Broadband Satellite Communications
the DVB-RCS-NG Standard

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DVB-RCS Next Generation

What is it?
- A broadband access system via satellite for fixed and mobile applications

Market segments
- Fixed networks
  - Consumer, Multi-dwelling, Corporate, SCADA
- Mobile networks
  - Aeronautical, Railway, Vehicular, Nomadic, Maritime

Objectives
- Low cost for consumer terminal
- Robustness
- Capabilities competitive with ADSL2+ and cable
- Ability to support star and mesh networks
- Interoperability at all layers
- Fast definition of the standard
Broadband Access: a key element for economic recovery
The International approach to Broadband Access

- Development of “Broadband Access” is considered worldwide as a key element for Economic Recovery:
  - The European Commission, as part of its “Economic Recovery Plan”, aims at achieving 100% high-speed internet coverage for all citizens by 2010
    - 30% of the European Rural Areas are not reached by broadband access
    - Constant rate investment until 2015 in “broadband access” can produce 1 million jobs and 850 billion economy growth
    - 1 billion euro has been earmarked in January 2009 to extend broadband access to rural areas
  - On November 5, 2007, the European Parliament and the Council of Ministers agreed a new telecom package that foresees 12 reforms among which
    - “Accelerating broadband access for all Europeans“
    - ”Encouraging competition and investment in next generation access networks”
  - The US Government issued “the American Recovery and Reinvestment Act” on February 2009
    - The extension fo broadband deployment in unserved, underserved, and rural areas and to strategic institutions is identified as a way to create jobs, spur investments in technology and infrastructure, and provide long-term economic benefits
    - 7.2 billion dollars have been reserved as “Broadband Stimulus”
BROADBAND ACCESS OUTLOOK
IN OECD COUNTRIES

Source:
OECD
Organization for Economic Co-operation and Development
www.oecd.org
OECD countries

- Austria
- Belgium
- Czech Republic
- Denmark
- Finland
- France
- Germany
- Greece
- Hungary
- Ireland
- Italy
- Luxembourg
- Netherlands
- Poland
- Portugal
- Slovak Republic
- Spain
- Sweden
- United Kingdom
- Norway
- Switzerland
- Turkey
- United States
- Canada
- Mexico
- Japan
- Korea
- Australia
- New Zealand
- Iceland
Broadband penetration

OECD Broadband subscribers per 100 inhabitants, by technology, December 2008

Source: OECD

OECD average
Broadband Penetration and Country Landmass

Source: OECD

(correlation: 0.02)
Broadband penetration vs. Population dispersion

Source: OECD
Broadband penetration vs. GDP per capita

**OECD broadband penetration and GDP per capita**

- **GDP per capita (USD PPP, 2007)**
- **Broadband penetration (subscribers per 100 inhabitants, Dec 2008)**

Simple correlation = 0.65

**Source:** OECD
Broadband Service Cost

Entry and average monthly broadband price as a percentage of monthly GDP per capita

Source: OECD

OECD Broadband subscribers per 100 inhabitants, by technology, December 2008

Source: OECD
Considerations

- Broadband penetration is limited by the service cost and service quality, e.g.
  - Wildblue customers’ location closely follows the population density map
  - There almost no perceived bias towards rural area
  - Customers are typically suburban with poor DSL services

- Recent studies have shown that the coverage costs through a fiber infrastructure increase exponential with the coverage (the last 7% coverage would cost as much as the entire network!)

- Unlikely that the total coverage objective can be reached through a fiber-based approach (too expensive)
  - Wireless solutions among, which Satellite Networks, represent a viable and competitive alternative provided that service cost and quality are comparable

Source: DVB RCS CM presentation
Examples of Service offering on 2-way satellite Broadband Access

<table>
<thead>
<tr>
<th>Offer Service Provider X</th>
<th>Equipment Cost: €299-399</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Down-link (kbps)</strong></td>
<td><strong>Up-link (kbps)</strong></td>
</tr>
<tr>
<td>2048</td>
<td>384</td>
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<tr>
<td>2048</td>
<td>384</td>
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<td>2048</td>
<td>384</td>
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<td>2048</td>
<td>384</td>
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<table>
<thead>
<tr>
<th>Offer Service Provider Y</th>
<th>Equipment Cost: €399</th>
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<tbody>
<tr>
<td><strong>Down-link (kbps)</strong></td>
<td><strong>Up-link (kbps)</strong></td>
</tr>
<tr>
<td>512</td>
<td>96</td>
</tr>
<tr>
<td>1024</td>
<td>128</td>
</tr>
<tr>
<td>2048</td>
<td>128</td>
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</table>

<table>
<thead>
<tr>
<th>Offer Service Provider Z</th>
<th>Equipment Cost: €615</th>
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<tbody>
<tr>
<td><strong>Down-link (kbps)</strong></td>
<td><strong>Up-link (kbps)</strong></td>
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<tr>
<td>512</td>
<td>256</td>
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<td>1024</td>
<td>256</td>
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<tr>
<td>2048</td>
<td>512</td>
</tr>
<tr>
<td>3072</td>
<td>768</td>
</tr>
</tbody>
</table>

*Source: ESOA “Satellite broadband: a sustainable solution”*
Total broadband market size available > 20 Million in Europe and North America

The cost of the service will significantly drop due to a more efficient exploitation of the spectrum thus making the consumer market more appealing

Satellite broadband access market booming thanks to multi-spot satellite systems
Large multi-spot beam satellite networks, most in Ka band have recently been deployed or are being developed and will be operational over the coming years:

- **US:**
  - WildBlue (2006, 30 Gbps, 41 beams),
  - Spaceway-3 (2007, 10 Gbps, 100 beams),
  - ViaSat-1 (2011, 100 Gbps)

- **Europe:**
  - HylasOne (2009, 8 beams),
  - KaSat (2010, 70 Gbps, 80 beams)

- **Asia/Pacific:**
  - IPStar-1 (2005, 84 Ku beams)

**Terminals market:**

- 125,000 consumer VSATs have been shipped in the US in 2006 (source: COMSYS)
- WildBlue ordered 500,000 terminals in 2007
- By mid-2007, Hughes and WildBlue had already around 450,000 subscribers (source: COMSYS)

**Large population in Europe, but also in Latin America, still not reached by terrestrial access technologies**
Broadband Satellite Access: open standard approach

- Need for an open standard to ensure
  - Low cost device: economy of scale in chip development and manufacturing
  - Terminal Interoperability

- Next generation of Digital Video Broadcasting Return Channel via Satellite
The Digital Video Broadcasting (DVB) Project

- Point to multipoint transmission standards for large volume of information at high data rate
- Information is mainly audio and video (MPEG2 format) but can also be other data

**Transmission (FL)**

- **DVB-S and S2** → Satellite channel
- **DVB-T/H** → Terrestrial channel (fixed and mobile)
- **DVB-SSP** → Satellite Services to Portables (aka DVB-SH)
- **DVB-T2** → Terrestrial 2nd generation
- **DVB-NGH** → New Generation Handheld (still in study mission phase)
- **DVB-C** → Cable channel
- **DVB-MS** → Multipoint transmission system @ 10 GHz and above
- **DVB-MC** → Multichannel Distribution System below 10 GHz
- **DVB-MT** → Microwave terrestrial transmission

**Interactivity (RL)**

- **DVB-RCC** → cable TV distribution systems
- **DVB-RCP** → ISDN, PSTN
- **DVB-RCD** → DECT
- **DVB-RCL** → Local Multipoint Distribution Systems (LMDS)
- **DVB-RCG** → GSM
- **DVB-RCCS** → Satellite Master Antenna TV (SMATV)
- **DVB-RCS** → Satellite (now with Mobile Extension DVB-RCS+M)
- **DVB-RCT** → Digital TV including multiple access OFDM
- **DVB-RCGPRS** → GPRS

**Ad-hoc groups**

- **DVB-CBMS** → Convergence of Broadcast and Mobile Services
DVB Broadcasting and Broadband Standards

**DVB-S2 (published in 2003)**
- Strong forward error correction (LDPC)
- High order modulation
- Adaptive Coding and Modulation (interactivity)

**DVB-SH specification for Broadcasting to handheld**
- Frequency bands below 3GHz
- DVB-SH A (OFDM DVB-H sat. link + DVB-H terr. Link)
- DVB-SH B (S2 modified sat. link + DVB-H terr. Link)

**DVB-H added to DVB-T (2004):**
- Broadcasting to handheld
- Evolution of DVB-T

**DVB-T2 (started in 2007):**
- Evolution of DVB-T
- Specifications approved in 2008

**DVB-RCS Annex L (April 2005):**
- Guidelines for RCS applicability to mobile
- Limited scope, no changes to the standard

**DVB-RCS (2001):**
- Fixed services (e-medecine, e-education, internet, VoIP)
- VSAT antennas ➔ AWGN Channel
- Mobility effects only due to satellite movement

**DVB-RCS+M extension to mobile broadband (March 2006):**
- Mobile Services to collective terminals (aircraft, ships, train, buses, cars)
- Specifications approved in June 2008

**DVB-T (1997):**

**DVB-S (1993):**

**DVB-S2** ➔ **DVB-SH** ➔ **DVB-T/H** ➔ **DVB-T2** ➔ **RCS+M** ➔ **DVB-RCS-NG**

DVB-RCS-Next generation
- Activity started end of 2008

TODAY
Digital Video Broadcasting Project

- DVB General Assembly (all DVB Members)
  - Elections
  - Reports

  * Ad-hoc groups
    - CM-RCS
    - CM-3DTV
    - ....

  * Commercial Module

- Steering Board
  - Specifications
  - Technical Specifications
  - Commercial Requirements
  - Study Mission

  * Ad-hoc groups
    - TM-RCS
    - TM-SSP
    - TM-T2
    - ....

  * Technical Module

- Standard Development Organizations e.g., ETSI
  - Specifications
  - Technical Specifications
  - Commercial Requirements

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  - Technical Specifications
  - Commercial Requirements

A. Vanelli-Coralli, Broadband Satellite Communications, Roma - Nov. 11, 2009
Standard production

- **External SDO**
  - TM to monitor developments
  - TM to produce guidelines
  - TM to produce specs
  - TM to select Technologies
  - SB Approval
  - CM to produce CR
  - TM to produce CfT
  - Technologies’ proposals
  - Members & non-members
  - External SDO

A. Vanelli-Coralli, Broadband Satellite Communications, Roma - Nov. 11, 2009
DVB-RCS Next Generation: a new standard

Objectives (from CM-RCS)
- Low cost for consumer terminal
- Robustness
- Capabilities competitive with ADSL2+ and cable
- Ability to support star and mesh networks
- Interoperability at all layers
- Fast definition of the standard

Market segments (from CM-RCS)
- Fixed networks
  - Consumer, Multi-dwelling, Corporate, SCADA
- Mobile networks
  - Aeronautical, Railway, Vehicular, Nomadic, Maritime
DVB-RCS-NG Organization
(source: DVB-RCS 1049, TM-RCS)

DVB NG “SatCom” = DVB-RCS2+ DVB-S2 + DVB-HLS

DVB-HLS (Higher Layer Satellite)
IP, Management, higher layers

DVB-RCS2
PHY LINK

DVB-S2
PHY LINK

System Group
- System aspects
  - Review
  - Quality
  - Testability
  - Classes
  - Migration
  - RCS1 comp
  - CM reqs.

Study Group
- Simulations
  - Verifications
  - Parameters
  - Support

Mesh Extension
Mobile Extension
Security Issues
# DVB-RCS-NG Call For Technologies (from TM-RCS)

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<th>Technology Area</th>
<th>Aspects</th>
<th>Example of Technology Proposals</th>
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<td>Physical Layer</td>
<td>Coding</td>
<td>Turbo-Phi, 3D Turbo, LDPC</td>
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<tr>
<td></td>
<td>Modulation</td>
<td>BPSK, QPSK, 8PSK, M-APSK/M-QAM, CPM, ACM, SRRC with low rolloff factor</td>
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<tr>
<td></td>
<td>Framing</td>
<td>Pilot symbol insertion, Enhanced Framing</td>
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<td>Advanced Techniques</td>
<td>Co-/Adjacent-channel interference cancellation</td>
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<tr>
<td>Lower Link Layer (MAC)</td>
<td>Access Scheme</td>
<td>Enhanced Random Access Channel integrated with DAMA</td>
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<td>IP Encapsulation</td>
<td>Continuous carrier integrated with DAMA</td>
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<td>Transport of Return Link Signalling</td>
<td>Optimized Signalling</td>
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<tr>
<td><strong>Section B</strong></td>
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<tr>
<td>Upper Link Layer</td>
<td>Virtual Satellite Networks</td>
<td>MPLS, VLAN (IEEE 802.1Q), VPN</td>
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<td>Differentiated QoS &amp; Bandwidth Management</td>
<td>Request classes, QoS mapping</td>
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<td>Support for TRANSEC</td>
<td>Hooks for TRANSEC</td>
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<td>IP and Upper Layers</td>
<td>Header Compression</td>
<td>ROHC</td>
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<td>Performance Enhancing Proxy</td>
<td>TCP acceleration, web caching</td>
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<td>IP QoS Differentiation</td>
<td>DiffServ</td>
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<td>Support for COMSEC</td>
<td>COMSEC and PEP integrated solution</td>
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<td>Management and Control</td>
<td>FCAPS</td>
<td>Interfaces towards terrestrial broadband networks</td>
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<td>Service management interfaces</td>
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<td>Management protocols</td>
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<td>SW download protocols</td>
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<td>C2P</td>
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<tr>
<td></td>
<td>Installation Procedures</td>
<td>Plug&amp;Play Tools</td>
</tr>
<tr>
<td></td>
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<td>Terminal configuration</td>
</tr>
</tbody>
</table>
Proposed Technologies at lower layer

- LLC
  - STM

- MAC LAYER
  - Random Access ESA/DLR
  - CRDSA SE
  - Aloha Modification HNS
  - TDMA+RA STM
  - Symb Synchronous SE
  - Condensed Band Assign. TBTP HNS
  - Distributed Band Assign. ETRI/UAB

- PHYSICAL LAYER ADAPTATION
  - RGSE
    - DLR

- PHYSICAL LAYER
  - Turbo-Phi STM (ENST)
  - 3D Turbo ENST
  - CPM & eBCH ETRI-Mavigex
  - Flexible CPM Newtec
  - Linear Modulation STM
  - Heavy Fading Support ESA
Proposed Technologies Selection

- LLC STM
- Random Access and Interference Cancellation
  - ESA/DLR
  - CRDSA SE
  - Aloha HNS
  - TDMA+RA STM
- Synchronous SE
- Condensed Band Assign. TBTP HNS
- Distributed Band Assign. ETRI/UAB

MAC LAYER

- RGSE + Modifications DLR

PHYSICAL LAYER ADAPTATION

- Turbo-Phi STM (ENST)
- 3D Turbo ENST
- CPM & eBCH ETRI-Mavigex
- Flexible CPM Newtec
- Linear Modulation STM
- Heavy Fading Support ESA

PHYSICAL LAYER
PHY LAYER SELECTION DETOUR
Physical Layer Proposals Selection

- **Continuous Phase Modulation**
  - Good performance against nonlinear effect/ freq. instability
  - Reduce the ODU cost against linear modulation
  - More flexibility to select ODU component according to IDU function/capability

- **Linear Modulation**
  - High spectral efficiency can be achieved
  - Evolutionary approach wrt RCS 1° generation
  - Suitable for high end terminals (e.g., professional)
  - Less robust wrt non-linear distortion
Physical Layer based on Linear Modulation (STM proposal)

- **FEC**
  - Turbo-Φ coding scheme
  - Several burst size (Log-on, Control, Short and Long)
  - 5 vs. 8 iterations according to the burst size

- **Modulation scheme**
  - Linear modulation: QPSK, 8PSK, and 16QAM

- **Pulse shaping**
  - Fixed roll-off factor: 0.20

- **Spectral efficiency**
  - From 0.55 bit/s/Hz to 2.80 bit/s/Hz

- **Frame format**
  - Preamble, distributed pilots and postamble (size and distribution depends on the code-modulation pair)
  - Known symbols overhead
    - about 35% for Log-on/Control bursts
    - from 3% up to 14% for traffic bursts
  - Bursts should match a slot-grid
Physical Layer based on Continuous Phase Modulation (ETRI proposal)

- **FEC**
  - extended-BCH scheme
  - Continuous packet sizes

- **Modulation scheme**
  - Quaternary CPM waveform
  - Bandwidth limitation 99% and 77%

- **Spectral Efficiency**
  - $0.75 - 1.0 - 1.25 - 1.5 - 1.83$ bit/s/Hz

- **Frame format**
  - Preamble and midamble: always 32+32 known symbols
  - Overhead below 10% for the traffic bursts
DVB-RCS-NG physical layers: link capacity analysis

ACI=+3dB

![Graph showing spectral efficiency vs. Eb/N0 for Linear Modulation and CPM methods.](image_url)
HPA MODEL

Output Power [dB]

OBO > 0

Non Linear region: Max Power Eff. Non linear Distortion

Linear region: No distortion Power loss

IBO > 0  IBO < 0

Input Power [dB]

IBO > 0

No distortion Power loss
Performance example: QPSK

LTB4 Performance (k=1504 bits, r=1/2, QPSK, 8 iter.)

Total degradation: 0.5dB
Performance Example: 16-QAM

STB11 Performance (k=1400 bits, r=3/4, 16QAM, 8 iter.)

- Total degradation: 3.1 dB
StudyGroup Simulations: Linear Modulation vs. CPM

- Linear Modulation
- CPM

Spectral Efficiency [bit/s/Hz] vs. Eb/N0+OBO [dB]
The minimum IBO is limited by design to -5dB.
DVB-RCS-NG physical layers: link capacity - ODU instabilities

Linear Modulation vs. CPM

Source: DVB-RCS 1130
DVB-RCS-NG physical layers: System capacity (1/2)

4 colour frequency re-use pattern over the 500 MHz with 125 MHz per colour on both user up and downlink (opposite polarisations in Tx/Rx).

Source: DVB-RCS 1130
## DVB-RCS-NG physical layers: System capacity (2/2)

<table>
<thead>
<tr>
<th></th>
<th>CPM</th>
<th>Linear Modulation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>OBO var 1 dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nominal</td>
</tr>
<tr>
<td>Average b/s/Hz</td>
<td>1.36</td>
<td>1.45</td>
</tr>
<tr>
<td>Max baud rate [Mbaud]</td>
<td>10.67</td>
<td>7.2</td>
</tr>
</tbody>
</table>

Source: DVB-RCS 1130
DVB-RCS-NG physical layers: comparisons and conclusions

- **Link layer performance**
  - Linear modulations have comparable performance to the CPM modulations up to about 1.8 b/s/Hz when considering operations at the ODU optimum working point and no ODU instabilities.
  - At higher spectral efficiency linear modulations perform better than CPM’s.
  - CPM schemes show significantly better performance than linear modulations when ODU instabilities are considered.

- **System level performance simulations**
  - For the considered network scenario (interference limited) CPM schemes outperform linear modulations in average spectral efficiency when considering ODU instabilities.
  - For networks with higher C/I in the uplink linear modulations could perform better (example lower frequency re-use, separate RX/TX satellite antennae) than CPM.
  - Whenever low terminal output power is considered CPM approach is preferable.

- **Decision not yet taken** ➔ **DVB-RCS Commercial Module to select one of the following two configurations:**
  - Linear modulation for high end terminals and CPM for low cost terminals.
  - Linear modulation only for both high end and low cost terminals.
Lessons Learned from PHYL Selection

- Performance is not everything in system design!
- Robustness is a plus
- Commercial Interests are also important in standardization bodies

The final decision will be the best weighted trade-off among performance, robustness, flexibility, and commercial support
END OF DETOUR
DVB-RCS-NG workplan

- **Activity started:** End of 2008

- **Call for Technology deadline:** May 4, 2009

- **Physical layer definition:** January 2010

- **Specifications for fixed systems:** End 2010

- **Specifications for mobile systems:** End 2011
Conclusions

- Broadband Access is recognized as cornerstone for economic development
- Satellite broadband communication market has huge potential and can play a significant role in the “Economic Recovery”
- Satellite technology is mature for large multi-spot beam satellite networks able to provide for high capacity access competitive with DLS connection
- Key elements to meet the market requirements are
  - Service quality and availability
  - Service Costs
- A new initiative (DVB-RCS-NG) is on-going to create an open standard able to provide the enablers for low cost and high efficient broadband satellite systems
- The new standard is foreseen to be available by mid/end 2010
Acknowledgements

- The ESA “2° Generation DVB-RCS Standardization Support” project

- The DVB-RCS Study Group

- The Digicomm Group of the University of Bologna
Thank you!