Optical Access Technology and Architecture Considerations for CATV Networks

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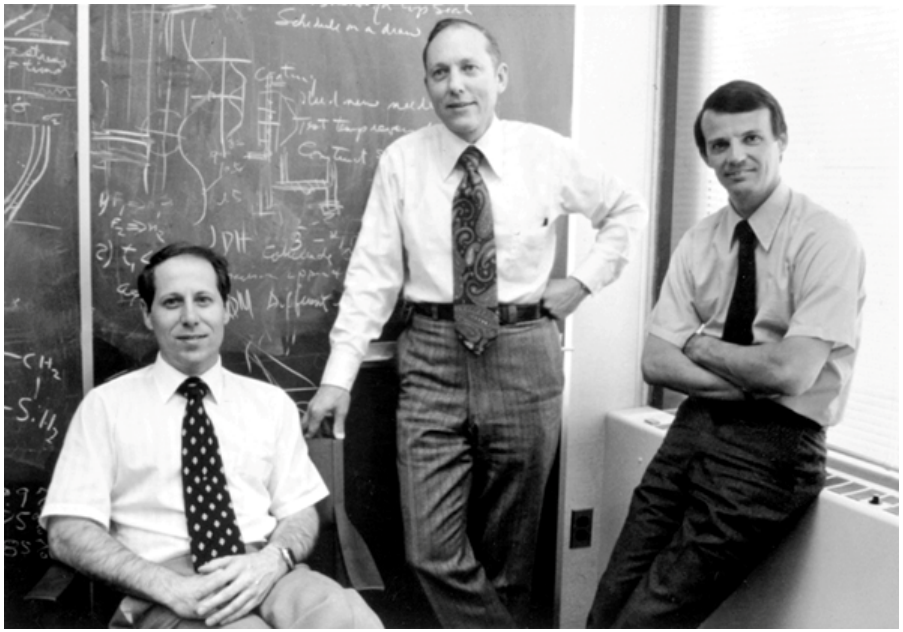
Agenda

- Fiber Basics
- FTTH Overview
- Architectures
- SFU
- MDU

History – How it Came to Pass?

48 years ago three Corning scientists created the first low loss optical fiber

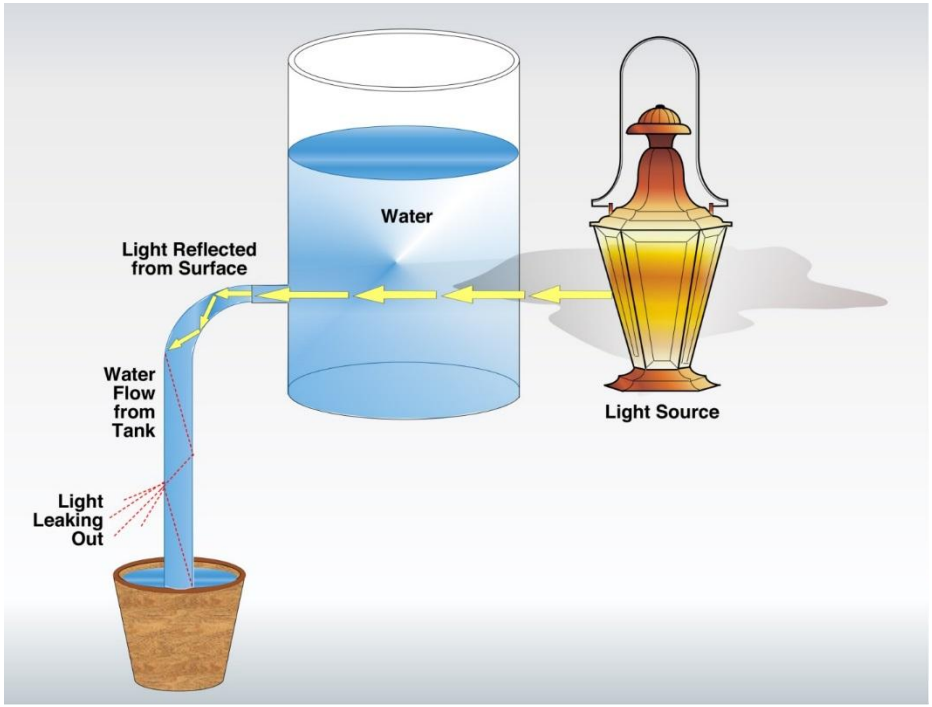


Optical fiber was invented by:

- Dr. Donald Keck,
- Dr. Peter Schultz
- Dr. Robert Maurer

History – How it Came to Pass?

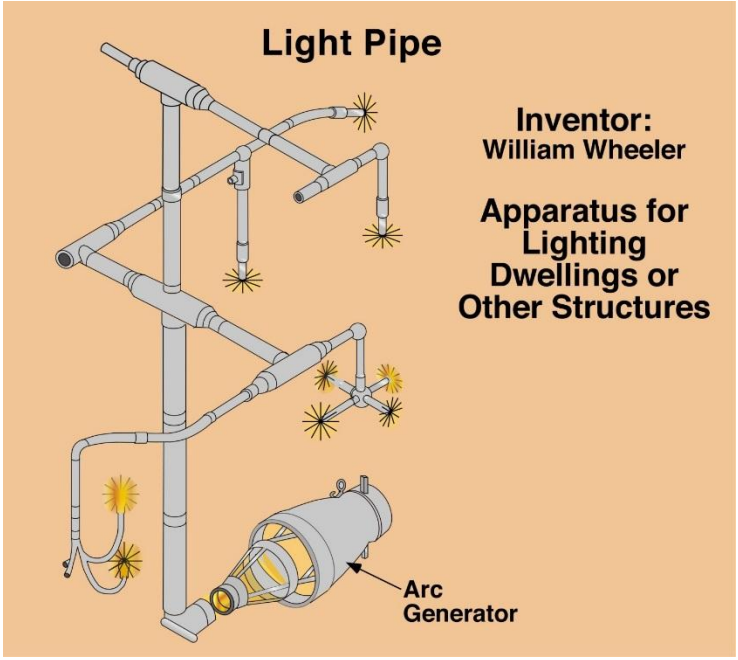
David Colladon Guided Light Experiment



- Inventor: Daniel Colladon
- 1841 – Colladon's guided light experience in water

History – How it Came to Pass?

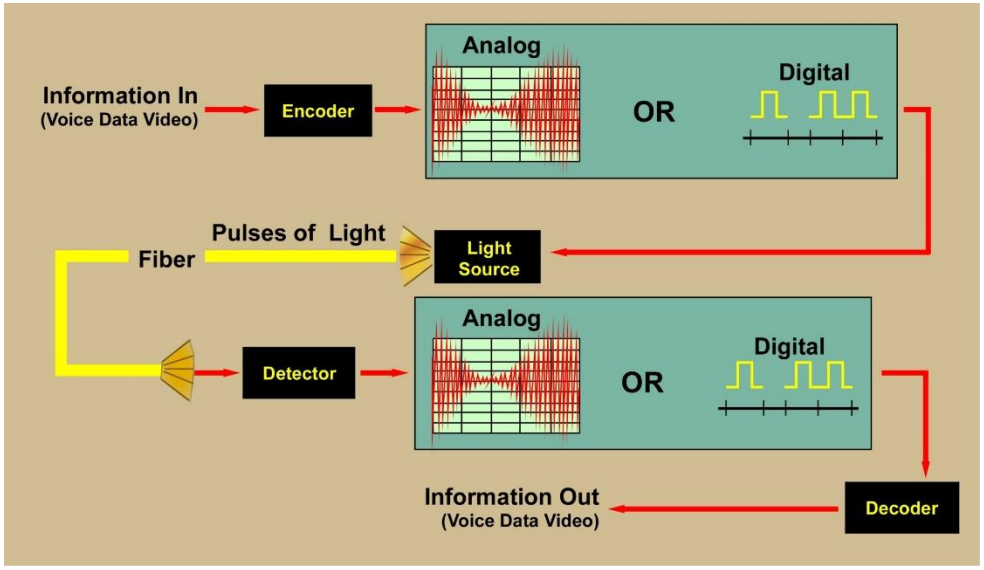
Failed Attempt to Light a Building = Fiber Optics



- William Wheeler patented a scheme for piping light through buildings.
- Wheelers light pipes probably wouldn't have reflected enough light to do the job. However, his idea of light piping reappeared again and again until it finally coalesced into optical fiber

History – How it Came to Pass?

The Sequence

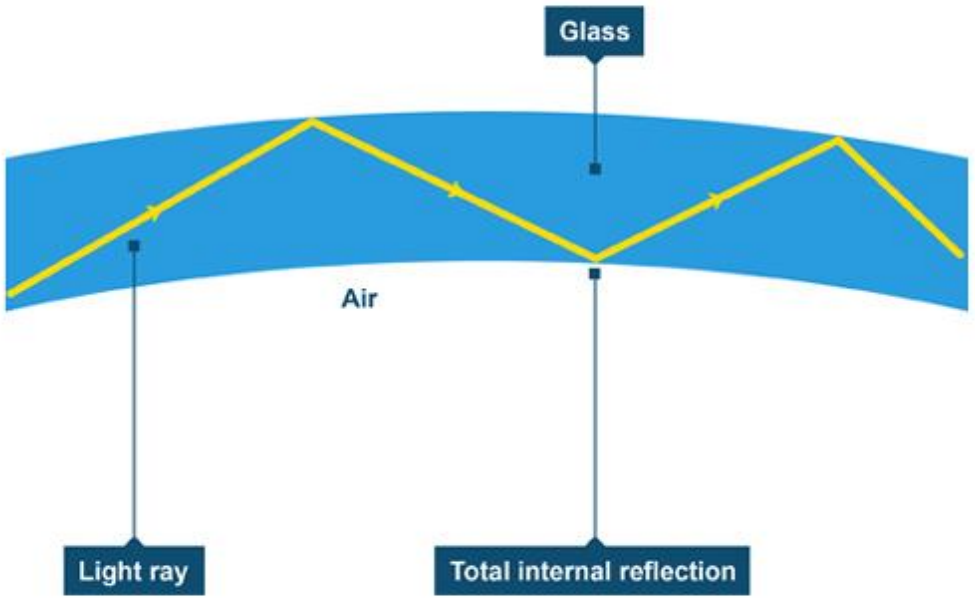


Transmission Sequence

1. Information is encoded into electrical signals
2. Electrical Signals are converted to digital or analog signals that modulate a laser.
3. Light travels down the fiber
4. A detector changes the light signals into electrical signals
5. Electrical signals are decoded into information

The Science

How Does it Work?



Total internal reflection: Encoded into a pattern of light waves, information travels through each optical fiber

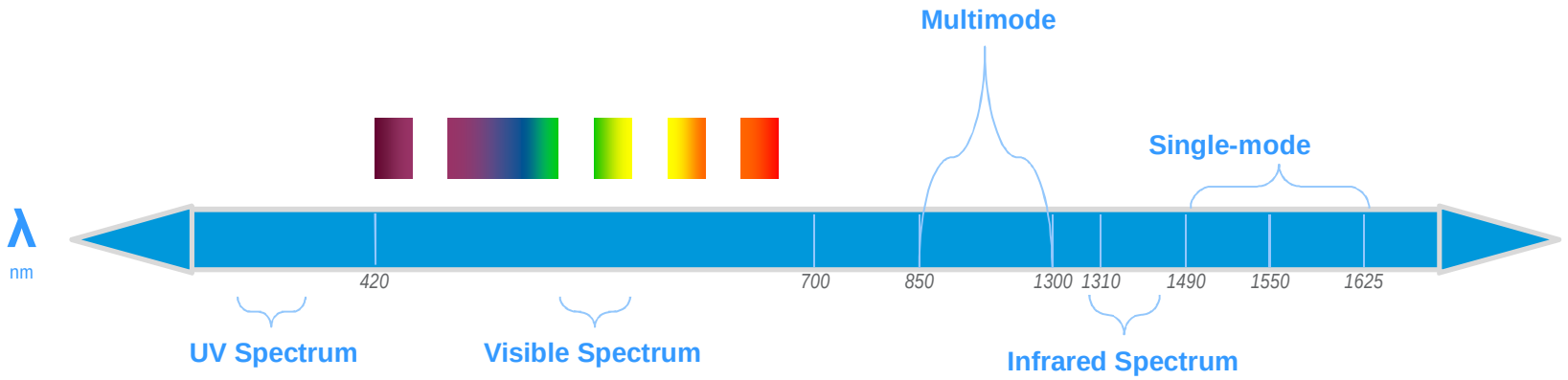
The waves move through the fiber from a given source to a destination such as an **O**ptical **N**etwork **T**erminal where it is then decoded.

The goal: Trap the light in the fiber and keep it there.

The Science

Electromagnetic Spectrum

Wavelength: The distance between identical points on a wave (nanometers or nm)

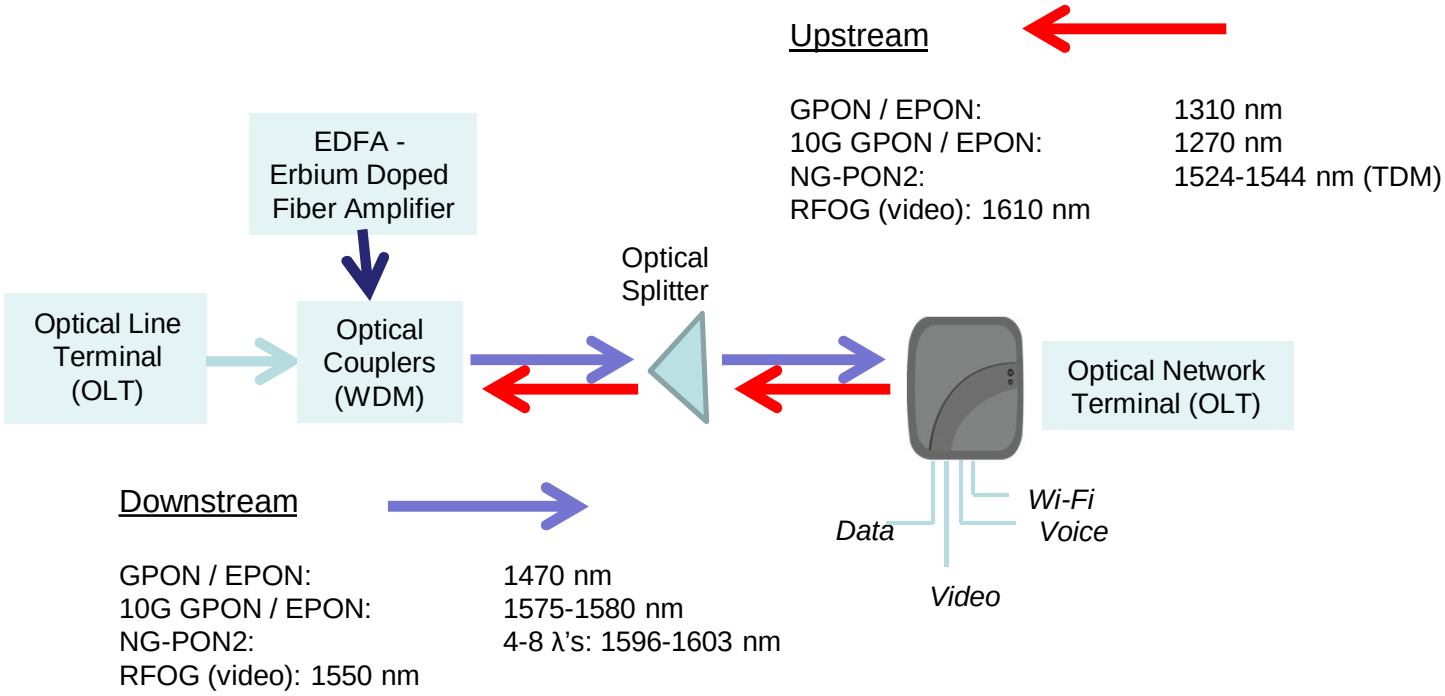


Operating Wavelengths:

- 850 nm = Short Wave Multimode
- 1300 nm = Long-Wave Multimode
- 1310 nm = Traditional Standard Single-mode
- 1490 nm = FTTx (Downstream Data/Voice)
- 1550 nm = Long-Wave Single-mode
- 1625 nm = Extra Long-Wave Single-mode (WDM)

PON Technology Wavelengths

Wavelengths selected by Standards bodies to support co-existence



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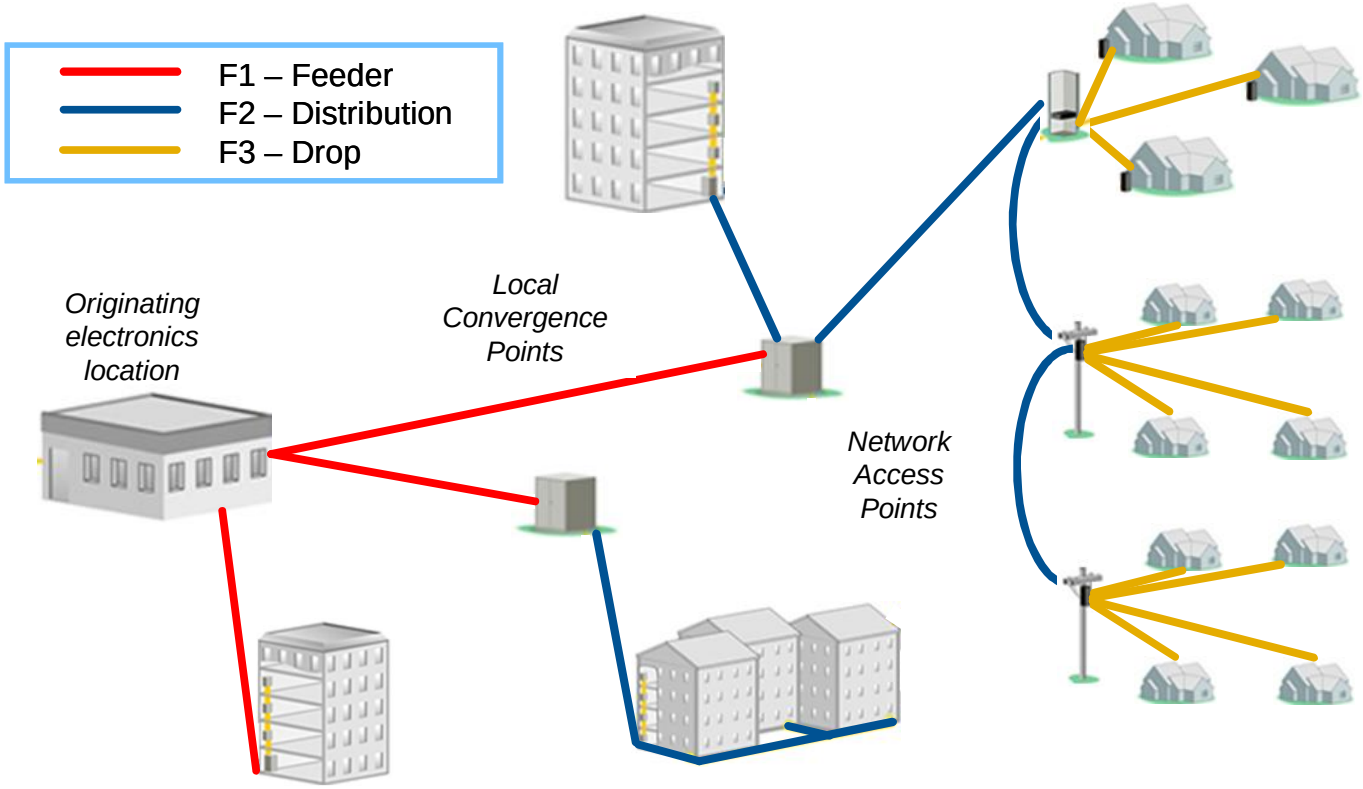
FTTH – Generic Component Layout



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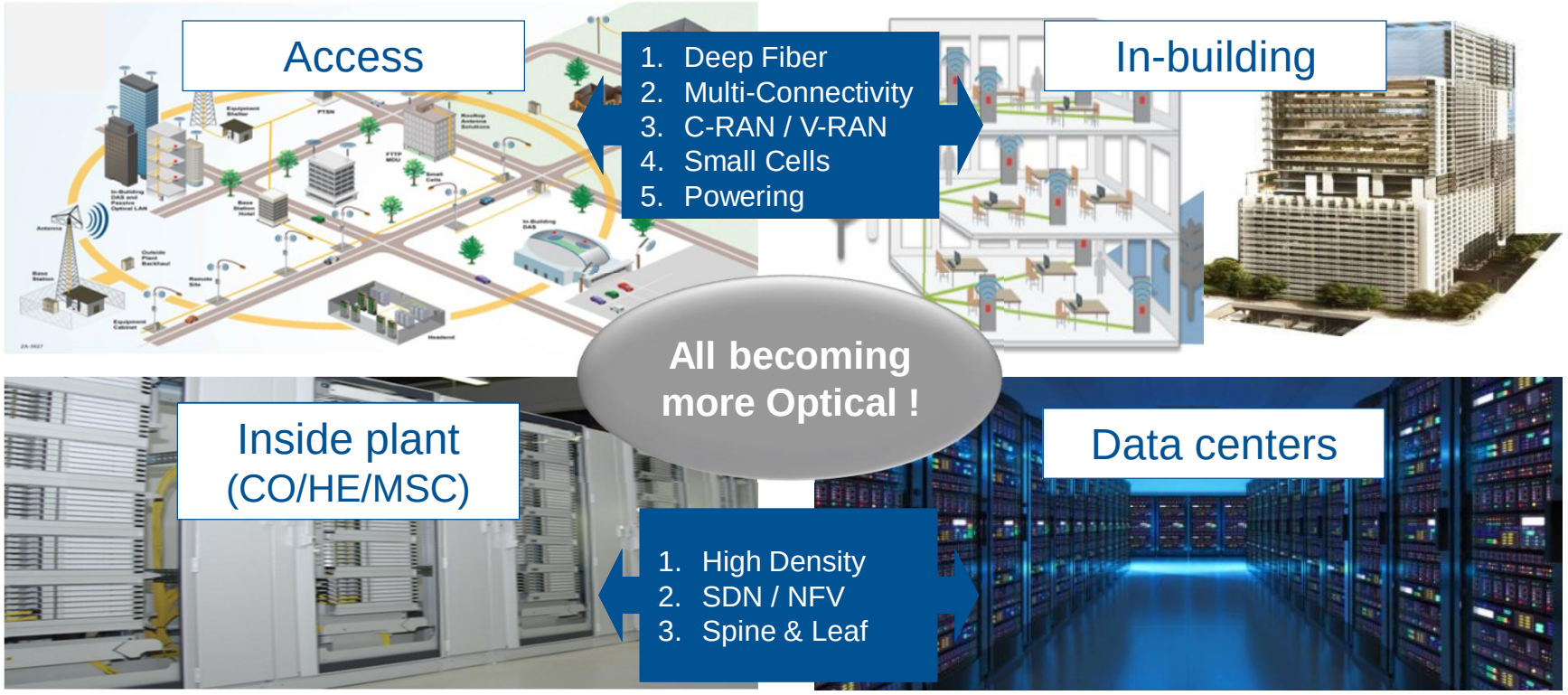
Some observations on trends and convergence



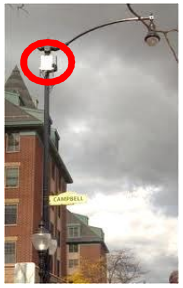
Market & Technology Trends:

Wireless Access as a Natural Complement to FTTx

Source: AT&T Analysis "A Small Cell Aug

Network investments targeted to today's needs will quickly age out.

Build with the end in mind: ubiquitous, high speed access



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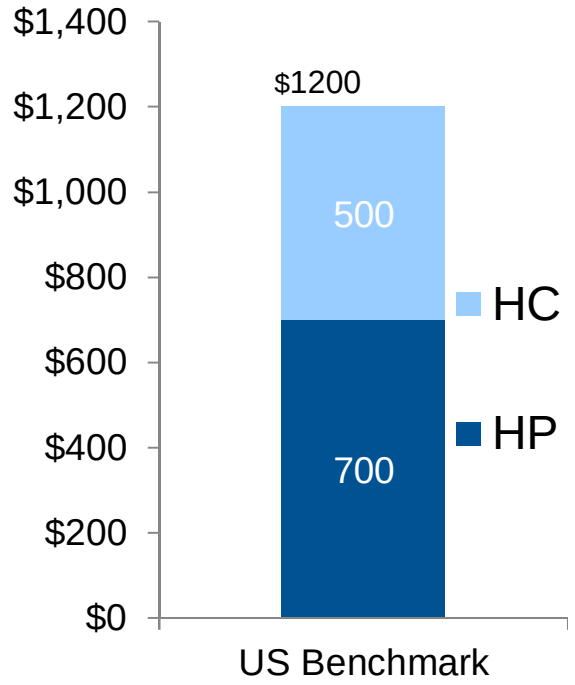
FTTH cost for US benchmark

Cost Highly Dependent on a Few Deployment Factors

US Benchmark Basic Assumptions	
• Buried/Aerial mix*: 50%/50%	
• SFU/MDU mix**: 70% 30%	
• Carriers build primarily to areas with the best business case	40%-75%
– Suburban/urban/high income/ high broadband penetration	
– Build in areas of highest competition	
• Over provisioning 1.2	
– Network built to support existing premises with some room for growth	
• No redundancy for residential users	
• "Demand drop" connect on service request	30%-50%
• ONT moving from outdoor to indoor	
– Placed immediately inside home access	



* Underground labor/deployment is 2-3 x higher cost than aerial

**SFU is typically 25% higher cost than MDU

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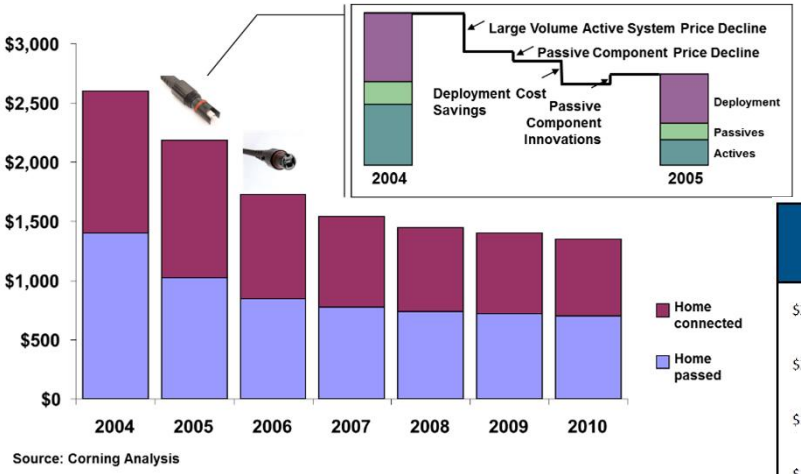
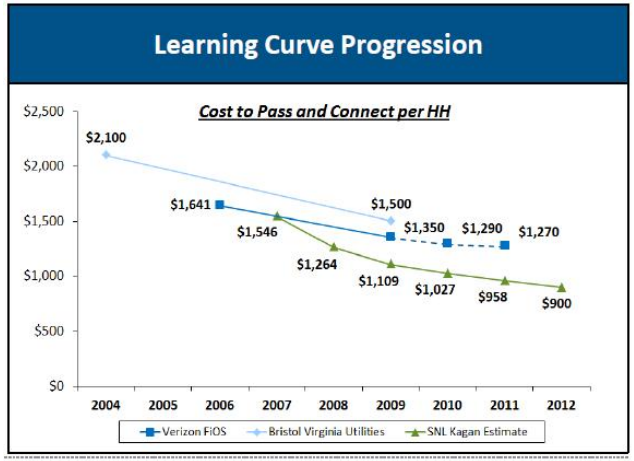
FTTH learning curves

All FTTP deployments have experienced learning curve cost improvements



Source: Corning Analysis

- Costs based on North American deployments
- Average of SFU/MDU, aerial, buried, factory terminated and pre-connectorized terminals.
- Buried labor costs can be 2-3x aerial labor costs
- MDU costs can be 20-40% lower than SFU costs

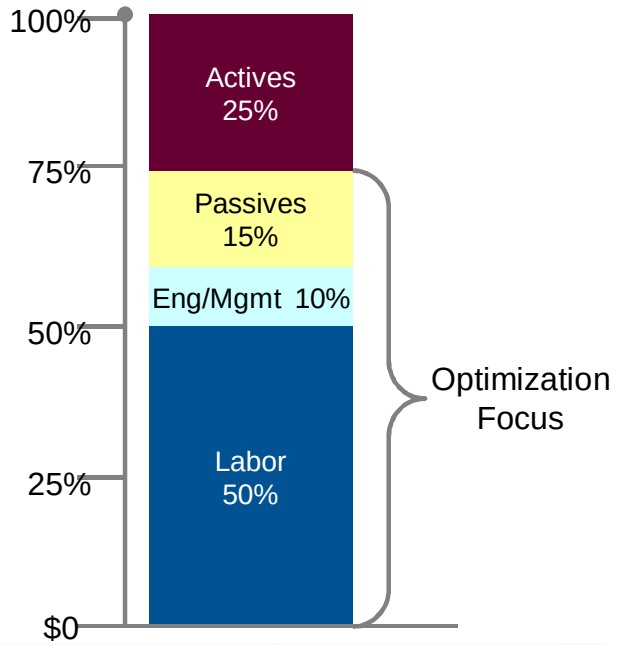


- Cost per premise is decreasing from earliest rollouts due to:
  - Improved field efficiency
  - Labour-saving methods
  - Materials cost reductions (purchase volumes)
  - Fixed cost allocation over a larger passed HH base

FTTH – Total Cost Equation

FTTH Characteristics

- Labor and installation account for half of the cost of deployment
- Availability of skilled labor is a challenge with large scale deployments
- Involves the installation of cable and up to 40 different hardware components
- Challenge is to reduce skilled labor requirements to enable deployment with a given level of man power



Labor costs make up an increasingly higher percentage of the total cost as equipment suppliers reduce network component/solution costs

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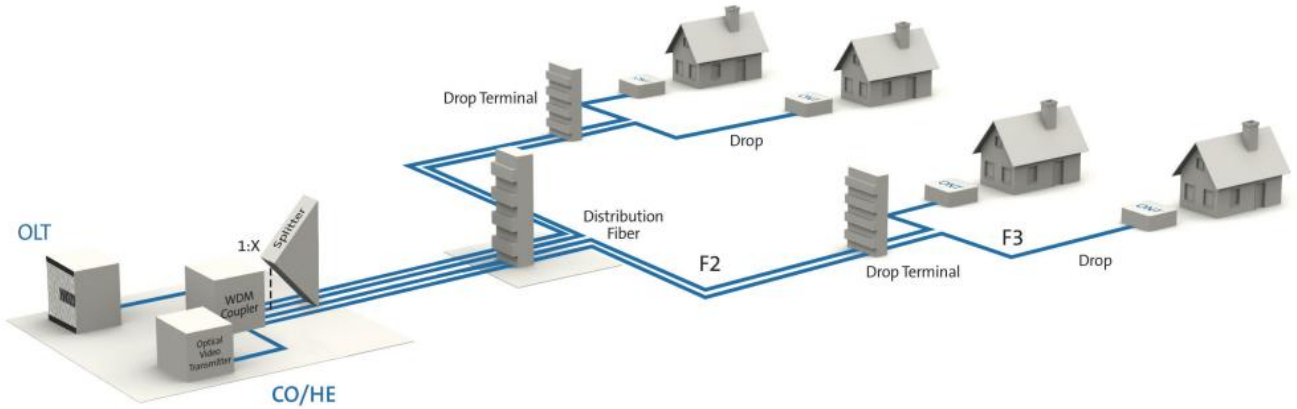
Central Switch Homerun (CSH)



Benefits

- Dedicated optical path to subscriber
- All switching and/or splitting at central point
- Highest bandwidth capacity and adaptability
- System admin from one location

Cost Considerations

- Additional up-front capital investment
- Fiber-rich F1 and F2 system
- CO/HE real estate

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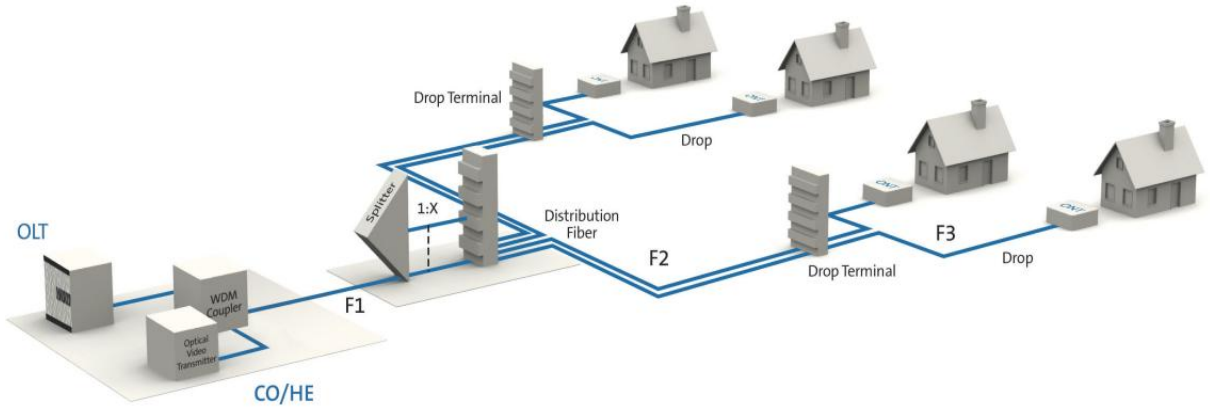
Local Convergence (LC)



Benefits

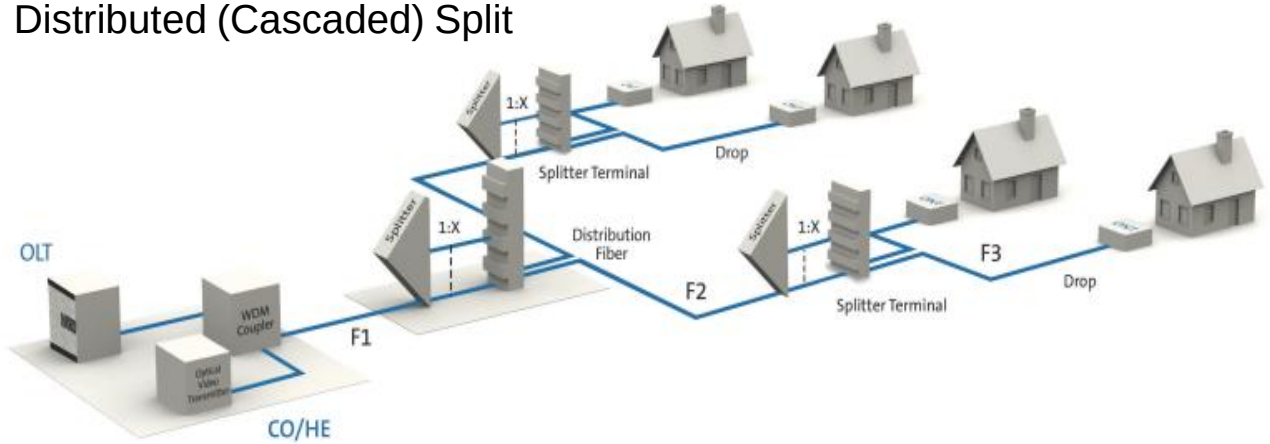
- Fiber lean feeder (F1) and fiber-rich distribution (F2) system
- Ability to transition to point-to-point with F1 upgrade
- Provides dedicated optical path from LCP to subscribers

Cost Considerations

- Requires truck-roll to LCP for splitter connection / management

Distributed Splitting (DS)

Distributed (Cascaded) Split



Benefits

- Uses fiber-lean feeder (F1) and distribution (F2) system
- Minimal up-front network CAPEX requirements

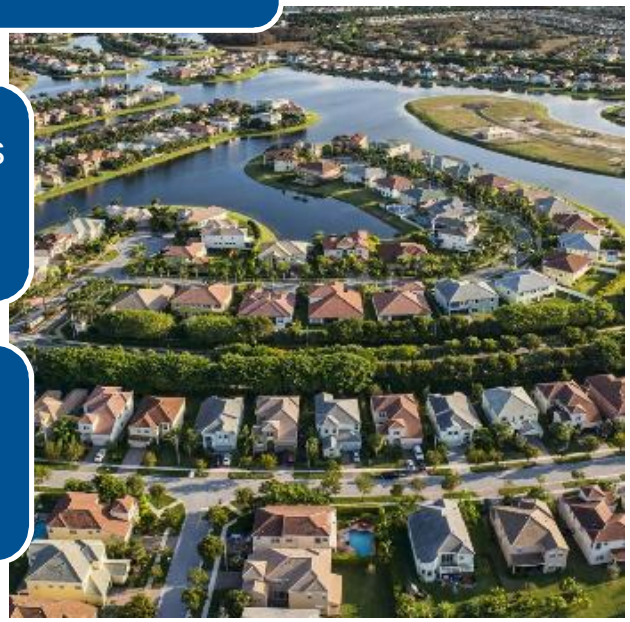
Cost Considerations

- Possible limitations on adaptability and scalability
  - No single splitter configuration or adaptation point
  - More complex system administration

Architecture and Deployment Considerations

Architectural choices driven factors such as

- Initial and target take rates
- Active electronics / services requirements
- Capital (CAPEX) vs. Operational expense (OPEX)
- Growth strategy

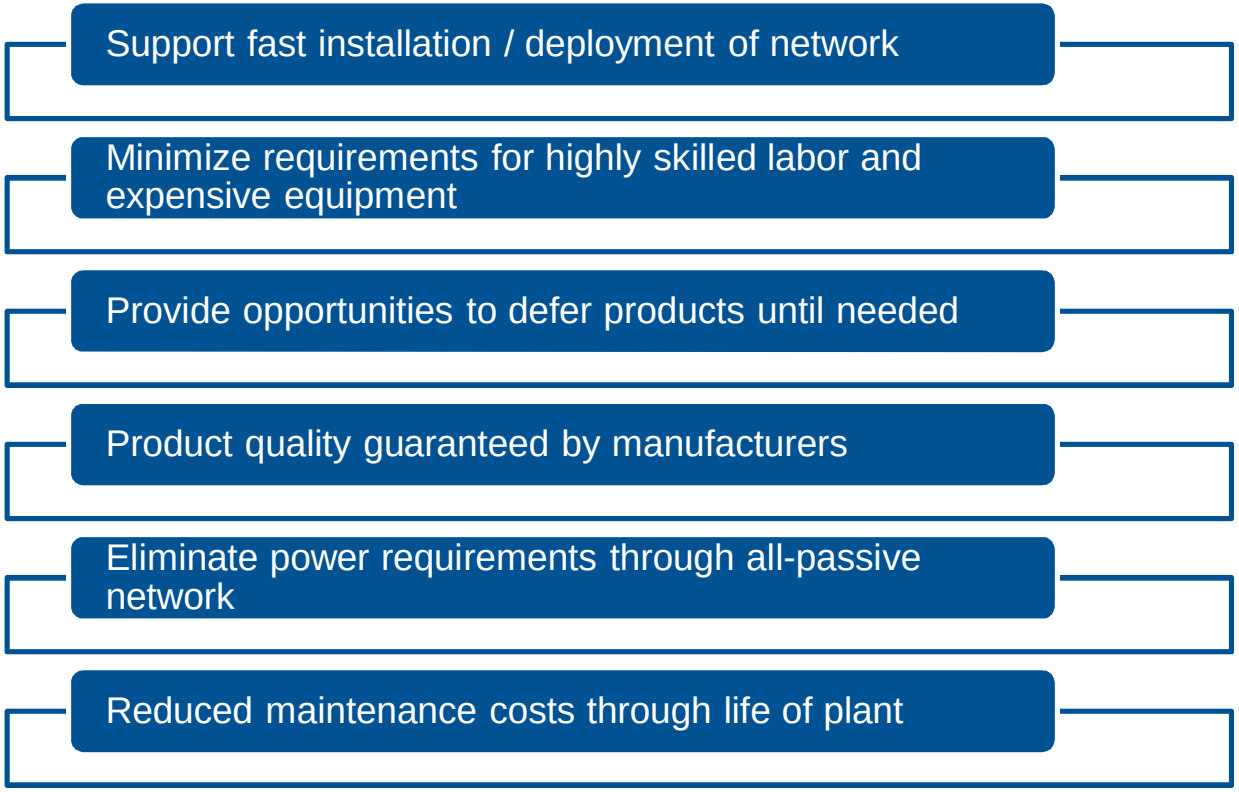


Take Rate

- The percent of homes passed that subscribe and generate revenue for provider
  - Anticipated take rates initially and over time impact investment / CAPEX decisions

Low Take Rate Anticipated	Med to High Take Rate Anticipated
Look for ways to lower initial CAPEX	Higher CAPEX supported by higher potential revenue
Product deferment to be considered	Less product deferment needed

PON Benefits



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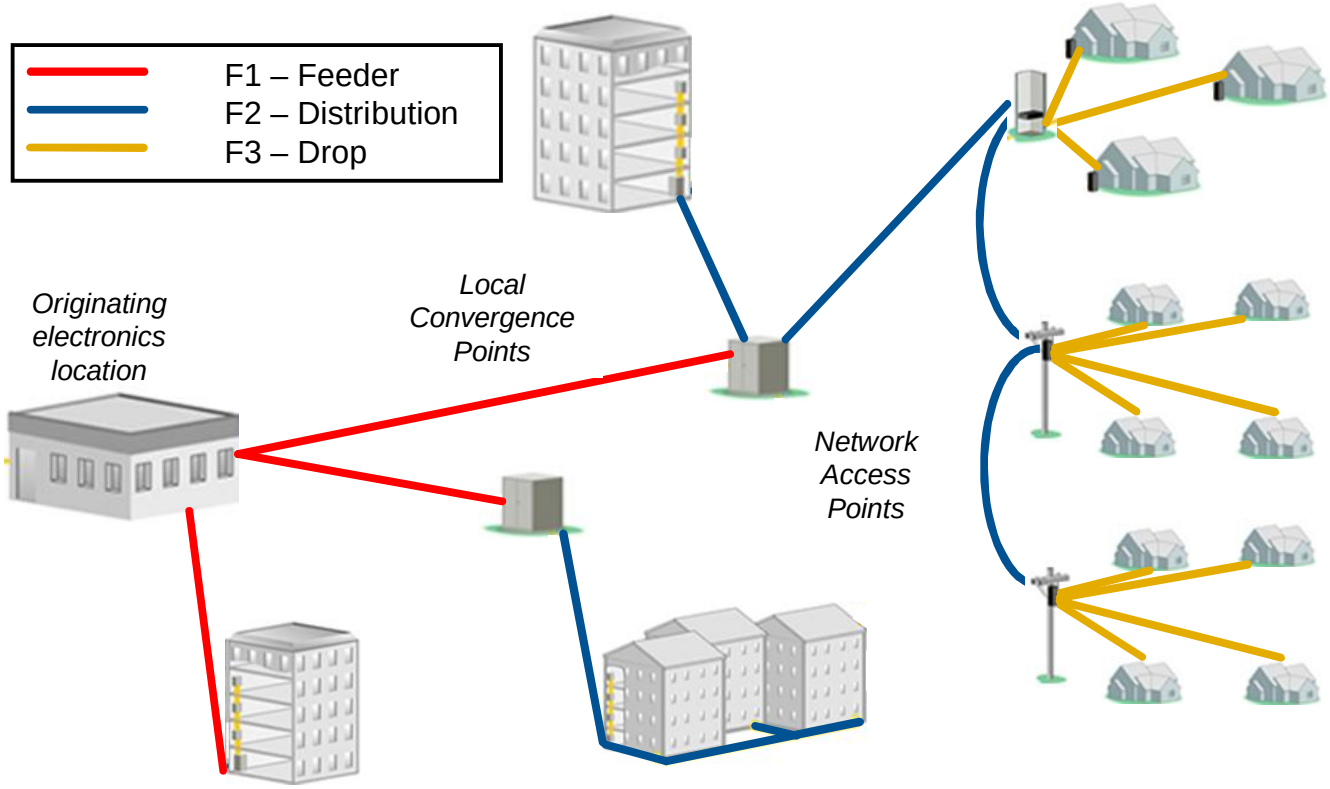
Product Application Areas



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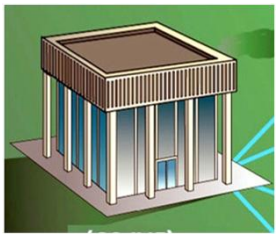
Head End

- Location of originating electronics
- Can also be located in hut, cabinet or node



CSH architecture

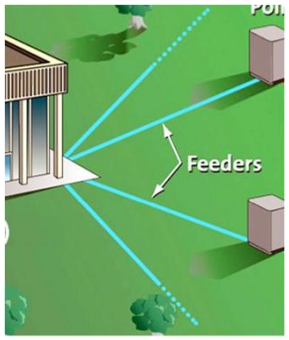
- Manage both splitters and distribution fibers in rack
- Potentially large number of fibers
- Maximize OLT / splitter port usage

LC / DS / SS architectures

- No splitters in HE
- Smaller number of fibers than CSH

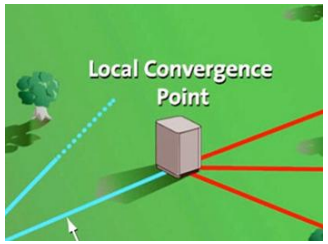
Feeder (F1) Cable

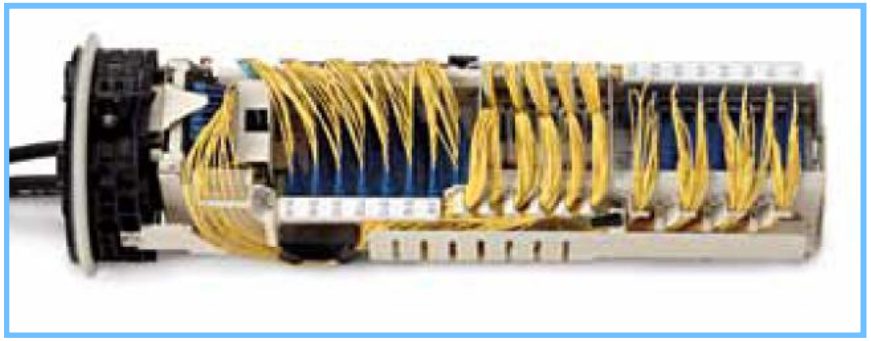
- Located from HE to Local Convergence point
- Minimal mid-spans compared to F2 cable
- CSH architecture
  - High fiber counts
- LC, DS, SS architectures
  - Mid to low fiber counts



Local Convergence Point

- May be splice point or cross-connect cabinet in CSH architectures
- Houses splitters in LC, DS and SS architectures
- Connectors provide for easy adds, drops, changes





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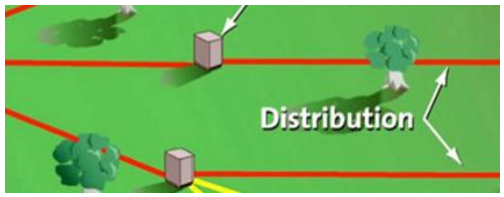
Distribution (F2) Cable Products

- Brings fiber from convergence point to locations near homes
- Cable accessed multiple times
  - Higher fiber count designs may make access more difficult
  - Typically loose tube cable for ease of access
- Pre-terminated cable options available
- Can use same cable types as feeder cables
- Aerial / buried / duct installations
- All dielectric or armored



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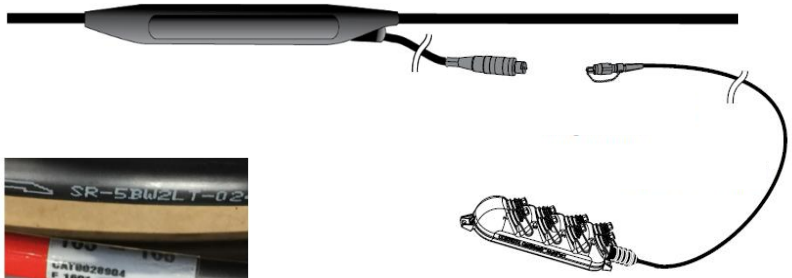
Distribution Cable

- Bulk Cable
- Pre-terminated FlexNap™ cable
  - Supports fast deployment of network – reduces access and splicing in field
  - Tap placement customized based on specific requirements
  - “The design is marked on the cable” – locations IDs, fiber assignments at locations, terminal count, tap and tether #, slack
  - System generated splice plan for each cable
  - Allows deferment of drops and multiports



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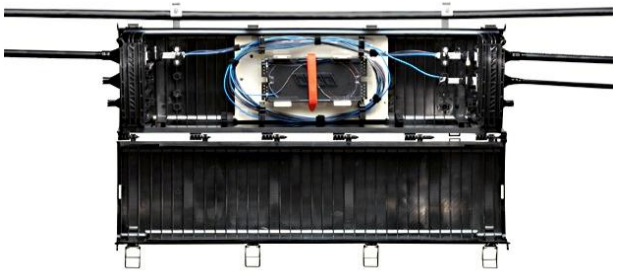
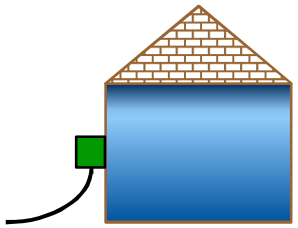
Network Access Point (NAP)

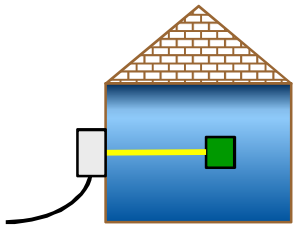
- Splice terminals
- Multiports
- Taps included in pre-terminated FlexNap cables

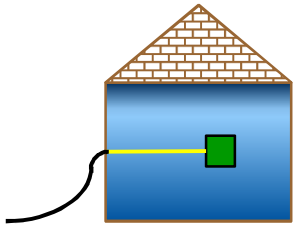


Connecting to the ONT

- Outdoor ONT
  - Direct connection from drop cable
- Indoor ONT
  - Transition between outdoor and indoor drops
- Indoor / outdoor drop cable
  - Eliminates transition requirement







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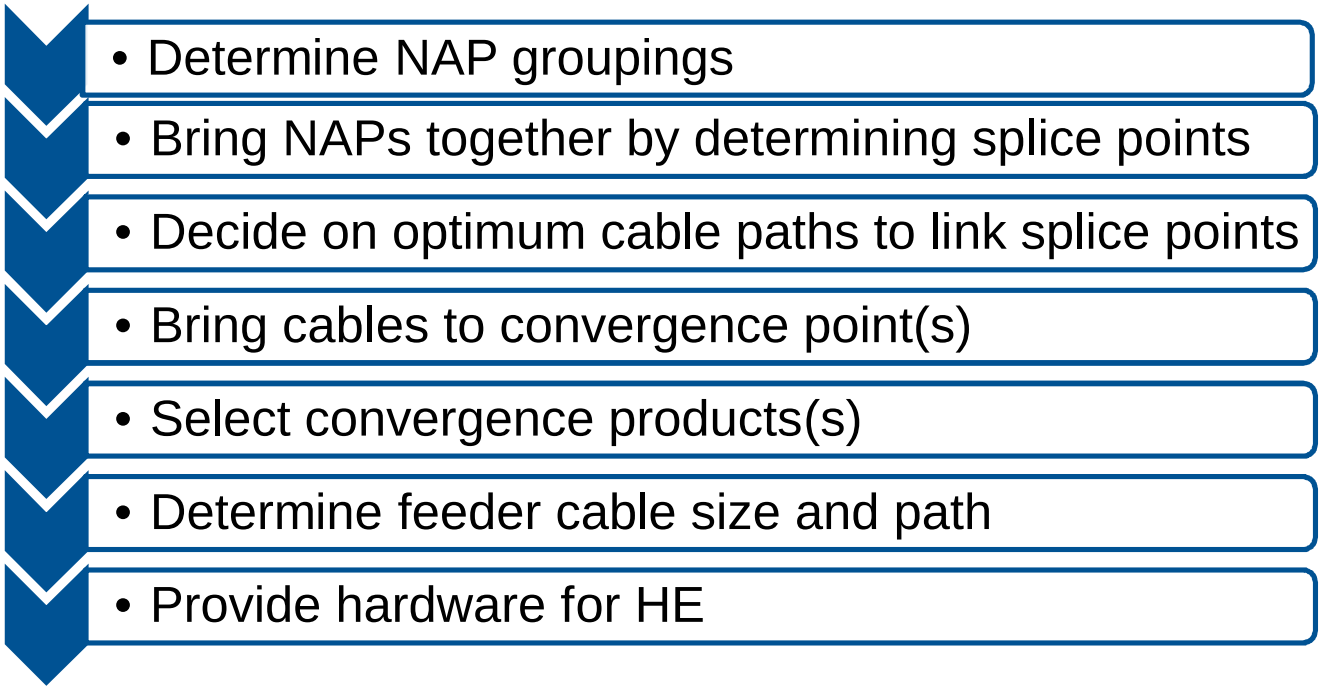
SFU Design and Cost Considerations

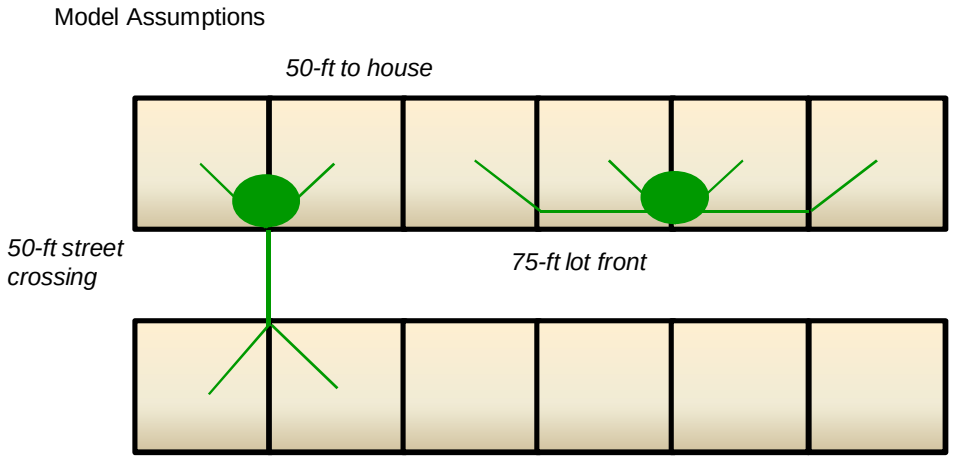
Overview of Design Process Steps

"Start from homes and work back"

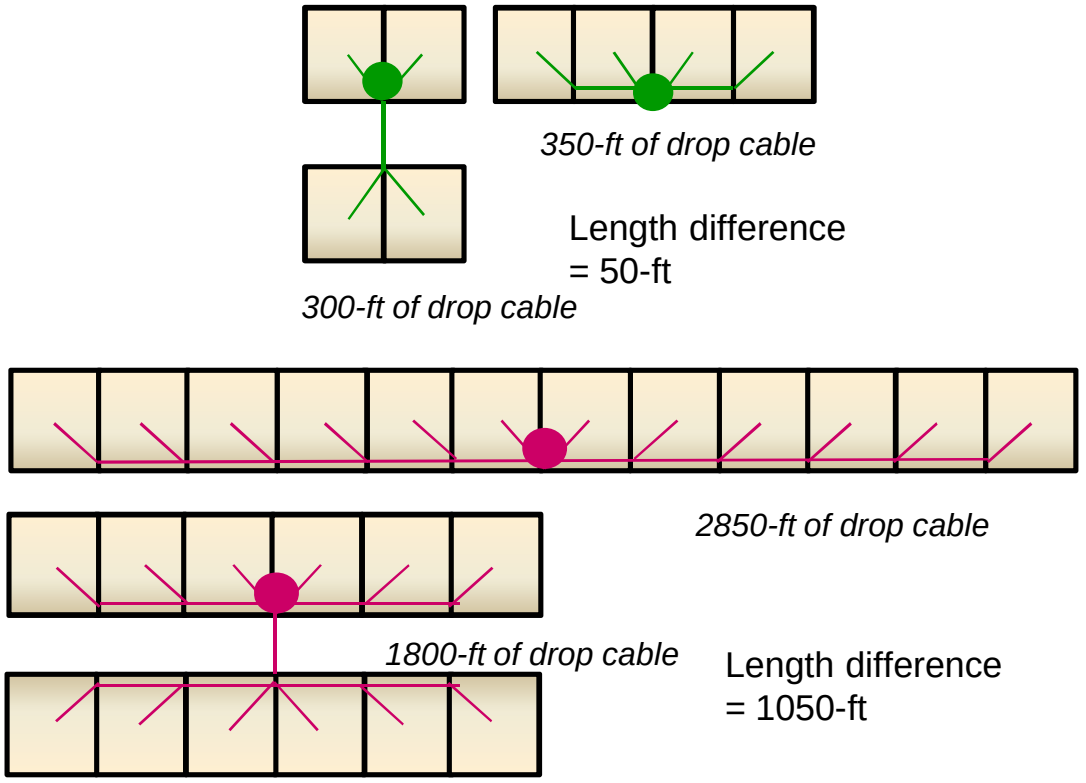


Impact of Crossing Street with Drops

- Typically requires shorter drop lengths
- Reduces number of lot crossings
- Installation requirements have big impact
  - Trench, pull or bore across lot or street



Drop Length Impact (crossing vs. same side of street)



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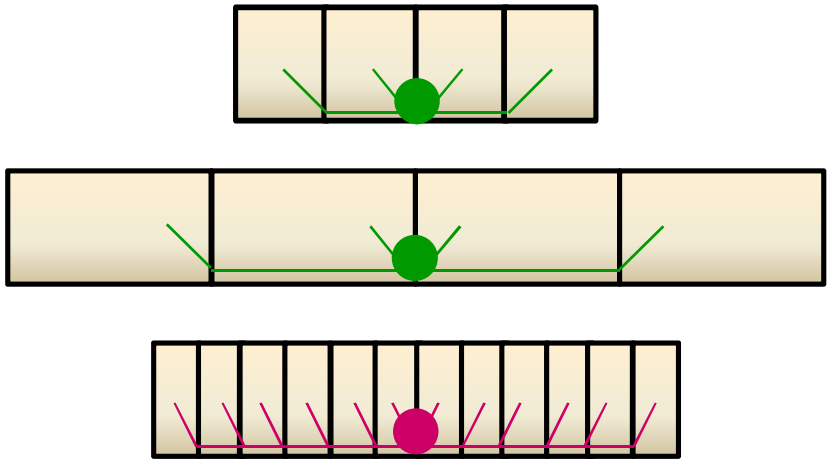
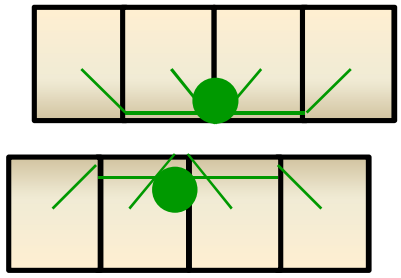
Lot Front Distances

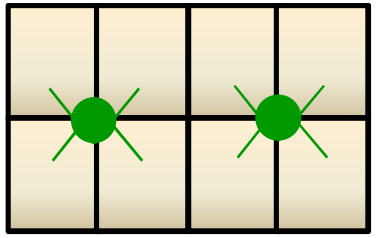
- Larger lot fronts require longer drops
- Cost of longer drops and to install drops might outweigh savings gained from larger NAP size
- Dense areas may benefit from large NAP size



Street front vs. Back lot

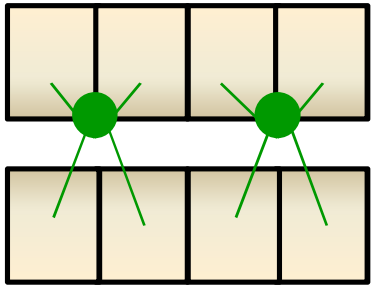


Street front



More prevalent in Greenfield

Back lot



Aerial

Easy to defer drops

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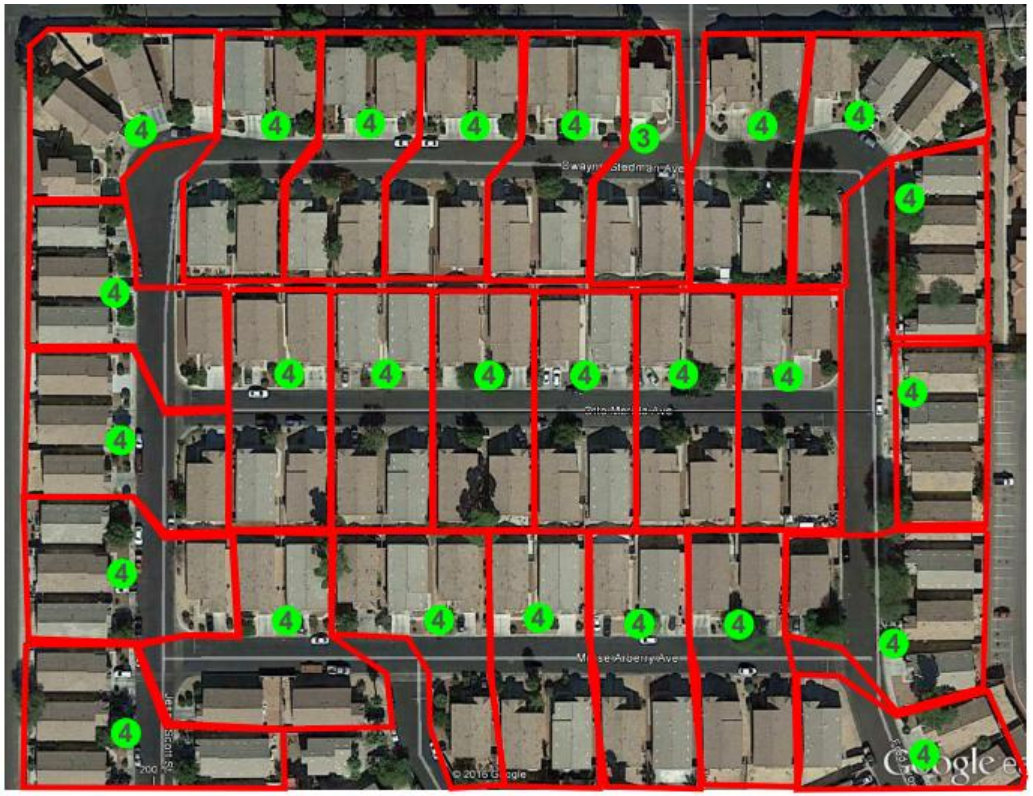
Sample Design – NAP Placement



4-port Multiport (# HP)

Wiring limits

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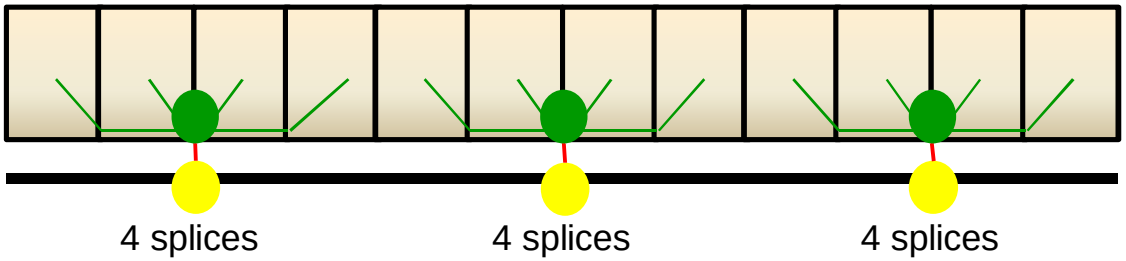
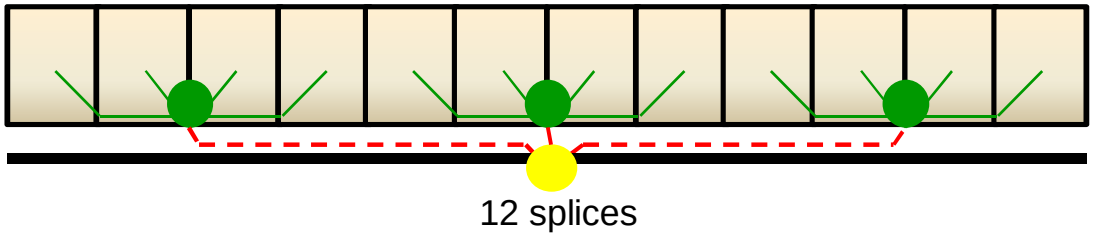
Determining Cable Access Points

Factors to consider

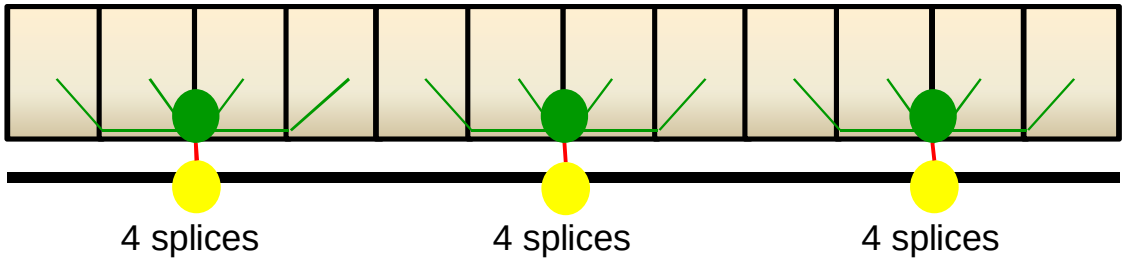
- Impact on deployment speed
- Physical cable access
  - Slack cable placement / requirements
  - Products needed to store splice product and extra cable
- Cable paths
- Fiber splicing
  - Setup cost
  - Per splice cost
- Product costs
  - Different products required for different splicing strategies
- Product inventory impacts

Cable Access Points – One Side of Street



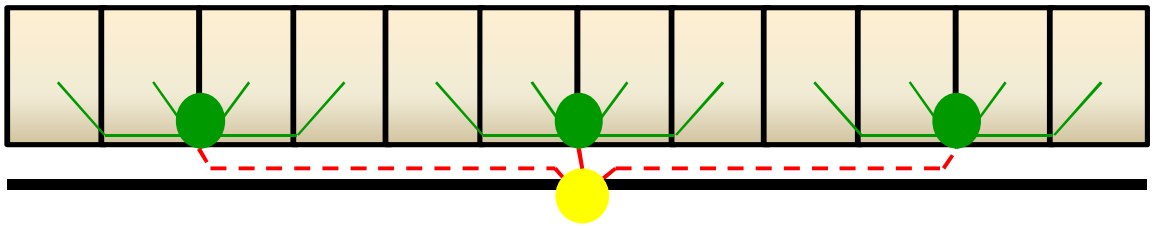


Access Cable at Each NAP Point



- Considerations
  - Three cable midspans
    - Splice setup time and charges
    - Cable fiber count impacts ease of accessibility
    - Additional slack / slack storage
  - Three splice closures / terminals / multiports

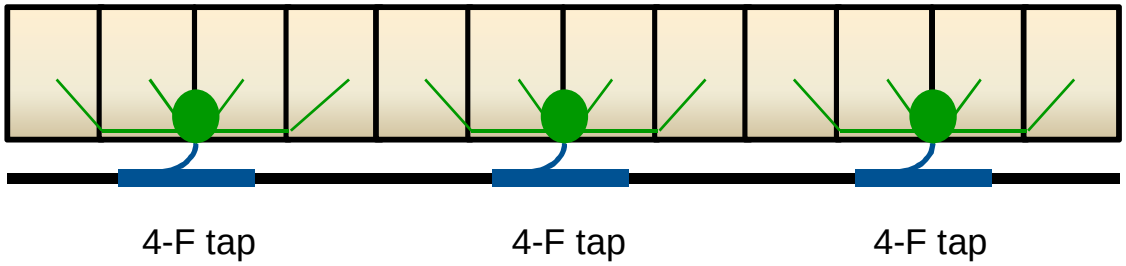
Access Cable at Single Point



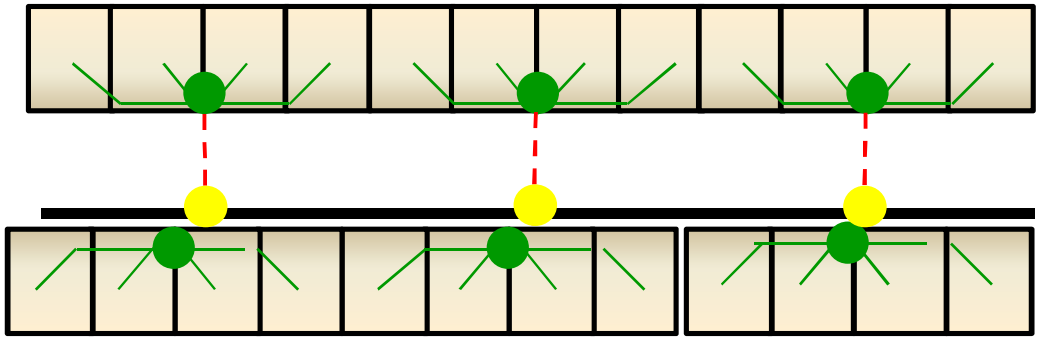
- Considerations
  - One cable midspan
    - Decreases splice setup time and charges
    - Reduces slack / slack storage
  - Requires multiport tail installation
    - Installed with distribution cable or separately
    - May be able to be deferred
    - May require additional per-foot charges
    - Can be significant based on multiport tail lengths

FlexNAP™ System

- Replaces splice points with factory installed tap
- Allows deferment of multiport

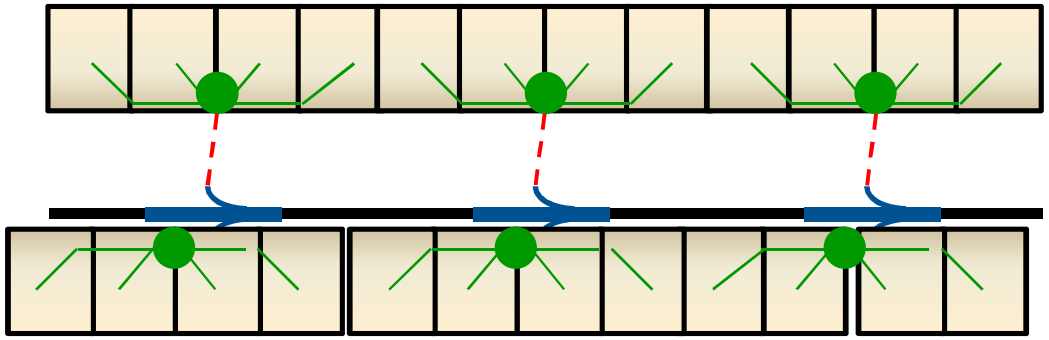


Splicing – Access Cable and Cross Street



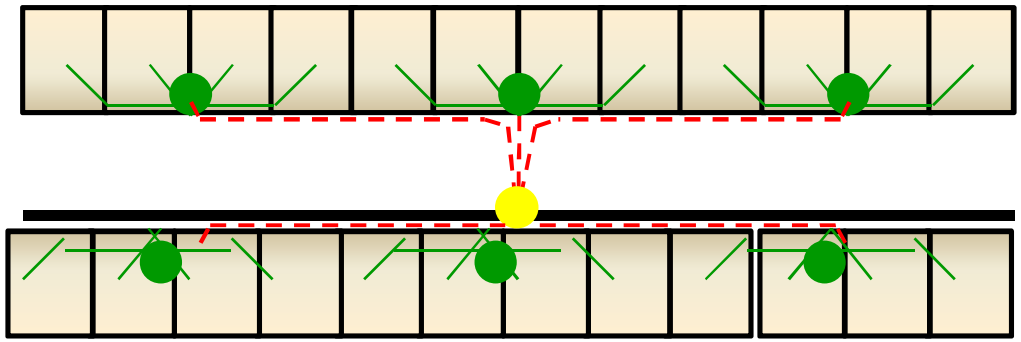
- Considerations
  - Three cable midspans
  - Multiport tail installation for 2nd multiport
  - Cost to install across street

FlexNAP™ System – Access Cable and Cross Street



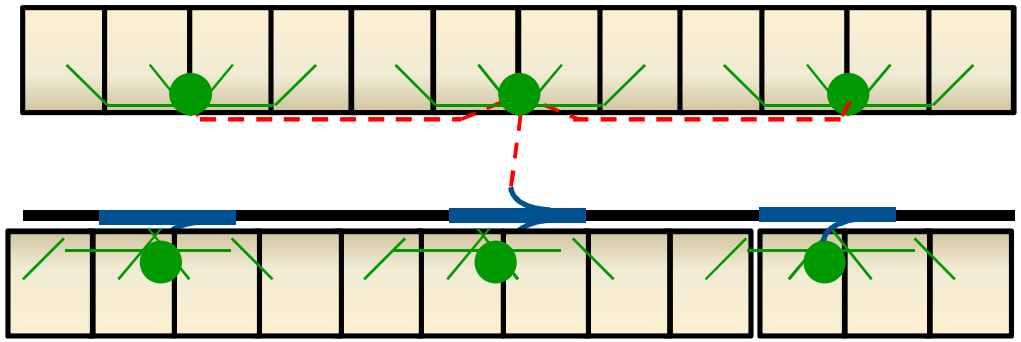
- Decision Factors
  - Cable midspans eliminated
  - Ability to defer local multiports
  - Additional cost for three pre-installed taps
  - Multiport tail installation for 2nd multiport
  - Cost to install across street

Spliced Cable – Access Cable at One Point



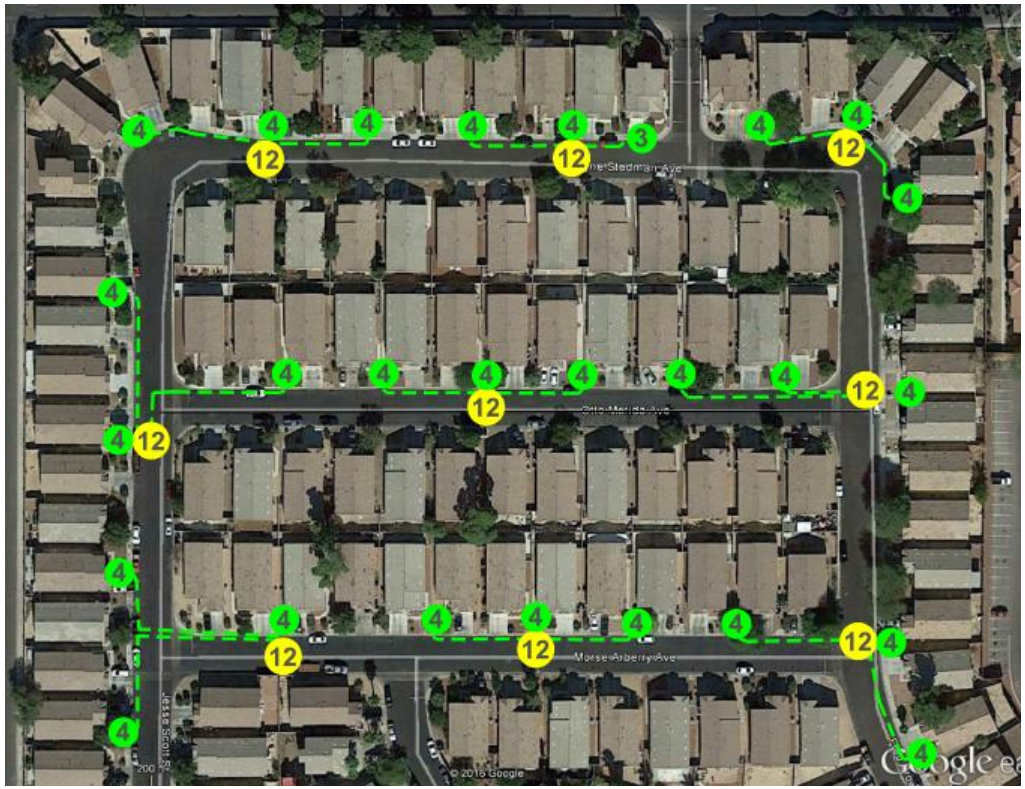
- Considerations
  - One cable midspan
  - One street crossing
  - Costs to install multiple multiport tails

FlexNAP™ System – Access Cable at One Point



- Considerations
  - Cable midspan eliminated
  - Single street crossing
  - Ability to defer local multiports
  - Costs to install multiple multiport tails

Sample Design – Multiport Tails and Splice Points



4-port Multiport

Splice point

Multiport tail

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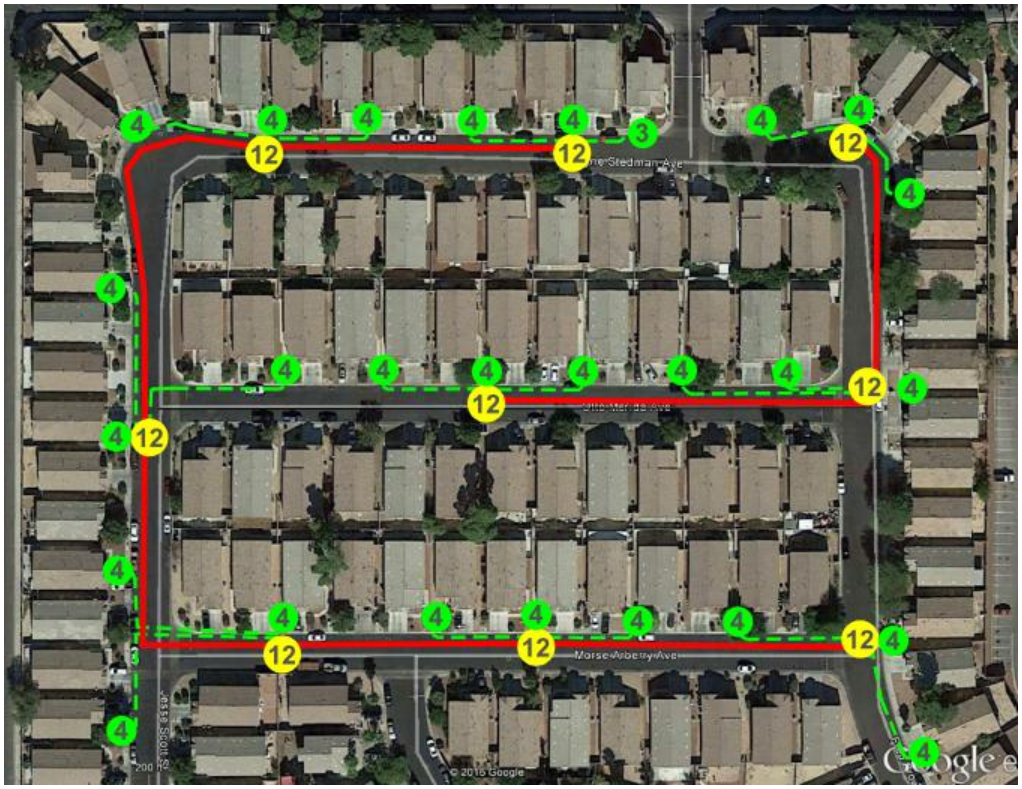
Sample Design - Cable Paths



4-port Multiport

Splice point

Multiport tail

Cable Path

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Sample Design – LCP Placement

- # 4-port Multiport
- # Splice point
- Multiport tail
- 96-F cable (72F / 24 spare)
- 48-F cable (36F / 12 spare)
- 144F cabinet 108F (4) 1x32 splitters

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Sample Design – FlexNap Cable

- # 4-port Multiport
- # Splice point
- FlexNap tap
- 96-F cable (68F / 28 spare)
- 48-F cable (40F / 8 spare)
- 144F cabinet 108F (4) 1x32 splitters

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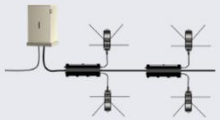
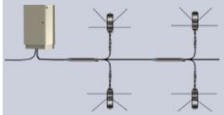
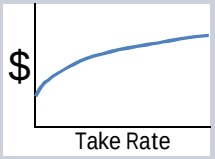
Three Basic Solution Families

Evaluated Against Large-Scale Deployment Challenges

	Capex/ Opex Equation	Speed / Cost of Installation	Optimal Subscriber Density	Level of Risk assumed	Optimal Method of build
Full Splice 		• Fast planning • Slow first install • Slow subscriber connection • $$$ Labor	Low to Medium	Moderate to High	Aerial, Duct, Plow, Trench
Semi Splice 		• Medium planning • Slow first install • Fast subscriber connection • $$ Labor	Low to High	Moderate	Aerial, Duct, Plow, Trench
Light Splice 		• Detailed planning • Fast first install • Fast subscriber connection • $ Labor	Medium to High	Low	Aerial, Duct (others possible but less common)

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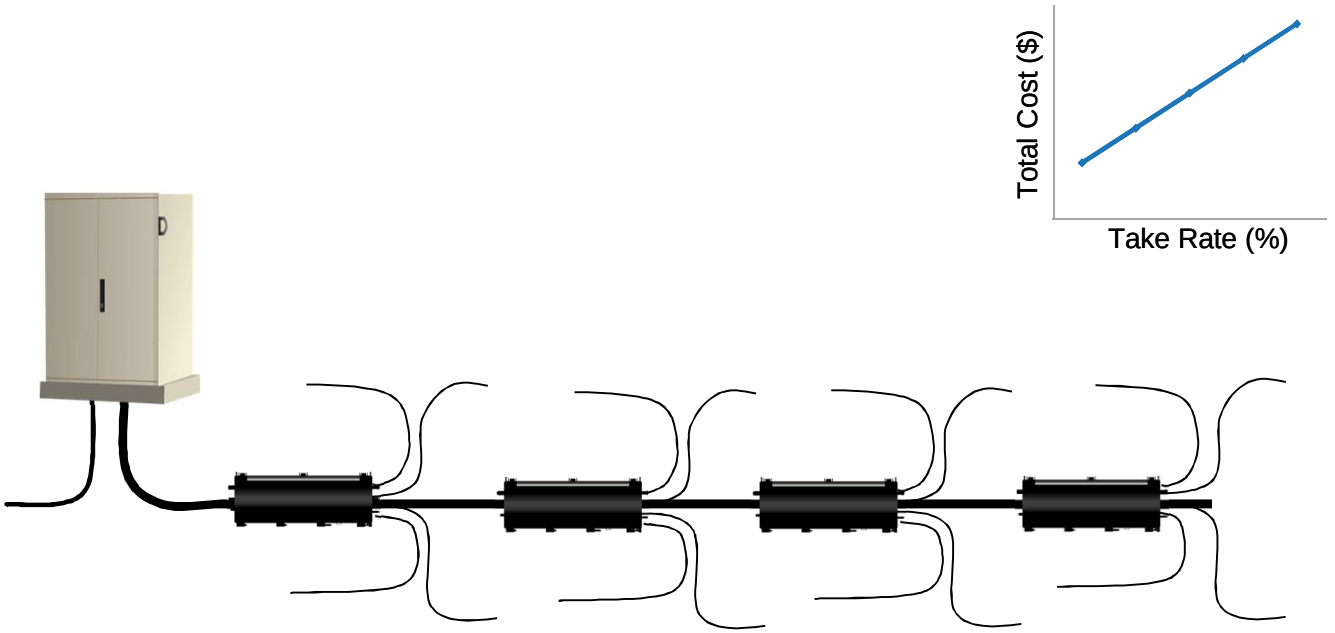
Total Cost Curve:

Full Splice



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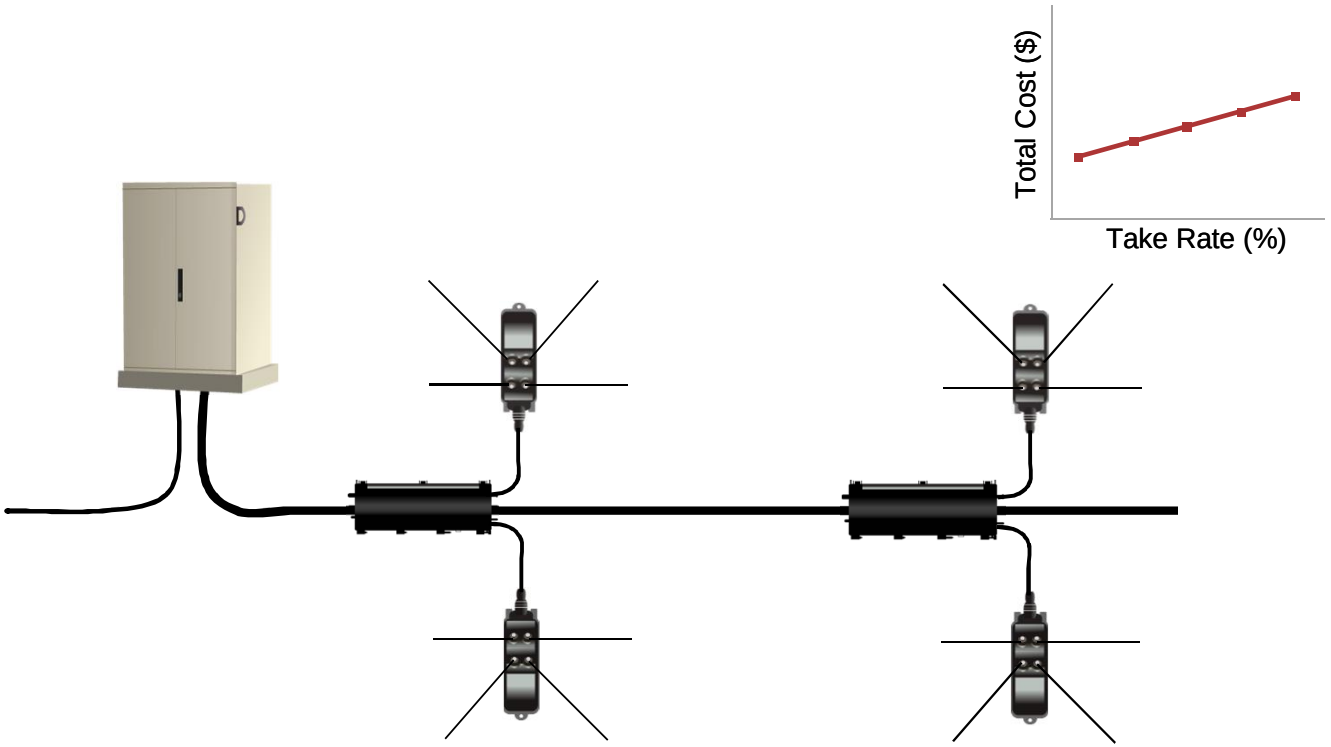
Total Cost Curve:

Semi-Splice



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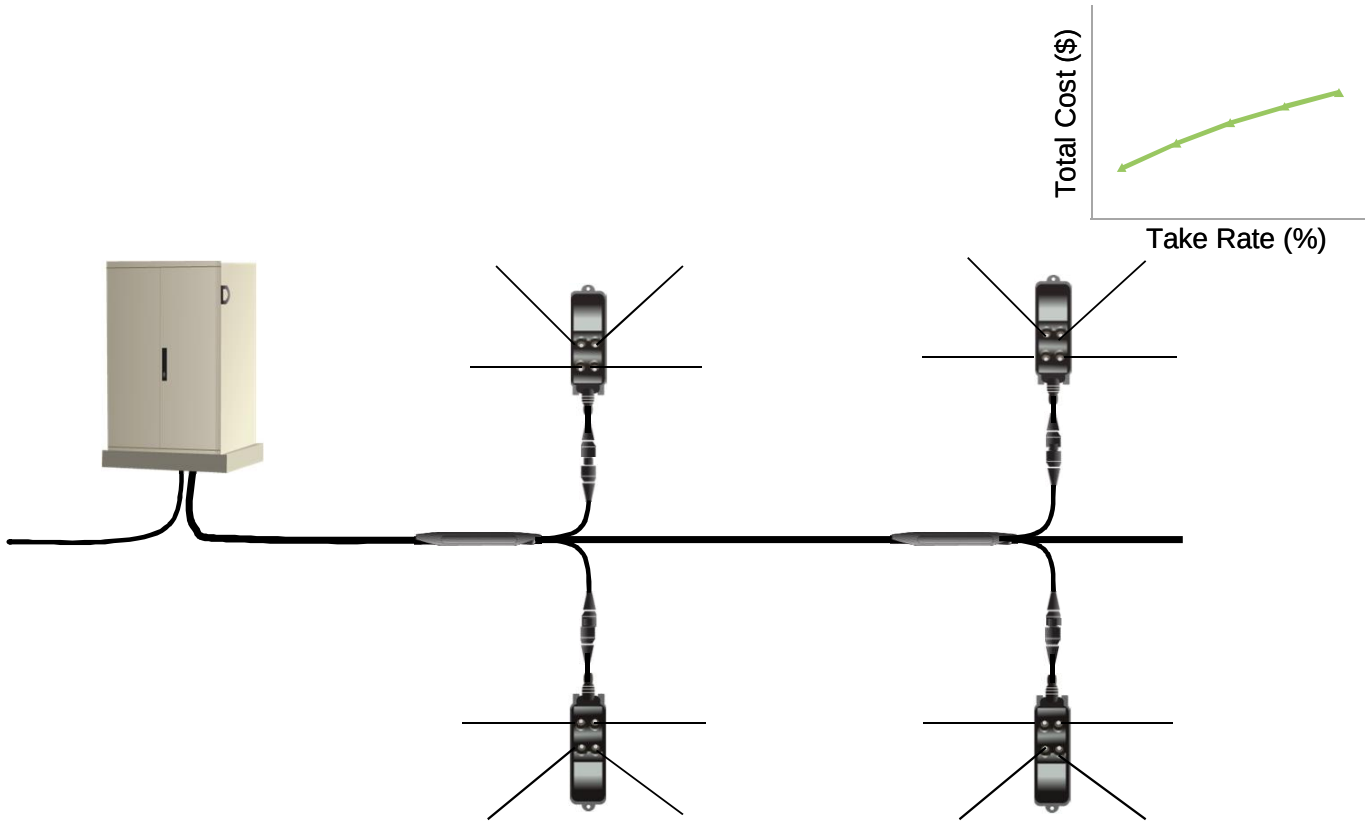
Total Cost Curve:

Light Splice



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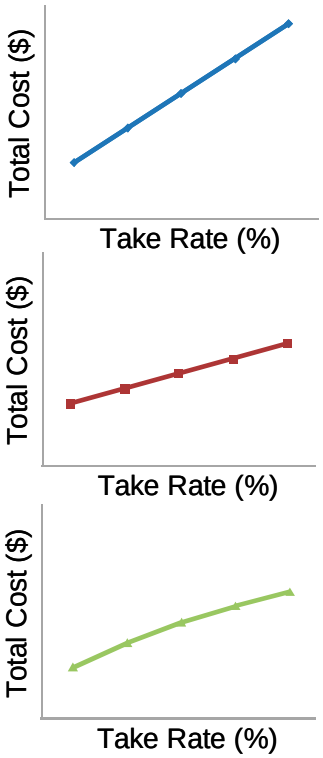
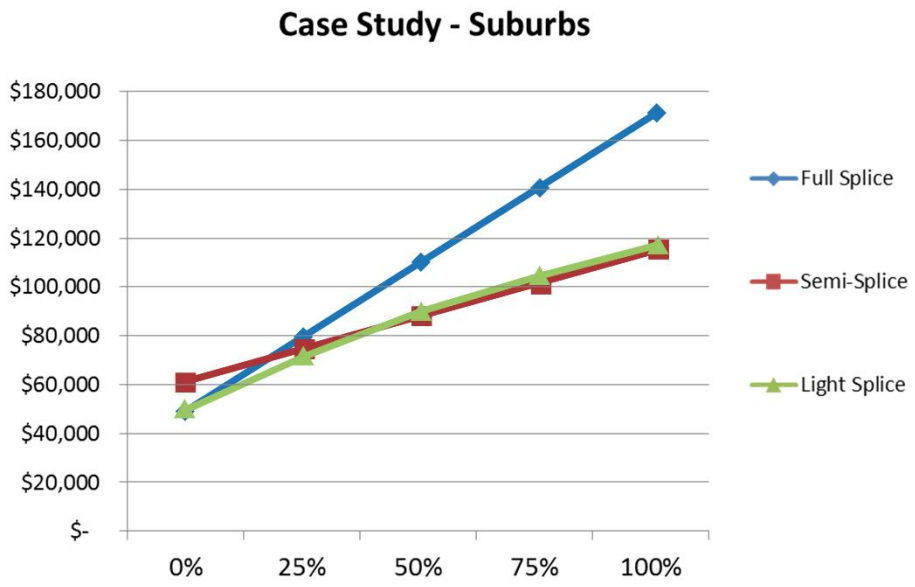
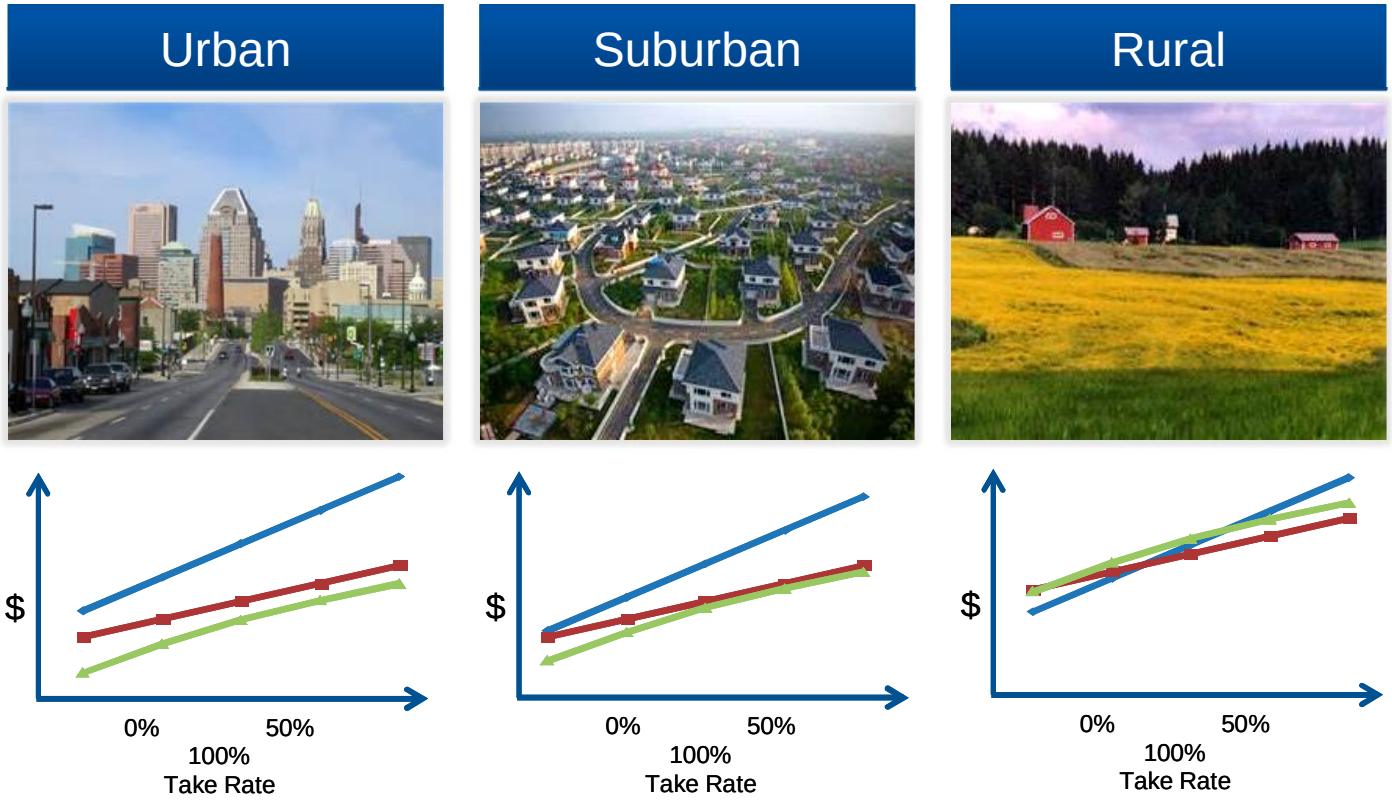
Total Cost of Ownership





Optimization Around Subscriber Density



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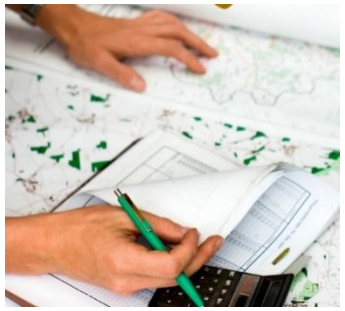
Time Savings Enabled by Optimized Solutions

Cable Placement	Splicing	Testing and QC	Whole Service Area
			
Cable placement footage reduction of **10% to 20%** Example: Cable pull reduced from 3 days to 2 days	Splicing time reduction of **50% to 70%** Example: Splicing time per build reduced from 5 days to 2 days	Testing and network QC reduction of **50%-70%** Example: One day of testing reduced to 2-4 hours	Total Design Area Build Time Reduction of slightly over **3x** Example: Complete LCP service area reduced from 20 days to 6 days

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MDU Demographics: Building Size

< 3 Floors; 12 Living Units

< 6 Floors; 72 Living Units

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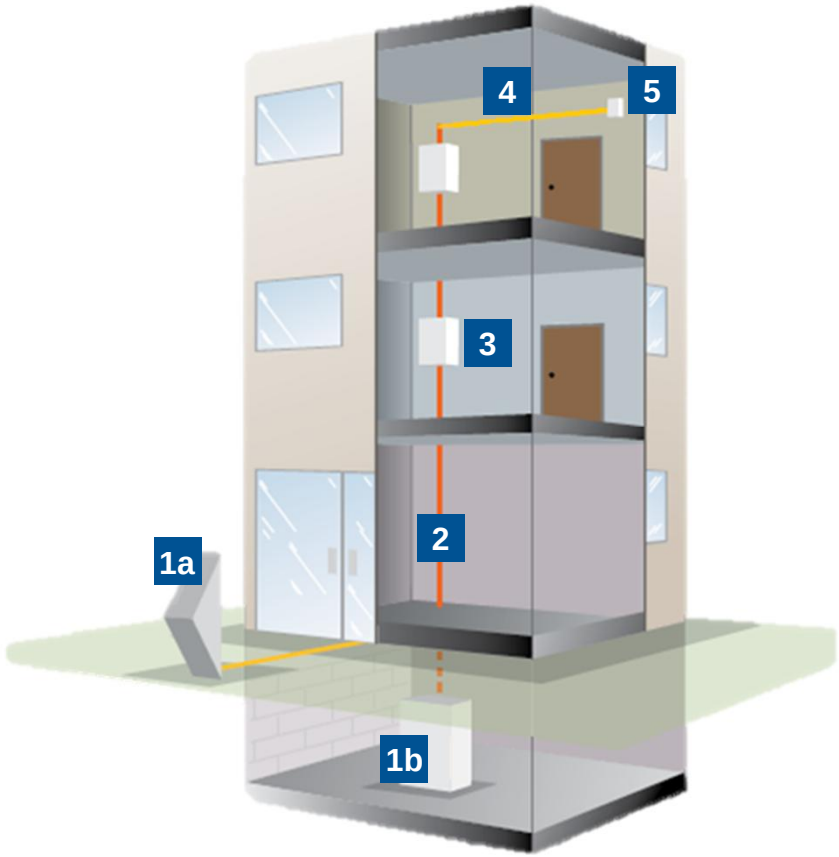
MDU Application Spaces

1. Splitter Cabinet (Outdoor or Indoor)
2. Riser Cable
3. Floor Distribution Terminal (FDT)
4. Horizontal Drop Cable
5. Premise Connection Point



Challenges in the MDU Space

- Unique access, distribution and routing challenges in every building
  - Infrastructure planning for every MDU
  - Fiber pathways cannot always be hidden
  - Various building sizes/architectures require different solutions
- Existing ducts are full, unusable, not continuous
- Limited space in the basement and in the floors for hardware and cable management
- Negative impact on tenants during install
- Timing – gaining builder/owner permits, then quickly completing the installation
- Working with or around other contractors

MDU Deployment Options

Full Splice



- Slowest to deploy with spliced drops
- Labor intensive with highly skilled workers
- Least upfront planning (measure to length)
- Low initial material cost; Highest total cost

Semi-Precon



- Pre-conn. drops for subscriber connection
- Slow initial install (labor to splice terminals)
- Medium upfront planning effort needed
- Moderate level of risk during installation

Full Precon




- Fastest installation with full preconn.
- Lowest total installed cost solution
- Highest level of pre-engineering upfront
- Minimized risk, least intrusive install

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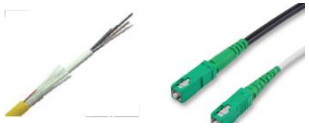
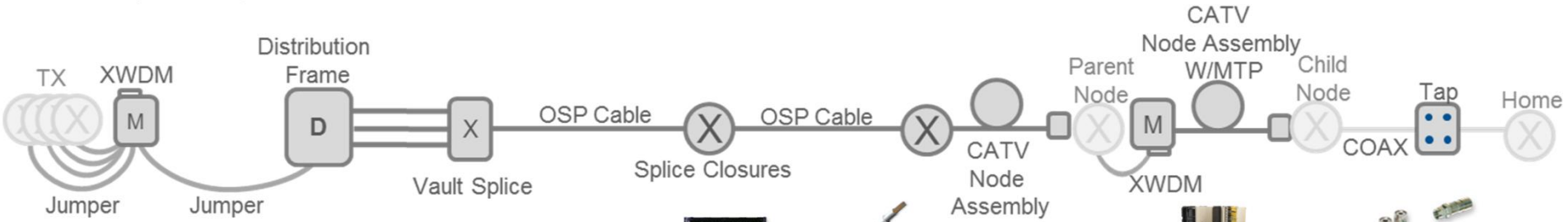
NOTE: Assessments based on Corning models, field trials and deployments.

MDU Solutions Summary

	Full-Precon Solutions	Semi-Precon Solutions	Full-Splice Solutions
			
Speed of Deployment	Fast	Moderate	Slow
Subscriber Connection	Fast	Moderate	Slow
Type of build	High to Mid-rise	Mid to Low-rise	All
Design verification/planning	High	Moderate	Low
Level of Risk	Low	Moderate	Moderate to High
Splices in the field	Low	Moderate	High
Labor Skill Level	Low	Moderate	High
Deferability	High	Moderate	Low

CATV Network Solutions

N+X, N+0, FTTH



SCAPC Jumper

JIB Jumper-in-a-Box

Attenuators

Eclipse® WDM Modules

Centrix™ Splitter + WDM Cassettes

Eclipse® Frames

Eclipse® Housings

Centrix™ Frames

Centrix™ Housings

OSE Optical Splice Enclosure

OSE Splice Trays

MiniXtend® Microduct Cables

ALTOS Figure-8 Cable

UCAO Splice Closures

SCF Splice Closures

CamSplice™ Mechanical Splice

SST Ribbon Cables

ALTOS® Aerial + Duct Cables

SOLO® Cable

CATV Node Assembly

CATV Node Assembly (Hybrid)

SCF Splice Closures

LCPE Closures

Gen3 Splitters

CATV Node Assembly (W/MTP)

RF Drop Connectors

Broadband Trunk and Distribution Connectors

Tap with True Split Technology

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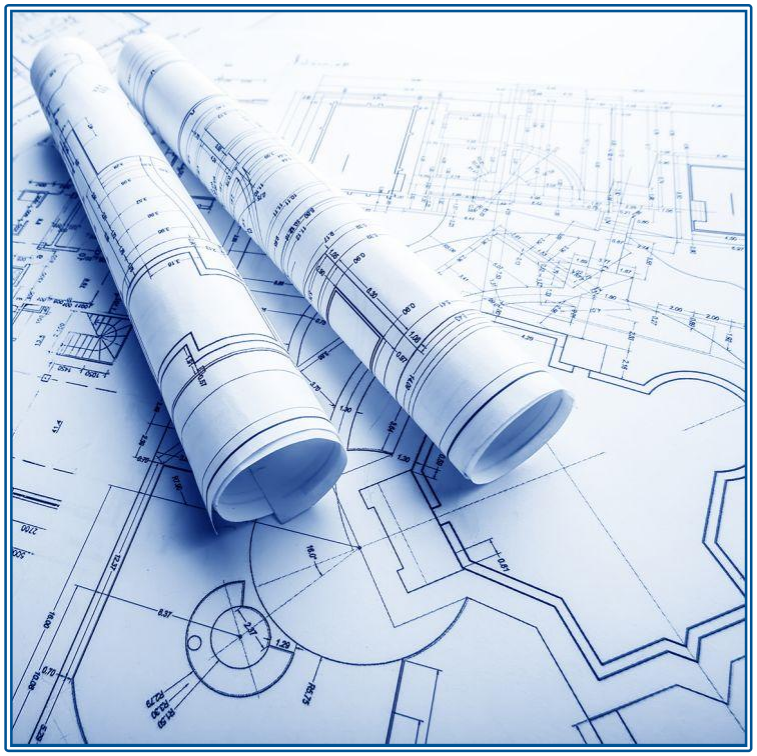
Questions?

catherine.mcnaught@corning.com



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Another 165 years of Innovation and Independence…
…and a world that is better because of our efforts
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