Network Architecture of Internet Backhaul by DVB-RCS Standards for Shipborne and other Mobile Applications

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Abstract: In this paper is introduced a new Digital Video Broadcasting-Return Channel via Satellite (DVB-RCS) for the implementation of modern satellite Internet for shipborne, Vehicleborne and airborne mobile applications via Geostationary Erath Orbit (GEO) satellites. Mobile Satellite Internet aims at providing the next generation satellite broadcasting service through C, Ku and Ka-band DVB-S2 standard for Mobile Earth Stations (MES) via GEO satellite and Land Earth Stations (LES) to the ground or other mobile subscribers. It is de facto a mobile interactive broadcast satellite access system, which provides both TV broadcasting and high-speed Internet broadband based on DVB-S/DVB-RCS standards, Internet Protocol (IP) network, World Wide Web, IPTV, E-solutions and Communication, Navigation and Surveillance (CNS) systems to the passengers and crews onboard ships, land and aeronautical vehicles.

Keywords: *DVB-RCS, GEO, MES, LES, IP, CNS, MSC, VoIP, VDVoIP, FIT, MIT, VSAT*

1. Introduction

Today, it is increasingly required implementation of modern mobile DVB-RCS multimedia and broadband networks including Internet service by traditional Mobile Satellite Communications (MSC) or through new broadcasting Ku or Ka-band satellite channels. Mobile DVB-RCS networks have been designed to provide Voice, Data and Video (VDV) broadcasting service to ships, land vehicles (road and rails) and aircrafts, which network and service via Hub and GEO spacecraft is shown in **Figure 1**. This broadcasting network includes Point of sale, Voice over IP (VoIP), VDVoIP, Broadband mobile Internet, Banking ATM, Distance learning including all E-solutions, IP Video/IPTV and so on. The rapid growth in the demand for mobile broadband and Internet services has driven the implementation of DVB-RCS networks to transport and deliver IP-based backbone in addition to traditional VDV broadcasting content.

A variety of DVB transmission methods have been used to support interactive IP satellite services, that is, DVB-Satellite (DVB-S) or second-generation DVB system for broadband satellite services (DVB-S2) as the forward link and digital video broadcast-return channel via satellite (DVB-RCS) as the return link. In the forward link, the Moving Pictures Expert Group (MPEG) transport stream packet is used as a container for IP packets; hence, several encapsulation methods are developed to encapsulate IP packets into MPEG cells.

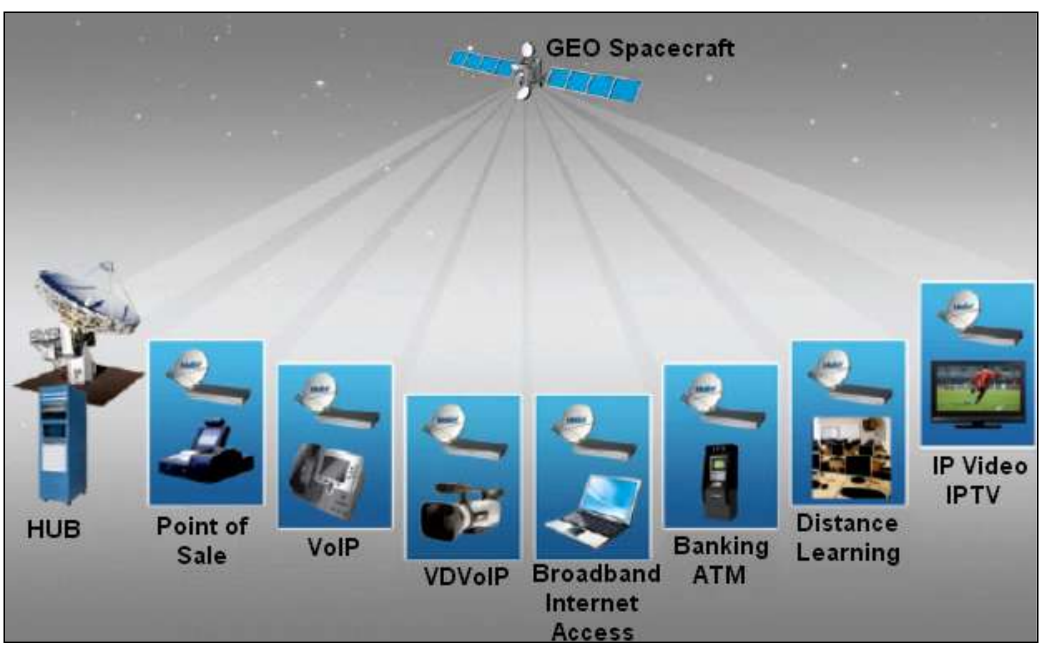

Fig. 1. DVB-S Applications via GEO Spacecraft and HUB Terminal

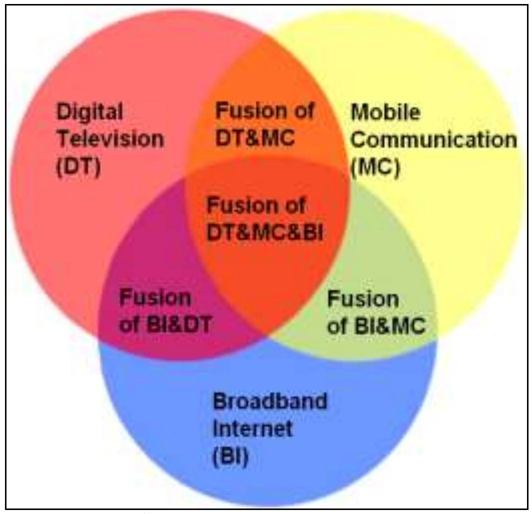

Fig. 2. Fusion of Fixed and Mobile Services

The Internet's complexity is growing not only from the mere perspective of protocol development, but also from the operational architectural and technological viewpoint. In such a way, heterogeneous systems integrated with mobile DVB-S content are becoming an essential ingredient to realize ubiquitous services for both fixed (DVB-RCS2+F) and mobile (DVB-RCS2+M) Internet. The DVB provides service in the fusion of digital television, broadband Internet and mobile communications access for all transport systems. Generally, fixed and mobile satellite networks can be connected widely to the terrestrial services via wired technologies, and in particular they can be backbone to the demanding world of Small to Medium-size Enterprise (SME), Small Office-Home Office (SOHO), Wide Area Network (WAN), Local Area Network (LAN), Worldwide Interoperability for Microwave Access (WiMAX) and Wireless Fidelity (WiFi).
The integration among the broadband Internet (usually wired) and mobility transportation platforms is new challenge for research activities. Due to the availability of cheaper devices onboard mobiles and sophisticated infrastructure, the integration process has become cost effective and widely assessable between consumers and transportation communities. Today, mobile communication transition is undergoing towards a broadband mobile communications convergence, where IP goes mobile onboard transportation systems as broadband mobile multimedia. Emergence of varied personal mobile technologies, increased demand of broadband multimedia service and ubiquitous service requirements by end users, will lead to the worldwide convergence of networks and fusion of technologies including Digital Television (DT), Broadband Internet (BI), Mobile Communications (MC) and some innovative techniques, as shown in **Figure 2.**

2. Development of DVB Technology

In 1993 the DVB via Satellite (DVB-S) was introduced in order to standardize the distribution of digital television (TV) content to the clients. This standard was very successful in driving down the cost for satellite modems. Within a few years, the DVB service became not only for digital TV distribution, either for data distribution as the cheapest "low cost" demodulator for deployment of new satellite data distribution markets. The success of DVB-S encouraged DVB company to study an extension, such as two way DVB-RCS, which added a standardized satellite based return channel for multi-user data distribution. In addition, DVB-S was also being used for news contribution via satellite distributing TV and radio channels to terrestrial and mobile receivers.
The standardization technology process continues to advance and since 1994 silicon density has increased by 16 times, so Forward Error Correction (FEC) has been transformed by iteractive decoding. The FEC mode provides a mathematical means of correcting errors in a transmission link enabling improved efficiency. Since the creation of DVB-S the world has also become much more IP focused. In 2002 DVB company decided to create a new satellite specification, including a radical new FEC scheme, and to take advantage of latest silicon process technology, to enable more efficient and higher throughput satellite transmissions, so DVB-S2 was conceived. The key driver for the rapid development of the DVB-S2 was the scarcity of available Ku-band, which improves the efficiency of transmission by 30%.
These standard are designed by the ETSI (European Telecommunication Standard Institute) as DVB Project, which define the complete air interface specification for two-way satellite broadband Very Small Aperture Terminal (VSAT) systems. The low cost VSAT equipment can provide highly dynamic, demand-assigned transmission capacity for a broad range of fixed and mobile users. The main feature of DVB-RCS2 that this standard provides users with a broadband Internet connection, without a need for any local terrestrial infrastructure. The DVB-RCS2 was approved by the DVB in 2012 with mobility extension (DVB-RCS2+M was added), supporting mobile/nomadic terminals and direct terminal-to-terminal (mesh) connectivity. Therefore, since the DVB-RCS2+M function has become available in DVB-RCS2 standard, the opportunity to provide Internet onboard of the mobile platforms.

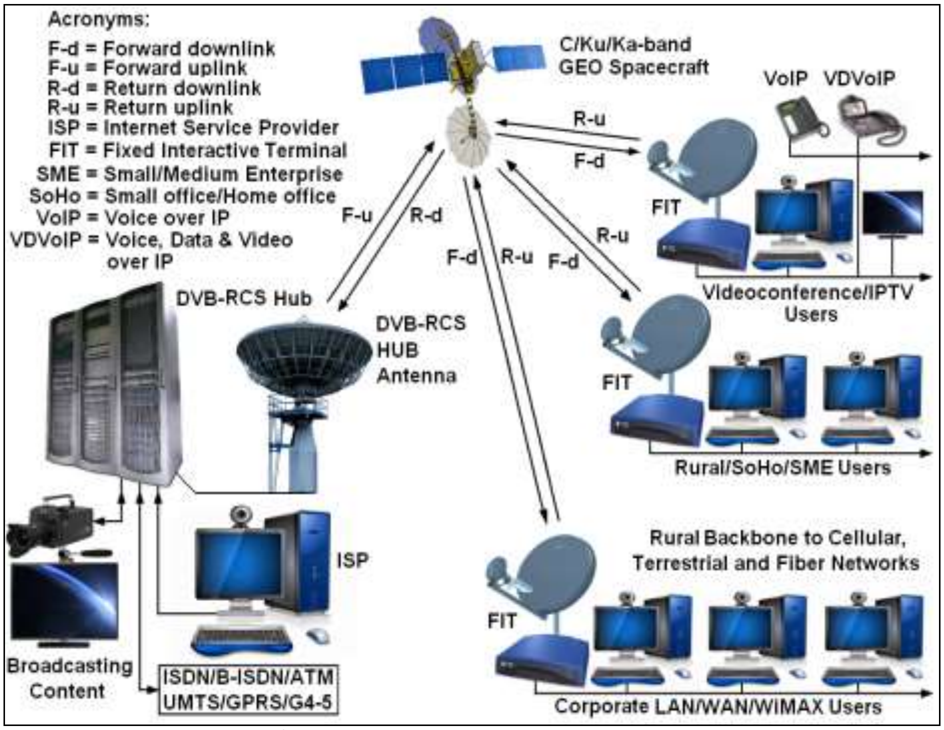

Fig. 3. DVB-RCS+F Backbone for Fixed Applications

The DVB-RCS standards are the best tool that can be applied in in urban, rural or remote areas and to provide a backbone to terrestrial telecommunication, cellular, fixed and mobile networks for complete communication coverage in one Country. To enable modern IPTV and Voice, Data and Video over IP (VDVoIP) via Satellite Broadcast, Broadband, Multimedia and fast Internet is necessary to include Space Segment, Hub as Ground Earth Station (GES) and Fixed Interactive Terminals (FIT) and Mobile Interactive Terminals (MIT) or simply Remotes, also known as Very Small Aperture Terminals (VSAT). In **Figure 3** is illustrated DVB-RCS Backbone for fixed applications, which is a precursor to the development of mobile DVB-RCS applications and which can connect urban with remote, rural and suburban environments. The summary of improvement and comparison of the key technical features of DVB-RCS/RCS2 standards are presented in **Table 1.**

Table 1. The comparison of features of DVB-RCS/RCS2 standards.

Features:	DVB-RCS	DVB-RCS2
Harmonised management and control	None	Yes (optional)
Harmonised IP-level QoS	None	Yes
Multiple virtual network support	None	Yes
Security	Single solution	Support for multiple security systems, for applications with widely different requirements
Return link access scheme for traffic	TDMA (continuous carrier)	TDMA, continuous carrier, random-access
Modulation schemes	QPSK	Linear: BPSK, QPSK, 8PSK, 16QAM, Constant-envelope: CPM
Channel coding	RS/convolutional, 8-state PCCC turbo code	16-state PCCC turbo code (linear modulation), SCCC (CPM)
Burst spread-spectrum	Burst repetition	Direct-sequence

The proposal for development of mobile DVB-RCS networks came from South African company "CNS Systems" earlier in 2000, and almost 5 years later is proposed DVB for maritime applications. At the beginning of 2005 the first fitted out ship with DVB-RCS Nera SatLink Marine system was luxurious supper Motor Yacht M/Y Lady Marina. The Norwegian company Nera developed its first DVB-RCS VSAT for ships implementing telephony, data, radio, daily news delivery and broadcast services. Two years later, Inmarsat has developed similar broadcasting mobile systems such as FleetBroadband for ships and SwiftBroadband for aircraft.

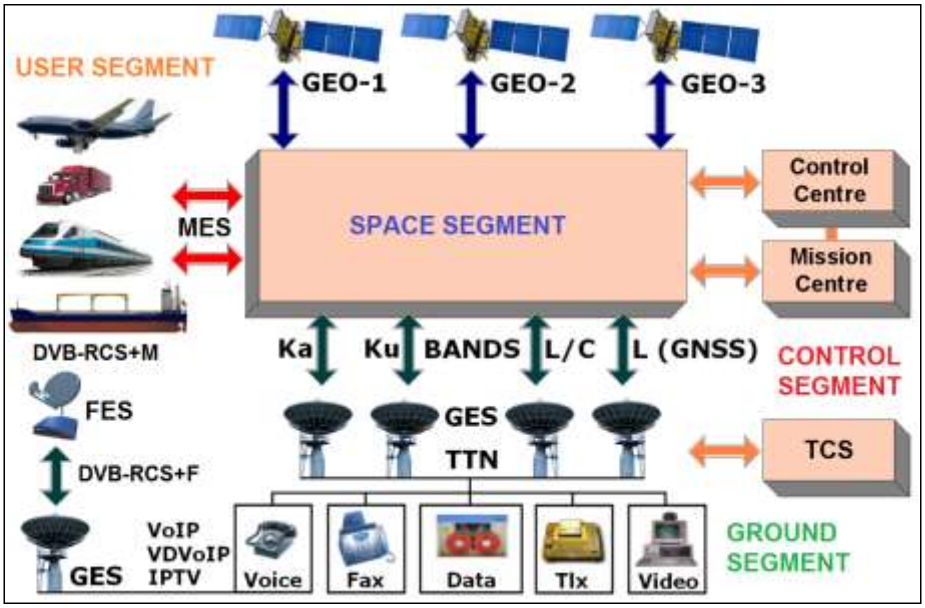

Fig. 4. Space, Ground and User Segments for Fixed and Mobile DVB-RCS System

3. Operational Architecture of DVB-RCS Network

The main componentes of the DVB-RCS betworks are space, control, ground and user segments for fixed and mobile applications illustrated in **Figure 4.**

1. Space Segment – It consists minimum one or more GEO satellites with a single, spot or multi-beam coverage and provides interactive connections between HUB (LES) sites interfaced to the Terrestrial Telecommunication Network (TTN) and DVB-RCS mobile stations or VSAT terminals via the regulated frequencies at L/C, Ku or Ka-band. At present, there are many satellite operators worldwide providing GEO constellations suitable for DVB-RCS/S/S2 standards for interactive fixed and mobile connections, such as Intelsat, SES-NewSkies, PanAmSat, Eutelsat and other satellite constellations, with regional or global and spot beam coverage. However, Inmarsat GEO satellite constellation for mobile communications and navigation is launching new generation of Inmarsat-5 spacecraft designed by Boeing.

The new developed DVB/Inmarsat Hybrid is a product for bi-directional asymmetrical satellite connectivity, with a broadband receive channel based on DVB-S, and with a transmit channel based on Inmarsat Mobile Packet Data Service (MPDS). The mobile user needs hybrid equipment like an Inmarsat MPDS terminal, comprising a stabilized L-band satellite antenna and an MPDS transceiver, a stabilized C or Ku-band satellite receive only antenna, a DVB-S receiver with IP user interface and a PC with software necessary for inter-working between the DVB-S and Inmarsat MPDS infrastructure. This product provides interconnectivity to an asymmetrical digital satellite network, offering the additional services like Internet and E-mail access, VDV, IP streaming of audio and video. Otherwise, Inmarsat network is providing new service known as Digital Video Broadcasting-Satellite services to Handhelds (DVB-SH), as additional solution to their existing handhelds for personal communications.

2. Control Segment – Contains Mission and Control centres and for satellite mobile tracking is used Tracking Control Station (TCS) supported by DVB-RCS and Global Navigation Satellite Satellite (GNSS) networks, such as the US GPS and Russian GLONASS. Otherwise, the GPS and GLONASS networks belong to the first generation of GNSS (GNSS-1), while the Chinese BeiDou or Compass and the European Galileo are still in the development phase as the second generation of GNSS (GNSS-2).

2. Ground Segment – This segemnt sonsists of HUB or Ground Earth Stations (GES), which is providing bridges between all DVB-RCS+M mobile and DVB-RCS+F fixed terminals to the terrestrial subscribers via adequate GEO satellite. This infrastructure may have Mission Centre to control the Network; Control Centre to manage Spacecraft and four Land Earth Stations (LES) for Ka, Ku, L/C communication and L-band of Global Navigation Satellite System (GNSS), respectively. The TTN infrastructures are connecting civilian or military subscribers via digital VDV facilities locally or worldwide. The Traffic Control Centre (TCC) is common synonym for Ship Traffic Control (STC), Land Traffic Control (LTC) and Air Traffic Control (ATC) employing Regional Satellite Augmentation System (RSAS) for CNS solutions.

3. User segment – This segment consists of DVB-RCS+M or (MIT) mounted onboard mobile platforms as Mobile Earth Stations (MES) on ocenagoing ships, land vehicles (road and rail) and aircraft. While DVB-RCS+F or FIT and PIT stations can be installed in urban, remote and rural areas as Fixed Earth Stations (FES), all operating as local access points for the users via its equipment.

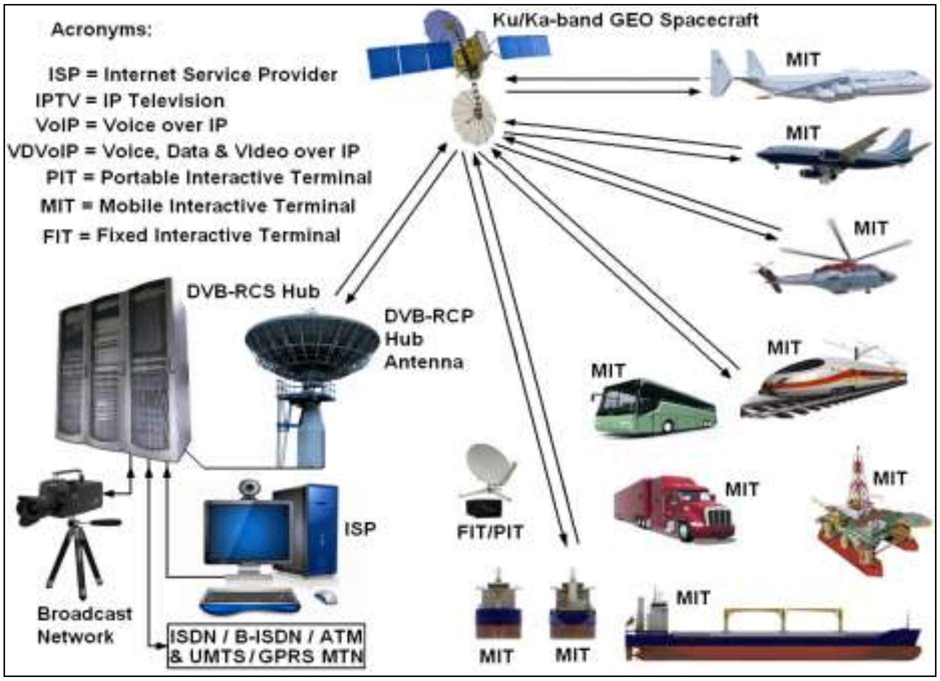

Fig. 5. DVB-RCS+M Backbone for Mobile Applications

In **Figure 5** is shown DVB-RCS+M backbone for mobile applications extends the terrestrial broadband, broadcasting, Internet Service Providers (ISP), Asynchronous Transfer Mode (ATM), Universal Mobile Telecommunications System /General Packet Radio Service (UMTS/GPRS), TTN, Cellular, Private and Public Networks, Virtual Private Networks (VPT), Fiber Optical Networks (FON) and any other civilian corporate or military networks to the onboard mobiles VSAT stations. The DVB-RCS Ground and User segments can be connected via GEO spacecraft and Hub or Gateway terminals to the Terrestrial Internet Network (TIN), which architecture is shown in **Figure 6.**

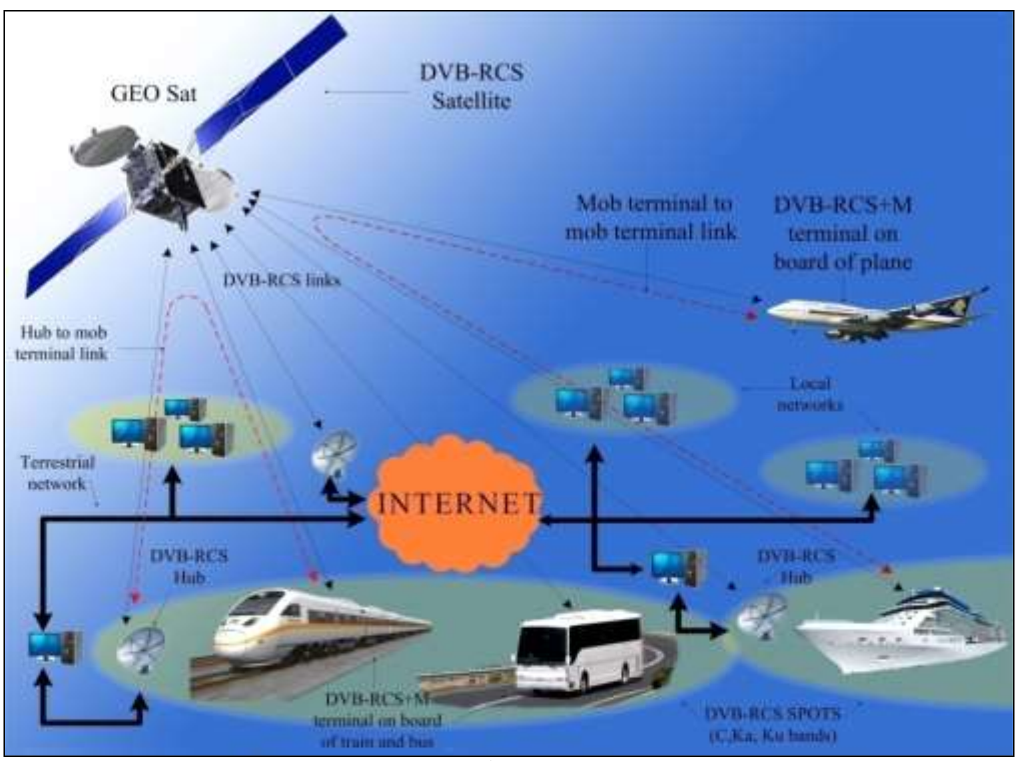

Fig. 6. Interactive Internet via DVB-RCS+M Backbone for Mobile Applications

Fig. 7. Fixed VSAT Antenna with VSAT Units (Transceivers), Shipborne and Airborne Mobile VSAT Antennas

The main characteristics of HUB Network fro fixed and mobile applications are as follows:
a) Up to 1Gb/s: 5 x 200 Mbps Forward Links capacity with 5:1 redundancy and up to 3 x 240 Mb/s Return Links per rack capacity
b) Downstream interface is MPEG/DVB-S (Moving Picture Expert Group/DVB-Satellite)
c) Upstream interface is DVB-RCS
d) Optimized for IP (Internet Protocol) and multi-media contenting Remote (FIT and MIT) terminals (SIT) or VSAT
e) Open standard design (DVB-RCS) Broadband & Multimedia
f) Qualified with multiple IP/DVB broadcast platform vendors
g) The System is designed to support up to 180,000 SIT units
h) Every Remote Terminal (VSAT) is able to support many PC or IPTV in LAN (more than 100), depending on used bandwidth
i) DVB-S can be upgraded by the most effective and cost less 2nd generation DVB-S2 CCM and 3rd generation DVB-S2 ACM platform, forward and reverse compatible
The DVB-RCS Ground and User segments can be connected via GEO spacecraft and Hub or Gateway terminals to the Terrestrial Internet Network (TIN) and Internet enabling the following major satellite services:
1. Service Provider Platforms – This service provides rural and remote communications;
2. Enterprises and Private Networks – Provides small flexible network with lower cost for up to 20 sites for wide geographic coverage;
3. Broadcasting and Content Distribution – Enables all broadcast distributions over satellite;
4. Satellite News Gathering (SNG) – This is one of the new tools available to the broadcasting industry;
5. Satellite Emergency, Distress and Security Management – Provides remote broadband interactive satellite VDV and Internet backbone communications for commercial and military users;
6. Defense Information Management – Provides unparalleled satellite solutions for military tactical and defense applications for Navy, Ground and Air forces. This broadcast and broadband network significantly enhances the performance of any existing military service and enable the following solutions: a) Rebuilding efforts; b) Secure and encrypted communications; c) Troop communications; d) Logistics Managements and e) E-Training and Education; and
7. Mobile Satellite System – Provides broadcasting civilian solutions at see, on the ground and in the air.
The DVB-RCS VSAT network has been designed to minimize the cost of scaling a broadcast, broadband and multimedia access via Hub between number of mobile terminals and even thousands of simultaneously logged-on terminals in urban, rural or remote areas. Satellite interactive DVB-RCS terminals via VSAT Hub deploy larger C (4-8 GHz), smaller Ku (12-18 GHz) or smallest Ka-band (27-40 GHz) antenna systems.
Therefore, GEO satellite is providing foothprint of DVB-RCS spot C, Ka and Ku-bands, which includes conections of local fixed (DVB-RCS2+F) and mobile core networks (DVB-RCS2+M to the DVB-RCS Hub terminals.
The DVB-RCS2+M architecture provides mesh and star connectivity between transport systems as an user side and fixed local network as an Internet wider subscriber side via GEO spacecraft and Hub terminals and mesh direct terminal-to-terminal connectivity or inter mobile communications. In fact, all mobile connections are going through GEO satellite on-board processors that mirrors the functions of a ground-based Hub terminal or through transparent satellites, using terminals equipped with an additional demodulator.

4. Antenna Eequipment for DVB-RCS2+M VSAT Stations

The parabolic antennas for mobile application installations on transport vehicles should be equipped with mechanical satellite tracking systems, which can provide constant tracking of GEO satellite to provide stable communication when the unit is in motion by keeping the antenna dish constantly directed to the GEO satellite. The VSAT antenna for fixed DVB-RCS applictions with VSAT units for fixed and mobile applications are illustrated in **Figure 7 (Lrft)** operating on radio frequency C, Ku or Ka-band. The same or similar VSAT units can be used for installations onboard oceangoing ships with shipborne VSAT antenna shown in **Figure 7 (Midle),** and for installation onboard aircraft or helicopters can be used airborne VSAT antenna depicted in **Figuere 7 (Right)**.

Fig.8. VSAT for Installation on the Roof of a Car

The compact folding VSAT antenna can be used for installation on the roof of a vehicle as shown in the **Figure 8 (Left).** This vehicle has a VSAT equipment installed inside that can be used for Satellite News Gathering (SNG). In **Figure 8 (Right)** is shown DVB-RCS portable antenna with VSAT satellite transceiver on the bottom. The phased antenna array is a contemporary alternative to parabolic antennas. This type of antenna has many tangible advantages to the parabolic antennas. As an example of the phased antenna array, which is "SpeedRay 1000" low-profile Ku-band satellite antenna, is presented in **Figure 9.**

Fig. 9. Low Profile Ku-band Phased Array Antenna for Trains and Buses

The VSAT satelite antenna offers commercial transportation vehicles the ability to easily upgrade entertainment systems with DVB-RCS2+M. This antenna can replace already installed parabolic antenna without any change to the rest of system being done. In contrast to a parabolic antenna the phased array antenna causes less drag due to its size and low profile and it doesn't comprise of any mechanical driving mechanism to track a satellite, which increase reliability of the antenna. The installed examples of low profile phased antenna array on the roof of the bus and train is shown in **Figure 10.**

The DVB-RCS+M technology provides satellite communication in C, Ka and Ku-bands. Utilizing of these frequency bands requires relatively small size of parabolic antenna, which are named as VSAT due to the size. As was mentioned before to provide operation and constant access for DVB-RCS2+M special antenna system with tracking is required. Two common types of antenna such as a parabolic antenna and phased antenna array for DVB-RCS2+M are considered.

All three bands are showing good propagation performances; however, going above 10 GHz the problems grow. At Ku-band, at 10 - 18 GHz range, in clear weather the attenuation is less than a decibel, but when it rains, this band is much more susceptible to rain fall than C-band, a noticeable degradation occurs, due to the problems caused by and proportional to the amount of rain fall, commonly known as known as "rain fade". A similar phenomena called "snow fade" (when snow accumulation significantly alters the dish's focal point) can also occur during Winter Season.

Fig. 10. The Phased Antenna Array Installed on the Roof of the Train and Bus

4. Conclusion

The presented material in the article shows application operation, architecture and communication abilities of DVB-RCS. The effective operation of the standard is achieved by means of convenient and technically smart arrangement of forward and return channels, which allows to provide up-link and down-link data speed more than 10 Mbit/sec.

Particularly DVB-RCS2+M technology allow internet access for mobile terminals, which can be installed on board of transportation vehicles. This standard requires all mobile units to be equipped with special satellite antenna system, which can track the satellite for constant satellite communication. Two types of satellite antenna systems parabolic and phased array antennas for DVB-RCS2+M technology were considered. Application of the phased array antenna is more advantageous due to absence of mechanical tracking mechanism and significantly smaller profile sizes.

Mobile DVB-RCS operators are deploying a range of different sub-networks to meet different demands in the satellite communications market to provide Internet to both urban and remote locations including the mobile segment. In order to provide high QoS at reasonable costs, operators will continuously aim to streamline an efficient and effective network operations organization.

By 2008, there were already more than 200 DVB-RCS systems deployed worldwide, serving around 150,000 fixed and mobile terminals at C, Ku and Ka-band. It can be expected that this number has significantly grown since then. Today DVB-RCS/RCS2 is the only multi-vendor VSAT standard, so for this reason it is often mandated in systems procurements by customers who wish to ensure that their choice of terminal vendor remains with maturity and capability well recognized.

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