The Next Wave
Building Tomorrow's Network Today

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BICSI

Remember when…

In the Beginning…

- Long Haul Routes Established

Metro Buildout

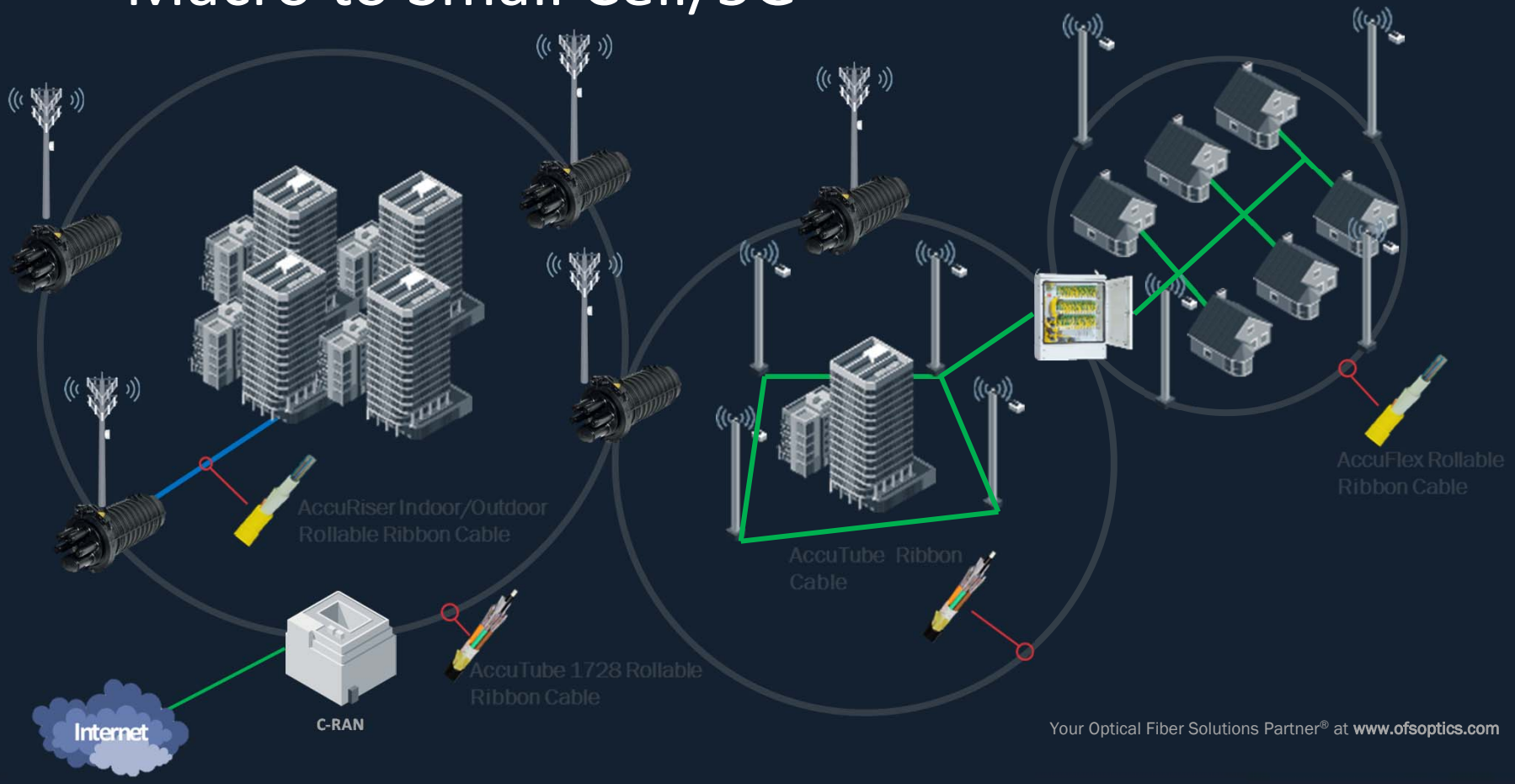
Access Networks

- FTTx

Diarri

The next wave

- Macro to Small Cell/5G



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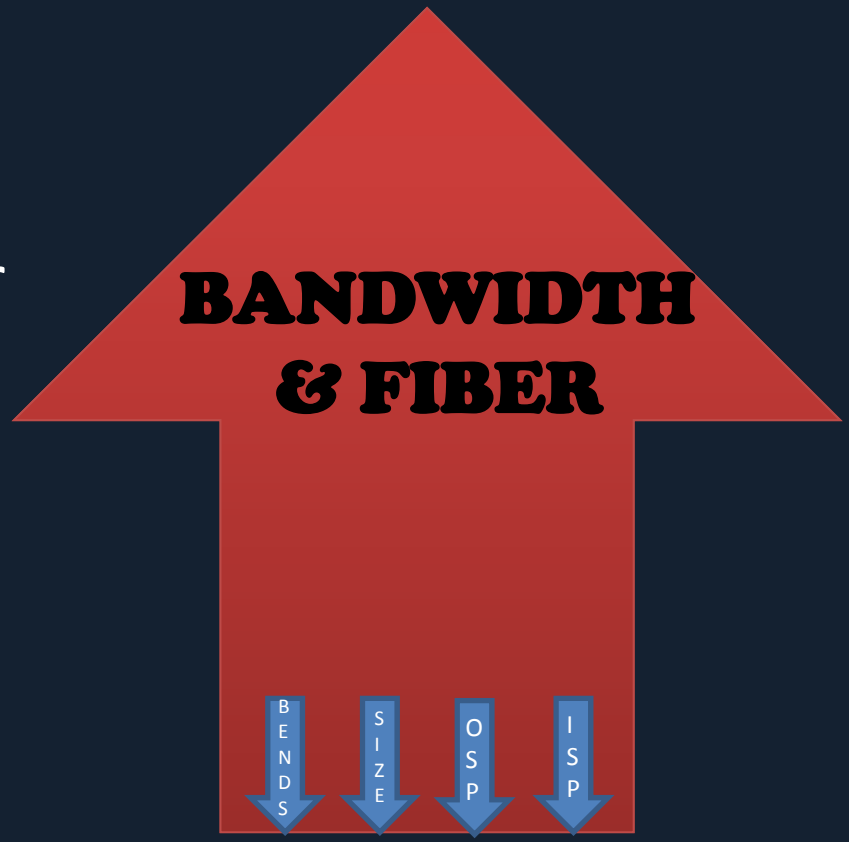
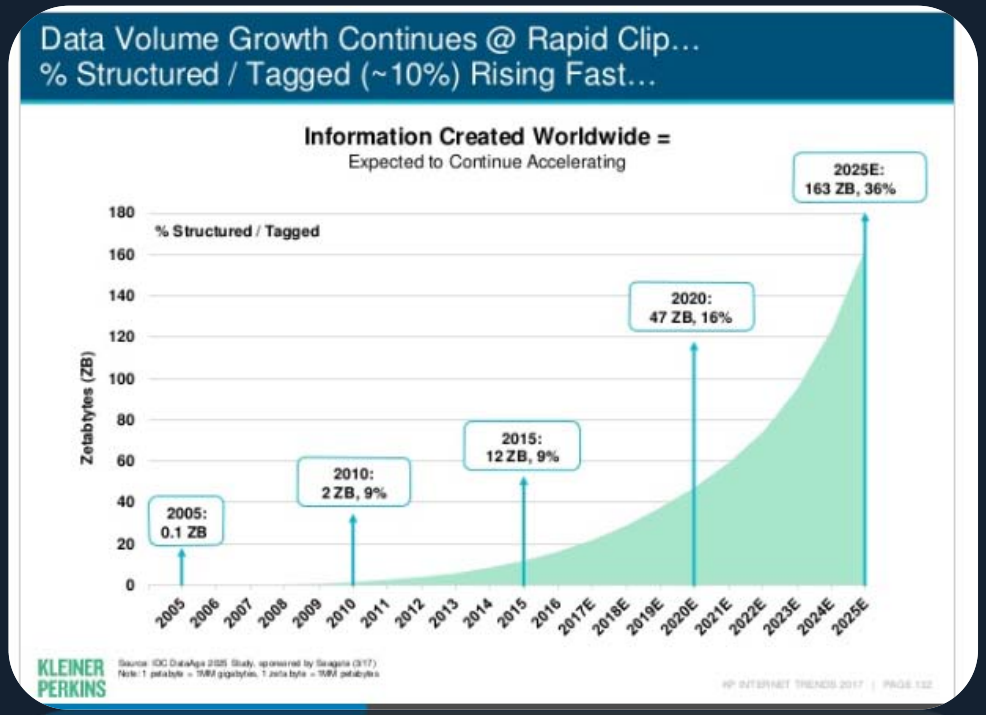
Big and Small

- Big demand
  - Bandwidth and fiber
- Smaller bends
- Smaller fiber
- Smaller OSP Cable
- Smaller ISP Cable



Bandwidth growth is accelerating

- In the past 15 years, we've seen…
  - The Internet, iPods
  - HDTVs, DVRs
  - Smartphones, Tablet computers
  - Streaming services
- All require every increasing amounts of bandwidth
- Where to get additional bandwidth
  - Faster equipment
  - Use more wavelengths
  - Install more fiber
- Change is constant



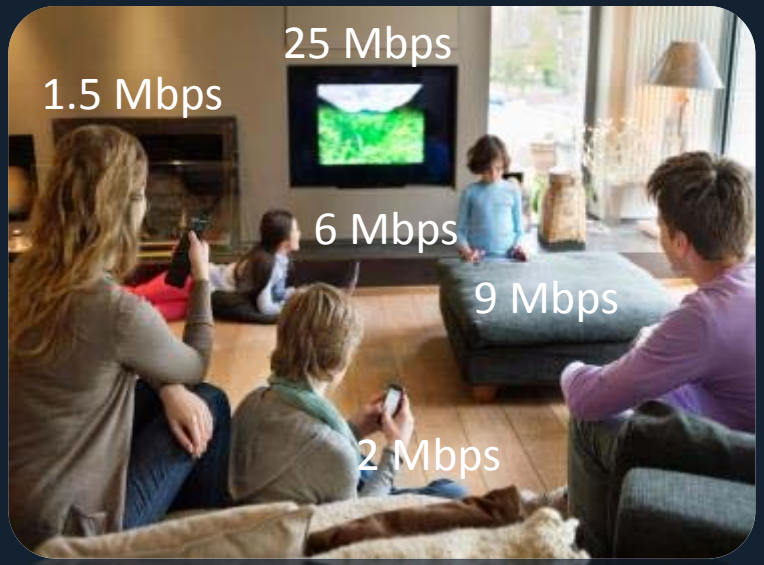
Mary Meeker (Kleiner Perkins) Information forecast

1,024 Gigabytes = 1 Terabyte. 1,024 Terabytes = 1 Petabyte. 1,024 Petabytes = 1 Exabyte (In 2000, 3 exabytes of information was created.) 1,024 Exabytes = 1 Zettabyte.

Bandwidth – then, now, and next

Then

Now



Next

4K (Ultra HD) TV

- Next gen TV format – 2x resolution, roughly 2X bandwidth
- Content online and growing rapidly
- **For the first time ever, higher quality video is available via Internet streaming versus standard packages**
- Price continues to drop rapidly
  - UHDTV 70” ~$1,000 USD

Source: Best Buy

NETFLIX

Help Center > Internet Connection Speed Recommendations

Internet Connection Speed Recommendations

Below are the Internet download speed recommendations per stream for playing movies and TV shows through Netflix.

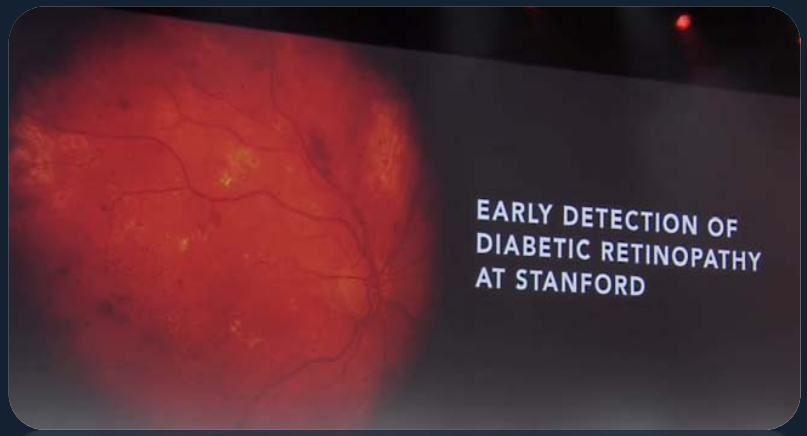
- 0.5 Megabits per second - Required broadband connection speed
- 1.5 Megabits per second - Recommended broadband connection speed
- 3.0 Megabits per second - Recommended for SD quality
- 5.0 Megabits per second - Recommended for HD quality
- 25 Megabits per second - Recommended for Ultra HD quality

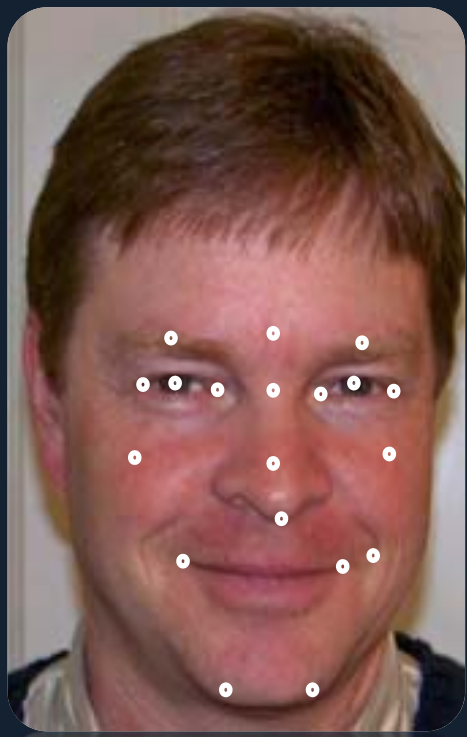
25 Mbps/screen – How many screens used at once?

Bandwidth – then, now, and next

IoT/5G

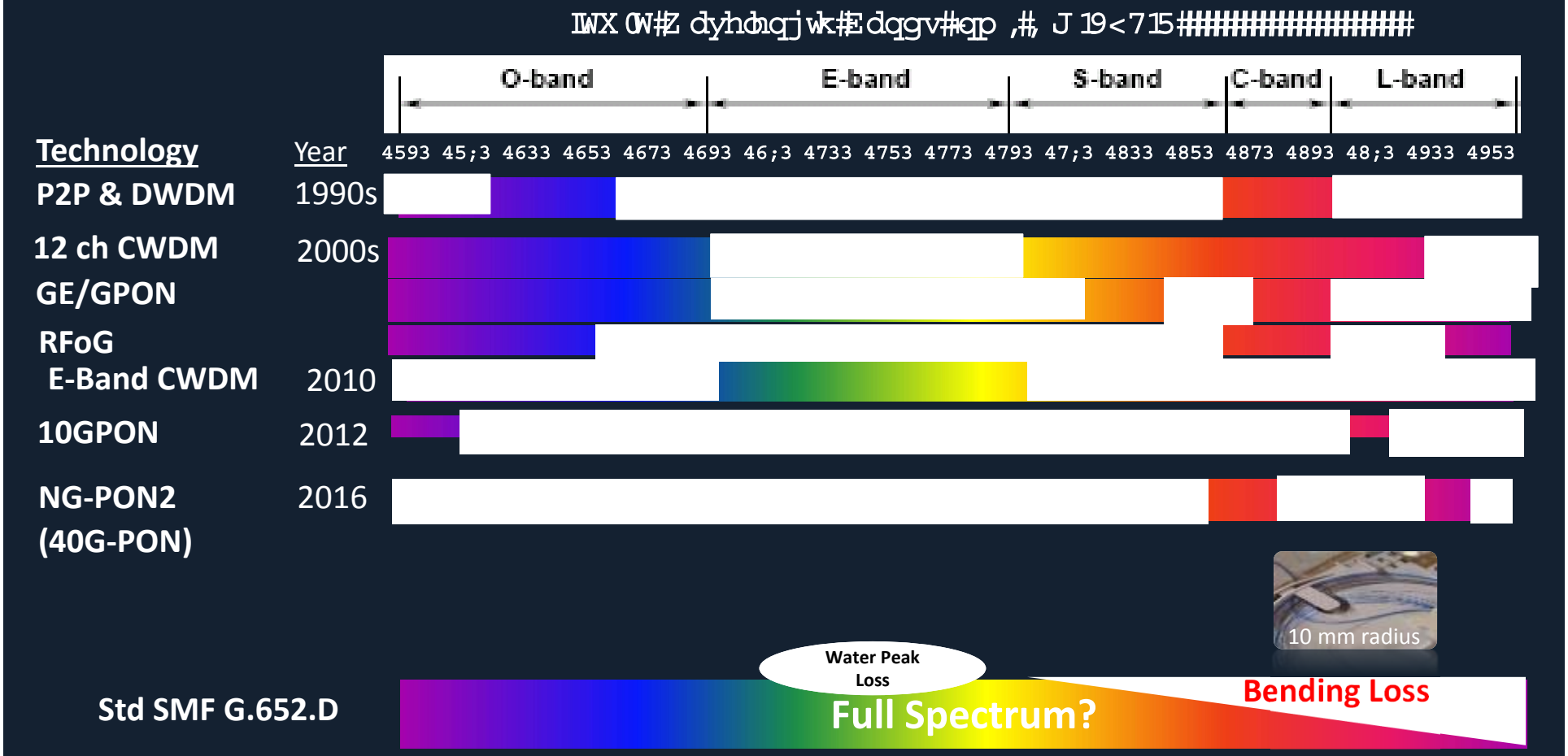
Artificial Intelligence





- Already in widespread use behind the scenes
- Image analysis, voice analysis
- Natural language
- Autonomous vehicles & robotics
- Enormous potential for early medical screenings using smartphones

Optical spectrum needed for the future

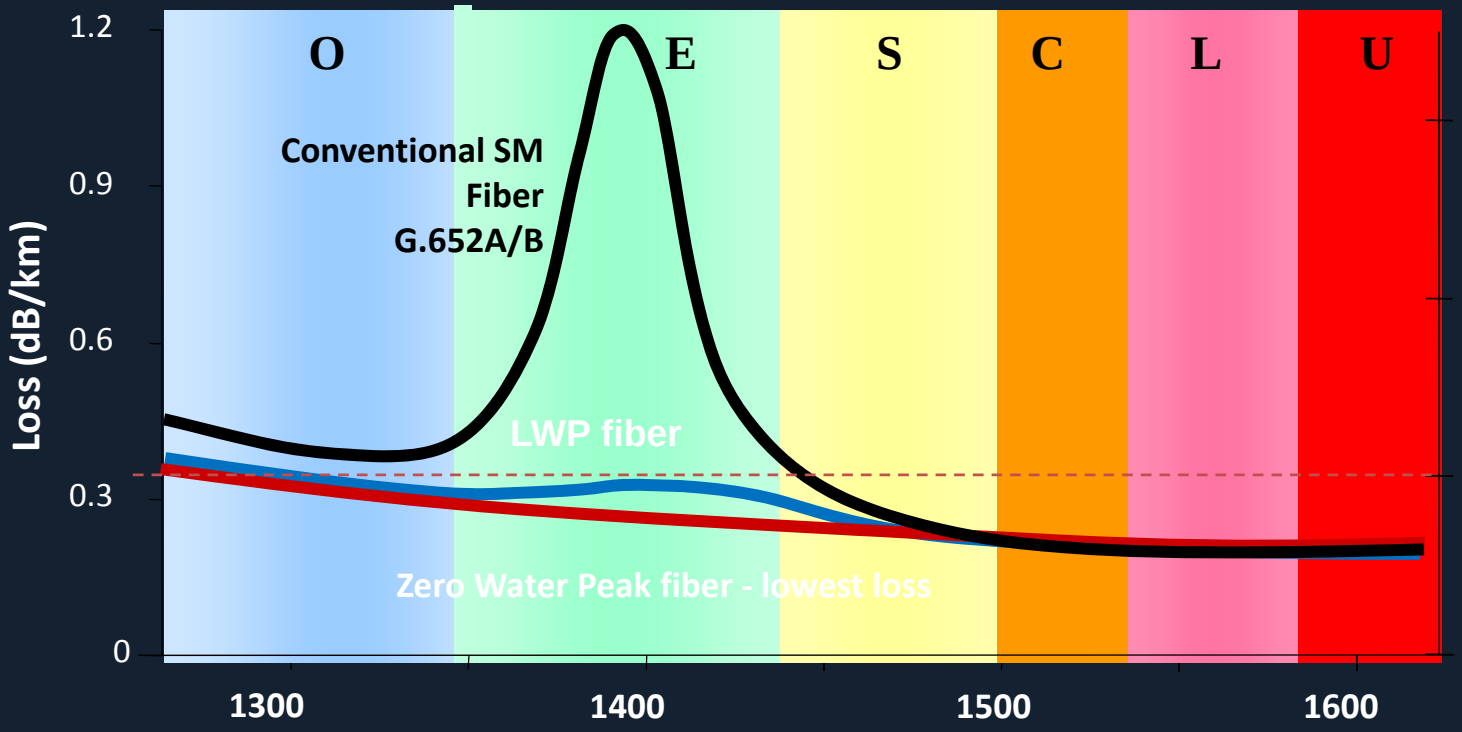


The first 30 years used 1310/1550 nm.

The next 30 will require the entire ITU spectrum.

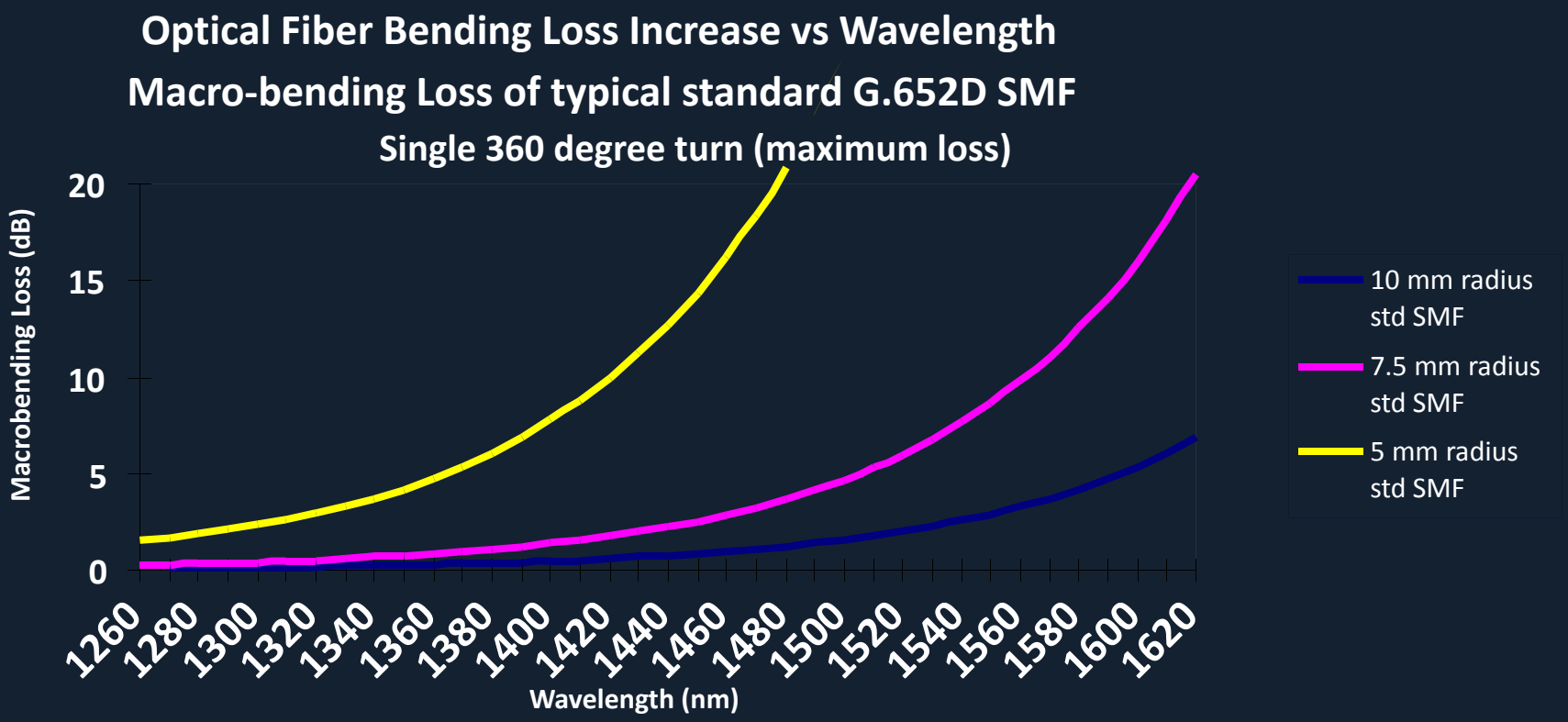
Zero Water Peak Performance

Clean performance through the optical spectrum



ZWP has up to 22% lower attenuation in the water peak region

Bend loss vs wavelength and radius



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Bending Loss will become an even Bigger Challenge

Increasing 2 to 4 times from Current Systems

Application	Standard	Current Generation		Next Generation on Same Fiber Network		Bending Loss Increase
FTTH	IEEE	GE-PON downstream	1490 nm	10G E-PON downstream	1577 nm	3X
	ITU-T	G-PON Downstream		10G-PON downstream		
				40G-PON (NG-PON2)	1603 nm	4X
DOCSIS and HFC	SCTE /ITU	RF-Video downstream	1550 nm	RFoG upstream	1610 nm	2X
Metro and some Long Haul	ITU	C-Band DWDM /CWDM	1560 nm	L-Band DWDM /CWDM	1625 nm	2.5X

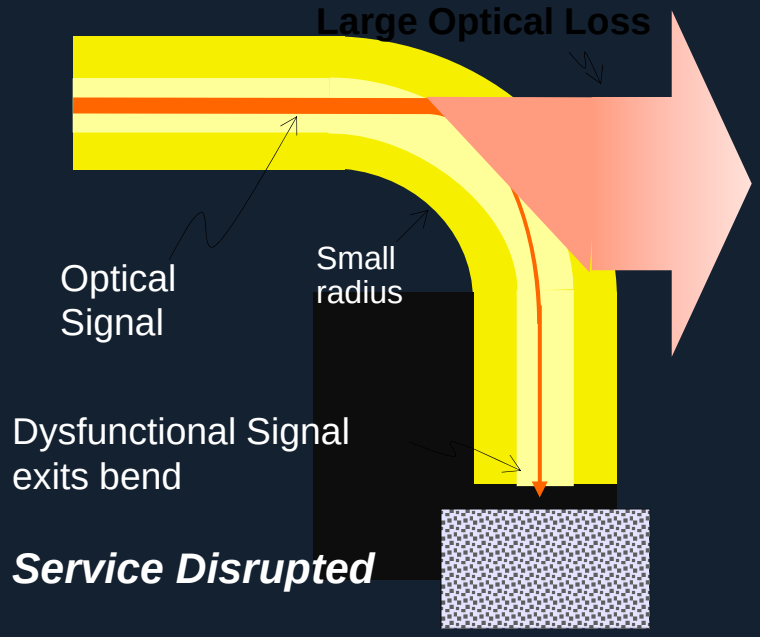
New challenges in the network

More bends, tighter bends

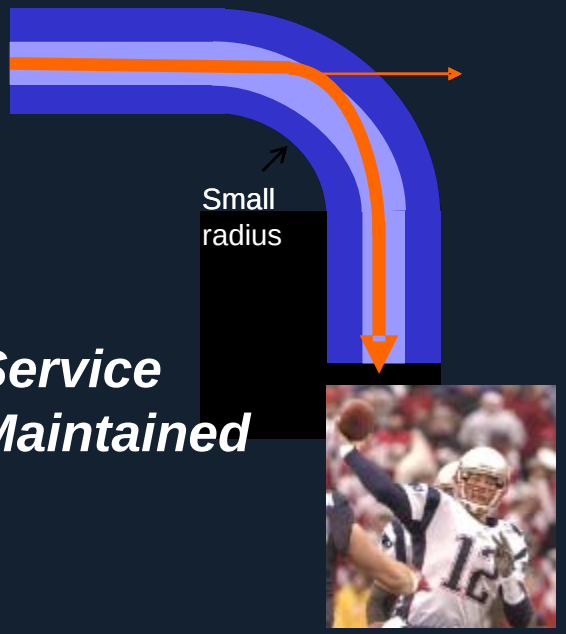
- Outdoors
  - Limited duct space
    - Demands smaller cable diameters
      - Demands smaller closures and hand holes
- Indoors
  - Fiber management challenges in CO
  - New indoor applications in homes and buildings

Macro/Micro-bending

Conventional Single-mode fiber
High optical loss around bends



Bend Optimized Singlemode fiber



SM/BIF/UBIFDemo

Small bends can mean big losses (G.652 Fiber)

Two 10 mm radius half bends can lose up to 10 KM of reach

2016 GPON 1490 nm
2 half bends 10 mm radius

20 KM reach preserved

2017 10G-PON 1577 nm
2 half bends 10 mm radius

5 KM less reach

2022 – NG PON 2 1603 nm
2 half bends 10 mm radius

10 KM less reach

Sounds like an opportunity for bend insensitive fibers

New OSP Fibers can Preserve PON reach

2016 GPON 1490 nm downstream
2 half bends 10 mm radius

20 KM reach preserved

2017 10G-PON 1577 nm downstream
2 half bends 10 mm radius

20 KM reach preserved

2022 – NG PON 2 1603 nm downstream
2 half bends 10 mm radius

20 KM reach preserved

Meeting the bending challenge in the OSP

New fibers can help

Smaller cables reduce installed costs

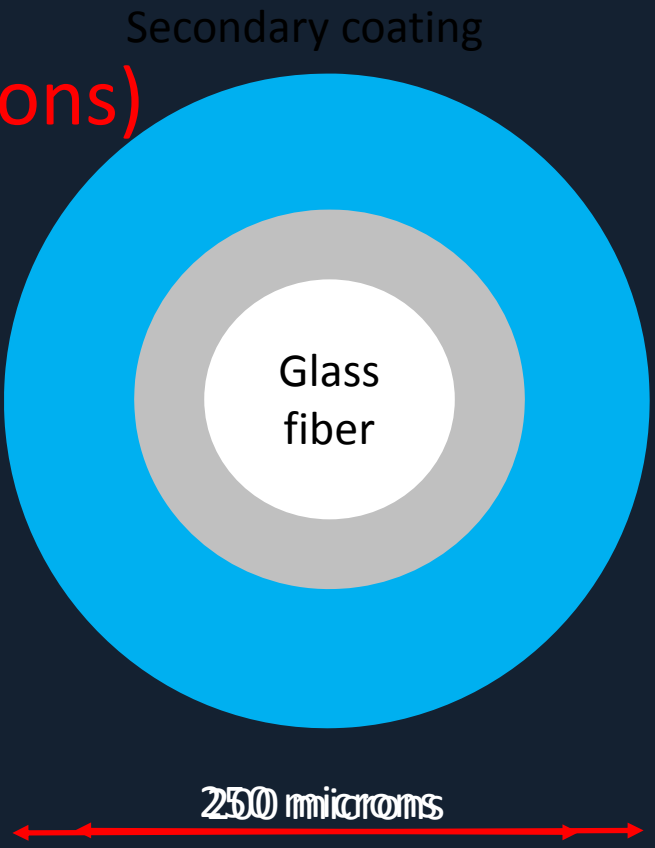
Greater flexibility to use existing infrastructure

Less bend sensitive fibers may enable smaller handholes for some designs

200 micron fiber

- Enables 2x fibers in same tube (or smaller tubes)
- Glass stays the same (125 microns)
- > 12 fibers/tube, last 12 fibers ring marked
- Fully compliant to fiber standards
- Fully tested in standard cable designs
- Reliability is not sacrificed
- Millions of KMs deployed already

24 fibers fit in a typical 12F tube
2X the cabled fiber density



200 µm fiber splicing – Loose tube cables

- Seamless splicing with the installed base
- Spliced with the same tools and procedures as 250 µm coated fibers
- Why?

Splicers hold the glass fiber, not the coating!

Rollable Ribbons (aka. Pliable Ribbon)

- Enables 2x Ribbons in same tube (or smaller tubes)
- Intermittent bonds between fibers in a ribbon
- "Rollable" into a smaller package than flat ribbons

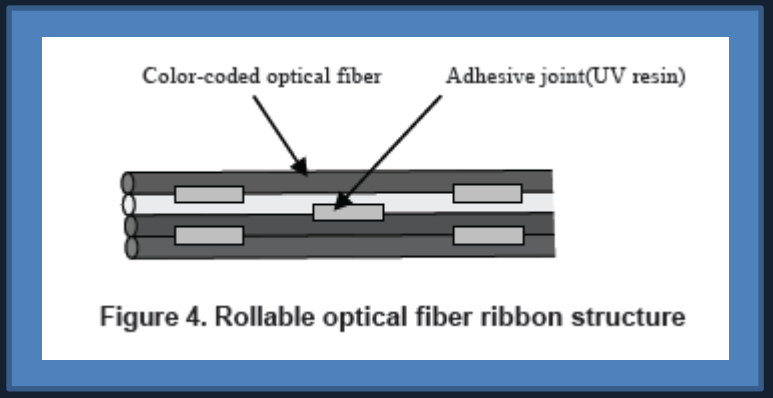


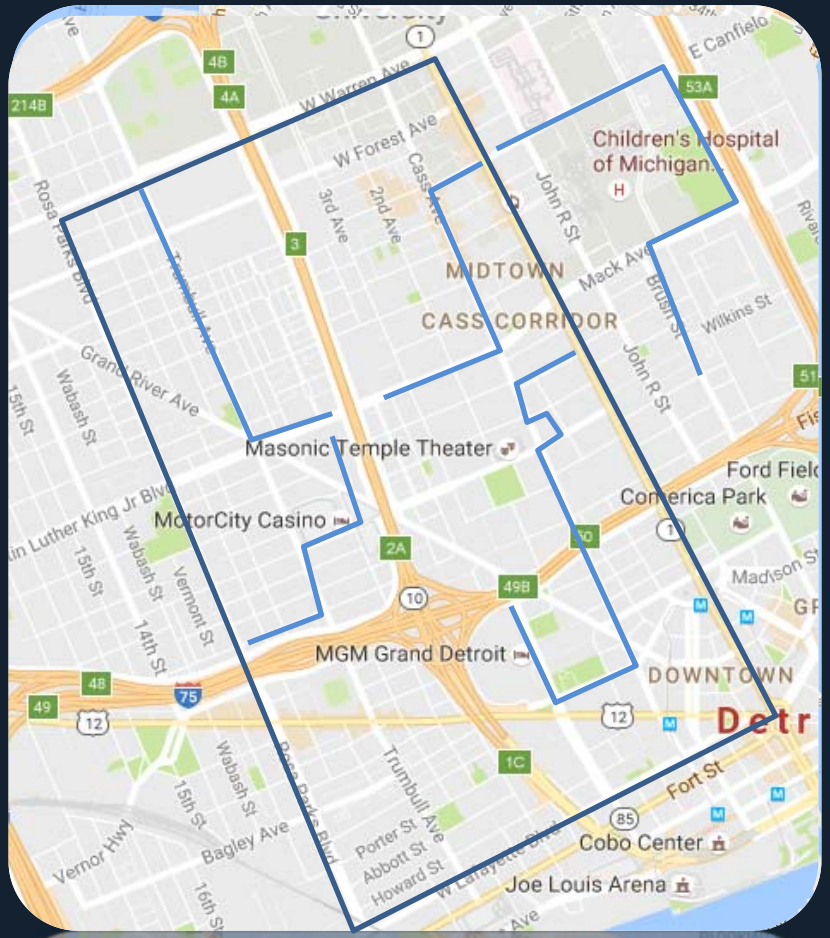
Figure 4. Rollable optical fiber ribbon structure

Furukawa (2012) Illustration

- Development driven by NTT – Proposed in early 2000s
- "Classic" Japanese development – multiple companies work on similar problem

Ultra high fiber count/density applications

- "Classic" application
  - Connects data centers together
  - 1728 fibers and more
  - Little to no mid-span fiber access
  - 3456 already being installed
- Emerging application
  - FTTH distribution
  - Main cable connected to micro (or other) cables
  - Frequent access for butt splicing and mid-span access



Where Rollable Ribbons make sense

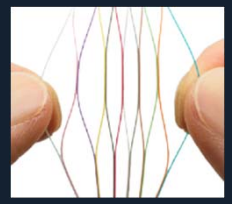
- Ultra high fiber counts
  - Significant diameter reductions
  - Enables 1728 fibers in 1 ¼” duct
  - 3456 fibers and higher are practical
- Lower fiber counts
  - 200 µm ribbons have more familiar performance and handling
  - Cables with 200 µm ribbons have similar diameters to rollable ribbons
  - When will 200um rollable ribbons be available?

Where Rollable Ribbons make sense

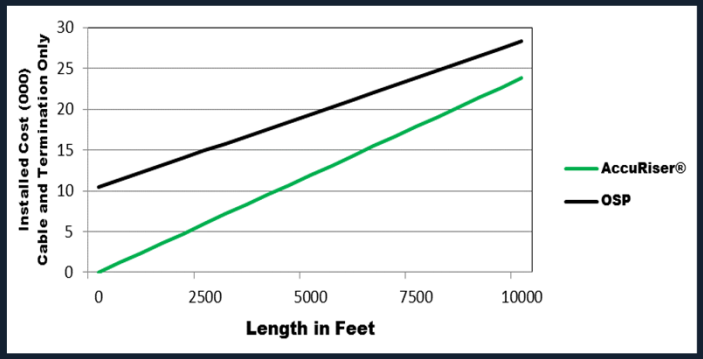
Data Center Interconnect fiber density can be doubled at lower cost with Rollable Ribbon Cable

Conventional - OSP Spliced to ISP Cable

Dual Rated RR cable can avoid 1000s of splices

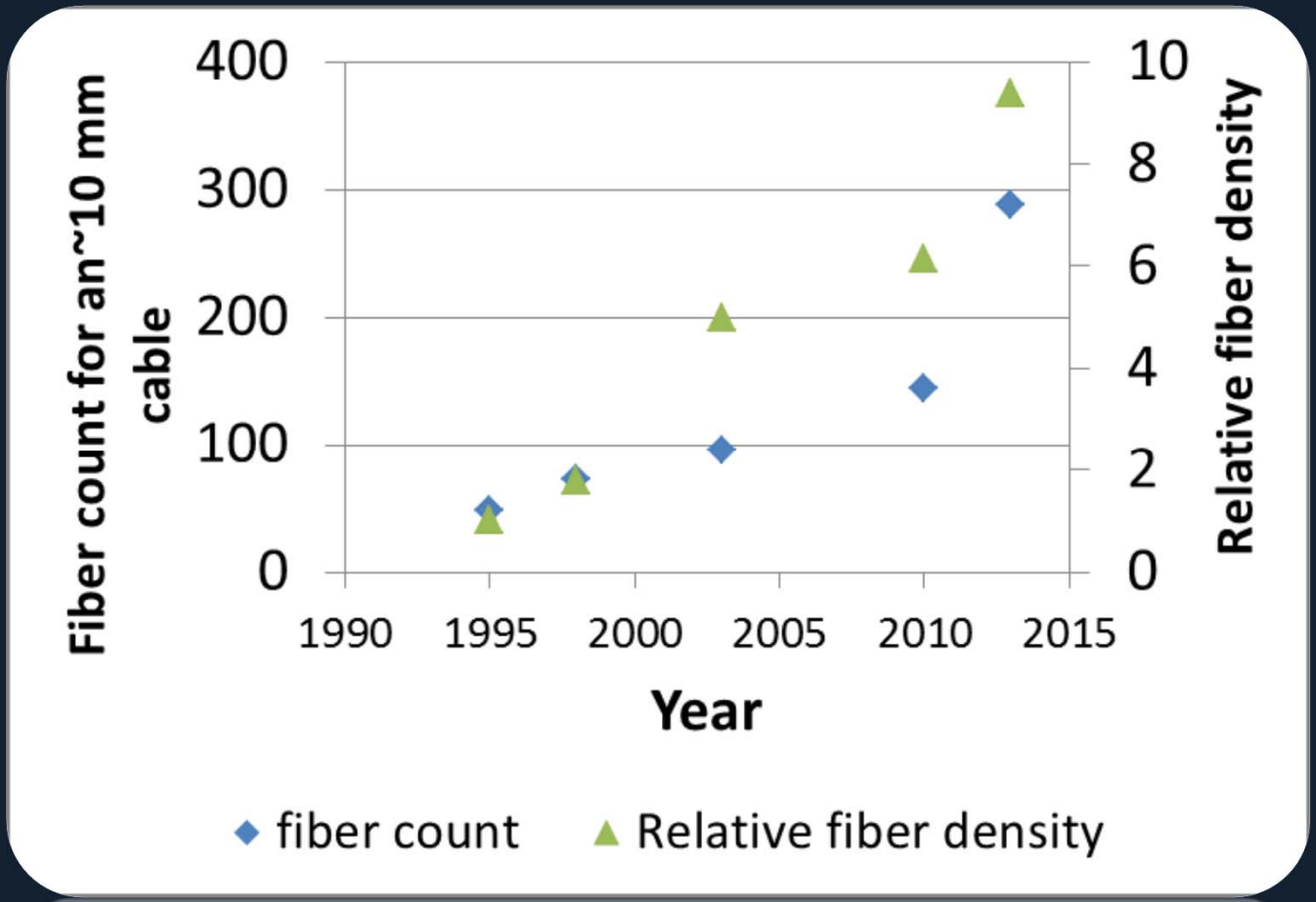


Dual Rated Cable can lower cost by avoiding an outdoor to indoor splice



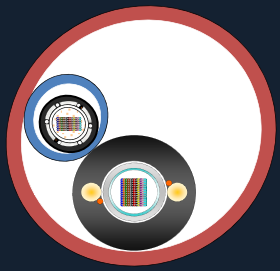
- Double fiber density vs. conventional flat ribbon cables, $10Ks savings by avoiding new duct
- Indoor/Outdoor can bypass splice points saving $10Ks
- Lighter weight and small size maximizes fiber count in congested raceway and trays

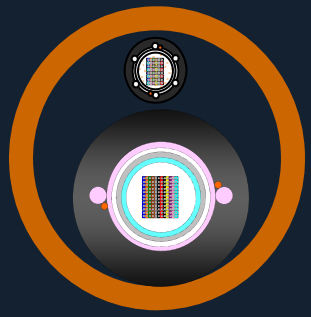
Evolution of optical cable – microcables



Microcables and Microducts

- Benefits
  - Materials
    - High fiber density - 200% better space efficiency
  - Labor
    - Blown cable enables faster deployment than pulled cable
    - Longer blowing distances, fewer splice points
    - Smaller, easier to handle, equipment needed for install
  - Financial/Intangible
    - Flexibility to grow network as needed





Evolution of Optical Cable – Microcables

144 fiber cable example
(Traditional cable = 15.7mm)

First generation microcable – GR-20

Small – 9.7 mm

Second generation microcables – smaller tubes

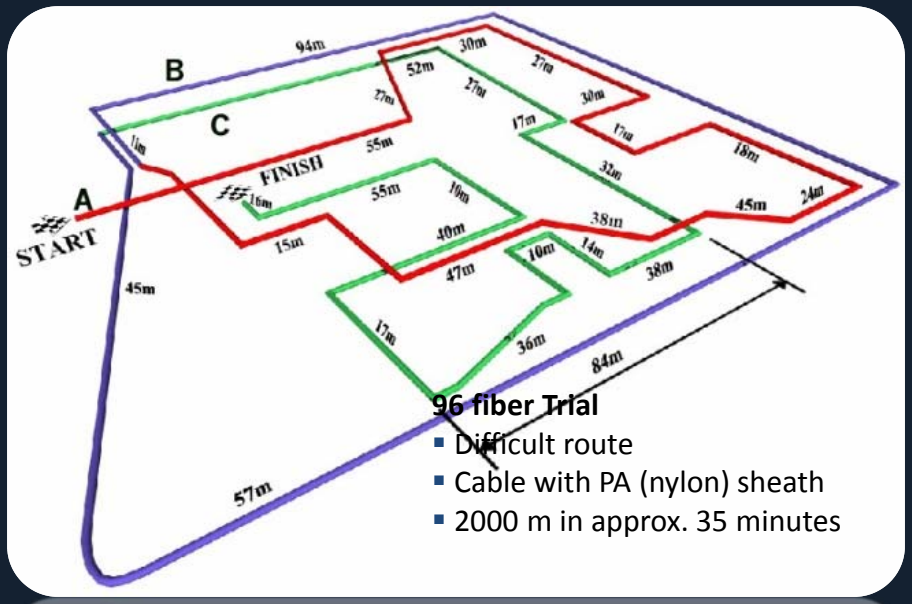
Smaller – 8.6 mm

3rd and 4th gen – smaller tubes and 200 µm fiber

Smallest – 5.7-6.3 mm

Microcables sometimes require caution

- Not as standardized as traditional OSP cables
- GR-20 rated cables can be pulled with caution
- Next gen microcables should be blown – less mechanically robust
  - Requires specialized handling
- Typical cable/microduct fill ratios (diam. to diam.) – 65%-75%
- Not intended for aerial deployments (without microduct)
- Use caution with FTTH distribution applications requiring expessing in pedestals



96 fiber Trial

- Difficult route
- Cable with PA (nylon) sheath
- 2000 m in approx. 35 minutes

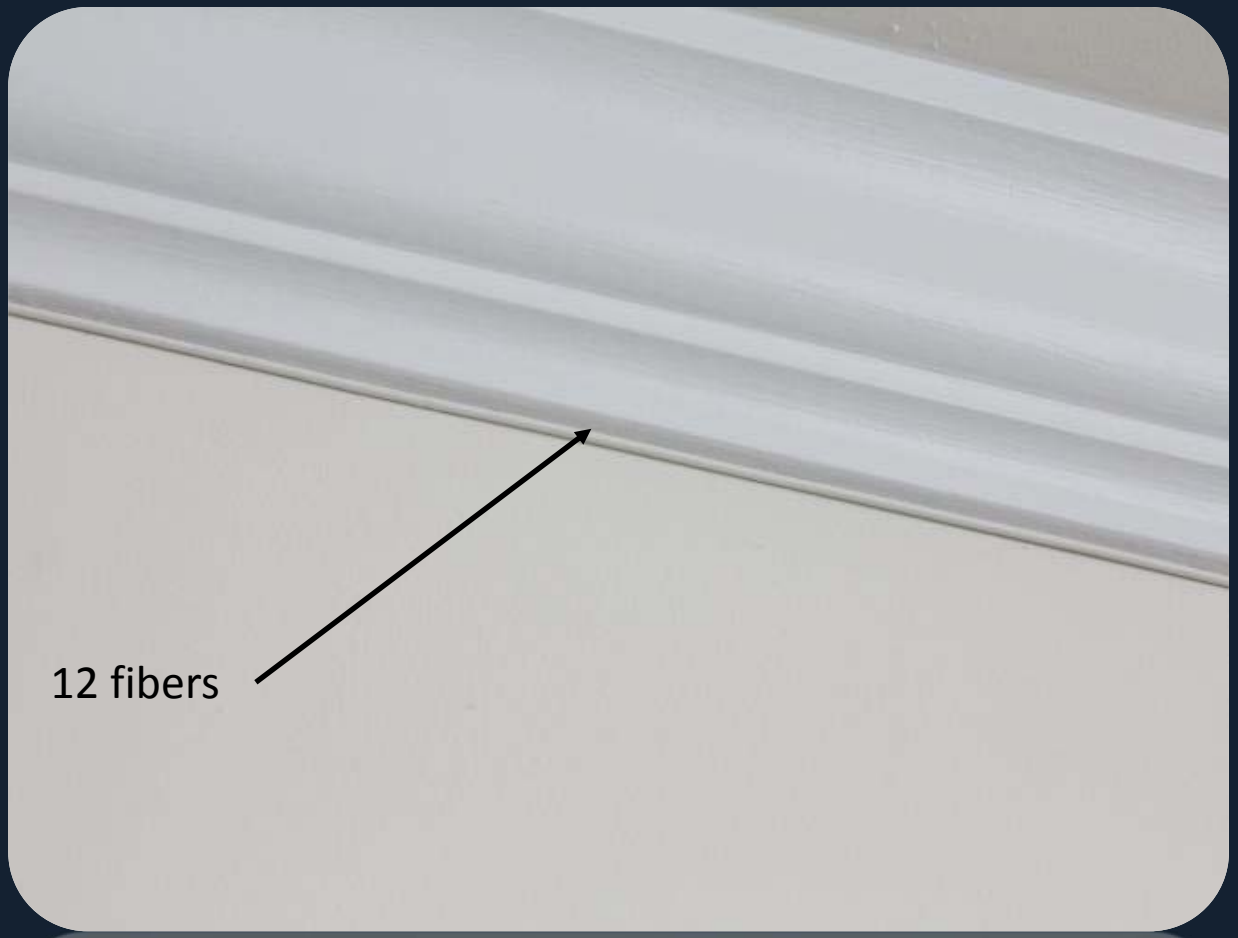
Small Solutions to the MDU/MTU

Existing methods for MDU/MTU hallway deployments

- Traditional methods of hallway cable deployments are often costly and distract from the décor.
  - Large and visible
  - Time consuming to install

Moldings and tapes are typically very visible

Smaller solutions for hallway deployments



Bend Optimization allows for complex hallway deployments

Clean, completed installation

Summary

- Bandwidth demand is big, really big, and keeps growing
- Small size lowers cost and increases fiber density
- Outdoors
  - New OSP fibers help manage smaller bends
    - G.657A2 and 9.2 µm MFD
  - 200 µm fibers enable smaller cables
  - Rollable Ribbons reduce cable size and weight for large fiber counts
  - Smaller cables increase fiber density and lower costs
- Indoors
  - UBIF enables fiber to the MDU/MTU quickly reducing labor costs
  - Rollable Ribbon allows for smaller, lighter cables in trays and raceways

Thank You

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