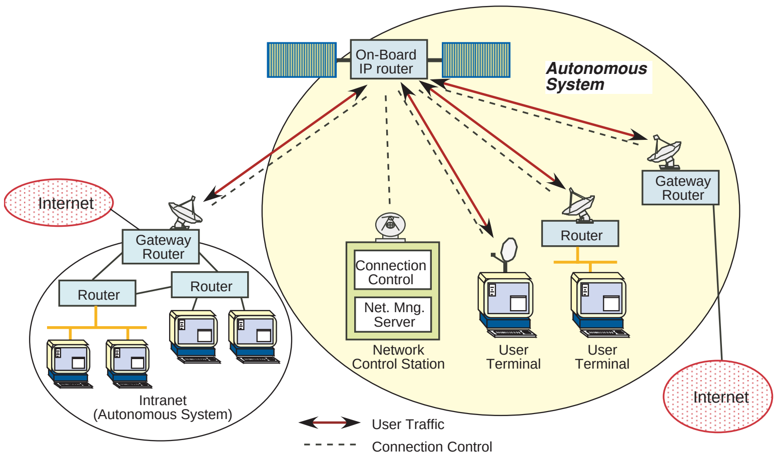

Fig.1 Networking Concept with On-Board Switch

OVERVIEW OF WINDS' MISSION PAYLOAD

The WINDS is currently under initial designing phase, and will be launched in 2005. The mission configuration has been discussed and the current one is shown in Fig.2. The mission payload will be configured by fixed multi-beam antennas (MBA), Ka-band active phased array antennas (APAA), Ka-band multi-port power amplifier (MPA), on-board ATM switch (ABS), IF switch (IFS), and switch controller (SW-CONT).

Fixed MBA covers Japan and several cities in Asia-Pacific region, and APAA can cover almost all visible area from WINDS though EIRP and G/T are much smaller than MBA. MPA can allocate power flexibly to each beam and this feature can be used for powerful and efficient rain attenuation compensation. ABS is the on-board processor for ATM-based switching. Because the WINDS employs a multi-beam antenna in order to achieve high EIRP and G/T, an on-board switch can provide an efficient inter-beam connection function. SW-CONT controls routes of communication signals according to ABS and network control station on the ground.

The transponder can be operated in bent-pipe mode bypassing the ABS and regenerative mode passing through the ABS.

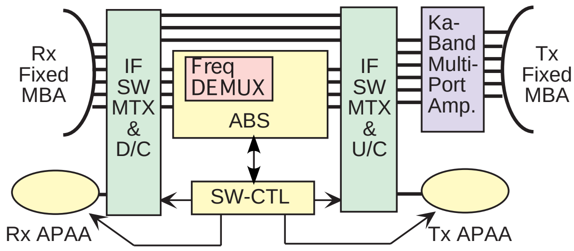

Fig.2 Mission Payload Configuration of The WINDS

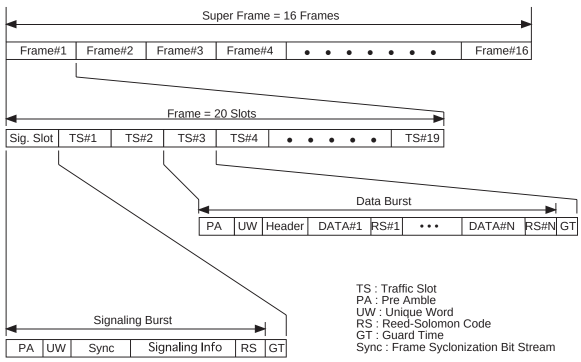

Fig.3 Frame Format

NETWORKING WITH WINDS

Access Scheme

WINDS employs both of fixed MBA and APAA. In order to provide identical access scheme for users covered by each antenna beam, TDMA-based access scheme is employed. The frame format is shown in Fig. 3. 20 time slots consist a frame, and 16 frames consist a super-frame. Each slot has a time duration of 2 msec. The first slot of a frame contains bit stream for frame timing synchronization and signaling information, then the first slot is named as the Signaling Slot. Other slots are called as Traffic Slot and used to carry user data. The Signaling Slot and the Traffic Slot are accessed with Slotted ALOHA and demand assignment manner, respectively.

Outline of Signaling Process

A user terminal sends a request burst in the signaling slot with slotted ALOHA scheme, then a Network Control Station (NCS) processes the request and assigns traffic slots to the source user terminal and destination user terminal to communicate.

In the bent-pipe mode, NCS sends burst time plan to WINDS to control IFS according to the slot assignment determined by signaling process.
In regenerative mode, ATM switching table to ABS of WINDS and IFS is controlled by the information from ABS.

FUNCTIONS AND PERFORMANCES OF THE ABS

The on-board ATM Switch, which is called an ATM Baseband Switch (ABS), has been developed by CRL in the Gigabit Satellite Project. The WINDS employs this technology as a layer-2 switch for space-based HDR internetworking.
As shown in Fig. 4, the ABS consists of on-board demodulator employing digital signal processing (D-DEM), an ATM switch (ATMS), and on-board modulator (MOD). We developed tank-limiter type demodulator to treat higher uplink signal, but it will not be on-board because of its weight and stability problem. The hardware components were completed in March 2001, and combined as a subsystem in Sep. 2001
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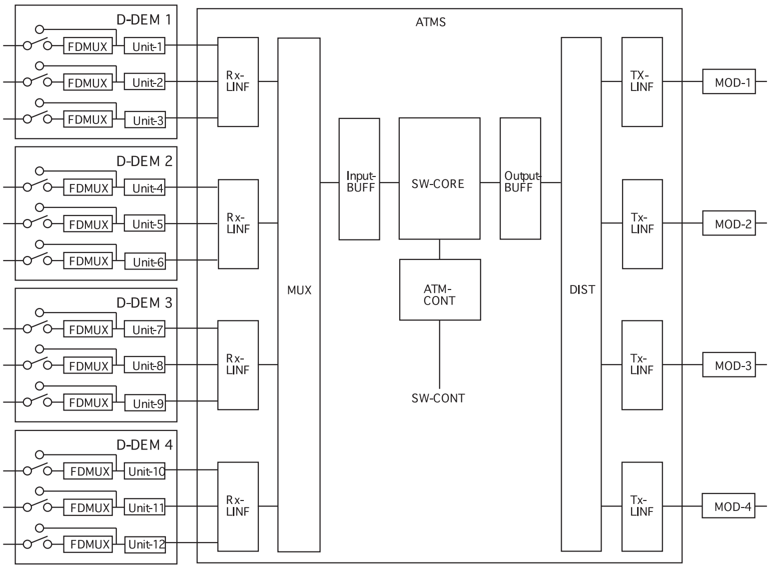

Fig.4 Configurtion of The ABS

Table 1 Performances of D-DEM

Functions	Performance
Variable TransmissionRrate [info rate (symbol rate)]	1.536 Mbps (1.157 Msps) / 6.144 Mbps (4.628 Msps) / 24.00 Mbps (18.51 Msps) / 51.84 Mbps (37.02 Msps)
BER Characteristics	Eb/No 9.9 dB-Hz for BER of 10e-4 (no FEC)
UW Capture Ratio	100 % for better than Eb/No 10 dB-Hz
Capture Range	± 100 kHz (24.00 Mbps, 51.84 Mbps), ± 50 kHz (1.536 Mbps, 6.144 Mbps)
Dynamic Range	10 dB for all transmission rate

HDR On-Board Modem

The D-DEM has been developed for the application to the ABS. Each D-DEM has three demodulation units and each unit can handle transmission rates of 6.144, 24.00, 51.84 Mbps. Frequency demultiplexer (FDMUX) is added to provide 14 channels of 1.536 Mbps carrier with the equivalent bandwidth to a 51.84 Mbps carrier. The 155.52 Mbps stream can be treated by a parallel three 51.84 Mbps demodulation units. Therefore, a single 155.52 Mbps stream must be divided into three 51.84 Mbps streams to be transmitted by an Earth station.
This bread-board-model (BBM) which uses a radiation-hardened FPGA was developed to verify the signal-processing scheme for HDR applications. Fig.5 shows the developed board of D-DEM. We plan to develop a gate array (G/A) model with reduced mass, weight, and consumption power at a later stage. A fully functional BBM is already completed and the functions and performances that we have already confirmed are shown in Table 1. Fig.6 shows the bit error performance of the D-DEM when Reed-Solomon decoding turned off. The degradation of Eb/No from the theoretical curve at the BER of 10E-4 is 1.5 dB.

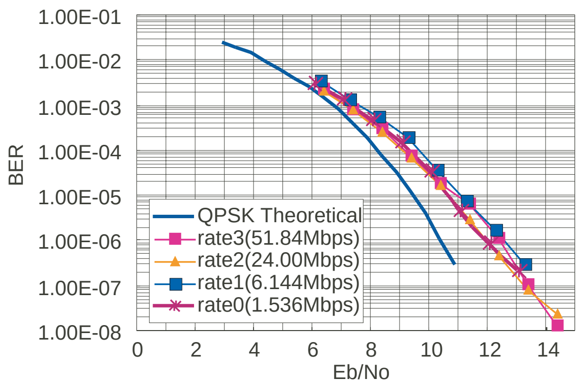

Fig.5 Bit Error Performance of D-DEM

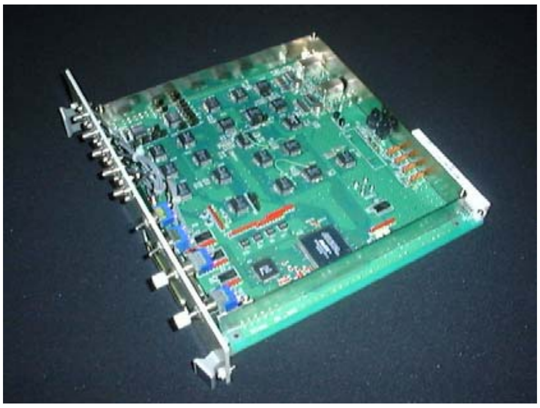

Fig.6 D-DEM Board

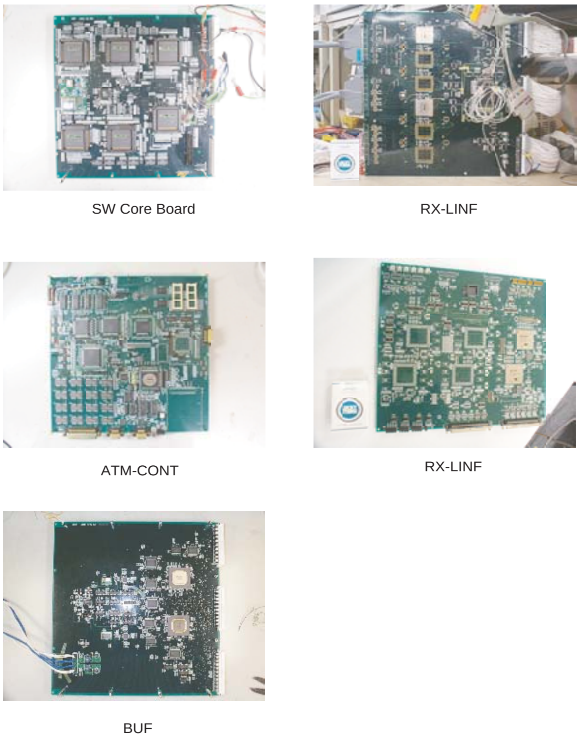

Fig.8 Developed Boards of ABS

The BBM of the on-board modulator was completed in March 2000. It can transmit 155.52 Mbps information in burst mode.

On-Board ATM Switch (ATMS)

As shown in Fig.4, the ATMS consists of a receiving line interface (Rx-LINF), ATM core switch (ATM CORE SW), buffer (Tx-BUFF), transmitting line interface (Tx-LINF), and ATM controller (ATM CONT). Four types of core switch LSIs were developed in 1999, and those were integrated as a switch card. The RX-LINF, Tx-LINF, Tx-BUFF and ATM CONT hardware and related software have already been developed. Fig.7 shows developed boards of these functional blocks.

We already verified that the ATMS functions as designed, and maximum throughput is 2.4 Gbps. This ATMS is modular-based designed, then much higher throughput can be achieved with multiple modular configuration.

AN ON-BOARD IP ROUTING SCHEME

Achieving a high-speed on-board IP router requires newly designed hardware and large scale software. CRL is investigating an IP router technology based on the hardware technology of ATM switches . One of the methods is IP datagram relaying with a fixed long cell format. An IP datagram is transformed into long cells at the front-end of the on-board router and transferred very quickly with cell switching technology.

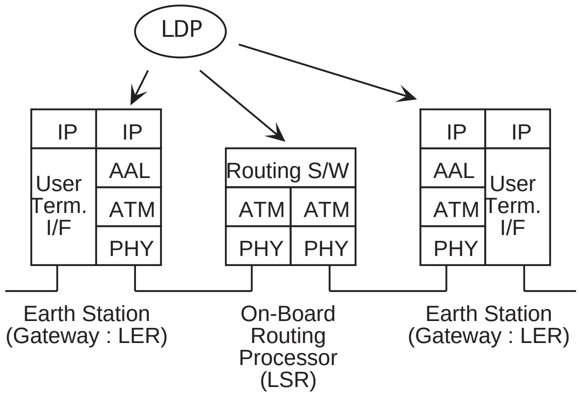

Fig.9 Application of MPLS to ABS

On the other hand, the Internet community has achieved high-speed IP routing with high-speed layer-2 switch such as an ATM switch. Multi-Protocol Label Switching (MPLS [4][5]) is a very feasible candidate. With MPLS, routers nearest end terminals should work as Label Edge Routers (LER), and the ATM switch onboard should be a Label Switched Router(LSR) as shown in Fig.9. The Label Distribution Protocol (LDP) should be implemented both in ground routers and in the on-board ATM switch. This can be achieved by software in the on-board ATM switch and does not affect the throughput in data transfer phase. We will develop an MPLS-based IP routing function for the Space Internet Project as we continue our investigations of hardware-based IP routers.

CONCLUSIONS

Satellite communications network is one of very useful infrastructure to facilitate global scale high speed Internet, and it can help for bridging digital divide. The satellite on-board switch / router is the key technology to provide highly efficient satellite channels to large number of users.

CRL has been heavily involved in the R&D of high throughput on-board switch / router. Firstly, we investigated networking architecture and protocols, then we developed the BBM of ABS. Its functionality and performance have been verified as written in earlier sections. The development of ABS will lead on-board processing technology to be operational in the next generation of satellite communications systems.

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