2Way-Sat
by
Newtec

The Last Mile via DVB – RCS : IP over Satellite offering a valuable broadband access alternative

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Abstract

This article describes the DVB-RCS access technology as a valuable alternative for overcoming the last mile. After positioning DVB-RCS within the arena of other access methods, more insight into the DVB-RCS technology is given. Then we will describe Newtec's approach towards "2Way-Sat" communication based on DVB-RCS and the Service Level Agreement concepts. Finally, a general description of all network elements and the organisation supporting this project are given.

Introduction

Newtec has been playing and active role in the definition of the DVB-RCS standard due to its involvement in precurrent satellite systems like SES's – ARCS and Eutelsat's Skyplex. Presently, Newtec is developing a fully commercial DVB-RCS network in partnership with Spacebridge Semiconductors (specialised in wireless-access-ASICs) and Alcatel Bell Space (specialised in broadband Access Servers used in ADSL Networks and Traffic Scheduling).

This article gives insight in the different types of applications and their relation to access network methods. Furthermore the DVB-RCS Access method is highlighted and the Newtec "2 Way-Sat" solution is covered in extent.

Looking at applications running over the Last Mile

Data- and telecommunications networks or services always have had the need for reliable access facilities, in order to make the connection between the Customer premise and the core of the network backbone. In the past, access consisted typically of analogue lines equipped with modems, dial-in connections or digital leased lines.

Recently, we more and more observe the need for networks and access methods capable of supporting bandwidth hungry applications; applications requiring broadband connectivity.

In fact, the categorisation of the applications, which run over the last mile, can be based on two important parameters namely transport delay and also jitter (jitter being a measurement for the variance in delay) and the required bandwidth for that type of application.
Figure 1 illustrates these applications mapped on these parameters. Mainly we can divide these into three access types categories:

- **Pure One –Way**
- **Narrowband Two-Way**
- **Broadband Two-Way**

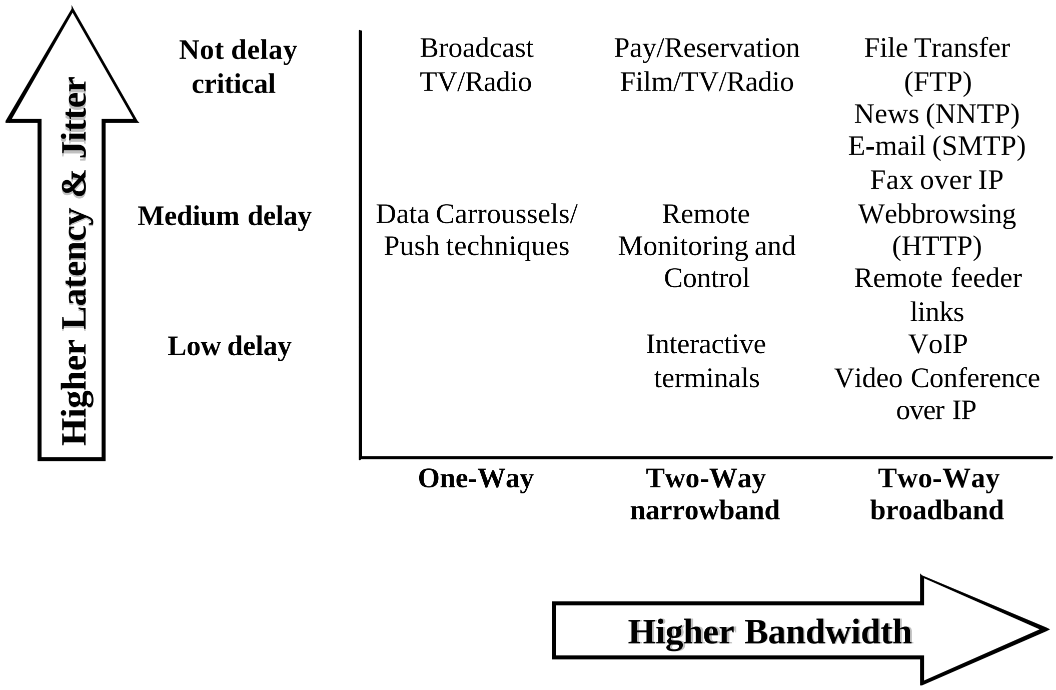

Figure 1 : Applications in relation to delay sensitivity and bandwidth requirements

The market place is currently evolving towards the use of more and more broadband IP applications (streaming, FTP, News feed) which is also due to the fact that reliable and cost efficient broadband access technologies are being introduced and deployed at high rates.

Within the satellite environment, access for this last category (Broadband Two-way) is often released in a hybrid form: forward link via satellite, the return link via terrestrial (dial-in PSTN) manner.

DVB-RCS, Digital Video Broadcast – Return Channel via Satellite, is a standard which was finalised by the DVB group. This standard is typically targeting at the broadband access networks requirements but offering a solution that is totally based on satellite communication (without any terrestrial links involved).

In the following paragraph we will position and compare this relatively new access technology with other technologies currently available on the business market.

Last Mile Technologies: DVB-RCS amongst others …

Depending on the required bandwidth and the population density, several access technologies are presently used. The most popular are mentioned in Figure 2. The access technologies fall into five broader categories:

(i) Based on Copper Lines (from early telephony links)

- Analogue and digital leased lines :
  Analogue lines are becoming more and more scarce and are phased out by the PTOs. Digital leased lines are still frequently used as access method but are peak rate dimensioned and rather expensive for limited bandwidths.
- Dial-up modems :
  This is still one of the most common access methods, due to the fact that it is relatively cheap for moderate volumes. However dial-in access suffers from limited bandwidth capabilities (typical up to 128 Kbit/s).
- ADSL-modems (Asymmetric Digital Subscriber Line) and xDSL-modems (x=A (asymmetric), S= (symmetric), H

= (high density), V = (Very High Speed)):
This relatively new access method is very successful in dense urban and urban areas. However there is a rapid degradation of the service in function of the distance between the customer and the DSLAM (Digital Subscriber Line Access Multiplexer) located at the CO (Central Office) of the PTO. Therefore this method is less suited for sub urban areas and certainly not suited for rural and remote regions.

(ii) Via installed Cable networks, Docsis technology (from early TV distribution):
Cable networks are less widespread than copper and satellite networks. Therefore this access method is only valid for those countries that operate extensive cable networks. Since the cable is also a shared medium (bus topology), capacity and eventually performance decreases with the number of users.

(iii) Via terrestrial wireless connectivity: MMDS (Multichannel Multipoint Distribution System), LMDS (Local Multipoint Distribution System), 3G (Third Generation Wireless e.g. UMTS, W-CDMA,…), Optic Wireless (short range, high capacity IR links).
Most of the above mentioned access techniques have still limited capacity means and imply most often large investments for network roll-out. Also regulatory issues can be quite cumbersome for these wireless methods. Aspects such as Line of Sight and signal fading and interference should be considered thoroughly. Therefore the target markets are typically situated in dense or urban population areas.

(iv) Via Satellite Wireless connections: VSAT, Inmarsat. These current satellite solutions are rather expensive and mostly limited to low capacities. DVB-RCS method overcomes these shortcomings as you will notice reading through this article.

(v) Via Fibre Optic Networks, FTTR (Fibre to the Riser), FTTC (Fibre to the Home)
FTTH (Fibre to the Curb): Currently Fibre networks are predominantly used in network backbones and for the long haul. For access networking, the level of penetration is still rather low. The methods FTTR, FTTH, FTTC allow high bandwidth capacity with very low bit error rates, but they are only cost effective in areas where high revenue potential is available.

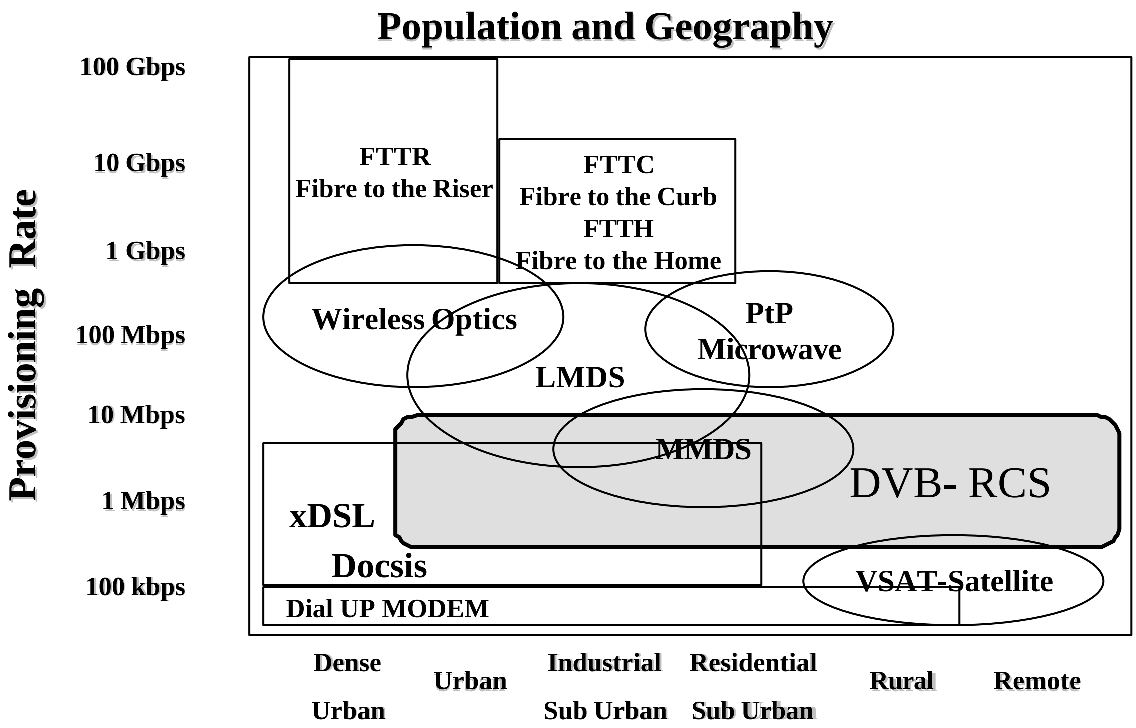

Figure 2 : Access technologies

DVB-RCS as Last Mile Technology

The main target group of DVB-RCS are broadband Two Way networks requiring asymmetrical connectivity; forward rates of 1 to 10 Mbps and return rates of 0.2 – 2 Mbps.
This is also typically the segment for which in dense urban areas the ADSL access technology is a very suitable solution. However, due to high investment and relative short haul (ADSL runs over copper up to about 4 km) ADSL is certainly not the right choice for other areas. DVB-RCS however is well suited as access method for all SMEs located in suburban and rural regions. At the right time also the full potential of consumer and residentials residing in those regions will become a target market.

On the long term, medium delay applications requiring high bandwidth will be served via a Star Configuration using transparent satellites (Ku/Ku – Ka/Ku – Ka/Ka).
For application requiring a short delay and high bandwidth, a Meshed structure is possible, using in this case On board Processing satellite transponders (similar to the existing Skyplex transponders).
Figure 3 illustrates the Star and Meshed topologies.

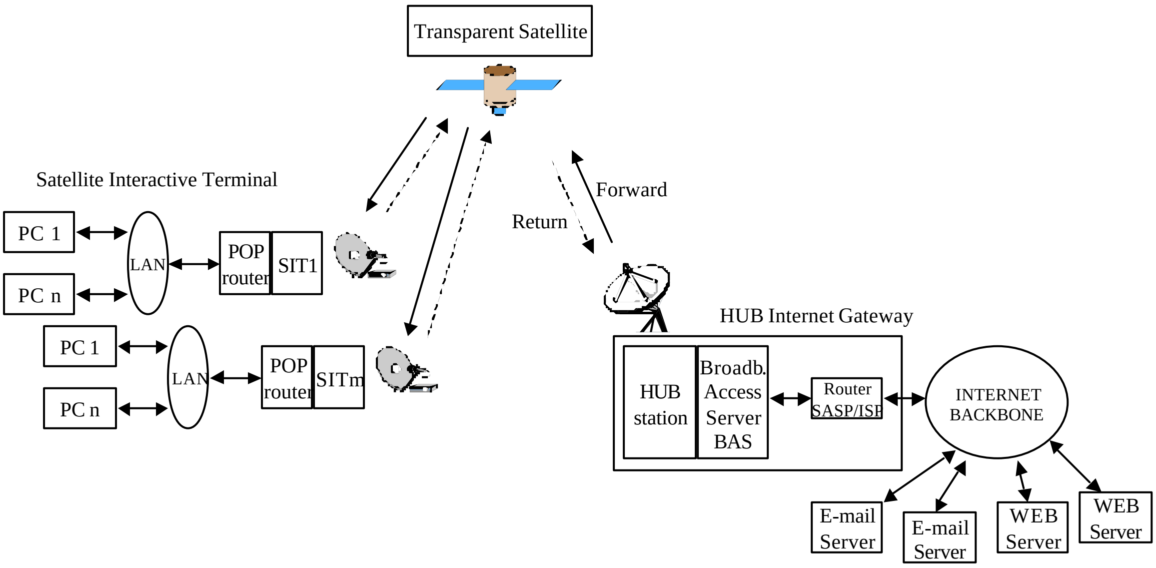

Figure 3a : DVB-RCS Star topology

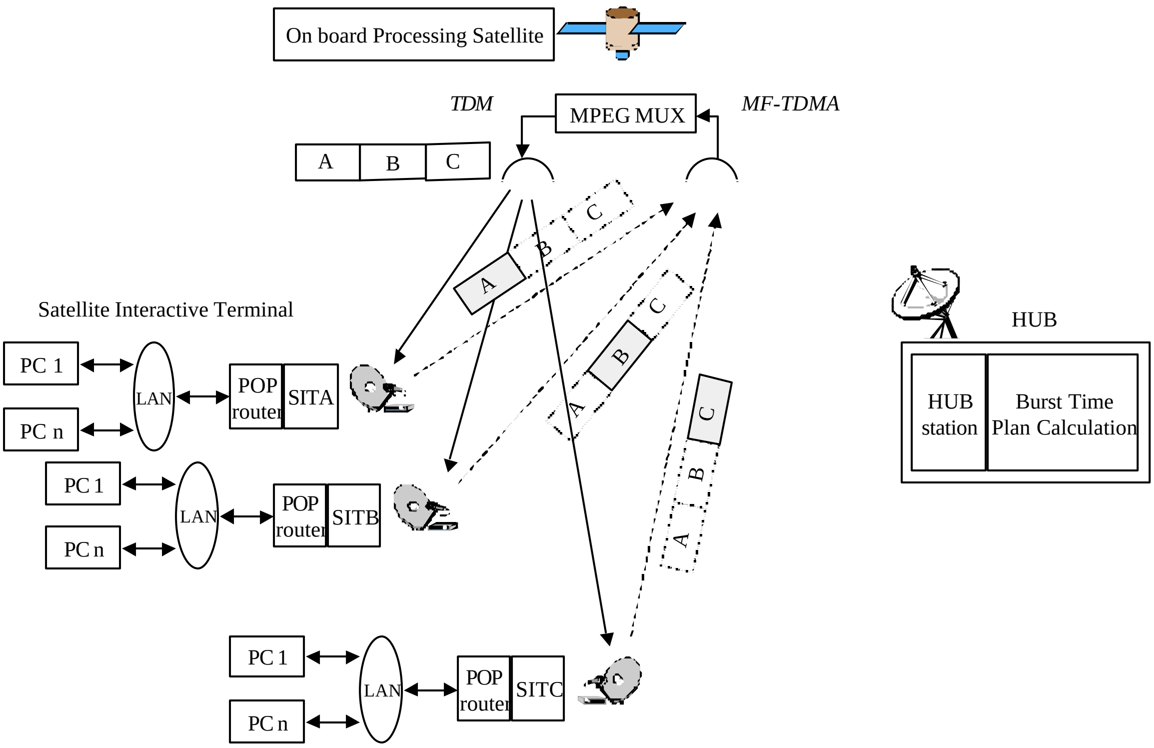

Figure 3b :DVB-RCS meshed topology; a possible future enhancement

Newtec's " 2Way-Sat" Solution

The way Newtec has implemented and developed the DVB-RCS standard into the "2 Way-Sat" solution leads to the following major advantages:

Scalability

The Newtec "2 Way-Sat" solution is scalable to specific markets and their needs; it also allows to start with a limited sized access network, which has the potential to grow in size and this without endangering prior investments.

- A **"2Way-Sat-Light"** version allows to upgrade today's existing One-Way solutions (DVB) to become DVB-RCS compliant. This would allow networks up to 100 Satellite Interactive Terminals (SITs)
- A **"2Way-Sat-Medium"** version allows to realise a medium sized access network of 100 to 3000 SITs (using a single satellite transponder)
- A **"2Way-Sat-Large"** version is scaled to large access networks, requiring connectivity to 3000 up to 50000 SITs. These networks are realised by using multi transponders.
- A **"2 Way-Sat-Consumer"** version is foreseen for consumer networks of 100K up to 10 M SITs using Ka/Ka multi spot beams.

The first 2 versions are operational in 2001; the "Large" version will be ready in 2003 and finally the Consumer version is targeted for 2004-2006.

DVB-RCS compliant

The "2Way-Sat" is DVB-RCS compliant (cfr EN301790) which has the following major advantages:

- Large Scale Integration – of the DVB –S market can be reused incl. future evolutions (e.g. turbo coding – 8PSK) of this global used technology.
- An interoperability roadmap with other SIT and Hub manufacturers using the DVB-RCS standard is facilitated.
- Statistical multiplexing features like VBDC, CRA, FCA (Volume-Based Dynamic Capacity, Constant Rate Assignment, Free Capacity Assignment) can be used in an intelligent way to maximise the return link transmission efficiency.
- DVB-RCS has defined an innovative and low cost way to synchronise the SITs in time and frequency

Guaranteed Service Levels

The Newtec "2Way-Sat" solution realises guaranteed Service Levels for the different classes of users in both the return and the forward links. In the Return link the DVB-RCS concepts are implemented and designed in a very innovative manner; which results in an extreme performant solution. This is realised by the Scheduler sub system.
In the forward link, ATM-QoS algorithms will be implemented to match the return QoS. This is realised and implemented by means of Alcatel's XANA- Broadband Access Server (BAS).

TCP Protocol Enhancement Proxy*

Data networking over satellites is faced with overcoming the large delay typical of satellite communications, as well as the asymmetric bandwidth design of most satellite networks. This results in a limited throughput for TCP/IP links over satellite. This is conventionally solved by using a Performance Enhancing Proxy (PEP) between the User-POP/ Routers and the ISP Data Center (IDC) (Figure 4).

Satellite conditions adversely affect a number of elements of the TCP architecture, including its congestion avoidance algorithms, data acknowledgment mechanisms, and window size limitations, which combine to severely constrict the data throughput rate that can be achieved over satellite links.

- Congestion Avoidance: In order to avoid the possibility of congestive network meltdown, TCP assumes that all data loss is caused by congestion and responds by reducing the transmission rate. However, over satellite links, TCP misinterprets the long round trip time and bit errors as congestion and responds inappropriately. Similarly, the TCP "Slow Start" algorithm, which over the terrestrial infrastructure prevents new connections from flooding an already congested network, over satellites forces an excessively long ramp-up for each new connection. While these congestion avoidance mechanisms are vital in routed environments, they are ill-suited to single-path satellite links.
- Data Acknowledgements: The simple, heuristic data acknowledgement scheme used by TCP does not adapt well to long latency or highly asymmetric bandwidth conditions. To provide reliable data transmission, the TCP receiver constantly sends acknowledgements for the data received back to the sender. The sender

does not assume any data is lost or corrupted until a multiple of the round trip time has passed without receiving an acknowledgement. If a packet is lost or corrupted, TCP retransmits all of the data starting from the first missing packet. This algorithm does not respond well over satellite networks where the round trip time is long. Further, this constant stream of acknowledgements wastes precious back channel bandwidth. If the back channel bandwidth is small, the return of the acknowledgements to the sender can become the system bottleneck.

- Window Size: TCP utilises a sliding window mechanism to limit the amount of data in flight. When the window becomes full, the sender stops transmitting until it receives new acknowledgements. Over satellite networks, where acknowledgements are slow to return, the TCP window size generally sets a hard limit on the maximum throughput rate. The minimum window size needed to fully utilise an error-free link, known as the "bandwidth-delay product," is 100 KB for a T1 satellite link and 675 KB for a 10 Mbps link. Bit errors increase the required window size further. However, most implementations of TCP are limited to a maximum window size of 64 KB and many common operating systems use a default window size of only 8 KB, imposing a maximum throughput rate over a satellite link of only 128 Kbps per connection, regardless of the bandwidth of the data pipe.

This PEP enhancement overcomes these obstacles and is transparent for the TCP/IP links running between User site and the Internet. Since UDP is a data gram protocol (no acknowledgements), within the IP stack PEP will not intervene in these packets.

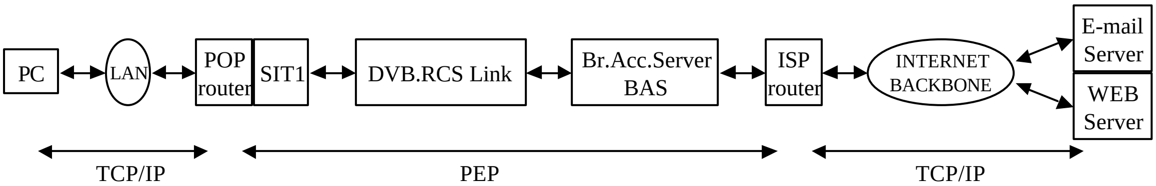

Figure 4 : TCP Protocol Enhancement Proxy - PEP Concept

Concept of SLA

An increasingly popular concept is the Service Level Agreement, or SLA. This concept describes the quality and the level of services offered to the Access Users. For ISPs (Internet Service Providers) SLA is one of the main differentiators in the highly competitive arena of the ISP market.
SLAs mostly consist of several items such as, committed delivery periods, access availability, throughput guarantees and guaranteed delay.

Below, we focus on the throughput SLA parameter. Newtec's DVB-RCS implementation offers the possibility to create different classes of users based on their typical traffic profile. This feature will allow the ISPs to differentiate their services (Internet Access and Value Added Services) towards their targeted end customers; the SME market and further in time the residential user market.

The return access rate and availability is maximised by the following means:

- The SPPA (Solid State Power Amplifiers) operate at saturation delivering the strongest power today. This results in the highest possible rates.
- In case of interference or fading the rate is dynamically adapted, resulting as such in an availability higher than 99.9%
- In case of too many concurrent capacity requests, a fair traffic sharing is implemented between classes of users and different applications.
- Traffic Volume/sec is varying heavily over daytime. Statistical multiplexing techniques and multiple classes of users are implemented in order to make cost

efficient use of the available satellite bandwidth within the access network.

Classes of users / User Profiles

Different types of end users will subscribe with an ISP to obtain Internet Services provided through the means of a DVB-RCS access network. The differences can be due to:

- Number of PCs and hosts connected to the Local Area Network (LAN) of the end user
- The (mix of) applications mainly used by the end users (Web browsing, FTP, Streaming services, E-mail), all resulting in different traffic patterns.
- The variances in time and volume (number of concurrent users) of the use of the Internet Services.

In order to deliver the end user a good performance of the purchased Internet, it is important to anticipate this different behaviour by offering the choice of different classes to match the different user profiles.

For instance, one could envisage the following different classes based on bandwidth and consumed volume (Table 1 & 2).

Bandwidth Classes	FW link (kbps) per SIT		Return link (kbps) per SIT	
	Max	Min(*)	Max	Min(*)
A	512	128	128	32
B	1024	256	256	64
C	2048	512	512	128
D	2048	1024	512	256

Table 1 : Bandwidth Classes FW & RT bandwidth specifications

Theoretically, such bandwidth classes would result in the following monthly volume amounts (considering the SME market and if bandwidth would be constantly used)

22 * 8 * 3600 * bandwidth

Business days * business hours * seconds in an hour * bandwidth

Bandwidth Classes	FW link monthly volume (Gbytes) per SIT		Return link monthly volume (Gbytes) per SIT	
	Max	Min(*)	Max	Min(*)
A	40	10	10	2.5
B	81	20	20	5
C	162	40	40	10
D	162	81	40	20

Min(*) stands for the minimum committed capacity that a SIT is always capable of transmitting or receiving.

Table 2 : Bandwidth Classes FW & RT link volume specifications

Therefore we could imagine a possible pricing scenario based on the different classes of users (bandwidth) and also on the consumed monthly volume (Table 3). Doing so, we can further distinguish e.g. between the heavy bandwidth users requiring almost continuously this bandwidth or users only requiring periodically high throughput to smoothly run their applications.

	Volume on FW+RT link (Gbyte/Month)				
Bandwidth classes	< 0,25	< 0,5	< 1	<2	>2
A	P1	P2	P3	P4	P5
B	P2	P3	P4	P5	P6
C	P3	P4	P5	P6	P7
D	P4	P5	P6	P7	P8

Pi : indicates a price range where P1 < P2< ……<P8

Table 3 : Possible Pricing Scenario

Transponder bandwidth

Example, assuming a monthly volume for the average user is estimated to be 0,4 Gbytes in the forward link and 0,1 Gbytes in the return link, we derive the required bandwidth for the transponder.

Example for 4000 SITs:

Monthly volume
= 4000 SIT * 0,4 Gbytes/SIT
= 1600 Gbytes/month for the FW link

Monthly volume
= 4000 SIT * 0,1 Gbytes/SIT
= 400 Gbytes/month for the RT link

In order to compute the required bandwidth for the satellite transponder, we must adjust our calculation with a Most Busiest Hour (MBH) factor. This MBH factor expresses the ratio of volumes handled in the Most Busiest Hour over the volume handled in an average business hour. The level of this MBH factor has to be experienced in practice. Presently a factor 2 is assumed.

Transponder BW forward link
= 1600 Gbytes / (3600 * 8 * 22) * 8 * 2
= volume / (sec per month business days) * bits per byte * MBH
= 40 Mbps

Transponder BW return link = FW /4
= 10 Mbps

The HUB station

This can be split in the Satellite Access Part and the ISP Data Center Part as shown on Figure 5.

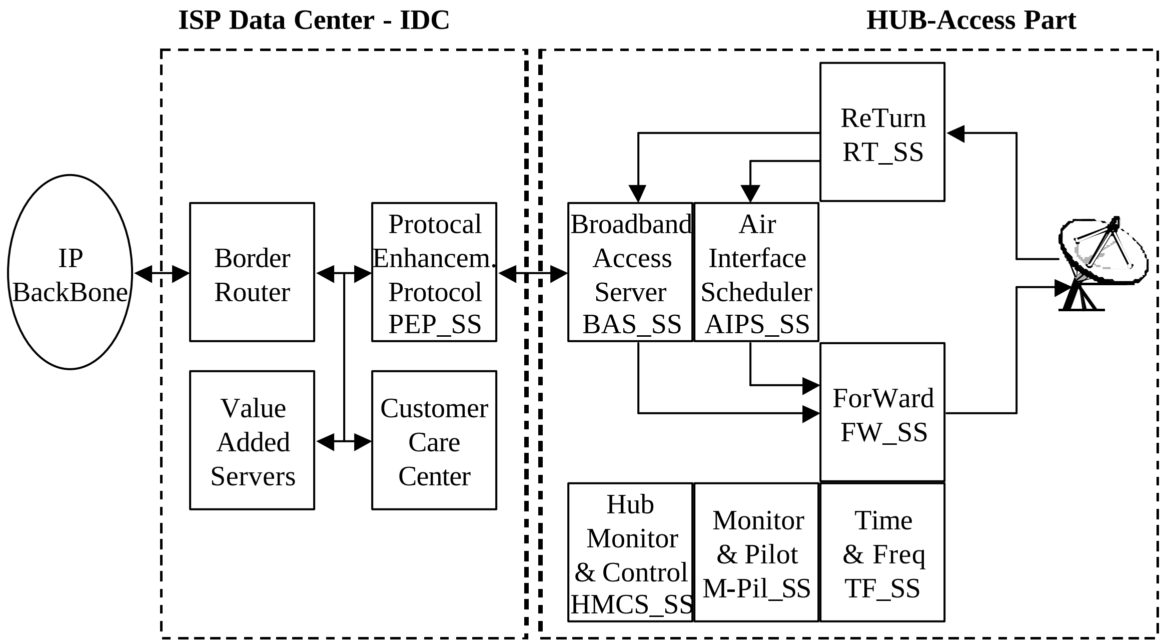

Figure 5 : Block Diagram HUB Earth Station

(i) The focal point of the Access Part is the Broadband Access Server Subsystem (BAS_SS). Alcatel's XANA Server is selected, since it is specialised in large broadband ADSL networks. It's redundant backplane allows a throughput of 2 to 20 Gbps, which is sufficient for the targeted DVB_RCS network. In the forward direction, ATM QoS algoritms are implemented which allows to match the forward SLA to the return SLA, which is controlled by the AIPS_SS (Air Interface Processor - Scheduler subsystem).

(ii) The forward BAS signal (IPoETH) is encapsulated into a DVB stream. An NCR (Network Clock Reference), based on a GPS received 10 MHz and 1 pps is inserted into the Forward transport stream. This transport stream (at ASI interface) allows the Return_SS and the SITs to extract a very accurate frequency reference (for carrier frequency generation), symbol clock reference and time reference (for time slot generation).
The output of the FW_SS at RF frequency is send to the Tx port of the antenna.

(iii) The received signal from the antenna is converted to L-band, via a PL_LNB_SS (which Local Oscillator is also slaved to the 10 MHz of the Time & Frequency_SS). The L-band signal is applied to a bank of Burst Demodulators in the Return Link SS (RT_SS). Burst Demodulators are combined in a return group, which supports several return MF_TDMA carriers. The traffic output of the Burst Demods in such a group is recombined in a single OC3 data stream, via an ATM_Combiner Unit to the BAS_SS.

(iv) The AIPS_SS (Scheduler_SS) is placed in parallel with the BAS_SS. It receives the bandwidth requests of the SITs. It calculated an optimum SIT-Transport Schedule every 140 msec, based on high performant VBDC, FCA and CRA algorithms. It sends to the SITs a BTP for the Return Carriers. The Return Carriers are grouped in several baud-rate carriers. Based on the measured link performance, the AIPS_SS will detect possible fading conditions or interference conditions at each SIT-site.
As a consequence, each SIT will be placed in the highest possible baud rate, which corresponds to it's fading or it's interference.

(v) All frequencies of the HUB and SITs are slaved to the 10 MHz of the T&F_SS, except the Satellite. The Monitor & Pilot Subsystem therefore measure the frequency translation of the satellite. This information is sent to all bursts demodulators, which allows to use a minimum acquisition range in these Burst Demodulators.

(vi) All the subsystems of the HUB station are monitored and controlled via the HMCS_SS (Hub Monitor & Control Subsystem).

(vii) Another important element in DVB_RCS is the PEP Server (the protocol Enhancement proxy), which converts the TCP protocol to a Sky X protocol ; which has windows optimised for the satellite delay. This is also called a "TCP-Accelerator". As a result, the TCP performance limit over satellite is increased from 300 kbps to above 1.5 Mbps.

(viii) The CCC_SS (Customer Call Center) allows to configure all required parameters of each SIT in the network (e.g. position, SLAs. etc.). The SIT access parameters are sent to the HMCS_SS data base.

(ix) The interconnection to the Internet Backbone is realised via typical ISP-Border routers, incl. the required Fire-Wall equipment.

(x) Finally, several VAS_SS (Value Added Servers) will be implemented such as Reliable Multicast File Transfer: Video Streaming, etc.

The Satellite Interactive Terminal (SIT)

This can be split in 3 parts (Figure 6) :
- the outdoor part
- the indoor part
- the existing Customer LAN Equipment (PC's and LAN).

(i) The output part consists of an antenna (Ku, Ka or other frequency bands). Typically, a 75 cm antenna is considered, since this is easily accepted by the authorities and it allows sufficient broadband access. In those contours, where reception and transmission is not very good, larger antennas would be used (e.g. 90 & 120 cm).
In reception, a commercial LNB is used (Ku, Ka or other frequency bands). The L-band interface is connected to the Indoor Unit via a coax cable.
In transmission, a High Power Block Up Converter to Ku, Ka (or other frequency bands) is used. Typically, a 2Watt is used for Ku and 1 Watt is used for Ka-SITs.
An S-band interface cable from the Indoor Unit allows an easy implementation.

(ii) The indoor part consists of the SIT-Indoor Unit and the SIT-POP Router. Both functions are split, since the POP router is usually a delivery of the DVB_RCS operator.
The Indoor Unit (IDU) contains a DVB_S demodulator ; a DVB_RCS Burst Modulator ; a MAC processor and optionally an IPsec processor. The POP-Router Box contains the PEP functions, Caching functions and possible NAT and DHCP functions for the LAN.

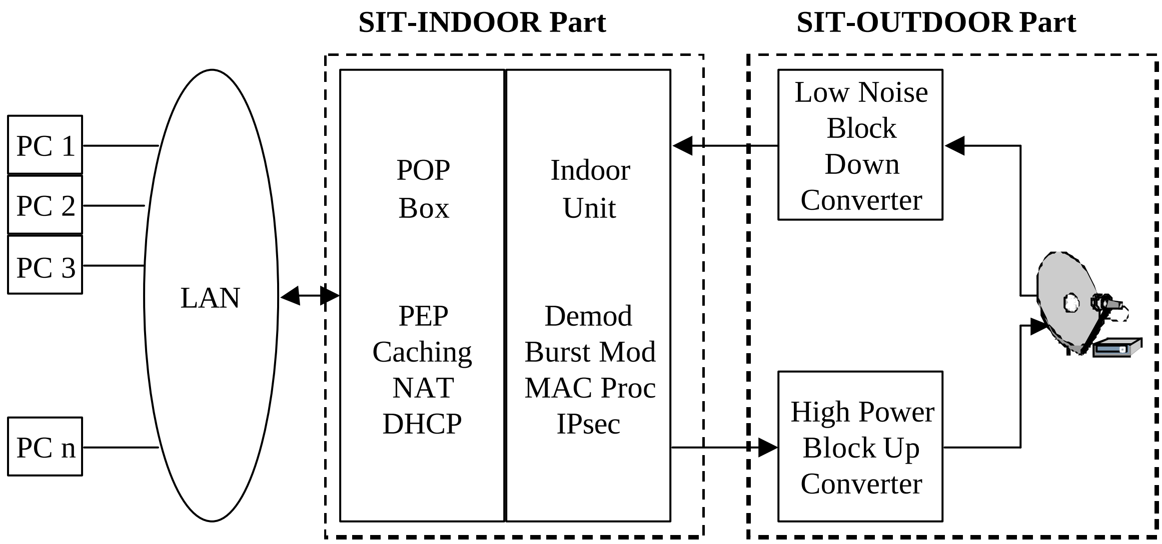

Figure 6 : Block Diagram SIT (Satellite Interactive Terminal)

Consortium Organisation

The "2 Wat-Sat" consortium is led by Newtec Cy ; which has a high experience in DVB networks and is providing the HUB-RF and Modem equipment ; the SIT-Outdoor Unit and Indoor Unit assembly. Alcatel Bell Space has a high experience in Access Networks (Scheduling_SS, the Broadband Access Server and HMCS_SS). Spacebridge Semiconductors is the WIRELESS-ASIC developer specialist of the team.

Conclusion

In this article we presented the DVB-RCS access technology and positioned it in the arena of access technologies. Since applications require more and more broadband based connectivity, DVB-RCS broadband access is a very well placed player in this arena. Inherent and related specifically related to satellite communications is the capability to reach any type of population within large geographic areas. The unique multicast capabilities of Satellite Communication is an other strong asset. Furthermore DVB-RCS has the benefit of delivering QoS possibilities, resulting in an attractive SLA for the end users.

Newtec has been very active in the definition of the DVB-RCS standard. This results in a profound know how and intelligent and innovative ways of implementing the DVB-RCS standard into commercial DVB-RCS access network systems.

About Newtec

Newtec is a Belgian Company, with Sales Offices in North America and south-east Asia, recognised as a leading manufacturer of satellite telecommunication equipment world-wide. The expertise of Newtec relies on more than 16 years of experience in manufacturing and providing satellite equipment, earth stations, communication networks and related services for applications such as digital television exchange, interactive and broadband access, internet and intranet communication, corporate networks, telecom operator infrastructure and scientific programs.

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