PASSIVE OPTICAL NETWORKING
EXPLANATION OF PASSIVE OPTICAL NETWORKING (NOTE: THIS IS NOT NOKIA HARDWARE AT POLYLAB, BUT WILL USE NOKIA SLIDES IN SOME EXAMPLES)
BASIC ELEMENTS OF PON – NEXT GEN OPTICAL NETWORKING

- PON Core, which sits in an *optical line terminal* (OLT)
  - Hosts PON modules, which are high-power optical interface modules (usually in an SFP+ packaging), too much power to directly connect to user equipment. Our systems have 8 PON ports per OLT
  - Single-fibre, bidirectional, different optical frequencies in each direction
  - Uplink ports to main network (usually needs to be a lot of bandwidth). Our 1U systems have 2 x 10 Gbps uplinks, SFP+, often standard optical pairs (P2P optical) with one frequency

- Optical distribution network (ODN)
  - Simply a set of passive (hence the name) splitters to spread each PON port to users, with a minimum splitting factor of 8, and up to 128. Cheap and rugged: $’s to $10’s per splitter, using nanotechnology, usually a Planar Lightwave Circuit (PLC)
  - PON has a deterministic MAC that then does TDMA over stations in the network, potentially with per-user encryption – *created for* US military networks, so sharing not a security issue
  - Think of it as a Ethernet-like old-style hub, *but with more than 56 THz of bandwidth*

- User device, Optical Networking Unit (ONU) or Terminal (ONT)
  - Low-cost powered box, can have splitting factor x number of PON ports of them per OLT (so, for our hardware, 128 x 8 = 1024 ONUs)
  - Come in various versions, such as various numbers of Ethernet ports, Wi-Fi, and even cable TV outputs
  - If you have Fibre-to-the-Home (FTTH), this is the “router” that they put in your house
Many, but important ones are the following:

- **GPON**: 2.5 Gbps down, 1.25 Gbps up, shared, per PON port (what we have so far, for emergency management work), usually 1 GigE ONUs (and what FTTH is becoming, right now, with older, slower, EPON), pair of optical frequencies

- **NG-PON2**: 4 pairs of frequencies, different to GPON, total of 40 Gbps TPUT, 10/10 Gbps (or 10/2.5, 2.5/2.5). Uses tunable optical filters on user equipment

- **XGS-PON**: Cheaper, transition, version of NG-PON2, generally just one pair, no tunable filters, but 10/10 Gbps

- All standardized (ITU and IEEE standards)

- Low-latency, but proportional to number of clients

- Latency low enough to actually be used *inside RF physical layer for 5G, way less than 1 ms timing needed*

- By working in different frequencies, and with so much splitter bandwidth, can just add standards and equipment, same splitter/ODN infrastructure, so upgrades cheap
EXTRACT OF NOKIA (CANADA) SLIDES FOR PON PRODUCTS
Shaping the future with ultra-broadband
Fiber evolution

Same fiber – same passive and active platform

Step 1: Introducing XGS-PON
- Add Co-existing element
- Install universal NG-PON line card
- Add XGS optics & XGS ONT

Step 2: Introducing TWDM-PON
- Add wavelength multiplexer
- Add TWDM optics in the existing line card
- Add TWDM ONT

OLT
GPON
NGPON
ISAM FX
Wavelength multiplexer
Co-existing element
CEx
XGS ONT
TWDM ONT
GPON ONT
TWDM ONT
TWDM ONT
7362 ISAM DF-16GW
High-density, high-capacity compact OLT

7362 DF-16GW is the first product in the DF series
- Supports up to 16 GPON ports or 4 XGS PON or 4 NG PON2 ports
- Optimized for low (up to 1000) subscriber density applications (e.g. MDU or cabinet deployments)

Key features
- 1U pizza-box, no removable linecards, hot swappable removable fan tray and filter
- GPON and XGS-PON / TWDM-PON support
  - 8 XFP cages for 16 GPON ports using dual GPON XFP
  - 4 XFP cages can support XGS-PON fixed wavelength optics / NG-PON2 optics for ONTs with tunable optics
- Network connectivity for up to 8x 1/10G (SFP+) with LAG support
- Non-blocking design
  - 40 Gbps full-duplex when deployed in point-to-point configurations, up to 120Gbps when deployed in a ring
- Forwarding, QoS and management as per 7360 ISAM
  - Layer 2 forwarding modes (1:1 VLAN, N:1 VLAN) + related subscriber management
7362 ISAM SF-8GW “Sealed Fiber” OLT
Physical Description

- Clamshell package, passive cooling, strand, wall and pedestal mount
- Fixed Configuration with hot swappable dual power supplies and optical modules
- Temp range -40C to +65C (pedestal), -40 to 46C+solar load (strand)
- Sealed access ports for power, fiber and diagnostics interfaces
- PSU options: Coax or AC powered (accepts 14mm or 18mm AC power cable)
- 4x 1/10G (SFP+) uplink ports
- 8x GPON (4x dual GPON XFP) or 4x XGS-PON / NG-PON2 (XFP) subscriber ports
10G PON Portfolio Roadmap

**XS-020X-A**
- 1x GE, 1x 10GE
- Temp Hardened

**XS-250WX-A**
- 3x3 802.11b/g/n
- 4x4 802.11ac
- 2x POTS
- 4x GE, 1x 10GE
- USB3.0

**XS-250X-A**
- 2x POTS
- 4x GE, 1x 10GE
- Temp Hardened

**U-050X**
- GPON/XGS/NGPON2
- 4x GE, 1x 10GE
- ToD/1588v2
- Temp Hardened

**Future 10G PON**
- Fiber or Electrical WAN
- 4x4 802.11b/g/n
- 4x4 802.11ac
- Tri-Band
- 2x POTS
- 3x GE, 1x NGBASE-T

- XGS SFP+ ONT

---

1Q 2018 | 3Q 2018 | 2018+
7368 ISAM ONT XS-250WX
XGS-PON RGW ONT

Key Features

- XGS-PON Uplink (BOSA on Board), G.9807 series standard compliant
- 2x POTS ports
- 4x RJ-45 10/100/1000 auto negotiating Ethernet ports
- 1x 10G electrical, support 1G/2.5G/5G/10G rates
- Dynamic Bandwidth Allocation (DBA)
- IGMPv2 and IGMPv3
- AMS Managed
- Optical RSSI, advanced PMs and statistics support
- Per-subscriber, per-service bandwidth control
- Support bridge mode or routed mode for each Ethernet port
- TR-069 support, TR-142 compliant, TR-143
- Supports dual concurrent 802.11ac at 5GHz and 802.11b/g/n at 2.4GHz
- Supports 4x4 MIMO 802.11ac, 3x3 MIMO 802.11b/g/n
- Supports up to 500mW WiFi per band
- 2x USB 3.0
- WPS on wireless authorization support, 5 SSIDs
- Firewall, NAT, PPPoE, DHCP, WiFi-offload via GRE/VLAN Tunnel
- BRCM 6858 SOC.
- Operating temperature -5° C – 40° C

Key Benefits

- Integrated residential gateway for XGS-PON Network, one box solution for FTTH deployment. Supports full triple play services: voice, Data, IPTV.
- Full range of fault management, configuration, accounting, performance, and security (FCAPS) functions
60 GHZ WIRELESS AND PON
Next IEEE standard is 802.11ax, deterministic OFDMA (like LTE) high-efficiency and reliability, 60 GHz

Facebook has the *Telecom Infrastructure Project* to get Internet access to the parts of the world that don’t have it
  + Part of this is Terragraph, a 60 GHz wireless mesh technology

Nokia has Wireless PON, also using 60 GHz IEEE 802.11 tech

Facebook and Nokia teaming up to standardize Terragraph into the upcoming IEEE 802.11ay standard

May be a bit of an 802.11ax vs 802.11ay competition

But an obvious set of candidates for short-range LTE/5G-like wireless

But also 5G will handle some of this area, now that fixed 5G services are coming to customers in next 6 months, mobile late this year/early next (but 6 GHz, ~28 GHz)

60 GHz systems are tiny
THE PROBLEM TO SOLVE

- FTTH/FTTx PON technology is great
- But providers often, after putting it into a block of housing or offices/shops, have to come in and add another fiber run to a new office/shop/home
- PON is cheap, but laying fiber isn’t (fiber cheap, digging trenches and placing it isn’t)
- WPON (and the fixed 5G business) is all about getting around this, with last 10’s of meters wireless, rest optical
- Also, of course, LTE and 5G often optically backhauled, with PON, especially NG-PON2, being considered as primary optical backhaul for future
No strings attached

Fixed Wireless Access brings ultra-broadband to more people, sooner

Fixed Wireless Access overview

FWA BU
March 2018
Fixed Wireless Access (FWA): The new tools in the toolkit

- **5G TTH**
  - Licensed mm-wave 28 and 39 GHz
  - Urban and suburban densities
  - <500 m range
  - 1 Gb/s peak speeds
  - Future technology

- **Wireless PON**
  - Unlicensed 60 GHz (802.11ad)
  - Urban and suburban densities
  - <300 m range
  - 1 Gb/s peak speeds
  - Existing technology

- **Nokia FastMile for LTE TTH**
  - Licensed 1.8-3.7 GHz
  - Suburban and rural densities
  - <10 km range
  - 10-25 Mb/s guaranteed, up to 100 Mb/s+ peak
  - Existing solution

© 2017 Nokia
Nokia FWA portfolio
Positioning

- **Fiber Speed**
  - Gbit/s
- **Macro Speed**
  - 100s Mbit/s
- **Sub 6 GHz**
- **mmWave**

- **FastMile R1.0**
- **FastMile R2.0**
- **FastMile R2.0 ABA**
- **FastMile R3.0 5G (sub 6 GHz)**
- **WPON**

- **Rural**
- **Suburban**
- **Urban**

WPON Home Unit
FastMile Compact ODU
FastMile ABA ODU
60 GHz Wireless PON

Accelerating Gigabit Access
802.11ad enabled key features:

Unlicensed 60 GHz mmWave
- Unlicensed spectrum - any operator can use it
- Broad unlicensed spectrum available: 13 GHz in FCC (9 GHz in ETSI)
- Clear channel, with limited interference and large bandwidth (2.16 GHz), allowing to achieve high bit rates with simple modulation schemes
- High bitrates and low cost with future evolution
- Inherent interference limitation, because of narrow beams and propagation limitation. Hence systems can coexist with limited interference

High gain beam forming
- Fast and reliable wireless connection
- No need to aim the home antenna

1 Gbps at <300 m
- Line of sight ➔ avoid obstructions
- High attenuation ➔ outdoor antennas

Self backhaul

WiGig 802.11ad delivers on the promise

© 2018 Nokia
Wireless PON provides a wireless drop on PON/fiber networks

Nokia Optical Line Terminal
- Add Wireless PON to existing network
- Manage as part of your PON network

WPON Access Point
- Mount to poles or building façade
- Connect wirelessly to home units

WPON Home unit
- Small, unobtrusive and easy to install
- Wireless connection to AP

Nokia Smart Home Gateway
- Same robust home experience as PON
- Ethernet interface to home unit

OLT
Fiber
Access point
Self backhaul
Home Unit
CPE
RG CPE
Home Unit
WPON Home unit
Nokia Optical Line Terminal
WPON Access Point
Home Unit
CPE
RG CPE
Home Unit
Nokia Smart Home Gateway
Wireless PON Access Point (AP)

Key features
- 1 Gb/sec aggr. throughput to homes up to 100m
- Beam forming antennas
- MCS 8 (2310 Mb/sec PHY rate)
- GPON or P2P fiber fed (SFP)
- Daisy chain WiGig BH
- Non-sticky surface

Key benefits
- Faster, more flexible deployment
- Use wireless BH to reduce fiber costs
- No need to aim the antenna
- Different antenna configs & applications
- Robust design for harsh conditions (IP66)

Deployment and configuration details
- Small form factor (25 x 16 x 7cm)
- Input Power: AC Mains: 110-230VAC
- Power consumption: 20~35W max. (dependent on variant)
- Pole or wall mount
- FoV configurations: Horizontal 180-360 deg, vertical 60 deg
- Managed by Fixed Networks management systems
Wireless PON Home Unit (HU)

Key features
- 1 Gb/sec aggr. throughput to homes up to 100m
- Beam forming antennas
- Self alignment
- Gigabit Ethernet to CPE
- Power over Ethernet fed
- Non-sticky surface

Key benefits
- Gigabit speeds
- Small, barely noticeable on building
- Simple installation
- No need to aim the antenna
- Robust design for harsh conditions (IP 66)

Deployment and configuration details
- Small form factor (13 x 13 x 7cm)
- Low power: 15 W max.
- Wall mount
- FoV: Horizontal 180 deg, vertical 60 deg
- Managed by Fixed Networks management systems
Home Outdoor Unit
Entering the home

DRILLING THROUGH THE WALL

WINDOW SILL MOUNT

CONTACTLESS OUTDOOR UNIT

1. Drill hole into wall
2. Pull cable through wall
3. Attach outside mount to wall
4. Pull cable into home
5. Thread cover mount plate and secure cable

© 2018 Nokia
Wireless PON topologies
Deploy where no fiber has gone before

Relay Access Point
• Extend your reach without fiber
• Support up to 5 relay AP per side of host AP
• Capacity planning required

Access Point extension
• Second AP on a pole for a 360° field of view
• Extends Host or relay AP via Ethernet cable
• Does not impact allowed number of relay points

Split relay topology
• Split configuration for greater deployment agility
• Connect up to 5 relay APs from head AP

3 Access Point variants:
- Head – Fiber uplink
- Relay – WiGig uplink
- Extension – Ethernet uplink
Home Unit connectivity

Home units per access point
- Up to 8 Home Units per access point

Resiliency
- (1) Home Unit initial connection strongest AP
- (2) Connects to next best AP if signal is obstructed
- Future mesh support
Partner Collaboration
Nokia 2nd gen WPON portfolio

Meshed nodes

POP

relay

AP

Drop

relay

AP

Drop

HOU

Distribution

WPON Gen-1 scope

WPON Gen 2 scope
Case study #1: Strung-out suburbs

- Avoid costly buried drops (driveways)
- Hybrid cable for network power and fiber
- <100 m from access point to home
- 1Gbps peak speeds
- Single Access point serves up to 6 homes
- 1 Access point every second pole

Up to 1/4th of FTTH upfront costs
-50% Lower TCO (25 years)
Considerations

- Avoid entering the street
- Deploy fiber only to street corners
- Relay Access points extend coverage
- Add subscribers without fiber drop costs
WPON example design
Expanding use cases - morphologies
Intelligent Access

Faster TTM, lower cost
• Avoid cost and time of the final drop
• Take the complexity out of fixed wireless access

Better Gigabit coverage
• True gigabit experience for end users

Smarter use of WiGig technology
• Integrate WiGig and PON
• Leverage fiber investment with wireless drops
RELEVANCE TO WWG AND LOP-G

- PON can become a good internal networking approach to wireless-grade connections
  - Including simple connections to Wi-Fi APs
  - But also for LTE and 5G base stations
  - PON is being examined for aircraft avionics
  - Already a (non-PON) optical standard, MOST, in cars, & PON may replace it
  - Only need power at ends of networks, no complex switches and power systems throughout spacecraft

- WPON is a way to build out short-range wireless

- Also need to consider RF over optical (for RRH) connections (can be PON or other)

- *Is this avionics, or part of the wireless network? What happens when the avionics are wireless?*