고속열차대상의 위성인터넷 서비스 제공을 위한 위성무선연동 기술(서비스 시나리오 관점)

Development of Satellite and Terrestrial Convergence Technology for Internet Services on High-Speed Trains (Service Scenarios)

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요 약

최근 이동환경에서의 고속 위성통신 서비스에 대한 요구가 증가하고 있다. 이러한 요구를 만족시키기 위해 유럽 및 북미지역에서는 지난 수년간 Ku대역을 활용한 고속이동체 대상의 이동형 위성통신 시스템 개발이 활발히 진행되고 있다. 하지만 기존의 이동형 위성통신 시스템은 수십 Kbps 정도의 전송속도를 제공하기 때문에 고속열차와 같이 다수의 그룹 사용자들을 대상으로 한 위성 인터넷 서비스 제공에 한계가 있다. 또한, 철도 운행구간에서 발생하는 N-LOS 환경에 대처하는 기술의 부재로 서비스 가용도가 크게 저하된다. 본 논문에서는 고속열차 승객을 대상으로 위성무선연동 전송기술을 이용하여 지상무선망과 동일한 수준의 끊김없는 인터넷 서비스를 제공하기 위한 이동형 광대역 위성 인터넷 접속 시스템에 대해 기술한다. 고속열차를 대상으로 이러한 서비스 제공을 위해서는 터널이나 역사(Railway Station)와 같은 N-LOS 환경에 대한 대처기술이 필요하며, LOS 환경에서도 철로상에 설치되어 있는 Electric Power Post 나 Power Bridge 등으로 인한 주기적이고 짧은 시간 동안의 신호열화 현상이나 고속 이동에 따른 도플러 현상에 대한 극복기술이 필요하다. 이를 위해 본 시스템에서는 안테나 다이버시티 기법 및 갭필러와 지상무선망과의 연동기술이 적용되어야 하며, 상위 레이어에서의 에러 정정 기술이 적용된다. 본 논문에서는 위와 같은 기술이 적용되어 고속열차 승객들을 대상으로 한 위성인터넷 서비스 기술에 대해 기술한다.

키워드: 양방향 위성통신, DVB-S2, DVB-RCS, 이동형 위성통신, 갭필러, 안테나 다이버시티

ABSTRACT

Recently, the demands for the satellite broadband mobile communication services are increased. To provide these services, mobile satellite communication systems for the passengers or crews on the high-speed moving vehicles, are being developed for the last several years especially in the Europe and North America. However, most of these systems can provide only several hundred kbps of transmission rate and this is not enough performance to provide satellite internet service for the group users such as passengers on the high-speed train. Moreover, service availability with these systems is limited to be rather low because they don't have any countermeasure scheme for the N-LOS environment which happens often along the railway. This paper describes mobile broadband satellite communication system, which is on the development, to provide high data-rate internet services to the high-speed trains. This system is applied with the inter-networking scenarios of both satellite/terrestrial network and satellite/gap-filler network so that it can provide seamless service even in the train operating environment, and these inter-networking schemes result in high service availability. And this system also has the countermeasure schemes, such as upper layer FEC and antenna diversity, for the short fading which is occurred periodically on the railway due to the power supplying structures so that it can provide high speed internet services. Mobile DVB-S2 technology which is now being standardized in the DVB is used for the forward-link transmission and DVB-RCS for the return-link.

Key Words *:* bi-directional satellite communication, DVB-S2, DVB-RCS, mobile satellite communication, gap-filler, diversity

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※본 연구는 정보통신부 및 정보통신연구진흥원의 IT 신성장동력핵심기술개발 사업의 일환으로 수행하였음. [2007-S-020-02, 고속이동체 인터넷 위성무선연동기술개발]

1. Introduction

The plethora of recent and ongong R&D activities and trials, as well as the existence of several commercial systems, indicates that there is substantial interest in broadband mobile systems. The application of mobile functionality to the existing standards for broadband satellite systems, such as DVB-S2[1] and DVB-RCS[2], is essential for the success of those systems, especially when used to provide interactive services for the users in moving condition. Even though these standards are originally intended for fixed terminals, upgrading them to support mobility using same air interface is of great interest to create new market for satellite communication services.

Satellite communication system can provide highly efficient and economic services, owing to its advantages such as a wide coverage of area, flexibility of network configuration, direct access to mobile users and fast deployment of the services, which can be hardly provided by the terrestrial communication networks. Due to these reasons, a number of pilot projects and trials aiming to provide broadband internet and/or broadcasting service with on-board users in moving vehicles, have been launched in the past recent years[3][4][5]. Moreover, integration of mobile satellite networks with the several terrestrial communication networks, such as gap-fillers, Wi-Fi and/or Wibro(mobile WiMax version in Korea), extends service coverage for the mobile users and this definitely becomes a good alternative solution both for terrestrial network services operators and satellite service providers to overcome their service limitations and reduce the economic burden.

FIFTH project[3] conducted many basic researches to provide satellite digital TV service and internet service to high-speed trains. The project scope included railway channel modeling, organization of network components and service scenarios to cope with train operating environment. SAET project[5] continues, taking advantages from the experiences of FIFTH, to develop satellite network architecture for the multimedia service provisions to European high-speed trains. Technically, SAET aims at designing and implementing an engineered train terminal prototype and market issues are taken into account during all phases of the project. There are several other pilot projects, like “Broadband to Trains” and “iHST” which are funded by ESA, to develop broadband satellite systems, and companies like 21NET, ICOMERA and PointShot Wireless are trying to commercialize this service.

This paper addresses mobile satellite system called XpeedSAT which aims at providing the internet services for the users on-board trains using mobile DVB-S2/RCS standards. In section 2, system architecture is introduced, and in section 3, service scenarios for the satellite/terrestrial networks interoperability are shown. Finally we draw the conclusion in Section 4.

2. XpeedSAT System Overview

XpeedSAT system is the mobile satellite access system to provide broadband internet service seamlessly with the users on-board high-speed trains. While moving on the trains, users can access the service basically through the direct connection via satellite during LOS(Line-of-Sight) area. And either of bi-directional gap-filler network or wireless terrestrial network is supposed to be used in the N-LOS(Non-LOS) area, such as urban area, tunnels and railway stations, for seamless connection.

Figure 1 presents XpeedSAT system architecture and service concepts.

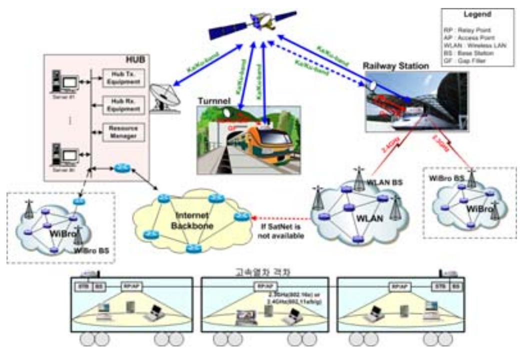

Figure 1. XpeedSAT system architecture

The basic system architecture of the XpeedSAT system is an interactive satellite mobile communication system that uses DVB-S2 on the forward-link and DVB-RCS on the return-link in order to provide broadband internet access services to group users on the high-speed trains. In addition to this baseline concept, some other technologies to support mobility are considered. Figure 2 describes the system configuration which shows that the system is composed of 3 segments of Hub, Terminal and Gap-filler. Hub segment includes Satellite Network Gateway (SNG), Satellite Interface Subsystem(SIS), and Terminal segment includes Mobile Antenna Subsystem(MAS), Satellite Mobile Terminal(SMT) and Wireless Network Access Subsystem(WiNAS). And Gap-filler is composed of Gap-filler subsystem(GFS) itself. SNG and SMT are key component for satellite transmission in LOS environment but GFS and WiNAS are for N-LOS environment.

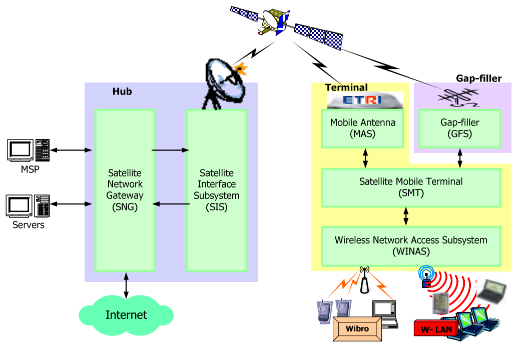

Figure 2. XpeedSAT system configuration

In LOS environment, services are supposed to be provided over direct satellite connection. However, since DVB-S2/RCS standards are not designed for mobile applications, some other schemes are required to be applied for mobile conditions, especially for the deep fading channel, which is expected in the railway channel.

For the purpose, MPE-FEC and spreading schemes are considered, on the forward-link transmission carrier, to accommodate the system to railway mobile channel condition. MPE-FEC is originally developed for the DVB-H, which is the DVB standard for providing multimedia services to handheld terminals, in order to improve C/N performance in mobile channels. In the XpeedSAT system, MPE-FEC scheme is used for obtaining higher C/N margin to compensate short deep fading in the mobile channel which is periodically occurred mainly by power arches on the railway. And spread spectrum scheme is also included to reduce interference in the system for the forward-link transmission, which is discussed in the DVB-S2+M group for adapting to DVB-S2 standard. For the return-link transmission, only MPE-FEC scheme is considered. Antenna diversity scheme is optionally considered in the LOS environment to compensate deep short fading as a complementary solution.

In the railway channel, N-LOS environment is expected to occur frequently in tunnels, railway station and urban area. Thus, the scenarios for the service link in those situations are provided for seamless connection. Network convergence scheme with the other wireless network, which can be either of gap-filler network or wi-fi(or wibro) network, is used for N-LOS environment in the system.

Interoperability with gap-filler is designed to operate in the vicinity of the tunnel area and handover process between satellite network and terrestrial wireless network, like wi-fi(or wibro) network, is carried out around the railway station area. Gap-filler system receives satellite signal and retransmit the signal into the tunnels with the different frequency band for the forward-link connection and vice versa for the return-link connection. And when a train enters railway station, the traffic communicated with satellite network should be handed over to the wi-fi(or wibro) network, which is supposed to be installed in the railway station, before the system loses satellite signal. This handover process is accomplished by WiNAS in Figure 2. Within the urban area, hybrid scheme with terrestrial wireless network is likely to be selected preferably by the service provider.

3. Service Scenarios Definition

I. State Transition Mechanism

Service scenarios supported by the XpeedSAT should cover various operational environments. Figure 3 envisages the cases which the terminal encounters as it moves on the trains. The service areas are classified according to what is the most efficient and feasible infrastructure for the region, and is divided in where channel condition changes significantly so that a certain technology can not provide seamless service anymore.

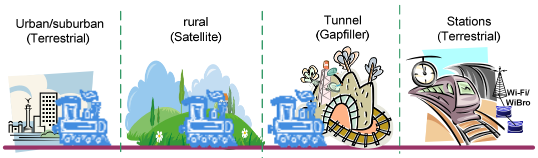

Figure 3. Service area definition

Service areas can be classified into urban/suburban, rural, tunnel and railway station area. Each of the service areas in Figure 3 can be characterized as below:

- Urban/suburban area
  - Satellite signal is possibly blocked by buildings during the most of time period
  - Probably covered by any of the terrestrial wireless networks
- Rural area
  - Open area which is guaranteed to have LOS to the satellite
  - But significant signal fading by power arches should be considered
- Tunnel area

  - Comparatively long signal blockage can be expected in some cases according to the tunnel length
  - Hard to expect any broadband access network near the region
- Railway station area
  - Satellite signal can be definitely blocked by the roof/buildings. May be in underground
  - usually provided terrestrial wireless networks thesedays

As described in Section 2 slightly, rural area is considered to be LOS environment which can be supported with direct satellite connection, and the other areas are considered as N-LOS environment which should be covered by either of gap-filler or terrestrial wireless network. Since all kinds of the environments that is encountered during the motion should be taken into account for the required seamless service, terminals have to support at least 3 physical interfaces which include satellite direct interface, gap-filler interface and terrestrial wireless interface. If antenna diversity scheme is also requested, 4 physical interfaces should be supported.

In order to provide on-board users with internet services seamlessly while a terminal moves across the service areas, service scenario should be precisely defined for the terminal to handover between different networks. Also, internal processes of the terminal to switch over between different physical interfaces are required.

First of all, each of service areas is assigned into a certain state according to a terminal's position in order to define network transition process between different service areas. This state definition is shown in Table 1 and applied network technology for the corresponding service area is also described.

Table 1. State definition for service areas

Service area	Applied tech.	State
Urban	Terrestrial wireless	State I
Rural	Satellite(Antenna diversity)	State II
Tunnel	Gap-filler	State III
Railway station	Terrestrial wireless	State I

In the first stage of the service operation, a terminal will be on the one of 3 states. From that state, the terminal would transit into other state whenever its channel condition varies. For example, suppose that terminal just starts a railway station. Then terminal would be on the State I at the first time. As a train moves, terminal is getting far from the station and receives satellite signal directly. At some time later, satellite signal level comes to above a threshold and if there is still no gap-filler signal detected at that time, input interface change process to satellite network is performed and then the terminal goes to the State II. Input interface change process includes initial logon to a new network, logoff to the previous network, packet synchronization between different networks in some cases, etc. Figure 4 describes state transition mechanisms occurred between states whenever channel condition changes.

In the expression on the state transition arrow in Figure 4, a numerator part is the condition that should start state transition process and a denominator part is the action to be taken when the condition meets.

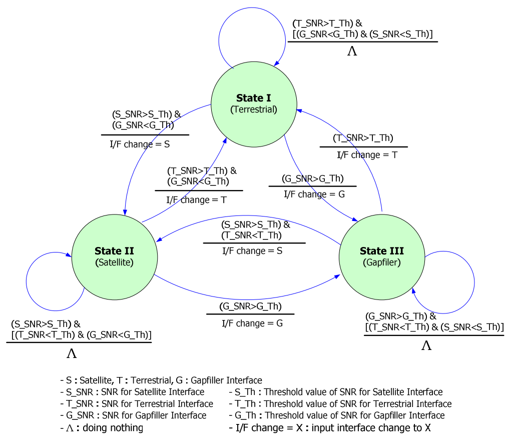

Figure 4. State transition diagram for handover

II. Network change process

When a certain network should be changed to the other network for data reception is quite straightforward, as in the Figure 4. In Figure 4, SNR value from the demodulator of a corresponding network interface is used for the criteria of transition. In addition to how we determine the time to change current input network, defining what needs to be done for handover during the transition period is also important. In Figure 4, 'I/F change = S' means the process required to handover into the satellite network from any other network.

A top level view of network change process is shown in Figure 5. When a certain channel condition change occurs and the corresponding action should be taken, network interface change process enters the flow in Figure 5 and follows the steps according to the currently operating network and next network selected.

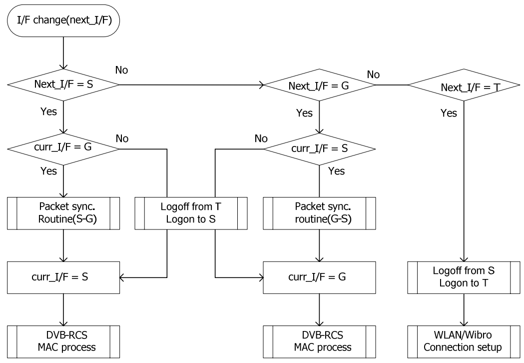

Figure 5. Network change flow

Handover process between satellite network and gap-filler network requires packet synchronization scheme since there is transmission delay difference because of the gap-filing relay time through the tunnels and therefore packet level mismatch happens that may result in service discontinuity. Similar mechanism for the packet synchronization is proposed in the literature[6], which is carried out in the layer 3(IP packet layer). But it is not applicable for our system because the system requires network synchronization that relies on NCR(Network Clock Reference) TS packets. So we need to select input network interface on the TS packet layer and recover NCR packet stream as it transmitted.

And handover process should be completed in the transition duration where both of the two networks are alive. Figure 6 presents transition duration(*T_ta*) when a train enters a tunnel that the terminal should be handed over from satellite network to gap-filler network.

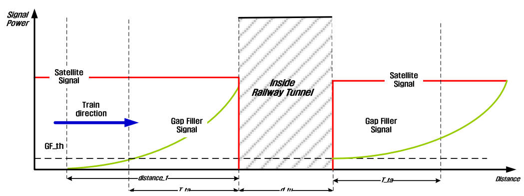

Figure 6. transition duration for gap-filler network

This transition duration time is determined by gap-filler transmission power, threshold value of the gap-filler signal and train speed. The same consideration should be taken into for the terrestrial wireless network.

4. Conclusions

In this paper we introduced operating scenarios for the mobile broadband satellite system which can provide mobile internet services with the users on-board trains. Operating environment is classified into 4 service areas and most appropriate technologies for the areas are defined. To cope with the channel condition changes, top level service scenario is described for interoperability of the several networks. For the service scenario to be completed, some of details should be supplemented to the system in the further works.

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