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DENVER, CO
OCTOBER 17-20

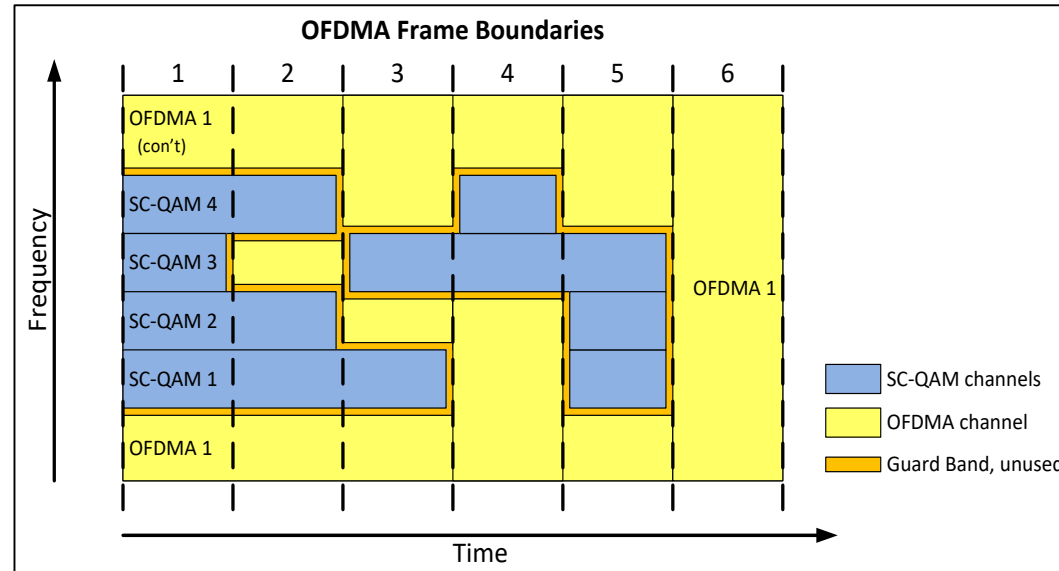


When Does the DOCSIS 3.1 TaFD Feature Increase the Capacity of My Network?

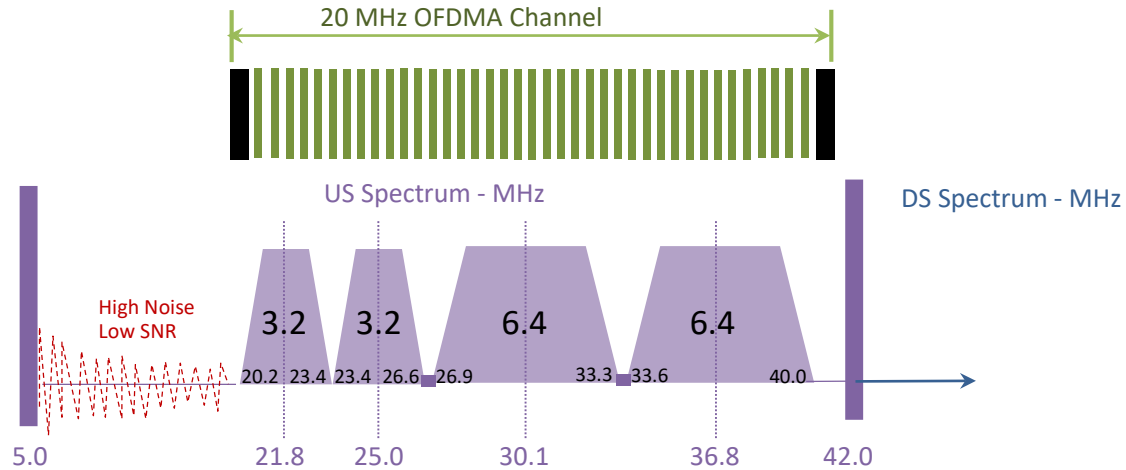
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Engineering Fellow, CTO Office
ARRIS

Flexible & dynamic spectrum allocation: A spectral region is allocated to either technology as needed!

MULPI View



What is the T_{\max} that can be offered using TaFD?



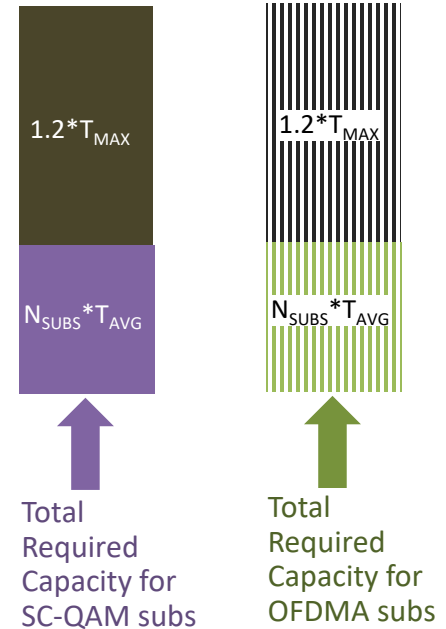
SC-QAM spectrum = 19.2 MHz

OFDMA Variable	Value
Mean US SNR	35 dB
FFT Size	2K FFT
Cyclic Prefix	1.875 μ sec
Frame Size	10 OFDMA symbols
Guard Band	0.5 MHz on each end
Code Word Size	Large
SNR Margin	2 dB
Modulation	QAM256
Bonding SC-QAM and OFDMA	Yes

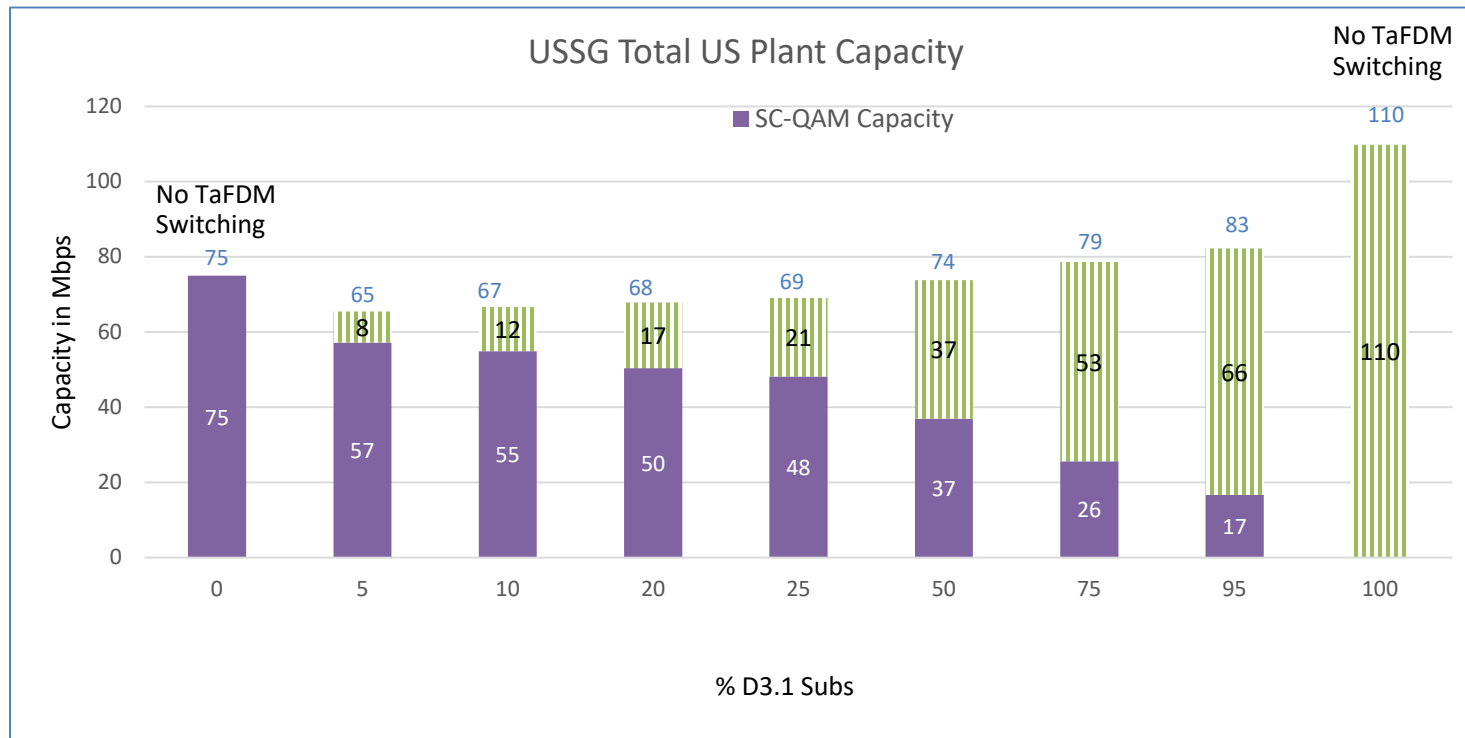
OFDMA Spectral Efficiency						
OFDMA Channel Width (MHz)	10	20	40	60	80	96
Spectral Efficiency (bps/Hz) @ PHY Level	5.40	5.79	5.98	6.04	6.08	6.09

TaFD Analysis Assumptions

TaFD Parameters	Value
Total Usable Spectrum for OFDMA	20 MHz (20 - 40 MHz)
Overlapping Spectrum with SC-QAMs	19.2 MHz
OFDMA-only Spectrum	0.8 MHz
MAC Overhead	5%
TaFD Switching Overhead	20 % (guard time, guard band and scheduling inefficiencies)
D3.0 Spectral Efficiency (PHY)	4.15 bps/Hz
T_{avg} for SC-QAM and OFDMA Subs	250 kbps
T_{max} for SC-QAM Subs	12 Mbps
Total Subs	180
ARRIS QoE Formula	Needed Capacity = $N_{subs} * T_{avg} + 1.2 * T_{max}$



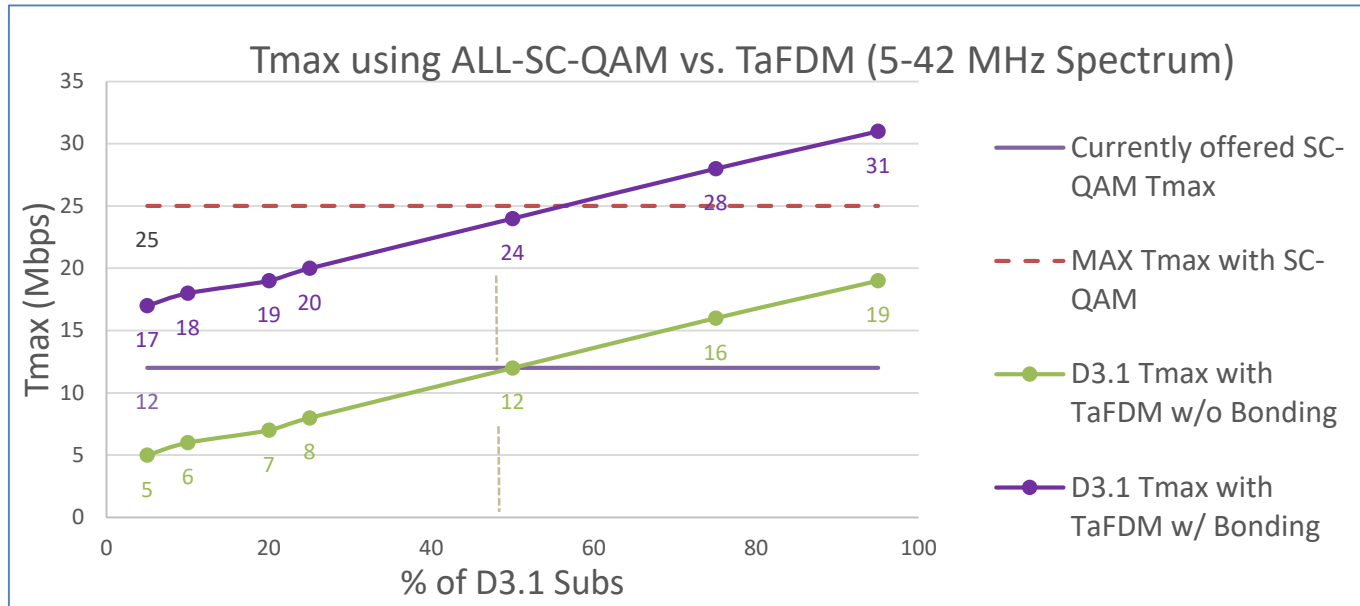
Total Usable Plant Capacity* with TaFD 5-42 MHz Plant – Scenario A



* This is the net capacity after switching overhead is taken into consideration

T_{max} for OFDMA Subs, 5-42 MHz Plant – Scenario A

- 25 Mbps can be offered using SC-QAM only
- T_{max} service beyond 25 Mbps cannot be offered using 5-42 MHz Spectrum w/o Bonding
- With Bonding, at least 55% of subs need to be D3.1 to offer higher than 25 Mbps service

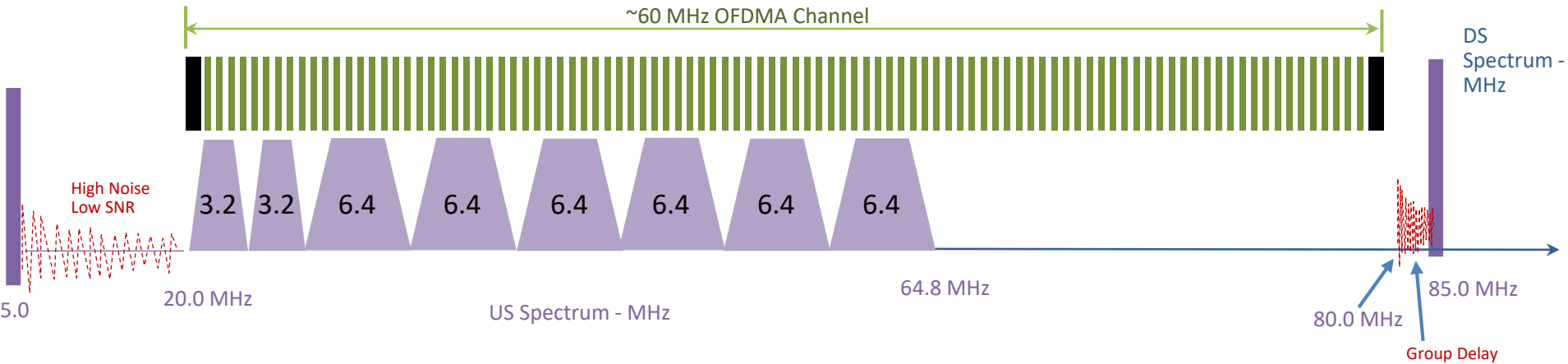


Why TaFD Has Marginal Benefit in 5-42 MHz Plants? Scenario A

- **OFDMA is less efficient with small channel widths**
 - 20 MHz is just about one fifth of the maximum channel size of 96 MHz defined by CableLabs
- **Most subscribers are DOCSIS 3.0 subs today which leaves little room for spectrum access for OFDMA subscribers**
 - Not only the OFDMA channel width is small, it also time-shares the spectrum with SC-QAMs and therefore reducing the throughput further
- **TaFD Switching overhead is significant compared to the gained capacity**
 - Switching between OFDMA and SC-QAM channels requires guard time and/or guard bands
- **There is a slight capacity gain from using OFDMA however:**
 - The benefit of this gain is marginalized by the switching overhead

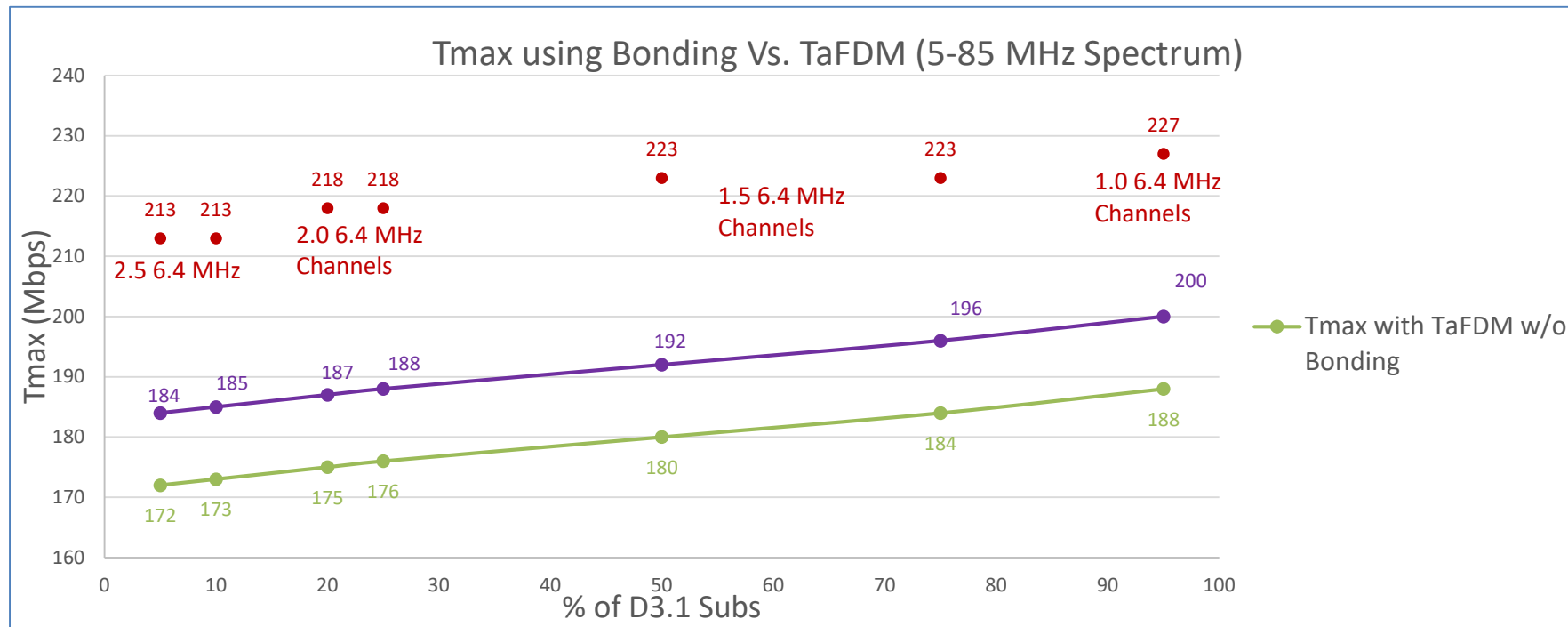
5-85 MHz Spectrum Transition Plan

- MSO X current plan for 5-85 MHz (~60 MHz of Usable Spectrum)



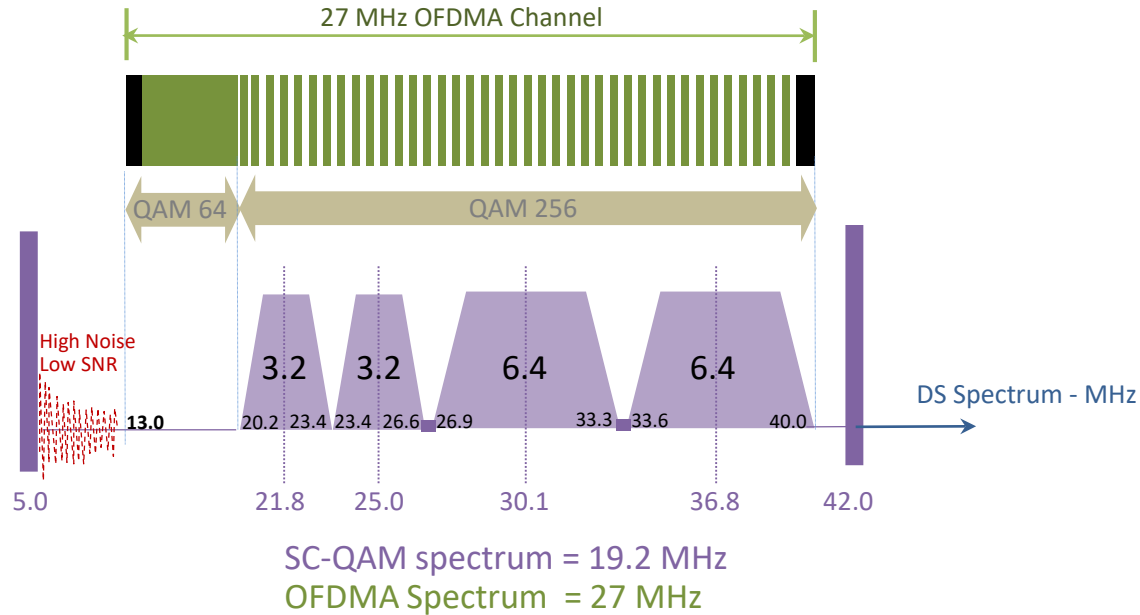
- MSO X plans to use TaFD between SC-QAM and OFDMA
- The analysis on the next slide will show that using just enough spectrum for SC-QAM & reclaiming the rest of spectrum for OFDMA & then using non-overlapping Spectra for SC-QAM and OFDMA and utilizing the channel bonding feature will provide more efficient spectrum usage

5-85 MHz Spectrum: TaFD vs. FD? Scenario A



- It is more efficient to stay with SC-QAM for 5-42 MHz spectrum when the percentage of D3.1 subs is less than 50%
 - T_{\max} up to 25 Mbps can be offered using SC-QAM only
- T_{\max} service beyond 25 Mbps can only be offered using 5-42 MHz Spectrum when the percentage of D3.1 subs is greater than 50%
 - This is done using TaFD and Bonding
 - T_{\max} of 31 Mbps can be offered
- Offering higher T_{\max} values (for Symmetrical services) will require migration to 5-85 MHz Spectrum & deployment of DOCSIS 3.1
 - T_{\max} of 213 Mbps can be offered when the percentage of D3.1 subs is 5%
 - T_{\max} of 227 Mbps can be offered when the percentage of D3.1 subs is 95%

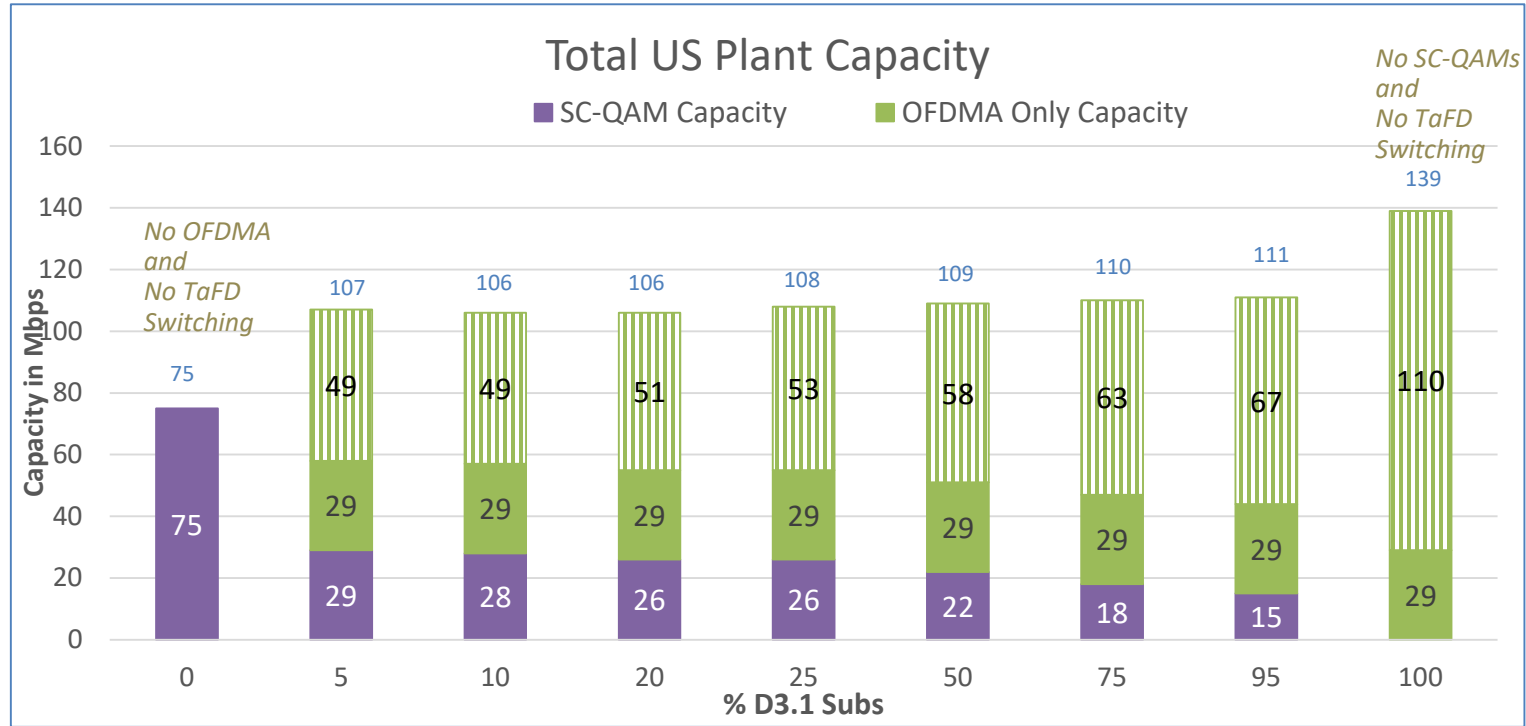
What is the T_{max} that can be offered using TaFD?



Scenario B Assumptions (Differences from Scenario A)

Scenario A	Scenario B
Number of subs per SG = 180 (Internet modems)	Number of subs per SG = 180 (Internet modems)
$T_{avg} = 250$ kbps per Sub	$T_{avg} = 84$ kbps per Sub
US Spectrum from 20 to 40 MHz	US spectrum from 13 to 40 MHz
4 US SC-QAMs (2X3.2 + 2X6.4 MHz) between 20 and 40 MHz – all using 64 QAM OFDMA starts at 20 MHz	4 US SC-QAMs (2X3.2 + 2X6.4 MHz) between 20 and 40 MHz – all using 64 QAM OFDMA starts at 13 MHz with variable bit loading (QAM64 in 13-20 MHz, QAM256 otherwise)
No DOCSIS carrier below 20 MHz	Assume 64 QAM with OFDMA carrier between 13 and 20 MHz

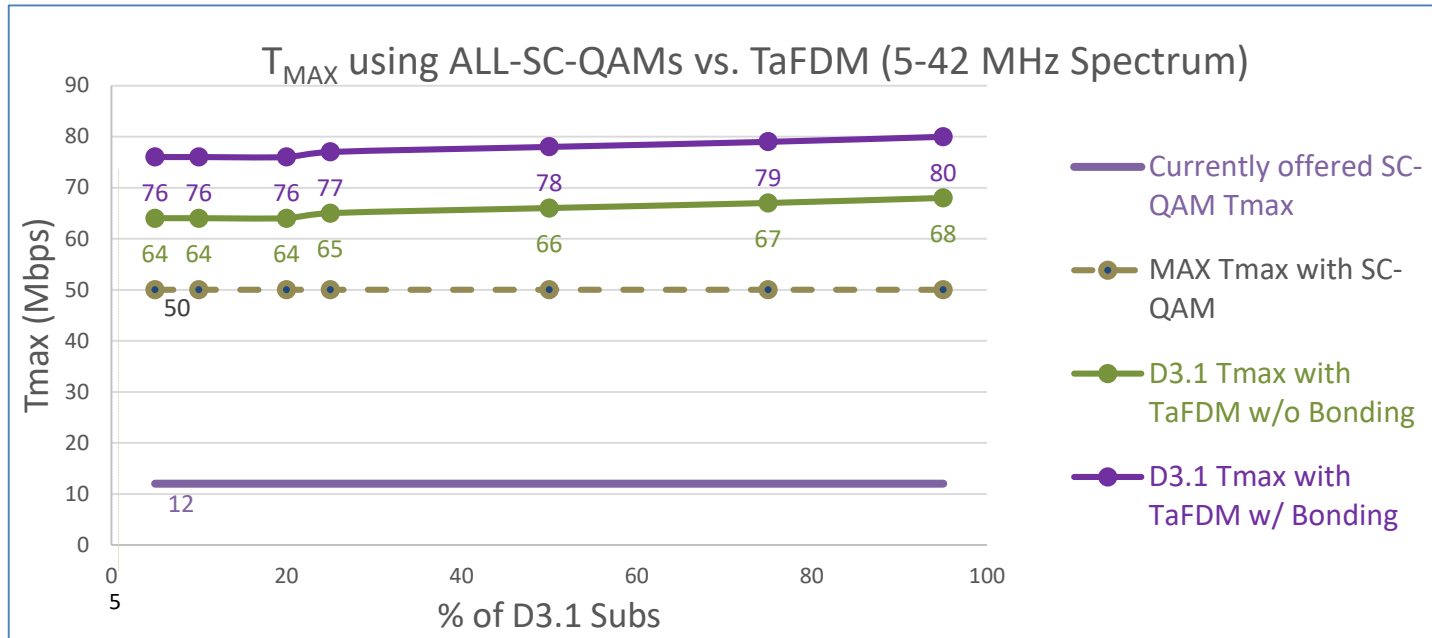
Total Usable Capacity* with TaFD in 5-42 MHz Plant – Scenario B



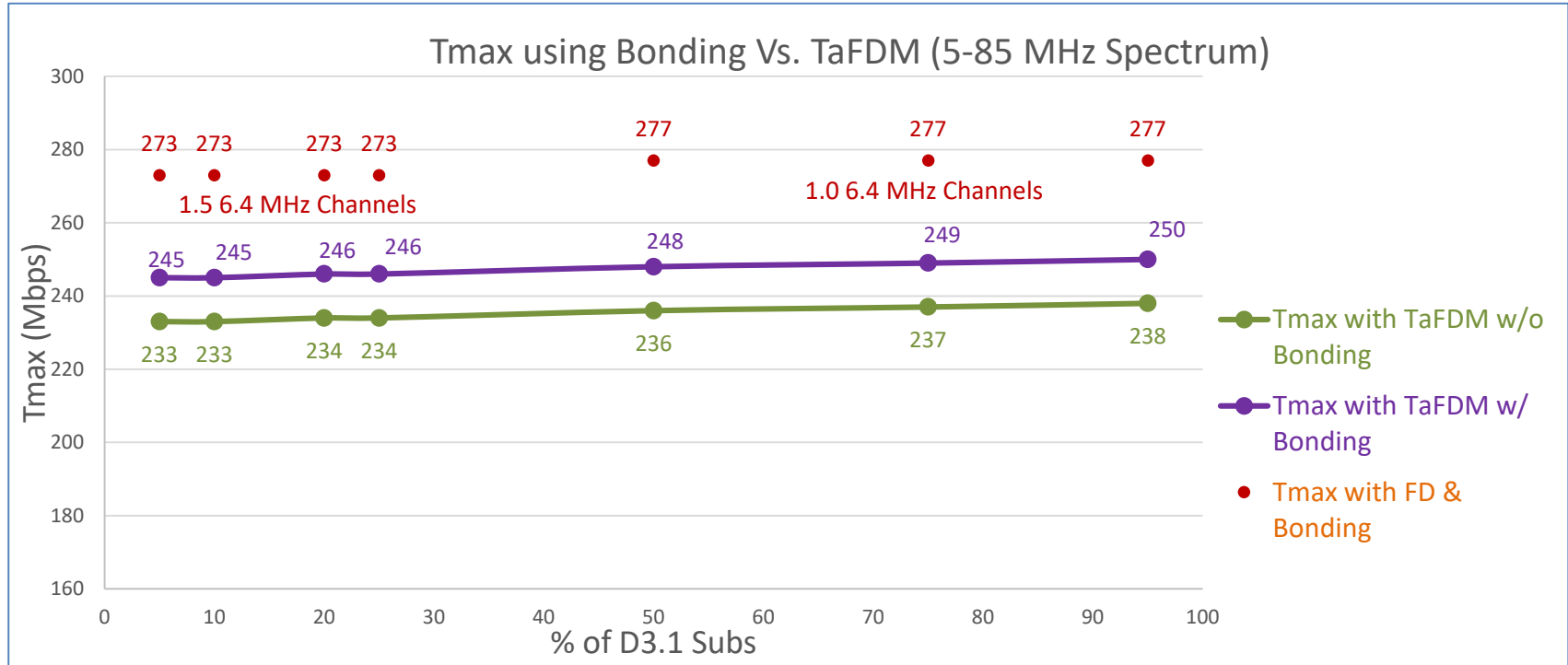
- * This is the net capacity after TaFD switching overhead is taken into consideration
- OFDMA Only Capacity refers to the capacity gained from non-overlapping spectrum between 13 and 20 MHz

T_{max} for OFDMA Subs with TaFD in 5-42 MHz Plant Scenario B

- 50 Mbps can be offered using SC-QAM only
- TaFD w/o bonding provides about 28% gain in T_{max} in initial deployments (with 5% D3.1 subs)
- TaFD w/ bonding provides about 52% gain in T_{max} in initial deployments (with 5% D3.1 subs)



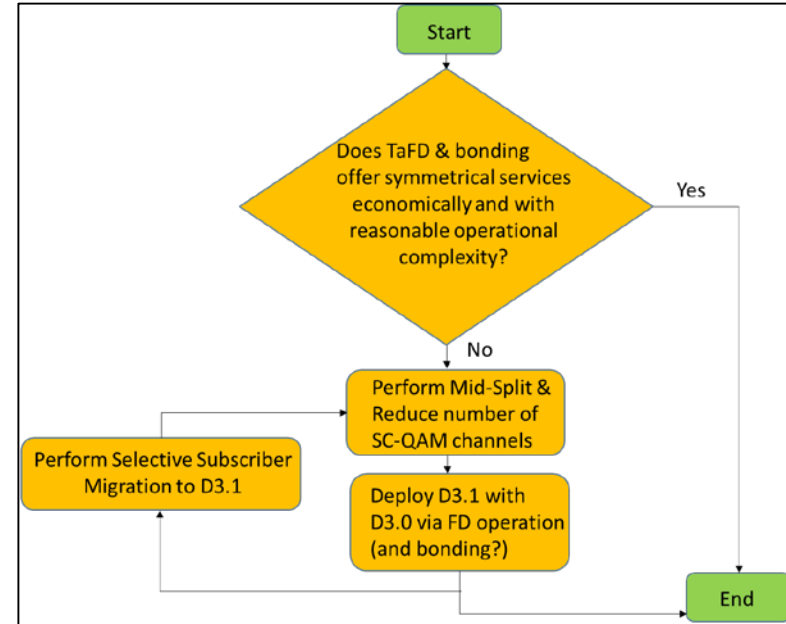
5-85 MHz Spectrum: TaFD vs. FD? Scenario B



- SC-QAM alone can offer T_{\max} up to 50 Mbps in 5-42 MHz plants
- The TaFD feature can increase the offered T_{\max} for initial deployments with 5% D3.1 subs
 - T_{\max} up to 64 Mbps with TaFD and without bonding
 - T_{\max} up to 76 Mbps with TaFD along with bonding
- Increasing the percentage of D3.1 subscribers beyond 5% does not change the results significantly
- Offering higher T_{\max} values (for Symmetrical services) will require migration to 5-85 MHz Spectrum & deployment of DOCSIS 3.1
 - T_{\max} of 273 Mbps can be offered when the percentage of D3.1 subs is 5% (without TaFD, just OFDMA and Bonding)
 - T_{\max} of 277 Mbps can be offered when the percentage of D3.1 subs is 95% (without TaFD, just OFDMA and Bonding)

Proposed Migration plan for 5-85 MHz Spectrum & DOCSIS 3.1 deployment to offer higher T_{max} than possible with 5-42 MHz plants

- Selectively change the plant to support 5-85 MHz Spectrum
- Deploy DOCSIS 3.1 US
- Allocate just enough spectrum for SC-QAM via the ARRIS QoE formula
- Allocate the rest of spectrum for OFDMA
- Use channel bonding between SC-QAM and OFDMA to offer high T_{max} values for DOCSIS 3.1 subs
- Can also use Selective Subscriber Migration to DOCSIS 3.1 to further relieve the pressure on SC-QAM channels



- The value added by the TaFD feature depends on the network parameters
- The MSOs need to perform Operational complexity/business case analyses for the available migration strategies
 - TaFD vs. Mid-split
- Migration to the mid-split architecture *selectively* when offering symmetrical services is an attractive option
 - TaFD may not provide enough gain for high-rate symmetrical services
- Selective subscriber migration to DOCSIS 3.1 can provide an added benefit

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THANK YOU!

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