ASMS2004 Tutorials

DVB-S2
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Motivation for DVB-S2

- DVB-S2 is the second generation DVB system for broadband satellite services
- DRAFT ETSI EN 302 307 (2004-01)
- The DVB-S legacy:
  - DVB-S is an extremely successful standard
  - DVB-S was devised for broadcasting applications where
    - the physical layer is fixed
  - and optimized for the worst-case
  - For unicast applications this worst-case design approach causes a large waste of satellite resources
- DVB-S2 is designed to increase spectral efficiency and quality
- DVB-S2 does so by combining:
  - Adaptive Coding and Modulation (ACM)
  - Near Shannon-limit Forward Error Correction (FEC)
  - Multi-spot Ka-Band satellite antenna
  - New video and audio coding schemes can be used

DVB-S2 Applications

- Broadcast Services (BS)
  - BS as for DVB-S, but with the added flexibility of VCM (Variable Coding and Modulation) enabling different levels of protection for each service (e.g. robust SDTV, with less-robust HDTV)
  - BC-BS (backwards compatible broadcast services) for interoperability with DVB-S decoders, and a more optimised NBC-BS (non-backwards compatible)
- Interactive Services (IS)
  - IS are provided with existing DVB return channel standards (e.g. RC-PSTN, RCS, etc.)
  - DVB-S2 can operate in CCM (constant coding & modulation) and ACM (Adaptive Coding and Modulation) modes
  - Digital TV Contribution and Satellite News Gathering (DTVC/DSNG)
- DTVC/DSNG builds on the DVB-DSNG standard, facilitating point-to-point, or point-to-multipoint communications of single or multiple MPED transport streams using either CCM, or ACM modes.
- Professional Applications (PS)
  - E.g. data content distribution/trunking, using CCM, VCM or ACM
**ACM Background**

INTERFERENCE DISTRIBUTION: ACM exploits the entire C/I range

ATMOSPHERIC CONDITIONS: ACM maximizes instantaneous data-rate as a function of time/location

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**How does ACM operate?**

According to the user SNR, the system selects the optimum couple [code-rate / modulation]

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**Shannon bound for M-ary modulations**

<table>
<thead>
<tr>
<th>Modulation Scheme</th>
<th>Losses from Shannon Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK</td>
<td>1.76 dB</td>
</tr>
<tr>
<td>8PSK</td>
<td>2.2 dB</td>
</tr>
<tr>
<td>16QAM</td>
<td>4.1 dB</td>
</tr>
<tr>
<td>32QAM</td>
<td>5.1 dB</td>
</tr>
<tr>
<td>64QAM</td>
<td>7.5 dB</td>
</tr>
</tbody>
</table>
Discretization for coded M-ary modulations

DVB-S2: Tx Block Diagram

Mode Adaptation

MA (Mode) \( UPL = \text{Number of UPs} \)  
\( DFL = \text{Dr} \)  
\( \text{SYNC} = \text{Synchronization bit} \)  
CRC applied to BBHEADER

UPL (User Packet Length) = constant value, 188 bytes (MPEG)
FEC encoding

- Encoding is performed in three stages:
  - Outer coding → BCH
  - Parity check bits (BCH) are appended to BRFEC
  - Inner Coding → LDPC
  - Parity check bits (LDPC) are appended to BCH field
  - Bit interleaving
- Each BRFEC (K_BCH bits) are processed by the FEC coding subsystem to generate a FEC parity, K_LDPC bits

BCHcode | LDPCcode | N_BCH | K_BCH | N_LDPC | K_LDPC
--- | --- | --- | --- | --- | ---

Coding parameters

- Two different FEC formats are available:
  - The “normal” FEC format: N_LDPC = 64800
  - The “short” FEC format: N_LDPC = 16200
- Available code rates: 1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9, 9/10

Low-density parity-check codes

- Discovered by Gallager (1961)
- Rediscovered during 1990’s by Mackay
- Block codes that have parity-check matrix H |
- Every row and column of which is “sparse”
  - Regular LDPC
    - Every column of H has the same weight j
    - Every row as the same weight k
  - Irregular LDPC
    - Every column and row of H has a particular rate X and check-node degree
- Defined also in terms of sparse random graphs
  - Their property is that each constraint involves a small number of variables in the graph
  - The number of edges in the graph scales roughly linearly with K rather than quadratically
  - Randomness ensures a good code while sparseness enables efficient decoding
- Decoded by a simple probability-based message-passing algorithm
  - Most used in the sum-product algorithm
  - Is not the optimal decoder
  - Results are record-breaking
Message Passing

- Practical codes should have simple coding and decoding, but generally the decoding requires a lot of time and resources
- This problem can be solved by message-passing algorithm
  - Complicated calculations are simple distributed among simple processors
  - After a few steps the solution of the global problem is available

Message Passing

- This algorithm can be used if the “soldiers” are arranged in a graph that contains no cycles!
- If there are cycles, a modified message-passing algorithm must be used
  - Cycles are opened and a cycle-free graph (tree) is obtained

Sum-product algorithm: the most likely path

- The sum takes place at each node by adding messages from predecessors
- The product comes in by weighting terms in the sum
- The sum-product algorithm is a form of belief propagation
Code Construction and Decoding

- There is a relationship between the locations of 1's in the matrix and
  - the cycles in the code graph
  - the number of decoding iterations
- Good codes should have graphs without short cycles (closed loops)
  - A closed loop in parity-check matrix is a sequence of connected alternating horizontal and vertical lines
  - The last line in the sequence terminates at the beginning of the first line
  - Every line stats in a vertex, which is a point where the parity check matrix contains a 1
- The sum-product decoding algorithm is optimal if there are no cycles → sub-optimal with cycles
- Increasing the matrix size, it becomes easy to produce matrices without cycles of any given length → it is possible to ignore cycles

DVB-S2: Bit-Interleaver

- Performed only for 8-PSK, 16-APSK, and 32-APSK modulation schemes
- LDPC encoder output is interleaved using a simple block interleaver
  - Interleaving depth is a function of the adopted modulation format

Modulation Schemes

- LDPC codewords are mapped into the following constellations:
  - QPSK
  - 8-PSK
  - 16-APSK
  - 32-APSK
Mode Adaptation

- The receiver estimates the instantaneous SNR
- This is fed-back to the gateway station by the return channel (DVB-RCS)
- The gateway adapts the transmission mode accordingly
- SNR estimation is not a trivial task

SNORE: Analytical Characterization

\[ P_1 \sim \chi^2 \left( \frac{1}{2} \frac{\sigma_1^2}{\sigma_2^2} \right) \]

SNORE: Cramer-Rao Bound

\[ \sigma^2 \geq \frac{N_0}{2N_p - \frac{3}{4}} \left( \frac{3}{4} \right) \]

Mean Estimation Error

\[ \mu_e = \frac{1}{2N_p - \frac{3}{4}} \left( 1 + \frac{3}{2} \right) \]

NOISE ACTS BOTH AS NUISANCE AND TARGET!
DVB-S2: more info

- www.dvb.org

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DVB-RCS

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DVB-RCS Services and Applications (1/2)

- Interactivity in previously under-served locations
- Extend services in areas lacking conventional terrestrial infrastructure

- Internet S
- Applicatic
- UMTS bas
- Digital Su
- Point-to-P
**DVB-RCS Services and Applications (2/2)**

- For government, education and business:
  - Real-Time services and applications
  - VoIP and Videoconferencing
  - CoLo: Colocation for web servers and web hosting
  - Finance and stock market services
  - Banking and financial services
  - LAN Interconnection: VPNs
  - Distance learning
  - Video, text, voice
  - Telemedicine
  - Interactive TV broadcasting
  - Distributed TV Broadcast
  - IP Multicast and IP Streaming
  - Near Video on Demand (NVoD)
  - Push Services
  - Interactive Gaming

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**Interactive Network Model**

- Broadcast Channel
  - Unidirectional broadband broadcast channel
- Interaction Channel
  - Bidirectional interaction channel between the service provider and the user
  - Return Interaction Path (Return Channel) from the user to the service provider
  - Forward Interaction Path from the service provider to the user
- Return Channel Satellite Terminal (RCST) formed by:
  - Network Interface Unit (consisting of the Broadcast Interface Module and the Interaction Interface Module)
  - Set Top Unit
- The RCST provides interface for both Broadcast and Interaction Channels

**DVB-RCS Architecture**

- Network Control Centre (NCC)
  - Provides monitoring & control functions
  - Control and timing signals
- Traffic Gateway (TG)
  - Receives the RCST return signals
  - Provides accounting functions
  - Interactive services and/or connections to external public
  - Proprietary and private service providers and networks
- Feeder
  - Transmits the forward link signal
  - Standard satellite digital video broadcast (DVB-S) uplink
  - Are multiplexed the user data and/or the control and timing signals
**DVB-RCS Burst Formats**

- There are four types of bursts:
  - Traffic (TRF)
  - ATM (152 bytes)
  - MPEG (188 bytes)
  - Acquisition (ACQ)
  - Synchronization (SYNC)
  - Common signaling channel (CSC)
  - Used by an RCST to identify itself during the log-on.

- ACQ and SYNC bursts are required for accurately positioning the RCS.
  - Terminal (RCST) burst during and after log-on.

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**Channel Coding and Modulation**

- Coding for channel error protection is applied to traffic and control data.
- Two alternative coding schemes can be implemented:
  - Turbo code
  - Concatenated code
- In the case of the concatenated coding, the outer code is a Reed-Solomon (RS) code and the inner code is a nonsystematic convolutional code.
- For both coding schemes, a by-passable CRC can be also applied on CSC and SYNC bursts in order to allow error detection.
- Modulation format is QPSK.

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**Turbo Codes**

- Background:
  - Turbo codes were proposed by Berrou and Glavieux in the 1993 International Conference in Communications.
  - Performance within 0.5 dB of the channel capacity limit for BPSK was demonstrated.

- Features of turbo codes:
  - Recursive convolutional encoders
  - Parallel code concatenation
  - Serial code concatenation
  - Nonuniform or “Pseudo-random” interleaving
  - Iterative decoding
Two double-binary Circular Recursive Systematic Convolutional (CRSC) codes

- The most significant bit (MSB) of the first byte is assigned to A, the next to B, and so on.
- Seven coding rates are defined:
  - 1/3, 2/5, 1/2, 2/3, 3/4, 4/5, 6/7
- These rates are achieved by puncturing the parity bits

Turbo Decoder

Turbo Code Performance: AWGN Channel
DVB-RCS: Multiple Access

- The multiple-access capability is either fixed or dynamic slot MF-TDMA.
- The RCS shall indicate its capability by using the MF-TDMA field present in the CSC burst.
- MF-TDMA allows a group of RCSs to communicate with a gateway using a set of carrier frequencies each of which is divided into time-slots.
- The Network Control Center (NCC) allocates to each active RCS a series of bursts (slots), each defined by a frequency, a bandwidth, a start time and duration.

DVB-RCS: more info

- Standard Ref: EN 301 790 Edition: 1.3.1
  - Interaction for Satellite Distribution Systems
- Standard Ref: TR 101 790 Edition: 1.2.1
  - Guidelines for the Implementation & usage of the DVB Interaction Channel for Satellite Distribution
- www.dvb.org

THANK YOU!