Video/Audio distribution

CDN

Analog TV standards comparing

The first three systems have the following similarities:

- Despite the encoding differing, all nevertheless use a similar type of colour system, involving a luminance and two chrominance signals based on red, green and blue primaries.
- All use interlaced scanning.
- All use two separate carrier signals, one FM modulated for sound and one AM modulated for picture.

	PAL	SECAM	NTSC	NHK HDTV	EU95 HDTV
Lines per frame	625	625	525	1125	1250
Field rate	50	50	60	60	50
Interlace ratio	2:1	2:1	2:1	2:1	1:1
Aspect Ratio	4:3	4:3	4:3	16:9	16:9
Bandwidth/MHz	6.7 or 8	8	6	25.5 or 27	n/a*
Viewing angle	13º	13º	11º	30º	30º

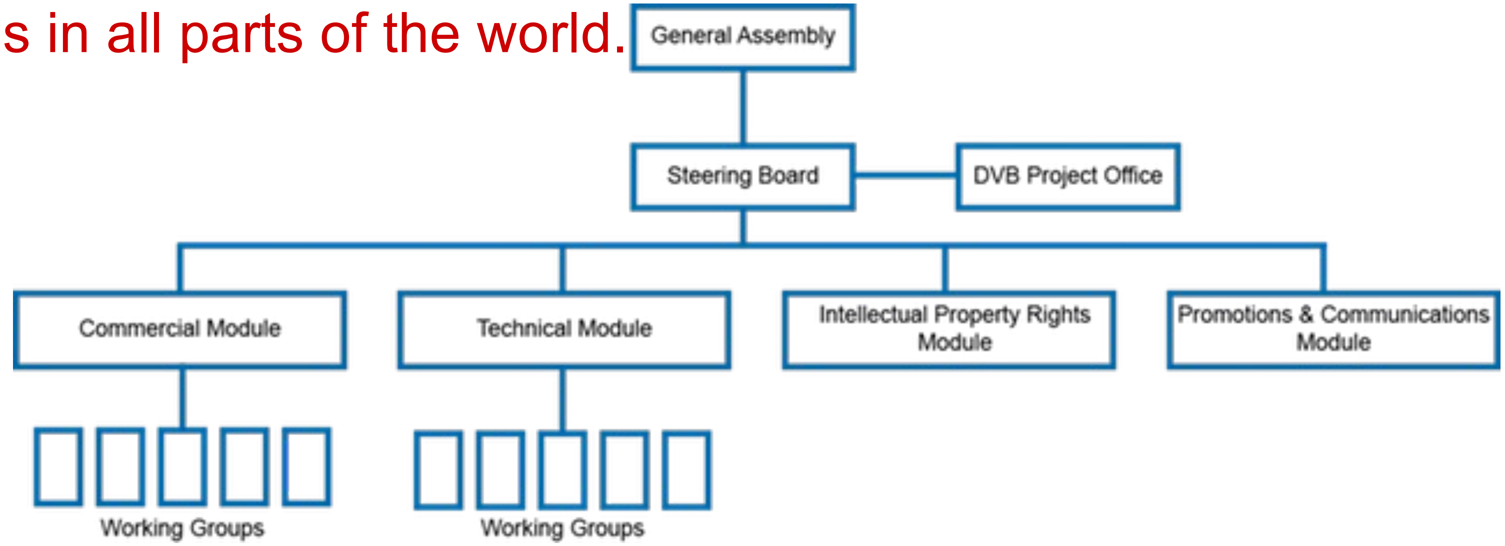
HDTV analogue standards did not succeed commercially and are not compatible with the old standards.

Advantages of digital television

- More digital channels than analogue in the same bandwidth, thanks to MPEG-2 compression technique of DVB
- CD quality stereo sound thanks to MPEG Layer II (mp2)
- Service information, such as on-screen programme guide
- Near Video On-Demand (NVOD)
- Simulcasting (HDTV & SDTV)
- Adaptivity to the channel
- Quasi Error Free (QEF)
- Support to Internet data services

Structure of the DVB project

- The project officially started in 1993.
- Commercial Modules have the task to formulate requirements for the systems, which is the basis for the work of the Technical Module, ad-hoc groups works on special subjects. After the completion of development work the commercial working groups verify the specifications for the new systems and forward them, if necessary, to the 'Steering Board' for final decision.
- Promotion Module is a group whose task it is to look after interested persons in all parts of the world.



Media distribution and families of standards

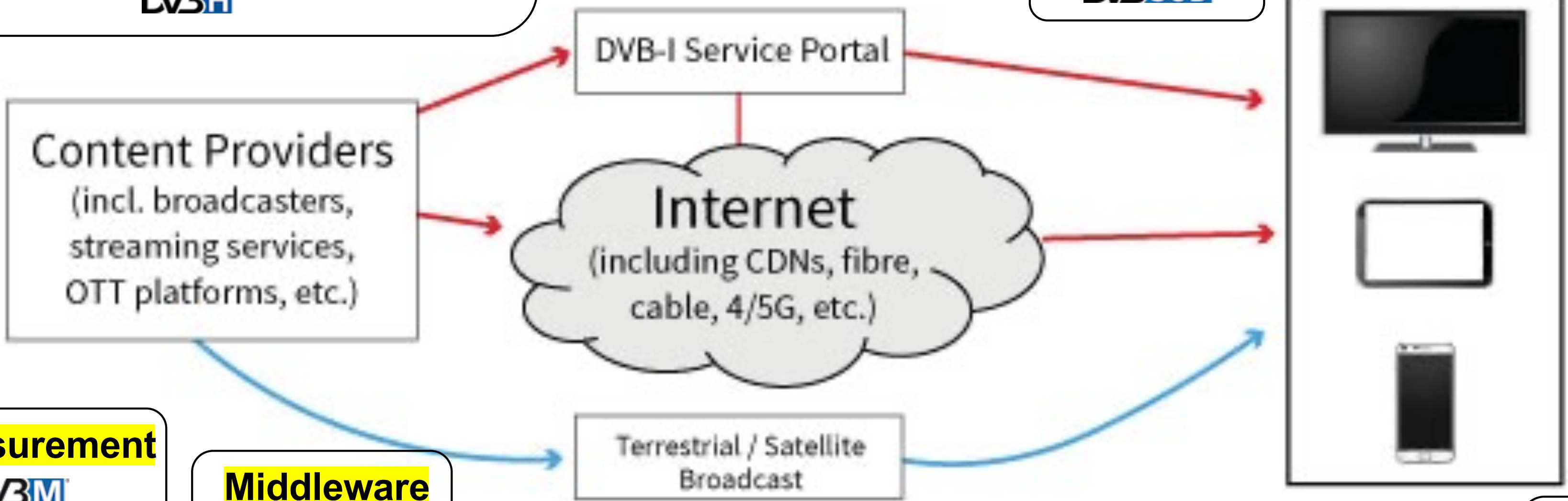
Transmission
DVB-C, DVB-SIS, DVB-S2, DVB-SH, DVB-CID, DVB-T, DVB-C2, DVB-CS, DVB-T2, DVB-S2X, DVB-S, DVB-MDS, DVB-H

Interfacing
DVB-PDH, DVB-SDH, DVB-ATM, DVB-PI

Internet Protocol
DVB-DASH, DVB-IPTV

Source coding
DVB-MPEG

Subtitling
DVB-SUB



Measurement
DVB-M

Middleware
DVB-GEM

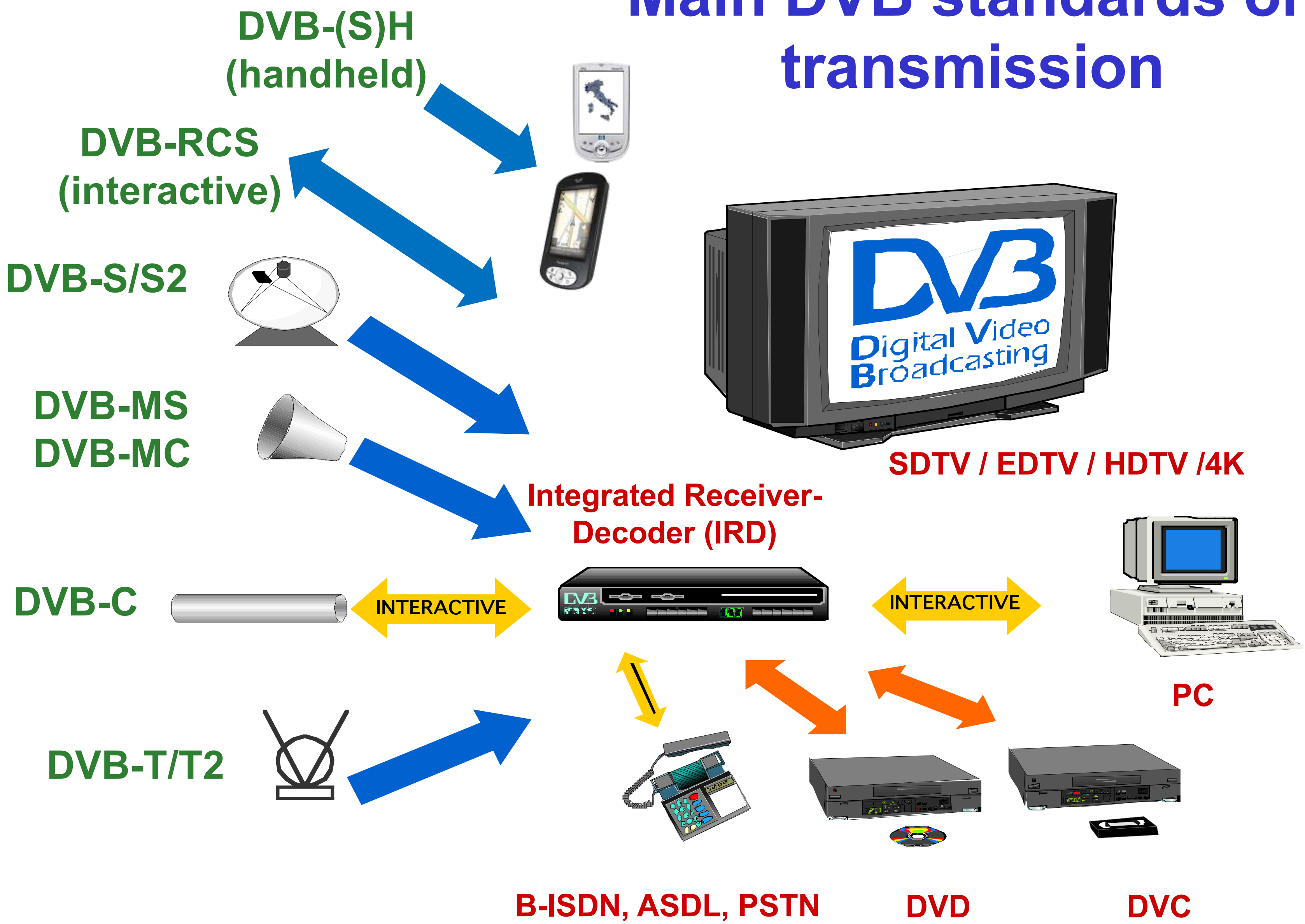
3D TV
DVB-3DTV

Multiplexing & Service Information
DVB-SI, DVB-DATA, DVB-SSU, DVB-SRM, DVB-CMT, DVB-TVA, DVB-FF, DVB-GSE

Interactivity
DVB-RCS2, DVB-NIP, DVB-RCC, DVB-RCS, DVB-RCP, DVB-CSS, DVB-RCD, DVB-RCL, DVB-RCG, DVB-RCT, DVB-RCCS, DVB-RCGPRS

Conditional Access
DVB-SIM, DVB-CI, DVB-CSA3

Main DVB standards on transmission



DVB Standards structure and documents

- DVB S – EN 300 421
  - DVB S2 – EN 302 307-1
    - DVB S2X – EN 302 307-2
  - DVB RCS – EN 301 790
    - DVB RCS2 – TS 301 545-1 (OSL, overview), EN 301 545-2 (LLS, lower layers) TS 301 545-3 (HLS, higher layers).
- DVB C – EN 300 429
  - DVB C2 – EN 300 769
- DVB T – EN 300 744
  - DVB T2 – EN 302 755
- DVB H – EN 302 304
  - DVB SH – TS 102 585

S = Satellite
C = Cable
T = Terrestrial
H = Hand held
2 → second generation
RCS = Return Channel on Satellite

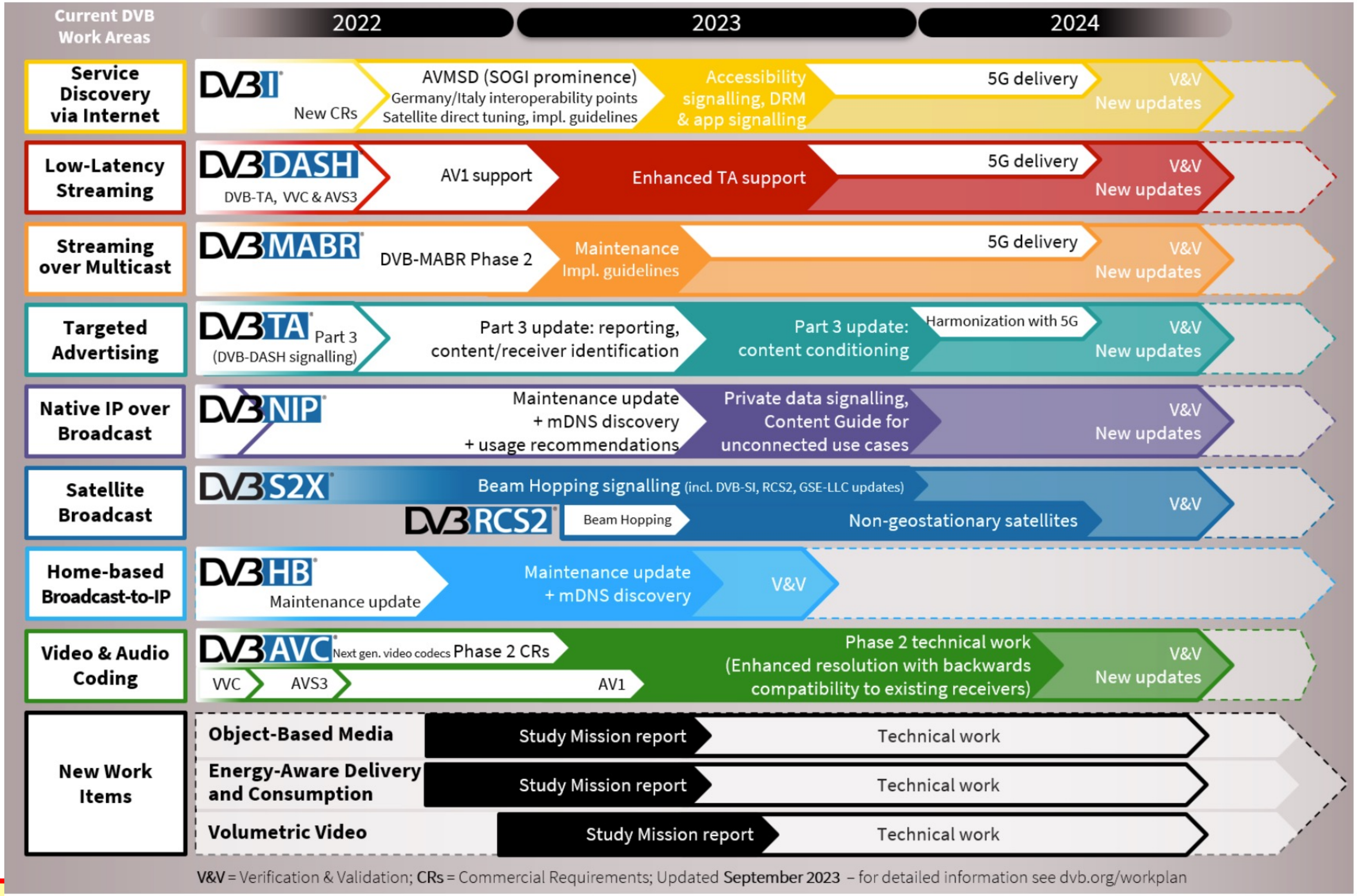
In particular for satellite:

DVB-S *Framing structure, channel coding and modulation for 11/12 GHz satellite services*

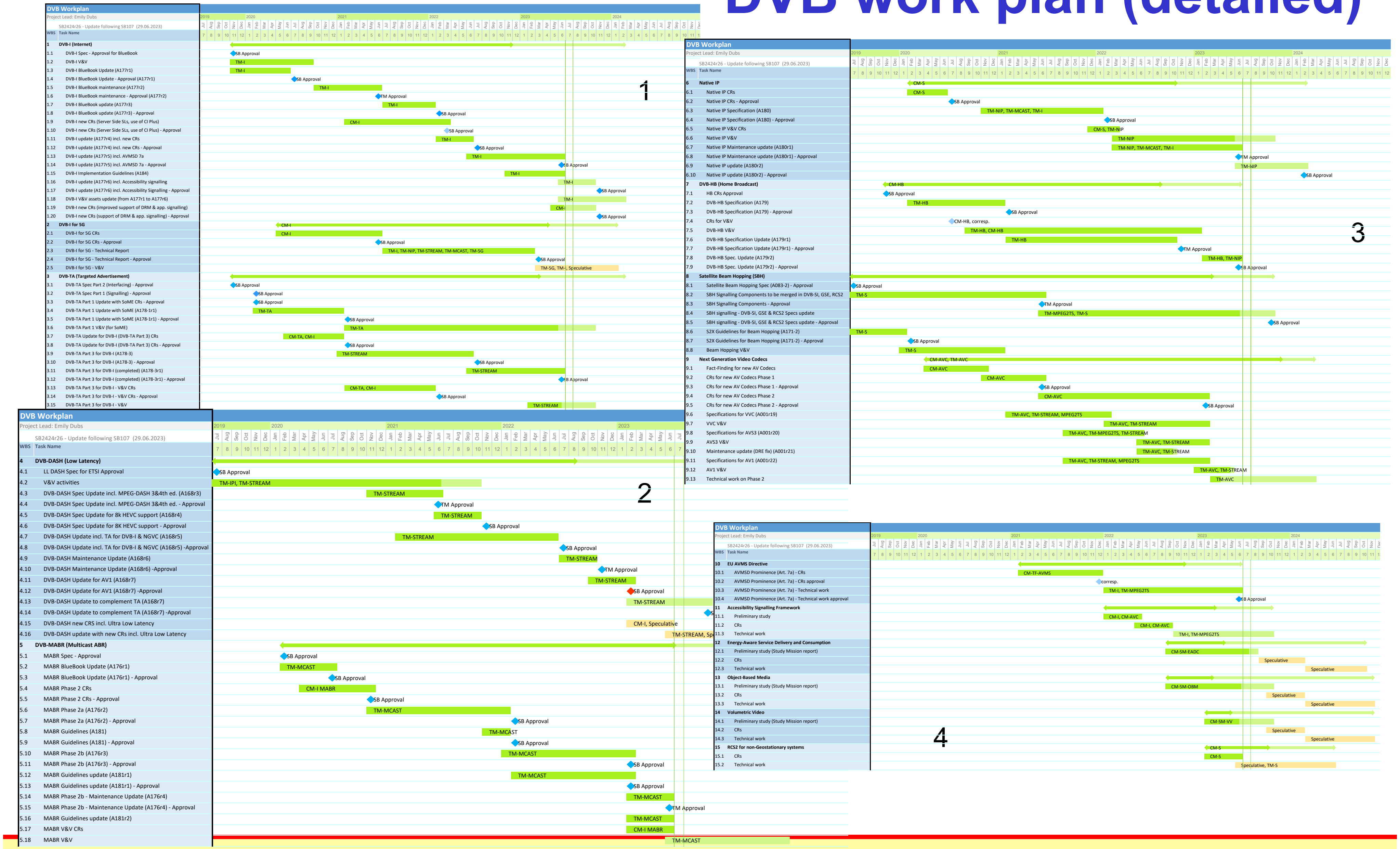
DVB-S2 *Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications*

DVB RCS *Interactive services using DVB in the forward link and RCS in the return link.*

DVB Workplan (high level)



DVB work plan (detailed)



Nomenclature

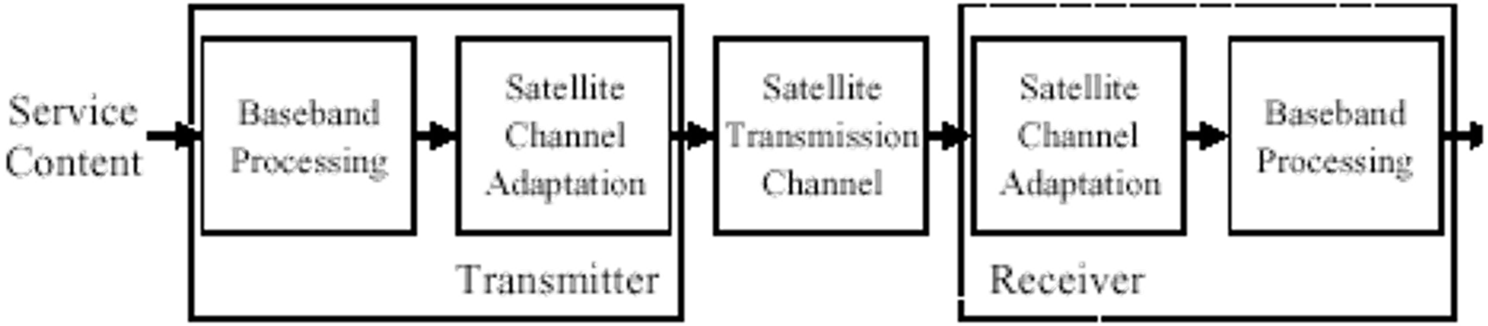
- **Programme:** in MPEG terminology the word is used to refer to a collection of elementary data streams that are logically related and belong together. A simple example is a video stream and an audio stream that together form a conventional TV programme. In conventional (broadcast) terminology, the word "programme" is used to refer to a time-limited transmission such as a film or a TV show.
- **Television channel:** a sequence of TV programmes from the same service provider. However, in MPEG terminology, this sequence of time-limited transmissions would still be referred to as a programme.

DVB

- **Event:** time-limited transmission ➔ **television programme**
- **Service:** sequence of time-limited transmissions ➔ **television channel**

Digital Satellite Transmission System

- In general the service content is composed of any mixture of video, audio and data.
- DVB standard concerns mainly two operations: **Baseband Processing** and **Satellite Channel Adaptation**

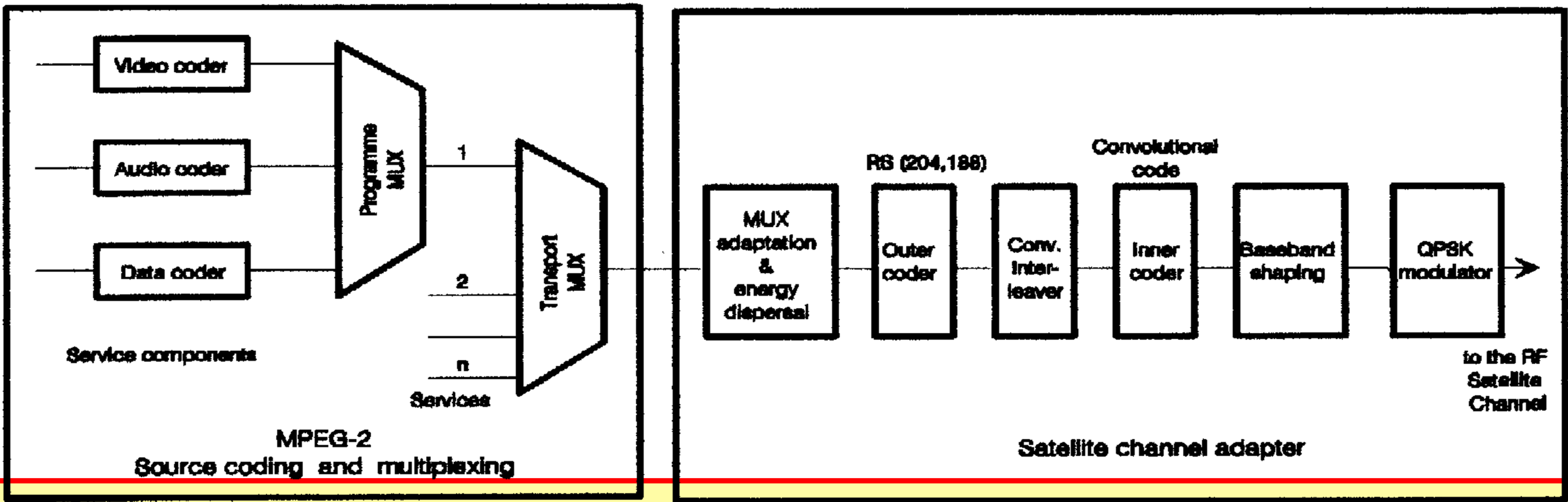


- The receiving user equipment can be either a conventional digital television set or a personal computer
- In a practical system the transmitter elements in Figure would not necessarily be implemented at the same location
  - baseband processing would be performed at a point close to the programme source.
  - channel adaptation would be most likely be done at the transmit satellite earth station,

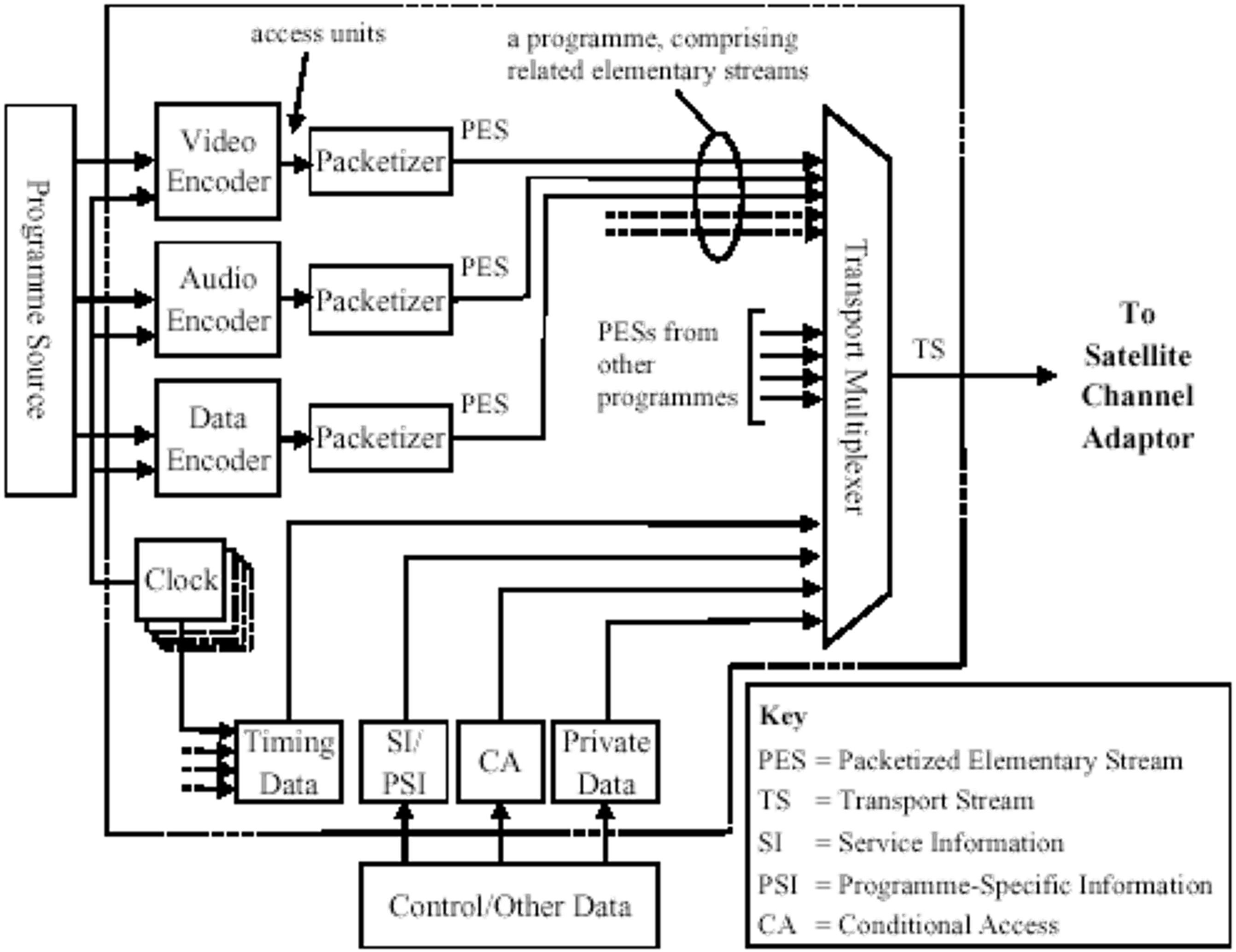
DVB-S Transmitter

(1st generation)

- Due to the typical power limitation the use of QPSK modulation and concatenated codes (convolutional and RS) was considered to get the system protected against noise and interference, guaranteeing a BER of 10^{-11} (this means one error every hour).
- In the more recent releases of the standard higher order modulations and other coding schemes have been also considered.



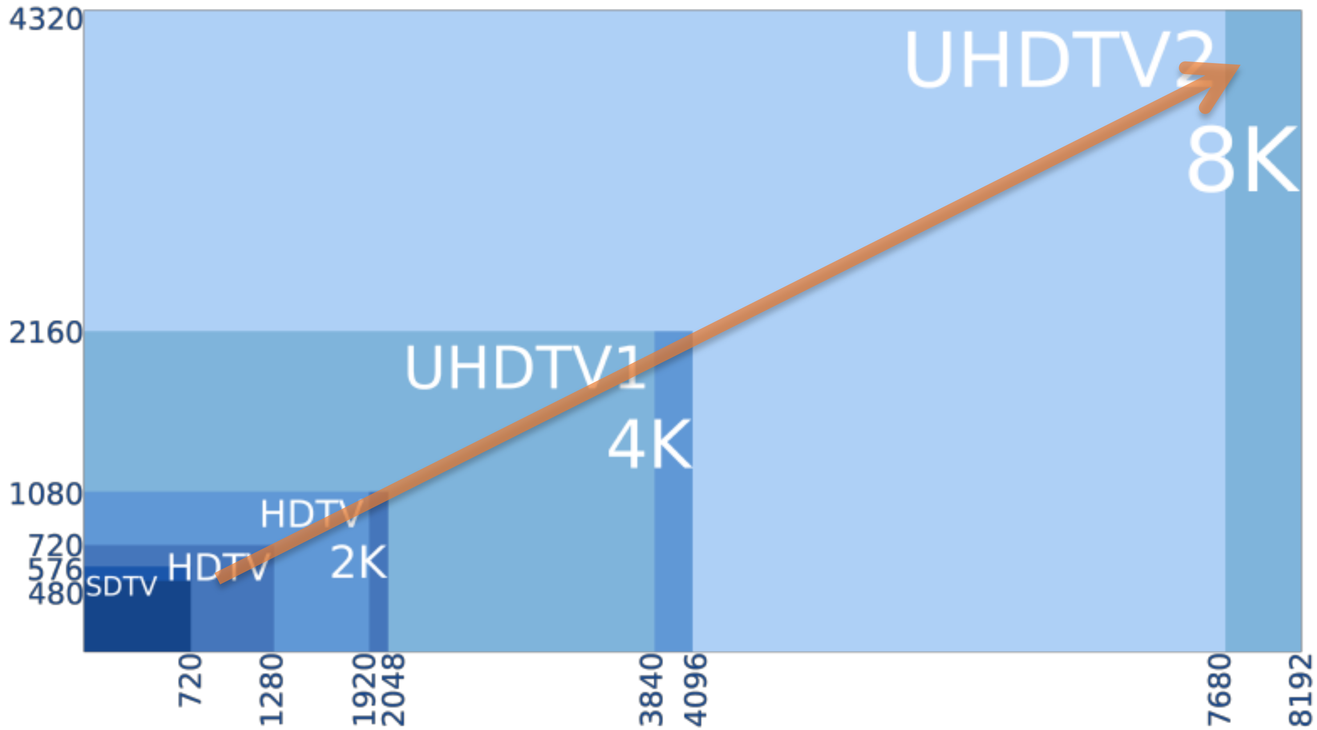
Conceptual Model of a DVB (MPEG-2) Baseband Processor



Source coding (compression)

- A digital video signal created in a TV studio has a bit rate of 166 Mbit/s (ITU-R Recommendation BT.601-5). Since the bit rate of the Transport Stream on a DVB-S transponder is typically about 38 Mbit/s, a significant degree of data compression is required.
- Data compression is possible because video sequences typically contain a significant amount of statistical and subjective redundancy within and between video frames. Audio is compressed as well (mp3/mp2).
- In DVB-S/C/T and DVDs, the video compression is implemented using the international MPEG-2 video standard.
- The **Moving Picture Expert Group (MPEG)** is a ISO/IEC working group developing standards for coding and transport of video-audio signals.
- Standard MPEG2 is adopted within DVB-S with the use of Transport Stream multiplexing for delivery of multiple channels.
- **A standard definition (SD) video compressed in MPEG2 for satellite broadcasting has a bitrate in the range of 3-10 Mbit/s** (typically 6 Mbit/s). Thus, compression allows normally 7 TV channels in the same transponder where before a single analogue channel was. (Note: a high definition (HD) video is compressed in MPEG4/h.264 and has a bitrate in the range of 10-30 Mbit/s, typically 16 Mbit/s).

Image resolution



No relation with screen geometrical dimension but higher resolution allows to use larger screens

Definition	Horizontal lines	Vertical lines
SD (Standard Definition)	576 or 480	
HD ready HDTV (High Definition)	720	
FullHD	1080	1920
2k	1080	**2048**
UHD (Ultra High Definition)	2160	3840
4k	2160	**4096**
UHD2 (8k)	4320	7680-8192

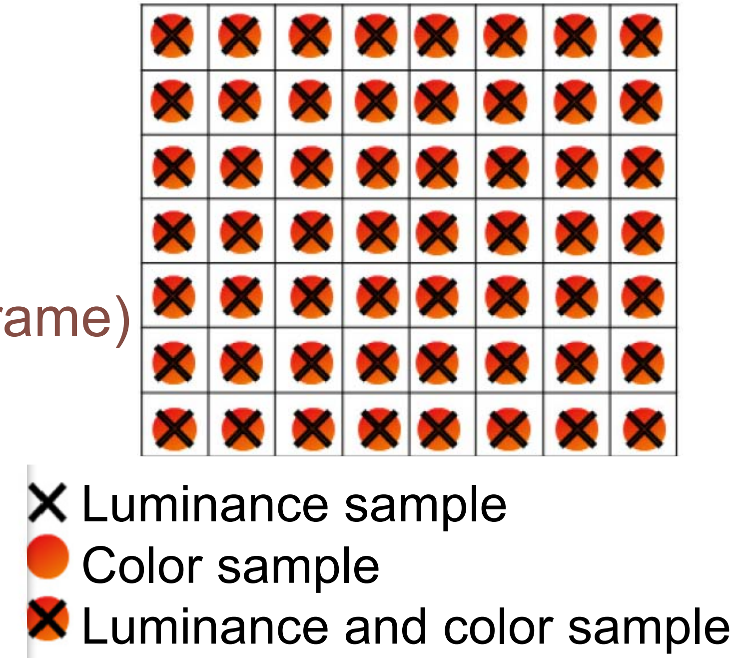
frame resolution 2.2-2.6 times higher

frame resolution 5-6 times higher

frame resolution 4 times higher

frame resolution 4 times higher

Bit rate calculation (no compression) for HDTV signal



- Assumptions
  - Sampling scheme: 4:4:4
  - Spatial resolution: 1920x1080 (pixel/frame)
  - Speed: 25 interleaved (frame/s)
  - Quantization levels: 1024 bit (2^{10})

- Bit rate formula

  1x(1920x1080)+1x(1920x1080)+1x(1920x1080)]x25x10 bit/s

  Color coefficient + resolution + color depth

- Bit rate

  1555200000 bit/s ≈ 1.6 Gbit/s

- Needed bandwidth ⇒ Depends on the modulation scheme

Frame resolution

- From a TV standard to the following one, we have an increase of information (i.e., the frame resolution) between 2.2 to 6 times, and typically 4 times.
- Increasing also the frame rate (interleaved or progressive, from 30 fps to 60 fps or more) figures can be even higher
- In the evolution of TV standards, video compression (source encoding) must be more and more effective: the goal is to compensate the ~ 4x increase of information with a limited increase of the transmission bitrate (in Mbit/s)
  - A more effective encoding requires more HW/SW resources, also in decoding
  - Increasing compression degree but trying to keep constant quality of experience (in case increasing bandwidth)
- Evolution:

Definition	Source coding standard	TV standard
SD	MPEG2	DVB-S
FullHD - UHD	MPEG4 (i.e., h.264)	DVB-S2
UHD (4k)	HEVC (i.e., h.265)	DVB-S2 and DVB-S2X

Compression evolution

- Thanks to the video compression evolution, it is possible to limit the bitrate growth, assuming the following reference values:

	MPEG2	H264	H265
SD	2-4 Mbit/s		
Full HD	12-20 Mbit/s	8-12 Mbit/s	
UHD1		20-44 Mbit/s	20-25 Mbit/s

- A significant achievement is for instance in the transition from Full HD in h.264 to UHD1(4K) in h.265, which shows a bitrate of just about 2 times more despite the frame size which is 4 times higher.

Baseband Processing Functions

- The input to the processor consists of a number of programme sources. Each programme source comprises any mixture of raw data and uncompressed video and audio, where data can be, for example teletext and/or subtitling information and graphical information such as logos.
- A traditional television broadcast would comprise **three elementary streams**: one carrying coded **video**, one carrying coded stereo **audio** and one carrying **teletext**.
- Each of the program sources (video, audio and programme-related data) is encoded separately and formatted into a Packetized Elementary Stream (PES).
- Each Packetized Elementary Stream can carry timing information, "time stamps", to ensure that related elementary streams, for example video and audio, are replayed in synchronism in the decoder. *Programmes can each have a different reference clock, or can share a common clock*.

Baseband Processing functions (2)

- Once synchronized, the decoder can correctly interpret the time stamps and can determine the appropriate time to decode and present the associated information to the user.
- DVB baseband processors do not necessarily physically implement all of the blocks shown. For example, ETR 154 states that physical implementation of Packetized Elementary Streams (PES) is not required.
- Following packetization, the various elementary streams of a programme are **multiplexed** with packetized elementary streams from other programmes to form a **Transport Stream** (TS).
- In addition to video, audio and data streams (strictly belonging to the TV channel), additional "management" information are required for the handling of the muxing and demuxing functions, and providing additional informative elements (channel name, program name and duration, etc.). This is included into "DVB-SI"

DVB-SI (1/2)

DVB-SI (Service Information) adds information that enables DVB IRDs (Integrated Receiver Decoder) to automatically tune to particular services and allows services to be grouped into categories with relevant schedule information. It is based on four tables. It is adopted in all the DVB broadcast systems and in particular DVB-S and DVB-T. Each table contains descriptors outlining the characteristics of the services/event being described:

- NIT: Network Information Table groups together services belonging to a particular network provider (for example more satellites located at a single orbital position form a satellite network). It contains all the tuning information that might be used during the set-up of an IRD (Integrated Receiver Decoder). It is also used to signal a change in the tuning information.
- SDT: Service Description Table lists the names and other parameters associated with each service in a particular MPEG multiplex. The receiver use SDT to compile and display a list of available services.
- EIT: Event Information Table provides information (event name, start time, duration, ...) in chronological order regarding the events contained within each service.
- TDT: Time and Date Table carries time and data information in UTC format.

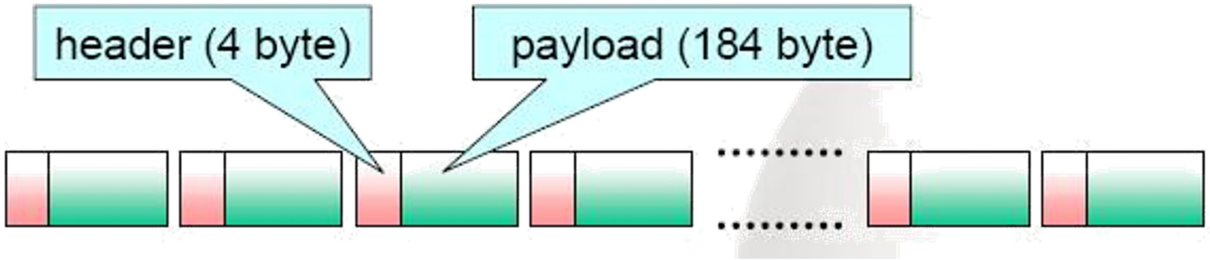
DVB-SI (2/2)

In addition there are three optional SI tables:

- BAT: Bouquet Association Table provides a means of grouping services that might be used as one way an IRD presents the available services to the viewer, for example "children's channels", "sports channels", etc.
- RST: Running Status Table it's used to rapidly update the running status of one or more events, that may be necessary when an event starts early or late due to scheduling change. The Running Status sections are sent out only once, at the time the status of an event changes, unlike the other SI tables which are normally repetitively transmitted.
- ST: Stuffing Tables may be used to replace or invalidate either sub-tables or complete SI tables.

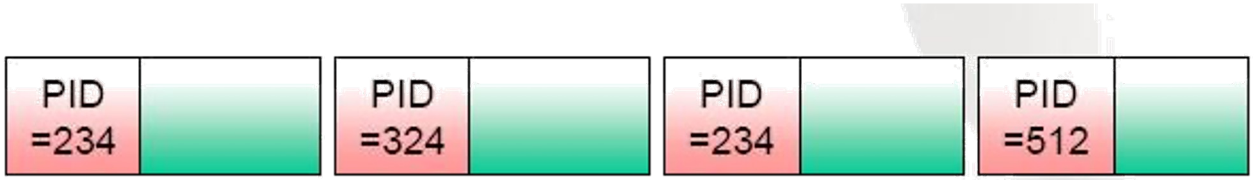
MPEG Transport Stream (1/2)

- **MPEG2** standard defined both compression technique and encapsulation (TS). The next generations (MPEG4) updated only on compression.
- MPEG Transport Stream (MPEG-TS) is composed of a sequence of **Transport Packets** of 188 bytes



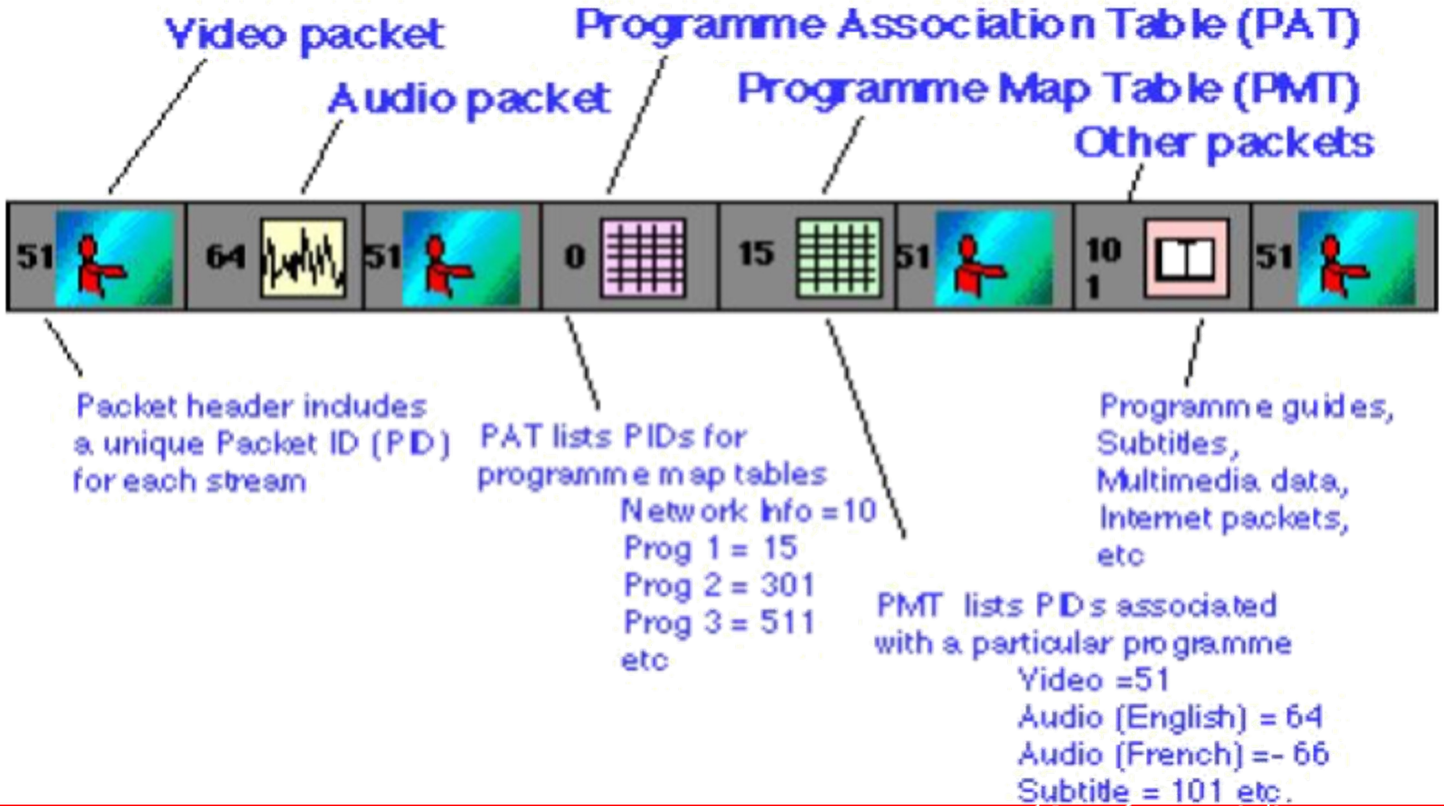
- Transmitted information are identified through a 13-bit **Packet Identifier (PID)**. At each PID is associated a particular information flow.

PID	F_type
234	Video 1
324	Audio 3
512	Data 1

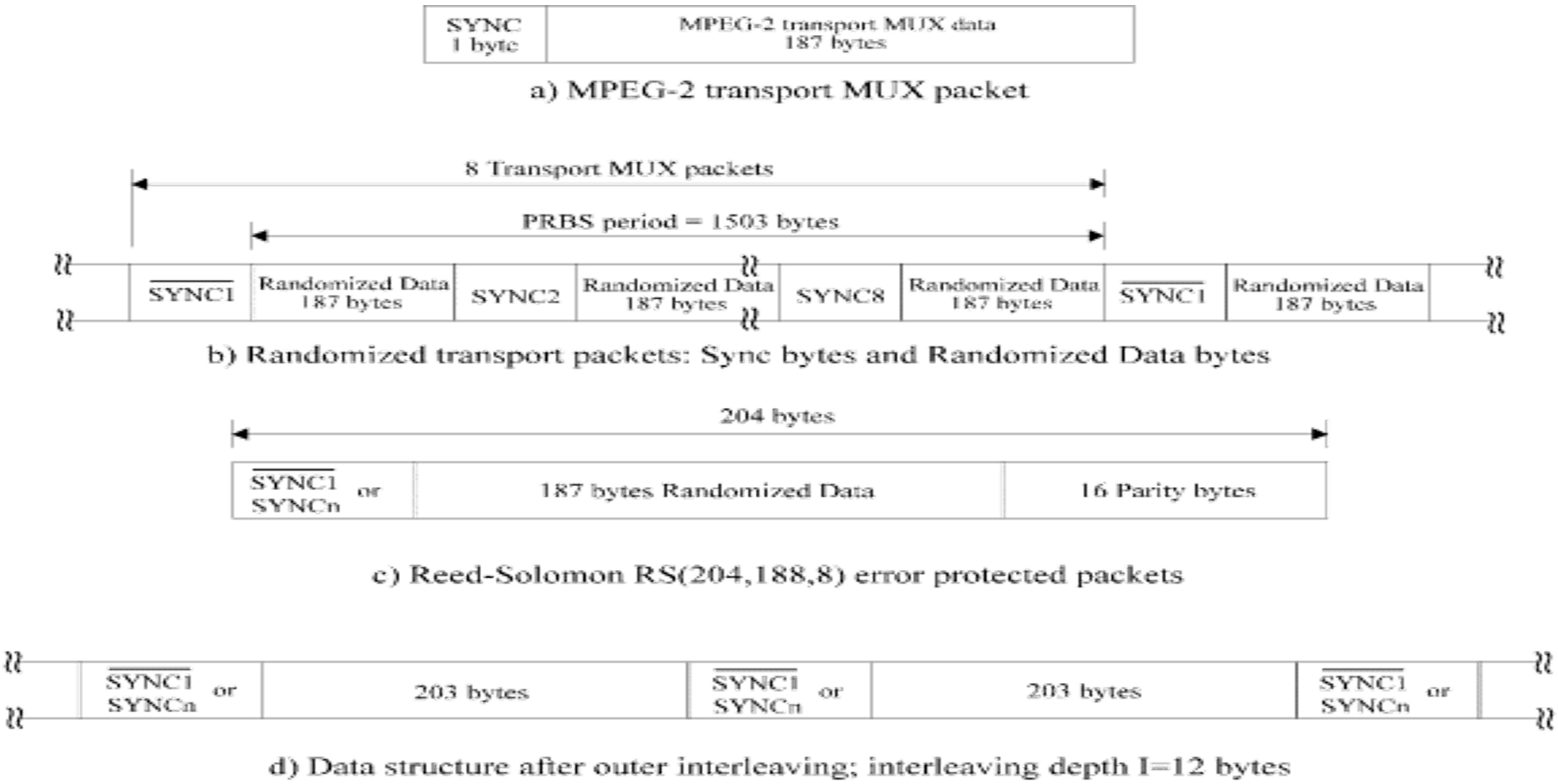


MPEG Transport Stream (2/2)

- **Video and Audio** TS-packets are interleaved with DVB-SI information (useful for their management).
- **PAT** (identified by PID=0x0000) lists all programmes of the transport stream and defines PID of the Program Map Table (**PMT**) of each programme
- **PMTs** refer to the particular PID of the elementary streams (video, audio).



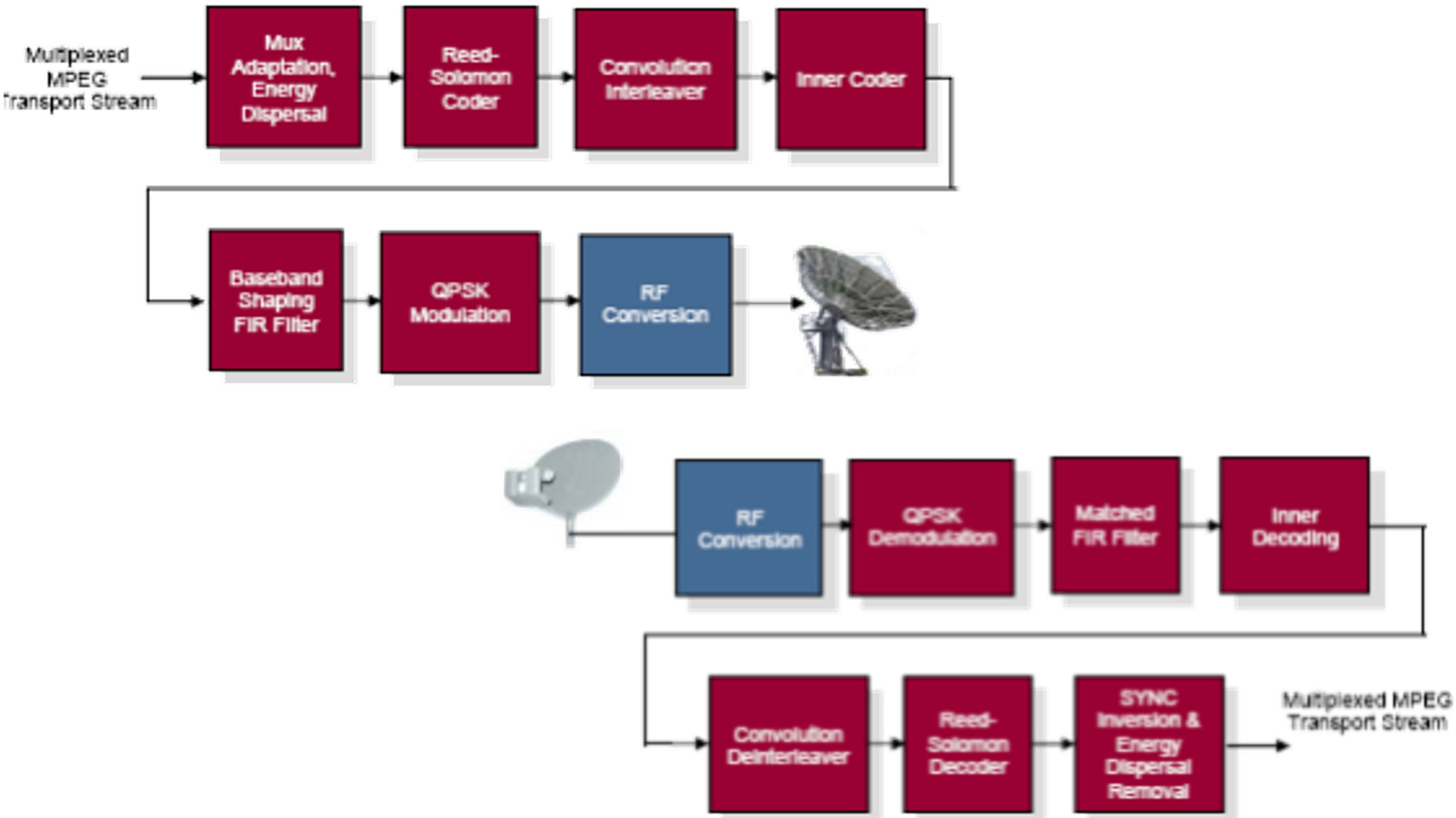
Framing structure



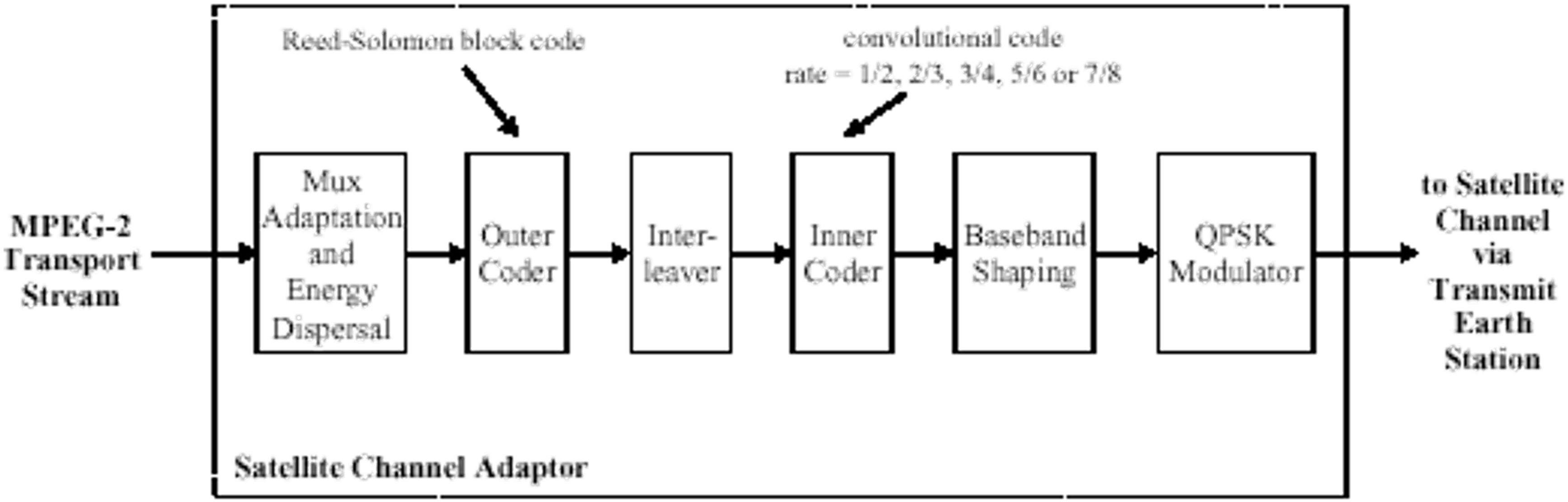
$\overline{\text{SYNC1}}$: Non randomized complemented sync byte

SYNCn: Non randomized sync byte, n=2, 3, ...,8

DVB-S Transmitter/Receiver

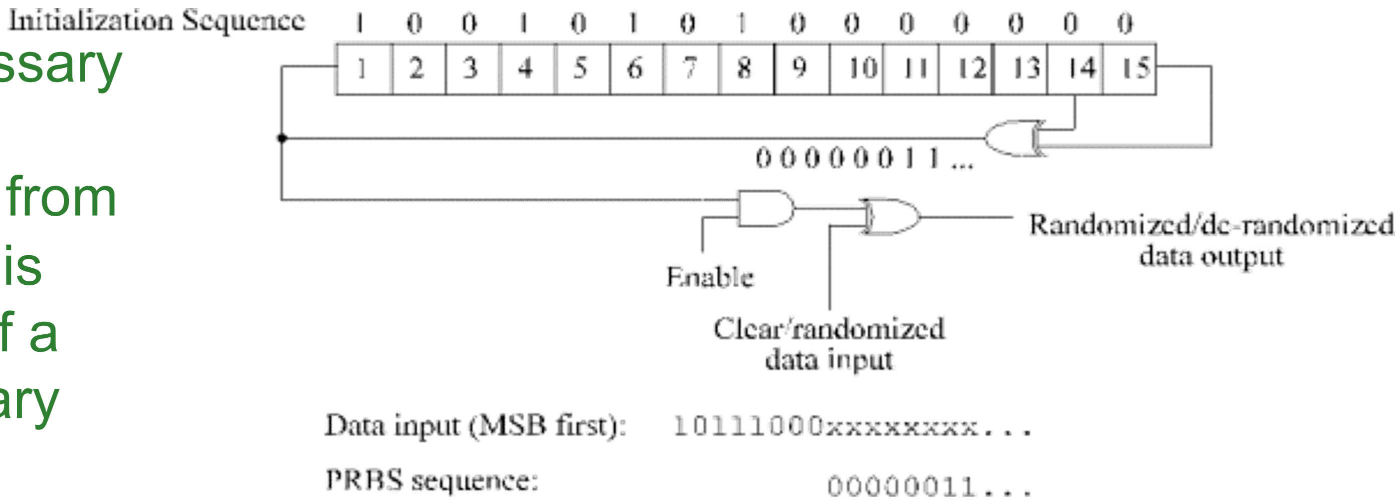


Functional Block Diagram of the DVB-S Satellite Channel Adaptor

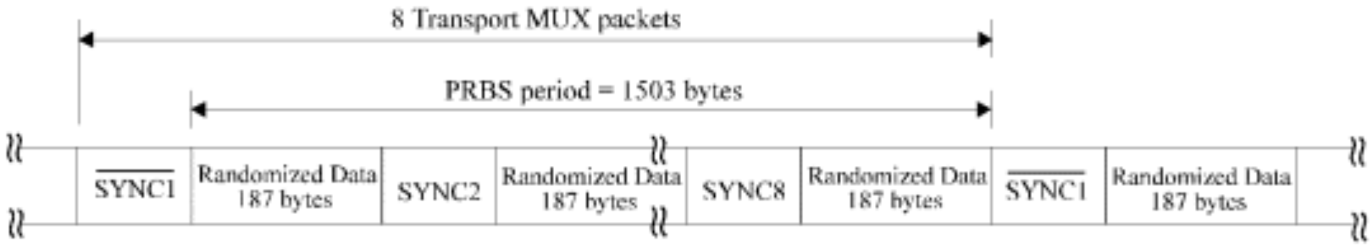


Randomization for energy dispersal

Randomizing is necessary to decorrelate the transmitted spectrum from the data content, this is achieved by means of a Pseudo Random Binary Sequence generator



- Polynomial for PRBS shall be $1+X^{14}+X^{15}$
- Sequence "100101010000000" loaded at start of every 8 packet
- Sync byte not randomized
- Also operating if there is no input stream
- SYNC1 bit-wise inverted to initialize the descrambler



Error correction

- The three blocks: "outer coder", "interleaver" and "inner coder" provide a powerful error correction mechanism.
- The outer code is a Reed-Solomon block code. A Reed-Solomon RS (204, 188, T = 8) shortened code, derived from an RS (255, 239, T = 8) code, is applied to each of the randomized transport packets (188 bytes).
- The interleaver is in charge to mix payloads in a predictable order to spread consecutive errors and optimizing the role of error correction codes.
- The inner code is a convolutional code with configurable "protection" rate
- In the receiver, a "Viterbi decoder" decodes the inner (convolutional) code and precedes the de-interleaving and the RS decoder. The function of the RS decoder is to correct residual errors (per TS packet) appearing at the output of the Viterbi decoder and de-interleaver.

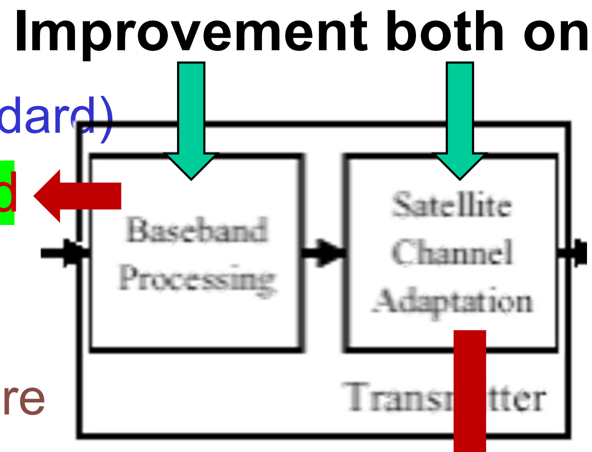
Inner Code Rate	Available Capacity	Power Requirement (E_b/N_0)	Receive Antenna Diameter
1/2	-33.3 %	-1.0 dB	-11 %
2/3	-11.1 %	-0.5 dB	-6 %
3/4	reference		
5/6	+11.1 %	+0.5 dB	+6 %
7/8	+16.7 %	+0.9 dB	+11 %

Baseband shaping and modulation

- Gray-coded QPSK modulation with absolute mapping (no differential coding) is employed. This classical modulation scheme was chosen for its ruggedness against noise and interference. It also provides reasonable spectrum efficiency (amplifiers always operated close to saturation).
- Prior to modulation, the baseband signal is square root raised cosine filtered with a roll-off factor of 0.35.

DVB-S2

(2nd Generation Broadband Satellite Standard)

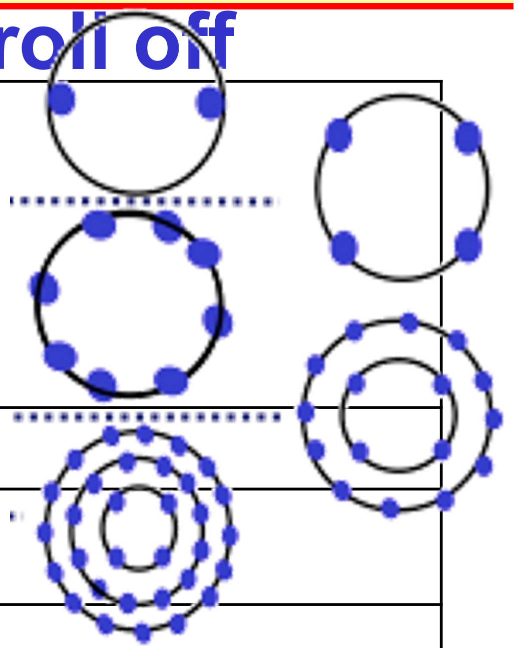


- Multiple compression and resolutions supported
  - MPEG-2, **MPEG-4 (H.264)** for either SD and HD TV transport streams
  - Some extensions to use also **HEVC (H.265)**, more efficient for 4K, are foreseen
- Multiple coding/modulations, adaptive coding and modulation
- Increased system capacity over DVB-S
  - up to 40% better satellite transponder utilization in broadcast mode;
  - more subscribers per unit of bandwidth in interactive mode;
  - backward compatibility with DVB-S
- Improved link margin
  - increased availability, extended coverage and enhanced robustness to noise and interference
- Flexibility to match a wide range of transponder characteristics
- Possible use of bigger packets than MPEG-TS (188 bytes); possible use of generic stream of IP packets and ATM cells

DVB S2 - FEC

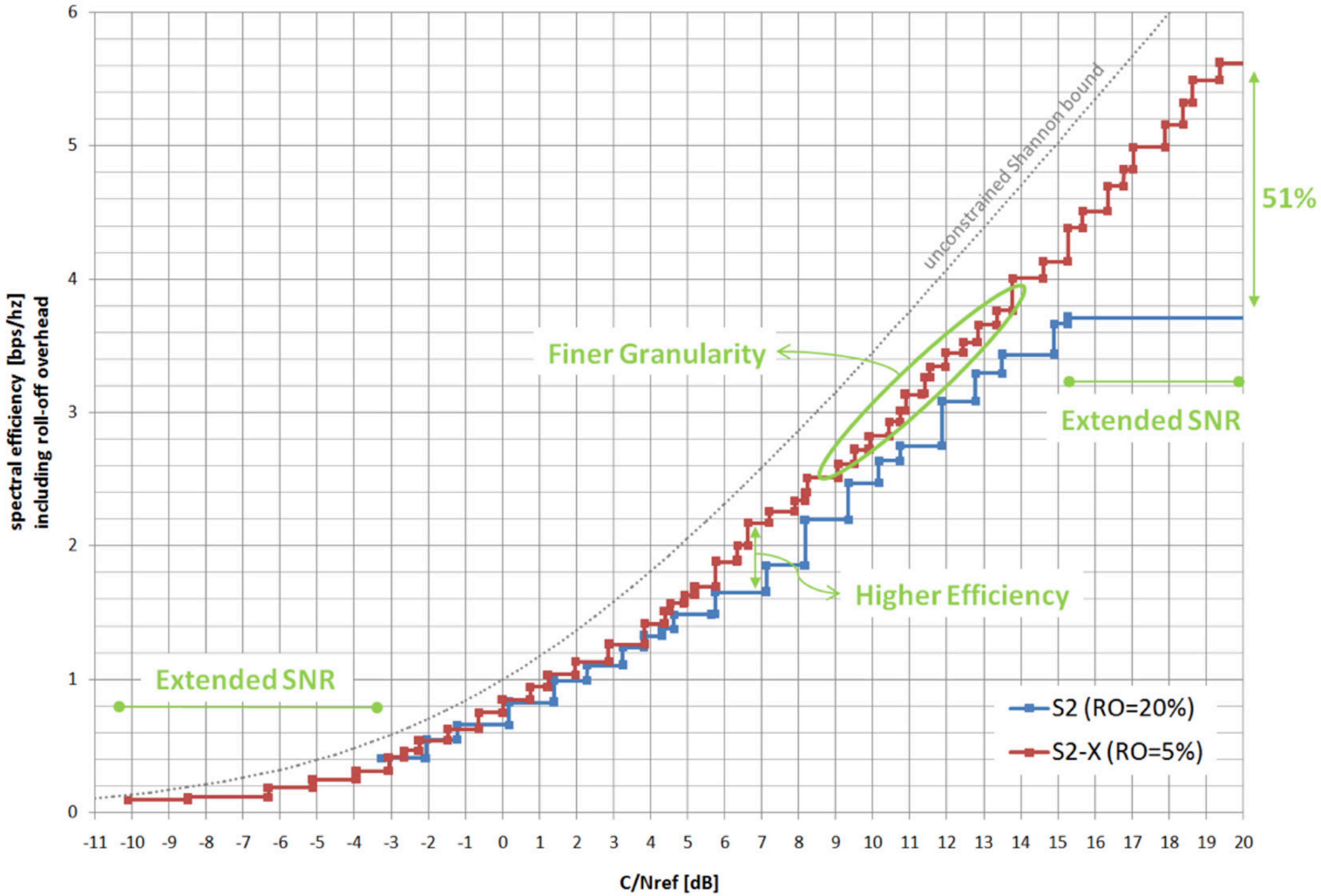
- Outer coding Bose-Chaudhuri-Hocquenghem (BCH) systematic code, concatenated with inner code Low Density Parity Check Codes (LDPC);
- BCH used to correct from 8 to12 bits of the information block with a fixed output of 64800 bits (or 16200 bits).
- The adopted LDPC belongs to extended IRA (Irregular Repeat-Accumulate) family where the sparse matrix H_1 is quasi-cyclic
- Periodic structures facilitating parallel decoding; about 50 decoding iterations
- Available coding rates for the LDPC code are:
  - 1/4, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9, 9/10

DVB S2 - Modulation format and roll off

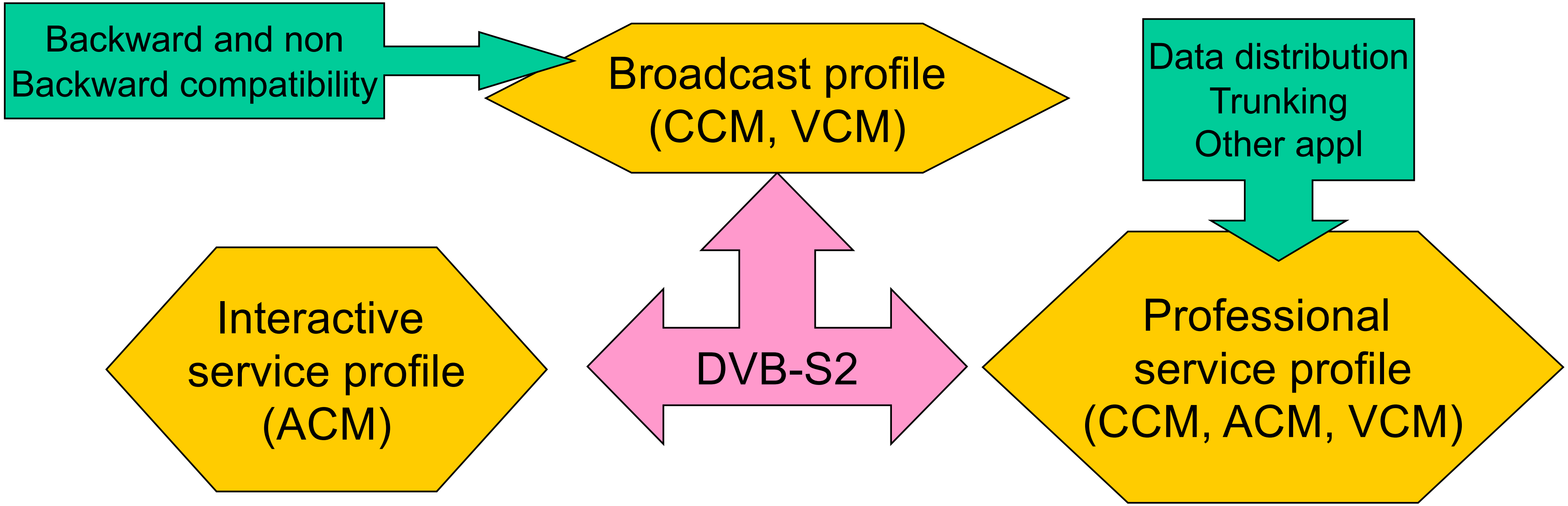


5 modulation schemes (all optimized to operate over non linear transponders)	• BPSK (1 bit/s/Hz) • QPSK (2 bit/s/Hz) • 8PSK (3 bit/s/Hz) • 16APSK (4 bit/s/Hz): 4-12-APSK • 32APSK (5 bit/s/Hz): 4-12-16APSK
3 roll off factors	• 0.35, 0.25, 0.20
DVB S2X	
Improves the spectral efficiency by 20% and 51% compared to DVB-S2)	• 64APSK, 128APSK, and 256APSK • new LDPC coding ratios (13/45, 9/20, 11/20, 23/36, 25/36, 13/18, 5/9, 26/45, 3/5, 28/45, 7/9, 77/90, 5/9, 8/15, 1/2, 2/3, 11/15, 7/9, 4/5, 5/6, 32/45, …..) • additional Modulation and Coding (MODCODs) optimized for linear satellite channel • Smaller roll-off factors (0.05, 0.10, and 0.15). • Additional scrambling options for critical co-channel interference situations • Channel bonding of up to 3 channels • Very low SNR operation support down to -10 dB SNR • Super-frame option

Spectral efficiency: DVB-S2X vs DVB-S2



Use of different MODES



CCM: Constant Coding and Modulation (constant protection)
VCM: Variable Coding and Modulation (user controlled protection)
ACM: Adaptive Coding and Modulation (different protection per stream)

Operational Modes

CCM: repeating frame configuration

Physical layer #N (e.g. 8PSK r=2/3)	Physical layer #N (e.g. 8PSK r=2/3)	Physical layer #N (e.g. 8PSK r=2/3)	Physical layer #N (e.g. 8PSK r=2/3)

VCM: periodic frame configuration

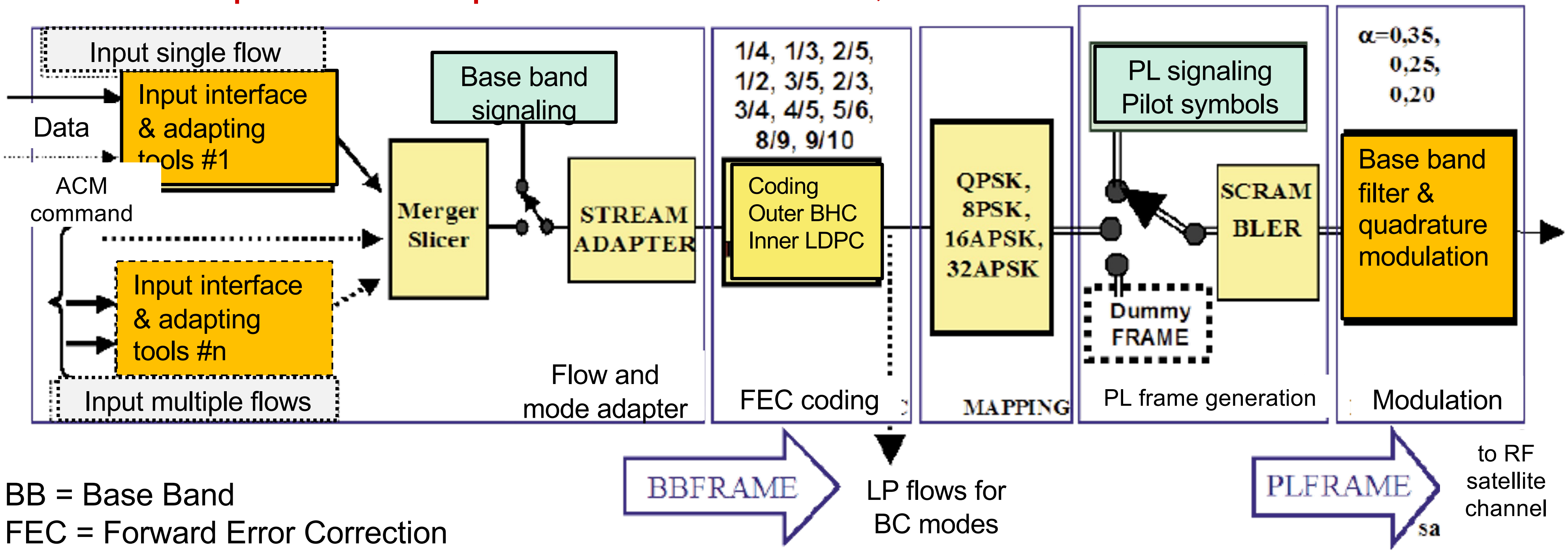
Physical layer #N (e.g. QPSK r=2/3)	Physical layer #N (e.g. 8PSK r=3/4)	Physical layer #N (e.g. QPSK r=2/3)	Physical layer #N (e.g. 8PSK r=3/4)

ACM: irregular frame configuration

Physical layer #K (e.g. 16PSK r=4/5)	Physical layer #N (e.g. 8PSK r=2/3)	Physical layer #M (e.g. QPSK r=3/4)	Physical layer #O (e.g. 16PSK r=2/3)

DVB-S2 sequential framing

- DVB-S2 system has a more complex and strictly coupled source coding and channel adapter blocks
- They rely on a sequence of functional blocks allowing the sequential composition of: BBframe, FECframe and PLframe



BB = Base Band
FEC = Forward Error Correction
PL = physical layer

BBframe

- BBFrame is the baseband main data structure of DVB-S2.
- BBFrame contains a signaling header (80 bytes) that includes:
  - Input stream identifier in case of multiple streams (i.e. MPEG)
  - Stream Type (generic: Generic Stream, or TS: Transport Stream)
  - Mode (CCM, VCM o ACM)
- The rest of the BBFrame contains the payload (e.g., many MPEG-TS cells). BBFrames have variable payload length, so that combined with Forward Error Correction reach a fixed output of 64800 bits (or 16200 bits) to form a FECframe.
- FEC is performed by LDPC/BCH coding; the bigger frame length in DVB-S2 improves wrt DVB-S on:
  - Transmission efficiency
  - Robustness against noise

FECFrame

- FEC frame has fixed size of 64800 bits (although for some special reasons 16200 can configured as alternative in the whole system)
- Strongest FECs leaves less space to the BBFrame (which contains the payload).
- FEC is provided by outer and Inner coding (BCH and LDPC) which can be variable and change during transmission (see ACM)

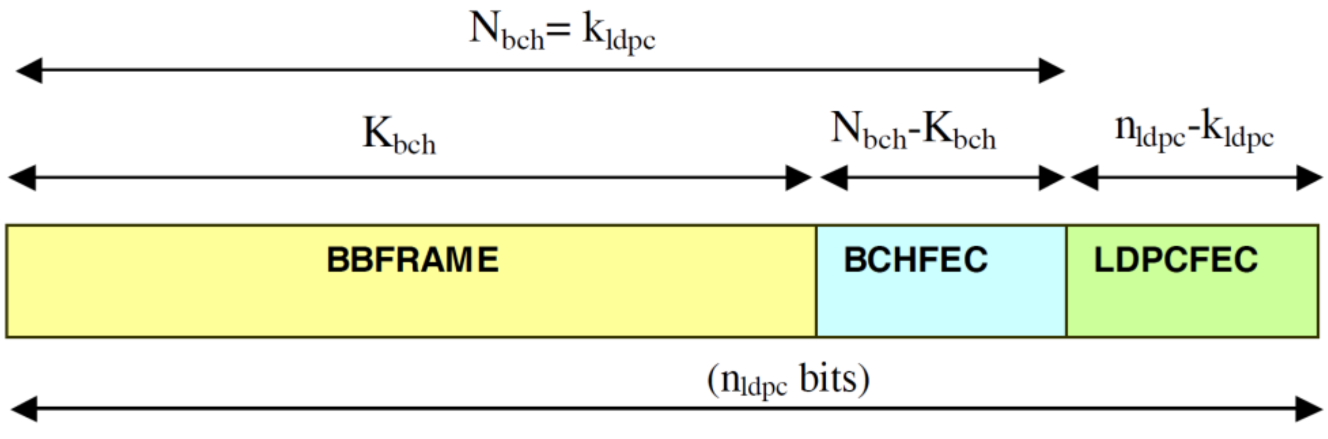
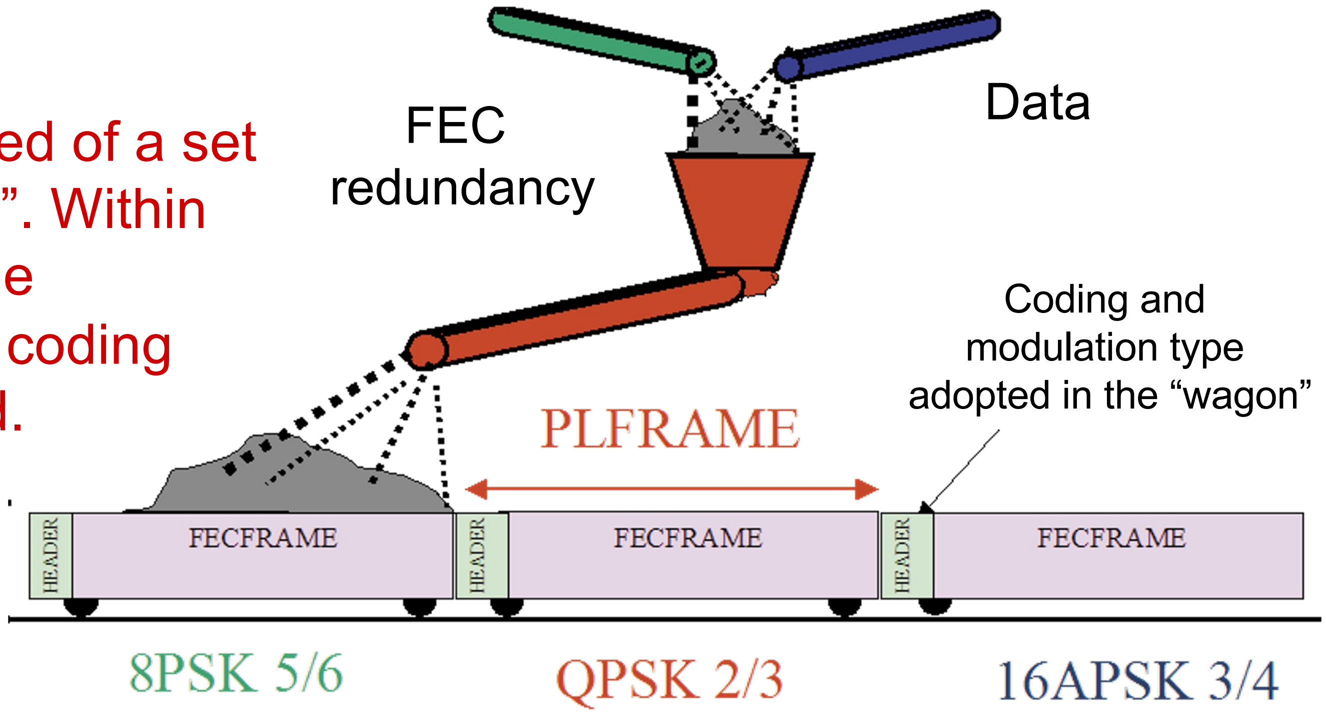


Figure 6: format of data before bit interleaving
(n_{ldpc} = 64 800 bits for normal FECFRAME, n_{ldpc} = 16 200 bits for short FECFRAME)

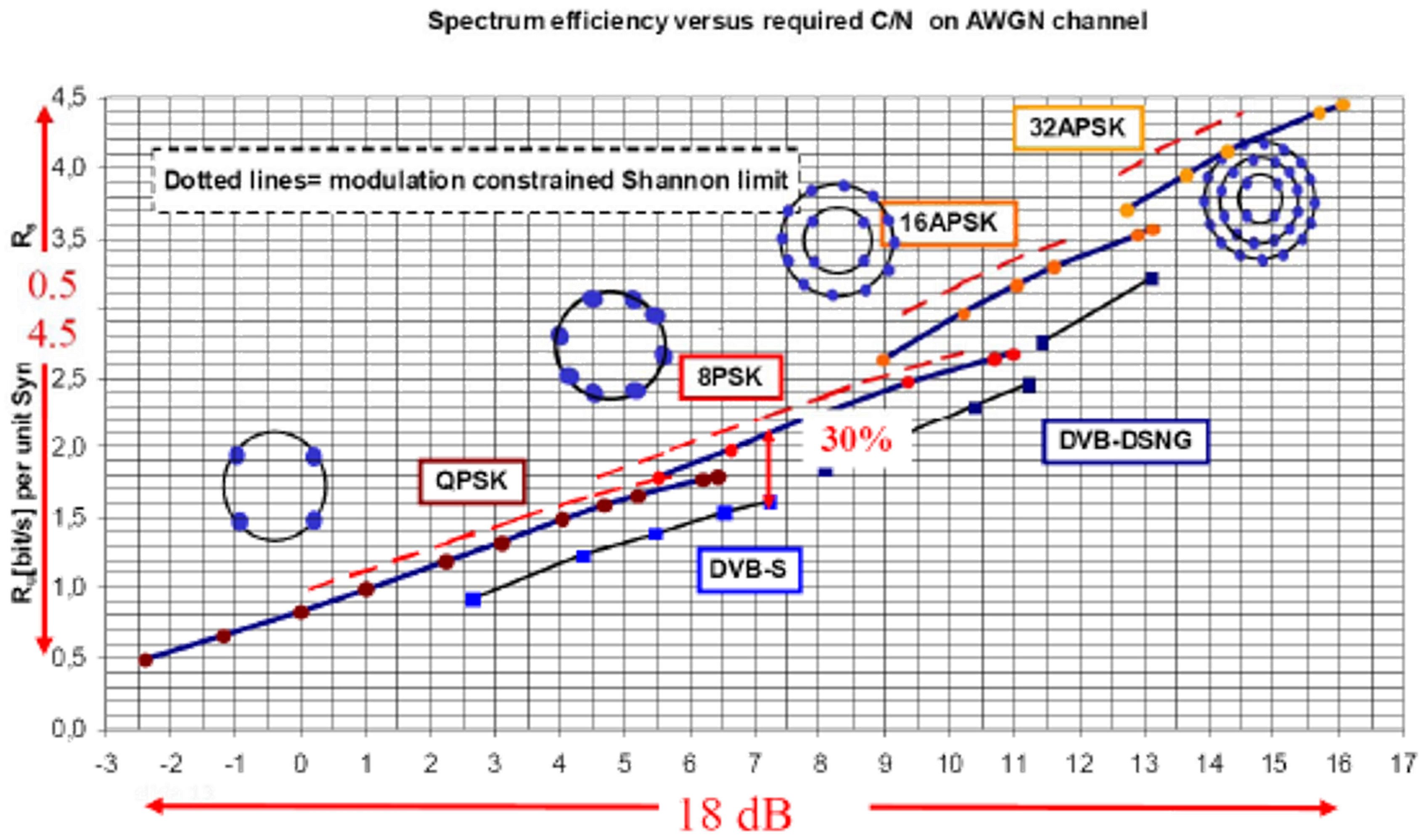
PLframe (Physical Layer Frame)

- PLframe was designed to:
  - detect both used modulation and coding parameters before demodulation and FEC decoding of the received signal.
  - To syncronize the receiver

- PLframe is composed of a set of periodic “wagons”. Within each wagon both the modulation and the coding are kept unchanged.



DVB-S2 nearer to Shannon’s limits



DVB SH

- Broadcasting of classic Radio and TV content;
- Broadcasting of audio or video content customized for Mobile TV (e.g. virtual TV channels, pod-casts);
- Data delivery ("push"), e.g. for ring tones, logos;
- Video on demand services;
- Informative services (e.g. news) including location-based services;
- Interactive services, via an external communications channel (e.g. UMTS or satellite return link)
- Companion of DVB-H standard for terrestrial handheld broadcasting in VHF band
- At present not in use any longer.

Features

- DVB-SH supports mobile broadcasting for frequencies up to 3 GHz for hybrid satellite/terrestrial networks
- Seamless service continuity between SC (Satellite Component) and CGC (Complementary Ground Component) coverages;
- Support of all reception conditions associated to portable and mobile terminals: indoor/outdoor, urban/sub-urban/rural, static/mobile conditions. Typical mobility conditions covers pedestrian as well as land vehicular scenarios;
- Possible implementation of power saving schemes to minimize the power consumption of battery activated terminals in order to maximize autonomy;
- Local insertion of broadcast services on CGC;
- Use different kinds of distribution network to feed the CGC repeaters, such as Satellite (DVB-S/S2) and/or terrestrial (Optical fiber, Wireless Local Loop, xDSL…) resources;

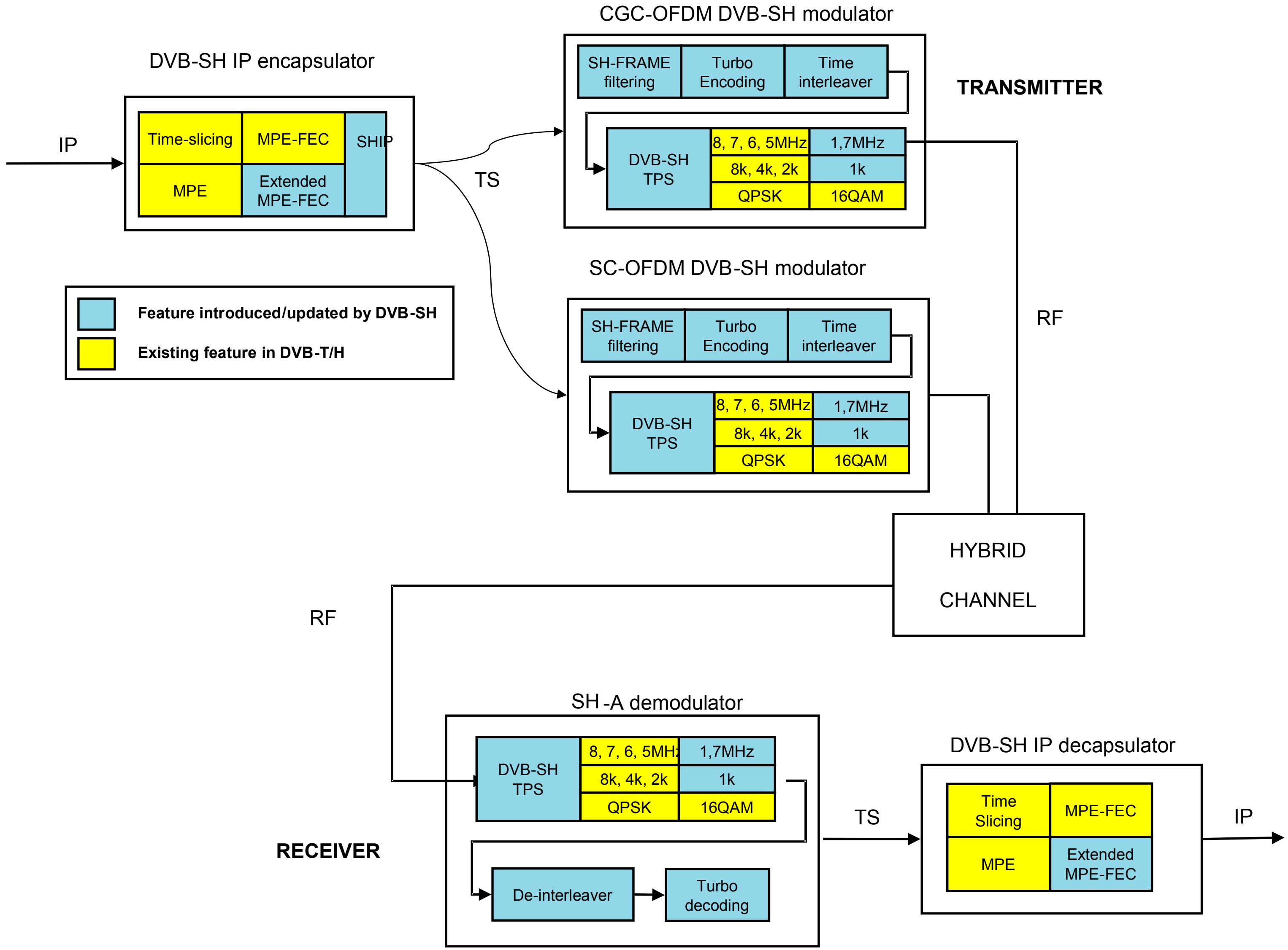
Configuration/Receiver

- Two main system configurations:
  - SH-A uses OFDM both on the satellite and the terrestrial link
  - SH-B uses TDM on the satellite link and OFDM for the terrestrial link
  - In both cases satellite/terrestrial SFN (Single-Frequency Network) and MFN (Multi-Frequency Network) configurations can be supported
- Two receiver classes:
  - The first (Class 1 Receiver) is able to cope with rather short interruptions and mobile channel fading using appropriate mechanisms on the physical layer but supports the handling of long interruptions using redundancy on the link layer
  - The second (Class 2 Receiver) is able to handle long interruptions (in the order of magnitude of 10 seconds) directly on the physical layer. This is made possible via the use of a large memory directly accessible to the receiver chip.

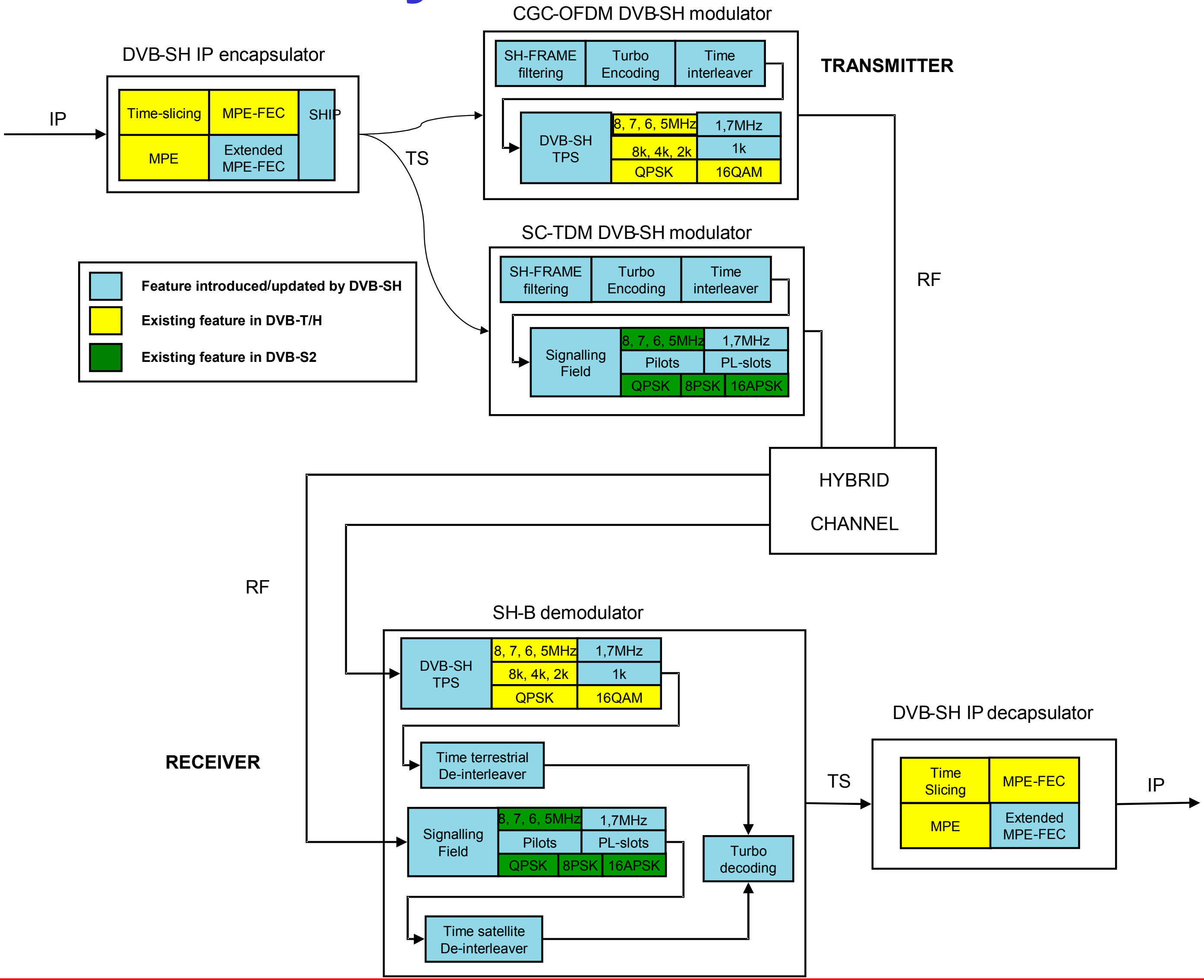
System Architecture

- Universal coverage by combining a Satellite Component (SC) and a Complementary Ground Component (CGC):
  - in a cooperative mode, the SC ensures geographical global coverage
  - CGC provides cellular-type coverage.
- Target terminals include handheld (PDAs, mobile phones), vehicle-mounted, nomadic (laptops, palmtops…) and stationary terminals
- The repeaters may be of three kinds:
  - "Terrestrial Transmitters"
  - "Personal Gap-fillers"
  - "Mobile transmitters"

SH A System Architecture

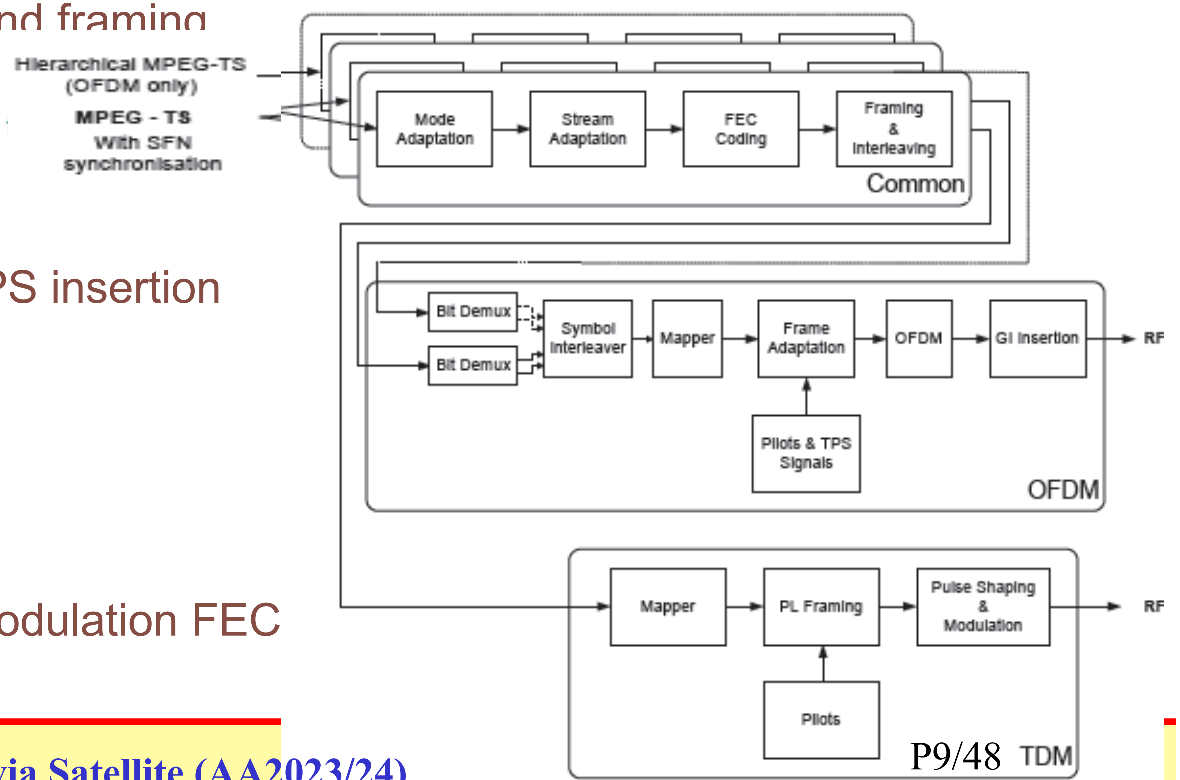


SH B System Architecture



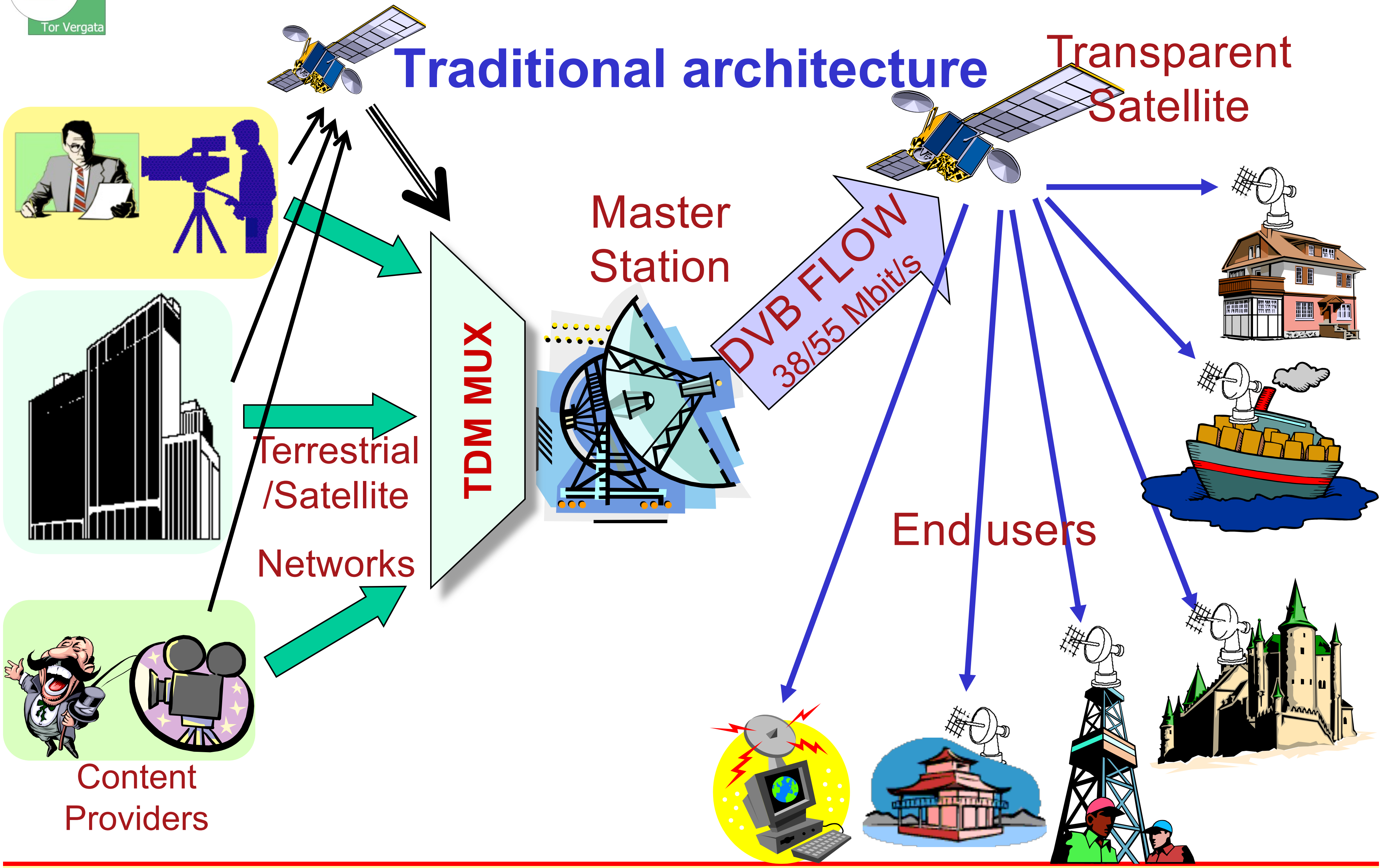
Block Diagram

- Both modes:
  - Mode adaptation: CRC-16 and insertion of the Encapsulation Frame Header.
  - Stream adaptation: padding and scrambling of the Encapsulation Frame.
  - Forward Error Correction (FEC) encoding using 3GPP2 [3] turbo code.
  - Bit-wise interleaving applying on a FEC block. The latter is meanwhile shortened to comply with the modulation frame structure of OFDM and TDM.
  - Convolutional time interleaving and framing
- SH-A OFDM mode:
  - Symbol interleaver.
  - Bit mapping to the constellation.
  - OFDM framing with pilots and TPS insertion
- SH-B TDM mode:
  - Bit mapping to the constellation.
  - TDM physical layer framing.
  - Pilots insertion and scrambling.
  - Pulse shaping and quadrature modulation FEC

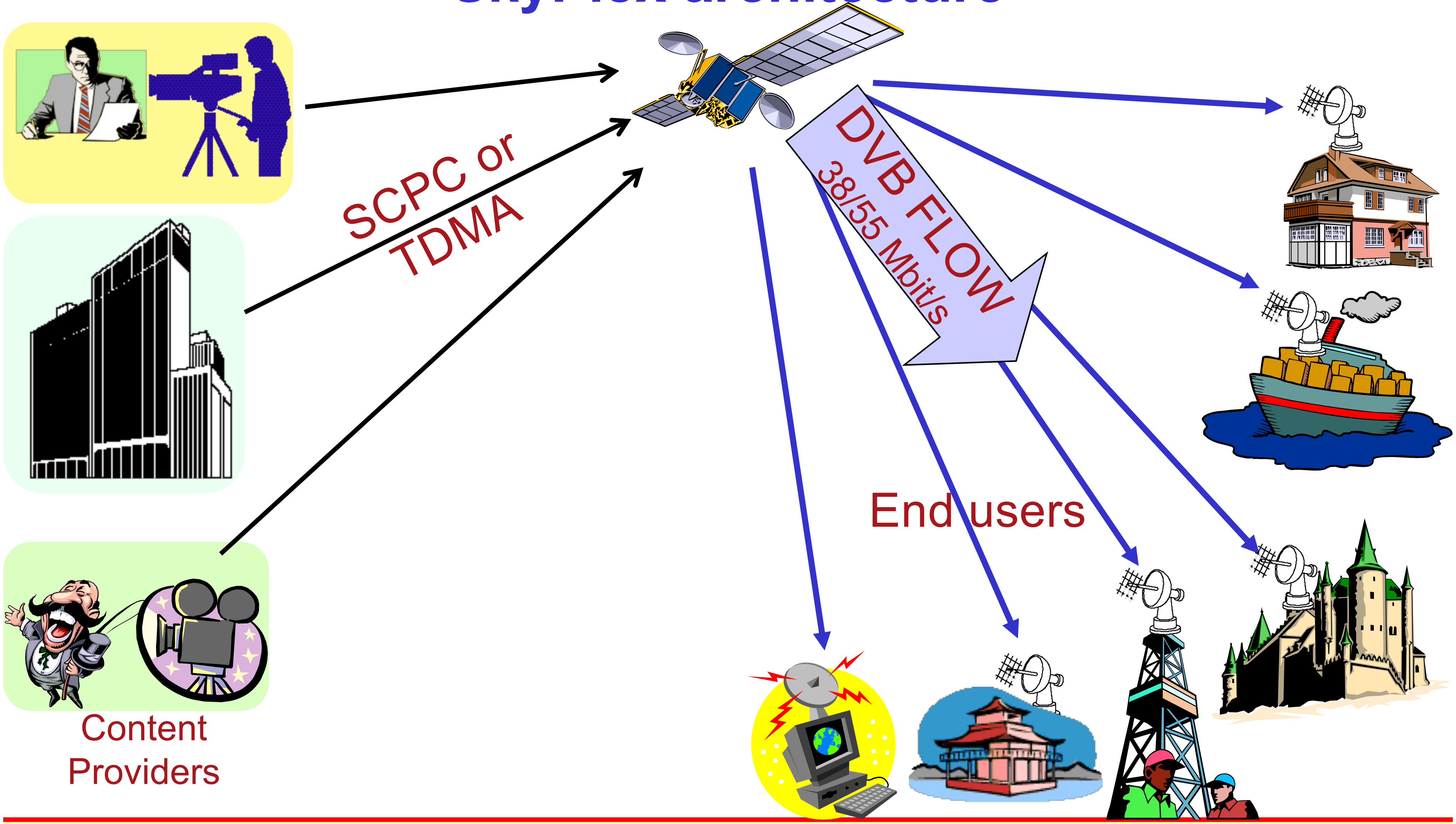


Broadcasting system architectures

Traditional architecture



SkyPlex architecture



Skyplex concept

- The Skyplex_Net system architecture is based on a quite innovative technology, namely the Skyplex on board multiplexer, designed and developed by Alenia Spazio
- The basic idea is to avoid any kind of centralization regarding the management of the space resource, making available the direct access to the satellite transponder
- Operated in downlink in full compliance with the DVB (Digital Video Broadcasting) standard through up-link stations relatively simple and not expensive.
- The key feature of Skyplex system is the possibility to avoid the cost of the terrestrial tails to reach the master up-link station.
- Although designed for TV broadcasting it has revealed enormous advantages regarding the IP based applications due to MPEG2-Transport Stream inherent capability to transport also IP packets.

Generalities

- The Skyplex_net system optimizes separately the two basic links of a satellite broadcasting system
- This because Skyplex re-combines different up-streams into a single 55 Mbit/s down-link stream compatible with DVB-S standard
- End users do not perceive any difference between a Skyplex transmission and the one operated through a usual transparent transponder.
- It enables uplinking of television, multimedia or Internet programming formatted as MPEG - 2 transport streams from independent, geographically dispersed locations; multiplexing them on-board the satellite; and transmitting them as a single signal in DVB (digital video broadcast) format to consumer receivers connected to a television set or personal computer.
- The received Skyplex signal is of an identical format to a DVB multiplexed on the ground.

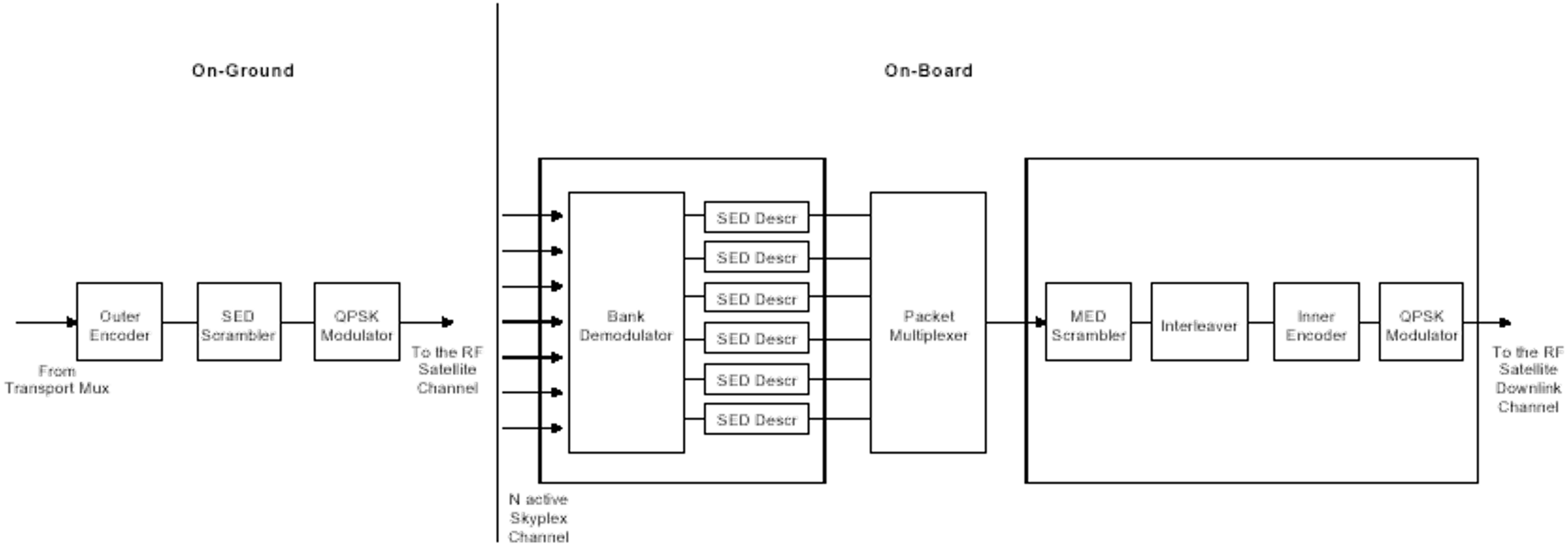
Transmission schemes

- On the uplink, stations access either in a continuous mode, referred to for convenience as SCPC, or in a TDMA mode. The TDMA mode offers the flexibility such that a full Skyplex channel may be shared by up to 6 uplink stations and in unequal proportions. Both types of access are at a maximum transmission rate of the order of 6 Mbits/s.
- Two classes of information rate are defined in the SCPC mode.
  - 'high data rates' (RH) at approximately 6 Mbits/s and
  - 'low data rates' (RL) at approximately 2 Mbits/s.
- On the downlink, the single output stream transmitted by the satellite is a continuous TDM digital stream R_{dw} at 27.5 Msymbols/s (55 Mbits/s).
- The exact RH and RL rate values may be deduced from the following equation:
- $R_{dw} = (NH * RH + NL * RL) * (204/188) * (1/2r)$
  - RL is fixed at 2.112 Mbits/s
  - r = the FEC rate (3/4, 2/3, 1/2)
  - NH = the number of 'high data rate' active channels
  - NL = the number of 'low data rate' active channels
  - 204/188 = the Reed-Solomon expansion ratio

On ground and on board processing

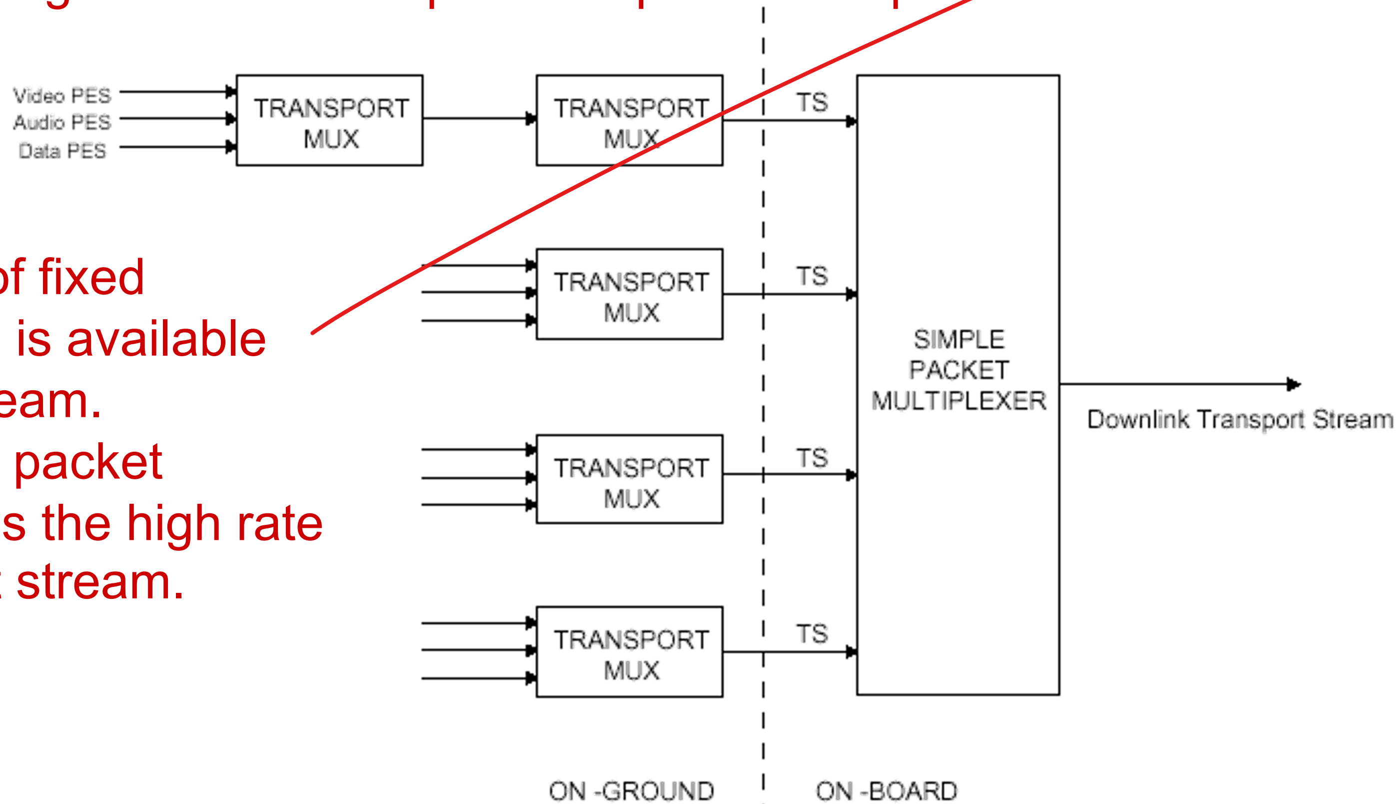
- The on-ground functions include
  - transport packet generation and multiplexing,
  - Reed-Solomon outer encoding,
  - Short Energy Dispersal (SED) scrambling
  - QPSK modulation.
- The on-board functions include
  - demodulation of each Skyplex channel,
  - SED descrambling,
  - multiplexing,
  - Modified Energy Dispersal (MED) scrambling,
  - Viterbi inner encoding
  - QPSK modulation.
- An MPEG - 2 transport stream is composed of transport packets, each packet containing 184 bytes of payload data and 4 bytes of header data.

DVB Satellite Channel Adaptation for Skyplex



Multiplexing

- The generation of transport packets is performed independently on the ground for each uplink transport stream.
- Packet Elementary Streams (PES) of video, audio and data are multiplexed on the ground in a transport multiplexer for uplink transmission.



- A limited number of fixed transmission rates is available for each uplink stream.
- A simple on-board packet multiplexer, creates the high rate downlink transport stream.

System Architecture (1/2)

- The **Network Operation Center (NOC)**, to manage the Skyplex_net system so that the appropriate transponder quota is guaranteed to each up-link station. Basic services:
  - the monitoring and control of the subnetworks
  - customer managent system.
- The **Service Center (SC)** , co-located with the skyplex up-link station. Composed of two major components:
  - the first strictly linked to service management,
  - the second connected to all supervision and control functions which have to be considered common to all applications. Into the latter class can be also included all the elements needed to handle the end user and the interactive channel interface.

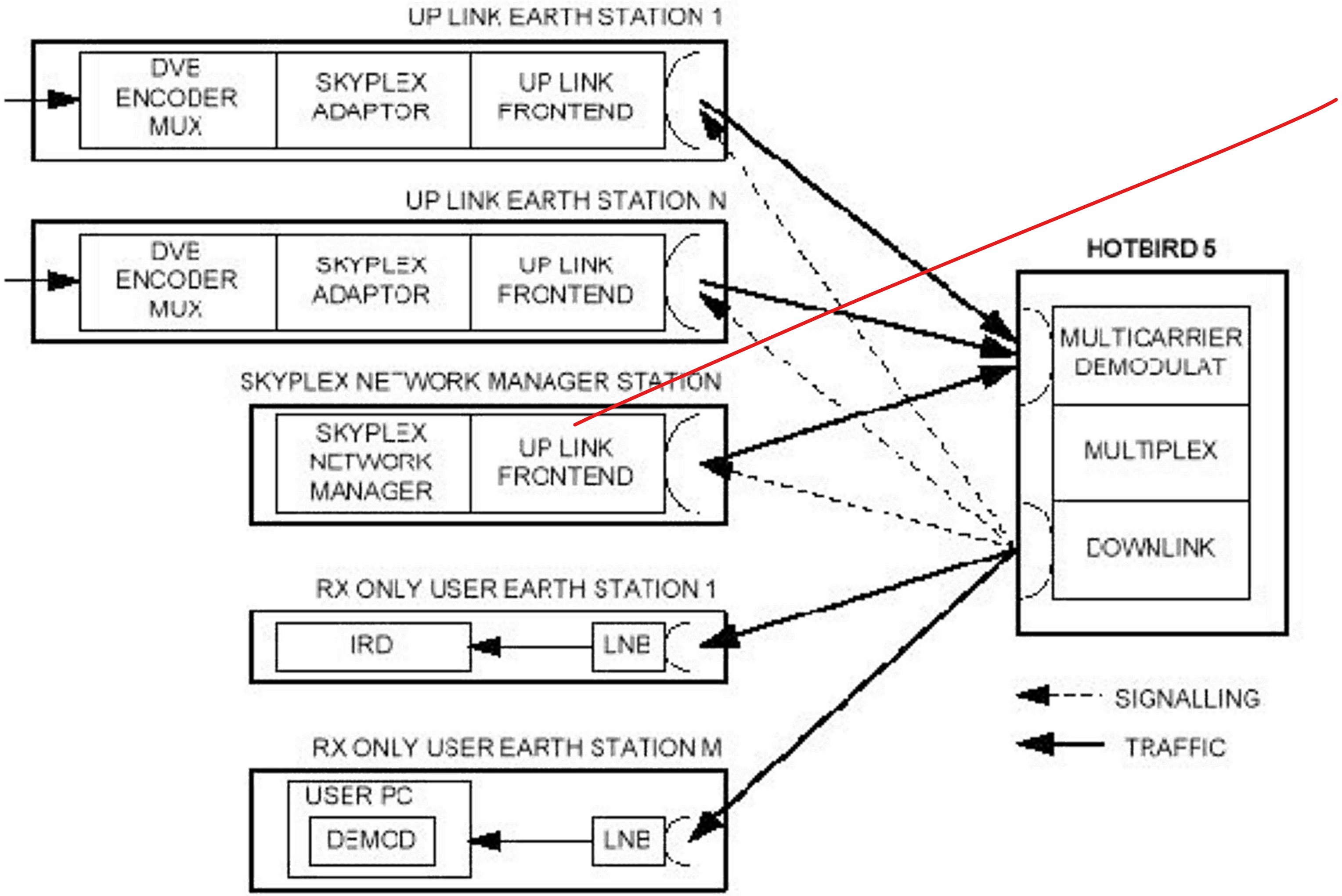
Main subsystem composing the SC will be:

- transaction server, content server, service scheduler and control, a conditional access system, an Internet server and a DVB mux (and/or a DVB/IP Gateway).

System Architecture (2/2)

- The **DVB Client Platform** at the end user premises. He will be equipped with:
  - A PC with a multimedia kit, enough powerful to join the services;
  - A Data Browser User System, with navigation Software and the data receiving card to put on the PC;
  - A modem to access the Internet, useful for those "Spread Content" services both in Broadcast – Internet way.
- The Data Browser manages the user station contents, spread both in Broadcast and Internet way, so that the user is able to freely navigate in one whole integrated environment.

Skyplex elements



System Architecture view

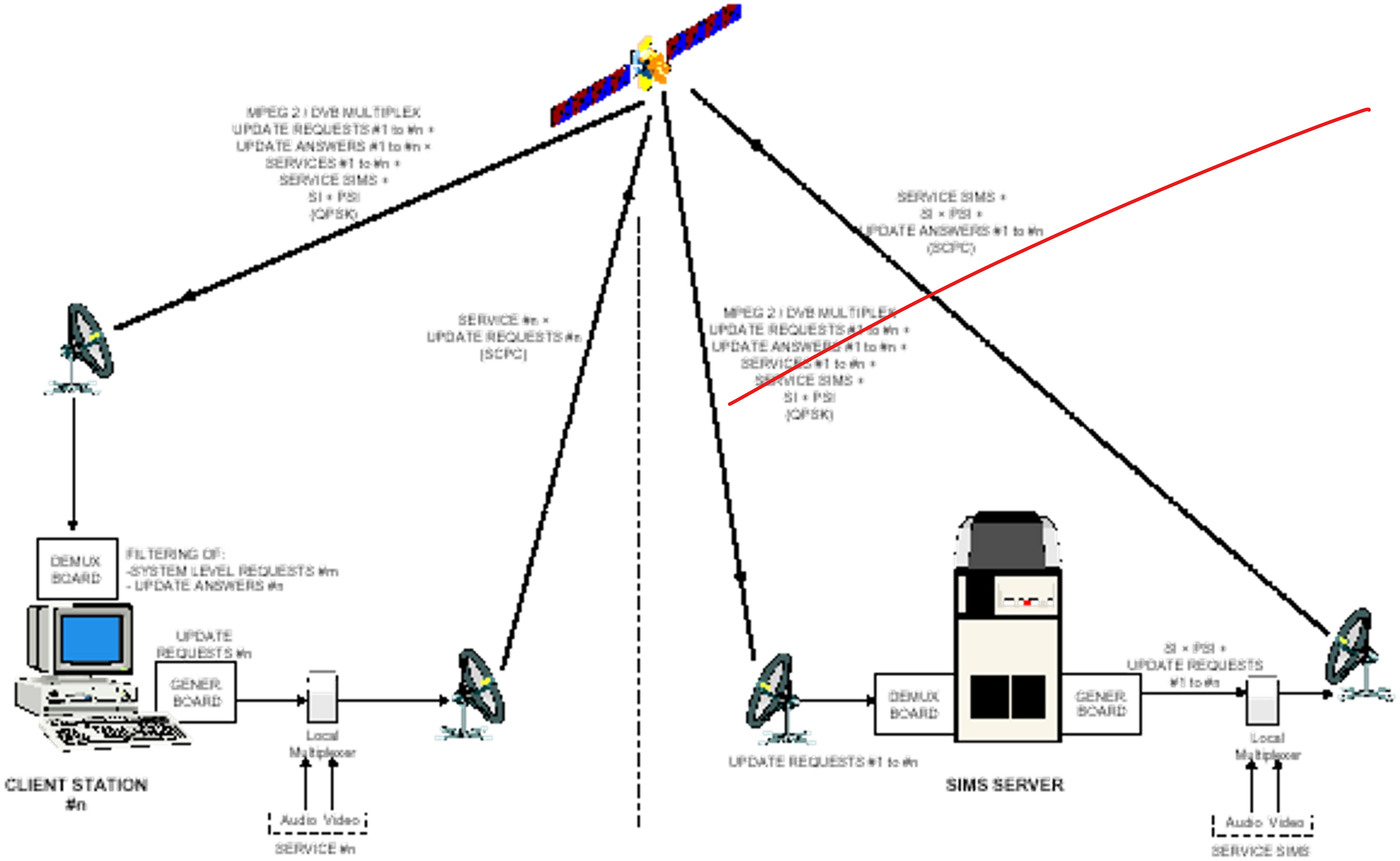


Figure 7 : Skyplex Network Management

DAB and BROADCAST RADIO SYSTEMS

DAB (Digital Audio Broadcasting)

- Digital Radio Broadcasting was promoted in Europe decided to satellite (project EU 147).
- Features:
  - OFDM modulation,
    - use of the Single Frequency Network (SFN) concept (reuse of the same frequency on all transmitters),
  - MPEG 2 layer 2 (MUSICAM) audio coding.
- Both for the satellites and the terrestrial repeaters
- The Archimedes satellite project was envisioned
- Unfortunately, satellite technology was not able to provide satisfactory performance at that time, and the thought in Europe that satellite could not be used for Digital Radio Broadcasting emerged.

T-DAB

- Activities only limited to terrestrial broadcasting (T-DAB).
- EU 147 based T-DAB has achieved only limited development. Main reasons are:
  - limited number of attractive programs,
  - limited coverage
  - limited capacity of programs (inefficient audio coding scheme, older than MP3)
  - limited FEC performance

S-DAB

- Digital audio signal compression has improved
  - digital audio signal occupies less bandwidth than an analog signal for the same quality, much lower than the CD standard.
  - ISO MPEG 2 Audio layer 3 (MP3): quasi-stereo CD quality at 64 kbit/s, reduced by more than 15 fold compared to CD.
  - ISO MPEG-2 AAC/AAC+ audio coding: CD quality at 48 kbit/s.
- Digital signals are more robust with respect to external interference (error correcting digital signal processing).
- Digital audio signals may be multiplexed with any other signal (image, test or files, and offers an enriched multimedia content). Interfaces with other applications are eased.
- Digital signal processing is cheaper than analog processing thanks to silicon large scale integration.

Radio Broadcasting

- Satellite is now optimised for radio broadcasting, particularly to portable or mobile receivers, compared to terrestrial broadcasting that requires far more investment.
- Europe has been involved for several years in the development of terrestrial DAB, but this system has a lot of difficulties to emerge commercially, partly due to its lack of coverage outside large cities.

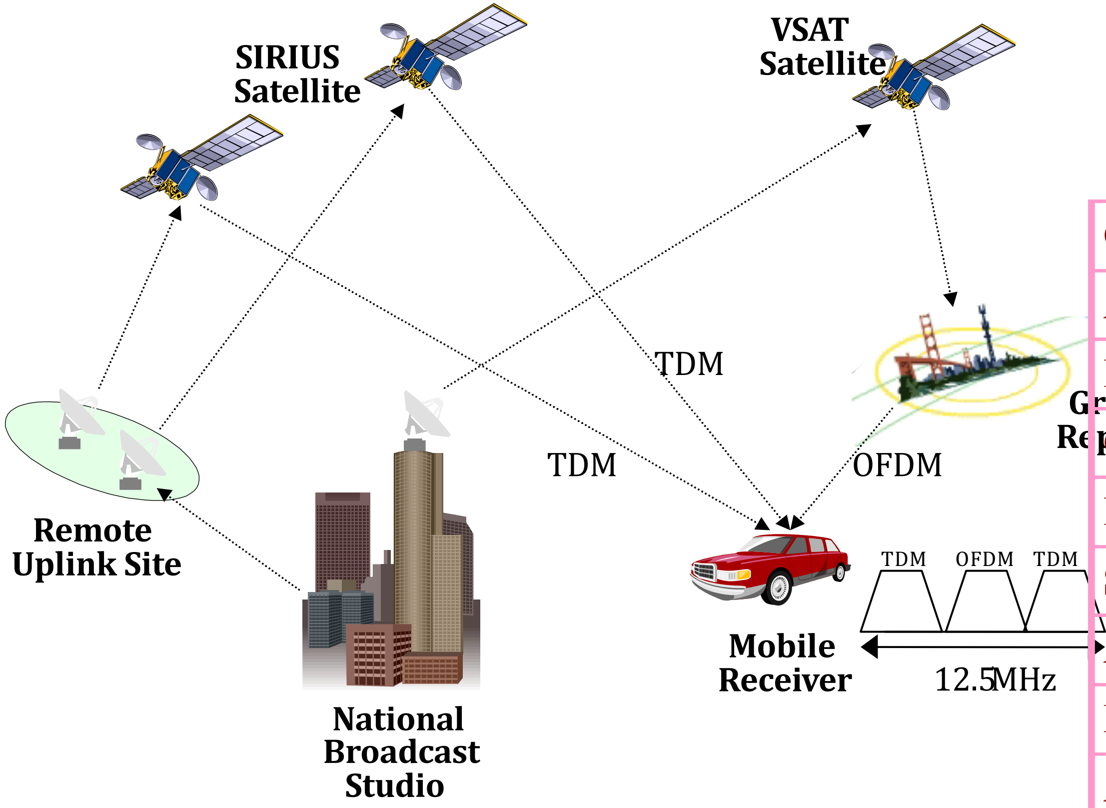
Spectrum allocation

- WARC 92 allocated the 1452 -1492 MHz band (L band) for Digital Radio Broadcasting over the major part of the world, including the WorldSpace service area, and Europe.
- In the US, the FCC has allocated the 2320 to 2345 MHz band for Digital Radio Broadcasting.

The Sirius system

- Aim
  - Digital Audio Broadcasting (DAB) service directly from satellites to vehicles across the Continental United States
- Constellation
  - three satellites in elliptic orbits at an inclination of 63.4°, with two satellites in visibility in any moment
- Gap fillers to permit continuous reception
- Frequency plan:
  - Rx: X-band (7060-7072.5 MHz), Tx: S-band (2320-2332.5 MHz).
- The 12.5 MHz S-band segmented into three sub-bands
  - The upper and lower sub-bands, each with a bandwidth of 4.2 MHz, are assigned to the two transmitting satellites that transmit the same broadcast material, time shifted of 4 s to increase diversity.
  - The middle sub-band, 4.1 MHz wide, is used by terrestrial repeaters which get the signal from a separate satellite
- Multiple access
  - Satellite: TDM (Time Division Multiplex), terrestrial: OFDM

Architecture



Orbit	Elliptical
Altitude, km	47102 x 24469
Period, hours	24
Orbit inclination	63.4°
Planes	3 x 120°
Satellites/plane	1
Antenna coverage	CONUS
Minimum elevation	60°
Access method	TDM/OFDM
Audio compression	PAC
Lifetime, years	15
Earth to Space, MHz	7060-7072.5
Space to Earth, MHz	2320-2332.5

The XM™ Satellite

- Frequency: S band (2332.5 to 2345 MHz)
- Constellation: two satellites in GEO orbit (complemented by a network of terrestrial repeaters)
- One hundred of channels of music and voice, each of which can be supplemented by service components (sub-channels) for carrying text and other data
- Coverage: USA
- Wide service areas, high digital sound quality, user friendliness, and portable and mobile reception.
- In addition to sound complementary services: broadcasting of multimedia and internet data

SDARS Receiver

SDARS Compatible
Human Machine Interface (HMI)

SDARS Antenna

Sirius XM

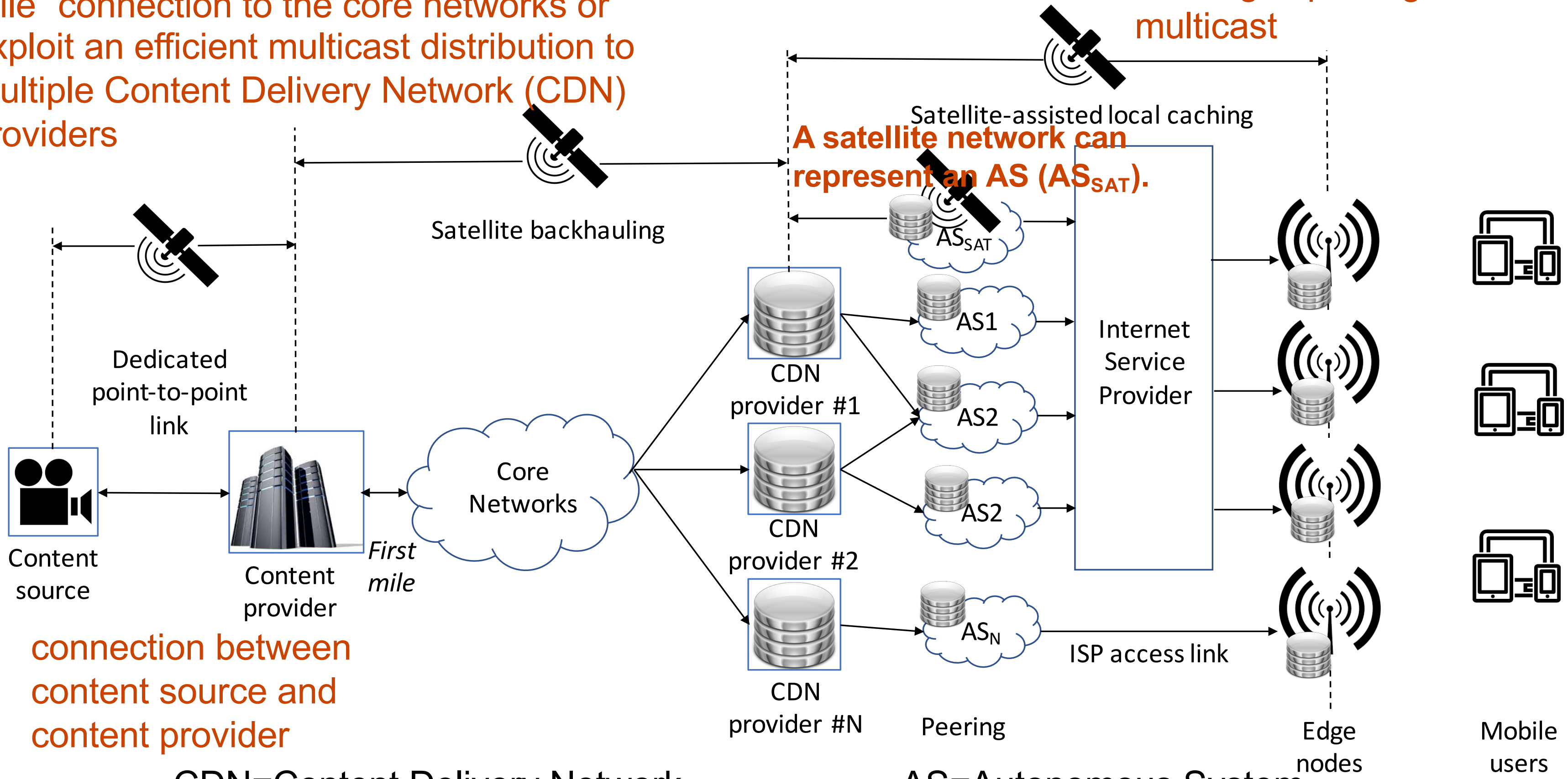
- Acquisition of XM Satellite Radio Holding, Inc. by Sirius Satellite Radio, Inc. on July 29, 2008
- Through Q2 2016, Sirius XM has 30.6 million subscribers.
- As of October 2012, there are nine satellites in orbit:
  - four XM
  - five Sirius satellites.

Satellite Service Delivery Model for content distribution

Content provider offloads video flows over a satellite link to
- mitigate possible congestion in the "first mile" connection to the core networks or
- exploit an efficient multicast distribution to multiple Content Delivery Network (CDN) providers

a satellite-assisted local caching exploiting multicast

A satellite network can represent an AS (AS_{SAT}).

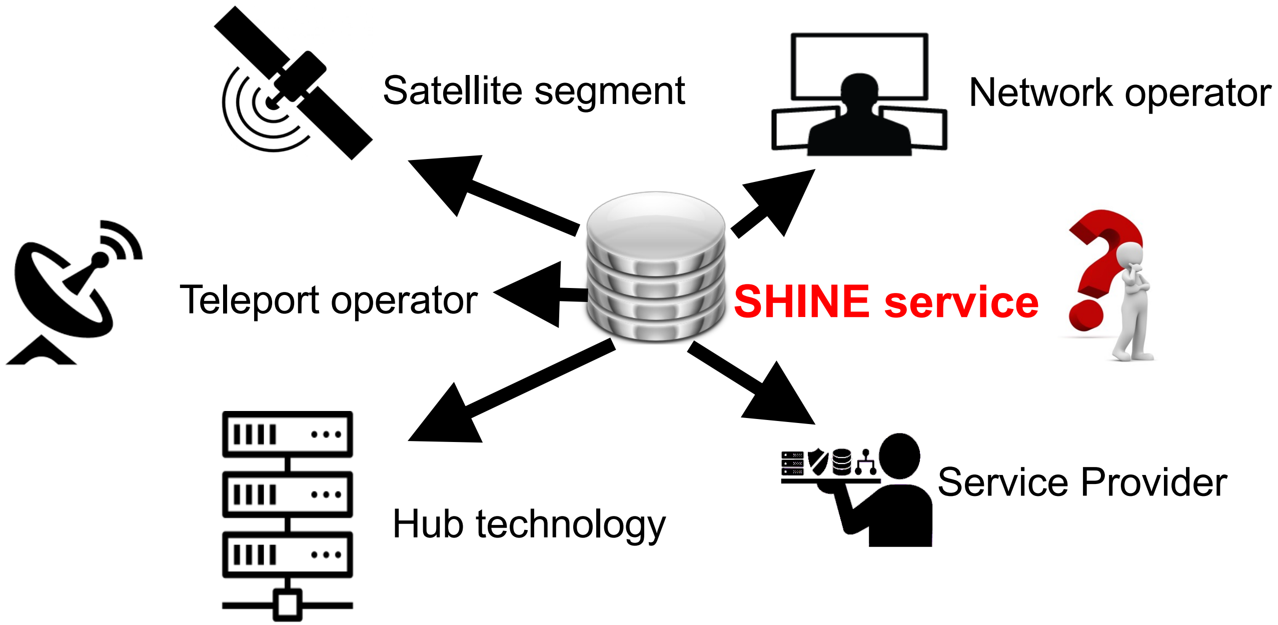


connection between content source and content provider

CDN=Content Delivery Network AS=Autonomous System

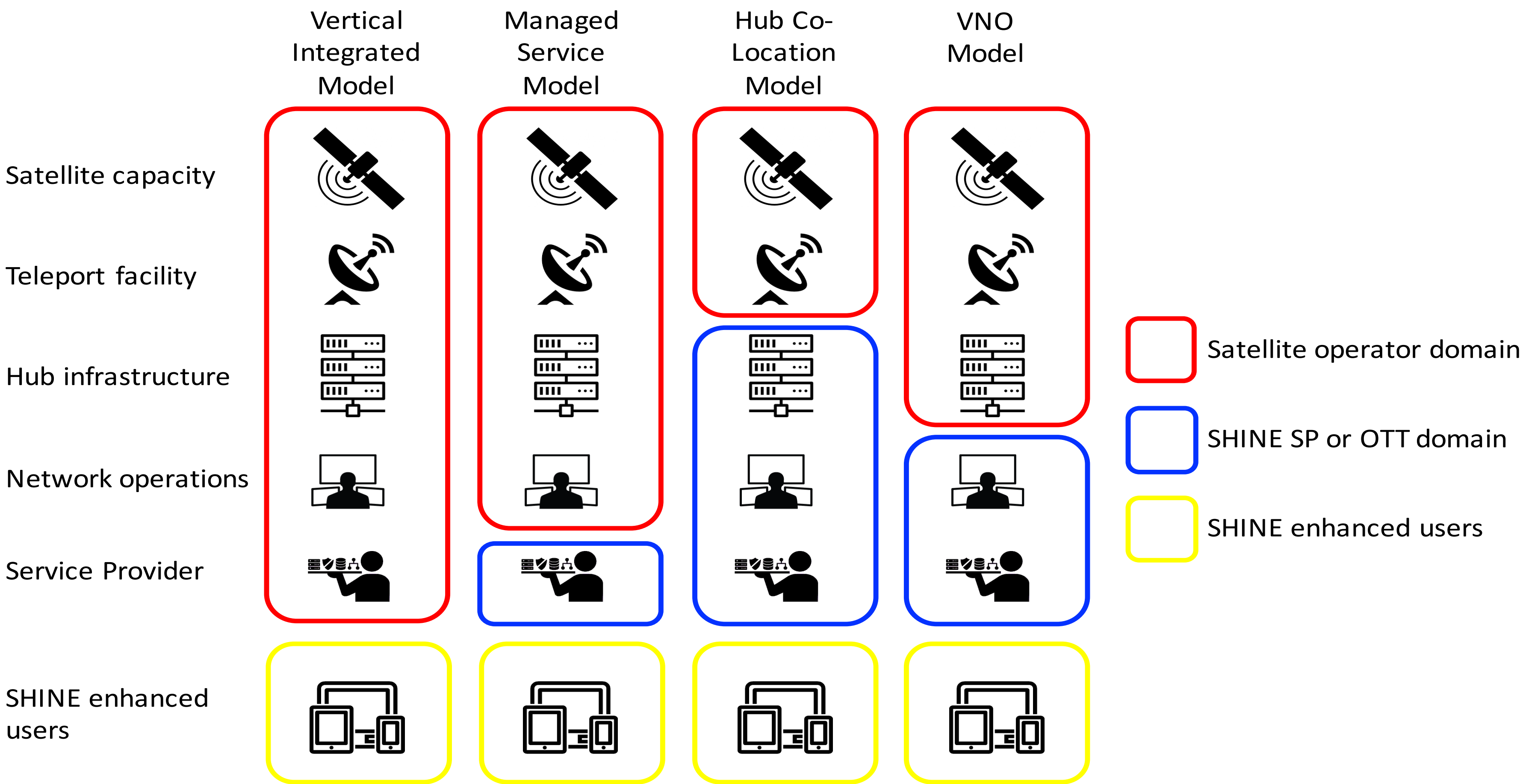
Models for satellite integration in the SHINE service

Satellite configuration entities:



SHINE (Secure Hybrid In Network caching Environment) Security and content rights management in satellite assisted in network caching systems

Models for satellite integration in the SHINE service



CDN configurations

CDN basic services:

1. **Request redirection and content delivery services** - content request must be redirected to the "closest"/ "best" CDN cache using performance criteria
2. **Content outsourcing and distribution services** - content in the origin server must be replicated and/or cached in distributed CDN caches.
3. **Content negotiation services** - each user or group of users requires a specific set of services (i.e. security services) when requiring content delivery.
4. **Management services** – CDN needs to manage the spread network components, to handle accounting and to monitor content usage.

CDN components:

1. **Content delivery component** - It consists of the origin server and a set of replica servers (or mirrored servers or simply caches), that deliver copies of the same content.
2. **Request-Routing component** - It is responsible for redirecting client requests to appropriate caches and for interacting with the distribution components in order to keep an updated view of the distributed content storage.
3. **Distribution component** - It performs copies of content from the origin server to the distributed caches ensuring consistency of the cached copies.
4. **Accounting component** - it maintains logs of the accesses and records the usage of the caches for billing.

CDN requirements to implement SHINE concept

Requirement 1 – Exploitation of satellite broadcast channel to fetch content

- Definition and Management of **multicast groups**
- number of users + geographical distribution + digital rights impact on the content suitable for the initial placement

SHINE fetching component

- Initial spread of content on the satellite-assisted local caches;
- Such an initial content dispatching can be initiated directly from origin servers. Therefore, once defined the multicast group, direct connections between the origin server and the Network Coding (NC) server can be established to move content for the initial SHINE local cache placement. NC server caches content, performs NC operations and sends coded data using the IP multicast address

CDN requirements to implement SHINE concept

Requirement 2 – Minimize local cache misses

Maximization of **content hits in the satellite-assisted local caches**, then reducing experienced delivery latency and load on the telco/access networks

SHINE request-routing component

SHINE local cache must act as local iterative DNS-server. It processes all the request-routing signaling. Therefore, if the content is cached, the **request is locally satisfied**.

In case of cache miss, the content request is processed by the SHINE request-routing component, which basically hierarchically queries Telco access network caches, core CDN caches and finally origin server.

"Basic" CDN distribution component

Once found cache/server having the requested content, transfer is directly carried towards the end-users, leveraging "standard" CDN protocols.

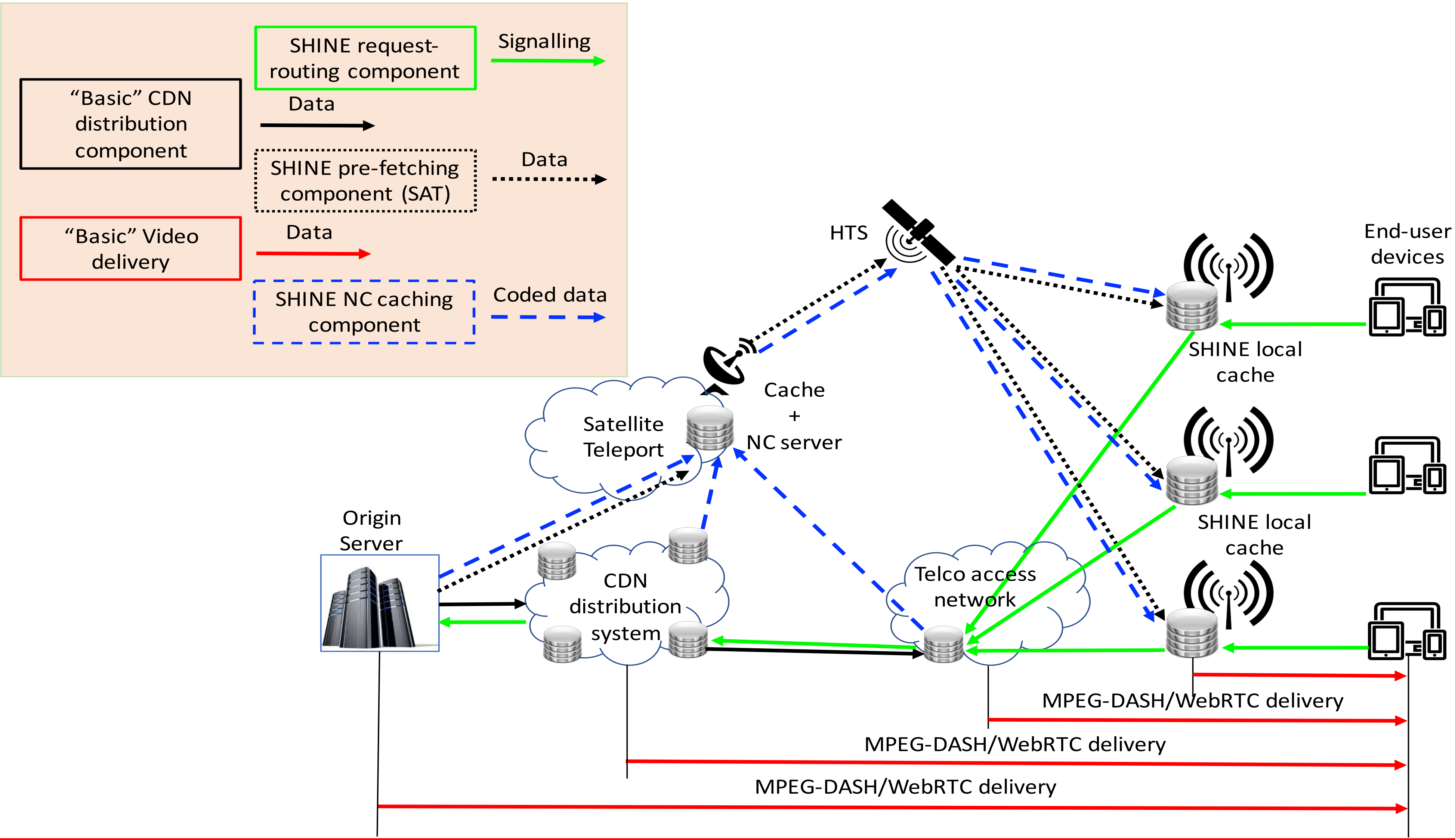
"Basic" video delivery

Actual multimedia transfer will be performed between the cache server, matching the video/chunk request and the end-user through either MPEG-DASH or WebRTC either directly to the user or towards the NC server

SHINE NC caching component

As a SHINE-related add-on, when request is originated by a SHINE local cache, the serving CDN cache MUST forward the target content also to the NC server.

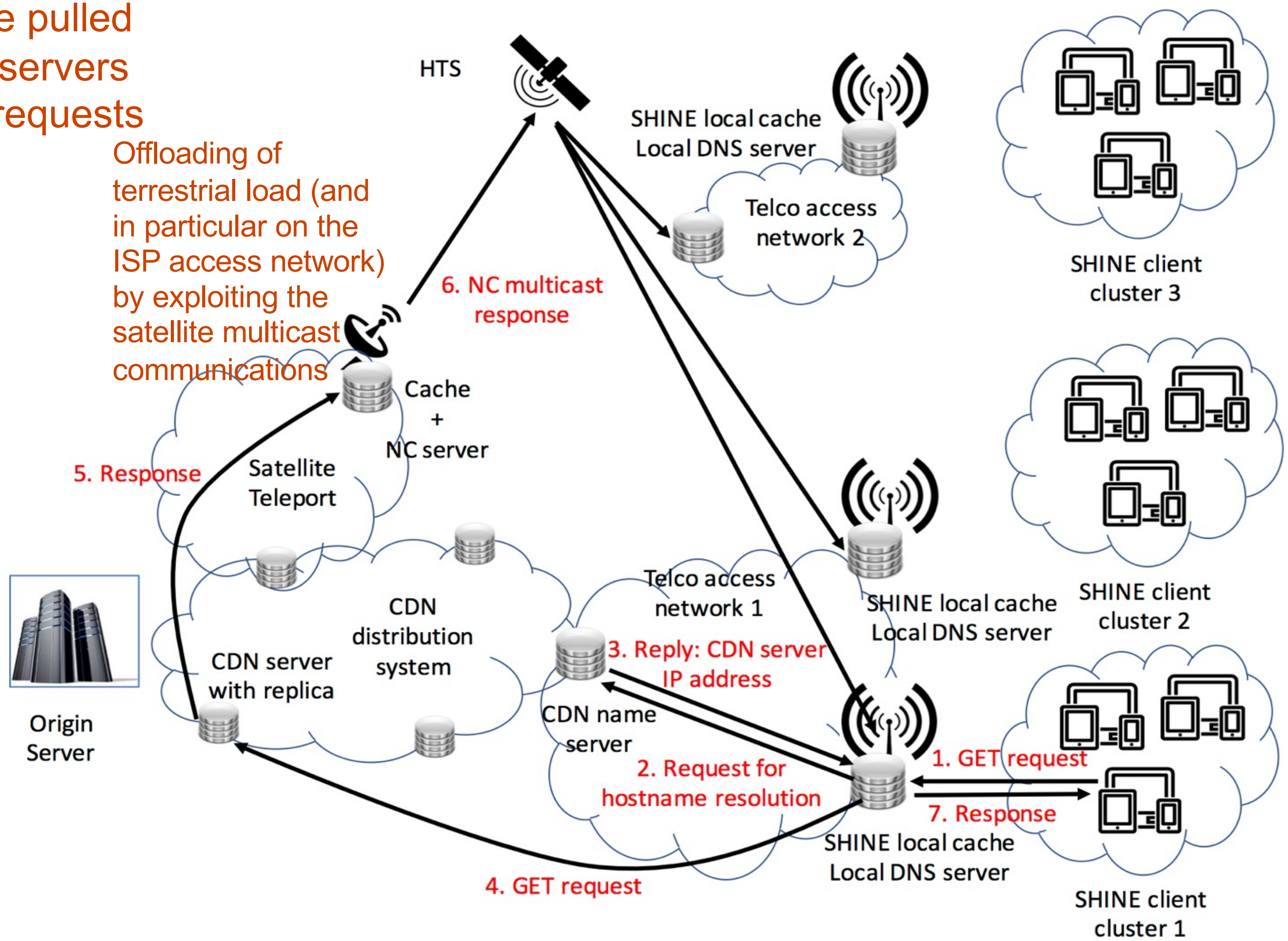
SHINE baseline CDN scenario configuration



Cooperative SHINE pull-based CDN architecture

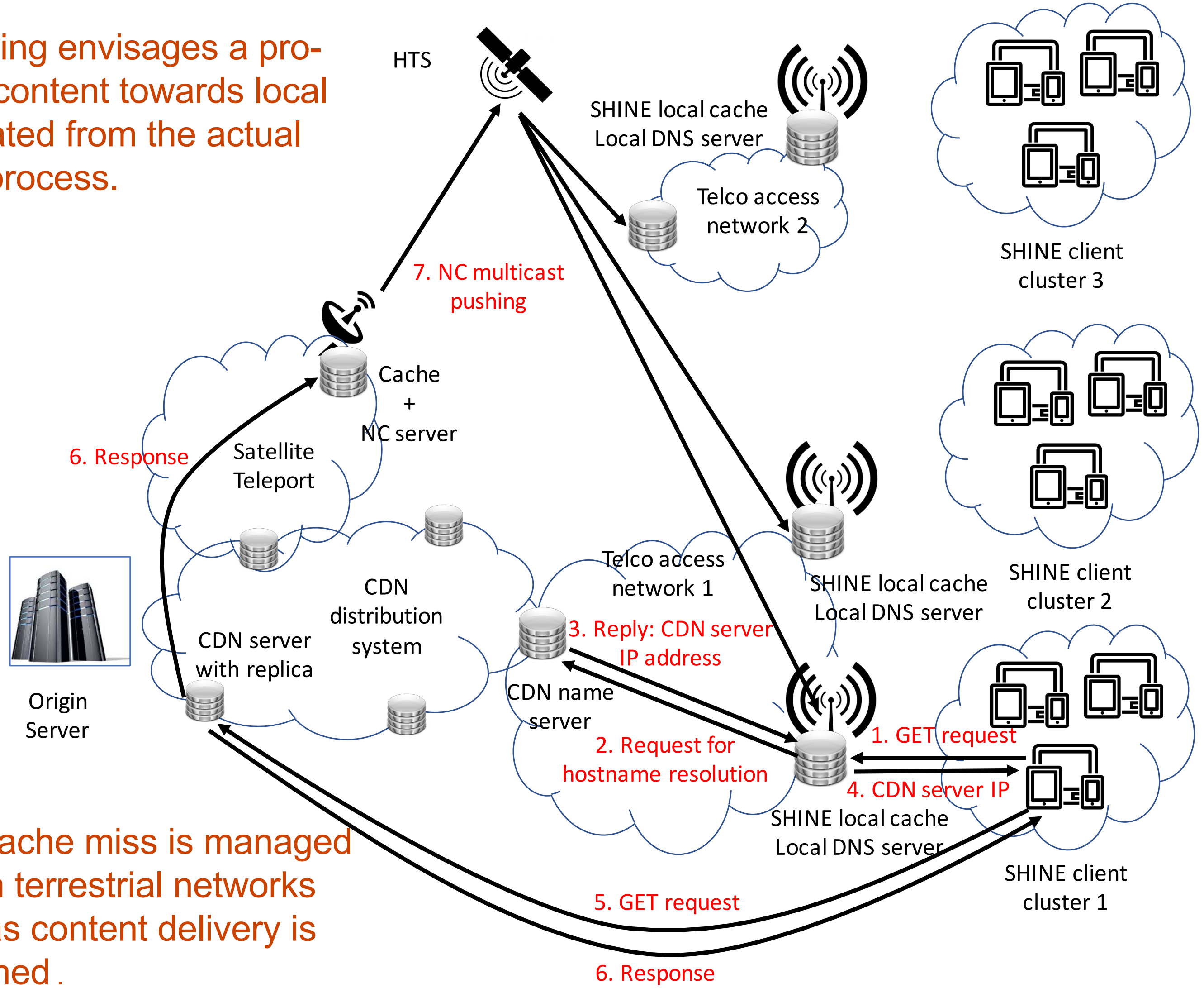
Contents are pulled to the edge servers upon client requests

Offloading of terrestrial load (and in particular on the ISP access network) by exploiting the satellite multicast communications



Cooperative SHINE push-based CDN architecture

Push-based caching envisages a pro-active moving of content towards local caches, uncorrelated from the actual content delivery process.



Local cache miss is managed through terrestrial networks as far as content delivery is concerned.

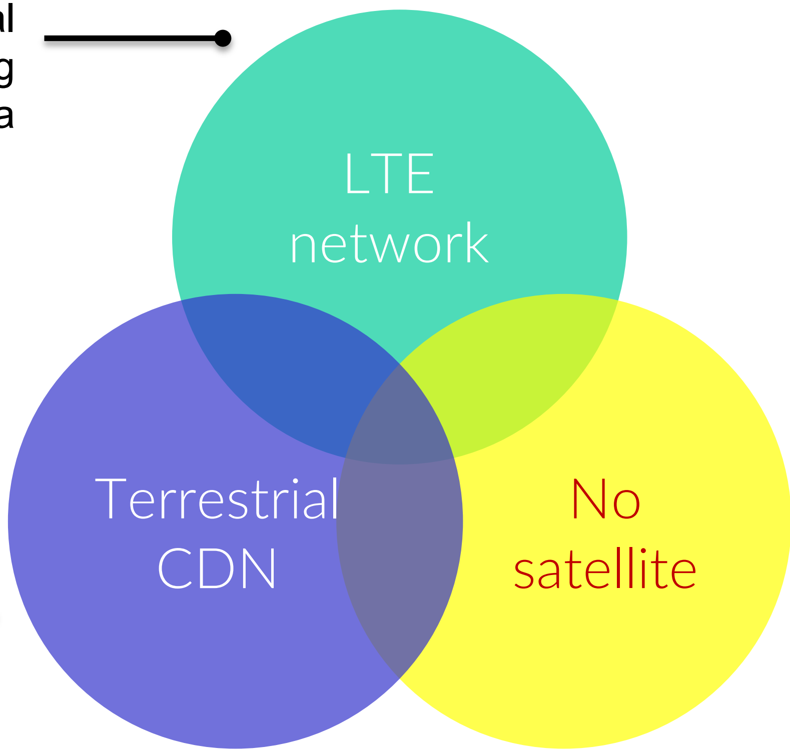
Review of the integrated scenarios from SCORSESE to SHINE

4G mobile network
No support for local caching when delivering multimedia

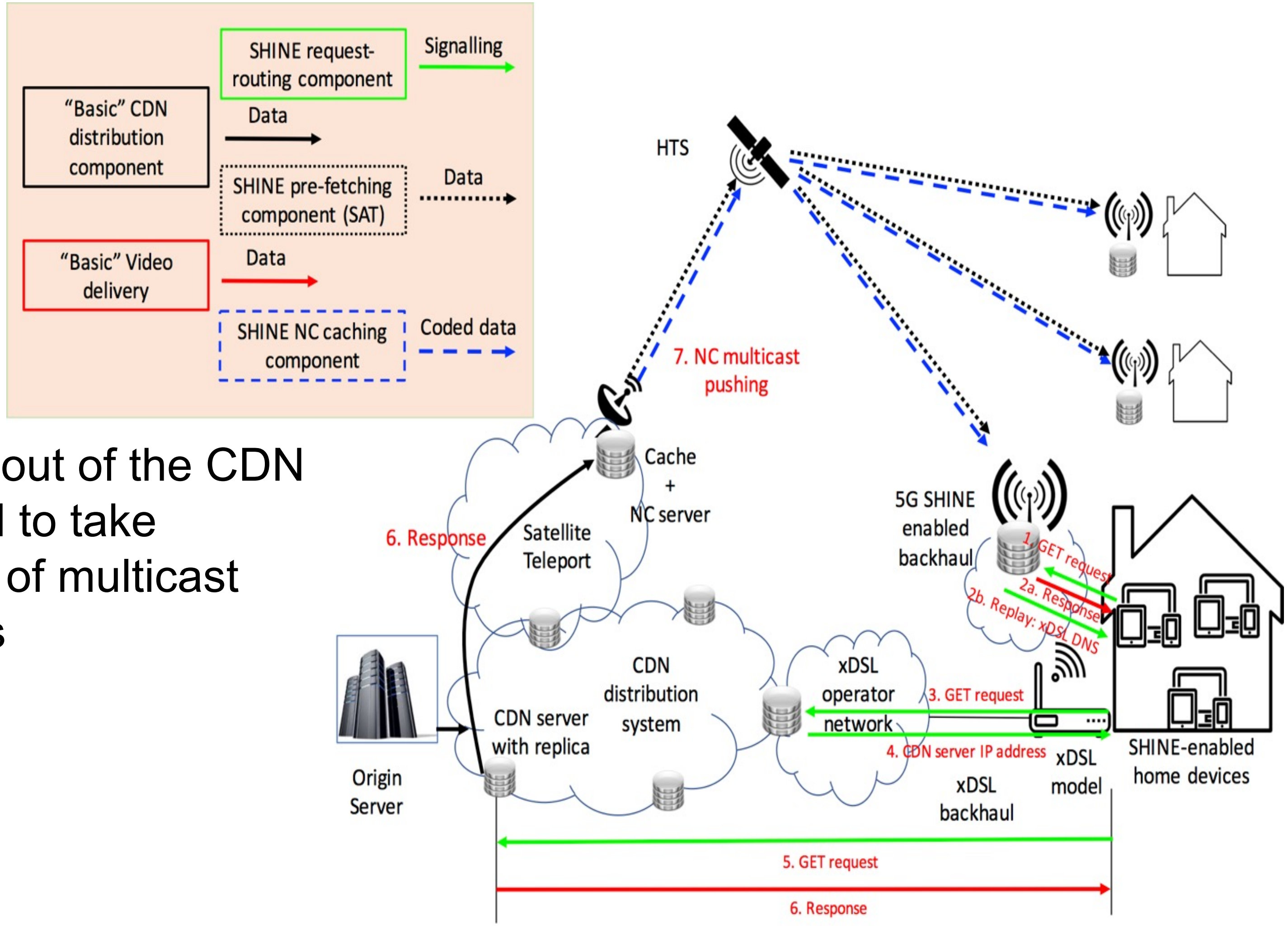
Reference scenario

CDN
Standard CDN configuration with surrogate server at the ISP level

No satellite access
Possible satellite backhaul link transparent to the users

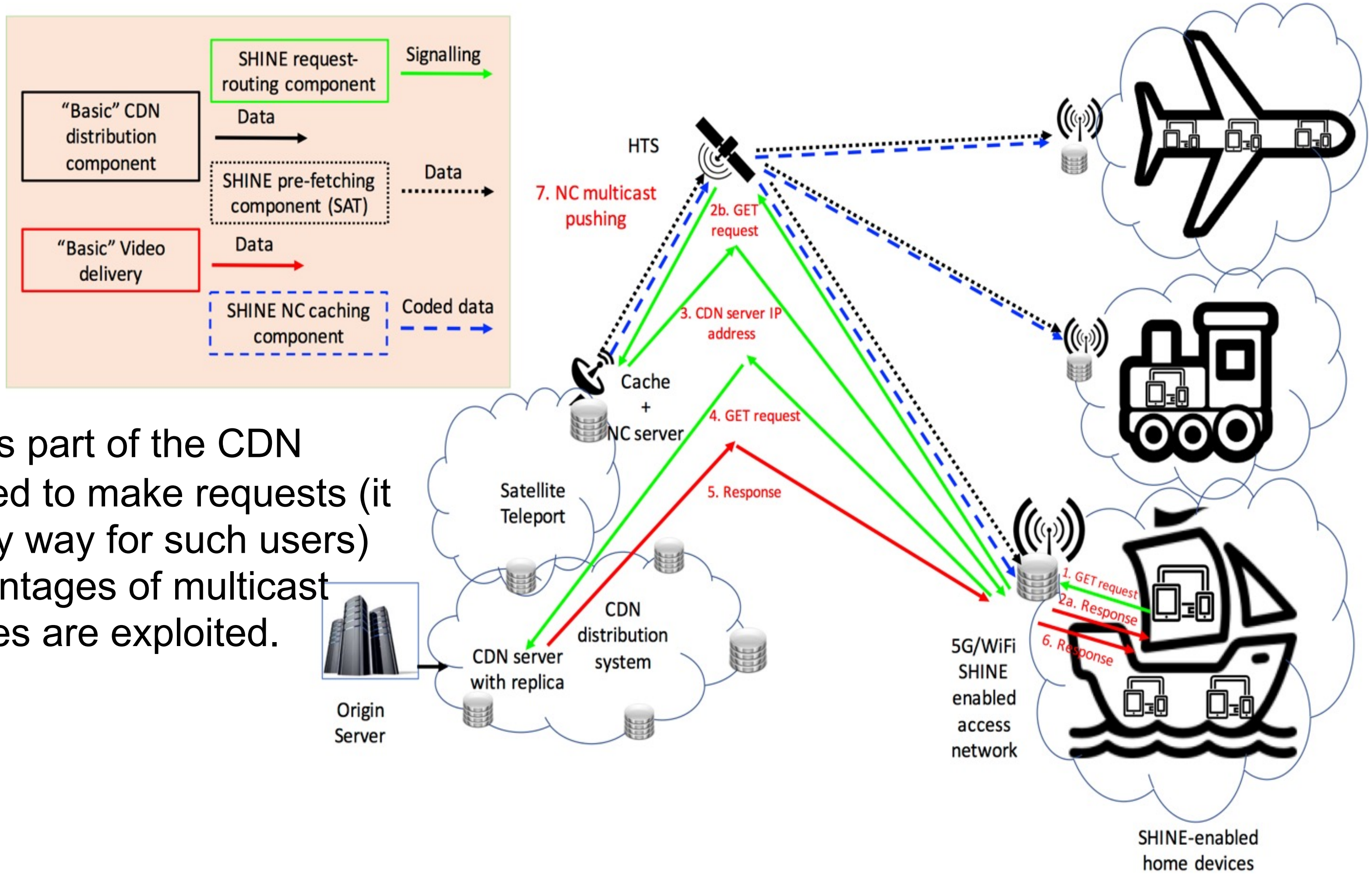


Satellite as hybrid backhaul for 5G ultra-dense networks (scenario 1)



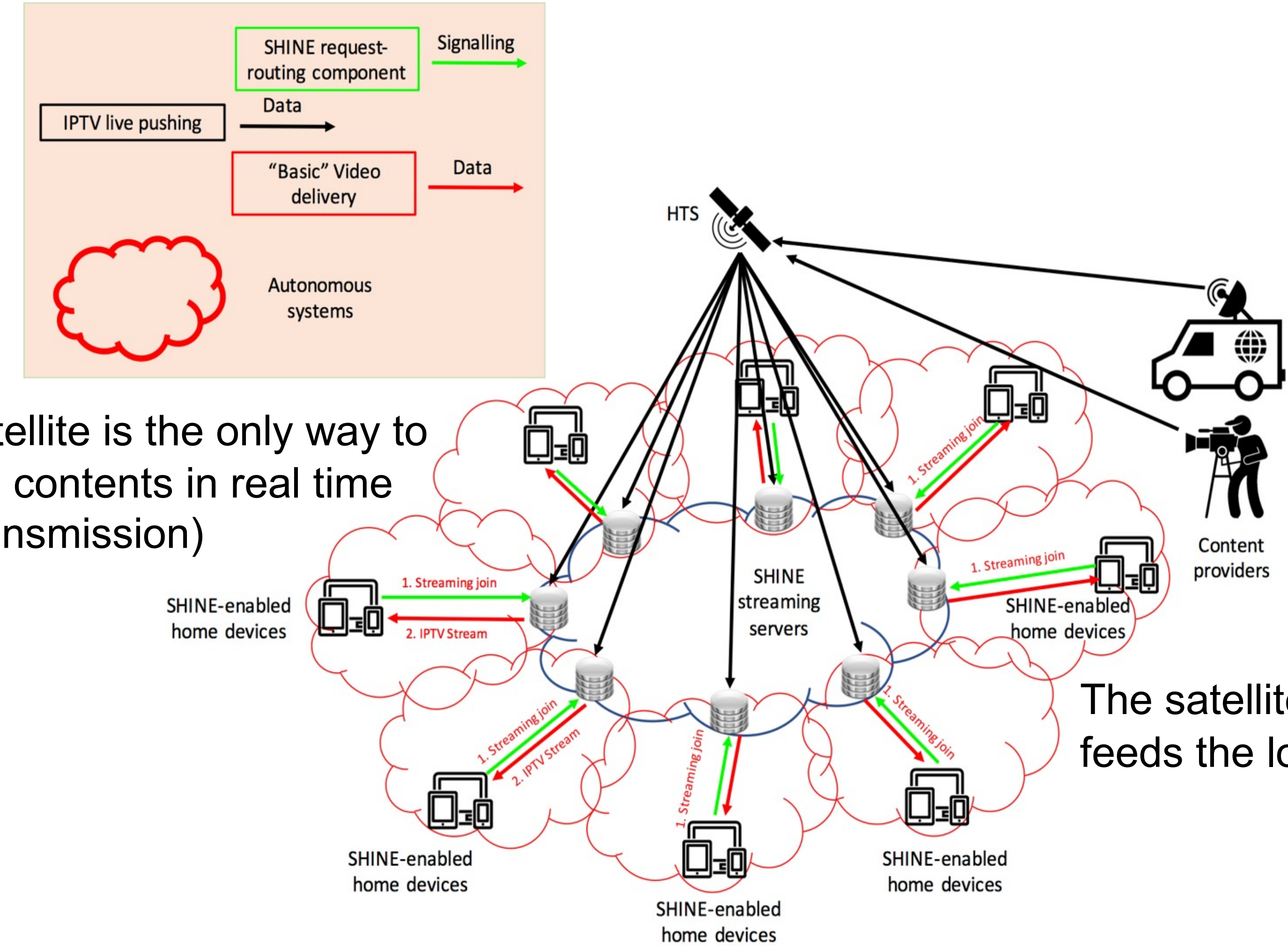
Satellite is out of the CDN
It is utilized to take advantage of multicast capabilities

Satellite for intra-CDN Content Retrieval for Moving Vehicles (scenario 2)



Satellite is part of the CDN
It is utilized to make requests (it is the only way for such users) and advantages of multicast capabilities are exploited.

Satellite live/linear stream feed into Point of Presence (scenario 3)



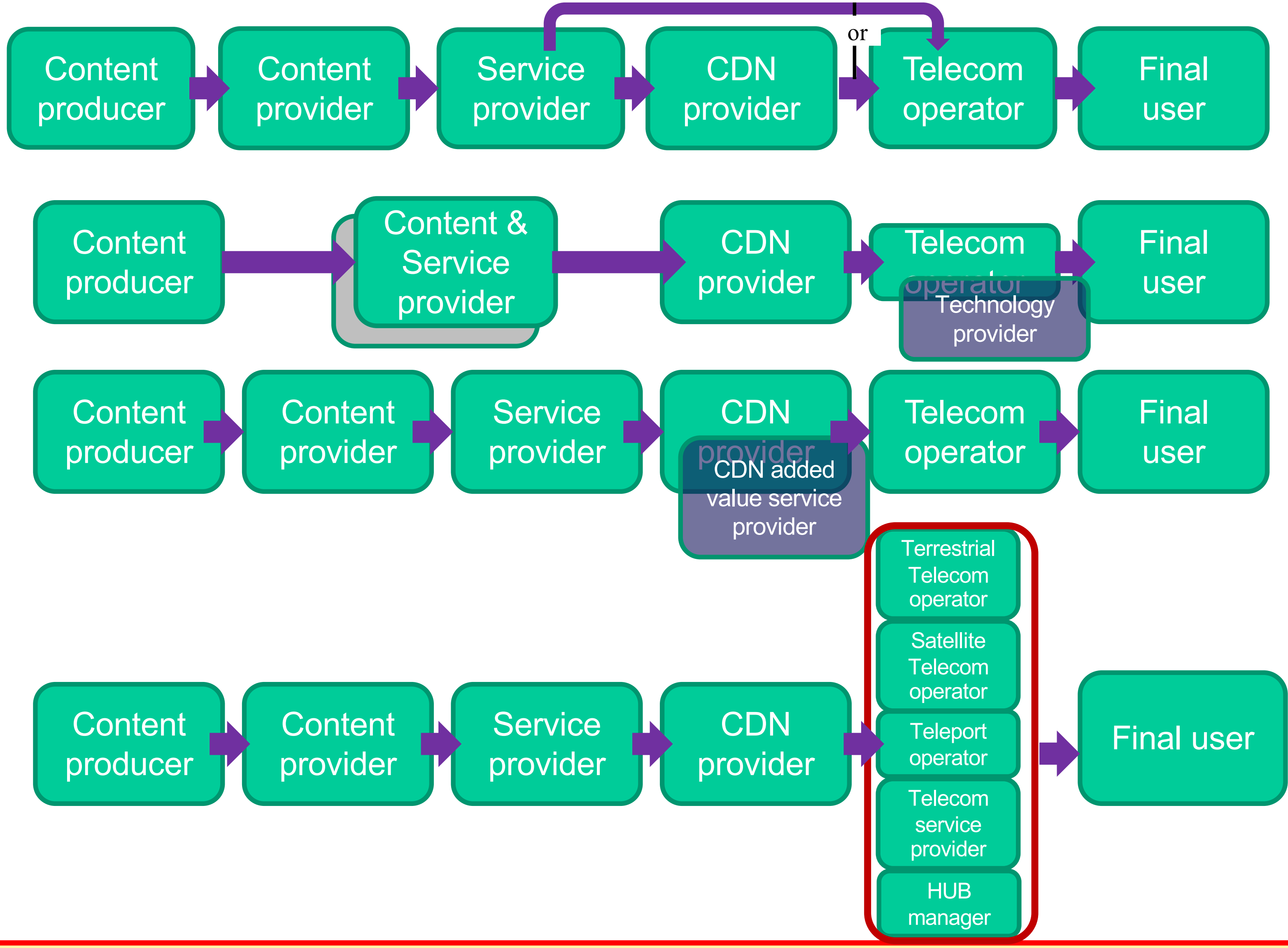
The satellite is the only way to provide contents in real time (live transmission)

The satellite directly feeds the local caches

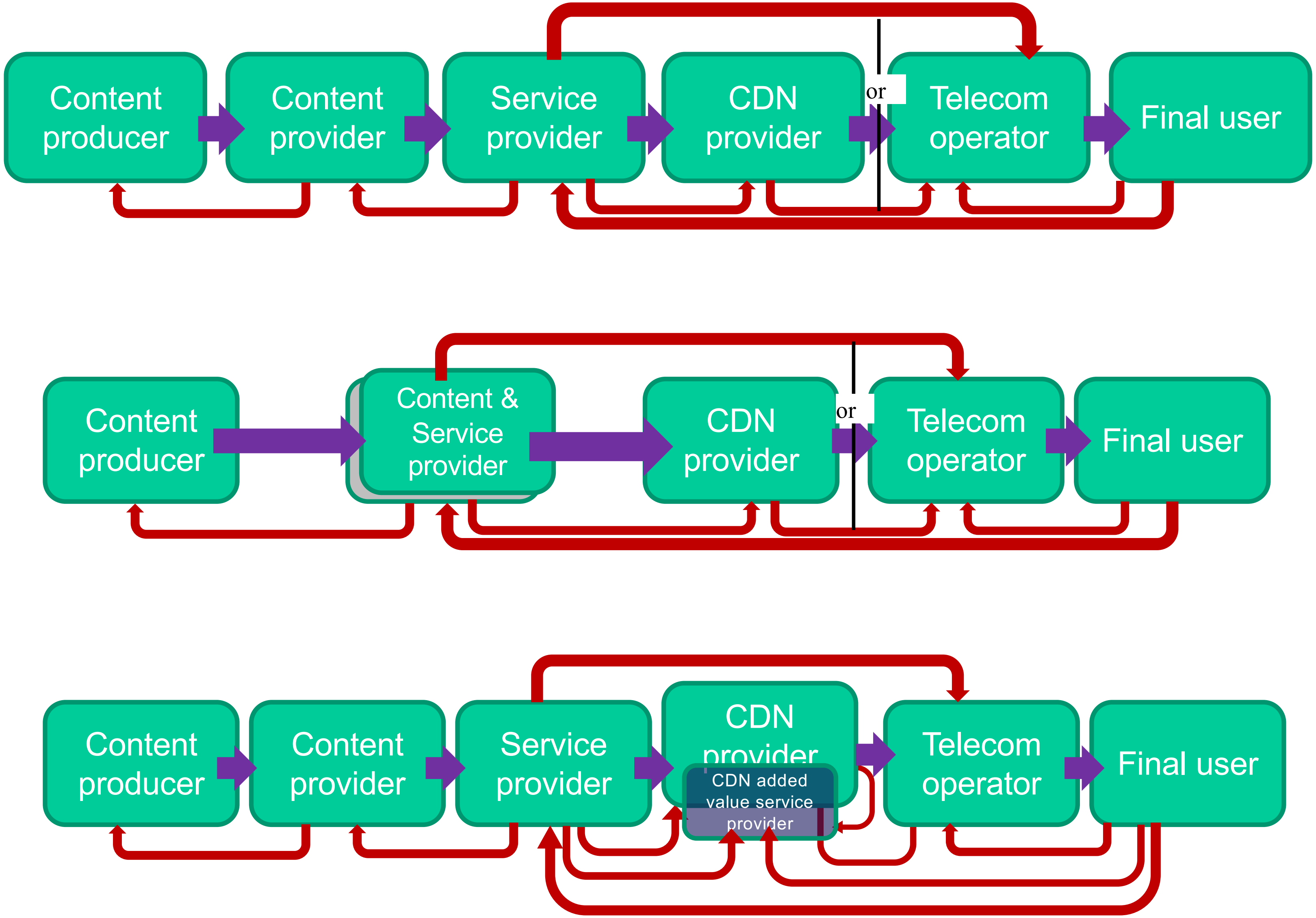
Other scenarios

- Satellite as hybrid backhaul of home gateway (S4):
  - same configuration as S1
- Content distribution for Catch-up TV services leveraging existing broadcast channels (S5):
  - same configuration as S3
- Satellite for Direct to UE Communication (S6):
  - same configuration as S1
- Content caching in Set-Top-Boxes (S7):
  - same configuration as S3

CDN Value Chain



Business model



Business model remarks

- Over-the-top video (OTT) services are alternative to traditional TV services, which led to the disintermediation of traditional TV broadcasters and the consequent disintegration of the traditional value chain.
- OTT became synonymous of TV over Internet (IPTV), then enabling an enhanced set of services:
  - Linear TV is the traditional television broadcasting, where consumers can not control program scheduling
  - Pay TV makes video scheduling available to consumers as different subscription packages
  - Video-on-Demand requires a media device, for example a Digital Video Recorder (DVR) or a PC, allowing to drive and set up program scheduling. Generally available functions are pausing, rewinding, fast forwarding and recording programs so that they can be watched when user decides
  - Catch Up TV allows to access on demand for a time-limited window programs that have already been broadcast. It is a time shifting service.

Business model remarks (2)

OTT impact on traditional TV players

- Content Providers (e.g. Disney, Warner Bros.):
  - can engage directly with consumers (new services or distributing content through OTT players
- Broadcasters (e.g. ABC, RTL):
  - can extend their business model by diversifying into premium services and following eyeballs onto on-demand platforms as advertising revenues
- Internet players (e.g. YouTube, Netflix):
  - can foster integration between TV and PC and are even rolling out their own CDN infrastructure
- Consumer electronics manufacturers (e.g. Apple, Samsung):
  - can enforce partnerships with broadcasters and OTTs

Business model remarks (3)