Welcome and Introduction

B R O A D B A N D

Acceleration

Seminar

Event

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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:

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

### 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

### 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

2:15 - 2:35  **Automated Deployment of Cloud-based Access Infrastructure & Services**

- Tim Carey, Lead Technology Strategist, Nokia

2:35 - 2:55  **Intelligent Broadband Access & Home Maintenance**

- Wei Lin, System Architect, Huawei Technologies

### Segment 3 Panel Discussion and Audience Q&A

- Moderated by Alison Diana, Editor, Light Reading

### Break

3:10 - 3:25  **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
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<thead>
<tr>
<th>Time</th>
<th>Session</th>
<th>Speaker</th>
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<tbody>
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</table>
Applications for Gigabit Age

David Tomalin
Group CTO / CityFibre
david.tomalin@cityfibre.com
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
Social, cultural & political change
Education: e-learning & tailored tutoring
Education: virtual exploration
Healthcare: data-driven analysis & care planning

LIVER AND DIGESTIVE SYSTEM CHECK-UP

- Taking blood sample
- Ultrasonography
- Liver elasticity measurement
- Liver biopsy
- Consultation with the doctor

CityFibre
Healthcare: rapid emergency response
Healthcare: remote consultation & diagnosis
Digitally enriched community & family

CityFibre
Immersive gaming & sports
The digital divide
Enabling the future
CityFibre
The Next-Gen Access Ecosystem and Market: Technologies, Applications, and Vendors

Julie Kunstler
Principal Analyst | Ovum
Julie.Kunstler@ovum.com
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.

**Early Adopters**

“Vision” regarding the impact of fiber access.

- Government support for vision.
- Patience regarding return-on-investment.

This gap is closing rapidly
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.
- Fiber access costs are declining while revenue generating subscribers are being brought onto networks faster.
- 5G represents an opportunity for fiber access – PON can support 5G cell densification for MBH (mobile backhaul) and possibly MFH (fronthaul).
- The vision is spreading to city/local governments – the value of fiber access is a crucial asset.
- PON is supporting “universal” access – one access network for different customers and applications.
VR forecasts hide the broadband network requirements

<table>
<thead>
<tr>
<th>Mobile VR</th>
<th>Dedicated VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>HD</td>
<td>HD per eye at 90fps</td>
</tr>
<tr>
<td>4K</td>
<td>4K per eye at 90fps</td>
</tr>
<tr>
<td>4K at 60fps</td>
<td>4K per eye at 120fps</td>
</tr>
<tr>
<td>HD x 1</td>
<td>HD x 6</td>
</tr>
<tr>
<td>HD x 4</td>
<td>HD x 24</td>
</tr>
<tr>
<td>HD x 8</td>
<td>HD x 32</td>
</tr>
</tbody>
</table>

Source: Ovum
Movement to fiber enables future-proofing, economically

- 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

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.

Ovum continues to revise upwards its FTTx household subscriber forecast.

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

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

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
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 FTTSstreet 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

Service bundles are key

<table>
<thead>
<tr>
<th>Bundle</th>
<th>Typical level of churn*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single play broadband</td>
<td>20–25%</td>
</tr>
<tr>
<td>Dual play</td>
<td>15%</td>
</tr>
<tr>
<td><strong>Triple play</strong></td>
<td><strong>10%</strong></td>
</tr>
<tr>
<td>Quad play</td>
<td>5%</td>
</tr>
</tbody>
</table>

*based on typical rates in WE

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

Source: Ovum survey

Source: Ovum
Looking backwards – significant milestones
Wireline broadband access equipment market – strength in PON segment continues

Source: Ovum

2Q18 – would have been a record breaking PON equipment quarter if not for ZTE’s woes.
Next-gen PON equipment revenues – ONT/ONU revenues strong in 2Q18

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.
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.

Network future-proofing

Major drivers for next-gen PON

Competition for residential customer

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.

Non-residential customers and applications

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:

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

Almost all OLTs and ONTs/ONUs will be next-gen equipment

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

5G subscriptions by region, 2019–22

Top 5G markets by subscriptions, 2022

Source: Ovum
## Three major application areas for 5G

### Enhanced mobile broadband (including fixed wireless access)
- 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

### Ultrareliable, low-latency communications
- 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

### Massive machine-type communications (IoT)
- 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

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Potential Solution</th>
</tr>
</thead>
</table>
| 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
## Challenge

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</table>
| 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

- 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.

<table>
<thead>
<tr>
<th>Smart cities services/applications</th>
<th>Leading telco providers</th>
<th>Leading technology and industry partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart lighting</td>
<td>Deutsche Telekom</td>
<td>Philips Lighting</td>
</tr>
<tr>
<td>Public security</td>
<td>AT&amp;T</td>
<td>GE Lighting</td>
</tr>
<tr>
<td>Traffic management &amp; smart parking</td>
<td>AT&amp;T</td>
<td>Telensa</td>
</tr>
<tr>
<td>Environmental management &amp; services</td>
<td>Deutsche Telekom</td>
<td>Hitachi</td>
</tr>
<tr>
<td>Smart buildings &amp; venues</td>
<td>AT&amp;T</td>
<td>MOTOROLA</td>
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<tr>
<td>Smart public transport</td>
<td>AT&amp;T</td>
<td>MOBILITI</td>
</tr>
<tr>
<td>Total Smart City Solutions</td>
<td>CISCO</td>
<td>HUAWEI</td>
</tr>
</tbody>
</table>

Source: Ovum
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IoT and the Future of the Connected Home

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IoT and the Future of the Connected Smart Home

Alan DiCicco
Senior Director, Thought Leadership Marketing
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 built 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?
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?
What’s the **service provider** opportunity in the connected smart home?
IoT ingredients of success

- Wi-Fi Connectivity
- Universal IOT Gateway
- Platform Extensibility
- Security and Privacy

EASY
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

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

Your reputation is built on exceptional Wi-Fi
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!
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

Physical Unclonable Function (PUF)

Open source PUF database

Network Telemetry
• Analytics
• Machine Learning
• AI

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.

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, increase the Internet speed during the Zoom call.
Alexa, give my Zoom video call top priority on the Wi-Fi network.
Alexa, when will the dryer be finished?
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

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New Business Opportunities with 5G

October 28th, 2018
Hotel Encore, Las Vegas
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
5G will be Key Enabler of the 4th Industrial Revolution

1st 18th Century
Steam Engine

2nd 19th Century
Electricity

3rd 20th Century
Computer

4th 21st Century
Internet of Everything

Transformed Industries

ALL Industries
Multiple Challenges and Gaps to reach 5G

5G Latency: 1 ms E2E Latency

5G Throughput: 10Gbps Per Connection

5G Connections: 1,000K Connections Per Km2

5G Mobility: 500 km/h High-speed Railway

5G Network Architecture: Slicing Ability Required

LTE Gap Latency: 30~50ms

LTE Gap Throughput: 600Mbps

LTE Gap Connections: 10K

LTE Gap Mobility: 350 Km/h

LTE Gap Network Architecture: Inflexible

5G vs LTE:
- Latency: 1 ms vs 30~50ms
- Throughput: 10Gbps vs 600Mbps
- Connections: 1,000K vs 10K
- Mobility: 500 km/h vs 350 km/h
- Architecture: Slicing Ability Required vs Inflexible
Key 5G Capabilities

- **mMTC** (Massive Machine Type Communications)
- **uRLLC** (Ultra-reliable and Low-latency Communications)

Future IMT

- eMBB (Enhanced Mobile Broadband)
  - Gbps
  - 3D Video, UHD Screen
  - Work and play in the cloud
  - Augmented reality
  - Industry automation
  - Mission critical applications
  - Self driving car

- Smart Home/Building

- Smart City

- mMTC (Massive Machine Type Communications)

- uRLLC (Ultra-reliable and Low-latency Communications)

**ITU-R**

- Peak Data Rate (Gbit/s)
- User Experienced Data Rate (Mbit/s)
- Area Traffic Capacity (Mbit/s/m²)
- Network Energy Efficiency
- Spectrum Efficiency
- Mobility (km/h)
- Connection Density (devices/km²)
- Latency (ms)

**3x**

10 Gbit/s

100 Mbit/s

100x

1x

10

100

1

1

10

10

10

100

100

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10

100

100

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5G Market size forecast

5G subscriptions by 2021

- 45% North America
- 35% China, Japan, South Korea, and Europe
- 10% Middle East, Africa, and others

Examples of new revenue opportunities

- IoT revenue forecast by 2024 ($bn)
  - Total IoT Ecosystem Revenue: $4.3bn
  - Operator IoT Addressable Revenue: $15bn
  - Operator IoT Expected Revenue: $9bn

AR/VR revenue forecast (billion)

- 2017E: AR $50, VR $10
- 2018E: AR $70, VR $15
- 2019E: AR $90, VR $20
- 2020E: AR $110, VR $25

- 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
Exponential Mobile Data Traffic Growth

Network traffic consumed per month, per user (GB)

Sources: Cisco Visual Networking Index; BCG analysis.
Networks Cannot Support Data Traffic Growth

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

<table>
<thead>
<tr>
<th>Use Case category</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
<th>2022</th>
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<tbody>
<tr>
<td>eMBB (B2C)</td>
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</tbody>
</table>

1st Wave 5G use case by regions

- **USA**: WTTx 28GHz
- **Japan/ S.Korea**: All new innovations connected cars, VR/AR, network slicing
- **W. Europe**: on its key assets
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

Estimated average network spend 2020-2025 (indexed to 2013-2018)

Traffic CAGR (%)

<table>
<thead>
<tr>
<th>Traffic CAGR (%)</th>
<th>Traffic multiple</th>
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<tbody>
<tr>
<td>25</td>
<td>1.4x</td>
</tr>
<tr>
<td>30</td>
<td>1.5x</td>
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<tr>
<td>40</td>
<td>1.6x</td>
</tr>
<tr>
<td>50</td>
<td>1.8x</td>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Telcos</th>
<th>New business models</th>
<th>Telco ecosystem partners</th>
</tr>
</thead>
<tbody>
<tr>
<td>5G deployment</td>
<td>• Push eMBB to protect customer base and improve monetization</td>
<td>• Explore partnering options with telco network operators to further build innovative services and digital infrastructure</td>
</tr>
<tr>
<td></td>
<td>• Introduce FWA as attacker or fixed line substitute</td>
<td>• Recognize the long-term economics of infrastructure build-out in investment decisions</td>
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<td></td>
<td>• Promote network slicing for mission-critical B2B</td>
<td>• Launch 5G handsets in all price ranges early on</td>
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<td>• Rigorously exploit massive IoT opportunities for long run revenue growth</td>
<td>• Become a technology transformation partner</td>
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<td>• Innovate service offering and contracting options</td>
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<td></td>
<td>• Explore further infrastructure wholesale opportunities, such as small cells</td>
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<td></td>
<td>• Review existing pricing models regarding 5G</td>
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<tr>
<td>Regulators &amp; governments</td>
<td>Infrastructure access</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Facilitate fronthaul and backhaul infrastructure</td>
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<td></td>
<td></td>
<td>• Release more, and more affordable, spectrum</td>
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<td></td>
<td>• Provide advantageous macro- and small-cell site locations</td>
<td>• Encourage and allow network sharing agreements (especially small cells)</td>
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<tr>
<td></td>
<td></td>
<td>• Facilitate small-cell deployment</td>
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<td>• Harmonize power density limits with WHO and ICNIRP recommendations</td>
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<tr>
<td>Tower companies</td>
<td>Regulatory environment</td>
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<tr>
<td></td>
<td>• Facilitate small-cell deployment</td>
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<tr>
<td>Vendors</td>
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<td></td>
<td>• Harmonize power density limits with WHO and ICNIRP recommendations</td>
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<tr>
<td>Handset manufacturers</td>
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<td>Service providers</td>
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<tr>
<td>Investors</td>
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<tr>
<td></td>
<td></td>
<td>• Recognize the long-term economics of infrastructure build-out in investment decisions</td>
</tr>
</tbody>
</table>
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
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**
- Encouraging forward-leaning rights of way, pole attachments, battery back-up policies and more to help build fiber faster

**Investment Incentives**
- Pursuing light-touch regulation to benefit consumers

**Community Broadband**
- Advocating for an ownership-agnostic view of fiber networks to support facilities buildout

**Rural Broadband**
- Encouraging government support for Universal Service

Federal, State, and Local
Why Fiber?

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

**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

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

**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

- **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

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.

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.
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.
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 2 km
- 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
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

• 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

$\text{$} \quad 55\text{Gb}

\downarrow \quad 1.3\text{Gb}
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

- 30Mbps xDSL
- Wi-Fi link between households
- 20Mbps xDSL
- 20Mbps 4G
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
Segment 1
Panel Discussion & Audience Q&A

Moderator: Lisa Youngers
President and CEO, Fiber Broadband Association
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
Super-PON:
A PON Architecture for Access Infrastructure Consolidation

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

• Why Super-PON
• Super-PON Technology
• Super-PON Applicability
• Standardization
Super-PON Goal

From here...

Up to 20 km

Up to 64

...to here

Up to 50 km

Up to 1024

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

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

Super-PON: 3 COs

- Feeder fiber
- Wavelength splitter feeder fiber
- Power splitter feeder fiber
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

From here...

Up to 20 km

Up to 64

...to here

Up to 50 km

Up to 1024

CO

Passive ODN

Google Fiber
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

MUX/Amplifier

OLT

10G-PON 1

10G-PON 2

10G-PON m

Pt2Pt 10G 1

Pt2Pt 10G 2

Pt2Pt 10G q

Booster

Preamp

DMUX

BAND MUX

CO

MUX

λ Router

A: up to 40 Km

B: up to 20 Km

A + B ≤ 50 Km

ONU 1

ONU 2

ONU n

Super-PON Architecture

CO

MUX/Amplifier

OLT

10G-PON 1

10G-PON 2

10G-PON m

Pt2Pt 10G 1

Pt2Pt 10G 2

Pt2Pt 10G q

Booster

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A + B ≤ 50 Km

ONU 1

ONU 2

ONU n

Super-PON Architecture

CO

MUX/Amplifier

OLT

10G-PON 1

10G-PON 2

10G-PON m

Pt2Pt 10G 1

Pt2Pt 10G 2

Pt2Pt 10G q

Booster

Preamp

DMUX

BAND MUX

CO

MUX

λ Router

A: up to 40 Km

B: up to 20 Km

A + B ≤ 50 Km

ONU 1

ONU 2

ONU n
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
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 $\rightarrow$ 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
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

Fiber optic cabling, Wavelength Combiner Amplifier, Wavelength Splitter, and Power Splitter (Channel)

OLT

PMD

MDI

PMA

ONU

PMD

PMA

PMA

PMA

CO

Wavelength Combiner Amplifier

Wavelength Splitter

Power Splitter

Passive ODN
NG-PON2 PtMP Support

- NG-PON2 OLT CT 1
- NG-PON2 OLT CT 2
- NG-PON2 OLT CT 3
- ... NG-PON2 OLT CT n

- SNI
- S/R-CP
- S/R-CG
- ODN
- R/S
- UNI

- IF_{NG-PON2}
- IF_{NG-PON2}
- IF_{NG-PON2}
- IF_{NG-PON2}

- NG-PON2 ONU
- NG-PON2 ONU
- NG-PON2 ONU
- NG-PON2 ONU

CG – channel group
CP – channel pair
CT – channel termination
WM – wavelength mux

G.989.2(14)_F6-1
NG-PON2 Tunable PtP (Annex A)

- The branching node is a power splitter
- $\lambda$ 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 $\lambda$. 

G.889.2(Amd.16)_FC.1
Super-PON PtMP (1)

Super-PON OLT CT 1

Super-PON OLT CT 2

Super-PON OLT CT n

SNI

S/R-CP

S/R-CG

WM

Branching node

λ selection function

λ1

λ2

λn

Power splitter

Power splitter

Power splitter

R/S

UNI

S-PON ONU

S-PON ONU

S-PON ONU

S-PON ONU

S-PON ONU

S-PON ONU

S-PON ONU

S-PON ONU

S-PON ONU

ODN
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


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

Kevin Bourg
Optical Architect Director | Corning Optical Communications
Kevin.Bourg@corning.com
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
Predicting consumer demand

Nielsen’s Law
Billboard speeds grow 50% per year

SHOULD WE PREPARE FOR A HIGHER TRAJECTORY
What came first: Demand or Infrastructure?

THE VIRTUOUS CYCLE OF TECHNOLOGY
Demand drivers

- OTT Video
- Social Media
- Augmented & Virtual Reality
- Autonomous Vehicles
- Hi-def Gaming
- Connected World (IOT)
- Security
- Remote Learning
- 4K/8K TV
- Smart City
- Telemedicine
- E-Commerce

Increasing high-speed broadband network deployments
Competition is heating up!

CONSIDER YOUR BUSINESS
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**
Converged approach offers up to 40% CAPEX AVOIDANCE VERSUS REDUNDANT BUILDS
Be future-ready!

EVALUATE A CONVERGED FIBER APPROACH IN YOUR NEXT UPGRADE CYCLE
NG-PON2 Solution for 10G Internet Service: SK’s Development & Deployment

Choongbok Lee
Senior Manager | SK Broadband
choongbok.lee@sk.com
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.

<table>
<thead>
<tr>
<th>Rich Multimedia Contents</th>
<th>More devices per household</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hologram</td>
<td>6Gbps</td>
</tr>
<tr>
<td>360° UHD VR</td>
<td>500Mbps</td>
</tr>
<tr>
<td>UHD(8K)</td>
<td>140Mbps</td>
</tr>
<tr>
<td>UHD(4K)</td>
<td>35Mbps</td>
</tr>
<tr>
<td>FHD</td>
<td>15Mbps</td>
</tr>
<tr>
<td>More cloud-based service</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>More bandwidth per device</td>
<td></td>
</tr>
<tr>
<td>UHD/VR</td>
<td>802.11ac wave2 Wi-Fi</td>
</tr>
<tr>
<td></td>
<td>Better Smartphone performance</td>
</tr>
<tr>
<td></td>
<td>Backhaul for 5G Femto</td>
</tr>
</tbody>
</table>
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.
NG-PON2 Development Timelines

- 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 1st 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

- 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.

<table>
<thead>
<tr>
<th>Subscription Plan (max. throughput)</th>
<th>Smart (100M)</th>
<th>Giga Lite (500M)</th>
<th>Giga (1G)</th>
<th>Giga Premium (2.5G)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Contract</td>
<td>33</td>
<td>45</td>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>3 yr Contract</td>
<td>20</td>
<td>30</td>
<td>35</td>
<td>40</td>
</tr>
</tbody>
</table>

※ 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)

<table>
<thead>
<tr>
<th>Item</th>
<th>Last-mile</th>
<th>Access Technology</th>
<th>Structure (Topology)</th>
<th>Service Speed (Per Household)</th>
</tr>
</thead>
<tbody>
<tr>
<td>①</td>
<td>Optical Cable</td>
<td>NG-PON2</td>
<td>FTTH</td>
<td>10G/5G/2.5Gbps</td>
</tr>
<tr>
<td>②</td>
<td>UTP Cable (4Pair Per Household)</td>
<td>NG-PON2</td>
<td>FTTB</td>
<td>5G(TBD)/2.5Gbps</td>
</tr>
<tr>
<td>③</td>
<td>UTP Cable (2Pair Per Household)</td>
<td>NG-PON2</td>
<td>FTTB</td>
<td>2.5G(TBD)/1Gbps</td>
</tr>
<tr>
<td>④</td>
<td>Telephone Line</td>
<td>NG-PON2 (G.fast)</td>
<td>FTTB</td>
<td>1Gbps</td>
</tr>
<tr>
<td>⑤</td>
<td>Optical Cable</td>
<td>NG-PON2</td>
<td>FTTH</td>
<td>10G/5G/2.5Gbps</td>
</tr>
<tr>
<td>⑥</td>
<td>Coaxial Cable</td>
<td>DOCSIS 3.1</td>
<td>HFC</td>
<td>2.5Gbps</td>
</tr>
</tbody>
</table>
10G Internet

• Devices support 802.11ax are likely to appear next year.
• Legacy G-PON network will be a hurdle for Home services.
thank you
NG-PON2 Optics Update: Path to Massive Deployment

Wei-Ping Huang

Founder and Chief Scientist | HiSense Broadband Multimedia Technologies Co.

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Dealing with Capacity Growth in Access Networks

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Co-Founder and CTO | PICadvanced

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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!”
Company presentation

- Portuguese startup founded in 2014
- Located in Aveiro

“Think outside the box, with us!”
PICadvanced – our facilities
Bandwidth is increasing

Cloud services

Number of subscribers

IoT

Usage per subscriber

Quality of services

UHD Contents

4.0 Industry
How is the access networks spectrum?

From
20-30nm wavelength wondering (GPON)
to
6-20nm wavelength wondering (XGSPON)

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

To
Next generation 5G enabler
Near Future

INTEGRATION

Increasing bandwidth

More power consumption, size and costs

Hardware Complexity

But, will this be suitable for access?
Components packaged

Photonic integrated circuits (monolithic or hybrid or even mixed)
Why PICs?

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

PICs are the way to make the systems and subsystems ubiquitous

– M Smit

@2014

PICadvanced
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

Depending on technology, some 2-20 chips for testing will cost from 3k-25k$ for couple of mm²

Source: Roadmap JePPix 2018
How to design a chip?

- **System Theory**
  - Concept of the architecture
    - Conven the concept into an optical system
    - Choose the material
    - Choose the fab

- **Optical Architecture**
  - Simulate the whole architecture

- **Simulations**

- **PIC Design**
  - Design the chip in concordance with the design rules

- **DRC + Mask Layout**
  - Design rule check, generate the .gds mask and delivery to the selected fab

- **PIC production**
  - Manufacture the chip, lithography, etching, dicing and others

- **PIC testing**
  - Test the functionalities of the PIC

- **PIC packaging**
  - Encapsulate the chip
PICs have innumerous applications!
PICs have innumerous applications!

- Microwave Photonics
- Access Networks
- Transport Networks
- Datacom

Optical Communications
PICs have innumerous applications!
PICs have innumerous applications!

- Quantum optics
- Metrology
- Spectroscopy
- Beamforming

Optical Signal Processing
PICs have innumerable applications!
Trends due to diversity

Increasing number of application and fields
Roadmap for access optics
Roadmap for access optics

- Wider sub component competition
- More efficient processes
- Mass production

- Photonic integration
- Efficient packaging
- Mass production
Which should be a PIC cost to be competitive?

Source: Roadmap JePPix 2018

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)
Growing rate in access?

Chip cost for different fab scenarios

1\textsuperscript{st} year 1-5k
2\textsuperscript{nd} year 30-100k
3\textsuperscript{rd} year 500k-1M
4\textsuperscript{th} 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
PIC based transceivers

Test chips
- $6 \times 4 = 24 \text{mm}^2$

Commercial grade chips
- $<3 \times <3 = < 9 \text{mm}^2$
PIC based transceivers

Test chips
➢ 6x4 = 24mm²

Commercial grade chips
➢ <3 x <3 = < 9mm²

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

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

Thermal management

Wire bonding, flip-chip

Optical alignment

Holders with V-grooves
Si-holder with V-Grooves

Design
Solidworks 3D CAD

Production
Photolithography and Etching

Testing

Packaging
Wire-bonding

PIC glued with UV-epoxy

Current supply
Voltage supply
Fiber
Testing Chip
Electrical Packaging

Present

- Large existing infrastructure
- Programming flexibility
- Low cost

Moving to...

- Higher thermal and electrical performance
- Substrate flexibility
- Highest I/O capability
- Lower inductance
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 thermal stability
Power complexity main contributors

- SFP power limitations
  1.5W
- XFP power limitations
  3.5W
- Other form factors, e.g.
  CFP 8..32W
General trends

- **Low**
  - Simple biasing
  - Towards SR and low data rate (e.g. GPON)

- **Optical requirements**
  - Simple biasing with some feedback
  - Programmed biasing with high feedback control and high count of actuators

- **High**
  - Chip selection + techniques and fine wavelength
  - High complexity DSP and control interfaces with LUT’s and ADC’s / DACs
  - Towards LR DWDM or SR High data rate
General trends

(DSP)UDWDM, (DSP)coherent, ...

Tunable DWDM, NGPON2

N/tunable (D)WDM, OLT

10GE/XG(s)PON

E/GPON

Simple biasing

Chip selection and wide wavelength

Chip selection and limited wavelength

Optical requirements

Low

Towards SR and low data rate (e.g. GPON)

High

Towards LR DWDM or SR High data rate

High complexity DSP and control interfaces with LUT’s and ADC’s / DACs

Programmed biasing with high feedback control and high count of actuators

Programmed biasing with some feedback

Simple biasing with some feedback

Chip selection + techniques and fine wavelength

Chip selection + techniques and fine wavelength + reach

Power

N/tunable (D)WDM, OLT

10GE/XG(s)PON

E/GPON

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Optical requirements

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Simple biasing

programmed biasing with some feedback

programmed biasing with high feedback control and high count of actuators

High complexity

DSP and control interfaces with LUT’s and ADC’s / DACs

+ PICadvanced

E/GPON

10GE/XG(s)PON

N/tunable (D)WDM, OLT

Tun DWDM, NGPON2

(DSP)UDWDM, (DSP)coherent,…
Price evolution and adoption for access

Prices are indicative

- E/GPON BOSA: $<60$
- 10GE/XG(s)PON BOSA: $<400$
- NGPON2 BOSA: $<100$
- DSP FREE Optics: Solved with analogue and digital electronics

2010 - 2020

20-24 March 2016, Anaheim, CA, USA

DSP based
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

Thank you!

António Teixeira
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.
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
Making it all work

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

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

TR-069 Certification Program launched in 2012

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

- **Gfast**:
  - Certified Device List: [https://bbf-gfast-cert.iol.unh.edu/](https://bbf-gfast-cert.iol.unh.edu/)
  - Certification Test Lab: [UNH-IOL](https://www.iol.unh.edu/)

- **GPON**
  - Certification Test Lab: [LAN Park](https://www.lanpark.eu/)

- **TR-069**
  - Certified Device List: [https://www.broadband-forum.org/tr-069-cert](https://www.broadband-forum.org/tr-069-cert)
  - Certification Test Lab: [UNH-IOL](https://www.iol.unh.edu/)
Thank you

Learn more about the Broadband Forum at:

http://www.broadband-forum.org/
Segment 3
Fiber Extension Technologies, Standards and Solutions

Moderator: Alison Diana
Editor, Light Reading
**Agenda Segment 3**

<table>
<thead>
<tr>
<th>Time</th>
<th>Session Title</th>
<th>Speaker</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:15 - 1:35</td>
<td>Gfast Comes of Age In 2018</td>
<td>Mileend Gadkari, VP Business Development Americas, Sckipio</td>
</tr>
<tr>
<td>1:35 - 1:55</td>
<td>Fibre Access Extension - Reusing In-Building Coaxial Cabling for Multi-Gigabit Performance</td>
<td>Helge Tiainen, Senior Director Business Development, InCoax</td>
</tr>
<tr>
<td>2:15 - 2:35</td>
<td>G.hn Fiber Extenders as an Alternative to Multiport DPU’s.</td>
<td>Paul Arola, Senior Design Specialist, Telus</td>
</tr>
<tr>
<td>2:55 - 3:10</td>
<td>Segment 3 Panel Discussion and Audience Q&amp;A</td>
<td>Moderated by Alison Diana, Editor, Light Reading</td>
</tr>
<tr>
<td>3:10 - 3:25</td>
<td>Break</td>
<td></td>
</tr>
</tbody>
</table>
Gfast Comes of Age in 2018

Mileend Gadkari
VP Business Development Americas | Sckipio
mileend@sckipio.com
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
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

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

---

Reduce Deployment Barriers ➔ Use existing infrastructure
## Existing MDU Infrastructure – Coax or Copper

### Cable Attribute

<table>
<thead>
<tr>
<th></th>
<th>Coax Cable Network</th>
<th>Twisted Pair Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age of in-building wires</td>
<td>☺</td>
<td>☹</td>
</tr>
<tr>
<td>Cable availability at entry point</td>
<td>☺</td>
<td>☺</td>
</tr>
<tr>
<td>Cabling reach home location of TV-set</td>
<td>☺</td>
<td>☹</td>
</tr>
<tr>
<td>Low cable attenuation @ high frequency</td>
<td>☺</td>
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<tr>
<td>Support for multi-gigabit</td>
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<tr>
<td>Roadmap for 10 gigabit</td>
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</table>
# Coax Access Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>DL Mbps</th>
<th>UL Mbps</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.fast over coax (106 MHz profile)</td>
<td>900</td>
<td>100</td>
<td>Supports only point-to-point topologies</td>
</tr>
<tr>
<td>G.fast over coax (212 MHz profile)</td>
<td>1800</td>
<td>100</td>
<td>Supports only point-to-point topologies</td>
</tr>
<tr>
<td>G.hn (200 MHz profile)</td>
<td>1200</td>
<td>200</td>
<td>Supports only 15 modems in point-to-multipoint</td>
</tr>
<tr>
<td>MoCA Access 2.5</td>
<td>2500</td>
<td>2000</td>
<td>Not a baseband technology</td>
</tr>
</tbody>
</table>

- **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
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 1.0
100 Mbps
2005
MoCA 1.0 Field Tests
Demonstrated 100+ Mbps in 97% of all outlets
250 homes (U.S.)

MoCA 1.1
175 Mbps
2006

MoCA 2.0
1 Gbps
2007
MoCA 2.0 Field Tests
Demonstrated 400 Mbps in 90% of all outlets
212 Homes (U.S.)

MoCA 2.5
2.5 Gbps
2010

MoCA Access 2.5
2.5 Gbps
2015

MoCA 3.0
10 Gbps
2018
MoCA Wi-Fi® Mesh Field Tests
MoCA 2.0: 800 Mbps in 100% of homes
MoCA 2.0: 900 Mbps in 75% of homes
Orbi: 300 Mbps in 50% of homes
Eero and Plume: less than 200 Mbps

BASE Las Vegas - October 28th 2018
January 16, 2019
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

QoS, Shaping, Link Booking, Security, VLAN, IGMP, Management

Ethernet

2 RF-channels, 200MHz
3 RF-channels, 300MHz
4 RF-channels, 400MHz
5 RF-channels, 500MHz

250 m

IEEE1905

MoCA Access MIB’s / TR-181 / YANG

Fiber

Network Processor

MoCA 2.5
MAC-PHY

CPE

Ethernet

CPE

Ethernet

CPE

Ethernet
InCoax Fibre Access Extension Node

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

CLC2524
Questions?
Automated Deployment of Cloud-based Access Infrastructure & Services

Tim Carey
Lead Technology Strategist | Nokia
timothy.carey@nokia.com
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: **Broadband Access Abstraction** under BBF’s **Open Broadband** 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 diagram](image)
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!
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.
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?

- Fiber risers installed around building
- Suite entrance for fiber
- Fiber termination point in suite
Why do we need a fiber extender?

Field tech on ladder (3rd story)

Returned with lift another day to finish job
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.
… 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

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
- 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
- Reset
- UART interface
- System on Chip (SoC) mounted on underside
- 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
- Reset
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.
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.
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.
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.
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.
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.
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.
Monte Carlo simulation of G.fast vs G.hn

- High crosstalk MDU modelled
  - 54 active links (e.g. ~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

<table>
<thead>
<tr>
<th>Performance estimate</th>
<th>Current traffic</th>
<th>5 years, 15% CAGR</th>
<th>10 years, 15% CAGR</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>G.fast</td>
<td>G.hn</td>
<td>G.fast</td>
</tr>
<tr>
<td><strong>7 links active</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Downstream</td>
<td>1.12</td>
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<td>1.12</td>
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<tr>
<td>Upstream</td>
<td>0.79</td>
<td>0.81</td>
<td>0.79</td>
</tr>
<tr>
<td><strong>12 links active</strong></td>
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<td></td>
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<tr>
<td>Downstream</td>
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<tr>
<td>Upstream</td>
<td>0.76</td>
<td>0.75</td>
<td>0.72</td>
</tr>
</tbody>
</table>
Thank you
Intelligent Broadband Access & Home Maintenance

Wei Lin
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Access & Home O&M automation & intelligent

For BASE Las Vegas

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

<table>
<thead>
<tr>
<th>The complexity introduced by new technologies</th>
<th>The complexity of the terminal authentication mechanism</th>
<th>Troubleshooting with P2MP</th>
</tr>
</thead>
</table>
| High learning cost DBA, TCONT, GEMport...  | Copper age  
Single user per port; CPE born to be plug and play | Copper age  
P2P test chip & technology ready; SELT/MELT |
| OSS integration complexity:  
The original interface cannot be reused; OSS has to be re-developed | Fiber age  
Multi user per port; ONT requires authentication; it is inevitable to go to the door | Fiber age  
ODN is dumb resources; 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?
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)

② trying hard to improve the networking/application experience, **but**
   Experience issues are hard to locate and happens again and again

③ provide much faster and more efficient troubleshooting, **but**
   Most issue are complaint-driven

---

**Experience visibility**

**Powerful in-home O&M**

**Operators’ requirement**

Active O&M; remote troubleshooting; less to-door
AI: Decoupling OPEX & Network Scale

"We’re using 21st century networks, but network O&M is somehow like being stuck in the 18th century."

- 70% Major faults caused by human errors
- 90% Passive maintenance
- €175 Home visit cost in Europe

**Key Concepts**

- **Network infrastructure**
  - Online data
  - Offline data
  - AI model synchronization
  - AI model library and offline training

- **AI Platform**
  - Online AI reasoning and control
  - Automation
  - Self-healing
  - Self-optimization
  - Autonomy

**Efficiency Categories**

- O&M Efficiency
- Energy Efficiency
- Resource Efficiency

**Self-driving & self-evolution**
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%

*Network Cloud Engine*
- Intent Engine
- Automation Engine
- Intelligence Engine
- Analytics Engine

*BRAS CR OLT STB ONT AP*

*Customer journey*
- Second-level playback

*Quality Insights*
- Bandwidth
- Experience
- Availability

*Intent Engine*
- AI Use Case: Fast Trouble-shooting
- Customer journey
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

- Predicted Risk
- Existing Failure

Demarcation with Root Cause

- 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**

User TV screen at 14:17:35

Loading...
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

**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

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 prediction in real-time

Physical Infrastructures:
- ONT
- ODN
- OLT
- BRAS
- CR
- Home
- WAN

Intent Engine
- Business intent
- Consumer intent

Network Cloud Engine
- Emulation
- Quality Analysis
- Network data collection

Business Plan
- Expansion & SLA Reminder
Segment 3
Panel Discussion & Audience Q&A

Moderator: Alison Diana
Editor, Light Reading
Segment 4
Wireless Broadband

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

John Colvin
Senior Vice President Global Field Operations | Mimosa
john.colvin@mimosa.co
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 Broadband

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.
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

Healthy

- ADSL
- FWA
- 4G/5G Licensed

Unhealthy

- Fiber to the Home

$0 $1000 $2000

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

Public-Private and Utilities, city-wide Wi-Fi, and Digital Divide

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

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

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

MIMO

Massive Capacity

Spectral Efficiency

TDMA
Modern Fixed Wireless Architecture

- MIMO
- TDMA
- Massive Capacity
- Spectrum Reuse
- SYNC
- Spectral Efficiency
Modern Fixed Wireless Architecture

- MIMO
- TDMA
- SYNC
- CLOUD

- Massive Capacity
- Spectrum Reuse
- Spectral Efficiency
- Network Orchestration
The Power of Spectrum Reuse

MicroPoP without SRS
- Partial Town Coverage
- 250 Subscribers
- 25 Mbps+ Service
- 15 Channels
- 600 MHz of Spectrum

MicroPoP with SRS
- Full Town Coverage
- 750 Subscribers
- 200 Mbps+ Service
- 2 Channels
- 160 MHz of Spectrum

Underserved Population

Complete Coverage
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’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.
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
NTCA/RWA Fixed Wireless Example
Hub-Home MicroPoP
Subscriber Client

- Residential broadband
- 1000 households/mi²
- 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?
More sub-6 GHz is necessary to solve core suburban and rural broadband access
FCC 6 GHz draft NPRM Approved this week to open up Wi-Fi AND outdoor multipoint fixed wireless.
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.
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
Fixed-Wireless Solutions

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

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

<table>
<thead>
<tr>
<th>1G</th>
<th>2G</th>
<th>3G</th>
<th>4G</th>
<th>5G</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.4 Kbps</td>
<td>&lt;0.5Mbps</td>
<td>~5-15Mbps</td>
<td>100Mbps-1Gbps</td>
<td>10G+ and very low rates. PLUS: low latency, reliability, ubiquity</td>
</tr>
</tbody>
</table>
5G market will start with enhanced mobile broadband

Enhanced mobile broadband market starts

- High capacity and coverage
- Ultra high capacity

2018 2019 2020 2021

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

Machine markets will start 2022+
- Need for coverage layer and low cost devices
- No immediate market need for new IoT connectivity
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

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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/km² | 15 | 50 | 150 | 300

"It is a small step for FTTH but a huge leap for Mobile"
### 5G Cells Go Deep

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

Sample FTTH Distribution Area (~500 homes)

![Map of Sample FTTH Distribution Area](image)

Business demographics in WE (source: Point Topic 2017)

- Micro 89%
- SME 10%
- XLE 1%

**=15%** Of total residential HH

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

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### Centralization of Functionality (x-haul variants to transport)

<table>
<thead>
<tr>
<th>X-Haul variant</th>
<th>At BBU (centralized)</th>
<th>At RRH (antenna) (distributed)</th>
<th>Transport Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Backhaul</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Distributed</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bandwidth: 1x Variable bit rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Max RTT latency: &gt;20mSec</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Suitable PON technology: TDM PON, TWDM PON</td>
</tr>
<tr>
<td><strong>Midhaul (F1)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3GPP – PDCP/RLC split</td>
<td>“Cloudified BTS”</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Bandwidth: 1.2x Variable bit rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Max RTT latency: &lt;2.2 mSec</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Suitable PON technology: TDM PON, TWDM PON</td>
</tr>
<tr>
<td><strong>Fronthaul (Option 7 / eCPRI)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phy split</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Fully cloudified BTS”</td>
<td></td>
<td></td>
<td>Bandwidth: ~5-10x Variable bit rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Max RTT latency: &lt;0.25 mSec</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Suitable PON technology: PtP WDM PON, TDM PON, TWDM PON</td>
</tr>
</tbody>
</table>

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

**New Radio**
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Some 5G Concepts affect transport bandwidth

**OFDM and QAM signals**
- Spectrum band is divided into OFDM subcarriers (Orthogonal 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

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

Sketch from Dr. Emil Björnson  
Linkoping University
Relation between RU peak and RU average air capacities

**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.

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

*Figure is from LTE. 5G will support up to 256 QAM*
Estimating F1 Transport Capacity

Air interface capacity +20% => F1 Transport capacity

Average cell capacity = 1/5x

RU Cell peak

RU Cell average 288 Mbps

3 sector gNB as example (can be scaled up)

e.g. 1.4 Gbps for 8 MIMO x 40MHz

Theoretical Maximum (over-dimensioning)

Theoretical Minimum (insufficient)

Statistical muxing gain = 1/6x

Recommended dimensioning range

25 RU Cells = 9.9Gbps

Practical Minimum

Practical Maximum

+20% transport overhead (IPSec, Ethernet)

MAX((Σ average), peak) *1.2

All-Average/Single-Peak

(2 x average + 1 x peak) * 1.2

All-but-one-Average/Single-Peak

Recommended dimensioning range

All-Peak

All-Average

Maximum (over-dimensioning)

Practical Minimum

Theoretical Maximum (insufficient)

Fig. 8 Statistical multiplexing gains for high-load scenario

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

Potential further gains

e.g. 1.4 Gbps for 8 MIMO x 40MHz

>150 RU Cells = 9.9Gbps

37 © Nokia 2018
Estimating the Capacity of a PON to Transport F1 Traffic

- A factor of 6x increase could be possible with stat muxing.

Number of RU Cells carried per 10G PON - Using F1 Mid-Haul (for different MIMO levels)

- Can support 25 RU’s @ 40GHz x 8 MIMO (>150 if stat mux)
- Can support 5 RU’s @ 200GHz x 4 MIMO (>24 RU’s if stat mux)

Air Peak and Average Data Rate per RU Cell (for different MIMO levels)

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

No eCPRI

F1

NC backhaul

CU

DU

RU

UE

Air Data Rates

© Nokia 2018
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.
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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

<table>
<thead>
<tr>
<th>Round trip latency</th>
<th>Classical</th>
<th>Improved</th>
<th>Measures</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>OLT</strong></td>
<td>0.2 –1ms</td>
<td>(\rightarrow 0 - 0.1 \text{ ms})</td>
<td>Bi-pass or Optimize</td>
</tr>
<tr>
<td>•Ethernet switching, packet inspection, etc.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fiber Access</strong></td>
<td>0.125ms</td>
<td>(\rightarrow 0.05\text{ms})</td>
<td>vDBA &amp; sub-frame</td>
</tr>
<tr>
<td>•Dynamic Bandwidth Allocation</td>
<td>0.002ms</td>
<td>0.002ms</td>
<td></td>
</tr>
<tr>
<td>•FEC Coding and decoding</td>
<td>0.125ms</td>
<td>(\rightarrow) Eliminate 0.15ms</td>
<td>Use extra λ</td>
</tr>
<tr>
<td>•Ranging</td>
<td>0.15ms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>•Speed of light (15km rnd trip)</td>
<td>0.6-1.4ms</td>
<td>0.2 - 0.3 ms</td>
<td></td>
</tr>
</tbody>
</table>

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

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

No DBA but fixed allocation

4 burst of 31.25µs per PON frames

Max [250 µs ]

Due to HARQ retransmission loop

Distance achievable with RTT of 250µs

Max Number ONU with RRH connected on 1 PON at given CPRI rate
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
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### Sharing FTTH infrastructure with 5G: Some Deployment Scenarios

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

A variety of solutions are possible depending on situation
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SDN/NFV applied to the access network
Nokia’s approach

- **Per function scalability and elasticity**
- **Centralization of Intelligence and Control**
- **Separation of Management Plane**
- **Centralized Database-in-the-Cloud (3 to 1)**
- **Open Interface**
- **Programming**
- **Standard YANG-model**

**Feature**

**Benefit**

Built on solid experience to unlock SDN/NFV benefits
• 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

Wave fabric leveraging FTTH footprint

Zoning based on data center vicinity

<20km
- Wave fabric
- Central Offices
- Macro / container / Buildings
- Cell Sites
- OLT
- S-10-100G UNI

<300km
- COLO / Main Exchange
- Edge COLO / CO

<1ms APPs
- Motion control & factory automation

5ms APPs
- Smart grid, tactile internet

10ms APPs
- AR/VR, enterprise storage

30ms APPs
- Guided vehicle, transactional

100ms APPs
- Virtual desktop, process automation

250ms APPs
- Web, email, consumer IOT

<1ms APPs
- Cloud 1

5ms APPs
- Cloud 5

10ms APPs
- Cloud 10

30ms APPs
- Cloud 30

100ms APPs
- Cloud 100

250ms APPs
- Cloud 250
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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.
Thankyou
Overcoming the challenges of a managed connected home

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

Jason Walls
Technical Marketing and Standards
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.

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

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

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

Network Service Provider Controller (ACS)

Application Service Provider Controller

Managed Broadband Gateway

Smart Home Gateway

Controller on Smart Phone (on the road)

Controller on Smart Phone/Tablet (in the home)

USP Controller
USP Agent
OB-MAP Controller
OB-MAP Agent
Proxied Entity

USP Protocol
Carrier Grade EasyMesh (OB-MAP)
Other protocol

Multi-access point network
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.
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.

<table>
<thead>
<tr>
<th>Feature</th>
<th>CWMP (TR-069)</th>
<th>WebPA</th>
<th>LwM2M</th>
<th>User Services Platform (USP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supports Multiple Management Servers</td>
<td>✗</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Supports Use Case Driven Message Transfer Protocols</td>
<td>✗</td>
<td>✗</td>
<td>½ ✓</td>
<td>✔</td>
</tr>
<tr>
<td>Has an Efficient Data Encoding</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Has a Schema Driven Protocol Definition</td>
<td>✔</td>
<td>✗</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Has an Always-On Communications Mechanism</td>
<td>✗</td>
<td>✔</td>
<td>½ ✓</td>
<td>✔</td>
</tr>
<tr>
<td>Utilizes a Device:2 (TR-181i2) Driven Data Model</td>
<td>✔</td>
<td>✔</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Defines a Robust Set of Operations</td>
<td>✔</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Requires a Transport Layer Security Mechanism</td>
<td>½ ✓</td>
<td>✔</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Provides an Application Layer Security Mechanism</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✔</td>
</tr>
<tr>
<td>Provides an Access Control Mechanism</td>
<td>½ ✓</td>
<td>✗</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>Distributable Data Model Processing</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
<td>✔</td>
</tr>
</tbody>
</table>
It All Starts With Managed Wi-Fi

Greg Owens
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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

- 0% Ethernet Cables
- 30% 3G/4G
- >75% Wi-Fi

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

61%

39%
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 seems too slow: 40%
- Wi-Fi coverage problems: 25%
- Wi-Fi network stops working for some reason almost weekly: 24%
- Difficulty connecting multiple devices to the internet using Wi-Fi: 19%
- Difficulty connecting multiple devices to each other using Wi-Fi: 17%
- Problems at initial setup and configuration: 10%
- Difficulty setting up network security: 8%
- Difficulty managing passwords/access credentials: 8%
- Other issues: 5%
- No technical problems: 47%

© Parks Associates
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?
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.
A better alternative: ‘Managed Wi-Fi’

Managed Wi-Fi will:

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

**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

**Smart Home**
- Smart Home solution
  - Support connected home ecosystems
  - Extend coverage beyond Wi-Fi
  - Analytics-based automation and optimization

To be revealed tomorrow
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

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Enhancing Wi-Fi User Experience

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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

WiGig 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

- Highly Secure
- Highly Intelligent
- Always Connected
- Increasingly Autonomous
- Increasingly Electric (or hybrid)
Wi-Fi QoE
Enhancing Wi-Fi quality
Typical House

Wi-Fi Co-Channel Interference

Saturated AP

Low RSSI

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

- Apply the optimal policy for channel selection
- Smart Channel Selection
- Apply smart algorithm for Assessing the link quality
- Monitoring
- Apply air-time fairness
- Air-Time Management
- Non-intrusive band Scanning
- Smart Scanning
- Band steering from 2.4GHz and 5GHz
- Band Steering
- Sending notification if user intervention is required
- User Notification
- Wi-Fi QoE Manager
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
Wi-Fi AI: Predicting User Maximum bitrate

- Link Metrics
- Channel Metrics
- AP Metrics

Test scenarios for many client devices

Machine Learning

Maximum Client bitrate
**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 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

\[
\text{ChannelChangeIncrease in TP}[^\%] = \left(\frac{\text{BestChannelRankingScore}}{\text{Channel RankingScore}}\right) \times 100
\]

- Support for removing DFS channel from ACS in 5Ghz if required
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  Cloud UI | Client Statistics

- User Experience Quality: 3 stars
- WiFi Quality: 36%
- RSSI: -44 dBm
- PHY Rate: 117 kbps, 123.5 Mbps
- Bit Rate: 43.7 Mbps, 0.5 kbps

Predicted User Maximum Bitrate
## 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.{j}.AssociatedDevice.{k}. |
| QoElevel | String(256) | - | This identifies the user QoE as described above. Enumeration of below (*):  
  - Good  
  - Medium  
  - Critical  
  - Limited  
  - None |
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

<table>
<thead>
<tr>
<th>Area</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private</td>
<td>Enhance Wi-Fi user experience</td>
</tr>
<tr>
<td>Public</td>
<td>Development of “Free Wi-Fi” solution</td>
</tr>
<tr>
<td>Managed Home</td>
<td>Add Wi-Fi feature or App on residential gateway from the cloud</td>
</tr>
<tr>
<td>Business Wi-Fi</td>
<td>Implement V2X protocol for connected devices</td>
</tr>
</tbody>
</table>

## Cloud Applications

- User Notification
- Clustering & Son Data Collection & Aggregation
- Machine Learning Smart Algorithms
- Report & Analytics

## Wi-Fi QoE Apps

- Wi-Fi Daemons
- Wi-Fi Drivers

## App Configuration and Management

- Support
- Operations
- NOC
- Marketing
Wi-Fi ROI

Jake Sailana
Director Product Marketing | ZyXEL
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Agenda

• Managed Wi-Fi: What and Why?

• Customer Experience

• WiFi Service Capable Organization
Wi-Fi Isn’t Easy
Managed WiFi Service

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
Managing Customer Experience

Quality of Service Perception Gap

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

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
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
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
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
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
Segment 4
Panel Discussion & Audience Q&A

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

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

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www.broadband-forum.org/news-events/events-webinars/base-events-home

or, contact
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Thank you

See you again at the next BASE soon. Location TBD

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