



Overview of ITU-T SG15 Q4 xDSL and G.(mg)fast

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Overview

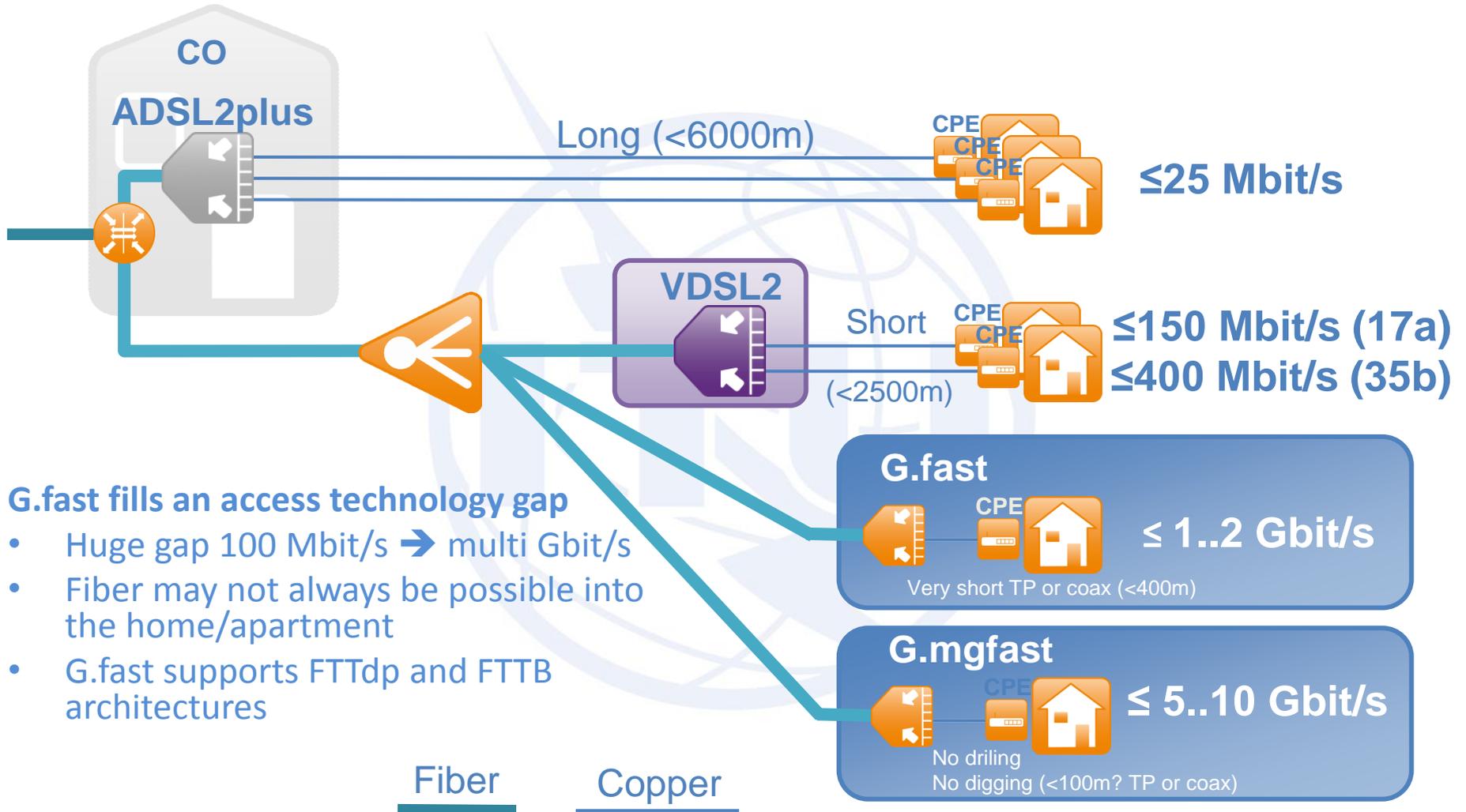
- About ITU-T SG15 Q4
- xDSL and G.(mg)fast access solutions
- VDSL2 : recent/ongoing enhancements
- G.fast : recent/ongoing/future enhancements
- G.mgfast : emerging new project

About ITU-T SG15 Q4

- SG15: Networks, Technologies and Infrastructures for Transport, Access and Home
- Q4: Broadband access over metallic conductors
- Covers all aspects of transceivers operating over metallic conductors in the access part of the network
- Projects: xDSL, G.(m)fast, testing, management
- Main liaisons: ITU-R, ETSI and BBF
- Meets face to face about 6 weeks per year



Overview Access Network Solutions



- G.fast fills an access technology gap**
- Huge gap 100 Mbit/s → multi Gbit/s
 - Fiber may not always be possible into the home/apartment
 - G.fast supports FTTdp and FTTB architectures

VDSL2

- **What is in the Recommendations (G.993.2/5, G.998.4)**
 - Aggregate data rates up to 150 Mbit/s (17a), 250 Mbit/s (30a), 400 Mbit/s (35b)
 - Operates over loops up to 2500m of 0.4mm copper
 - PHY layer retransmission and crosstalk cancellation (vectoring)
 - Down/up asymmetry ratio depends on band plan used (997 / 998 types)
 - Low power mode (reduced data rate and spectrum when user traffic is low)
- **Ongoing work (targets consent in June 2017)**
 - New Annex on mitigation of strong FEXT (operation in high crosstalk cables)
 - Defines a TIGAV procedure to adapt TX PSD under varying high FEXT levels
 - Long Reach VDSL2 (targets 10 Mbit/s over 4km of 0.5mm copper)
 - Defines a line probing during initialization to adapt TX power/PSD to the loop length
 - Uses ADSL2plus techniques (e.g., TEQ) for best performance on longest loops



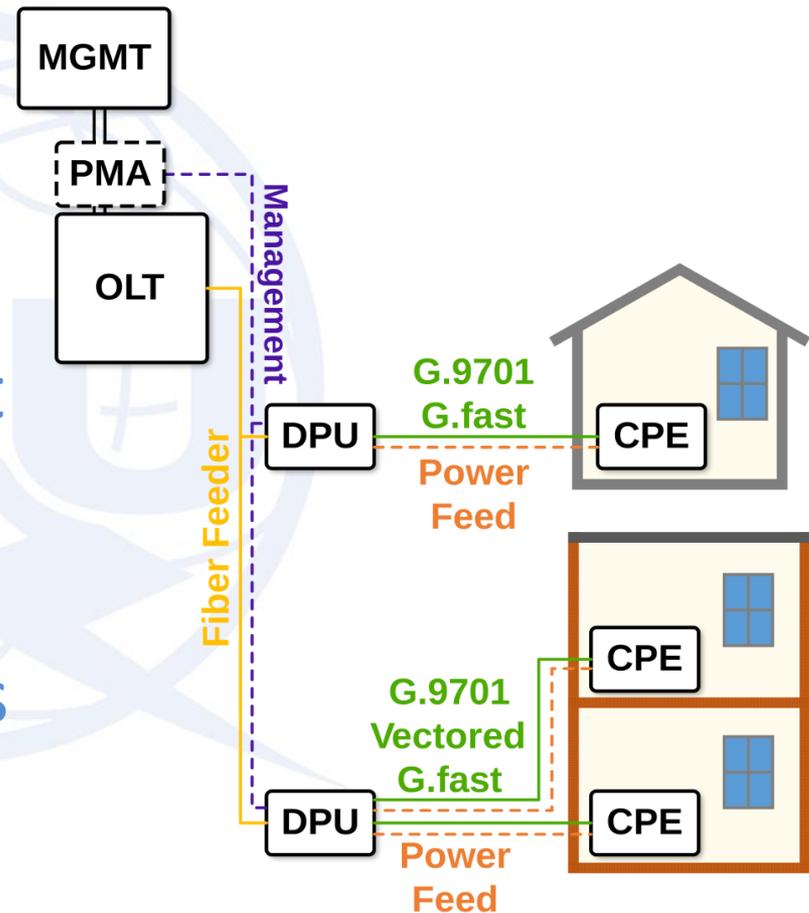
Key Aspects of G.fast

- **Aggregate service rate** (up+down) targets (over 0.5mm copper)
 - 900 Mbit/s at 100m
 - 600 Mbit/s at 200m
 - 300 Mbit/s at 300m
 - Operates up to 400m
- Operates over twisted pair, quad cables, and also coax.
- Customer **Self-Installable** CPE
- **Low power** consumption
- **Robust** with high immunity to disturbers
- **Crosstalk cancellation** for operation in multi-pair cable
- Down/up **asymmetry ratio** is static configuration of TDD split
- **NTR** and **Time-of-Day** support (expected accuracy < 50ns)

Far exceeding initial
ITU-T performance targets

Key aspects of FTTdp

- Reverse power feeding (RPF) the DPU from the user premises.
- Persistent Management Agent (PMA) acts as management proxy in the event the DPU loses power.



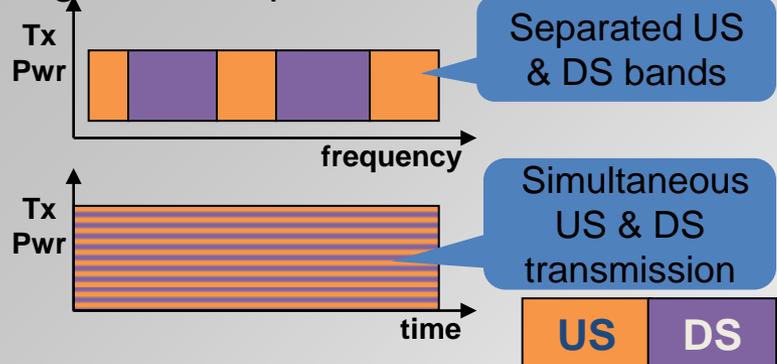
Using TDD as a Duplexing Scheme

- ⊕ Simple transceiver (only one iFFT/FFT)
- ⊕ Simplifies analogue front end
- ⊕ Easily supports low-power states
- ⊕ Discontinuous operation allows flexible trade-off of throughput vs. power consumption
- ⊕ Flexible US/DS data rate asymmetry (no bandplans)

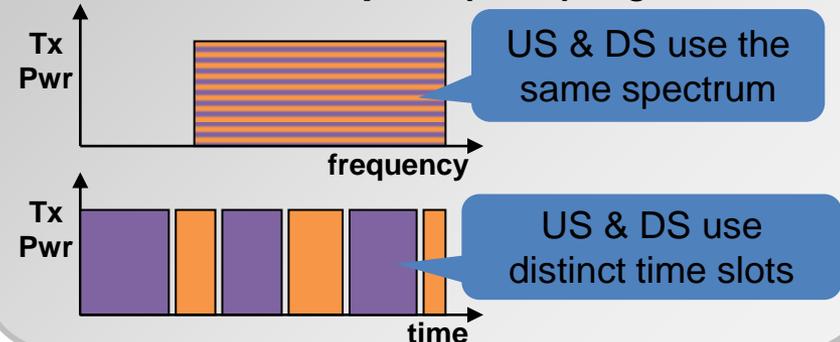
- ⊖ Synchronization of all transmitters required
- ⊖ Guard time between downstream and upstream required
- ⊖ Larger round trip time
- ⊖ Requirement to buffer data
- ⊖ No spectrum compatibility with ADSL/VDSL but can coexist (see further)

Frequency Division Duplex (FDD)

e.g. ADSL2/2plus, VDSL2



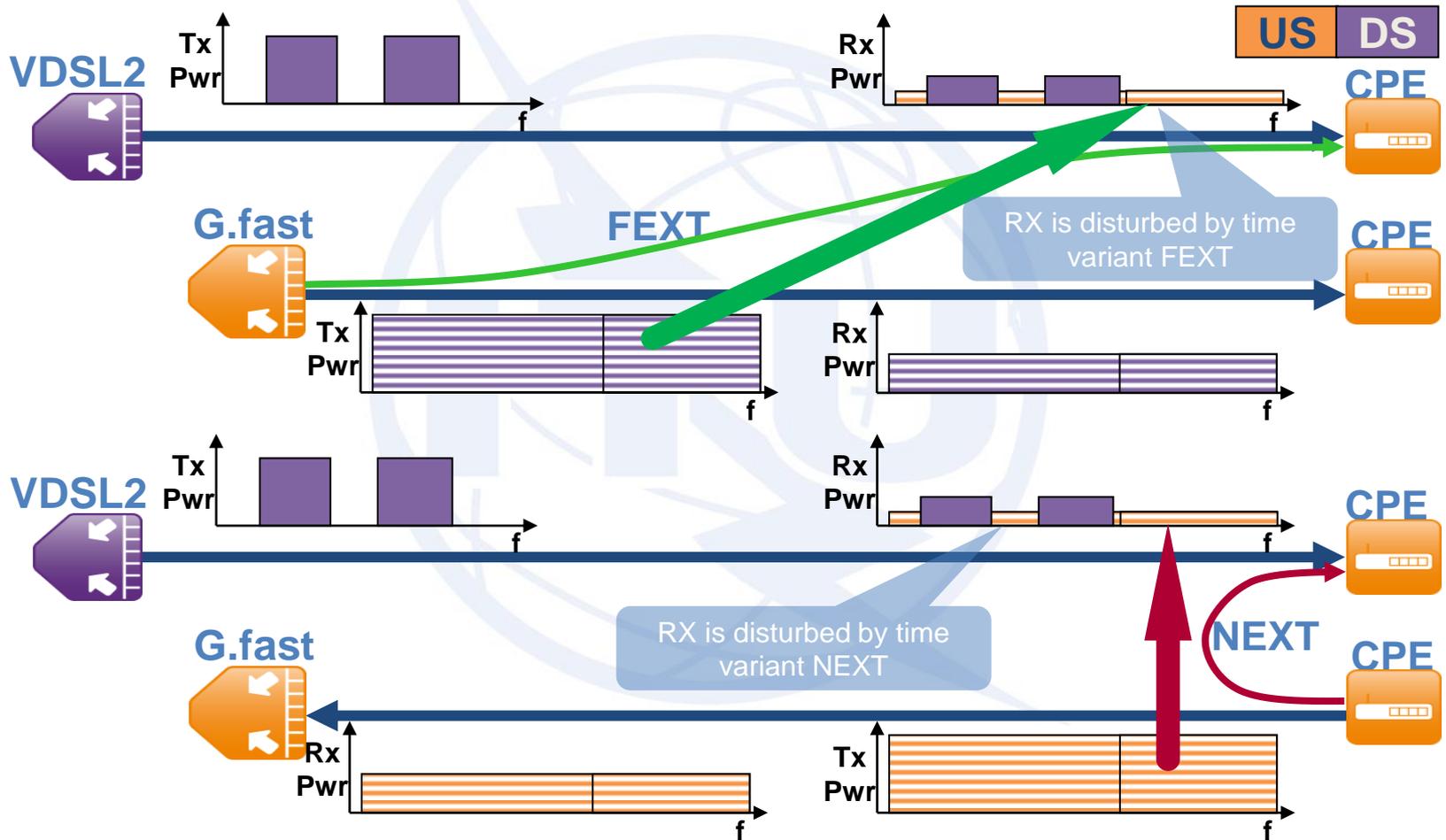
Time Division Duplex (TDD) e.g. G.fast



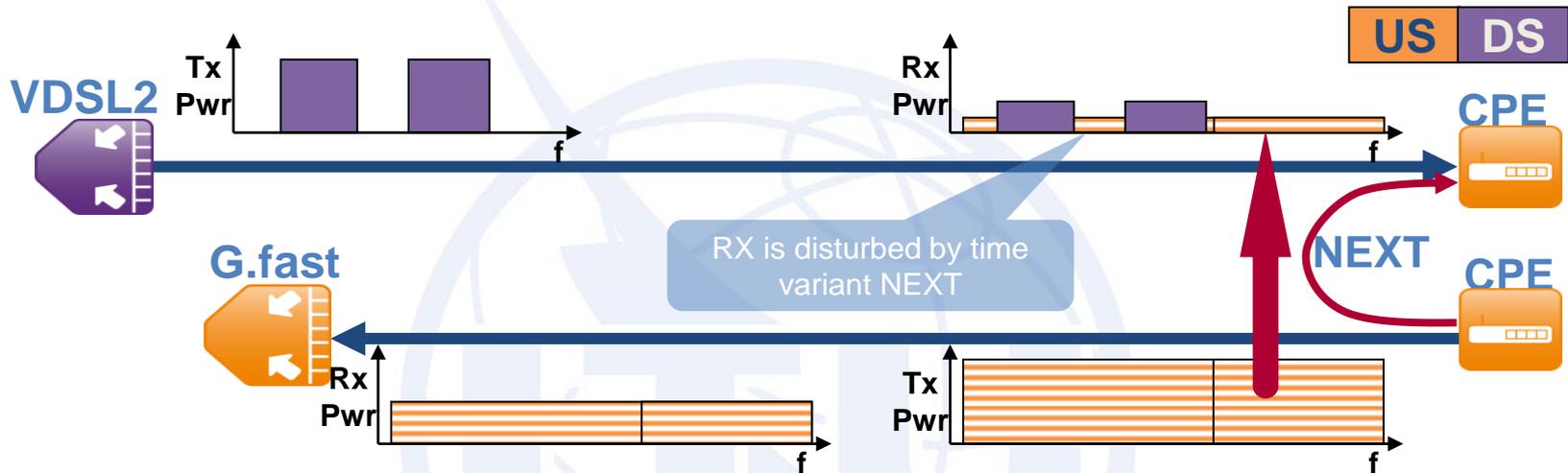
G.fast Characteristics

	G.fast	VDSL2
Modulation	DMT (up to 14 bits/Hz)	DMT (up to 15 bits/Hz)
Bandwidth (MHz)	106, 212	8, 12, 17, 30, 35
Max Transmit Power (dBm)	2 (coax) and 4 - 8 (TP)	11.5 - 20.5 (TP)
Duplexing	TDD	FDD
Distance	< 250m (400m) TP	< 1000m (2500m) TP
Bit Rate (up+dn) (Mbit/s)	< 1000 (106), <2000 (212)	< 400(35b), < 150(17a)
One way latency	< 1 ms	< 10 ms
Vectoring	Yes	Optional
Up/Down Rate Ratio	Provisioned, dynamic	Fixed by bandplan
Retransmission	Yes	Optional
Coding	Interleaved RS/Trellis	Interleaved RS/Trellis
Full init time (single line)	20 seconds (typical)	120 seconds (typical)

Coexistence Issue with ADSL/VDSL

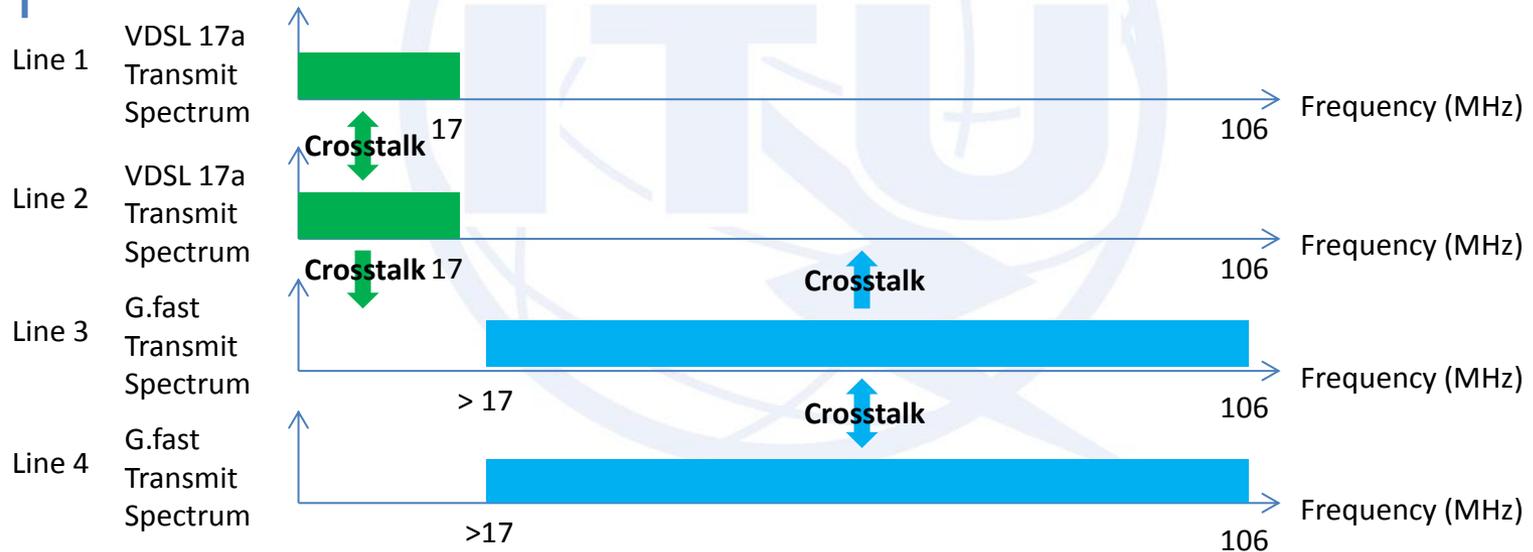
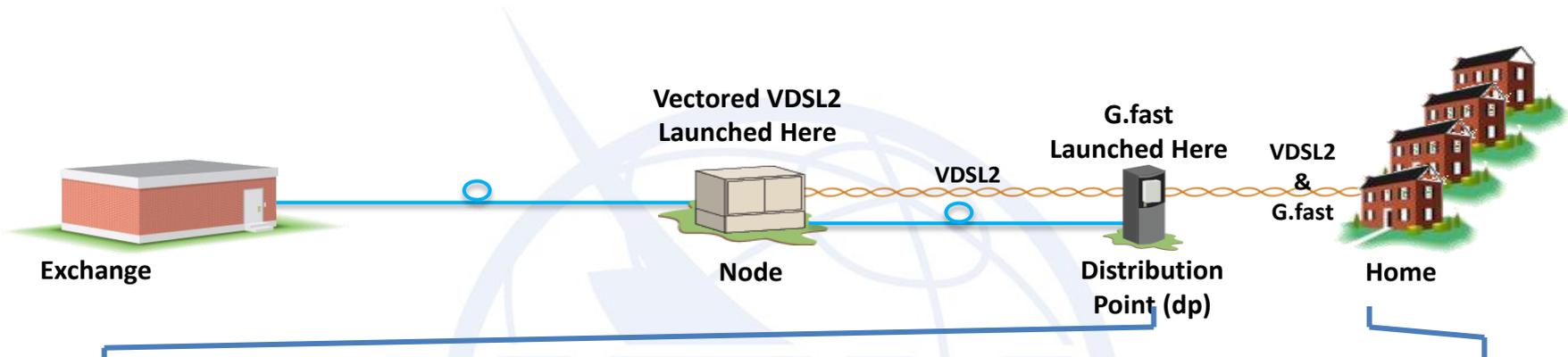


Coexistence Issue with ADSL/VDSL



- FEXT is one of the main impairment sources for xDSL systems
- NEXT is the main coexistence issue between G.fast and xDSL
- Example shows how an attenuated xDSL downstream is disturbed by time variant NEXT from G.fast on the remote side
- Depending on launch points NEXT may be an issue on both sides and transmission directions

Spectral Compatibility



G.fast Key Functionalities (1/5)

- Duplexing method: Time Division Duplex (TDD)
- Bandwidth:
 - 106 MHz profile
 - 212 MHz profile in Amendment 3 (approved 04/2017)
 - Configurable start and stop frequencies, PSD shaping and notching
 - Configurable start frequency and PSD shaping allows for coexistence with VDSL2 and a migration path to G.fast only
 - PSD notching allows for coexistence with various protected services (e.g., aerial broadcast, amateur radio).

G.fast Key Functionalities (2/5)

- Modulation:
 - Discrete multi-tone (DMT)
 - 2048 / 4096 subcarriers for 106 / 212 MHz
 - Subcarrier spacing 51.75 kHz
 - Default symbol rate 48.00 kHz
 - Bit loading of ≤ 12 bits/subcarrier
 - Optional ≤ 14 bits/subcarrier
 - Maximum transmit power of 4 dBm
 - Max 8 dBm for profile 106b

G.fast Key Functionalities (3/5)

- Mandatory support for vectoring
 - Far-end self crosstalk (FEXT) cancellation
 - Linear pre-coding
- Mandatory PHY layer retransmission
 - Improved robustness against impulsive noise (up to 10 ms) without loss of data while maintaining low latency
- Forward error correction (FEC)
 - Trellis code + Reed Solomon of VDSL2 (G.993.2) with the retransmission block (DTU) interleaving defined in G.998.4

G.fast Key Functionalities (4/5)

- Provides transport of network timing (8 kHz NTR)
- Support for Time of Day (ToD) – IEEE 1588
 - In order to support services that require accurate ToD at both sides of the G.fast link to operate the higher layers of the protocol stack (e.g., cellular backhaul)
- Various online reconfiguration methods
 - SRA, RPA and FRA for slow and fast noise changes
 - TIGA for transmit PSD adjustments under varying FEXT

Robust Management Channel (RMC)

- Robust Management Channel (RMC) is used to convey time critical management and control information
- Up to 64 RMC bytes sent per 0.75ms TDD frame (up to 680 kbit/s)
- Strong FEC with 16 bytes per RMC frame, dedicated tones, low bitloading
- Much more robust than data communication
- No direct NACK/ACK of RMC messages (repetition, SFDC)
- Key fields
 - ACK bit-map
 - TXOP data
 - Expected transmission time
 - DTU synchronization data
 - Current active bit-loading table
 - Discontinuous transmission configuration
 - FRA, Reply to SRA
 - Buffer fill information

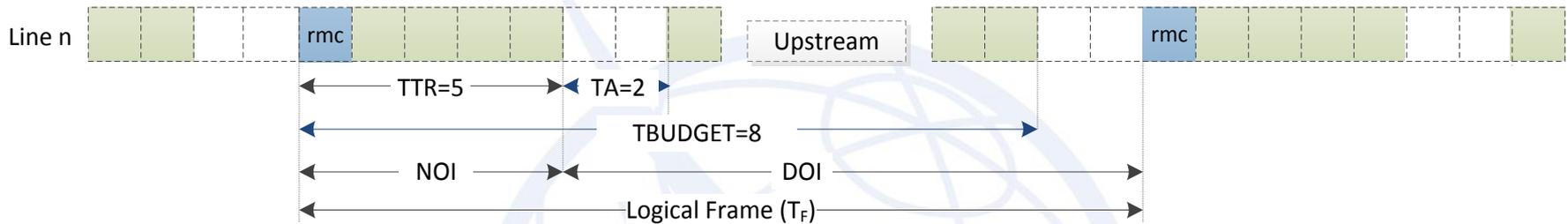
G.fast Key Functionalities (5/5)

- Power saving by discontinuous operation in L0 link state
 - Transmit only SYNC, RMC and symbols containing user data
- Low power link state L2.1 (mains and battery)
 - Transmit only SYNC and RMC symbols
 - Low data rate while maintaining QoS (e.g., for voice call).
- Low power link state L2.2 (battery only)
 - Transmit only SYNC and some RMC symbols
 - Keep-alive user data only, no QoS requirements
- Link transitions driven from system level
 - Based on user traffic and RPF BATTERY status
 - Cross-layer coordination (system L2+ to PHY)

On-line Reconfiguration (OLR)

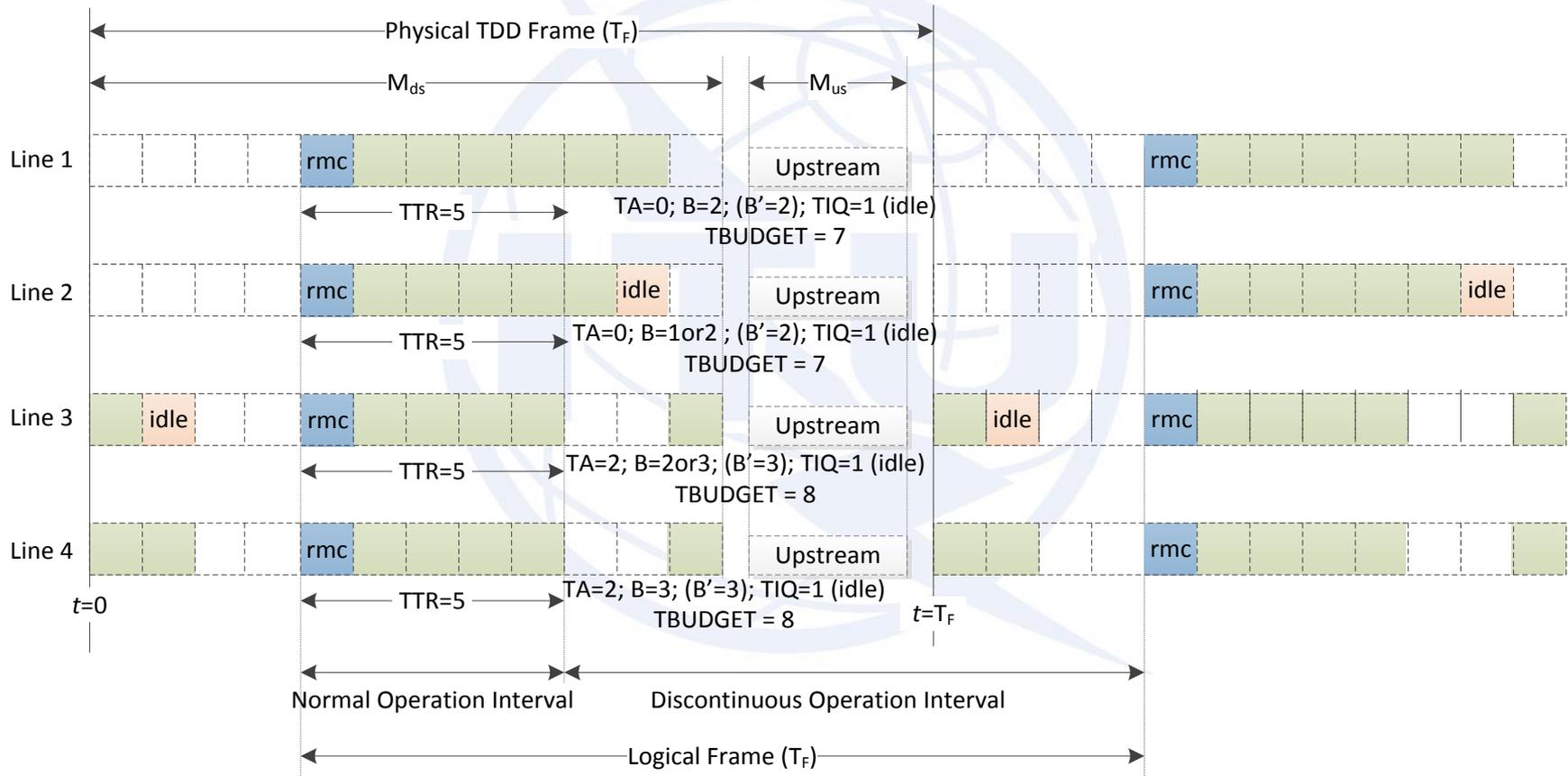
- Seamless rate adaptation (SRA): used to reconfigure the total data rate by modifying the data frame parameters, modifying the bit loadings and gains, and modifying the DTU size.
- Bit Swapping: used to reallocate the bits and transmit power among the allowed sub-carriers without changing the bit rate.
- Transmitter initiated gain adjustment (TIGA): provides the VCE means to address changes in the downstream precoded direct channel gain. Used to prevent violation of the transmit PSD mask as the crosstalk channel matrix changes).
- RMC parameter adjustment (RPA): provides reconfiguration of the RMC parameters (RMC subcarriers set, bit-loading for RMC subcarriers).
- Fast rate adaptation (FRA): provides fast adaptation of the bit rate. The fast adaptation of the bit rate may be used to mitigate unexpected SNR loss in cases of abrupt changes in the channel. It is an RMC-based procedure rather than an eoc-based procedure.

Discontinuous Operation



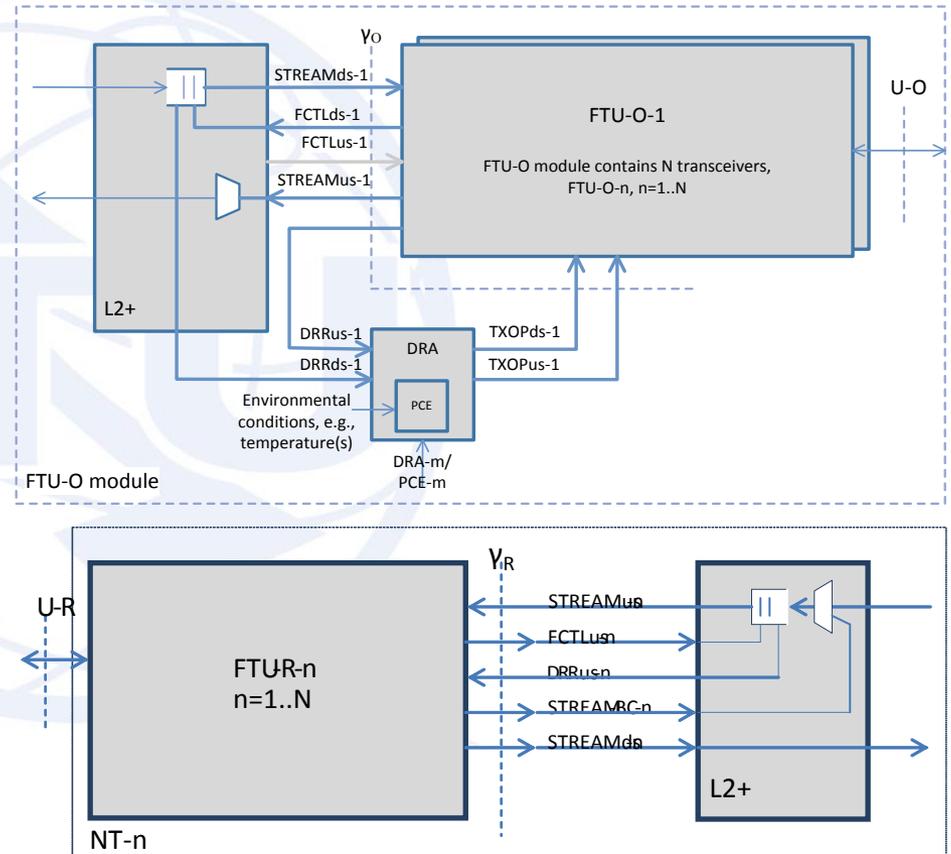
- For both downstream and upstream, a logical frame is divided into a normal operation interval (NOI) and a discontinuous operation interval (DOI)
- Timing of transmissions is controlled by the following parameters allowing a flexible split between NOI and DOI:
 - Transmission budget (TBUDGET): Total number of allocated symbols in the combined normal and discontinuous operation intervals
 - TTR: the number of symbols in the normal operation interval
 - TA: the number of quiet symbols inserted at the beginning of the discontinuous operation interval
 - TIQ: indicates whether idle or quiet symbols shall be used during the symbol periods of the discontinuous operation interval allocated for active symbols
- Discontinuous operation can be used in the NOI or DOI !
- Discontinuous operation is more challenging for vectoring

Example of Discontinuous Operation



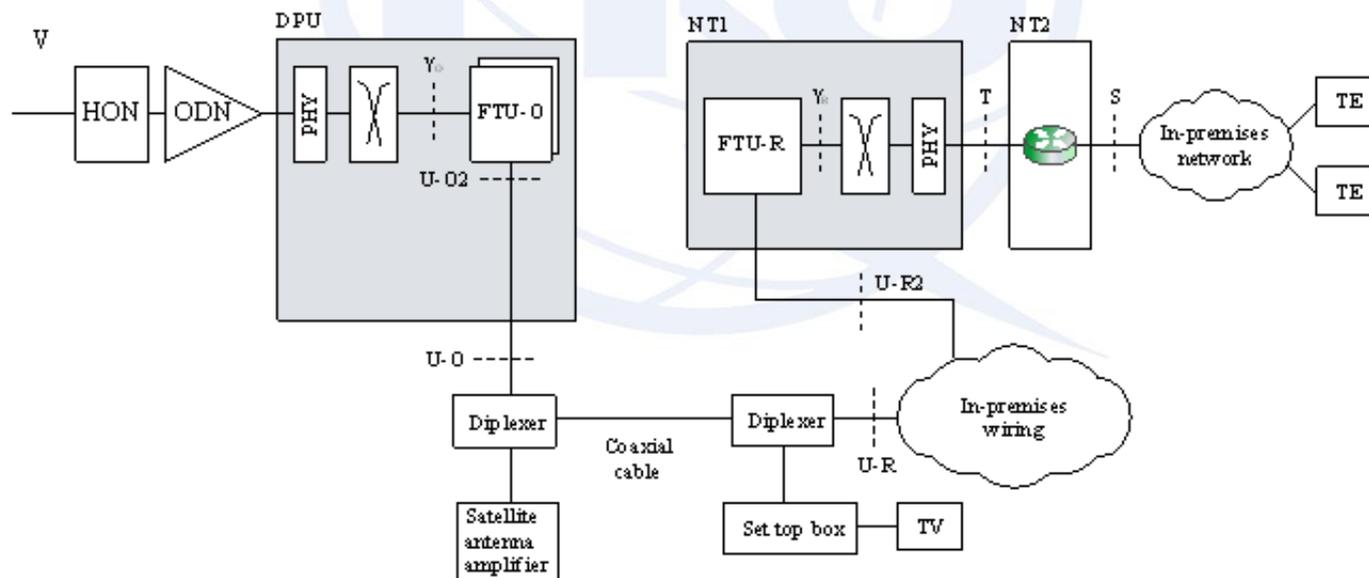
DRA and Upstream Dynamic Resource Reports

- In order to schedule upstream resources the DRA block needs information about the buffer fill state
- Buffer fill information can be requested via FTU-R
- Reporting is done in RMC per traffic class
- DRA block schedules transmit resources



Operation over coax

- Approved April 2017 as part of G.9701 Annex X
 - Operation without coordination across lines
 - 106 and 212 MHz profiles with 2 dBm max TX power
- Use case:
 - G.fast overlay on existing in-building SAT TV coax distribution



Dynamic Time Assignment (i-DTA)

- Approved April 2017 as part of G.9701 Annex T/X
 - Operation without coordination across lines (i-DTA)
- Concepts:
 - AN/DPU system monitors up/down throughput needs
 - Requests FTU-O to change the TDD up/down ratio
 - FTU-O and FTU-R implement the change within 12 msec
 - Ratio between 5/30 and 30/5 with default 7/28
- Use case:
 - Improve end user experience (QoE) by dynamically allocating the aggregate capacity to the direction that best serves the instantaneous needs of the user's applications.



NT Software Download

- Approved April 2017 as G.9701 Annex S
 - Software download from DPU over the G.9701 eoc to NT
- Concepts:
 - NT software image gets downloaded to the AN/DPU
 - DPU forwards the NT software image to the NT over the G.9701 eoc
 - Typical software image takes 1-2 sec to send over eoc
 - Protocol based on the G-PON OMCI ONU software download
 - Managed objects defined in support of YANG data model (TBD in BBF)
- Use case:
 - NT is simple device (SFP or PHY adapter without IP address)

Future G.fast work

- Impulse noise monitoring (*)
 - To facilitate characterization and source identification
- Metrics for service rate estimation (*)
 - Attainable throughput under current noise conditions
- Improved UPBO (*)
 - Frequency dependent UPBO, more advanced mechanisms
- Coordinated DTA
 - Dynamic change of up/down split over the vectored group
- Line reconfiguration without retrain
 - Selected set of configuration parameters (e.g., SNRM, MAXNDR)
- Short TDD frames for delay sensitive applications
 - Radio fronthaul, CPRI transport, Ethernet backhaul
 - Assessing the requirements/need, liaising with 3GPP

(*) Targets consent in June 2017



Emerging G.mgfast

Multi-Gigabit FAST

- New project to address functionality beyond G.fast
 - Profiles beyond 212 MHz (e.g., 424 MHz and 848 MHz)
 - Full-duplex operation (echo cancelled mode)
- Targets
 - Aggregate data rates of 5 - 10 Gbit/s over single TP/coax.
 - Operation over **low quality twisted pair and quad, high quality twisted pair and coaxial cable.**
 - Consent early 2019.
- Open points under discussion
 - Advanced coding (e.g., LDPC)
 - Multi-stream support for QoS differentiation / 5G slicing
 - Convergence of access and in-home networking



Thank you

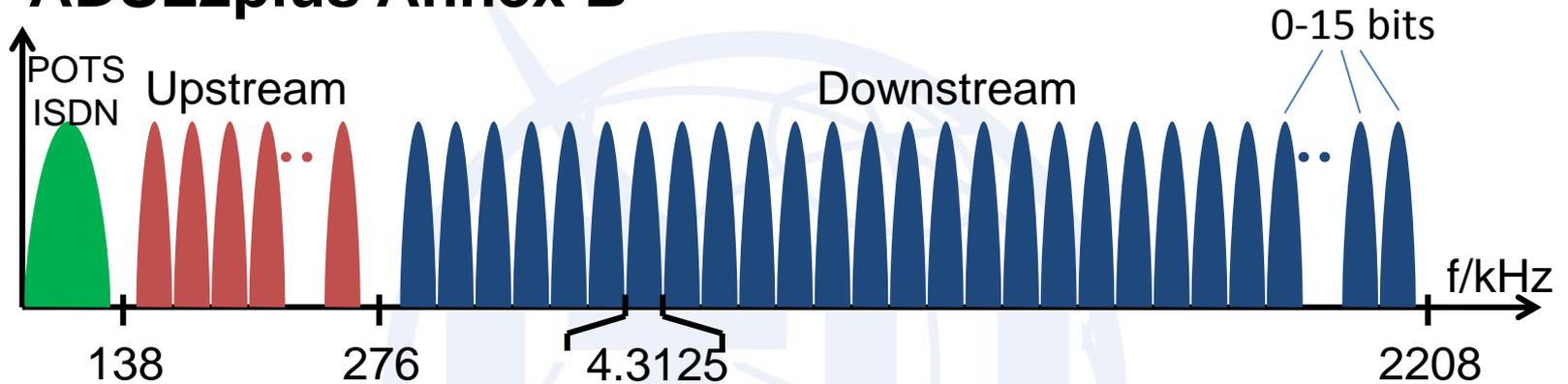


Backup

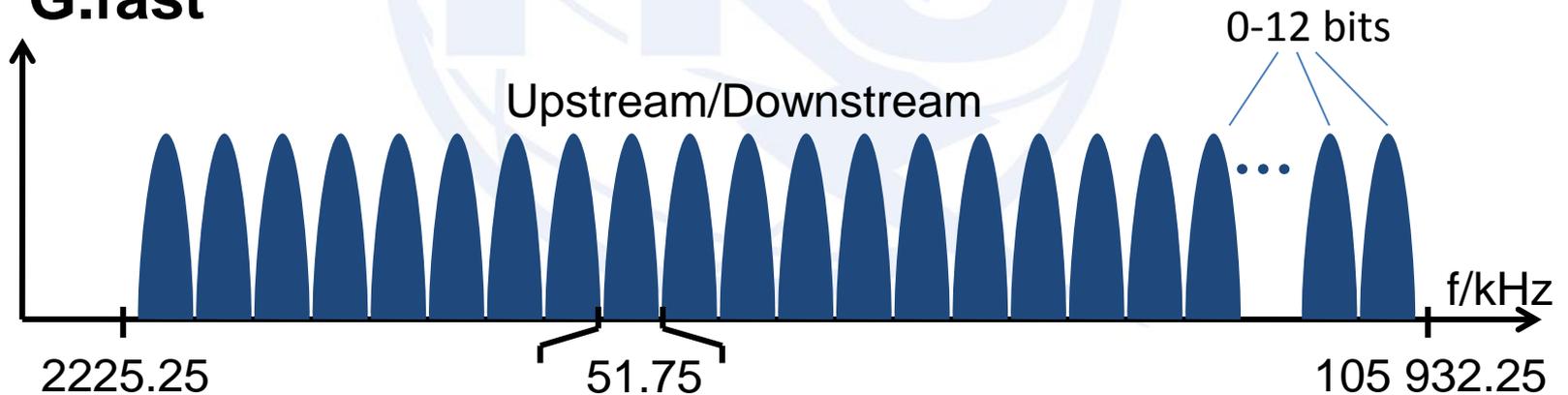


DMT Modulation

ADSL2plus Annex B



G.fast



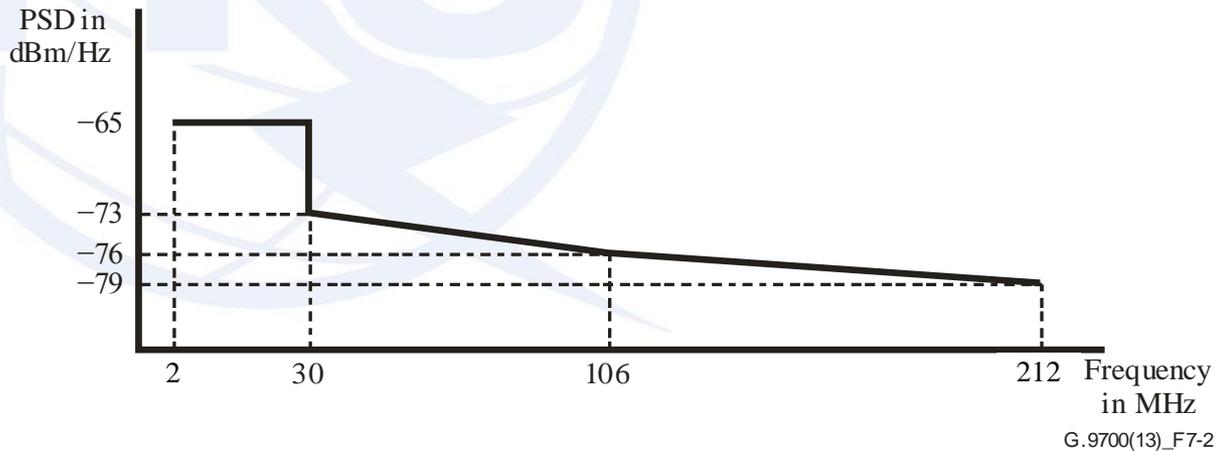
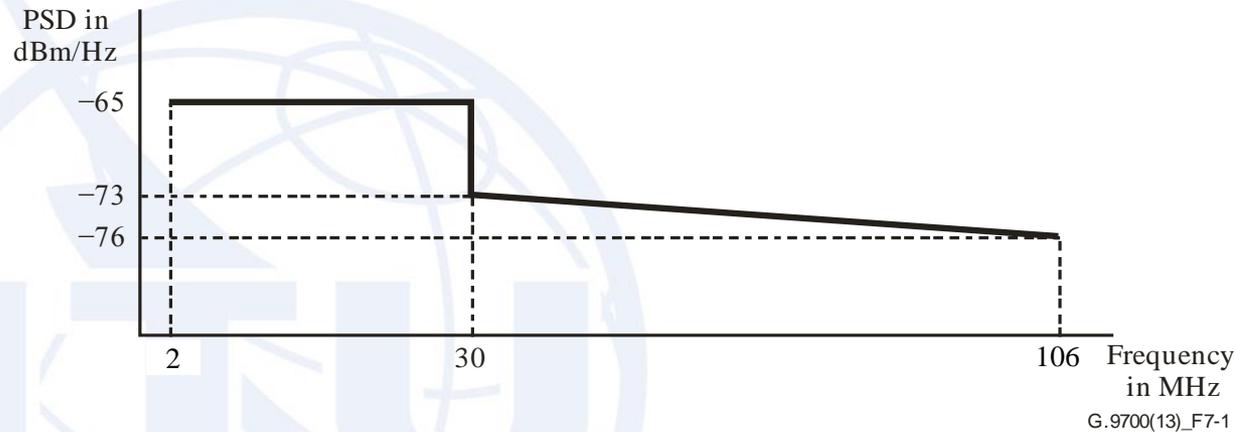
PSD Construction Tools

- Subcarrier masking
 - Eliminates transmission on one or more subcarriers
 - A subcarrier mask (SM) is defined as a number of masked frequency bands (start - stop subcarrier index)
- Notching of specific frequency bands
 - To protect radio services one or more specific frequency bands can be notched
 - Notch in the notching mask (NM) is defined start and end subcarrier index
 - Within the notched band, all subcarriers shall be turned off and emission shall be at least 20 dB below the limit mask
- PSD shaping
 - Power spectral density (PSD) shaping allows reduction of the transmit PSD mask in some parts of the spectrum
 - PSD shaping mask (PSM) consists of one or more frequency segments. The boundaries of the segments are defined by set breakpoints
 - Transceiver shall support at least 32 PSM breakpoints

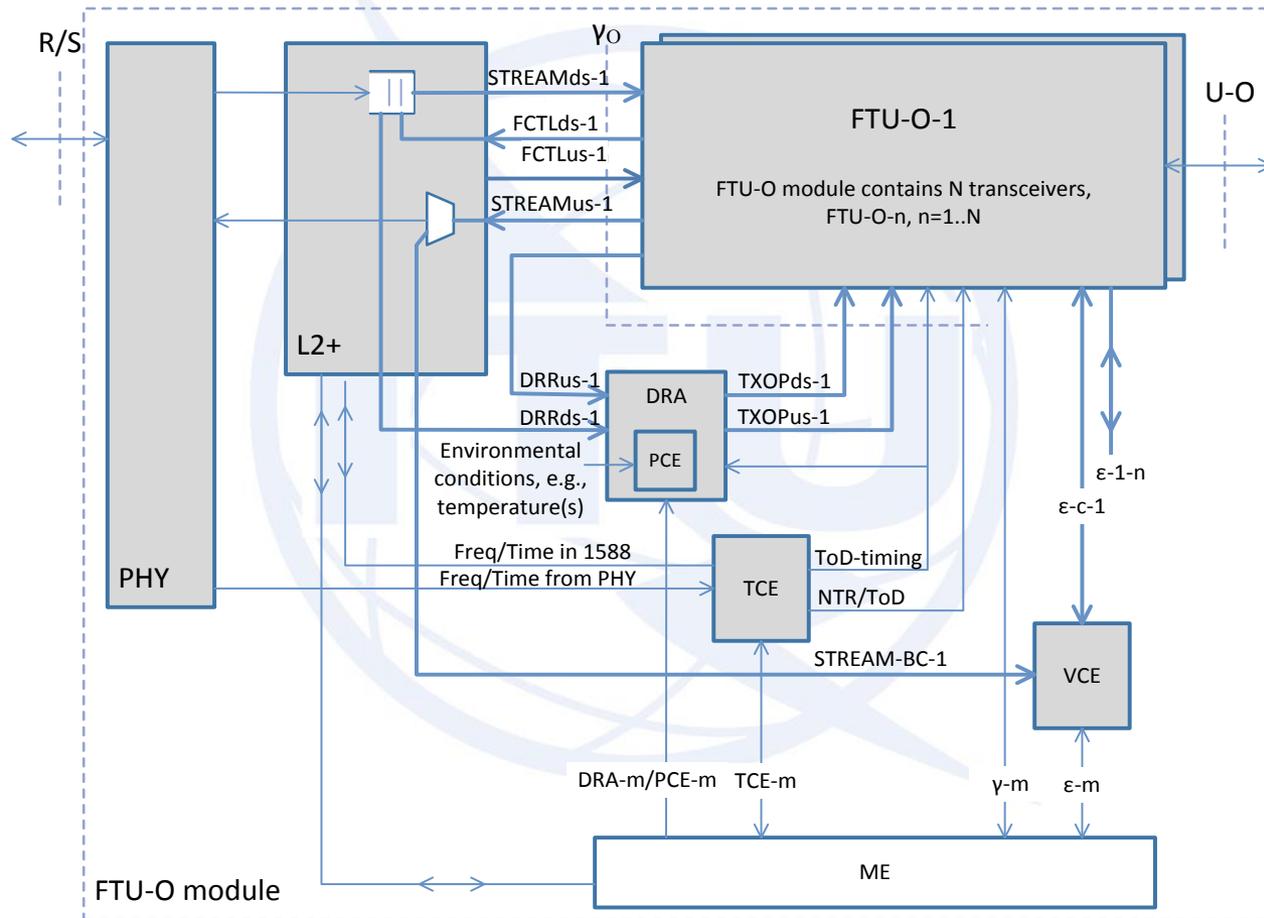


G.fast Profiles & Limit PSD (G.9700)

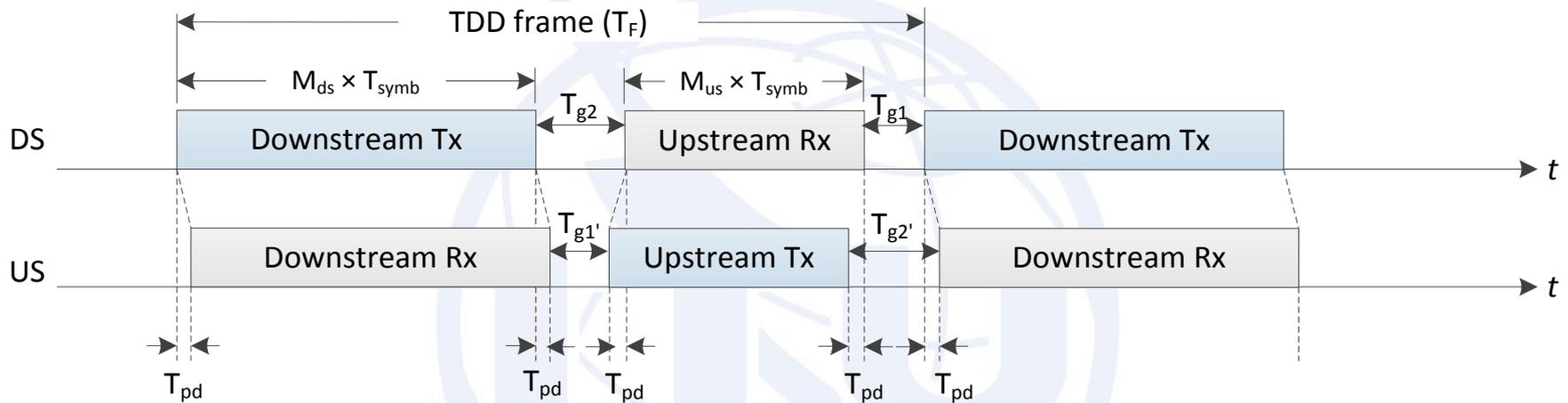
- G.9700 contains the limit mask definitions for the profiles
 - 106 MHz
 - 212 MHz
- Current transceiver specification (G.9701) only supports the 106 MHz profile
- Max aggregate transmit power is 4 dBm for 106 MHz profile 106a
- G.9700 provides PSD construction tools (masking, notching, shaping)



G.9701 Ref. Model of FTU-O Module

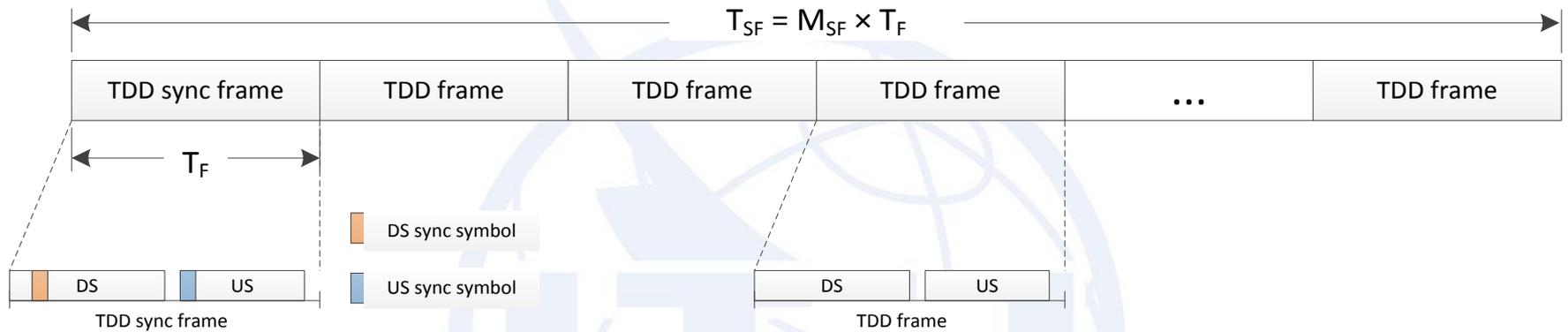


TDD Frame Structure



- TDD frame lengths (0.145 to 0.875 ms, default 0.75 ms)
 - $T_F = 36$ and 23 symbols supported in the main body
 - $T_F = 12$ and 7 symbols may be supported in later Amendment
(requirements/need under study, liaison with 3GPP)

Superframe Structure



- Superframe lengths (5.75 to 7 ms, default 6 ms)
 - $M_{SF} = 8$ for $T_F = 36$ supported in the main body
 - $M_{SF} = 12$ for $T_F = 23$ supported in the main body
 - $M_{SF} = 24$ for $T_F = 12$ may be supported in an Annex in a future amendment
 - $M_{SF} = 41$ for $T_F = 7$ may be supported in an Annex in a future amendment
- Sync symbol: modulates probe sequences and is used for synchronization and channel estimation. ToD reference samples are associated with the sync symbol.





End of Backup

