Welcome and Introduction

BROADBAND

Acceleration Seminar event

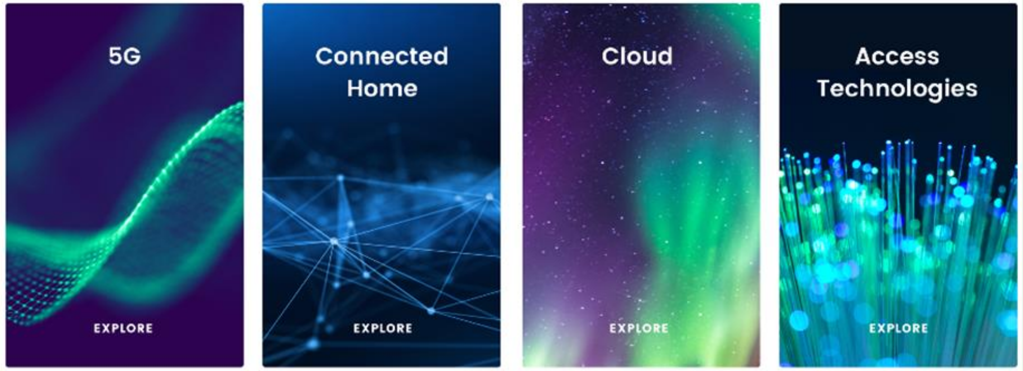
THANK YOU TO OUR SPONSOR

Calix

Introduction

Broadband Acceleration Seminar event BASe is an
educational industry event to update the market on the latest innovative technology and use cases.

Four major areas:



open broadband

Workshops are **quarterly events** and will ensure to **cover all regions**.

BASe will focus on updates and readiness for deployment of next generation technologies, hearing from leading component and system vendors, as well as network operators, sharing their insights on the latest technologies, applications, use cases, and deployments.

Today's Segment Topics

- **Segment 1: Network Access: Applications and Opportunities**
  - Moderator: Lisa Youngers, President & CEO Fiber Broadband Association
- **Segment 2: 10 Gigabit and Beyond With Fiber**
  - Moderator: Julie Kunstler, Principal Analyst Ovum
- **Segment 3: Fiber Extension Technologies, Standards and Solutions**
  - Moderator: Alison Diana, Editor, Light Reading
- **Segment 4: Wireless Broadband**
  - Moderator: Lincoln Lavoie BBF Technical Chair

BASe Las Vegas Workshop Program

	Introduction and Welcome
8:00 - 8:05	Bernd Hesse, BASE Event Chair and Broadband Forum Board Member
8:05 - 8:15	Robin Mersh, CEO, Broadband Forum
Segment 1	**Network Access: Applications and Opportunities**
8:15 - 8:45	**Applications for the Gigabit Age**
	David Tomalin, Group CTO, CityFibre
8:45 - 9:05	**The Next-Gen Access Ecosystem and Market: Technologies, Applications, and Vendors**
	Julie Kunstler, Principal Analyst
9:05 - 9:25	**IoT and the Future of the Connected Home**
	Alan DiCicco, Solutions Marketing Senior Director, Calix
9:25 - 9:45	**New Business Opportunities with 5G**
	Fernando Gordo Jiménez, Chief Transformation Officer, Carrier Business Group, Huawei Technologies
9:45 - 10:05	**The Future of Fiber**
	Lisa R. Youngers, President and CEO, Fiber Broadband Association
10:05 - 10:25	**The Evolution of Hybrid Access Networks**
	Paul Evans, CEO, Hybrid Access Technologies
10:25 - 10:40	**Segment 1 Panel Discussion & Audience Q&A**
	Moderated by Lisa Youngers, President and CEO, Fiber Broadband Association
10:40 - 10:50	Break
Segment 2:	**10 Gigabit and Beyond With Fiber**
10:50 - 11:10	**Super-PON: A PON Architecture for Access Infrastructure Consolidation**
	Claudio DeSanti, System Architect, Google
11:10 - 11:30	**FTTH: Adapting to the Needs of Tomorrow with New Protocols & Architectures**
	Kevin Bourg, Director, Optical Network Architect, Corning Optical Communications
11:30 - 11:50	**NG-PON2 Solution for 10G Internet Service: SK's Development & Deployment**
	Choongbok Lee, Senior Manager, SK Broadband
11:50 - 12:10	**NG-PON2 Optics Update: Path to Massive Deployment**
	Wei-Ping Huang, Founder and Chief Scientist, HiSense Broadband
12:10 - 12:30	**Dealing with Capacity Growth in Access Networks**
	Antonio Teixeira, Co-Founder and CTO, PICadvanced
12:30 - 12:45	**Segment 2 panel discussion and audience Q&A**
	Moderated by Julie Kunstler, Principal Analyst, OVUM

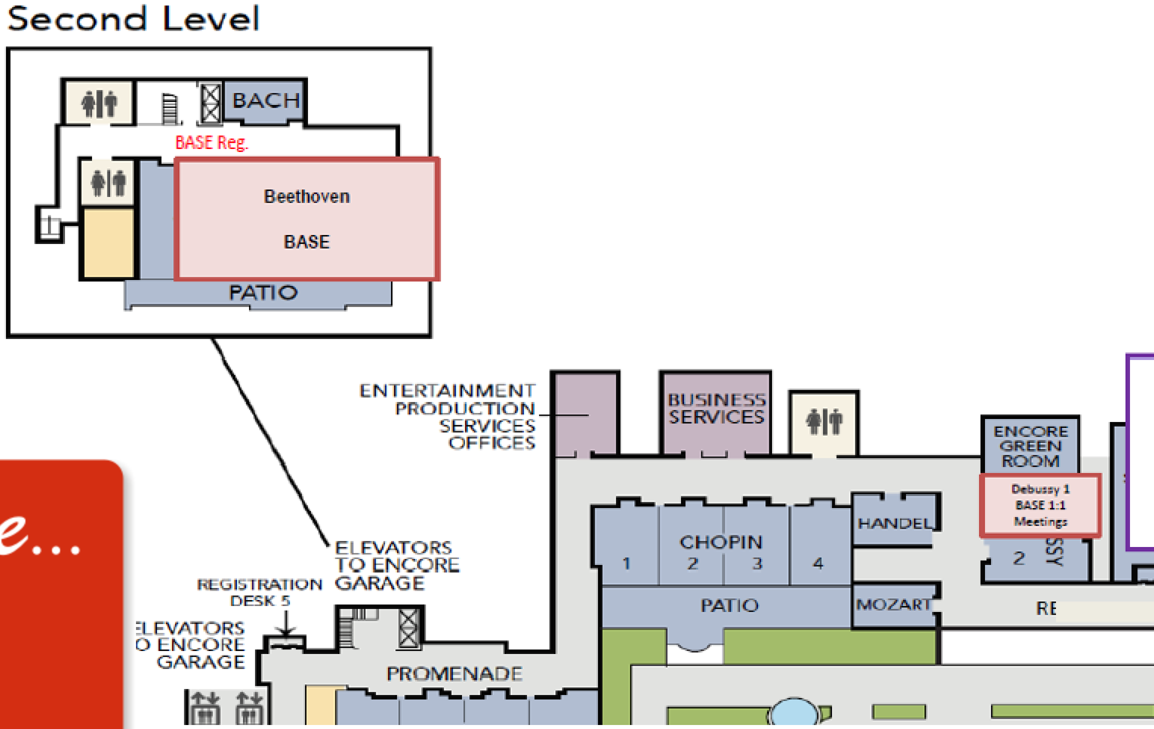
12:45 - 1:15	**Lunch** Brown bag working session **Making it all work - BBF Certification Programs & Interoperability** Lincoln Lavoie, Senior Engineer, Broadband Technologies, InterOperability Laboratory at University of New Hampshire
Segment 3	**Fiber Extension Technologies, Standards and Solutions.**
1:15 - 1:35	**Gfast Comes of Age In 2018**
	Mileend Gadkari, VP Business Development Americas, Sckipio
1:35 - 1:55	**Fibre Access Extension - Reusing In-Building Coaxial Cabling for Multi-Gigabit Performance**
	Helge Tiainen, Senior Director Business Development, InCoax
1:55 - 2:15	**Automated Deployment of Cloud-based Access Infrastructure & Services**
	Tim Carey, Lead Technology Strategist, Nokia
2:15 - 2:35	**G.hn Fiber Extenders as an Alternative to Multiport DPU's.**
	Paul Arola, Senior Design Specialist, Telus
2:35 - 2:55	**Intelligent Broadband Access & Home Maintenance**
	Wei Lin, System Architect, Huawei Technologies
2:55 - 3:10	**Segment 3 Panel Discussion and Audience Q&A**
	Moderated by Alison Diana, Editor, Light Reading
3:10 - 3:25	Break
Segment 4:	**Wireless Broadband**
3:25 - 3:45	**Fixed-Wireless Broadband - Accelerating Closing the Digital Divide**
	John Colvin, Senior Vice President, Global Field Operations, Mimosa Networks
3:45 - 4:05	**New Optical Technologies for Future 5G Transport and Multi-Service Access**
	Ronald Heron, Director Network & Portfolio Strategy, Nokia
4:05 - 4:25	**Overcoming Challenges in the Managed Connected Home**
	Jason Walls, Director of Technical Marketing, QA Cafe
4:25 - 4:45	**It All Starts With Managed Wi-Fi**
	Greg Owens, Product Marketing Director, Premises, Calix
4:45 - 5:05	**Enhancing Wi-Fi User Experience**
	Ruthy Zaphir, BLE Software Lead, Siano Mobile Silicon
5:05 - 5:25	**Wi-Fi ROI**
	Jake Sailana, Director Product Marketing, ZyXEL
5:25 - 5:45	**Segment 4 Panel Discussion and Audience Q&A**
	Moderated by Robin Mersh
5:45	Close

Rules and further information

- Start on time and end on time
- Wi-Fi password

  Primary SSID: **Calix2018**

  Passphrase: **AXOS2018**
- Brown bags during lunch session
- Coffee & refreshments during breaks
- Please set your mobile phone on silent mode



Segment 1
Network Access: Applications and Opportunities

Moderator: **Lisa Youngers**
President and CEO, Fiber Broadband Association

Agenda Segment 1

	Network Access: Applications and Opportunities
8:15 - 8:45	**Applications for the Gigabit Age**
	David Tomalin, Group CTO, CityFibre
8:45 - 9:05	**The Next-Gen Access Ecosystem and Market: Technologies, Applications, and Vendors**
	Julie Kunstler, Principal Analyst, Ovum
9:05 - 9:25	**IoT and the Future of the Connected Home**
	Alan DiCicco, Solutions Marketing Senior Director, Calix
9:25 - 9:45	**New Business Opportunities with 5G**
	Fernando Gordo Jiménez, Chief Transformation Officer, Carrier Business Group, Huawei Technologies
9:45 - 10:05	**The Future of Fiber**
	Lisa R. Youngers, President and CEO, Fiber Broadband Association
10:05 - 10:25	**The Evolution of Hybrid Access Networks**
	Paul Evans, CEO, Hybrid Access Technologies
10:25 - 10:40	**Segment 1 Panel Discussion & Audience Q&A**
	Moderated by Lisa Youngers, President and CEO, Fiber Broadband Association
10:40 - 10:50	Break

Applications for Gigabit Age

David Tomalin
Group CTO | CityFibre
david.tomalin@cityfibre.com

broadband forum

BASe

Applications for the Gigabit Age

David Tomalin
CTO | CityFibre

CityFibre

Bandwidth drives transformation

A catalyst for growth, efficiency and innovation

Reinventing public services

eLearning, remote health & social care, connected communities, service efficiencies

Powering enterprise & innovation

Cloud computing, data-driven intelligence, augmented reality, holographic display

Boosting mobile capability

High speed mobile data, 4/5G, IoT, public Wi-Fi, autonomous cars, smart sensors

Enabling homes of the future

Homeworking, HD streaming, smart devices, immersive online gaming, artificial intelligence

CityFibre

Social, cultural & political change

Education:

e-learning & tailored tutoring

CityFibre

Education: virtual exploration

CityFibre

Healthcare:
data-driven analysis & care planning

CityFibre

Healthcare: rapid emergency response

CityFibre

Healthcare: remote consultation & diagnosis

CityFibre

Digitally enriched community & family

CityFibre

Immersive gaming & sports

CityFibre

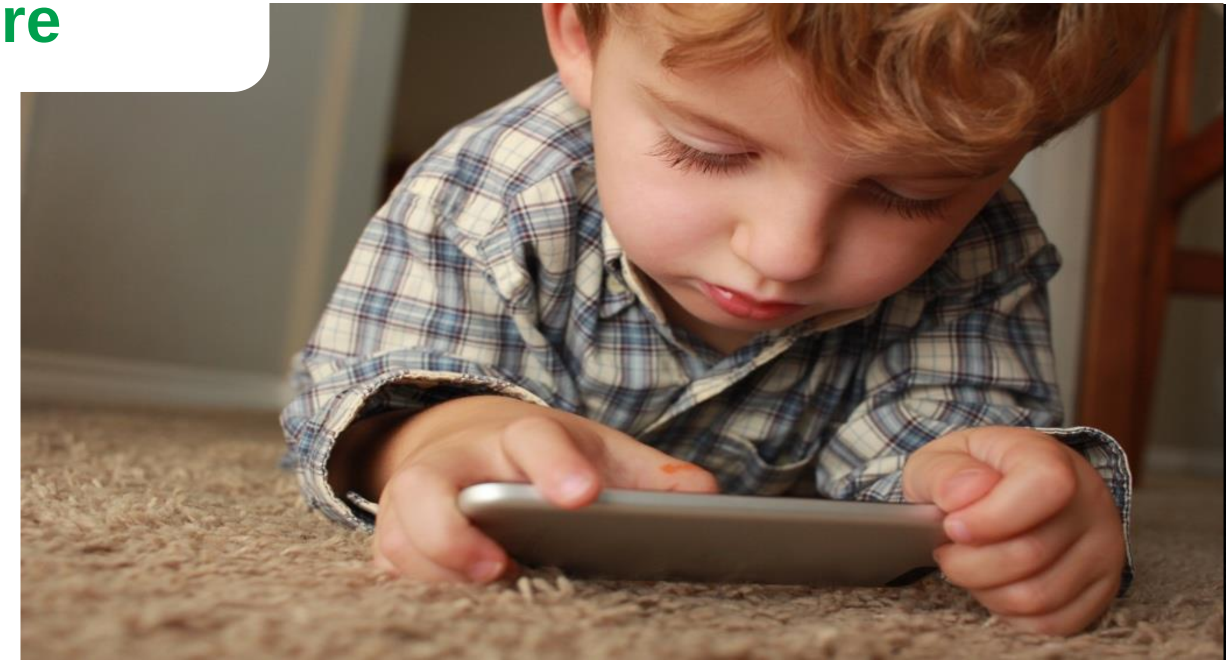
Security & privacy

CityFibre

The digital divide

CityFibre

Enabling the future



CityFibre

The Next-Gen Access Ecosystem and Market: Technologies, Applications, and Vendors

Julie Kunstler

Principal Analyst | Ovum

Julie.Kunstler@ovum.com

broadband forum

BASe

The Next-Gen Access Ecosystem and Market – technologies, vendors and applications

Broadband Forum – BASE Event – Las Vegas

28 October 2018

Julie Kunstler, Principal Analyst, Network Infrastructure and Software, Ovum

Julie.Kunstler@ovum.com

The early adopters, the later arrivals – but the gap is closing rapidly

Later Arrivals

"Vision" finally begins:

Acceptance that operating multiple networks is expensive.

Acceptance of longer time horizon for return-on-investment.

Governments adopt vision-friendlier policies.

Cost efficient network builds.

This gap is closing *rapidly*

Early Adopters

"Vision" regarding the impact of fiber access.

Government support for vision.

Patience regarding return-on-investment.

What's changed – why is fiber access accelerating?

Video, high quality video (4K today and 8K will come), video everywhere, video all the time, video for Virtual Reality.

5G represents an opportunity for fiber access – PON can support 5G cell densification for MBH (mobile backhaul) and possibly MFH (fronthaul).

PON is supporting "universal" access – one access network for different customers and applications.

Fiber access costs are declining while revenue generating subscribers are being brought onto networks faster.

The vision is spreading to city/local governments – the value of fiber access is a crucial asset.

VR forecasts hide the broadband network requirements

Mobile VR

HD

x 1

4K

x 4

4K at 60fps

x 8

Dedicated VR

HD per eye at 90fps

x 6

4K per eye at 90fps

x 24

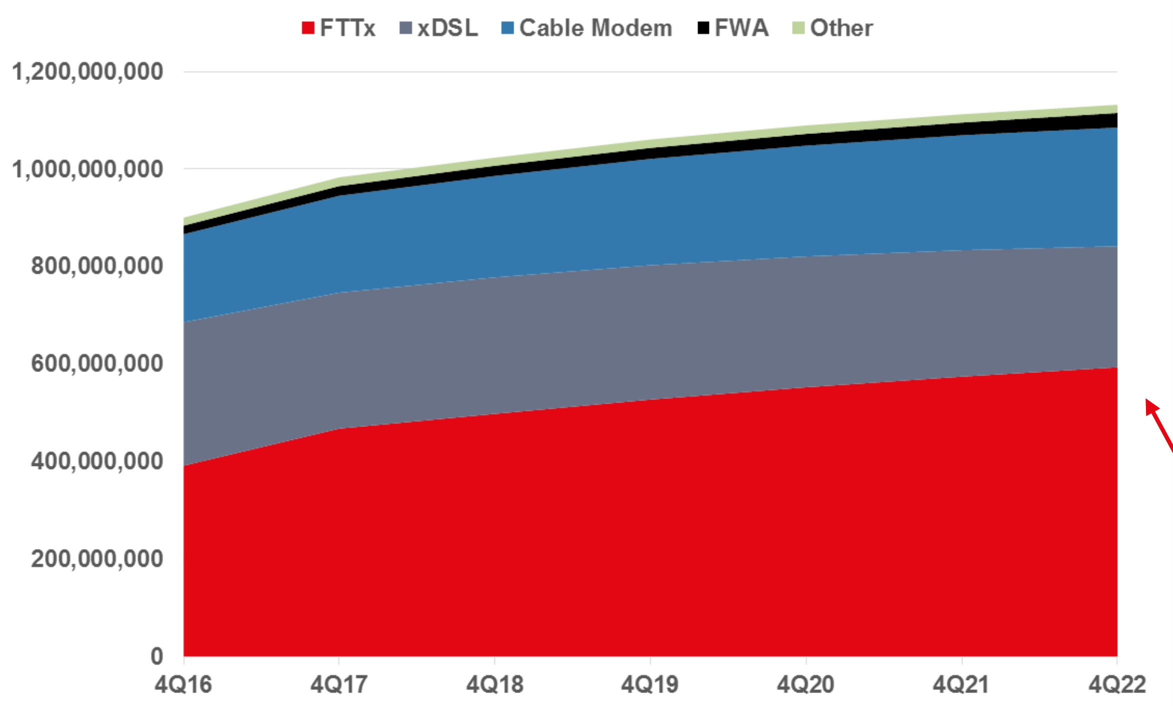
4K per eye at 120fps

x 32

Source: Ovum

Movement to fiber enables future-proofing, economically

Household subscriber forecast by technology



Source: Ovum

- FTTx deployment costs are declining rapidly:
  - Network design tools
  - End-to-end project management skills
  - Experienced network builders
- Monetization continues to improve:
  - Accurate order entry
  - Faster at-home installations
  - Faster subscriber provisioning

Ovum continues to revise upwards its FTTx household subscriber forecast.

In many "expensive" regions, costs have fallen from $2500 to under $500 per home.

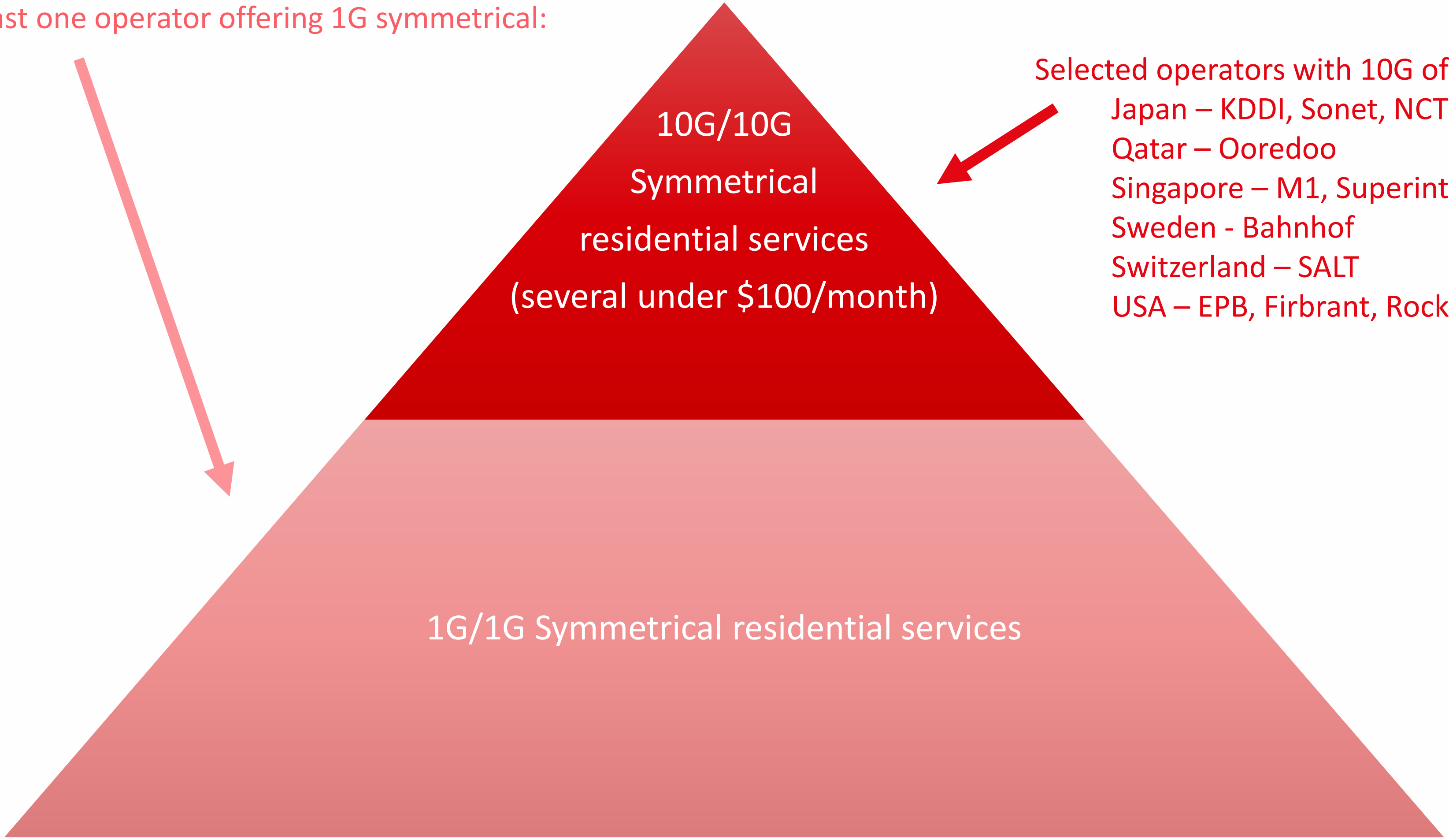
Monetization has moved from beyond 20 years to less than 7 years.

In response, regulators are increasing minimum broadband speeds, while operators have revised their FTTH plans.

Fiber speeds gaining momentum - 1G and 10G residential offerings are expanding rapidly

Selected countries with at least one operator offering 1G symmetrical:

- Bosnia & Herzegovina
- Bulgaria
- Canada
- Denmark
- Estonia
- Hong Kong
- Hungary
- India
- Indonesia
- Israel
- Japan
- Laos
- Macao
- Norway
- Qatar
- Singapore
- Slovakia
- Spain
- Sweden
- Switzerland
- UK
- USA



Selected operators with 10G offerings:

Japan – KDDI, Sonet, NCT
Qatar – Ooredoo
Singapore – M1, Superinternet
Sweden - Bahnhof
Switzerland – SALT
USA – EPB, Firbrant, Rocket Fiber, Vtel, UTOPIA

Copper upgrades – often difficult and incomplete

Copper Upgrades

- Tremendous copper-based bandwidth advancements
- Vectoring, 35b, Gfast

"Tough"

- Requires good line quality
- Often requires shorter loops
- "Open access" can be difficult

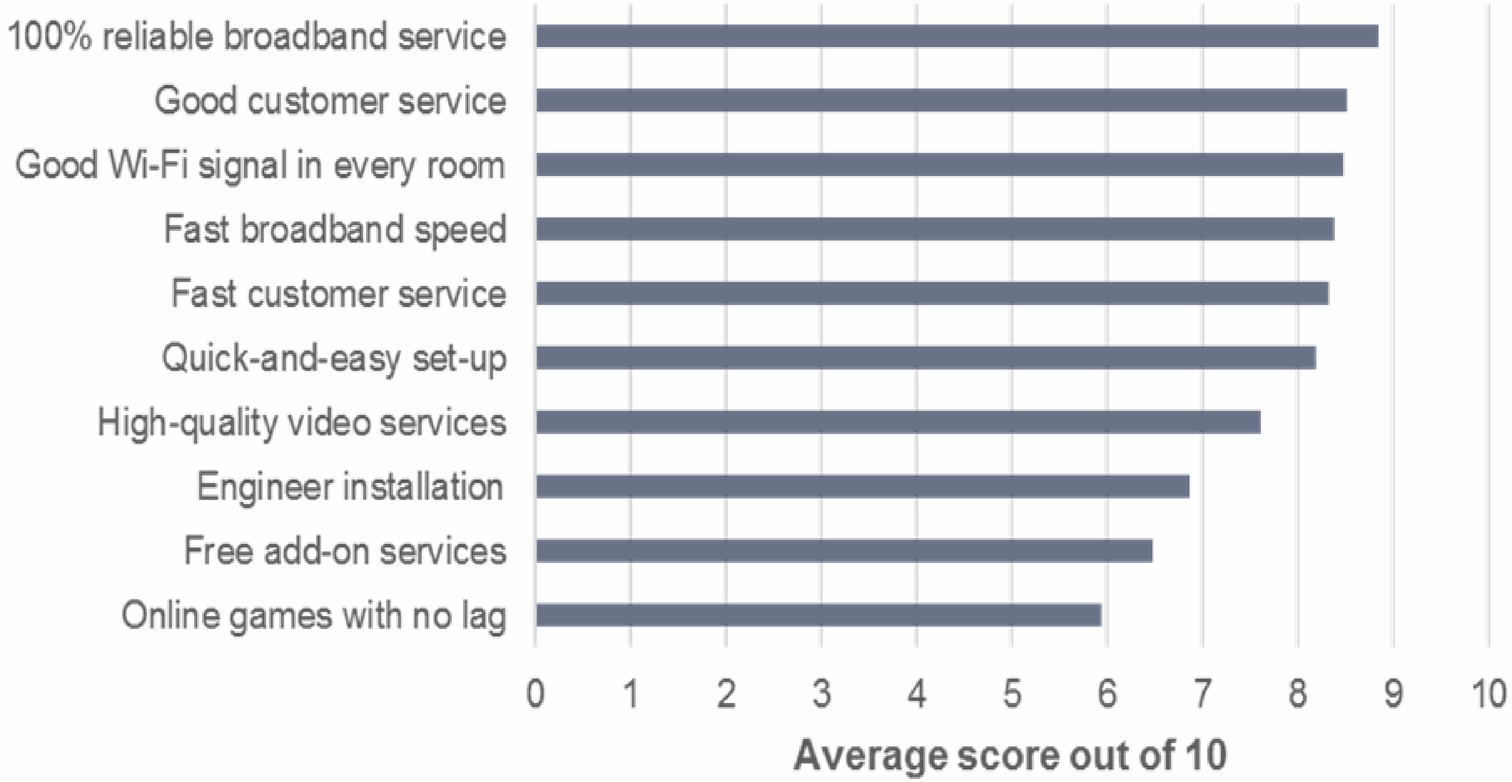
O&M

- Not every copper network can be upgraded, leaving telcos with multiple, copper-based networks

Very different upgrade strategies across operators.

- NA interviews:
  - Our marketing team is not interested in anything that cannot support 1G today.
  - We will eventually consider Gfast for MDUs where FTTH is too hard to do.
  - Copper-based upgrades are expensive too.
  - Fiber access is important for 5G MBH. It is also important for smart city applications. We need the fiber and point-to-multipoint fits the future.
- Other operators, especially in Western Europe:
  - Swisscom FTTStreet with Gfast makes the most sense given relatively low urban densities but, keeping an eye on competition from other operators around 1G and 10G FTTH offerings.

Service provider perspective:
Bandwidth is important although not enough to reduce subscriber churn



Source: Ovum survey

Service bundles are key

Bundle	Typical level of churn*
Single play broadband	20–25%
Dual play	15%
Triple play	**10%**
Quad play	5%

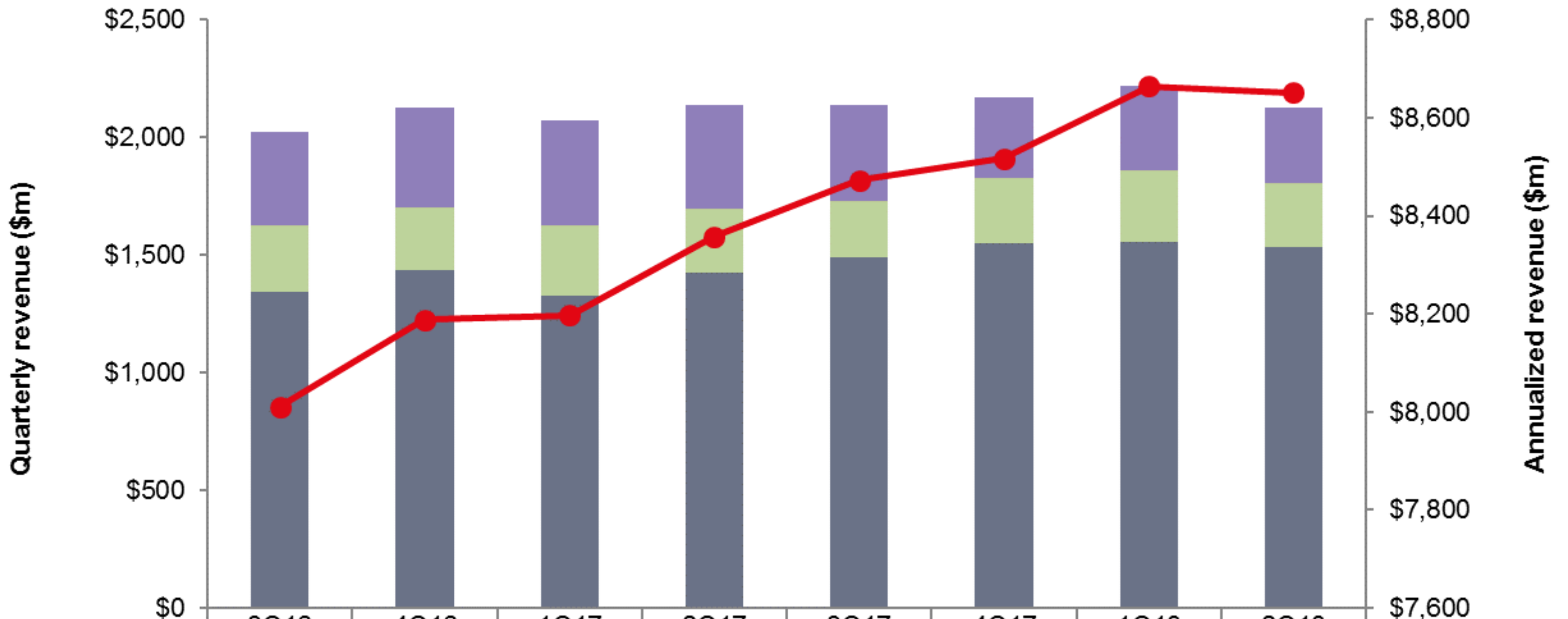
*based on typical rates in WE

Integrated operator has competitive advantages but needs to control upgrade and operating costs of two networks.

Source: Ovum

Looking backwards – significant milestones

Wireline broadband access equipment market – strength in PON segment continues

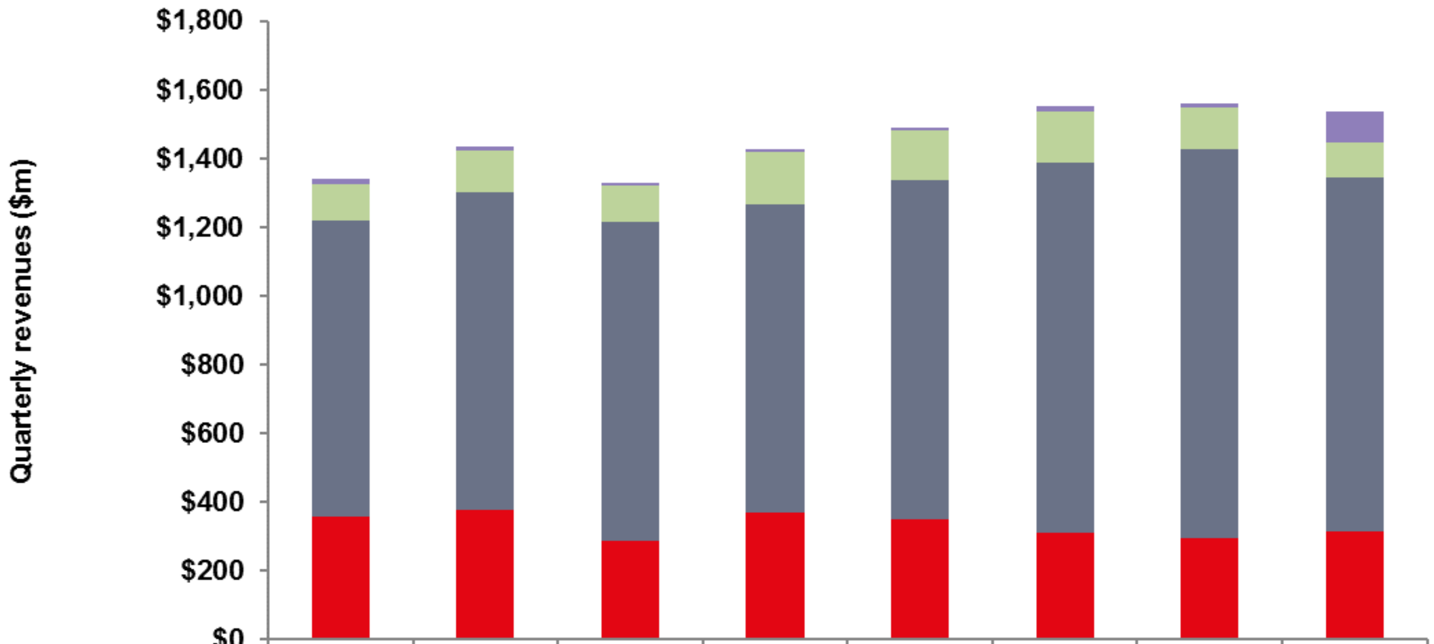


	3Q16	4Q16	1Q17	2Q17	3Q17	4Q17	1Q18	2Q18
DSL + G.fast	$400	$423	$447	$440	$405	$341	$360	$320
CMTS and CCAP	$281	$270	$296	$270	$242	$278	$302	$270
PON	$1,342	$1,434	$1,329	$1,427	$1,490	$1,552	$1,558	$1,535
Annualized	$8,010	$8,188	$8,198	$8,358	$8,472	$8,517	$8,664	$8,652

2Q18 – would have been a record breaking PON equipment quarter if not for ZTE's woes.

Source: Ovum

Next-gen PON equipment revenues – ONT/ONU revenues strong in 2Q18



	3Q16	4Q16	1Q17	2Q17	3Q17	4Q17	1Q18	2Q18
next-gen ONT/ONU	$19	$12	$7	$8	$9	$16	$9	$88
next-gen OLT	$105	$119	$106	$152	$145	$148	$122	$103
non-next gen ONT/ONU	$860	$926	$928	$898	$988	$1,078	$1,132	$1,031
non-next gen OLT	$358	$376	$287	$368	$348	$310	$294	$313

INDUSTRY FIRST
2Q18 – North America next-gen PON equipment revenues matched those in China.

Don't expect this to happen every quarter but it was noteworthy.

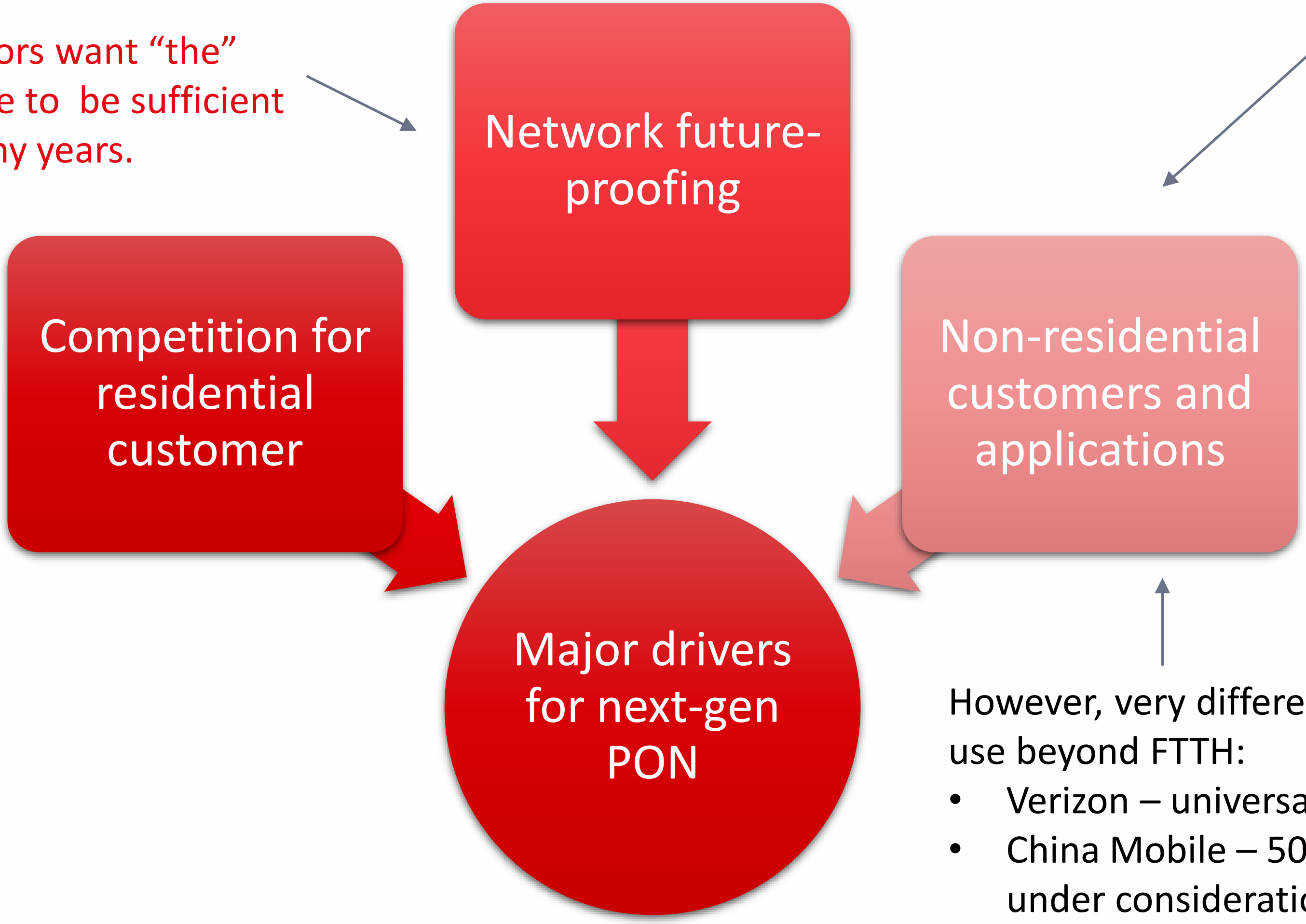
Source: Ovum

Looking forward

Next-gen PON market is accelerating – key drivers

Operators want “the” upgrade to be sufficient for many years.

The bandwidth-to-the-home marketing battle is moving from 1G to 10G, leading to 10G ONT/ONU shipments.

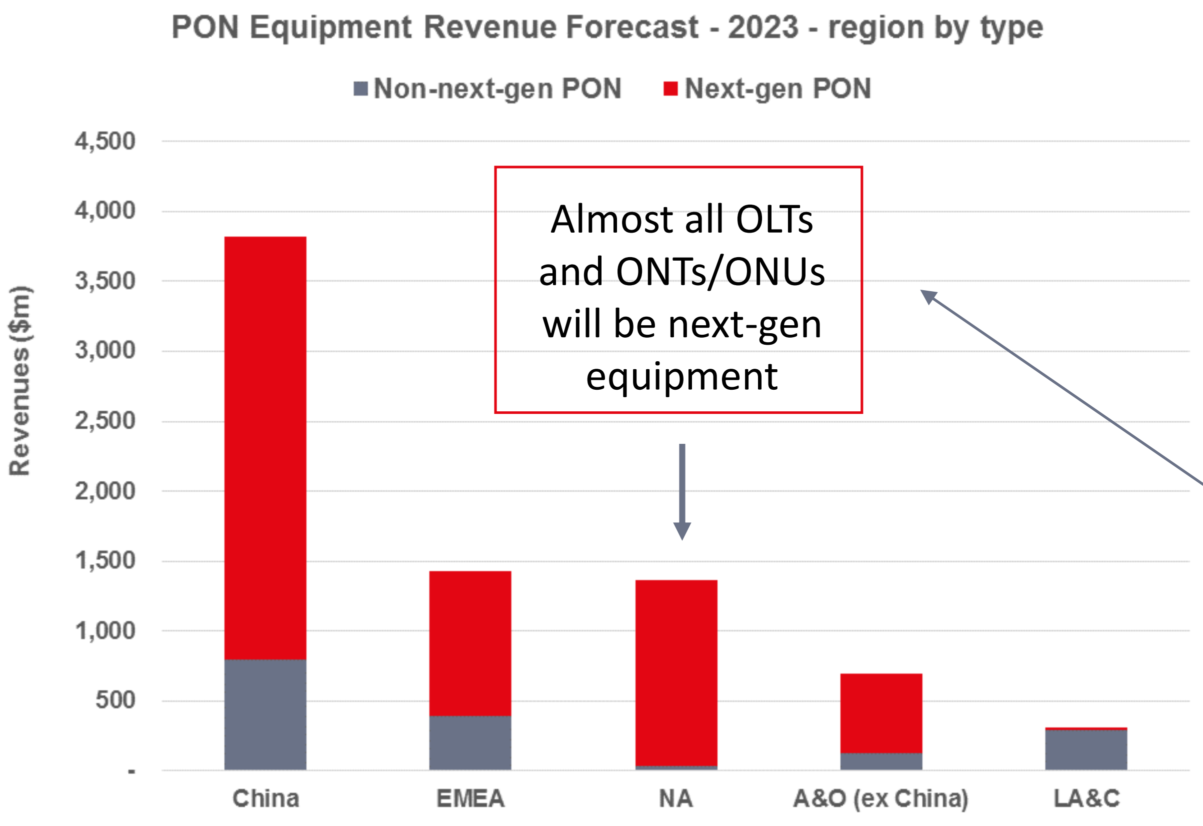


Includes use of PON for:
- Businesses and small enterprises
- “Haul” – backhaul and/or fronthaul
- Smart city applications
- POL – passive optical LANs for universities, hospitals, hotels.

However, very different strategies regarding PON’s use beyond FTTH:
- Verizon – universal access network.
- China Mobile – 50G PON for 5G small cell MBH under consideration.

Next-gen PON equipment revenue forecast – by region – optimistic in most regions

Next-gen PON exceeds 78% of total PON equipment revenues in 2023



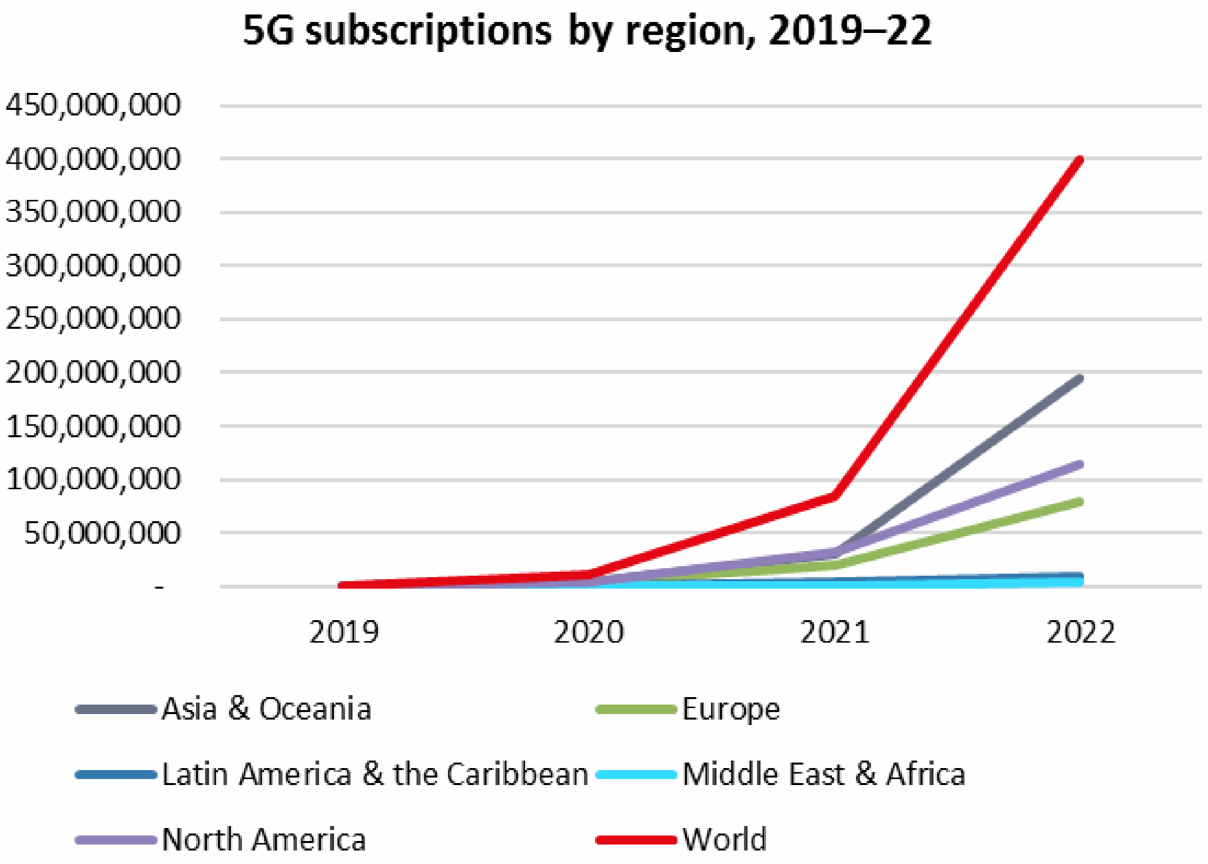
Regional/Country Analysis – based on full year 2023:

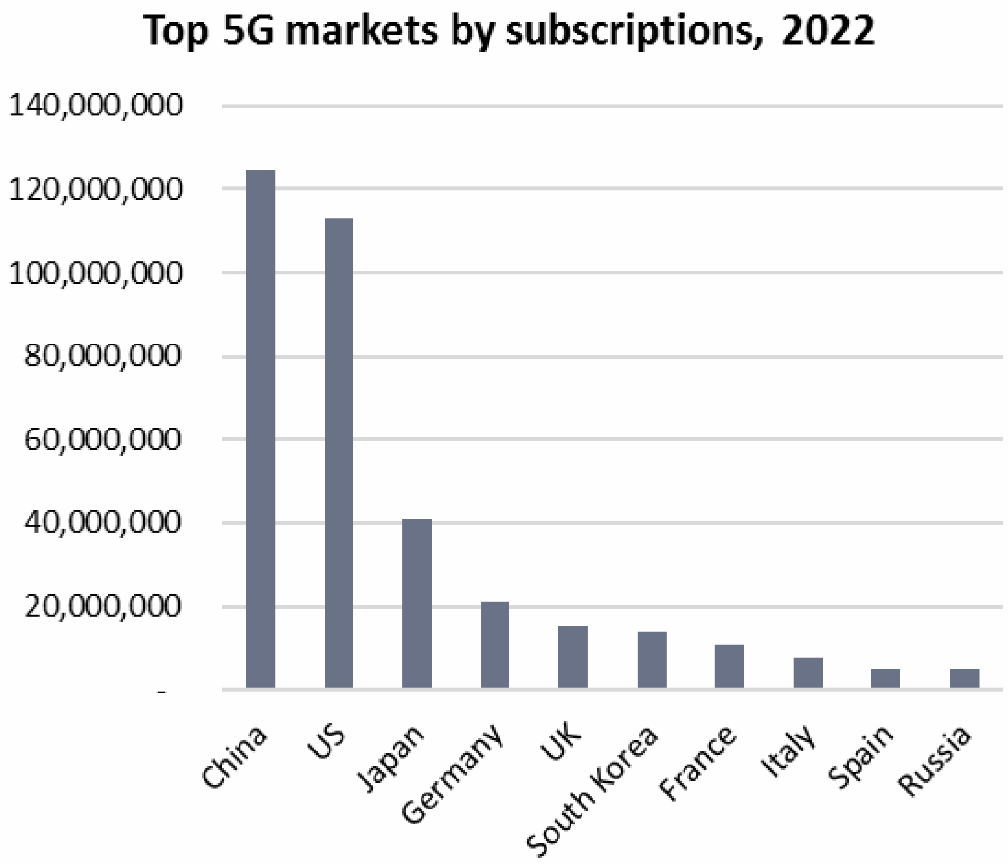
	2023 PON equipment revenues ($m)	% next-gen	% non-next gen
China	$3,818	79%	21%
EMEA	$1,426	72%	28%
NA	$1,361	98%	2%
A&O ex China	$697	81%	19%
LA&C	$315	6%	94%
Global	$7,617	78%	22%

Largest catalyst or inhibitor is ASP for next-gen PON ONT/ONU at OC (optical component) level

Source: Ovum

But what about transport for 5G - Consumer subscription forecast





Source: Ovum

Three major application areas for 5G

Enhanced mobile broadband (including fixed wireless access)	Ultrareliable, low-latency communications	Massive machine-type communications (IoT)

• Offers wider bandwidths than LTE
• Uses spectrum above and below 6GHz
• Uses licensed and unlicensed spectrum
• Incorporates technologies such as massive MIMO
• Examples:
  • **3D video/UHD video**
  • **Rich media and entertainment**
	• Supports ultra-low latency transmission (<1ms)
	• Supports highly resilient communications with redundancy
	• Offers reliable device-to-device communication
	• Examples:
	  • Industrial automation
	  • **Autonomous vehicles**
	  • Telemedicine
	  • Augmented and virtual reality
		• Evolves out of narrow-band LTE (eMTC/NB-IoT)
		• Has low complexity, and requires low energy
		• Follows the ultra-dense, small cell network model
		• Eventually adds new waveforms and architectures (e.g. multihop mesh)
		• Examples:
		  • Smart grid
		  • Smart cities
		  • Health monitoring

Next-gen PON for Mobile Backhaul (MBH) – becoming a transport solution

Challenge	Potential Solution
Organizational silos at operator: • Wireless engineers handle MBH • Wireline engineers handle FTTx	Vendors must work with both sides of the operator; bring the two organizations together.
Technical – can PON support MBH?	• Yes, but operators want proof. • 10G is sufficient in numerous scenarios. NG-PON2 can support 20G and more with wavelength bonding.
Competitive solutions – there are well-known solutions such as point-to-point fiber and microwave.	• Vendors must provide detailed analysis of pros/cons of the various solutions. • Vendors must solve their internal positioning of various solutions for MBH.
Explosion of small cells, especially in dense, urban areas.	• FTTx PON network can support small cells, particularly in urban areas.
Strategy – FTTx supports more than just FTTH.	• PON becomes one piece of the transport solution.

Ovum's MBH equipment forecast:

- Optical-fiber is forecast to represent 59% of total MBH equipment market in 2022.
- Why is fiber only 59% in 2022 – it does not catch up with rapid growth of 5G/small cells traffic growth.

Source: Ovum

Next-gen PON for Mobile Fronthaul (MFH) – increased R&D efforts

Challenge	Potential Solution
Organizational silos: • Wireless engineers handle Fronthaul. • Wireline engineers handle FTTx	• Vendors must work with both sides of the operator; bring the two organizations together.
Technical – can PON really handle MFH technical requirements?	**Issues to be solved – bandwidth, latency, timing:** • **NG-PON2 has the bandwidth.** • **Solutions for low latency and precision timing are being developed.**
Competitive solutions – there are well-known, proven solutions such as point-to-point fiber.	• Vendors must provide detailed analysis of pros/cons of the various solutions. • Vendors must solve their internal positioning of PON for fronthaul.
Strategy – FTTx supports more than just FTTH.	• PON becomes one piece of the transport solution.

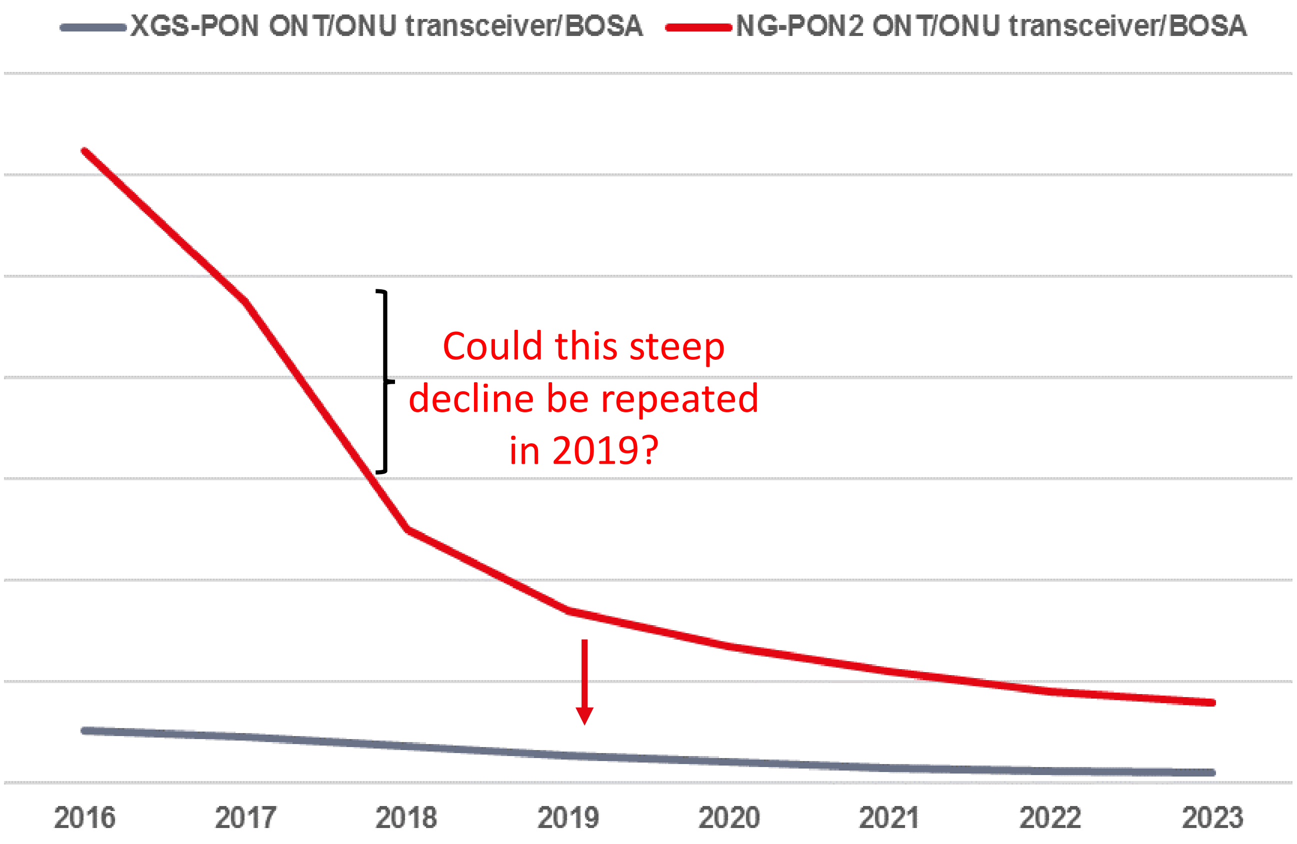
Ovum's MFH equipment forecast:

- Optical fiber dominates wireless fronthaul equipment market due to bandwidth requirements.

Source: Ovum

Key challenge for NG-PON2 remains optical component ASPs

Forecasting dramatic decline – can the declines continue?



Key challenge for NG-PON2 is optics costs, especially for subscriber-side.

However, significant R&D efforts have led to lower costs already.

If cost declines can be repeated, focus moves to other KPIs.

For example, advantages of NG-PON2's multiple wavelengths – supporting different applications and customers by type, including smart cities, support for "open access."

Source: Ovum

Service providers are taking an active role in the smart city ecosystem

Smart cities services/applications	Leading telco providers	Leading technology and industry partners
Smart lighting	Deutsche Telekom, telenor, AT&T, vodafone	Philips Lighting, GE Lighting, Telensa
Public security	AT&T, etisalat	Motorola, HITACHI, PELCO, GE Security
Traffic management & smart parking	China unicom, vodafone, Deutsche Telekom, du	SMART PARKING, HUAWEI
Environmental management & services	Telefónica, vodafone	SPARK COMPASS, CENSIS, fybr, ferrovial, Bigbelly, ECUBE Labs
Smart buildings & venues	Singtel, ncs, vodafone	Philips Lighting, Johnson Controls, Schneider Electric, HITACHI, mitie
Smart public transport	Telefónica, vodafone	mobike, AMTRAK, ERICSSON
Total Smart City Solutions	CISCO, ERICSSON	HUAWEI, SIEMENS

- City governments recognize the “power” of being smart.
- Their concern is building a holistic strategy that encompasses multiple services and applications (based on extensive Ovum worldwide survey).
- Connectivity is a basic requirement for smart cities.
- CSPs (communications service providers) are leading with **connectivity and services/applications.**

Source: Ovum

Thank You

Copyright notice and disclaimer

IoT and the Future of the Connected Home

Alan DiCicco
Senior Solutions Marketing Director
Calix
alan.dicicco@calix.com

broadband forum

BASe

IoT and the Future of the Connected Smart Home

Alan DiCicco
Senior Director, Thought Leadership Marketing

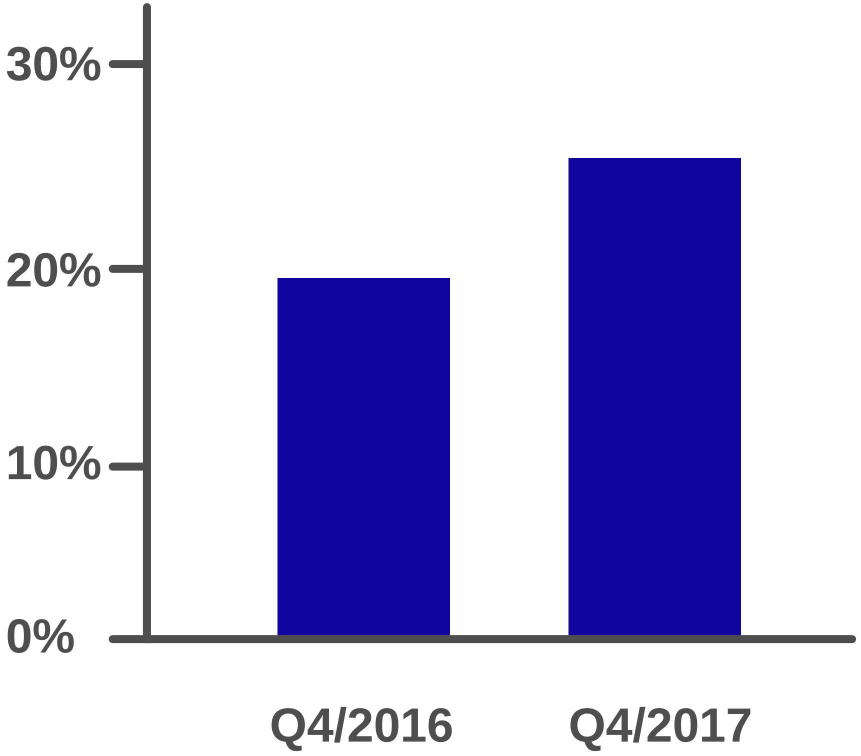
Calix


ZOLTAR
.25¢

Are you ready for the smart home?

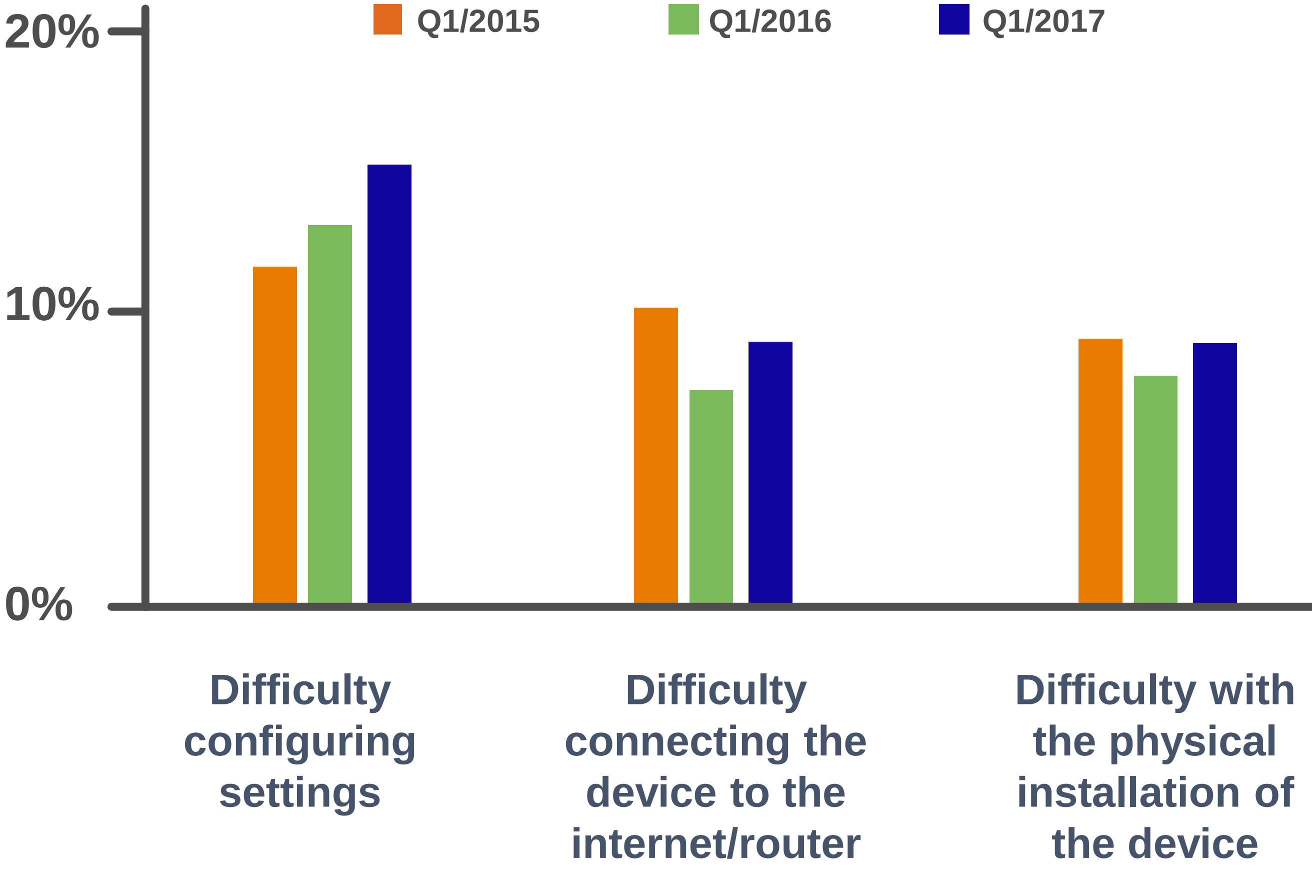
Because it's already here

- Of U.S. broadband households, **26% own at least one smart home device**
- Of those with smart home devices, **60% own more than one**
- **48% reported an intent to purchase** a smart home device in the next year
- Most popular devices: smart thermostats, networked cameras, smart lightbulbs, video doorbells, smart garage door openers, and smart door locks.



© Parks Associates

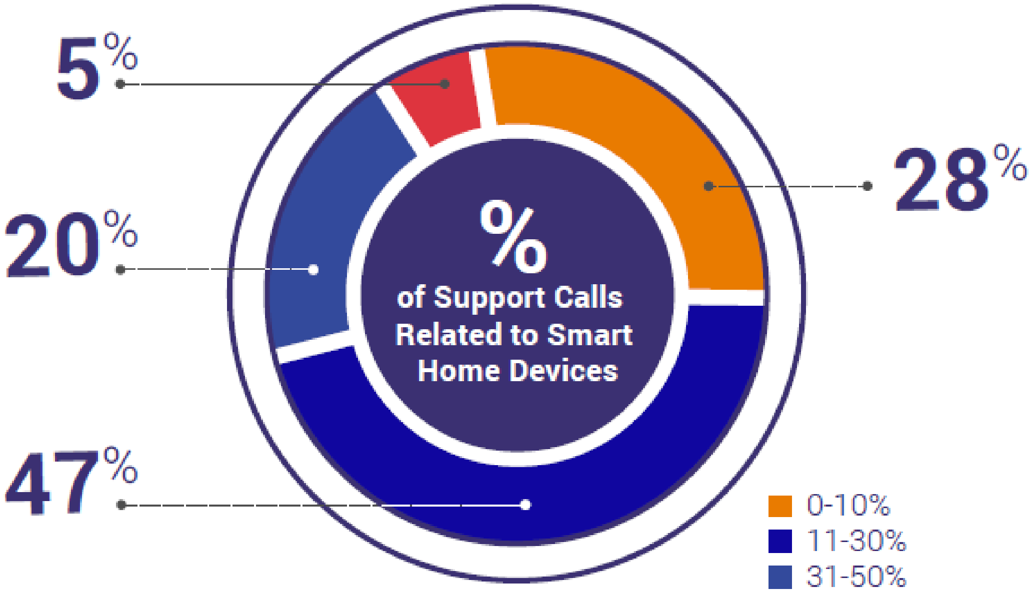
What's slowing IoT adoption?
Top 3 issues with smart home devices



50% of US households reported issues setting up Smart Home devices

Regardless of where setup problems arise, **13% of households that have experienced a tech problem contact their service provider** for help resolving smart home device problems.

Percentage of support calls related to smart home devices



Q: "How much of an increase in support calls have you, as a service provider, seen over the past 12-18 months because of smart home devices?"

Source: Poll of 92 service providers during two recent Calix webinars.

Some IoT Observations

- Most service providers have not build a smart home business beyond Wi-Fi
- Ease of use and interoperability are clear pain points
- Lack of compelling justification for recurring high costs
- DIY IoT installation of lower-tier products is on the rise
- Developments in data analytics and AI are increasing the consumer benefit
- Security and privacy concerns are limiting adoption
- Promise of monetizing data to unlock new revenue is spurring investment
- Broadband router can be used as the entry point to offer smart home services

What’s the opportunity in the connected smart home?


NETFLIX
hulu
YouTube
Linear TV

Many big fish are already swimming about in this big blue ocean.

Can you build a better smart…

- Appliance?
- Speaker?
- Light bulb?
- Entertainment system?
- Cult of loyal followers?
- Complementary business model… search, commerce, lifestyle accessories?

SAMSUNG PHILIPS SONOS LG

BOSE Disney Roku

Google amazon

What’s the service provider opportunity in the connected smart home?

IoT ingredients of success

Wi-Fi Connectivity

Universal IOT Gateway

EASY

Platform Extensibility

Security and Privacy

Wi-Fi Connectivity

The future only knows Wi-Fi

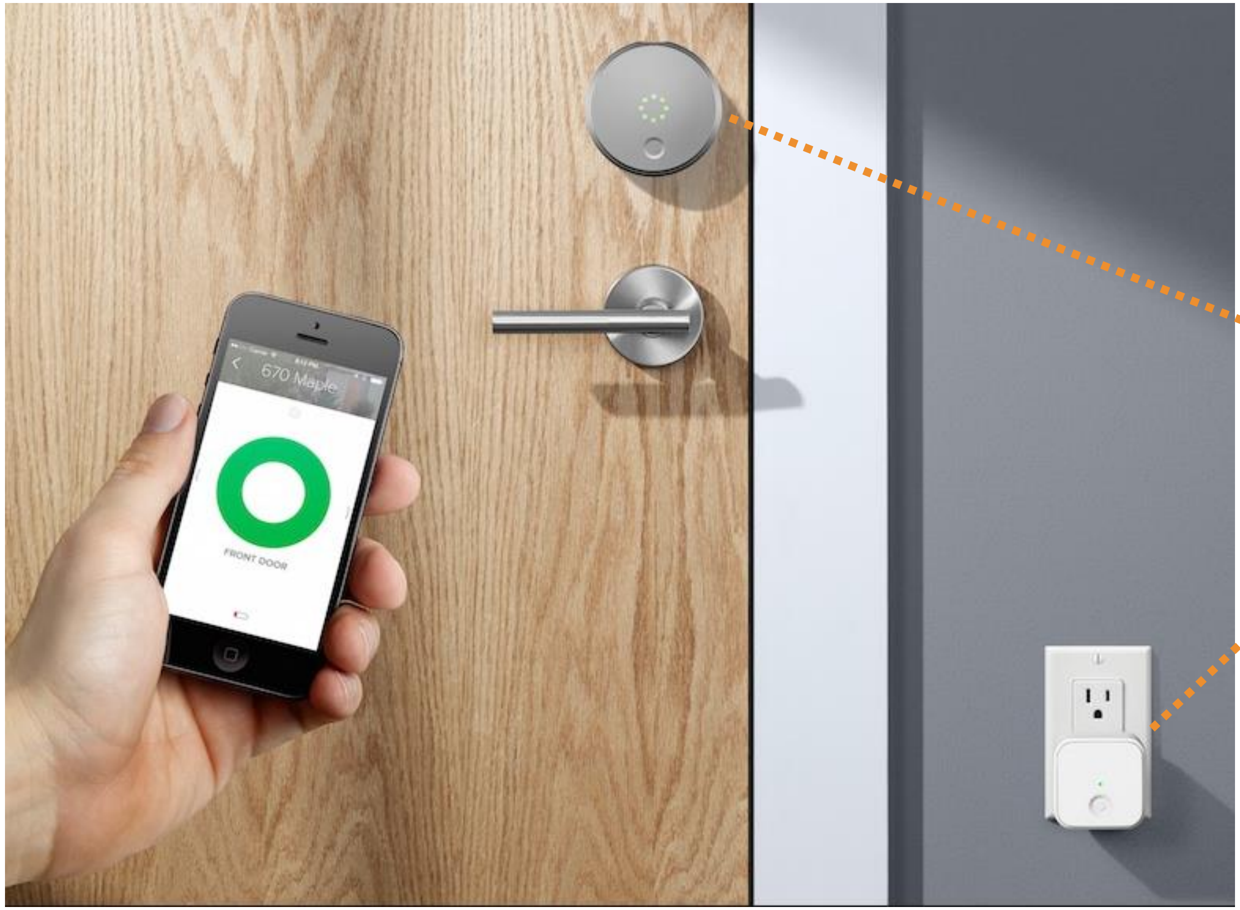
- Generation Z+ does not know what an Ethernet cable is, and many have never had a TV ‘cord’
- Wi-Fi is the path to everything
- Anything less than whole-home coverage is unacceptable
- Consumers will solve Wi-Fi connectivity issues with or without service provider help

Your reputation is built on exceptional Wi-Fi

Multi-Gigabit Wi-Fi
802.11ax, 12x12 antennas, wireless mesh, MU-MIMO, beamforming, channel steering

Universal IoT Gateway

Additional hubs and bridges are required



Fine print… additional ‘smart hub’ is required to ‘translate’ into Wi-Fi

Price is $90

… times 3!

Bluetooth®

ZigBee®

Z WAVE

Universal IoT Gateway

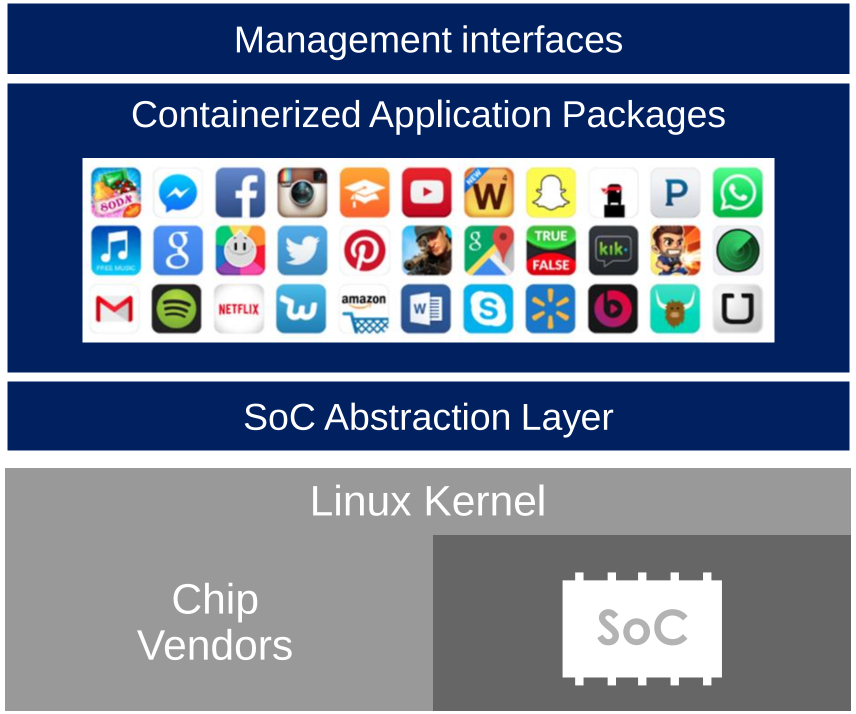
Integration is simplification

- Can't fight the global device ecosystem, but can eliminate the need for smart hubs
- Service provider manages the IoT complexity
- Whole-home IoT connectivity
- Save time, eliminate subscriber frustration

Platform Extensibility

Software platforms underlie every service & application

- An embedded software platform
  - Hardware independent operating system
  - Running containerized applications
  - Programmatic open standard interfaces
- Part of a monetized ecosystem
  - Application lifecycle management
  - Service provider visibility and control
- The possibilities are nearly limitless
  - Subscriber-located edge compute resources coupled with innovation-driven apps



Security and Privacy

Trust is the service provider currency

Open source
PUF database

Physical Unclonable Function (PUF)

ALERT: A smart TV was added to your home network. The unit's software is out of date and should be updated. Use this link to start the process.

Network Telemetry

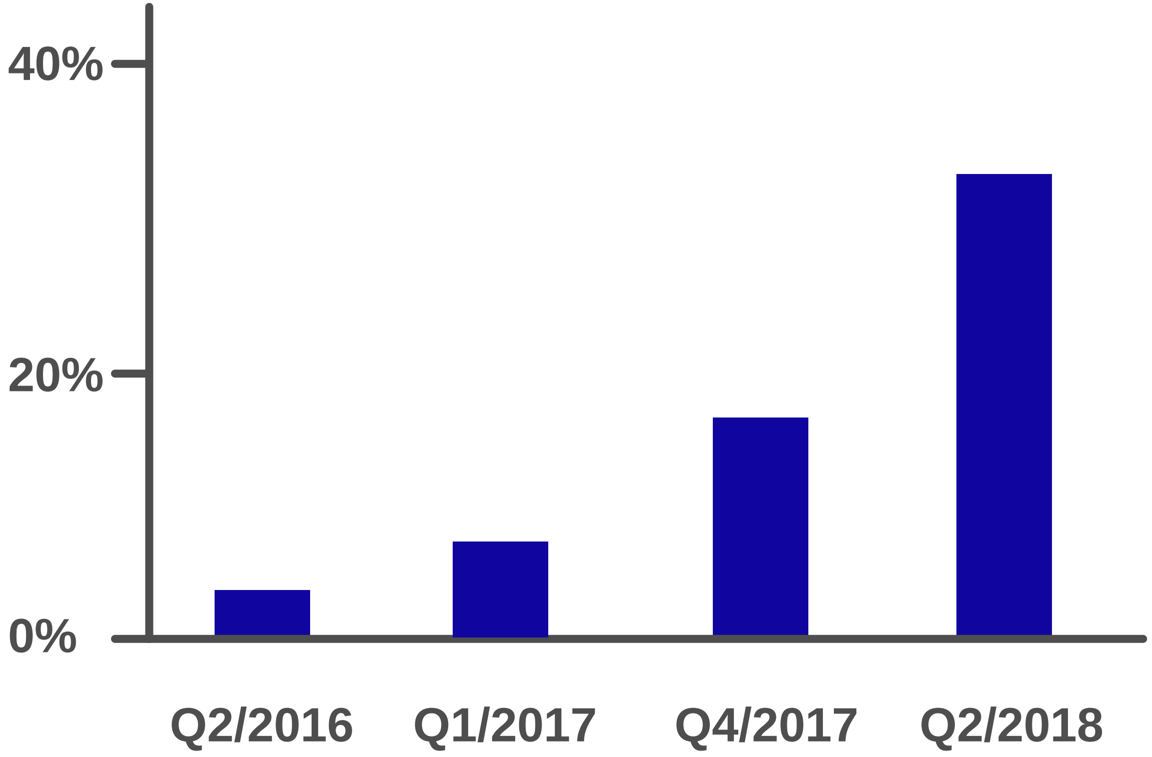
- Analytics
- Machine Learning
- AI

WARNING: Your Amazon Echo attempted several credit card transactions at 2:13am. All transactions were blocked and the unit was quarantined.

Make it EASY

Voice activation makes the smart home easier

- **28%** of U.S. broadband households own a smart speaker with voice assistant (growing to **47%** by 2022)
- Voice control driving adoption and usage of devices and apps
- **55%** of U.S. broadband households find voice control of connected entertainment devices to be appealing



© Parks Associates

Voice makes it EASY

You can’t beat them, so integrate them

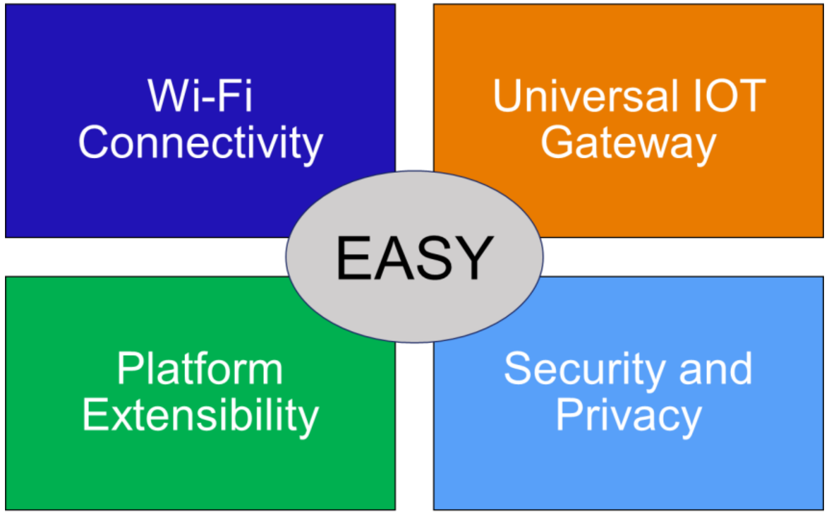
- Google’s machine learning word accuracy exceeds the threshold of human accuracy
- 30K+ Amazon Echo voice Skills
- Imagine… AI-based self-care customer service Skills
- Imagine… the service provider at the center of the subscriber’s smart home experience

Alexa, give my Zoom video call top priority on the Wi-Fi network.

Alexa, when will the dryer be finished?

Alexa, increase the Internet speed during the Zoom call.

The future of IoT



- Embrace and co-opt the web-scale ecosystem innovations
- Privacy and security: you are the customer’s IoT advocate
- Freemium business model
- Be aggressive, not defensive


Be a barracuda.
Swim with the barracuda!

New Business Opportunities with 5G

Fernando Gordo

Director of Chief Transformation Office,

Carrier Business Group | Huawei

Fernando.gordo@huawei.com

broadband forum

BASe

HUAWEI

New Business Opportunities with 5G

October 28th, 2018

Hotel Encore, Las Vegas

Brief introduction

Fernando Gordo

Director of Chief Transformation Office,
Carrier Business Group, Huawei

Experience

- 2018-Present: Huawei Chief Transformation Office of Carrier Business Group
- 2014-2018: Huawei Global Solutions Elite Team – CTO for DC, IT and Cloud Solutions
- 2012-2014: Telefonica Global Technology-Transformation Director
- 1998-2014: COLT Technologies – Global Operations Director
- 1988-1998: BOSCH Telecom – Business Development Manager
- 1983-1988: HITACHI – Technical Service Manager

5G will be Key Enabler of the 4th Industrial Revolution

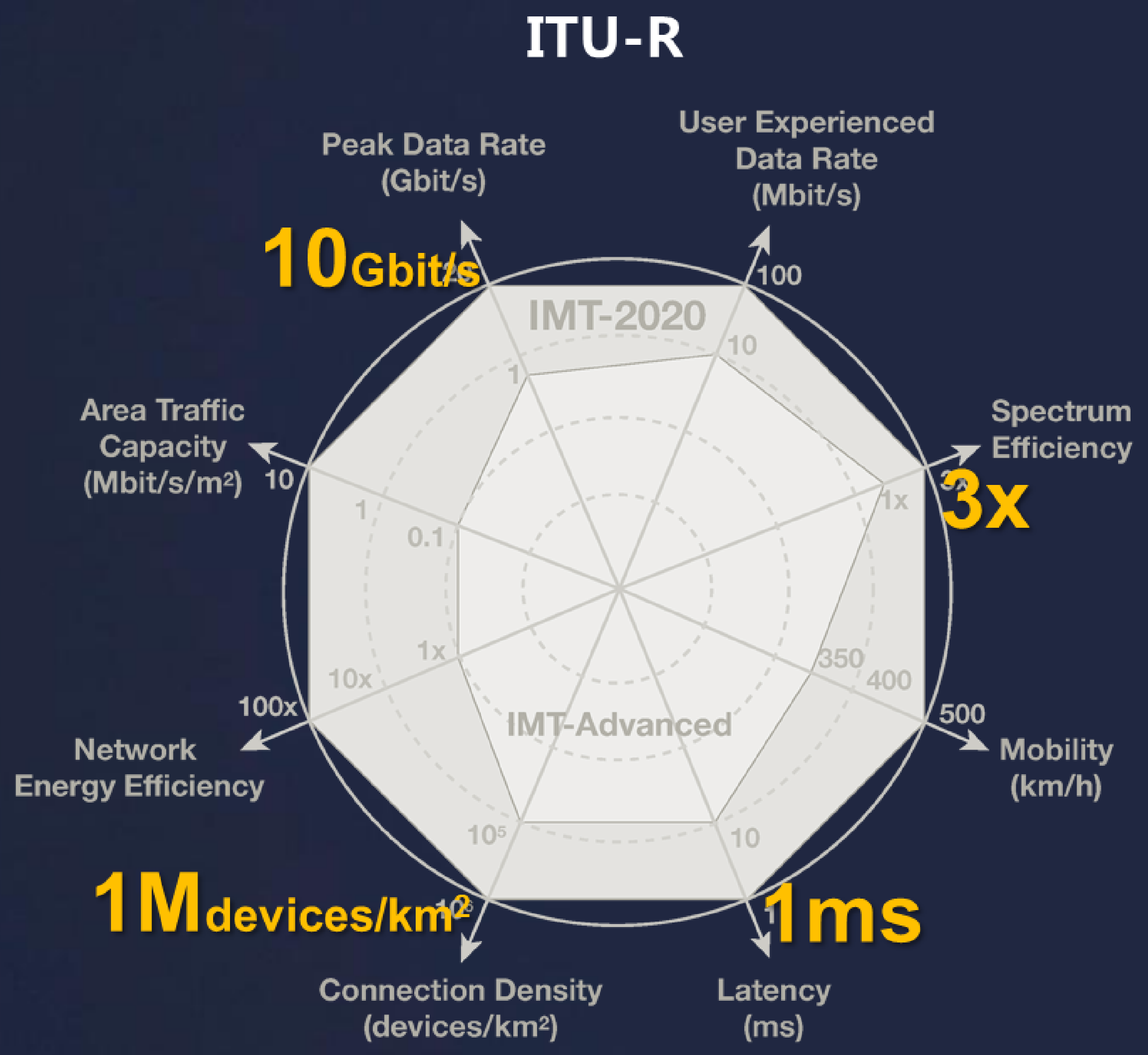
HUAWEI

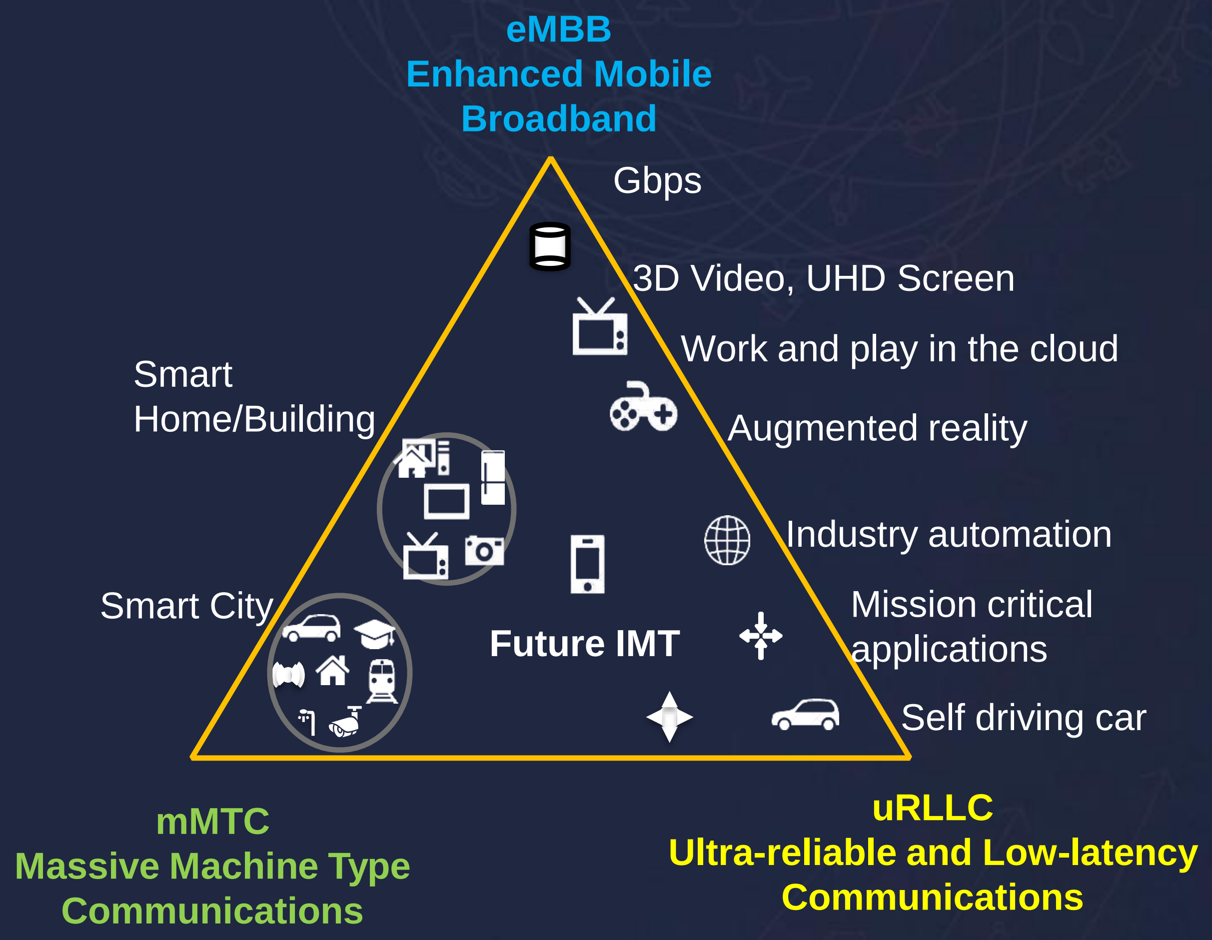
Industrial Revolution	1st	2nd	3rd	4th
	18th Century	19th Century	20th Century	21th Century
Tipping Point	Steam Engine	Electricity	Computer	Internet of Everything
Transformed Industries	…	…	…	ALL Industries …

Multiple Challenges and Gaps to reach 5G

	Latency	Throughput	Connections	Mobility	Network Architecture
5G	1 ms E2E Latency	10Gbps Per Connection	1,000K Connections Per Km2	500km/h High-speed Railway	Slicing Ability Required
GAP	30~50x	16x	100x	1.5x	NFV/SDN
LTE	30~50ms	600Mbps	10K	350Km/h	Inflexible

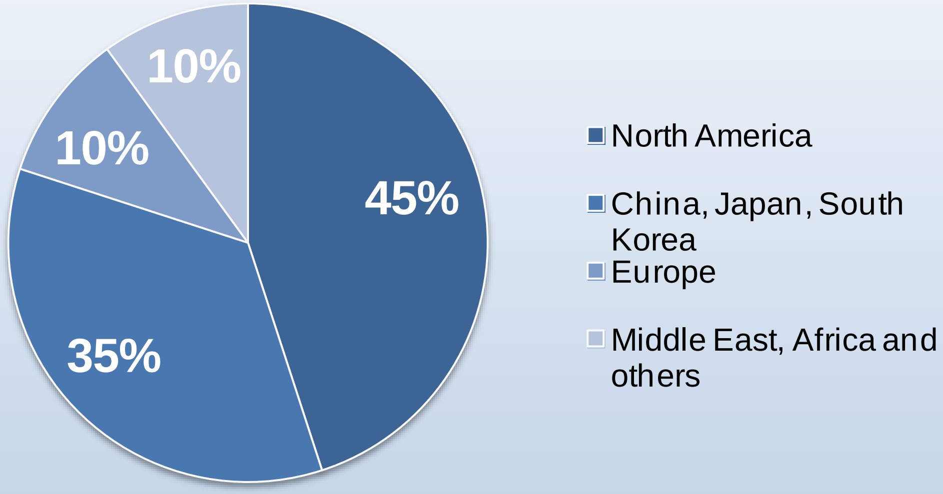
Key 5G Capabilities





5G Market size forecast

5G subscriptions by 2021

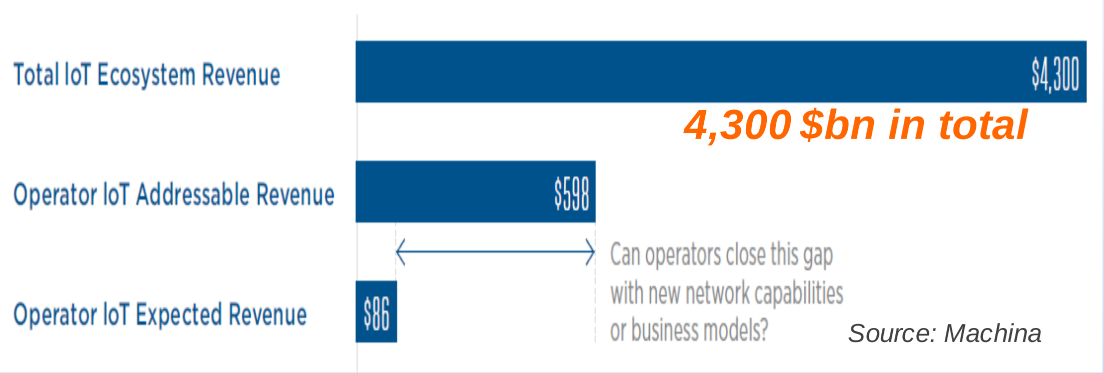


Source: Ovum

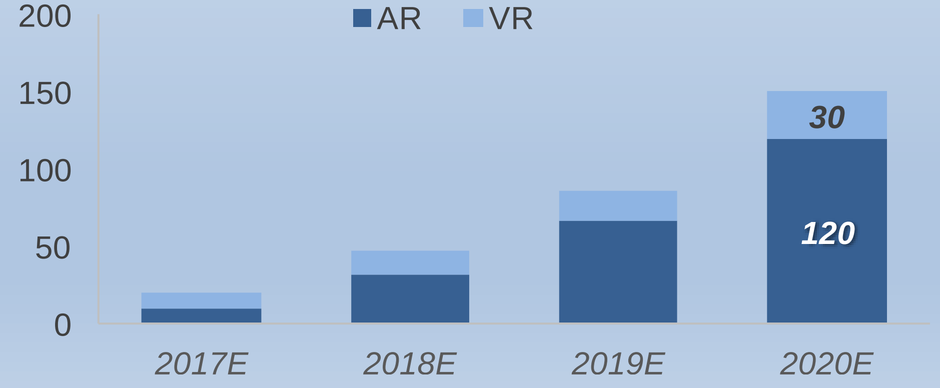
- By 2021, more than ***50 operators*** will offer 5G in 30 countries,
- It forecasts that total ***25 millions subscriptions*** worldwide, with 4% upward.
- Top-4 markets (US, China, Japan and South Korea) will account for 80% of the world's 5G subscriptions

Examples of new revenue opportunities

IoT revenue forecast by 2024 ($bn)

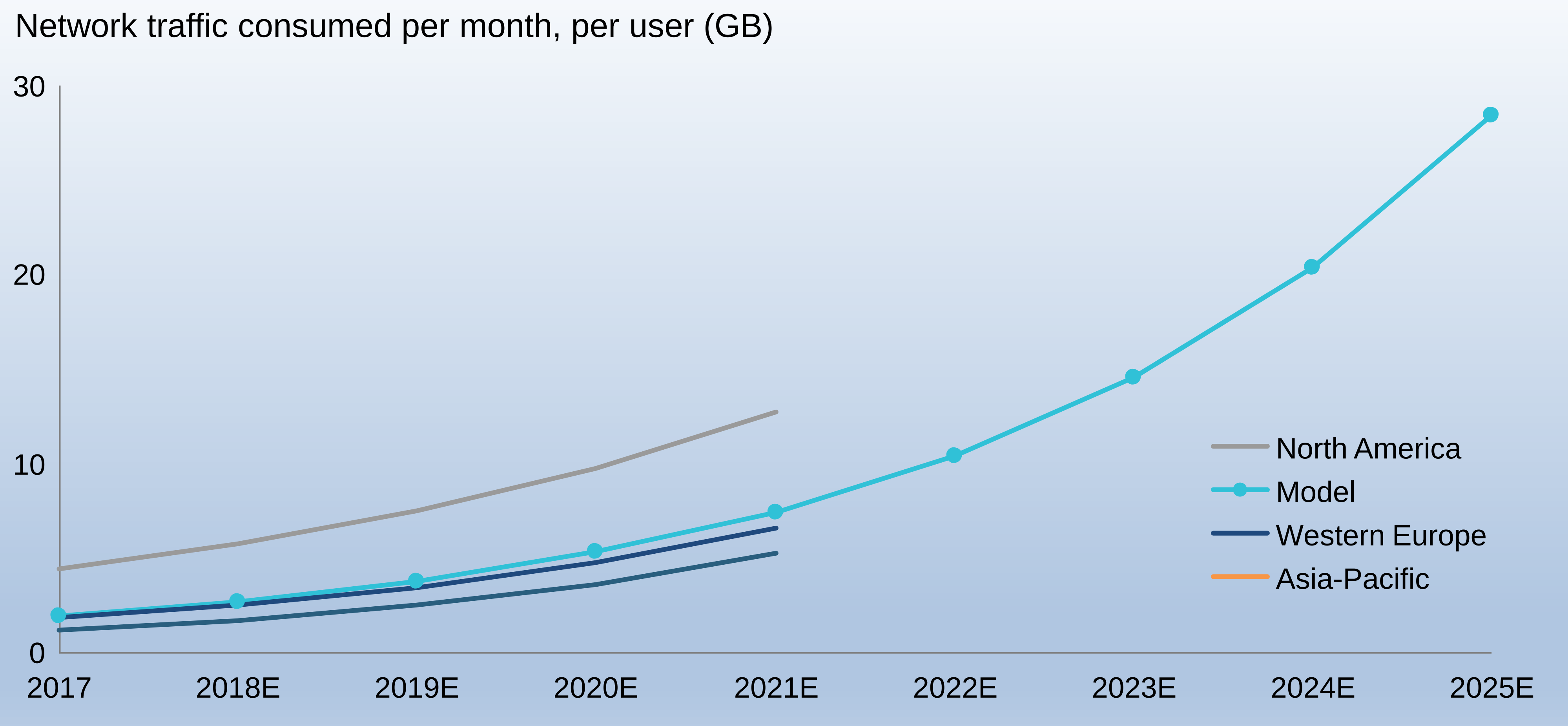


AR/VR revenue forecast (billion)



Source: Digi-Capital, CCS Insight,

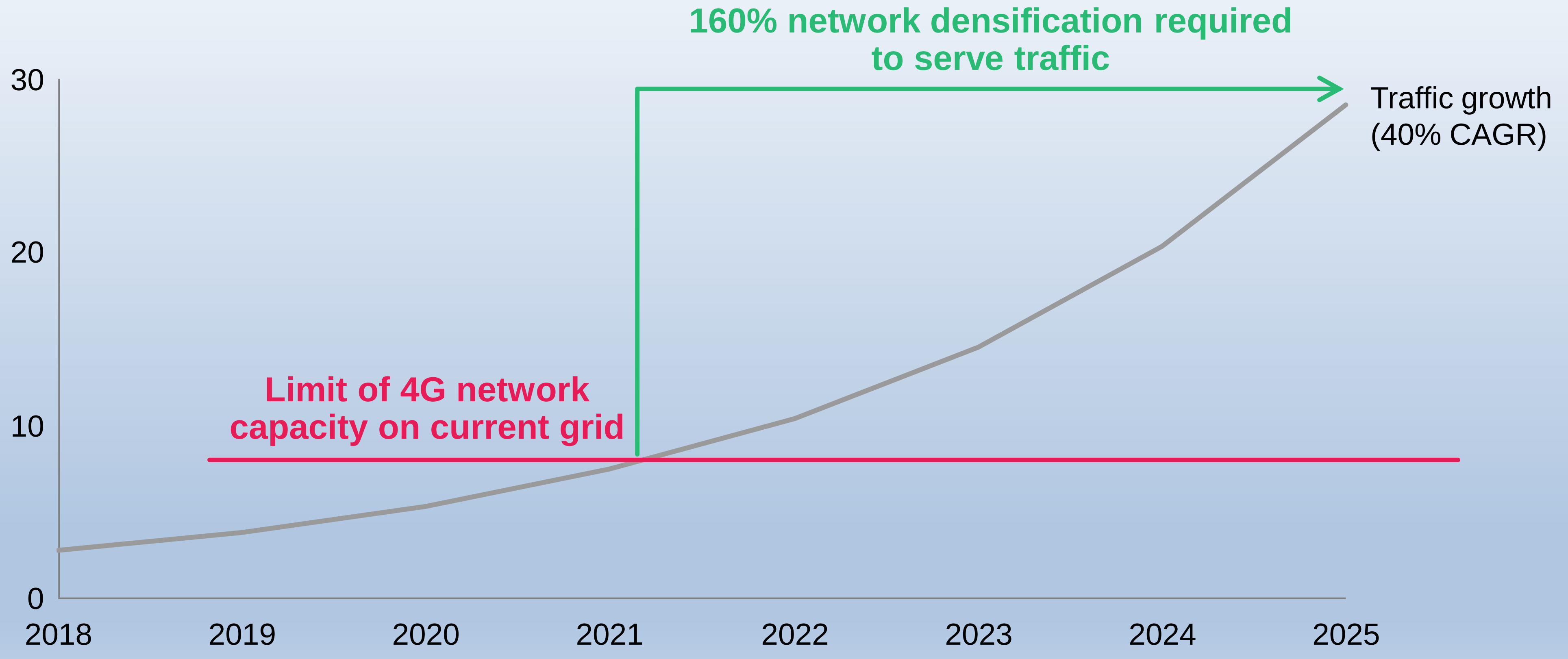
Exponential Mobile Data Traffic Growth



Sources: Cisco Visual Networking Index; BCG analysis.

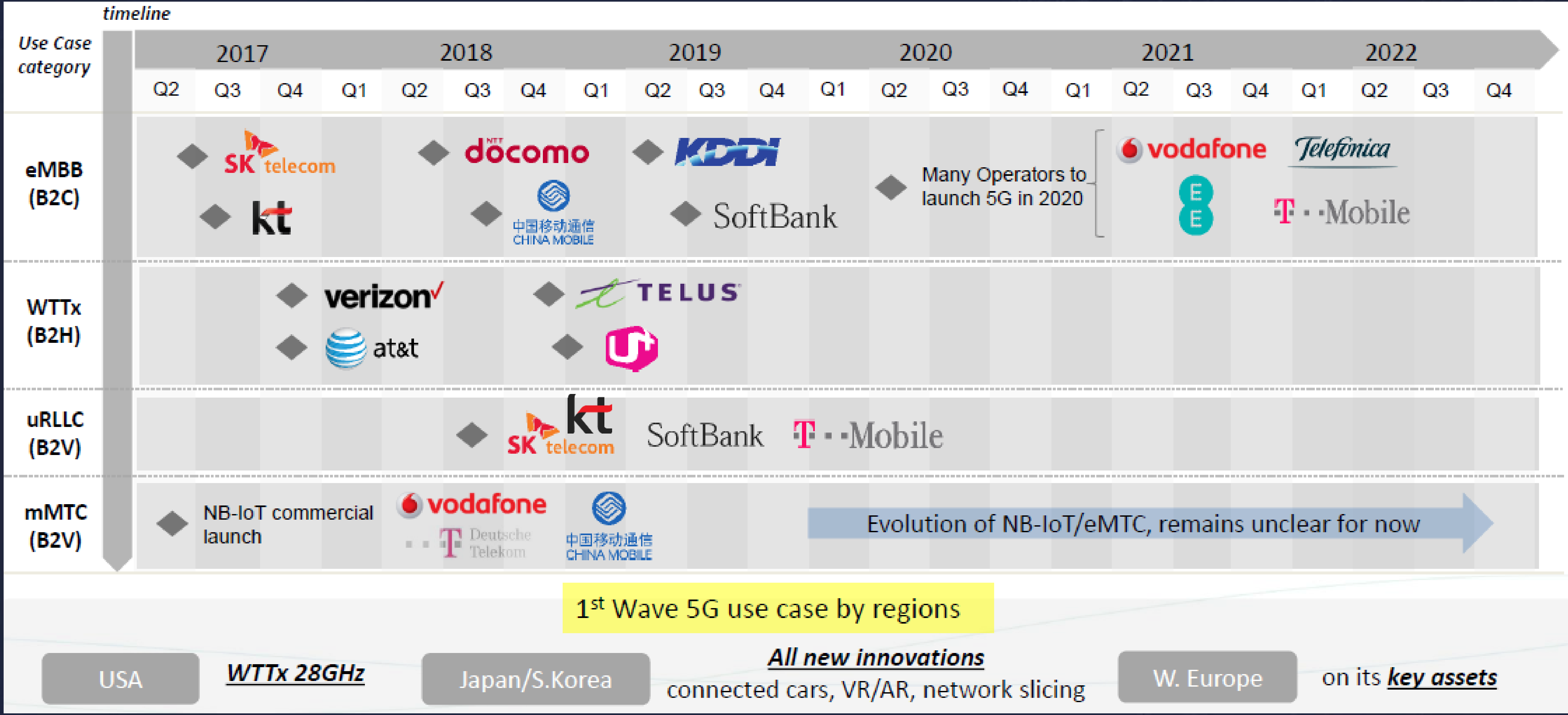
Networks Cannot Support Data Traffic Growth

Estimated network traffic consumed per month, per user (GB)

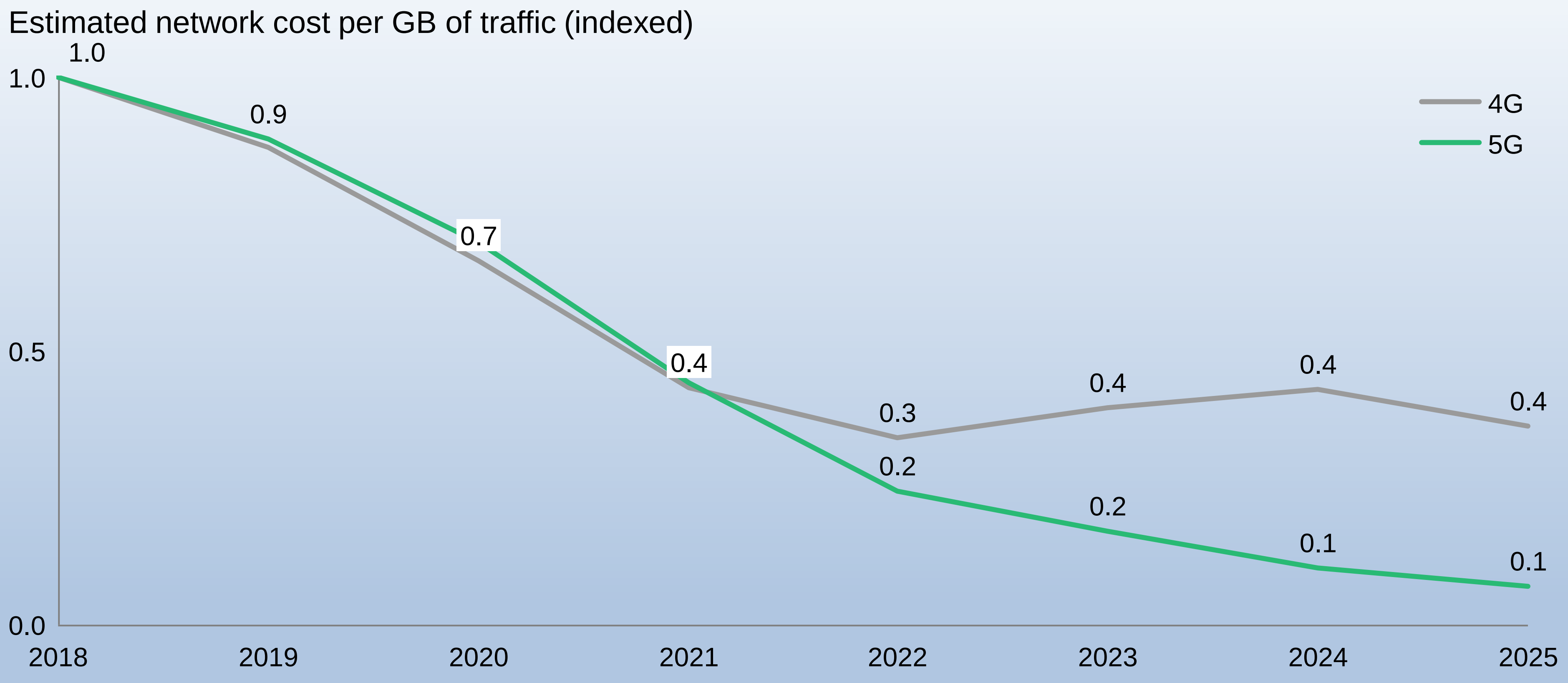


Source: BCG network model.
Note: Densification = an increase in the number of cell towers and antennae in a given area.

Telcos have different launch Strategies

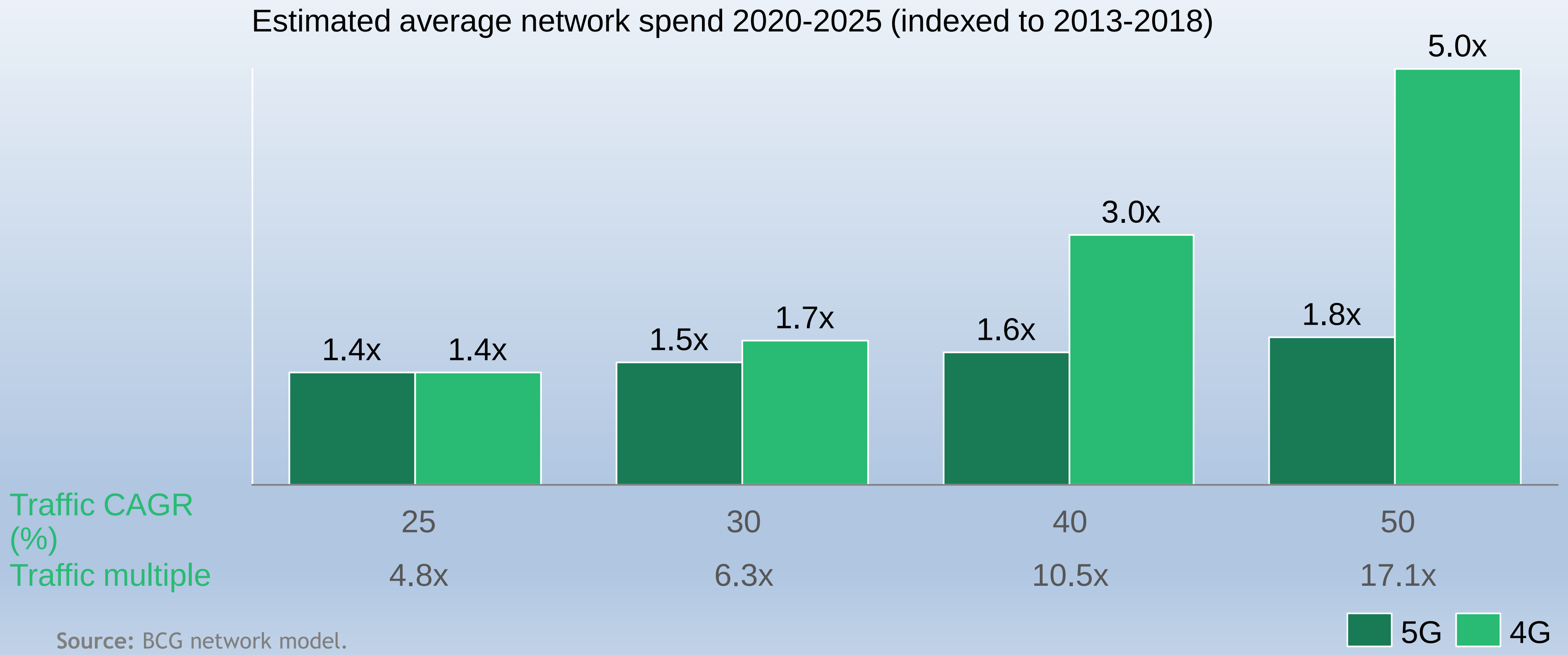


5G : Cheapest Way to Serve Rising Data Demand



Source: BCG network model.
Note: Graph represents three-year moving average network spend.

With Higher Traffic Growth, 5G Cost Benefits Grow



Source: BCG network model.
Note: Analysis is based on 5G-100MHz with 64 transmitters and 64 receivers and no smart deployment and value-based rollout.

Exploring 5G New Business Opportunities

271+
Industry partners

5
Research directions

47+
On-going projects


Connected Vehicles


Wireless Robotics


Cloud VR/AR


Connected Drones


Wireless eHealth

Top 10 5G Use Cases
wirelessxlabs.com

5G Ecosystem Challenges

Telcos

5G deployment
- Invest with a targeted and value-based approach
- Build partnerships to disrupt cost of standalone rollout
- Gain network efficiencies from transformation of network architecture

New business models
- Push eMBB to protect customer base and improve monetization
- Introduce FWA as attacker or fixed line substitute
- Promote network slicing for mission-critical B2B
- Rigorously exploit massive IoT opportunities for long run revenue growth

Regulators & governments

Infrastructure access
- Facilitate fronthaul and backhaul infrastructure
- Provide advantageous macro- and small-cell site locations

Regulatory environment
- Release more, and more affordable, spectrum
- Encourage and allow network sharing agreements (especially small cells)
- Facilitate small-cell deployment
- Harmonize power density limits with WHO and ICNIRP recommendations

Telco ecosystem partners

Tower companies
- Review existing pricing models regarding 5G
- Explore further infrastructure wholesale opportunities, such as small cells

Vendors
- Become a technology transformation partner
- Innovate service offering and contracting options

Handset manufacturers
- Launch 5G handsets in all price ranges early on

Service providers
- Explore partnering options with telco network operators to further build innovative services and digital infrastructure

Investors
- Recognize the long-term economics of infrastructure build-out in investment decisions

Summary

- 5G is part of ICT Transformation. Not only Radio evolution but requires also Cloud oriented infrastructure evolution.
- Most of 5G use cases need eco-system cooperation to bring it into reality. New business models and platform openness are necessary
- Operators will leverage 5G not just for new revenues, but also for cost efficiency.
- 5G is now !!!

Thank You

Fernando Gordo

Director of Chief Transformation Office,
Carrier Business Group, Huawei

HUAWEI

The Future of Fiber

Lisa Youngers
CEO & President, Fiber Broadband Association
lyoungers@fiberbroadband.org

The Future of Fiber

Lisa R. Youngers

President and CEO

Fiber Broadband Association

The Fiber Broadband Association

Our Mission

The Fiber Broadband Association's mission is to accelerate deployment of all-fiber access networks by demonstrating how fiber-enabled applications and solutions create value for network operators and their customers, promote economic development and enhance quality of life.

Our Vision

To be the voice for ultra high-speed wireline broadband deployment throughout the Americas.

Our Members Are Industry Leaders

We represent vendors, manufacturers, contractors, network operators, engineering firms and all contributors to fiber deployment.

Premier members:

What We Do

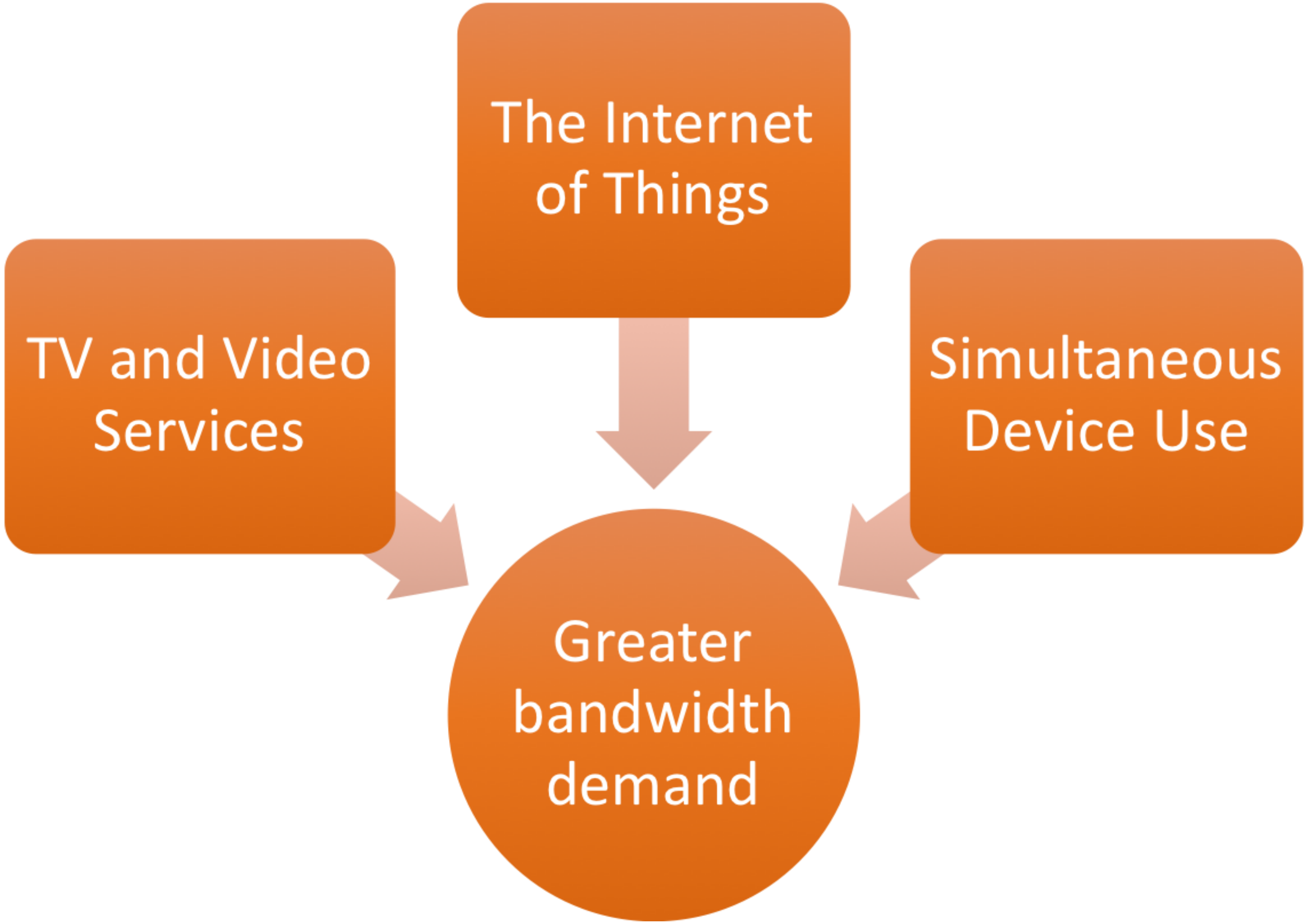
- Provide resources for existing and potential network operators
  - Educational tracks at conferences
  - Market research
  - Toolkits to deploy and monetize all fiber networks
  - Webinars to educate and demonstrate case studies
  - Certifications and training discounts
  - White papers and wiring guidelines
- Offer essential networking opportunities
- Support ***all*** regulatory efforts to expand fiber broadband deployments

Key Public Policy Focus in North America

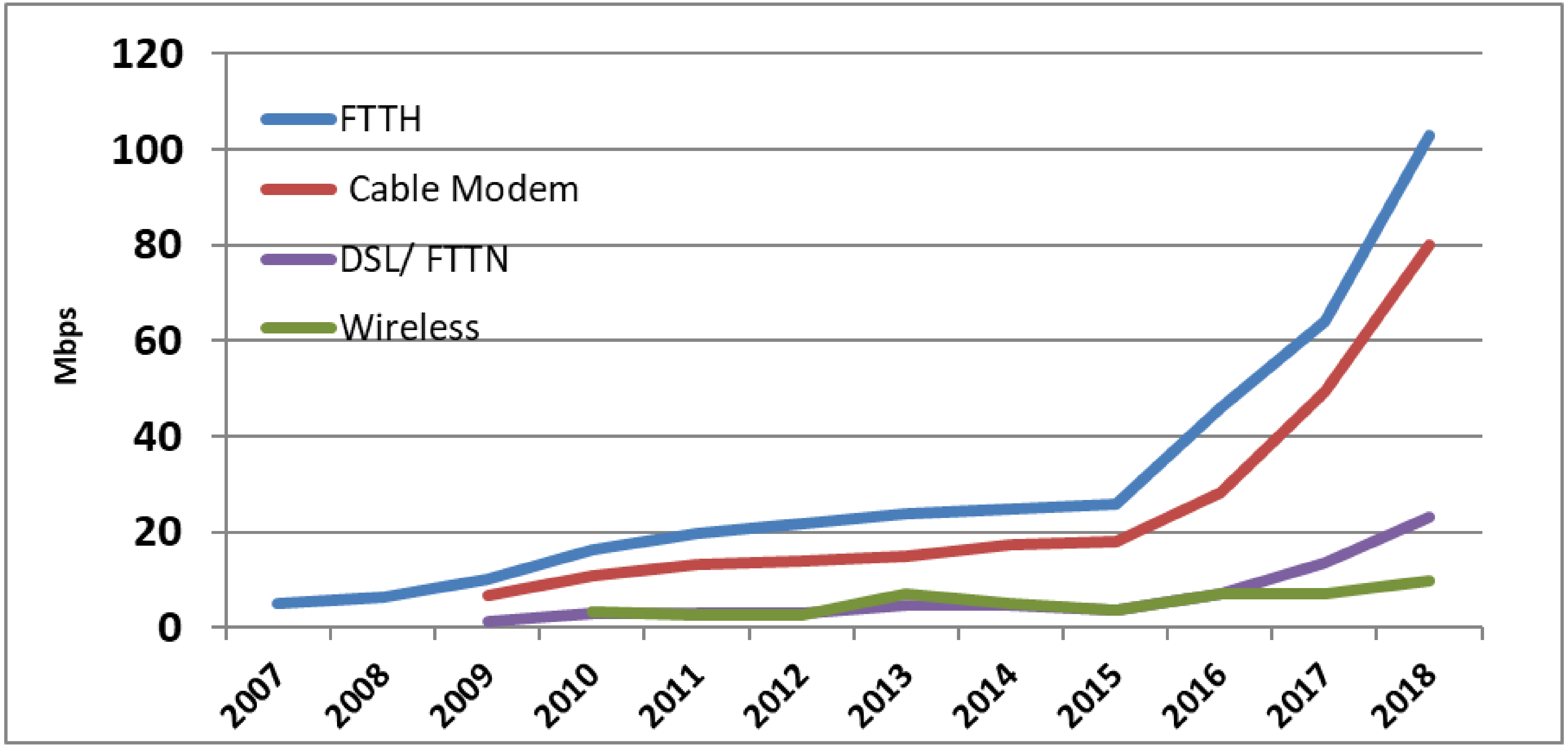
Barriers to Deployment	Investment Incentives	Community Broadband	Rural Broadband
Encouraging forward-leaning rights of way, pole attachments, battery back-up policies and more to help build fiber faster	Pursuing light-touch regulation to benefit consumers	Advocating for an ownership-agnostic view of fiber networks to support facilities buildout	Encouraging government support for Universal Service

Federal, State, and Local

Why Fiber?


The Internet of Things
TV and Video Services
Simultaneous Device Use
Greater bandwidth demand

Fiber Has Faster Tested Download Speeds



According to a 2017 study from RVA, LLC

The North American Fiber Industry

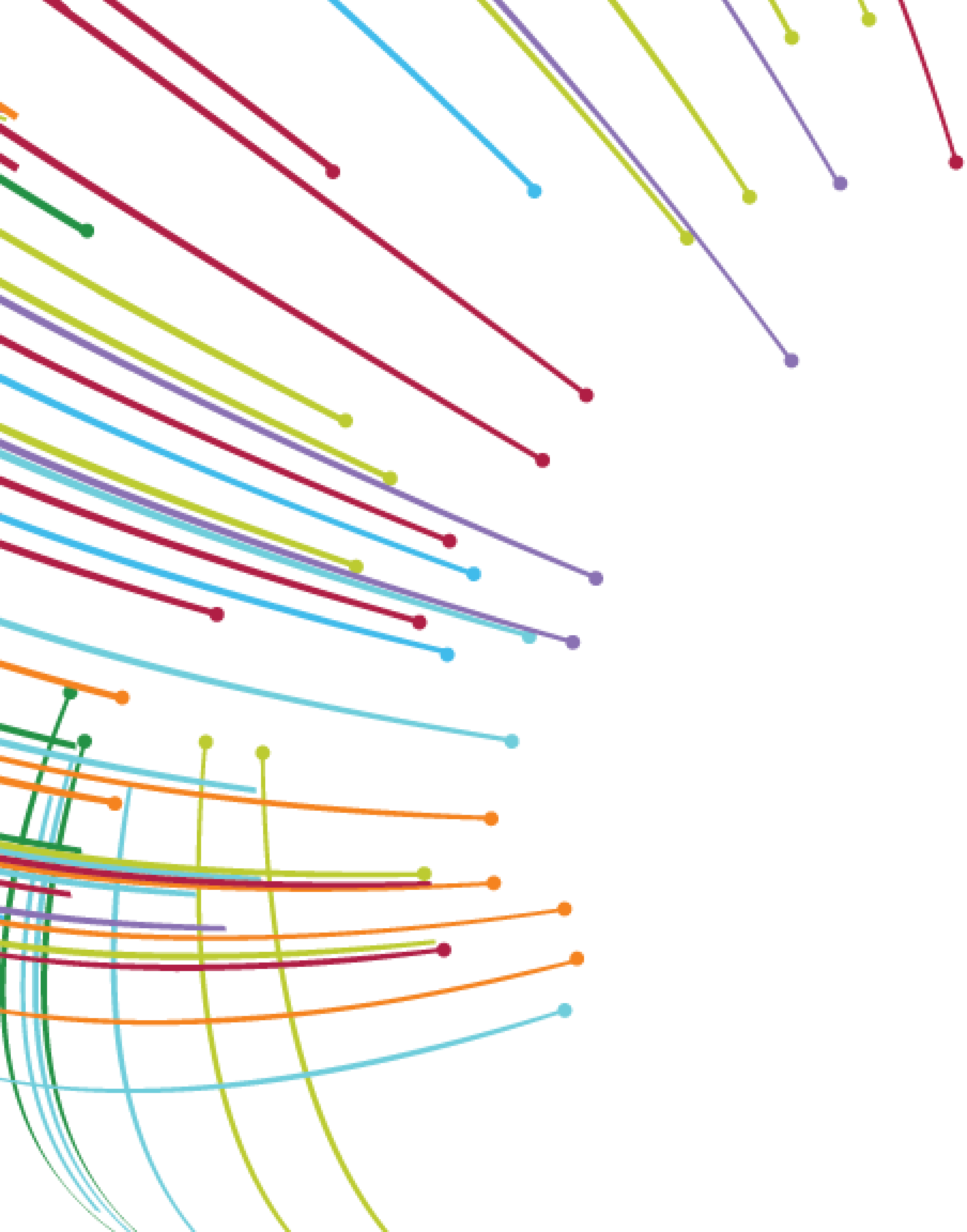
United States

- **40 Million** Homes Marketed
- **16%** Growth over 2017
- **18.2 Million** Homes Connected

North America

- **57.3 Million** Homes Marketed
- **16% Growth** in 2017
- **23.2 Million** Homes Connected

According to a 2017 study from RVA, LLC



Fiber and the Smart Future

Fiber Feeds the Innovation Economy

SMART CITIES
From electrical grid management to traffic management

5G NEXT GEN SERVICES
Enhanced mobile broadband, machine communications, ultra-reliable

STREAMING VIDEO
Video accounts for 70% of internet traffic - and growing

CLOUD COMPUTING
Computing, hosted servers, storage and backup need to move terabytes of data, quickly

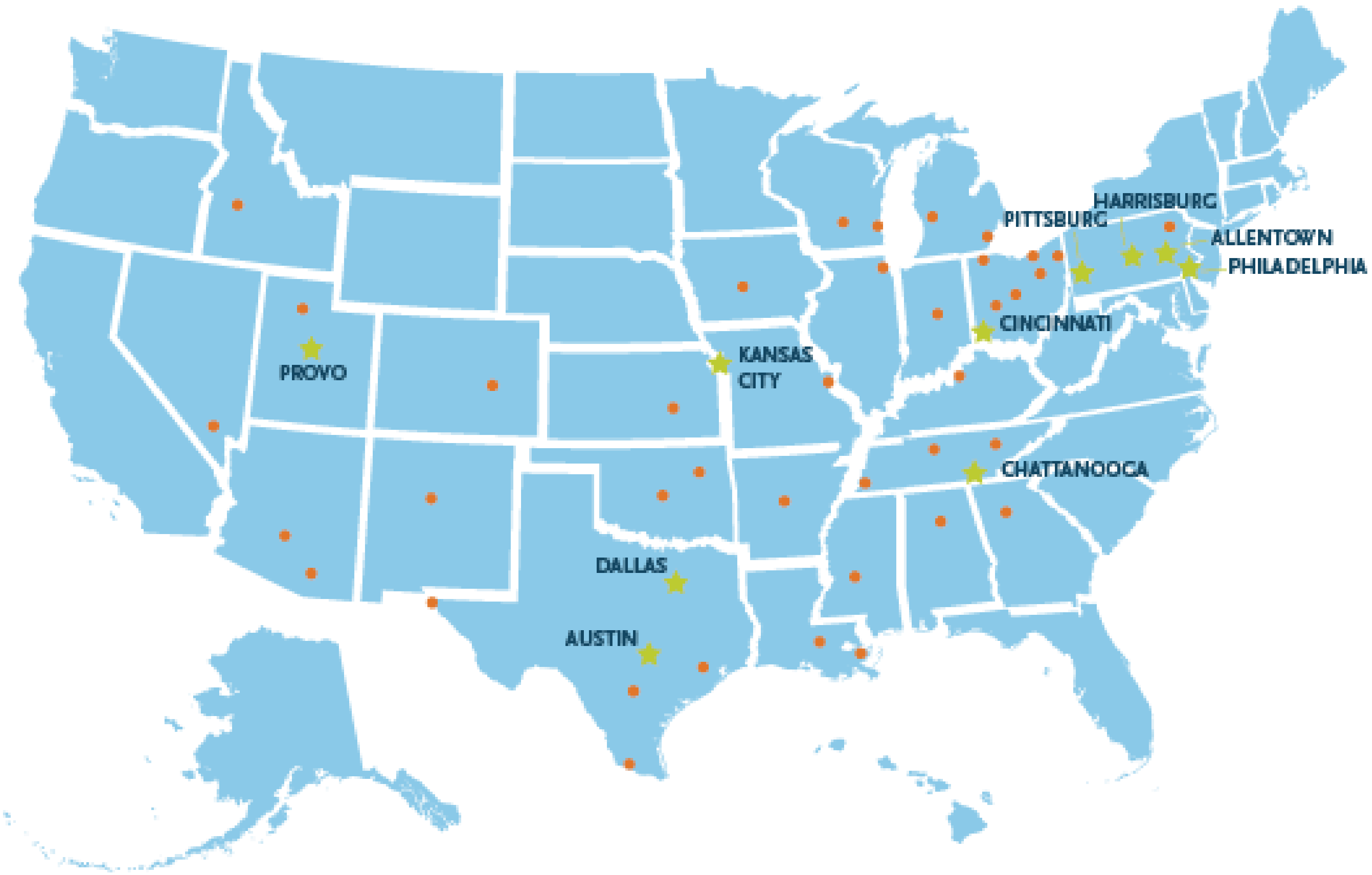
INTERNET OF THINGS
50 billion connected devices by 2020; hundreds in each home

Economic Development: Fiber's Killer App

Ten Year Gross Metropolitan Product:
64% better for FTTH Cities

Ten Year Job Impact:
72% better for FTTH Cities

Better Year New Business Formation:
46% better for FTTH Cities



According to a 2017 study from RVA, LLC

Mounting Evidence Says Fiber Is a Big Add

MDUs

A 2017 RVA, LLC study found MDU residents are willing to pay **2.8% more** to purchase a condo or apartment with access to fiber optic service. Renters are willing to pay a premium of **8%** (based on a $1000 monthly rent) for access to fiber.

Home Values

The 2017 RVA, LLC study, also found access to fiber may increase a home's value by up to **3.1%.**

GDP

A 2014 FBA study found **higher per capita GDP** (1.1%) in communities where gigabit Internet was available. Fiber communities enjoyed approximately **$1.4 billion** in additional GDP over other similarly situated communities.

Smart Cities Need Smart Infrastructure

Smart Grid

Smart Health

Sensor Network

Smart Mobility

City Wi-Fi

Energy Efficiency

EPB in Chattanooga built out a fiber network to reliably manage its energy and electrical systems

Healthier Cities

Hiawatha Broadband in Minnesota piloting project to use its fiber as a platform for home monitoring of patients with dementia

Civic IoT

US Ignite and cities around the U.S. (and the world) are developing a smart city app store predicated on big bandwidth

Safer Streets

Verizon and the City of Boston are using sensors and advanced traffic signal controls to measure traffic, improve safety

Connected Community

Santa Monica City Net provides fiber-supported Wi-Fi to its residents in public places

Smart Cities Invest in Smart Infrastructure Like Fiber

According to 2018 research from RVA, LLC:

Fiber Cities are more likely to be Smart Cities

- Cities with fiber have, on average, 37% more deployed small cells and just over 35% more smart city applications

- 33% of cities without fiber report small cell activity, versus 60% of cities with fiber to the residence

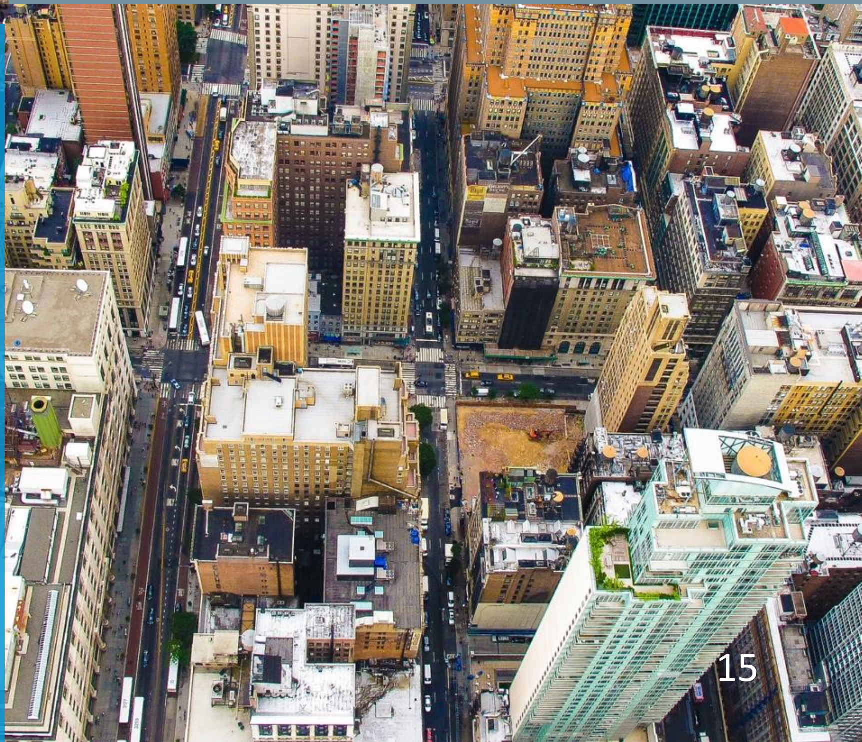
If you do NOT get a fiber backbone for your city, it may well trigger a new generation of economic distress. Quoting once again: "Fiber networks are seen by many as one of the most important infrastructure developments of the 21st century."

Jesse Berst: Smart City Council

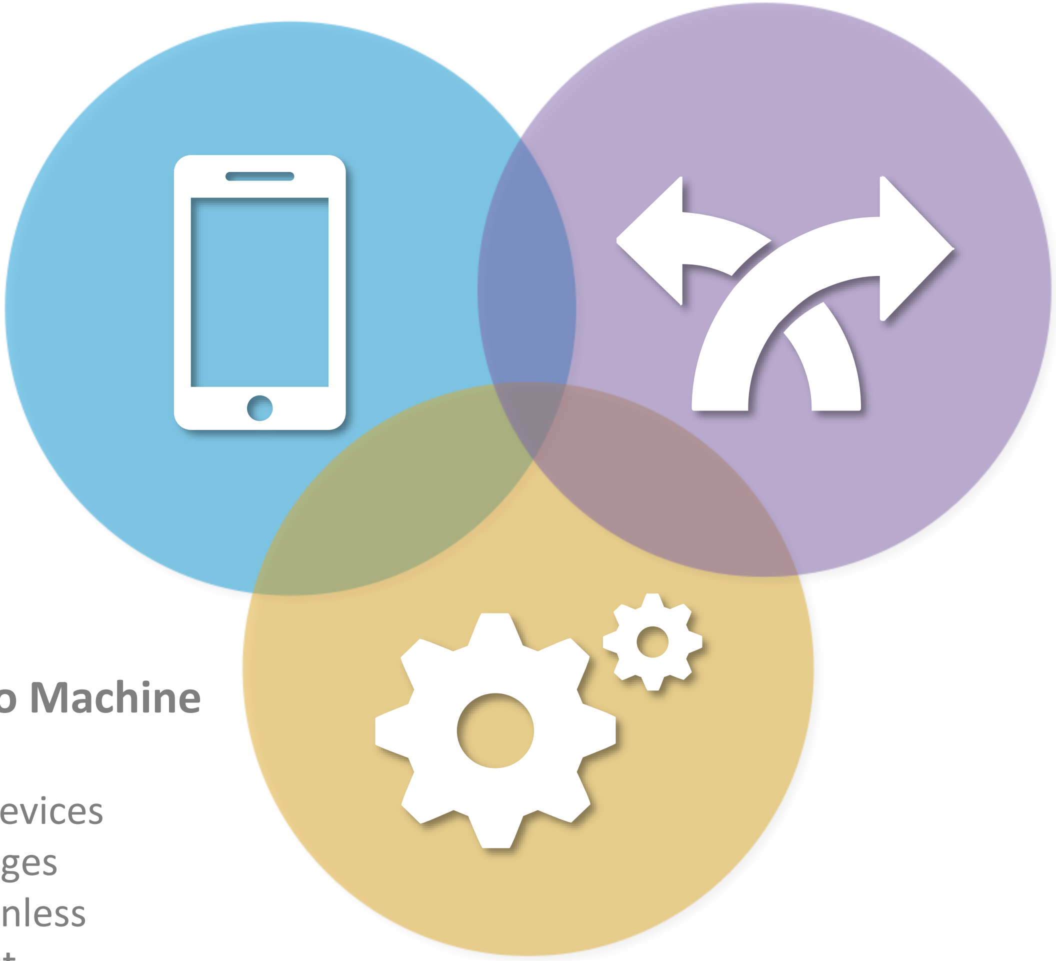
Senior managers in state and local government, survey by the Governing Exchange:

70% believe fiber networks should be considered a public good that government regulates and sometimes runs, similar to water, sewer and other utility services.

Fiber backhaul can be a middle-mile network within the smart city ecosystem. High-bandwidth links between different parts of the city can serve as conduits for shorter cable runs to traffic lights, municipal buildings, surveillance cameras and similar assets.



Speed, Performance of 5G Needs Fiber



Enhanced Mobile Broadband

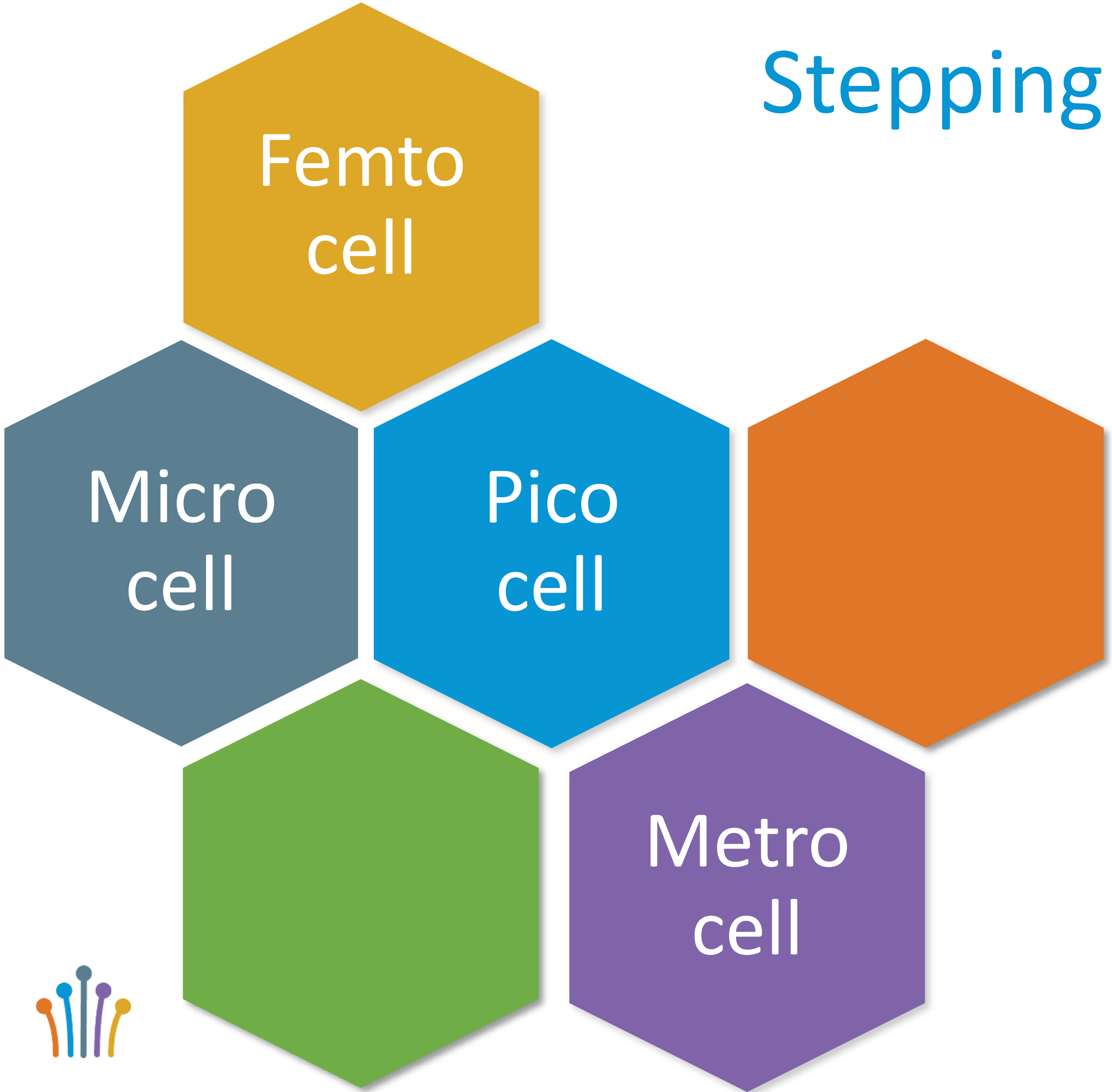
- avg. + peak channel capacity
- total network capacity
- ubiquitous availability
- high mobility, fast handover

Ultra-reliable, low latency communication

- high reliability
- guaranteed availability
- low latency

Massive Machine to Machine Communication

- huge amounts of devices scarce short messages
- random, connectionless
- low power, low cost



Stepping Stones to 5G, Paved with Fiber

Network Densification

Cisco estimates small cells will have increased 11-fold between 2013 and 2018.

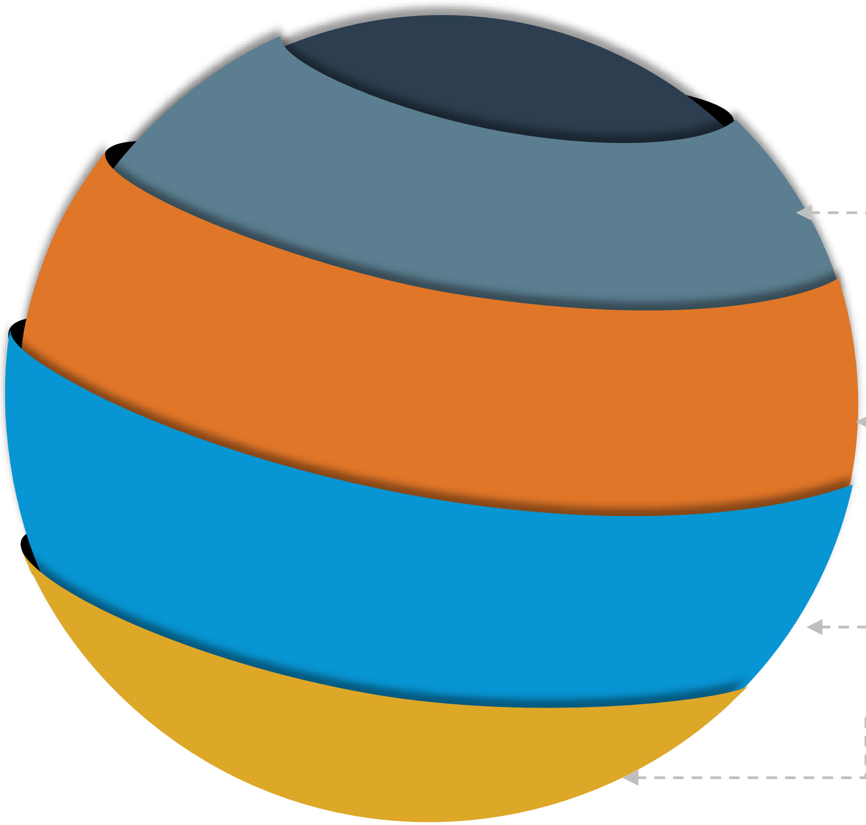
Backhaul

Small cells need expanded backhaul capabilities. As in other places in the network, fiber is the backhaul solution.

Mobile Providers in Need

A report from Strategy& says providers with the largest installed base of fiber will win the day.

5G fiber needs



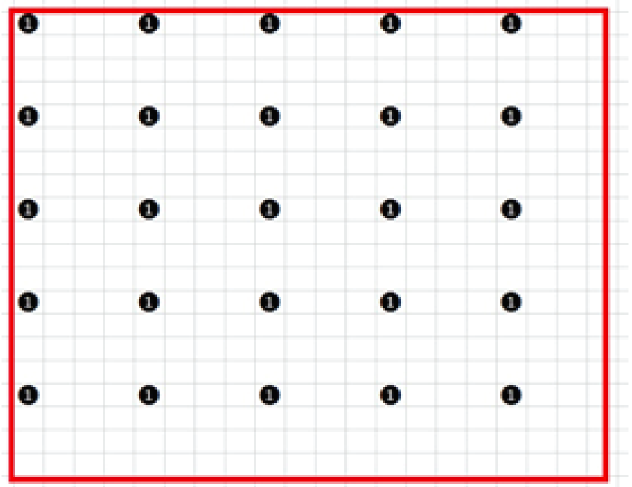
- The ITU-T defined 5G base station requirements to be 20 Gbps download and 10 Gbps upload. This can only be realized through fiber-based networks.
- 5G will deliver more than 10 Gbps speed, connectivity for IoT devices, high speed mobility.
- Ultra low latency is critical for self-driving connected cars, remote robotic surgery, industrial automation and big data transfer.
- As shown on next slide – requires massive new fiber deployment for coverage.

Densification requires much more fiber:

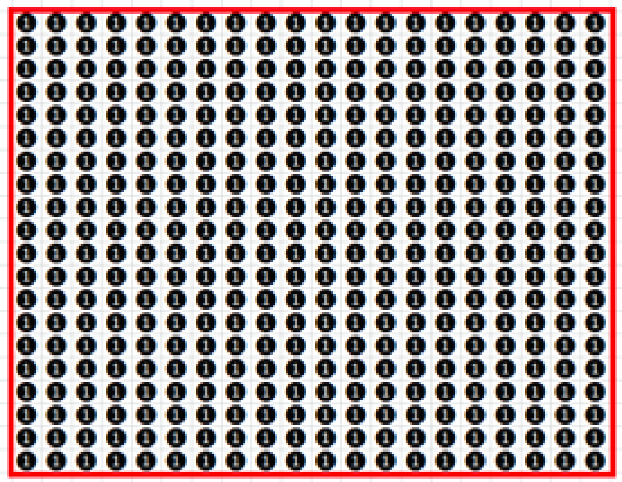
to go from 3G to 4G requires 25X more fiber

to go to 5G requires at least 16X more fiber

3G
1 site every 10 km
Cell density=1 cell/100 km2



4G
1 site every 2km
Cell density= 5 x 5
= 25 cells/100 km2



5G
1 site for every 0.5 km
Cell density= 20 x 20
= 400 cells

How Can Cities Become Fiber Ready?

1. Organize your community and tell your story
2. Find local leaders to be your champions
3. Build partnerships with local businesses, schools, libraries, and the city
4. Build the business case
5. Explore partner and funding options

Get Involved

Join the Fiber Broadband Association

- Benefit from FBA's educational webinars and certification programs
- Stay current on key fiber policy issues
- Network with key leaders in the industry
- Learn more at: www.fiberbroadband.org/join

Attend Fiber Connect June 3-5, 2019 in Orlando

- Explore new products and strategies for fiber deployment
- Learn from industry leaders about deploying and growing fiber networks
- Connect and network with industry leaders
- Learn more at: www.fiberconnect.org

The Evolution of Hybrid Access Networks

Paul Evans

CEO | Hybrid Access Technologies

paul.evans@hybridaccess.com

broadband forum

BASe

EVOLUTION OF HYBRID ACCESS

Paul Evans, CEO, Hybrid Access Technologies

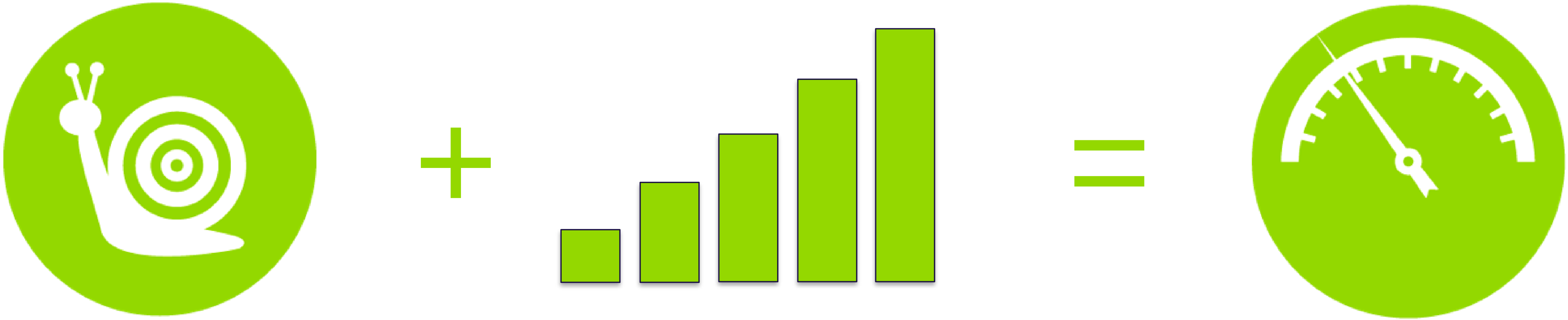
DSL + LTE BONDING

“Meh”

Quote from a typical service provider

DSL + LTE BONDING

hybrid access



THE WAY IT'S BEEN VIEWED BY SPS

hybrid access

- Niche
  - For slow xDSL customers only
- Cost - CPE, bandwidth, back-end
  - Kills mobile network
  - Customers won't pay for it
- Will only do it when they have to

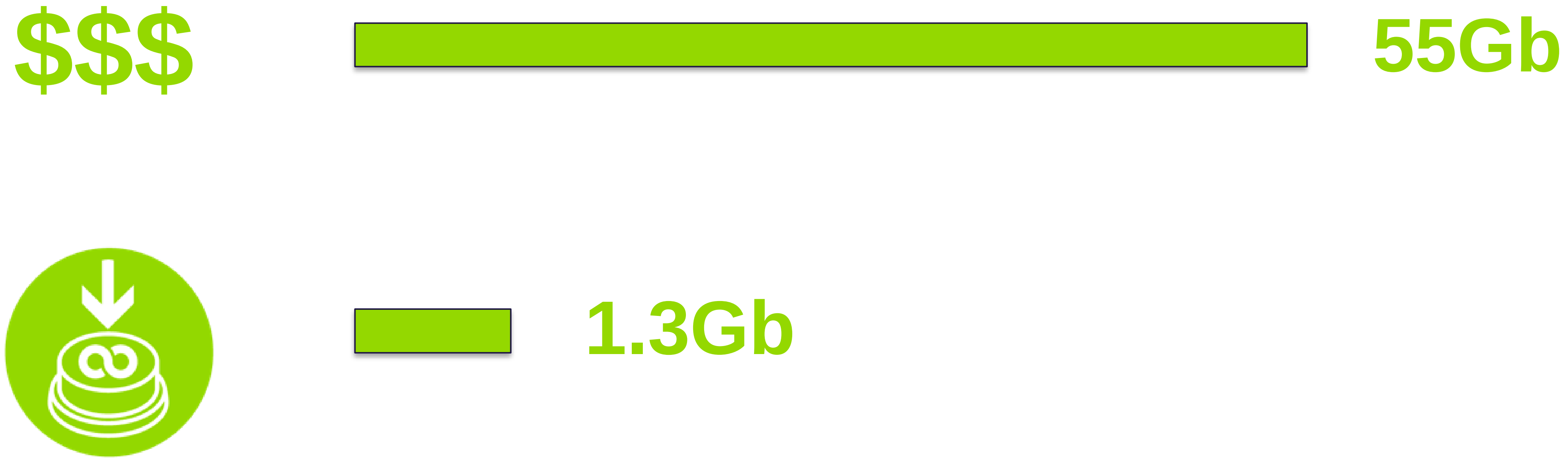
THE WAY IT’S BEEN VIEWED BY SPS

- Niche
  - For slow xDSL customers only
- Cost - CPE, bandwidth, back-end
  - Kills mobile network
  - Customers won’t pay for it
- Will only do it when they have to

TO MAKE IT WORK YOU NEED TO REFINE

1. Customer proposition
2. Have fixed and mobile teams work together
3. The economics
   I. CPE
   II. Servers
   III. Mobile data consumption

MOBILE CONSUMPTION



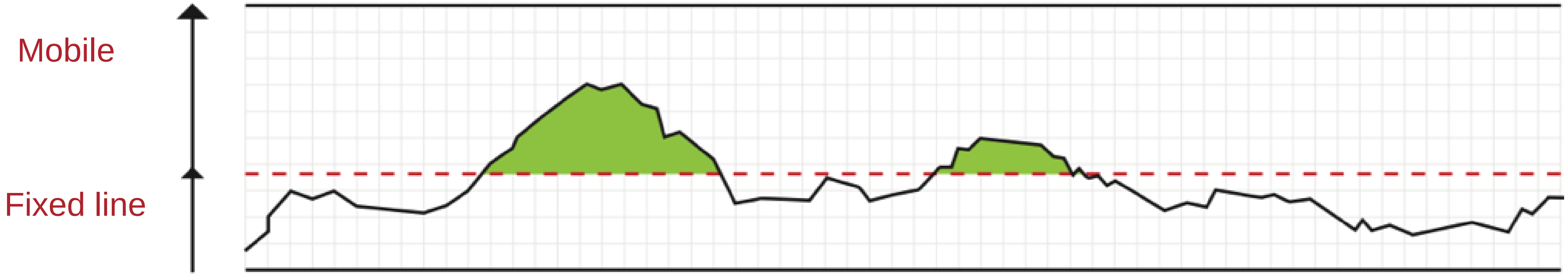
MOTIVATION

- Cable competition threat
  - More Mbps for less $$$
- Customer experience
  - More Mbps but more variability
- Reliability
  - Mbps more of the time

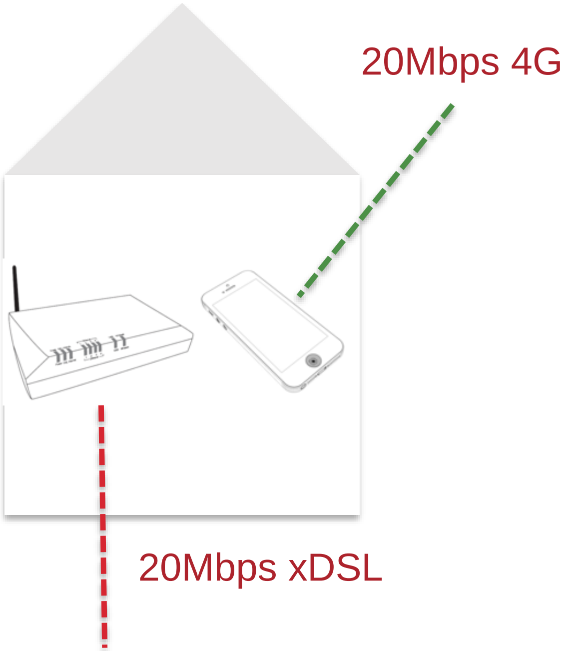
COMBAT CABLE THREAT

500Mbps !?

CUSTOMER EXPERIENCE

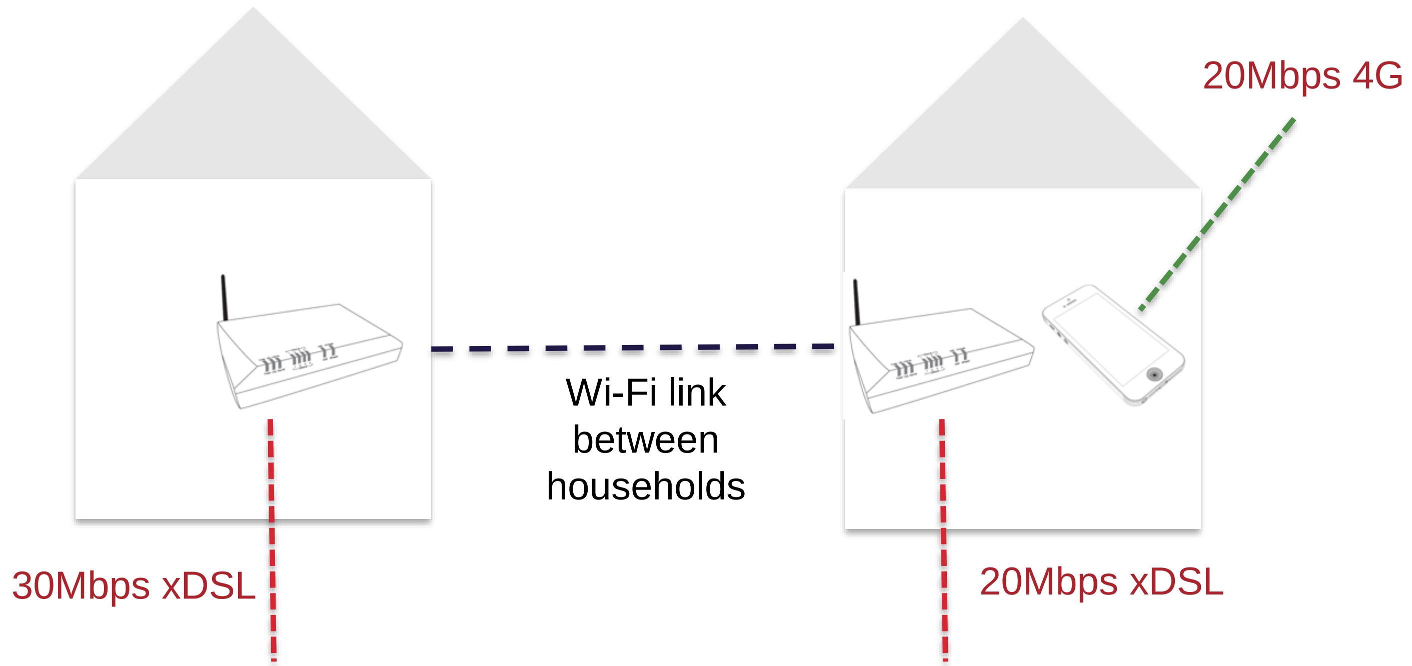


RESILIENCE



Why can't we use the smartphone we've sold them to offer seamless failover if xDSL fails, or as a seamless top-up when xDSL performance is poor?

HYBRID NOT LIMITED TO XDSL + LTE



SUMMARY

- Hybrid fixed / wireless should not be seen as niche
- Opportunity for every residential / SMB customer to
  - Get faster, more consistent speeds
  - Improve the reliability of their broadband
  - By better using what the customer already has
- Benefits to SP
  - Strengthen bundling / customer lock-in
  - Reduce support costs / churn
  - Differentiator

Paul Evans

paul.evans@hybridaccess.com

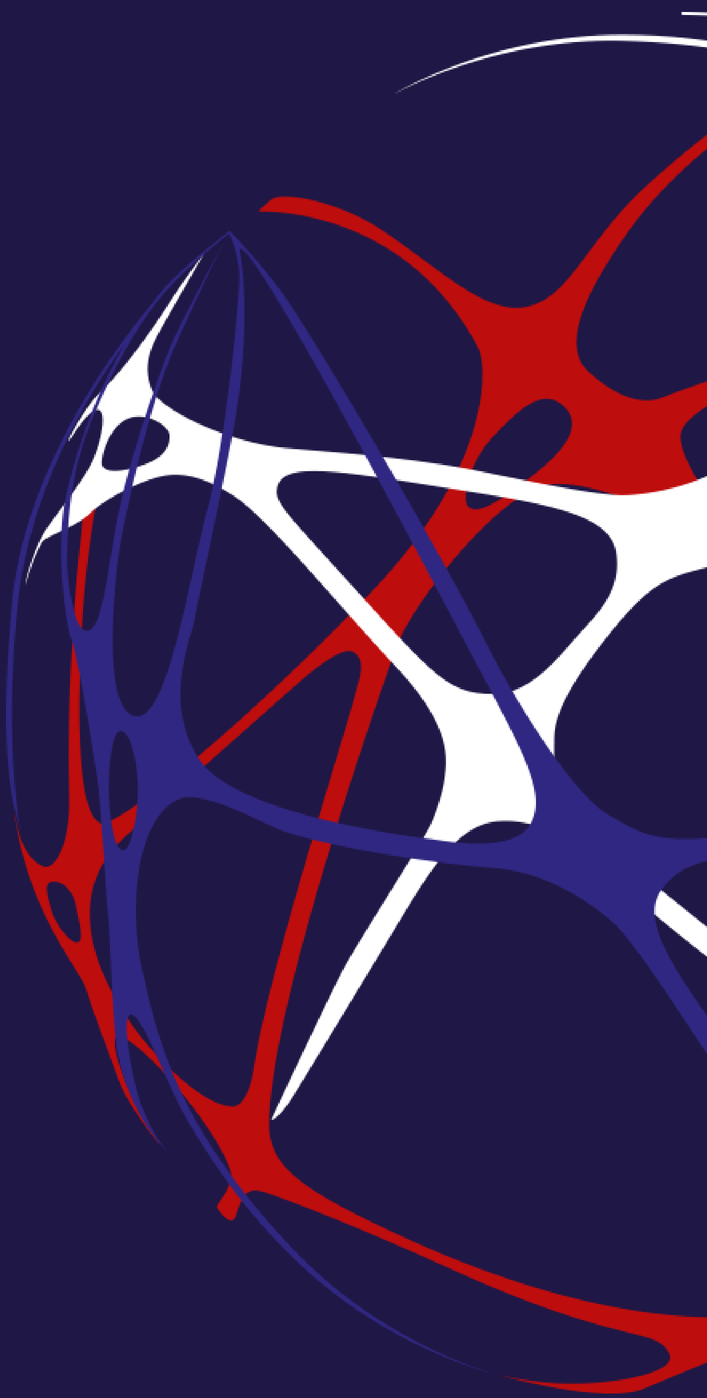
hybrid access

+44 1473 372 141

40 Princes Street, Ipswich, Suffolk, IP1 1RJ, UK

www.hybridaccess.com

@hybrid_access



Segment 1
Panel Discussion & Audience Q&A

Moderator: **Lisa Youngers**
President and CEO, Fiber Broadband Association

10 MINUTE break

THANK YOU TO OUR SPONSOR Calix

Segment 2
10 Gigabit and Beyond With Fiber

Moderator: **Julie Kunstler**
Principal Analyst, Ovum

Agenda Segment 2

	10 Gigabit and Beyond With Fiber
10:50 - 11:10	**Super-PON: A PON Architecture for Access Infrastructure Consolidation**
	Claudio DeSanti, System Architect, Google
11:10 - 11:30	**FTTH: Adapting to the Needs of Tomorrow with New Protocols & Architectures**
	Kevin Bourg, Director, Optical Network Architect, Corning Optical Communications
11:30 - 11:50	**NG-PON2 Solution for 10G Internet Service: SK's Development & Deployment**
	Choongbok Lee, Senior Manager, SK Broadband
11:50 - 12:10	**NG-PON2 Optics Update: Path to Massive Deployment**
	Wei-Ping Huang, Founder and Chief Scientist, HiSense Broadband
12:10 - 12:30	**Dealing with Capacity Growth in Access Networks**
	Antonio Teixeira, Co-Founder and CTO, PICadvanced
12:30 - 12:45	**Segment 2 panel discussion and audience Q&A**
	Moderated by Julie Kunstler, Principal Analyst, OVUM

Super-PON: A PON Architecture for Access Infrastructure Consolidation

Claudio DeSanti
System Lead Architect | Google
cdssdc@google.com

broadband forum

BASe

Super-PON:
A PON Architecture for Access Infrastructure Consolidation

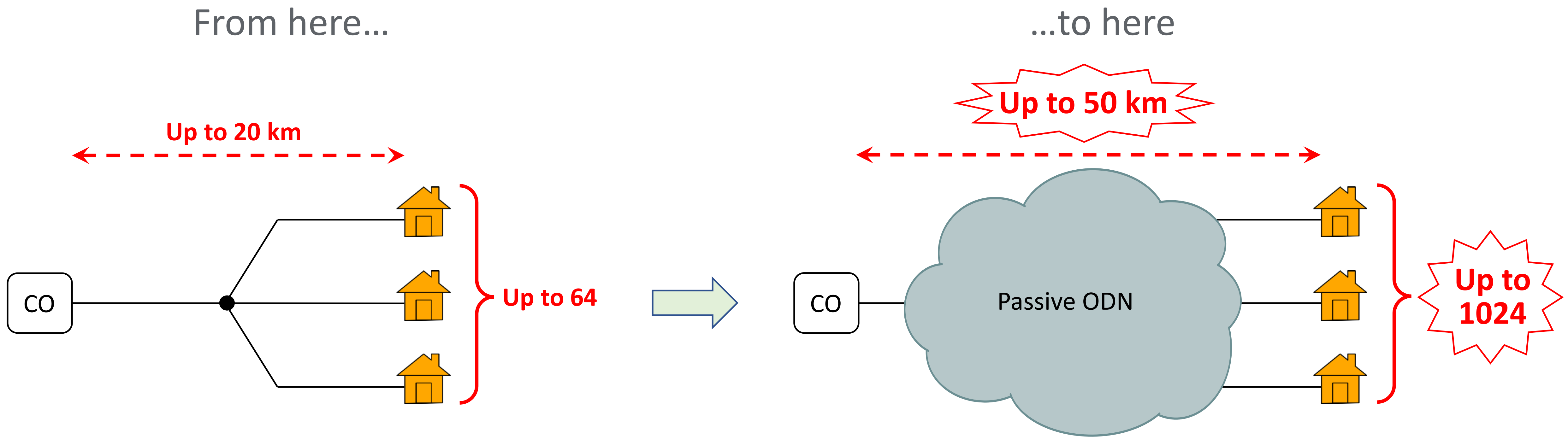
Claudio DeSanti
(cdssdc@google.com)
October 28, 2018

Google Fiber

Agenda

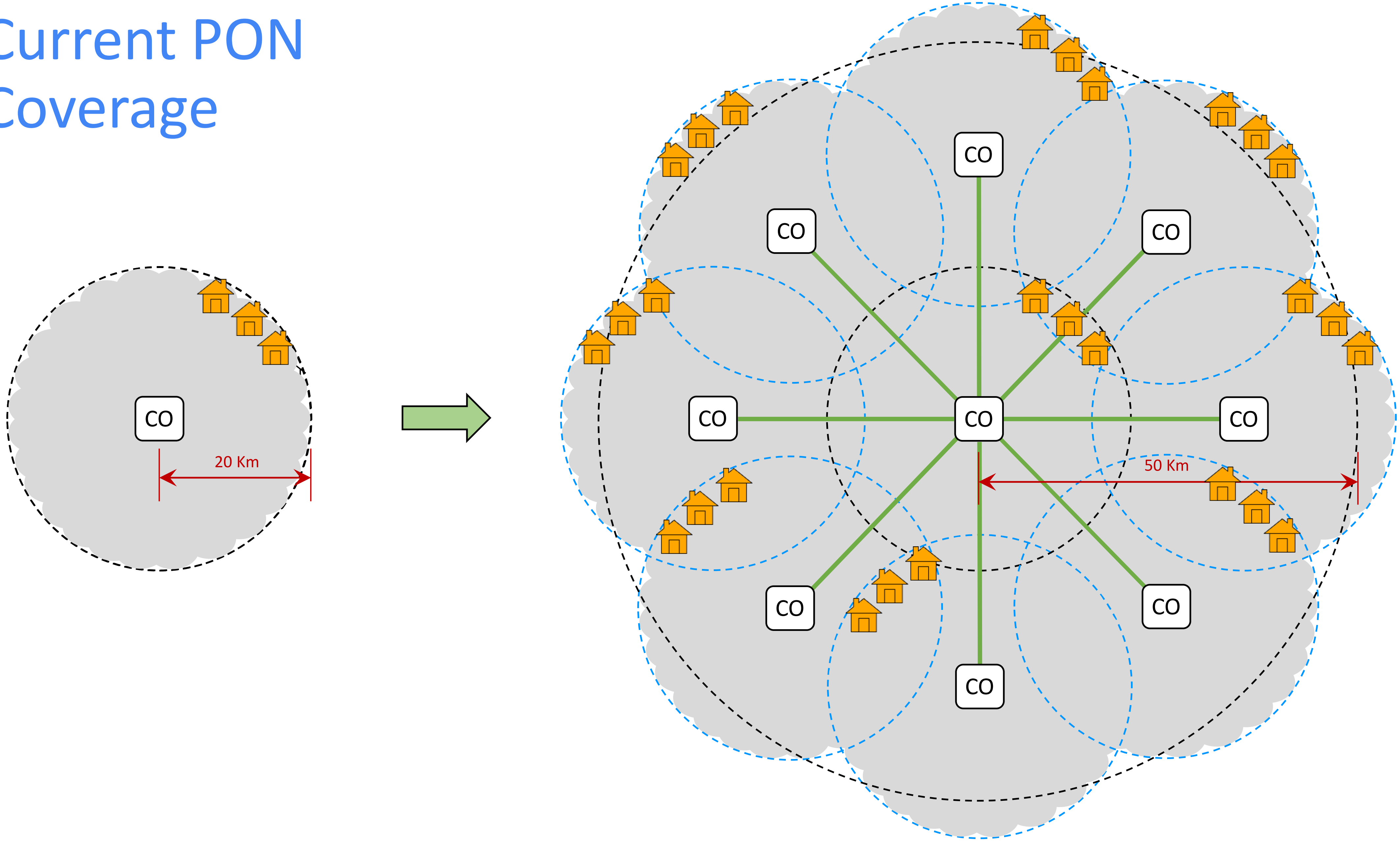
- *Why Super-PON*
- *Super-PON Technology*
- *Super-PON Applicability*
- *Standardization*

Super-PON Goal

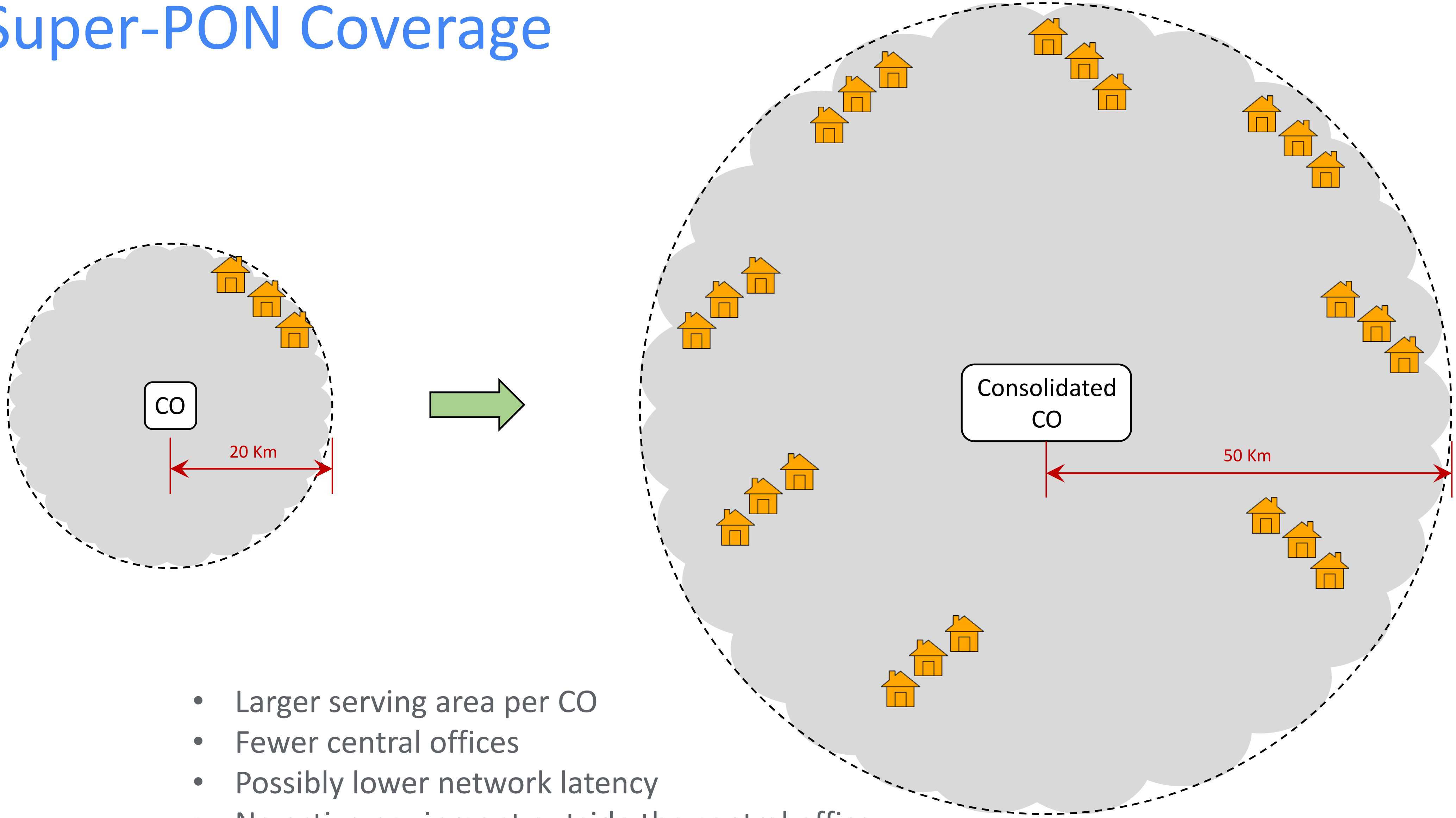


ODN: Optical Distribution Network

Current PON Coverage



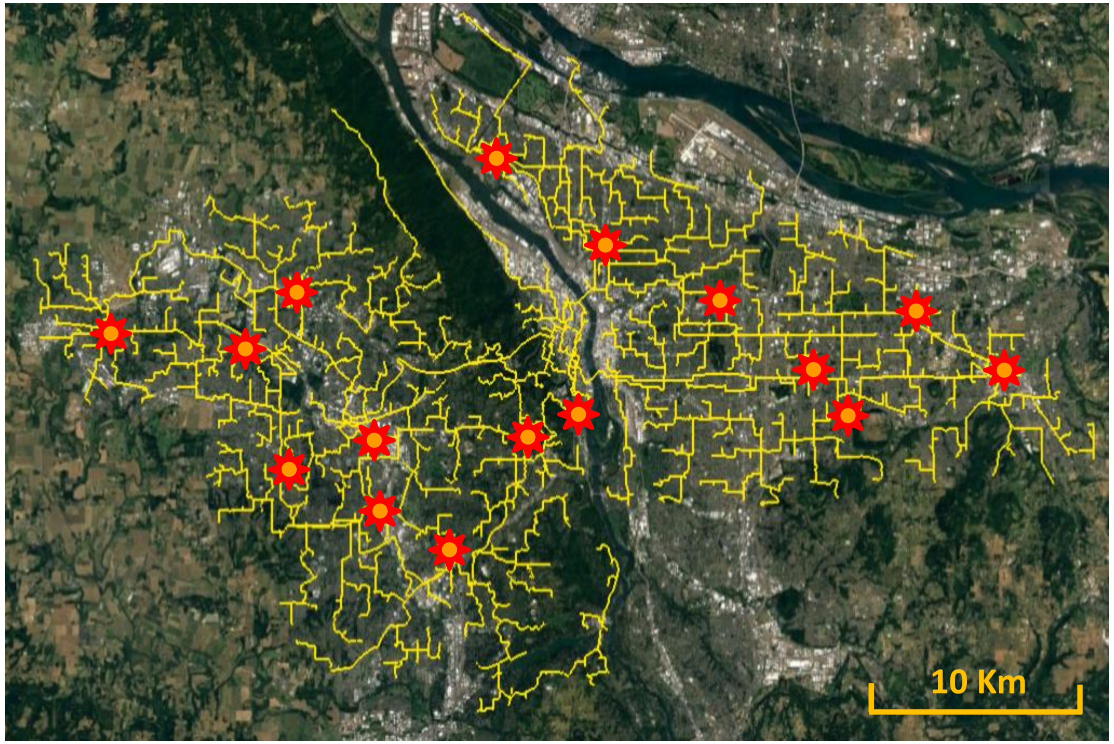
Super-PON Coverage



- Larger serving area per CO
- Fewer central offices
- Possibly lower network latency
- No active equipment outside the central office

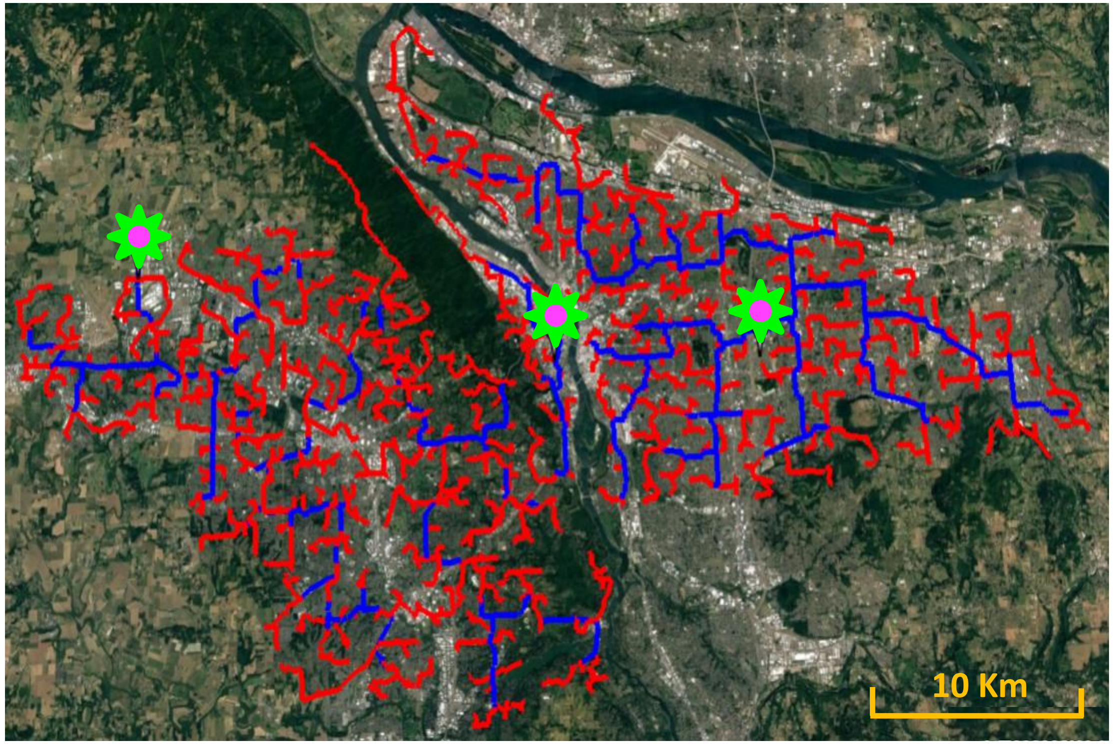
On Medium Sized US Metropolitan Area

Current PON: 16 COs



Feeder fiber

Super-PON: 3 COs



Wavelength splitter feeder fiber

Power splitter feeder fiber

- Fewer central offices
- Lower-count fiber cables
- Less backbone and feeder fiber
- Simplified access infrastructure

Advantages

- *Fewer fibers needed to support the same number of customers*
  - *Enables smaller/fewer cables*
    - *From 432-fiber cables to 12-48-fiber cables*
- *Easier OSP construction*
  - *Smaller cables can be longer and are easier to bend/handle*
  - *Allows use of micro-trenching techniques*
  - *Easier to repair*
- *CO consolidation*
  - *The same number of feeder fibers can serve a much greater area*
  - *Fewer COs → less OPEX*

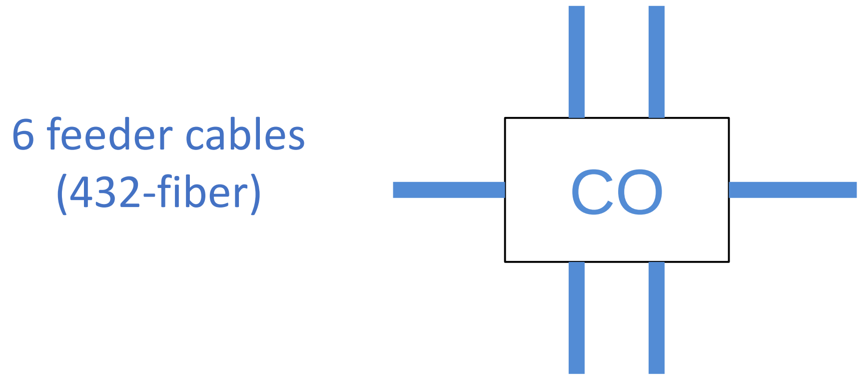
About Trenching…

Traditional Trenching

Directional Boring

Micro Trenching

…and Repairs



A 432-fiber cable:

- Contains 36 ribbons of 12 fibers
- ~10 min to splice a ribbon
- ~6 hours total to splice a broken cable
- Additional ~2 hours for cable manipulation
- Average time to repair a cable damage: ~8 hours

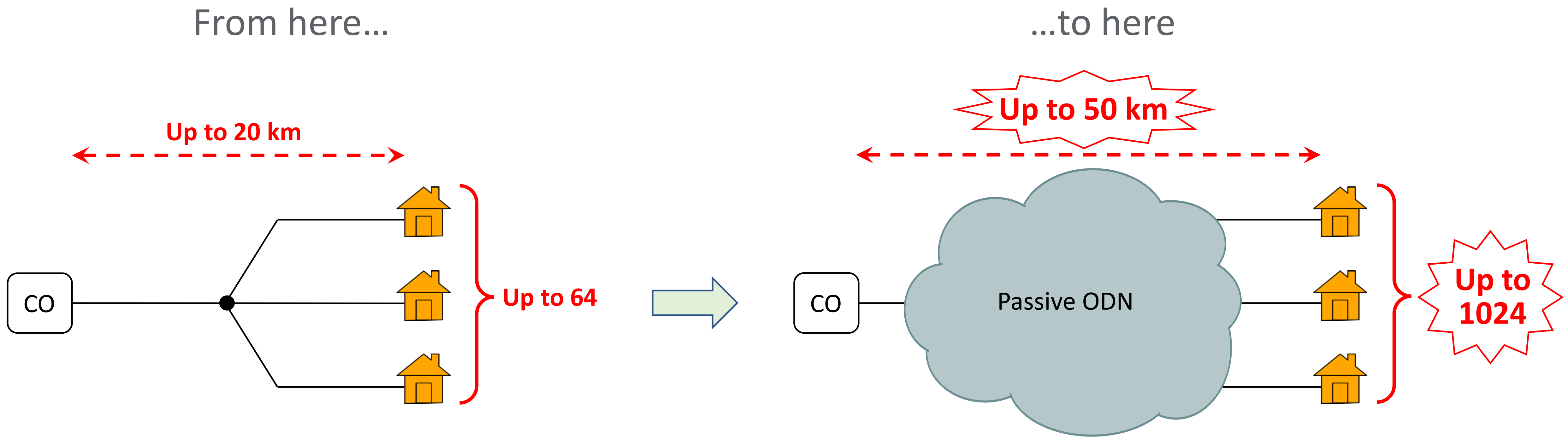
A 24-fiber cable:

- ~40 mins total to splice a broken cable
- Additional ~1 hour for cable manipulation
- Average time to repair a cable damage: ~1 hour 40’

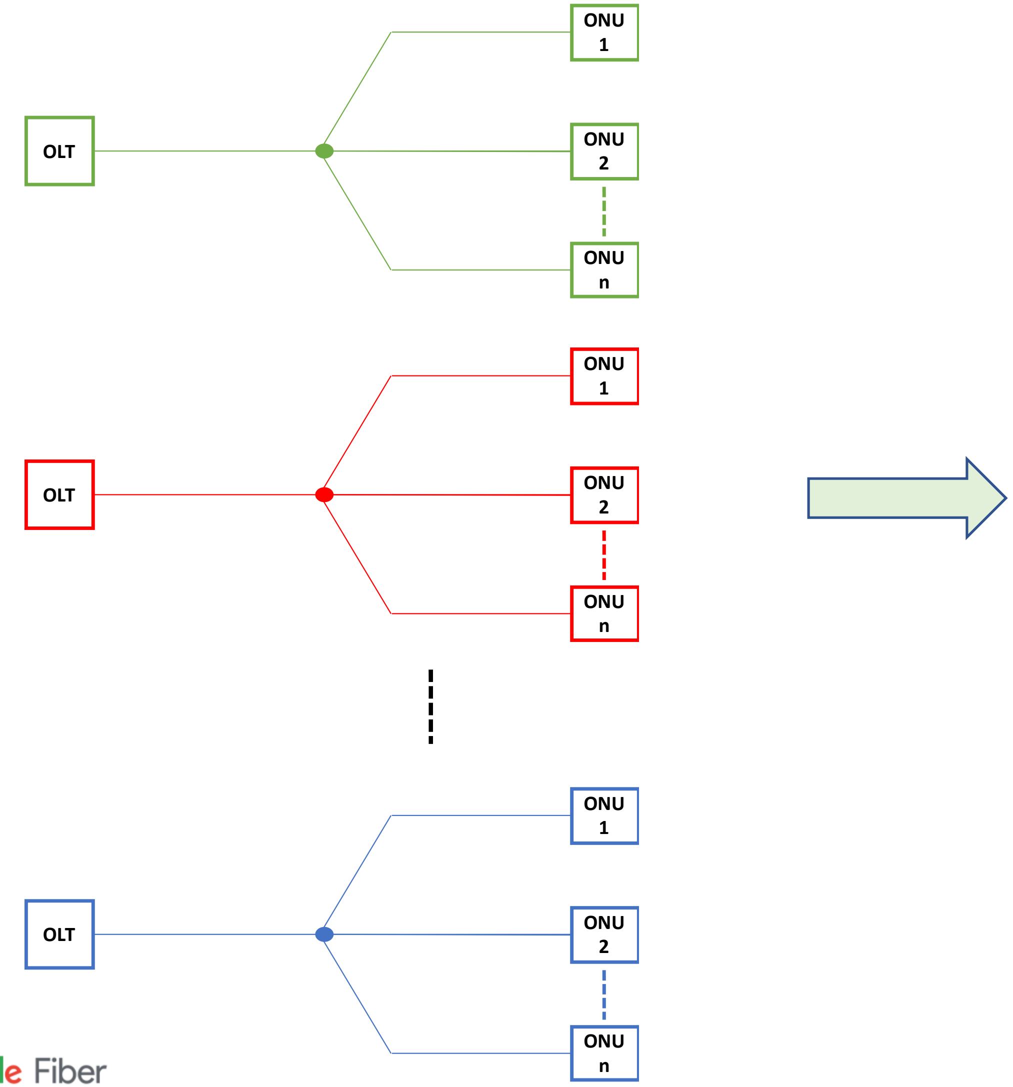
Agenda

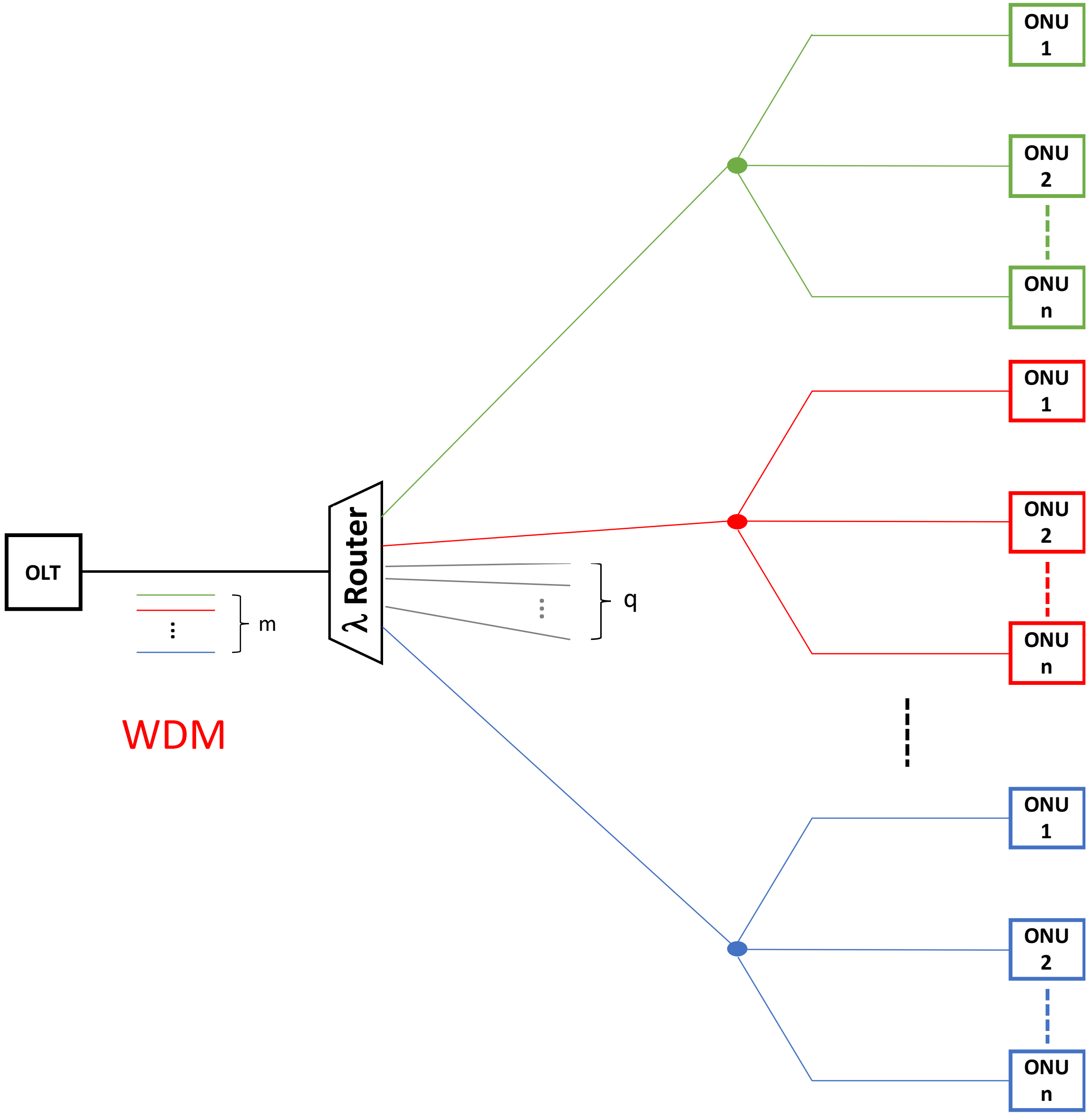
- *Why Super-PON*
- *Super-PON Technology*
- *Super-PON Applicability*
- *Standardization*

Super-PON Goal

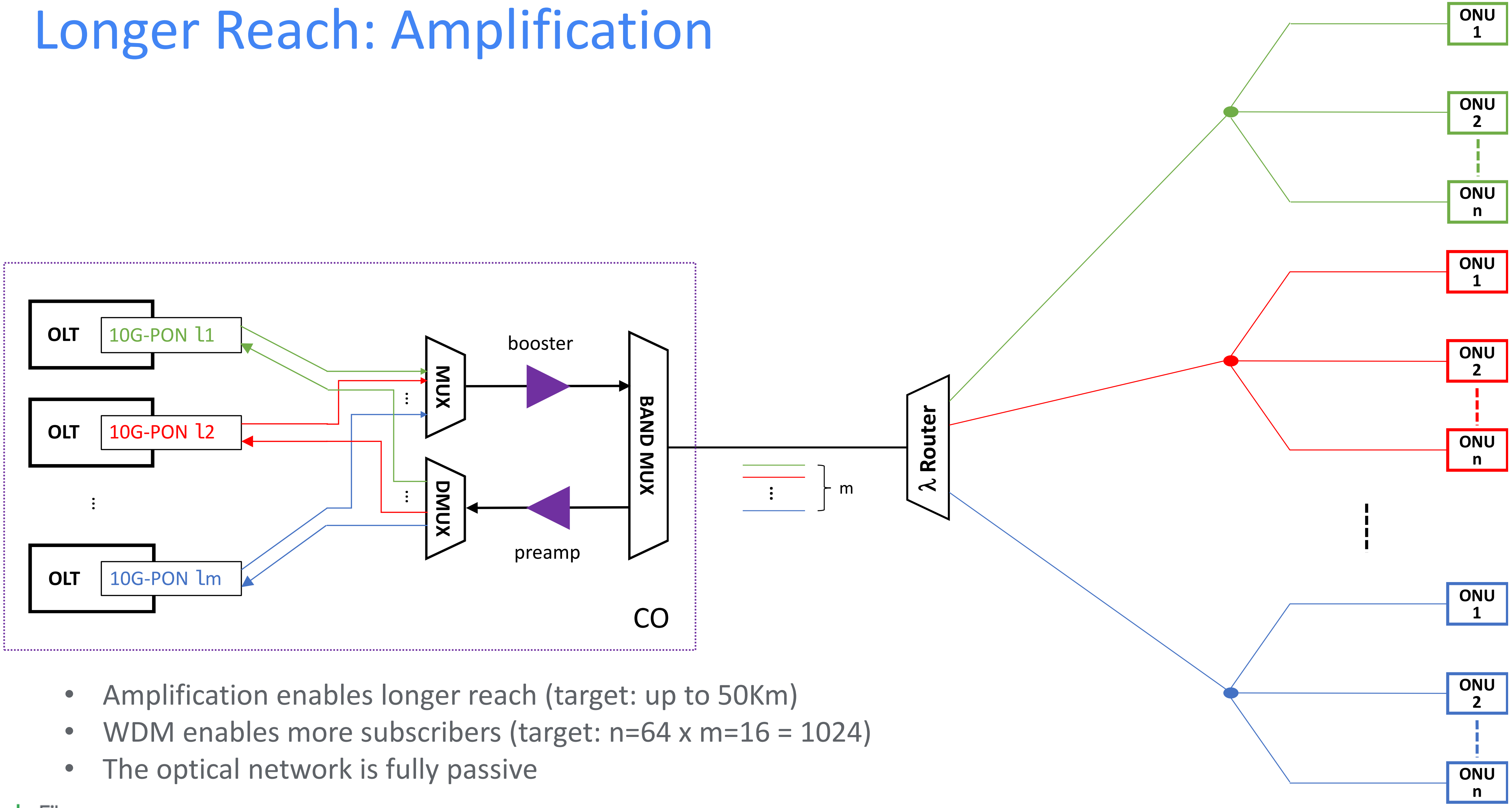


More Subscribers: WDM



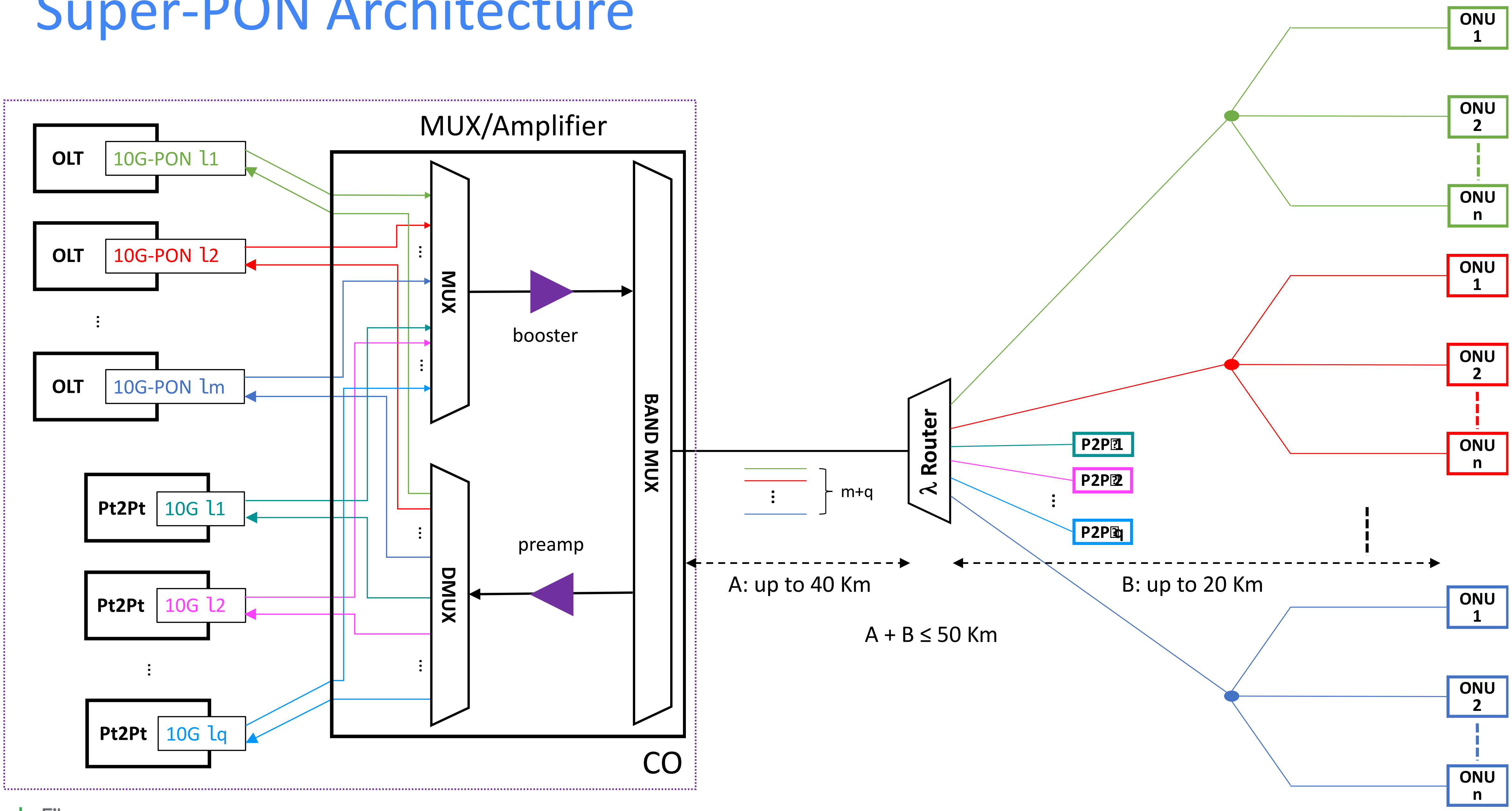


Longer Reach: Amplification



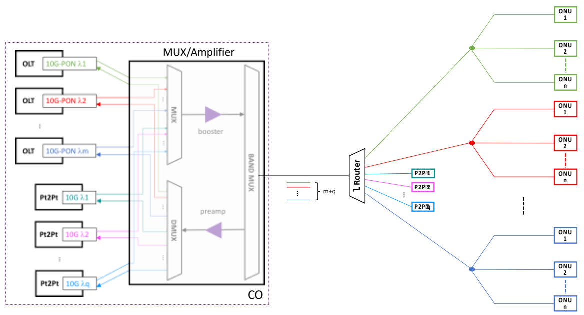
- Amplification enables longer reach (target: up to 50Km)
- WDM enables more subscribers (target: n=64 x m=16 = 1024)
- The optical network is fully passive

Super-PON Architecture



Google Fiber

Super-PON Summary



- *A WDM system*
  - *Multiplexes multiple channels over a single feeder fiber*
  - *Separates the channels with a passive wavelength router in the OSP*
  - *Supports more (customers) with less (fiber)*
- *An amplified system*
  - *Achieves long reach through amplification*
  - *Single amplifier for all channels in one direction to reduce the cost impact*
- *Supports different types of subscribers*
  - *Cost-effective asymmetric ONUs for residential customers*
  - *Guaranteed-performance symmetric ONUs for business customers*

Agenda

- *Why Super-PON*
- *Super-PON Technology*
- *Super-PON Applicability*
- *Standardization*

Super-PON Applicability

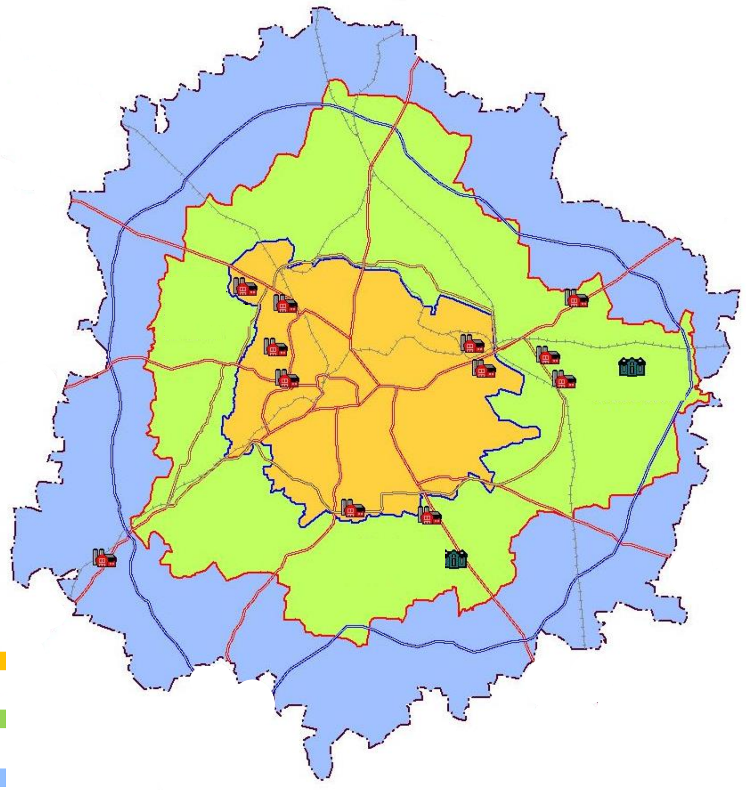
- *Well suited for new (green field) optical distribution networks (ODNs)*
  - *Significant savings in cabling and building cost*
- *Valuable as a retrofit to existing ODN for cellular/business use cases*
  - *Support both point-to-point and residential customers over the same ODN*
- *Can be used to consolidate COs leveraging existing fiber plants*
  - *Increased typical utilization of OLT ports*
  - *Enables central office redesigns as data center*

New Infrastructures

- *Many countries have government sponsored/funded projects aimed at developing large scale broadband connectivity*
  - *India*
  - *Brazil*
  - *Indonesia*
  - *Thailand*
  - *Vietnam*
  - *South Africa*
  - *Morocco*
  - *Kenia*
  - *Philippines*
  - …

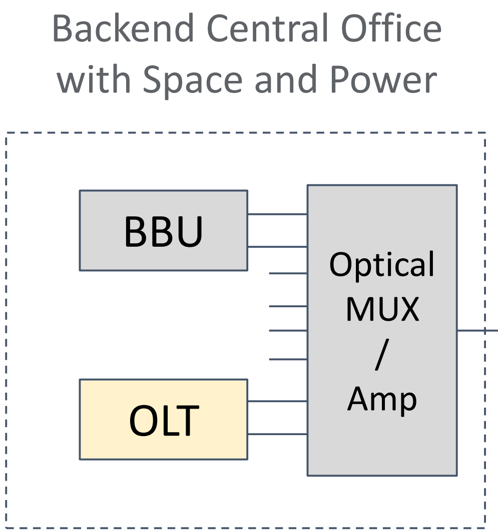
New ODN Builds

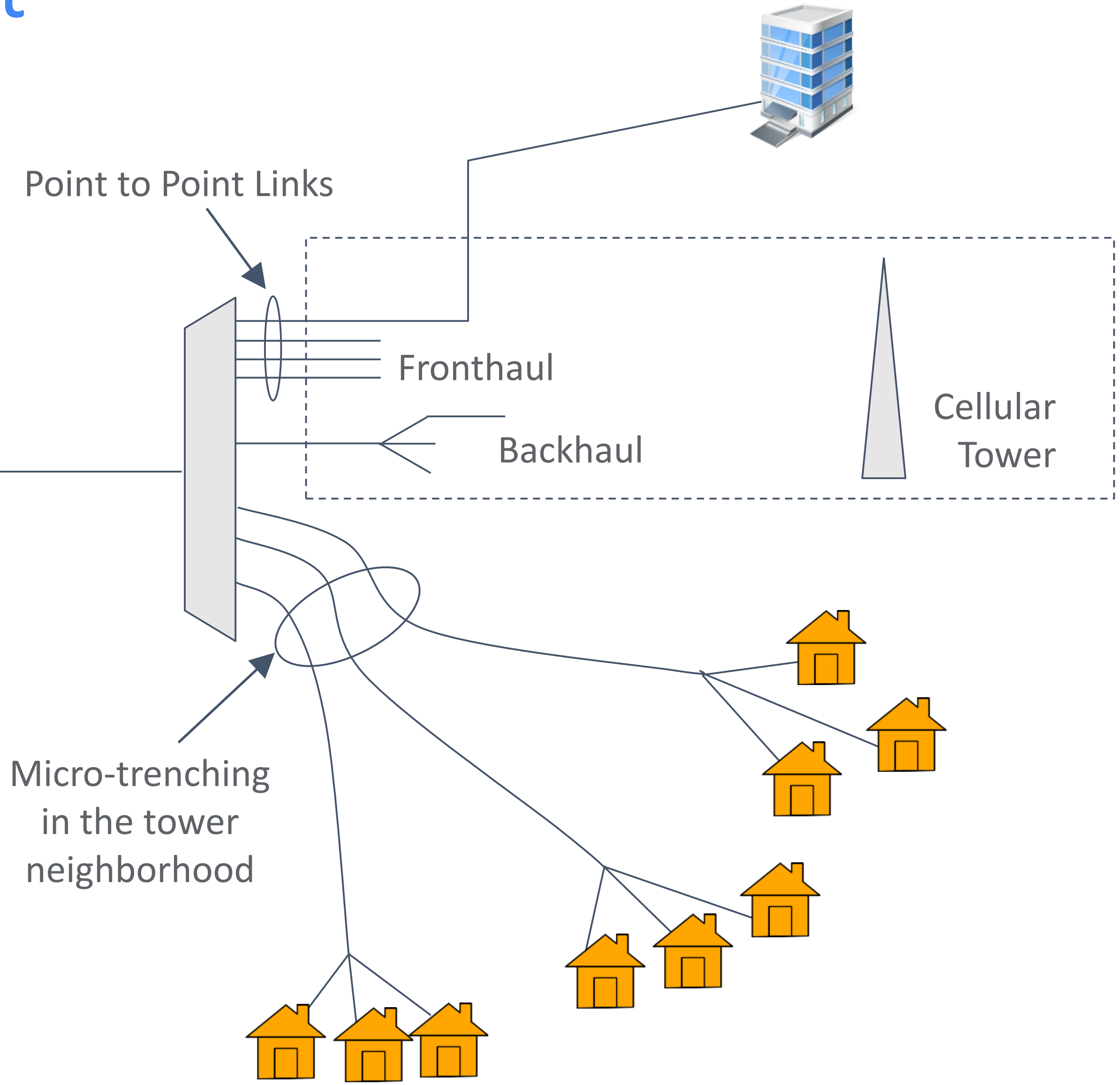
- *ODN expansion for new residential developments*
  - *E.g., new US residential developments*
  - *Avoid active equipment between CO and customer premises*
- *ODN expansion to suburban areas*
  - *These areas are difficult to serve not just in developing countries*



Central urban area
Outer urban area
Suburban area

Cellular/Business Support



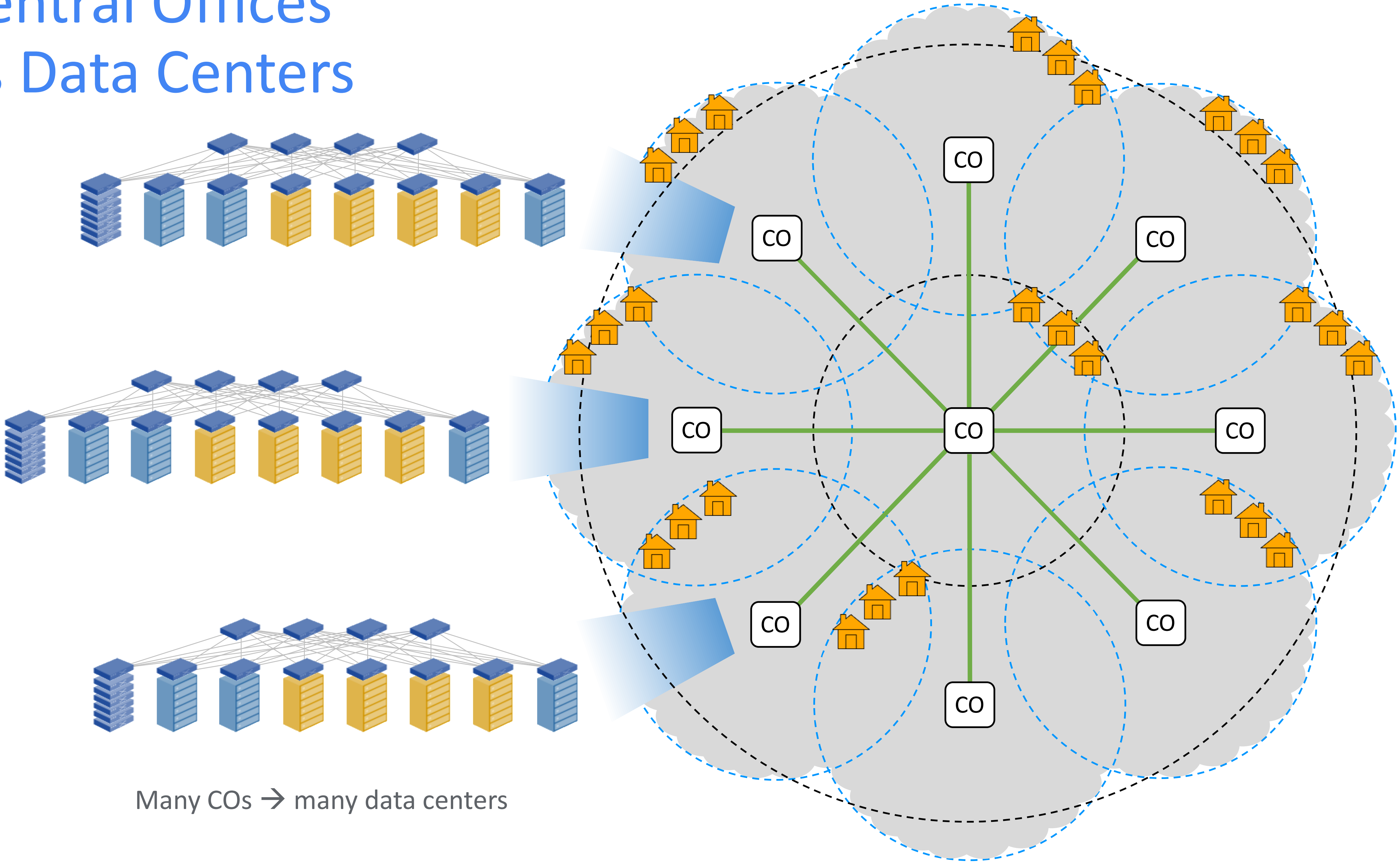


- *Support both point-to-point and residential customers over the same ODN*
  - *Use point-to-point for cellular support*

Central Offices Consolidation

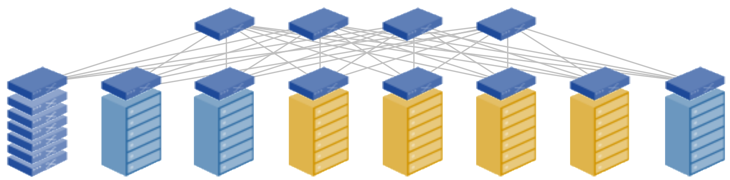
- *ODN optimization for central office redesign as data center*
- *Multiple efforts are on-going to re-implement the central office functionalities as a data center*
  - *Not cost effective with many COs*
  - *More viable by consolidating COs or by building ODNs with fewer COs*

Central Offices as Data Centers

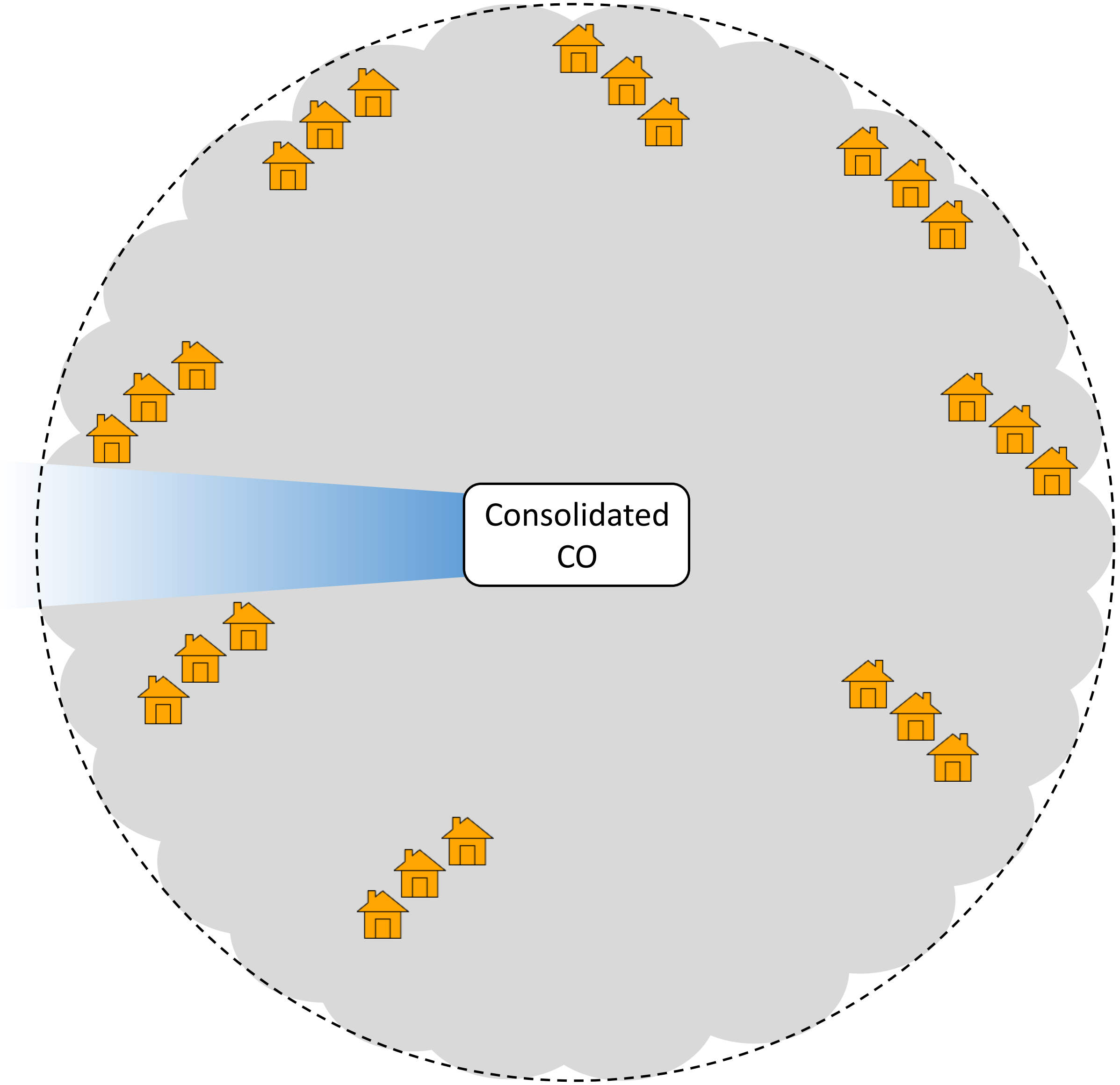


Many COs → many data centers

Data Center in Consolidated CO



Consolidated CO data center



Agenda

- *Why Super-PON*
- *Super-PON Technology*
- *Super-PON Applicability*
- *Standardization*

PON Standards

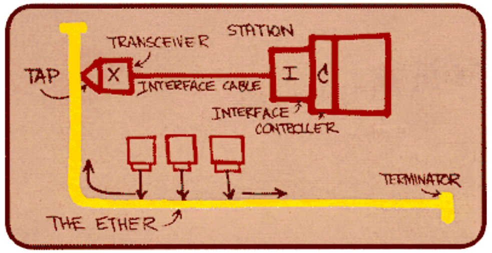
- *PON technologies are by three organizations:*
- *IEEE 802.3, for the EPON suite of protocols*
  - *Including 1G-EPON, 10G-EPON, 25G-EPON, 50G-EPON*
- *ITU-T Study Group 15 Question 2 (Q2/SG15), for the GPON suite of protocols*
  - *Including GPON, XG-PON, XGS-PON, NG-PON2*
- *The Full Service Access Networks (FSAN), an industry consortium that brings together operators to create requirements for ITU-T Q2/SG15*

IEEE

FSAN
Full Service
Access Network

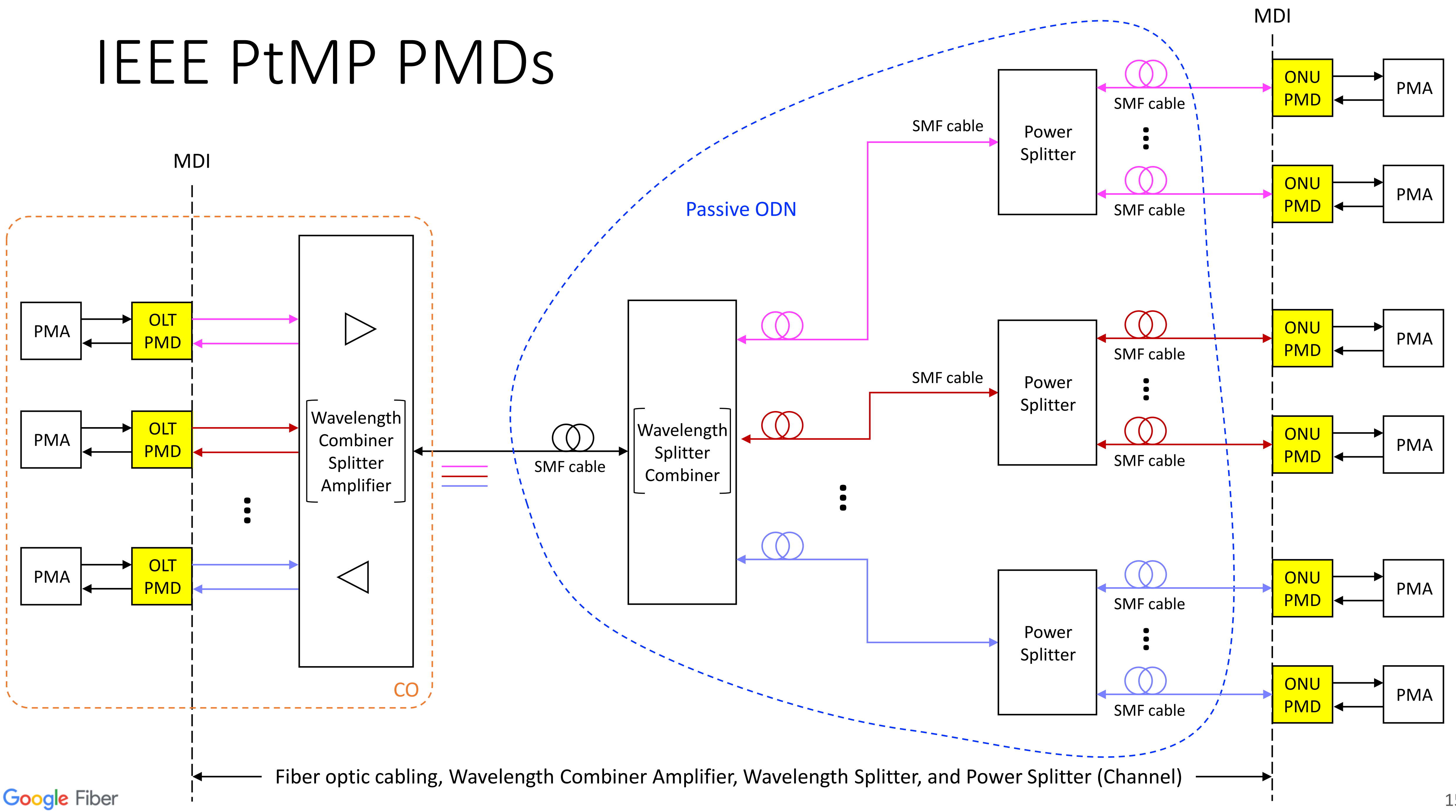
ITU

Super-PON Standardization

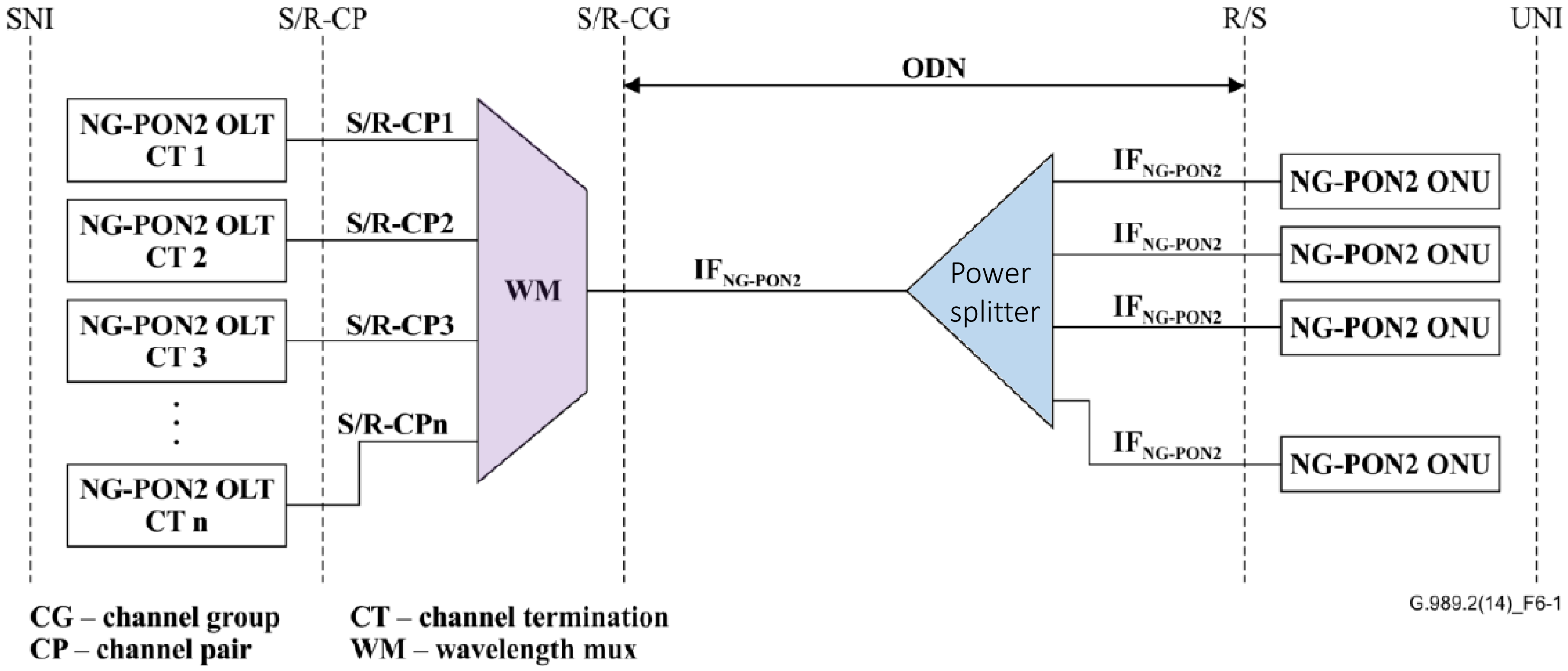


- *Super-PON standardization began in January 2018 with a presentation at the New Ethernet Applications group of IEEE 802.3*
- *In July 2018, IEEE 802.3 approved the formation of the Super-PON Study Group*
  - *The first step in the making of an IEEE standard*
- *Super-PON has been presented to both ITU-T Q2/SG15 and FSAN*
  - *The idea is to define it as an NG-PON2 extension*
- *The two efforts go hand in hand*
  - *To enable a common optical layer across both suites of protocols*

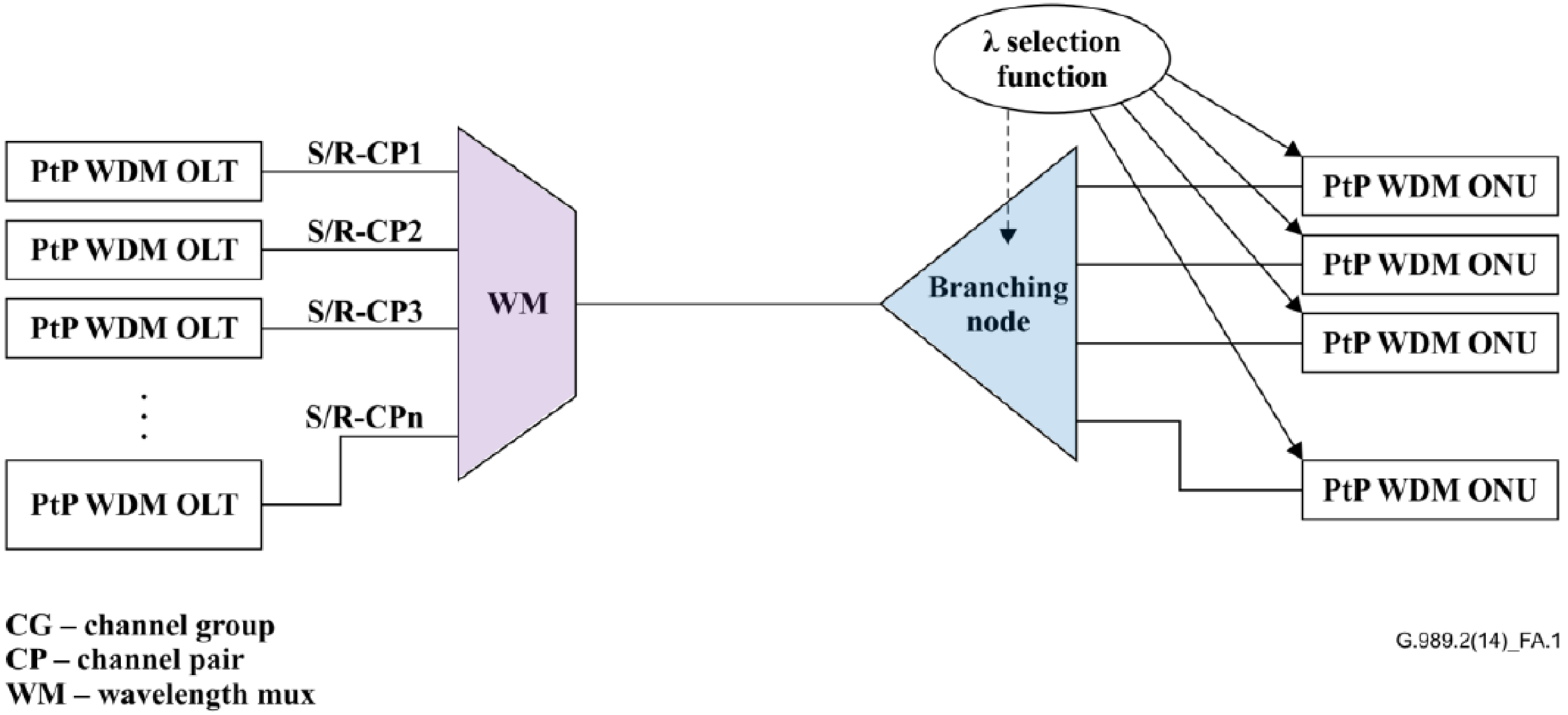
IEEE PtMP PMDs



NG-PON2 PtMP Support

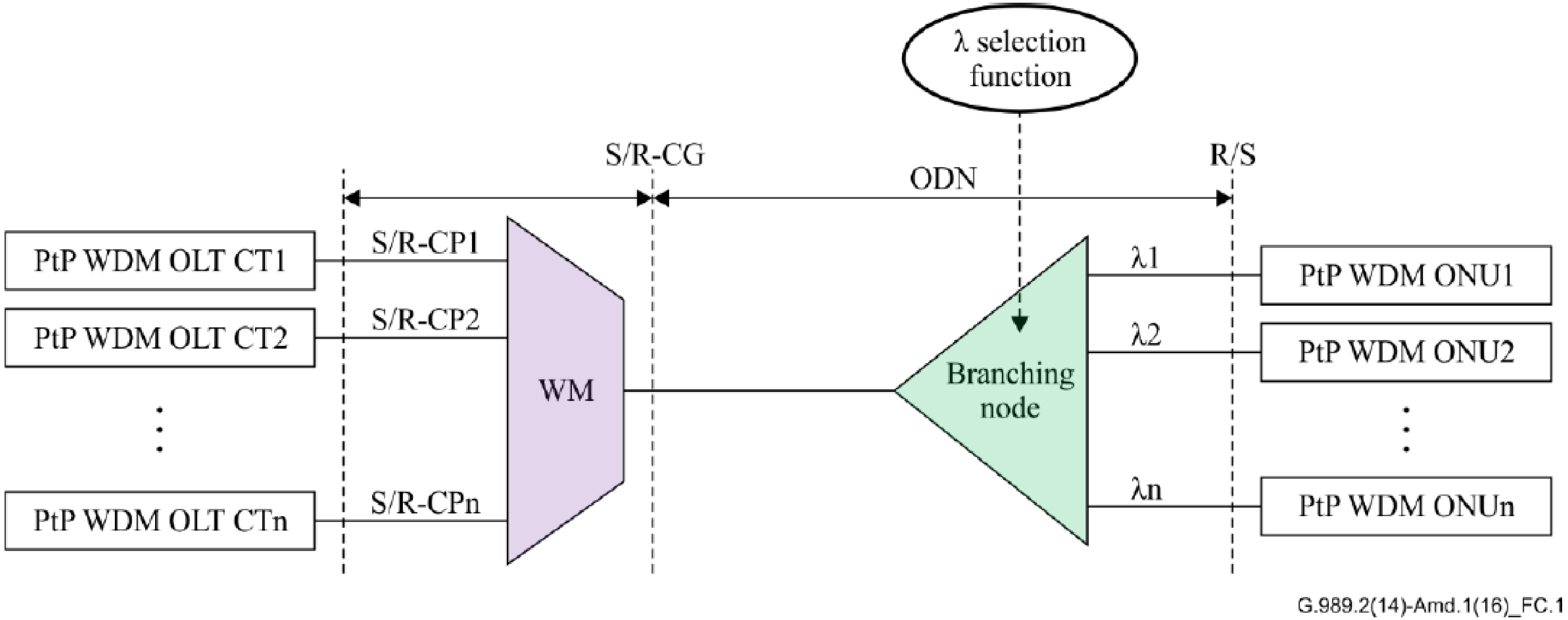


NG-PON2 Tunable PtP (Annex A)



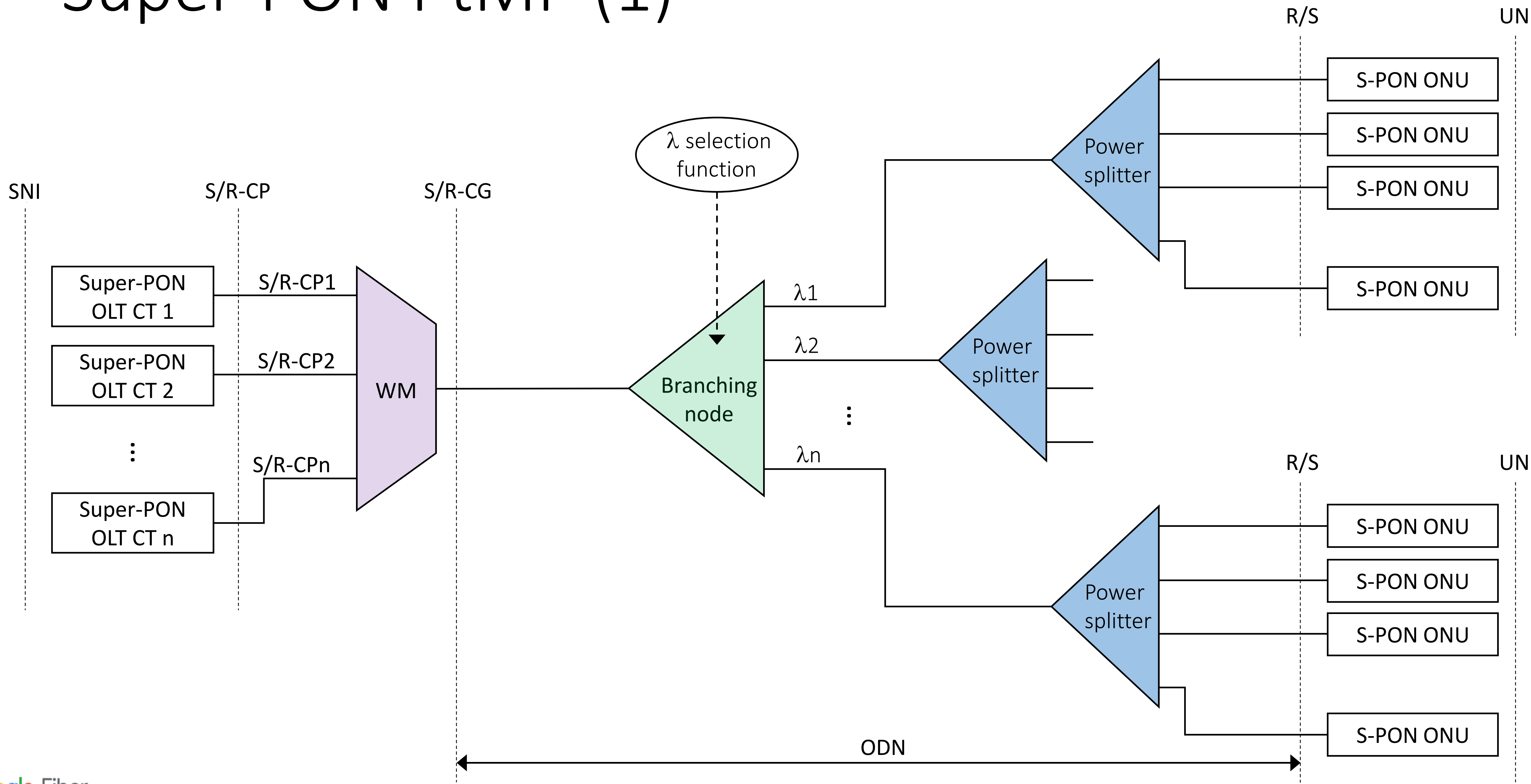
- The branching node is a power splitter
- λ selection is performed by the PtP ONU

NG-PON2 Low-Loss PtP (Annex C)

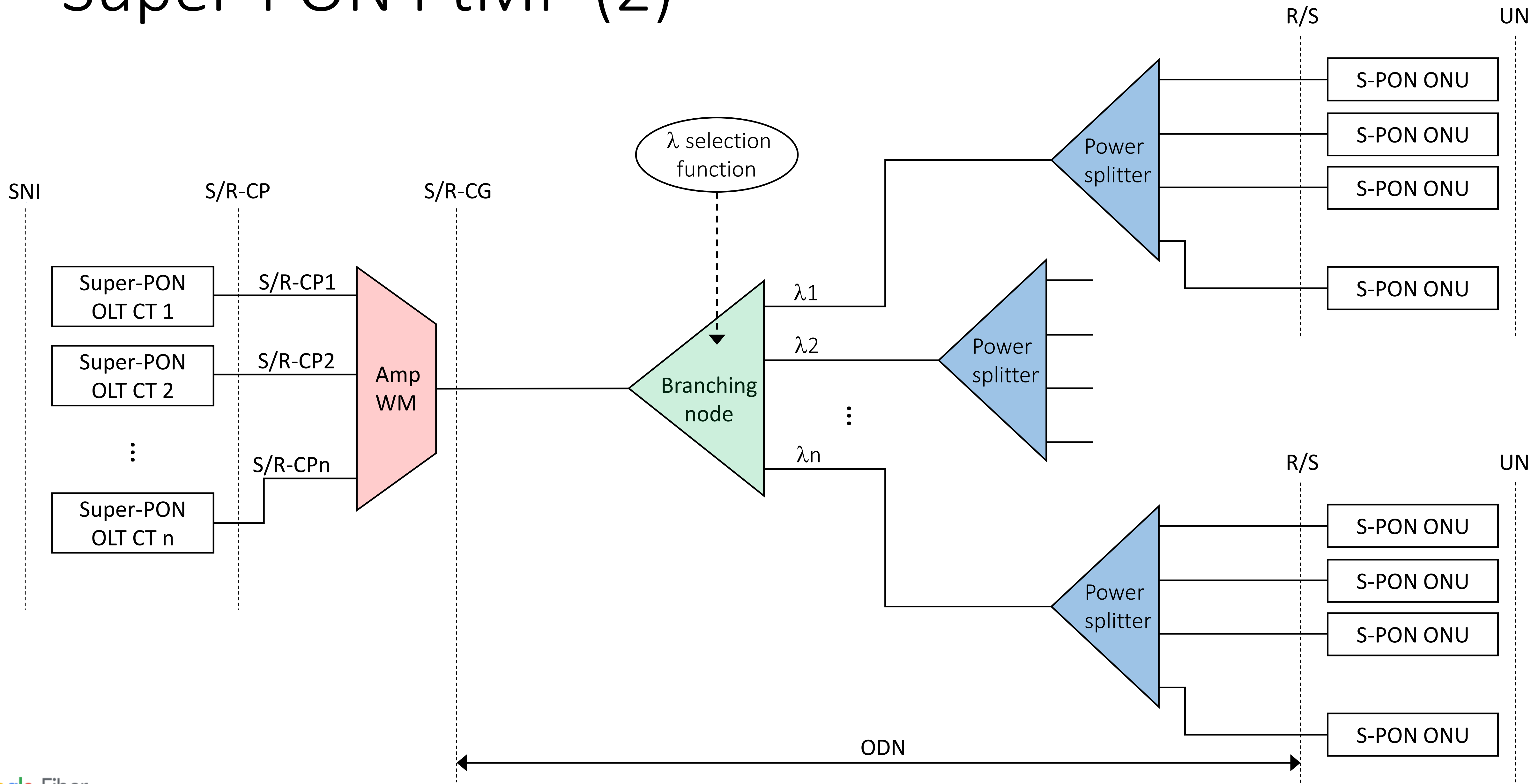


- The branching node is a wavelength router
- Each PtP ONU receives a single λ

Super-PON PtMP (1)

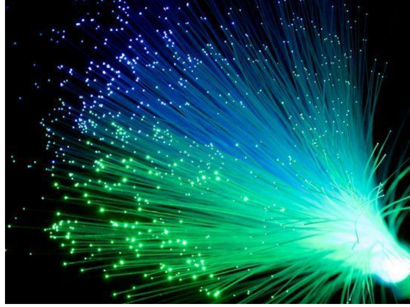


Super-PON PtMP (2)

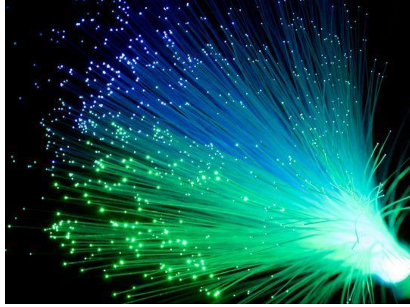


Summary

- *Super-PON is an evolved access solution aimed at simplifying the access infrastructure*
  - *Extends the reach of PONs*
  - *Increases the number of subscribers per fiber strand*
  - *Operates over a passive ODN*
- *It is intended to complement existing solutions, not to replace them*
  - *Each operator will make (or has made) its choices*
- *Standardization is on-going in order to openly define the technology*
  - *Across all relevant organizations*
- *It is a feasible solution*
  - *A pre-standard implementation is deployed in the field and serving customers*



Questions?



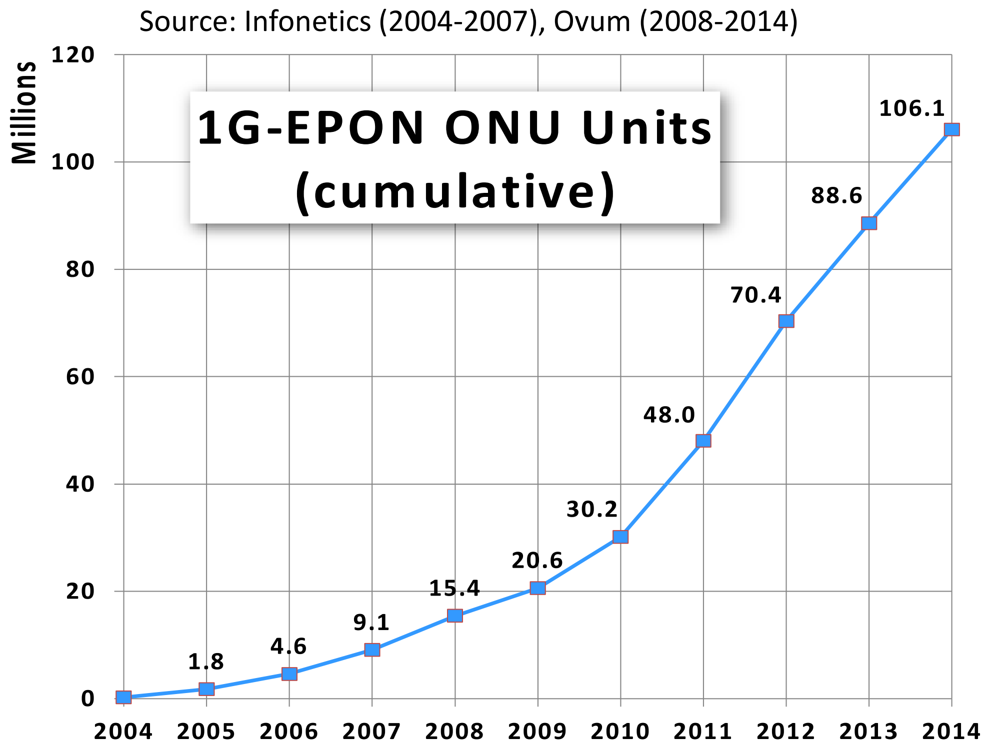
Thank you

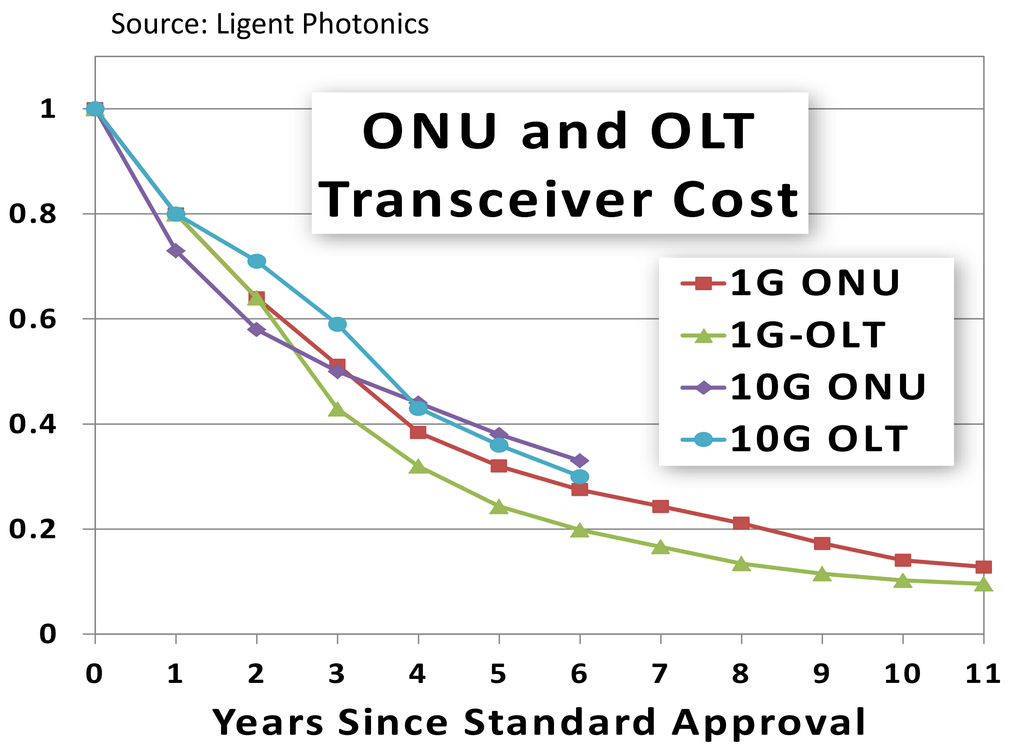
Team:

Adam Barratt, Claudio DeSanti, Liang Du
Joy Jiang, Cedric Lam, Shuang Yin
Tao Zhang, Xiangjun Zhao

Optics Cost Trend

- *Cooled (i.e., wavelength-stabilized) lasers have today a ~10X cost vs. uncooled ones*
- *Also 1G-EPON optics were ~10X of today's cost when they were introduced*
- *Cost is strongly related to volumes*





Google Fiber

FTTH: Adapting to the needs of tomorrow with new protocols and architectures

Kevin Bourg

Optical Architect Director | Corning Optical Communications

Kevin.Bourg@corning.com

broadband forum

BASe

CORNING

FTTX Network Evolution

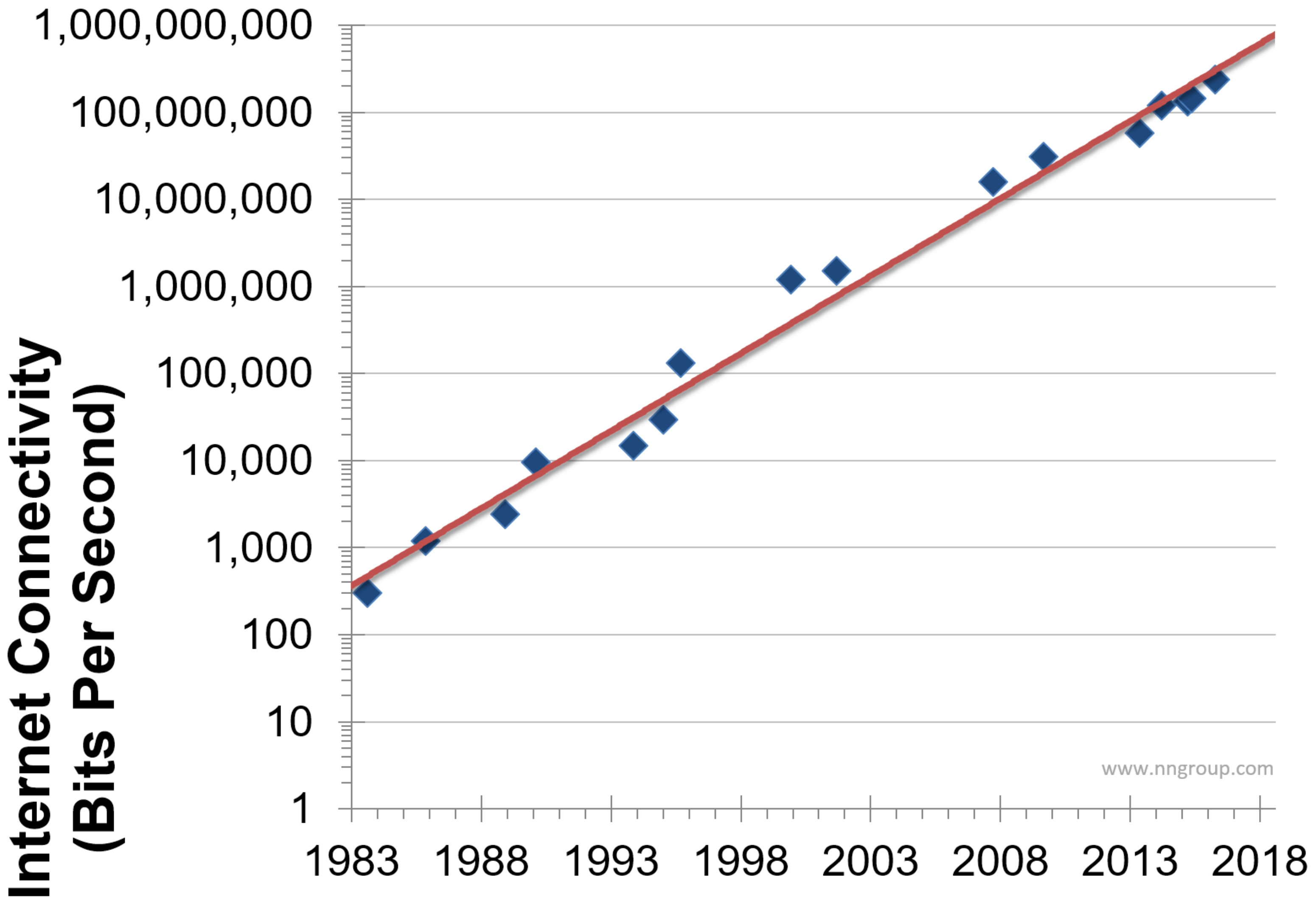
Kevin Bourg
Director, Optical Network Architect
October 2018

By 2023:

Peak broadband demand to reach 7.5 Gbps

EXTRAPOLATION OF NIELSEN'S LAW

Predicting **consumer demand**

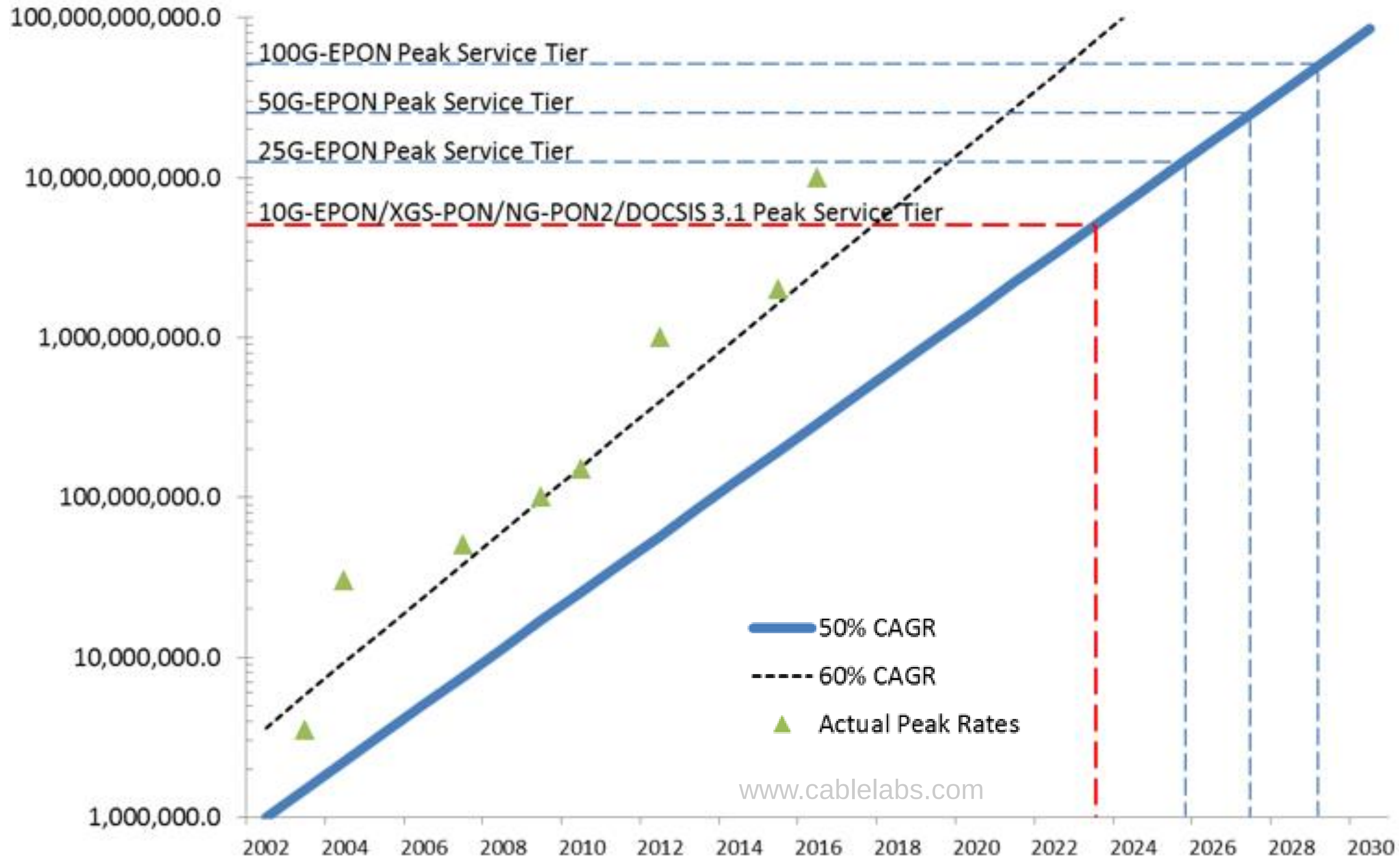


Nielsen’s Law

Billboard speeds grow 50% per year

CORNING

Predicting **consumer demand**



Nielsen's Law

Billboard speeds grow 50% per year

SHOULD WE PREPARE FOR A **HIGHER TRAJECTORY**

CORNING

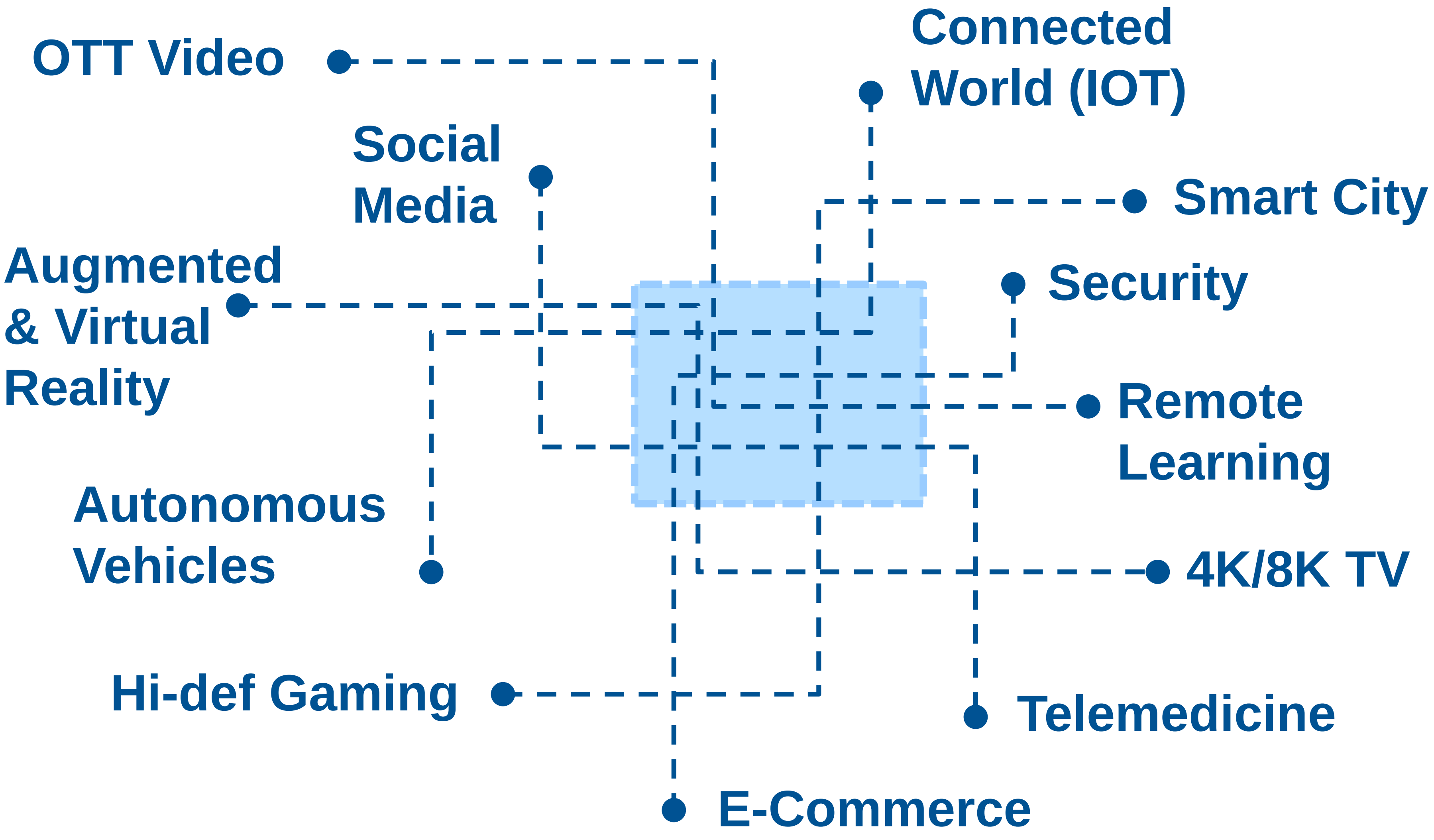
What came first:

Demand or Infrastructure?

THE VIRTUOUS CYCLE OF TECHNOLOGY

CORNING

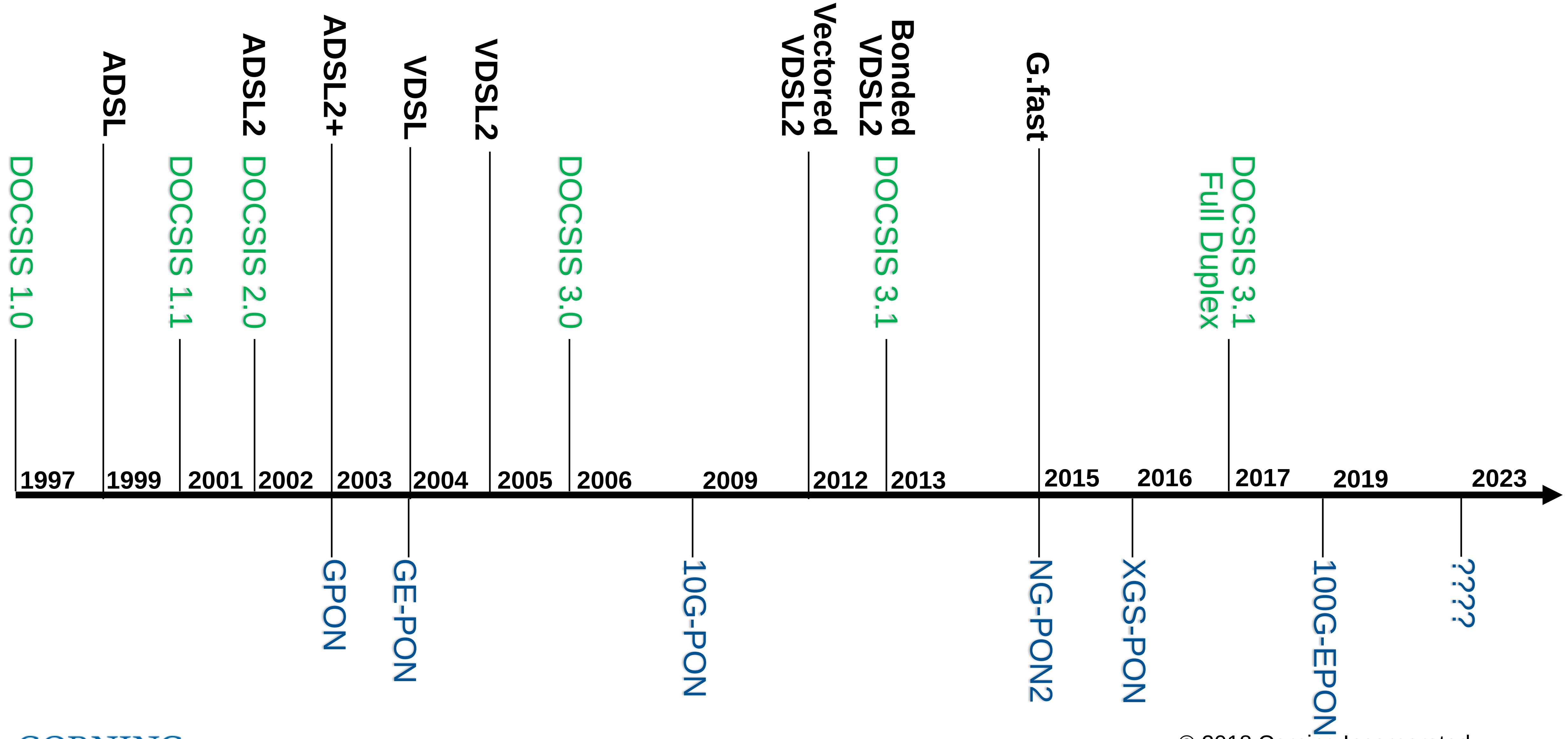
Demand **drivers**



Increasing high-speed broadband network deployments

CORNING

Broadband technology **evolution**



CORNING


Competition is
heating up!
CONSIDER YOUR BUSINESS
CORNING
© 2018 Corning Incorporated

Access networks begin to **converge services**

RESIDENTIAL SUBSCRIBERS
COMMERCIAL BUSINESS SERVICES
WIRELESS FRONT/BACKHAUL

It comes down to:

Time and Money

UPFRONT CAPEX, ONGOING OPEX AND UPGRADABILITY

CORNING

Converged approach

offers up to 40%

CAPEX AVOIDANCE VERSUS REDUNDANT BUILDS

Be future-ready!

EVALUATE A CONVERGED FIBER APPROACH IN YOUR NEXT UPGRADE CYCLE

CORNING

Let's **connect**,

FOLLOW US ON SOCIAL MEDIA FOR OUR LATEST INNOVATIONS

YouTube
@CorningOpticalCommunications

Linked in
@CorningOpticalCommunications

Twitter
@CorningOpComm

Kevin Bourg
Kevin.bourg@corning.com

#FiberToThePeople

CORNING


CORNING

NG-PON2 Solution for 10G Internet Service: SK's Development & Deployment

Choongbok Lee

Senior Manager | SK Broadband

choongbok.lee@sk.com

broadband forum

BASe

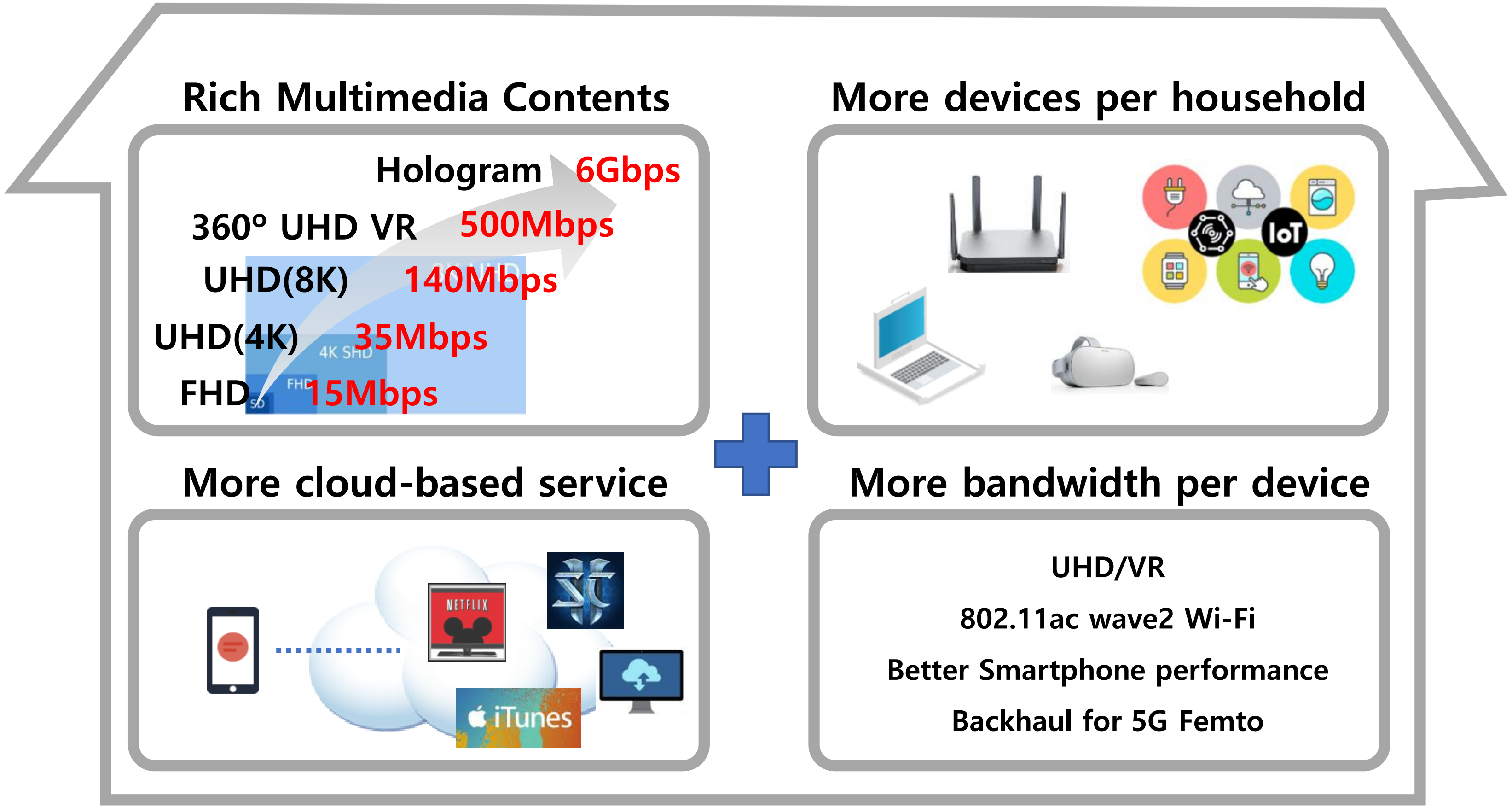
NG-PON2 Solution for 10G Internet Service: SK's Development & Deployment

2018.10.28

SK Broadband
Choongbok Lee

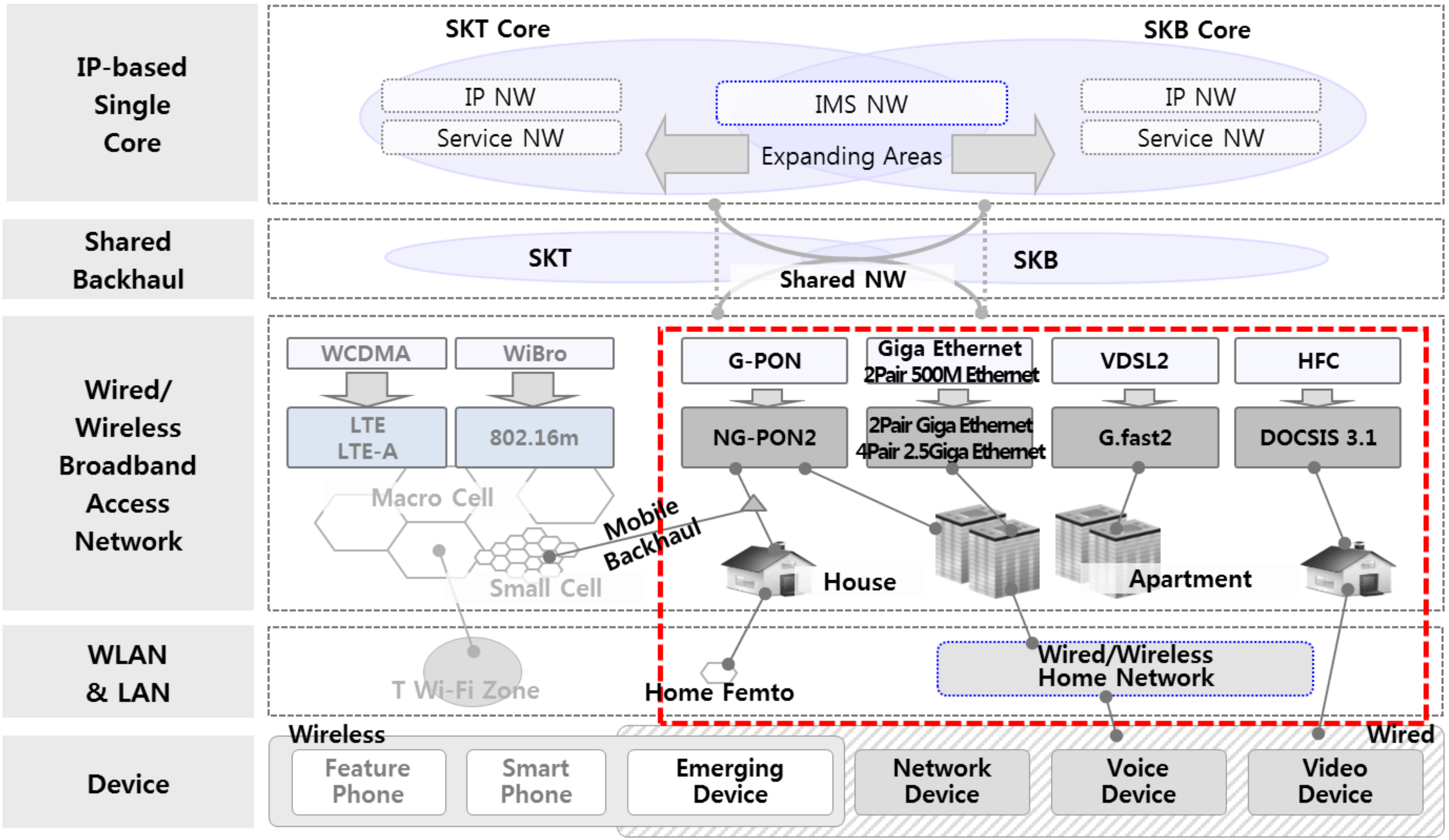
Bandwidth Increase in Residential Broadband Service

- 4 Factors to increase the bandwidth in residential broadband service
- Operators need to get prepared for the bandwidth over than 1 Gbps per household.



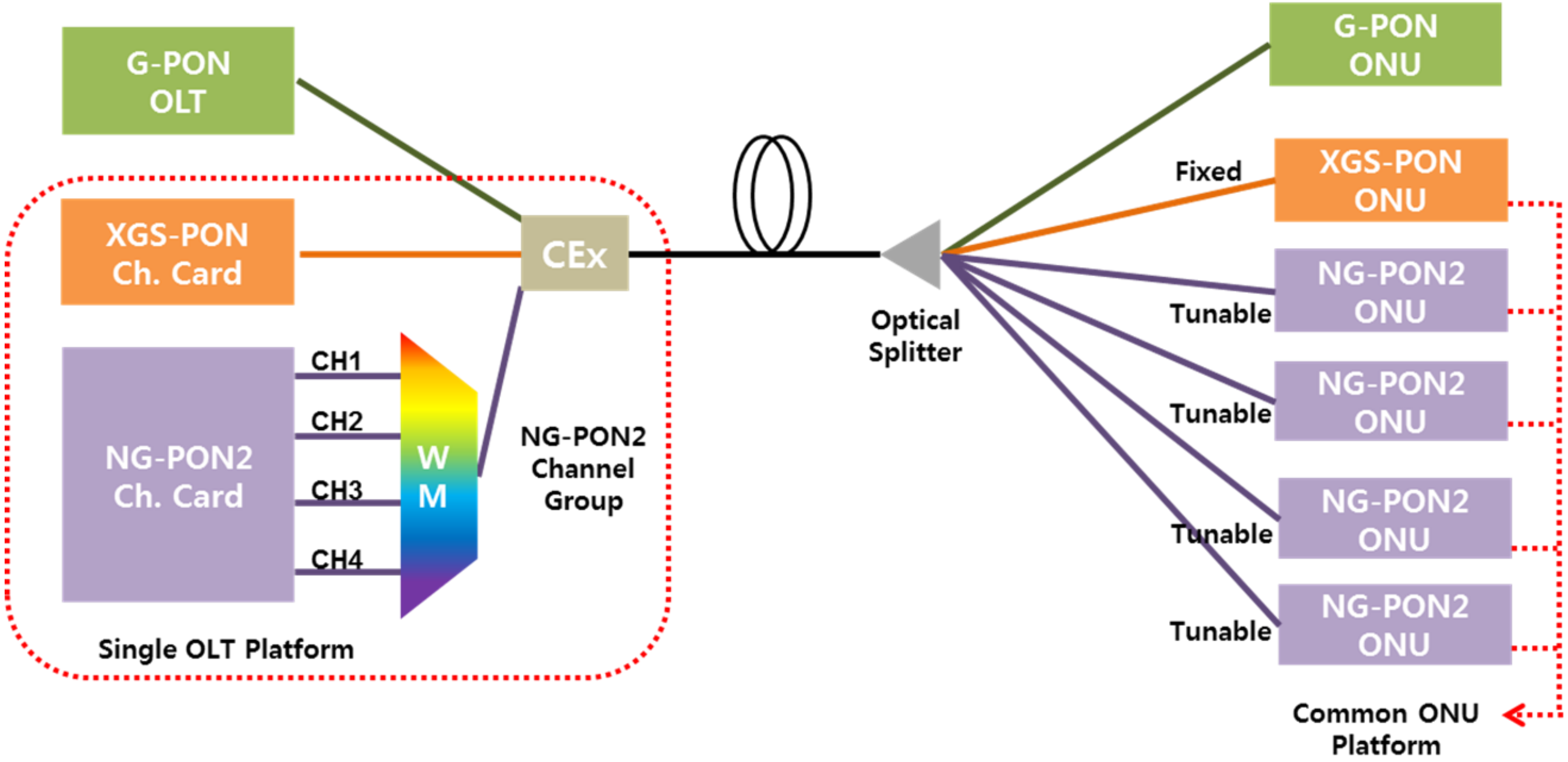
Last mile Technologies

- Developing next generation broadband technologies for 4 different wireline medium



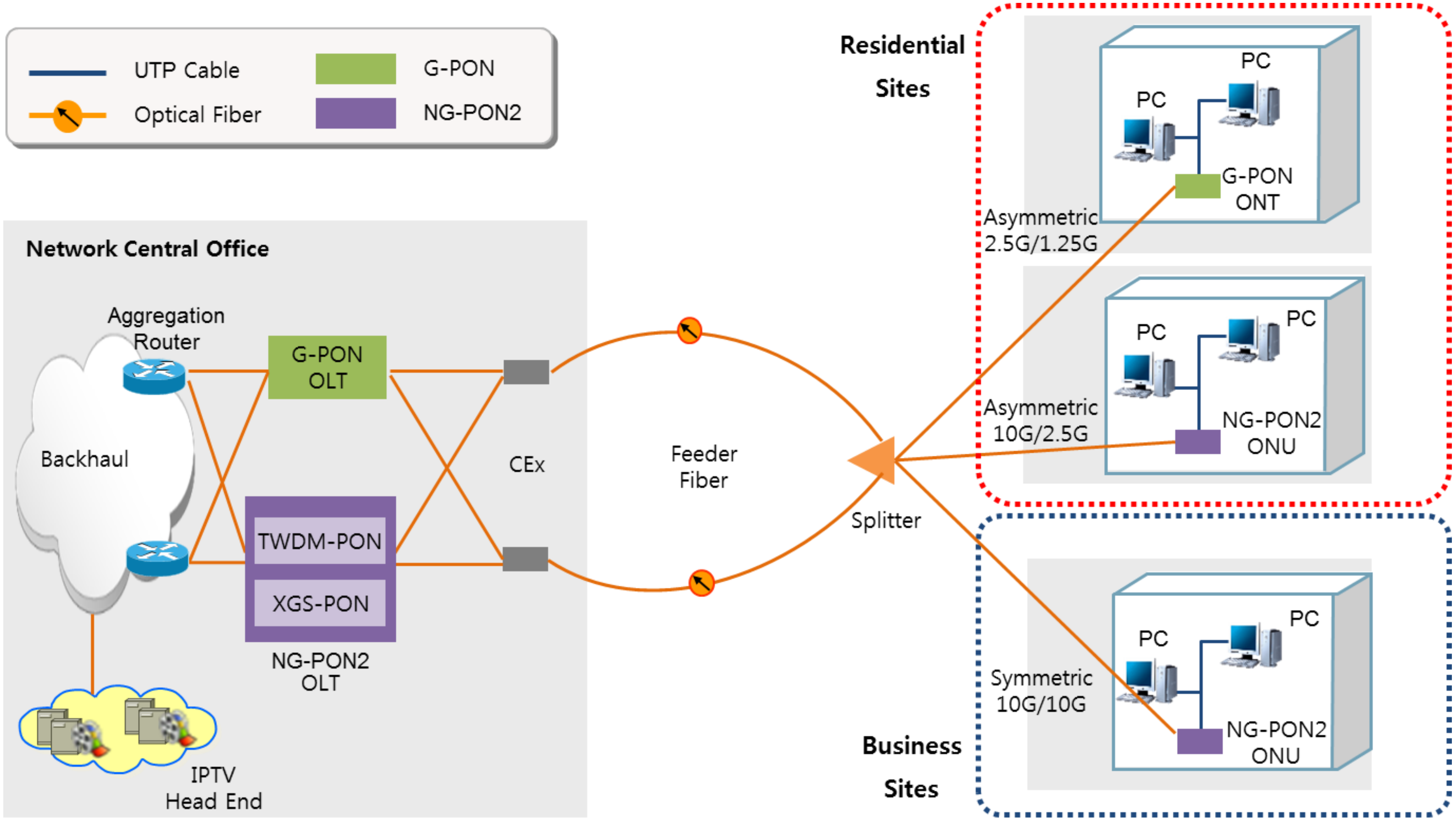
Key Requirements of SK NG-PON2 – 1

- Deployment strategy of next generation PON system: A fixed XGS-PON will be introduced first and tunable TWDM-PON next
- Single OLT platform to accommodate XGS-PON channel card and NG-PON2 channel card
- Common ONU platform to be XGS-PON ONU with fixed transceiver and to be NG-PON2 ONU with tunable transceiver.



Key Requirements of SK NG-PON2 – 2

- 10/10 Gbps symmetric bandwidth to accommodate residential services and business services on the same system and with the same feeder fiber
- SK uses Multicast Protocol for IPTV service.



Key Requirements of SK NG-PON2 – 3

- Residential traffic consumption over than 1 Gbps is expected due to more devices, higher definition video and Wi-Fi IEEE 802.11ac Wave2.
- The solution to deliver 2.5 Gbps on the existing CAT 5e UTP cable, based on IEEE 802.3bz
- ONU with 2.5GBase-T UNI ports and CPE @customer's home with 2.5GBase-T uplink.

[2.5G ONU]

[2.5G CPE]

front

rear

NG-PON2 Development Timelines

1. PMD layer Test @Lab — April 2015
2. PoC Test @ Seoul — July 2015
3. Issued spec. for Field Trial — January 2016
4. System Test for Field Trial — July 2016
5. 1^{st} Field Trial @ Seoul — October 2016

- SK cooperated with the vendor partners on NG-PON2 development from 2015.
- The requirements for the field trial were issued and the system test was performed.
- In Oct. 2016, SK announced the world 1^{st} field trial of NG-PON2 with live residential customers.
  - 2 sites in Seoul
  - Total bandwidth of 52.5Gbps (G-PON, XGS-PON, NG-PON2 w/4 WL)
  - IPTV by multicast protocol

1. Issued spec. for Roll-out — April 2017
2. End of DVT 2.5G ONU/CPE — August 2017
3. End of BMT for Roll-out — October 2017
4. Beta Service @ Incheon — January 2018
5. Released 2.5G Plan — May 2018

- During 2017, SK prepared a 10G PON commercial service.
- Beta service was started in Incheon and 2.5Gbps subscription plan was released.

Broadband Subscription Plans

- The 1st 2.5Gbps subscription plan for residential customers
- G-PON ONT for FTTH (Optic cable) or 2.5G ONU/CPE for FTTB (UTP) for Giga Premium.
- 55 USD per month and a reduced price with multi-year contract
- 10Gbps plan will be released soon.

Subscription Plan (max. throughput)	Smart (100M)	Giga Lite (500M)	Giga (1G)	Giga Premium (2.5G)
No Contract	33	45	50	55
3 yr Contract	20	30	35	40

※ Subscription price per month in USD

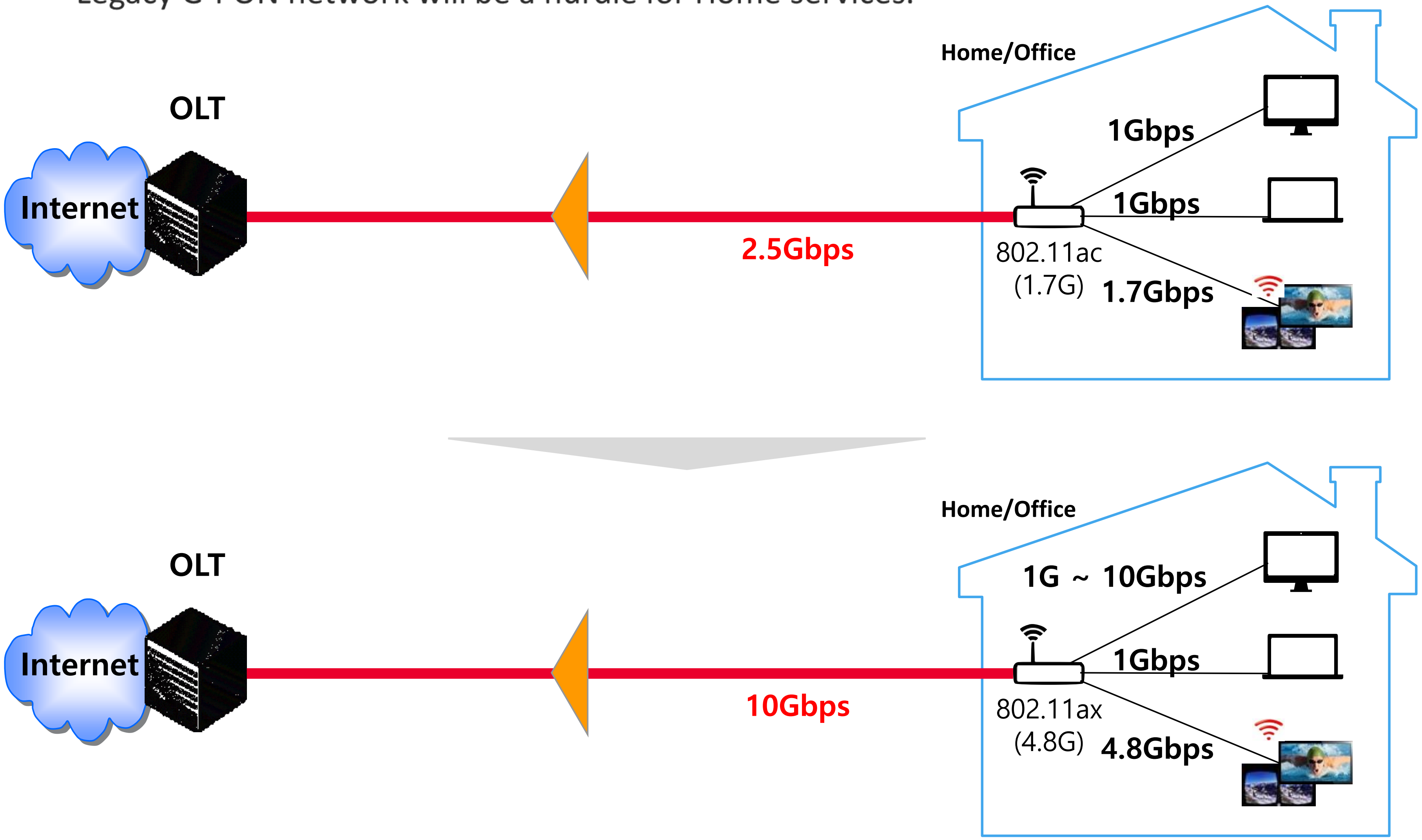
10G Internet

- From 2.5Gbps to 10Gbps for Home and CPE provide over 1Gbps
- Can provide 10G service regardless of media(but telephone line)

Item	Last-mile	Access Technology	Structure (Topology)	Service Speed (Per Household)
Apartment	① Optical Cable	NG-PON2	FTTH	**10G/5G/2.5Gbps**
	② UTP Cable (4Pair Per Household)	NG-PON2	FTTB	**5G(TBD)/2.5Gbps**
	③ UTP Cable (2Pair Per Household)	NG-PON2	FTTB	**2.5G(TBD)/1Gbps**
	④ Telephone Line	NG-PON2 (G.fast)	FTTB	1Gbps
	⑤ Optical Cable	NG-PON2	FTTH	**10G/5G/2.5Gbps**
	⑥ Coaxial Cable	DOCSIS 3.1	HFC	**2.5Gbps**

10G Internet

- Devices support 802.11ax are likely to appear next year.
- Legacy G-PON network will be a hurdle for Home services.




рахмат
danke
謝謝
ngiyabonga
spas
teşekkür ederim
Баярлалаа
mersi
kia ora
barka
welalin
tack
mahalo
tapadh leat
спасибо
faafetai lava
vinaka
спасибі
blagodaram
dank je
misaotra
matondo
paldies
grazzi
kiitos
dankie
nanni
nandri
dhanyavad
mauruuru
thank you
gracias
хвала
asante
manana
bedankt
bayarlalaa
gracie
hvala
koszonom
dankon
aciū
akun
obrigada
murakoze
tenki
enkosi
djiere dieuf
tau
mochchakkeram
дякую
mamnun
dziękuję
chnorakaloutioun
gratias ago
gracies
sulpay
go raibh maith agat
chokrane
sobodi
dėkuji
sagolun
sukriya
kop khun krap
taiku
obrigado
mèsi
didi madloba
ありがとう
tanemirt
grazie
arigatô
takk
dakujem
trugarez
najis tuke
kam sah hamnida
rahmat
terima kasih
rahmet
ευχαριστώ
diolch
dhanyavadagalu
shukriya
merce
мерси
감사합니다
xiexie
merci

NG-PON2 Optics Update: Path to Massive Deployment

Wei-Ping Huang

Founder and Chief Scientist | HiSense Broadband Multimedia Technologies Co.

wphuang_canada@hotmail.com

broadband forum

BASe

Dealing with Capacity Growth in Access Networks

Antonio Teixeira

Co-Founder and CTO| PICadvanced

teixeira@picadvanced.com

Dealing with Capacity Growth in Access Networks

PICadvanced

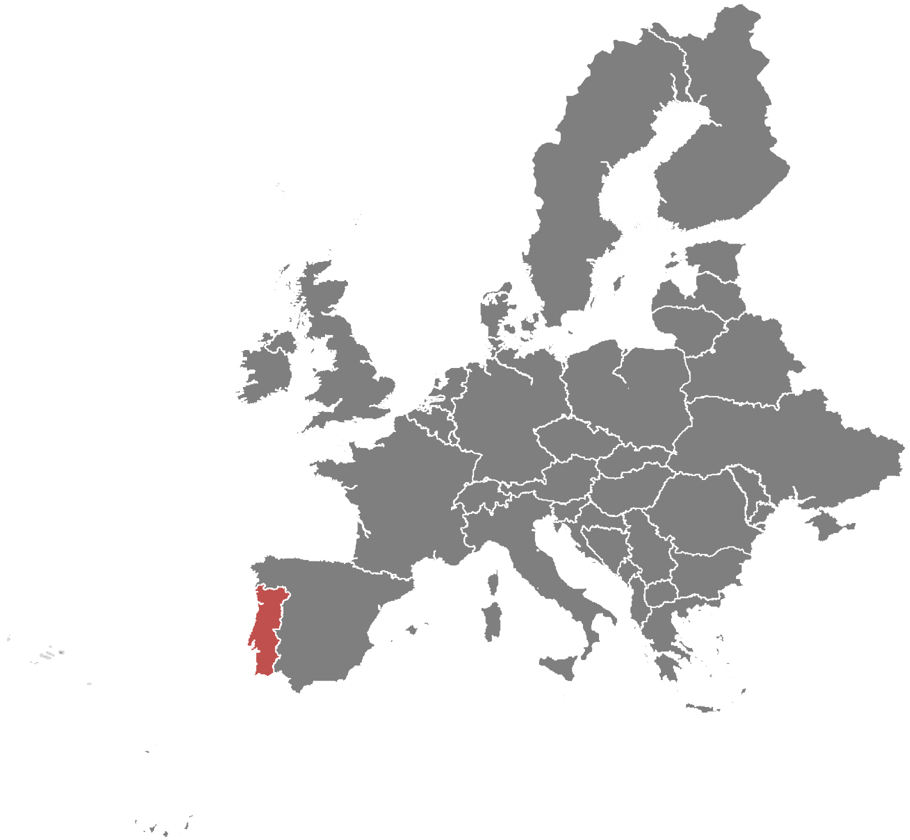
António Teixeira

Co-founder, PICadvanced | member BBF

Universidade de Aveiro, Portugal

Company presentation

- Portuguese startup founded in 2014
- Located in Aveiro



"Think outside the box, with us!"

PICadvanced

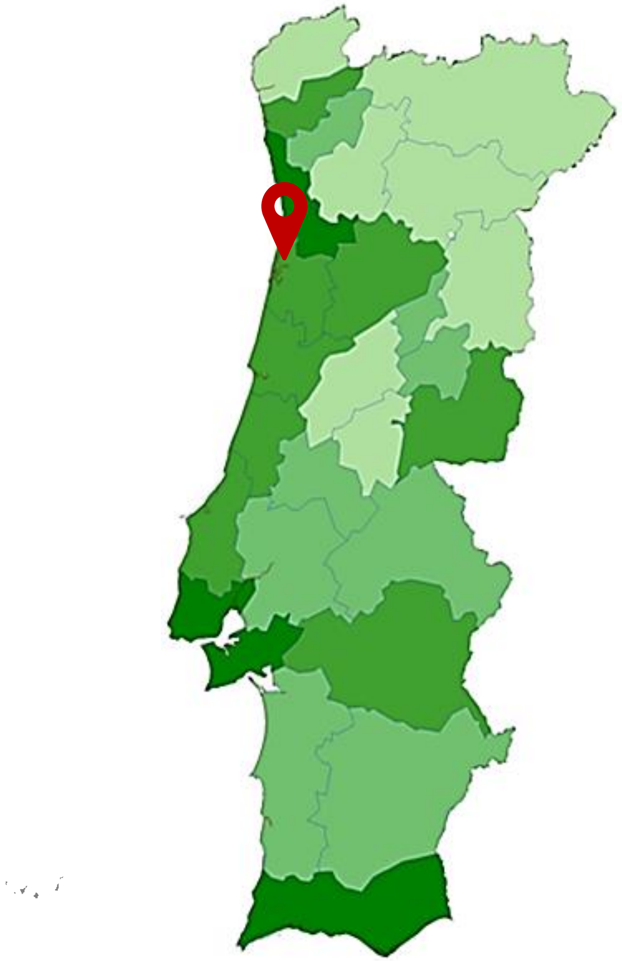
instituto de telecomunicações

universidade de aveiro

broadband forum

Company presentation

- Portuguese startup founded in 2014
- Located in Aveiro



“Think outside the box, with us!”

PICadvanced – our facilities

pci · creative science park
universidade de aveiro incubator

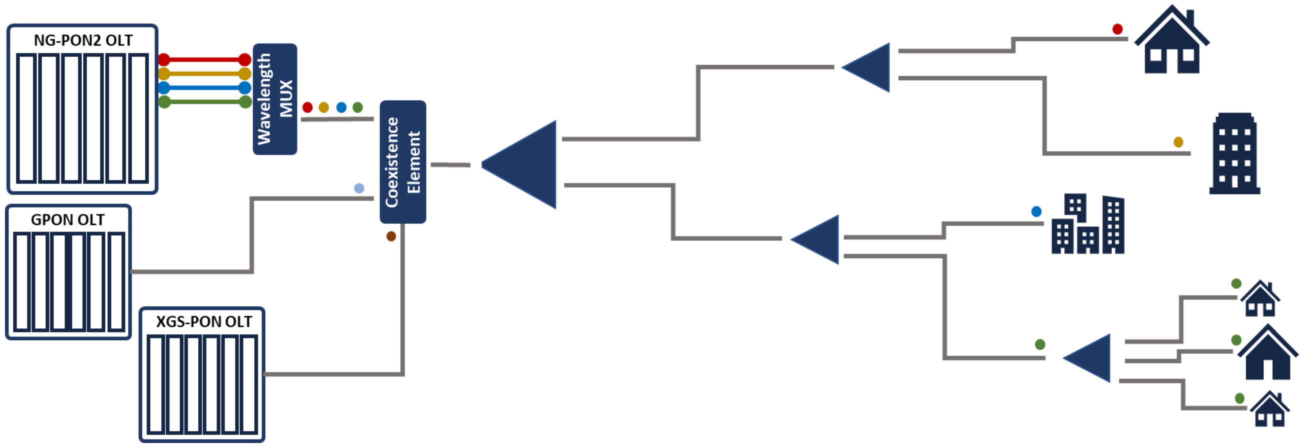
PICadvanced
instituto de telecomunicações
universidade de aveiro

Bandwidth is increasing

Cloud services

Number os subscribers

IoT



UHD Contents

4.0 Industry

Usage per subscriber

Quality of services

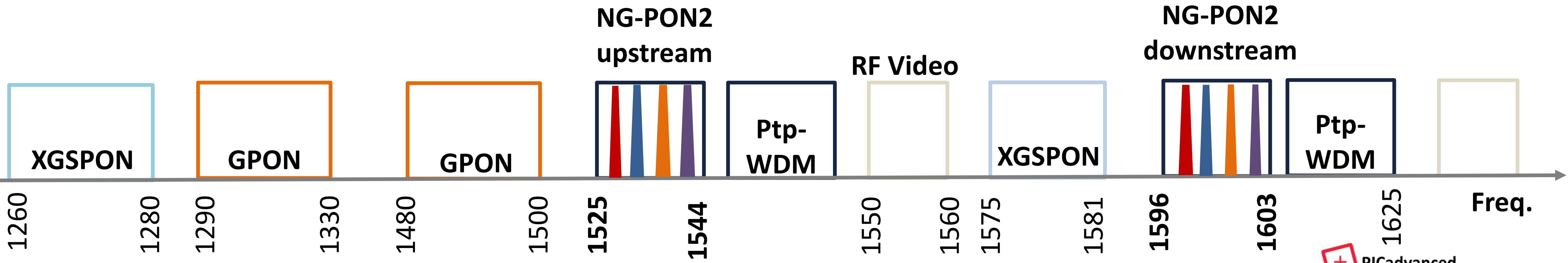
How is the access networks spectrum?

From
20-30nm wavelength wondering (GPON)

to
6-20nm wavelength wondering (XGSPON)

To
100GHz channel tunning within +/-20GHz precision

To
Next generation 5G enabler



Near Future

Increasing bandwidth

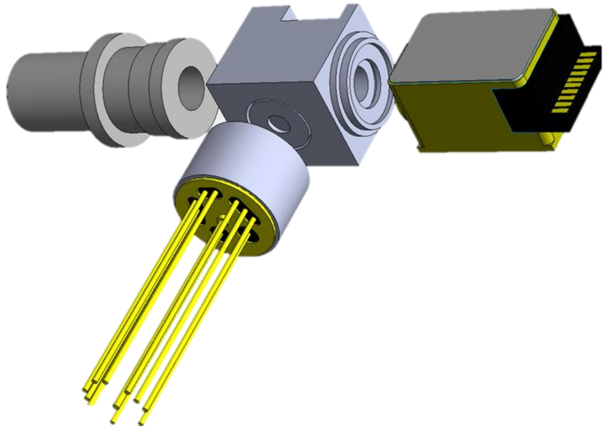
More power
consumption,
size and costs

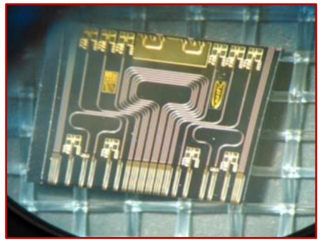
INTEGRATION

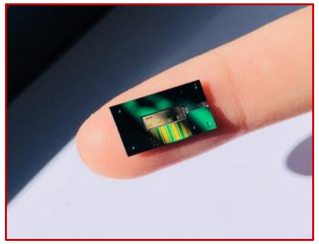
Hardware Complexity

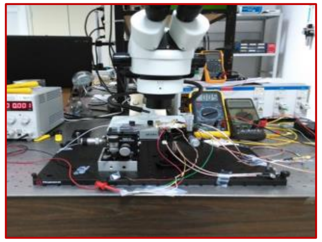
But, will this be suitable for access?

Natural evolution…









Components packaged

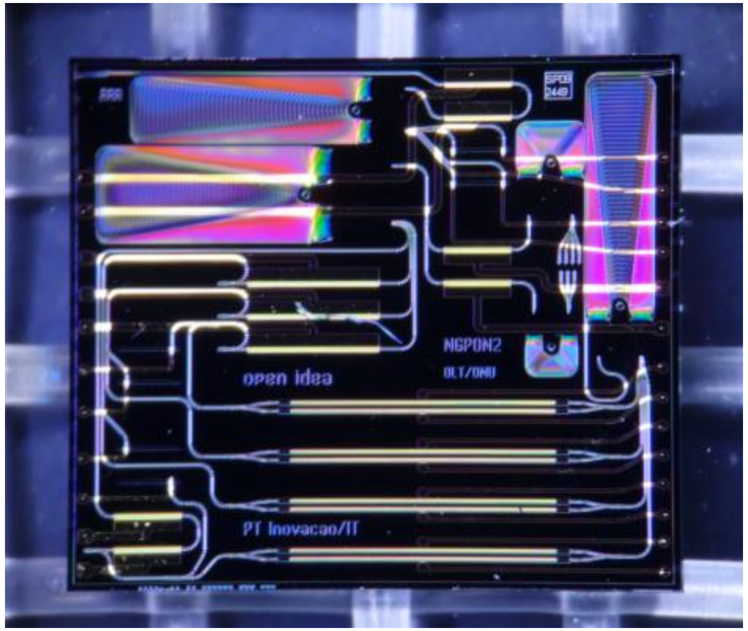
Photonic integrated circuits
(monolithic or hybrid or even mixed)

Why PICs?

> *PICs are the way to make the systems and subsystems ubiquitous*
> – M Smit

+ Integration in a single chip
    - Lasers
    - Modulators
    - Amplifiers
    - Detectors
+ Decrease size to milimeters
+ Lower power consumption
+ Improves reliability
+ Reduce the costs
+ Reduce the O-E-O conversions

@2014



4 mm

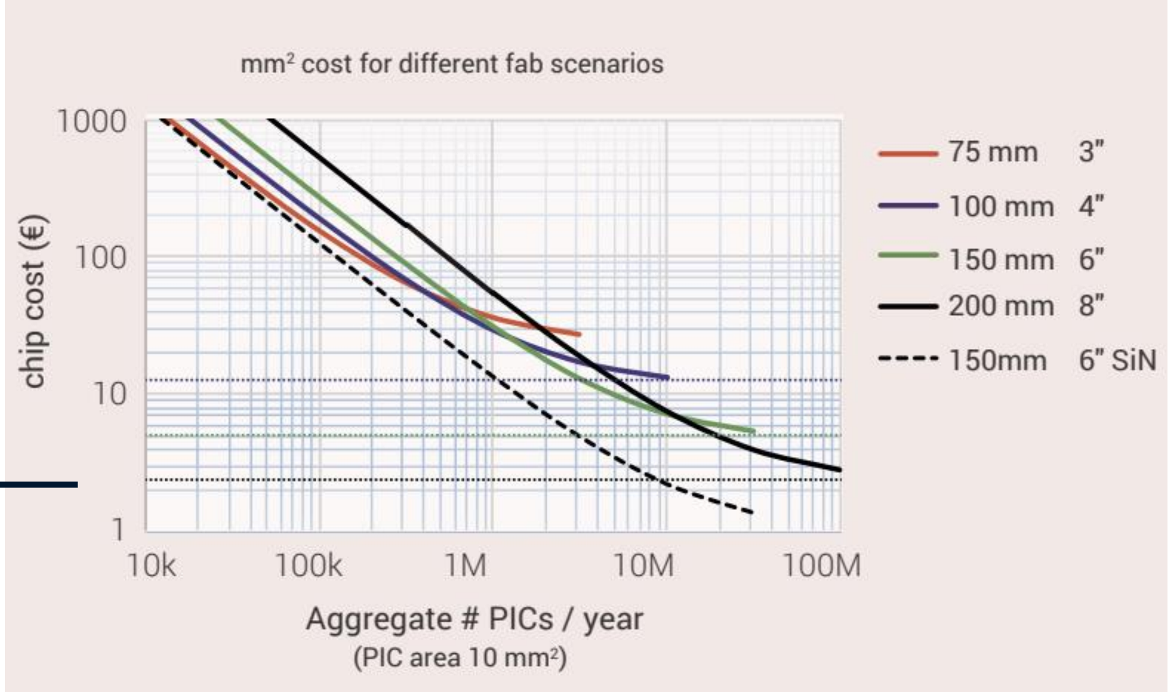
6 mm

Why to invest on PICs?

At low chip volume (R&D) the prices are very high…

SOLUTION? Multi Project Wafer Runs

+ MPWs is a vehicle for low-entry cost
  + Shared infrastructure, shared tools, shared wafers



Source: Roapmap JePPix 2018

Depending on technology, some 2-20 chips for testing will cost from 3k-25k$ for couple of mm^2

How to design a chip?

System Theory	Optical Architecture	Simulations	PIC Design	DRC + Mask Layout	PIC production	PIC testing	PIC packaging
Concept of the architecture	Convent the concept into na optical system + Choose the material + Choose the fab	Simulate the whole architecture	Design the chip in concordance with the design rules	Design rule check, generate the .gds mask and delivery to the selected fab	Manufacture the chip, lithography, etching, dicing and others	Test the functionalities of the PIC	Encapsulate the chip

PICs have innumerous applications!

Sensing

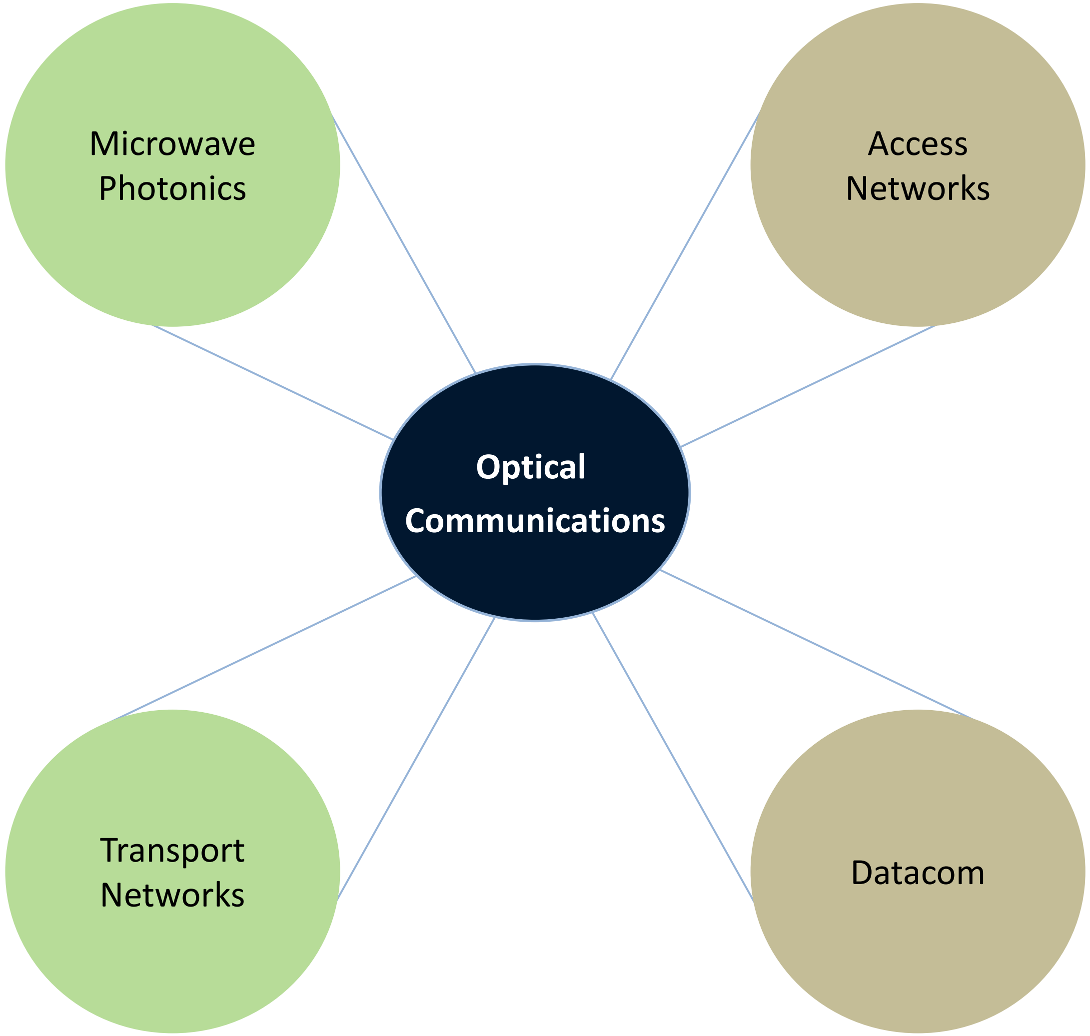
Optical Communications

Optical Signal Processing

Biomedicine

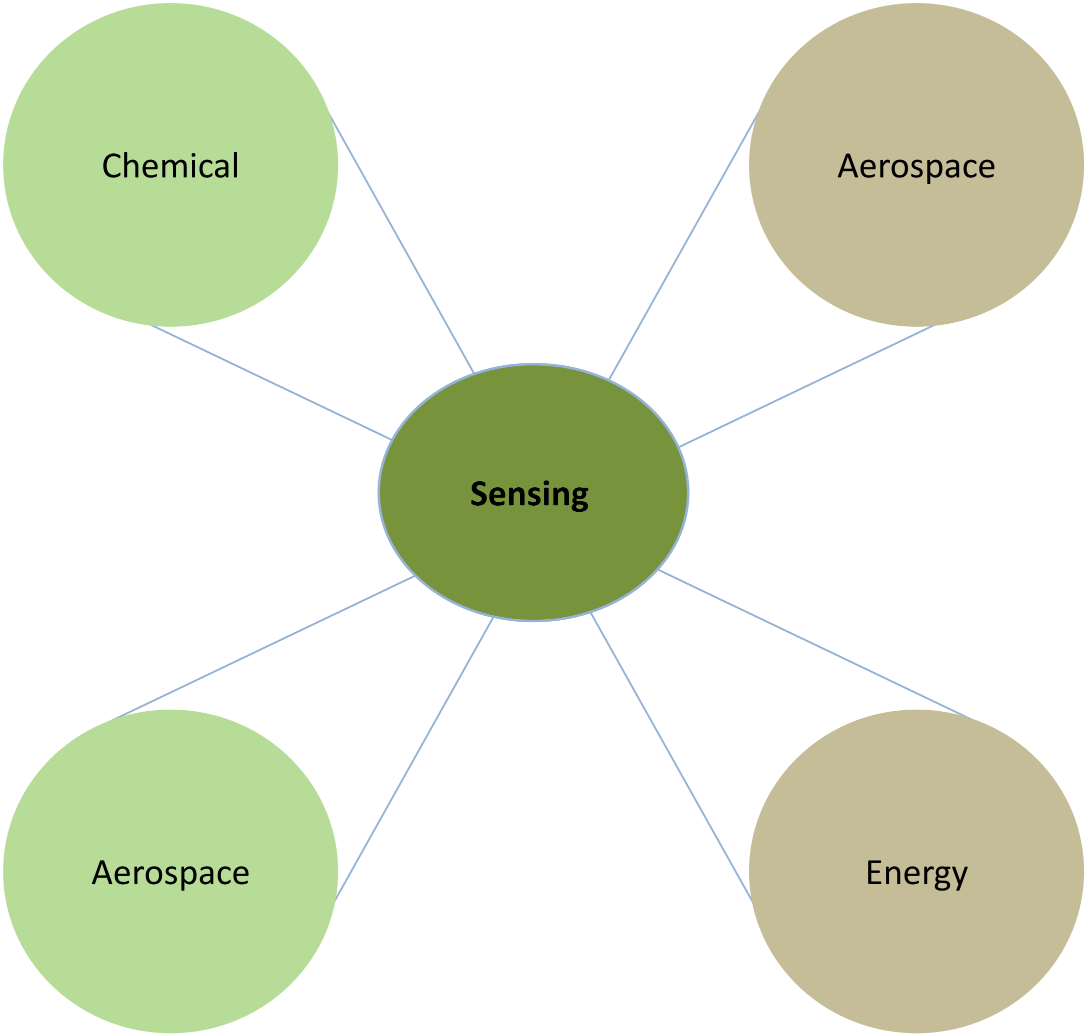
204

PICs have innumerous applications!



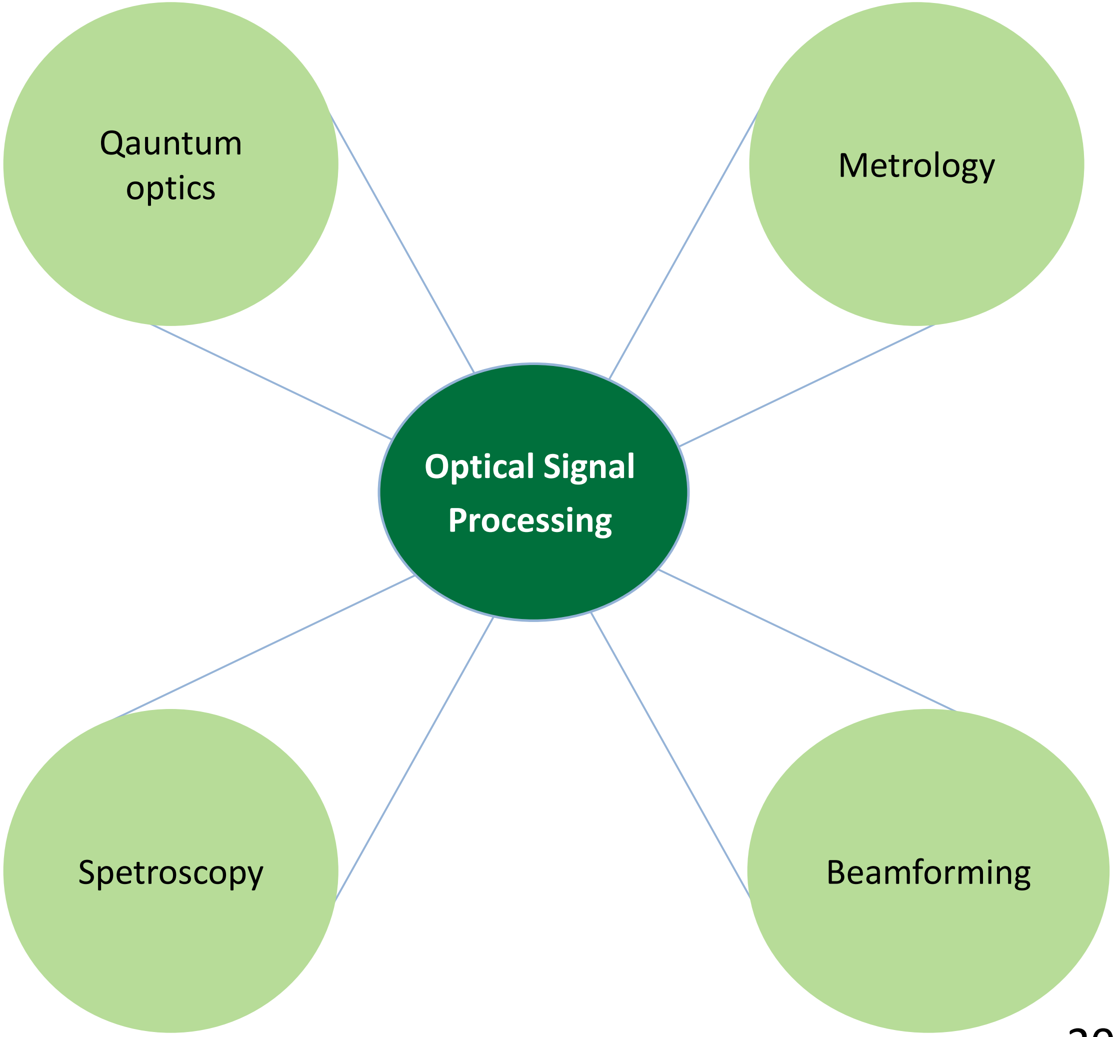
205

PICs have innumerous applications!



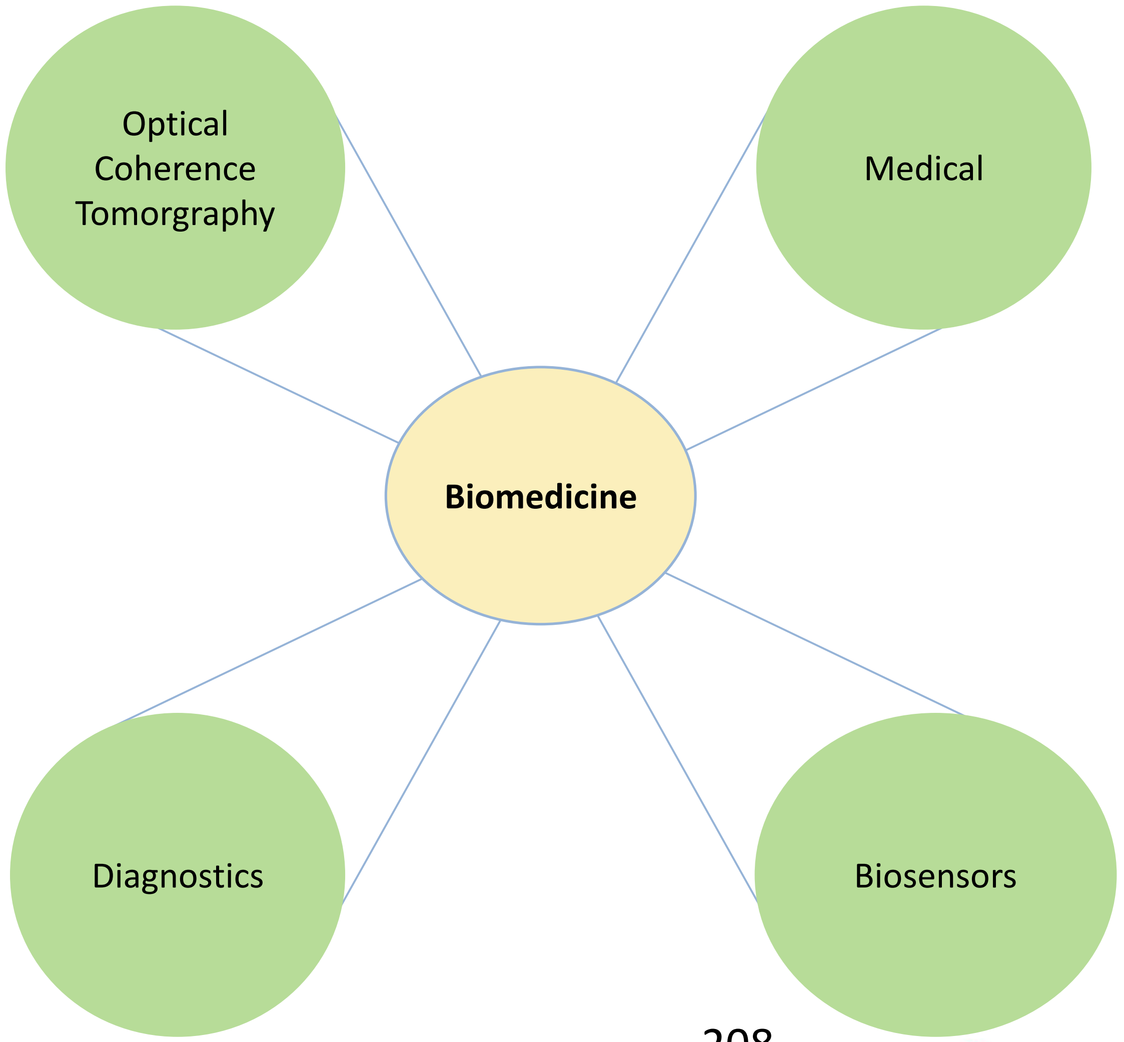
206

PICs have innumerous applications!



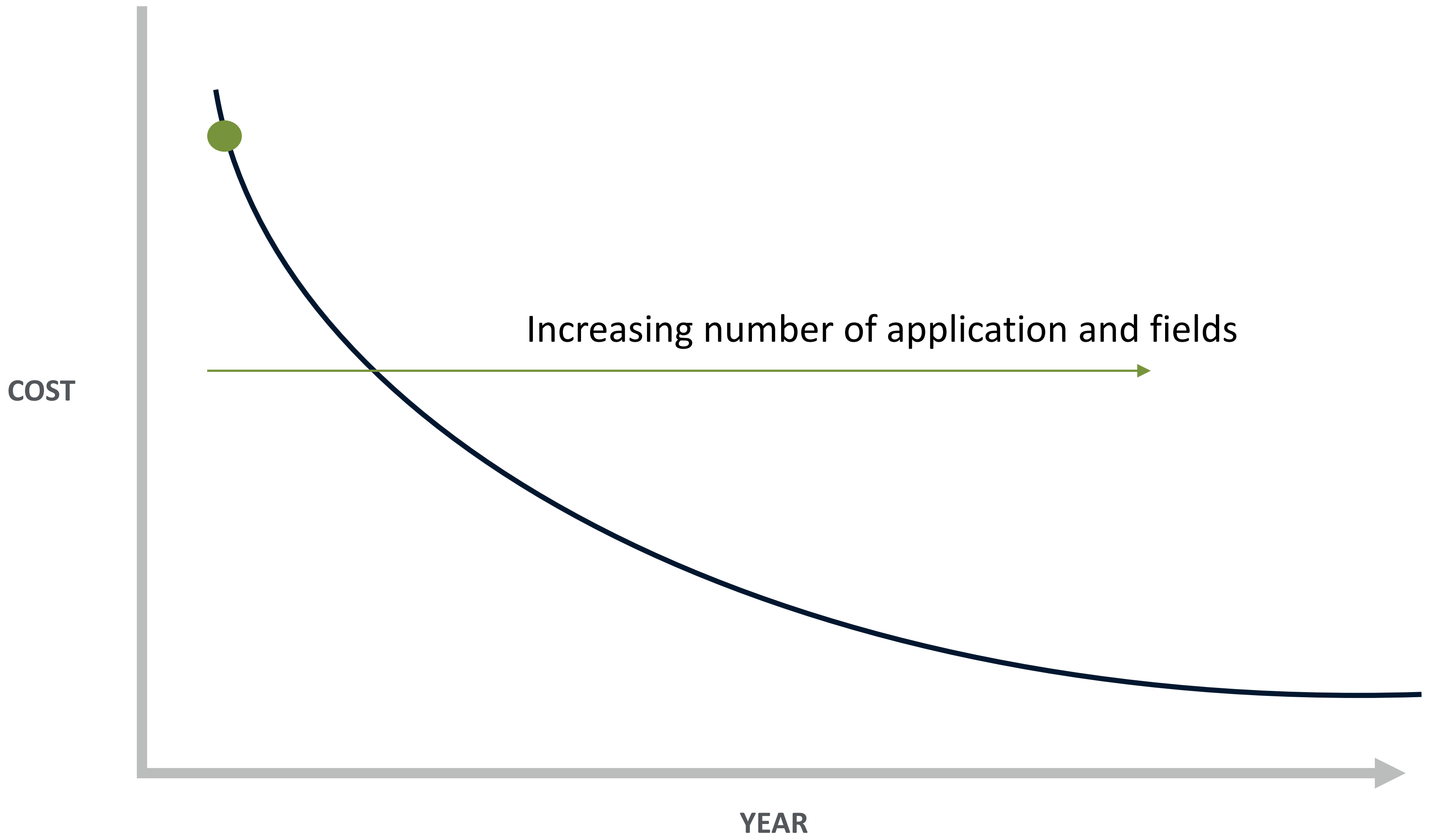
207

PICs have innumerous applications!

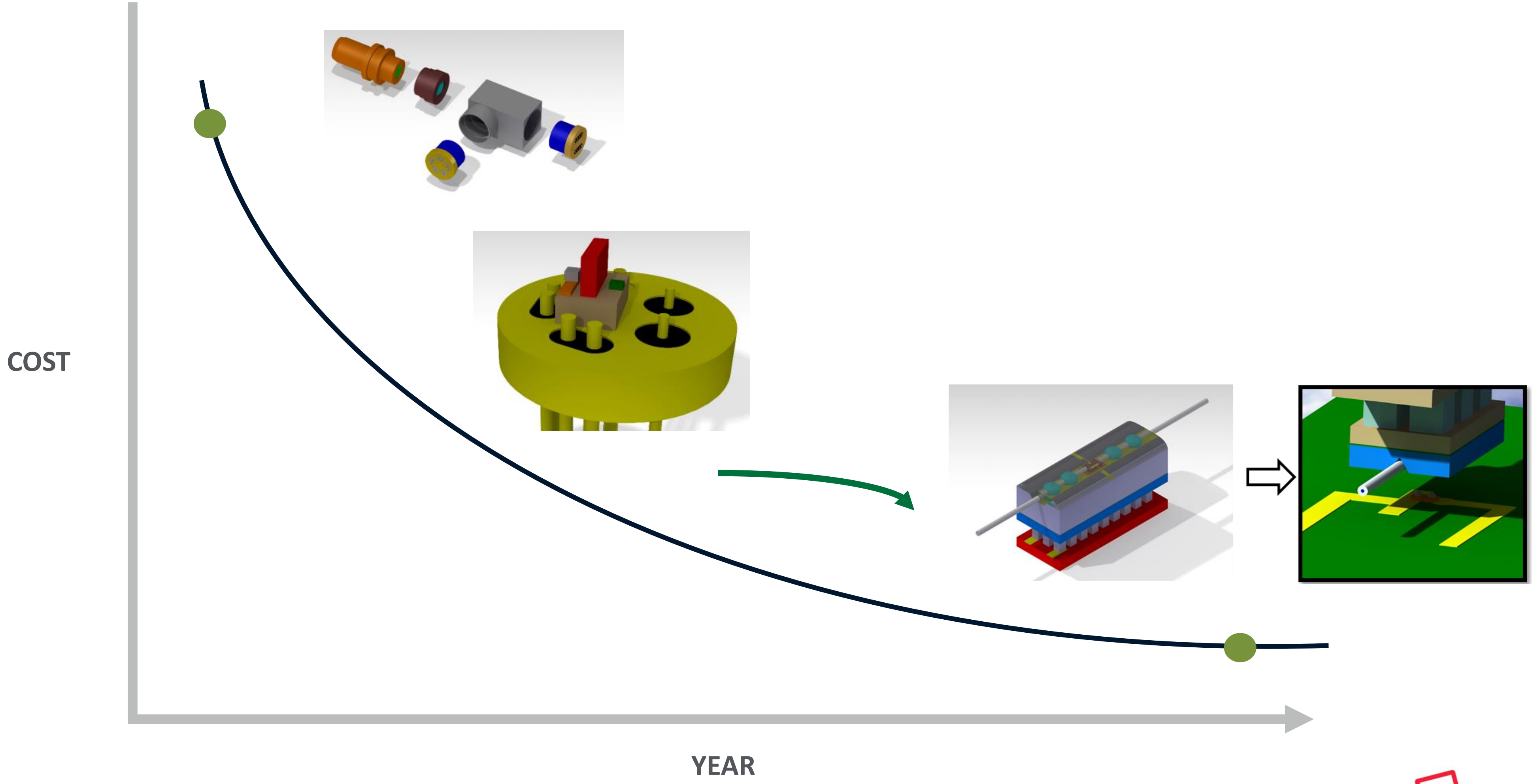


208

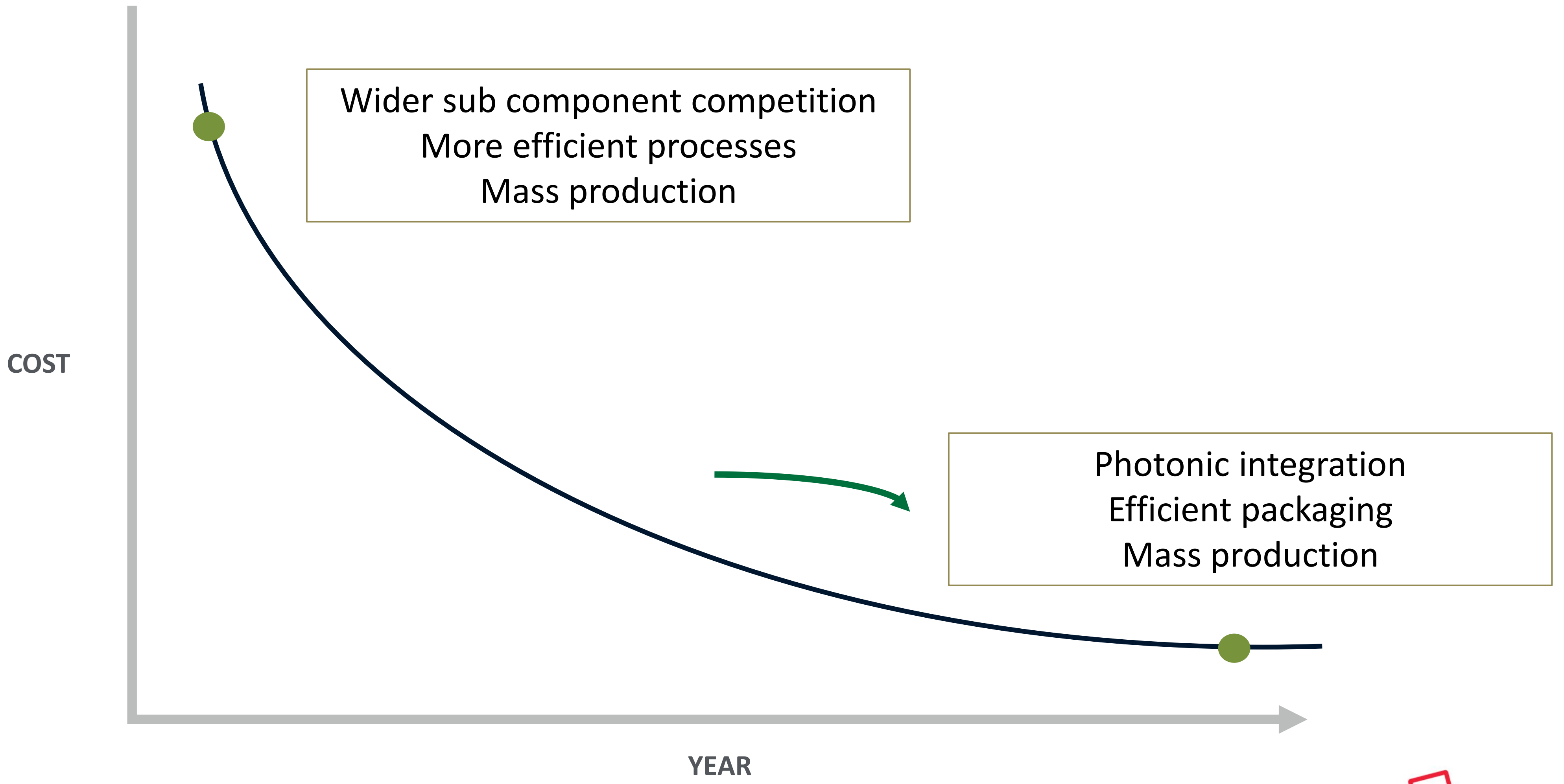
Trends due to diversity



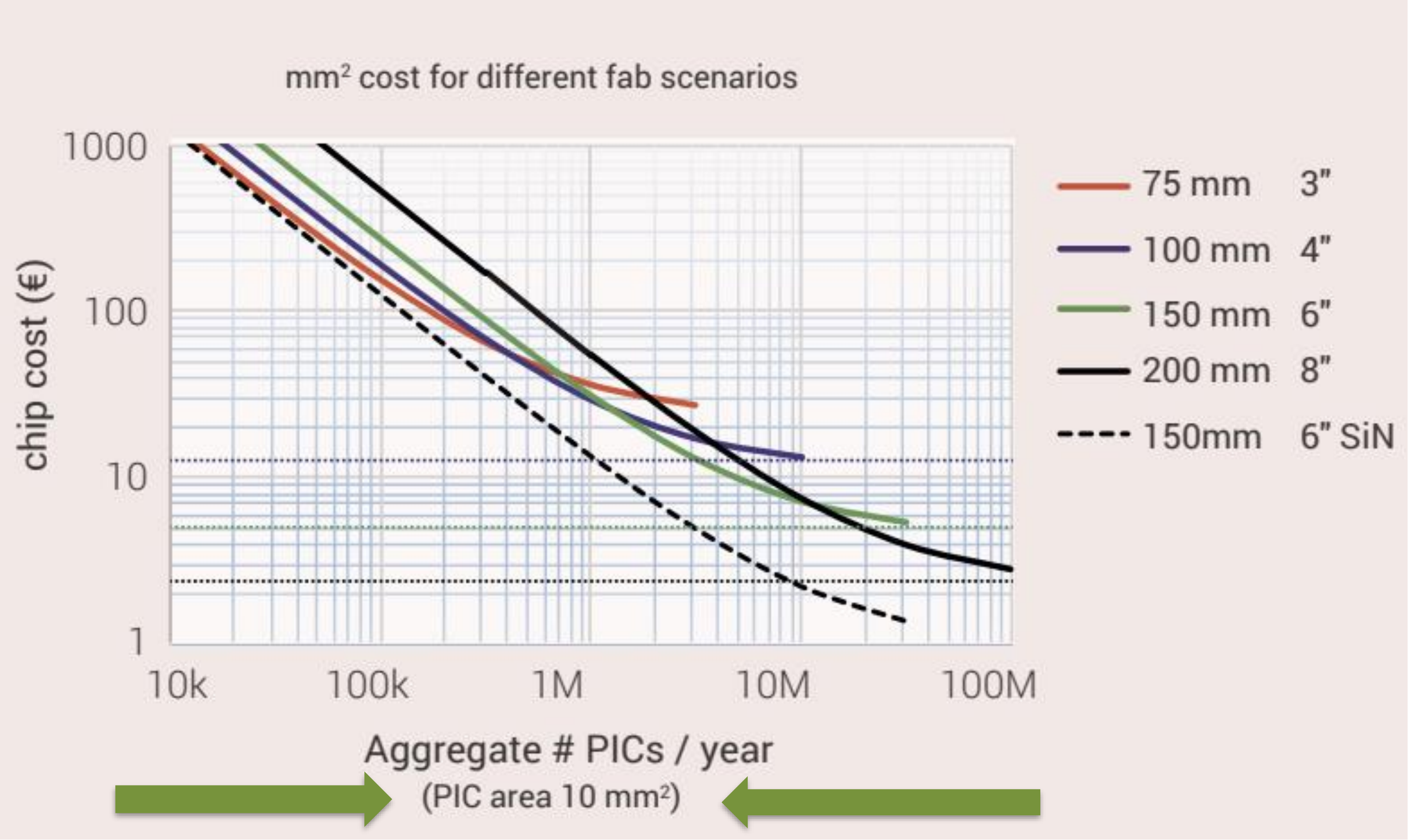
Roadmap for access optics



Roadmap for access optics



Which should be a PIC cost to be competitive?



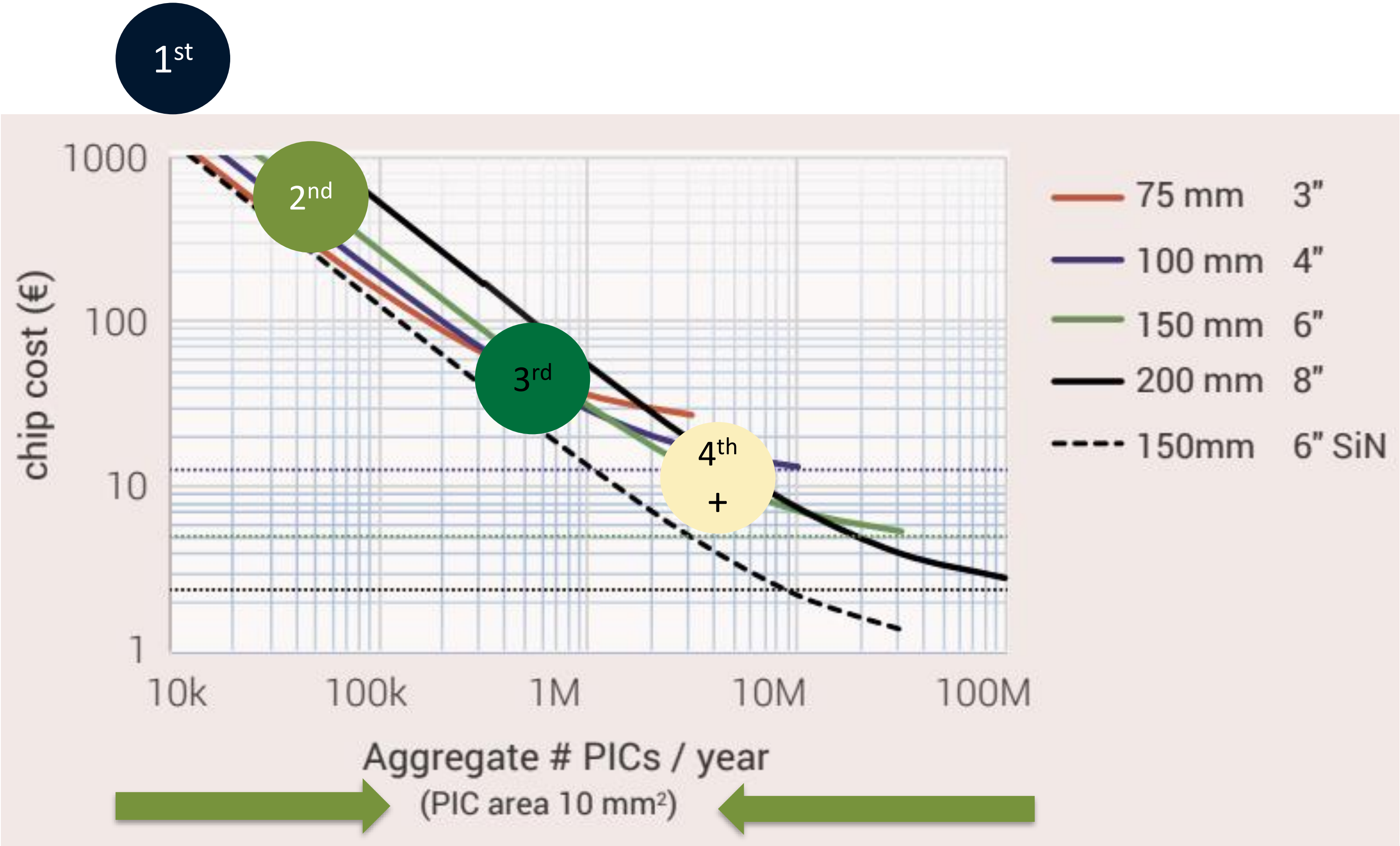
Some fabs are (InP):
- Increasing number of parallel wafers processed (3”)
- Moving to 4”

Some solutions are:
- Following monolithic (3-4”)
- Following hybrid (all)
- Following mixed (all)

Source: Roapmap JePPix 2018

Growing rate in access?

Chip cost for different fab scenarios



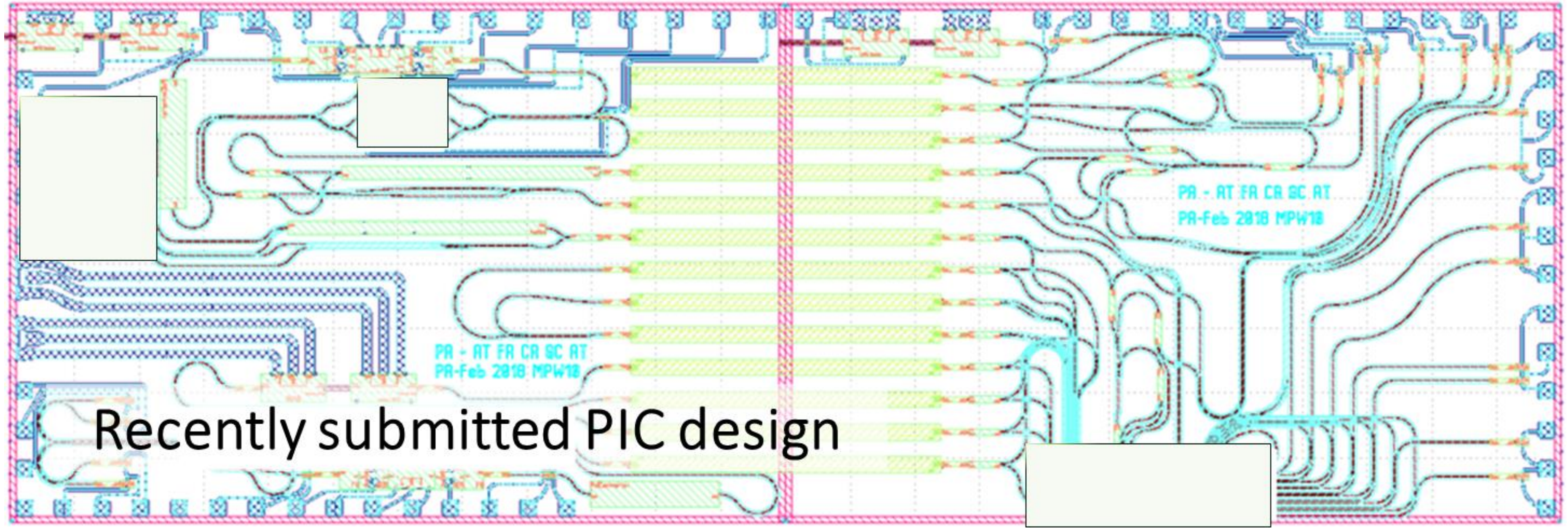
1st year 1-5k
2nd year 30-100k
3rd year 500k-1M
4th and upper 2+M

Or, reduce the area!!

Source: Roapmap JePPix 2018

PIC based transceivers

- Innovative approach brings coherent to PON through optic integration
- Proprietary BB that reduce complexity and floor space on the PIC increasing the potential of low cost integration
- Several iterations of the design already done through MPW runs – mature design



Recently submitted PIC design

PICadvanced

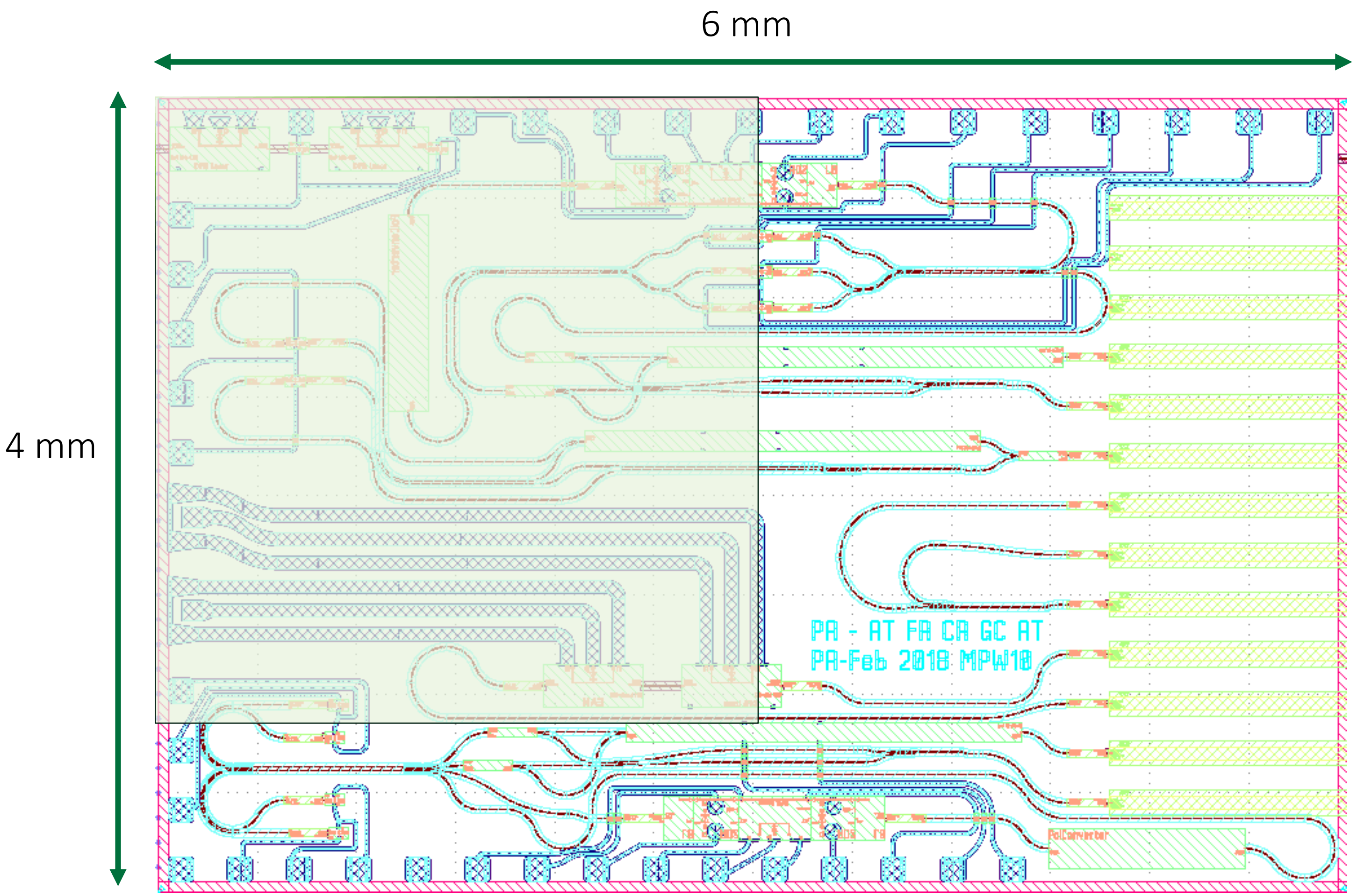
instituto de telecomunicações
universidade de aveiro

broadband forum

PIC based transceivers

Test chips
- ➢ 6x4 = 24mm²

Commercial grade chips
- ➢ <3 x <3 = < 9mm ²



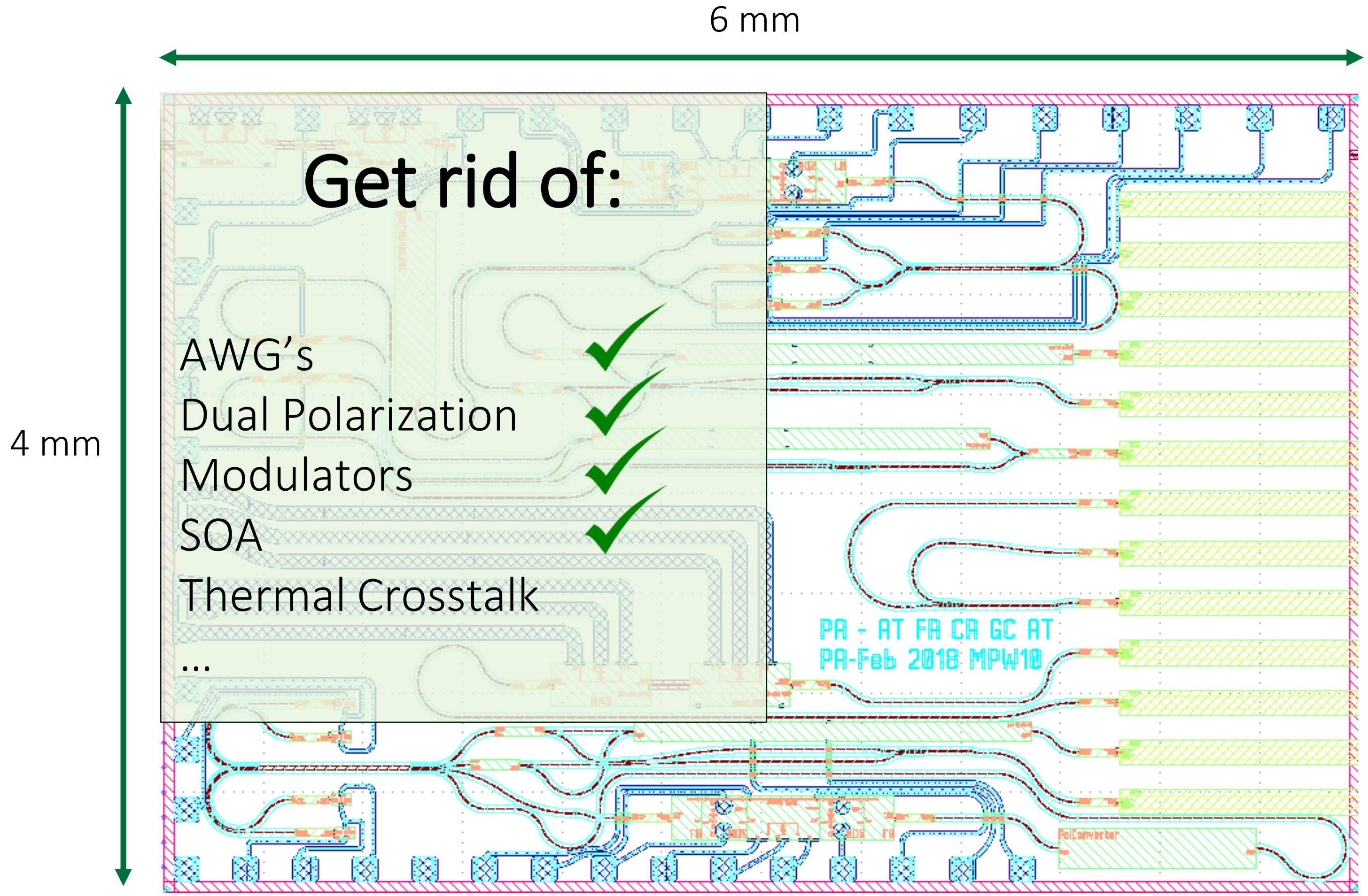
PIC based transceivers

Test chips

- ➢ 6x4 = 24mm²

Commercial grade chips

- ➢ <3 x <3 = < 9mm ²



Get rid of:

- AWG's ✔
- Dual Polarization ✔
- Modulators ✔
- SOA ✔
- Thermal Crosstalk
- …

Photonics Packaging

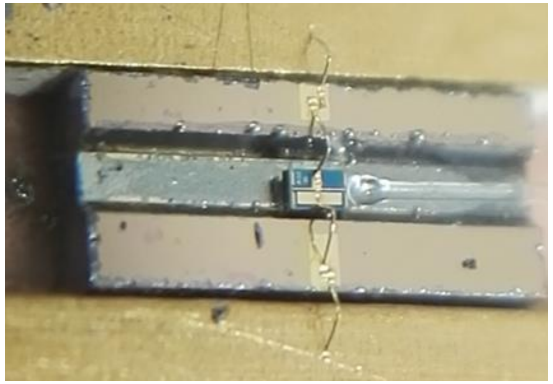
Packaging Design Rules (PDR)

Optical Packaging

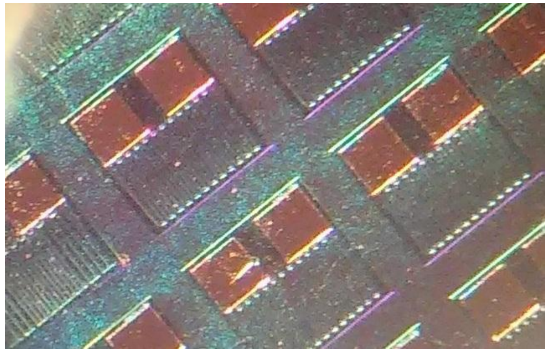
Electrical Packaging

Thermal Management

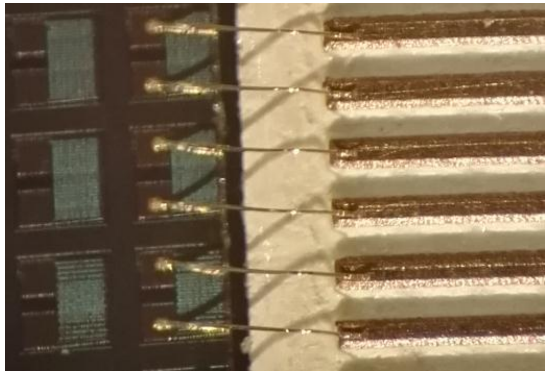
Present roadmap tech bets



Thermal management

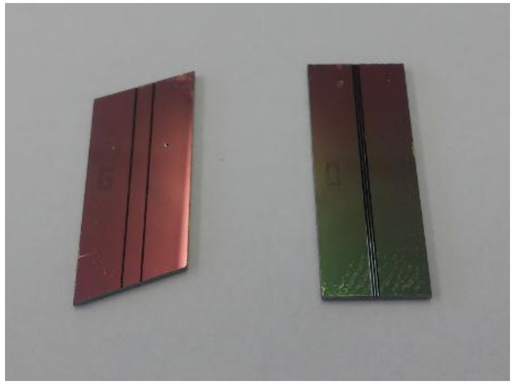


- Under prototyping tests are
  - Improved hosting processes
  - Higher efficiency local temperature monitoring
  - New materials for improved thermal efficiency
  - Passive alignements



Wire bonding, flip-chip

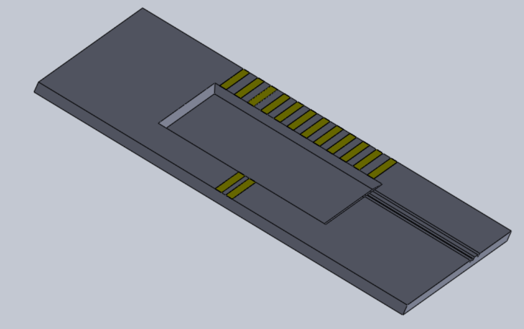
Optical alignment



Holders with V-grooves

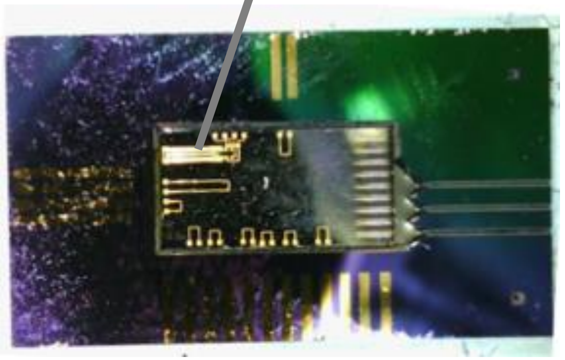
Si-holder with V-Grooves

Design
Solidworks 3D
CAD

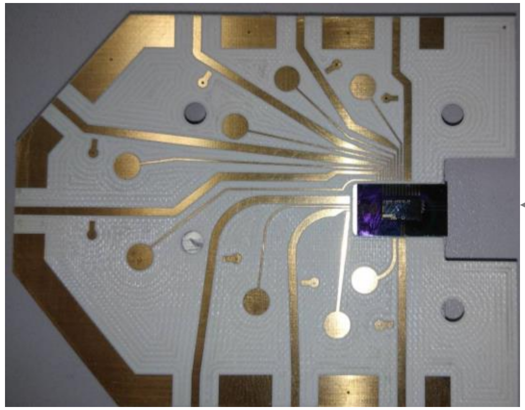


Production
Photolitography
and Etching

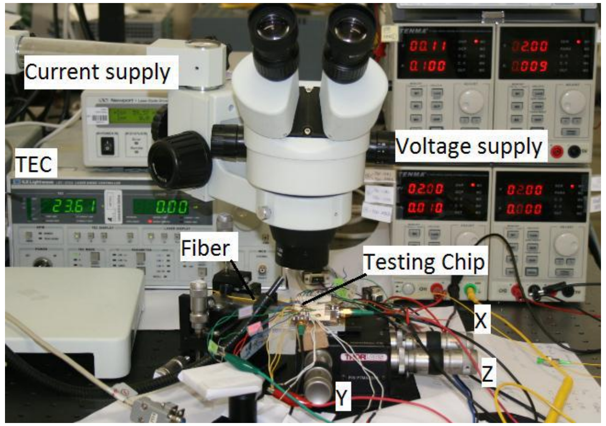
PIC glued with UV-epoxy



Packaging
Wire-bonding

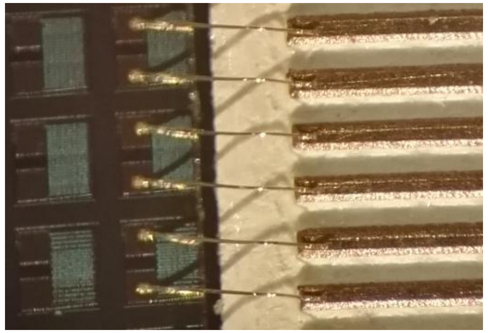


Testing



Electrical Packaging

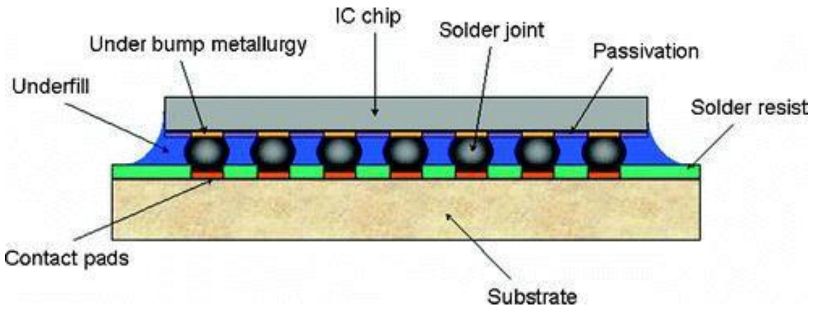
Present



Wire-Bonding

- Large existing infrastructure
- Programming flexibility
- Low cost

Moving to...

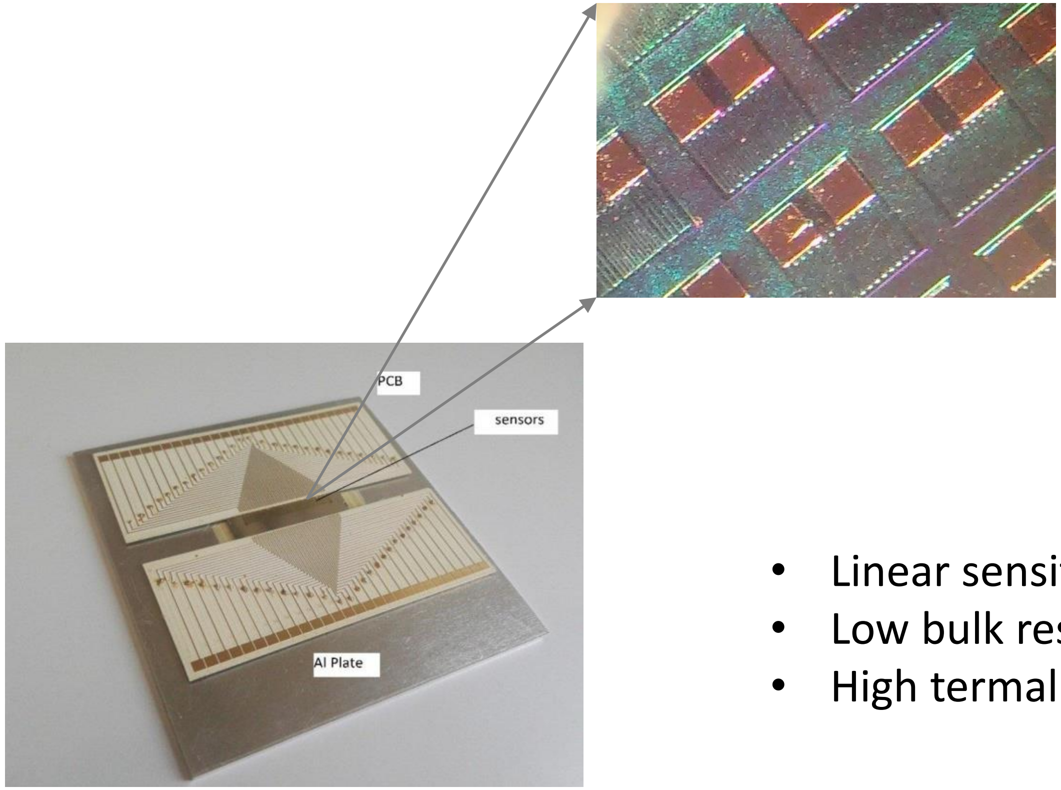


Flip-Chip

- Higher thermal and electrical performance
- Substrate flexibility
- Highest I/O capability
- Lower indutance

Thermal management

- Development of thermal sensors for Si-holder with PIC surface temperature control
- Sensors based on Titanium and Platinum
- Production at INESC-MN clean room facilities
- Integration with Si-holder



- Linear sensitivity drift
- Low bulk resistivity
- High termal stability

Power complexity main contributors

- SFP power limitations

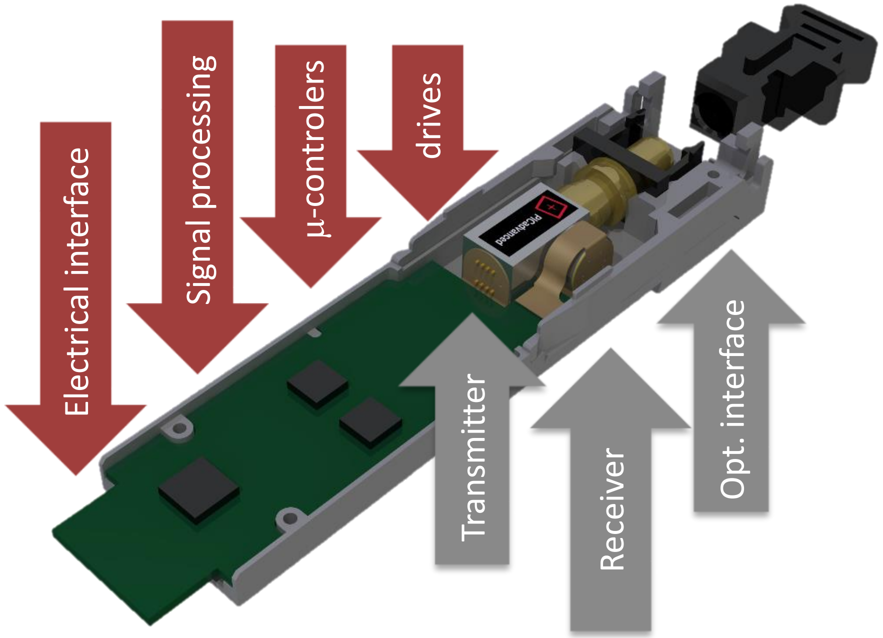
1.5W

- XFP power limitations

3.5W

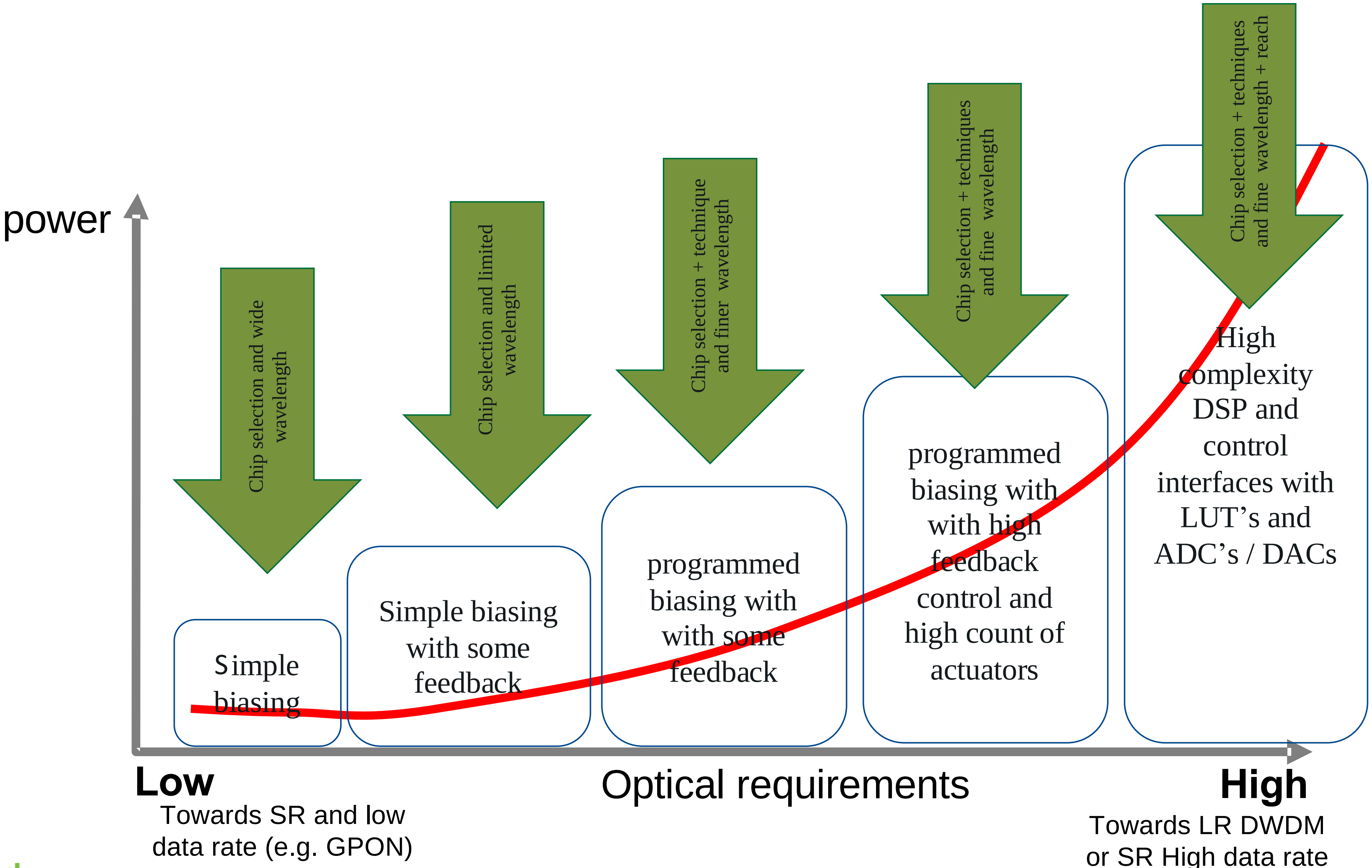
- Other form factors, e.g.

CFP 8..32W

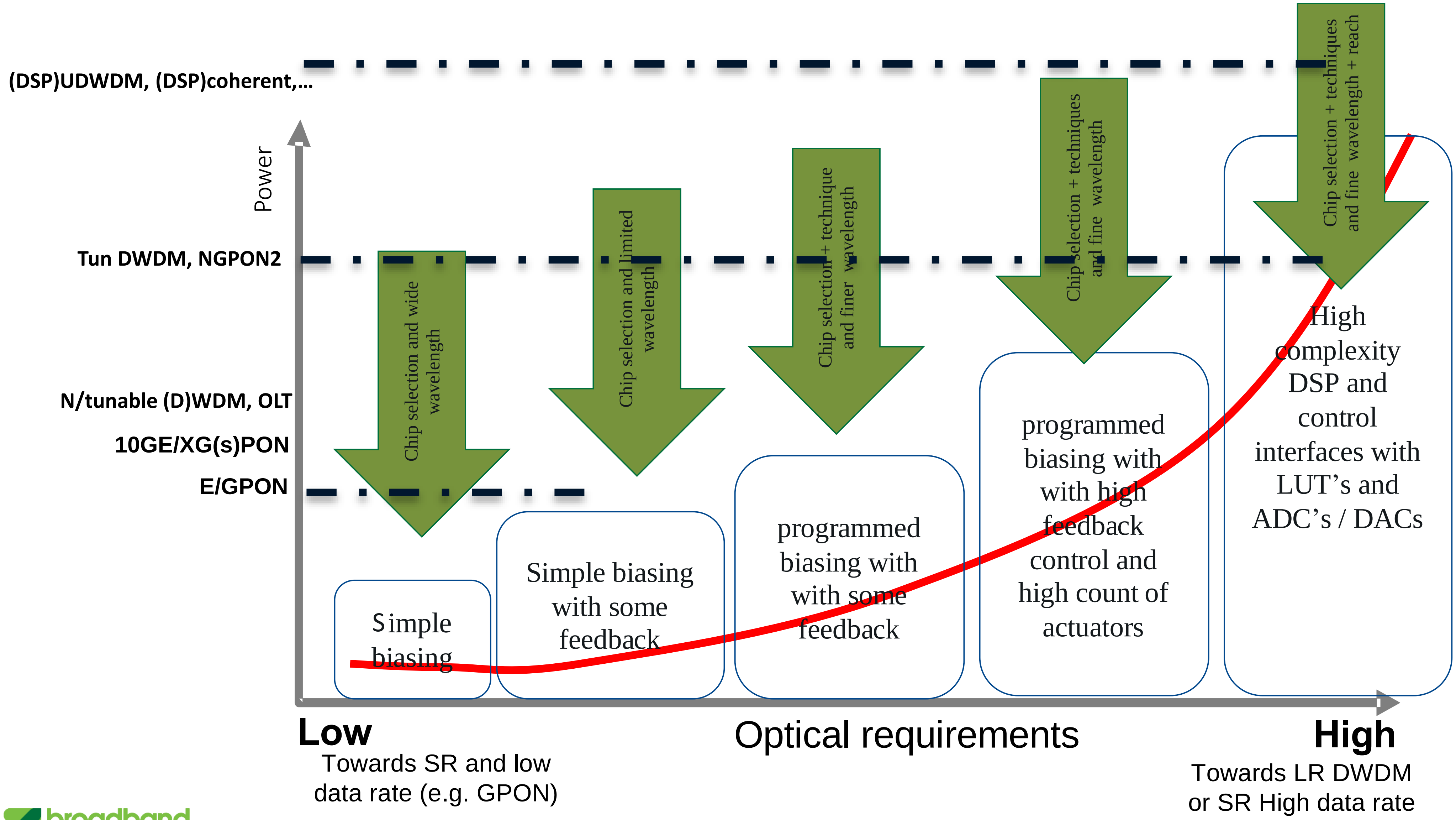


PICadvanced
instituto de telecomunicações
universidade de aveiro

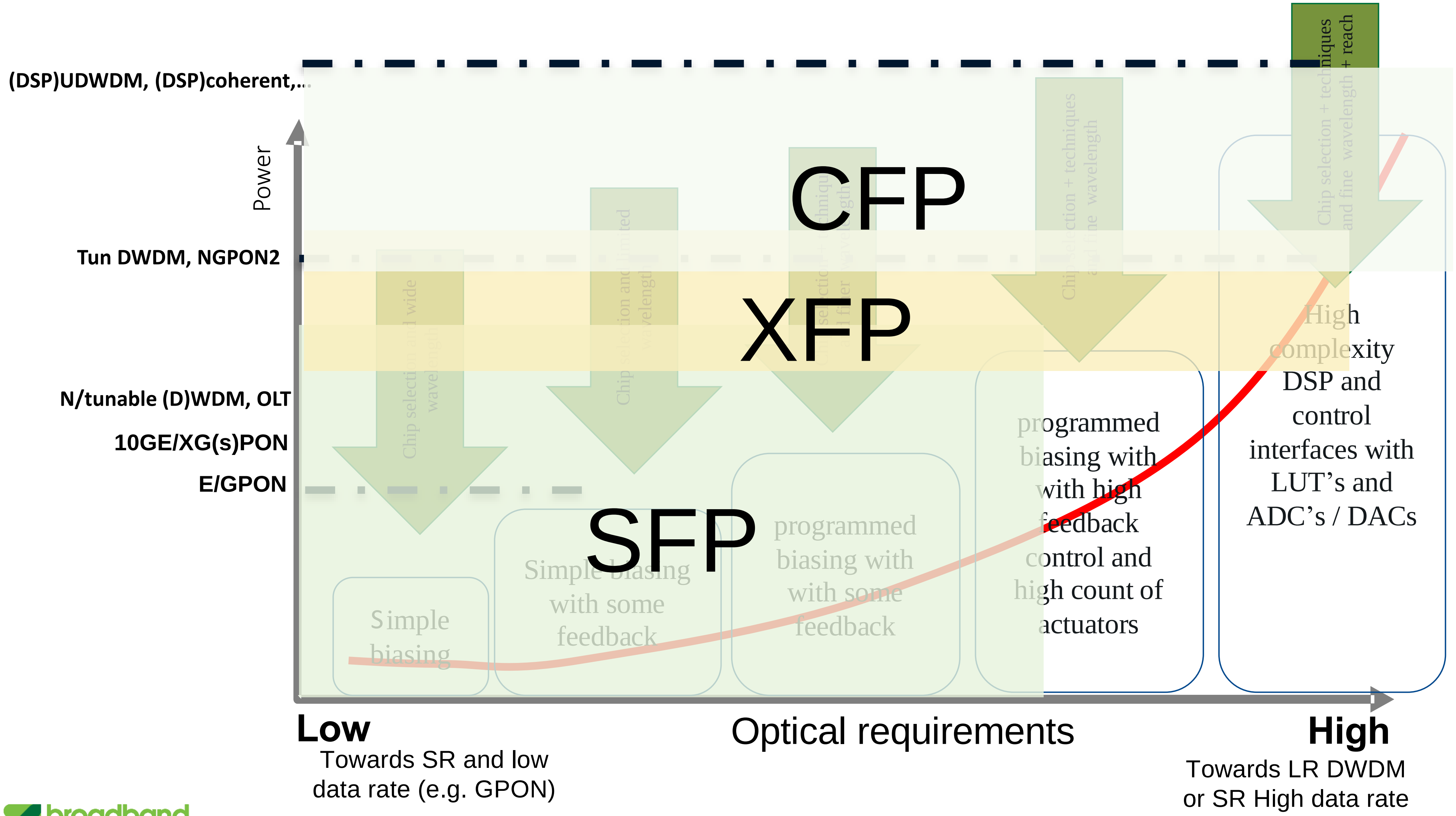
General trends



General trends

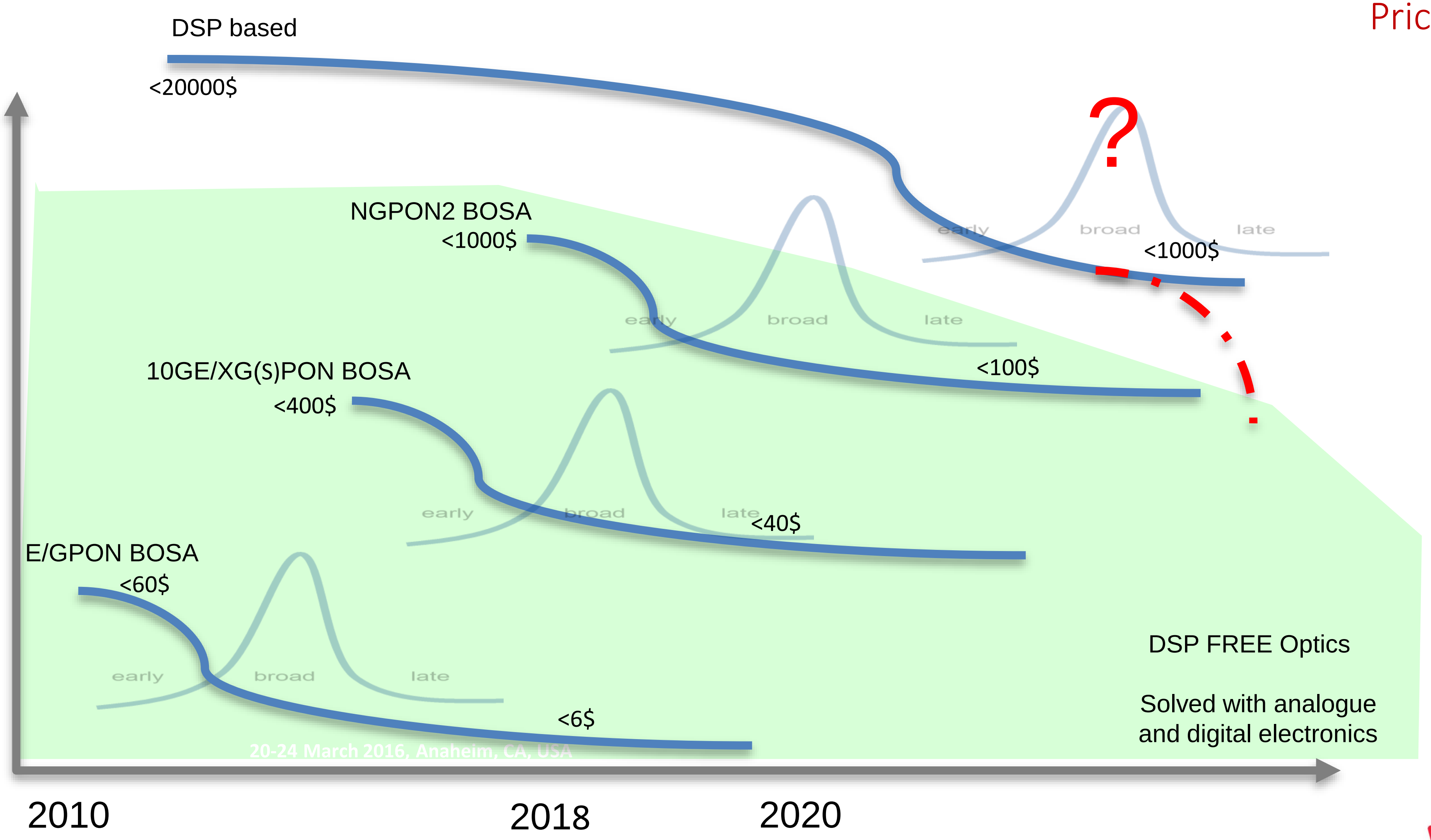


General trends

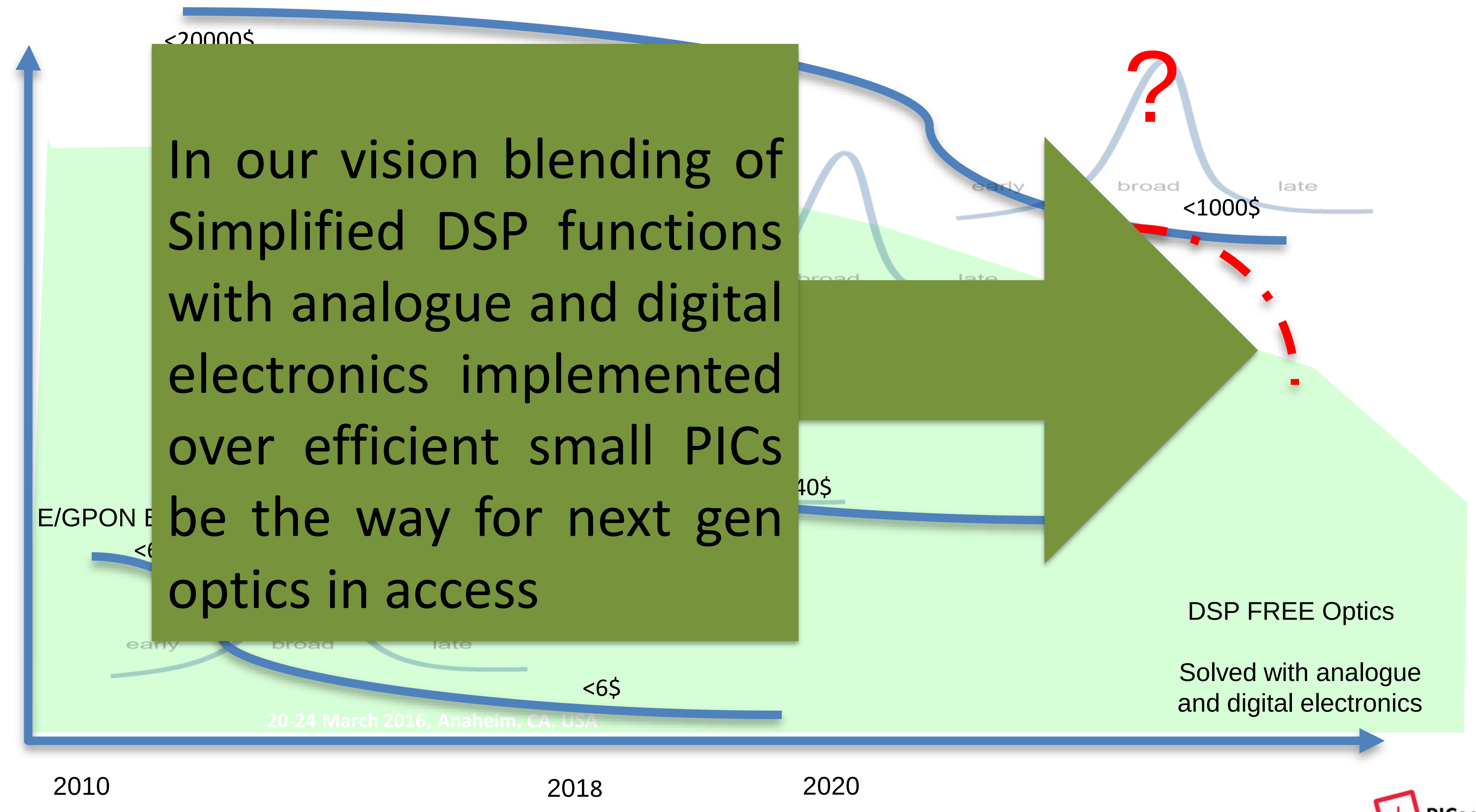


Price evolution and adoption for access

Prices are indicative



Price evolution and adoption for access



In our vision blending of Simplified DSP functions with analogue and digital electronics implemented over efficient small PICs be the way for next gen optics in access

Acknowledgements

Cofinanciado por:

UNIÃO EUROPEIA

Fundo Europeu
de Desenvolvimento Regional

Thank you!

António Teixeira

more at picadvanced.com

teixeira@picadvanced.com

This work was supported by Fundação para a Ciência e a Tecnologia (FCT) under the project “COMPRESS - All-optical data compression” – PTDC/EEI-TEL/7163/2014 and the QREN/COMPETE P2020 project “HeatIT” ref. 17942 and “Virtual Fiber Box”, H2020 “Terranova”, and PICadvanced for the financial support..

Cofinanciado por:

Segment 2
Panel Discussion & Audience Q&A

Moderator: **Julie Kunstler**
Principal Analyst, Ovum

30 MINUTE lunch (Brown bag working session)

12:45 - 1:15 **Making it all work - BBF Certification Programs & Interoperability**
Lincoln Lavoie, Senior Engineer, Broadband Technologies, Interoperability Laboratory at University of New Hampshire

THANK YOU TO OUR SPONSOR Calix

Making it all work

Lincoln Lavoie
BBF Technical Chair
Senior Engineer, Broadband Technologies
University of New Hampshire

broadband forum

BASe

Making it all work

BBF Certification Programs & Interoperability

Lincoln Lavoie
BBF Technical Chair

Senior Engineer, Broadband Technologies
University of New Hampshire
InterOperability Laboratory

What we're going to talk about

- Challenges, Testing, & Deploy-ability
- Leveraging Certification Programs
- Existing BBF Programs
- Going Forward – driving continuous interoperability and deployment

Starting At The End

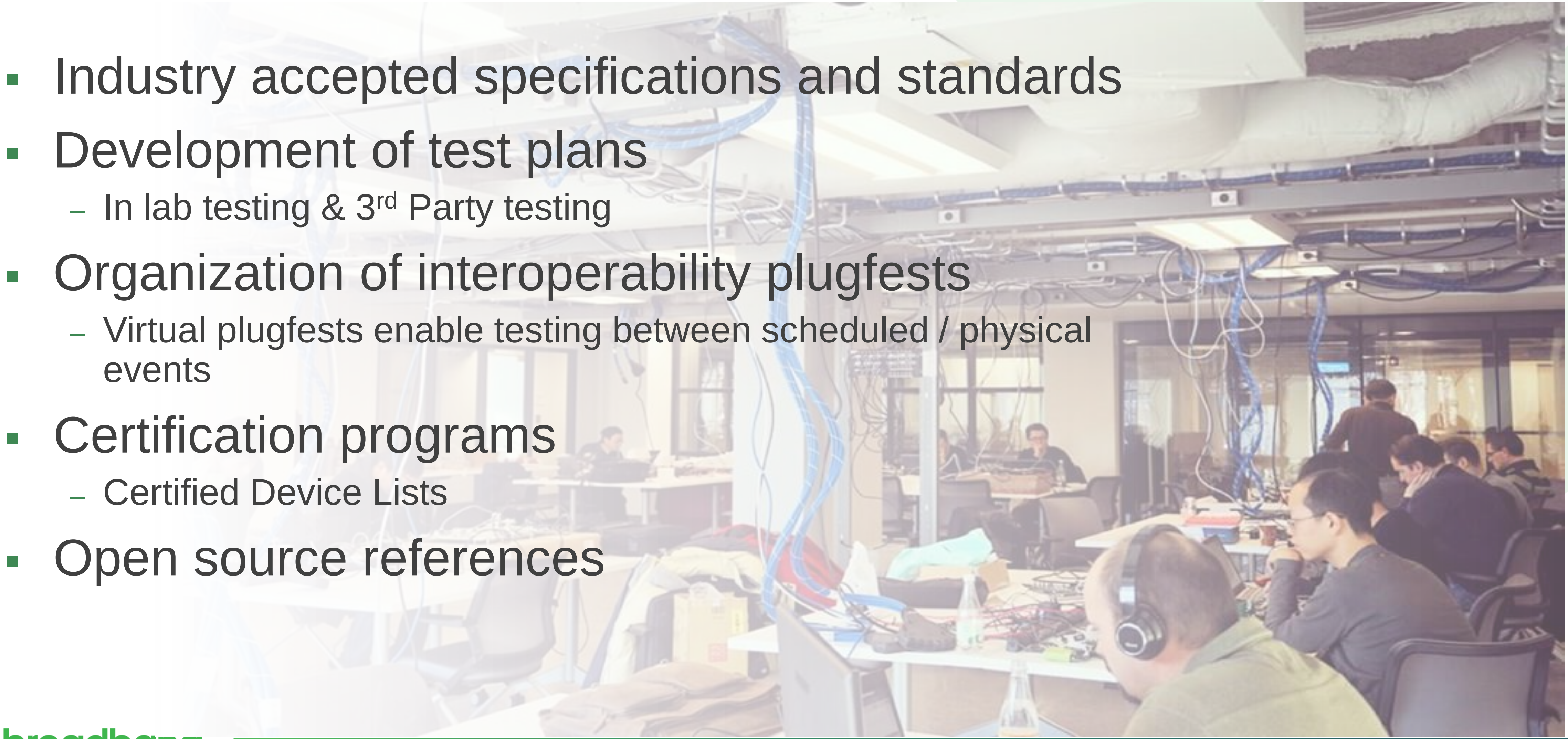
- What are the real goals of a deployment?
  - Stability & Performance?
  - Supply chain management?
  - Upgrade Paths?

- What are the road blocks to get there?
  - Vendor / Product Selections?
  - Book ended or specialty solutions?
  - Vendor lock-in?

What Do We Need?

- Specifications & Standards
  - Traditional Standards
  - Open Source References
- Interoperability
  - Multi-vendor Deployments
  - Future Proofing
- Testing
  - 3rd Party Results
  - Pre-deployment Testing
  - Regression Testing

BBF Role – Creating a language of interoperability



- Industry accepted specifications and standards
- Development of test plans
  - In lab testing & 3rd Party testing
- Organization of interoperability plugfests
  - Virtual plugfests enable testing between scheduled / physical events
- Certification programs
  - Certified Device Lists
- Open source references

Use Case:
Gfast Deployment Planning

Problem: A service provider is planning to deploy Gfast into MDU locations within their service area. This requires selection of equipment meeting the afore mentioned deployment needs.

Solution: Selection of equipment from certified devices lists (https://bbf-gfast-cert.iol.unh.edu/) or reference to certification in solicitation to vendors ensures products meet baseline requirements.

Key features: Reduced lead time in SP lab trials; interoperable devices expand selection sizes; prevents future lock-in to proprietary solution.

Gfast Certification Program

BBF Testing & Certification Programs

DSL Performance & Functionality Test Plans (ADSL, ADSL2/2plus, VDSL2)

BBF.069
Managing the Connected Home

TR-069 Certification Program launched in 2012

2002 | 2004 | 2006 | 2008 | 2010 | 2012 | 2014 | 2016 | 2018 | 2020

GPON ONU Certification Program launched in 2011, with 50+ devices certified! Continued evolution for PON speeds and device types.

BBF.247
G-PON CERTIFICATION

Gfast Certification Program launched in 2017, with 40+ device pairings certified. Development for 212 MHz certification is underway!

G.fast™ CERTIFIED

- Interoperability, Functionality, Performance, & Stability Testing
  - Correct implementation of critical features (SRA, FRA, TIGA, Re-Tx)
  - Performance (throughput vs. loop length, vectoring performance)
  - Stability (noise immunity, mean-time-between-failures)
  - Deployment & Control (spectrum control, bandwidth allocation)
- Device pairs certified (DPU & CPE)
  - Cross chipset interoperability
  - 40+ pairings currently certified (and growing) – 106 MHz

Next Gen Gfast & Certification

- Currently implementing updates for 212 MHz profiles and new features
  - Increased performance requirements (higher throughput)
  - New features (test parameters, increase bit-loading)
- Expecting first 212 MHz certified device pairs in early 2019

- Future improvements will include:
  - DTA (dynamic bandwidth splitting)
  - Additional profiles (106b – increased power / range)
  - Robust Management Channel Recovery (RMCR)
  - Software Management (downloads to NT)

BBF.247
G-PON CERTIFICATION

- Certification for ONU devices
  - GPON, NGPON2
- Test coverage
  - VLAN Manipulation (1:1, N:1, VBES)
  - QoS and Policy Enforcement
  - Multicast (IGMP)
  - Firmware Management
  - Alarm Reporting
- Enforces strong OMCI processing rules, ensuring robust ONU implementation of the protocol

ADTRAN, altice labs, arcadyan, ASKEY, Calix, CIG, DZS, ECONET, FiberHome, HUAWEI, intel, NOKIA, Sagemcom, SERCOMM, soft at home, technicolor, ZTE

Next Gen PON Certification (IR-247i4)

- Updates based on TR-280 requirements (multi-service broadband network architectures)
  - Expanded VLAN and enhanced multicast requirements
  - Additional QoE Tests
  - Alarm threshold reporting
  - Remote debugging
- Extended coverage to new device types (i.e. PON fed DPU)
- Support for newest PON technologies (i.e. XGS-PON)
- Expected to launch in January 2019

- Certification of TR-069 CPE devices
- Full Protocol Coverage
  - All mandatory RPCs
  - Events and Notification Reporting
  - Security (TLS sessions)
  - Optional Features: DHCP Options, XMPP, Factory Reset, Scheduled Informs, Notification Throttling
- Additional Testing
  - Data Model Compliance (Device:2 a.k.a. TR-181)

BBF.069
Managing the Connected Home

Actiontec ARRIS BROADCOM Calix CISCO D-Link
GREENWAVE SYSTEMS HUAWEI intel SERCOMM ZTE

Going Forward: Interop and Compliance

USP Certification is on the horizon. Test plan is nearly complete, with program launch expected in first half of 2018.

Gfast Certification for 212 MHz devices is imminent, with future expansion planned for additional features.

GPON ONU Certification is continuing to expand coverage, based on TR-280 requirements, as well as extending coverage to new PON technologies.

broadband forum

Certification Resources

- Gfast:
  - Certified Device List: https://bbf-gfast-cert.iol.unh.edu/
  - Certification Test Lab: UNH-IOL (https://www.iol.unh.edu/)
  - Program Guidelines: https://www.broadband-forum.org/private/download/OD-362_G.fast_Program_Guidelines.Issue.01.pdf
  - Test Plan: https://wiki.broadband-forum.org/download/attachments/54886565/IR-337_Corrigendum-1.pdf
- GPON
  - Certified Device List: https://www.broadband-forum.org/implementation/certified-products/bbf-247-g-pon-products
  - Certification Test Lab: LAN Park (https://www.lanpark.eu/)
  - Test Plan: https://www.broadband-forum.org/private/download/IR-247_Issue-3.pdf
- TR-069
  - Certified Device List: https://www.broadband-forum.org/tr-069-cert
  - Certification Test Lab: UNH-IOL (https://www.iol.unh.edu/)
  - Test Plan: https://www.broadband-forum.org/private/download/IR-069_Issue-2_Corrigendum-1.pdf

University of New Hampshire InterOperability Laboratory

Your digital lab

Thank you

Learn more about the Broadband Forum at:
http://www.broadband-forum.org/

broadband forum

Segment 3
Fiber Extension Technologies, Standards and Solutions

Moderator: **Alison Diana**
Editor, Light Reading

Agenda Segment 3

	Fiber Extension Technologies, Standards and Solutions
1:15 - 1:35	**Gfast Comes of Age In 2018**
	Mileend Gadkari, VP Business Development Americas, Sckipio
1:35 - 1:55	**Fibre Access Extension - Reusing In-Building Coaxial Cabling for Multi-Gigabit Performance**
	Helge Tiainen, Senior Director Business Development, InCoax
1:55 - 2:15	**Automated Deployment of Cloud-based Access Infrastructure & Services**
	Tim Carey, Lead Technology Strategist, Nokia
2:15 - 2:35	**G.hn Fiber Extenders as an Alternative to Multiport DPU's.**
	Paul Arola, Senior Design Specialist, Telus
2:35 - 2:55	**Intelligent Broadband Access & Home Maintenance**
	Wei Lin, System Architect, Huawei Technologies
2:55 - 3:10	**Segment 3 Panel Discussion and Audience Q&A**
	Moderated by Alison Diana, Editor, Light Reading
3:10 - 3:25	Break

Gfast Comes of Age in 2018

Mileend Gadkari

VP Business Development Americas | Sckipio

mileend@sckipio.com

broadband forum

BASe

BBF Base USA 2018 Presentation

Mileend Gadkari

VP Business Development

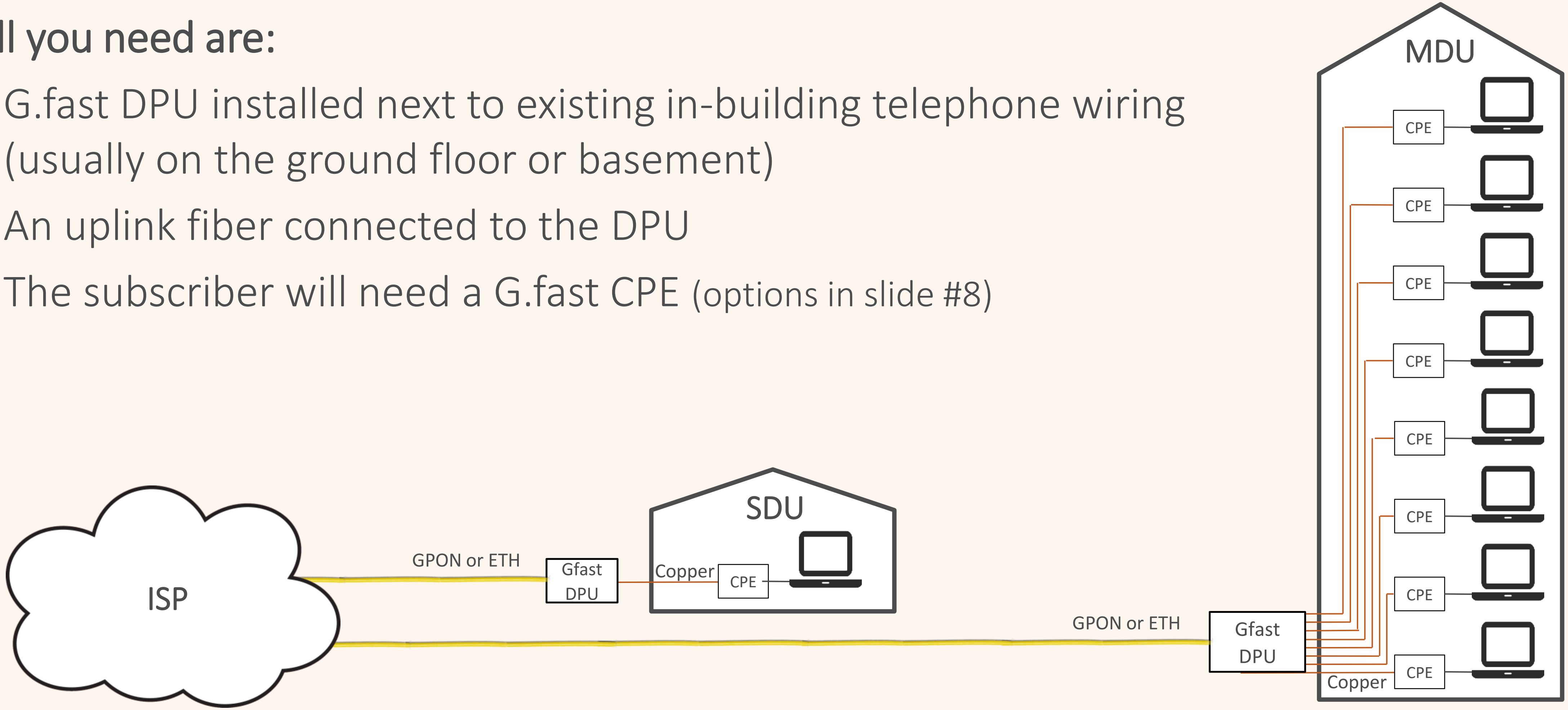
Where is Gfast today?

- Being deployed or in field trials around the world
  - AT&T in the US, BT in the UK, SKBB in Korea, NBN in Australia
- Second Generation Gfast solutions are now available
  - Significant advantages over gen 1

Deployment Model

All you need are:

- G.fast DPU installed next to existing in-building telephone wiring (usually on the ground floor or basement)
- An uplink fiber connected to the DPU
- The subscriber will need a G.fast CPE (options in slide #8)



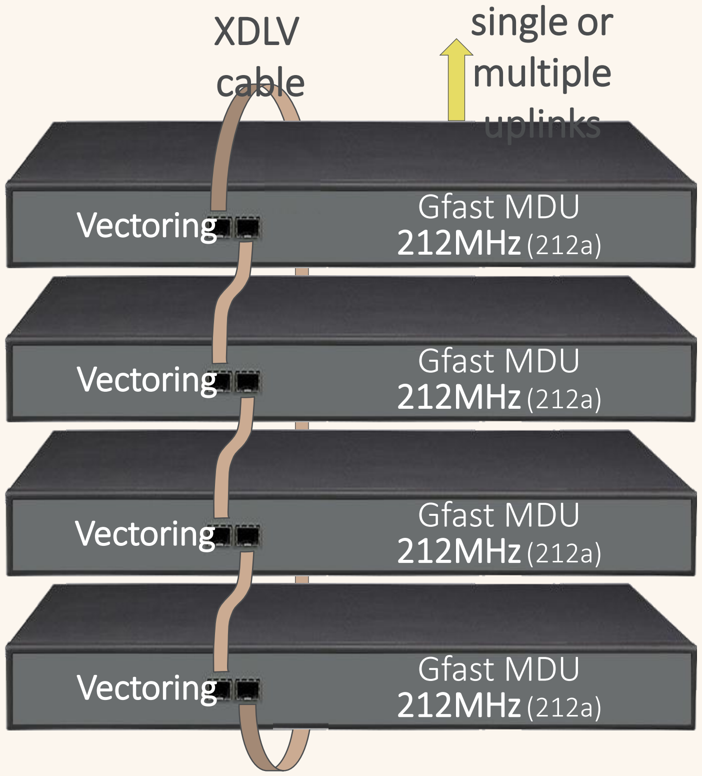
Issues to overcome

- Cross talk between copper pairs in binders reduces the overall performance capacity
  - Requires vectoring or the ability to cancel the cross talk between copper pairs

- Currently deployed (gen 1) solutions are 16/24 port. 1/4/8 port DPUs are preferred
  - Smaller port DPUs need the capability to be stacked with cross DPU vectoring

Gen 2 solutions save the day!!

- Stackable DPUs that allow cross DPU vectoring
  - Allows smaller DPUs (1, port, 4 port, 8 port) designs
  - Supports the add as you grow model without the upfront cost of larger DPUs
- Supports single pair, Gbs rates
- Bonding allows multi-Gbs rates
- Reverse power feed
  - No need to provision power to the DPUs

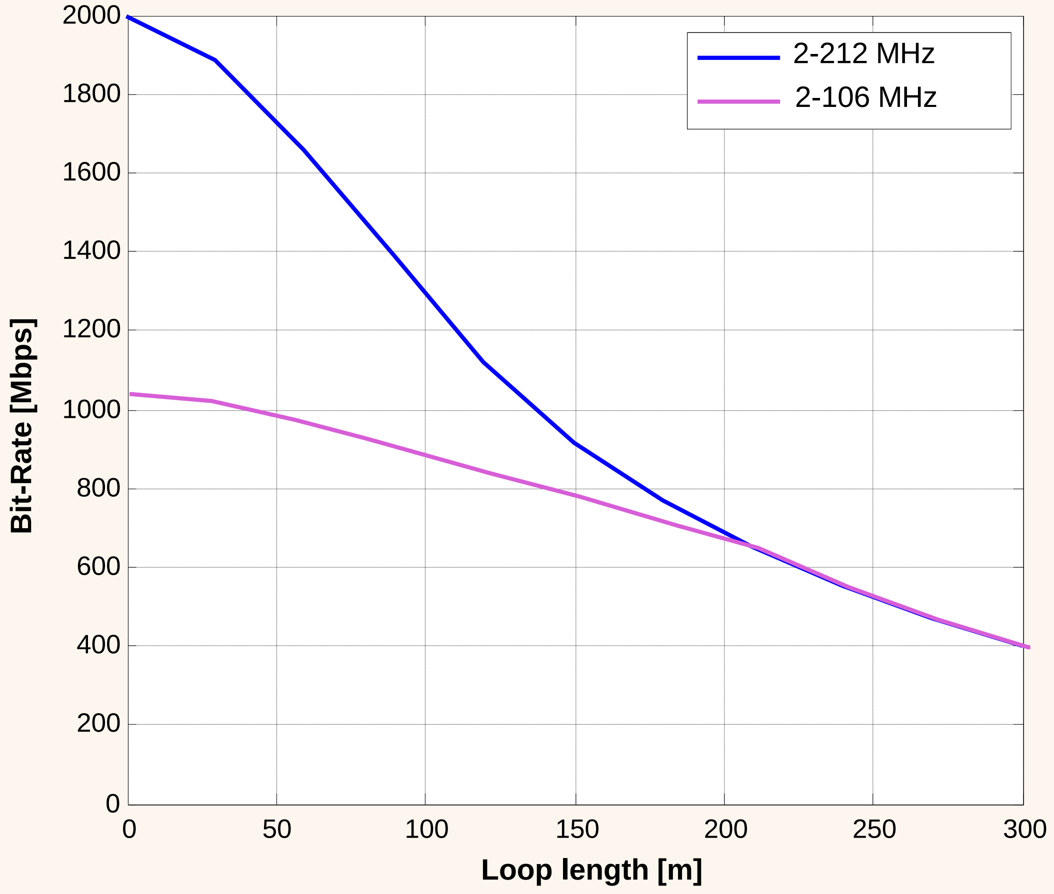


Gfast can now offer the best fiber extender solutions

Gen 2 performance – single pair

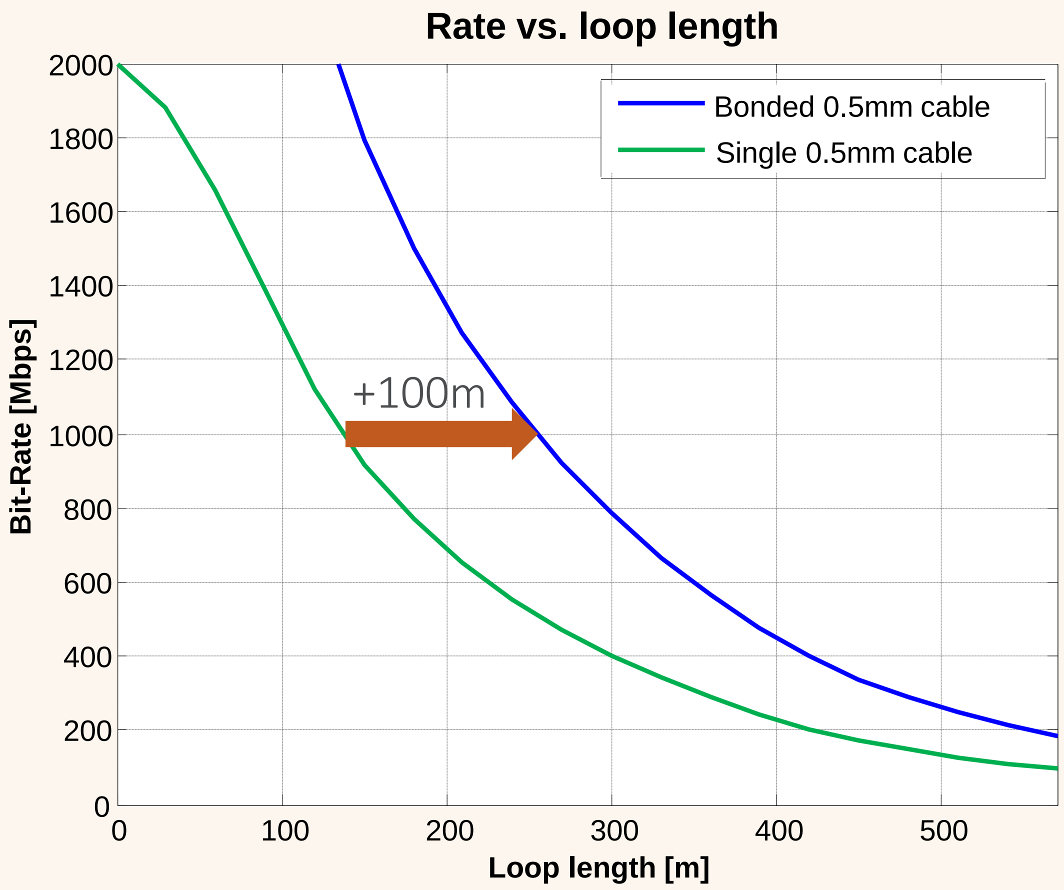
- 1.2 Gbs aggregate at 100m
- cDTA can provide 1Gbs up/1Gbs down
  - **cDTA mechanism alters US/DS ratio on a binder to provide bandwidth where it is required**

106a vs 212a Rate/Reach @0.5mm



Bonding Extends Coverage

- 2-pairs bonding is a great way to extend Gfast coverage area
- Bonding adds 100m @1.0Gbps so coverage area exceeds 200m (over standard 0.5mm cables)



Summary

- Smaller port count Gen1 fiber extenders (1/4/8) sufferer from cross talk issues in a multi pair binder scenario.
  - No ability to vector between multiple fiber extenders
  - Gbs performance not possible
- Gen 2 addresses this
  - cDTA can offer the symmetrical Gbs speeds
  - Supports both small and large port count fiber extender solutions
    - Stackable with cross fiber extender vectoring
    - Less upfront cost, add as you grow
  - Bonding can extend the 1Gbs coverage area

GFast really offers many advantages as a fiber extender technology

Fibre Access Extension – Reusing In-Building Coaxial Cabling for Multi-Gigabit Performance

Helge Tiainen

Senior Director Business Development | InCoax

helge@incoax.com

Fibre Access Extension – Reusing The In-Building Coaxial Cabling for Multi-Gigabit Performance

Helge Tiainen, Business Development, InCoax Networks
Chair, MoCA Access Work Group

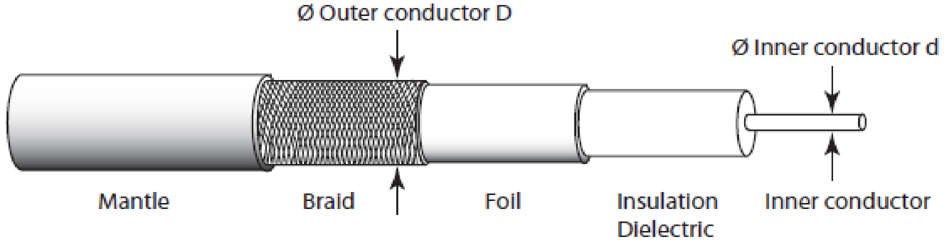
BASe Las Vegas - October 28th 2018

Challenges In MDU GPON Deployments

Potential Barrier	Potential Delay	Cause
New cabling	Several months	Approval from all condo owners
Cable construction work in apartments	Several months	Condo owner don't see any benefit of new wiring
Apartment installation	Several weeks	Key handling and access to apartments
Reluctant to convert to fibre services	Length of existing subscription contracts	Understand the benefits with fiber based services
In-building wiring cost (paid by building owner)	Depending of annual condo meeting	Need to be approved by a majority

Reduce Deployment Barriers → **Use existing infrastructure**

Existing MDU Infrastructure – Coax or Copper



Cable Attribute	Coax Cable Network	Twisted Pair Network
Age of in-building wires	☺	☹
Cable availability at entry point	☺	☺
Cabling reach home location of TV-set	☺	☹
Low cable attenuation @ high frequency	☺	☹
Support for multi-gigabit	☺	☹
Roadmap for 10 gigabit	☺	☹

Coax Access Technologies

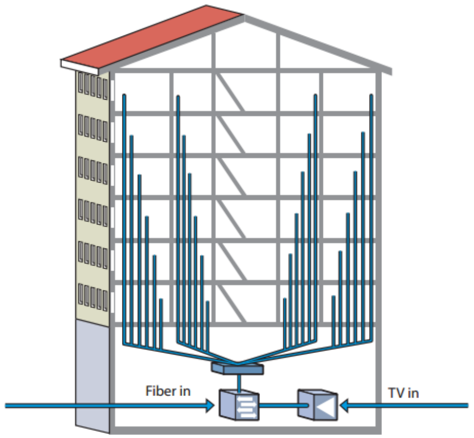
Technology	☺	☹
G.fast over coax (106 MHz profile)	DL 900 Mbps / UL 100 Mbps	Supports only point-to-point topologies
G.fast over coax (212 MHz profile)	DL 1800 Mbps / UL 100 Mbps	Supports only point-to-point topologies
G.hn (200 MHz profile)	DL 1200 Mbps / UL 200 Mbps	Supports only 15 modems in point-to-multipoint
MoCA Access 2.5	DL 2500 Mbps / UL 2000 Mbps	Not a baseband technology

Best technology match to GPON fibre access extension

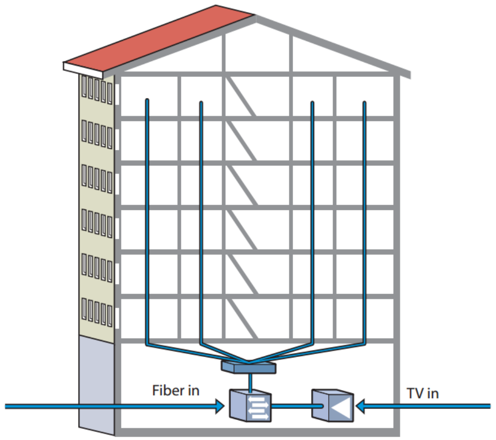
MoCA Access 2.5

Coax Network Topologies

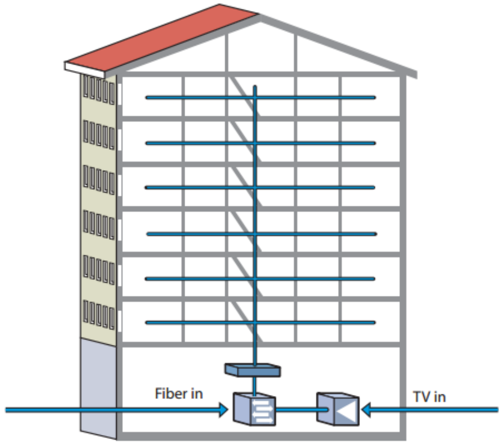
- Star, cascade, tap and tap/splitter
- Point-to-point and point-to-multipoint



Star



Cascade



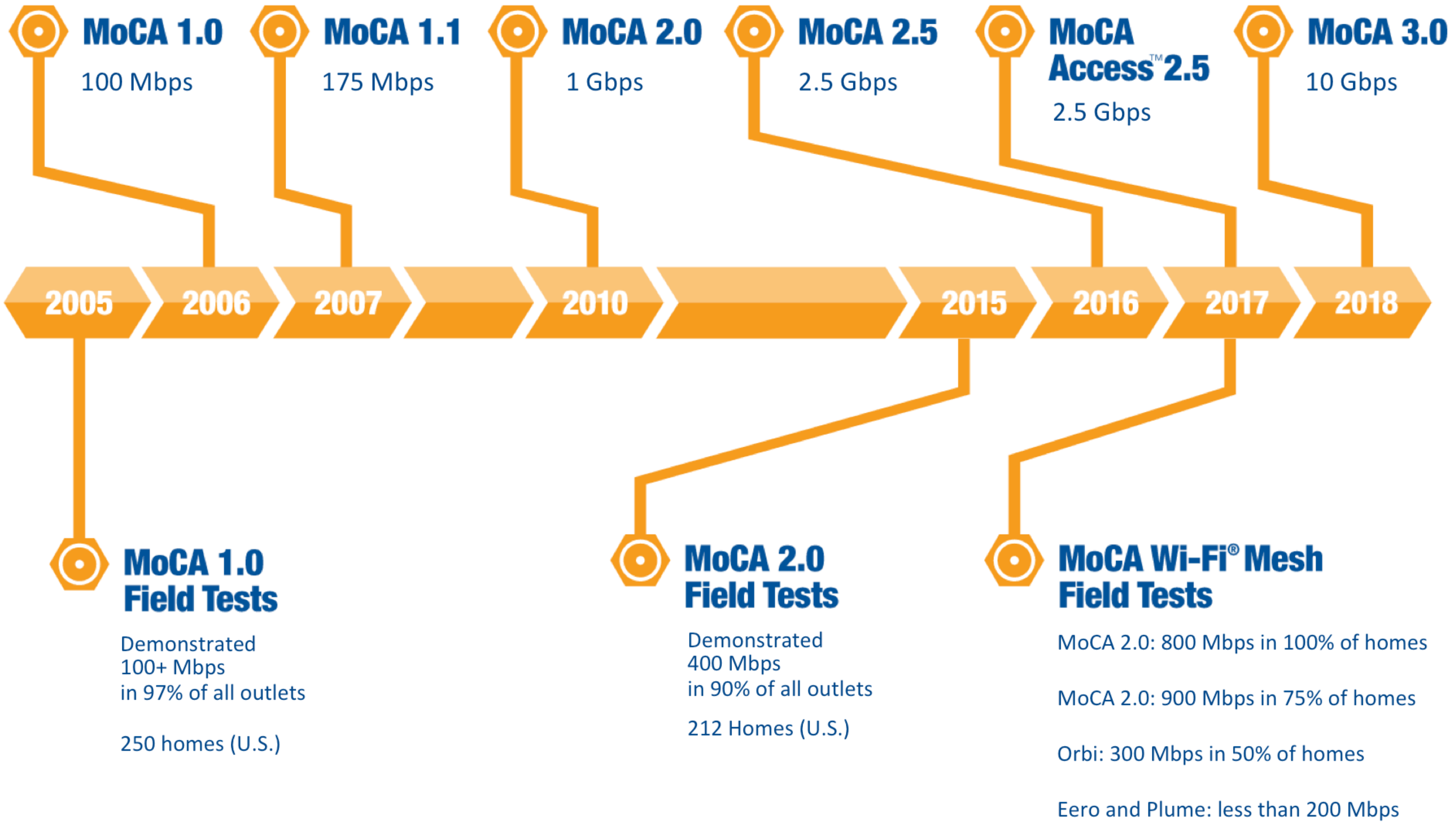
Tap

MoCA Overview

- Alliance established in 2004.
- Fastest and most reliable home networking technology standard available.
- Actual data rates (MAC):
  - 1 Gbps (MoCA 2.0)
  - 2.5 Gbps (MoCA 2.5)
  - 10 Gbps (MoCA 3.0)
- Uses existing coaxial cabling. Not dependent on type or age of wiring.
- MoCA in deployment by cable, telco and satellite operators worldwide.
- More than 270 million chipsets in the field.
- 228 certified products.
- MoCA Access 2.5 in trials at operators in Europe and China.

MoCA Technology Roadmap

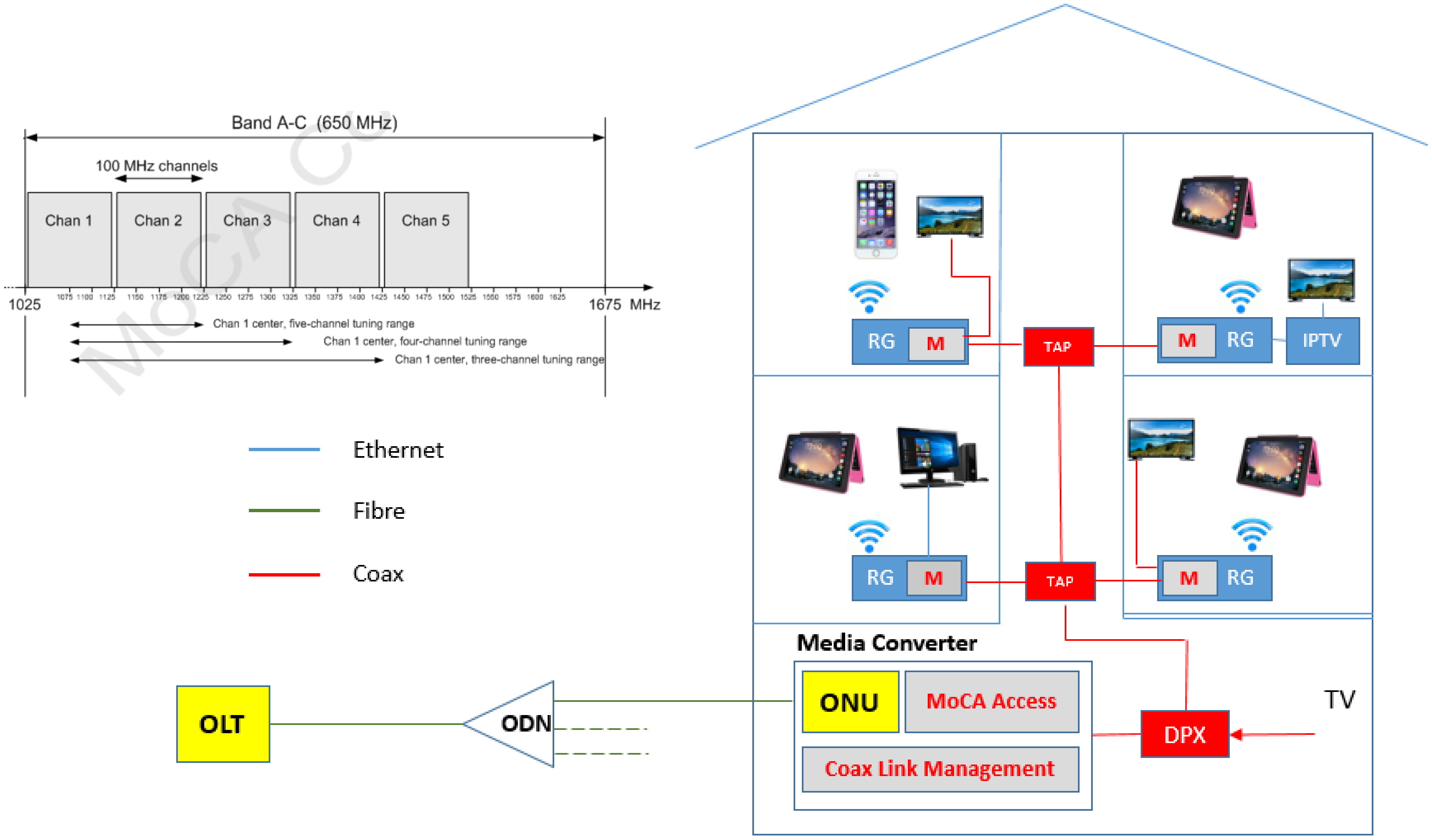
Numbers shown indicate actual data rates.



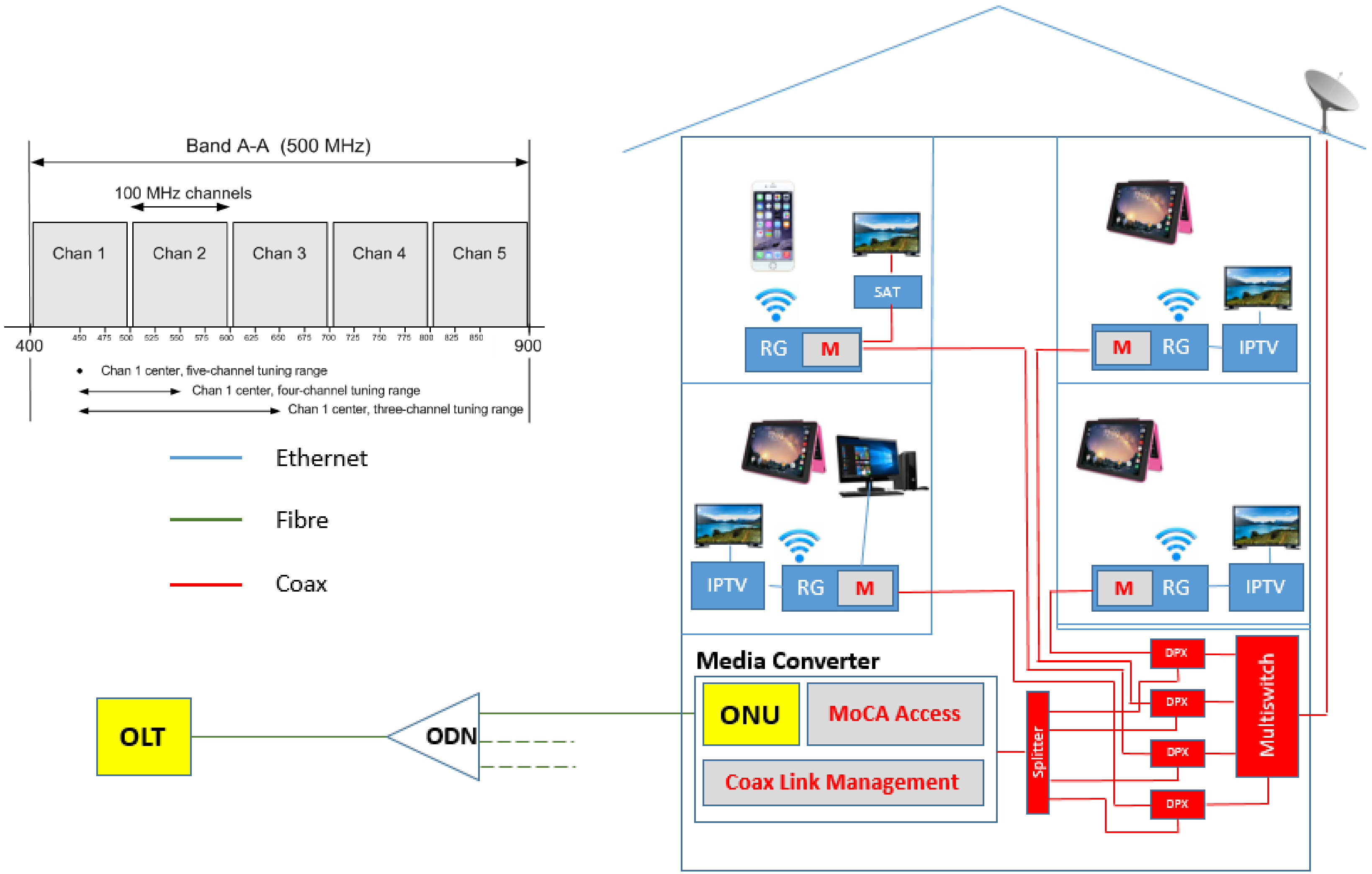
MoCA Access 2.5 Features

- Transparent IEEE802.3 bridge
- MAC speed up to 2.5Gbps (DL:2.5/UL:2.0)
- Configurable DL/UL ratio
- Profiles for 1.0 /1.5/2.0 or 2.5Gbps MAC rates
- MAC using time division multiple access (TDMA)
- Supports up to 512 multicast addresses and full VLAN range
- Shaping and QoS up to eight classes
- Average latency < 3ms
- Max MTU size 2k
- Client node with three power states
- Frequency range 400-1675MHz
- Profile C 225MHz/profile D 300,400 or 500MHz bands with channel bonding
- P2PM up 63 modems
- PHY using time division duplexing (TDD) and OFDM modulation
- Up to 1024QAM
- Packet error rates < 10^{-6} or 10^{-8}
- Supports multicast over a coax link
- 5 pre-defined bands for AL-IP or co-exist TV services
- AES cryptographic algorithm with 128-bits key with AATEK refreshment within six hours
- Three power contours with 45dB, 55dB or 65 dB link budget

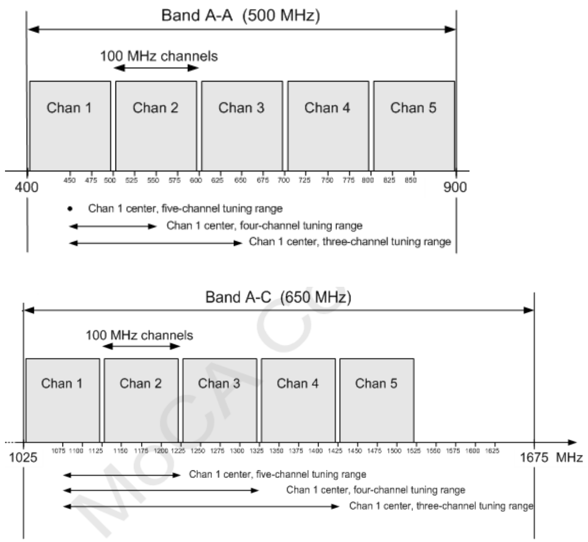
GPON Co-existence With TV

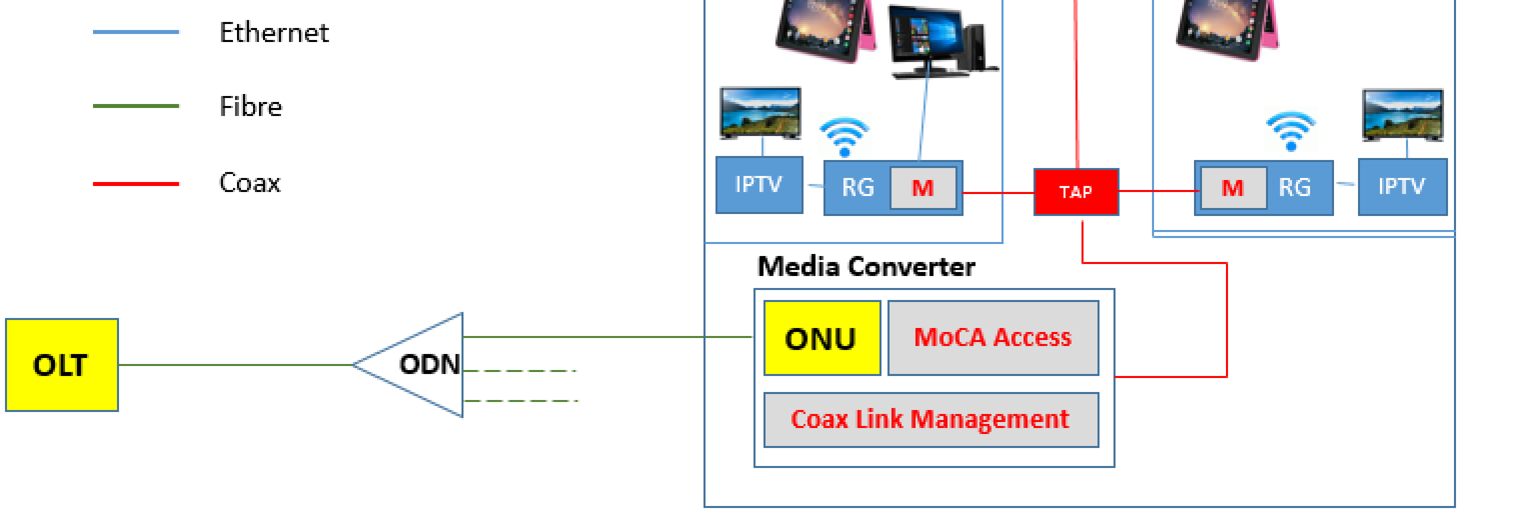


GPON Co-existence With Satellite

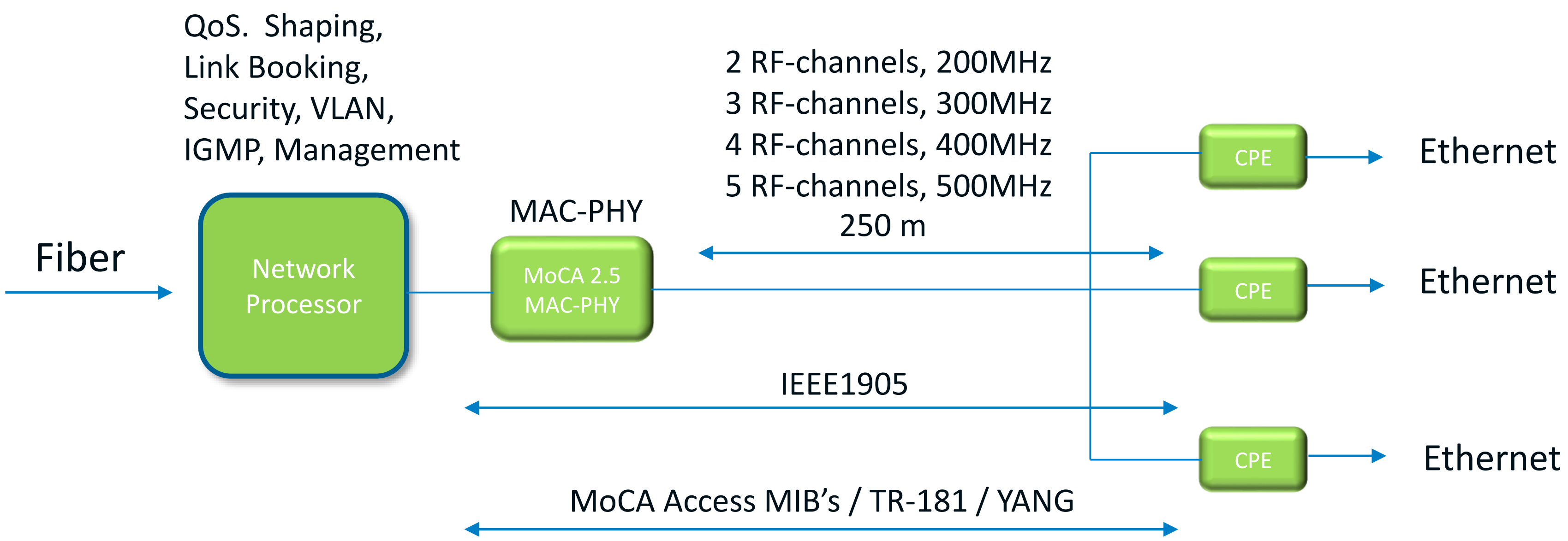


GPON Using Full Coax Spectrum





MoCA Access Principals



InCoax Fibre Access Extension Node

CLC2524

Key features:

- **Accumulated 10 Gbps over four RF-ports**
- **Each RF-port delivers 2.5 Gbps**
- **Delivers IPTV, VoIP and high-speed Internet**
- **Operational bands between 400-1675 MHz**
- **Co-exist with terrestrial and cable-TV services**
- **Uses existing in-building coaxial cables**
- **Delivers broadband through existing antenna outlet**
- **Fast and cost-efficient in-building deployment**

Questions?

Automated Deployment of Cloud-based Access Infrastructure & Services

Tim Carey

Lead Technology Strategist | Nokia

timothy.carey@nokia.com

broadband forum

BASe

Topics of Discussion

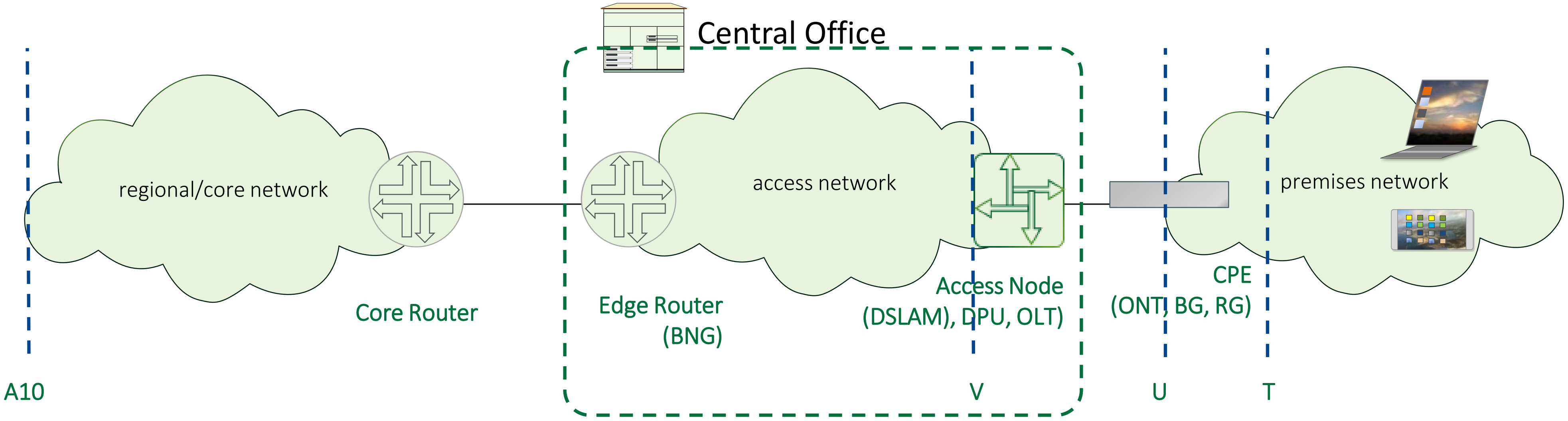
- How and why the Access network is being transformed

- What OB-BAA and its impact on the stakeholders in the Access network ecosystem

- Further information about the current release of OB-BAA

Today's Access

Today's access/edge network segments form a collection of application specific, purpose built boxes - foundation for massive successful deployment

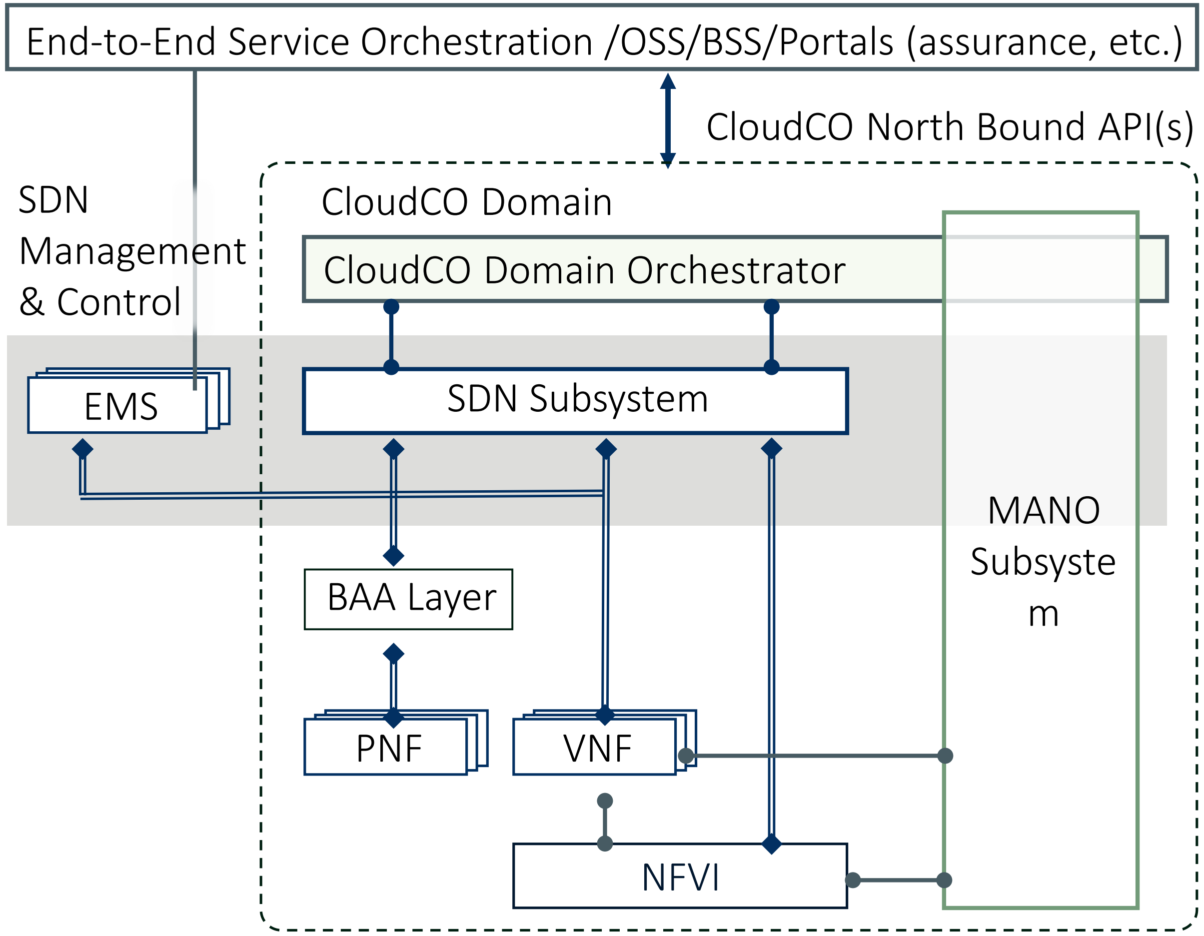


However …

Emergence of new technologies/approaches has resulted in a re-examination of the network in the quest for a more responsive, agile ecosystem to better enable new revenue opportunities and operational cost savings

The not-so-quiet revolution in networking

- The Central Office is being transformed where functions that were previously “locked” are now virtualized in the Cloud
- Management and control of the functions are automated via portals, NB interfaces and orchestrators/controllers.
- Enabling technologies are developed in open-source communities using open APIs, data and specifications



So, here’s the big challenge ...

It’s the business and deployment issues - not the tech

- The global economy, information, personal communications depend on the telecom industry
- Successful introduction of new technology/devops approaches must minimize risk of disruption to business viability, technical stability of providers and customer services alike
- 3 key ways to achieve this are:
  - **Seamless migration** driven by market acceptance, revenue, RoI
  - **Long term coexistence** to protect investment and local conditions
  - **Agile architecture** capable of adapting to rapidly emerging Software Defined Access models

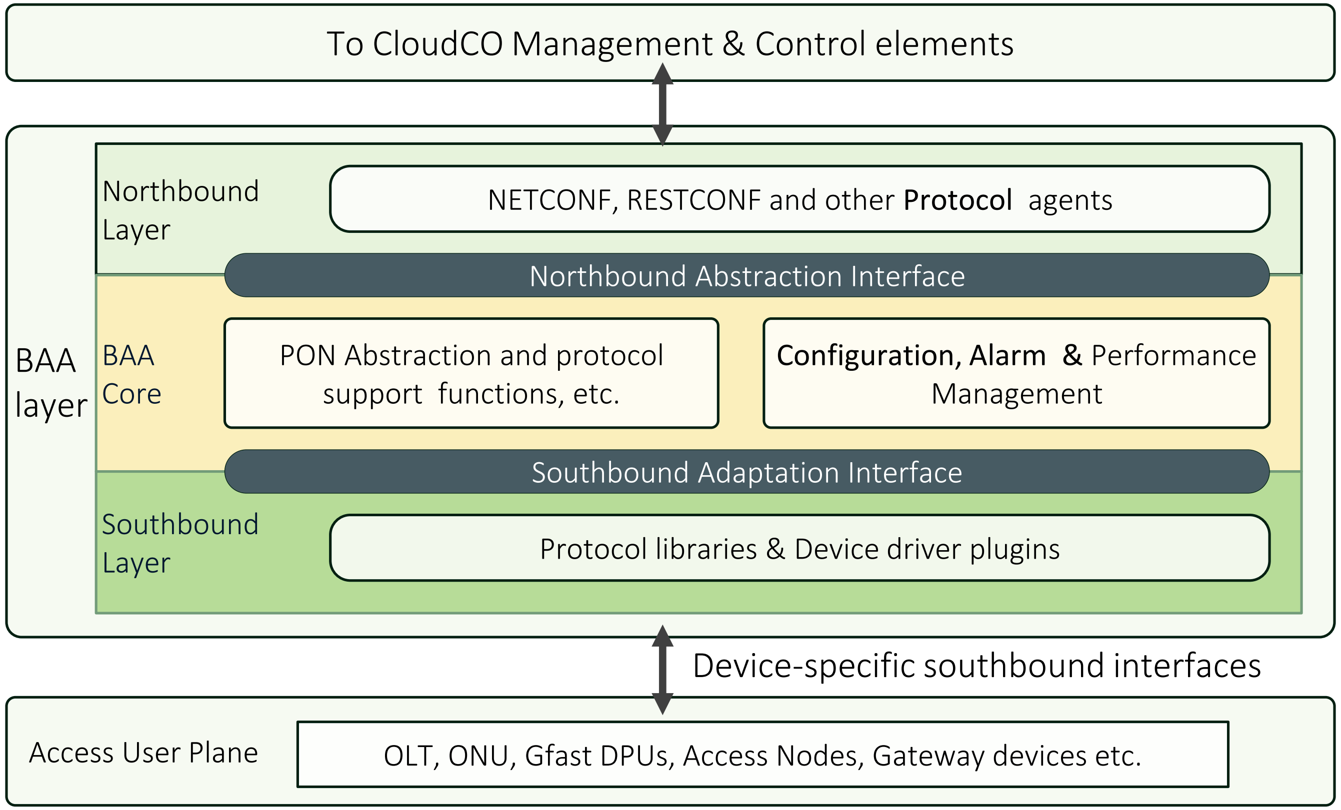
This is where OB-BAA’s layered approach plays a key role …

What is OB-BAA?

- Stands for: **B**roadband **A**ccess **A**bstraction under BBF's **O**pen **B**roadband initiative.

- An open source project delivered as source code/docs
- Provides standardized, automated deployment for cloud-based Access Services
- Unifies new & deployed access nodes/device types provisioned, controlled & maintained by SDN management and control systems
- Combines open source practices with Forum's goal of developing large-scale standardized solutions

BAA layer reference implementation



What is the Impact?

In General OB-BAA reduces

- Risk of introducing new technologies, architectures and individual products
- Cost of validation, engineering and operations
- Time to deploy services

Service providers can

- Introduce new infrastructure incrementally instead of a total replacement approach
- Use OB-BAA to migrate to and manage programmable networks environments
- Have increased choice in implementing best of breed solutions
- Deploy services rapidly as they can interact with a common abstraction of Access Nodes

Equipment manufacturers and service providers can

- Streamline and cost-optimize development by implementing the standard interfaces
- Use stable standardized platforms to build differentiated service offerings

OB-BAA Release 1 Features and Deliverables

- Core Framework
  - NETCONF/YANG based Southbound and Northbound Interfaces
  - BAA management allows Access Nodes to be configured offline and synch when reconnected
- Functionality to discover and manage an Access Node that includes the ability to:
  - Discover an Access Node based on Direct SSH, TR-301 CallHome
  - Create, retrieve, update and delete (CRUD) Access Nodes within the BAA layer as well the AN's data
  - Load YANG module sets for a type of Access Node
- Deployment & Usage instructions
  - Simulator recommendations and examples of requests to the BAA layer and YANG modules for DPUs, OLT/ONU and ONTs
  - Release docs & links to OB-BAA code may be found at https://obbaa.broadband-forum.org
- More information about OB-BAA, including its whitepaper description is:
  - Available at https://www.broadband-forum.org/baa

Broadband Access Abstraction Project Summary

- Open Broadband BAA is released and available
- Provides standardized, SDN-automated, accelerated deployment of cloud-based access infrastructure and services
- Facilitates co-existence, seamless migration and the agility to adapt to new software defined access models
- BAA layer reduces risks & time to introduce virtualized infrastructure, services
- Part of BBF's Connected Home, Access, 5G and Cloud strategy
- Participating companies (13): Altice Labs, Broadcom, BT, Calix, CenturyLink, China Telecom, Furukawa Electric, Huawei, Nokia, Telecom Italia, Tibit, UNH and ZTE

- **Get involved in the future of Broadband and Cloud-based Access**
  - Full details at https://wiki.broadband-forum.org (members) and **broadband-forum.org/membership**

Thank You!

G.Hn Fiber Extenders an Alternative to Multiport DPU's

Paul Arola
Senior Design Specialist | Telus
Paul.Arola@TELUS.COM

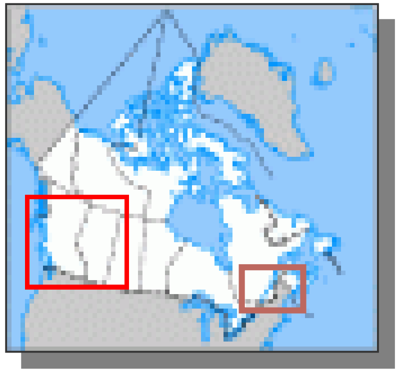
broadband forum

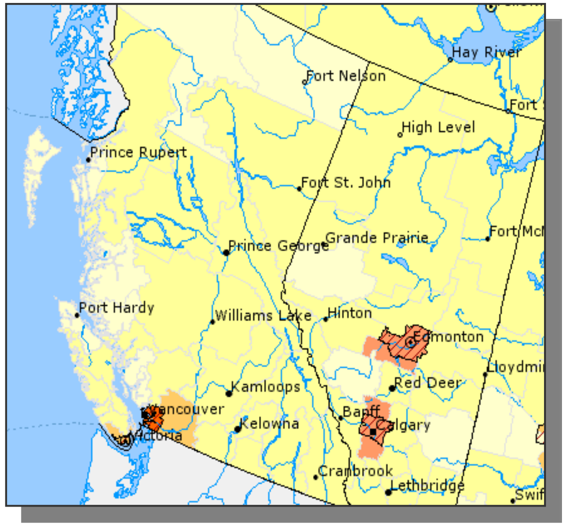
BASe

microDPU - Boldly Go Where GPON Cannot

Paul Arola

Who is TELUS ?



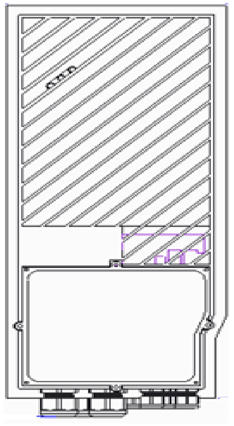


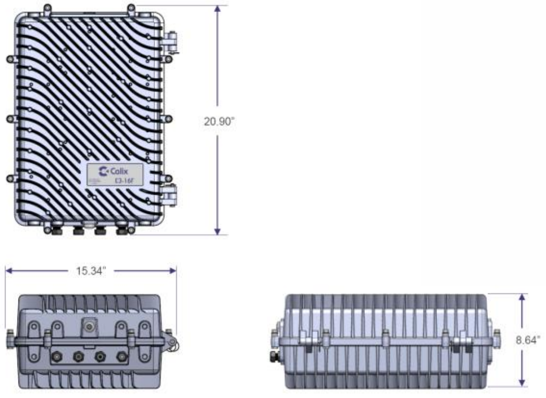
- Canadian national mobile carrier, wireline ILEC in Alberta, BC and parts of Quebec.
- $13.5 billion in annual revenue.
- ~10 million mobile subscribers.
- 1.5 million broadband subscribers.
- 1 million IPTV subscribers.
- Aggressive brownfield FTTH build.

TELUS®

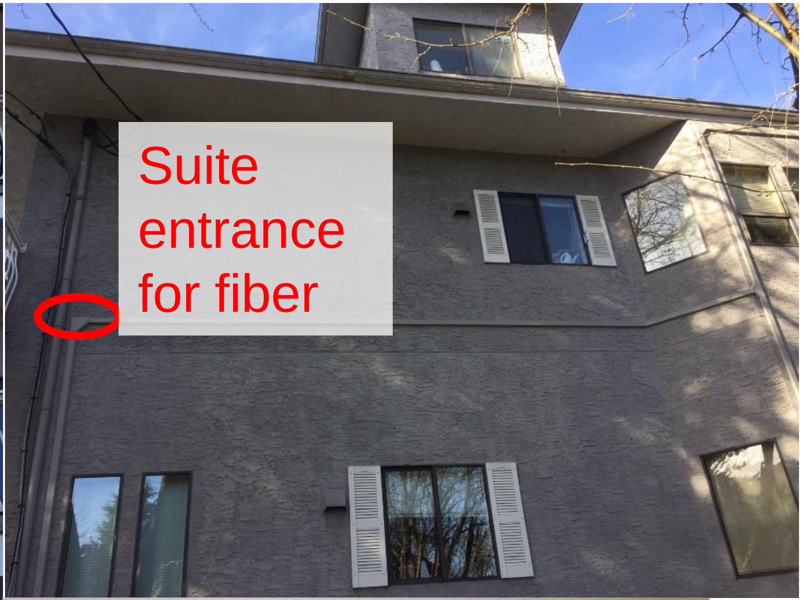
G.fast deployment to date

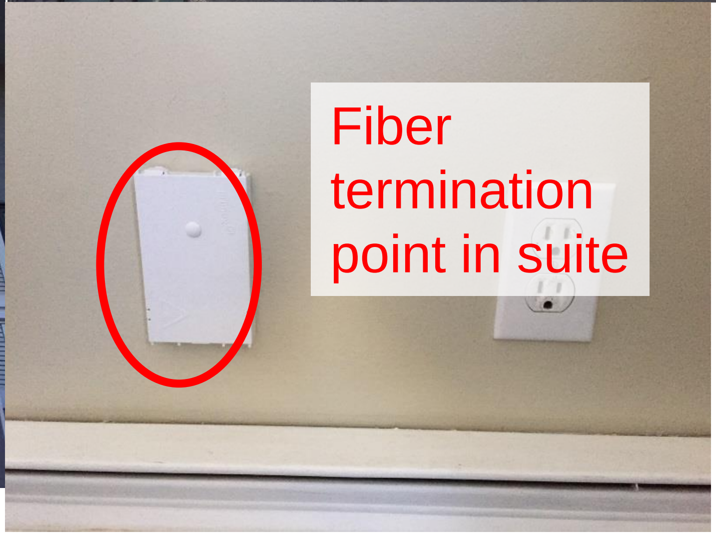
- We field trialed two different 16 port DPU’s in 2016, with a launch in 2017 at an MDU in Vernon BC.
- Immediately our planning organization put the G.fast build program on hold, citing excessive costs, differences compared to GPON, etc.
  - Not related to equipment costs (the 16 port DPU was cheap)
  - Different techs required for power, fiber, device turn up.
  - Span powering very expensive for lower port count device.
    - Local AC powering requires battery backup.
  - Provisioning/activation systems were different.
  - G.fast gen 1 was *only* 500mbit symmetric best case.





Why do we need a fiber extender ?





Why do we need a fiber extender ?

TELUS®

Why do we need a fiber extender ?

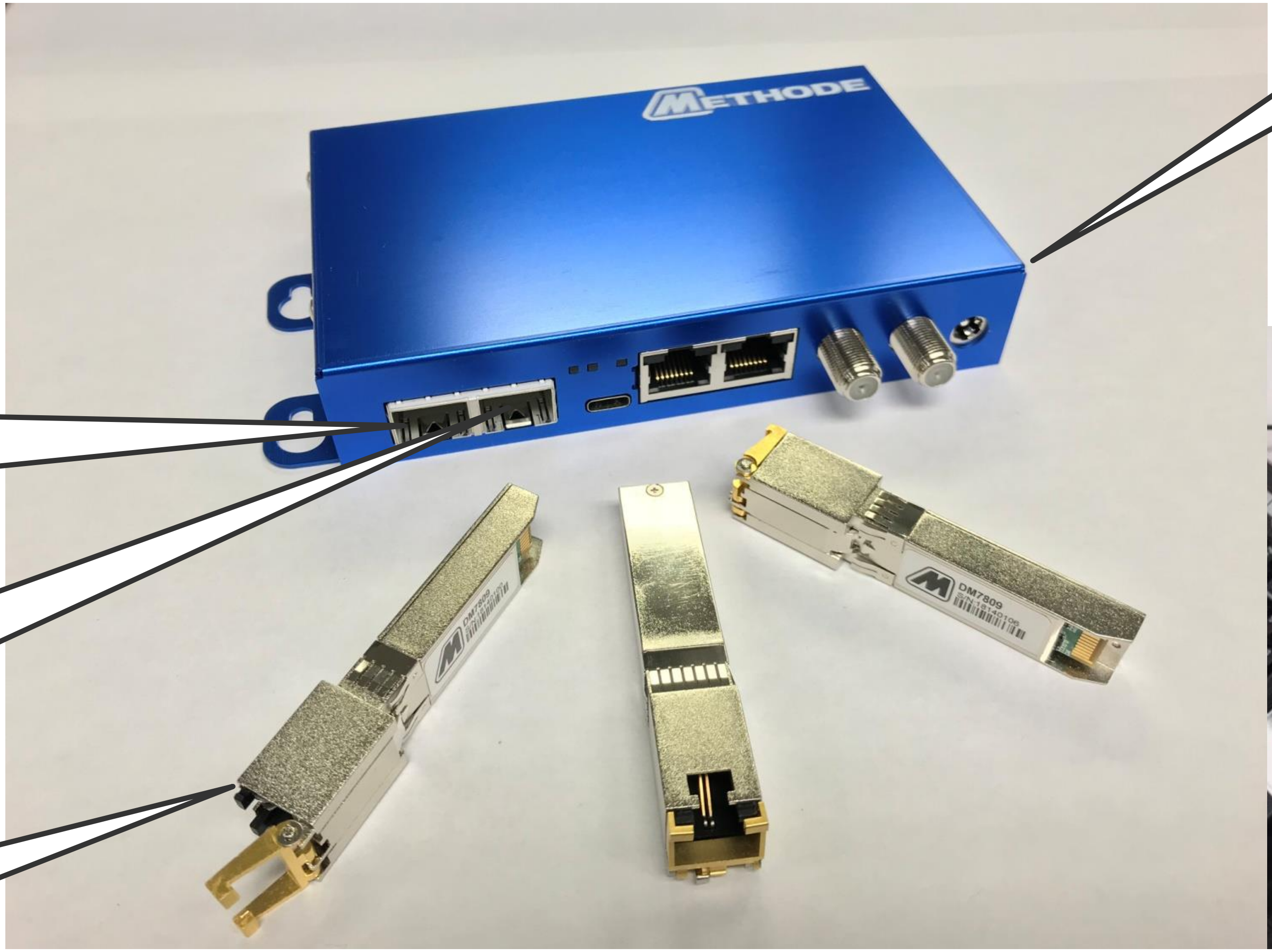
- In some MDU’s doing GPON/FTTS is cost prohibitive and time consuming.
- Condo board may prevent build, or condo owners may not allow drilling in their condo during time of install.
- Our planning group says 30% of MDU suites within our FTTH footprint couldn’t get service for various reasons.
- For MDU’s that can get FTTH, 18% of orders are cancelled as non-doable.
- To solve this problem we proposed placing a fiber extender in the equipment room/closet for each subscriber.
- We need a solution that looks like GPON, yet uses the existing drop.
- Leverages reverse powering from customer suite.

TELUS®

… but why with G.hn ?

- Supports over 1Gbps throughput on coax & twisted pair today in sub 2 watt footprint.
- Twisted pair bonding (MIMO) supported at transceiver level
- Supports crosstalk measurement and mitigation between separate DPU's (# of ports doesn't matter).
- NEXT prevention through DPU synchronization via 1588v2 or timing distribution through crosstalk channel.
- Already using LDPC coding, QoS aware retransmission and integrated encryption.
- Supports vendor agnostic standardized YANG models via BBF TR-374 (similar to TR-355 for G.fast).

The micro-DPU



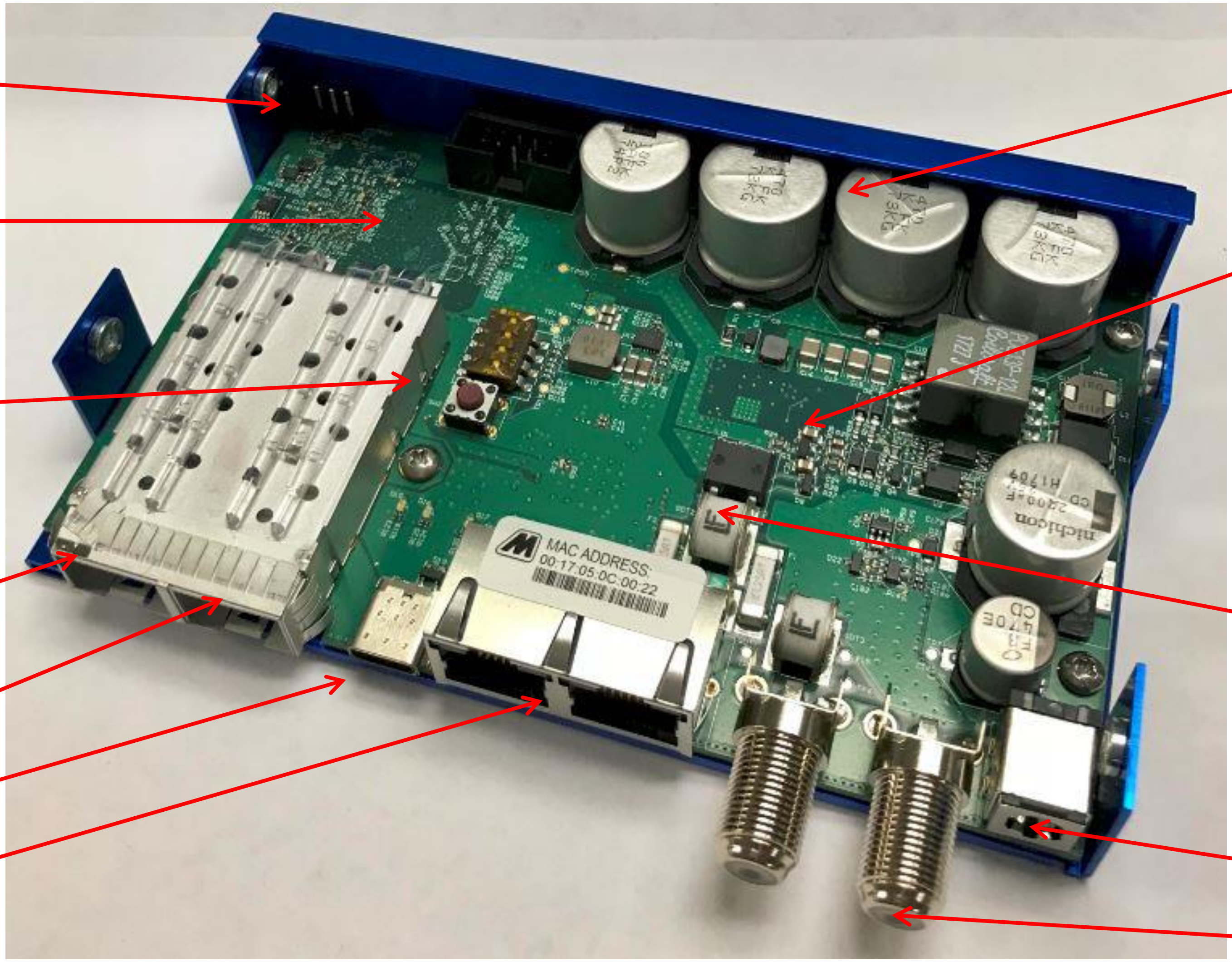
Micro-DPU

SFP port for GPON SFP ONT or optical SFP module

SFP port for G.hn SFP module or other copper SFP module

G.hn SFP module

Anatomy of micro-DPU



UART interface

System on Chip (SoC) mounted on underside

Reset

Optical SFP

Copper SFP

USB Type C for local MGMT

RJ Interface

Charge storage for dying gasp

Power supplies

Lightning protection

Local DC power input

Coax Interface

TELUS®

micro-DPU advantages

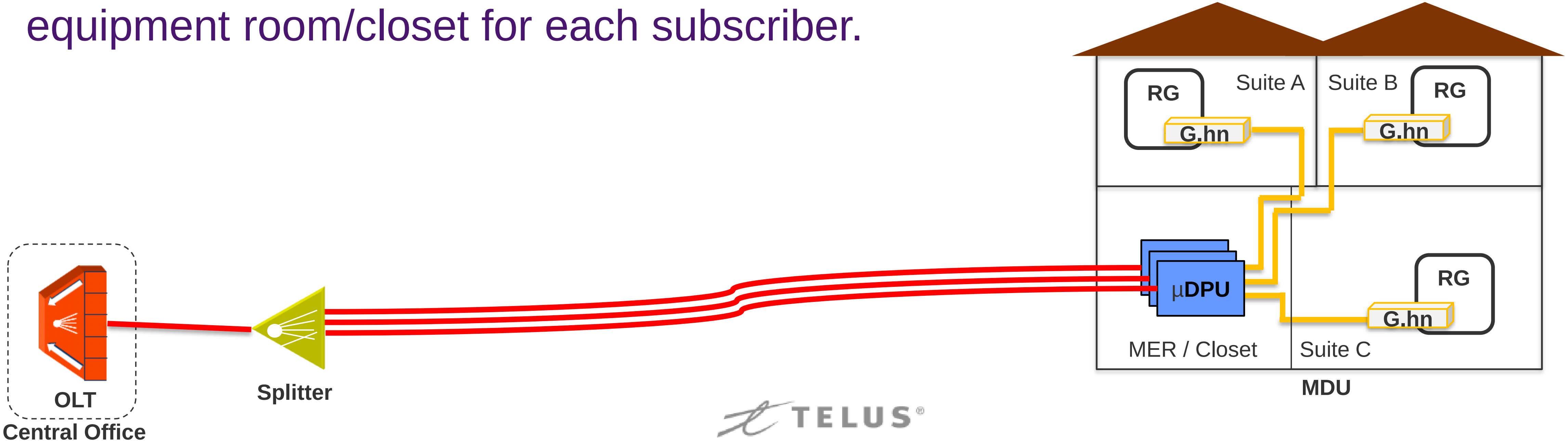
- Versatile
  - SFP modules for downlink and uplink physical layer interfaces
  - All copper interfaces supported (RJ11, RJ14, F-type and CAT-5e)
  - Can be used for residential, business and hospitality applications
  - 4GiB eMMC storage, upgradeable to 256GiB via removal eMMC module.
- Cost effective
  - Pay-as-you-grow, scalability because of single-channel architecture
  - Minimizes build times costs, most costs are at connect time when the subscriber orders service and the micro-DPU is placed.
  - Saves on installation CAPEX compared to FTTH or multi-port DPU's.
- Flexible powering options
  - Reverse powering via ETSI TS 101 548.
  - Reverse power injector provided by LEA networks.
  - Local DC option as well.

micro-DPU software design

- The 1st single-channel access device that is fully SDN-NFV enabled
- Working with Sartura.hr to bring microDPU into mainline OpenWRT; no proprietary vendor SDK's required.
- Runs Linux 4.14 LTS or 4.19rc8 kernel and latest Open vSwitch.
- Management through NETCONF, TR69, or SNMP.
- Dataplane acceleration is possible with DPDK but we're focusing development on AF_XDP support for Marvell's mvneta driver.
- Initially bridge only config, but residential gateway functionality will be supported by end of 2019.

MDU use case

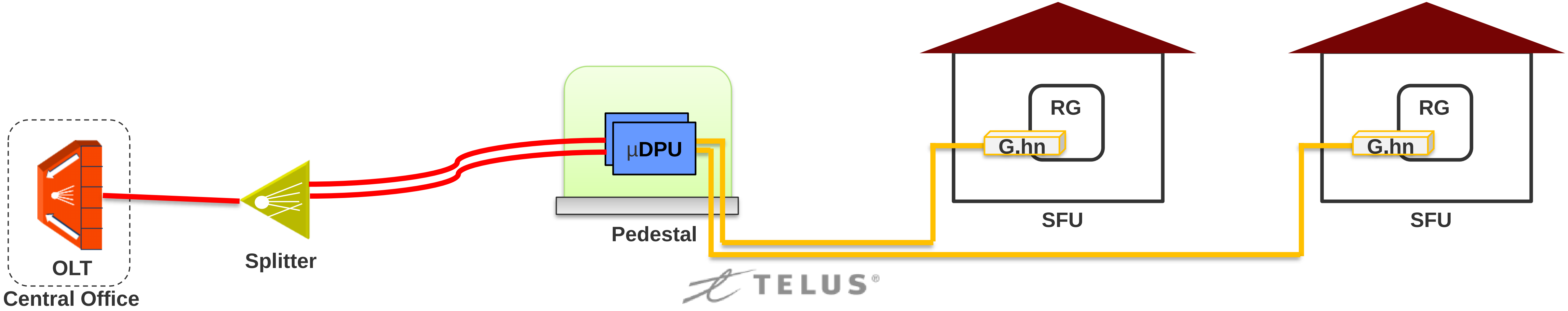
- In some MDU’s doing GPON/FTTS is cost prohibitive.
- Condo board may prevent build, or condo owners may not allow drilling in their condo during time of install.
- To solve this problem we place a micro-DPU in the equipment room/closet for each subscriber.



TELUS

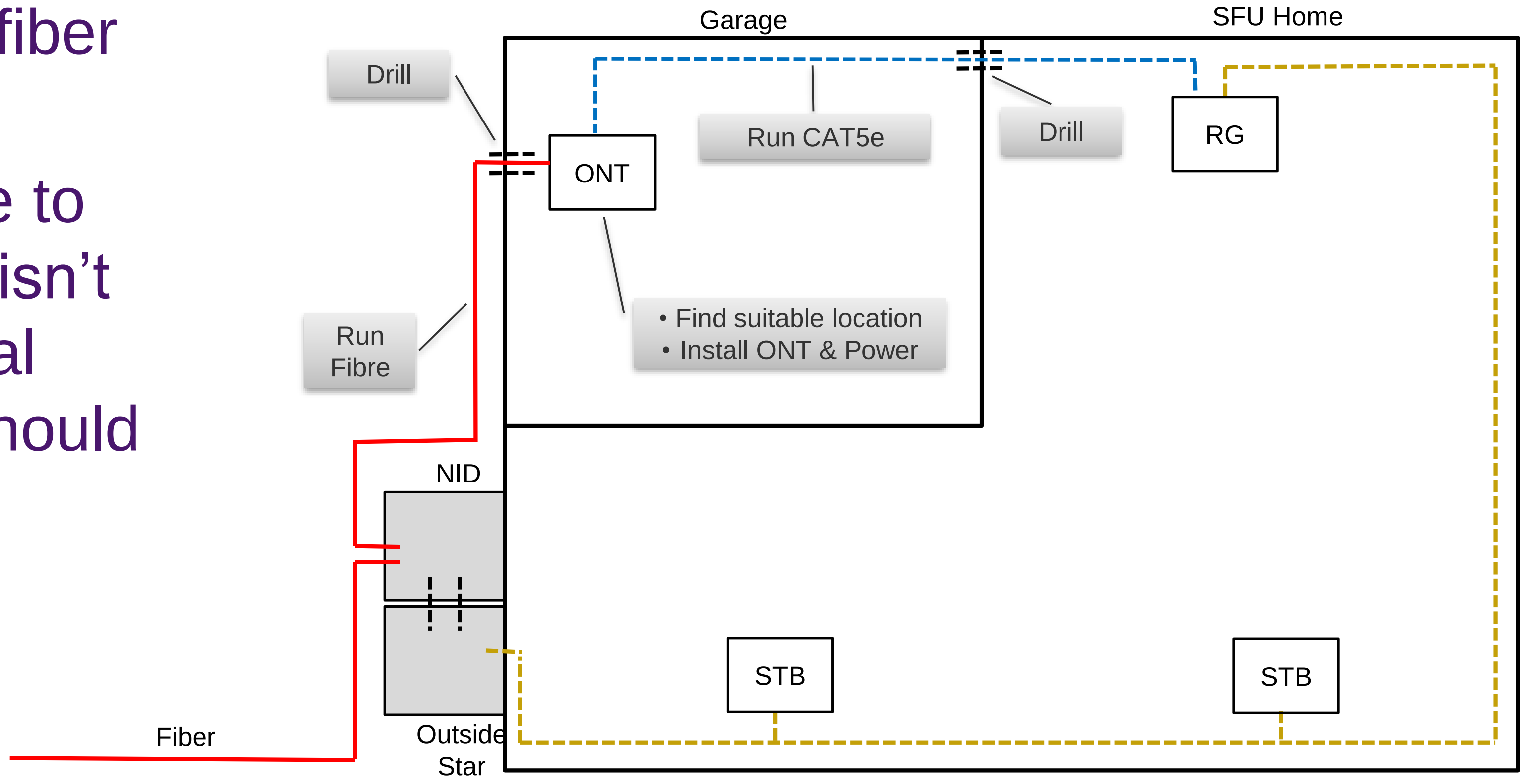
FTTdp use case

- In brownfield direct neighbourhoods, GPON/FTTH is difficult, lengthy and expensive due to the fiber drop placement required for each home.
- Directional drilling/boring can only be done while the ground is thawed, limiting the build schedule.
- With the micro-DPU's, we append the existing GPON/FTTH build practice, and extend a bundle of fiber from an FDH to a nearby pedestal housing the micro-DPU's.



How can we use for single family homes ?

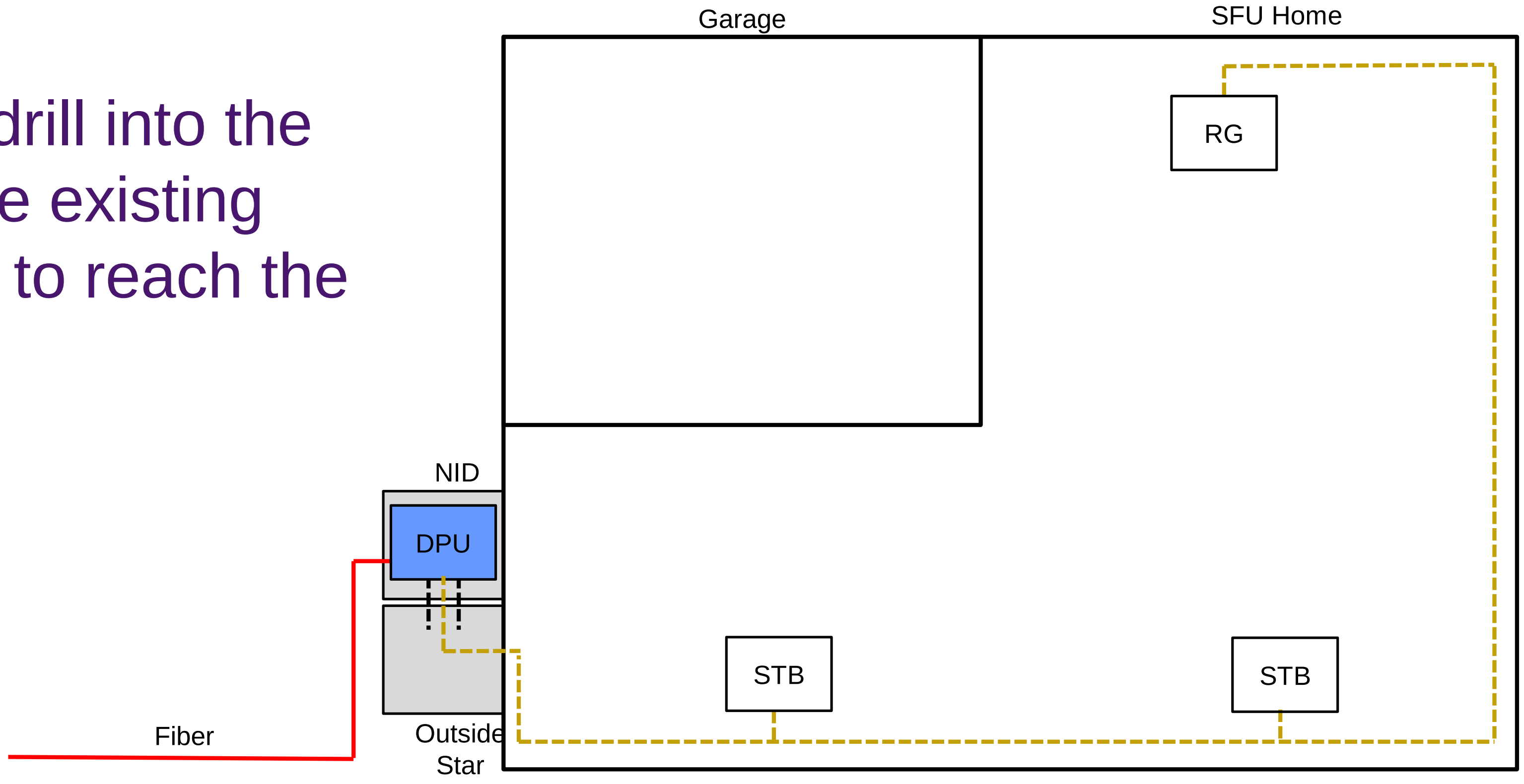
- For brownfield GPON/FTTH installs we currently place the ONT indoors. Which requires bringing the fiber drop into the home.
- Sometimes the easiest place to bring the fiber drop indoors, isn't anywhere near the residential gateway, or where the RG should be placed for optimal WIFI coverage.



TELUS®

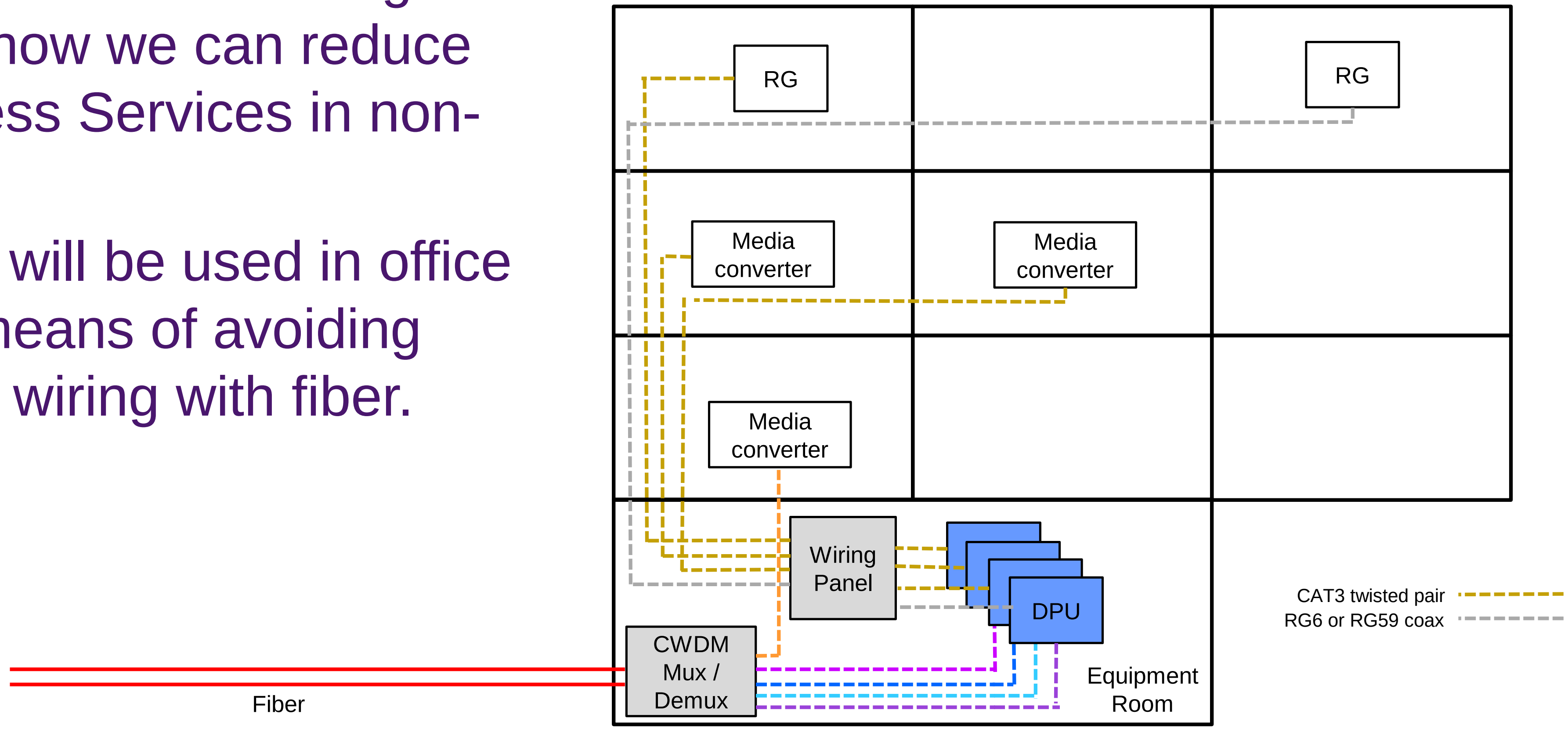
How can we use for single family homes ?

- We can solve these problems by using a micro-DPU, placing it outside the home, in or near the NID.
- We now no longer need to drill into the house, and can leverage the existing twisted pair or coax cabling to reach the residential gateway.



Business use cases ?

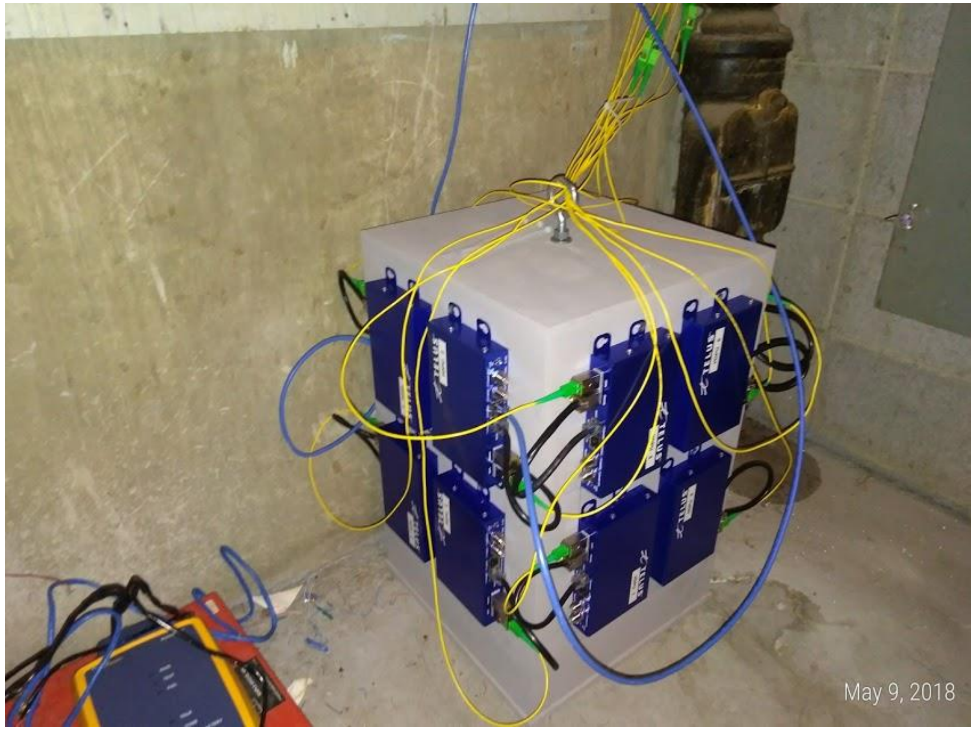
- Our Business Internet marketing team asked us how we can reduce costs for Business Services in non-ILEC regions.
- The micro-DPU will be used in office buildings as a means of avoiding replacing inside wiring with fiber.

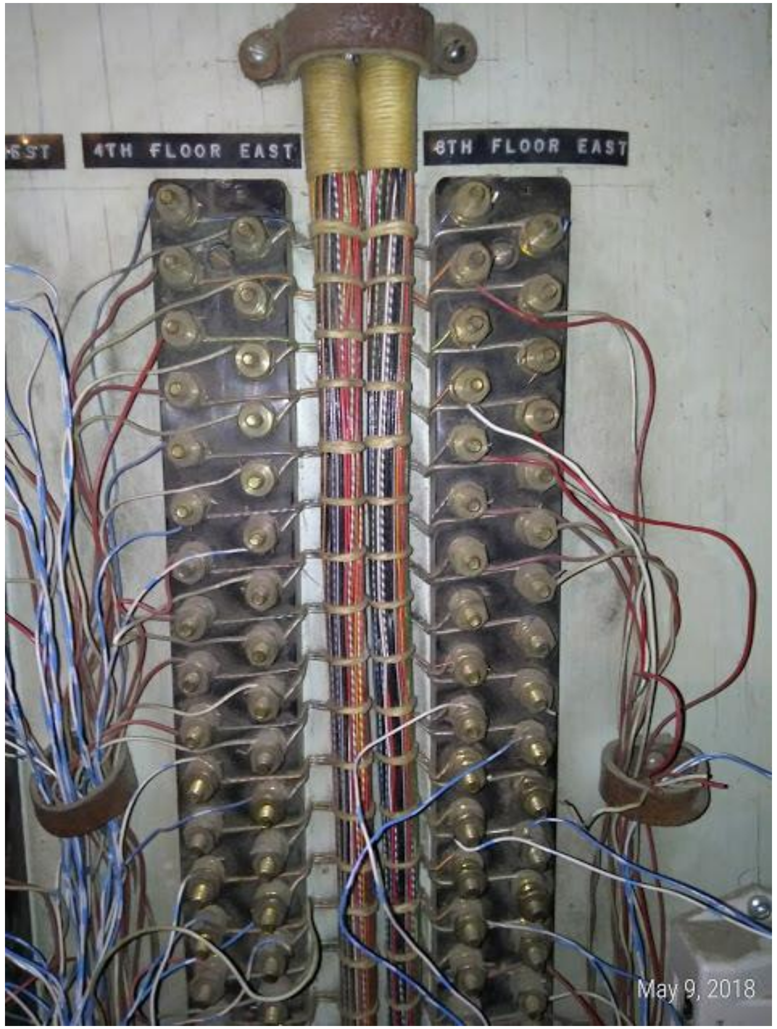


TELUS

microDPU field trial

- 10 subscribers in MDU in downtown Edmonton.
- Paper insulated station wire, with no twist. Very high crosstalk.
- Subscribers seeing 500-700mbit/s symmetric on speedtests.
- More stable than G.fast was in the same building.





TELUS®

Monte Carlo simulation of G.fast vs G.hn

- High crosstalk MDU modelled
  - 54 active links (eg: ~100 suite MDU with high penetration)
  - 12 active links (e.g. ~23 suite MDU with high penetration)
  - 7 active links (e.g ~12 suite MDU with high penetration)
- Dynamically changing spectrum settings on G.hn, no DSM L2 (flat PSD’s)
- Dynamically allocating between US and DS for both G.hn and G.fast (cDTA)
- “Tweaks” once per second
- Included both bursty and steady (primarily video) traffic
- Crude algorithms … improvable (especially upstream)

Monte Carlo simulation of G.fast vs G.hn

- Speed in Gbps, assuming 1.4 Gbps total (US + DS) link speed
- cDTA downstream limit of 90% (1.26 Gbps), upstream 70% (0.98 Gbps) in crude algorithm

Performance estimate	Current traffic		5 years , 15% CAGR		10 years, 15% CAGR	
	G.fast	G.hn	G.fast	G.hn	G.fast	G.hn
7 links active						
Downstream	1.12	1.04	1.12	1.03	1.11	0.96
Upstream	0.79	0.81	0.79	0.80	0.75	0.70
12 links active						
Downstream	1.13	1.06	1.13	1.01	1.10	0.88
Upstream	0.80	0.81	0.74	0.75	0.72	0.57
54 links active						
Downstream	1.12	1.03	1.11	0.98	1.07	0.85
Upstream	0.76	0.75	0.72	0.66	0.65	0.54

TELUS®

Thank you

TELUS

Intelligent Broadband Access & Home Maintenance

Wei Lin
System Architect | Huawei Technologies
wei.linwei@huawei.com

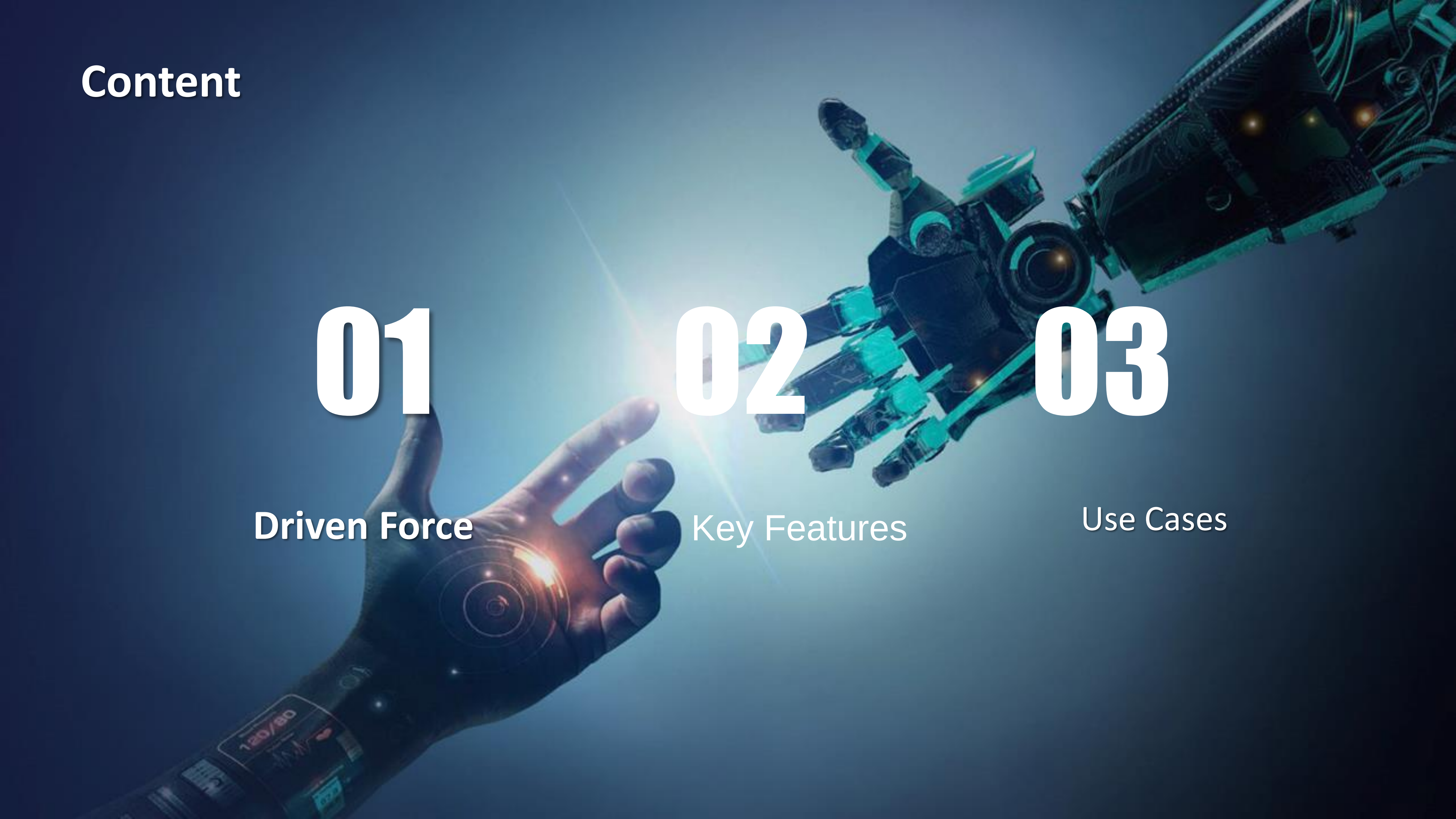
broadband forum

BASe

Access & Home O&M automation & intelligent

For BASE Las Vegas

Wei Lin



Content

01 Driven Force

02 Key Features

03 Use Cases

Trend 1: Telcos are transformed from copper to light, and the resulting operational complexity is its biggest challenge

The complexity introduced by new technologies

High learning cost
DBA, TCONT, GEMport…

OSS integration complexity：
The original interface cannot be reused; OSS has to be re-developed

The complexity of the terminal authentication mechanism

Copper age
Single user per port; CPE born to be plug and play

Fiber age
Multi user per port; ONT requires authentication; it is inevitable to go to the door

Troubleshooting with P2MP

Copper age
P2P test chip & technology ready; SELT/MELT

Fiber age
ODN is dumb resoures; OTDR based testing is quite expensive and the deployment is difficult

fiber and copper are totally different in nature. How to shield media/technical/network structure changes in operation and maintenance to ensure user experience consistency?

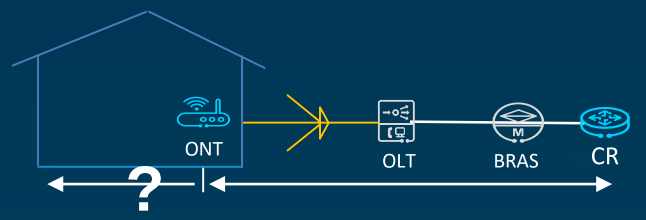
Active operation and maintenance, remote troubleshooting, less door-to-door

Trend 2: Operators are paying more and more attention to user experience, but experience operation and maintenance faces huge challenges

To focus on user experience means that

① the scope or management extends to in-home, but

Lack of location



- The traditional O&M focus on ONT->BRAS, the home network below ONT is a black box
- The lack of in-home O&M ability leads to high operation and maintenance costs (20-25% needs to go to the door; 40~60$/time)

Powerful in-home O&M

②trying hard to improve the networking/application experience, but

Experience issues are hard to locate and happens again and again

Experience visibility

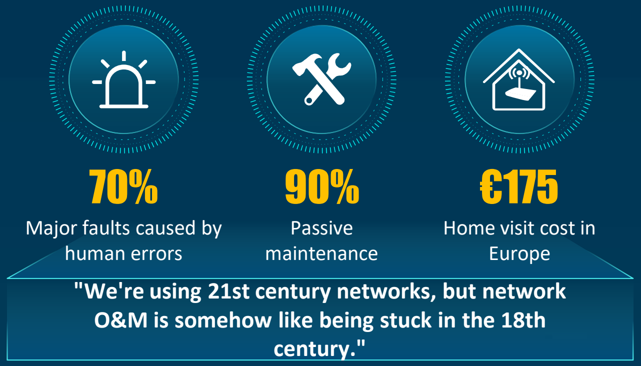
③ provide much faster and more efficient troubleshooting, but

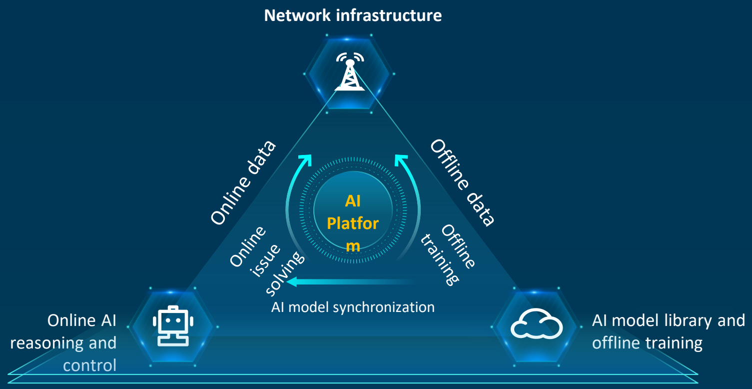
Most issue are complaint-driven

Active O&M; remote troubleshooting; less to-door

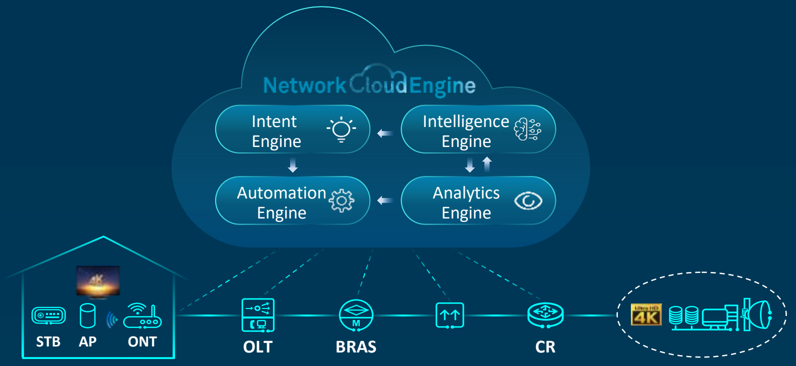
Operators' requirement

AI: Decoupling OPEX & Network Scale





AI Powered O&M: From Passive Response to Active Maintenance



AI Use Case: Fast Trouble-shooting

Churn rate ↓ 20%

Home visits ↓ 30%

Trouble-shooting time ↓ 50%

UC1: ODN Fault Real-time Awareness & Prediction

AS-IS

- <10% Auto ticket created, passive reaction to complaints
- Fault diagnosis by home/site visit, manual Analytics
- Risk evaluation by static threshold

TO-BE

- **Minutes-level** fault awareness, auto ticket created **>20%**
- **Automatic Root Cause Analytics** with **graphical topology**
- ODN Fault prediction for **1 months in advance by trend analytics**

Symptom & Trend Analytics

Physical Infrastructure

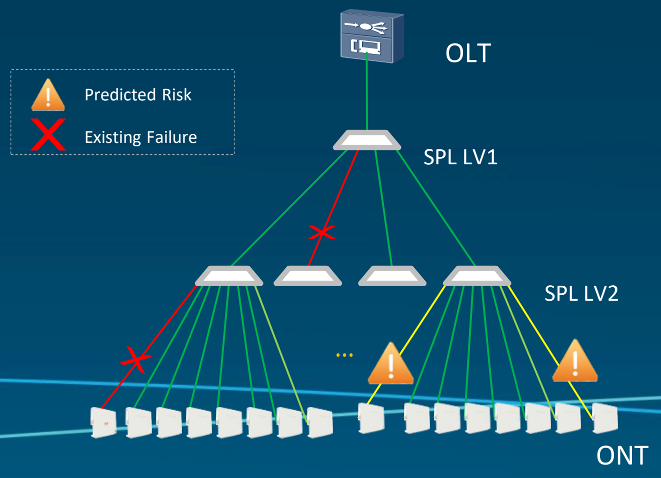
Telemetry

Big Data + AI

Training & learning

Digital Replica

ODN Topology Visualization



Demarcation with Root Cause

Feeder Fiber

Distribution Fiber

Drop Fiber

Fiber
- Over Bent
- Corrosion
- Over Pressed

...

Connector
- Dirty
- Damp

...

UC2: **Seconds-level Replay Helps Fast Resolve Sporadic Faults**

AS-IS

- 1 ticket handling: average **2+ days, 2+ home-visit**
- **Passively waiting** for fault reoccurrence
- **20% invalided** home-visit for problem no-show

TO-BE

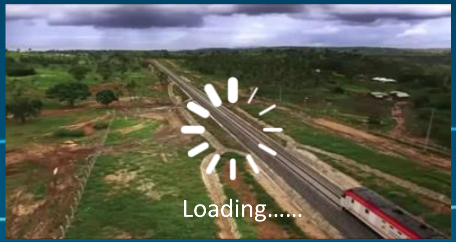
- Remote fault locating helps reducing home visit **30% for sporadic faults**
- Sporadic faults diagnosis Efficiency **↑80%**

- **Customer Journey**
- **Second-level Playback**
- **Minutes-level Root Cause Analytics**

Sporadic Faults

- Burst noise on DSL cable
- Fiber over bending
- Neighbor Wi-Fi channel interference
- OLT uplink Congestion
- …

User TV screen at 14:17:35



Customer Journey Time Line

14:00

00:00

24:00

Duration: 14:17:35 – 14:38:05
Issue Description: Massive packet loss
Root Cause: XXX
Suggested Solution: XXXX

UC3: Cloud-based Wi-Fi Channel Auto Optimization

AS-IS

68% Impacted by Wi-Fi Interference

Repeated Complaints

TO-BE

<30% Impacted by Wi-Fi interference

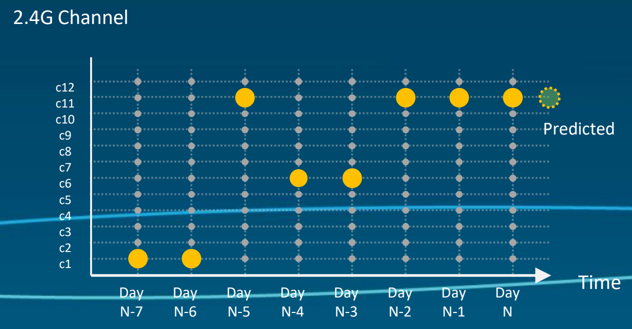
Big Data Analytics

Fault & Behavior Library

Machine Learning

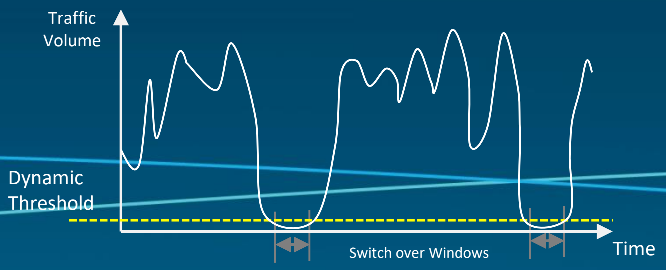
Sticking to Best channel

- Historical channel utilization
- Predict the best channel



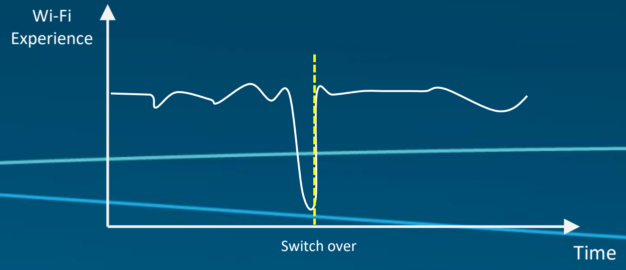
Switching Over insensibly

- Subscriber usage habit
- Auto Postpone when using



Switching when overwhelming

- Wi-Fi Experience monitoring
- Switch when interference affect experience severely



UC4: Intent-Driven Network Simulation, Shorten Time-To-Market

Scenarios:

1. Definition: SD -> HD IPTV service

2. Bandwidth:100Mbps -> 200Mbps

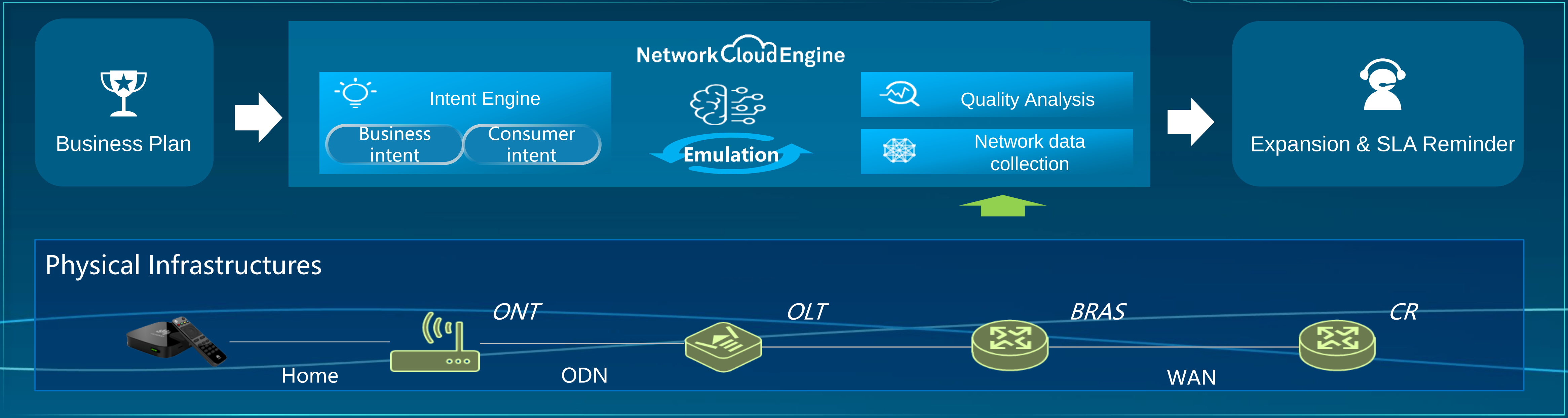
Availability? Bottleneck? Capacity?

AS-IS

- Capacity expansion evaluation every 6-12 months
- spent 1-3 months for one evaluation, slow reaction to market change
- Sampling data lead to less accuracy

TO-BE

- **Simulation accomplished in hours, New Business TTM<1 month**
- Experience Assurance, **Online simulation and validation**
- Risk Prevention, SLA degradation **predication in real-time**



Segment 3
Panel Discussion & Audience Q&A

Moderator: **Alison Diana**
Editor, Light Reading

15 MINUTE break

THANK YOU TO OUR SPONSOR

Segment 4
Wireless Broadband

Moderator: Lincoln Lavoie
BBF Technical Chair
Senior Engineer, Broadband Technologies
University of New Hampshire InterOperability Laboratory

Agenda Segment 4

	Wireless Broadband
3:25 - 3:45	**Fixed-Wireless Broadband - Accelerating Closing the Digital Divide**
	John Colvin, Senior Vice President, Global Field Operations, Mimosa Networks
3:45 - 4:05	**New Optical Technologies for Future 5G Transport and Multi-Service Access**
	Ronald Heron, Director Network & Portfolio Strategy, Nokia
4:05 - 4:25	**Overcoming Challenges in the Managed Connected Home**
	Jason Walls, Director of Technical Marketing, QA Cafe
4:25 - 4:45	**It All Starts With Managed Wi-Fi**
	Greg Owens, Product Marketing Director, Premises, Calix
4:45 - 5:05	**Enhancing Wi-Fi User Experience**
	Ruthy Zaphir, Head of WiFi Solutions, GlobalLogic
5:05 - 5:25	**Wi-Fi ROI**
	Jake Sailana, Director Product Marketing, ZyXEL
5:25 - 5:45	**Segment 4 Panel Discussion and Audience Q&A**
	Moderated by Robin Mersh

Fixed – Wireless Broadband – Accelerating Closing the Digital Divide

John Colvin

Senior Vice President Global Field Operations | Mimosa

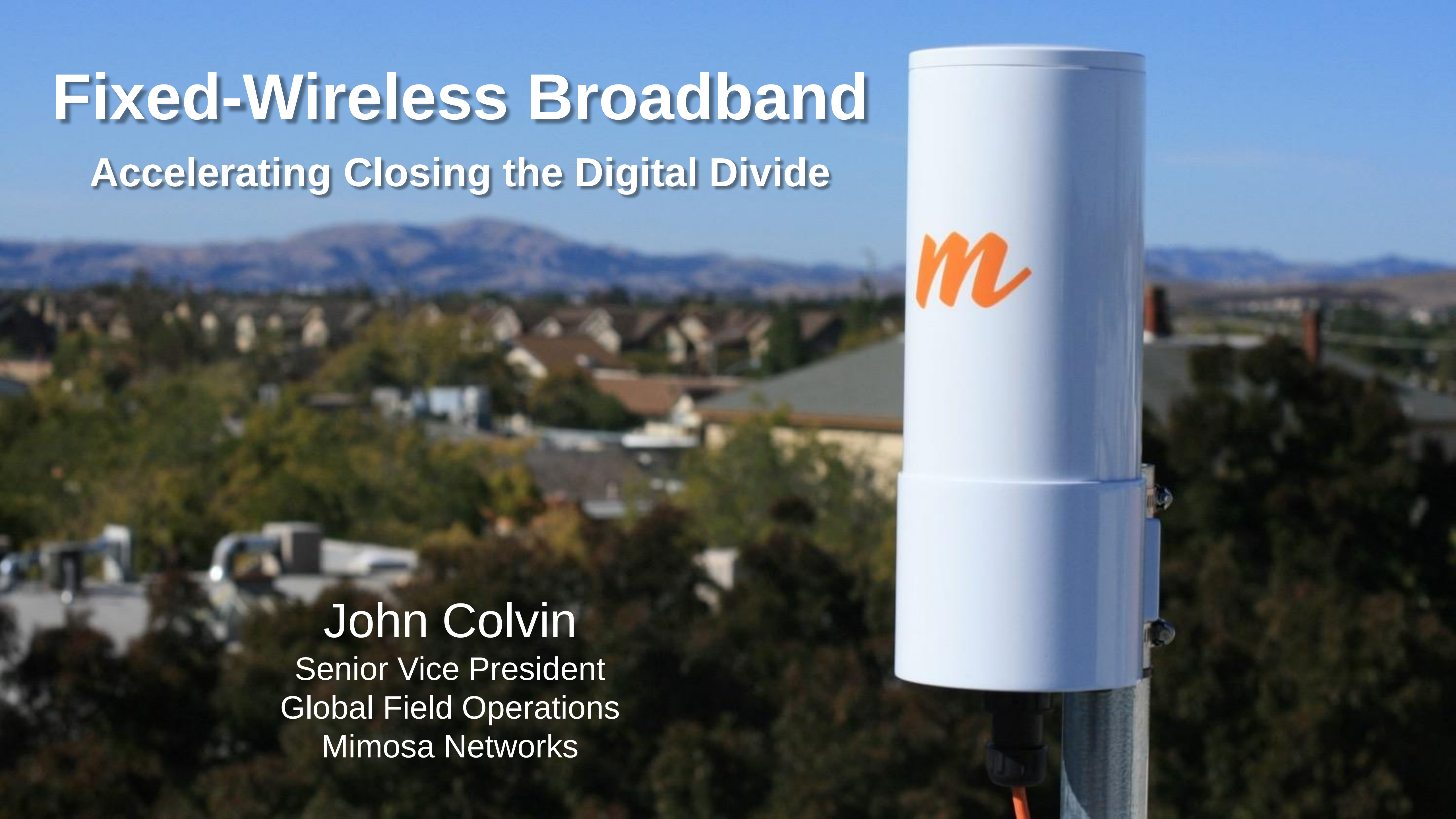
john.colvin@mimosa.co

broadband forum

BASe

Fixed-Wireless Broadband

Accelerating Closing the Digital Divide



John Colvin

Senior Vice President

Global Field Operations

Mimosa Networks

Wireless Landscape

Hybrid-Fiber Wireless solutions delivering Fiber-Fast Wireless Bro

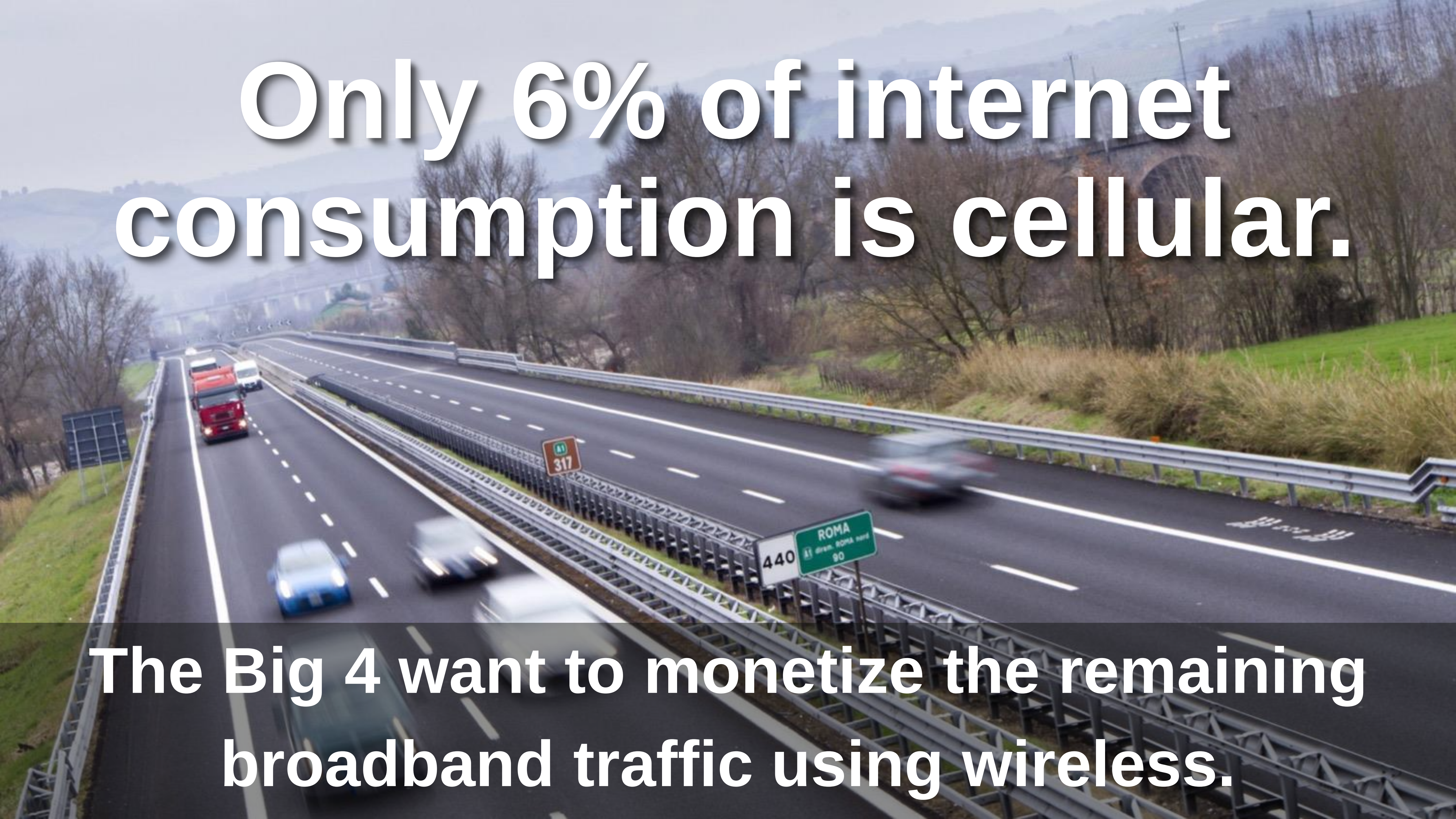
Indoor WiFi

Outdoor WiFi

Mobile

5G

Fixed Wireless


Only 6% of internet consumption is cellular.
The Big 4 want to monetize the remaining broadband traffic using wireless.
317
440
ROMA
90

Changing Patterns of Internet Activity

IoT

Proliferation of Devices

Dramatic Increase in Backhaul

39% **Rural America cannot access broadband***

78% **Developed areas have only 1 option**

* Broadband = 25 Mbps downstream, 3 Mbps upstream

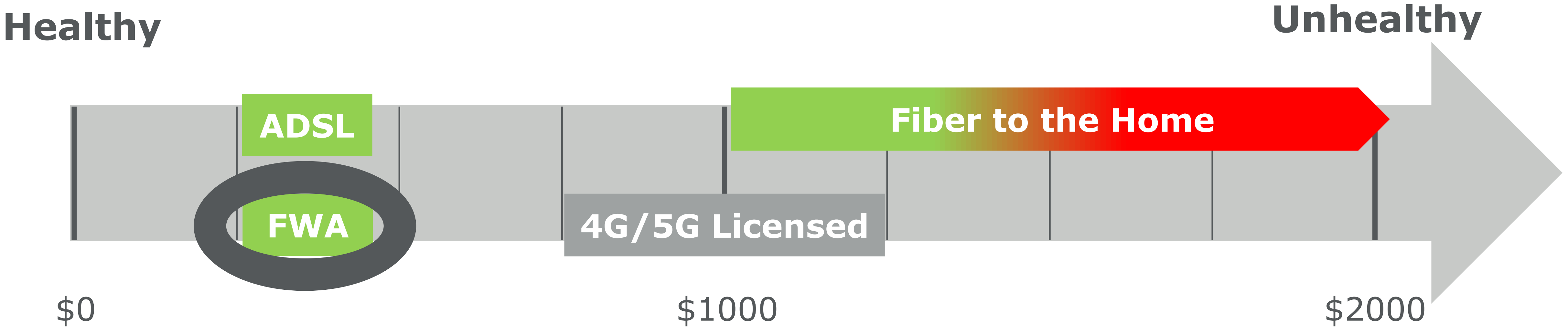
Does everyone really need 1 Gbps?

Consumers don't understand speed

Will typical consumer pay for it?

What's defensible with competition?

Broadband Costs & Time to Market



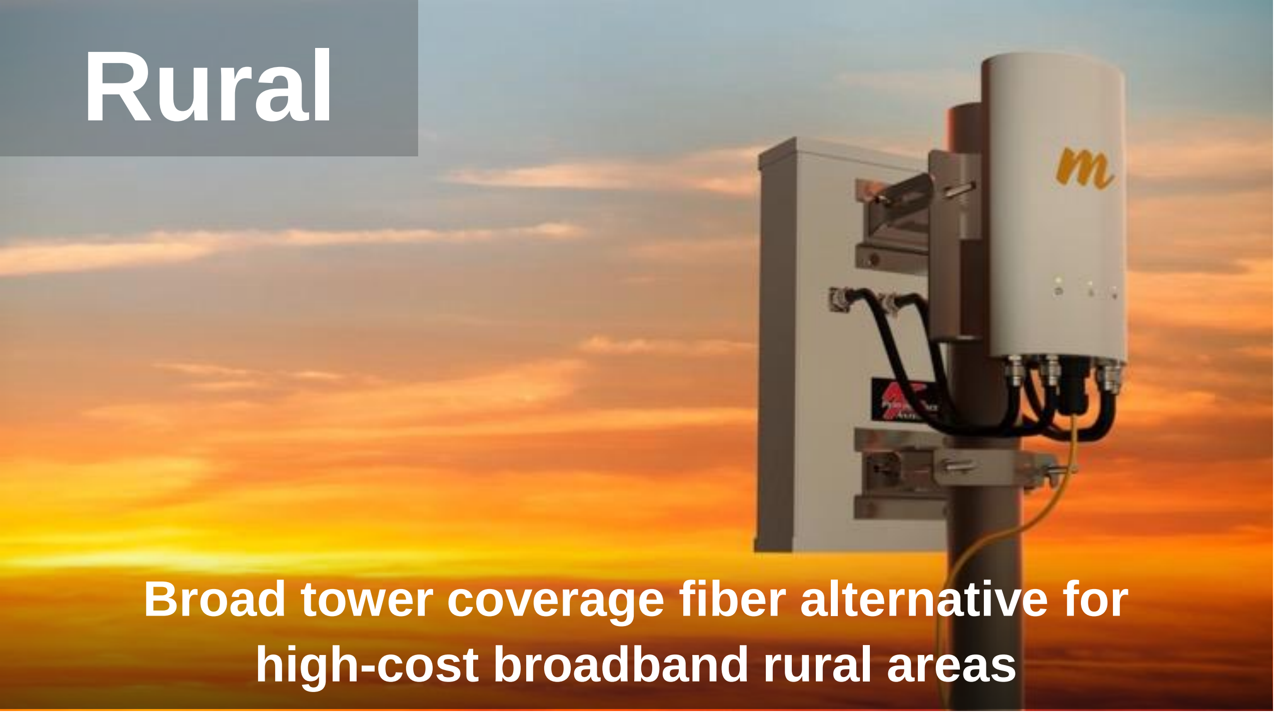
Commercially deployed Fixed-Wireless broadband today:

Urban	up to 1 Gbps	$250/sub
Suburban	up to 300 Mbps	$350/sub
Rural	up to 200 Mbps	$300/sub

USF Connect America Fund II

- $1.5B for 711,389 locations
  - 53% Above Baseline (100Mbps/20Mbps)
  - 19% Gigabit Services (1Gbps/500Mbps)
  - All but 0.25% at least Baseline (25Mbps/10Mbps)
- Majority of Winners to leverage Fixed-Wireless technology
- Top 20 ... $1.186B and 537,540 locations
  - 2/3 to use Fixed-Wireless
  - Represents $893M and 321,636 locations

Winners of the CAF II Auction

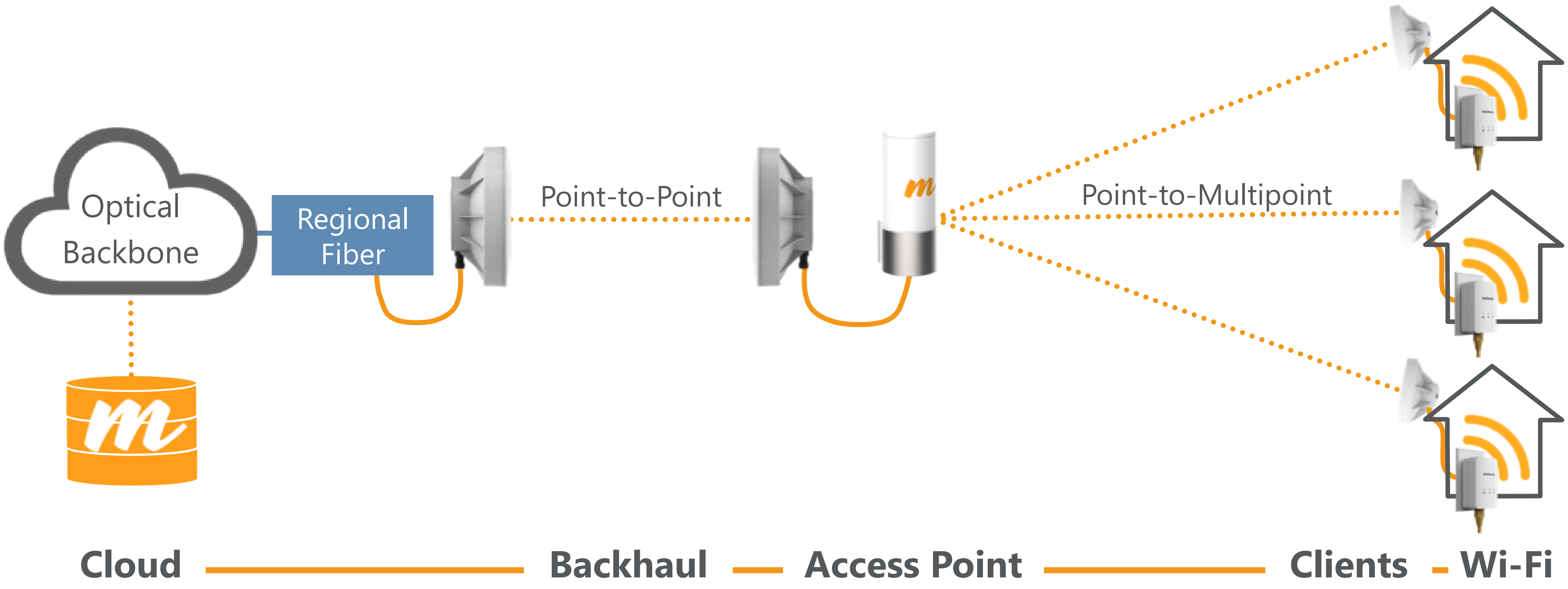

Rural
Broad tower coverage fiber alternative for high-cost broadband rural areas


Suburban
Low-cost alternative in suburban dense markets to FTTN & FTTP. Competition to Cable.

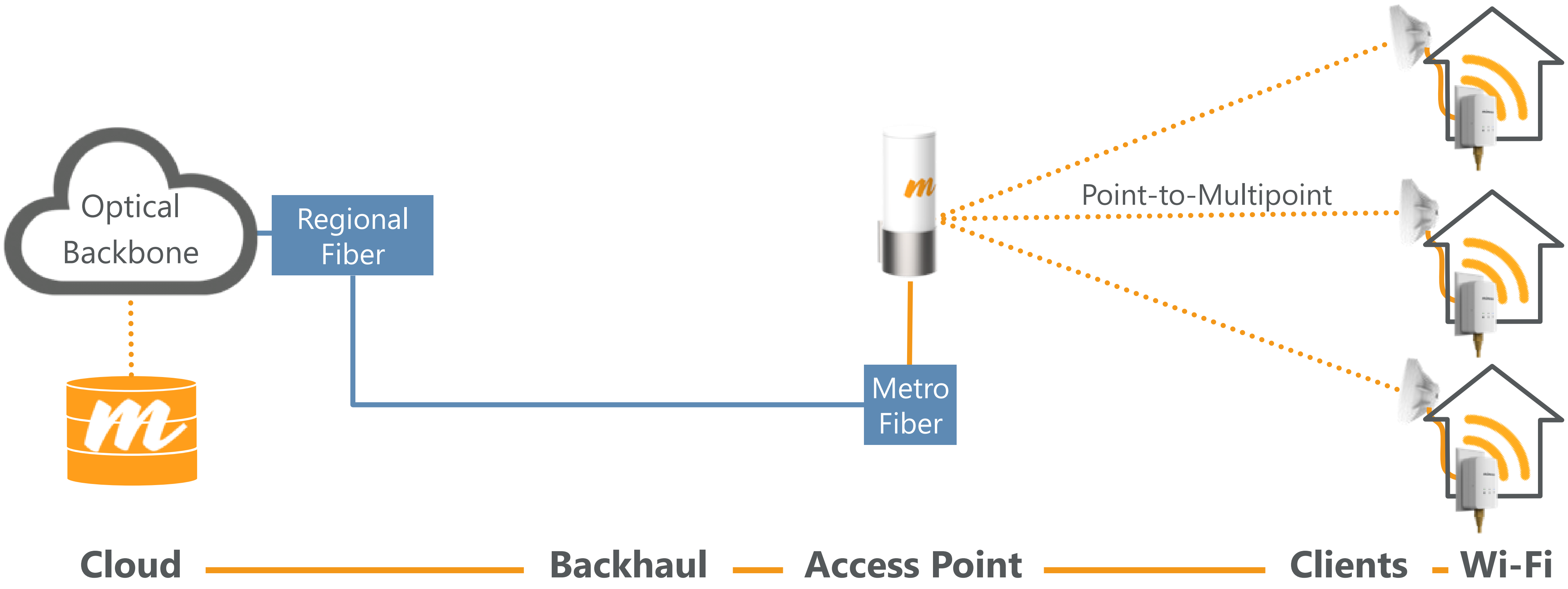

Building-to-Building licensed and unlicensed solution with advanced distribution to units
Urban


Public-Private and Utilities, city-wide Wi-Fi, and Digital Divide
Central Av
Smart Cities

Our 5GHz, 11GHz and 24GHz Fixed wireless solutions connect dense urban and hard-to-reach rural homes with the fastest deploy time and ROI.



Our 5GHz, 11GHz and 24GHz Fixed wireless solutions connect dense urban and hard-to-reach rural homes with the fastest deploy time and ROI.

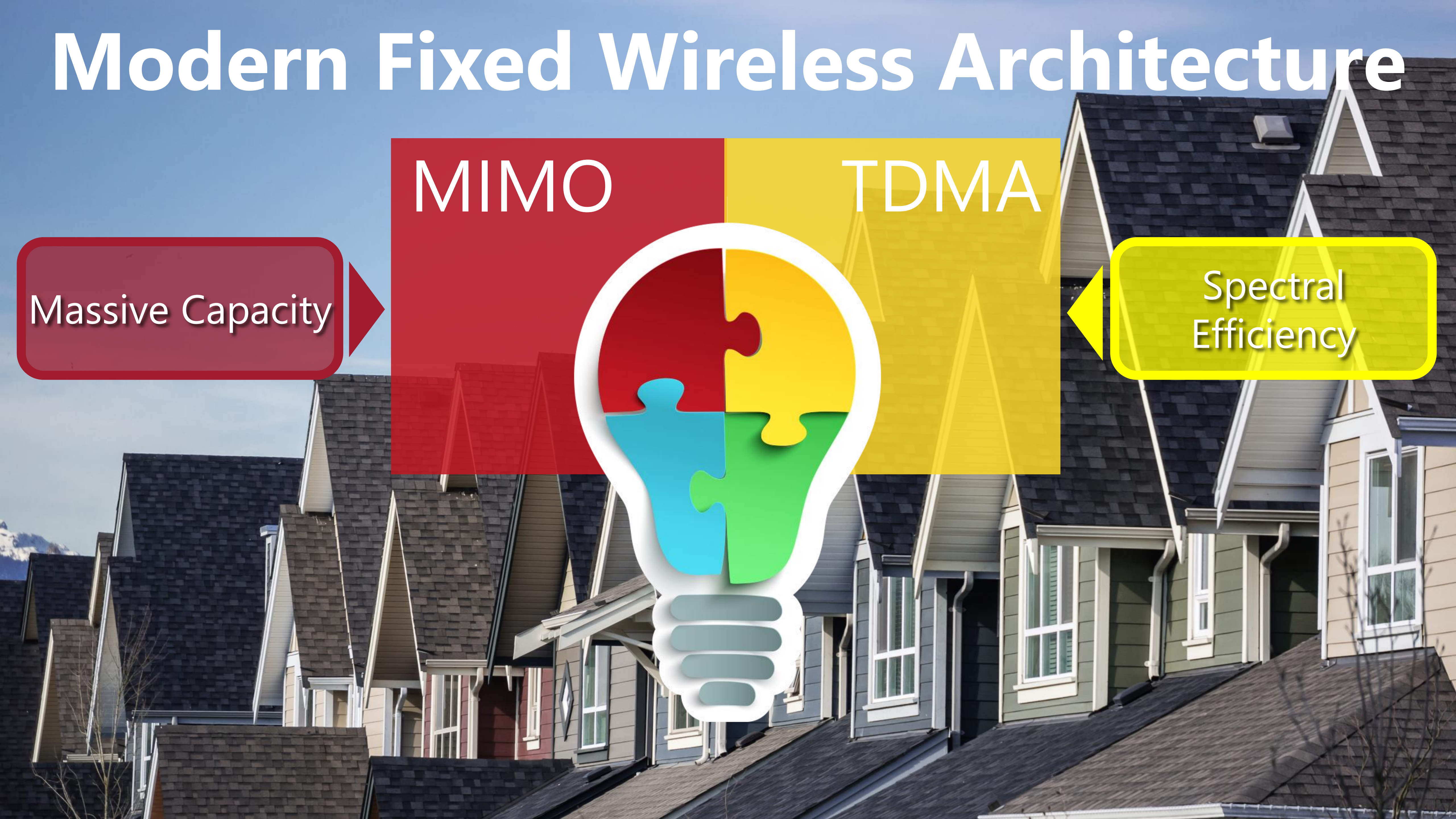


Modern Fixed Wireless Architecture

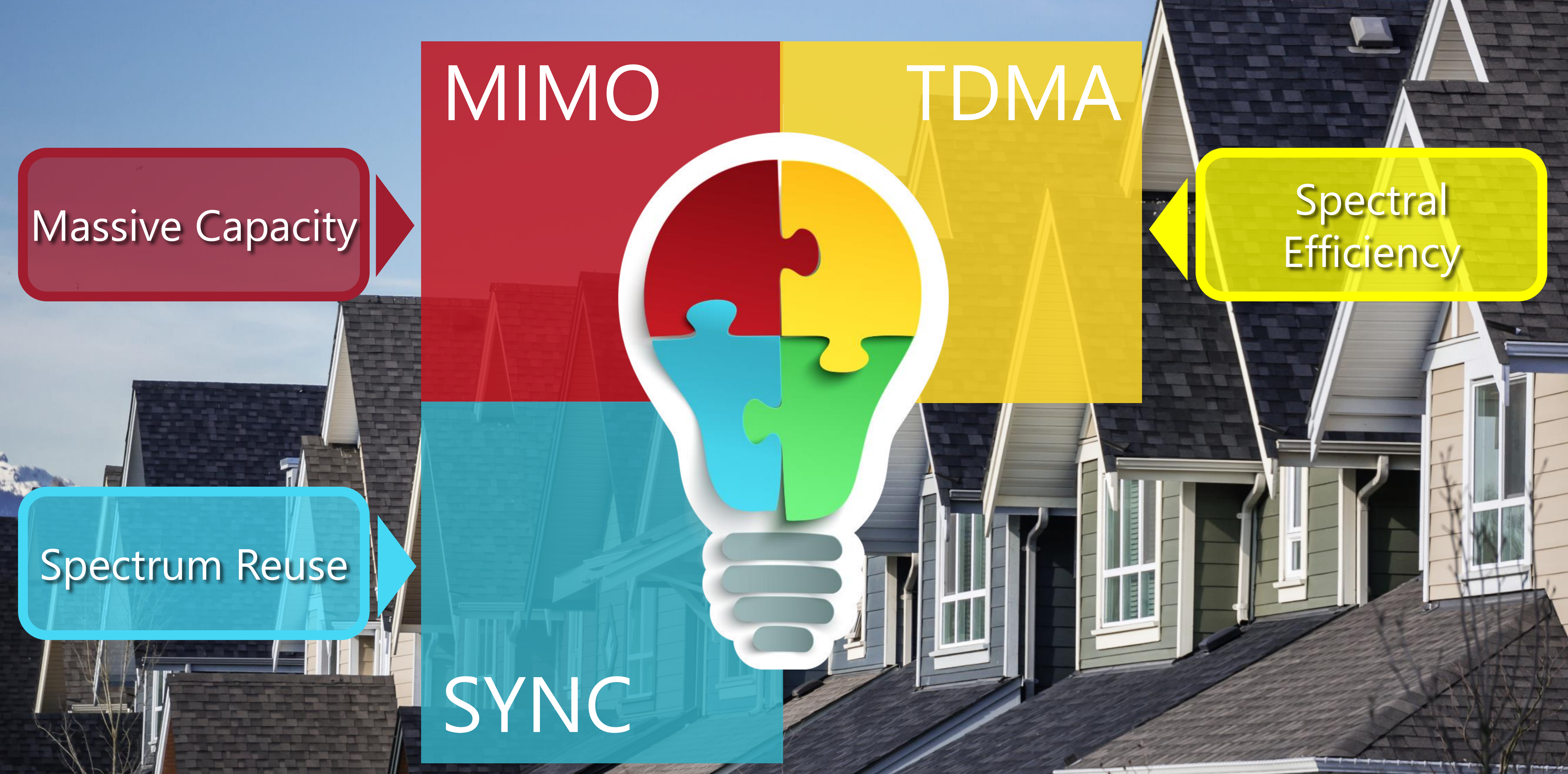
Modern Fixed Wireless Architecture

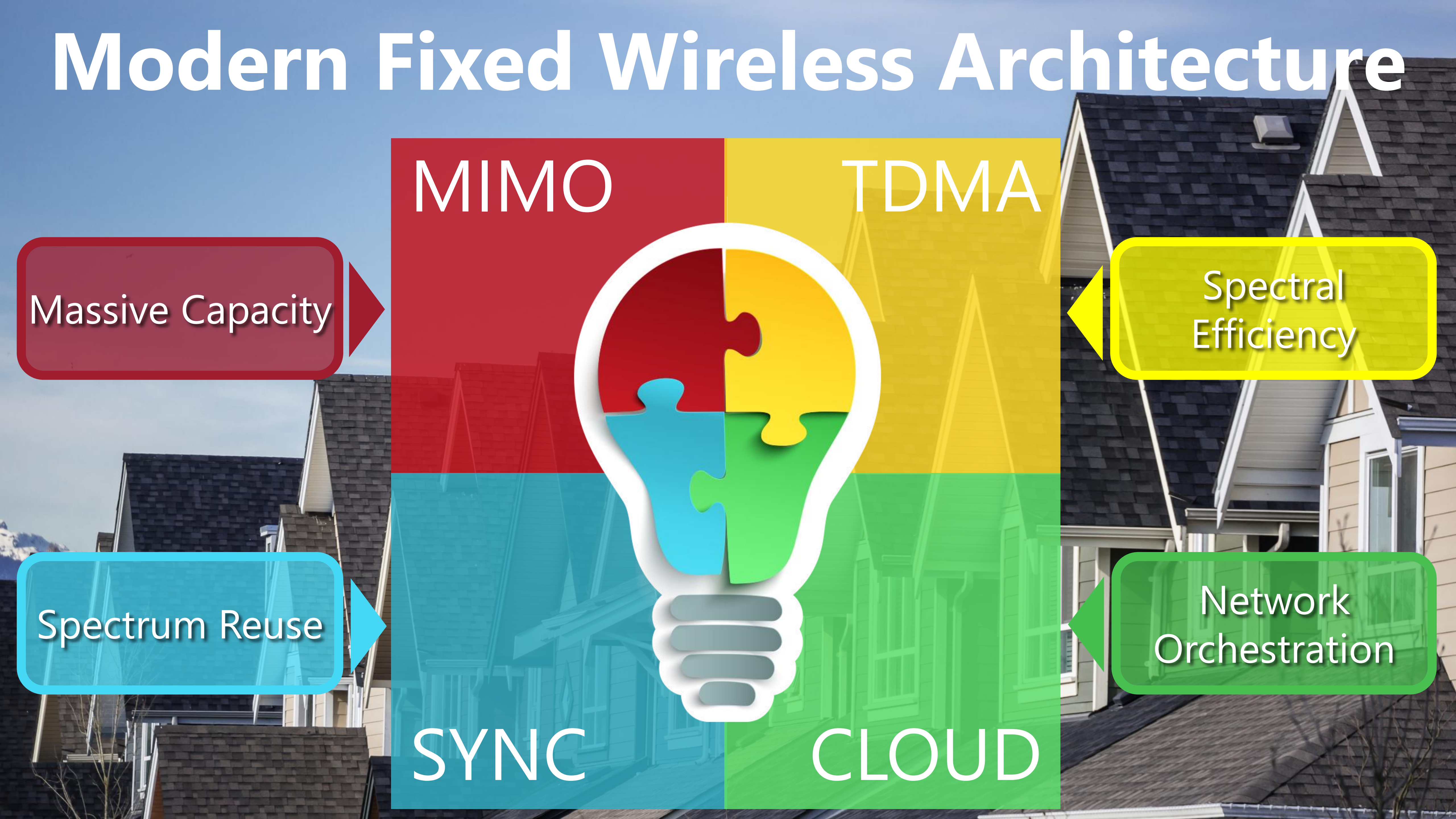
Massive Capacity

MIMO

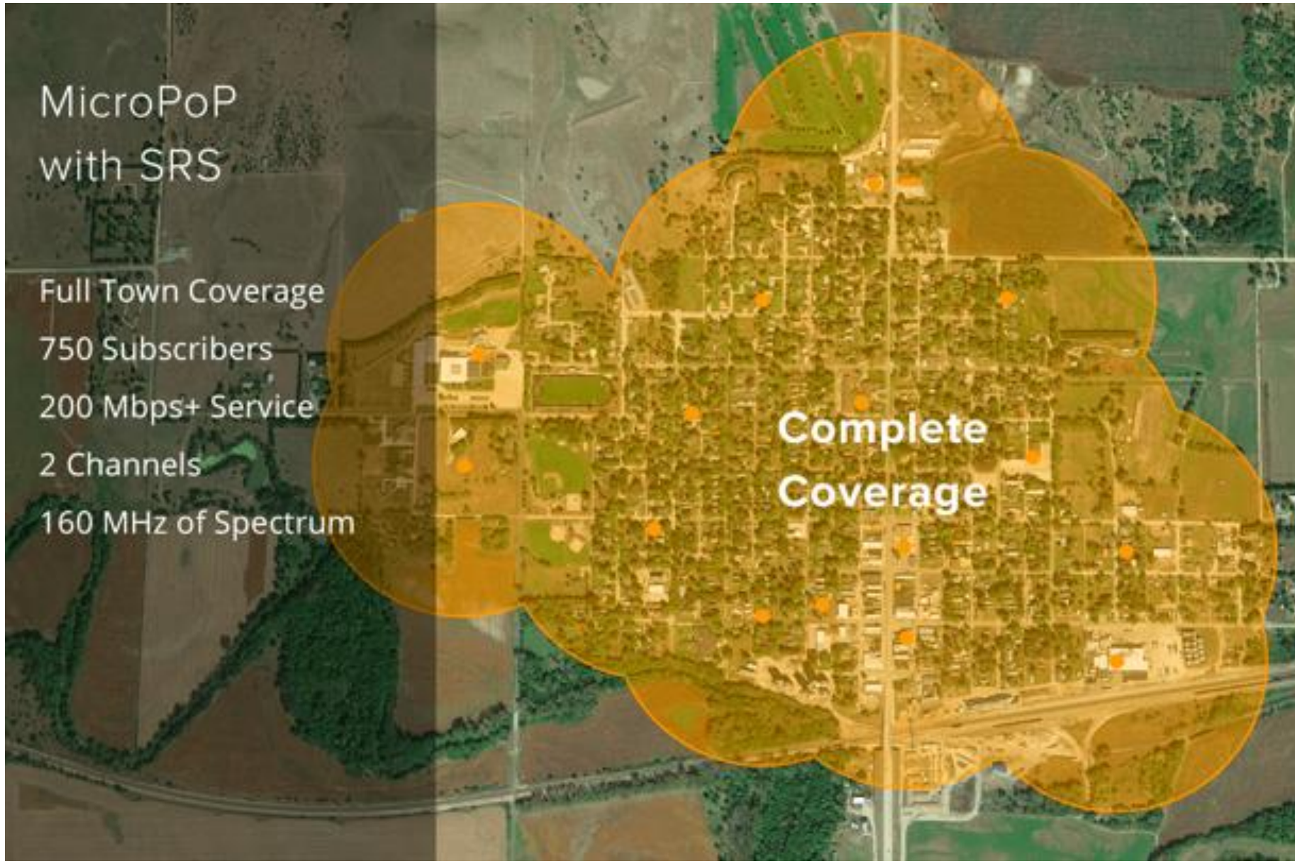

Modern Fixed Wireless Architecture
MIMO
TDMA
Massive Capacity
Spectral Efficiency

Modern Fixed Wireless Architecture




Modern Fixed Wireless Architecture
MIMO
TDMA
Massive Capacity
Spectral Efficiency
Spectrum Reuse
Network Orchestration
SYNC
CLOUD

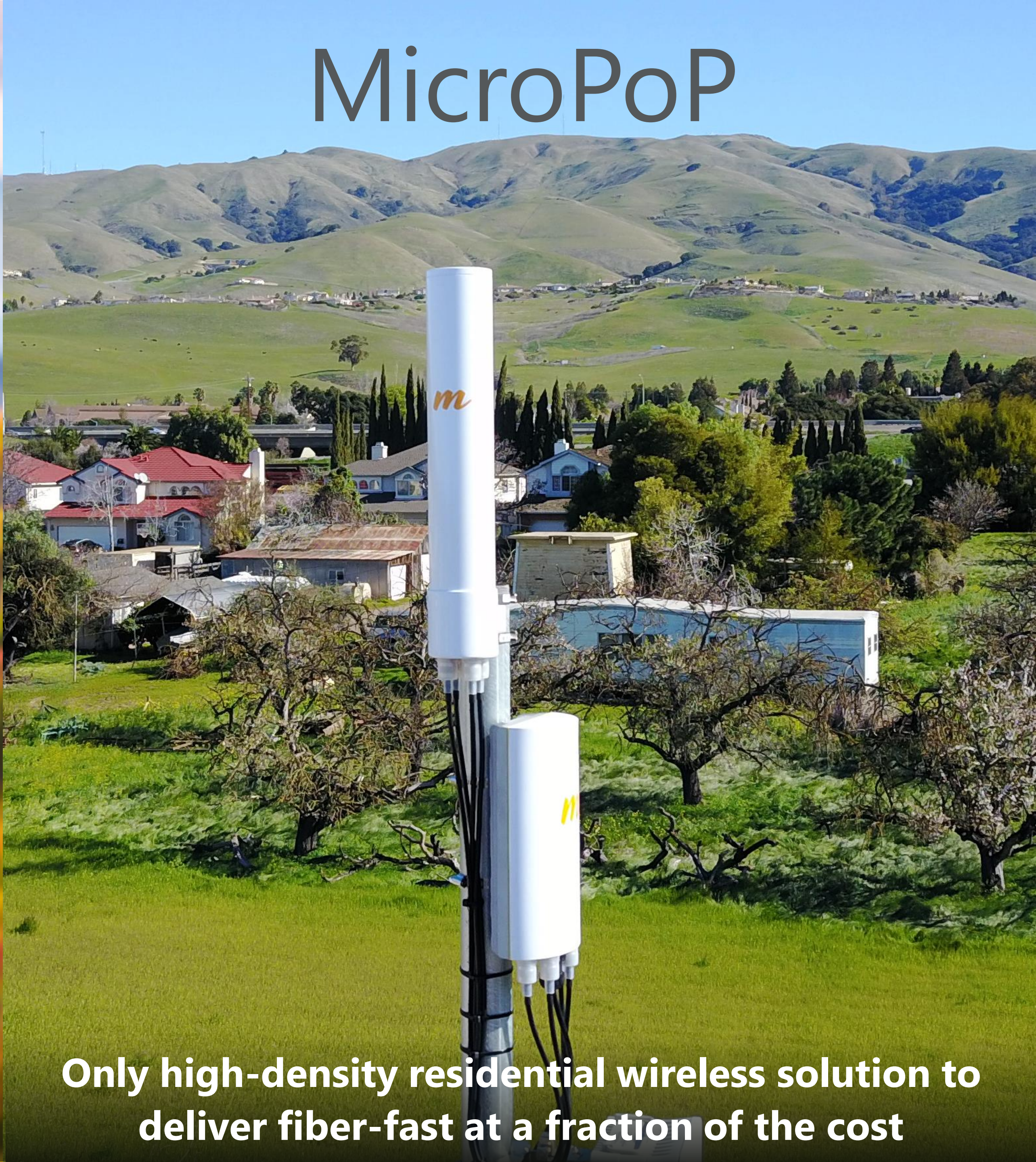
The Power of Spectrum Reuse



Towers

Highest industry tower scalability maximizes user subscriber capacity and speed

MicroPoP



Only high-density residential wireless solution to deliver fiber-fast at a fraction of the cost

C Spire and Mimosa in the 5G News

FierceWireless

WIRELESS TECH 5G IOT

"C Spire's work with Mimosa … part of the company's wider pledge … to use fixed wireless technologies to reach up to 200,000 consumers and businesses across its coverage area."

5G Fixed Wireless Service
120Mbps/50Mbps
$50 per month

There's a new speed in town.

MOBILE BREAKTHROUGH AWARDS

RWA Members deploying Fixed Wireless

Rural Wireless Association Members and Mimosa Networks Collaborate to Close the Digital Divide Across Rural America

SEPTEMBER 11, 2018

Key Members to Deliver Fiber-Fast Wireless Broadband to Unserved and Underserved Subscribers From Montana to Georgia

Santa Clara, CA – In a move demonstrating the strong momentum towards closing the digital divide, six key members of the Rural Wireless Association (RWA) today announced they have chosen Mimosa Networks to deploy fixed wireless solutions across the United States. The Rural Wireless Association is a Washington, DC-based trade association whose members are united in a common goal to drive wireless telecom and broadband policy to strengthen rural America for the benefit of all of America.

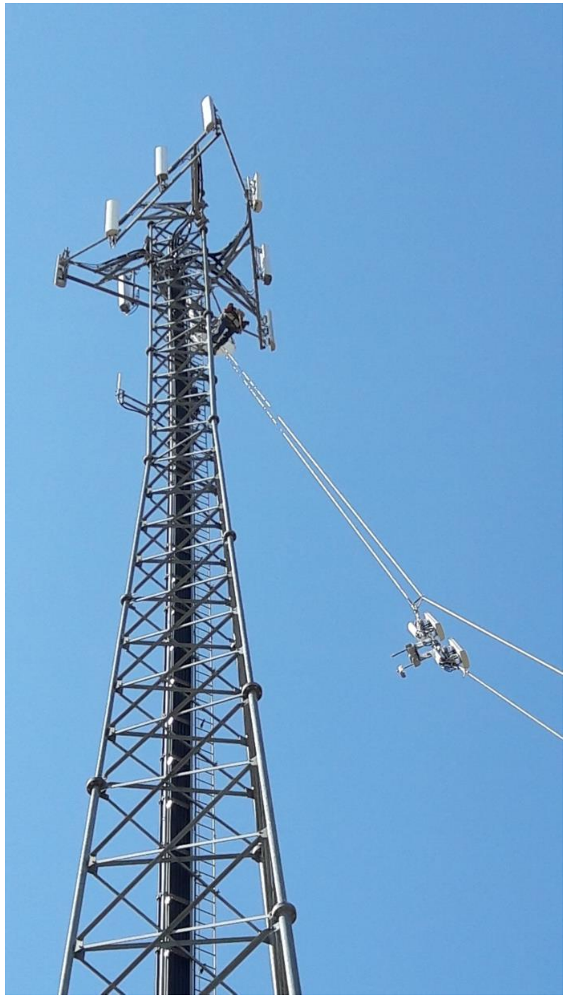
NTCA/RWA Fixed Wireless Example



- 5+ miles
- Sub 6 GHz
- Total CapEx < $300 / subscriber
- Goal of 25/3
- Actual speeds 200+ Mbps/ subscriber

Nemont

NTCA/RWA Fixed Wireless Example



Nemont

Hub-Home MicroPoP

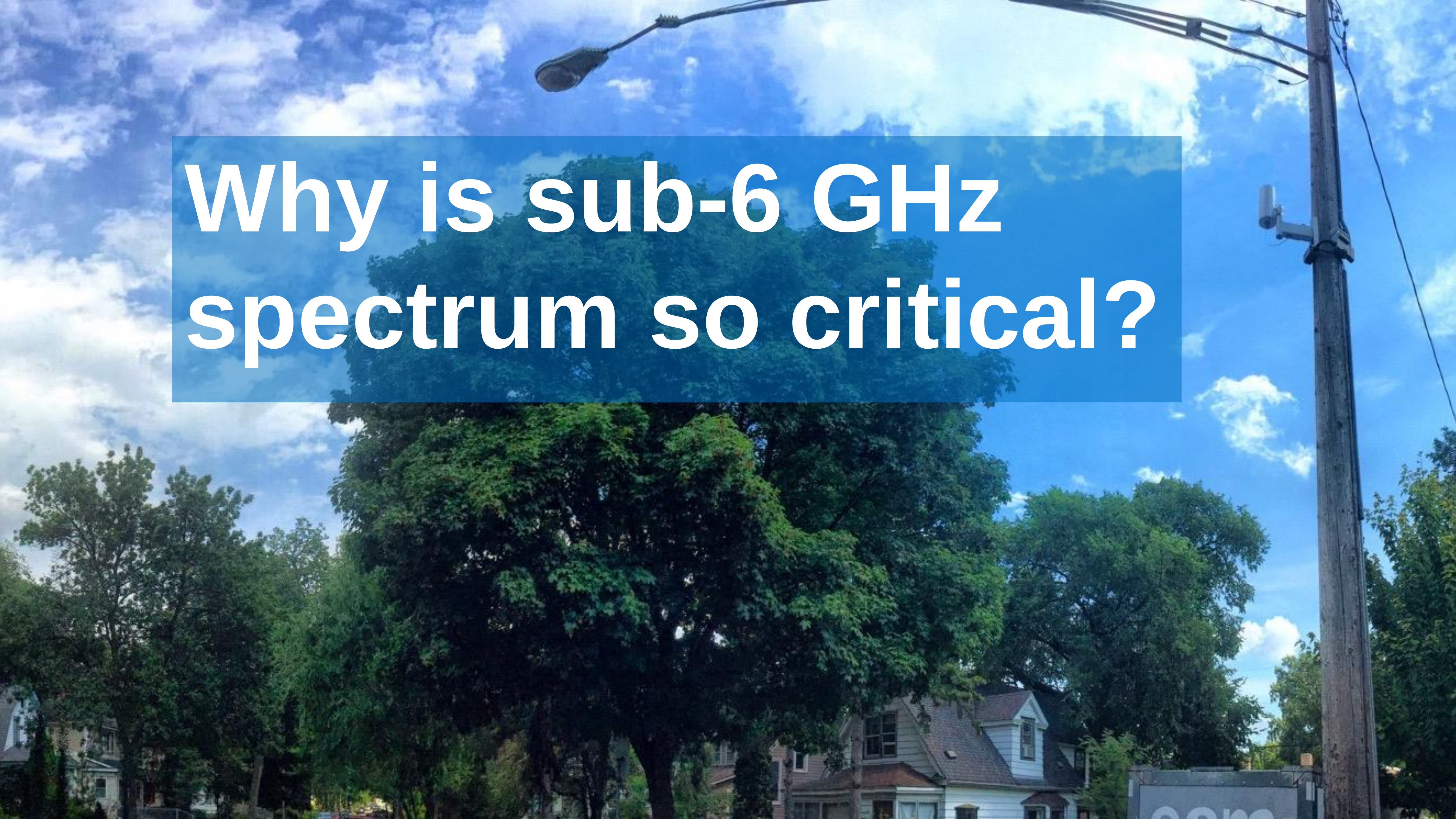
Subscriber Client

- Residential broadband
- 1000 households/mi^2
- 200-300 Mbps service offering
- Offering services competitive with the incumbent providers

Urban Multi-Dwelling Broadband

Battle for the Bands

Why is sub-6 GHz spectrum so critical?



Answer: Physics

More sub-6 GHz is necessary to solve core suburban and rural broadband access

6 GHz Outdoor Unlicensed NPRM!

Federal Communications Commission **FCC-CIRC1810-01**

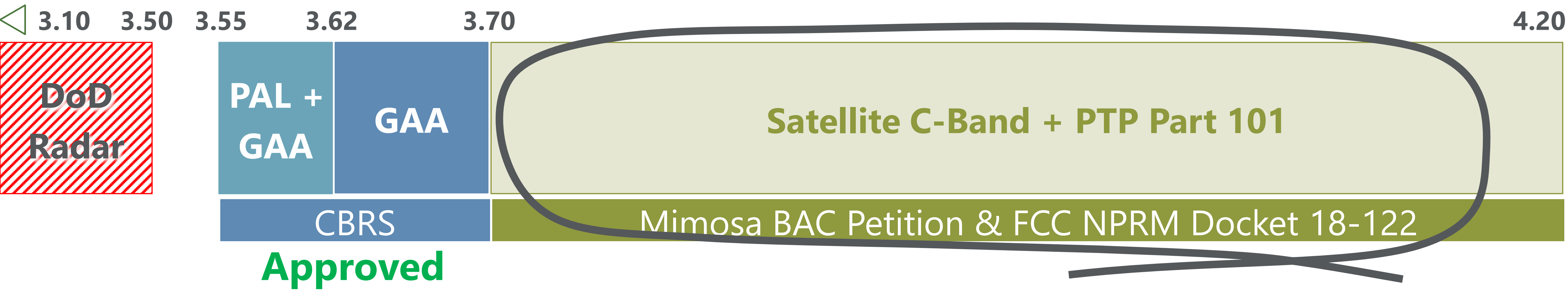
FCC 6 GHz draft NPRM Approved this week to open up Wi-Fi AND outdoor multipoint fixed wireless

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Unlicensed Use of the 6 GHz Band	)	ET Docket No. 18-295
	)	
Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz	)	GN Docket No. 17-183
	)	

NOTICE OF PROPOSED RULEMAKING*

FCC Docket 18-122 - New C-band NPRM

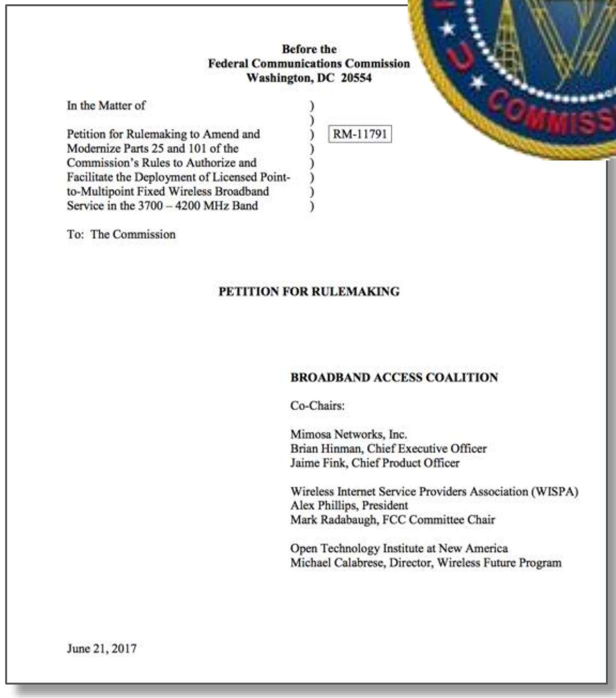


- Incumbent/legacy satellite broadcast industry downlink band is heavily underutilized and is optimal for more efficient terrestrial sharing
- 3.7-4.2 GHz represents fiber-speed opportunities up to 1 Gbps
  - FCC proposes clearing lower portion of band for 5G Mobile use and compensating satellite users via auction or private market deals
  - FCC proposes SHARING remaining in use spectrum with remaining satellite sites, coordinated with Fixed Wireless terrestrial services
- New rules likely to be completed by end of 2019

Mimosa Led FCC 3.7-4.2 GHz C-band Petition

Broadband Access Coalition

- 35+ Members proposing Fixed Wireless sharing with satellite
- Key support from Google, Microsoft, Cincinnati Bell, Frontier, Windstream, Consolidated, Rise, WISPA, DSA, NTCA, RSA and more.
- 500 MHz of possible sharing
  - Coordinate multipoint fixed wireless under Part 101
  - Protect incumbent satellite usage
  - Complementary to share for urban capacity 5GHz mobile use
  - Will accelerate broadband in the rural


Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of

Petition for Rulemaking to Amend and Modernize Parts 25 and 101 of the Commission's Rules to Authorize and Facilitate the Deployment of Licensed Point-to-Multipoint Fixed Wireless Broadband Service in the 3700 – 4200 MHz Band) RM-11791

To: The Commission

PETITION FOR RULEMAKING

BROADBAND ACCESS COALITION

Co-Chairs:

Mimosa Networks, Inc.
Brian Hinman, Chief Executive Officer
Jaime Fink, Chief Product Officer

Wireless Internet Service Providers Association (WISPA)
Alex Phillips, President
Mark Radabaugh, FCC Committee Chair

Open Technology Institute at New America
Michael Calabrese, Director, Wireless Future Program

June 21, 2017

Fixed-Wireless Solutions

- Reliable Ultra-Broadband Speeds
- Fastest Time-to-Market
- Lowest Installed CAPEX solution
- Fastest Time-to-Service
- Fastest Time-to-Revenue

Delivering amazing internet for the wireless generation

New Optical Technologies for Future 5G Transport and Multi-Service Access

Ronald Heron
Lead Technology Strategist| Nokia
ronald.heron@nokia.com

Bio:

Ronald Heron is responsible for next generation fiber technology strategies in the Nokia CTO team. As an engineering graduate from Concordia University in Montreal, he has assume several design and strategy roles in broadband access, optical and radio networks, first at Bell Canada, then Alcatel-Lucent and now Nokia. He holds patents and is an active contributor to standards and industry fora including FSAN, European FTTH Council and the Broadband Forum. He frequently speaks at access and fiber conferences around the world.

New Optical Technologies for Future 5G Transport and Multi-Service Access

2018-10-28

Ronald Heron

Lead Technology Strategist

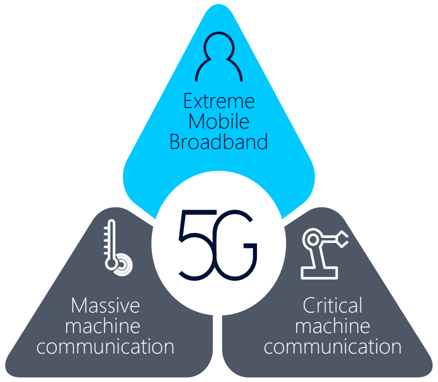
Fixed Networks CTO Team

Nokia

Outline

- The 5G Wave
- Proliferation of cells
- New split options: F1 and eCPRI
- Bandwidth considerations for TDM / TWDM
- Latency considerations for TDM / TWDM
- Deployment scenarios and a possible role for P2P WDM
- SDN, Cloudification and Slicing
- Conclusions

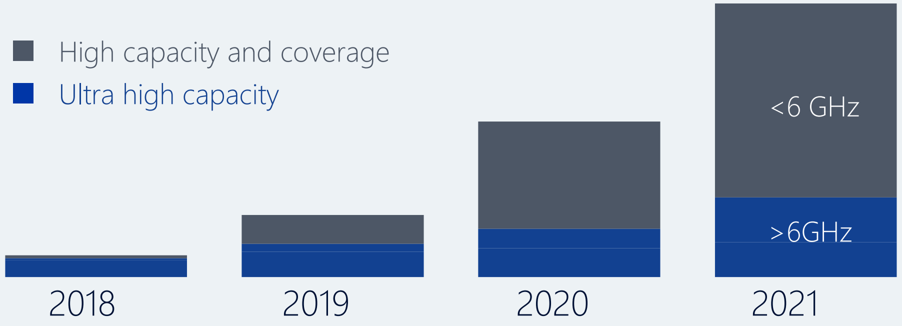
Evolution of Mobility

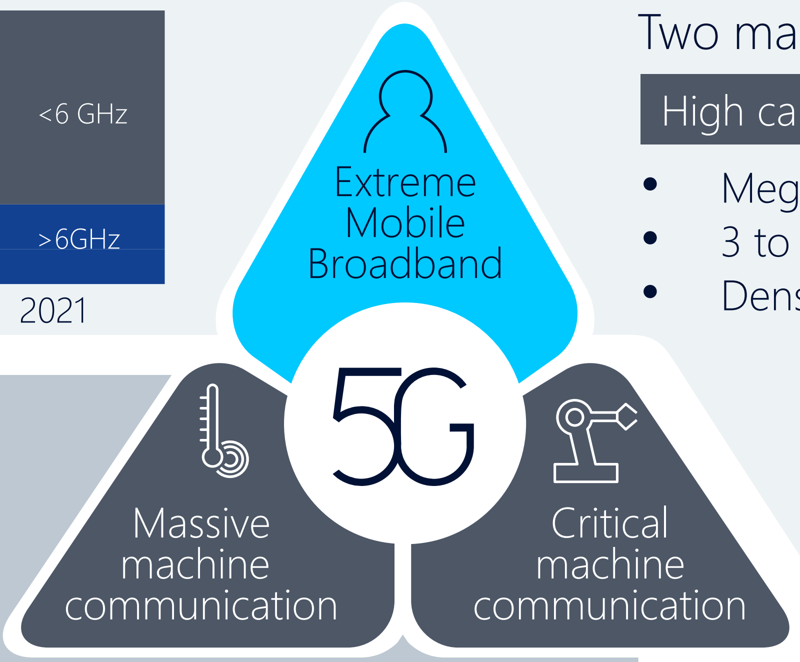


1G	2G	3G	4G	5G
1980-90s	1992	2001	2010	2018+
- Analog Voice	- Digital Voice - Simple Data	- Digital Voice - Some data consideration	- Designed primarily for data	- Extreme mobile BB, - Massive Machine (IOT), - Critical Machine (robotics)
14.4 Kbps	<0.5Mbps	~5-15Mbps	100Mbps-1Gbps	10G+ and very low rates. PLUS: low latency, reliability, ubiquity

5G market will start with enhanced mobile broadband

Enhanced mobile broadband market starts





Machine markets will start 2022+

- Need for coverage layer and low cost devices
- No immediate market need for new IoT connectivity

Two market segments

High capacity and coverage

- Megacity capacity densification
- 3 to 6GHz ~100MHz BW
- Dense urban grid – *3GPP Rel 15 NSA*

Ultra high capacity

- Ultra dense use cases
- cm/mmWave
- Short range, LOS preferable - *3GPP Rel 15 SA*

NOKIA

The Phenomena of the Cord Cutters and Cord Nevers

- Landline Phone → mobile and VoIP
  - Migration has been happening for 20 years

- Pay TV → IPTV, OTT & Netflix on small screens
  - Traditional cable, satellite and phone companies struggling to maintain subscribers

- Fixed BB service → evolving to LTE and 5G
  - Growth is modest as market begins to saturate
  - Flat-rate mobile data plans are becoming attractive

A new form of Broadband is mobile.
Fixed broadband will be feeding mobile nodes

Outline

- The 5G Wave
- Proliferation of cells
- New split options: F1 and eCPRI
- Bandwidth considerations for TDM / TWDM
- Latency considerations for TDM / TWDM
- Deployment scenarios and a possible role for P2P WDM
- SDN, Cloudification and Slicing
- Conclusions

NOKIA

Proliferation of small cells

	Traffic today	LTE <6GHz	5G cm spectrum	5G mm spectrum
Spectrum	20-60 MHz	200 MHz	600 MHz	2 GHz
Intercell distance	225m	140m	80m	57m
Sites/km^2	15	50	150	300

3x 3x 2x

=10% residential FTTH in urban area

"It is a small step for FTTH but a huge leap for Mobile"

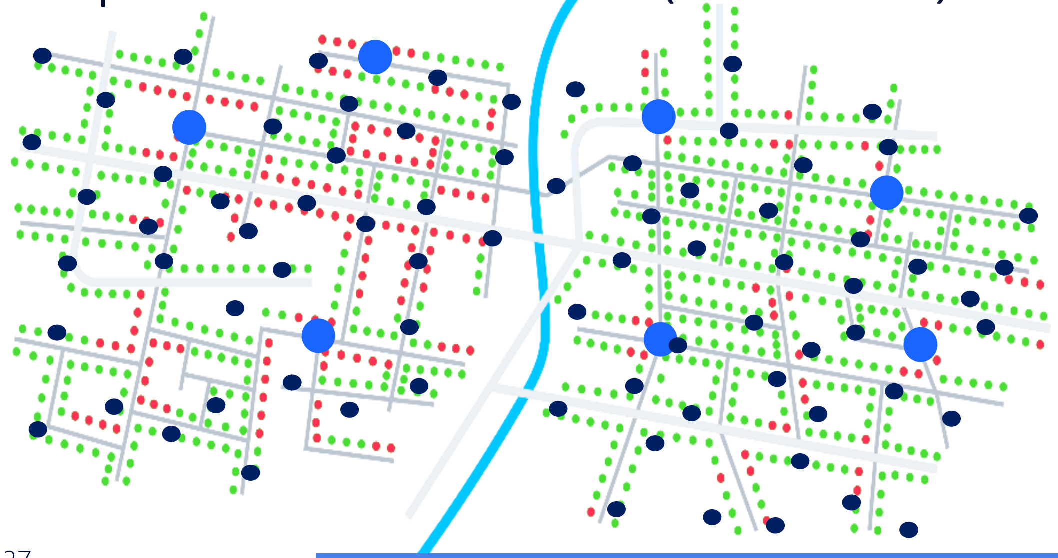
NOKIA

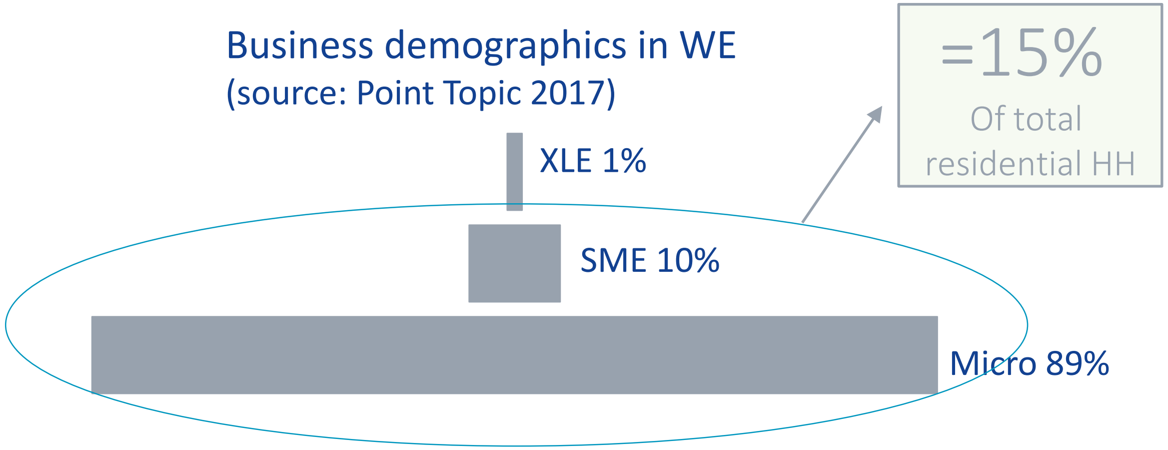
5G Cells Go Deep

	Fiber Application	# Terminals / Distrib. Area	Civil works savings*
●	Residential FTTH	500 homes	
●	Businesses (MicroBus + SME + XLE)	50-100 bus. (~15%)	$ 7k / bus
●	Large cells (400m+ spacing)	1-5 cells (~ 1%)	$ 60k / cell
●	Small cells (100-200m spacing)	10-50 cells (~10%)	$ 25k / cell

*Avoided cost of retrenching

Sample FTTH Distribution Area (~500 homes)





There is incentive to leverage the FTTH infrastructure ...but how?

NOKIA

Outline

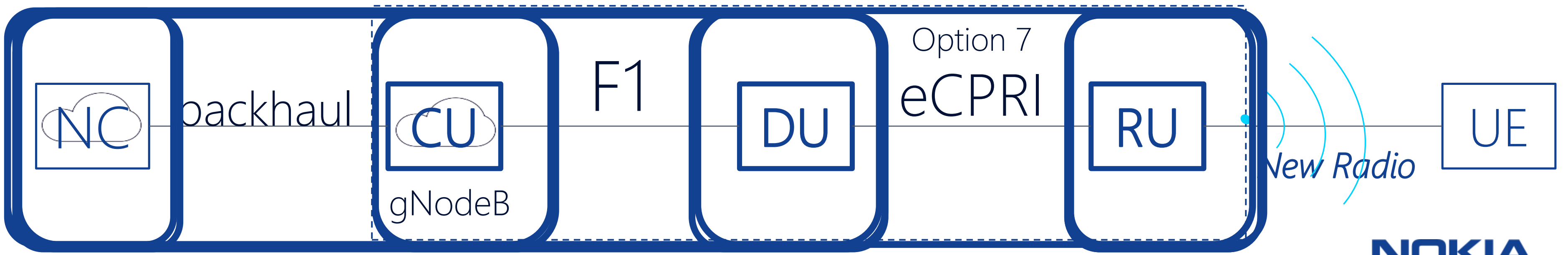
- The 5G Wave
- Proliferation of cells
- New split options: F1 and eCPRI
- Bandwidth considerations for TDM / TWDM
- Latency considerations for TDM / TWDM
- Deployment scenarios and a possible role for P2P WDM
- SDN, Cloudification and Slicing
- Conclusions

NOKIA

Centralization of Functionality (x-haul variants to transport)

X-Haul variant	At BBU (centralized)	At RRH (antenna) (distributed)	Transport Requirements: Bandwidth	Transport Requirements: Max RTT latency	Transport Requirements: Suitable PON technology
Backhaul Full Distributed	SON OAM APPS — Ethernet	RRC PDCP, RLC, MAC (Upper MAC, Lower MAC), PHY (Upper PHY, Lower PHY), RF	1x Variable bit rate	>20mSec	TDM PON TWDM PON
Midhaul (F1) 3GPP – PDCP/RLC split "Cloudified BTS"	SON OAM APPS, RRC PDCP — F1 Ethernet	RLC, MAC (Upper MAC, Lower MAC), PHY (Upper PHY, Lower PHY), RF	1.2x Variable bit rate	<2.2 mSec	TDM PON TWDM PON
Fronthaul (Option 7 / eCPRI) Phy split "Fully cloudified BTS"	SON OAM APPS, RRC PDCP, RLC, MAC (Upper MAC, Lower MAC), PHY (Upper PHY) — eCPRI Ethernet	PHY (Lower PHY), RF	~5-10x Variable bit rate	<0,25 mSec	PtP WDM PON TDM PON - tbc TWDM PON - tbc

NC : 5G New Core (virtualized)
CU : Central Unit (may be virtualized)
DU : Distributed Unit
RU : Radio Unit
UE : User Equipment



NOKIA

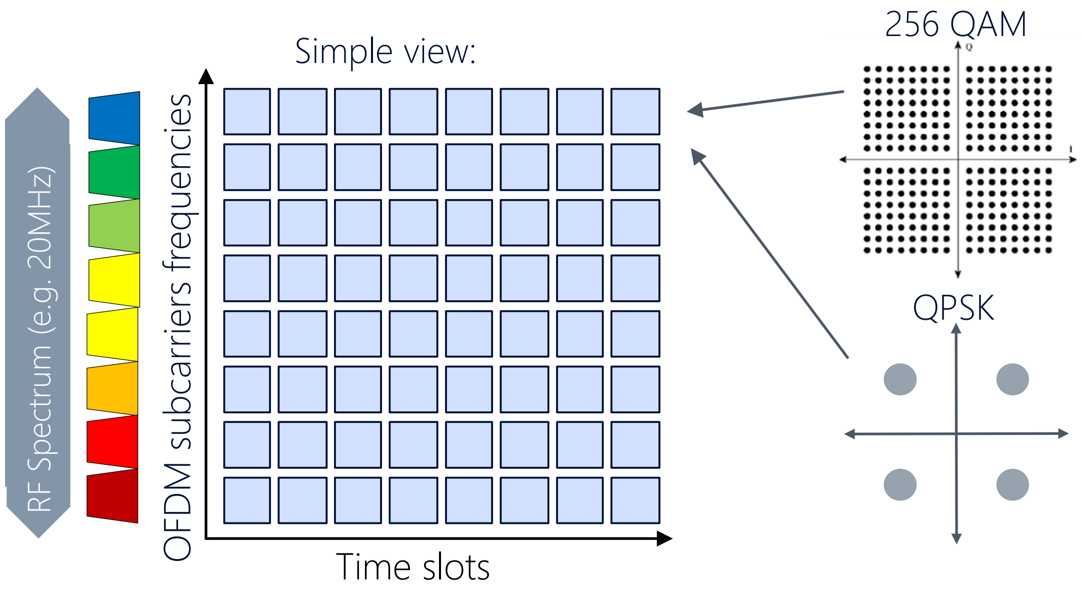
Outline

- The 5G Wave
- Proliferation of cells
- New split options: F1 and eCPRI
- Bandwidth considerations for TDM / TWDM
- Latency considerations for TDM / TWDM
- Deployment scenarios and a possible role for P2P WDM
- SDN, Cloudification and Slicing
- Conclusions

Some 5G Concepts affect transport bandwidth

OFDM and QAM signals

- Spectrum band is divided into OFDM subcarriers (Orthoganal Freq Div Mux'ing)
- Each subcarrier using N-QAM to modulate data (depending on noise of channel)
- Frequency and Time interleaved with pre-coding and FEC



Massive MIMO

- Base station has many small antennae and transmitters (arrays) – Spatial muxing
- Spectrum is reused using orthogonal signals
  - → improved spectrum efficiency
- Beam forming using multiple ant. to UE
  - → improved gain for UE
  - → improved data rate for UE

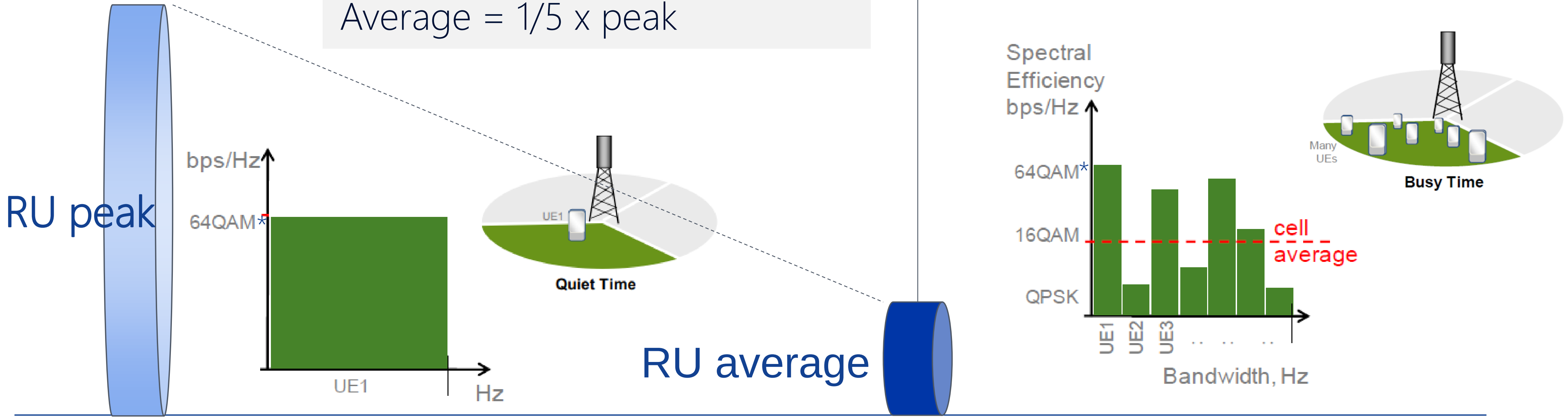
Sketch from
Dr. Emil Björnson
Linkoping University

Radio capacity (transport bandwidth) determined by:
RF Spectrum, QAM order and the number of independent MIMO streams

NOKIA

Relation between RU peak and RU average air capacities

NGMN recommendation (LTE)
Average = 1/5 x peak



RU peak

- Single UE, perfect channel
- Dependent on
  - QAM level
  - spectrum width (e.g. 20, 40GHz…)
  - Number of MIMO layers

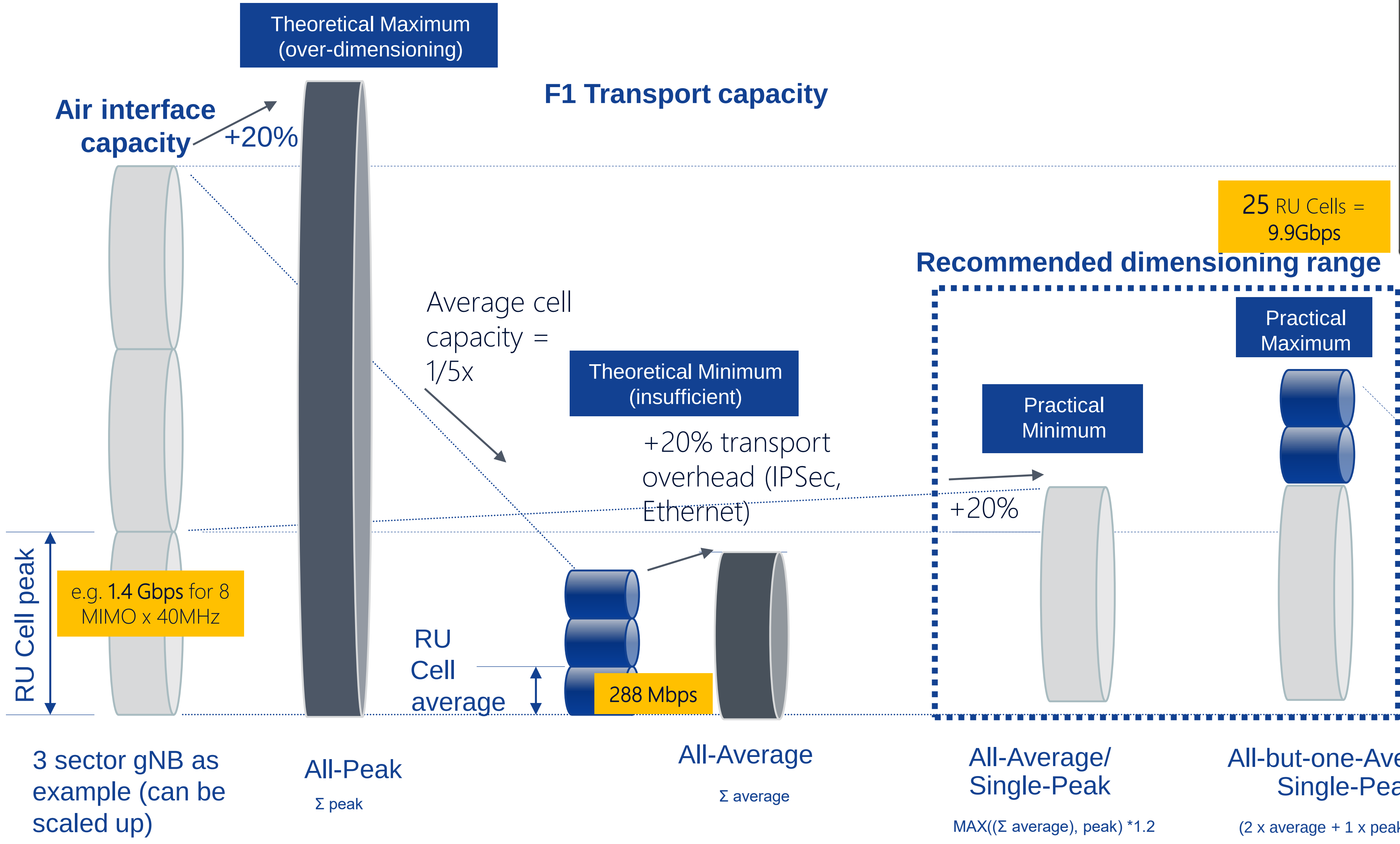
RU average

- Realistic max. capacity during peak hour, whether used or not.
  - E.g., this corresponds to ~2.5 Gb/s in GPON downstream, which is rarely if ever used.

*Figure is from LTE. 5G will support up to 256 QAM

NOKIA

Estimating F1 Transport Capacity



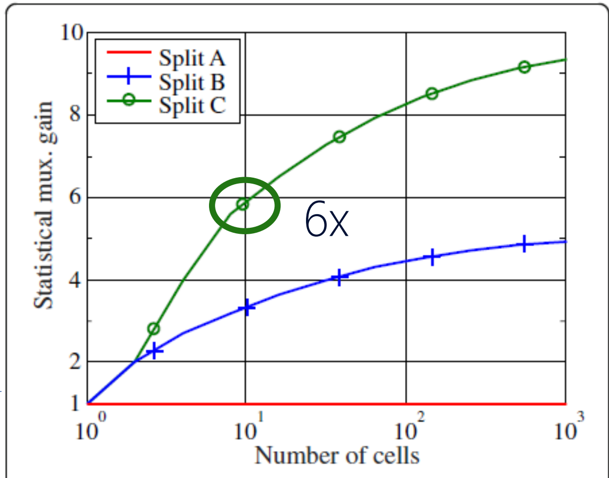
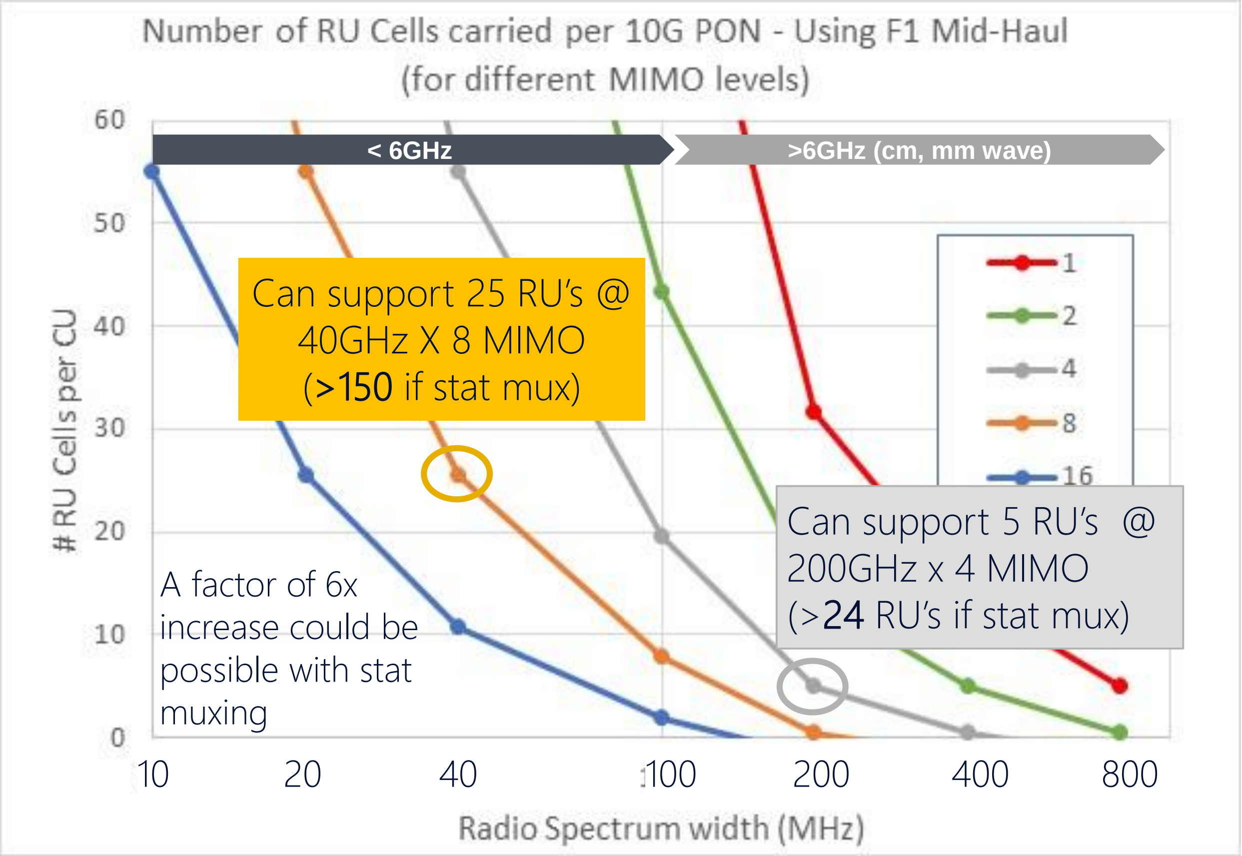
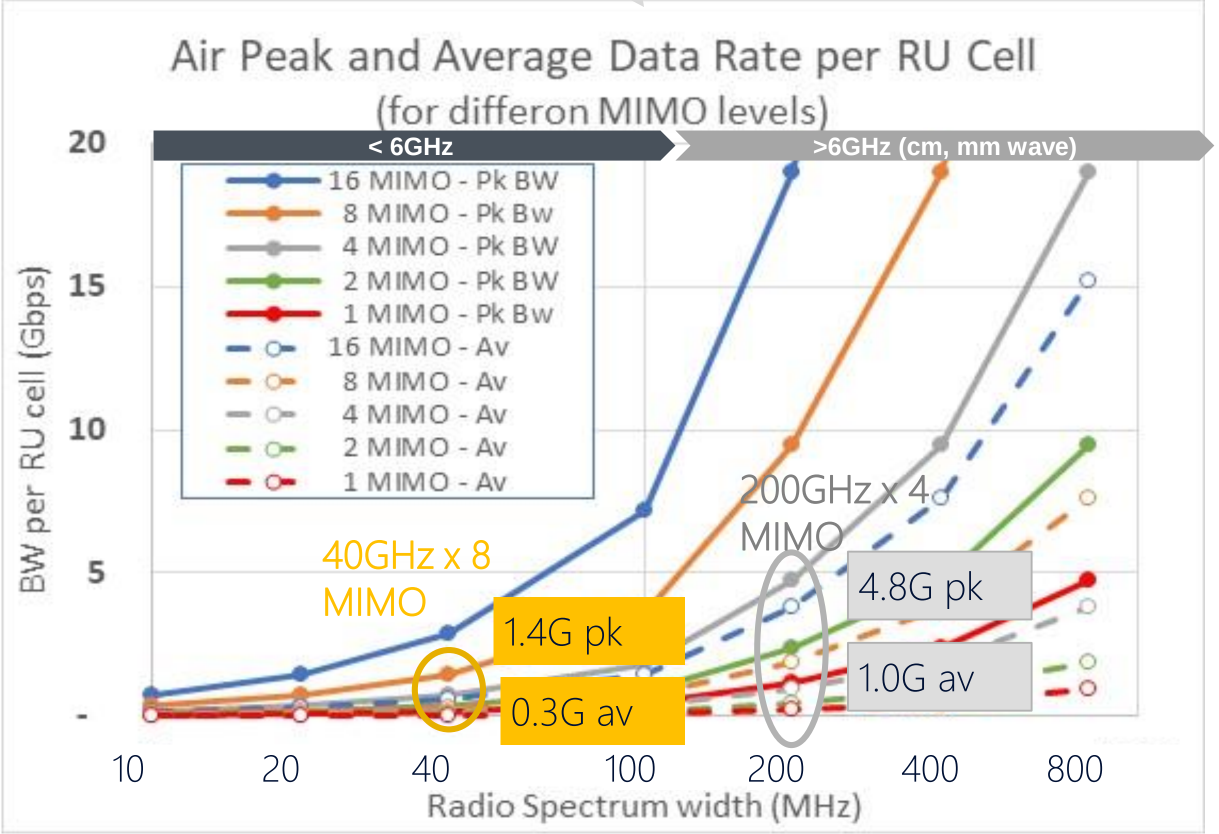


Fig. 8 Statistical multiplexing gains for high-load scenario

Bartelt et al. EURASIP J. Wireless Communications and Networking 2017:89

Estimating the Capacity of a PON to Transport **F1** Traffic

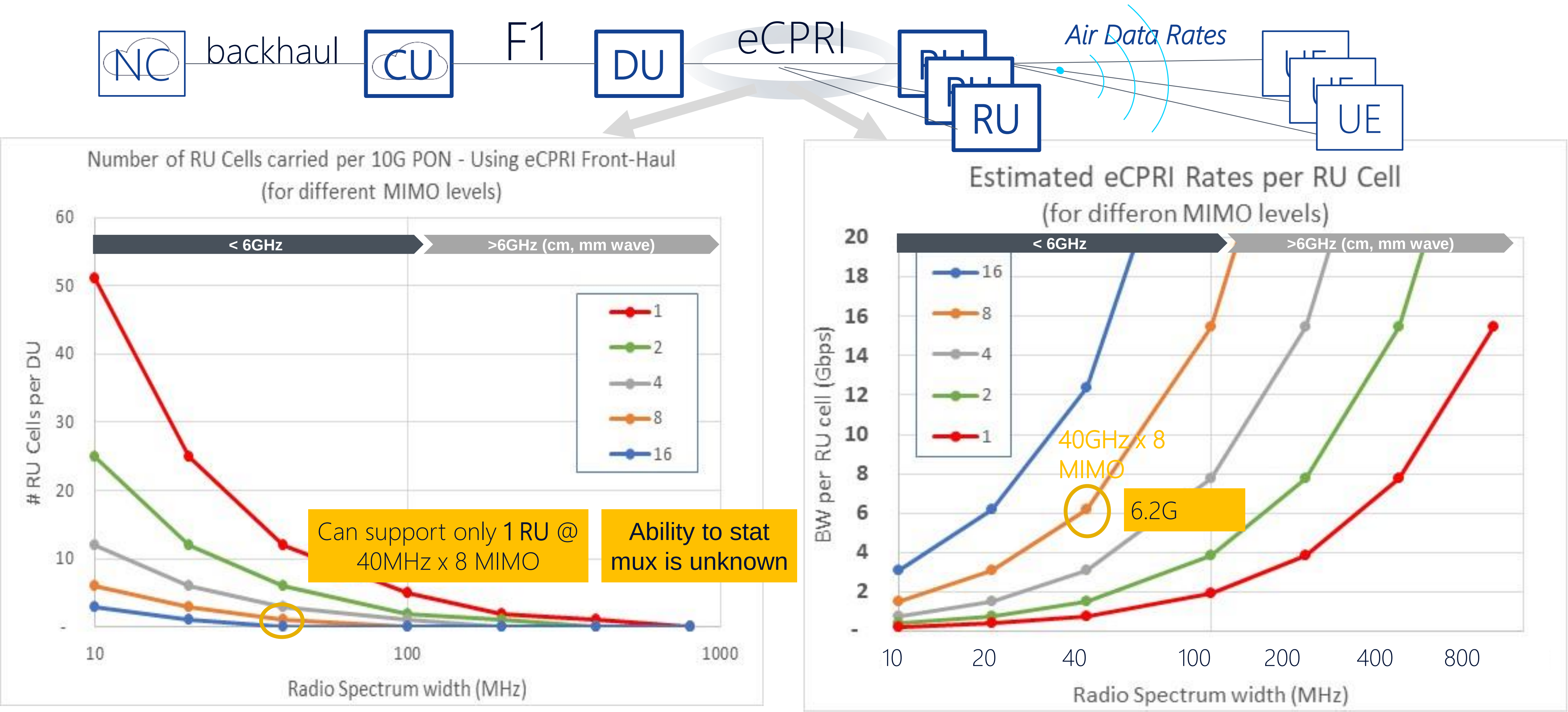




XGS & TWDM are well suited for many F1 applications (esp if stat mux is leveraged)

NOKIA

Estimating the Capacity of a PON to Transport **eCPRI** Traffic



TDM and TWDM PON can support a limited number of RU's. HSP will help. WDM could play a role.

Outline

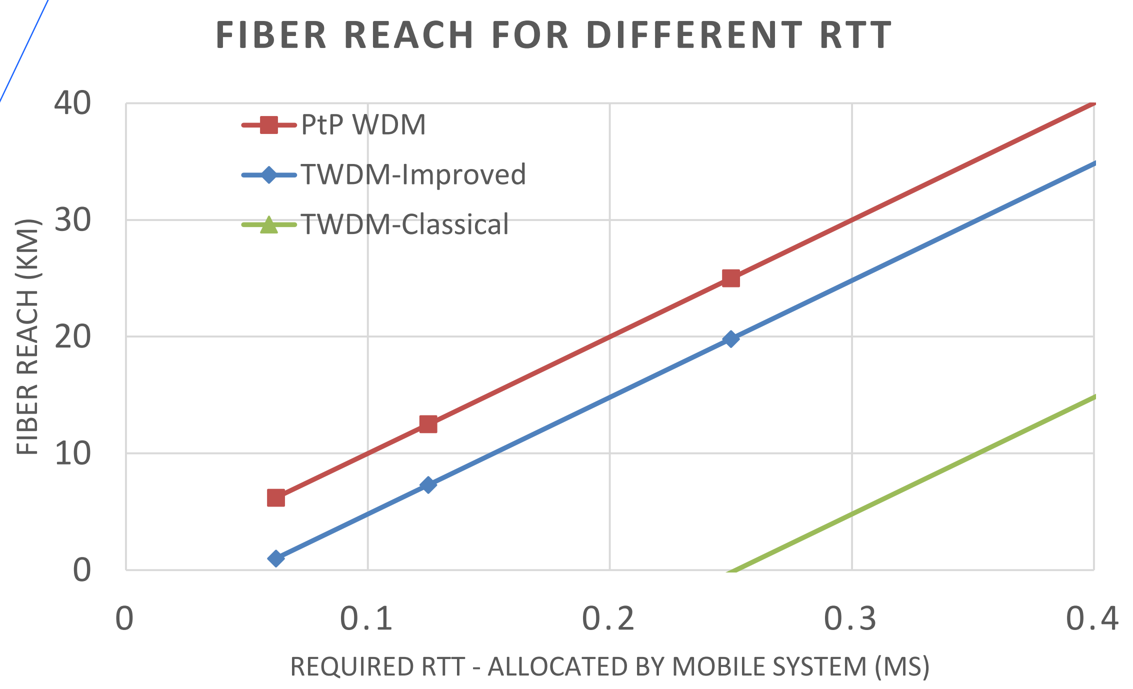
- The 5G Wave
- Proliferation of cells
- New split options: F1 and eCPRI
- Bandwidth considerations for TDM / TWDM
- Latency considerations for TDM / TWDM
- Deployment scenarios and a possible role for P2P WDM
- SDN, Cloudification and Slicing
- Conclusions

Improving Latency for eCPRI Fronthaul on TDM PON

- eCPRI requires latency of <0.25 ms
- Challenge: Traditional PON has latency from DBA & Ranging (125 µs + 125 µs).
- Possible solutions:
  DBA Optimization and alternative ranging

Ideas to reduce ranging window:
- Extra wavelength
- Short window for low level signal
- Use strobe laser with CD effect

Round trip latency	Classical	Improved	Measures
OLT			
•Ethernet switching, packet inspection, etc.	0.2 –1ms	→ **0 - 0.1 ms**	**Bi-pass or Optimize**
Fiber Access			
•Dynamic Bandwidth Allocation	0.125ms	→**0.05ms**	**vDBA & sub-frame**
•FEC Coding and decoding	0.002ms	0.002ms	
•Ranging	0.125 ms	→ **Eliminate**	**Use extra λ**
•Speed of light (15km rnd trip)	0.15ms	0.15ms	
•**Round Trip Time (RTT) (requirement <0.2ms)**	**0.6-1.4 ms**	**0.2 - 0.3 ms**	

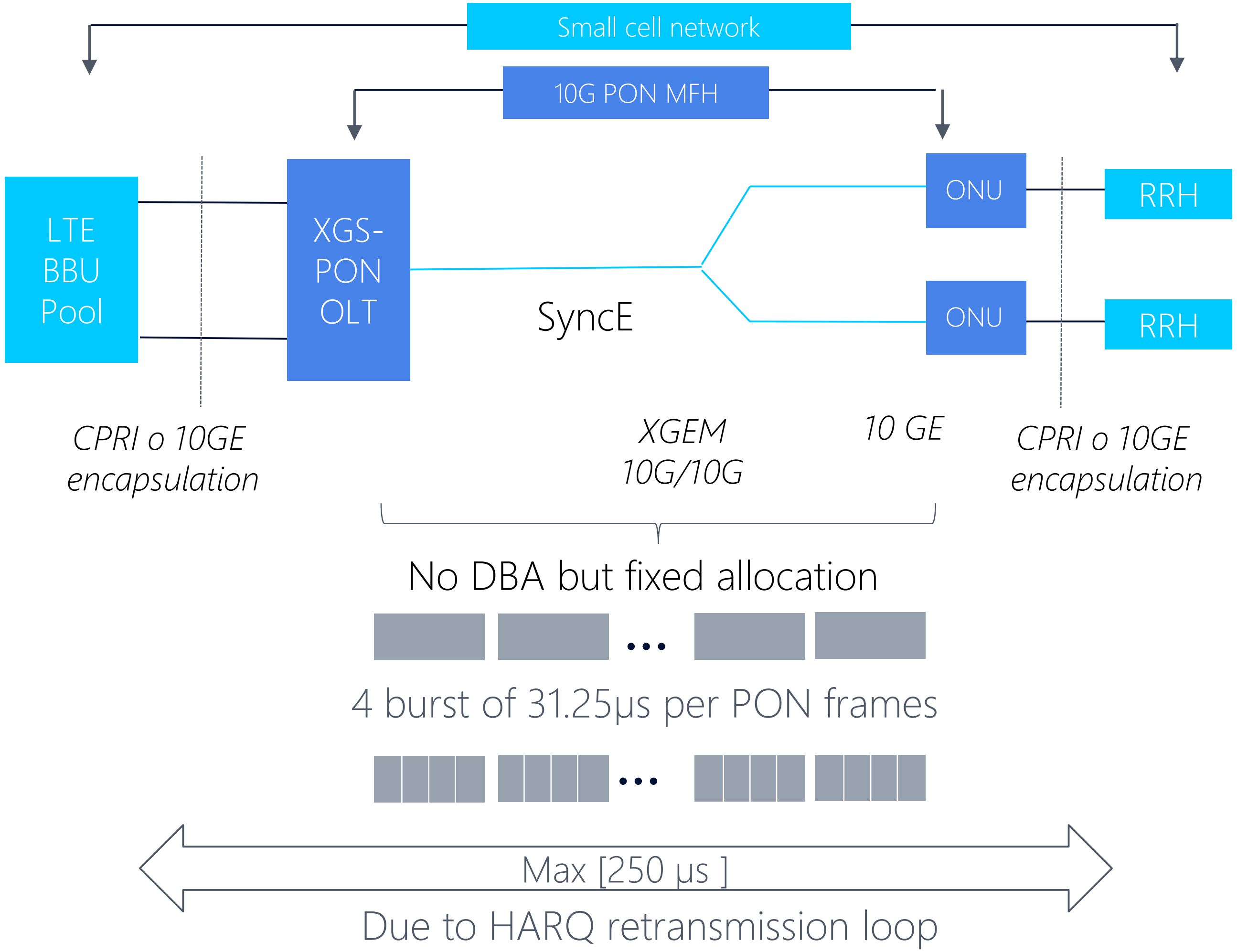


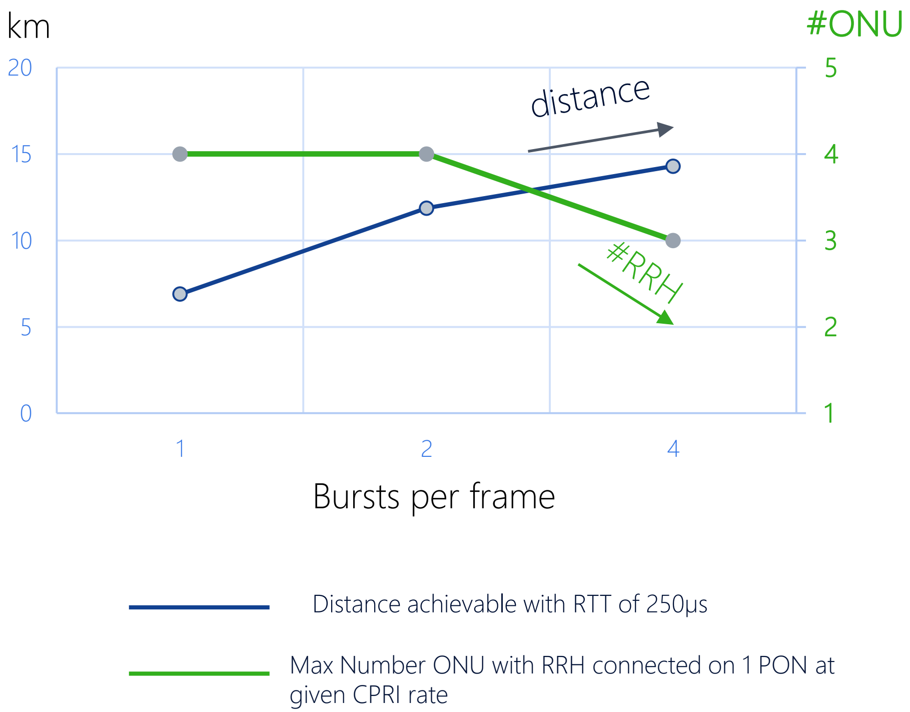
There are potential solutions, but there is still a latency penalty for TDM PON

NOKIA

Improving Latency for eCPRI Fronthaul on TDM PON

…Increased bursts per frame



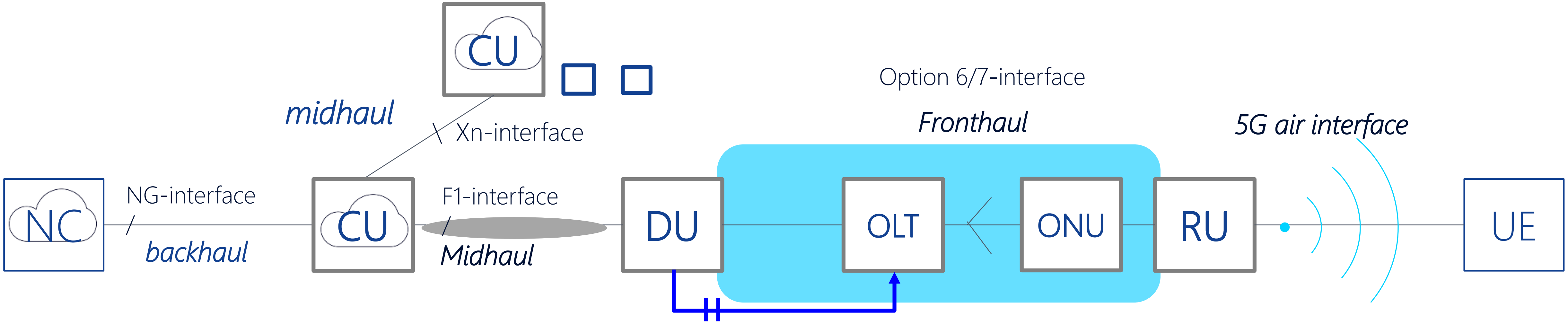


Reach improves from 7km to 14km with 4 bursts but there are increased inefficiencies

NOKIA

Improving Latency for eCPRI Fronthaul on TDM PON

…Cooperative DBA



Cooperative DBA signaling:
CU/DU informs (per TTI) the OLT about mobile scheduling decisions of UL traffic in future TTI

Predefined Signaling Interface (can be on same physical interface as data traffic)

Goal of Cooperative DBA is to improve PON **bandwidth efficiency** while keeping **acceptable latency**

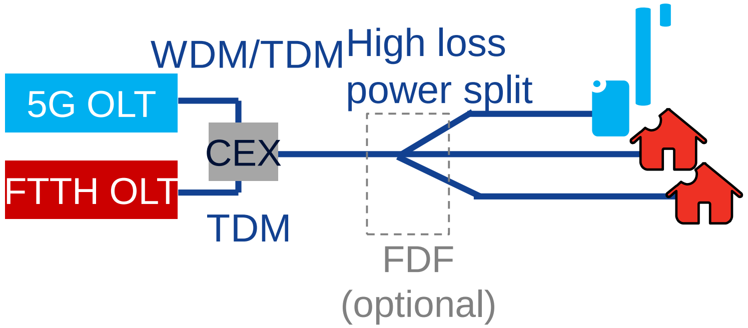
Outline

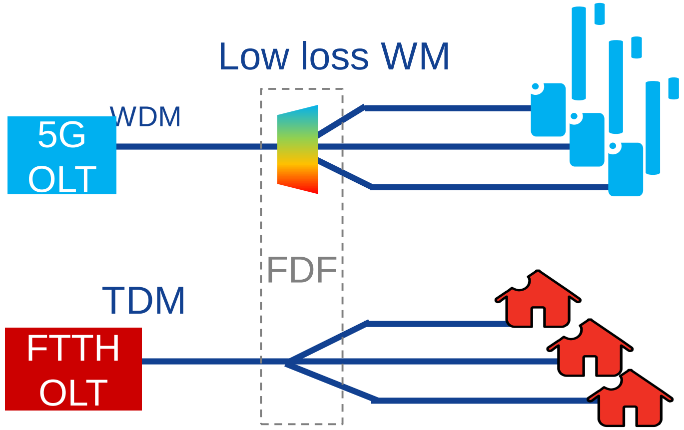
- The 5G Wave
- Proliferation of cells
- New split options: F1 and eCPRI
- Bandwidth considerations for TDM / TWDM
- Latency considerations for TDM / TWDM
- Deployment scenarios and a possible role for P2P WDM
- SDN, Cloudification and Slicing
- Conclusions

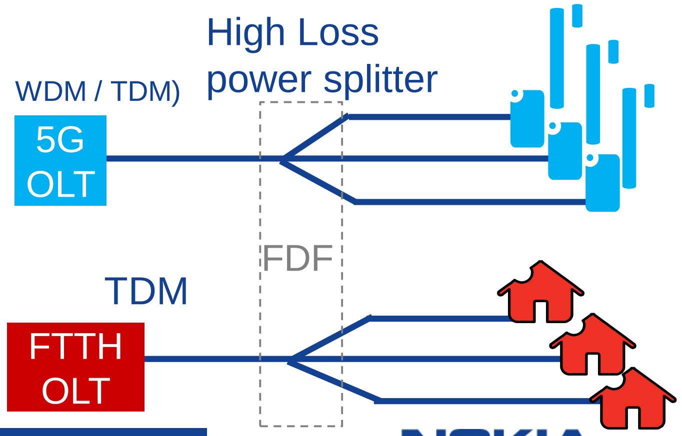
NOKIA

Sharing FTTH infrastructure with 5G: Some Deployment Scenarios

	1) Mixed PON w. Power Splitter	2) 5G-Only PON w. AWG	3) 5G-Only PON w. Power Splitter
Applic-ability	• Overlay on existing FTTH (0.5B lines) • No FDF activity required	• Dedicated PON for mobile (existing or new ODNs) • Requires FDF installation	• Dedicated PON for mobile (existing or new ODNs) • Requires FDF re-connect
# nodes	• 4-8 cells / PON	• 16+ cells / PON	• 16+ cells / PON
Optical budget	• Power splitters → 29dB	• AWG → 14dB	• Power splitters → 29dB
Waveband	• Need coexistence (e.g. NGPON2 band)	• Complete flexibility	• Complete flexibility
Technology	• TDM / TWDM / P2P WDM	• P2P WDM	• TDM / TWDM / P2P WDM







A variety of solutions are possible depending on situation

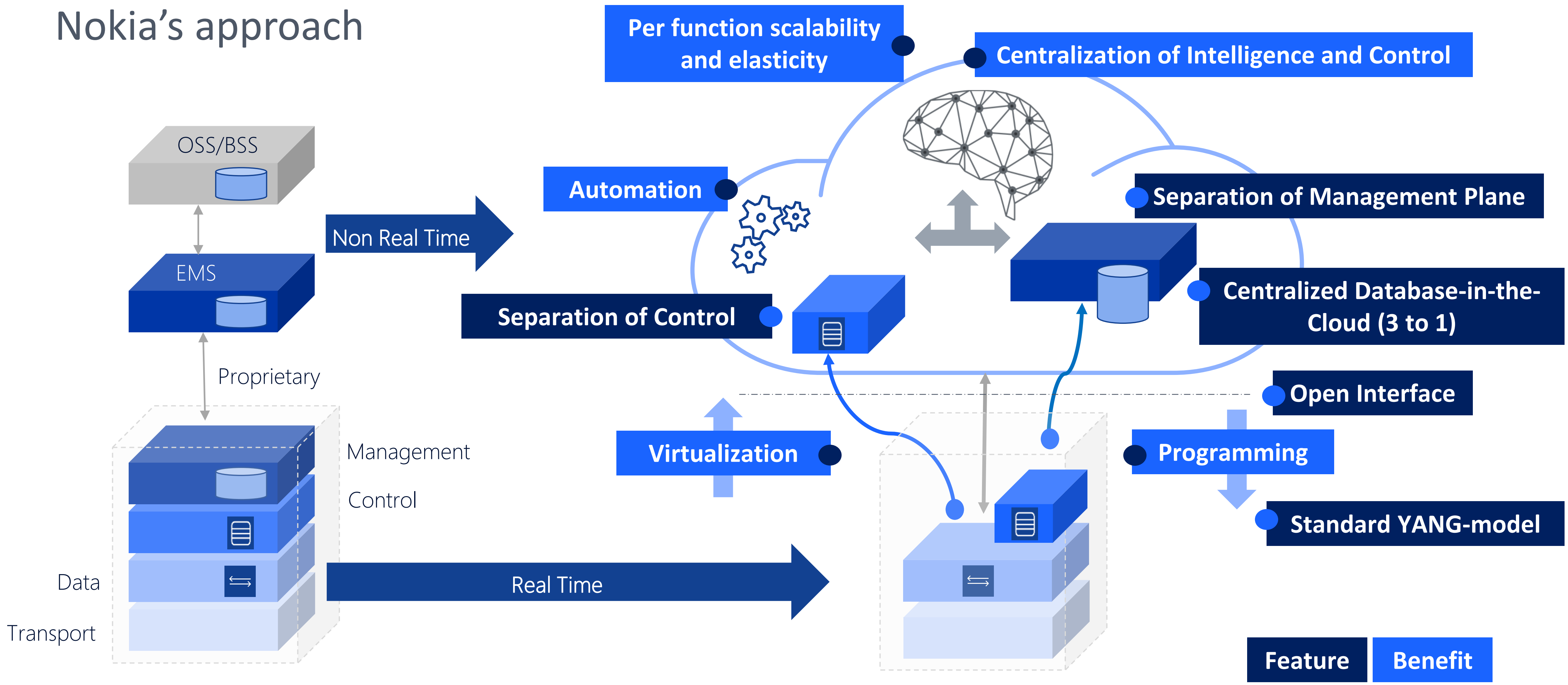
NOKIA

Outline

- The 5G Wave
- Proliferation of cells
- New split options: F1 and eCPRI
- Bandwidth considerations for TDM / TWDM
- Latency considerations for TDM / TWDM
- Deployment scenarios and a possible role for P2P WDM
- SDN, Cloudification and Slicing
- Conclusions

SDN/NFV applied to the access network

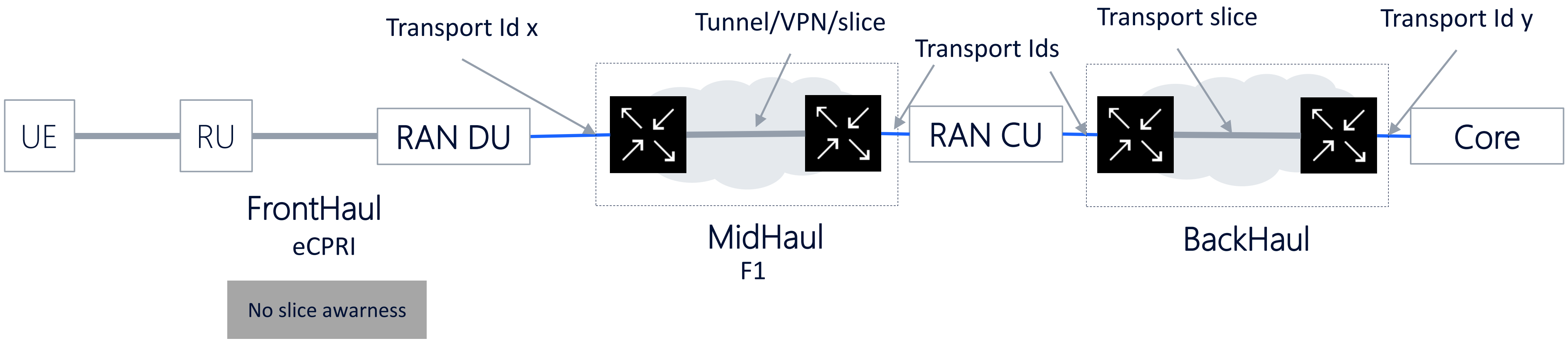
Nokia's approach



Built on solid experience to unlock SDN/NFV benefits

Network Slice in Transport network

- The mobile is looking at ways of slicking the end-to-end network to allow multiple operators to share a common network
- SDN will be an enabler of this



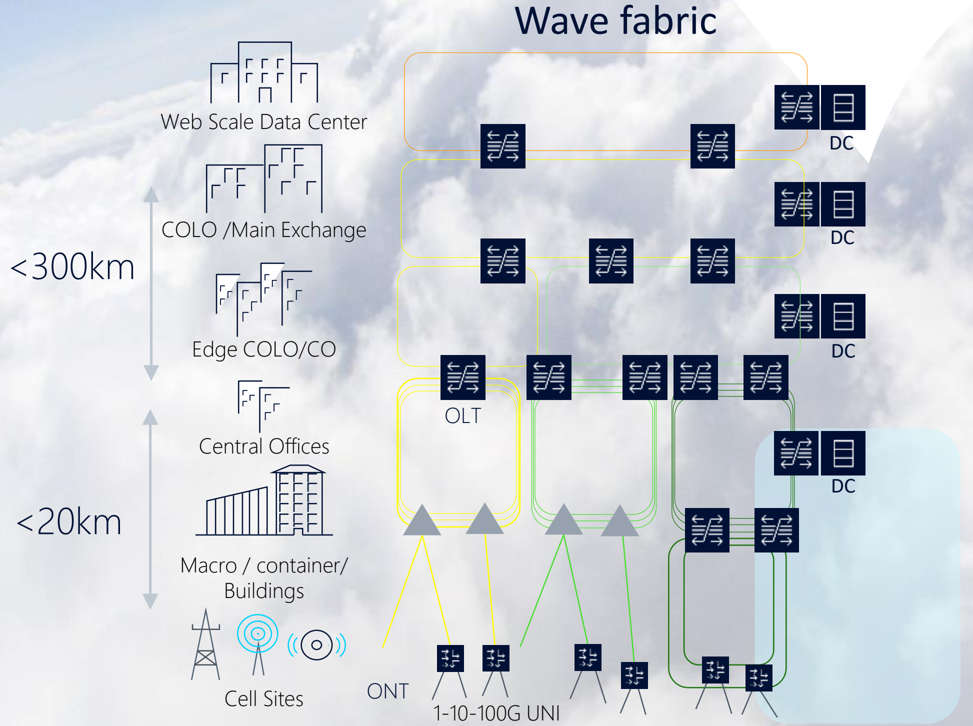
Slices will be enabled through SDN

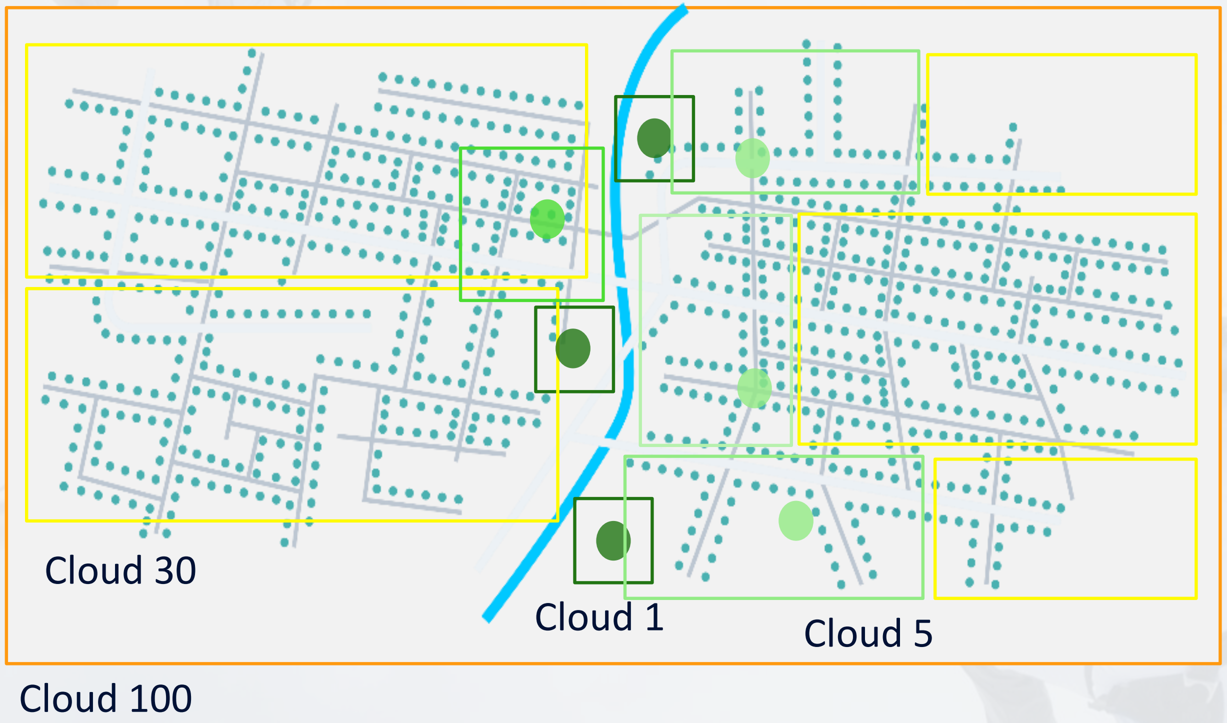
Use of Zones

<1ms APPs	Cloud 1	Motion control & factory automation
5ms APPs	Cloud 5	Smart grid, tactile internet
10ms APPs	Cloud 10	AR/VR, enterprise storage
30ms APPs	Cloud 30	Guided vehicle, transactional
100ms APPs	Cloud 100	Virtual desktop, process automation
250ms APPs	Cloud 250	Web, email, consumer IOT

Zoning based on data center vicinity

Wave fabric leveraging FTTH footprint





Outline

- The 5G Wave
- Proliferation of cells
- New split options: F1 and eCPRI
- Bandwidth considerations for TDM / TWDM
- Latency considerations for TDM / TWDM
- Deployment scenarios and a possible role for P2P WDM
- SDN, Cloudification and Slicing
- Conclusions

NOKIA

Conclusions

- The 5G wave is coming. The role of Fixed BB will evolve to transporting mobile.
- Cells are going deeper. There is great incentive to use common FTTH ODN
- F1 split is simple and can be supported with XGS & TWDM
- eCPRI split stretches the limits of XGS & TWDM. Could require HSP or P2P WDM
  - BW insufficient for many cases
  - Some ideas to combat latency on TDM and TWDM.
- Different deployment scenarios have different requirements (mixed/dedicate, splitter/AWG).
  - P2P WDM could play a role (in addition to TDM and TWDM) in addressing BW and latency needs
  - It may be possible to leverage TWDM optics for P2P overlay
    - Coexistence would be supported with the installed base of legacy PON.
    - May need some incremental work on 989.2 to allow for 25G.
- The optics network is being cloudified and will share data centers with mobile at optimal latency point. SDN will enable end to end network slicing for multiple operators.

NOKIA

Thankyou

Overcoming Challenges in the Managed Connected Home

Jason Walls

Director of Technical Marketing | QA Café

jason@qacafe.com

broadband forum

BASe

Overcoming the challenges of a managed connected home

Security, whole-home connectivity, and the evolution of TR-069

Jason Walls
Technical Marketing and Standards
qa|cafe

Who am I?

Director of Technical Marketing at

qa|cafe

creators of

CDROUTER

Co-Director of the Broadband User Services work area at the Broadband Forum, Chair of the BBF Connected Home Council

The top challenges of the connected home

Whole-home connectivity

Great strides in better connections, but there is a need to improve – getting to **carrier-grade** for the home. Managed Wi-Fi solutions are **proprietary and not interoperable**, and the amount of telemetry needed is exploding.

Security and privacy

We hear of new vulnerabilities every day in connected devices. **Users don't upgrade**, and consumer electronics vendors aren't used to the **longer-lifecycle**. Users are skittish about

Viable smart home business model

In addition to security and privacy concerns, **lack of interoperability and poor networks** has left a bad taste. Consumers don't want to get locked-in and **expect a viable system to "just work"** despite all of the moving pieces. Adoption and **monetization has been slow**.

Seamless user experience

Connected users call their connectivity either "the Internet", "the Wi-Fi", or some combination of both. In contrast, their mobile experience tends to be the same no matter where they are. The user experience needs to be **seamless between devices, connectivity types, and locations**.

LET’S GO BACK IN TIME.

In early 2000’s, broadband gateways became a regular part of operator deployments.

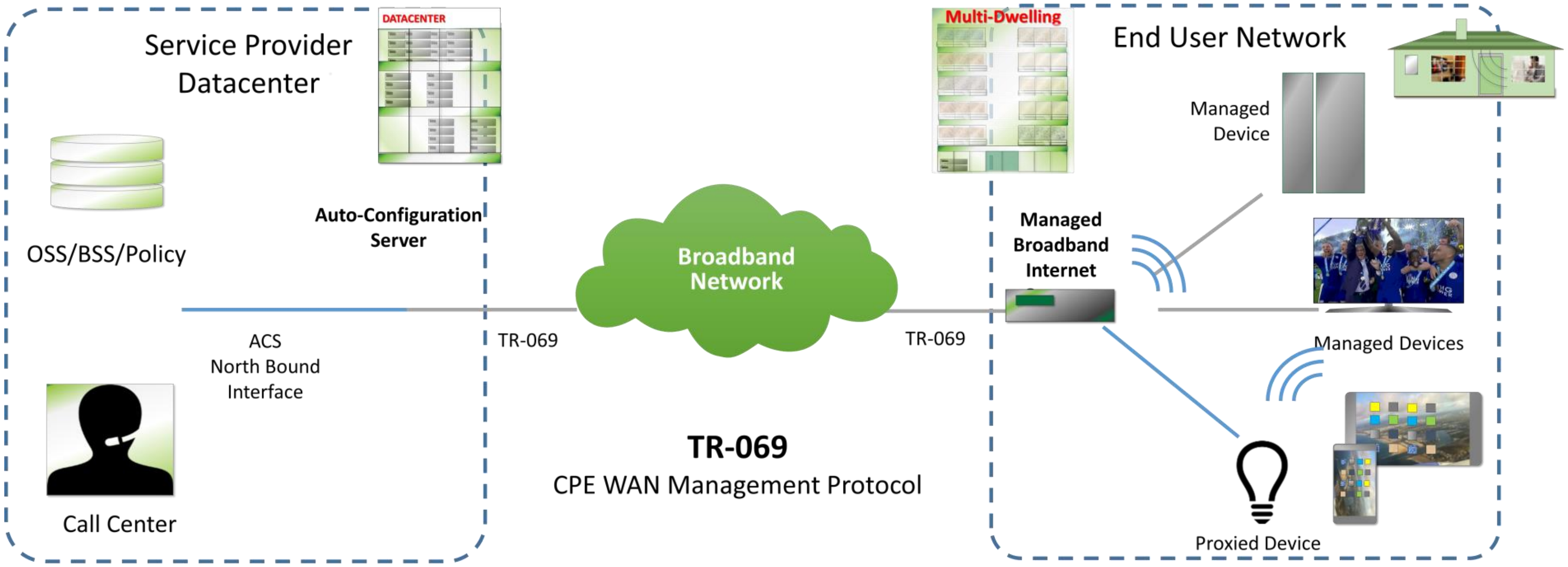
Deploying, onboarding and managing the broadband gateway was hard! Truck rolls, CD-ROMs, UPnP…

The key issues: LIFECYCLE MANAGEMENT, MAINTENANCE AND MONITORING, PROVISIONING NEW SERVICES

TR-069 (CWMP)

TR-069 Architecture

CWMP was designed for firmware management, provisioning, and troubleshooting of CPE.



The evolution of managed user experience

ISPs see **need for life-cycle management, monitoring, and provisioning** for gateway routers. CWMP (TR-069) is born.

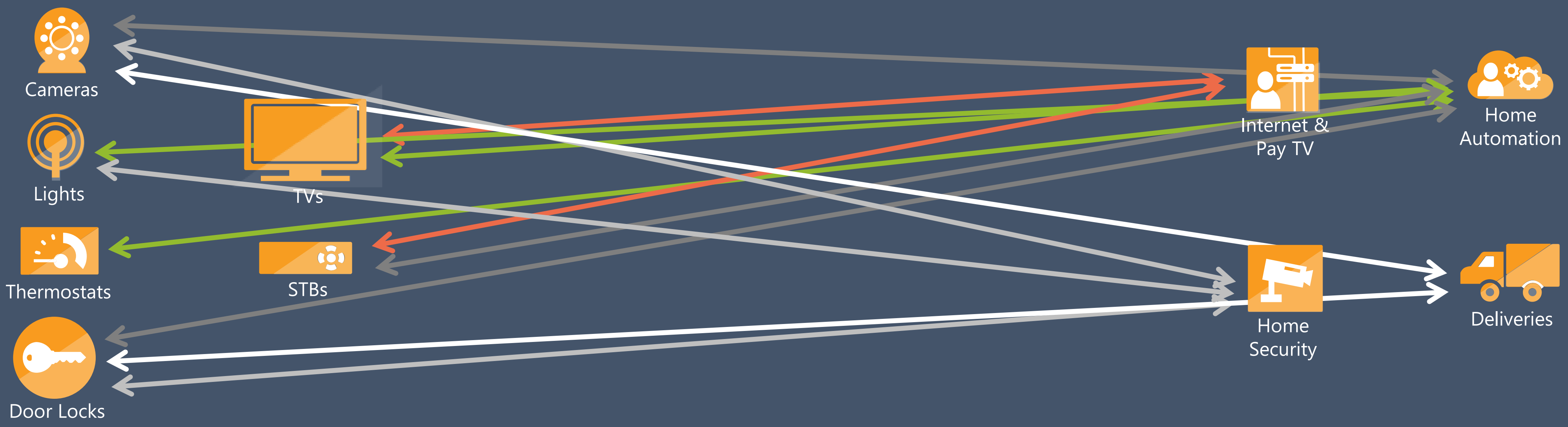
Cable/MSOs incorporate TR-069 for management of **advanced gateways/Wi-Fi using Device:2** data model.

2002 → 2004 → 2006 → 2008 → 2010 → 2012 → 2014 → 2016 → USP

TR-069 **expands to manage more** interfaces and more devices, like STB, VoIP, Wi-Fi, and more.

Explosion of new technologies and challenges for both networking and consumer electronics: IoT, Wi-Fi/Mesh, handling over-the-top and third party services, and desire for end-user control.

Why is this evolution necessary?



Bigger SCOPE

- New devices, new services, and the presence of virtualization
- User control, enabling 3rd party interactions
- Desire for seamless user experience, anywhere

Bigger SCALE

- Orders of magnitude more devices and connections
- Much longer product lifecycles for consumer electronics/IoT
- More data/bulk telemetry needs to enable Machine Learning (ML)

Bigger STAKES

- Security and product lifecycle/upgrade concerns
- Privacy and data security concerns
- Ownership, responsibility and access control concerns

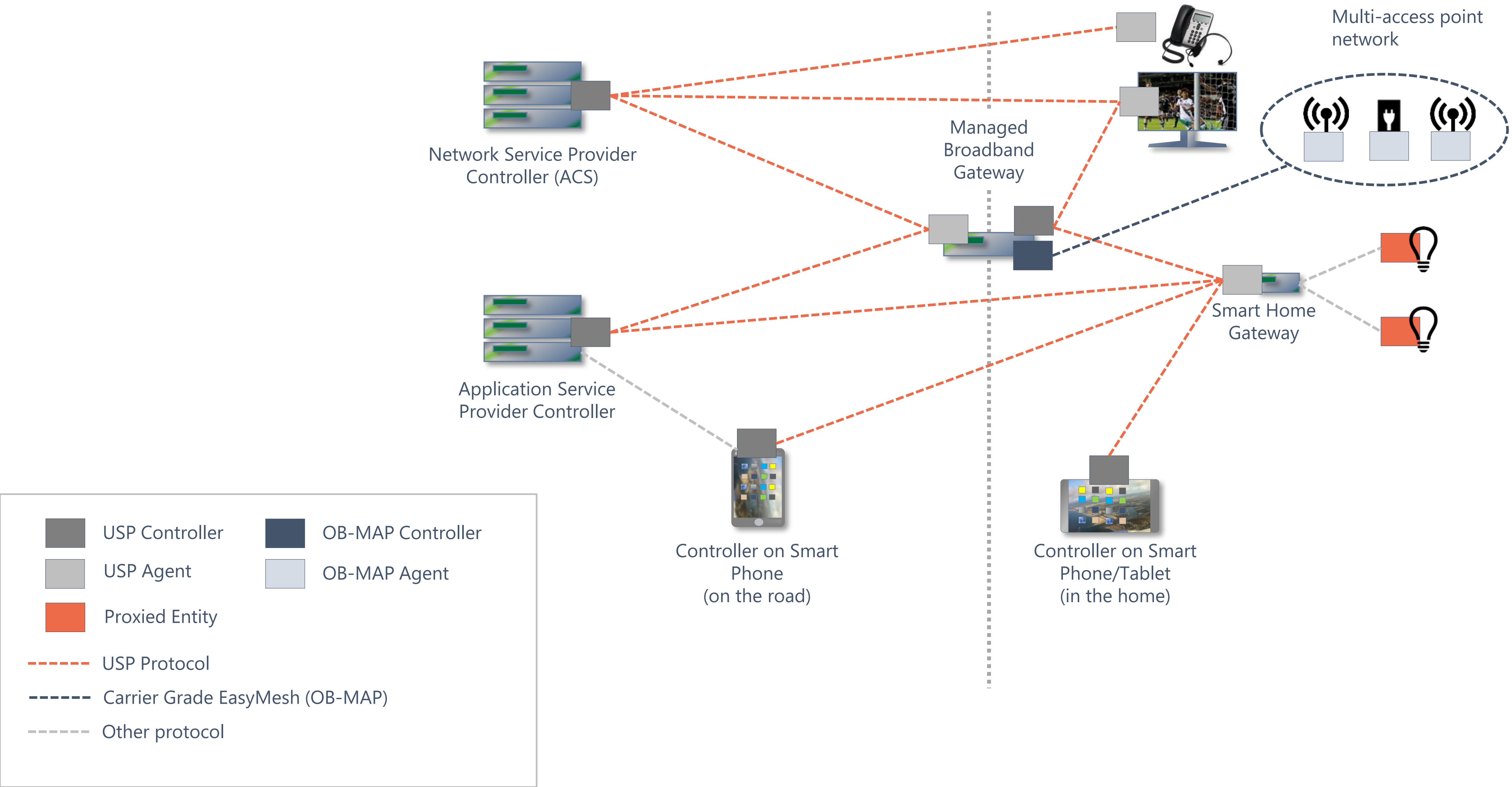
User Services Platform (USP/TR-369)

USP is the natural evolution of TR-069 built to meet these new challenges. It's built on what we've learned through 15 years of managing end-user networks, fused with new technologies, and **backwards compatible** with the Device:2 data model, making migration easy.

Carrier-Grade EasyMesh (OB-MAP)

OB-MAP is a collaborative open source project between the BBF and the PRPL Foundation. It is designed to produce requirements, specification details, and open source code to extend the PRPL Foundation's implementation of the Wi-Fi Alliance EasyMesh™ multi-access point specification. These extensions are intended to enable a truly "carrier grade" home network, and are expected to include a management interface via TR-069 or USP.

A vision of the fully managed connected home



Key aspects of the User Services Platform

Efficient, extensible messages with advanced path addressing

USP includes a set of RESTful messages (Add, Set, Delete, Get, GetInstances, GetSupportedDataModel, and GetSupportedProtocol) plus the Operate and Notify messages, which allow for asynchronous actions and events. Data model information can be addressed by unique key, with wildcards, or with search expressions.

Efficient, robust, and forgiving responses

USP reduces the size and round-trip overhead of Controller/Agent interaction. Requests and responses no longer require session build-up and tear-down. Failures can be isolated to individual objects and parameters, and relative paths reduce message size significantly.

Flexible, use-case driven transport bindings (MTPs)

USP's design makes clear lines of separation between messages and message transport, allowing for future extensibility while creating a flexible environment that meets the needs of traditional management (WebSockets, STOMP), mobile control points (STOMP), and resource constrained local network devices (CoAP).

Powerful subscription and notification mechanism

USP contains several core events built into the Notify message with the ability to define object-specific event types in the data model. Controllers "subscribe" to certain events and provide the specific objects and parameters that apply, even matching them with an expression.

End-to-end security, role-based access control

USP allows for an optional "session context" that provides TLS session security at the USP layer, ideal for when crossing proxies or other points of failure. In addition, it defines the trust mechanisms for Agent/Controller association and role-based access control on a per-resource level that can be managed via the USP data model.

Moving it forward, interop and compliance

There have been two plugfests to date - group test events with multiple participants including ARRIS, QA Cafe, Greenwave, Axiros, Orange, and Nokia. Next plugfest is being planned for April 2019. Your participation is welcome!

The Broadband Forum is developing both a certification test plan including conformance, interoperability, and functional testing, as well as a certification program. Look for more details in the first half of 2019.

Implementation Resources

How to start building implementations and requirements for using the User Services Platform

TR-369 specification at usp.technology

The specification for architecture, discovery, end-to-end message encoding, transport, and types, plus security and access control are defined in Broadband Forum TR-369. You can find it at https://usp.technology.

Device:2 data model definitions for USP

The data model for describing the service elements exposed by USP Agents are defined in the Device:2 Data Model (sometimes called TR-181). The models for CWMP and USP pull from the same common core with some minor changes for protocol-specific management objects. The models can be found at https://usp-data-models.broadband-forum.org.

OB-MAP Participation

OB-MAP is an open project that welcomes all who wish to contribute. Any company or un-affiliated individual who signs the participation agreement can join in the collaboration. BBF members who do not sign the agreement still have full visibility to it at https://wiki.broadband-forum.org/display/OBMAP.

Supplemental materials

For a more detailed look at your questions

How does USP compare to other options?

Some have part, but not all, of the pieces necessary for managing the connected user

	CWMP (TR-069)	WebPA	LwM2M	User Services Platform (USP)
Supports Multiple Management Servers	✘	✘	✔	✔
Supports Use Case Driven Message Transfer Protocols	✘	✘	½ ✔	✔
Has an Efficient Data Encoding	✘	✔	✔	✔
Has a Schema Driven Protocol Definition	✔	✘	✘	✔
Has an Always-On Communications Mechanism	✘	✔	½ ✔	✔
Utilizes a Device:2 (TR-181i2) Driven Data Model	✔	✔	✘	✔
Defines a Robust Set of Operations	✔	✘	✔	✔
Requires a Transport Layer Security Mechanism	½ ✔	✔	✔	✔
Provides an Application Layer Security Mechanism	✘	✘	✘	✔
Provides an Access Control Mechanism	½ ✔	✘	✔	✔
Distributable Data Model Processing	✘	✘	✘	✔

It All Starts With Managed Wi-Fi

Greg Owens
Product Marketing Director | Calix
Greg.owens@calix.com

broadband forum

BASe

Calix

BBF BASE

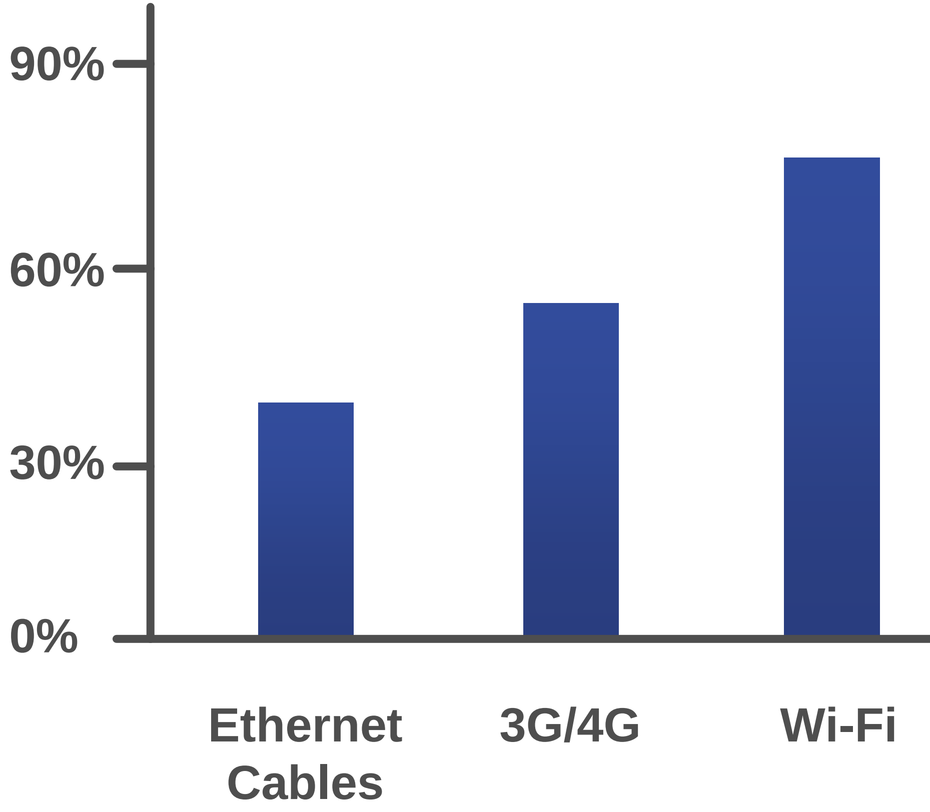
It all starts with Managed Wi-Fi

Greg Owens | Product Marketing Director
www.linkedin.com/in/owensgreg/

For consumers, it's all about the Wi-Fi

Home Networking Method used to Access Internet in the Home

U.S. Broadband Households



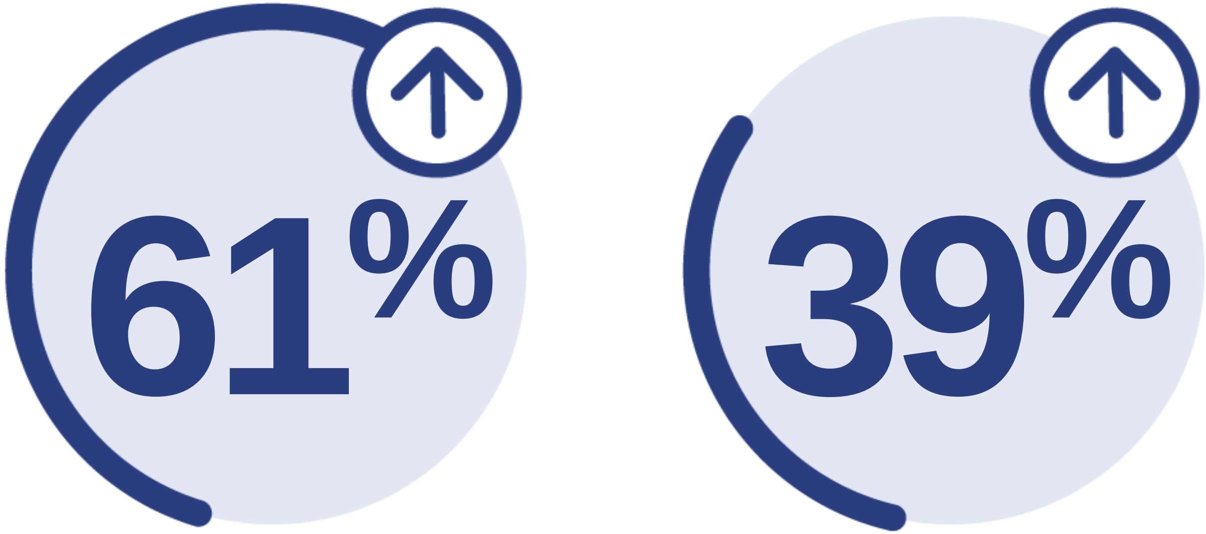
>75% Of U.S. households use Wi-Fi for in-home connectivity

© Parks Associates

Most households use a Wi-Fi Gateway provided by their ISP

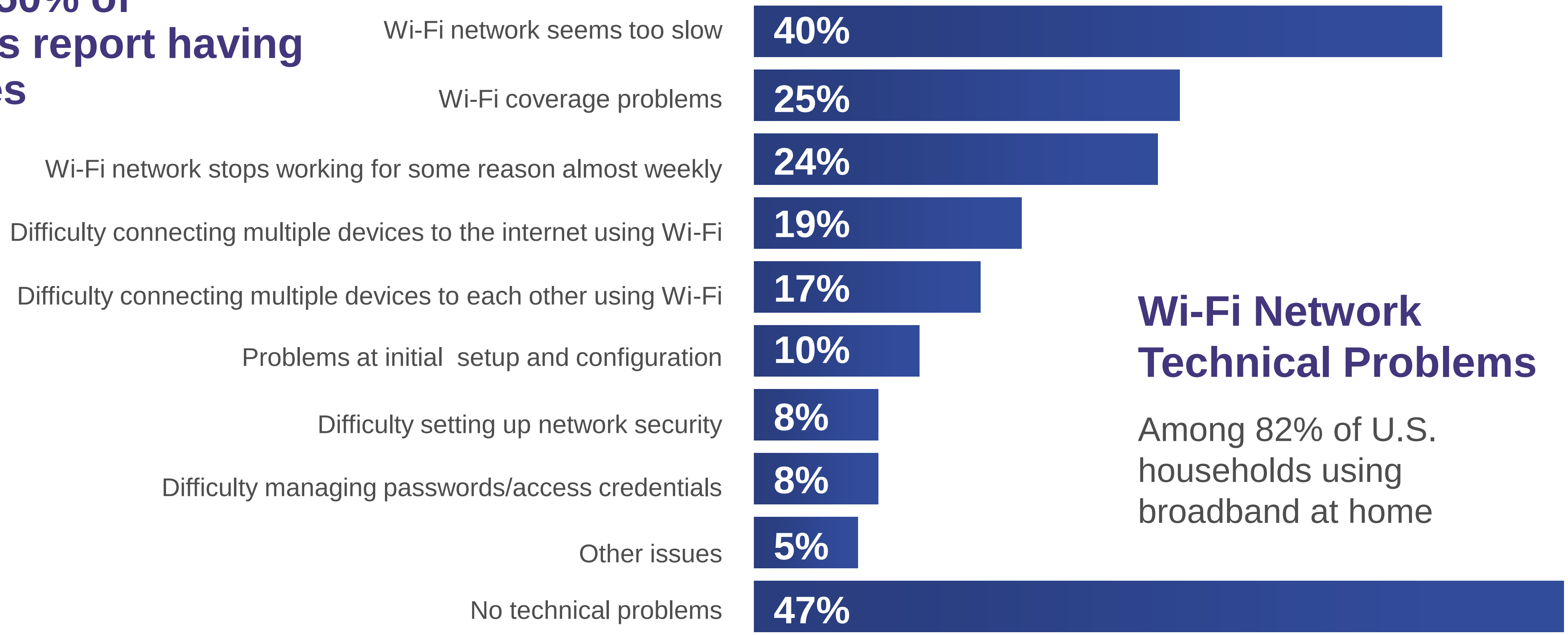
Home Network Routers Obtained from Broadband Service Providers

Owners of Networking Routers in U.S. Broadband Households



Wi-Fi is the foundation of the connected home; but also a source of consumer frustration

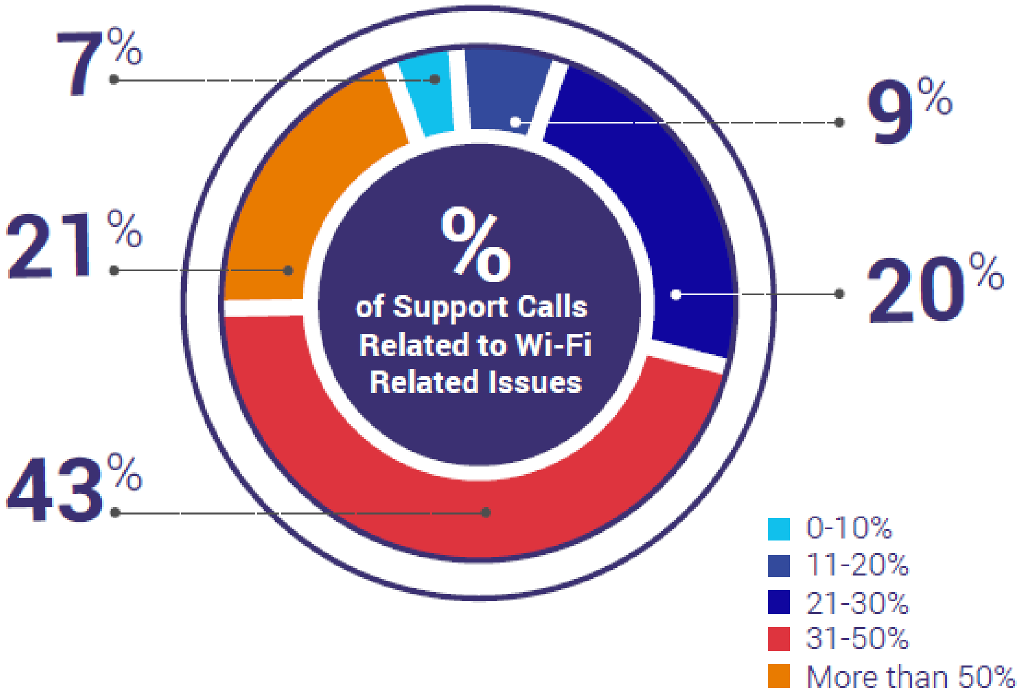
More than 50% of subscribers report having Wi-Fi issues



Wi-Fi Network Technical Problems

Among 82% of U.S. households using broadband at home

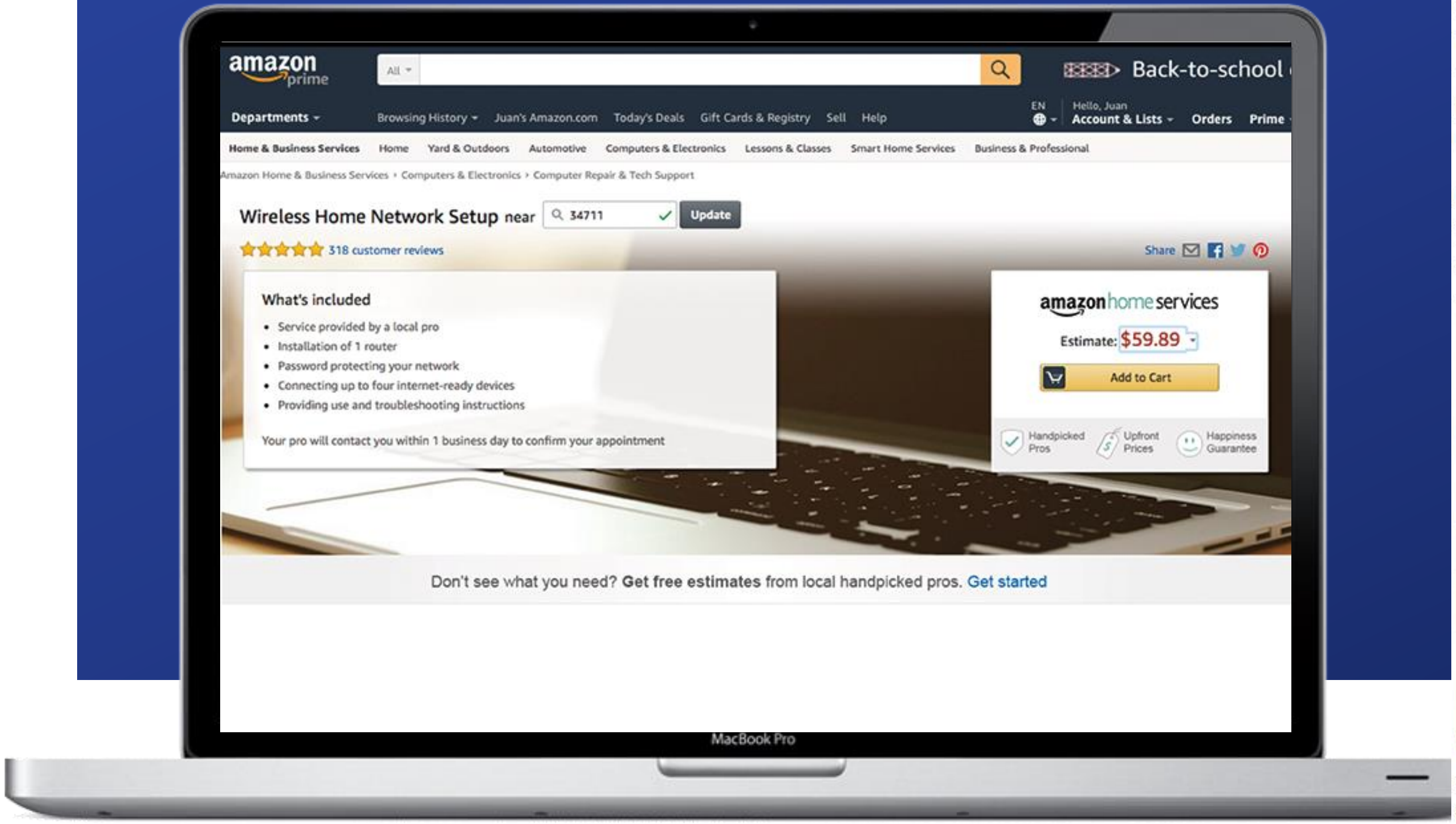
Percentage of Support Calls Related to Wi-Fi Related Issues



Q: What percentage of your help desk calls are driven by Wi-Fi related issues?

Source: Poll of 104 service providers during two recent Calix webinars.

Why is Wi-Fi such an important strategic initiative?



BUSINESS

Best Buy expands Geek Squad's role with nationwide rollout of 'Total Tech Support'

Best Buy is launching a subscription service that applies to all devices.

By Kavita Kumar Star Tribune | MAY 22, 2018 — 5:37AM

CONTRIBUTED PHOTO

Best Buy's Total Tech Support costs $200 a year and offers unlimited phone and online support and discounted in-home visits.

A better alternative: ‘Managed Wi-Fi’

Managed Wi-Fi means providing:

- the ‘strategic point of presence’ (wireless access point);
- effective, phone-based tech support (with remote troubleshooting capabilities); and
- enhanced/whole home Wi-Fi coverage.

804mesh

CalixCLOUD

gigacenter

A better alternative: ‘Managed Wi-Fi’

Managed Wi-Fi will:

- improve subscriber satisfaction scores;
- reduce churn;
- increase revenue; and
- lower customer support costs.

804mesh

CalixCLOUD

gigacenter

Show me, don't tell me: Managed Wi-Fi generates significant cost savings – and revenue generation opportunities

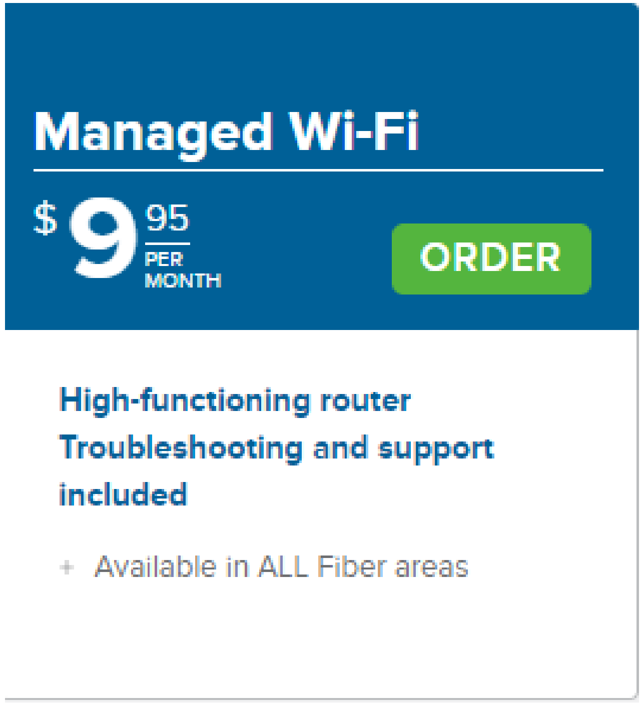
Benefits/cost savings for customers with Managed Wi-Fi vs BYOD (Consolidated, ND):

- **85%** faster call resolution = appr. $20 saving per trouble ticket;
- **94%** first call resolution;
- **50%** less likely to roll a truck; and
- reduced installation times.

Approximately 15,300 customers in Southwest North Dakota

Benefits/cost savings for customers with Managed Wi-Fi vs BYOD (All West, UT):

- **40%** first call resolution;
- **30%** less likely to roll a truck;
- **44%** faster resolution = appr. $20 saving per trouble ticket; and
- reduced installation times.



Approximately 16,000 customers in Northeast Utah and Southwest Wyoming

Revenue generation for service providers

Current Managed Wi-Fi Annual Recurring Revenue (Consolidated, ND): **$306K**.

Based on **33% penetration rate** (~5,100/15,300 subscribers).

80% of new Internet customers take Managed Wi-Fi.

Current Managed Wi-Fi Annual Recurring Revenue: **$250K**.

Based on **25% penetration rate** (~4,000/16,000 subscribers).

50% of new Internet customers take Managed Wi-Fi.

Managed Wi-Fi: The first step to owning the Smart Home

Managed Wi-Fi

No more BYOD

- Carrier-class managed home Wi-Fi
- Visibility into the premises system, allowing for remote troubleshooting
- Intelligence via analytics

Present

Whole Home Wi-Fi

Extended Wi-Fi Coverage

- 804Mesh - improve speed/coverage, and number of devices
- Enable user self-install
- Visibility into the whole network performance

Short term

Smart Home

To be revealed tomorrow

Smart Home solution

- Support connected home ecosystems
- Extend coverage beyond Wi-FI
- Analytics-based automation and optimization

Longer term

Where should I get started?

1. **Create a business case**
   - To charge or not to charge for Managed Wi-Fi?
   - Consider decreased support calls, truck rolls, happier customers and price points

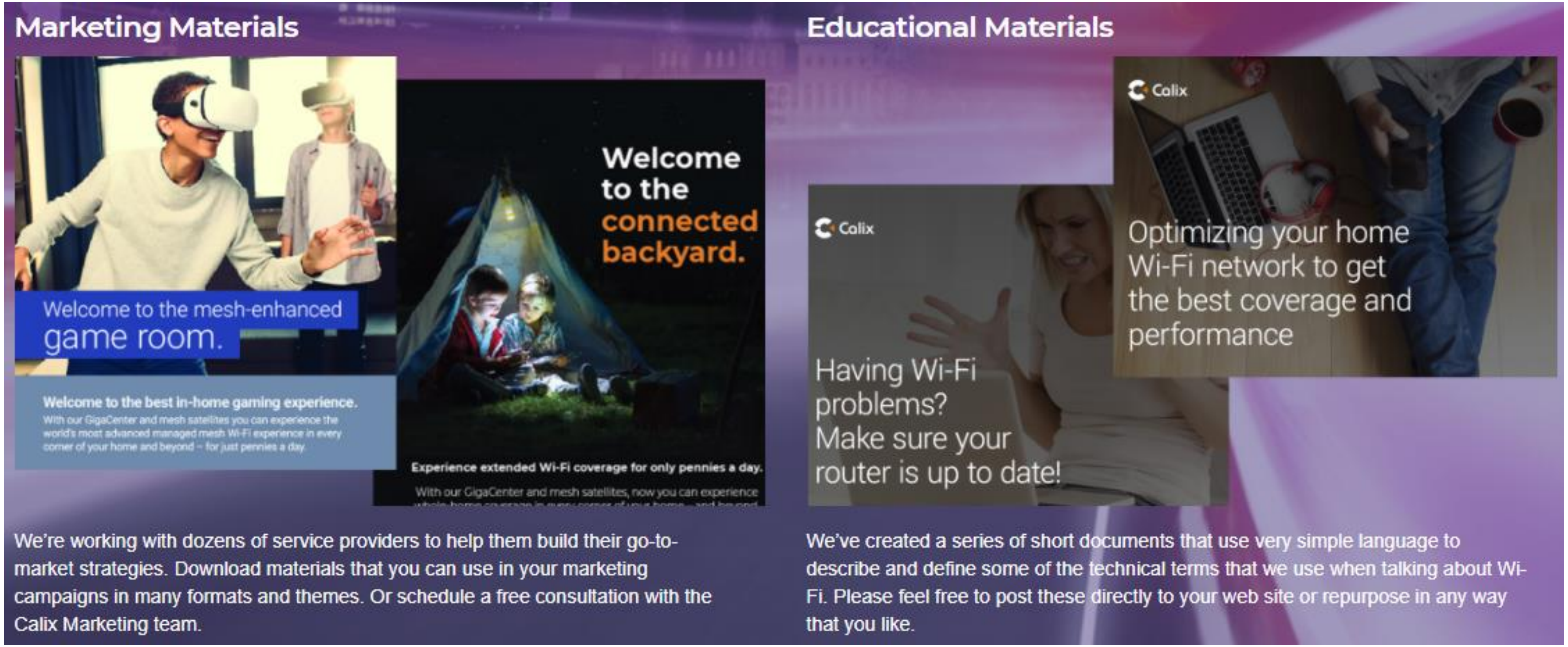
Where should I get started?

2. **Build a marketing strategy**
   - What %age of your subscribers have their own router?
   - What incentive(s) can you offer subscribers to adopt Managed Wi-Fi?
   - Education/awareness campaigns

Where should I get started?

3. **Find a good partner. Calix offers:**
   - Proven experience
   - Professional Services
   - Pre-defined marketing kits
   - Educational materials
   - Marketing consultations

Calix can help you get started on your journey



Dedicated site for marketing and educational materials (https://go.pardot.com/l/2172/2018-03-05/3nb85p).

THANK YOU!

Greg Owens | Product Marketing Director

Greg.owens@calix.com

Enhancing Wi-Fi User Experience

Ruthy Zaphir
Head of WiFi Solutions | GlobalLogic
ruthy.zaphir@globallogic.com

GlobalLogic®

Israel Innovation Center
Enhancing Wi-Fi User Experience

October 2018

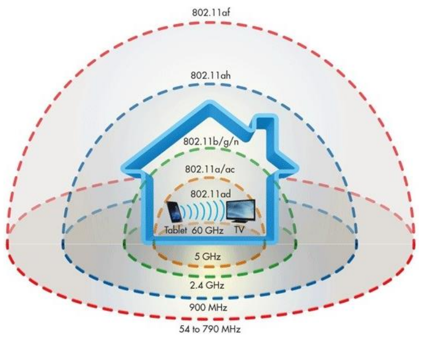
Author : Ruthy Zaphir
Head of Wi-Fi Solutions

Wi-Fi Next Ecosystem Evolution

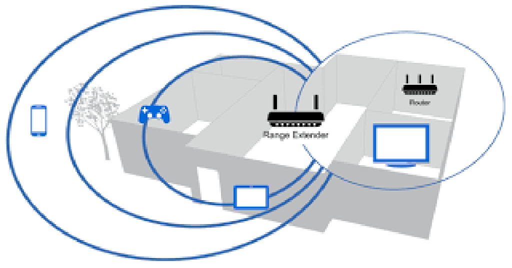
Emerging 802.11 standard & Growing Wi-Fi Spectrum range

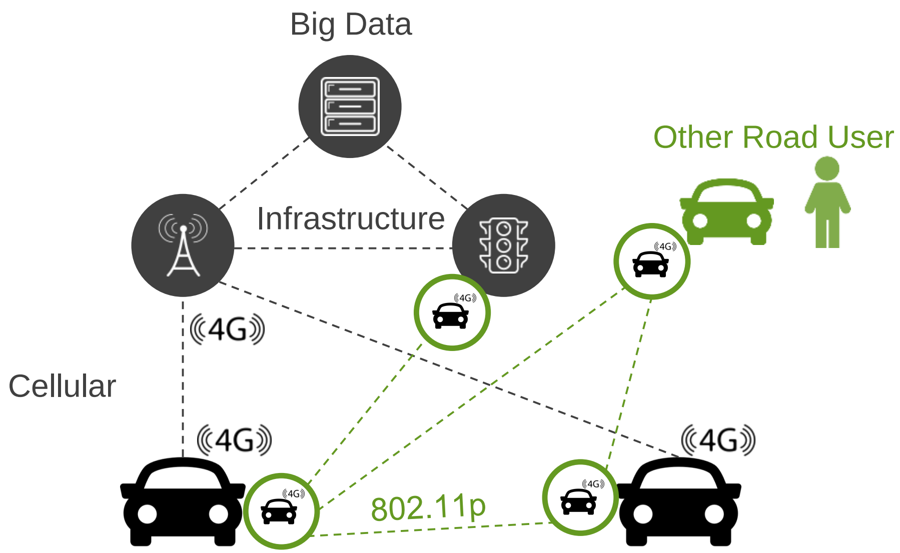
60 GHz band 802.11ad, also known as WiGig operating in 60 GHz ISM band

Evolving 802.11p standard in 5.9 Ghz band intended for use in vehicular communication systems



Extend Wi-Fi coverage



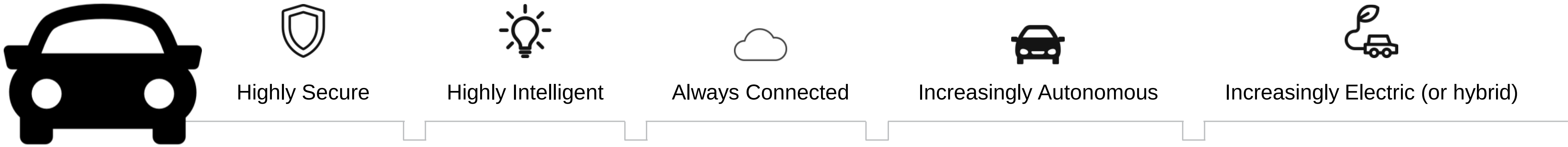


WiGiGg allows wireless devices to communicate at rates **up to 7 Gbit/s** Increasing Uses Cases with high performance wireless data, display and audio applications that supplement the capabilities of previous wireless LAN devices.

Next challenges of Wi-Fi product companies/vendors

- Increasing Demand for constant Wi-Fi User access
- Increasing number of deployed Wi-Fi devices everywhere will create Wi-Fi density and overlapping channels create interference and worsening Wi-Fi User experience
- Increasing request for Wi-Fi enhancement via App “on the fly”
- Increasing demand for Always- connected device vision

Our vision for the always-connected vehicle of the future



Wi-Fi QoE
Enhancing Wi-Fi quality

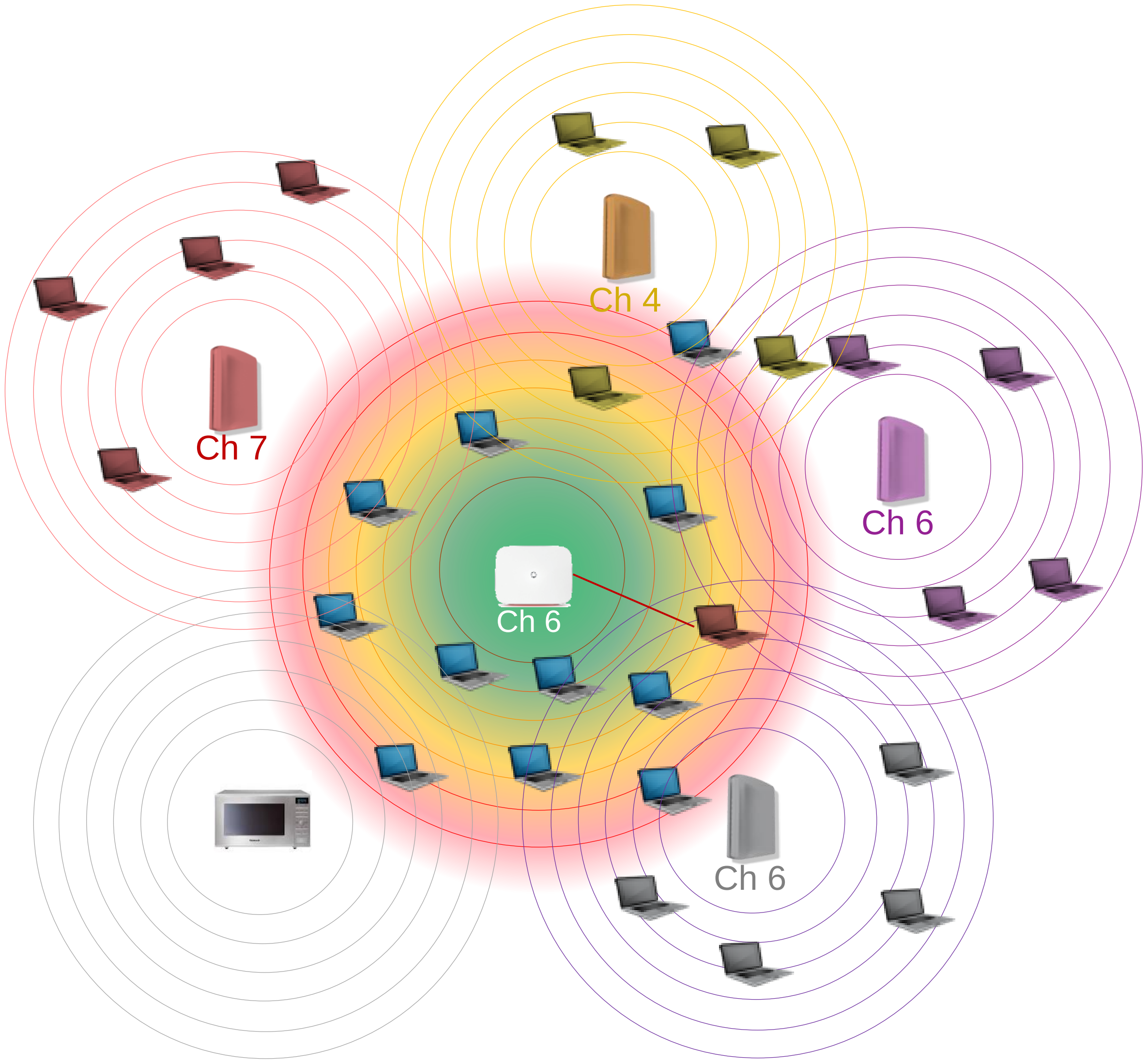
Typical House

Wi-Fi Co-Channel Interference

Low RSSI

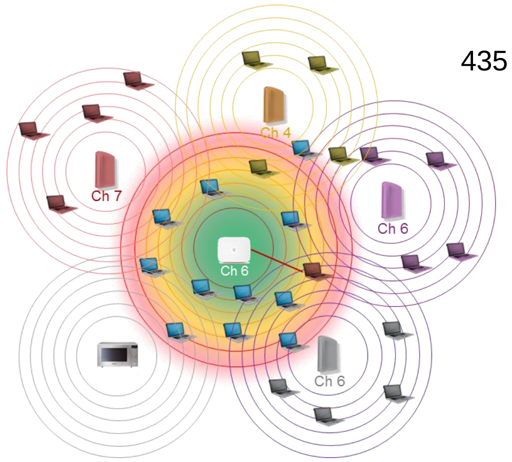
Saturated AP

Saturated Link



High non Wi-Fi Channel Interference

Channel loaded



Solution Highlights

- Mission – increase the **quality of experience** of Wi-Fi users
  - Challenge – how to measure quality of experience

- Solution Guidelines
  - Take no action unless necessary (potential QoE gain is much higher than the action’s “cost”)
  - If action is needed, select the most graceful one (i.e. no/minimal user impact)
  - Background activities (e.g. monitoring/analysis) are transparent to the user (i.e. no user impact)

- Implementation guideline
  - Modular architecture - self-contained modules, can be deployed separately
  - Use most common WiFi KPIs provided by all Wi-Fi chip vendors

Wi-Fi QoE | The Challenge & Solution

Solution

Quality scores generation
Quality of experience, air quality, channel ranking, etc.

Predictions & recommendations
Recommended action per link based on predictions

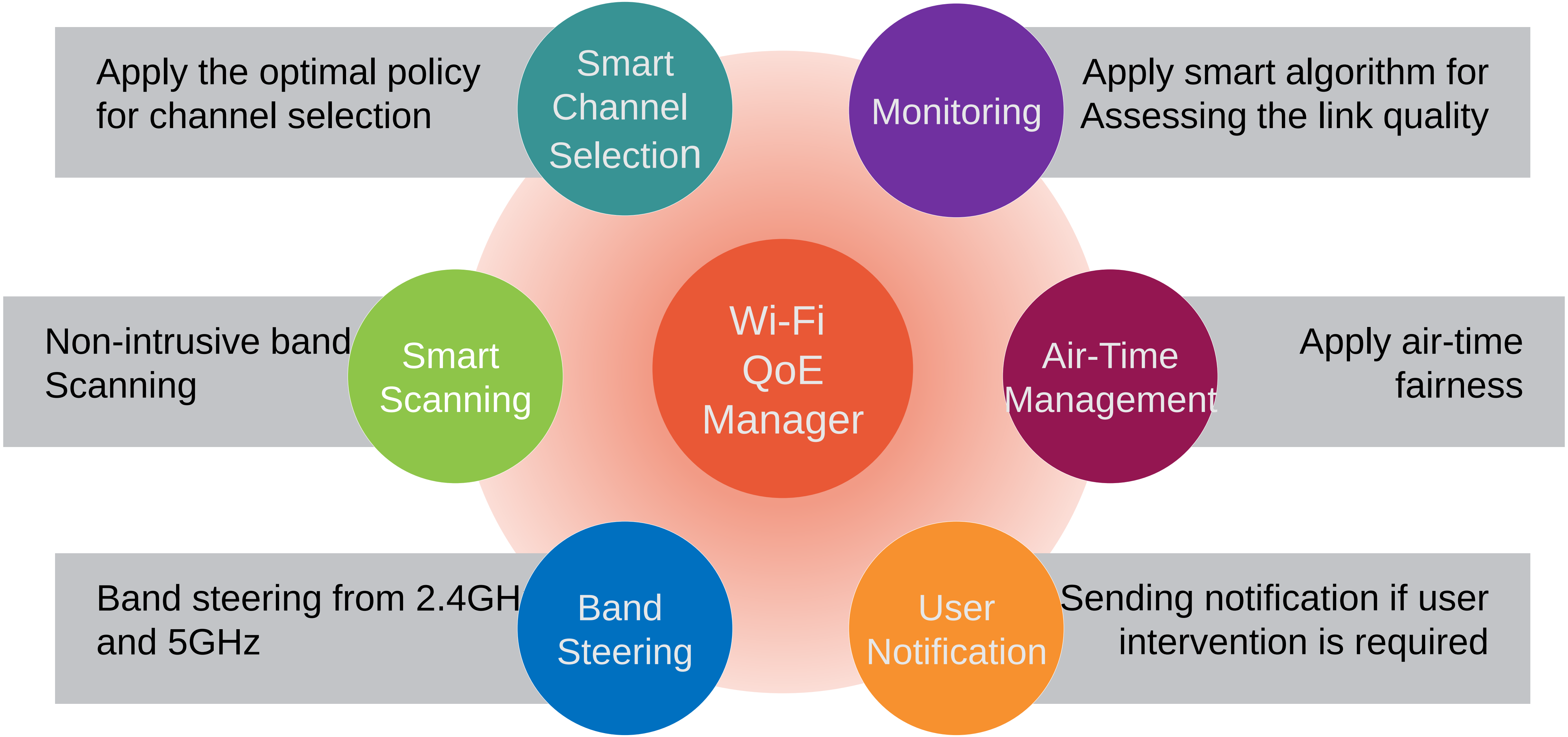
Actions to optimize the quality of experience
Taking actions based on recommendation and policy

Monitoring and visualization
Real-time and history view, hierarchal view

Offline analysis (using ML techniques)
Forecasting, multi-cpe optimization, policy optimization

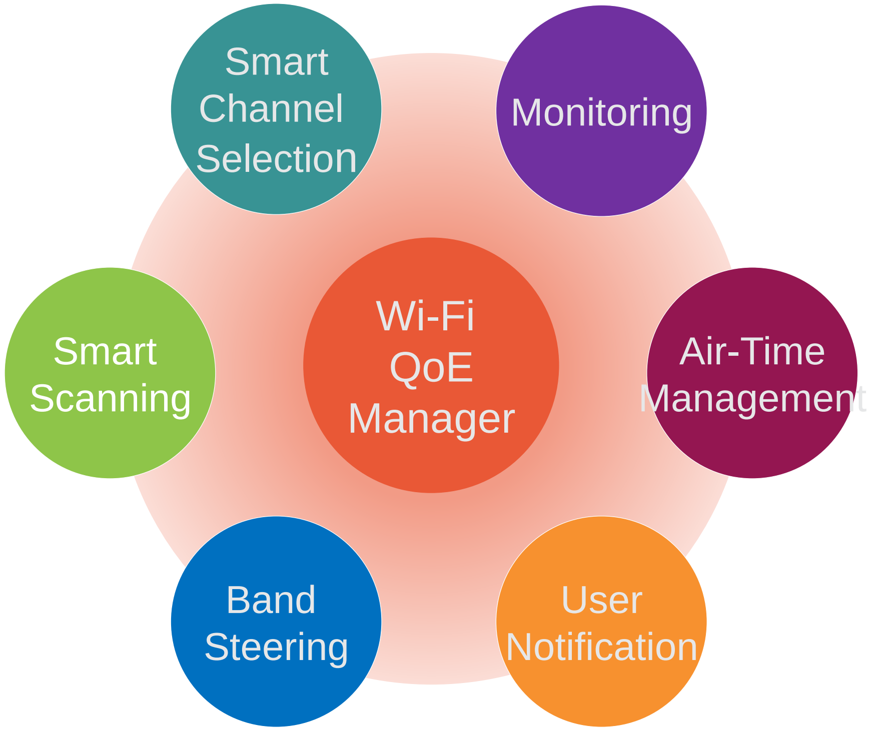
CPE
Cloud

Wi-Fi Management



Wi-Fi QoE Optimization - Main Modules

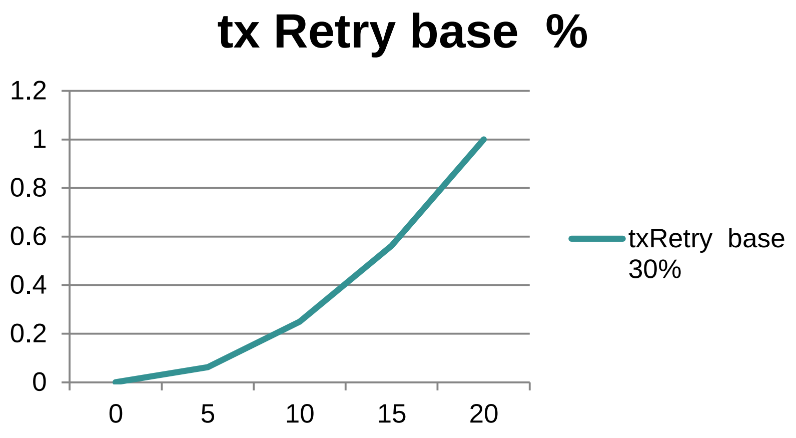
- Monitoring
- AI : Predicting User Maximum bitrate
- Smart Scanner
- Smart Channel Selection
- QoE Smart Action Manager
- QoE Cloud UI
- QoE Data Modeling



Monitoring : WIFI KPI Data Collection

WiFi App collects link KPIs over a sliding windows below of <X>seconds every 5 seconds:

- PHY rate
- Bytes Sent/Received ➔ Retrieving Rx/Tx Mbs
- RSSI
- Tx Failures
- Tx Retries
- WiFi standard (11b,g,n,a,ac)
- Channel BW, #spatial streams

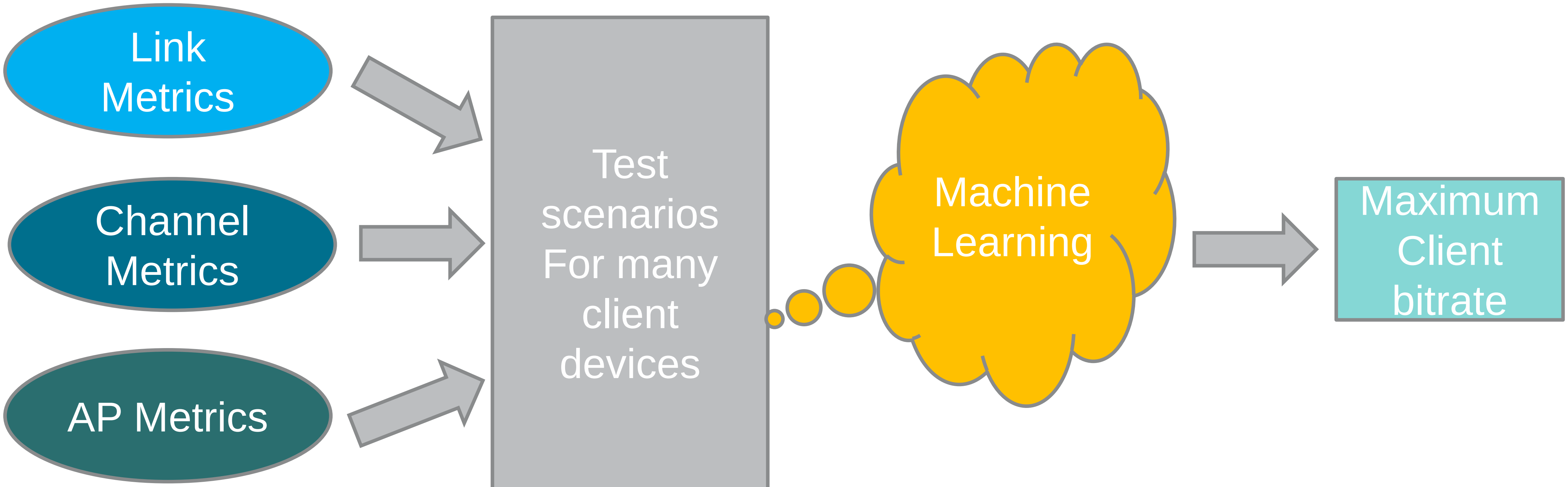


WiFi App collects Air KPI over a sliding windows below of <X>seconds every 5:

- Channel Load
- Channel interference
- Channel BG noise
- Channel Transmit Efficiency

Monitoring

Wi-Fi AI : Predicting User Maximum bitrate



GlobalLogic

Smart Scanner App

Wi-Fi Spectrum Analyzer

- Proceed to repetitive scan over a long period (5 minutes)
- Create a ‘Channel Ranking’ record showing both the absolute and the relative quality of the current channel
- Use a self logic to decide whether to proceed to ‘Full’ scan or ‘Incremental’ scan based on AP & clients metrics

Wi-Fi Incremental Scanning

- Channel scanning impacts system, the goal is to minimize its impact on clients
- Add ‘Incremental’ scanning to maintain channel list candidate along time
- Keep track on channel load, noise etc. on all other channels during scan on top of existing returned surrounding SSID results

Smart Scanning

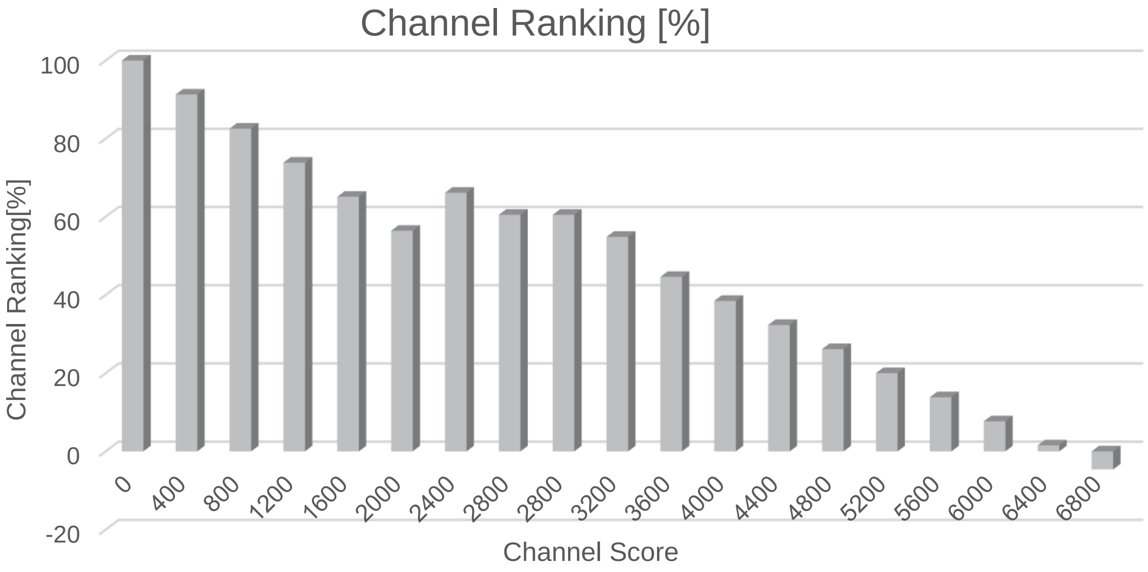
GlobalLogic®

Smart Channel Selection App

Wi-Fi Enhanced ACS

- Add criteria to decide that new channel is indeed better in both a quantitative and qualitative way than current channel

ChannelChangeIncrease in TP[%] = (BestChannelRankingScore/Channel RankingScore) * 100



- Support for removing DFS channel from ACS in 5Ghz if required

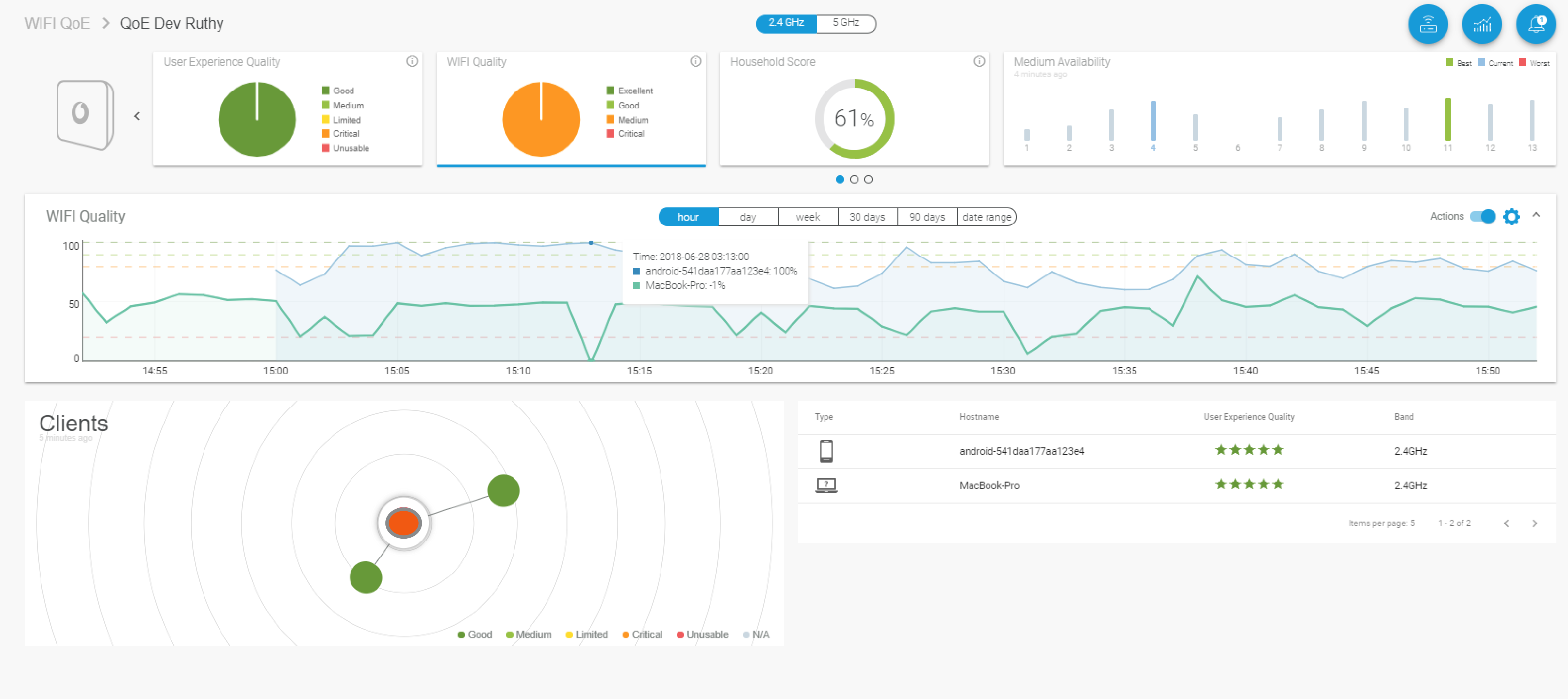
Smart Channel Selection

Wi-Fi QoE Smart Action Manager

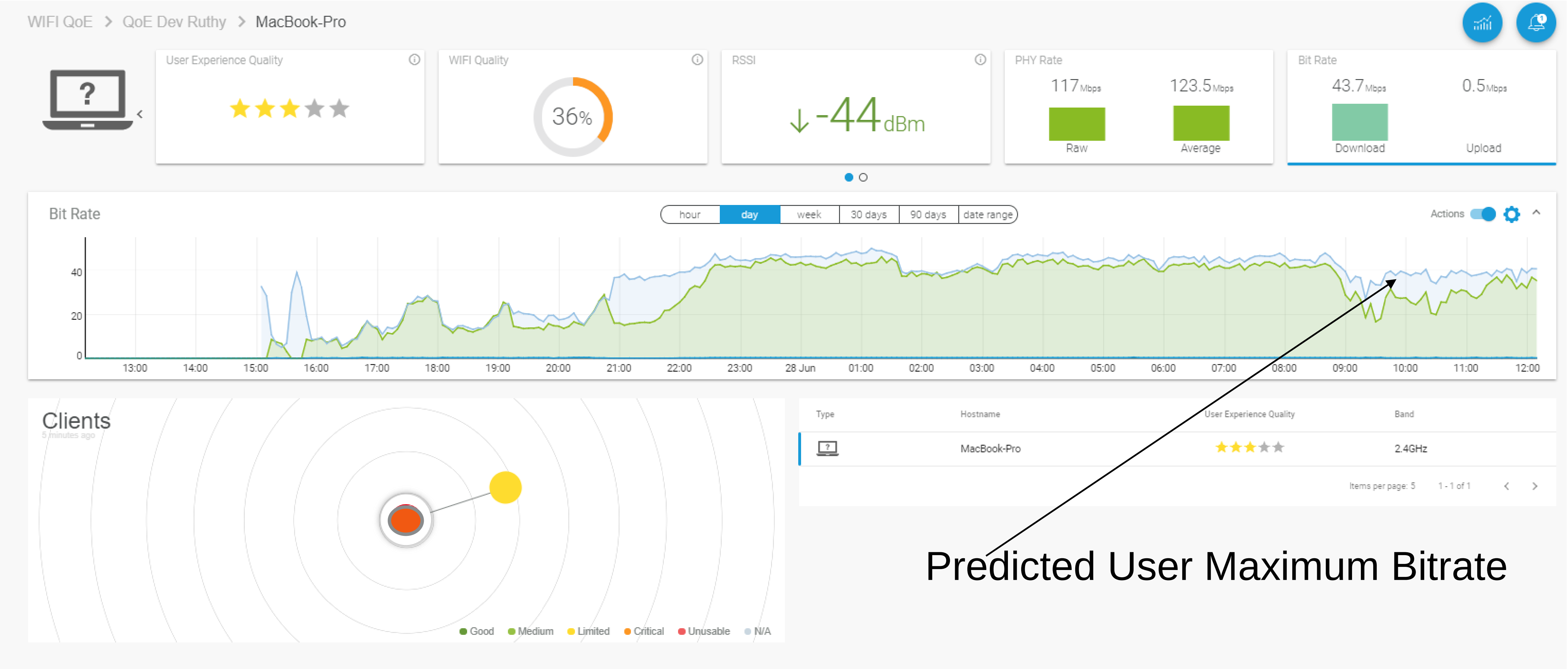
- QoE Smart Logic for minimizing user impact
  - Predict Maximum Bitrate from Link & Air collected KPI (from Monitoring)
  - Classifies User Experience from current bitrate to predicted maximum bitrate in such 5 levels (Good, Medium, Limited, Critical, Unusable)
  - Decides whether to proceed to action by comparing Channel Ranking from Best Channel (e.g. if current rank is > 80% do not do any action)
  - Based on User QoE decides to operate to:
    - Aggressive Action (ACS , Band Steering , ATF etc…)
      - Usually for Critical QoE users
      - E.g for ACS action use full scan
    - Smooth Action (ACS , Band Steering , ATF etc…)
      - Usually for Limited or Medium QoE users
      - e.g for Band steering use smooth mechanism as 11v non-intrusive protocol with clients (instead of black listing mechanism)

Wi-Fi QoE Manager

Wi-Fi QoE Cloud UI | CPE Statistics



Wi-Fi QoE Cloud UI | Client Statistics



Wi-Fi QoE Data Modeling

InternetGatewayDevice. X_JUNGO_COM_TR_181.Device.WiFi. QoE.User.Stats{i}.	object	-	This object is used to retrieve the Statistics of the different QoE levels for each client. Those levels can be a combination of the below enumeration: • Good • Medium • Critical • Limited • Unusable
AssociatedDevice	String(256)	-	The value MUST be the path name of the AssociatedDevice (or equivalent) table row that models the host, or an empty string if there is no such table. This should point to the entry: • InternetGatewayDevice.LANDevice.{i}.WLANConfiguration.{i}.AssociatedDevice.{i}.
QoELevel	String(256)	-	This identifies the user QoE as described above. Enumeration of below (*): • Good • Medium • Critical • Limited • None

GlobalLogic

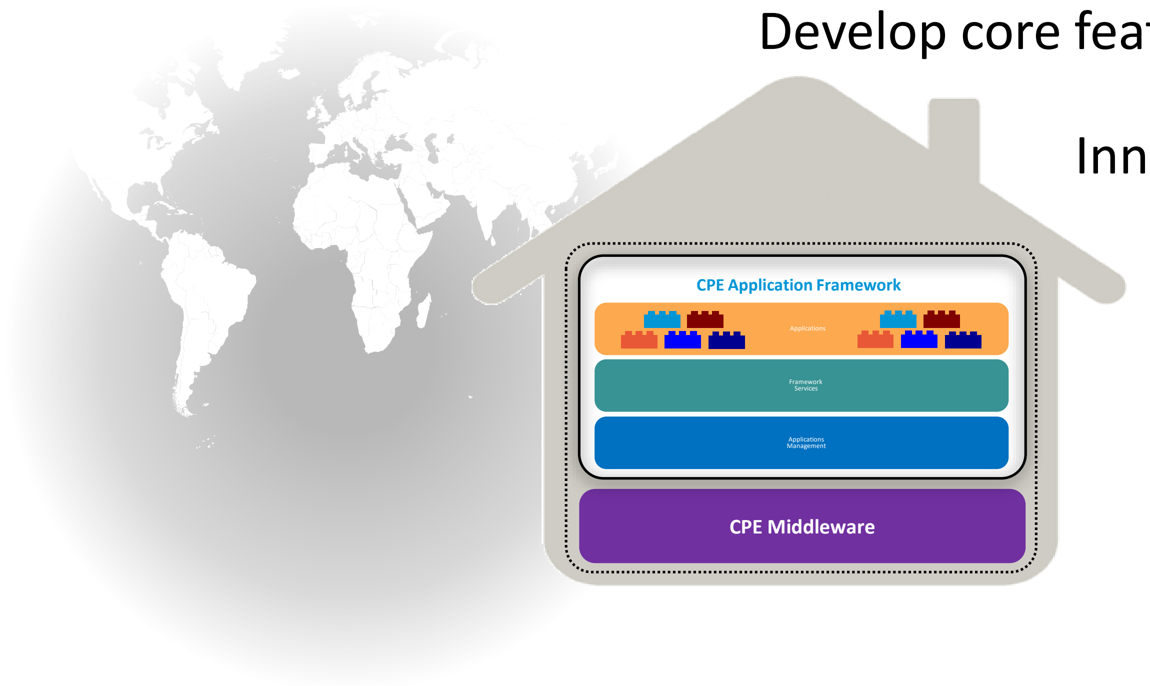
Leading software engineering services for RG

Support **full life cycle …**

Overall more than **60M** RGs deployed by Telcos, **CPE Middleware** running on different SoCs

Develop core features for Telco services in **an agile and CI methods**

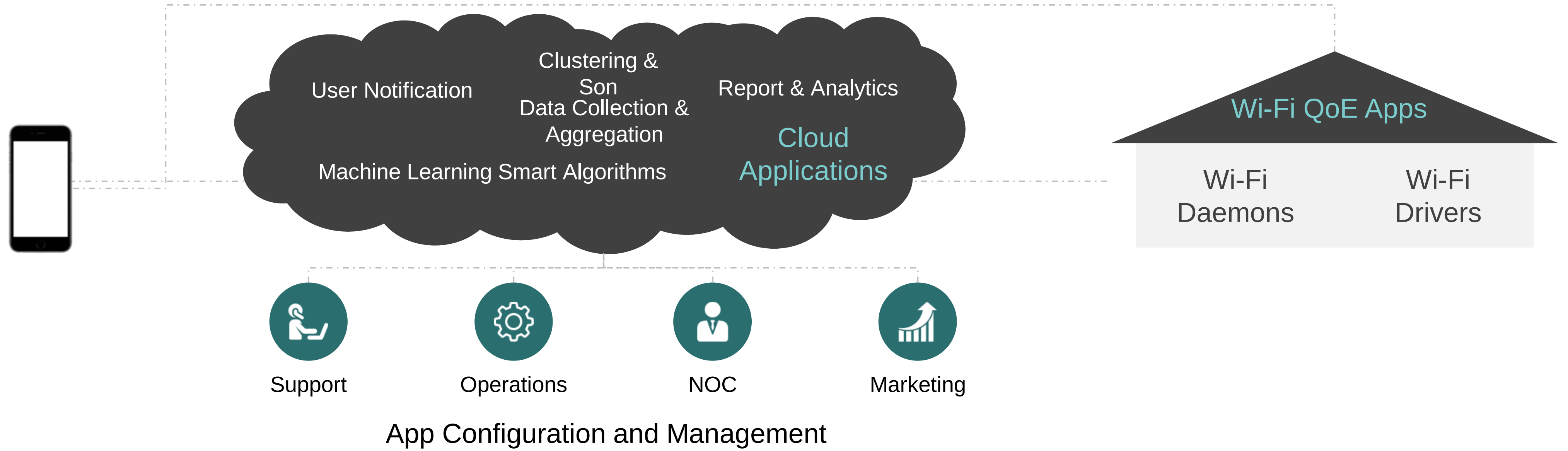
Innovate new **CPE and cloud Applications**



GlobalLogic Experience Areas

Private	Public	Managed Home	Business Wi-Fi	Public Wi-Fi	V2X

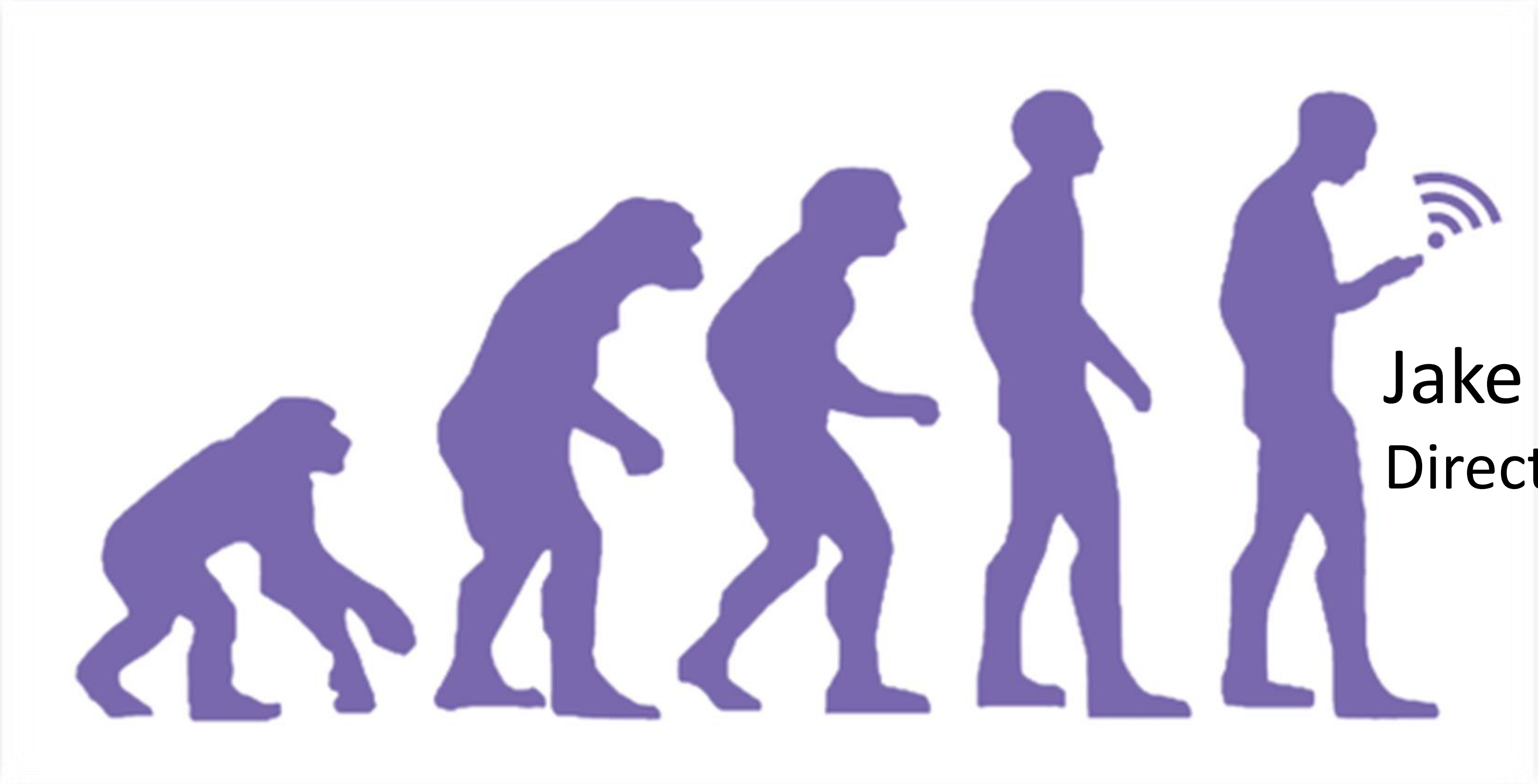
Enhance Wi-Fi user experience	Development of “Free Wi-Fi” solution	Add Wi-Fi feature or App on residential gateway from the cloud	Implement V2X protocol for connected devices



Wi-Fi ROI

Jake Sailana
Director Product Marketing | ZyXEL
jacobs@zyxel.com

Wi-Fi ROi

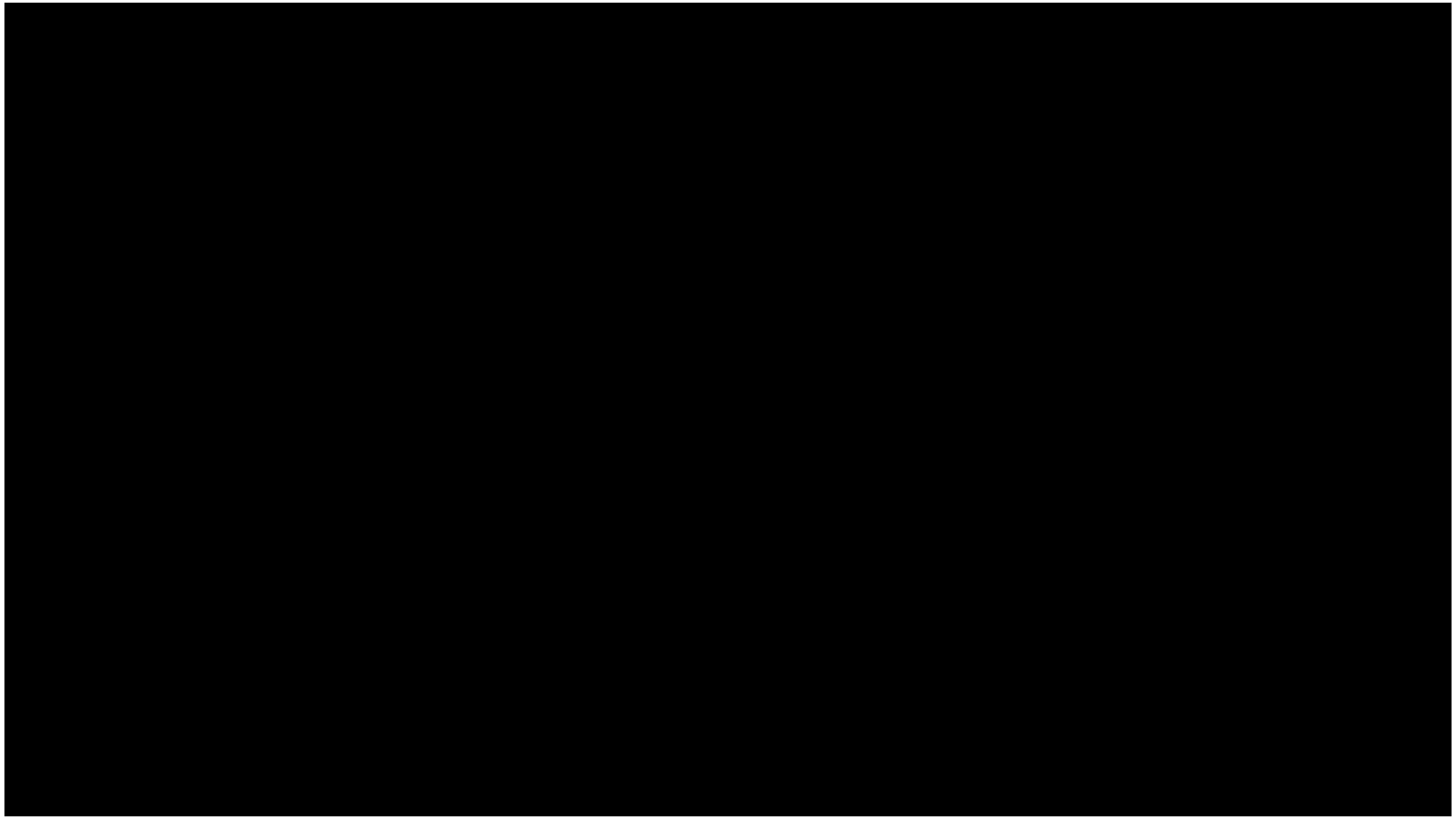


Jake Sailana
Director, Product Marketing

Agenda

- Managed Wi-Fi: What and Why?
- Customer Experience
- WiFi Service Capable Organization

Wi-Fi Isn’t Easy



What does it take?

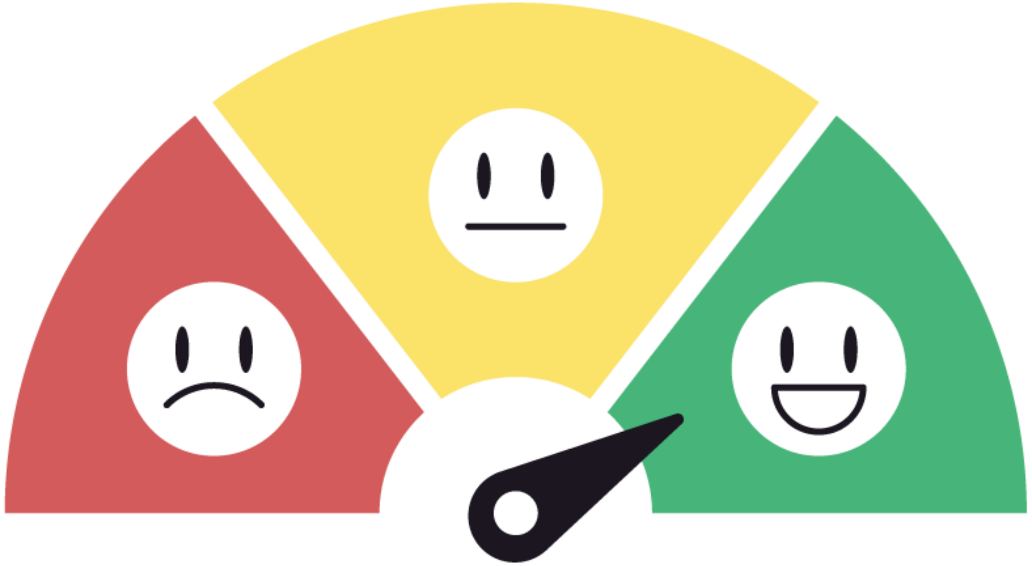
1. Whole Home Coverage
2. Network Optimized for Mobility & Video
3. Remote Manageability for Support and Quality of Experience
4. Network Visibility / Control for Subscribers

Business Case for Managed WiFi

- Cost Reduction
- Recurring Revenue
- Subscriber Stickiness
- Boost Customer Satisfaction
- Visibility into the network / subscriber behavior
- Potential for upsell

Customer Experience

Defining
Measuring
Managing



ZYXEL

Managing Customer Experience

Quality of Service Perception Gap

$$Perceived\,Value = \frac{Expectation}{Experience}$$

Upgrading all three essential components of service ready organization

- Products
- Personnel
- Processes

Products:
Managed WiFi System

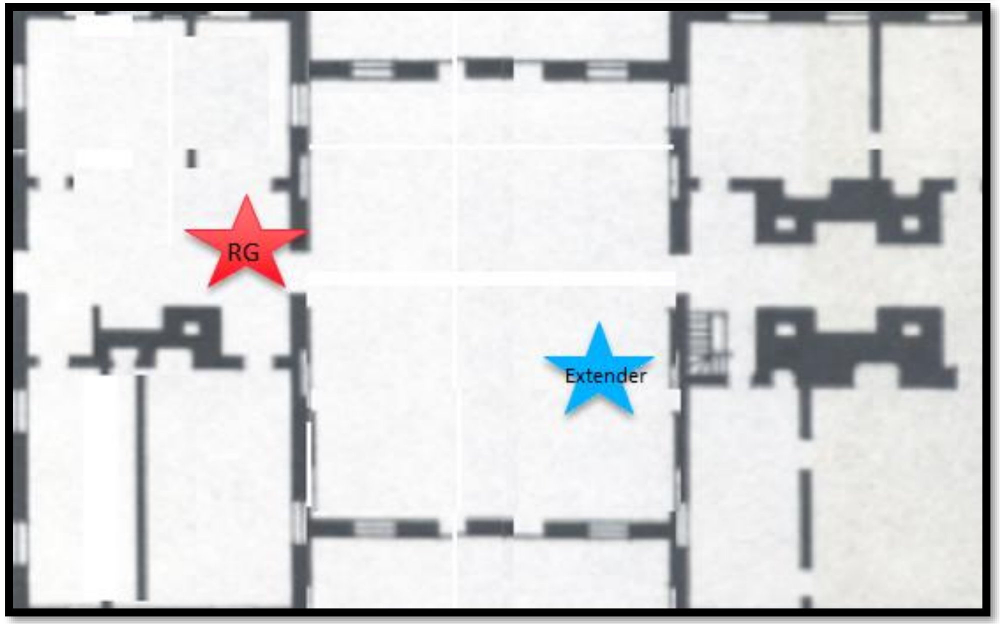
Essential Product Features

- ✓ Whole-home WiFi Coverage
- ✓ Single WiFi Network
- ✓ Auto-configuration
- ✓ Seamless Roaming
- ✓ Service Performance Guarantees
- ✓ Standard-based (TR-69) Manageability
- ✓ Subscriber self-help app

ZYXEL

Testing and Evaluation

- ✓ Understanding the system
- ✓ Testing it as a system
- ✓ Homes vs. Lab Testing
- ✓ When is an Extender necessary – how many?
- ✓ Steering and Roaming
  - ✓ 802.11kvr Clients
  - ✓ Legacy Clients
  - ✓ Changing WiFi Environment



Personnel

ZYXEL

Key Support Teams

- Sales
- Customer Support Reps
- Installation Technicians

- Education
- Incentives
- Evaluation

Customer Support

Installation Technicians

- Troubleshooting Wi-Fi issues
- Training
  - Awareness of common issues
  - Diagnostics
  - Using remote management system
- Wi-Fi Survey / Wi-Fi Checklist
- Upsell opportunity

Processes

Standard Operating Procedure

- Reducing the variables
- Improving predictability
- Effective trouble shooting
- Fast issue resolution
- Reducing cost + Improved customer satisfaction

Communication between Customer Support / Installation Crew

Wi-Fi Training: Terms and Issues

- WiFi Standards (802.11ac, 802.11n, Dual-band)
- WiFi Speed and Range
- Interference / WiFi Environment
- Repeater – Y / N
- Band Steering
- Client Roaming
- Sticky Clients
- Video Streaming

ZYXEL

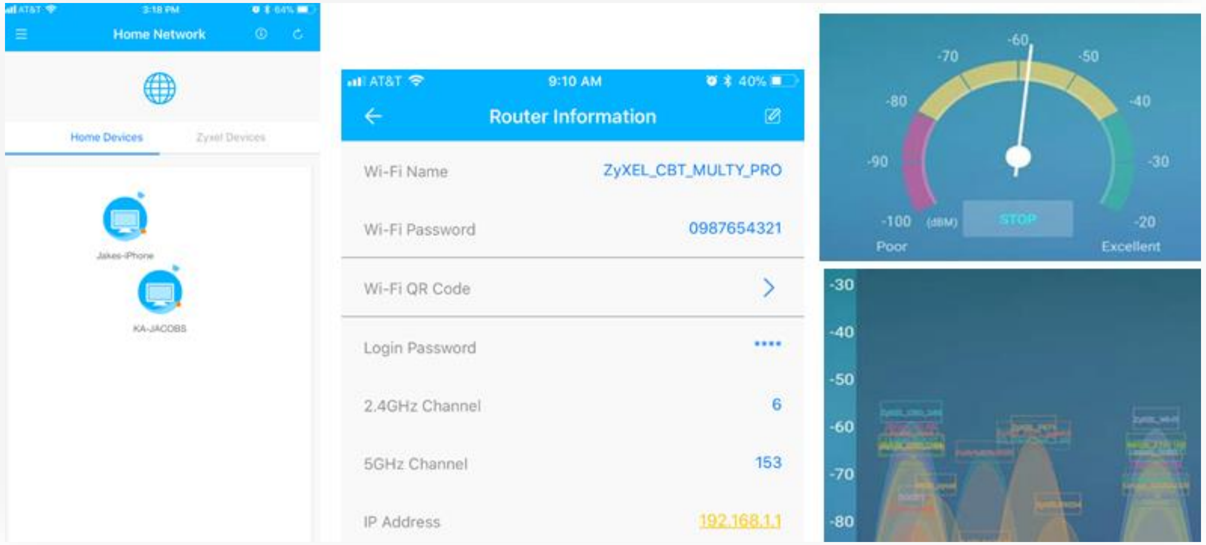
WiFi Check List – Wi-Fi Survey

1. Size and general layout of the house
2. Size of the family
3. Location for the RG
4. Neighboring WiFi Diagnostics
5. High usage areas – living room, office, bedrooms
6. Dead spots
7. Is the home wired for Ethernet and/or coax

ZYXEL

Other Tools for Managed Wi-Fi

- WiFi Analyzer for Install Technicians
- TR69 / TR181 Standard for Remote Management
- Self-install options
- Subscriber Self-help App
    - Keep it Simple
- Analytics



ZYXEL

ZYXEL

Your Networking Ally

Segment 4
Panel Discussion & Audience Q&A

Moderator: Lincoln Lavoie
BBF Technical Chair
Senior Engineer, Broadband Technologies

University of New Hampshire InterOperability Laboratory

For more information

Learn more about Broadband Forum at:
www.broadband-forum.org

Learn more about Broadband Forum BASe at:
www.broadband-forum.org/news-events/events-webinars/base-events-home

or, contact

rheier@broadband-forum.org

A Broadband Forum BASe event

THANK YOU TO OUR SPONSOR

Thank you

See you again at the next BASE *soon. Location TBD*

Bernd Hesse

BASE Chairman, Broadband Forum

Sen. Dir. , Standards Marketing & Thought Leadership Calix

bernd.hesse@calix.com