FDD VS. TDD COMPARISON

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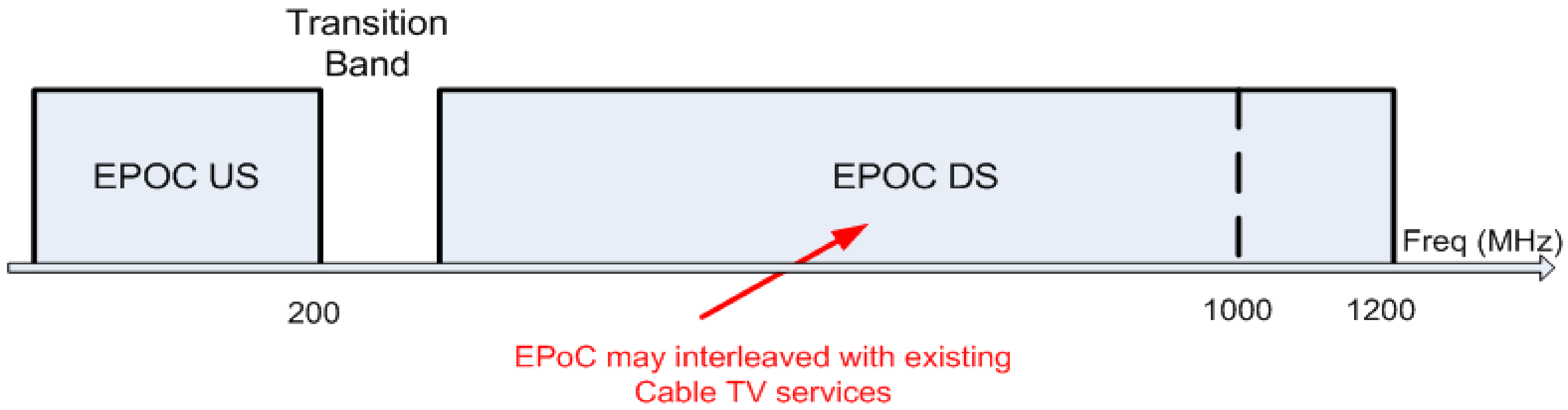
OUTLINE

- **EPoC installation options**
- **TDD and FDD in the Coax plants**
- **A respond to the “TDD and FDD a path forward” contribution from Minneapolis meeting**
  - Assumptions
  - Performance comparison
  - Complexity considerations
  - Conclusions
- **Summary**

FREQUENCY ALLOCATION OPTIONS FOR EPOC - 1

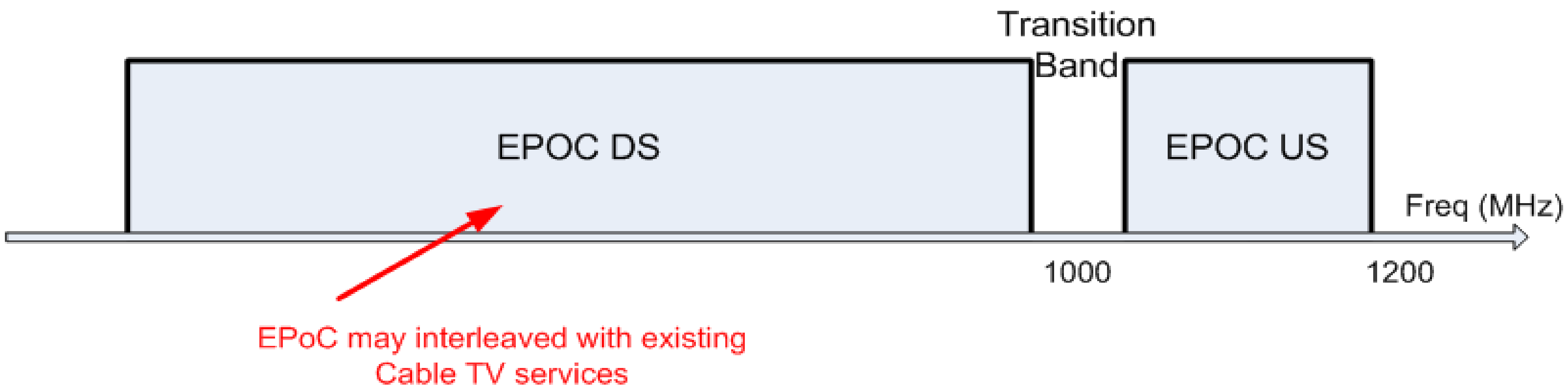
- Low Split



- **EPoC DS runs in downstream Cable TV frequencies**
  - May interleave with the Cable TV channels
  - Extendable to 1200 MHz with existing splitters
  - 120 MHz bands are enough to support 1 Gbps.
  - Several bands may be bonded to increase downstream rate
- **EPoC US runs in the low frequencies (~ <200)**
  - Enough BW is available for 1 Gbps
- **Amplifiers are available**
  - Plant can be adapted to support EPoC today
- **10G/1G is achievable with FDD**

FREQUENCY ALLOCATION OPTIONS FOR EPOC - 2

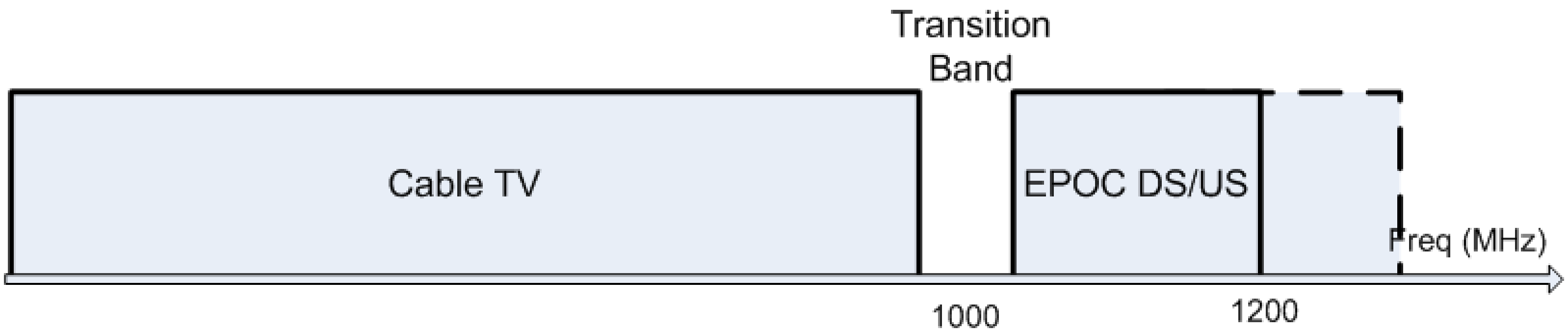
- Top Split



- **EPoC DS runs at downstream Cable TV frequencies**
  - May interleave with Cable TV channels
  - 120 MHz bands are enough to support 1 Gbps.
  - Several bands may be bonded to increase downstream rate
- **EPoC US runs above DS at frequencies upto 1200 MHz**
  - Enough BW is available for 1 Gbps
- **10G/1G is achievable with FDD**

FREQUENCY ALLOCATION OPTIONS FOR EPOC - 3

- EPoC Above Cable TV



- **EPoC DS and US run above Cable TV (above 1000 MHz)**
  - With installed passives available bandwidth is very poor
  - Only ~ 200 MHz including guard-bands
  - Not enough bandwidth to support 2 Gbps bi-directional – **Neither FDD nor TDD would support 1Gbps/1Gbps in the downstream and upstream**
- **Need taps and splitter (and amplifiers) replacement to extend available bandwidth**
  - Are they available?
  - If extendable, EPoC can use FDD with amplifiers to support EPoC requirements
  - TDD can be applied only in a Node+0 scenario

EPOC FDD ACHIEVES MULTI GBPS RATES ANYWHERE IN THE CABLE PLANT

- **FDD EPoC supports 1 Gbps throughput in the upstream and upto 10 Gbps (scalable) in the downstream**
  - With existing passive taps/splitters
  - Using frequencies upto 1200 MHz
- **TDD can be only applied in Node+0 scenarios as it cannot pass amplifiers**
  - Limited number of installations
  - Limited available bandwidth
  - Poor capacity above 1200 MHz as Leo Montreuil's contribution shows
- **FDD EPoC can support frequencies above 1200 MHz with required throughputs IF plant is upgraded with wideband taps**

RESPOND TO “TDD AND FDD A PATH FORWARD “ CALL FROM MINNEAPOLIS MEETING

- **Comparison conditions**
- **EPoC assumptions for the comparison**
- **Performance comparison**
- **Complexity considerations**
- **Conclusions**

EPOC FDD AND TDD – ASSUMPTIONS

- **EPoC frequencies 1000–1300 MHz**
- **Node +0 -> No amplifiers**
- **Loop length: 1000 ft**
- **40 CNUs**
- **DS/US rates : 1 Gbps on each direction**
  - Each CNU runs a CBR 25 Mbps service
  - Queues on each CNU are always loaded at the rate 25 Mbps

SIGNAL ASSUMPTIONS

- **Symbol size: optimized for TDD (32 uSec)**
- **CP size 1.5 uSec**
- **One-symbol Preamble for synchronization**
- **Upstream OFDMA parameters**
  - Minimal Frame size is 250 uSec (to protect against burst size)
  - Number of transmitters per frame: 40
- **Bandwidths**
  - Diplexer transition band 100 MHz
  - FDD US/DS 100 MHz
  - TDD US 200 MHz
  - FDD DS 300 MHz
- **Note: This is NOT a proposal to EPoC transceiver but reasonable assumptions for this analysis**

GUARD BANDS - FREQUENCY DOMAIN

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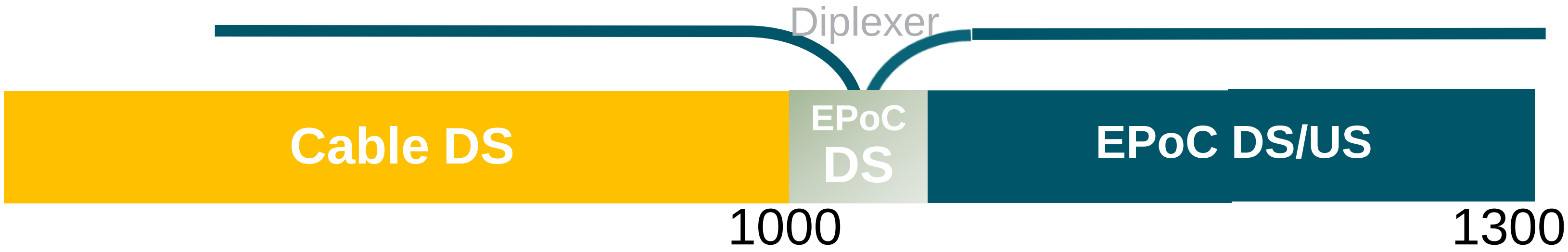
- EPOC FDD 1000 - 1300

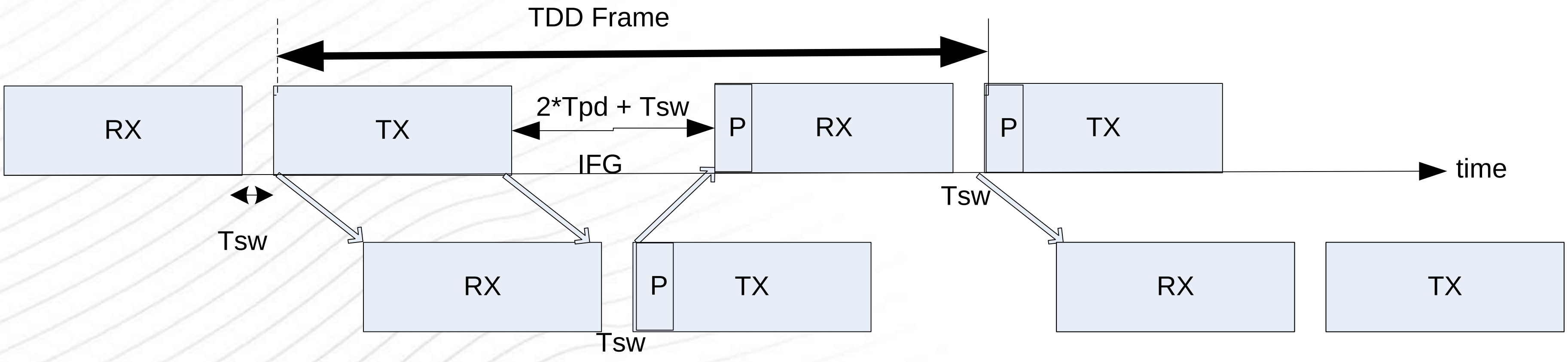
- EPOC TDD 1000 - 1300



- Frequency split are required in both TDD and FDD
  - FDD: split between downstream transmission and upstream transmission
  - TDD: split between cable and EPoC to protect legacy services
    - Guardband is used for the US not used for the Downstream
- Only possible with Node+0 networks
-

GUARD BANDS – TIME DOMAIN

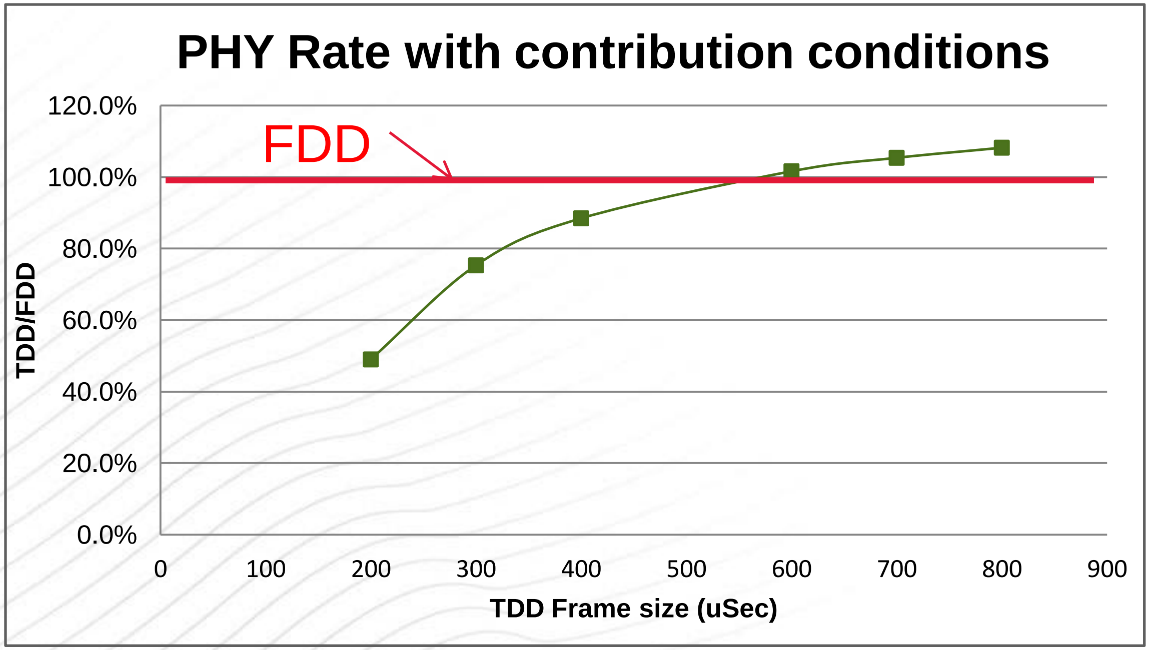
- **A Guard time required for TDD includes:**
  - Cable propagation delay (Tpd)
    - 1000 ft have propagation delay of about 1.2 uSec
  - Turn around time between receiver and transmitter (Tsw)
    - Analog turnaround time 6 uSec
    - Digital turnaround time with HW re-use: 1.2 * symbol time (1uSec with no reuse)
- **One Preamble symbol is assumed per Tdd frame for synchronization and channel estimation**



Tdd_frame = T_TX+T_RX+2*(Tpd+Tsw)

AGGREGATED PHY RATE COMPARISON

- **TDD has additional available bandwidth in the DS, increasing aggregated throughput**
- **Only efficient very large TDD frame (not efficient due to latency)**
- **Results assume re-use of HW for transmitter and receiver to get similar complexity to FDD**
- **Symbol size optimal for TDD and FDD**



OFDMA IN UPSTREAM PERFORMANCE

- **Upstream uses OFDMA frames**
- **A Frame consists synchronization overhead of 12.5%**
- **Frame size is 250 uSec for noise burst protection**
- **Payload per transmitter with two frame size**
  - FDD: 770 Bytes
  - TDD (1 mSec) : 2982 Bytes
  - TDD (0.5 mSec): 1546 Bytes
- **Minimal packet size per transmitter with TDD is very large**
  - Increase overhead when transmitter has short data to transmit (e.g. Polling)

COMPLEXITY CONSIDERATIONS – ANALOG/RF

- **TDD requires more transmission power to support same SNR**
  - Double the transmission power in the CNU (+3 dB)
  - Triple the transmitter power in the CMC (+5 dB)
  - More expensive and power consuming chip at the CNU and the CMC
- **Asymmetric data rates increases transmission power in the CNU**
  - DS:US ratio of 5:1 increase in transmission power : 7.8 dB
- **Triple/ Double the throughput when transmitting or receiving**
  - Triple the ADC sampling rate in the CNU
  - Triple RF tuner and analog filter bandwidth in the CNU

TRANSMISSION POWER EXAMPLE

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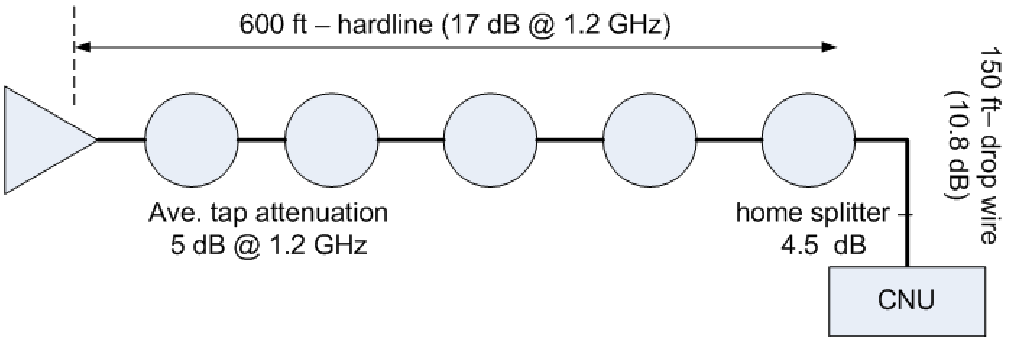
- **Attenuation to CNU: 57.5 dB**
- **Required SNR (for 12 bits) 45 dB**
- **CNU Noise Figure: 10 dB**
- **1dB point per transmission bandwidth :**
  - **100 MHz: 33.5 dB**
  - **200 MHz: 36.5 dB**
  - **300 MHz: 38.2 dB**

Typical installation:



- **Implications:**
  - **At these power levels and bandwidth 3 dB increase in transmit power is very significant**
  - **Examples:**

Amplifier	Freq Range	P1dB	IP3	Voltage	Current	DC Power	Technology	Relative Cost
	MHz	dBm	dBm		mA	Watts		
A	40 - 1200	24	43	5	380	1.9	pHEMT	1.00
B	400-4000	29.5	45	5	425	2.125	InGap/GaAs	1.05
C	700-4000	32.8	49.5	5	1000	5	InGap/GaAs	1.33
D	700-2900	37		12	750	9	InGap/GaAs	3.51

  - A significant increase in cost to increase the p1dB from 33 to 37 dBm.

COMPLEXITY CONSIDERATIONS – DIGITAL

- **CNU receiver runs at triple the speed with TDD**
  - 300 MHz vs. 100 MHz in FDD
  - HW re-use may be applied to reduce complexity however with an increase to the turn-around time, making the effective throughput lower than FDD
  - With no HW re-use CNU chip becomes significantly larger and more expensive when it is designed to support both TDD and FDD compared to FDD only
- **Additional Buffering is needed to accommodate for “holes” in the transmissions**
  - With frame sizes of 1 mSec and data rate of 1 Gbps buffers are large (~ 125KB)

CONCLUSION OF COMPARISON

- **TDD aggregated throughput equivalent or lower than FDD**
  - With HW re-use (depending on the TDD frame size)
- **TDD may provide throughput benefit with no HW re-use**
  - Significant increase of HW complexity (triple the processing power in the CNU!) is required
  - May not be economical
- **Upstream TDD OFDMA frame has additional overheads due to bandwidth increase**
  - Reduce average throughput

SUMMARY

- **FDD provides EPoC target throughput over all possible installation scenarios over existing Coax infrastructure**
  - Low split or High split
  - Can start deployment immediately with technology available
- **TDD may be beneficial in the narrow case of Node+0 at frequencies above 1 GHz**
  - Improvement over FDD if exists is not significant with increased complexity
- **Support TDD in addition to FDD adds significant complexity/cost**
- **Is it justified economically wise? We have concerns it does not**
- **Should we start a new EPoC TDD development if market requires?**

THANK YOU