Hybrid Fiber-Coaxial Networks: Technology and Challenges in Deploying Multi-Gigabit Access Services

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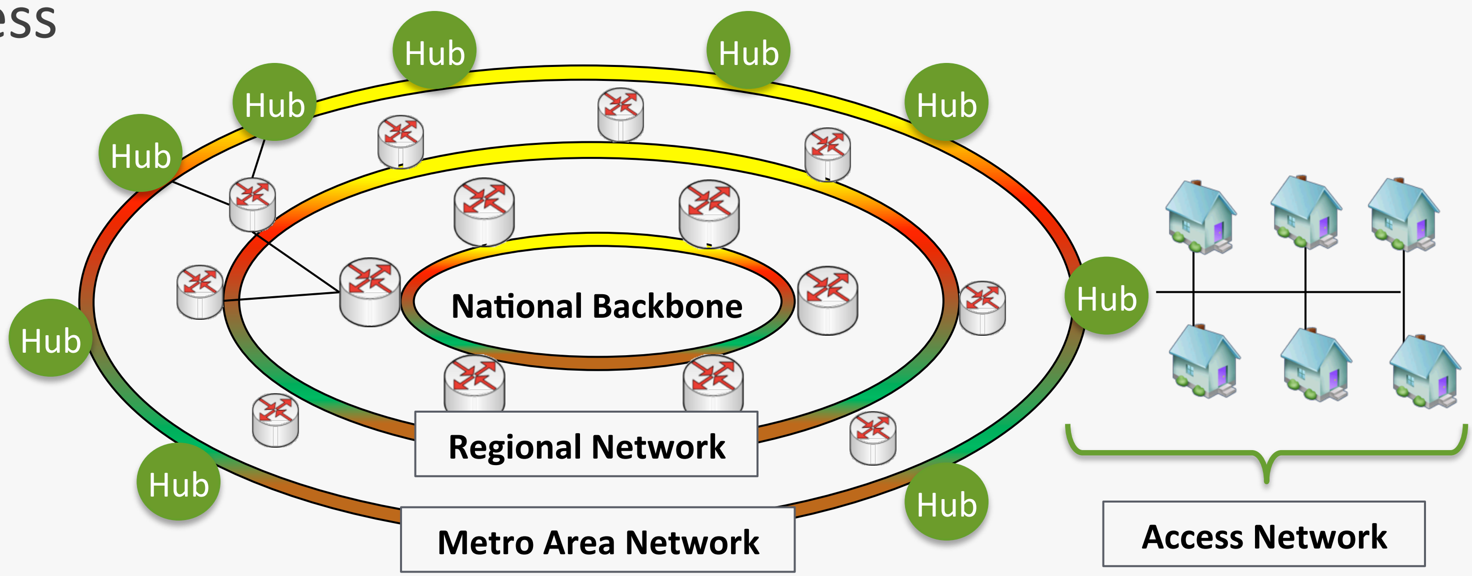
Network Structure

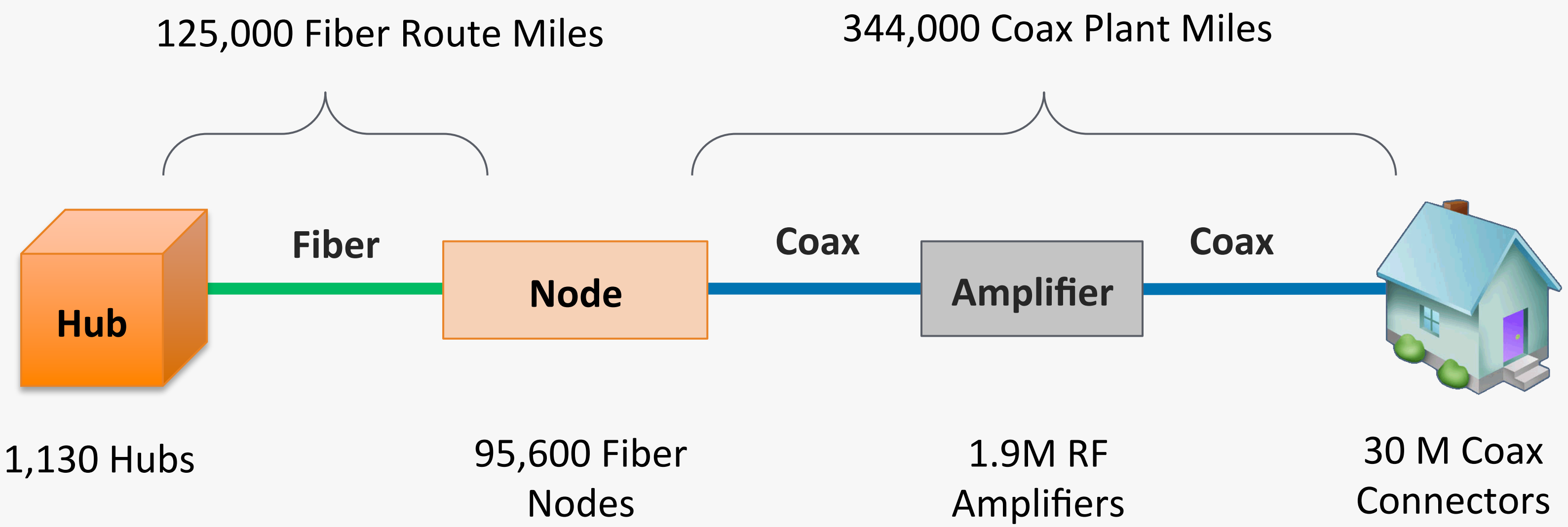
- Most networks are constructed as a 4-level hierarchy
  - Backbone
  - Regional
  - Metro
  - Access



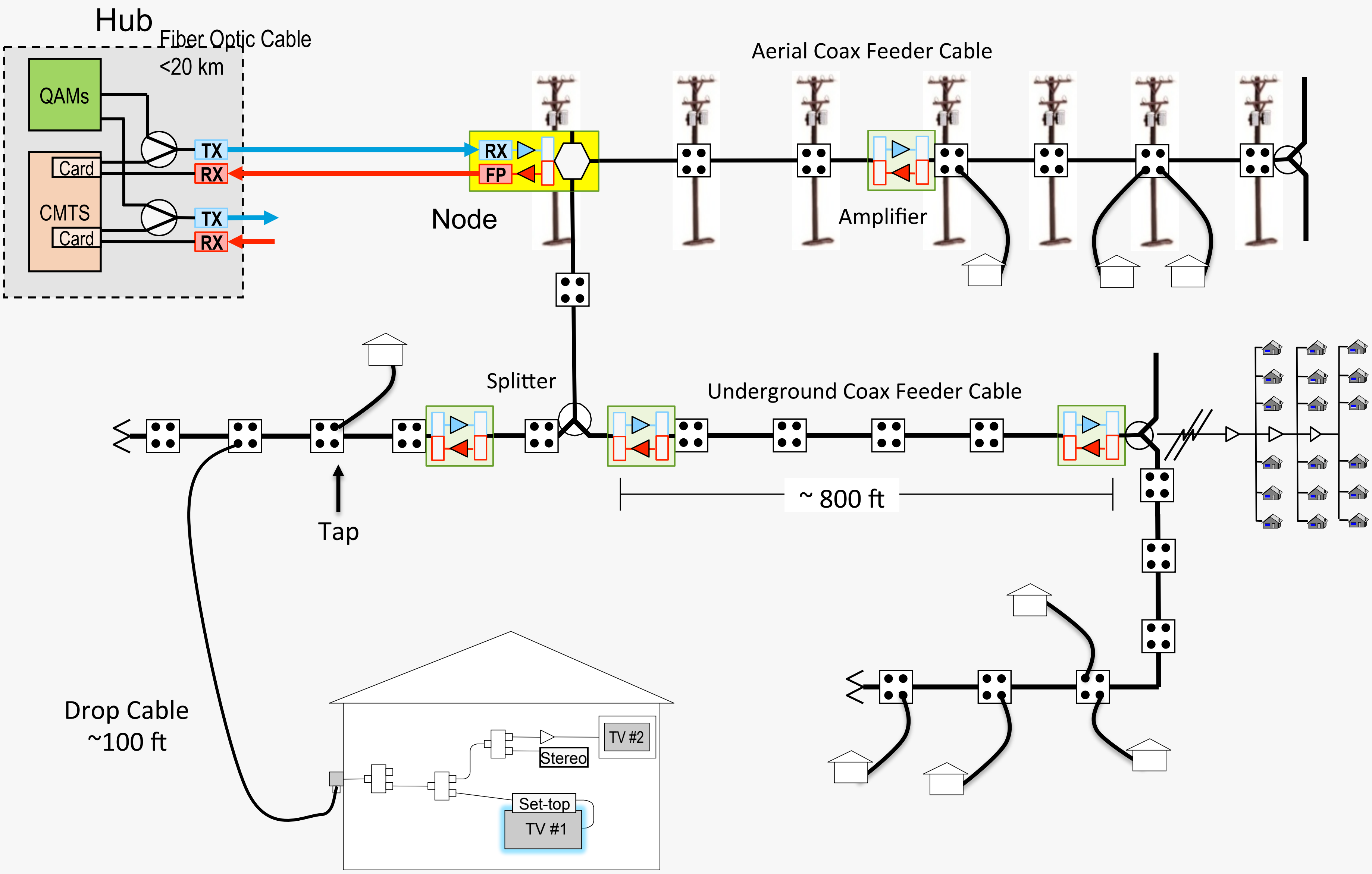
Access Network

- The largest component of the network in terms of
  - Physical/Geographic Size
  - Monetary Investment

TWC
Hybrid Fiber Coax (HFC) Access Network



HFC Network Components and Topology



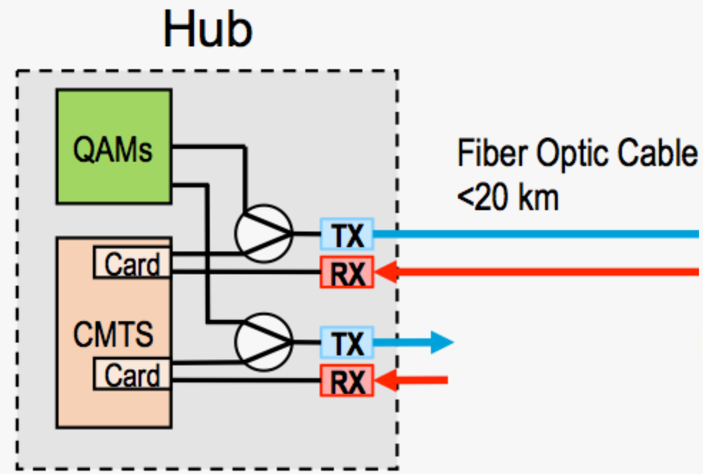
Hub

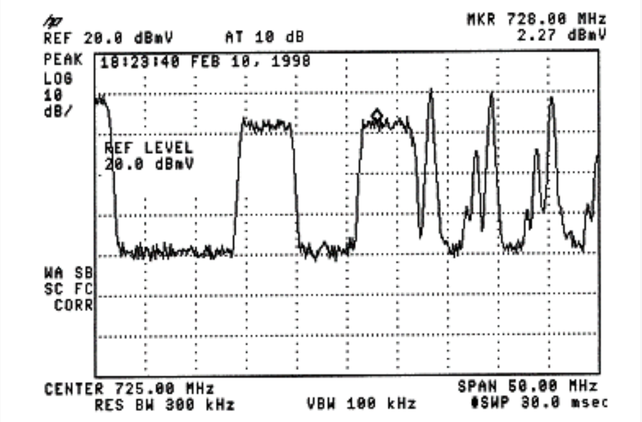
Node

Tap

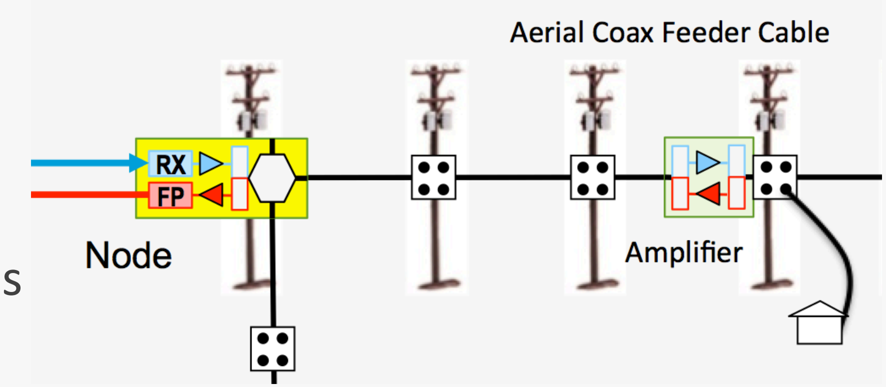
Functions in the Hub

- Reception of Video Signals from Content Networks/Programmers
- IP Connectivity to Metro/Regional Networks
- Modulation of Downstream Signals as
  - QAM (digital) or
  - VSB+DSB+SSB+FM (Analog)
- Pre-Conditioning of Downstream Signals to combat impairments in the optical and RF network
- Decoding of Upstream QAM/QPSK Signals
- Conversion of RF Signals to/from Intensity Modulated Optical Signals for long-distance transmission

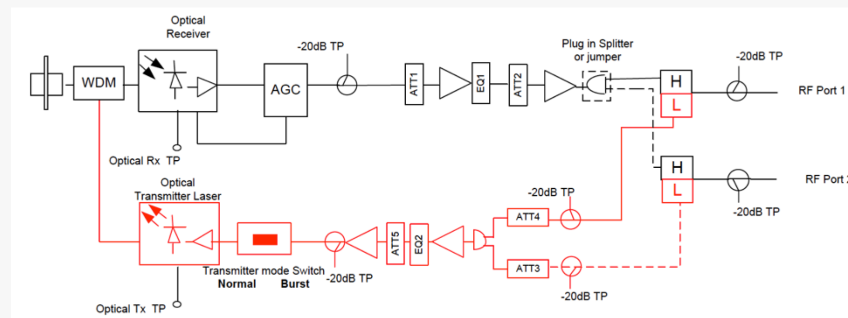




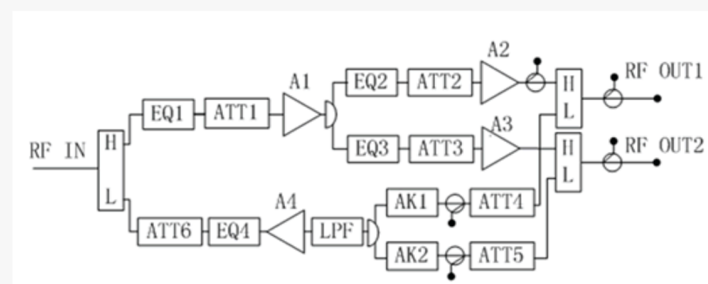
Functions of a Node and Amplifier



- HFC Node
  - performs OE conversion of RF signals to/from hub
  - can be located 50km or more from the hub

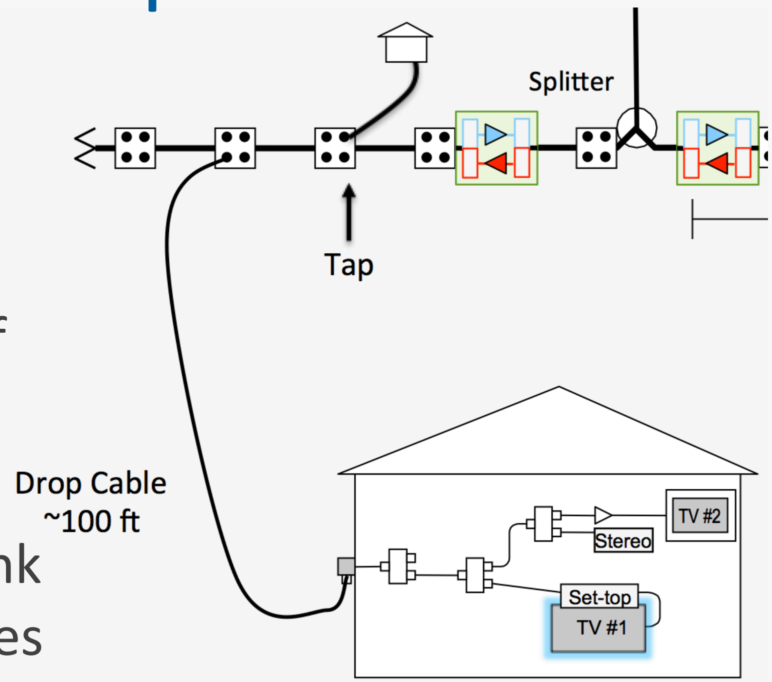


- Trunk/Distribution Amplifier
  - performs amplification of the RF signal after being degraded during transmission over coaxial cable
  - May be cascaded 5-deep past the node (node+N architecture)



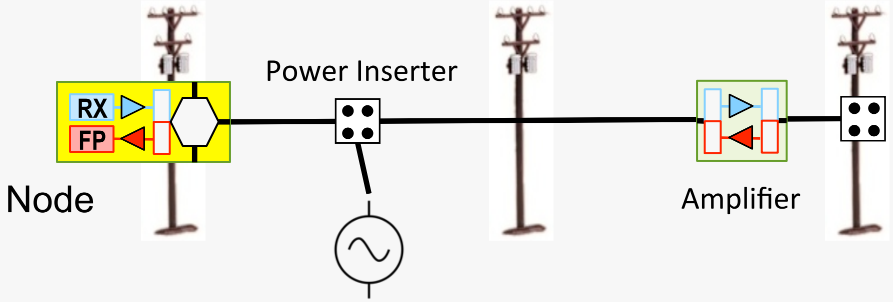
Functions of the Tap and Drop

- Tap
  - A multiport RF device that passes a specified amount of RF energy to a “TAP” port and passes the majority of RF energy from the “INPUT” to the “THRU” port
  - Used to create a branch from the trunk coaxial cable to a subscriber’s premises



- Drop
  - The coaxial cable that attaches the subscriber’s premises to the tap port

HFC Powering



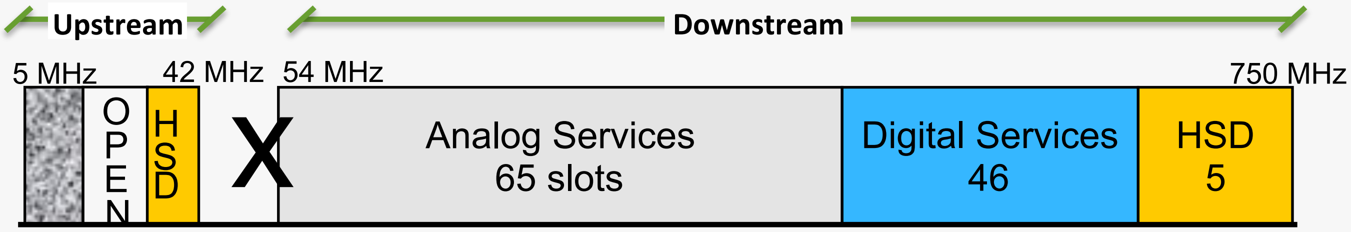
- The HFC Node and Amplifiers are electronic devices that require electrical power.
  - Power Supplies placed at regular intervals along the coaxial network provide power to the node and amplifiers
  - Power Insertion devices are used to couple AC and/or DC power to the same conductors carrying the RF signal

- The Coaxial Network is ALSO a power distribution network

Capabilities of a Typical HFC Network

- Downstream 54-750 MHz
  - 116 x 6 MHz Channels = 4.3Gbps @ 256 SC-QAM (single carrier)
  - ~ 6 bits/Hz
- Upstream 5-42 MHz
  - ~ 4 x 6 MHz Channels usable = 100 Mbps throughput @ 64 SC-QAM
  - ~ 2 bits/Hz

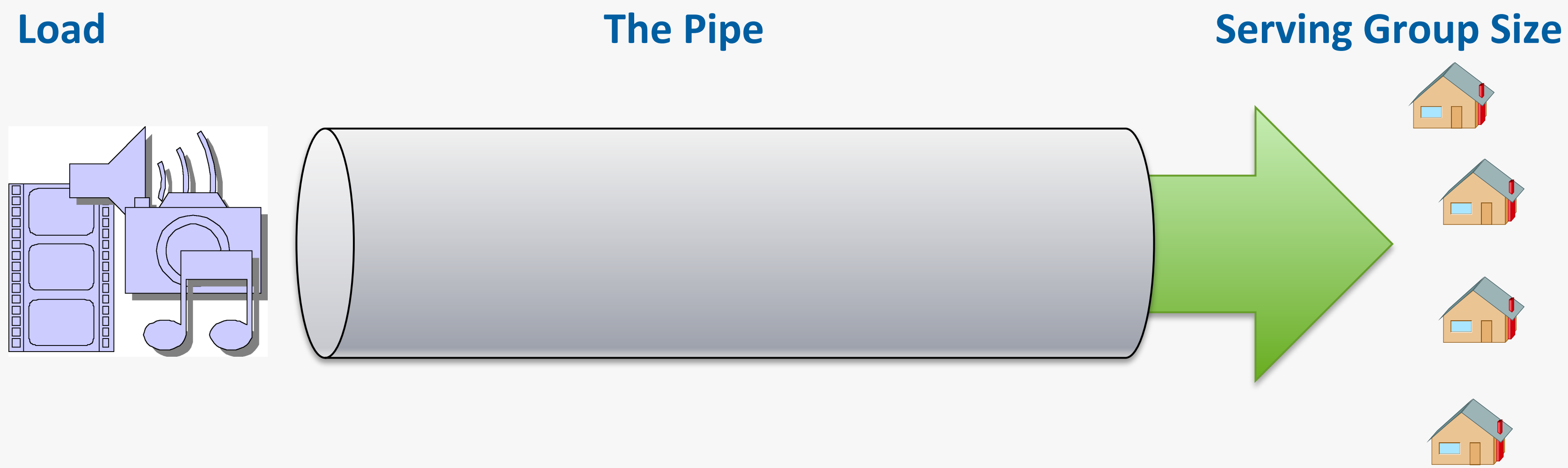
Typical 750 MHz System



6 MHz = 1 slot

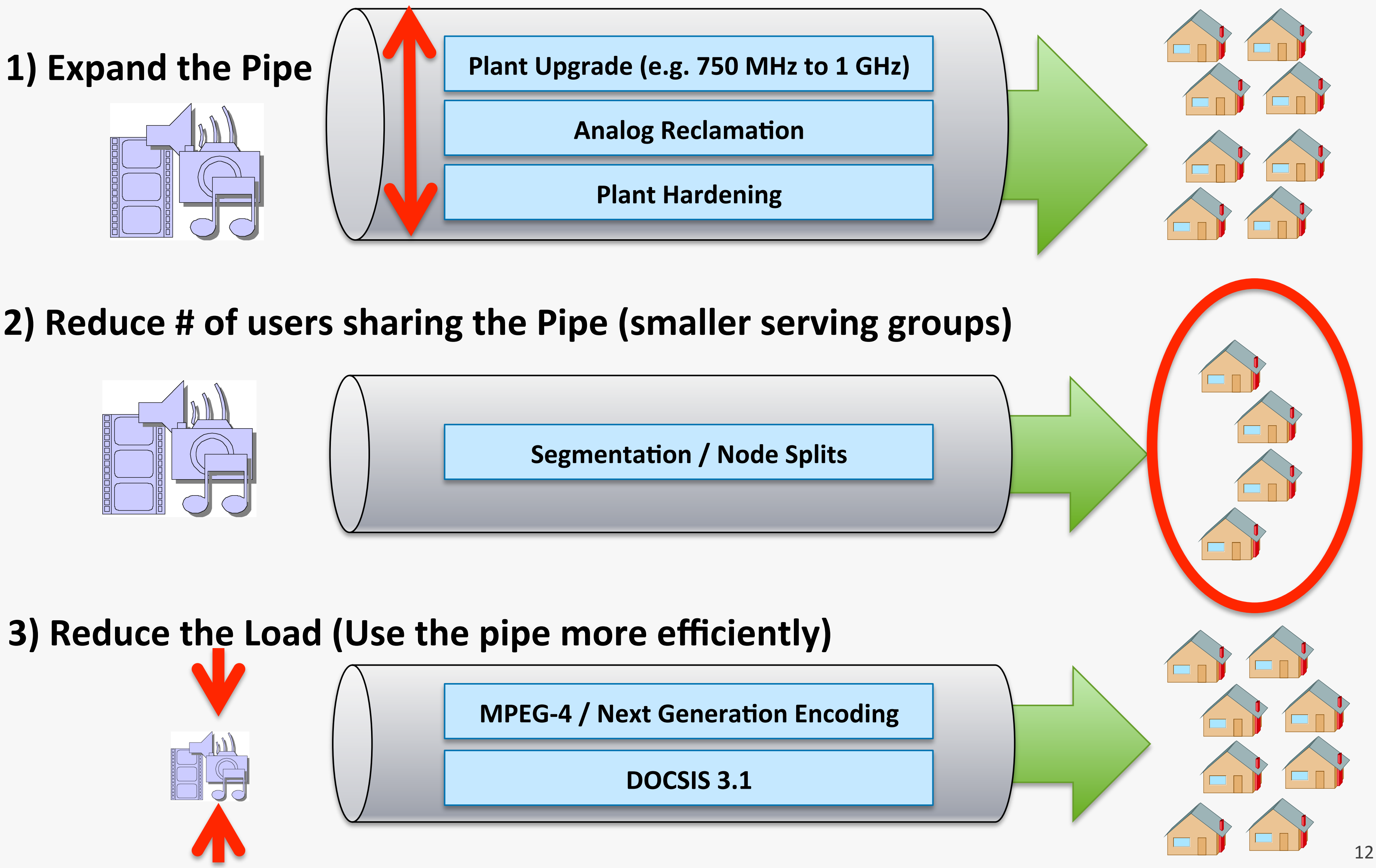
Increasing Capacity and Throughput

Three basic components influence network capacity

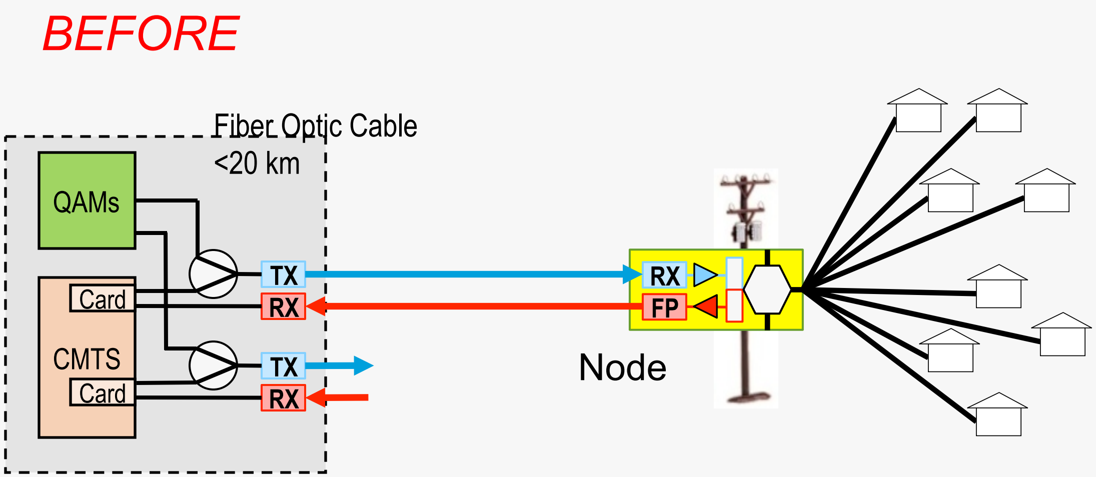


- Load = The amount of data requested and sent by users on the network
- Pipe = Throughput and Capacity available in the network
- Serving Group Size = the # of users sharing the Pipe

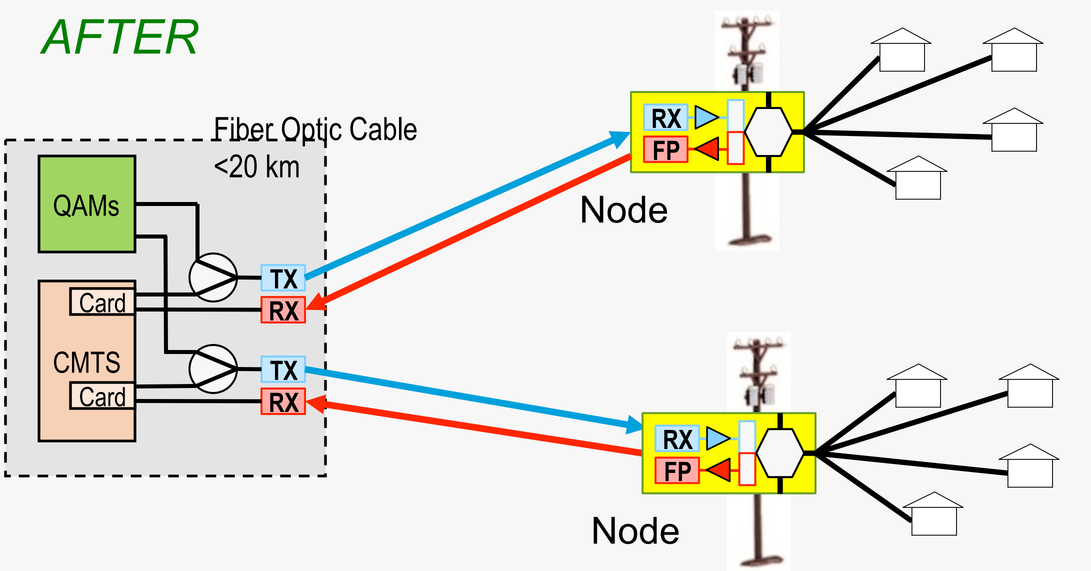
Increasing Capacity and Throughput



Reducing Serving Group Size



- Node Split
  - Reduces Serving Group Size by adding HFC Nodes and CMTS ports to serve the same number of users



- Increases Capacity ONLY
- Does NOT Increase Peak/Offered Speed

Expand the Pipe – Reclaim Spectrum

- Legacy Analog Signals are inefficient users of spectrum
  - 5% efficiency compared to MPEG-4
  - Typically can occupy 50% of the available spectrum
- Replace Analog with Digital Signals that are more efficient
  - MPEG-encoded Video on QAM can carry 2-20x more content than an analog channel
- Contractual Concerns must be satisfied
  - Franchise Agreements, Market Recognition, Must-Carry Agreements may be impacted by conversion of analog to digital
  - Deploy DTA to all subscribers who do not have Set-Top-Boxes (CAPEX $$, OPEX $$)

Expand the Pipe – Use the Unusable

- Some operators avoid using sensitive frequencies
  - 108-137 MHz – Aeronautical Mobile and Aeronautical Radio Navigation
  - 328-355 MHz – Aeronautical Glideslope frequencies
- Requires Plant Hardening to ensure no leakage of signals from the coax plant

Expand the Pipe – More Spectrum

- Expand the Available Spectrum
  – Move the upper limit to 1GHz or higher
  – Move the US/DS split

Moniker	Upstream Frequency	Description
Sub-Split	5-43 MHz	Most used today
Mid-Split	5-85 MHz	Reasonable option
High-Split	5-200 MHz	Difficult and Expensive
Top-Split	>1 GHz	Much higher CPE cost

  – Requires heavy-duty network upgrades

Expand the Pipe – More Spectrum

- Nodes, Amplifiers, Filters
  - All operate with a specific frequency-split
  - All must be re-configured
  - or replaced if not compatible with the new split

Sample Amplifier Specification

Specifications[15]	Units	Forward	Return
Frequency Split	MHz	54 – 1002 85 –1002 105 –1002[14]	5 – 42 5 – 65 5 – 85

Sample Node Specification

Forward	
Bandwidth	52 – 1 GHz, split dependent
Return	
Bandwidth	5 - 85 MHz, split dependent

Use the Pipe More Efficiently

- Better Compression Algorithms
  - Reduces RAW load on the network

- Higher-Order Modulation and FEC

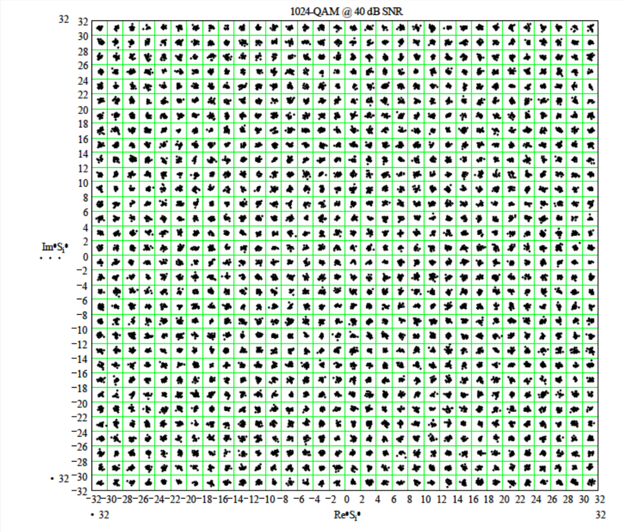


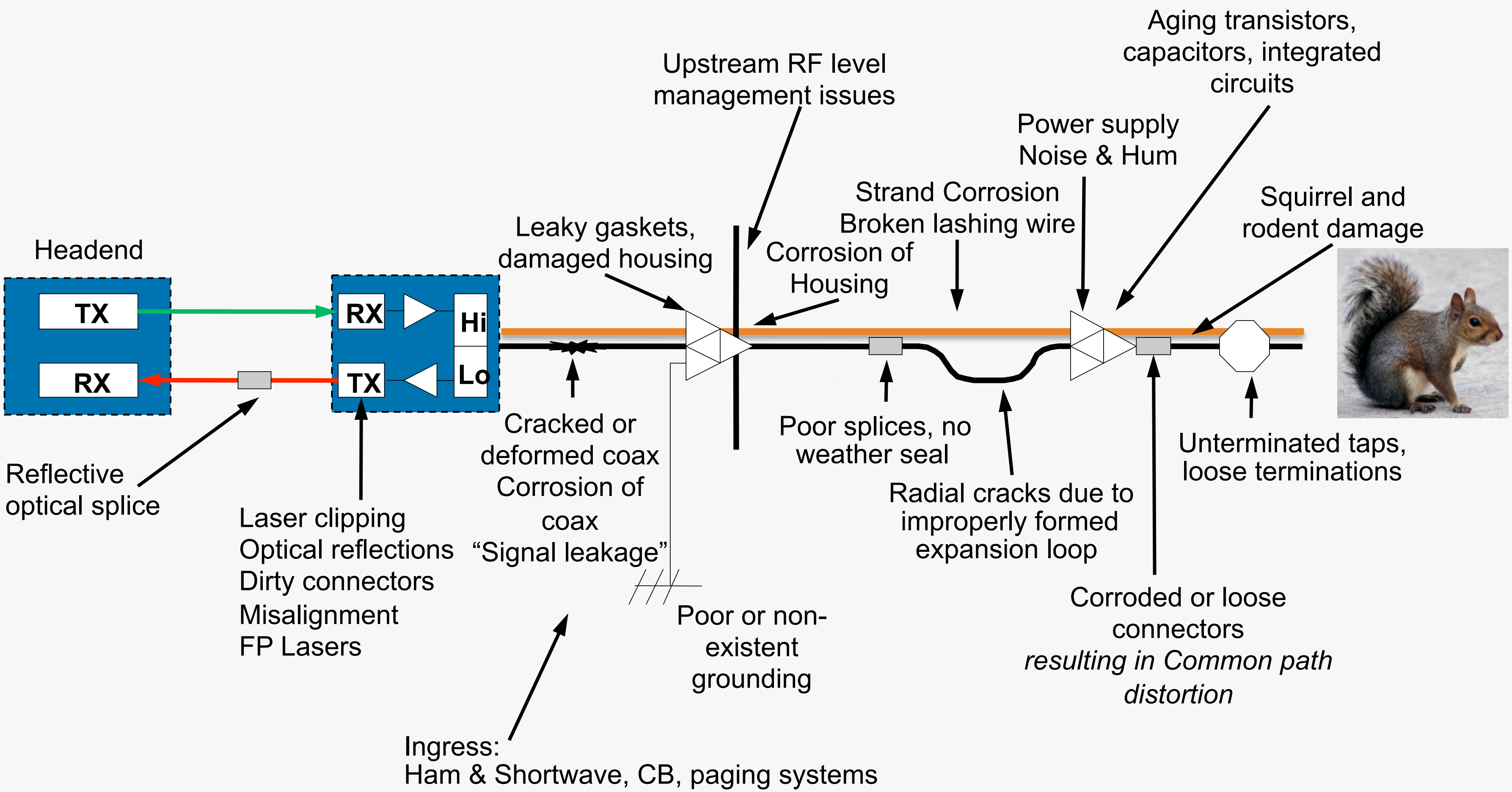
Figure 30 – 1024-QAM @ 40 dB SNR

Modulation	Efficiency (bits/symbol)	Bit Rate per 6 MHz (Mbps)	Required SNR (dB)
64 QAM	>5	~27	>18
256 QAM	>7	~40	>24
1024 QAM	>9	~50	>30
OFDM w/ 4096 QAM		~65	

Adapted from Chapman, Emmendorfer, Howald, Shulman, “Mission is Possible: An Evolutionary Approach to Gigabit-Class DOCSIS”, NCTA, May 2012

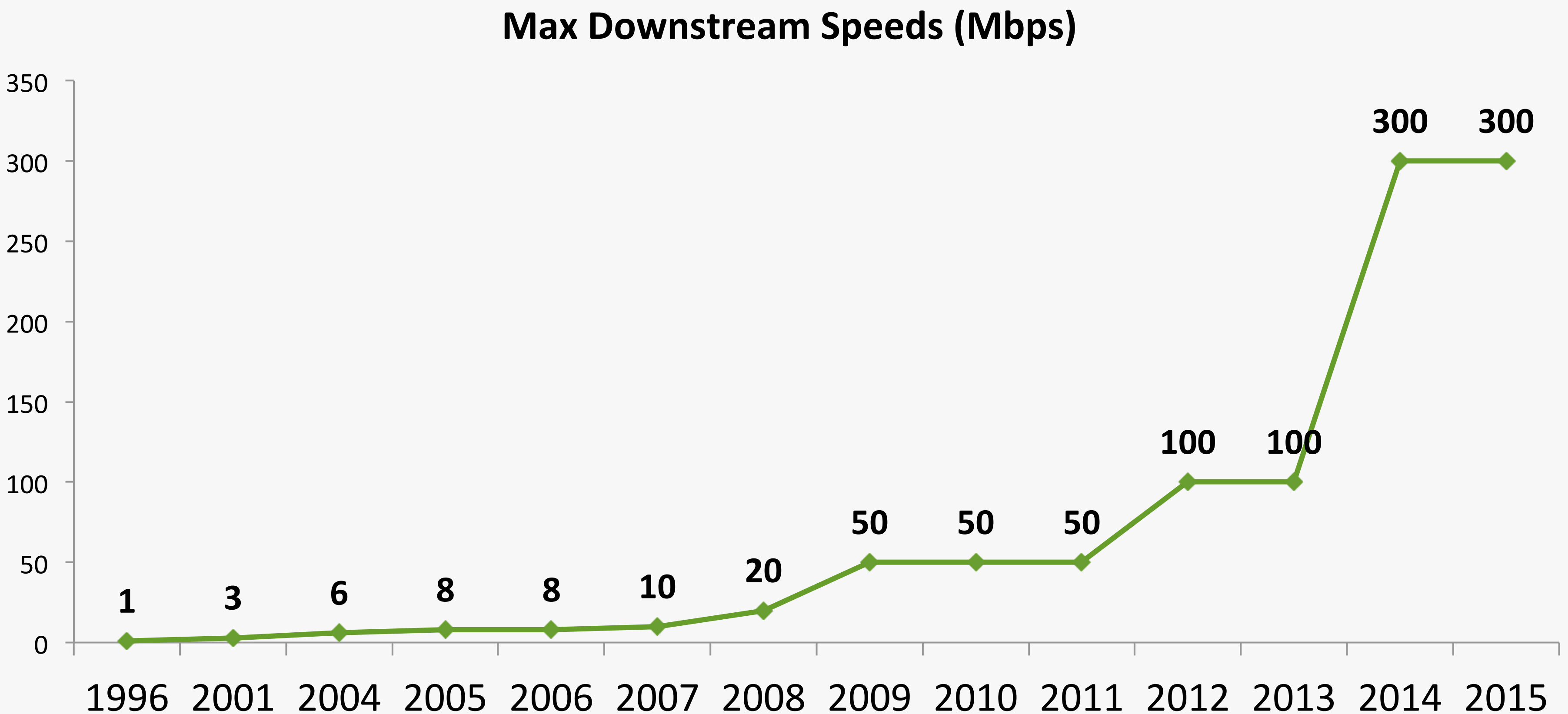
Use the Pipe More Efficiently

- How to Achieve Better SNR? – Plant "Hardening"

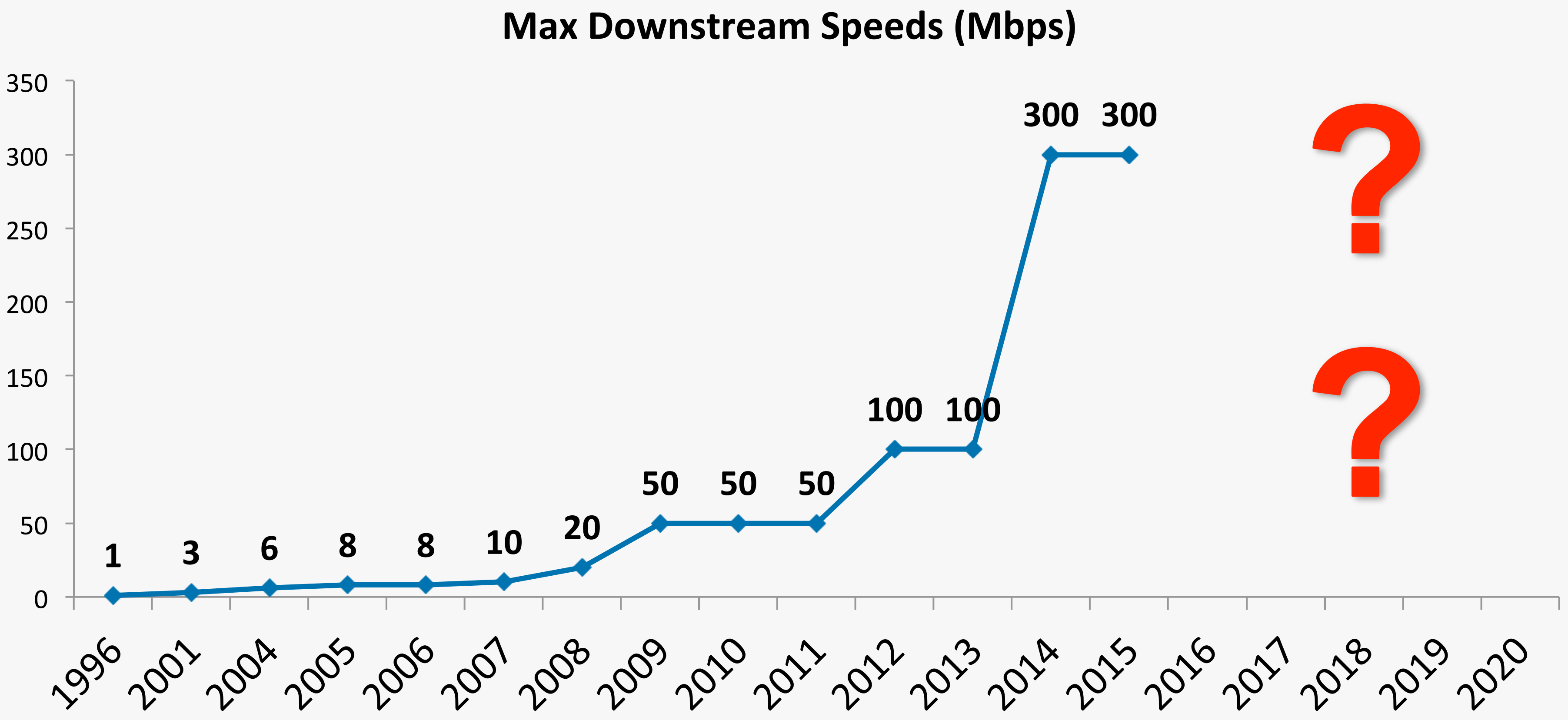


Plant Hardening

These tactics have enabled us to grow our max HSD speeds by ~300 over the last ~15 years (1 Mbps to 300 Mbps)



How long can we keep it up?



Q&A