EBU5303

Multimedia Fundamentals

Digital Broadcasting

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Learning Objectives

- Define broadcasting.
- Explain the building blocks of a digital broadcasting system.
- Describe the MPEG Transport Stream.
- Describe the DVB-S standard.

Reading

DVB—The Family of International Standards for Digital Video Broadcasting by U. Reimer

Available at: http://www.img.lx.it.pt/~fp/Klagenfurt/Study%20Material/DVB-The%20Family%20of%20International%20Standards.pdf

Reading

Fundamentals of Multimedia, by Ze-Nian Li, Mark S. Drew, Jiangchuan Liu (3rd edition)

Part III Multimedia Communications and Networking

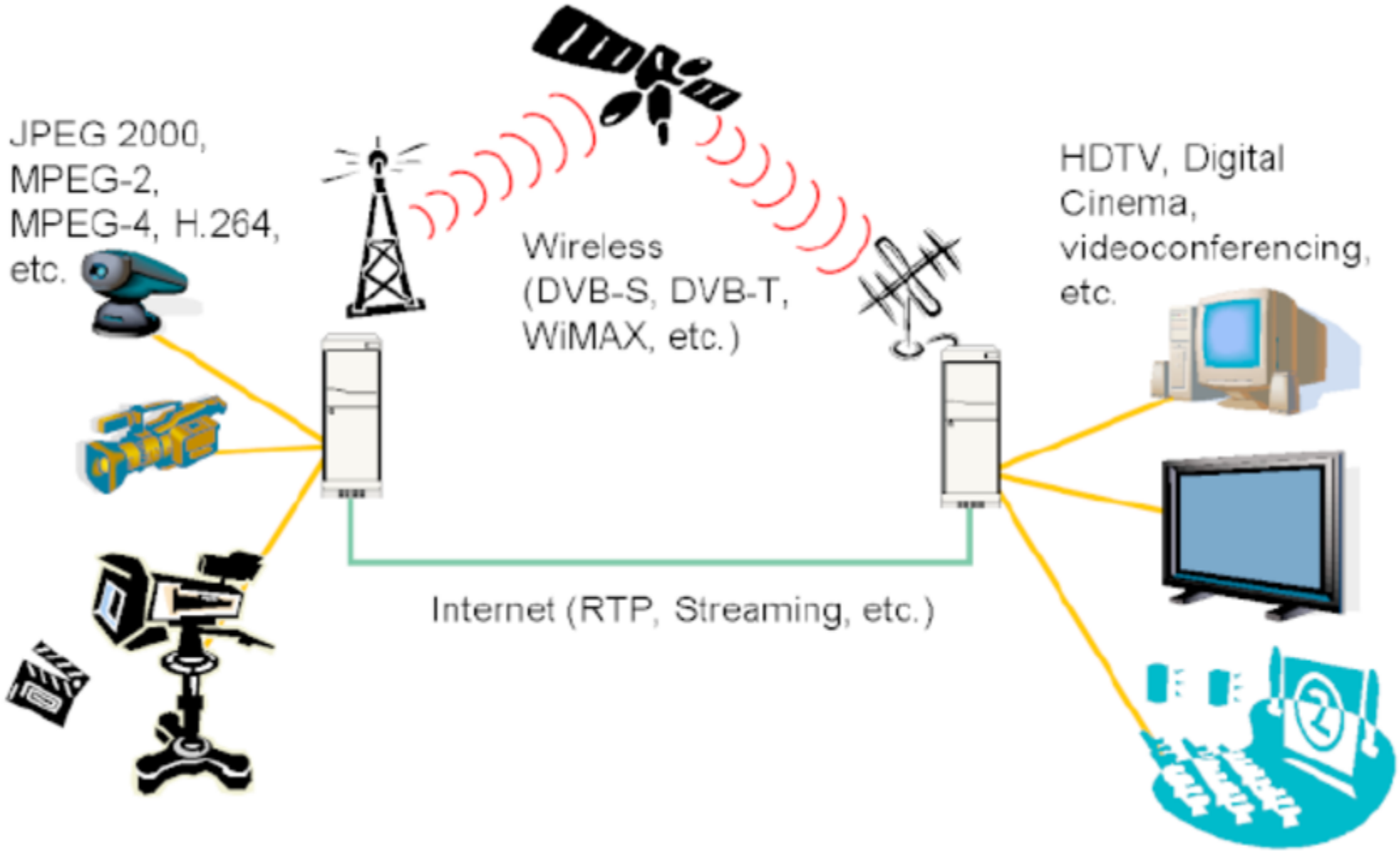
Agenda

- What is broadcasting?
- Building blocks of a digital broadcasting system
- Major standards for digital broadcasting
- Digital Video Broadcasting - Satellite (DVB-S)

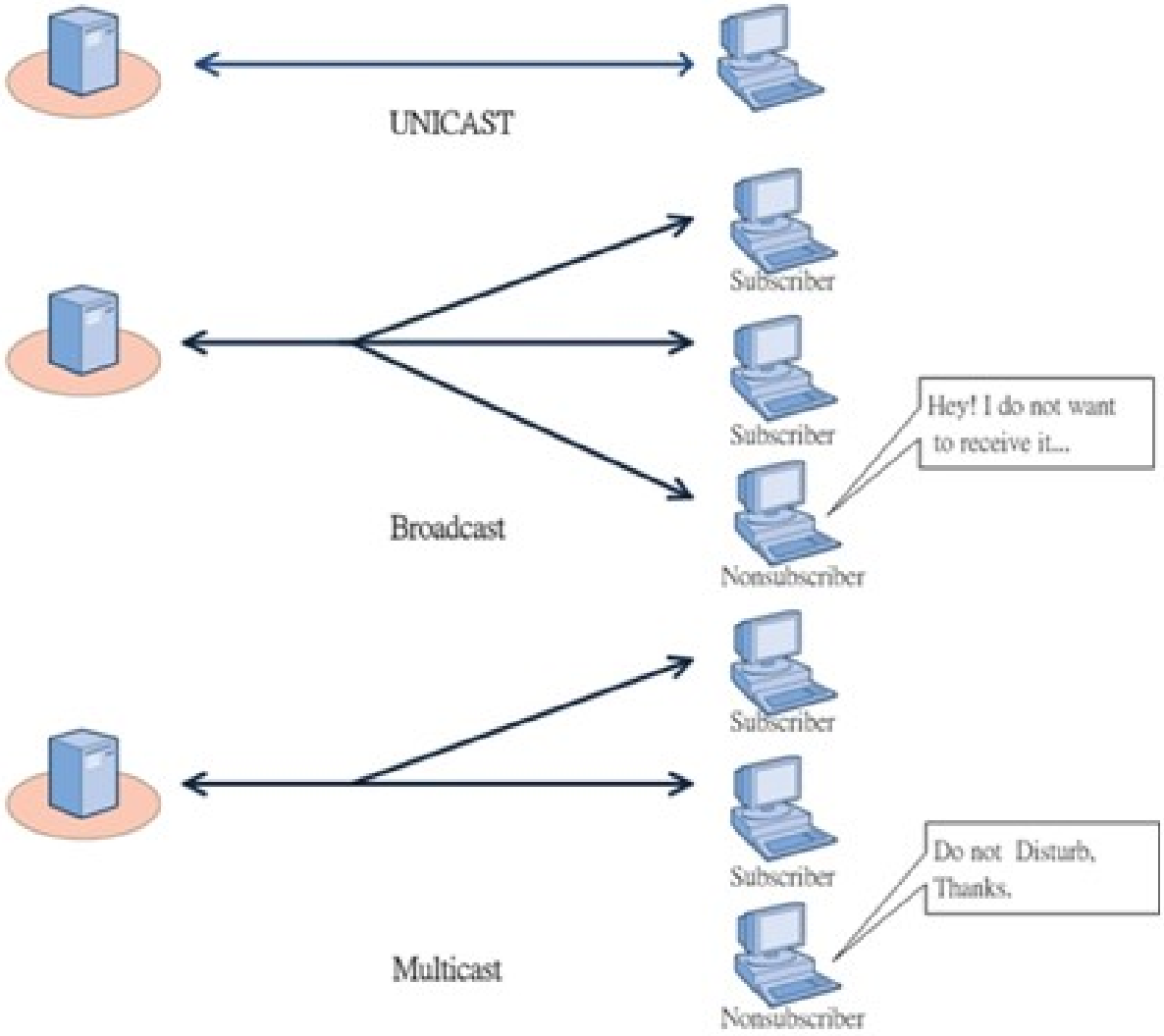
What is Broadcasting?

- In Telecommunications, broadcasting refers to a method of transferring a message to all recipients simultaneously.
- Traditionally Point-to-multipoint communication
  - Simpler transmission scheme than point-to-point
  - High transmission power
- In principle: one-way communication
  - In practice: increasingly interactive, thanks to digital technology
    - View on demand
    - Two-way (movies, shopping, …)

What is Broadcasting?



What is Broadcasting?



Why Digital Broadcasting?

- Digital signals are more robust
- Better quality: lossless data transmission
- More reliable
- Less expensive
- More flexible
- Time- vs. Frequency-Domain Multiplexing
- Additional devices requiring digital data
- Commercial reasons: better spectral efficiency, more channels, more services (gaming, shopping, internet), mobile reception, data transmission

Benefits of Digital Switchover

- Potential benefits to consumers:
  - A greater choice of services
  - Extra information on programmes and interactive features
  - Easier tuning and new functions
  - Less interference to pictures or sound
- Potential benefits for the company:
  - Less cost due to no more need of simultaneous analogue/digital transmission
  - Requires less spectrum and so saves huge capital expenditure
  - Possibility of diversifying devices, services and applications
- Potential Benefit to Government/regulatory body
  - Wider coverage [reducing digital inequality]
  - Freeing up spectrum which can be sold/offered for other services
  - Better management/regulation

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- What is broadcasting?
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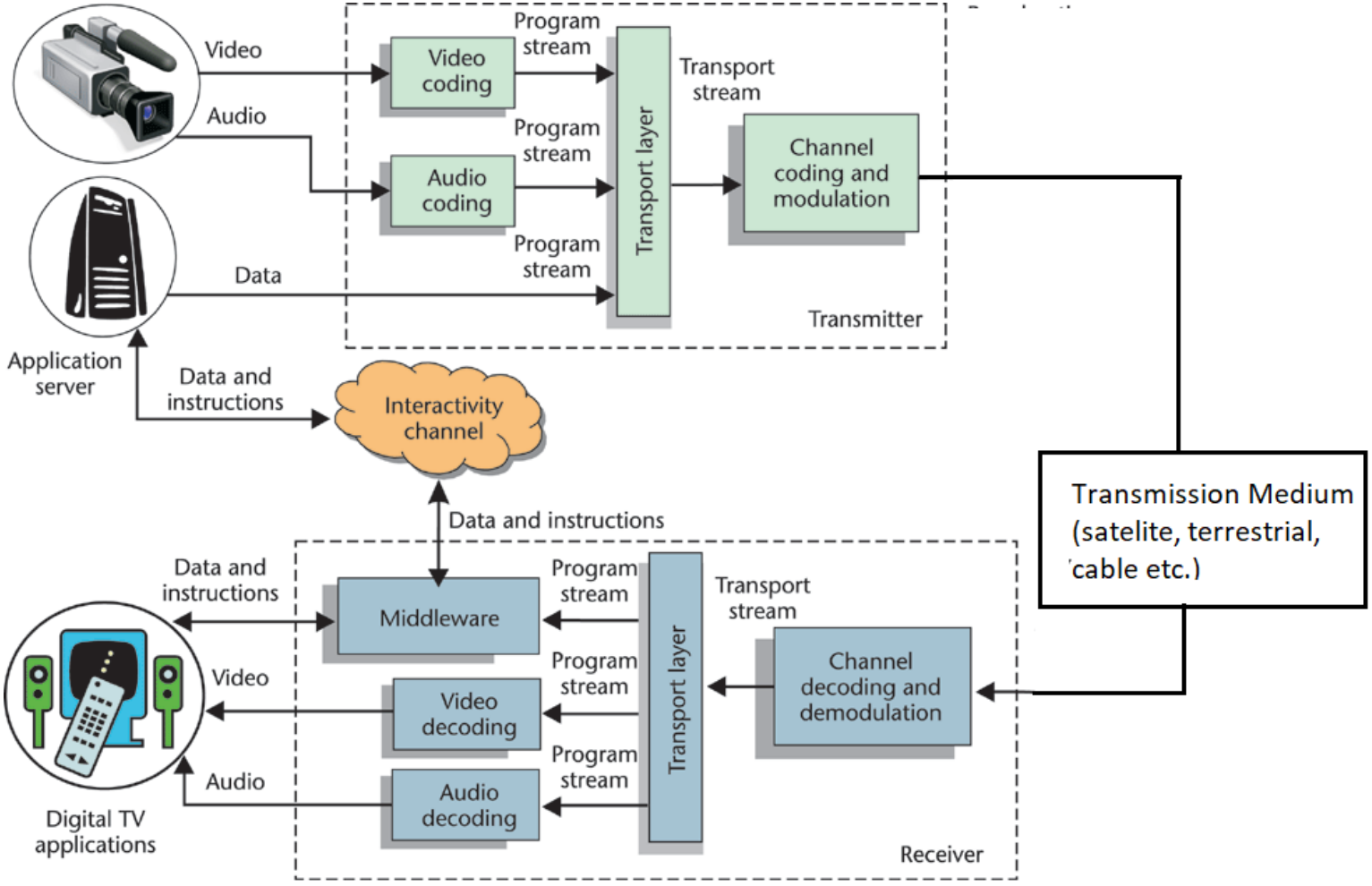
Aspects of Digital Broadcasting

- Essential stages:
  - Channel coding: error protection of bits
  - Modulation: for transmitting signal onto carrier
- But also…
  - Source coding: data compression
  - Multiplexing: combining into single data stream
  - Signal processing
- Involves video/audio and data

Building blocks of a Digital Broadcasting (DB) system

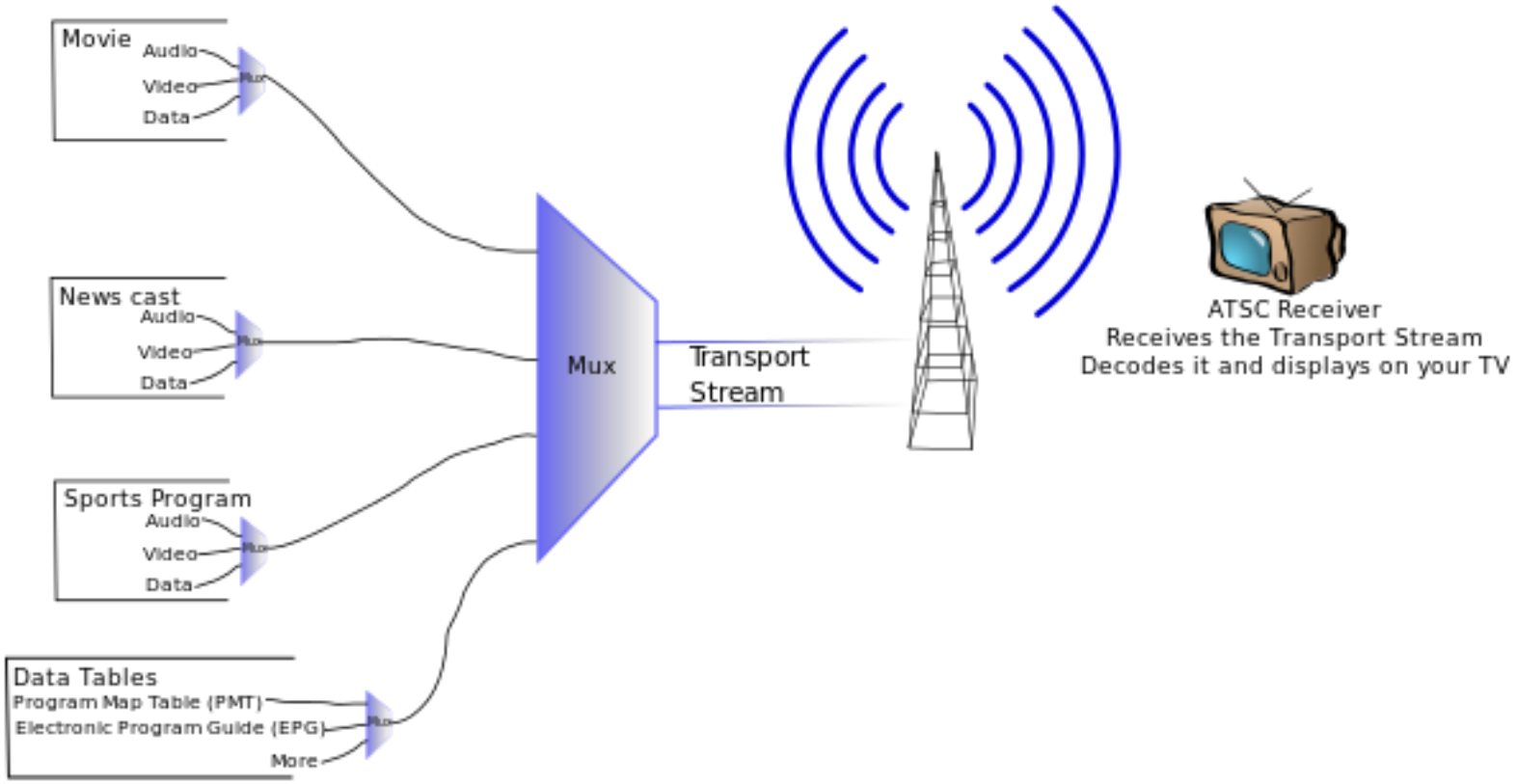


Fundamental Components of DB

- Audio,Visual (Still/Video), and/or Data
- Transmitter:
  - Compression (***source coding***), e.g., using MPEG2
  - Multiplexing information to single ***Transport Stream*** (TS)
  - ***Forward error correction*** (***Channel Coding***), e.g., Reed-Solomon
  - ***Modulation*** (e.g., OFDM: Orthogonal Frequency-Division Multiplexing)
  - ***Transmission*** (antenna (Yagi-Uda, dish) or optical fibre)
- Reverse process at receiver

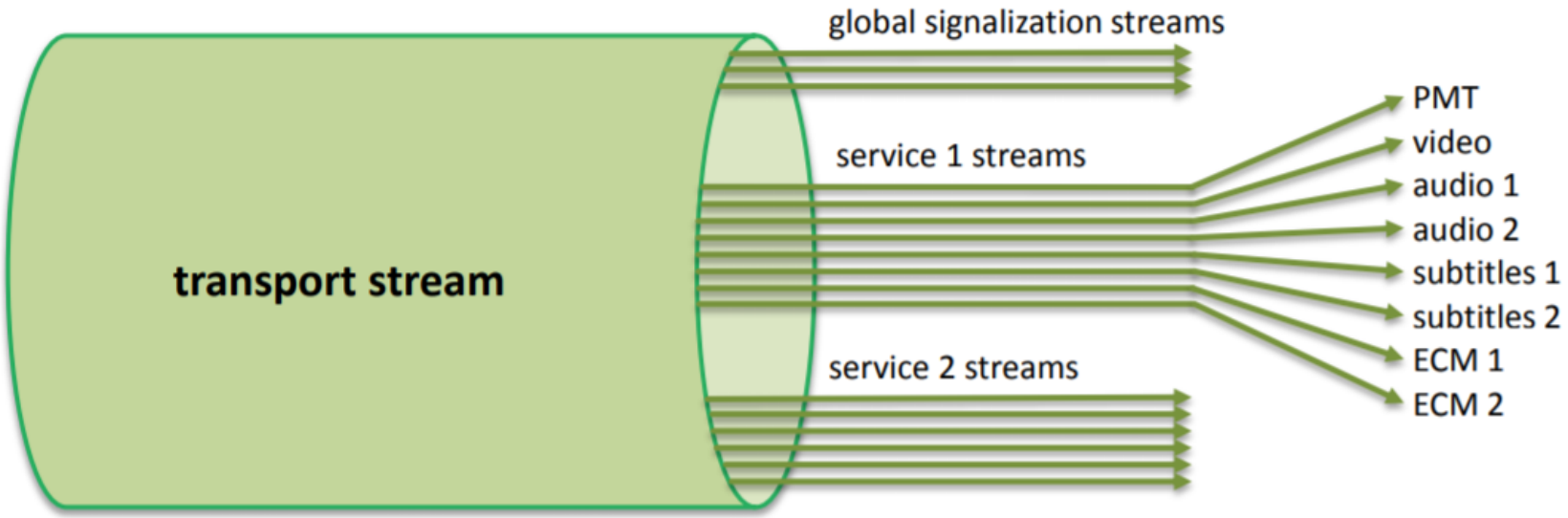
Transport Stream (TS)

- *Transport stream* specifies a container format encapsulating packetised Elementary Streams (ES).



Transport Stream (TS)

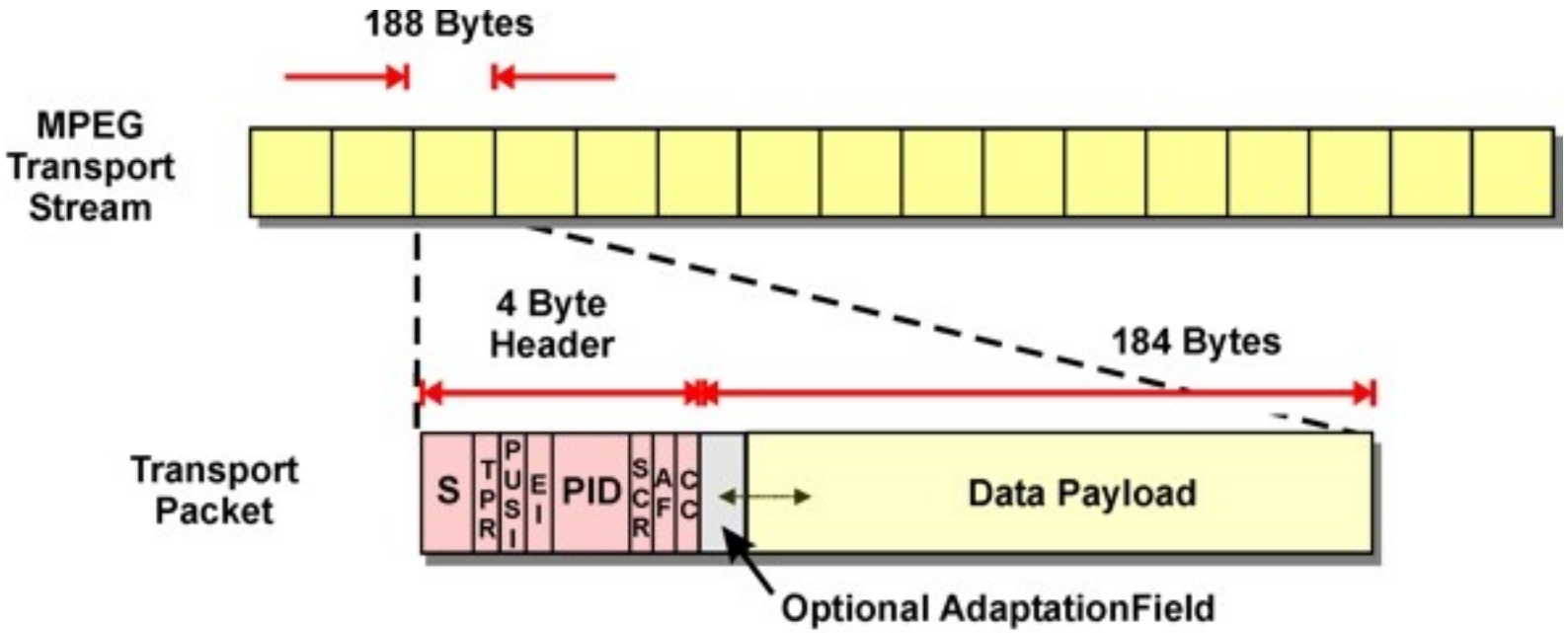
- A transport stream is a multiplex of elementary streams
  - elementary stream = sequence of TS packets with same PID value in header
  - one set of elementary streams for global signalization
    - describe the TS, the network, the operator, the services, the events, EMM's, etc.
  - one set of elementary streams per service
    - a service is typically a TV channel



E.g. MPEG-TS

- Structure of MPEG-2 TS defined in ISO/IEC 13818-1
- One operator uses several TS
- TS = synchronous stream of 188-byte TS packets
  - 4-byte header
  - optional « adaptation field », a kind of extended header
  - payload, up to 184 bytes
- Multiplex of up to 8192 independent elementary streams (ES)
  - each ES is identified by a Packet Identifier (PID)
  - each TS packet belongs to a PID, 13-bit PID in packet header
  - smooth muxing is complex, demuxing is trivial
- Two types of ES content
  - PES, Packetized Elementary Stream : audio, video, subtitles, teletext
  - sections : data structures

E.g. MPEG-TS

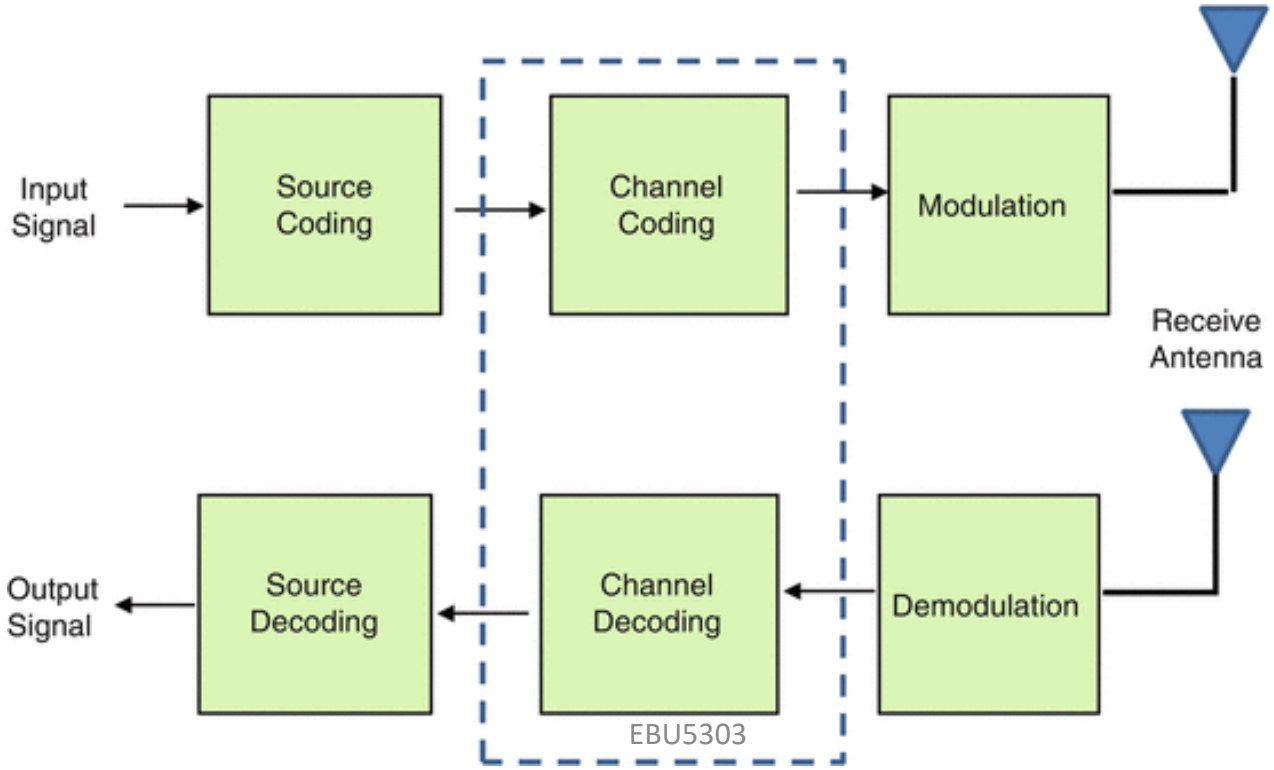


S - Sync
TPR - Transport Priority
PUSI - Payload Start
EI - Error Indicator

PID - Packet Identifier (stream ID)
SCR - Scrambling Control
AF - Adaptation Field
CC - Continuity Check Index

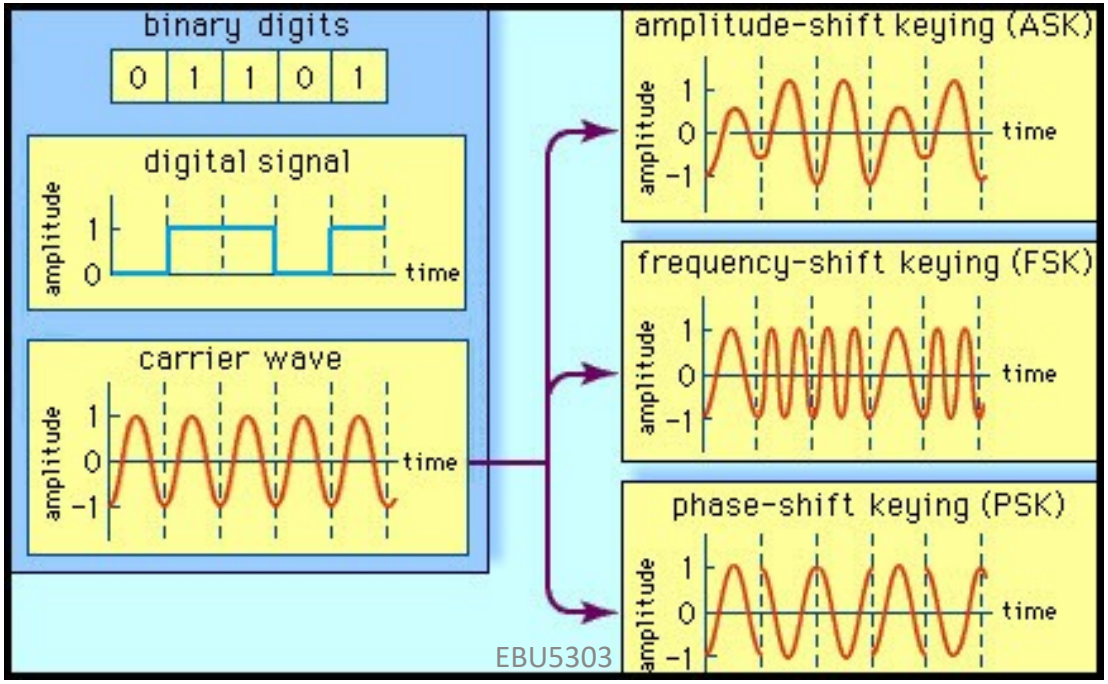
Channel Coding

- Channel coding, also known as *forward error control coding* (FECC), is a process of detecting and correcting bit errors in digital communication systems.
- It is performed both at the transmitter and at the receiver.

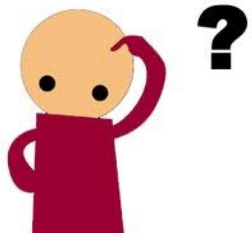


Modulation

- *Digital Modulation* uses discrete signals to modulate a carrier wave.
- The three main types of digital modulation are Amplitude Shift Keying (ASK), Frequency Shift Keying (FSK) and Phase Shift Keying (PSK).



Questions



- What is source coding?
- What is a transport stream?
- What is channel coding?

Today's agenda

- What is broadcasting?
- Building blocks of a digital broadcasting system
- Major standards for digital broadcasting
- Digital Video Broadcasting - Satellite (DVB-S)

Why do we need standards?

- **Safety and reliability**
  - Users perceive standardised products and services as more dependable
  - Increases sales and the take-up of new technologies
- **Support of government policies and legislation**

  Standards are frequently referenced by regulators and legislators for protecting user and business interests
- **Interoperability**

  The ability of devices to work together relies on products and services complying with standards

What would the world be like without standards?

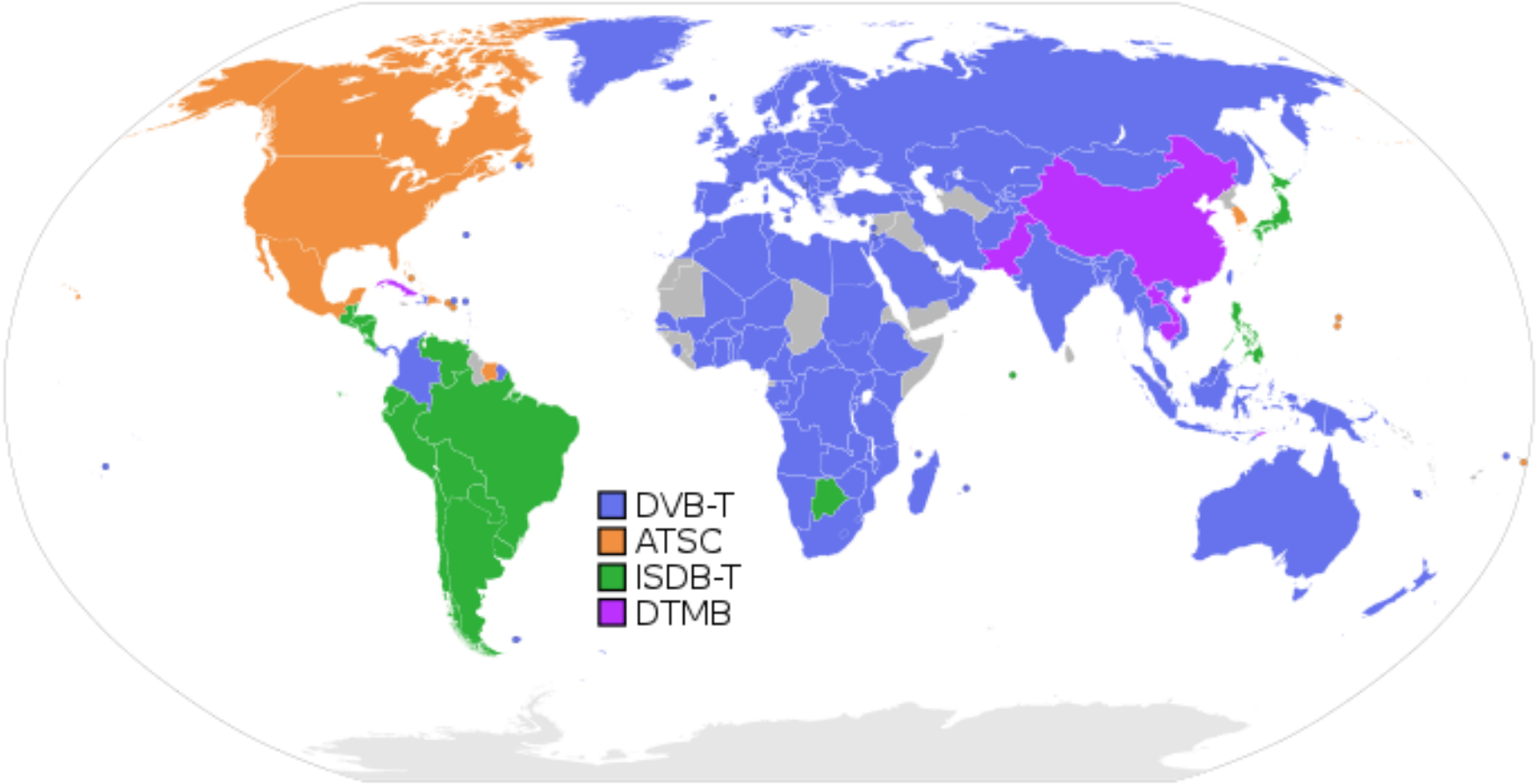
- Products might not work as expected
- They may be of inferior quality
- They may be incompatible with other equipment – in fact they may not even connect with them
- In extreme cases, non-standardised products may be dangerous
- Customers would be restricted to one manufacturer or supplier
- Manufacturers would be obliged to invent their own individual solutions to even the simplest needs, with limited opportunity to compete with others

Further info: http://www.etsi.org/standards/why-we-need-standards

Major Standards for Digital Brodcasting

- Digital Video Broadcasting (**DVB**)
  - Europe, Singapore, Australia and New Zealand.
- Advanced Television System Committee (**ATSC**)
  - United States, Canada, Mexico, South Korea, Dominican Republic and Honduras.
- Integrated Services Digital Broadcasting (**ISDB**)
  - Japan and the Philippines.
- Digital Terrestrial Multimedia Broadcasting (**DTMB**)
  - Peoples Republic of China.

Major Standards for Digital Brodcasting



DVB (Digital Video Broadcasting)

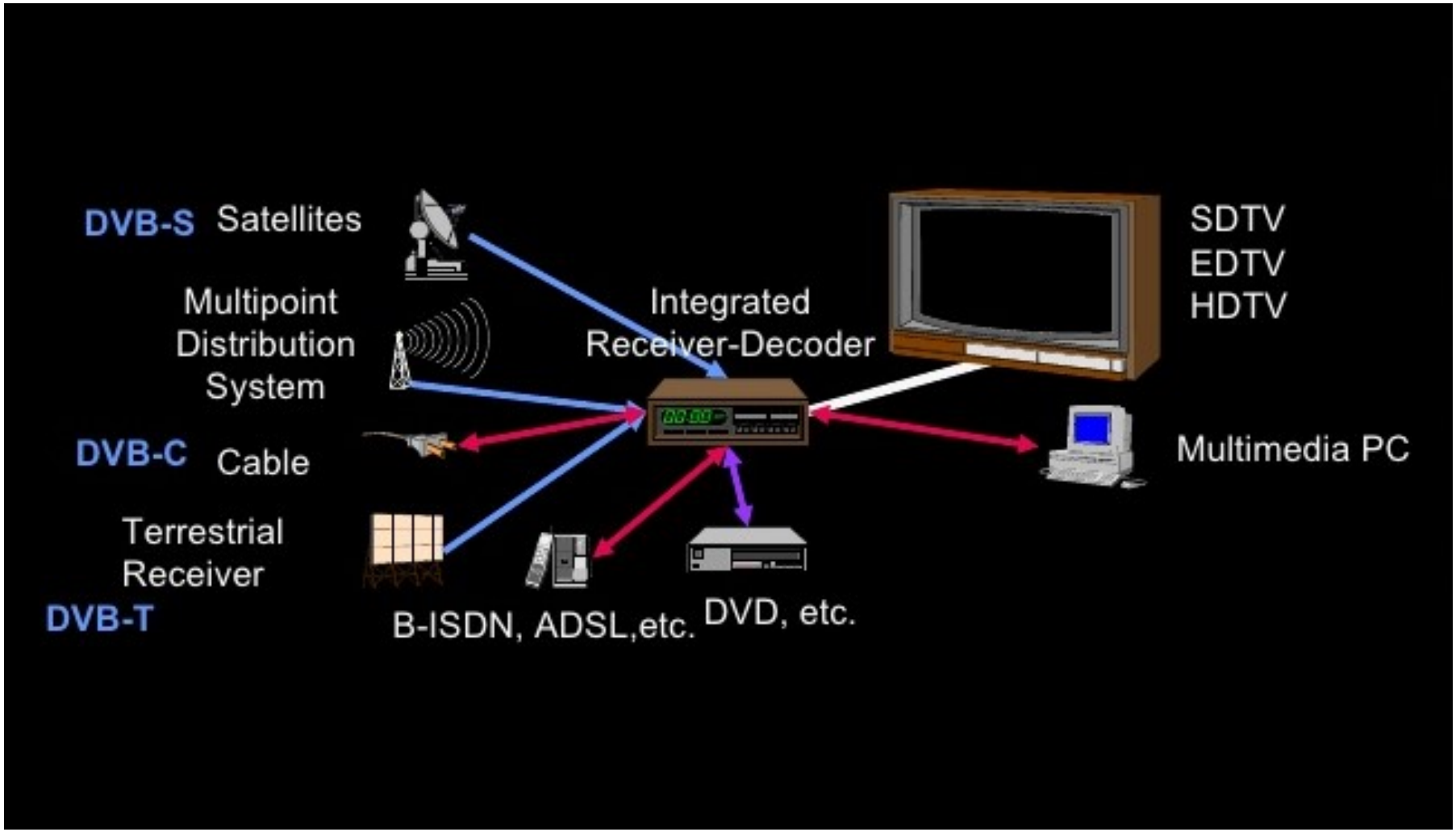
- Set of standards that defines digital broadcasting using existing satellite, cable, and terrestrial infrastructures
- Most widely used transmission standard in the world
- Focus of digital television development
- Based on MPEG2 source coding
- DVB-S (1993), -C (1994), -T (1995), -SH, …
  - Different coding and modulation w.r.t. channel
  - e.g. QPSK in DVB-S, QAM in DVB-C, COFDM in DVB-T
- Spawned ISDB-T, -C, -S (Japan) and A/53-T (US)

DVB family of standards

- Every DVB standard defines the ***channel coding*** and ***modulation***, since every channel has a different set of characteristics.
- But for all of them, the system input and output signals are ***MPEG-2 Transport Streams***.

  – DVB-S and DVB-S2 for satellite broadcasting
  – DVB-C for cable systems
  – DVB-T and DVB-T2 for terrestrial broadcasting
  – DVB-H for handheld systems
  – DVB-SH for satellite-to-handheld systems
  – DVB-IPDC for internet protocol datacastover
  – DVB-CPCM for content protection & copy management

DVB family of standards



ATSC (Advanced Television Systems Committee)

- ATSC depends on numerous interwoven standards
  - ATSC (Terrestrial, Cable, Satellite)
  - ATSC-M/H (Mobile/Handheld)
- Established 1990s
- Original specification for HDTV (High Definition Television)
- Uses Dolby, not MPEG for audio
- Mobile reception difficult/impossible until 2008
  - New ATSC-M/H since 2009

ISDB (Integrated Services Digital Broadcasting)

- Covers digital television (DTV) and digital radio
- Maintained by Association of Radio Industries and Businesses (ARIB), Japan
- Main differences compared to DVB:
  - ISDB-S uses 8-PSK (Phase Shift Keying) and Trellis coding instead of QPSK in DVB-S (modulation)
  - In ISDB-T, single 6 MHz TV channel can be split into 13 x 432 kHz subchannels for adaptive use
    - digital audio (1 subchannel),
    - SDTV (multiple subchannels),
    - HDTV (all 13 subchannels).

ISDB family of standards

- ISDB-S for satellite television
- ISDB-T for terrestrial television (mainly used in South America)
- ISDB-Tsb for terrestrial sound
- ISDB-C for cable television
- ISDB-1seg for cell phones, laptops, vehicles

DTMB (Digital Terrestrial Multimedia Broadcast)

- Chinese GB20600-2006 standard
- Initially called DMB-T/H
- DMB-T, T-DMB (South Korea)
- Established 2006
- China
- CMMB: Chinese Mobile Multimedia Broadcasting
  - Mobile and stationary
  - Satellite and terrestrial
  - Standard GY/T 220.1

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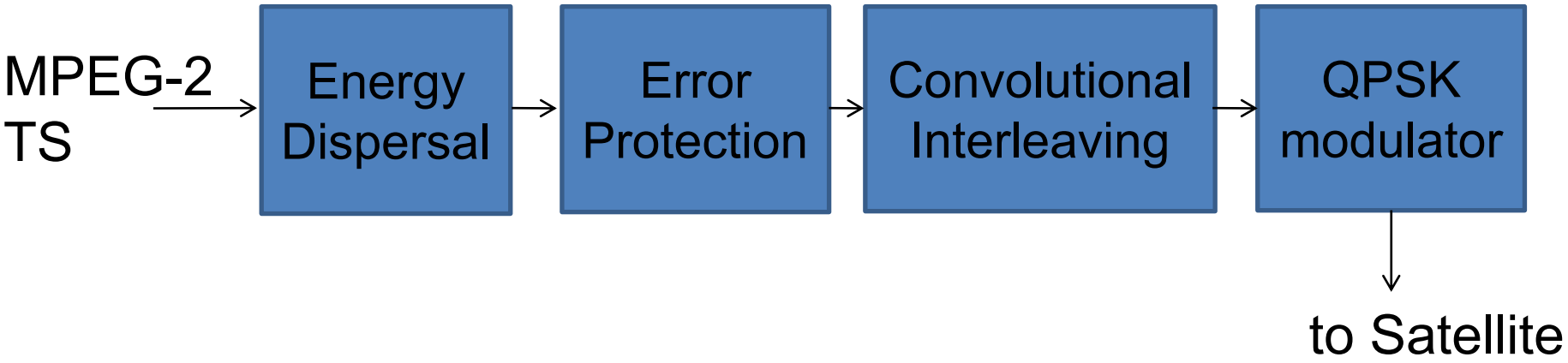
Digital Video Broadcasting – Satellite (DVB-S)

- DVB-S: standard for Direct-to-home Broadcasting via Satellite (DBS)
- Defined between 1993 and 1997 by European Standard EN 300 421.

DVB-S Encoding

After the data has been coded following the MPEG-2 standard, it needs to go through the next steps before being transmitted to the satellite:

- Multiplexing and randomisation for energy dispersion
- Reed-Solomon Encoder (Error Protection)
- Convolutional Interleaving
- QPSK modulation

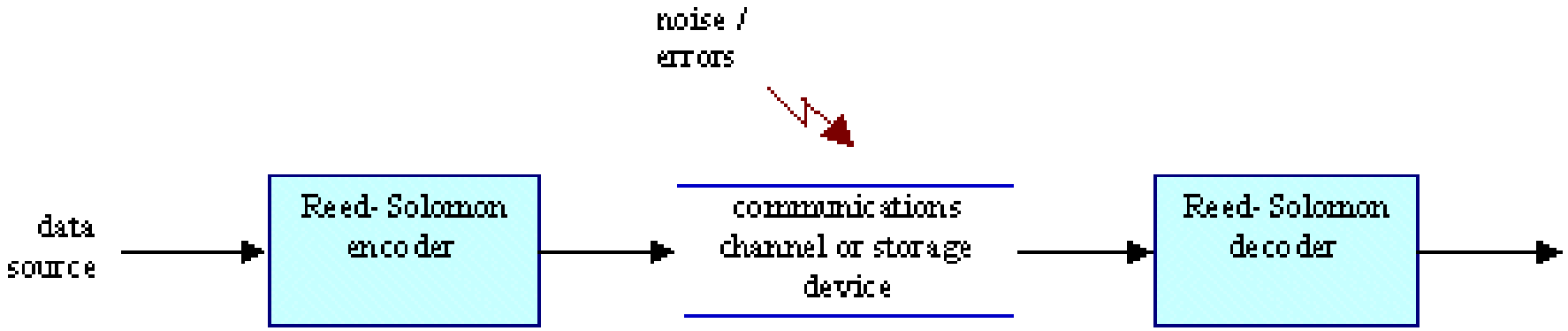


Energy Dispersal and Error Protection

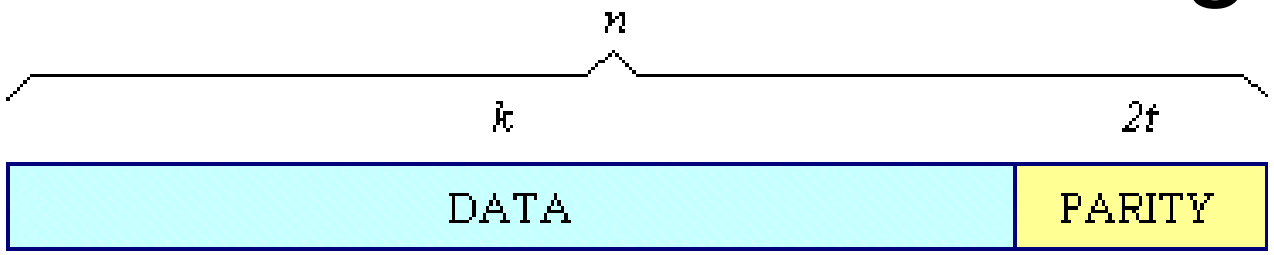
- ***Energy Dispersal*** is carried out at the encoding end by scrambling with a pseudo random sequence
  - Energy dispersion is the randomising of the input signal in order to achieve a power-density spectrum of the modulated signal that is as even as possible.
- ***Error Protection*** scheme permitting various code rate
  - ***Reed-Solomon coding*** RS(204, 188, t=8) is used, where 16 parity bits are introduced in each transport packet. With this the decoder is able to correct up to 8 error bytes in each packet of 204 received bytes.

Reed-Solomon coding

- The Reed-Solomon encoder takes a block of digital data and adds extra "redundant" bits.
- The number and type of errors that can be corrected depends on the characteristics of the Reed-Solomon code.
- A Reed-Solomon code is specified as RS(*n,k*) with *s*-bit symbols.



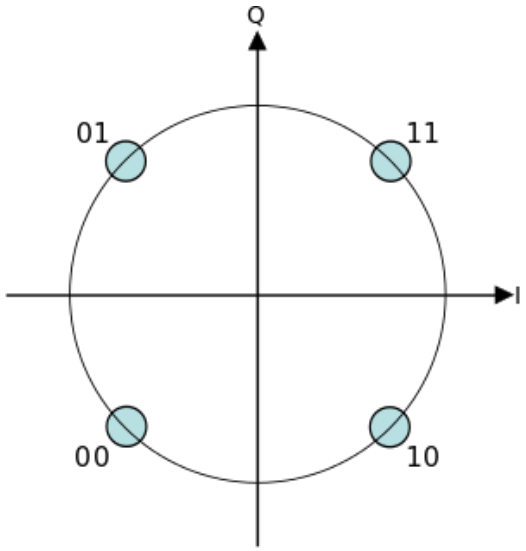
Reed-Solomon coding



- The encoder takes *k* data symbols of *s* bits each and adds parity symbols to make an *n* symbol codeword.
- A Reed-Solomon decoder can correct up to *t* symbols that contain errors in a codeword, where *2t = n-k.*
- Example: RS(204,188) with 8-bit symbols. Each codeword contains 204 code word bytes, of which 188 bytes are data and 16 bytes are parity. For this code:
  n = 204, k = 188, s = 8, 2t = 16, t = 8
  Errors in up to 8 bytes anywhere in the codeword can be automatically corrected.

Interleaving and Modulation

- ***Interleaving***
  - In order to avoid errors in consecutive packets, the packets are interleaved.
- ***Modulation***: QPSK (***Quadrature Phase Shift Keying***) is used for modulation
  - With four phases, QPSK can encode two bits per symbol



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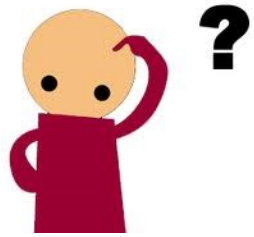


- What compression standard is used for source coding in DVB-S?
- How does the Reed-Solomon Error Protection scheme work?

Data Rate Calculation (example)

- Assuming the symbol rate is 27.5 MS/s.
- QPSK offers 2 bits/Symbol
- gross_data_rate = 2 bits/symbol X 27.5 Megasymbols/s
  = 55 Mbit/s;
- QPSK-modulated signal must first be provided with error protection before being fed into the actual modulator.
- Reed-Solomon code with rate (204, 188) is used.
- net_data_rate Reed-Solomon
  = gross_data_rate x 188/204
  = 55 Mbit/s x 188/204
  = 50.69 Mbit/s;

Data Rate Calculation (example)

- further error protection in the form of convolutional coding is inserted after the Reed Solomon forward error correction.
- This further expands the data stream.
- $CodeRate = \frac{Input\ Data\ Rate}{Output\ Data\ Rate}$
- In DVB-S, the code rate can be selected within the range of 1/2, 3/4, 2/3,...7/8.
- The net data rate in DVB-S with a code rate of 3/4, after convolutional coding, is then: $Net\_data\_rate_{3/4}$ = code_rate X $net\_data\_rate_{reed\ solomon}$

= 3/4 • 50.69 Mbit/s = 38.01 Mbit/s;

Observation on data rate

- If the code rate is 1/2, the data stream is expanded by a factor of 2. The error protection is now maximum and the net data rate has dropped to a minimum.
- A code rate of 7/8 provides only a minimum overhead but also only a minimum of error protection. The available net data rate is then at a maximum.
- The code rate can then be used to control the error protection and thus, as a reciprocal of this, also the net data rate.

Exercise

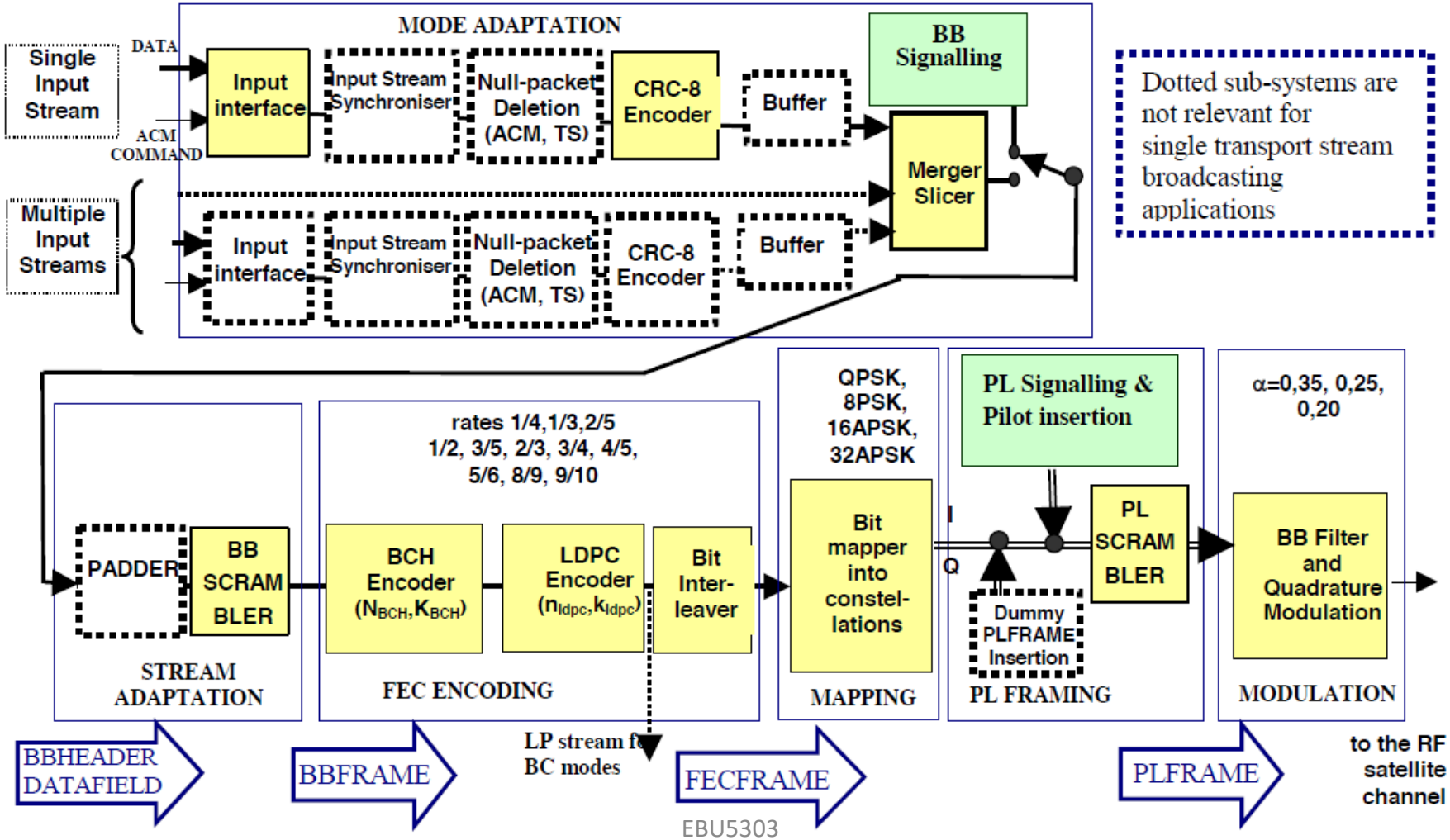
- Assuming a symbol rate of 25 MS/s and QPSK modulation, calculate the bit stream gross data rate.

- Using Reed-Solomon code with rate (204, 188) and a code rate of 1/2, calculate now the bit stream net data rate.

DVB-S2

- Improved version of DVB-S standard, ratified in March 2005.
- It has been designed for:
  - Broadcast Services for standard definition TV and HDTV.
  - Interactive Services including Internet Access for consumer applications
  - Professional applications, Data Content distribution, etc..
- Supports recent improvements in channel coding
- Supports recent improvements in channel modulation
- Typically offers 30% data rate increase under the same condition compared to DVB-S

Functional block diagram of the DVB-S2 system



DVB-S vs. DVB-S2

Satellite EIRP (dBW)	51		53.7	
System	DVB-S	DVB-S2	DVB-S	DVB-S2
Modulation & coding	QPSK 2/3	QPSK 3/4	QPSK 7/8	8PSK 2/3
Symbol rate (Mbaud)	27.5 (α =0.35)	30.9 (α =0.0)	27.5 (α =0.35)	29.7 (α =0.25)
C/N at 27. 5 MHz (dB)	5.1	5.1	7.8	7.8
Useful bitrate (Mbit/s)	33.8	46 (gain = 36%)	44.4	58.8 (gain = 32%)
Number of SDTV programmes	7 MPEG-2 15 AVC	10 MPEG-2 21 AVC	10 MPEG-2 20 AVC	13 MPEG-2 26 AVC
Number of HDTV programmes	1-2 MPEG-2 3-4 AVC	2 MPEG-2 5 AVC	2 MPEG-2 5 AVC	3 MPEG-2 6 AVC

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