Keio University Master's Thesis Academic Year 2003

Design of the Autonomous Satellite Link Operation Environment on the Internet

Keio University Graduate School of Media and Governance
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Abstract of Master's Thesis Academic Year 2003

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The Internet has matured as a fundamental infrastructure on that a number of services are provided and social communication is established. Now a days, connectivity to the Internet is a social requirement of where people exist. Satellite communication has wide coverage, broadcast capability, and flexibility in configuration as their characteristics, which other media does not have. Satellite communication is expected to contribute to expanding the Internet toward everywhere on the earth.

However, operational scheme of satellite links is heterogeneous depending on their data link scheme, such as multiplex modes, forms of earth stations, directions of connectivity, and so on. This heterogeneity makes the operational range closed in respective systems. Thus, from the view point of operating an IP network, satellite links are difficult to operate as an integrated data link of the network. Therefore, a satellite network can not be easily extended or interconnected with other satellite networks despite the distinguished characteristics of satellite communication.

This thesis designs the autonomous satellite link operation environment on the Internet. The essence of our operation environment is information exchange among earth stations and external nodes on the network. On our model, earth stations are abstracted as nodes that can be accessed from anywhere in the operational domain via the Internet. Satellite links can be operated in a unified scheme beyond the heterogeneity of their own data link schemes based on the information exchange among those nodes. We described the essential functionalities, the definition of an operational domain, and the operational information of the proposed environment. And then, we organized the required components to establish the environment.

On the implementation of our environment, we adopted SNMP as the protocol for exchanging operational information among nodes on the operational domain. According to the focus on satellite modems as the core equipment of earth stations, we classified the operational information and described it on a MIB by ASN.1.

We evaluated our operation model based on its design and achievement from the view point of establishing the autonomous satellite link operation environment. We showed that it is possible to shift the operation body from human operators to earth stations, and our model is superior to the existing operation scheme on granularity, cost, and flexibility of satellite network operation. The evaluation also showed that our model removes the heterogeneity of operational environment, and provides the infrastructure technology for flexible satellite link operation.

Key Words

1. Satellite Communication 2. Internet 3. Autonomous Operation

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インターネットの爆発的な普及により、社会生活の様々な場面でネットワークが利用されるようになった。今日では、インターネットへの接続性は人間が社会生活を営む上での要求事項となりつつある。衛星回線は、広域性・同報性を持ち、回線設定が柔軟に行える特徴がある。多くの通信路が研究、開発されるなかで、衛星回線は地上のあらゆる場所にインターネットを拡張するのに有効な通信路として期待されている。

しかし、衛星回線の運用手法は、地球局の形態や利用可能な機能、データリンクトポロジなどによって様々である。衛星回線の運用範囲が回線ごとに限定されるため、衛星回線をインターネットの一般的なデータリンク層として統合的に運用するのは困難である。このため、衛星回線は他の通信路にない特性を持つにも拘らず、衛星回線利用の効率化や衛星ネットワーク間の相互接続など、衛星回線の柔軟性を活かした運用が行えない問題がある。

本研究における着目点は、ネットワーク上で地球局や外部ノードが運用情報を互いにやり取りすれば、衛星回線のより効率的、且つ安定した運用が実現できることである。このため、インターネットを利用した衛星回線の自律的な運用環境を提案し設計した。提案したモデルにおいて衛星回線利用の効率と安定性の向上を実現するため機能について述べ、それぞれ異なる機能や運用インタフェースを持つ地球局をインターネット上で統一的に管理可能なノードとして抽象化する必要があると述べた。他方、衛星回線の自律的な振舞いを許可する運用境界を定義し、地球局が持つ一般的な情報を運用境界内で統一的にやり取りを実現するための運用情報を分類・定義した。また、地球局を構成する主要な機器として変復調器に注目し、回線設定に必要な運用パラメータを整理した。

本環境を実装するにあたり、運用情報をやり取りするプロトコルに SNMP を選択し、定義した運用情報は ASN.1 形式で SAT-MIB に記述した。本研究では、提案した運用モデルを既存の運用環境との比較、および本モデルの設計について定性的に評価した。その結果、異なる衛星回線の運用環境が混在するネットワークでの統一的、且つ柔軟な回線運用を実現できることを示した。また、本研究により衛星回線をインターネットのデータリンクとしてより一般的に運用可能にする技術基盤が構築できることを示した。

Key Words
1. Satellite Communication　　2. Internet　　3. Autonomous Operation

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Chapter 1

Introduction

1.1 Background

A satellite covers a wide area on the earth and can broadcast data beyond limitations of geographical boundaries. Satellite links are effective infrastructure to provide Internet connectivity in the areas where terrestrial data links or additional bandwidth for an existing data link is hardly available. Furthermore, satellite links have flexibility on their link configuration. Bandwidth for each link, link topology, and even antenna location can be easily changed. These are the distinguished features of satellite communication compared to other communication links used on the Internet.

In recent years, the environment for joining the satellite-based Internet is easily available by using satellite links as unidirectional links. A unidirectional link can be shared by a huge number of receive-only stations, and the operation in a receive-only station is simplified with cheap and easy-to-use equipments compared to a transmit-capable station. Beneficial contents such as distance education[12] can be shared on a satellite network as a broadcast capable shortcut to deliver data anywhere within the satellite footprints.

In order to use satellite links efficiently, satellite links should be operated more flexibly with maximizing the data link characteristics and satisfying requirements for traffic capacity. Satellite links are sensitive to their environmental conditions such as sun interference or weather depending on their frequency bands. Thus, status of satellite links often fluctuate and the links may go down due to such environmental changes. On the other hand, due to the growth of traffic and variety of applications on the satellite-based Internet, various requirements are raised from users and applications. The most likely requirements are the ones for keeping connectivity as long as possible and maximize the utilization of bandwidth resource.

It is essential for satellite links to respond to sudden changes in the environmental conditions, including weather conditions and amount of traffic on a network, or requirements from applications as quickly and safely as possible. Because any communication link can be used on the Internet, several operational schemes of satellite links can be mixed in a single network. Not all satellite links have the capability for flexible operation that satisfies every requirement toward the data link and reflects it on the link operation. Thus, although satellite link are effective as data link for the Internet, they are not utilized by taking the maximum advantage of their data link characteristics from the view point of managing them as the data link of an IP network.

1.2 Research Objective

The objective of this research is to realize a flexible satellite link operation environment that maximizes the data link characteristics and the utilization of satellite links on the Internet. This research contributes to build an infrastructure technology to realize a flexible satellite link operation that is independent of the heterogeneity of operation environments.

1.3 Organization of Thesis

This thesis consists of 8 chapters. The next chapter describes an existing satellite link operation scheme, explaining the AI^3 project as an example. Chapter 3 states the issues on satellite link operation and related works regarding automation of the satellite link operation. Chapter 4 proposes a new operation model of satellite links using the Internet as its communication infrastructure. Chapter 5 discusses requirements to implement our model, and then chapter 6 describes the implementation of the model on actual satellite network. Chapter 7 evaluates the model presented in this thesis based on the design and achievement from the view point of establishing the autonomous operation environment for the satellite-based Internet. Chapter 8 concludes this thesis and describes the future works.

Chapter 2

Existing Scheme of Satellite Link Operation

This chapter describes several typical topologies using satellite links as their data links, basic operation procedure of a satellite link, and an international satellite-based network operated by the AI^3(Asian Internet Interconnection Initiatives) project[14].

A satellite link is established between at least two earth stations via a satellite transponder. In this thesis, we assume the satellite as a geostationary satellite that is on the geosynchronous orbit about 36,000 kilometers above the equator.

2.1 Earth Station

2.1.1 Classification by Communication Capability

Earth stations can be classified into three types based on the feature of communication toward a satellite link:

Transmit-receive station: A transmit-receive station transmits a carrier and receives a carrier from the satellite. In this thesis, we call a transmit-receive station simply as an earth station.

Transmit-only station: A transmit-only station transmits a carrier but does not have receive capability.

Receive-only station: A receive-only station receives a carrier from the satellite but does not have transmit capability.

2.1.2 Basic Component

An earth station consists of several equipments. Each equipment has its own function that determines the communication characteristics of the link. Figure 2.1 shows the basic components of an earth station.

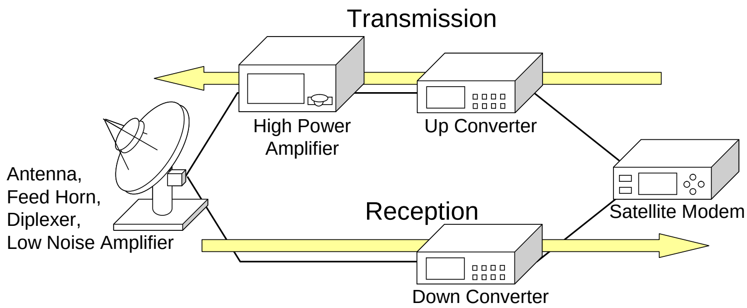

Figure 2.1: Earth Station Components

2.2 Forms of Earth Stations

There are a variety of forms of earth stations depending on intended purpose and functionality of them. Normally, an earth station has several facilities which in total determine the characteristics of the link, and the station is fixed in a same place. Forms of earth stations can be classified into a HUB station and a terminal station.

2.2.1 HUB Station

A HUB station is an earth station that connects to many earth stations. In some cases, a HUB station administers the links and controls the terminals stations which are located on the opposite end of those links. For example, if TDMA is employed to assign channels for each link, the HUB station should synchronize terminal stations on the link. And then, a HUB station allocates time slots and bandwidth for each channel.

A HUB station can be a single point of failure when it has a trouble. Therefore, some facilities have their backups to provide redundancy for the HUB station capability. In general, a HUB station is large in scale because it provides many functionalities and physical facilities to operate many links.

2.2.2 Terminal Station

A terminal station connects to a HUB station or another terminal station. But, a terminal station does not have a functionality for relaying received signals to another earth station. In a VSAT network, some terminal stations are fully controlled by a HUB station after the terminals receive the satellite signal. That is typical for VSAT systems, and users or operators in the terminal stations don't have to configure the frequency or information rate by themselves.

If an earth station is intended to be portable, the functionality of the earth station is integrated in small number of facilities. A VSAT (Very Small Aperture Terminal) is a portable earth station. Using a VSAT, a satellite link can be established in almost all places, only if a place to put an antenna is available and a satellite is acquired without obstacles between the antenna and the satellite.

Usually, a VSAT is composed of an antenna, an IDU (Indoor Unit) and an ODU (Outdoor Unit). Generally, an IDU is a modulator and a demodulator. An ODU is an electric equipment that provides the functionalities to communicate with a satellite: a feed horn, an up converter, a power amplifier, and a combination of low noise amplifier and down converter (LNB: Low Noise Block converter). A coaxial cable is used to connect between the ODU and the IDU. Figure 2.2 shows the basic topology of a VSAT earth station.

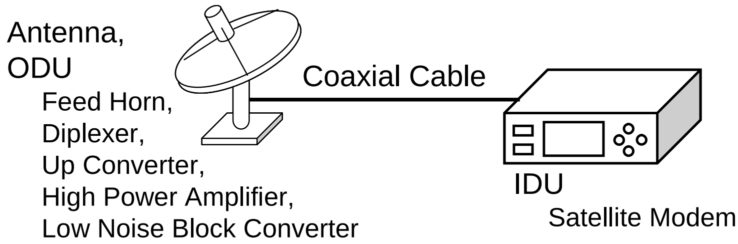

Figure 2.2: VSAT Components

2.3 Multiple Access Methods

A satellite link is established on a channel which is assigned to each link. In order to utilize frequency resource efficiently, multiple access is applied. Multiple access divides the band of transponder into several channels on which multiple links are established. This section describes two major fixed assign multiple access schemes.

2.3.1 Time Division Multiple Access (TDMA)

TDMA divides the band of transponder into multiple channels by time. Transmitting earth stations burst signals during the assigned time slots in periodical time frames in order. Receiving earth stations discriminate the transmit capable stations from the whole received signals from the satellite by the time slots and frames. Those time slots and time frame have to be synchronized among a transmitting station and a receiving station so that they can transmit or receive the signals promptly. Figure 2.3 shows the basic concept of TDMA.

If assigned bandwidth of a certain link is to be modified, TDMA does not need to modify the frequency assignment. This is because a link is determined by the total size of the time slots which are assigned for the link per unit of time. The functionality of on-demand bandwidth allocation is introduced on the system which applies TDMA as its multiple access method.

2.3.2 Frequency Division Multiple Access (FDMA)

FDMA divides the band of transponder into multiple channels by frequency. Transmitting earth stations transmit signals on the frequency which is assigned for each station. Receiving earth stations discriminate the transmit capable stations from the whole received signals from the satellite by the frequency which is assigned for each channel. Figure 2.4 shows the basic concept of FDMA.

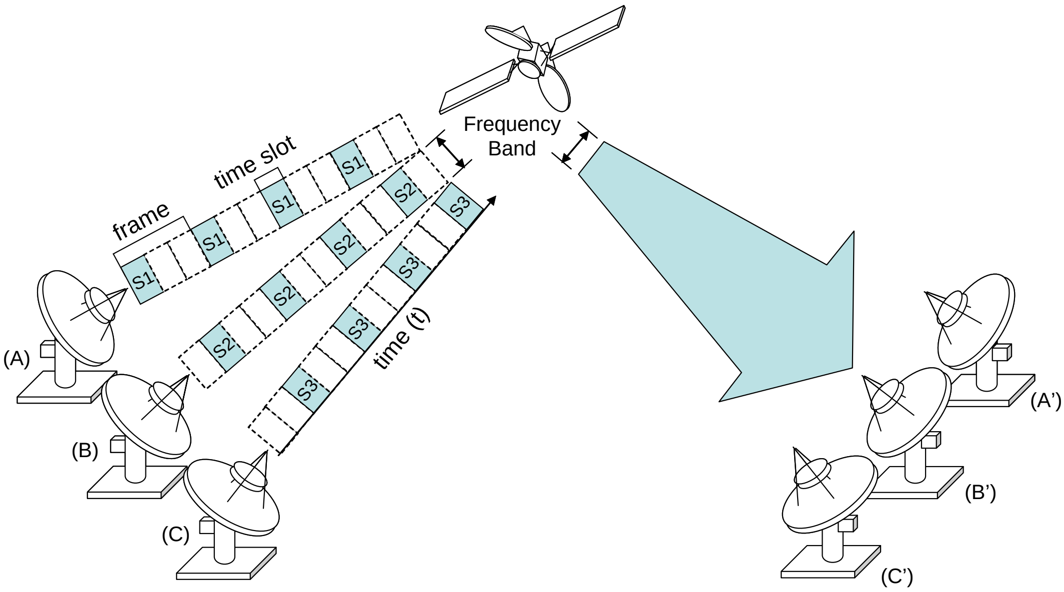

Figure 2.3: Basic Concept of TDMA

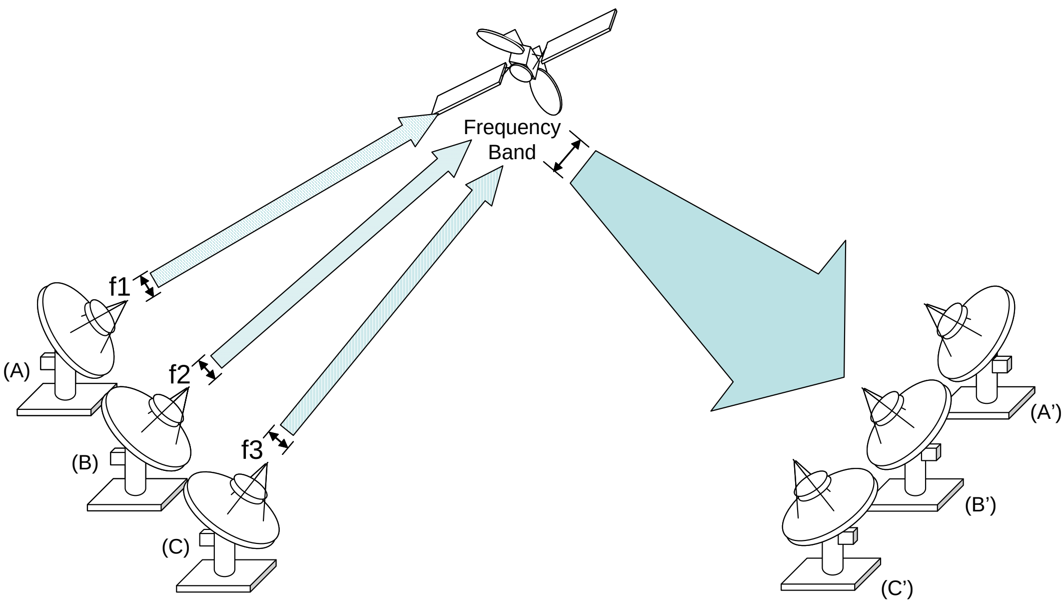

Figure 2.4: Basic Concept of FDMA

FDMA is more popular than TDMA as a multiple access method. One reason is that , in the case of FDMA, the procedure of multiple access is simple. Another is that the equipment of earth station is cheap compared with that of TDMA. And the other reason is that there is no need to have synchronization mechanism between each link.

2.4 Data Link Topologies

In general, there are three types of communication link topology by satellite links.

2.4.1 Point-to-Point Link

A point-to-point link directly connects two earth stations. These two earth stations transmit the signal to the satellite, and they have bidirectional communication capability with each other. A point-to-point link is composed of two communication channels, one channel is used for one direction and the other channel is used for opposite direction.

2.4.2 Star Topology

A star topology interconnects several terminal stations via a HUB station. Every terminal station establishes a point-to-point link to the HUB station. A star topology consists of $2(n-1)$ channels, when n is the total number of the terminal stations and the HUB station. On the other hand, if every earth station establishes point-to-point links with the other earth stations, $n(n-1)$ channels are consumed on the mesh. Thus, to establish a network where many earth stations are interconnected, a star topology is reasonable to apply, because they consume less channels than a mesh by point-to-point links. However, on the star topology, the number of hops are doubled on communication between terminal stations compared with the data link mesh. Figure 2.5 shows the basic concept of star-shaped links.

2.4.3 Point-to-Multipoint Link

A point-to-multipoint link broadcasts data from one transmit-only station to multiple receive-only stations at the same time. Figure 2.6 shows the outline of a point-to-multipoint link. A receive-only station is cheap in price. There is no limit on the number of receive-only stations that listen to the link in terms of consumption of frequency resources. Also, operation of a receive-only station is simple compared with earth stations which can transmit radio signals, because a receive-only station has limited functionalities and consists of equipments of small scale.

A point-to-multipoint link is used as a unidirectional link. However, because the Internet architecture assumes bidirectional connectivity of its data link, some functionalities of the Internet, such as the automatic MAC address resolution and dynamic routing protocols, do not work correctly on a unidirectional link. UDLR (Unidirectional Link Routing)[4] was developed to utilize a unidirectional link on the Internet by employing layer 2 tunneling and broadcast emulation. This technology makes it possible to use a satellite link as a broadcast link that is shared by many earth stations like Ethernet.

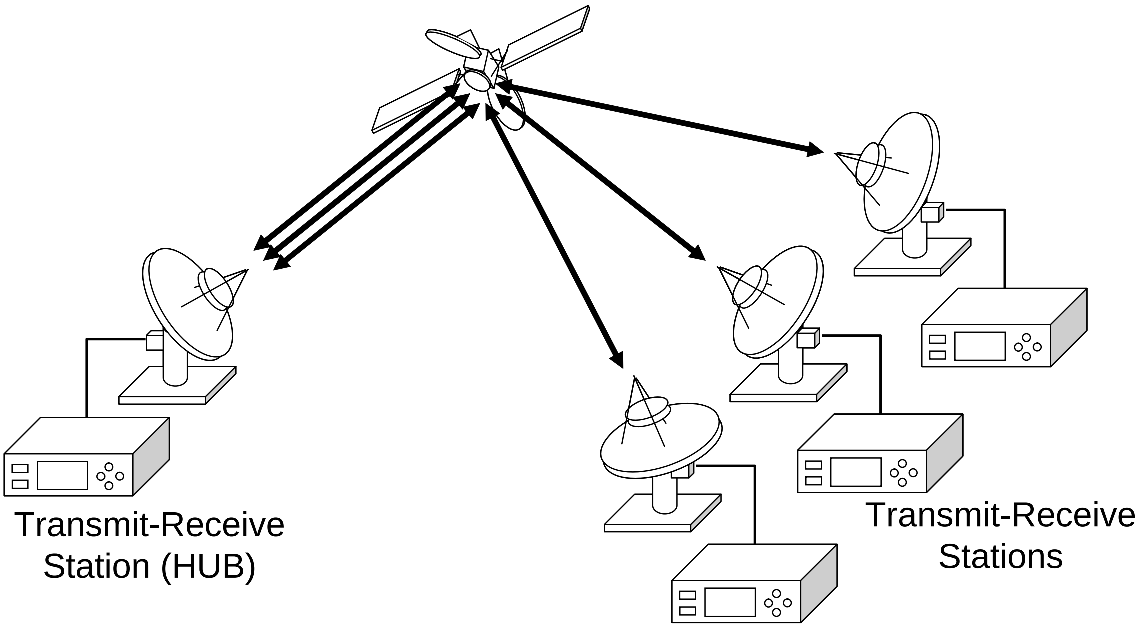

Figure 2.5: Star-shaped Links

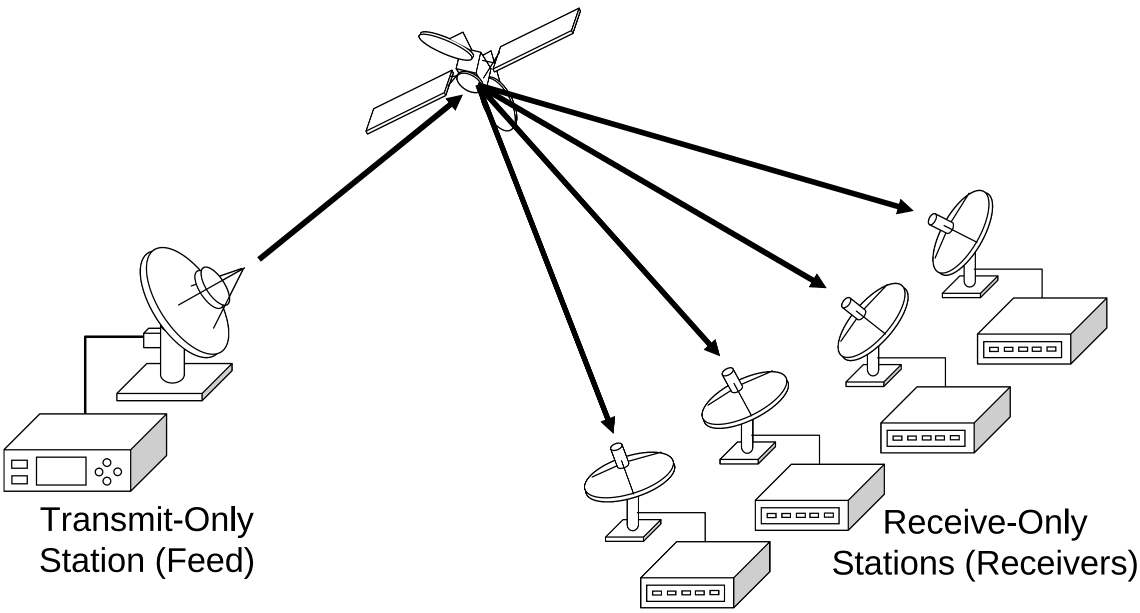

Figure 2.6: Broadcast Link

2.5 Basic Satellite Link Operation

Operation of satellite links is divided into two phases. One is setup phase, to configure and execute the parameter settings on each earth station. The other is operational phase, to monitor the status of satellite links to be aware of the link status changes. Figure 2.7 shows the outline of basic satellite link operation.

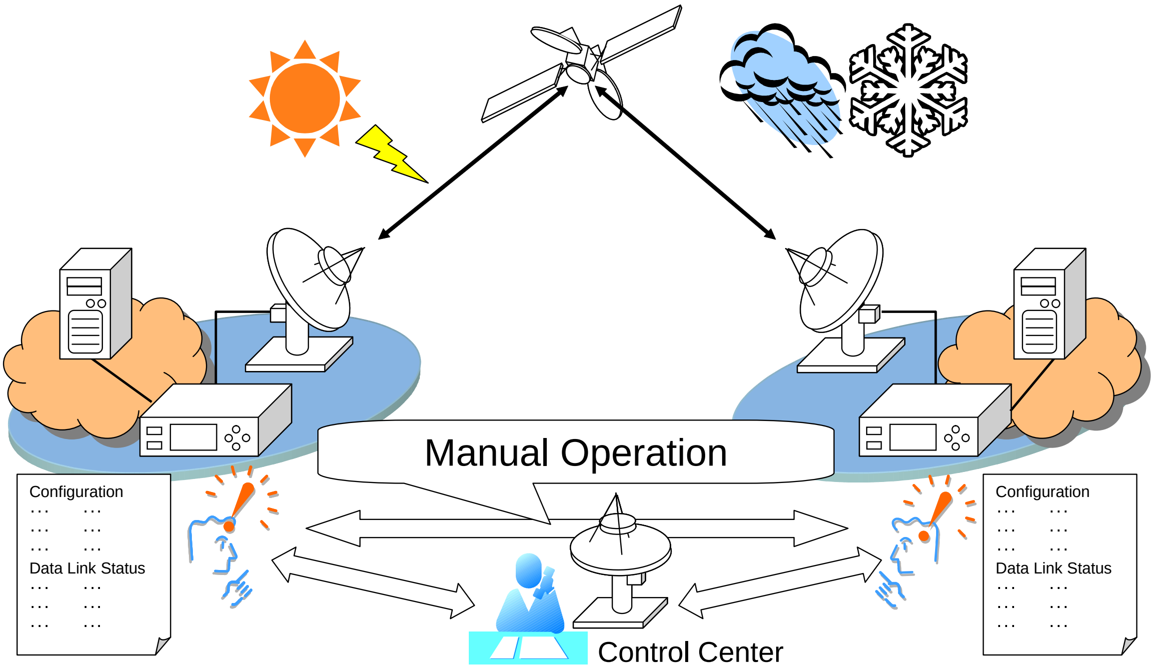

Figure 2.7: Outline of Satellite Link Operation

2.5.1 Satellite Link Configuration

Generally, the main component of satellite link operation is human operator at each earth station. Operators configure the parameter settings of satellite links at each earth station, based on the topology plan and the assigned bandwidth usage of the network to be constructed using these links. Parameters to establish a satellite link must be synchronized at every earth station which is connect to the link. Usually, operators use e-mail, telephone or facsimile, etc. in order to confirm and share the parameter settings of satellite links. If parameters in each earth station are set differently, the link can not be established. In addition, if the transmission frequency is accidentally set to use other users' frequency, communication on those other links are disturbed. Typical parameters that must be synchronized among earth stations are as followed.

- Transmission frequency
- Reception frequency

- Modulation parameters
- Demodulation parameters
- Coding parameters

In general, once the parameters of the links are set, these parameters are fixed for a long period of time. However, when operators change the setting of the links, they need to confirm the parameters to be changed and schedule the time and day of work. They have to stay in close contact with operators in the other earth station all the time during the work.

2.5.2 Communication Link Monitoring

Due to sensitivity of satellite links, monitoring communication link status is essential in the satellite link operation. The definition of the data link status depends on the data link type. In the cases of the IEEE 802.3[13] wired data links or the ATM links, the status of its data link is stable once the link is established. Thus, it is general that the status of those links is simply determined as "UP" or "DOWN", though they have some operational parameters. On the other hand, in the cases of the IEEE 802.11[5] wireless data links, those data link status fluctuates depending on their environmental conditions such as composition of air stations, channel allocation and so on. And then, end users can easily check their data link performance by estimated throughput, because the data link performance is monitored directly on the terminals.

The status of physical satellite link is determined by combination of several parameters that show the link status in different measures. Normally, those parameters are measured at the input interface of a demodulator or calculated in the demodulator. Typical parameters that show the data link status are as follows.

Received signal level (RSL): RSL is a measure of the received signal strength on the input interface of the demodulator.

Carrier to noise ratio (C/N or CNR): C/N is a measure of the received carrier strength to the received noise strength.

Bit error rate (BER): BER is a ratio of the total number of received bits to error bits. BER can be measured before or after error correction in the demodulator.

Energy per bit to spectral noise density (Eb/N0): Eb/N0 is a measure of the received signal strength to noise in digital communication. Eb/N0 shows the data link quality which is mapped to BER on a certain modulation type.

Because satellite links are established by several earth stations located at different places, the links have different status depending on the environmental conditions at the edges of the links. Thus, the total status of a satellite network has to be determined based on the collection of the monitoring result at all earth stations on that link.

Operators can not know the complete status of a satellite link by monitoring the link status at a single earth station. It is difficult to know the link status based on the information only from the local earth station. Thus, to interpret the situation correctly, operators need external information on the status.

Regarding a single point-to-point link, the link status should be monitored at both edge of the link. On the other hand, in order to monitor a broadcast link, the link status should be monitored on the input interface of every receive-only station which listens to the link. In both cases, the monitoring result in each earth station should be shared to indicate the total status of a satellite network.

2.6 Satellite Link Operation in the AI^3 Project

This section introduces the AI^3 project as the instance on that operates several types of satellite links in a single network. The AI^3 project is an organization for research and development activities of the Internet technology. The AI^3 project has established a wide area network that covers the Asian region utilizing satellite links as its data link. Several research institutions and universities in the Asian region join the satellite-based network. We call an organization which joins the AI^3 network as a "site".

2.6.1 Outline of Network

The AI^3 network is composed of three types of satellite networks: Ku-band point-to-point links, C-band point-to-point links and a C-band point-to-multipoint link. Figure 2.8 shows the basic network topology of the AI^3 network.

The Ku-band point-to-point links and the C-band point-to-point links form star topologies, putting hub stations in Nara Institute of Science and Technology (NAIST) for Ku-band and Keio University Shonan Fujisawa Campus (SFC) for C-band relatively. The C-band point-to-multipoint link, whose hub station is SFC, is a shared by several receive-only stations and transmit-receive stations which connected to the point-to-point links. Because the bandwidth of the link is wider than other point-to-point links, some transmit-receive sites use it as their high speed down link. In the AI^3 network, every site has a transmit-receive station or a receive-only station, or both of them.

2.6.2 Satellite Link Configuration

The earth station in each site is operated by local operators. Configuration of satellite links is done by manual operation in each site. When there is a major configuration renewal which involves all sites of the network, such as re-allocation of satellite link bandwidth, the work procedure and the schedule are fixed in advance and the related sites have to work at the same time.

In some sites, it is difficult for the local operators to configure the satellite link by them selves. Those sites are very newbie in the network and the local operators don't have enough skill to operate the earth station. In this case, operators from other site have to visit the site and configure the link on behalf of the local operators.

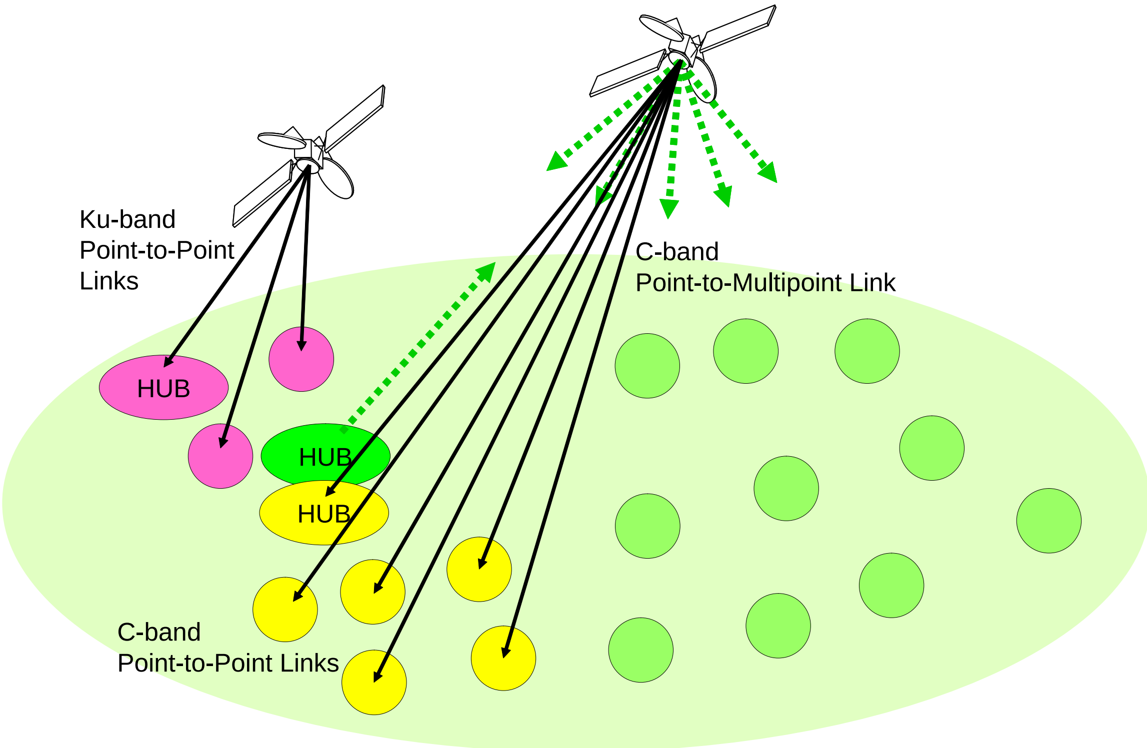

Figure 2.8: Overview of the AI3 Network

2.6.3 Satellite Link Monitoring

On the AI^3 network, the status of a satellite link is monitored at each earth station which listens to the link respectively. There are three types of satellite modems which are used to monitor the status of each satellite data link. Although each satellite modem is capable of displaying the data link status, display style and access method of these modems are different among them.

Currently, because each site is operated independently, the information captured in each site is not shared on the whole network. In some cases, the lack of information makes it difficult to detect the trouble or investigate the source of satellite link trouble.

Chapter 3

Operational Issues and Related Works

This chapter elaborates problems on the existing operational scheme of satellite network in a widely spread area.

3.1 Heterogeneity

3.1.1 Functionality and Capability on Operational Environment

The Internet does not rely on a specific data link protocol or the data link itself. Therefore, there are many forms of earth stations with different functionalities. And then, many kinds of satellite links can be introduced in a satellite network, only if those links are capable of delivering IP packets.

Operational environments that have their own characteristics can be mixed on a single satellite network. This factor makes the operation environment of satellite links heterogeneous. For example, followings are the typical components that make operational environment of satellite network heterogeneous: communication link topology and configuration schemes, controllable range of satellite link, availability of feedback from other earth stations or external nodes, etc.

Depending on forms of earth stations, their basic composition may be different. Their detailed composition is also different according to their economic, operational or functional constraint of equipment. The functionalities of earth stations can be different according to the objectives to settle the earth stations. Also, major functionalities of an earth station are to transmit a carrier to a satellite, receive a carrier from a satellite, or both of them. Depending on these functionalities, detailed functionalities are implemented on respective earth stations.

Heterogeneity of operational environment splits an operational domain into narrow sub domains. In those sub domains, operational functionalities are limited in their variety and applicable range depending on forms and specification of earth stations. Thus, the operation of satellite links is not systemized from the view point of communication link operation on the Internet.

Even though operation cost of a certain satellite link is low, the total cost of operation in the network may not be reduced radically. Furthermore, another cast can be created to achieve a operational balance between each link on that network. For example, even though a HUB station is capable of on-demand bandwidth allocation to terminal stations on a satellite link, some other earth stations may need manual operation to configure the parameter settings of the remaining satellite links.

3.1.2 Operational Interfaces and Parameters

Equipments of an earth station have their vendor's own operational interfaces, which are not designed to monitor and control the equipments via the Internet. In many cases, operators have to handle those equipments directly or implement some agents to monitor and control them from remote based on the specification of each equipment. From the view point of data link operation as a whole network, it costs much in time and human resources to operate equipments that are made by several vendors in different manners due to the system dependent interface specification.

On the other hand, the operational parameters are also defined differently depending on the specification of vendors. It is often the case that different units are used on a single parameter, some parameters are curtailed, and so on. For example, in the case of the AI^3 network,

- on an SNR-PS1000 satellite demodulator, demodulation information speed is set by only symbol rate with the unit of sps,
- on a NEXTAR-CLVR VSAT IDU, radio frequency is set by only channel of 25KHz step on its user interface.

Therefore, if several types of links are operated in a single domain, operators have to calculate the suitable parameter settings for each facility from the system-dependent conditions and the values of the target parameters. Additionally, in order to monitor the status of satellite links as correctly as possible, operators have to calculate the data link status from limited values that are available on the equipments.

Figure 3.1 shows three applications that are separated into different applications because of the heterogeneity of operational environment. Each application in the figure provides the same functionality. However, because the operational interfaces or parameters are different between respective systems, the applicable range is limited to a single satellite link. Therefore, three different applications are installed to provide the same service in a single satellite network.

3.2 Manual Operation

In the operation of satellite links, operators have to coordinate among themselves in order to synchronize the parameter settings depending on the status of the data link and environmental conditions. However, the cooperation among operators is often problematic.

One of typical problems in coordination among operators is language. In the wide area network operation that covers several countries and regions, it is often the case that operators have trouble with communicating among them, because they are working in different countries or regions. For instance, English is mostly spoken as the common language in the

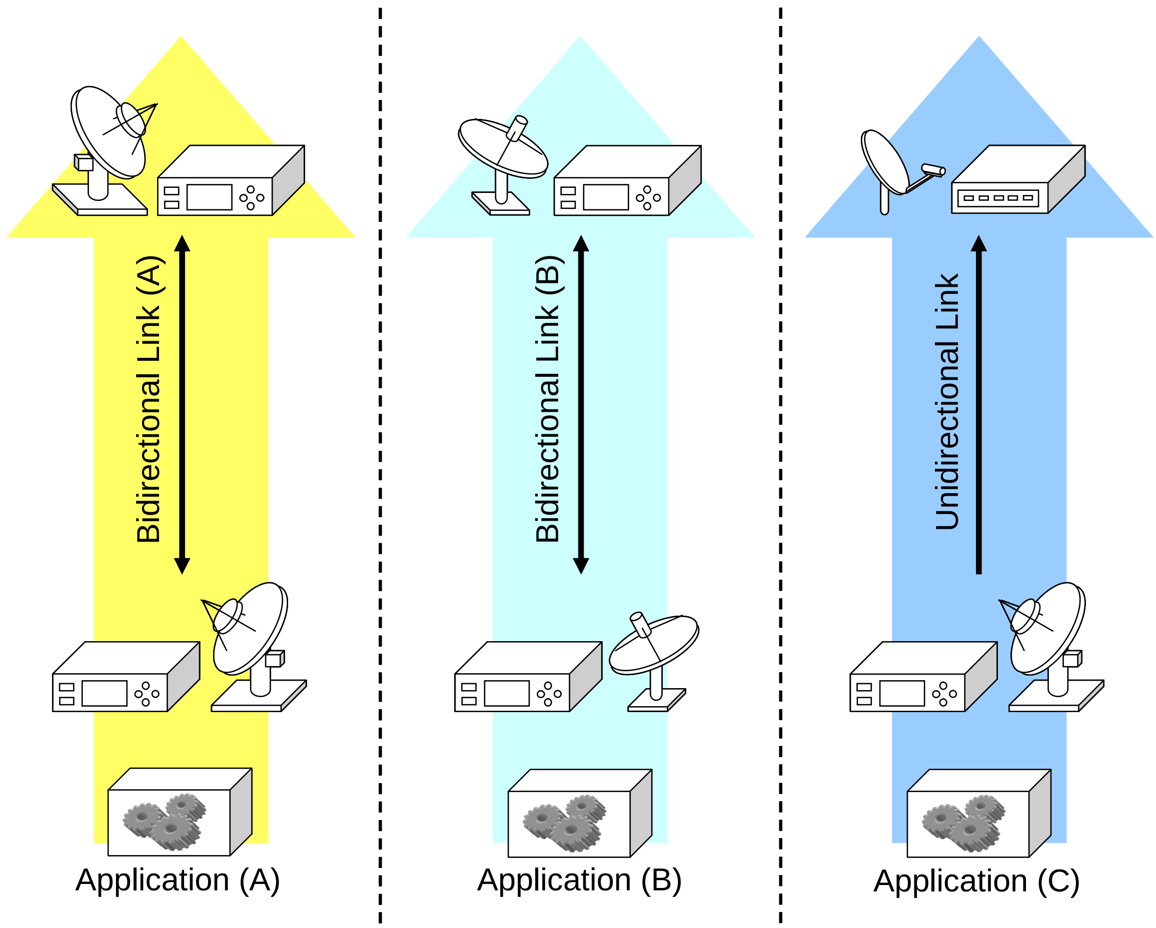

Figure 3.1: System Dependent Environment

Asian region. However, not all of the operators can speak English well enough to understand the dialog to establish the link and to adjust operational parameters in detail.

Besides that, operators have to configure and check many parameters and status in the operation. However, not all operators have enough knowledge and experience to operate a satellite link. In addition, because the earth station transmits amplified radio frequency wave in the air, operators are obligated by law to hold a license to operate a radio station in some countries. Therefore, in some cases, local staffs can not operate their earth station by themselves.

It is hard for operators to continue to adjust the data link setting to its status or environmental conditions in a short period of time. This is because the operators have to synchronize the operational schedule and stay at the earth station all the time. Thus, the operation cost by human operators is very high to realize the flexible data link operation on the widely spread area. In an earth station whose operation relies on human operators, it costs very much in human resources and time. Thus, the various kinds of information such as amount of traffic on network or data link status can't be reflected on the data link operation in real time. As a result, satellite links are operated without flexibility which the links have in nature.

3.3 Related Works

This section describes two systems are designed and implemented to minimize the operational cost of satellite links: Dynamic Bandwidth Allocation and Modem Watch Dog.

3.3.1 Dynamic Bandwidth Allocation (DBA)

DBA[7] describes a system which is designed to dynamically change the bandwidth of each satellite link based on the amount of traffic on the router of each link. DBA configures the parameter settings regarding link parameters on the satellite modems from remote on the Internet.

Figure 3.2 shows the overview of DBA system. A HUB server calculates optimized bandwidth allocation for each satellite link according to the notification of traffic from each link. And then, the server determines the parameter settings for each channel, such as information speed, frequency and so on. Those parameter setting are sent to the remote control module which controls satellite modems to change the parameter settings of the links. Each earth station has its own remote control module and the configuration is delivered on the Internet.

A remote control module works on a PC which is directly connected to a satellite modem with a serial cable. The remote control module administrates the procedure of satellite modem configuration that is executed by the modem control module that is running on the same PC. If the configuration on the modem is failed on any earth station, the configuration of all the earth station is resumed to the previous one.

DBA system realized the efficient utilization of the bandwidth resource on the C-band network of the AI^3 project. However, DBA system has to be authorized to use by satellite operators. Also, the system has a problem that the applicable range of the system is restricted. This is because the system is designed exclusively for the AI^3 C-band network,

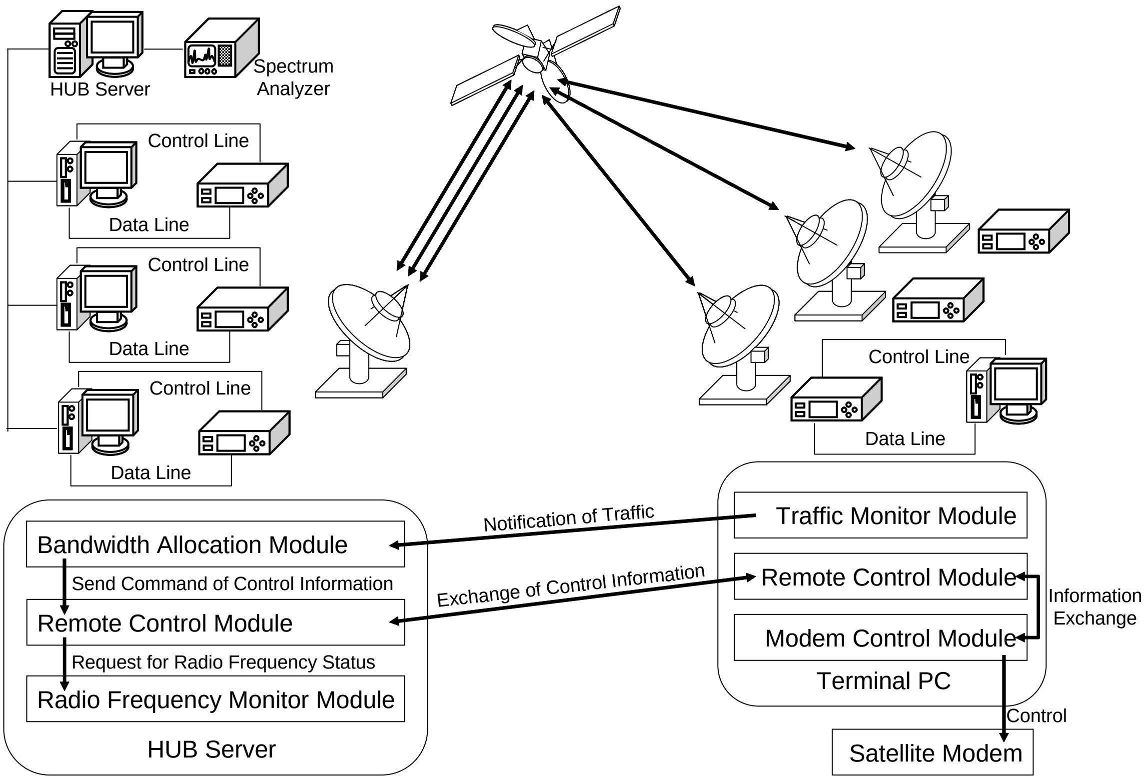

Figure 3.2: Overview of DBA System

and highly depends on the specification of satellite modem. Therefore, to deploy this system on other types of satellite links, the developers have to make many modules to suit the equipment of the earth stations to the system.

3.3.2 Modem Watch Dog (MWD)

MWD[9] is a system that automatically collects status of satellite links and summarizes it in a graph that shows continuous status of satellite data link. Operators can monitor the data link status from anywhere via the Internet. Figure 3.3 shows the overview of MWD.

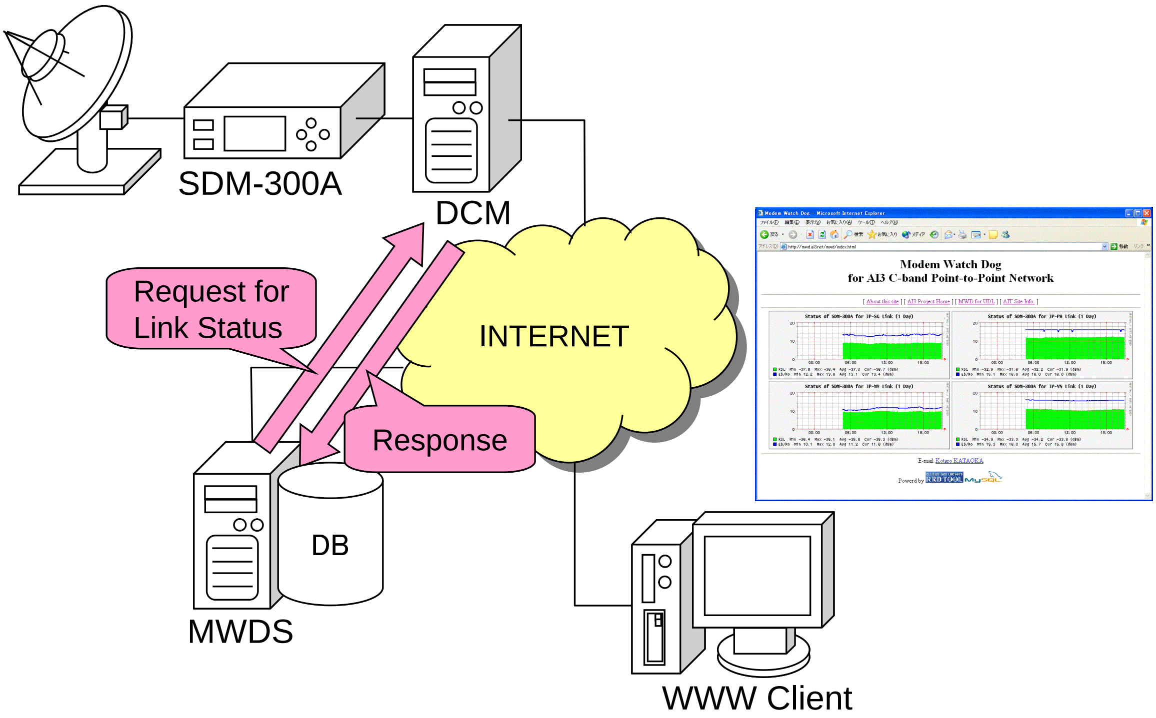

Figure 3.3: Overview of Modem Watch Dog

MWD is composed of the data collect module (DCM) and the MWD server. DCM works on a PC that is connected to a satellite modem with a serial cable. Because the satellite modems that are dealt with on this system do not have accessibility on the TCP/IP suite. Thus, DCM connects to control port of the satellite modem and sends several commands to request the necessary status information: Eb/N0, BER, and RSL. DCM, which is connected to the Internet, makes it possible for other nodes to access those parameters on the Internet. Figure 3.4 shows the functionality of DCM.

MWD server requests a DCM for the data link status of each satellite link. The server has a database and stores the status information in it. MWD server also visualizes the stored data link status in graphs on different time scale: three hours, one day and one week. The graphs are uploaded onto the web page and operator can check them on the Internet. Figure 3.5 shows the functionality of MWD server.

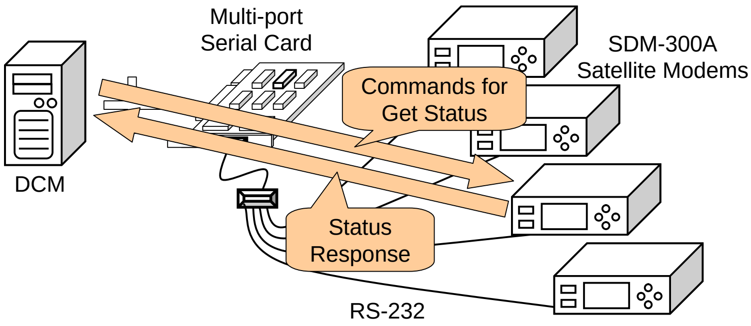

Figure 3.4: Functionality of DCM

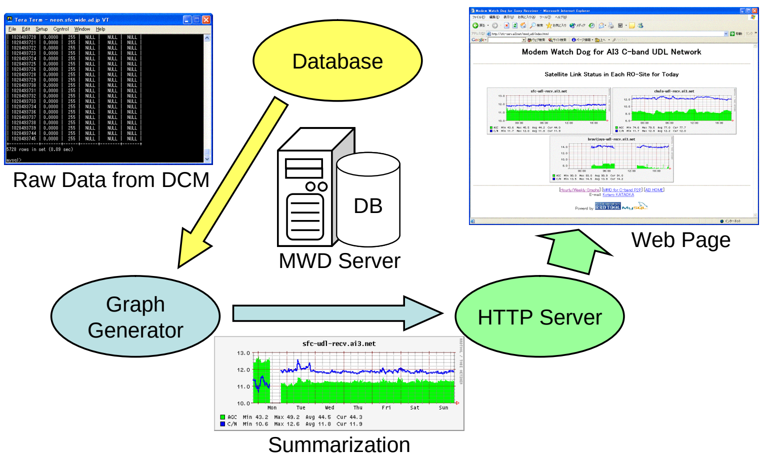

Figure 3.5: Functionality of MWD Server

MWD reduced the operational cost of satellite link regarding monitoring those data link status, because there is no need for an operator to touch the satellite modems to check the link status every minutes. However, as is the case with DBA system, MWD focuses on specific satellite modems in the AI3 network. Therefore, it takes cost to extend the system to different types of satellite modems.

Chapter 4

Autonomous Satellite Link Operation Environment

This chapter proposes a new operation model of satellite networks that is called "autonomous satellite link operation environment".

4.1 Operation Model Outline

The new operation model abstracts earth stations as nodes that are accessible from anywhere on the Internet. Figure 4.1 shows the basic concept of the proposed operation environment. In the real space, a satellite network is composed of several satellite link topologies, and earth station have different forms and accessibility from the links. However, when those earth stations are projected onto the proposed operation environment, they can be controlled from remote on the unified operation scheme beyond the heterogeneity of operational environment.

4.2 Objective of Operation Model

The objective of this operation model is to realize a flexible satellite network operation that provides following features to construct the operational infrastructure for generalized satellite link operation.

- Sustained connectivity of satellite links
- Routing Optimization
- Integrated Dynamic Bandwidth Allocation
- Operation Cost Minimization

4.2.1 Sustained connectivity of satellite links

A satellite link may go up and down intermittently when the data link status fluctuates. However, if the total data link status gets improved by some ways, the link may be kept established longer or the connectivity can be resumed.

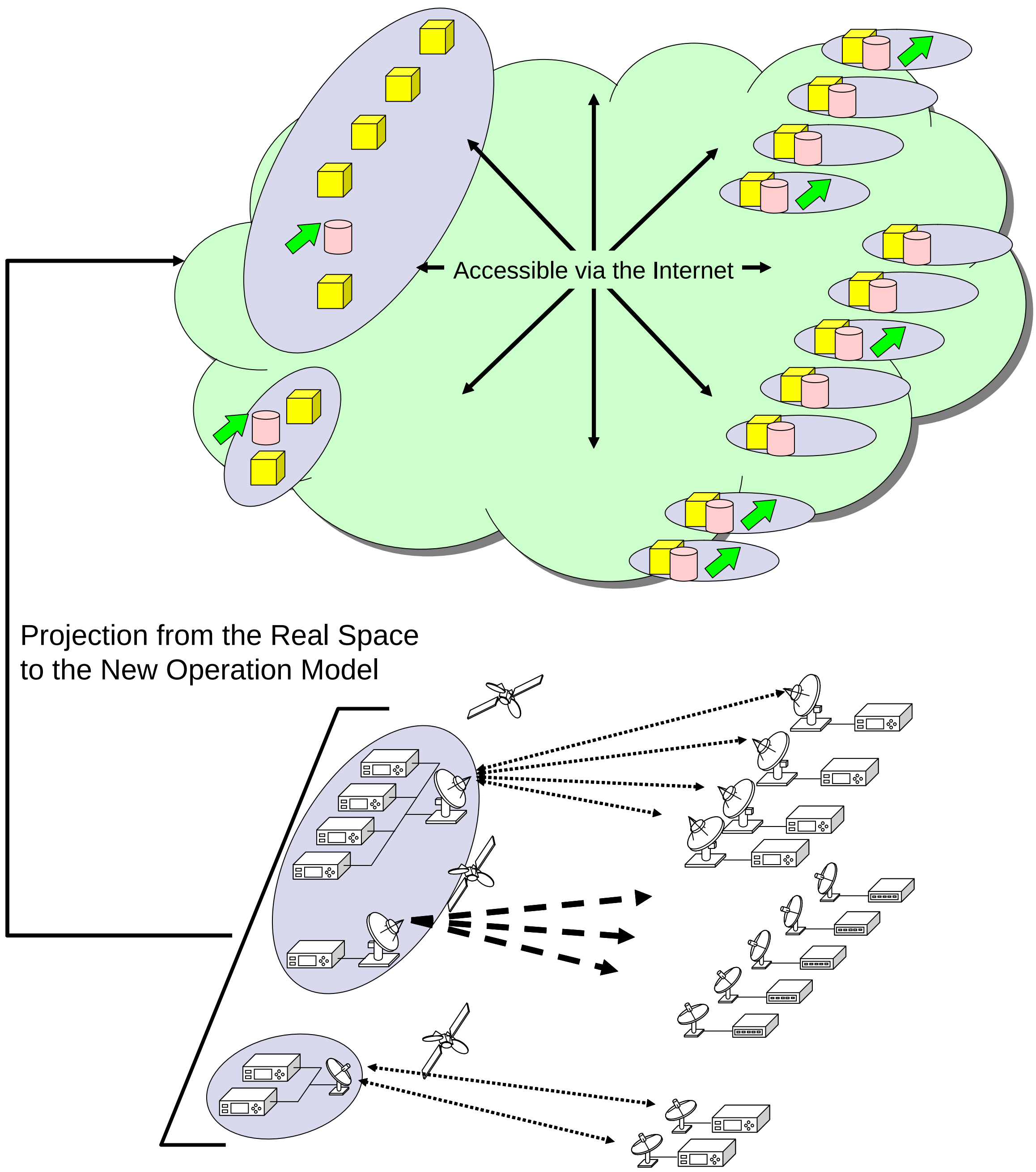

Figure 4.1: Concept of Autonomous Satellite Link Operation

There is a relationship between required Eb/N0, information speed and coding rate on desired BER. Figure 4.2[8] shows the shifting of BER that is calculated from several combinations of Eb/N0 and coding rate. A satellite modem has its own communicable range on every coding rate selectable on the modem. The communicable range is different between the coding rate settings. In general, if a coding rate employs the combination of high information speed and low FEC rate, a satellite link requires high Eb/N0 level in order to acquire the desired BER and to keep the link established. On the other hand, if the coding rate is set with slow information speed and high FEC rate, even though the Eb/N0 is low on a satellite link, the link can be kept established.

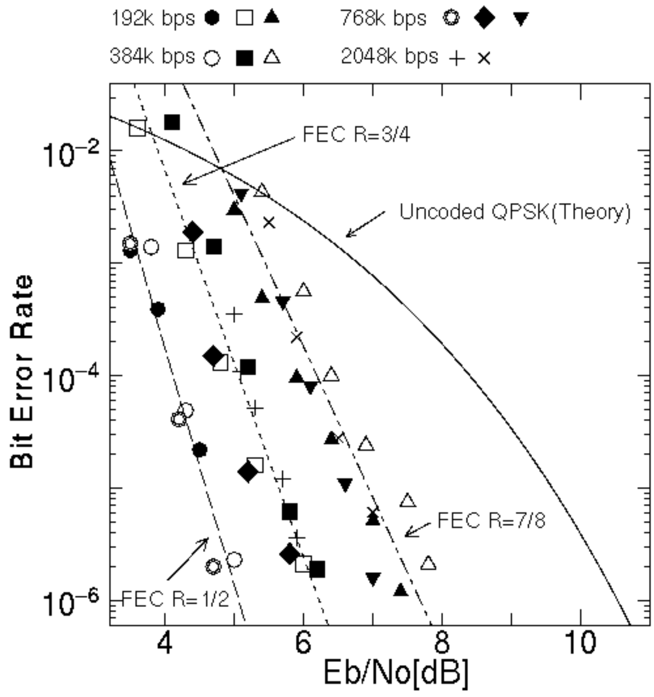

Figure 4.2: Relationship between Eb/N0 and Coding Rate

The coding optimization controls the information speed and the coding rate to acquire the coding gain of the link when the status of receiving carrier changes for worse. On the other hand, based on the communication link status, the information speed can be always maximized upon best effort. Figure 4.3 shows the basic concept of the rate optimization.

4.2.2 Routing Optimization

In order to build a routing table based on dynamic routing protocols, routers on the link periodically exchange routing information with their neighbors. However, those routing protocols do not hold the detailed data link status of each satellite link as their operational information. Thus, the routers can not correctly determine whether the link is available or not, if the data link connectivity fluctuates.

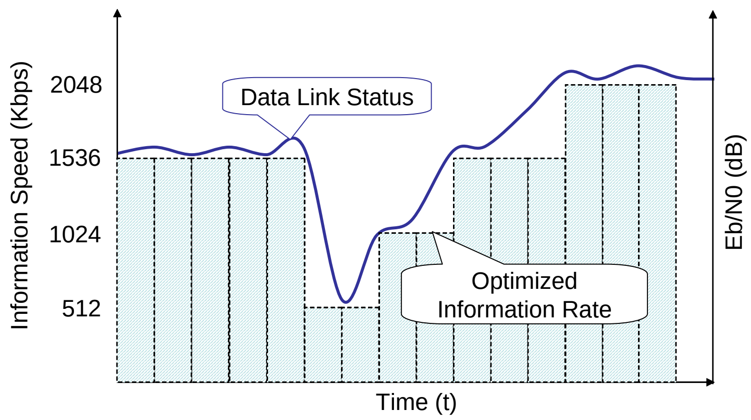

Figure 4.3: Basic Concept of Rate Optimization

When a satellite link fluctuates a little, the route that uses the link as its path to the next hop may not be advertised to the other neighbors, even though the link has good enough data link quality to establish it. On the other hand, the route may be treated as an available path all the time, even though the satellite link is down almost all the time. Route flaps[2] or incorrect selection of path may occur because of divergence between the actual data link status and the link status that is recognized by the routing protocols. As a result, the performance of a satellite network will be depressed.

Connectivity of a satellite link may continue to go up and down in a short period of time, or the link may keep to be barely up from the view point of data link status. Thus, routing optimization that ensures routers know the satellite link status is considered as a solution for stabilize dynamic routing on a satellite network. The routers can determine the link availability based on not the simple packet exchange among routers but the continuous status of the link status and advertisement policy of the link.

If the status of satellite data link is available on the network, the router can flexibly determine the availability of the link based on the link status. As a result, incorrect advertisements of dead path or route flaps can be reduced, and the stability on the satellite network will be improved.

4.2.3 Integrated Dynamic Bandwidth Allocation

DBA system creates a high cost in deploying among new equipments, because developer has to write the control module which is suitable for the new equipment. Therefore, the range of deployment is limited and the link utilization or performance can not be improved on the whole network. However, if uniformed accessibility to the operational information and interface are consolidated on every earth station, the cost for installing DBA system will be minimized.

In the network where the multiple satellite link utilized toward the single destination, load balancing in the data link layer beyond the difference of specification of equipments or the frequency bands is realized. If the load balancing in the upper layers is failed, the bandwidth of satellite data link is reconfigured and overflow of the link can be avoided.

4.2.4 Operation Cost Minimization

The autonomous satellite link operation allows human operators to be free from manual operation in the earth station unless mechanical failure occurs in the earth station. Manual operation by human is the bottle neck of the flexible satellite link operation which should be carried out in real time from the view point of potential of satellite date link itself.

The role of human operators will be decreased to check the visualized result of system administration or monitored data link status from remote. Human operators do not have to know all values of each parameter that is continuously acquired in the earth station. When any failure is detected by a system, human operators take some actions to fix it. This is the same with the general operation scheme of the Internet.

4.3 Functionalities of Autonomous Satellite Link Operation

The elements of this operation model are as follows.

- Dynamic configuration of satellite link
- Automatic monitoring of satellite link status
- Operational Information exchange among earth stations
- Reflection of information from external environments

Each earth station dynamically changes the parameter settings based on the operational information from other earth stations and external nodes on the Internet. Therefore, this operation model attaches importance to interaction among earth stations and nodes that have requirements or information to the link. Figure 4.4 shows the basic concept of cooperation between earth stations in this operation model.

Compared with the existing operation scheme mentioned formerly, the operation procedure is simplified and the operation cost is drastically reduced in our operation model. This is because the proposed model doesn't need human operators as the main component and a human friendly schedule can be eliminated from satellite link operation, because earth stations cooperate by themselves. Thus, interval of configuration modification can be shortened and the data link can be optimized according to the data link status in real time.

4.4 Communication Infrastructure

In the proposed model, connectivity among earth stations is necessary as well as that to the external nodes. We adopt the Internet as the communication infrastructure in the operational domain. Therefore, even if direct connection via a satellite link is down, an earth station can communicate with other earth stations. Even though an earth station only has receive-only connectivity to the satellite link, it can communicate with other earth stations by the UDLR technology. On the other hand, earth stations can easily communicate with external nodes, such as routers or any other nodes which may hold the information regarding bandwidth consumption, time schedule or any other requirements toward the satellite data link.

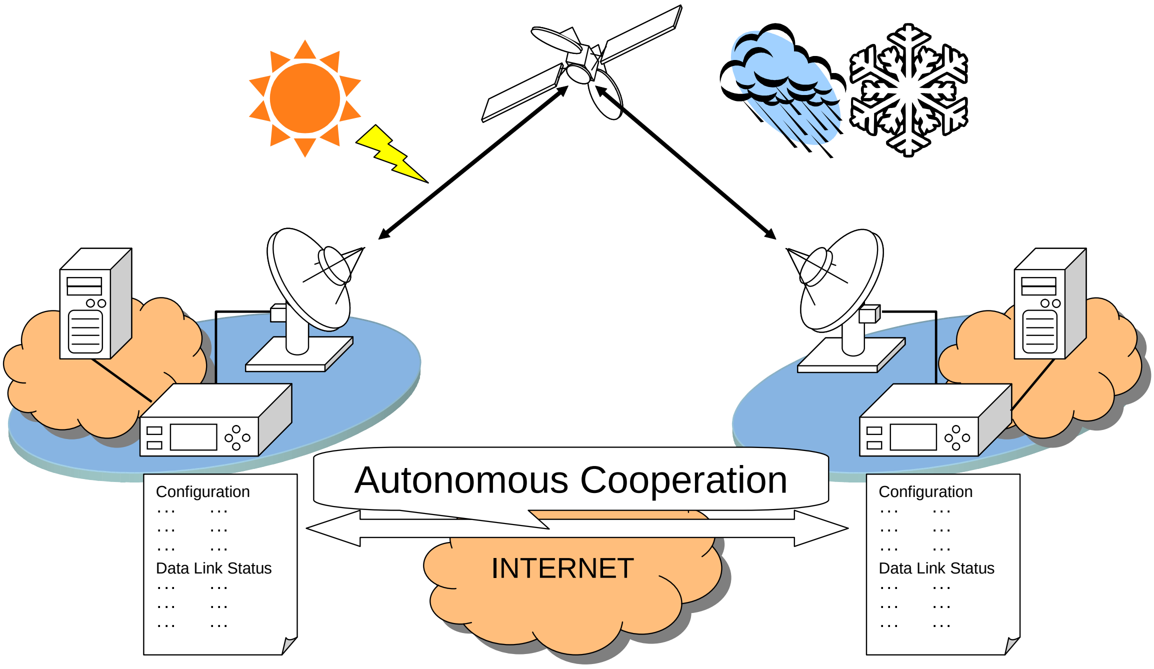

Figure 4.4: Cooperation between Earth Stations

4.5 Definition of Operational Domain

An operational domain is an administrative range of a satellite network that can be autonomously operated. The operational domain does not depend on a specific system or the types of the earth stations. The operational domain administrates the frequency bands allocated by the satellite communication carrier based on its own operational policy. In this domain, the operational information is shared among earth stations and external nodes. And then, each earth station configures the parameters to connect to the link. Also, external nodes can request an earth station to change the configuration of satellite links.

Figure 4.5 shows the basic concept of an operational domain. A circle and a box in the figure indicate an earth station and an external node respectively. Also, a cloud, a dashed oval and a dashed arrow indicate a network, a range of operational domain and information exchange. The case A, C, and D show that satellite links are established by several earth stations with communicating with external nodes. In the case A, an operational domain covers earth stations and external nodes across two networks. In the case C, an operational domain covers earth stations and an external node in a same network. In the case D, an operational domain covers 3 types of earth stations and an external node in a same network. Lastly, in the case B, an operational domain covers only earth stations in a same network, and the earth stations exchanges the operational information between them.

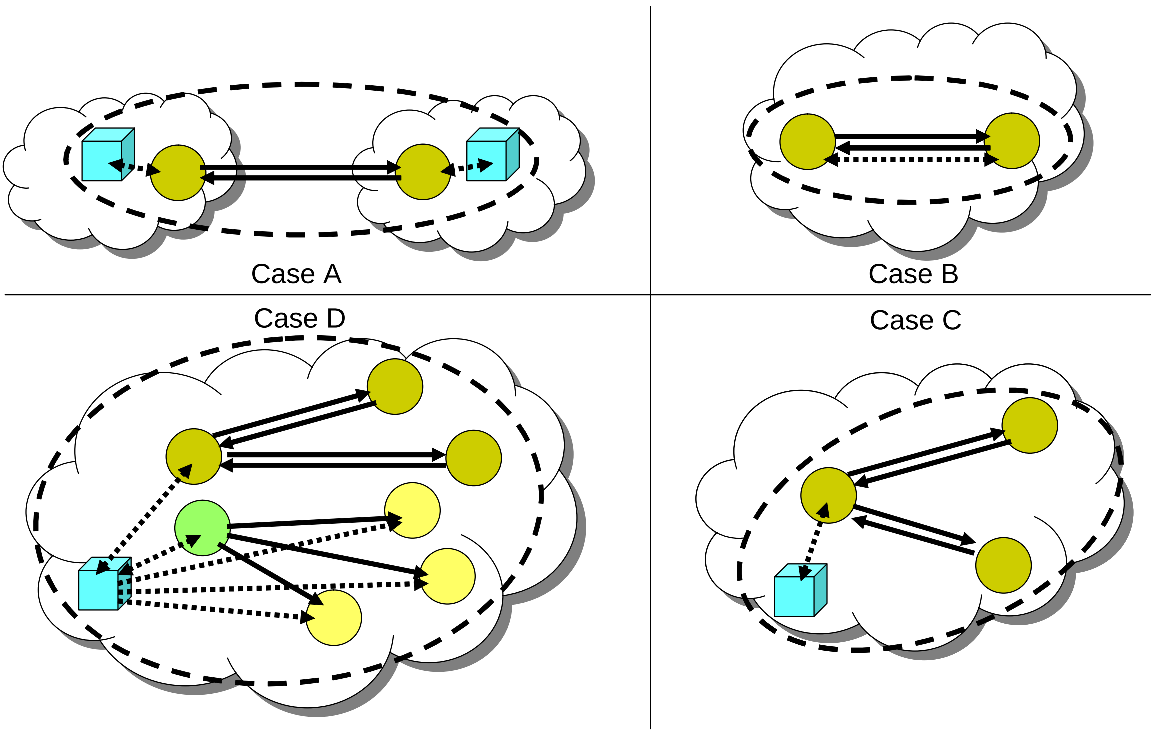

Figure 4.5: Basic Concept of Operational Domains

On the other hand, if an earth station is accessible without security consideration, satellite links can be configured illegally and impact other satellite links which share the same transponder. Therefore, this is desirable that the access to the operational domain is protected by some authentication methods and encryption. In this thesis, we focus on systemizing the information of satellite link operation based on the assumption that, because earth stations are treated as nodes on network, they are taken care of in the same way with other nodes according to the security policy of each network.

4.6 Definition of Operational Information

Operational information is held by earth stations in an operational domain. The operational information is exchanged by the earth stations in an operational domain and the information consists of three components. Figure 4.6 shows the main components of the operational information.

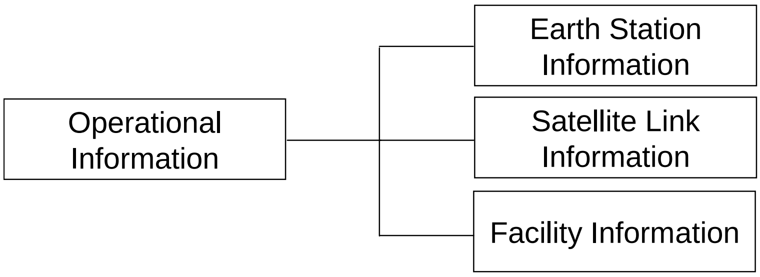

Figure 4.6: Structure of Operational Information

Earth Station Information: In an operational domain, an earth station is an administrative unit. Earth station information is the aggregation of parameters that identify each earth station by station ID or code name, location, responsible organization and so on.

Satellite Link Information: Generic link information is the aggregation of representative parameters that describe each satellite link operated in an earth station. The generic link information includes the name of target satellite and transponder, and carrier frequency, modulation information and so on.

Facility Information: Facility information is the aggregation of the parameters which each facility in the earth station has. The entries of facility information can differ according to composition of the earth station. If the earth stations is an VSAT, the entries should be the antenna, the IDU, the ODU and the Inter-Facility Lines (IFL) such as the coaxial cable. In the case of a HUB station, the many facilities are listed as entries in the facility information as described in the section 2.2.1.

In the generic information, the satellite link information and the facility information is cross-referred with each other so that the facility can be referred easily. If a trouble is occurring on a satellite link, all facilities which establish the link can be referred one after another. Assuming that every facility has its own status information, the reference to those facilities provides quick investigation of trouble source in the earth station.

4.7 Operational Information Focused on Satellite Modem

As mentioned in the section 2.1.2, an earth station is composed of several equipments. However, in satellite link operation, it is general that most of parameter settings for a satellite link are configured on a satellite modem.

In this thesis, we focus on a satellite modem and define the operational information to be shared among earth stations via the Internet. We define the operational information based on functionalities which are necessary to establish a satellite link. Figure 4.7 shows the structure of the operational information on a satellite modem.

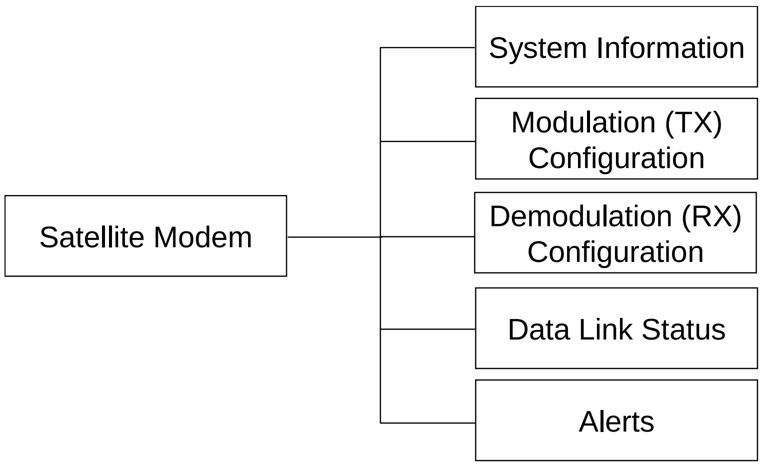

Figure 4.7: Structure of Operational Information on Satellite Modem

System Information: System information signifies the parameters which are related to identification of the satellite modem and the system specific information such as system time or network configuration to connect to the Internet.

Modulation Configuration: Modulation configuration is the aggregation of parameters which are related to transmitting a carrier to a satellite.

Demodulation Configuration: Demodulation configuration is the aggregation of parameters which are related to receiving a carrier from a satellite.

Satellite Link Status: Satellite link status is the aggregation of parameters which are related to the status of satellite data link. Because the satellite link status is not determined by a single parameter, several parameters are required to show the link status from different aspects.

Alerts: Alerts are the aggregation of parameters which are related to the alerts which a satellite modem issues to notify a mechanical fault or any other incident occurring on it.

4.8 External Information Available from the Internet

In this thesis, we avoid to define external information strictly. This is because the information from the external environment is boundless and the necessary information varies from objective that is intended to be achieved in each application or system. Thus, this operation model should provide an access interface that enables interaction with other applications or systems. This access interface increases the extensibility of this operation model.

The external information can contain any semantic data: operational command from human operator, real time status of weather condition or network, prediction of sun interference, and so on. This operation model provides any other nodes with the access interface to give feedback or reflect such information to the satellite link operation.

4.9 Summary

In a satellite network, frequency bandwidth is essential resources, and it may be shared by several satellite links. Thus, no matter what functionality is available on a satellite link, every link should be operated based on the cooperation with the other satellite links. However, in the existing operational scheme, the heterogeneity of operational environment depress the efficiency of satellite link operation. This is because heterogeneous operational methods and components coexist in a single satellite network.

This chapter proposed a new operation model for satellite networks: Autonomous Satellite Link Operation Environment. The objective of our model is to realize the flexible satellite link operation by cooperation among earth stations and external nodes on the Internet. Our model provides a unified platform for earth stations, human operators and any other nodes which want to access to the satellite link operation environment. As the main components of the new operation model, we described the functionality, communication infrastructure and the information to be exchanged among the earth stations. We focused on a satellite modem as the main facility of satellite link operation and classified the operational information by functionality of them.

Chapter 5

Requirements Organization

This chapter describes the requirements organization on the implementation of the autonomous satellite link operation environment. In the proposed model, the applicable range of an operational functionality is extended from a specific satellite link to a data link network.

Figure 5.1 shows basic concept of an applicable range that should be commonly kept in design of each application in the satellite network. Compared with the figure 3.1 in the section 3.1.2, a single application covers the whole satellite network beyond the heterogeneity of each satellite link.

Information exchange is the essential component on the autonomous satellite link operation. This is because integration of an operational functionality is achieved based on exchange of the operational information. Following sections describes the requirements in order to cover up the heterogeneity of the operational environment of satellite network.

5.1 Unified Operation Interface and Functionalities

Actual equipments in each earth station have physically different access lines or control interfaces respectively. On our operation model provides an operation interface by which any nodes or human operators can access earth stations in a same way. And then, on the Internet, those equipments are abstracted as nodes which are accessible from remote independently of difference of the physical specification of equipment. Basically, following two functionalities must be provided on the unified interface.

Get function: Get function retrieves and displays a requested parameter on equipment in an earth station.

Set function: Set function sets a parameter on equipment in an earth station. Set function should respond with some return values no matter whether the function is succeed in executing the function or not.

Considering the cost on adopting this unified interface on existing equipment and earth stations, it is desirable that there is no modification on them. Also, not all earth stations are capable of IP-based communication. It is practical to put agents that are capable of both connecting to the Internet and communicating with earth stations on their own access lines.

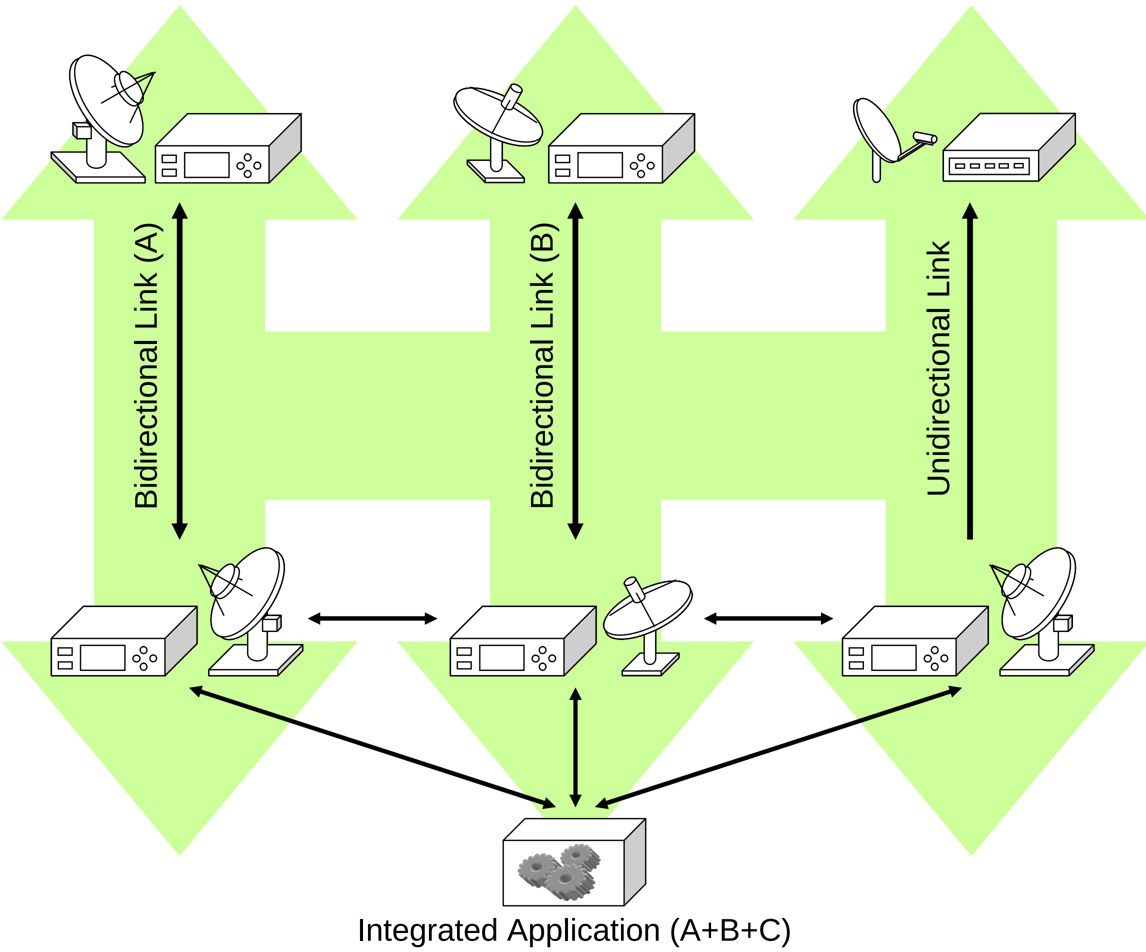

Figure 5.1: System Integration in Operation Domain

5.2 Redundant Connectivity to the Internet

If an earth station connects to the Internet only by a satellite link, the earth station may be isolated from its operational domain when the IP connectivity via the satellite link is lost. And then, the earth station can not communicate with other earth stations, and the satellite network may lose the total balance as an operational domain. Therefore, redundant connectivity to the Internet should be guaranteed in each earth station by some ways. It is desirable that another satellite link is excluded as the external link for the Internet. This is because both of those satellite links may go down at the same time because of weather conditions and so on.

5.3 Normalized Operational Information

The operational information should be defined clearly enough so that any satellite modem can recognize each parameter. Thus, every parameter should be defined with its suitable measure and granularity respectively. However, some parameters employ different manners of defining those parameters. For example, in general, the frequency is described in Hz, KHz or MHz. However, some satellite modems specify the frequency as channel with interval scales in several KHz. And then, KHz is chosen as the unified measure of frequency.

5.4 Degree of Freedom on Notification Convention

5.4.1 Strict Values

On the other hand, some parameters such as Forward Error Correction rate or Reed Solomon coding rate which are ratio of the redundant data in the total amount of data. In order to describe rates of those parameters, several types of values are used on satellite modems. FEC rate (ex. 3/4) can be described as follows. Both notifications have their advantage and disadvantage.

- String in a single value: FEC Rate (Data Bits/Total Bits) = 3/4
- Integer in plural values: Data Bits = 3, Total Bits = 4

The notification by string is human operators friendly. However, when the string value is specified wrongly, for example, "3/4" may be written as "3:4" or "4/3", which can't be recognized by a satellite modem. Thus, string notification costs in verification of the specified value and process after inconsistency is detected. On the other hand, the notification by two integers is not so human friendly. But, the meaning of each value is clear and the inconsistency of notification will be less than the case of the notification by string.

Assuming that any application can access to the values and human operators don't have to directly configure those values, the two integers are used for the notification of FEC and Reed Solomon coding rate.

5.4.2 Free Description

It is impossible to strictly classify the status of trouble which is occurring inside a satellite modem, because the granularity of error state can differ among satellite modems. It has a negative aspect of decreasing the degree of accuracy of information to unify the error state strictly. Thus, regarding the error status, the degree of freedom on notification convention should be high.

5.5 Coverage of Operational Information

The parameters which are available on an earth station are different depending of the specification of each earth station. It is probable that not all parameters are available directly on it. However, because some of those parameters are critical for the satellite link operation, we should acquire such parameters by means of calculation from other related parameters or other ways.

Table 5.1 shows the parameters which should be available on each earth station. We classified them by functionality of earth stations. If an earth station is a transmit-receive station, all of listed parameters are required. The parameters of the field (A) and (B) should be available on a transmit-only station, and those of the field (A) and (C) should be available on a receive-only station.

Table 5.1: Required Parameters on Satellite Link Operation

Identification of Satellite Link (A)	Earth Station ID
	Satellite Link ID
	Target Satellite
	Target Transponder
Transmitting Carrier (B)	Modulation Radio Frequency
	Modulation Intermediate Frequency
	Modulation Type
	Modulation Information Speed
	Modulation Coding Type
	Modulation Coding Rate
	Modulation Reed-Solomon Coding Rate
	Carrier Transmission Power
	Carrier Transmission Status
Receiving Carrier (C)	Demodulation Radio Frequency
	Demodulation Type
	Demodulation Information Speed
	Demodulation Decoding Type
	Demodulation Decoding Rate
	Demodulation Reed-Solomon Decoding Rate
	Carrier Detection
	C/N
	Eb/N0

5.6 Accessibility to Operational Information

Assuming the interaction between earth stations and external nodes or application on the Internet, the operational information should be easily accessed on the earth stations by the external environment. Therefore, this operation model should be implemented on the protocol which both earth stations and external nodes can cover.

Chapter 6

Implementation of Autonomous Satellite Link Operation Environment

There are some network management protocols and description languages that are generally used on the Internet, such as CMOT[15], SNMP (Simple Network Management Protocol)[3], and so on. The shape of implementation varies according to the objectives or the situation of normalization of information. In general, compared with CMOT, SNMP is light-weight[11] as an application to carry the network management information. Considering propagation and install cost of our model on satellite-based networks, we choose the combination of SNMP and MIB as the implementation platform of the autonomous satellite link operation.

6.1 Information Exchange on SNMP and MIB

We implemented the information exchange mechanism on SNMP and MIB. SNMP is a protocol that is widely employed for the network management on the UDP/IP suite. Earth stations in a operational domain exchange their operational information using SNMP. On SNMP, every earth station is treated as an SNMP agent that holds a MIB (Managed Information Base). MIB is an aggregation of operational parameters of satellite network, that is described by ASN.1. An external node works as an SNMP manager that exchanges the operational information with earth stations to provide the functionality of the autonomous satellite link operation. Figure 6.1 shows the interaction among nodes using SNMP and MIB via the Internet.

If an earth station can not deal with SNMP and MIB, a proxy agent exchange the operational information with other nodes by communicating with an earth station on the local protocol.

This thesis defines SAT-MIB that describes the parameters regarding satellite link operation. On SAT-MIB, we defined the parameters for earth station information, satellite link information, and satellite modem as the main facility in an earth station.

The SAT-MIB functions as an interface to set or acquire the operational parameters on an earth station. Therefore, SAT-MIB does not archive values, and the MIB holds the single field for each parameter so that earth station returns only latest values.

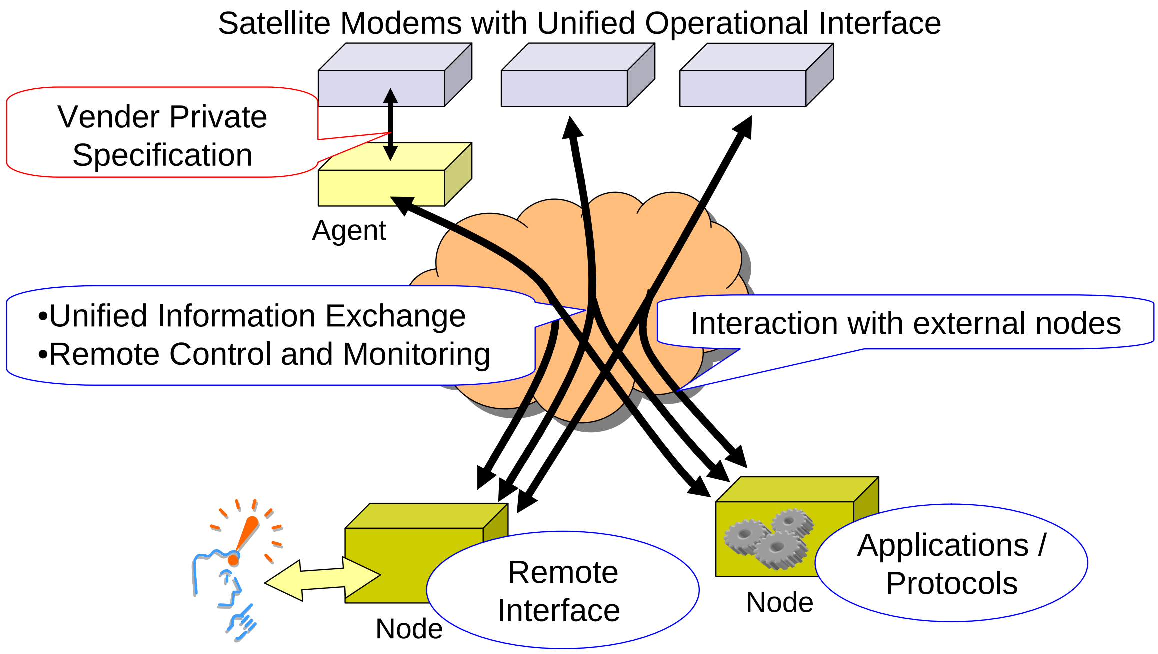

Figure 6.1: Interaction among Earth Stations and External Nodes using SNMP

However, some variable parameters may not make sense as instantaneous values. Because they need to be archived for a certain period of time to be summarized as the continuous status. Otherwise, the transition of status information can not be achieved and some functionalities of the proposed model may not work correctly. We assume that an external storage retrieves status information from an earth station by SAT-MIB, and then, applications access to the storage to utilize the status information.

6.2 Definition of Parameters

In order to describe parameters appropriately, we defined a data type "FloatGauge" and "Alternatives" in SAT-MIB using TEXTUAL-CONVENTION[10]. The FloatGauge type is defined to use floating point values in SAT-MIB, such as C/N, Eb/N0, Transmission Power and so on. The Alternatives type is defined to use alternatives, such as FEC types, coding types, interface types of equipments and so on. Figure 6.2 shows the definition of the two data types. TEXTUAL-CONVENTION is one of the ASN.1 macros to concisely convey the syntax and semantics of a textual convention.

```
FloatGauge ::= TEXTUAL-CONVENTION
    STATUS      current
    DESCRIPTION
            "A syntax for displaying gauge in the floating point value"
    SYNTAX     DisplayString

Alternatives ::= TEXTUAL-CONVENTION
    STATUS      current
    DESCRIPTION
            "A syntax for displaying alternatives to choice"
    SYNTAX      Integer32
```

Figure 6.2: Definition of Data Types

By fixing the appropriate units, operational parameters can be considered precisely by external nodes, human operators, and the earth stations themselves. Table 6.1 shows the units and the syntaxes of the common parameters defined in SAT-MIB.

6.3 Installation on Practical Satellite Network

6.3.1 Agent Implementation

In order to install the autonomous satellite link operation environment on a real satellite network, we implemented SNMP agents for the satellite modems operated in the AI^3 project. We implemented the part of managing the operational parameters for satellite link status on the satellite modems that are operated in the AI^3 network: SDM-300A modems and SNR-PS1000 receivers. Following table 6.2 shows the availability of data link status on the both types of satellite modems. A circle, a triangle and a cross in the table indicate that a

Table 6.1: Units and Syntaxes for Common Parameters

Parameter	Unit	Granularity	Syntax
Frequency	KHz	1 KHz step	Integer32
Information Speed	bps	1 bps step	Integer32
Coding Type	—	—	Alternatives
Symbol Rate	sps	1 sps step	Integer32
FEC Data Bit	bit	1 bit step	Integer32
FEC Block Bit	bit	1 bit step	Integer32
FEC Type	—	—	Alternatives
Transmission Power	dBm	0.1 dBm step	FloatGauge
Noise Ratio	dB	0.1 dB step	FloatGauge
Impedance	ohm	1 ohm step	Integer32

parameter is available by specification, available by calculation from other parameters, and not available respectively.

Table 6.2: Availability of Data Link Status Parameters

	SDM-300A	SNR-PS1000
RSL	◯	×
C/N	△	◯
Eb/N0	◯	△
BER	◯	×
AGC	×	◯
Carrier Detection	◯	◯

We converted C/N and Eb/N0 on the both types of modems according to the following expression. Bw indicates the receiver noise bandwidth, and fb is the information speed.

$$\frac{C}{N} = \frac{Eb}{No} * \frac{fb}{Bw}$$

Then Bw is calculated by the following expression. The ϕ indicates the number of phases of PSK modulation.

$$Bw = symbolrate * 1.0$$

$$synbolrate = \frac{fb}{FECRate * log2(\phi)}$$

Figure 6.3 shows for the parameter conversion from Eb/N0 to C/N on the SNMP agent.

6.3.2 Modification of Modem Watch Dog

In this research, we modified MWD to adapt it to the proposed operation model. In the autonomous satellite link operation environment, MWD is considered as one of the core

```
float
ebno2cn(float ebno, float fec_rate, int phi)
{
    float bw;
    float cn;

    bw = fec_rate * log2f(phi);
    cn = ebno + nlog10f(10, bw);

    return(cn);
}
```

Figure 6.3: Conversion from Eb/N0 to C/N

application to provide the functionality of automatic monitoring of satellite data link status. Every application that requires the data link status can retrieve the status information by MWD.

MWD stores every value of administrative satellite link status in a database on the network. The stored data can be retrieved by any nodes that requires the monitoring result of satellite links on the operational domain. Figure 6.4 shows the concept of this system which is implemented using on the unified interface.

6.4 Summary

This chapter described the implementation of the autonomous satellite link operation environment in a practical satellite network. The implementation mentioned here is to build the operational infrastructure to realize the functionalities of the autonomous satellite link operation. Those functionalities are implemented based on exchanging operational information among earth stations. We adopted SNMP as the protocol for exchanging the operational information in the operational domain. And then, we defined the operational information in SAT-MIB.

We adapted the parameters regarding satellite link status of SAT-MIB to the two types satellite modems that are operated in the AI^3 project. And then, we modified the MWD to retrieve the data link status from both types of satellite modem with the same operational interface. Regarding the automatic monitoring of satellite link status in the AI^3 network, it was achieved beyond the heterogeneity operational environment of those satellite modems.

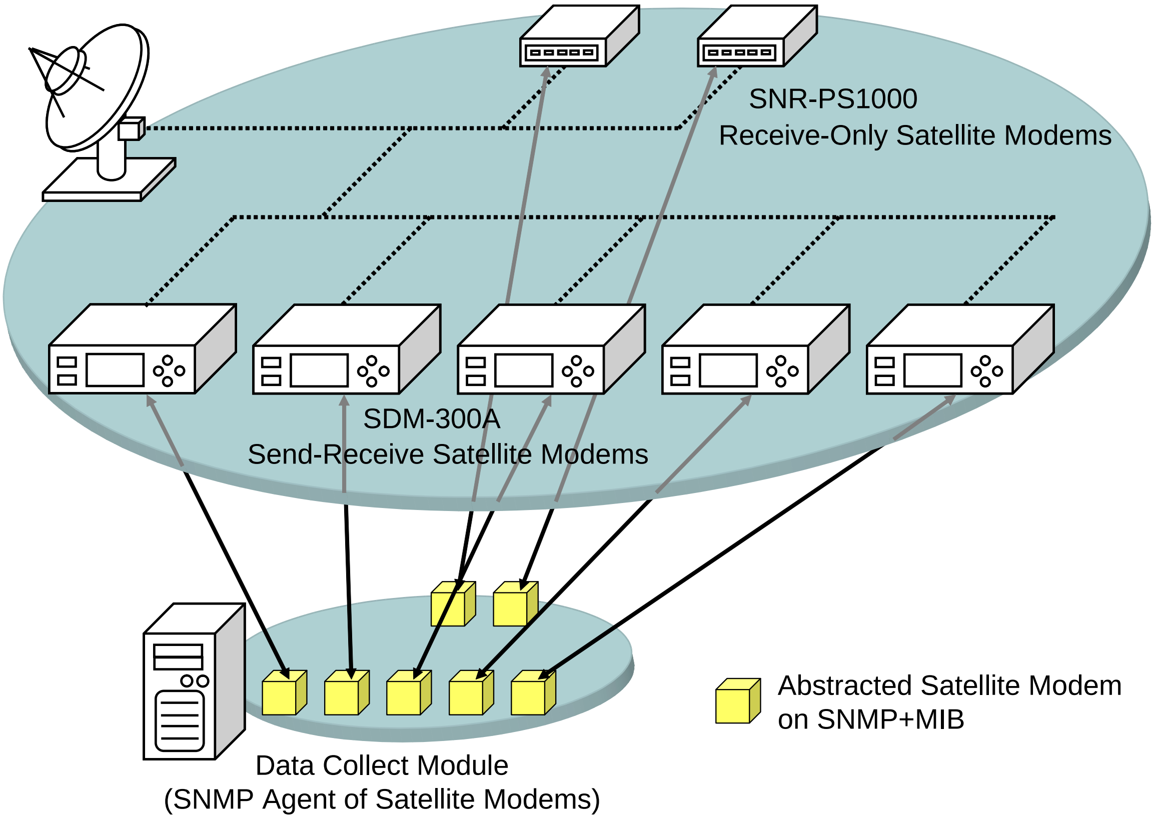

Figure 6.4: Satellite Modems and Abstracted Nodes on SNMP and MIB

Chapter 7

Evaluation

This chapter evaluates the autonomous satellite link operation environment based on the mode design and the comparison with the current AI^3 operation model.

7.1 Operational Components

Table 7.1 compares the operational components between our model and the existing operational scheme.

Table 7.1: Comparison of Operational Components

	Existing Scheme	Our Model
Operation Feature	Manual	Automatic
Operation Body	Human Operator	Earth Station
Information Exchange	E-mail, Telephone or Facsimile	Applications on the Internet
Operation Timing	Schedule Base	Real Time
Operation Cost	High	Low
Operational Interface	Many	Single
Extensibility of Operational Domain	Low	High
Application	System Specific	System Independent

7.2 Dissolution of Heterogeneity on Operational Environment

In general, an earth station is designed and composed to be suitable of the characteristics of each satellite link. Operational scheme, facility composition, available operational information and feedbacks, and many other aspects are different among earth stations and satellite links. Therefore, it is very difficult to completely get rid of the heterogeneity from operational environment of satellite networks. It is not realistic to integrate the physical or operational specification on every earth stations and all facilities among related venders.

Our model was designed to remove the heterogeneity of operational environment of satellite network. We organized the required components of the model to remove the heterogeneity: a unified operational interface, redundant connectivity to the Internet, and normalized operational information. We implemented a unified operational interface using SNMP which is a popular protocol for network management on the Internet. On the other hand, the operational information is defined in SAT- MIB. We considered the degree of freedom on the notification convention to keep accuracy and semantic volume of defined parameters in SAT-MIB. Because our model normalizes the essential parameters among different types of satellite links and different forms of earth stations, the heterogeneity of satellite link operation environment can be covered up.

7.3 Sustainability of Satellite Links

In the existing operation scheme, configuration of satellite links is apt to be fixed for a long period of time. Even if dynamic configuration systems are available for some satellite links, those systems are designed for the specific data links, and they can not cover other types of satellite links. Therefore, once satellite link go down because of change of environmental conditions, the links are not recovered until those conditions are dissolved.

On the other hand, our model is designed to provide the functionality of automatic monitoring and dynamic configuration of satellite links based on the assumption that the links can be recovered if their configuration is tuned according to their status. This functionality can be achieved by the information exchange and the unified operational interface which allows any node to set or retrieve the configuration and the status of satellite links on earth stations. As a result, our model provides the technical platform to keep all satellite links sustained upon best efforts.

7.4 Operation Cost of Satellite Network

It is requirement to monitor the status of satellite links all the time and to modify the parameter settings of the links on demand on the satellite network operation. In the existing operation scheme, a satellite network is not operated efficiently because of heterogeneity of operational environment or dependency on manual operation. Our model does not rely on human operators to operate satellite links, and earth stations are abstracted as nodes which are accessible on the Internet. Those nodes provide the normalized operational information via the unified interface regardless of the forms earth station and the type or directions satellite links.

On the other hand, a single application can be adapted to the all earth stations on the unified platform. Thus functionalities of satellite link operation can be available as a whole network, and the operational cost of those links is reduced compared with manual operations. Even if the operational domain gets larger, increment of operational cost will be suppressed. Following table 7.2 estimates the cost of operating the satellite links on the AI^3 network between the existing operation scheme and our operation environment. Currently, the AI^3 project administrates 2 Ku-band point-to-point links, 5 C-band point-to-point links, and 1 C-band Unidirectional link with more than 10 receive-only stations.

From the view point of operating the whole AI^3 network, our model can provide the same functionalities throughout the network. And then, our model reduces the total operational cost of the AI^3 network. Based on our design that gets rid of heterogeneity of satellite link operation environment, our model is expected to contribute to achieve the same performance and reduce its operational cost on other satellite networks.

7.5 Summary

The operational environment of satellite network is heterogeneous. The existing operation scheme relies on manual operation and independent systems which can not cooperate with other systems. Therefore, satellite link operation is apt to be specialized as an independent operation system and isolated from generic network operation. Our model solves those issues, and provides the new operational environment for heterogeneous satellite networks.

Table 7.2: Comparison of Operational Items on the AI^3 Network

	Existing Scheme			Our Model		
Operation Type	Direct Operation on Earth Station			Remote Operation via the Internet		
Link Description	Ku-band PtoP	C-band PtoP	C-band UDL	Ku-band PtoP	C-band PtoP	C-band UDL
Configuration Notification	× (Manual)	× (Manual)	× (Manual)	◯ (Automated by DBA)		
Satellite Link Configuration	× (Manual)	× (Manual)	× (Manual)	◯ (Automated by DBA)		
Uplink Access Test	× (Manual)	△ (Skipped by DBA)	× (Manual)	◯ (Automated by Integrated DBA)		
Data Link Monitoring	△ (MWD)	△ (MWD)	△ (MWD)	◯ (Automated by Integrated MWD)		
Satellite Link Reconfiguration	× (Manual)	△ (DBA)	× (Manual)	◯ (Automated by Integrated MWD and DBA)		

Chapter 8

Conclusion

8.1 Summary

Satellite links should be operated with maximizing the flexibility of configuration and satisfying the requirements raised from environmental conditions. However, we explained that the flexible operation is not realized on some existing operation schemes of satellite networks. We explained the existing scheme based on functionalities and forms of earth stations, and data link topologies to establish a network, and major components of satellite link operation. We described the operational issues which are raised from the heterogeneity of operational environment and the dependency on the manual operation by human operators.

In order to solve these issues, this thesis proposed a new operation model for satellite link operation that is called "autonomous satellite link operation environment". The objective of our model is to achieve operational features that realize the stability and maximum utilization of satellite data links as a whole network. We described the essential functionalities which can be achieved by the exchange of operational information among earth stations and external nodes on the satellite network.

- Sustained connectivity of satellite links
- Routing Optimization
- Integrated Dynamic Bandwidth Allocation
- Operation Cost Minimization

To realize the information exchange, we abstracted heterogeneous earth stations as homogeneous nodes that are accessible with the same manner throughout the operational domain. Our design was to make those abstracted nodes that have unified operational interface and normalized aggregation of the parameters regarding satellite link operation to remove the heterogeneity of operational environment.

In this thesis, we focused on satellite modems as the core equipment of earth stations. At the same time, we organized the operational information of an earth station and that of satellite modems. Our model was implemented using SNMP as the protocol for information exchange and defining the operational information on SAT-MIB.

This thesis evaluated our operation environment based on the comparison with the existing operation scheme and the achievement of our model on satellite network operation. This model provided the operational infrastructure for removing the heterogeneity of operation environment and acquiring the independency from manual operation by human operators. Our design increased the sustainability of Internet connectivity via satellite links upon best effort and minimized the cost of ordinal operation, installation of operational application, and extension of an operational domain.

As a result, our model provided the unified operational platform of satellite networks, and it was shown that our model contributes to realize the flexible satellite link operation environment on the Internet. Also, based on the autonomous satellite link operation environment, the infrastructure technology for operating heterogeneous satellite links as one of generalized data link on the Internet.

However, we should recognize that there is rising concern that the performance of administrative nodes might be depressed because SNMP can heighten the load of those nodes. SNMP is actually simple and light-weight as the protocol compared with CMOT. But when we build applications on our model, we should consider about the load of those nodes not to suppress their primary functionalities.

8.2 Future Works

8.2.1 Enhancement of SAT-MIB

This thesis focused on the aggregation of operational information on satellite modems. However, an earth stations is composed of several facilities that have their own functionality. Thus, our implementation still leaves room for organizing operational information of their facilities.

8.2.2 Extension of Applicable Range of Our Model

Currently, we are implementing our environment on the AI^3 network. At the same time, we should develop the prototype applications that realizes the feature of the proposed model. And then, we examine those applications in the actual satellite network and accumulate the operational experience. Such activity will creates practical feedback to improve our operational environment, and it will be the case study for installing our environment onto another satellite network.

8.2.3 Security Issues

Because we focused on organizing the operational information and realizing the information exchange on the operational domain, the security issues are not prioritized in this thesis. However, satellite links have to be operated very carefully in order to avoid a trouble such as incorrect transmission of radio wave by illegal access to the operational domain.

SNMPv3[6] describes the extension of the security subsystem of SNMP. However, it might be problematic to completely rely on that security subsystem. Therefore, we should take additional measure to enhance the security of the operational environment.

8.2.4 Standardization of Proposed Model

Considering propagation of the proposed model, discussion in the standardization organization is inevitable in order to extend our model on other satellite networks. We plan to make an internet-draft about our operation environment and have discussion in the IETF (Internet Engineering Task Force)[1] to standardize our model.

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January 14, 2004
Kotaro Kataoka

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Appendix A

SAT-MIB

```
SAT-MIB DEFINITIONS ::= BEGIN

--
-- Import helpful information
--
IMPORTS
    MODULE-IDENTITY                         FROM SNMPv2-SMI
    netSnmp                                 FROM NET-SNMP-MIB
    TEXTUAL-CONVENTION, PhysAddress         FROM SNMPv2-TC
    IANAifType                              FROM IANAifType-MIB

--
-- A brief description and update information about this SAT-MIB.
--
satMIB MODULE-IDENTITY
    LAST-UPDATED "200305080000Z"            -- 08 May 2003, midnight
    ORGANIZATION "Keio University"
    CONTACT-INFO "postal:   Keio University
                            5322 Endo Fujisawa
                            Kanagawa 252-8520, JAPAN
                   email:   kotaro@sfc.wide.ad.jp"
    DESCRIPTION  "A simple mib for the status of satellite links"
    ::= { WHERE?? }

--
-- Textual Convention
--
SatLinkIndex ::= TEXTUAL-CONVENTION
    DISPLAY-HINT "d"
    STATUS       current
    DESCRIPTION
            "A unique value, greater than zero, for each satellite link
            which is operated in the earth station"
    SYNTAX       Integer32 (1..2147483647)

SatModemIndex ::= TEXTUAL-CONVENTION
    DISPLAY-HINT "d"
    STATUS      current
    DESCRIPTION
            "A unique value, greater than zero, for each satellite modem
            in the managed system."
    SYNTAX       Integer32 (1..2147483647)

FloatGauge ::= TEXTUAL-CONVENTION
```

```
    STATUS      current
    DESCRIPTION
            "A syntax for displaying gauge by float"
    SYNTAX      DisplayString

Alternatives ::= TEXTUAL-CONVENTION
    STATUS      current
    DESCRIPTION
            "A syntax for displaying alternatives to choice"
    SYNTAX      Integer32

--
--  Definition of Objects in SAT-MIB
--

satEarthStationObjects  OBJECT-IDENTIFIER       { satMIB 1 }
satLinkObjects          OBJECT-IDENTIFIER       { satMIB 2 }
satModemObjects         OBJECT-IDENTIFIER       { satMIB 3 }

--
-- Definition of the estEarthStation subgroup
--
estIpAddress OBJECT-TYPE
    SYNTAX      IpAddress
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "IP Address for the earth station for identification on the Internet."
    ::= {satEarthStationObjects 1 }

estDefaultRoute OBJECT-TYPE
    SYNTAX      IpAddress
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "IP address for the default route of the earth station."
    ::= { satEarthStationObjects 2 }

estNameServer OBJECT-TYPE
    SYNTAX      IpAddress
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "IP address of name server."
    ::= { satEarthStationObjects 3 }

estPublicEarthStationId OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
            "Public ID for the earth station.  It can be an IP address
            or any other types of ID.  esPublicEarthStationId should
            be unique in the world.  If the ID is not defined or
            specified, leave this blank."
    ::= { satEarthStationObjects 4 }

estPrivateEarthStationId OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
```

```
    DESCRIPTION
            "Private ID for the earth station.  It can be an IP address
            or any other types of ID.  esPrivateEarthStationId should
            be unique in the operational domain such as the communication
            carrier you use.  For example, AI3C-F01 is the private ID
            inside JSAT.  If the ID is not defined or specified, leave
            this blank."
    ::= { satEarthStationObjects 5 }

estOrganization OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
         "Name of organization which operates the earth station"
    ::= { satEarthStationObjects 6 }

estLocation OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
         "Location the earth station"
    ::= { satEarthStationObjects 7 }

estDescription OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
         "Description of the earth station"
    ::= { satEarthStationObjects 8 }

--
-- Definition of the estEarthStation subgroup
--

satLinkNumber OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
            "The number of satellite links present operated in the
            earth station."
    ::= { satLinkObjects 1 }

satLinkTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF SatLinkEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
            "A list of satellite link information entries."
    ::= { satLinkObjects 2 }

satLinkEntry OBJECT-TYPE
    SYNTAX      SatLinkEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "description for satModemEntry"
    ::= { satLinkTable 1 }
```

```
satLinkEntry ::= SEQUENCE {
    linkIndex                                  Integer32,
    linkDescription                            DisplayString,
    linkTxSatelliteId                          DisplayString,
    linkTxXpdId                                DisplayString,
    linkTxXpdCenterFrequency                   Integer32,
    linkTxRfFrequecy                           Integer32,
    linkTxInformationSpeed                     Integer32,
    linkRxSatelliteId                          DisplayString,
    linkRxXpdId                                DisplayString,
    linkRxXpdCenterFrequency                   Integer32,
    linkRxRfFrequecy                           Integer32,
    linkRxInformationSpeed                     Integer32
}

linkIndex OBJECT-TYPE
    SYNTAX      SatLinkIndex
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
            "A unique value, greater than zero, for each satellite modem.
            It is recommended that values are assigned contiguously
            starting from 1 "
    ::= { satLinkEntry 1 }

linkDescription OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
            ""
    ::= { satLinkEntry 2 }

linkTxSatelliteId OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
            ""
    ::= { satLinkEntry 3 }

linkTxXpdId OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
            ""
    ::= { satLinkEntry 4 }

linkTxXpdCenterFrequency OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
            ""
    ::= { satLinkEntry 5 }

linkTxRfFrequecy OBJECT-TYPE
    SYNTAX      Interger32
    MAX-ACCESS  read-write
```

```
    STATUS      current
    DESCRIPTION
            ""
    ::= { satLinkEntry 6 }

linkTxInformationSpeed OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
            ""
    ::= { satLinkEntry 7 }


linkRxSatelliteId OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
            ""
    ::= { satLinkEntry 8 }

linkRxXpdId OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
            ""
    ::= { satLinkEntry 9 }

linkRxXpdCenterFrequency OBJECT-TYPE
    SYNTAX      Interger32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
            ""
    ::= { satLinkEntry 10 }

linkRxRfFrequecy OBJECT-TYPE
    SYNTAX      Interger32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
            ""
    ::= { satLinkEntry 11 }

linkRxInformationSpeed OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
            ""
    ::= { satLinkEntry 12 }

--
-- Definition of satModemObjects
--
satModemNumber OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
```

```
            "The number of satellite modems present in the earth station."
    ::= { satModemObjects 1 }

satModemTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF SatModemEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
            "A list of system information entries of satellite modem."
    ::= { satModemObjects 2 }

satModemEntry OBJECT-TYPE
    SYNTAX      SatModemEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "description for satModemEntry"
    ::= { satModemTable 1 }

satModemEntry ::= SEQUENCE {
    modIndex                                SatModemIndex,
    modVender                               DisplayString,
    modVenderSerial                         DisplayString,
    modDescription                          DisplayString,
    modHostName                             DisplayString,
    modMacAddress                           PhysAddress,
    modIpAddress                            IpAddress,
    modNetmask                              IpAddress,
    modDefaultRoute                         IpAddress,
    modNameServer                           IpAddress,
    modLocalFrequency                       Integer32,
    modTxIfType                             Integer32,
    modTxCoaxImpedance                      Integer32,
    modRxIfType                             Integer32,
    modRxCoaxImpedance                      Integer32,
    modAuxiliaryIfType                      IANAifType,
    modTerrestrialIfType                    IANAifType,
    modRemoteAccessIfType                   IANAifType
}

modIndex OBJECT-TYPE
    SYNTAX      SatModemIndex
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
            "A unique value, greater than zero, for each satellite modem.
            It is recommended that values are assigned contiguously
            starting from 1 "
    ::= { satModemEntry 1 }

modVender OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Vender Name."
    ::= { satModemEntry 2 }

modVenderSerial OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
```

```
    STATUS      current
    DESCRIPTION
        "Serial number of the satellite modem in vender private code."
    ::= { satModemEntry 3 }

modDescription OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Description of the satellite modem."
    ::= { satModemEntry 4 }

modHostName OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Host name of the satellite modem."
    ::= { satModemEntry 5 }

modMacAddress OBJECT-TYPE
    SYNTAX      PhysAddress
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "MAC address of the network interface of the satellite modem."
    ::= { satModemEntry 6 }

modIpAddress OBJECT-TYPE
    SYNTAX      IpAddress
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "IP address of the network interface of the satellite modem."
    ::= { satModemEntry 7 }

modNetmask OBJECT-TYPE
    SYNTAX      IpAddress
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Netmask of the subnet where the satellite modem connects."
    ::= { satModemEntry 8 }

modDefaultRoute OBJECT-TYPE
    SYNTAX      IpAddress
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "IP addresse of default route of the satellite modem."
    ::= { satModemEntry 9 }

modNameServer OBJECT-TYPE
    SYNTAX      IpAddress
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "IP address of name server."
    ::= { satModemEntry 10 }
```

```
modLocalFrequency OBJECT-TYPE
    SYNTAX      Interger32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Local Frequency of the satellite modem in units of KHz.  If the
        satellite modem is the IDU of VSAT system or Receiver, this value
        should be set to adjust to the target frequency band."
    ::= { satModemEntry 11 }

modTxIfType OBJECT-TYPE
    SYNTAX      Integer32 (0..255) {
                    BNC_Female(0),
                    BNC_Male(1),
                    F_Feimale(2),
                    F_Male(3),
                    N_Feimale(4),
                    N_Male(5),
                    Extension_Feimale(254),
                    Extension_Male(255)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Type of connecter for transmitting coaxial interface"
    ::= { satModemEntry 12 }

modTxCoaxImpedance OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Impedance of transmitting coaxial cable in units of ohm."
    ::= { satModemEntry 13 }

modRxIfType OBJECT-TYPE
    SYNTAX      Integer32 (0..255) {
                    BNC_Female(0),
                    BNC_Male(1),
                    F_Feimale(2),
                    F_Male(3),
                    N_Feimale(4),
                    N_Male(5),
                    Extension_Feimale(254),
                    Extension_Male(255)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Type of connecter for receiving coaxial interface"
    ::= { satModemEntry 14 }

modRxCoaxImpedance OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Impedance of receiving coaxial cable in units of ohm."
    ::= { satModemEntry 15 }

modAuxiliaryIfType OBJECT-TYPE
```

```
    SYNTAX      IANAifType
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Type of auxiliary interface type of the satellite modem"
    ::= { satModemEntry 16 }

modTerrestrialIfType OBJECT-TYPE
    SYNTAX      IANAifType
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Type of terrestrial interface type of the satellite modem"
    ::= { satModemEntry 17 }

modRemoteAccessIfType OBJECT-TYPE
    SYNTAX      IANAifType
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Type of remote access, i.e. monitor & control,  interface type
        of the satellite modem"
    ::= { satModemEntry 18 }

--
-- Definition of the txConfigTable subgroup
--
txConfigTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF TxConfigEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
            "A list of sending configuratoin entries."
    ::= { satModemObjects 3 }

txConfigEntry OBJECT-TYPE
    SYNTAX      TxConfigEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "description for satModemEntry"
    ::= { txConfigTable 1 }

txConfigEntry ::= SEQUENCE {
    txRfFrequency                          Integer32,
    txIfFrequency                          Integer32,
    txModulationType                       Integer32,
    txInfomationSpeed                      Integer32,
    txSymbolRate                           Integer32,
    txConvolutionalEncoderDataBit          Integer32,
    txConvolutionalEncoderBlockBit         Integer32,
    txConvolutionalEncoderType             Integer32,
    txCarrierType                          Integer32,
    txTransmitPower                        FloatGauge,
    txTransmitPowerOffset                  FloatGauge,
    txCarrierTransmission                  Integer32,
    txScramblerType                        Integer32,
    txScramblerMode                        Integer32,
    txDifferentialEncoderMode              Integer32,
    txReedSolomonEncoderTotalSymbols       Integer32,
    txReedSolomonEncoderDataSymbols        Integer32,
```

```
    txReedSolomonEncoderInterleave          Integer32,
    txReedSolomonEncoderMode                Integer32,
    txSpectrumRotation                      Integer32,
    txDvbFrameLen                           Integer32
}

txRfFrequency OBJECT-TYPE
    SYNTAX      Interger32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "RF frequency of the transmitting carrier in units of KHz."
    ::= { txConfigEntry 1 }

txIfFrequency OBJECT-TYPE
    SYNTAX      Interger32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "IF frequency of the transmitting carrier in units of KHz."
    ::= { txConfigEntry 2 }

txModulationType OBJECT-TYPE
    SYNTAX      Integer32 (0..255) {
                    BPSK(1),
                    QPSK(2),
                    OQPSK(3),
                    /4QPSK(4),
                    8PSK(5),
                    16QAM(6),
                    64QAM(7),
                    256QAM(8),
                    Extension(255)
                    }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Modulation type of transmitting carrier selected from choices above."
    ::= { txConfigEntry 3 }

txInfomationSpeed OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Information speed of modulated carrier in units of bps.
        txInformationSpeed can be automatically set according to txSymbolRate."
    ::= { txConfigEntry 4 }

txSymbolRate OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Number of symbols transmitted per second in units of sps.
        txSynmbolRate can be automaticallyl set according to
        txInformationSpeed."
    ::= { txConfigEntry 5 }

txConvolutionalEncoderDataBit OBJECT-TYPE
    SYNTAX      Integer32 (1..65535)
```

```
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Number of data bits on FEC rate. The value must not be less than 1."
    ::= { txConfigEntry 6 }

txConvolutionalEncoderBlockBit OBJECT-TYPE
    SYNTAX      Integer32 (1..65535)
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Number of block bits on FEC rate.  The value must not be less than 1."
    ::= { txConfigEntry 7 }

txConvolutionalEncoderType OBJECT-TYPE
    SYNTAX      Integer32 {
                    Viterbi(1),
                    Sequential(2),
                    tpc_2d(3),
                    tpc_3d(4)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "ECC Type for FEC selected from choices above."
    ::= { txConfigEntry 8 }

txCarrierType OBJECT-TYPE
    SYNTAX      Integer32 {
                    Normal Modulated(1),
                    Center_CW(2),
                    Dual_CW(3),
                    Offset_CW(4)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Type of transmitting carrier selected from choices above."
    ::= { txConfigEntry 9 }

txTransmitPower OBJECT-TYPE
    SYNTAX      FloatGauge
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Power of the transmitting carrier from the satellite modem in units
        of dBm.  The maximum value varies depending on the specification
        of the modem."
    ::= { txConfigEntry 10 }

txTransmitPowerOffset OBJECT-TYPE
    SYNTAX      FloatGauge
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Power offset of the transmitting carrier in units of dB."
    ::= { txConfigEntry 11 }

txCarrierTransmission OBJECT-TYPE
    SYNTAX      Integer32 (0..1) {
```

```
                    OFF(0),
                    ON(1)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DEFVAL      { 0 }
    DESCRIPTION
        "Mode of carrier transmission.  The mode is ON or OFF and the default
        value of txCarrierTransmission should be 0 (=OFF)."
    ::= { txConfigEntry 12 }

txScramblerType OBJECT-TYPE
    SYNTAX      Integer32 {
                    Default(0),
                    IESS_308(1),
                    IESS_309(2),
                    IESS_310(3),
                    OM73(4),
                    Extension(255)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Type of scrambler select from choices above.  Choose Default(0)
        if you have no choice."
    ::= { txConfigEntry 13 }

txScramblerMode OBJECT-TYPE
    SYNTAX      Integer32 (0..1) {
                    OFF(0),
                    ON(1)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Mode of scrambler. The mode is ON or OFF."
    ::= { txConfigEntry 14 }

txDifferentialEncoderMode OBJECT-TYPE
    SYNTAX      Integer32 (0..1) {
                    OFF(0),
                    ON(1)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Mode of differential encoder.  The mode is ON or OFF."
    ::= { txConfigEntry 15 }

txReedSolomonEncoderTotalSymbols OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Number of total symbols for Reed-Solomon coding."
    ::= { txConfigEntry 16 }

txReedSolomonEncoderDataSymbols OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
```

```
    DESCRIPTION
        "Number of data symbols for Reed-Solomon coding."
    ::= { txConfigEntry 17 }

txReedSolomonEncoderInterleave OBJECT-TYPE
    SYNTAX      Integer32 (4..16)
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Reed-Solomon Interleave Depth"
    ::= { txConfigEntry 18 }

txReedSolomonEncoderMode OBJECT-TYPE
    SYNTAX      Integer32 (0..1) {
                    OFF(0),
                    ON(1)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Mode of Reed-Solomon coding.  The mode is ON or OFF."
    ::= { txConfigEntry 19 }

txSpectrumRotation OBJECT-TYPE
    SYNTAX      Integer32 (0..1) {
                    normal(0),
                    inverted(1)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Spectrum rotation of transmitting carrier.  The choice is normal or
        inverted."
    ::= { txConfigEntry 20 }

txDvbFrameLen OBJECT-TYPE
    SYNTAX      Integer32 (188..204)
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Length of DVB MPEG2-TS frame in units of Byte."
    ::= { txConfigEntry 21 }

--
-- Definition of the rxConfigTable subgroup
--
rxConfigTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF RxConfigEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
            "A list of receiving configuratoin entries."
    ::= { satModemObjects 4 }

rxConfigEntry OBJECT-TYPE
    SYNTAX      RxConfigEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "description for satModemEntry"
    ::= { rxConfigTable 1 }
```

```
rxConfigEntry ::= SEQUENCE {
    rxRfFrequency                             Integer32,
    rxIfFrequency                             Integer32,
    rxDemodulationType                        Integer32,
    rxInformationSpeed                        Integer32,
    rxSymbolRate                              Integer32,
    rxConvolutionalDecoderDataBit             Integer32,
    rxConvolutionalDecoderBlockBit            Integer32,
    rxConvolutionalDecoderType                Integer32,
    rxDescramblerType                         Integer32,
    rxDescramblerMode                         Integer32,
    rxDifferentialDecoderMode                 Integer32,
    rxReedSolomonDecoderTotalSymbols          Integer32,
    rxReedSolomonDecoderDataSymbols           Integer32,
    rxReedSolomonDecoderInterleave            Integer32,
    rxReedSolomonDecoderMode                  Integer32,
    rxSpectrumRotation                        Integer32,
    rxDvbFrameLen                             Integer32
}

rxRfFrequency OBJECT-TYPE
    SYNTAX      Interger32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "RF frequency of the receiving carrier in units of KHz."
    ::= { rxConfigEntry 1 }

rxIfFrequency OBJECT-TYPE
    SYNTAX      Interger32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "IF frequency of the receiving carrier in units of KHz."
    ::= { rxConfigEntry 2 }

rxDemodulationType OBJECT-TYPE
    SYNTAX      Integer32 (0..255) {
                    BPSK(1),
                    QPSK(2),
                    OQPSK(3),
                    /4QPSK(4),
                    8PSK(5),
                    16QAM(6),
                    64QAM(7),
                    256QAM(8),
                    Extension(255)
                    }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Demodulation type of receiving carrier selected from choices above."
    ::= { rxConfigEntry 3 }

rxInformationSpeed OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Information speed of demodulated carrier in units of bps.
```

```
        rxInformationSpeed can be automatically set according rxSymbolRate."
    ::= { rxConfigEntry 4 }

rxSymbolRate OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Number of symbols to be received per second in units of sps.
        txSynmbolRate can be automatically set according to
        rxInformationSpeed."
    ::= { rxConfigEntry 5 }

rxConvolutionalDecoderDataBit OBJECT-TYPE
    SYNTAX      Integer32 (1..65535)
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Number of data bits on FEC rate. The value must not be less than 1."
    ::= { rxConfigEntry 6 }

rxConvolutionalDecoderBlockBit OBJECT-TYPE
    SYNTAX      Integer32 (1..65535)
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Number of block bits on FEC rate.  The value must not be less than 1."
    ::= { rxConfigEntry 7 }

rxConvolutionalDecoderType OBJECT-TYPE
    SYNTAX      Integer32 {
                    Viterbi(1),
                    Sequential(2),
                    tpc_2d(3),
                    tpc_3d(4)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "ECC Type for FEC selected from choices above."
    ::= { rxConfigEntry 8 }

rxDescramblerType OBJECT-TYPE
    SYNTAX      Integer32 {
                    Default(0),
                    IESS_308(1),
                    IESS_309(2),
                    IESS_310(3),
                    OM73(4),
                    Extension(255)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Type of descrambler select from choices above.  Choose Default(0)
        if you have no choice."
    ::= { rxConfigEntry  }

rxDescramblerMode OBJECT-TYPE
    SYNTAX      Integer32 (0..1) {
```

```
                    OFF(0),
                    ON(1)
                }
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Mode of descrambler. The mode is ON or OFF."
    ::= { rxConfigEntry 9 }

rxDifferentialDecoderMode OBJECT-TYPE
    SYNTAX      Integer32 (0..1) {
                    OFF(0),
                    ON(1)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Mode of differential decoder.  The mode is ON or OFF."
    ::= { rxConfigEntry 10 }

rxReedSolomonDecoderTotalSymbols OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Number of total symbols for Reed-Solomon decoding."
    ::= { rxConfigEntry 11 }

rxReedSolomonDecoderDataSymbols OBJECT-TYPE
    SYNTAX      Integer32
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Number of data symbols for Reed-Solomon coding."
    ::= { rxConfigEntry 12 }

rxReedSolomonDecoderInterleave OBJECT-TYPE
    SYNTAX      Integer32 (4..16)
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Reed-Solomon Interleave Depth"
    ::= { rxConfigEntry 13 }

rxReedSolomonDecoderMode OBJECT-TYPE
    SYNTAX      Integer32 (0..1) {
                    OFF(0),
                    ON(1)
                }
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Mode of Reed-Solomon coding.  The mode is ON or OFF."
    ::= { rxConfigEntry 14 }

rxSpectrumRotation OBJECT-TYPE
    SYNTAX      Integer32 (0..1) {
                    normal(0),
                    inverted(1)
                }
```

```
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Spectrum rotation of transmitting carrier.  The choice is normal or
        inverted."
    ::= { rxConfigEntry 15 }

rxDvbFrameLen OBJECT-TYPE
    SYNTAX      Integer32 (188..204)
    MAX-ACCESS  read-write
    STATUS      current
    DESCRIPTION
        "Length of DVB MPEG2-TS frame in units of Byte."
    ::= { rxConfigEntry 16 }

--
-- Definition of rxStatusTable Subgroup
--
rxStatusTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF RxStatusEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
            "A list of receiving status entries."
    ::= { satModemObjects 5 }

rxStatusEntry OBJECT-TYPE
    SYNTAX      RxStatusEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "description for satModemEntry"
    ::= { rxStatusTable 1 }

rxStatusEntry ::= SEQUENCE {
    rxRsl                                   FloatGauge,
    rxCn                                    FloatGauge,
    rxEbno                                  FloatGauge,
    rxBer                                   FloatGauge,
    rxAgc                                   FloatGauge,
    rxCarrierDetection                      Integer32
}

rxRsl OBJECT-TYPE
    SYNTAX      FloatGauge
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "Receive Signal Level"
    ::= { rxStatusEntry 1 }

rxCn OBJECT-TYPE
    SYNTAX      FloatGauge
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "Carrier over Noise Ratio"
    ::= { rxStatusEntry 2 }

rxEbno OBJECT-TYPE
    SYNTAX      FloatGauge
```

```
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "Eb/No"
    ::= { rxStatusEntry 3 }

rxBer OBJECT-TYPE
    SYNTAX      FloatGauge
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "Bit Error Rate"
    ::= { rxStatusEntry 4 }

rxAgc OBJECT-TYPE
    SYNTAX      FloatGauge
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "Automatic Gain Control"
    ::= { rxStatusEntry 5 }

rxCarrierDetection OBJECT-TYPE
    SYNTAX      Integer32 (0..1) {
                    Detected(0),
                    Lost(1)
                }
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "Carrier Detection Status"
    ::= { rxStatusEntry 6 }

--
-- Definition of sigAlertTable Subgroup
--
sigAlertTable OBJECT-TYPE
    SYNTAX      SEQUENCE OF SigAlertEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
            "A list of receiving status entries."
    ::= { satModemObjects 6 }

sigAlertEntry OBJECT-TYPE
    SYNTAX      SatelliteModemEntry
    MAX-ACCESS  not-accessible
    STATUS      current
    DESCRIPTION
        "description for satModemEntry"
    ::= { rxStatusTable 1 }

sigAlertEntry ::= SEQUENCE {
    sigAlertFlag                          Integer32,
    sigAlertDesc                          DisplayString
}

sigAlertFlag OBJECT-TYPE
    SYNTAX      Integer32 (0..2) {
                    none(0),
                    major_alert(1),
```

```
                    minor_alert(2)
                }
    MAX-ACCESS  read-only
    STATUS      current
    DEFVAL      { 0 }
    DESCRIPTION
        "Seriousness of alert.  If there is no alert, 0 is to be selected"
    ::= {sigAlertEntry 1}

sigAlertDesc OBJECT-TYPE
    SYNTAX      DisplayString
    MAX-ACCESS  read-only
    STATUS      current
    DESCRIPTION
        "Something is wrong..."
    ::= {sigAlertEntry 2}

--
-- Active Notification from Satellite Modem using TRAP
--
linkStateDown NOTIFICATION-TYPE
    OBJECTS { modIndex, rxCarrierDetection }
    STATUS  current
    DESCRIPTION
            ""
    ::= { satModemObjects 7 }

linkStateUp NOTIFICATION-TYPE
    OBJECTS { modIndex, rxCarrierDetection }
    STATUS  current
    DESCRIPTION
            ""
    ::= { satModemObjects 8 }

modSystemAlert NOTIFICATION-TYPE
    OBJECTS { modIndex, sigAlertFlag, sigAlertDesc }
    STATUS  current
    DESCRIPTION
            ""
    ::= { satModemObjects 9 }

--
--  Facility Related Objects to be discussed or implemented
--  satModem                { satMIB 3 }
--  satAntenna              { satMIB  }
--  satFeedHorn             { satMIB  }
--  satHighPowerAmprifier   { satMIB  }
--  satLowNoiseAmprifier    { satMIB  }
--  satUpConverter          { satMIB  }
--  satDownConverter        { satMIB  }
--  satInterfacilityLinks   { satMIB  }
--  satInteriorConditon     { satMIB  }
--      "Condition inside the earth station
--       such as temperature, air pressure, humidity, power supply"
--  satExteriorConditon     { satMIB  }
--      "Condition outside the earth station
--       such as weather, temperature, air pressure, humidity"
--

--
--  The End of SAT-MIB
```

--
END