CCAP EVOLUTION AND DOCSIS 3.1

Advantages and Deployment Strategies

Presented to the CCTA

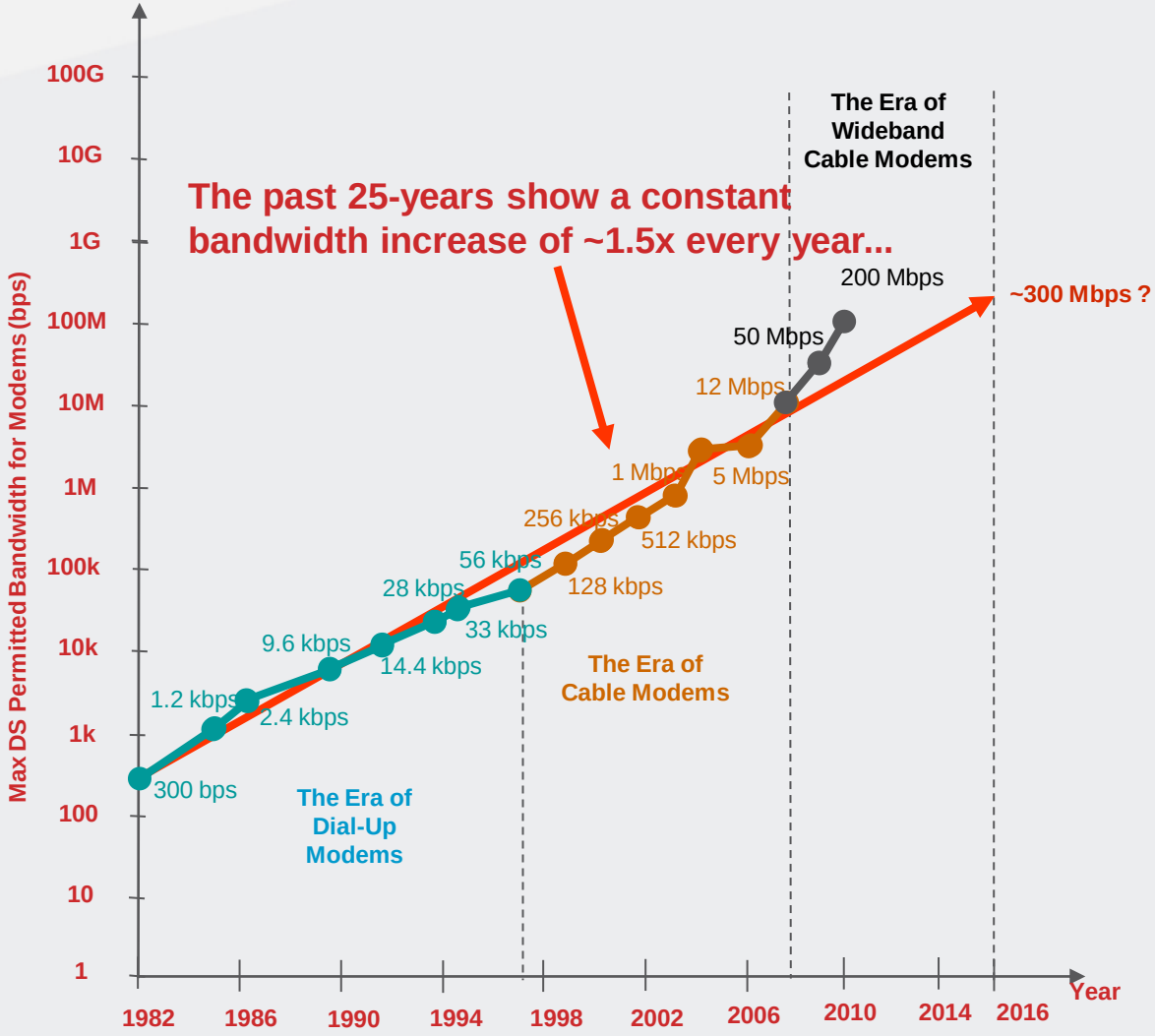
July 2014

AGENDA

- CCAP evolution
  - Purpose of CCAP
  - CCAP Advantages
  - CCAP into the future
- IPv6 migration
  - Case study from major US operator
  - Trends
- DOCSIS 3.1
  - Overview
  - Benefits
  - Possible deployment options

CCAP EVOLUTION

BANDWIDTH CONSUMPTION TREND

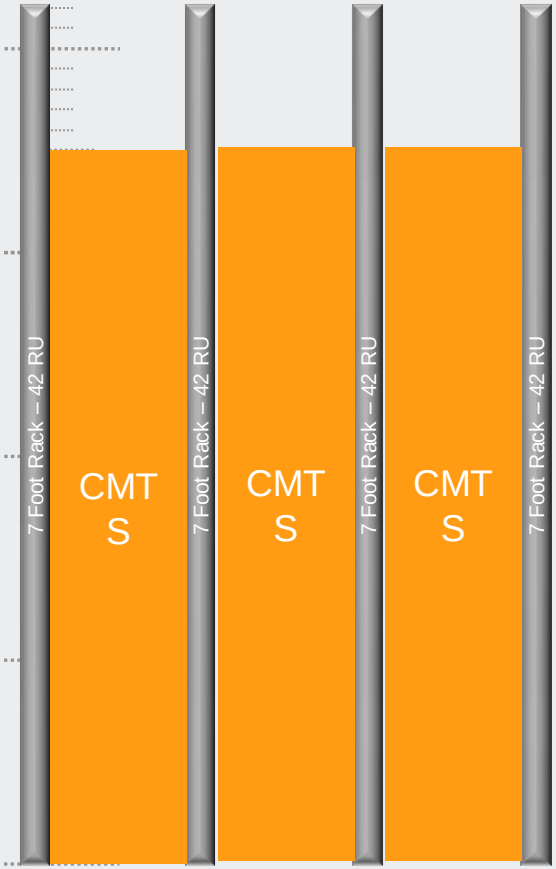


WHAT IS THE PURPOSE OF CCAP?

- Background: bandwidth consumption historically has increased roughly 50% year-over-year in the downstream for decades
- Background: delivering all services (video, HSD, telephony) over IP provides a number of operational and cost advantages
- The CCAP specs were developed with these two concepts in mind
- Myth: CCAP is useful or worthwhile only for those operators planning to converge MPEG video with DOCSIS carriers
- Fact: CCAP platforms are beneficial to any cable operator needing to increase their bandwidth per service group

EXAMPLE OF CCAP VALUE: 32 QAMS PER SERVICE GROUP, 100 SG HEAD-END

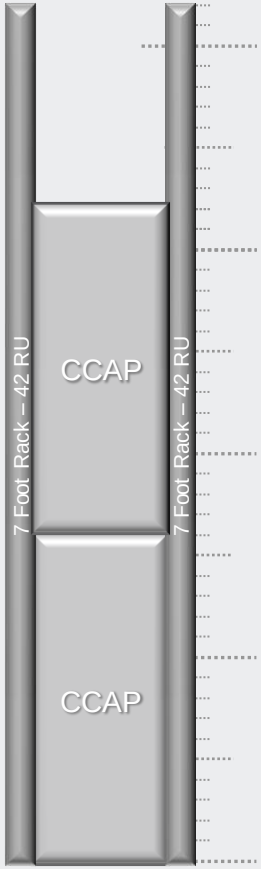
Legacy CMTS Solution



CCAP Benefits:

- ✔ Space savings
- ✔ Power consumption
- ✔ Price per DS

CCAP Solution



CCAP DECISION CRITERIA

- An operator should consider CCAP if…
  - Requires 8 or more DSs per F connector (rule of thumb)
  - Has 16 or more service groups in the head-end (for reasonable fill of CCAP chassis)
  - Plans to converge all services on a single F connector
  - Has long-term interest in evolution to DOCSIS 3.1

- But what if I don't need CCAP?
  - All CCAP vendors continue supporting DOCSIS 3.0 product
  - Bear in mind that DOCSIS 3.1 support may only apply to CCAP platform, not to DOCSIS 3.0 CMTS

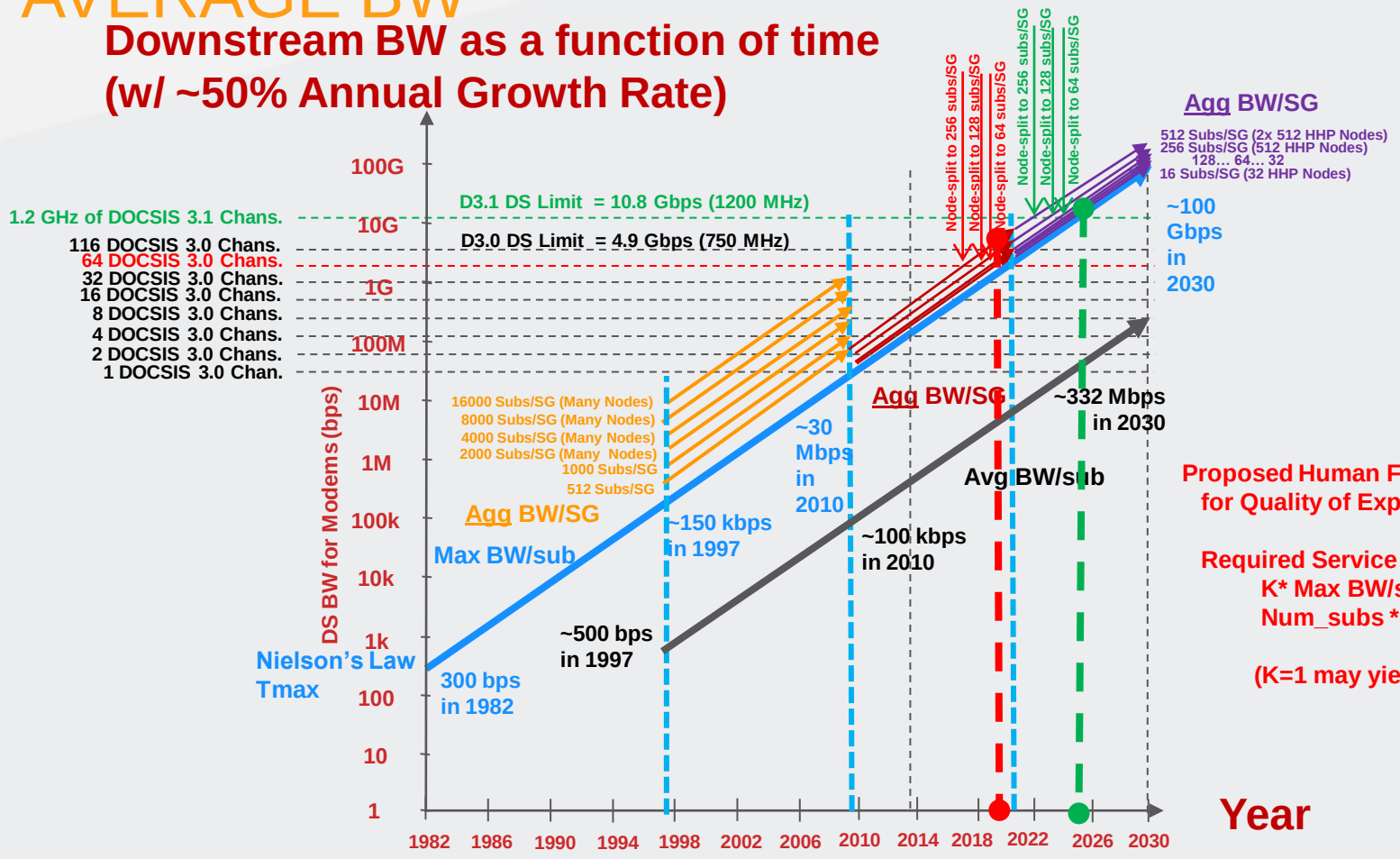
CCAP BENEFITS

- Lower price per downstream
- Reduced rack space
  - More RU available for other equipment
  - Avoid expensive space expansion
- Low power consumption
  - Lower utility bills
  - Avoid DC plant or HVAC expansion
- Redundancy
  - Reduce subscriber-impacting outages
- Integrated architecture

SAVES MONEY!

NEW TRAFFIC ENGINEERING MODELS DS – AGGREGATING Tmax AND AVERAGE BW

Downstream BW as a function of time (w/ ~50% Annual Growth Rate)



Proposed Human Factors Formula for Quality of Experience (QoE):

Required Service Group Capacity =
K* Max BW/sub +
Num_subs * Avg BW/sub

(K=1 may yield acceptable QoE)

If 50% Annual Growth Rates continue, Integrated CCAPs will carry MSOs until 2020-2025
If Annual Growth Rates slow to 30%, Integrated CCAPs will carry MSOs until 2023-2028
If more power/space is provided for CCAPs, these dates can be extended to 2030 & beyond

TWO MSO CONCERNS MAY LEAD TO EVENTUAL CHANGES IN THE HFC PLANT

- Concern #1: The Head-end Space/Power Issue
  - Can CCAPs support the Service Group growth while not blowing rack-space & power budgets?
  - This concern may not materialize for many years for most MSOs…at least 3 more rounds of node-splits are likely supportable by future CCAPs without rack-space & power increases
  - BUT… Distributed Access Architectures (DAAs) may help when it is a problem
- Concern #2: The Nonlinear Optical Noise Issue…
  - More Node-Splits → more Nodes
  - More Nodes → more lambdas per fiber & longer fiber runs
  - More lambdas & longer runs → more Nonlinear Optical Noise (Cross Phase Modulation, Stimulated Raman Scattering, Stimulated Brouillon Scattering
  - More Nonlinear Optical Noise → low SNRs
  - Low SNRs → difficulties using DOCSIS 3.1's higher-order modulations (4096QAM, 16384QAM)
  - The need for these higher-order modulations may be some time off
  - BUT… Distributed Access Architectures (DAAs) may help when it is a problem

CAN DISTRIBUTED ACCESS ARCHITECTURES MAXIMIZE FACILITY SPACE, POWER AND COOLING?

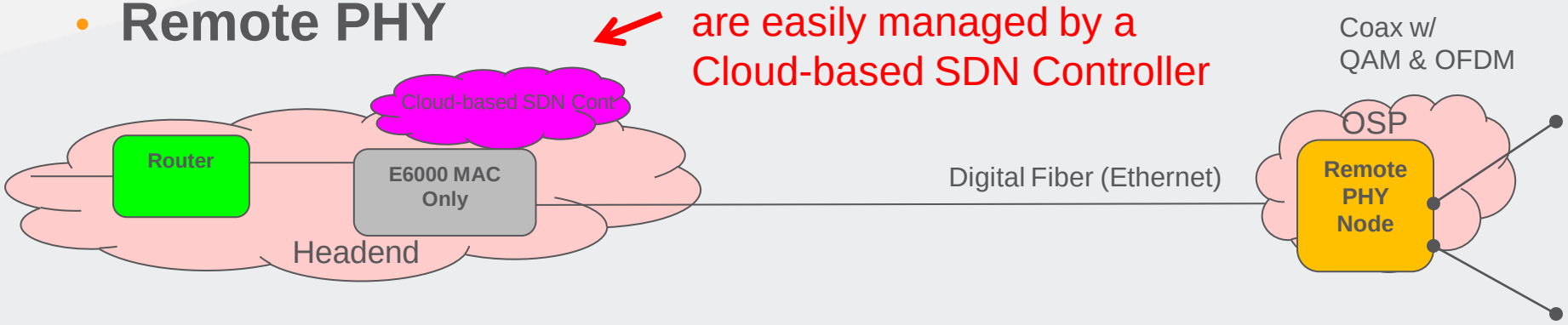
Answer: This may reduce headend requirement but increase the OSP

Configuration (assume Rack holds ~ 32 RUs (after power supplies))	Space Needed For ~200 SG	SG per 1 Racks	Relative Scale
Today's Head End – CMTS, EQAM, RF Combining, Optics (~20 SG/Rack)	~10 Racks	~20 SG	1X
2nd Gen Trad. CCAP (~70 SG?) + Ext. Digital Optics (80 SG per 12RU)	~2 Racks	~100 SG	5X
Future 2020 Trad. CCAP (~200 SG) + Ext. Digital Optics (120 SG per 12RU)	~1 Rack	~200 SG	10X
DAAs: NG CCAP w/ Rem. PHY (~396 SG… backplane limit) + + Ext. Demux Router (~24 SG per RU)	~0.5 Rack	~400 SG	20X
DAAs: Remote CCAP (~1536 SG per Rack)– Head End Aggregation Router (~24 SG per RU)	0.25 Rack	~800 SG	40X

EXAMPLES OF DISTRIBUTED ACCESS ARCHITECTURES

- **Remote PHY**

All Remote PHY Nodes are easily managed by a Cloud-based SDN Controller



Benefits: Provides average reduction in head-end power & rack-space requirements… and can re-use some existing head-end equipment

- **Remote CCAP**

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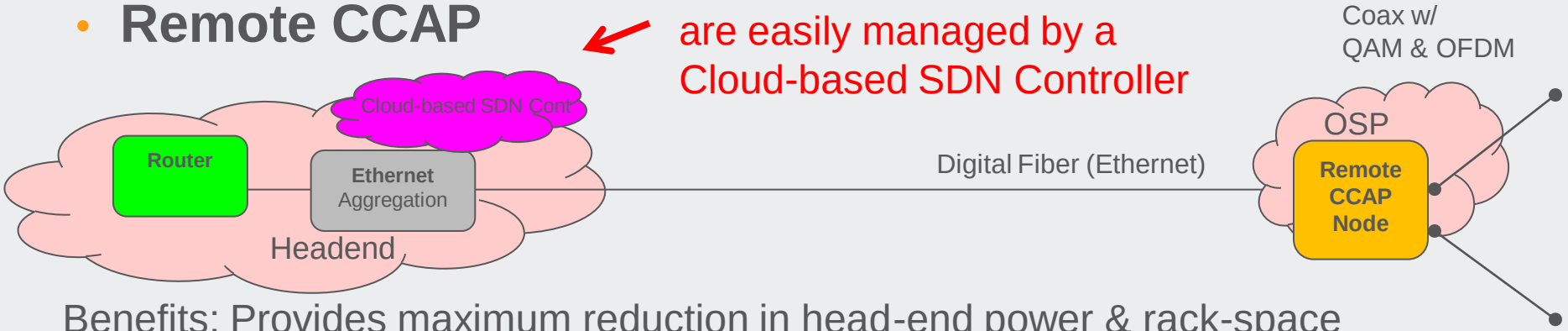

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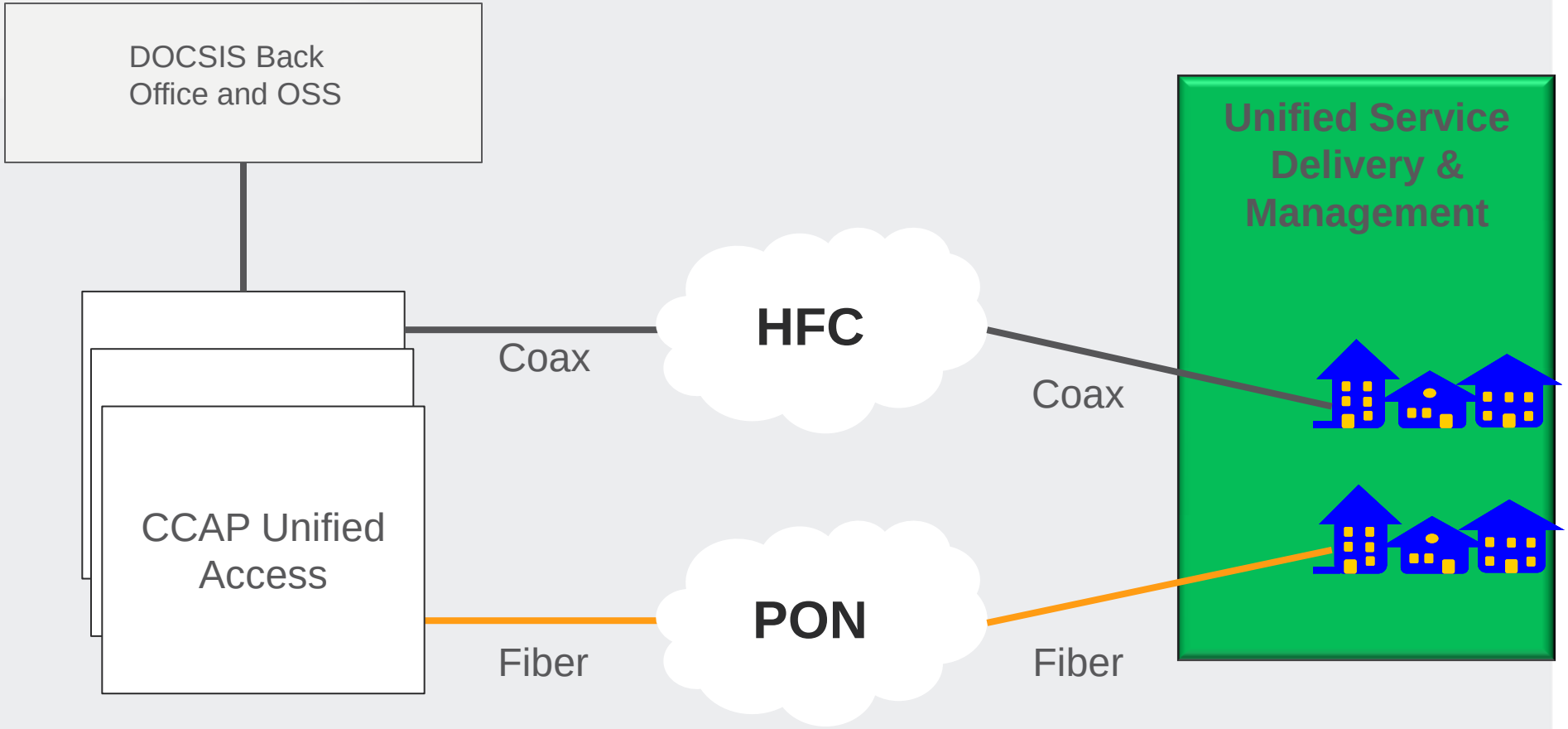
UNIFIED ACCESS SOLUTION



CCAP PLATFORM LIFETIME – KEY FACTORS

- Some factors that are important for longevity of the CCAP platform:
  - Power and cooling capacity: chassis should have significant “head room” of capacity over current max consumption to allow for future growth
  - Integrated architecture: best method of supporting hitless card failover, may be critical as all services converge
  - Line card surface area: more is better!
  - Mid-plane architecture: minimizes network disruptions due to re-cabling over life of product
  - Passive back-plane: allows for highest internal throughput

IPV6

IS IPV6 TRULY IMPORTANT?

lacnic

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No more IPv4 addresses in Latin America and the Caribbean

Latin America and the Caribbean have entered the IPv4 exhaustion phase; the delay in deploying Internet Protocol version 6 in our region is cause for concern.

La Casa de Internet de Latinoamérica y el Caribe, 10 June.- Today, the Internet Address Registry for Latin America and the Caribbean (LACNIC), the organization responsible for assigning Internet resources in the region, announced the exhaustion of its IPv4 address pool and expressed its concern regarding the fact that operators and governments throughout the region are delaying the deployment of Internet Protocol version 6 (IPv6).

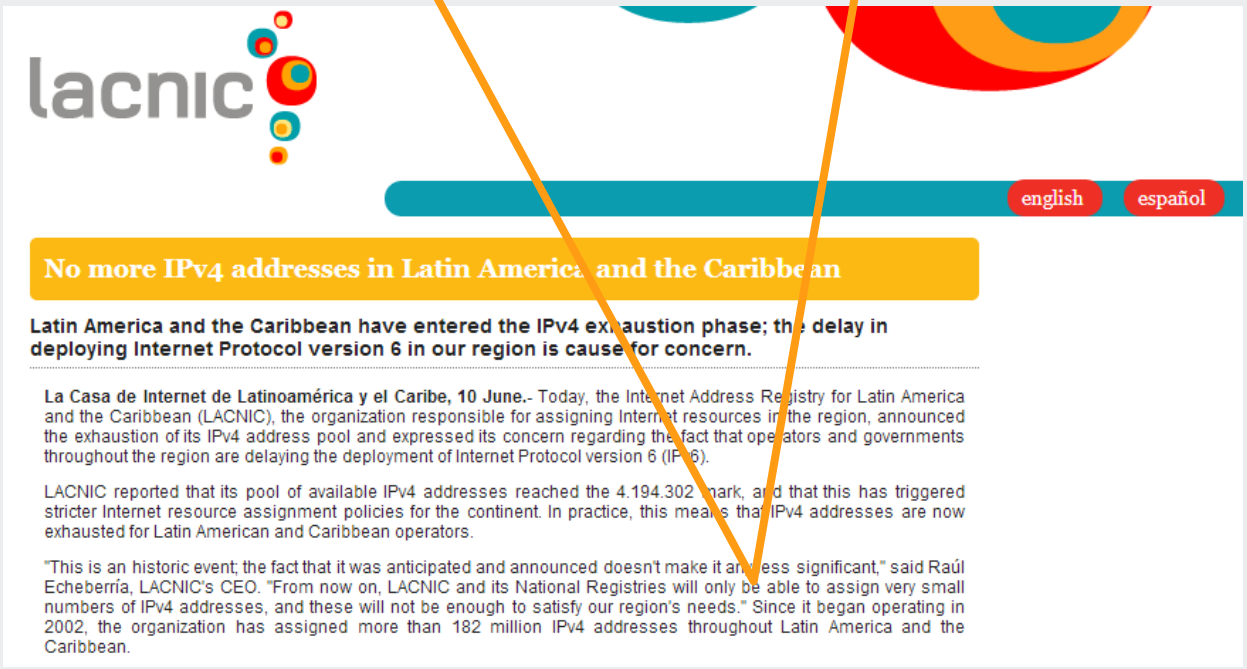
LACNIC reported that its pool of available IPv4 addresses reached the 4.194.302 mark, and that this has triggered stricter Internet resource assignment policies for the continent. In practice, this means that IPv4 addresses are now exhausted for Latin American and Caribbean operators.

"This is an historic event; the fact that it was anticipated and announced doesn't make it any less significant," said Raúl Echeberría, LACNIC's CEO. "From now on, LACNIC and its National Registries will only be able to assign very small numbers of IPv4 addresses, and these will not be enough to satisfy our region's needs." Since it began operating in 2002, the organization has assigned more than 182 million IPv4 addresses throughout Latin America and the Caribbean.

Source: http://www.lacnic.net/en/web/anuncios/2014-no-hay-mas-direcciones-ipv4-en-lac

IPV6 IN CALA REGION

"Today, the need to deploy IPv6 is now more pressing than ever. It cannot be delayed any longer if connectivity providers still wish to meet the demands of their customers and those of new users. LACNIC and the Internet community have been working for years in preparation for this very moment," said Echeberría. 67% of LACNIC member organizations have already been assigned IPv6 addresses by LACNIC and National Registries, NIC.br and NIC.MX.
LACNIC's CEO, however, expressed his concern that "10 years after LACNIC and National Registries, NIC.br and NIC.MX. began promoting IPv6 deployment, many operators and companies still haven't taken the steps needed to duly address this circumstance."



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IPV6 MIGRATION – CUSTOMER CASE STUDY

- A major US-based operator began IPv6 field testing in 2009 and began production use in 2010
- Key aspects of IPv6 use:
  - IPv6 modem management (config hard coded to either IPv4 or IPv6)
  - Dual-stack CPE
  - IGP
  - Security
  - DHCPv6 Prefix Delegation

IPV6 CASE STUDY

- Cable modem management
  - IPv4 or IPv6 only.
  - Developed procedure using config file to “flip” modem from IPv4 management to IPv4 management
  - APM and DPM not used
- Dual-stack CPE
  - Not a strategy for conservation or recovery of IPv4 addresses
  - Prepares for point in future when all Internet content and applications operate with IPv6
  - Intended to stimulate IPv6 migration on Internet
  - Operator’s goal is for IPv6 migration to be invisible/seamless to subscriber
  - 30% of CPE currently configured as Dual Stack
- IGP – OSPFv3 or IS-IS?
  - IS-IS was selected due to simplicity, MT function, and its agnostic nature to IP version

IPV6 CASE STUDY

- Security
  - Protocol throttling required for DoS resistance
  - Cable-centric features such as IPv6 TFTP Enforce, Cable Source Verify also required
  - Thorough testing using latest “hacker tools” such as THC6
- DHCPv6 Prefix Delegation
  - CMTS snoops DHCP traffic and injects route automatically
  - Residential and commercial applications
  - Prefix Stability maintains router’s assigned prefix even if host cable modem moves to different CMTS
  - Route table scaling PDRI coverage
- Results
  - Reclaiming IPv4 addresses means fewer and smaller supernets needed on CMTS.
  - Leads to reductions in north-bound IPv4 advertisement into backbone
  - Shrinking routing table size in backbone has a CAPEX benefit!!!
  - At a macro level across a large operator, creates a significant savings

OTHER IPV6 TRENDS

- IPv4/IPv6 Tunneling
  - Initially suggested as a means of facilitating transition
  - Appealing to operators concerned about being able to use IPv6 on the edge of their network
  - Not seeing continued interest – possibly because MSOs 6RD deployments didn't save them from having to deploy native IPv6
  - Tunneled IPv6 best suited for best-effort Internet, nothing more due to encapsulation
- CGNAT
  - Concept is to use IPv6 at network edge and translate to IPv4 in bulk at network core
  - In use today by some operators, but complex and service impacting
  - Can't replace native use of IPv6
- IPv4 Subnet Purchases
  - Common today
  - Some cable operators see this as a good investment, providing more time before migration to IPv6 is necessary
  - RIRs such as ARIN discourage abuse

IPV6 SECURITY – CRITICAL AREAS

- Prevention of theft of service
  - TFTP Enforce with Dynamic Shared Secret
  - Cable source verify
  - BPI+ Enforce
- Protection against Denial of Service attacks
  - DHCPv6 Throttling
  - ND Throttling
- Access Control
  - DOCSIS Subscriber Management Filters
  - Access Control Lists

DOCSIS 3.1

WHY DOCSIS 3.1?

- Traffic growth is driven by demand and competition!
- The DOCSIS 3.1 spec will greatly increase the bandwidth performance of the HFC plant using OFDM PHY & LDPC FEC
- 10+ Gbps Downstreams & 1+ Gbps Upstreams will permit DOCSIS to satisfy subscriber BW needs deep into the 2020 decade
- DOCSIS scales very well! Offers just-in-time investment steps, including:
  - Efficient spectrum utilization
  - Node splits
  - Adding BW (DS & US)
    - Mid-Split/High-Split architecture
    - DOCSIS Enhancements (higher modulations, new PHY/FEC, etc.)
  - FTTH (e.g., RFoG, PON)

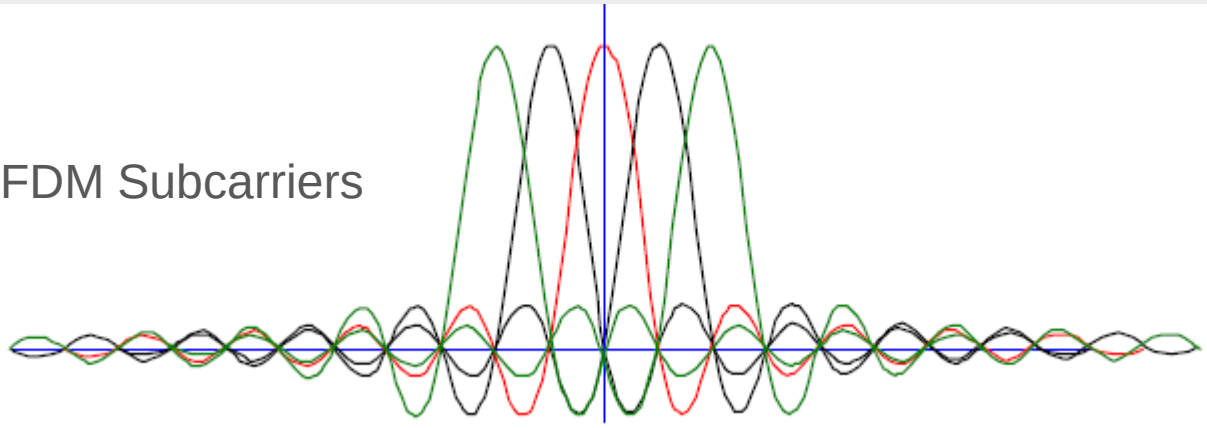
WHAT IS OFDM?

- OFDM
  - Orthogonal Frequency Division Multiplexing
  - Multi-Carrier Technology
  - Composed of “Subcarriers”
  - FFT-based Implementation

OFDM

Single-Carrier

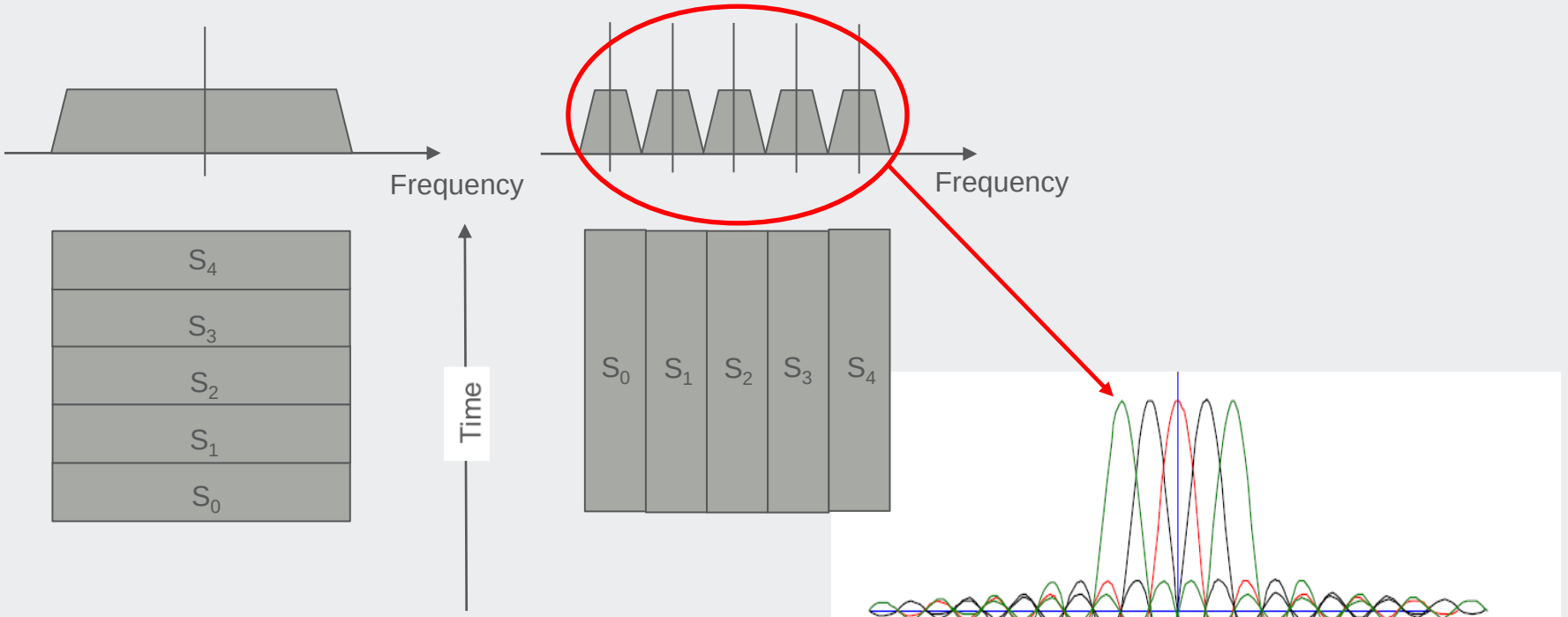
OFDM Subcarriers



OFDM for Cable was proposed in 2009 & 2010 by ARRIS [1] [2].

MULTI-CARRIER VS. SINGLE-CARRIER SYSTEMS

- Multi-Carrier: symbols sent in parallel at slow symbol rate
- Single Carrier: symbols sent sequentially at faster symbol rate



Single Carrier System
1. Symbols sent sequentially
2. Fast symbol transmit rate
3. Each symbol modulates the whole spectrum

Multi-Carrier System
1. Symbols sent concurrently
2. Slow symbol transmit rate
3. Each symbol modulates a subcarrier

DOCSIS 3.1 DELIVERS MORE THROUGHPUT IN EXISTING SPECTRUM!

- Capitalizes on the new LDPC FEC & OFDM PHY technologies
- Permits higher modulation orders (1024QAM, 4096QAM, etc.)
- Eliminates 6 MHz & 8 MHz channelizations (N.A. & Europe can unify)
- US operation up to at least 200 MHz
- DS operation up to at least 1.2 GHz
- Will use bit-loading to adjust to the HFC plant

MULTI-PHASE NETWORK MIGRATION

- PHASE 0: Use the available spectrum efficiently
- PHASE 1: Node segmentations and splits
- PHASE 2: Expand systems with CCAP systems densities
- PHASE 3: Add more Capacity with DOCSIS® 3.1 features
  - CATEGORY 1: Use DOCSIS® 3.1 with existing spectrum
    - Higher order modulations
    - New FEC (LDPC)
    - New PHY (OFDM)
  - CATEGORY 2: Expand the US spectrum using High split as goal architecture
    - Mid-Split (85 MHz) as an intermediate step?
    - High-Split (204 MHz, more?)
  - CATEGORY 3: Expand the DS spectrum beyond 1 GHz (i.e., 1.218 GHz or 1.794 GHz)
- PHASE 4: Unleash Latent, Higher Capacity of HFC networks
  - Unleash frequency range limitations – Extended Spectrum RFoG
  - Unleash SNR – digital optics (Remote PHY, Remote CCAP, etc.)
- PHASE 5: FTTH point-to-multipoint. Depending on PHASE 4, either use extended spectrum RFoG with current/Next Generation DOCSIS® or possibly GPON (BW shared by Service Group)
- PHASE 6: FTTH using WDM Arrayed Waveguide Gratings (Point-to-Point Optical Ethernet)

- Categories 1-3 of phase 3 can be done in any order (or concurrently) depending on MSOs specific circumstances
- Phases 3 & 4 may occur concurrently depending on MSOs specific circumstances

NETWORK MIGRATION IN DOCSIS® 3.1 ERA – ALTERNATIVE # 1 (DS OFDM FIRST, KEEPING US SPECTRUM UNCHANGED)

- Create a single DS OFDM channel (96 MHz?, 192 MHz?, or smaller like 48 MHz?)
  - Reclaimed spectrum or on top of existing DS spectrum
- Move heavy & power users to the DS OFDM channel
  - Accommodates high throughputs needed by heavy users and peak rates needed by power users
  - Requires less SC-QAM channels…. Spectrum could be reclaimed
  - Offers better service to the rest of customers
- Keep the US spectrum as-is and run in D3.0 mode (if no significant demand is present).
- Increase the number of DS and/or US DOCSIS® 3.1 channels as needed…Move more customers to DOCSIS® 3.1

- The above migration path can offer
  - Gradual phasing for DOCSIS® 3.1
  - Fast throughputs for heavy users
  - Better service to other users
  - Seamless co-existence between legacy and new equipment

NETWORK MIGRATION IN DOCSIS® 3.1 ERA – ALTERNATIVE # 2 (DS OFDM, AND GROWING US SPECTRUM)

- Create a single DS OFDM channel (96 MHz?, 192 MHz?, or smaller like 48 MHz?)
  - Reclaimed spectrum or on top of existing DS spectrum
- Move heavy & power users to the DS OFDM channel
  - Accommodates high throughputs needed by heavy users and peak rates needed by power users
  - Requires less SC-QAM channels…. Spectrum could be reclaimed
  - Offers better service to the rest of customers
- Grow the US spectrum (204MHz?)
  - Keep SC-QAM D3.0 channels in the middle of the US spectrum (e.g., 20-60 MHz)
  - Use the bottom and top portions of US spectrum for OFDMA (e.g., 5/10-20 & 60-160/204 MHz)
  - Move heavy and power users to the OFDMA channel
  - Requires less SC-QAM channels…. Spectrum could be reclaimed
- Increase the number of DS and/or US DOCSIS® 3.1 channels as needed…Move more customers to DOCSIS® 3.1

- The above migration path can offer
  - Gradual phasing for DOCSIS® 3.1
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NETWORK MIGRATION IN DOCSIS® 3.1 ERA – ALTERNATIVE # 3 (SEED THE MARKET WITH DOCSIS 3.1 CMS OPERATING IN DOCSIS 3.0 MODE

- Seed the market with D3.1 modems operating in D3.0 mode
  - This might be function of the cost of D3.1 CMs
- Once a the percentage of D3.1 exceeds some pre-defined threshold, assign DS (and US?) spectrum for D3.1 operation
- Move D3.1 CMs to new spectrum and operate in D3.1 mode
- Gradually move customers to D3.1 channels and grow D3.1 spectrum as needed
- US spectrum can be left as is or get expanded to 5-204MHz depending on traffic demand. These options are similar to the US options in alternatives # 1A/1B, 2A/2B
- This approach does not require turning on D3.1 spectrum immediately

QUESTIONS?

PLEASE FEEL FREE TO EMAIL ME:

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תודה רבה
DZIĘKUJĘ
TEŞEKKÜR EDERIM
THANK YOU
MUCHAS GRACIAS
MERCI BEAUCOUP
DANKE
GRAZIE
OBRIGADO
谢谢
ありがとうございます。
고맙습니다