TERACOM

DVB-T2, T2-Lite and DVB-NGH:

Second and third generation DVB terrestrial broadcasting standards

Erik Stare

KTH 2013-03-20

What does Teracom do?

TERACOM

We use terrestrial transmitters…

… often at 300 m height…

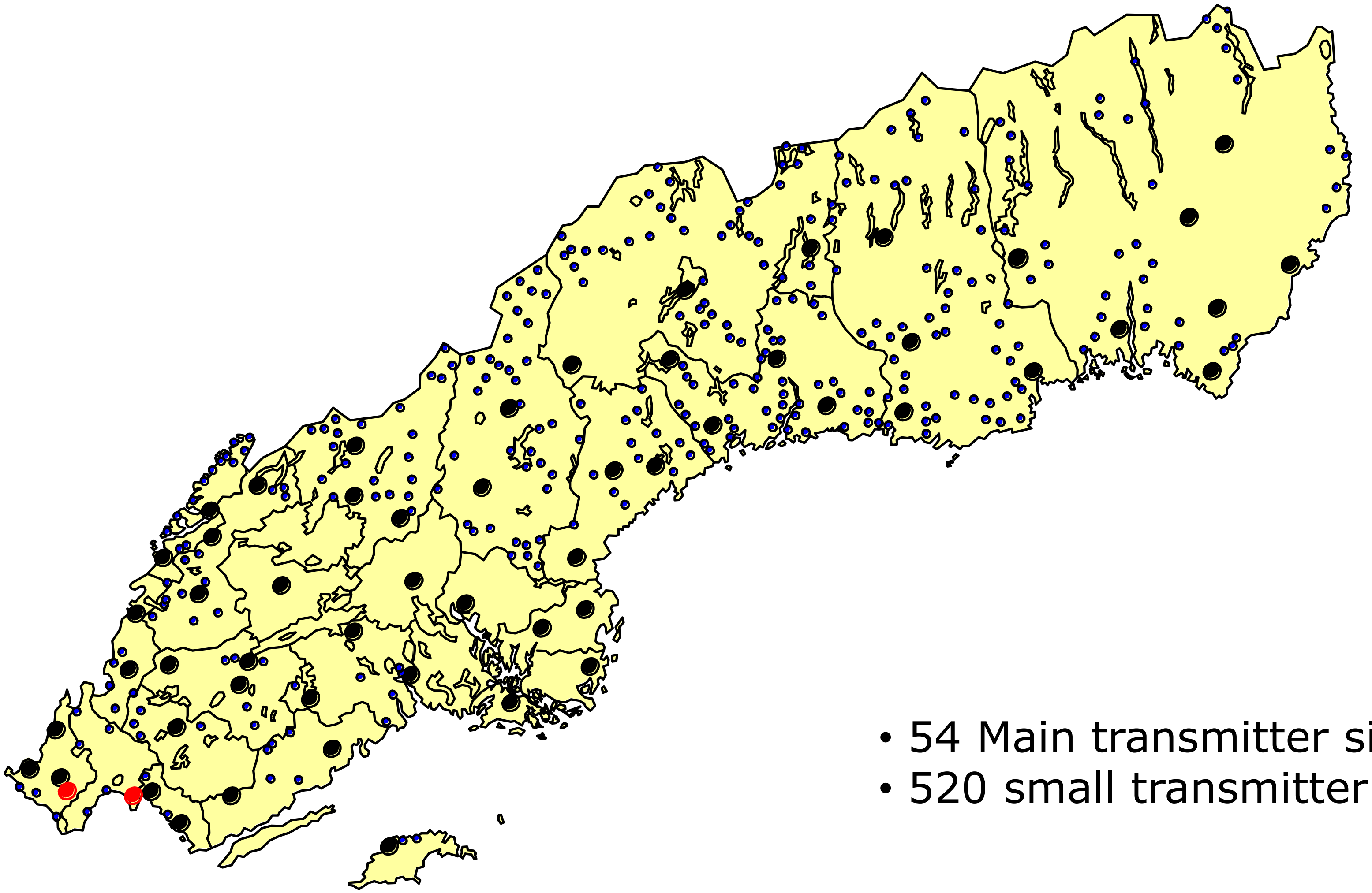
…to allow for roof-top reception of digital TV…

We also transmit FM radio…

…and in the future digital radio

… and in many cases in-door reception

Transmitter sites all over Sweden cover almost all population (>99.8%)



- 54 Main transmitter sites
- 520 small transmitter sites

We offer

Tv

Radio

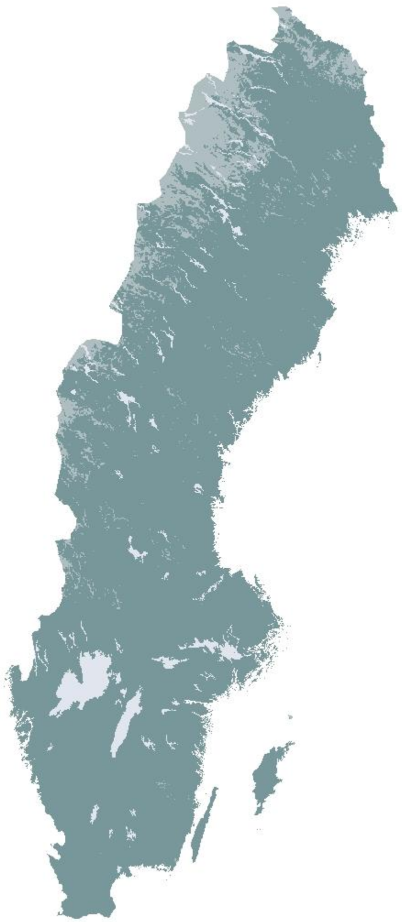
Capacity

Co-location

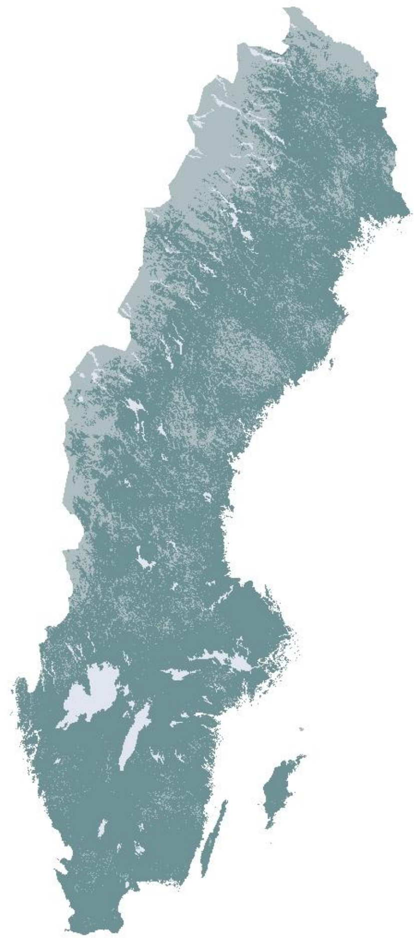
Service

Future-proofed products that are constantly evolving

We are located throughout Sweden



FM coverage



TV coverage

Backbone network

Some of our customers

- Sveriges Television
- TV4
- Boxer
- Viasat
- Eurosport
- NT Media

- Sveriges Radio
- UR
- Radio Sweden
- MTG Radio
- SBS Radio

- Telenor Sverige
- 3GIS
- Tele2
- 3
- TeliaSonera
- Nokia Siemens
- Net 1

The Teracom group

TERACOM
Holding company

TERACOM
Sweden

TERACOM
Denmark

BOXER
Sweden

BOXER
Denmark

plus TV
Finland

Network operator
Terrestrial broadcast

Pay-TV operator
Digital Terrestrial TV

Teracom Sweden

- 450 employees
- Offices in Stockholm and Sundsvall
- Service organization from Ystad to Kiruna

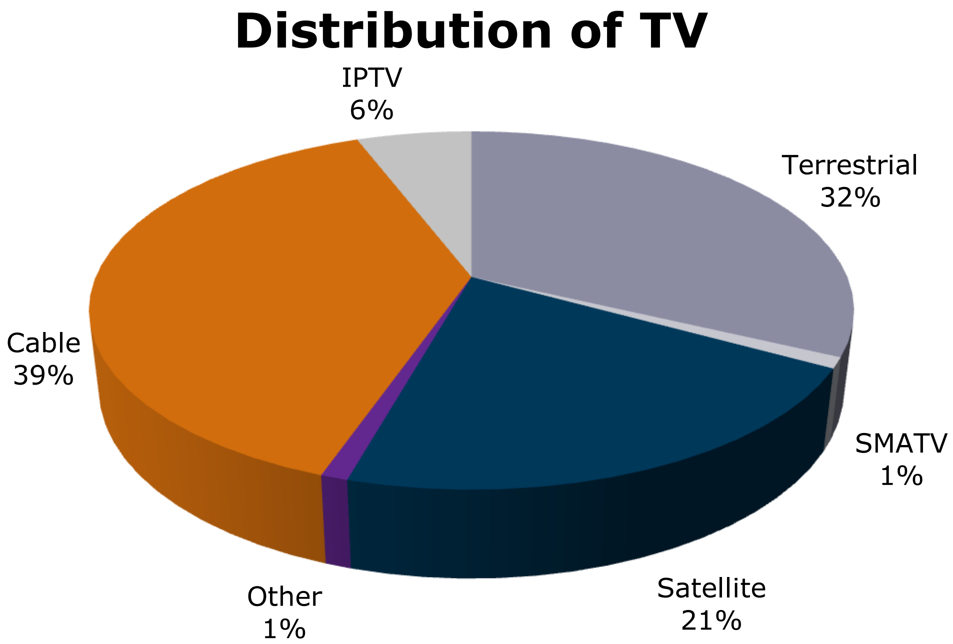
Which are the big TV actors in Sweden?

	Satellite	Satellite	Terrestrial	Cable	IPTV
Network operator	SES SIRIUS	telenor	TERACOM	ComHem	TELIA
Service Provider	VIASAT	Canal Digital telenor	BOXER	ComHem	TELIA
CA, SMS	VIASAT	Canal Digital telenor	BOXER	ComHem	TELIA
Content	MTG, 4, VIASAT, svt, CANAL+, ProSiebenSat.1 Media AG, Disney				

Terrestrial network

- Reaches "all" Sweden (>99.8%)
- Unique combination of free-to-air and pay TV
- Simplicity is the keyword
- High degree of regionalisation of content

Market shares – Distribution TV



- Main reception type in the home
- Individuals in Sweden 3-99 år
- Many can receive TV in different ways

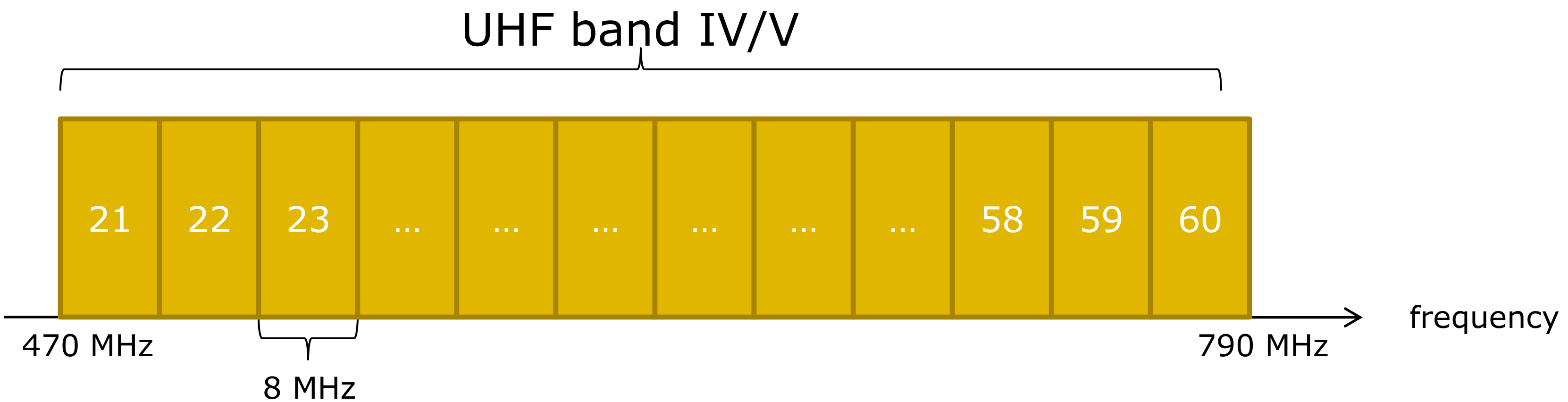
- IPTV and digital cable increasing
- Terrestrial is dominating for summer cottages (Sv: *fritidshus*) – more than 80%

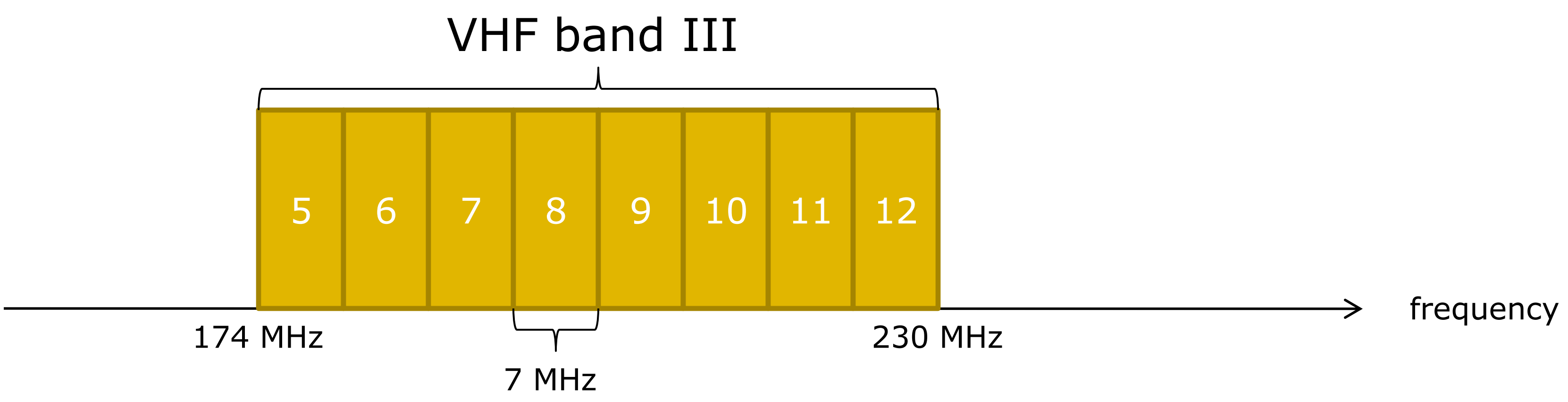
Source: Mediavision, MMS Basundersökning Q2 2010

Teracom's
Digital Terrestrial TV Network

Spectrum for Digital Terrestrial TV

- UHF band IV/V channel 21-60: 470-790 MHz
- VHF band III, channel 5-12: 174-230 MHz





DVB-T and DVB-T2

- DVB-T was the first emission standard for digital terrestrial TV
  - Possible to choose trade-off between capacity and C/N (C/I) performance
  - Used in mux 1-5
  - Capacity = 22.1 Mbit/s with same coverage as analogue TV
- DVB-T2 is based on DVB-T but with a lot of new functionality
- DVB-T2 allows for about 50% higher capacity than DVB-T for the same coverage
  - Mux 6: 36.6 Mbit/s
  - Mux 7: 30.8 Mbit/s

Key facts Teracom digital TV

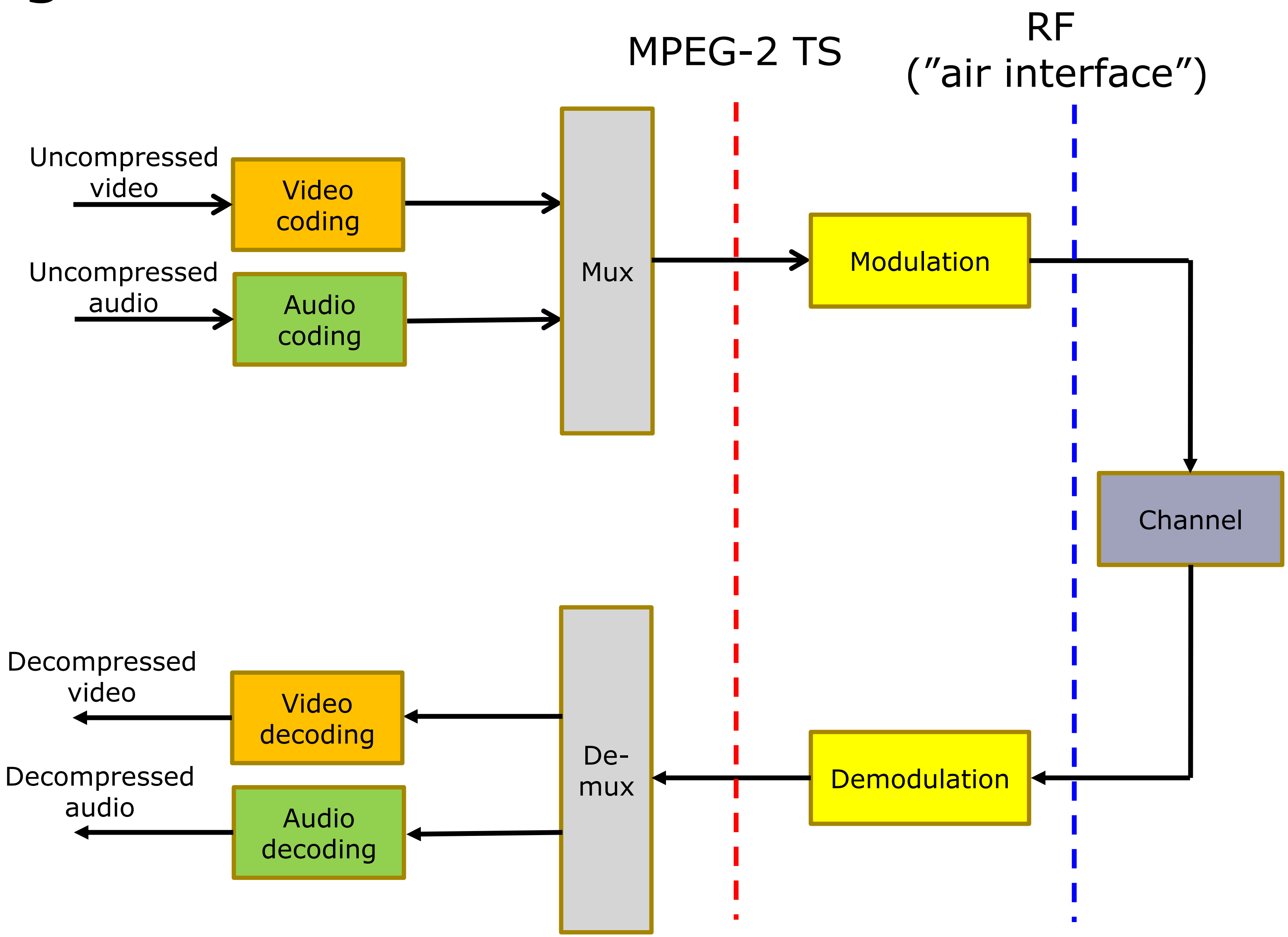
• Mux 1 (SDTV/DVB-T)	99,8 % population coverage (SVT)	
• Mux 2-5 (SDTV/DVB-T)	98% population coverage	
• Mux 6-7 (HDTV/DVB-T2)	98% population coverage	
• Main transmitter sites	54	(Mux 1-5)
• Small transmitter sites	102 st	(Mux 1-5)
• Additional sites for SVT	418 st	(Mux 1)

- Allows for regional services in a large number of areas
- E.g. local news and local advertising

Most of the sites also transmit radio

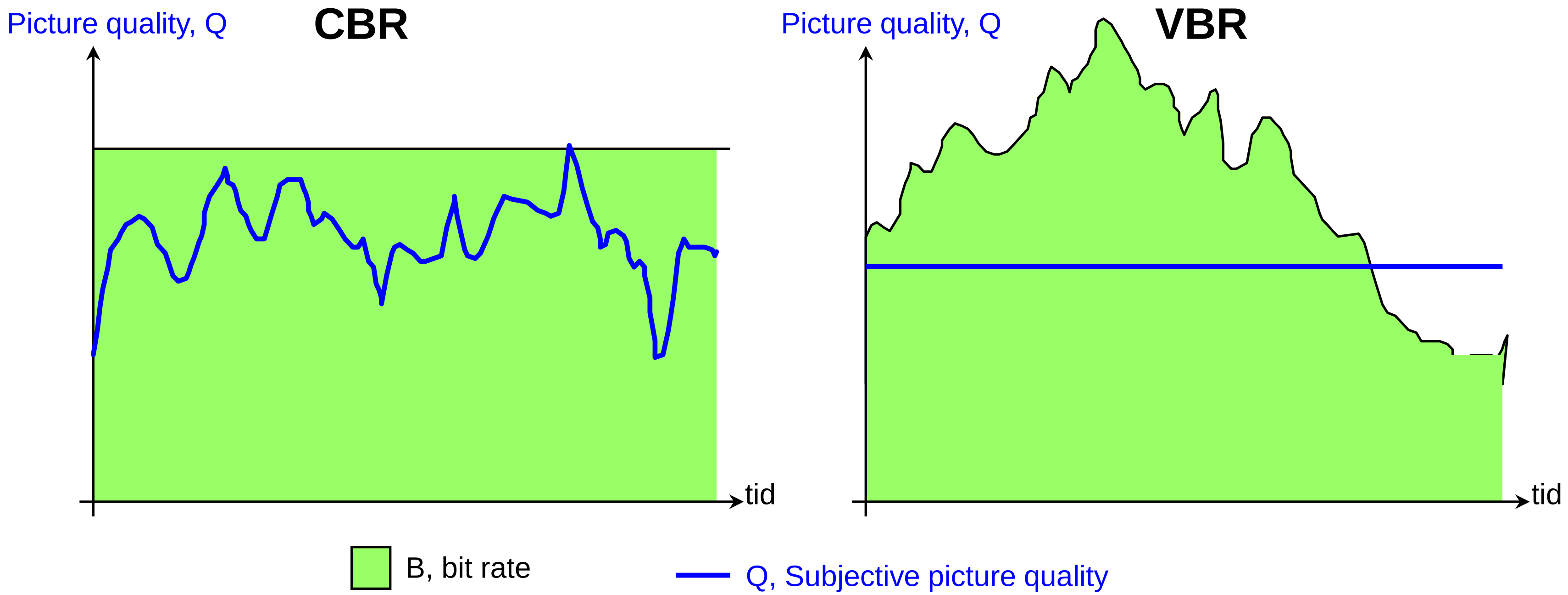
Very short tutorial about digital terrestrial TV

Simplified transmission chain for digital terrestrial TV



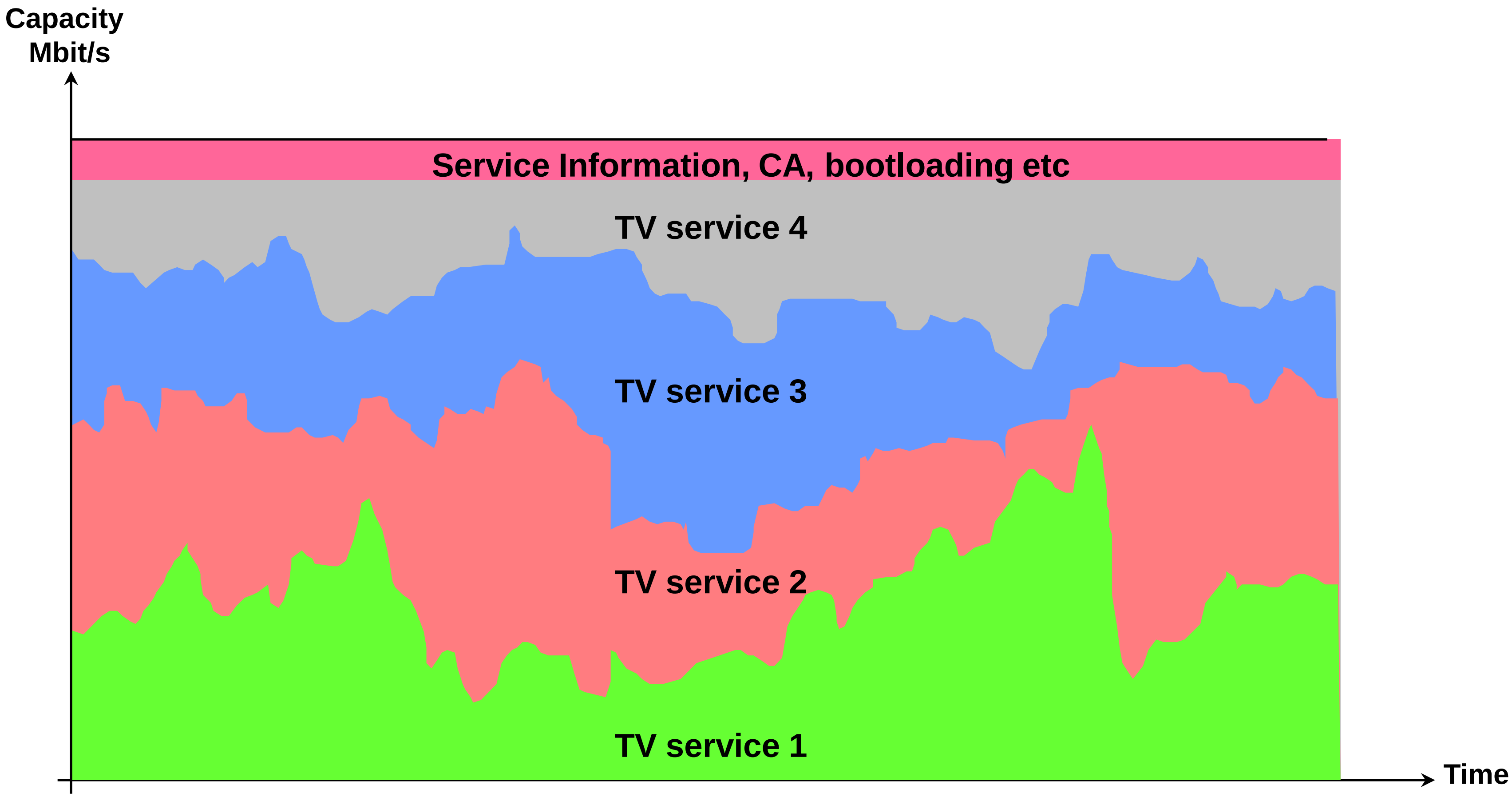
Constant and variable bit rate

- How efficient the bit rate reduction can be depends on a number of factors, e.g. how ”difficult” the material is
- Because the criticality of the material varies over time one gets the following relations:
  - With constant bit rate (CBR) the quality varies over time
  - With constant quality one gets a variable bit rate (VBR)
  - None of these are desirable!



Statistical multiplexing

- With statistical multiplexing one can ideally combine a large number of VBR video services to a stream that has both constant bit rate <u>and</u> a constant video quality

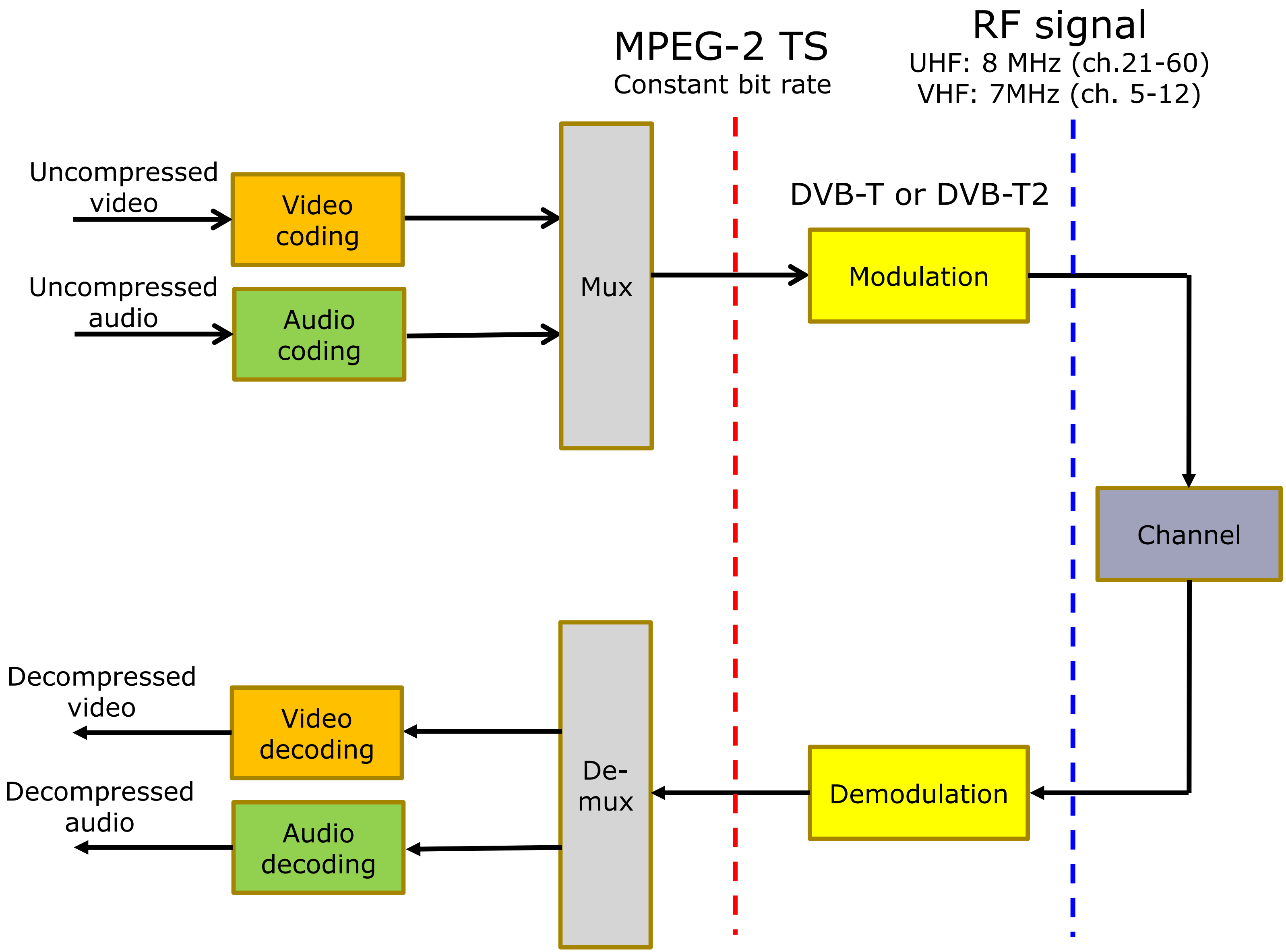


Multiplexing

- The result of the audio/video coding is put in so-called MPEG-2 Transport Stream packets (TS packets)
- The multiplexing operation assembles TS packets from different services to one single data stream – the MPEG-2 Transport Stream (MPEG-2 TS)
  - One ”colour” per service component (e.g. ”video of SVT2” or ”audio of SVT1”)
- This stream is broadcast over the air by the modulator/transmitter and is demultiplexed by the receiver

188 byte = 188 x 8 bits per TS packet

Modulation


MPEG-2 TS
Constant bit rate
RF signal
UHF: 8 MHz (ch.21-60)
VHF: 7MHz (ch. 5-12)
Uncompressed video
Video coding
Uncompressed audio
Audio coding
Mux
DVB-T or DVB-T2
Modulation
Channel
Decompressed video
Video decoding
Decompressed audio
Audio decoding
De-mux
Demodulation

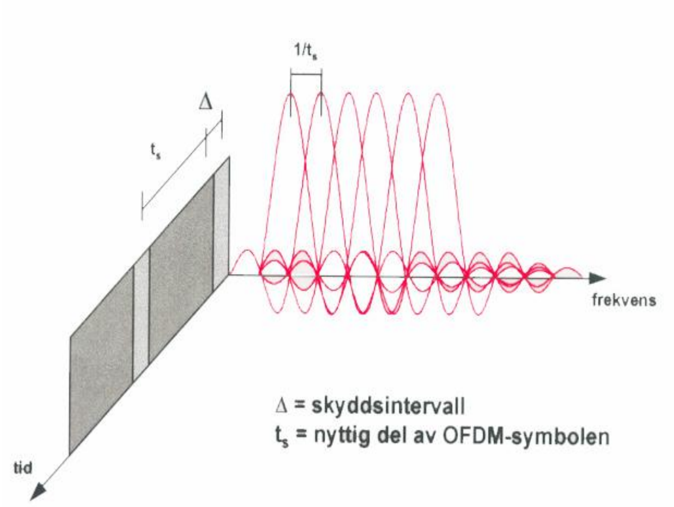
DVB-T2

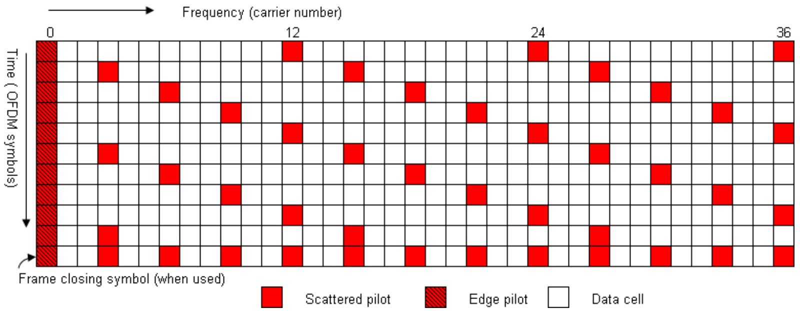
The DVB-T2 standard

- Driver: Need for more capacity for HDTV services
- DVB approved the DVB-T2 specification in June 2008
  - specifies the physical layer of the air interface (like DVB-T)
  - does not address receiver requirements
  - Video coding and multiplexing not included but will for digital TV/HDTV services be MPEG-4 AVC (H.264) over MPEG-2 TS
- ETSI standard September 2009
- DVB/ETSI standards/documents related to DVB-T2
  - Main DVB-T2 standard, Ref: ETSI EN 302 755 v.1.2.1 (draft v.1.3.1)
  - DVB-T2 Modulator Interface (T2-MI), Ref: ETSI TS 102 773
  - Implementation Guidelines, Ref: ETSI TR 102 831
  - Transmitter identification in SFNs (TX-SIG), Ref: ETSI TS 102 992
  - ETSI standards freely downloadable from ETSI: http://pda.etsi.org/pda/queryform.asp

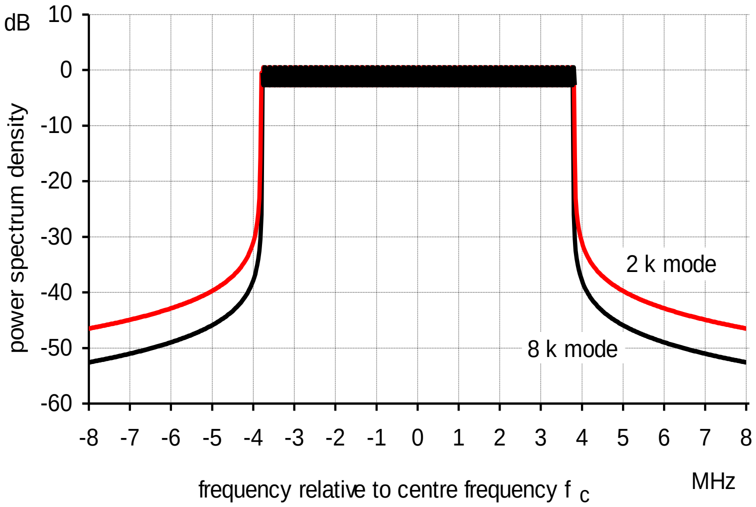
DVB-T och DVB-T2 use OFDM

Representation of OFDM in the time-frequency plane





OFDM spectrum



DVB-T2 builds on DVB-T

- OFDM based (thousends of orthogonal carriers)
- Same basic OFDM parameters as DVB-T
  - FFT size
  - Guard interval
  - Pilot patterns
- But also many new values
- Many other additions and improvements
- A lot of the signal processing in the receiver is similar to DVB-T

  ➔ Chips/receivers can be developed faster thanks to reuse of knowledge and experience from DVB-T
- From an HW point of view simple to have both DVB-T2 and DVB-T on the same chip (DVB-T comes for free)

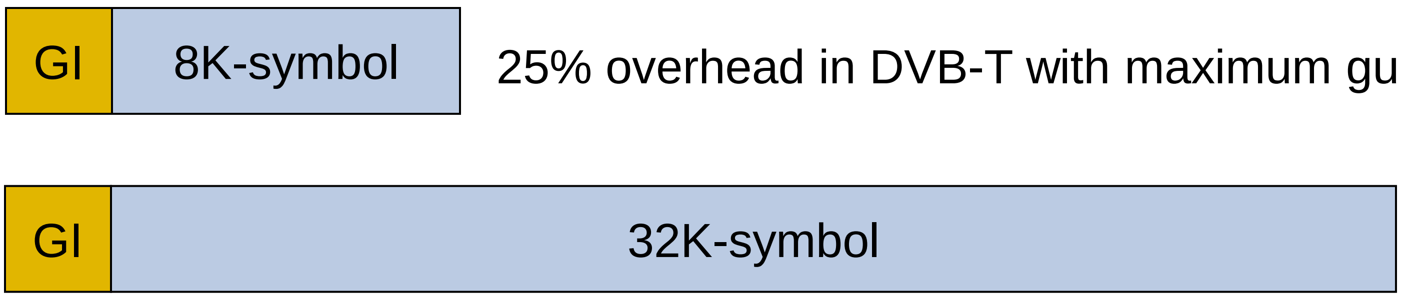
  ➔ T2 receivers also support DVB-T

Bandwidths and frequency bands

- The DVB-T2 specification as such does not specify any frequency band
- The system is primarily optimised for UHF band IV/V (470-862 MHz), but also VHF band III (174-230 MHz), L-band (1.5 GHz) and even higher frequencies are expected to work well
  - Flexible system parameters allow use within a very wide frequency range
- Specified channel bandwidths (channel raster):
  - 8 MHz (typically UHF band IV/V)
  - 7 MHz (typicallyVHF band III)
  - 1.7 MHz (same as DAB): typically VHF band III och L-band)
  - 6 MHz (e.g. USA and Japan)
  - 5 MHz
  - Also a 10 MHz mode for non-consumer use

Symbol time (FFT size) and guard interval

- With DVB-T2 the symbol time can be increased by a factor two (16K FFT) and four (32K FFT) compared to DVB-T
  - Reduces the overhead due to guard interval for a given size of guard interval (size of SFN) ➔ increased capacity



25% overhead in DVB-T with maximum guard interval

~6% overhead in DVB-T2

- Increases possible guard interval size and therefore size of SFN for a given percentage GI overhead

  ➔ potentially more efficient frequency plan

- DVB-T2 may also use the same symbol periods as DVB-T (8K, 4K, 2K) and also a shorter FFT size (1K)

  ➔ allows for flexibility for different frequency bands, network types and flexibilitet för olika frekvensband, RF bandwidths, network types and reception

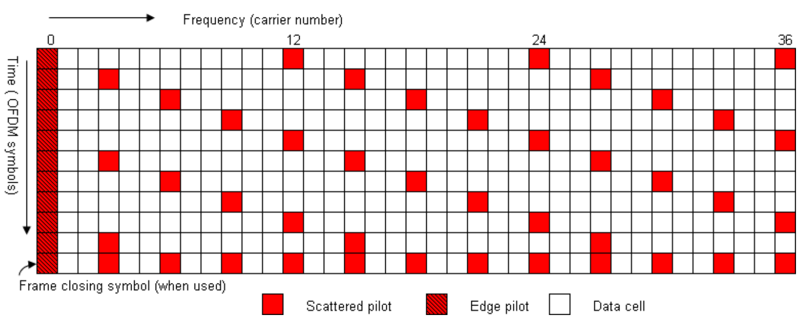
More flexibility in the choice of guard interval fraction

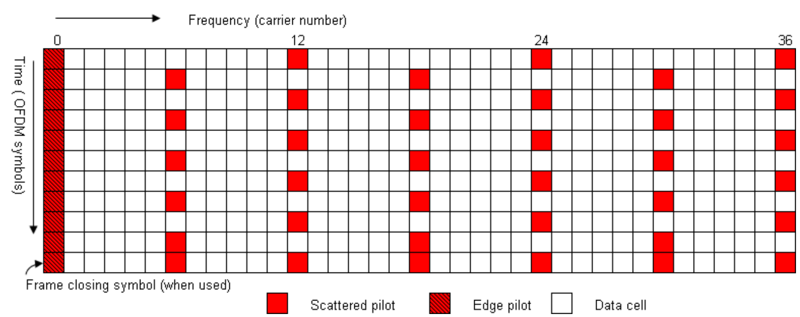
- T2 extends the set of allowed GI fractions with three more ➔ increased flexibility and reduced overhead: 1/128, 1/32, 1/16, 19/256, 1/8, 19/128, 1/4
- Allows for optimisation of guard interval to the actual network (e.g. transmitter spacing and network size)

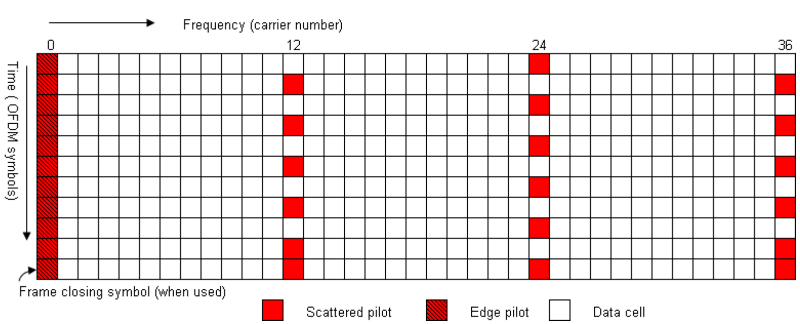
  ➔ maximises capacity

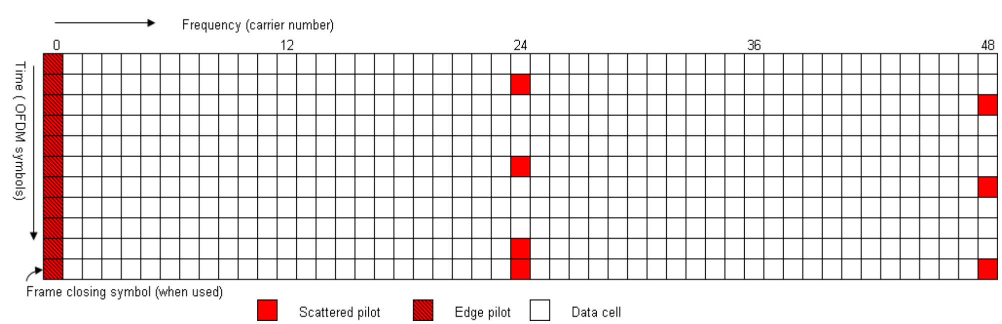
Flexibility in pilot pattern

- DVB-T has a fixed pattern of scattered pilot cells
- DVB-T2 has 8 different patterns to choose from, depending on network type and reception conditions
- Minimises pilot overhead



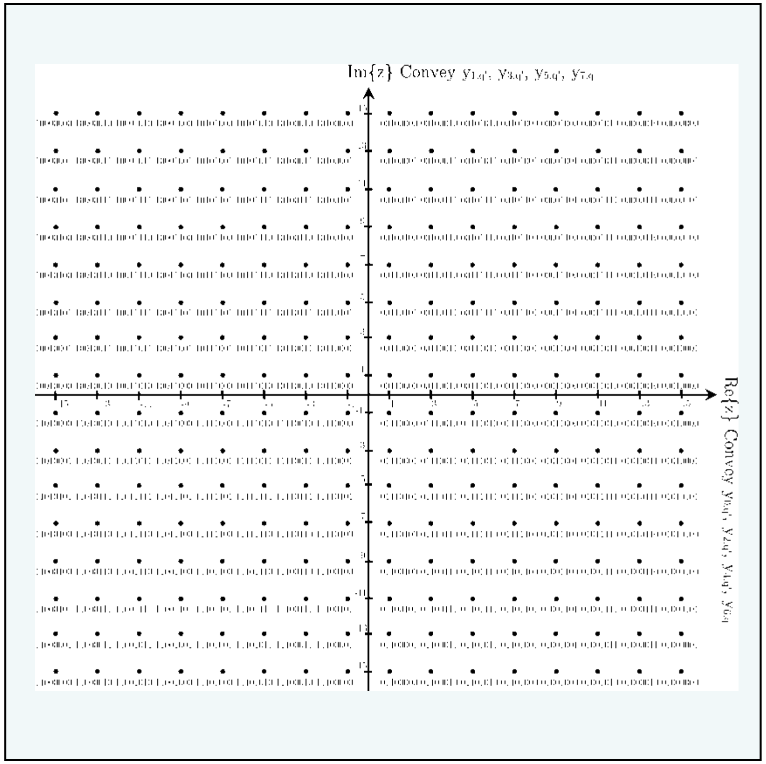




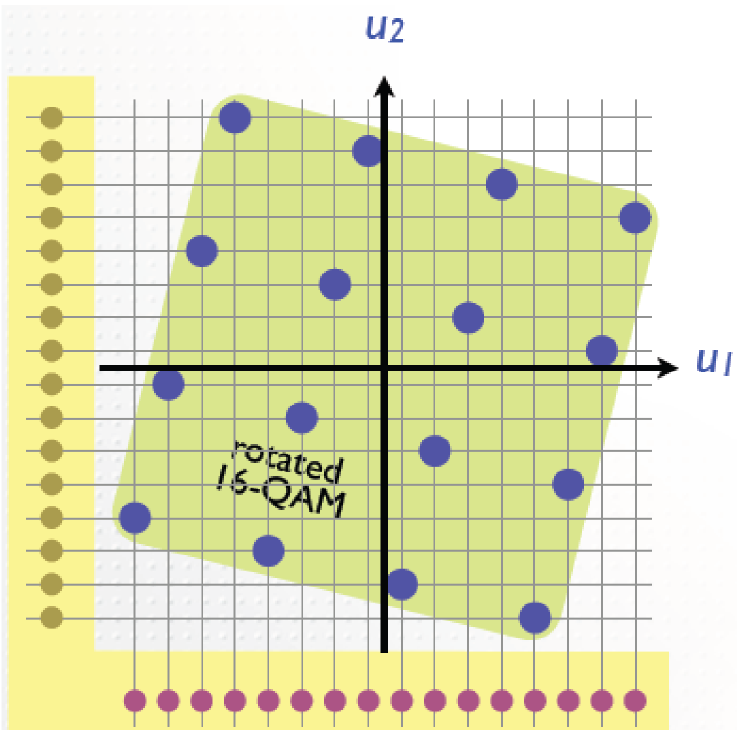


Modulation

- T2 has a 256-QAM mode
  - Carries 8 bits per data cell
    - (6 bits/data cell for 64-QAM)
  - Allows for 33% larger capacity
  - The T2 standard also includes
    - 64-QAM
    - 16-QAM
    - QPSK
  - … inherited from DVB-T

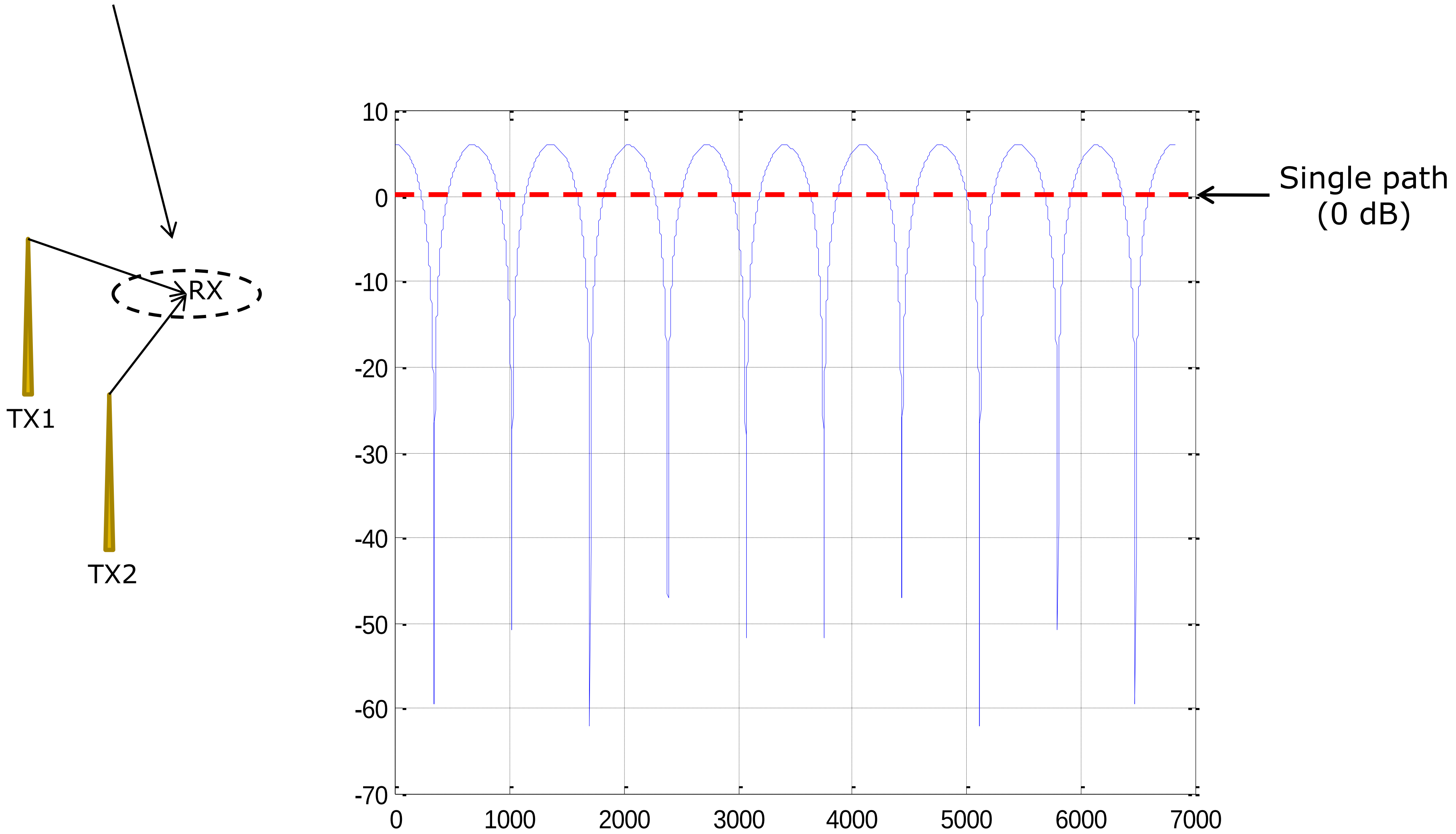


"Rotated constellation"



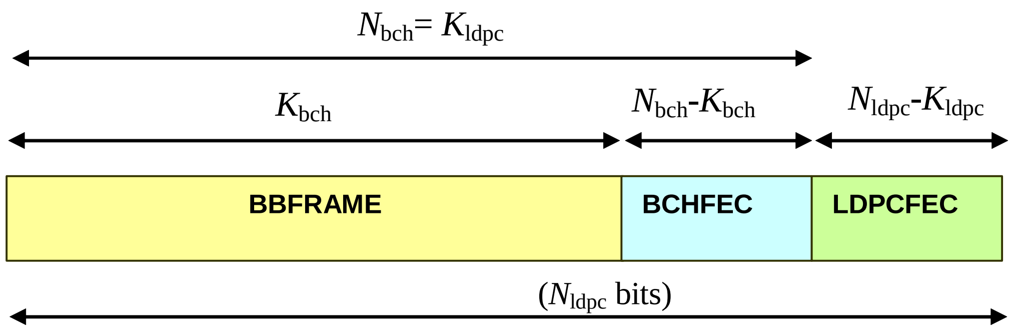
- Additional modulation stage with so-called "Rotated Constellation" allows for more robust reception in extreme radio environments
  - E.g. lots of echoes, part of the signal totally faded or interfered
  - Each constellation point gets unique projection on both u1 and u2 axes
  - Interleaving separates u1 and u2 values over the air ➔ increased diversity

0 dB echo totally kills some carriers



Forward Error Correction (FEC)

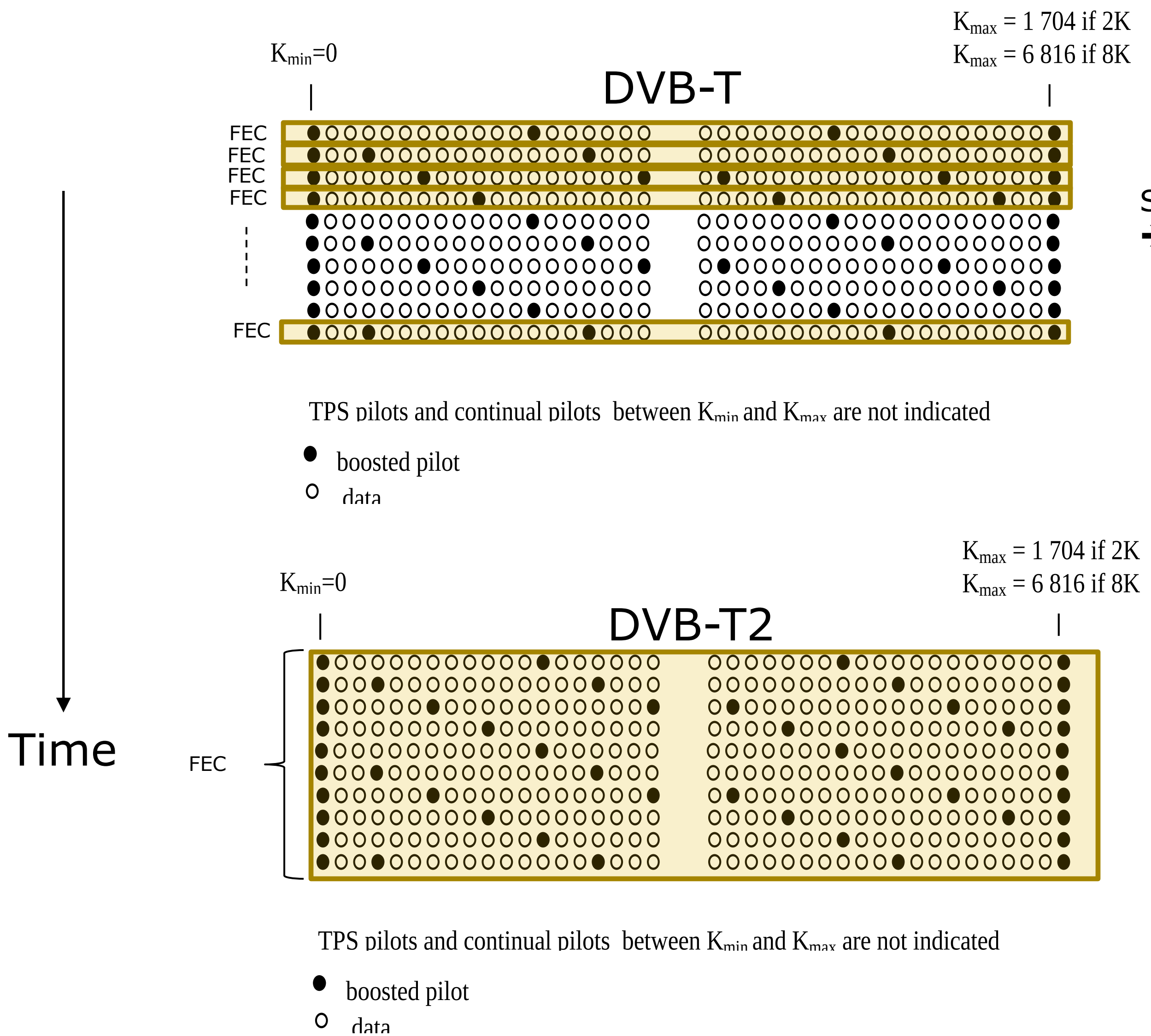
- DVB-T has a convolutional code + Reed-Solomon
- DVB-T2 has an LDPC code + BCH code
  - Same as in DVB-S2 (satellite) and DVB-C2 (cable)
  - Iterative decoding of LDPC, iterative demapping also possible
  - 6 code rates: 1/2, 3/5, 2/3, 3/4, 4/5, 5/6
  - Flexibility to make desired trade-off between capacity and robustness
  - Allows for about 30% more capacity for a given robustness
  - FEC block size (N_{ldpc}): 64800 bits or 16200 bits



Interleaving

- Interleaving is of fundamental importance for the RF performance on non-AWGN channels
- DVB-T2 has several interleavers
  - Bit interleaver within a FEC block
  - Cell interleaver within a FEC block
  - Time interleaving within a PLP (e.g. one TV program)
  - Frequency interleaving within an OFDM symbol
- The result is that bit errors caused by the channel are equally distributed among the FEC blocks, and also within FEC blocks ➔ maximises error correction ability of the LDPC/BCH code

Interleavning in DVB-T and DVB-T2

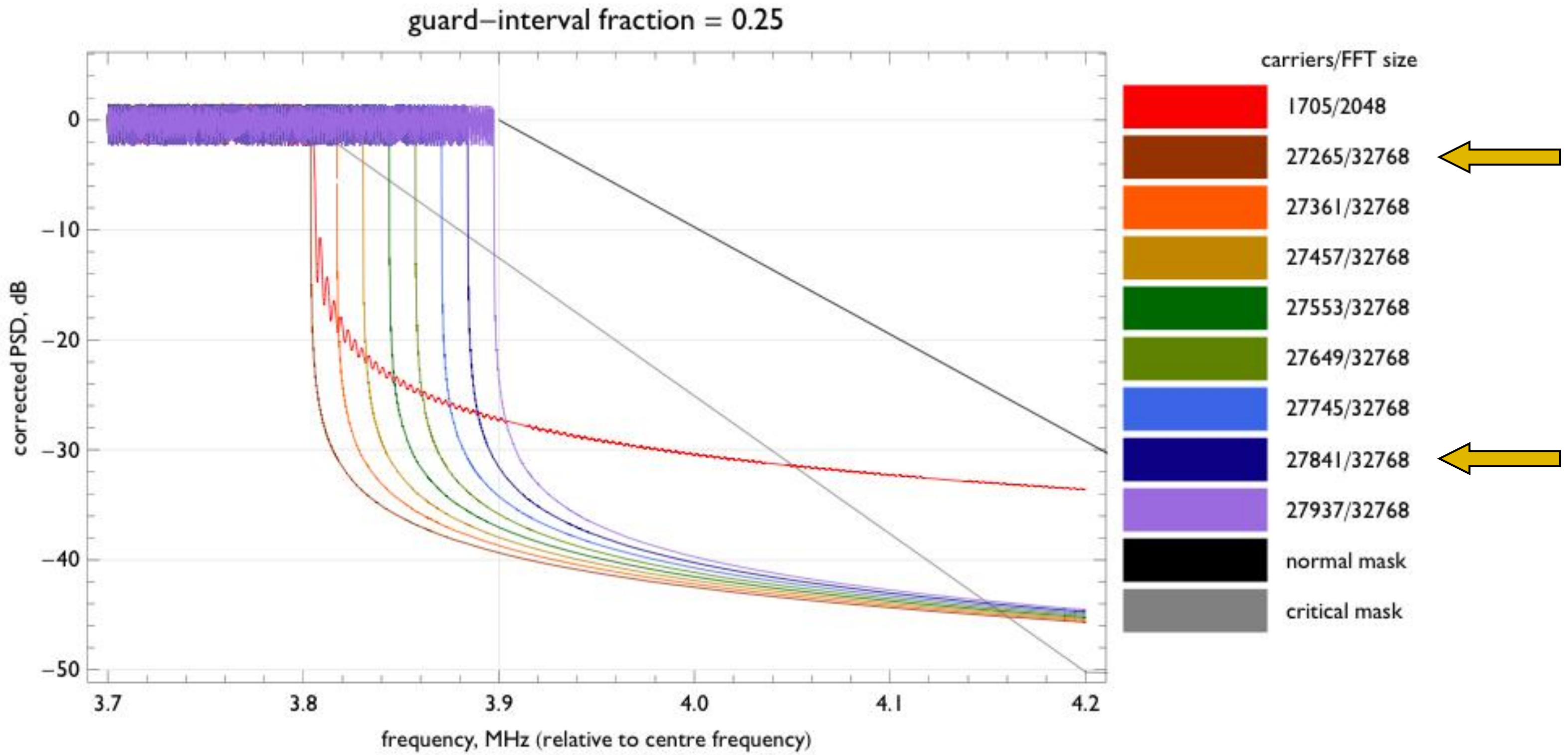


Single erased OFDM-symbol
➔ Bit errors

Single erased OFDM-symbol
➔ Can be corrected!

Extended bandwidth mode

- Transmitted spectrum falls-off much faster with 32K mode than with the 2K mode (used today for DVB-T in the UK)
  - Allows 2% additional bandwidth/capacity, while keeping spectrum mask requirements
  - The standard also allows a “normal mode”, without extended bandwidth

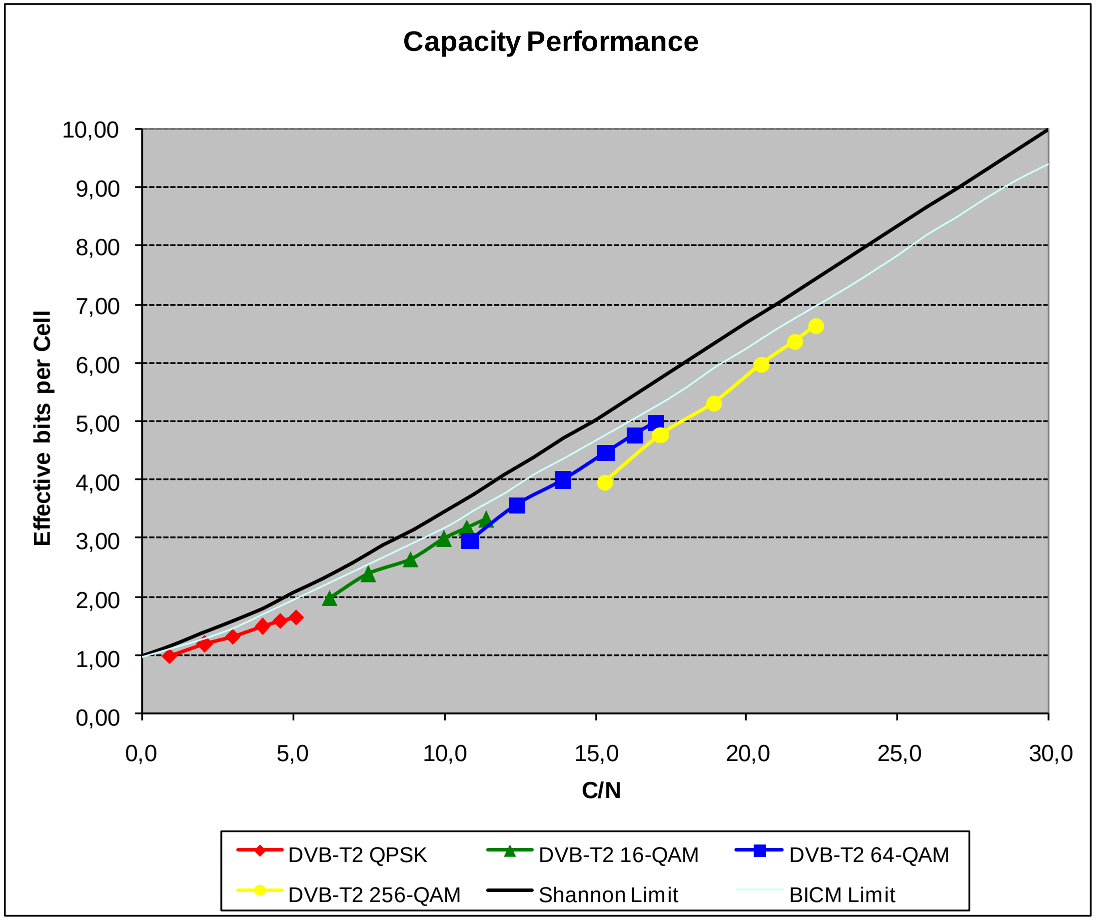


Capacity increase

- DVB-T2 allows for typically about 50% higher capacity for fixed reception than DVB-T (for a given coverage)
  - Exact increase depends on precise configuration of T2 parameters
- Example:
  - DVB-T today in Sweden: 22 Mbit/s on UHF (8 MHz bandwidth)
  - DVB-T2 can provide about 33 Mbit/s (+50%) on UHF with the same basic coverage as DVB-T
- Capacity on VHF somewhat lower
  - VHF bandwidth is 7 MHz
  - VHF has larger SFN areas ➔ requires a larger guard interval
  - However, VHF has a better link budget ➔ may be possible to increase code rate/capacity
  - Exact capacity depends on transmitter power

Performance for modulation and FEC close to theoretical limits

- Capacity limits for a channel with white noise (AWGN)
  - With LDPC coding T2 can come close to the theoretical limit
- Typically a 30% gain in capacity compared to DVB-T for a given required C/N

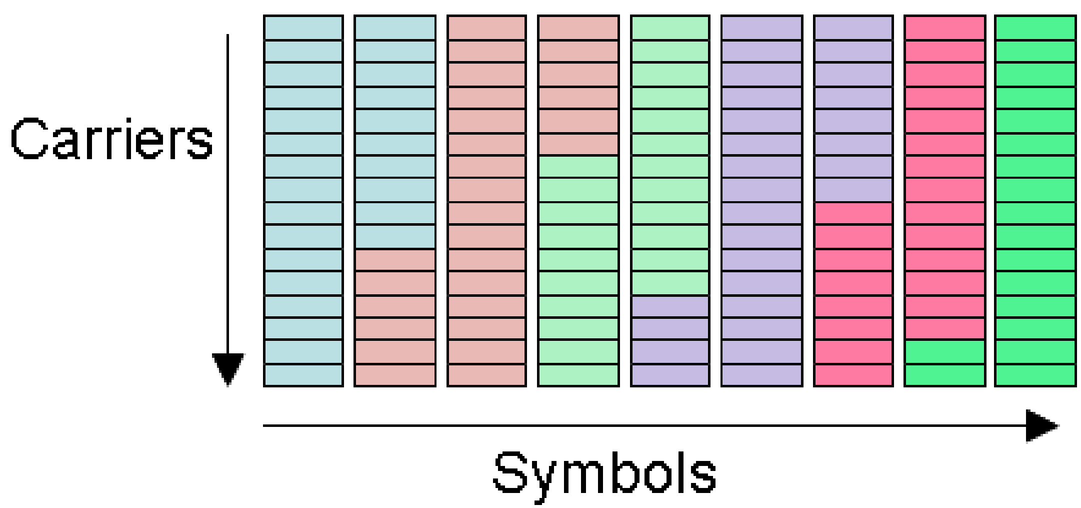


Improved robustness

- DVB-T does not include time interleaving and is therefore sensitive to impulsive interference and time varying channels
- DVB-T2 has support for deep time interleaving and longer symbol period (32K FFT), which together radically improve the robustness against impulsive interference
- Time interleaving also allows for much better performance in time varying channels
- The type of FEC (LDPC) and modulation (rotated constellation) that T2 has also allows for much better RF performance in difficult radio environments

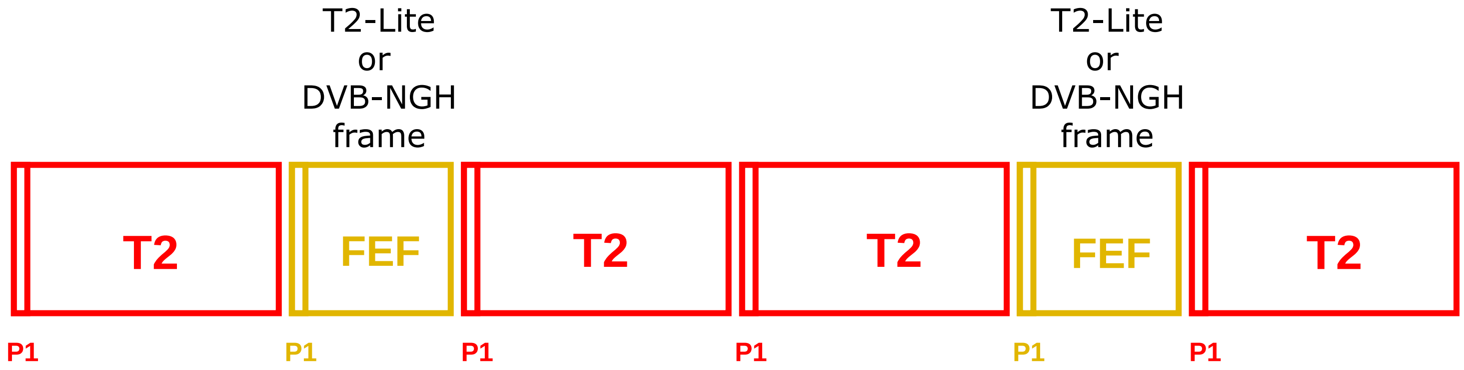
Physical Layer Pipes (PLPs)

- Input MPEG-2 TSs are carried by the corresponding Physical Layer Pipe (PLP)
- The stream carried in a PLPs may have a variable bit rate
- Statistical multiplexing over several PLPs is possible
- Every PLP can get its own robustness (code rate + modulation)
- PLPs may be sent in a bursty way ➔ allows for power saving in mobile devices (“time slicing”)
- Signalling data which is common for several PLPs may be sent in a dedicated PLP (“Common PLP”) to avoid duplication/overhead



Future Extension Frames (FEFs)

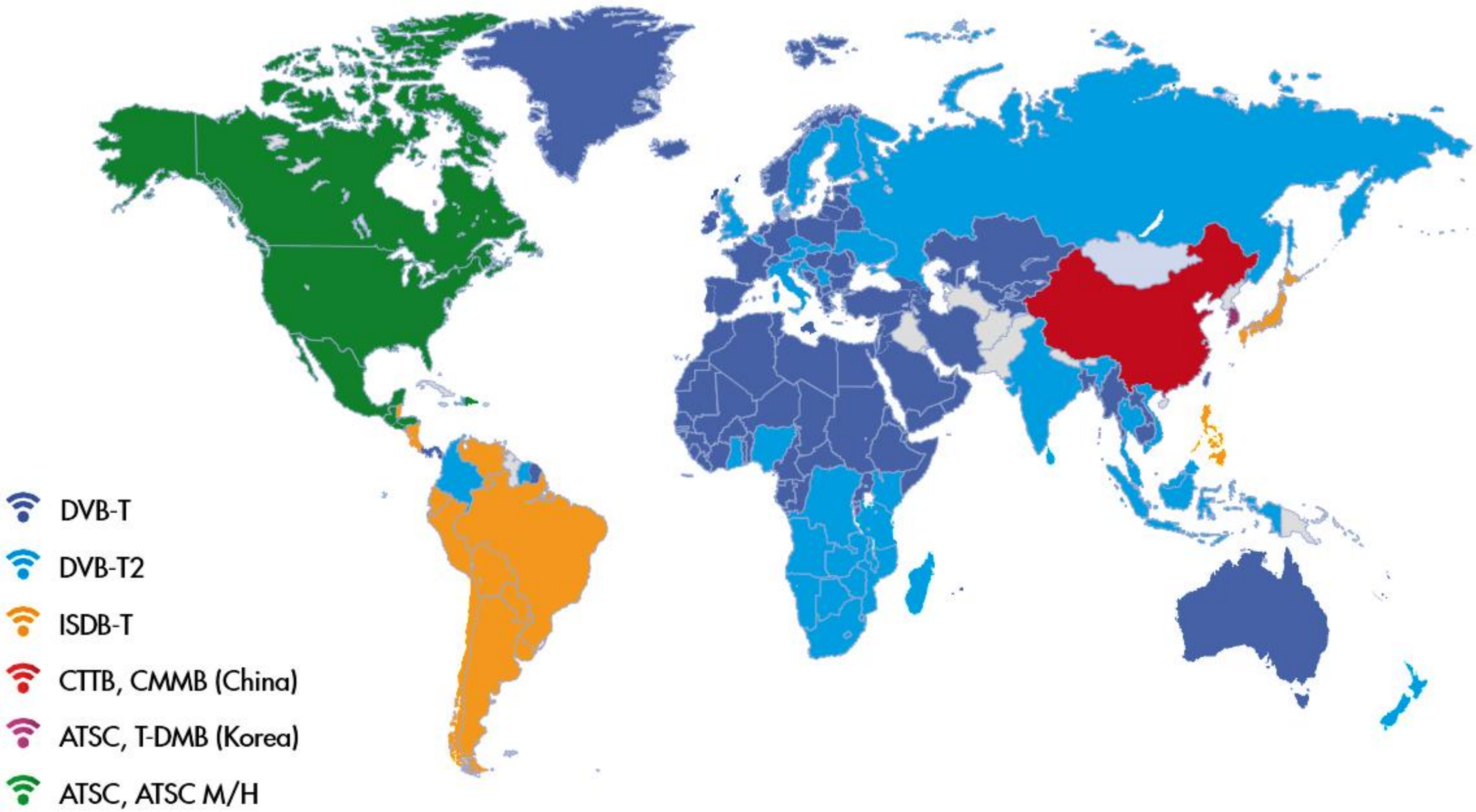
- A mechanism that allows a future system to be sent as “Future Extension frames” in T2 time slots
  - No restrictions in the allowed content of the FEF
  - FEF may use DVB-T2 Lite (specified subset of DVB-T2)
  - Will e.g. allow future transmission of the DVB Next Generation Handheld (DVB-NGH) standard currently developed by DVB
- The FEF mechanism does not exist in DVB-T
- Allows flexible capacity allocation to fixed and mobile services by adjusting the size of T2 frame and FEF



Summary of advantages with DVB-T2

- About 50% more capacity than DVB-T for a given coverage
- More robust reception in difficult reception conditions
- May be used on VHF and in large SFNs
- Several different ways of allowing different kinds of reception using the same transmitted signal
- Very large flexibility and a lot of “features”
- Opens the door for further performance improvements via the use of Time Frequency Slicing

Worldwide Digital Terrestrial Television Broadcast standards (updated mid 2012)

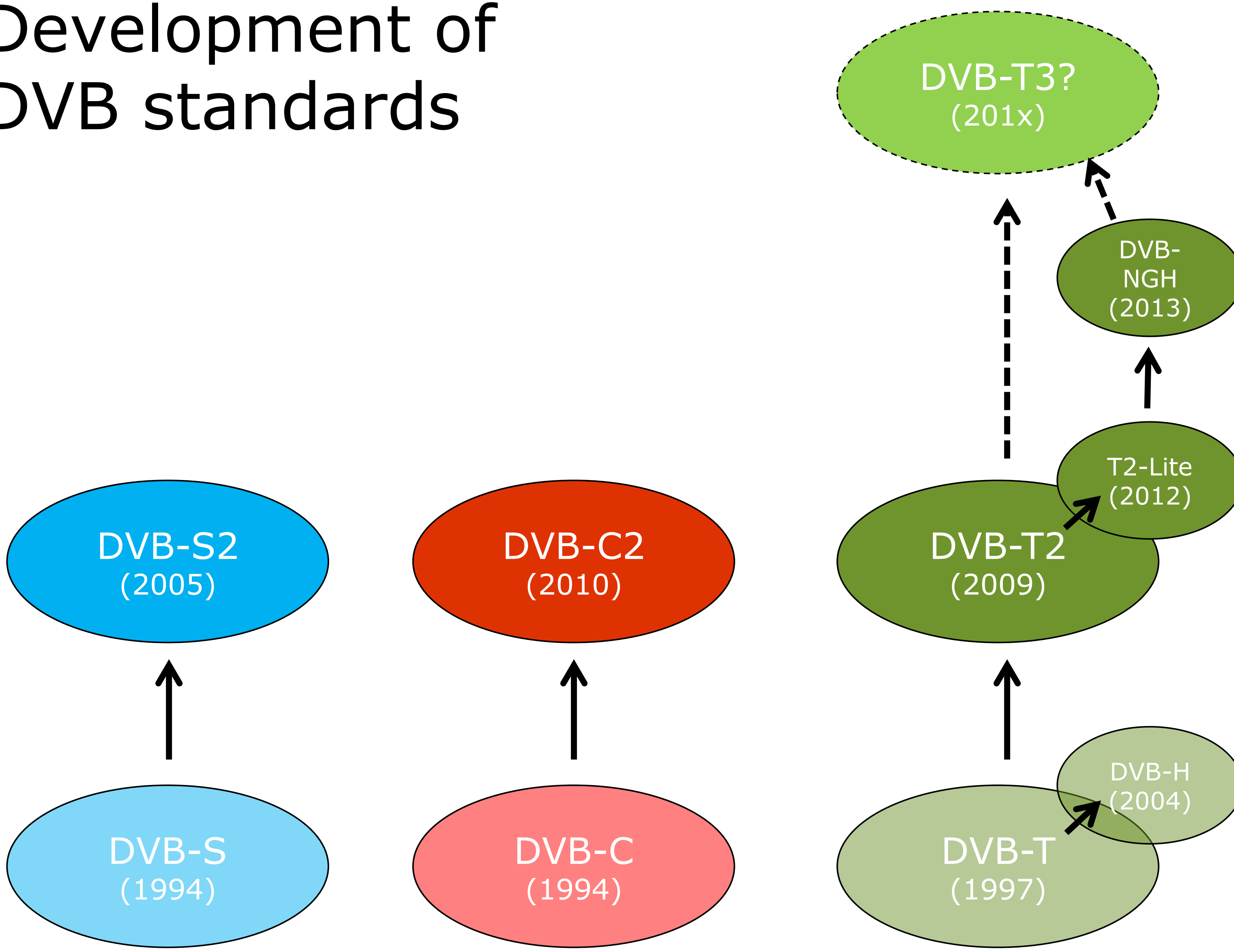


T2-Lite

T2-Lite

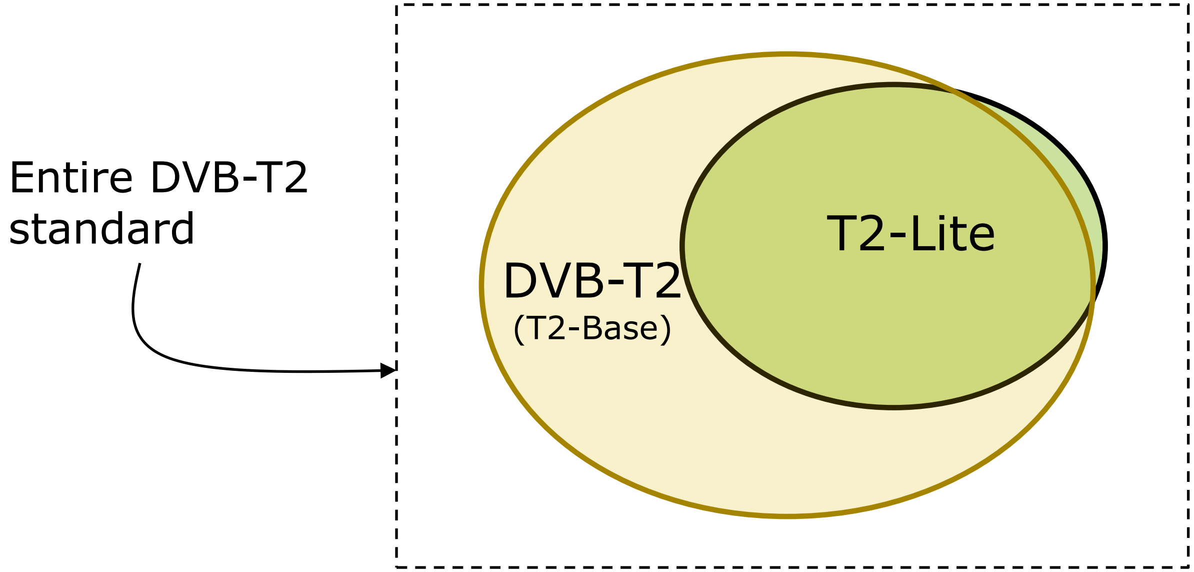
- The commercial focus on DVB-T2 was originally mainly on stationary reception, but DVB-T2 is also designed to work well in mobile/handheld conditions
  - deep time interleaving
  - supports power saving by time slicing
  - enables the introduction of “T2-Lite” or DVB-NGH services via Future Extension Frames (FEF)
  - T2-Lite is part of the DVB-T2 standard (from v.1.3.1)
  - DVB-NGH is based on DVB-T2

Development of DVB standards



What is T2-Lite?

- T2-Lite is a ”light version” of DVB-T2 that allows for implementation of of mobile devices with <u>low complexity</u> and <u>low power consumption</u>
- T2-Lite is <u>mainly</u> a subset of the main DVB-T2 standard (T2-Base), where components with high complexity are removed
- T2-Lite is specified in an updated version of the DVB-T2 standard
  - was published by ETSI in 2012 (EN 302 755 v.1.3.1)

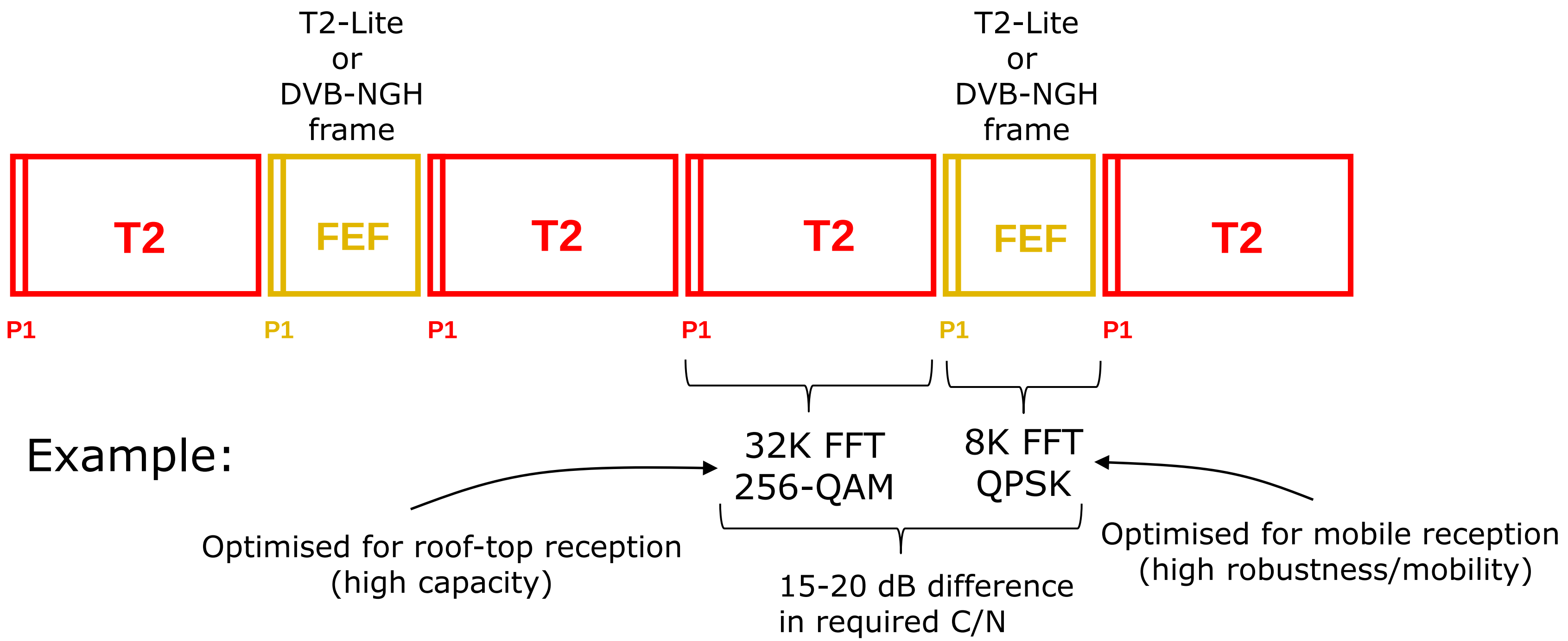


Differences between T2-Lite och T2-Base

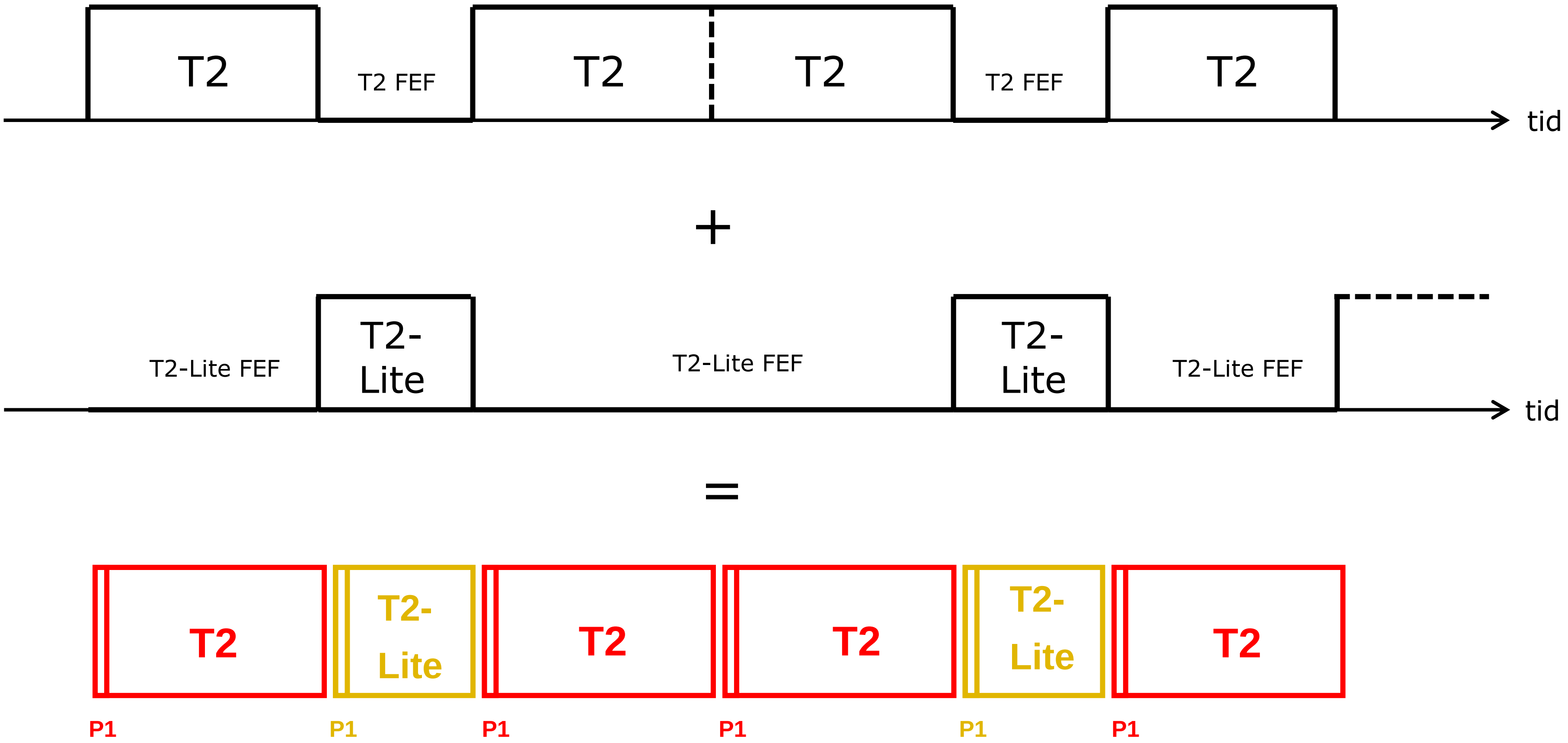
- T2-Lite has e.g. the following restrictions:
  - TS bit rate limited to 4 Mbit/s
  - Half the time interleaving memory
  - No 64K FEC-block (only 16K) → ¼ of the LDPC memory
    - Marginally lower C/N performance
  - No 1K or 32K FFT (but 2K-4K-8K-16K kept)
- T2-Lite also has some extensions, such as:
  - Code rates 1/3 and 2/5 are added

Future Extension Frames (FEFs)

- The T2 signal may include time slots where other systems (including future) may be transmitted
  - FEF may contain arbitrary waveform
  - FEF may consist of T2-Lite or DVB-NGH (or DVB-T3 in the future)



RF-signal = T2-signal + T2-Lite-signal



Combinations with WiFi

- In-door reception can be done directly with a T2-Lite receiver or with a combined T2-Lite/WiFi-extender
  - WiFi-extender receives via T2-Lite and retransmits over IP/WiFi
  - T2-Lite reception via roof-top antenna or window antenna
  - IP/WiFi retransmission allows reception on normal smartphones and tablets (e.g. iPAD) without any dedicated T2-Lite support
  - This type of product already exists (e.g. Legato)

- Reception outdoor or in vehicles can be done directly or with …
  - …vehicle-mounted WiFi-extender that retransmits within the vehicle (e.g. cars, buses, trains)
  - …mobile WiFi-extender (carried e.g. in the pocket, but needs charging)
  - …T2-Lite dongel connected to e.g. tablet (powered from tablet)

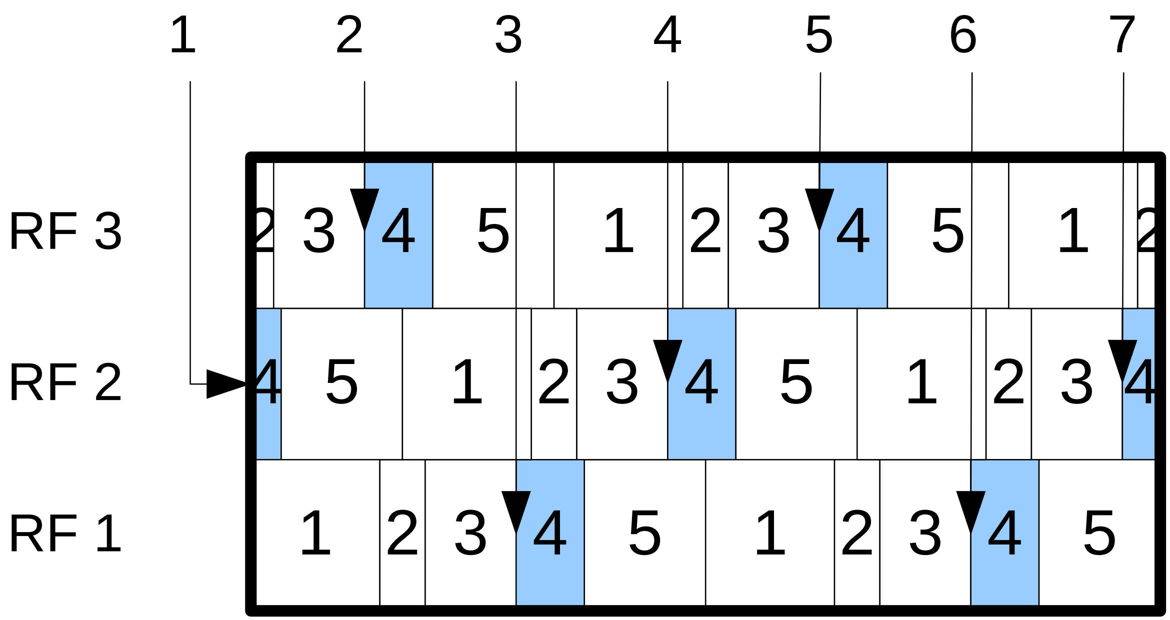
DVB-NGH

DVB-Next Generation Handheld (DVB-NGH)

- Addresses handheld & mobile reception
- Designed for state-of-the-art performance while keeping complexity limited
- Main new technologies compared to DVB-T2:
  - Time Frequency Slicing (TFS), using a single tuner
  - MIMO (X-polar)
  - Non-uniform QAM
  - Also adds an optional satellite component
- Standard approved by DVB in 2012
- Planned ETSI standardisation in 2013

Time Frequency Slicing (TFS)

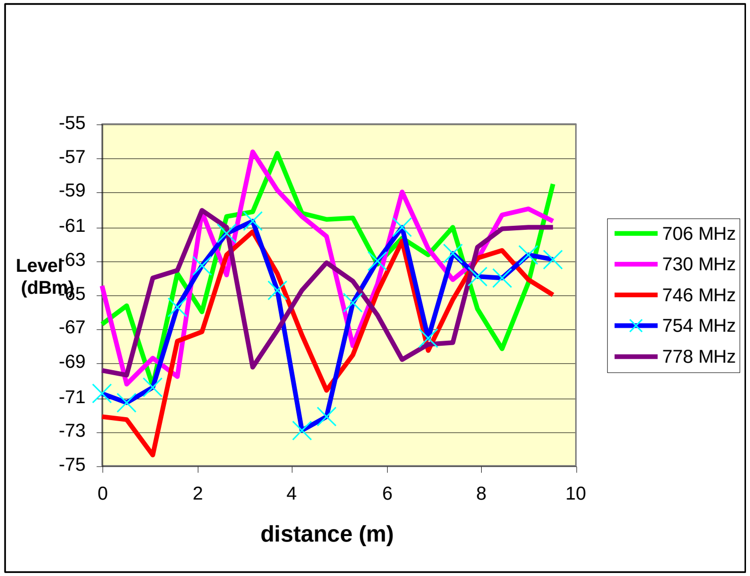
- With TFS several RF frequencies are used from each site as a common resource for a ”super multiplex”, where each service is jumping between several RF frequencies
- Statmux gain
- Network planning gain (focus here)
- Coverage of ”all services” depends on the average C/N of the muxes rather than the C/N of the worst multiplex



Network planning gains with TFS

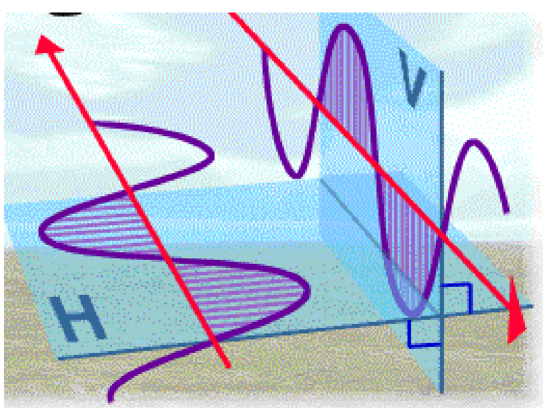
- Network planning gain w.r.t. the wanted signal
  - Homogenous and improved coverage for a group of multiplexes (3-4 dB gain)
- Network planning gain w.r.t. interference
  - Higher robustness against frequency-dependent interference
  - C/I variations expected to be larger than C/N variations across multiplexes ➔ TFS interference gain larger than TFS coverage gain
- A higher interference immunity can allows a fundamentally higher spectral efficiency
  - Higher capacity per network, or …
  - … fewer used frequencies per network (➔ more networks in a given total spectrum)

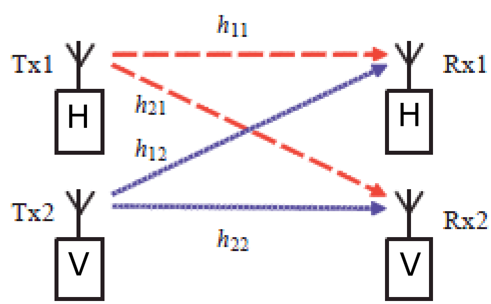
} More Mbit/s per used MHz



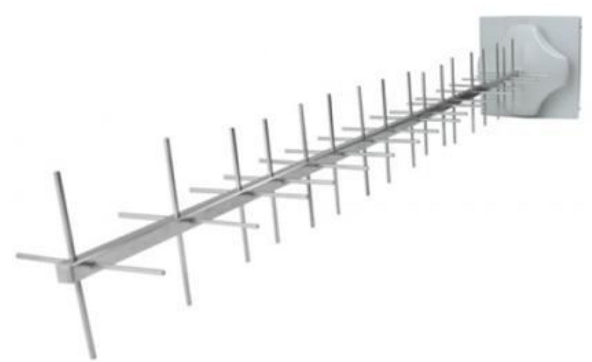
Cross-polarisation 2x2 MIMO

- MIMO = Multiple Input Multiple Output
- Horisontal **and** vertical polarisation are used at the same time from the same transmitter and frequency
- Requires reception with a X-polar antenna
- Receiver may use inversion of matrix h, but better methods exist
- MIMO precoding improves performance (”eSM + PH” in NGH)
- MIMO can potentially double the capacity





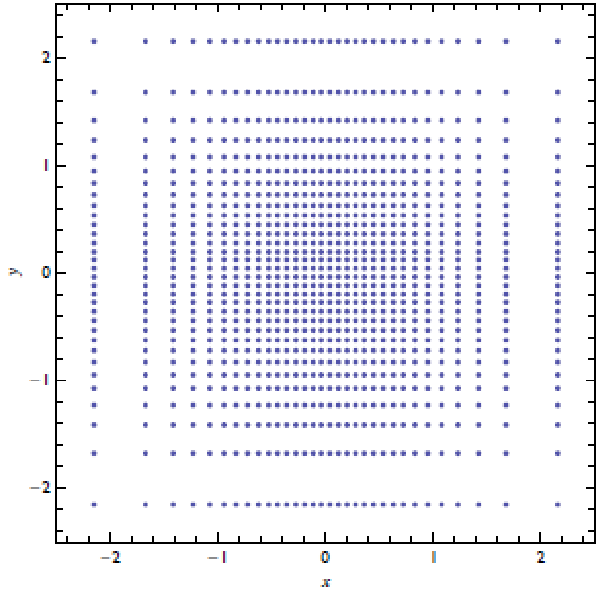
$$h = \begin{pmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{pmatrix}$$



Non-uniform constellations

- Approaching Shannon capacity requires the transmittted samples to have a Gaussian distribution
- This is not possible with uniform QAM of any size
  - Assuming equiprobable constellation points
- Fundamental 1.53 dB (pi/6) ”shaping loss” with uniform QAM
- With non-uniform QAM the amplitude distribution becomes closer to Gaussian
- High order NU-QAM constellations may approach Shannon capacity closely (assuming ideal coding)

NU-1024-QAM



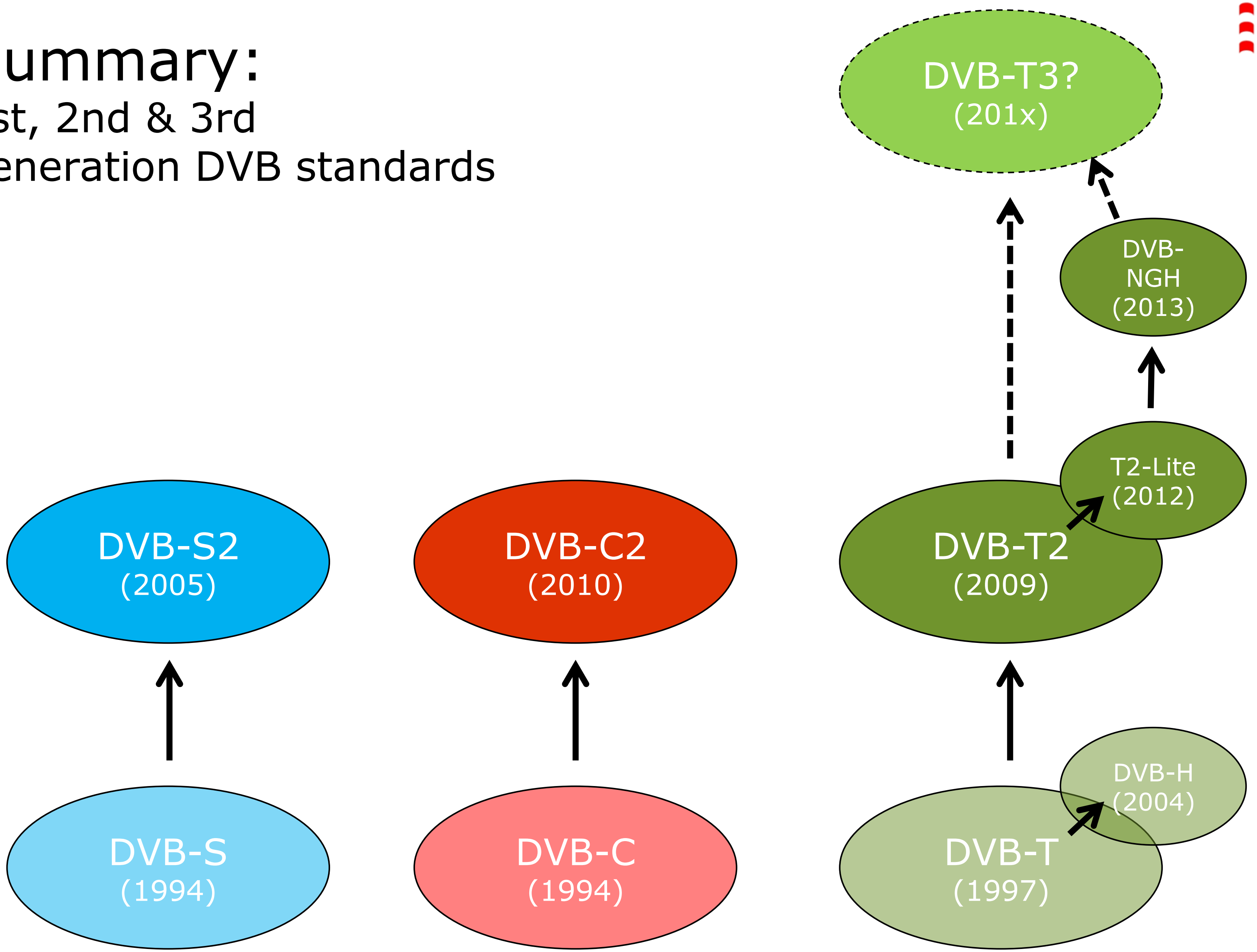
- In NGH NU-64-QAM and NU-256-QAM are used

DVB-T3 (?)

DVB-T3?

- Currently DVB conducts a technical ”Study Mission” to estimate the performance potential of MIMO and other new technologies for fixed roof-top reception with a directional antenna
- Hot candidates are cross-polar MIMO, TFS and NU-QAM
- MIMO gain higher for fixed roof-top reception
- Large potential gains using TFS
- In addition new generation video coding (HEVC) brings another factor 2 gain
- Unclear if/when DVB-T3 will be standardised and implemented

Summary:
1st, 2nd & 3rd generation DVB standards



Thank you!

Any questions?

(erik.stare@teracom.se)