Access-metro convergence in next generation broadband networks

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Content

• Why Access/Metro Convergence, why now?
  – Current network architecture
  – End-user requirements
  – Stake older requirements

• Access/Metro convergence
  – Network consolidation
  – Service multiplexing
  – Multi-tenancy
  – Is SDN the glue element for true access/metro convergence?

Acknowledgments
Much of the material is from the DISCUS project (www.discus-fp7.eu to see the full list of partners and deliverables), but results and ideas from other sources are also included.
Prof. David B. Payne from Trinity College Dublin.
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Access and metro network view

Depending on size/role, the central office hosts numerous functions and network boxes.

1G/10G Ethernet, ADSL/VDSL, SDH, GPON/EPON, POTS, ... BRAS, PE Router, SGSN/GGSN (Mobile), DPI, DSLAM, Carrier-grade NAT, MPLS, ...

Source: http://www.pipelinepub.com/
A telecommunications network (access/metro/core view)

Based on progressive customer traffic aggregation through Optical-Electronic-Optical (OEO) conversion
Converging the access and metro networks

Much fuss about integrating metro and access networks today

• Why change it?
• What’s different today?
• What are the drivers?
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Change in traffic requirements

Internet traffic keeps growing

Source: BT, Andrew Lord; ECOC '15

>65% CAGR

Cisco VNI 2014-2019

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<thead>
<tr>
<th></th>
<th>North America</th>
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<th>Middle East and Africa</th>
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<td>26%</td>
<td>30%</td>
<td>23% 29% 47% 52%</td>
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<td>Daily FTTx user download 2014 / 2019 / CAGR</td>
<td>5.4GB 9 GB 18%</td>
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<td>21.5MB 131MB 43.5% 5.6MB 65.5MB 63.5%</td>
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</table>
It’s more than bare capacity

• Bit/service disassociation: value in the service not in the bits

• Any content at a click’s reach: immersive interaction

Augmented Reality

Virtual Reality
OFCity challenge

• Smart location and transportation

• Smart health

• Smart education
5G requirements

5G is not 4G + 1G

5G is the full integration of end-user applications and network, and the network is a seamless convergence of different communications technologies, fixed and wireless!

Source: GPPP, “5G Vision,” available on www.5g-ppp.eu
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Operators/Providers Requirements

• Survival requires network simplification
  – Lower cost of running the network
  – Run multiple services in the same network infrastructure (existing and new ones)
  – Lower energy consumption
  – Enable the 5G vision: capacity anywhere to anything
    • Work with heterogeneous requirements (latency, capacity, reliability)

• Become a Virtual Network Operator: control network (capacity, QoS, connection availability) without owning it
  ➔ Build up required end-to-end connectivity pooling together virtual network instances from multiple and diverse resources

“The new status symbol isn’t what you own—it’s what you’re smart enough not to own”
Operators/Providers Requirements II

- Speed up service provisioning time:
  - CARRIER SDN / SDN ARCHITECTURES

  AT&T: SDN Is Slashing Provisioning Cycle Times by up to 95%
  
  Source: Lighreading, August 12th 2015

- Cost-effective flexibility: no capacity most of the week, to 10Tb/s for a few hours during an event
Government Requirements

• Broadband is a commodity in our information age
• Digital divide is a big social issue for all government and EU has a 2020 target of 30Mb/s to every household

Population and urban areas
70% of population in 17% of territory

FTTCab blue= available today

Area with no DSL

30% of population spread over 83% of territory

Planned FTTH

National Broadband Plan ➔ state intervention

• Lower cost technology means reduce the areas of state intervention
• Open-access models are very important for national broadband plans
Summary of requirements

Application-oriented approach to deliver real value
- Reliable applications (reliable capacity, latency, survivability,...)
- Application availability anytime anywhere (really ubiquitous network access)

5G requirements: data rate, latency, mobility, connections, energy, reliability,..
- Multiple technologies working seamlessly together
- Prepare for the unknown as most 5G applications are still unknown...

Improve network business case
- Reduction of network operating cost
  - Lower capital cost for network equipment
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Need for change?

- Considering these requirements:
  - Is this model obsolete?
  - Is access-metro convergence the solution? Why?
  - What is access/metro convergence???
What is access-metro convergence?

Much more than the integration of access and metro transmission technologies
Access/Metro Convergence

Space domain

Consolidation

Multi Tenancy

Ownership domain

Multi Service

Service domain

Heterogeneous Infrastructure

Access/Metro Convergence

CO

Operator 1

Shared Fibre

Operator 2

Shared ODF

Operator 1

Shared Fibre

Operator 2

Shared ODF

Shared Fibre

Apartment/Home

Operator 2

Operator 1

Ownership domain

Multi Tenancy

Multi Service
Access/Metro Convergence
DISCUS PON architecture enabling node consolidation

Once you start the convergence process you need to rethink of all network boundaries: What defines access-metro, metro-core, inner core?
From hierarchical to flat core

Flat core becomes the cheaper option when traffic is above a given threshold.

Study carried out for UK network, using 75 MC nodes

C. Raak et al., Hierarchical Versus Flat Optical Metro/Core Networks: A Systematic Cost and Migration Study, ONDM 2016
Node consolidation studies

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<thead>
<tr>
<th>Instance</th>
<th>Country</th>
<th>max $K_m$</th>
<th># MC nodes</th>
<th># Fiber links</th>
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<td>115 km</td>
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Dual-homed PON protection with maximally disjoint fibre routes
Node consolidation studies

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Architectural results

- 10x decrease in power consumption compared to Business as Usual (BAU)

- Lower cost compared to other optical access technologies
Summary of requirements

**Application-oriented approach to deliver real value**
- Reliable applications (reliable capacity, latency, survivability,...)
- Application availability anytime anywhere (really ubiquitous network access)

**5G requirements:**
- Data rate, latency, mobility, connections, energy, reliability,..
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**Improve network business case**
- Reduction of network operating cost
  - Lower capital cost for network equipment
  - Sharing cost of ownership
- Increase revenues with more and faster services
- Reduce energy consumption
Requirements enabled by consolidation

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Access/Metro Convergence

Consolidation

Space domain

Service domain

Heterogeneous Infrastructure
G. Talli et al., Demonstration of SDN Enabled Dynamically Reconfigurable High Capacity Optical Access for Converged Services. PDP paper Th5B.1
Fixed-mobile convergence

Question: how to increase mobile capacity by 1000 times (by 2020??)

Some popular estimates of factors for capacity increase:

- Efficiency (MIMO, Smart scheduling, enhanced-CoMP) -> x3
- Spectrum (Carrier Aggregation, New Bands, Authorized Shared Access) -> x2
- Density (Advanced Macros, HetNet management, Flexible small cells)

\[
\frac{1000}{2 \cdot 3} = 167
\]

This is in line with what happened in the past:

Cooper’s law (of spectral efficiency): 1 million times improvement in the past 45 years

Source: Nokia, enhance mobile networks to deliver 1000 times more capacity by 2020
Higher Cell Density
An existing FTTH infrastructure can be used to serve mobile cells, but also other businesses.

An optical access network, if well architected can allow service multiplexing: any access point (a home, a macro cell, a small cell, a business, a micro cache or small data center) can request assured capacity from the low Mb/s to multiple 100s Gb/s.

But things change quickly... i.e. Cloud RAN came into play chaning latency requirements.
Cloud RAN

Great example of changing requirements and need for flexible network architecture

Placing Base Band Unit (BBU) at different location than the Remote Radio Unit (RRU).

A well-known interface for this “Fronthaul” transmission is the Common Public Radio Interface (CPRI)

This gave the idea to move the BBU further out giving raise to the Cloud RAN concept

Examples of Fronthaul architectures

One virtual BBU to many RRU
Fronthaul

Problems:

1. High capacity: \[ B = R_s \times N_q \times N_a \times N_b \times R_c \times R_l \]

   - Take a macro cell: 8x8 MIMO, 3 sectors, 5x20MHz channels
     \[ \Rightarrow \text{backhaul rate (64-QAM): 9 Gb/s} \Rightarrow \text{fronthaul rate 148 Gb/s} \]
   - Take a small cell: 2x2 MIMO, 1 sector, 20 MHz channel
     \[ \Rightarrow \text{backhaul rate (64-QAM) 150 Mb/s} \Rightarrow \text{fronthaul rate 2.5 Gb/s} \]

   This is independent of usage... it's a sustained rate!

2. Strict latency requirements, 3 ms due to HARQ

   \[ \Rightarrow \text{considering this is the total latency budget, typically only a few} \]
   \[ \text{hundreds micro seconds left for optical transport} \Rightarrow \text{20-40Km max} \]

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J-I Kani et al., Options for future mobile backhaul and fronthaul, Elsevier OFT issue on access networks, November 2015
Solution for Fronthaul capacity issue

- Signal compression: bandwidth reduction by factor of 2-3 but deterioration of SNR
- Split processing or midhauling:

Flexible architecture

- Latency from front/mid-haul can restrict PON reach
- Latency-sensitive 5G applications might impose even tighter distance constraints

⇒ Flexibility: build overall network to target majority of applications, but allow shorter loops for latency-sensitive services (not just front/mid-haul).
Data centre integration

- Seamless connectivity of data centres in the access/metro convergence
  - DCs have already moved to the metro to reduce latency and core traffic
  - 5G will see a mix of different size DCs from large to micro caches, it could also include home storage

- Transparent optical connection directly to DC cluster or rack

Source: SFI/NSF project “Agile cloud service delivery using integrated photonics networking”
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Multi tenancy

PONs can offer very large capacity but requires substantial effort (cash and resources)

Large operators can afford (typically only in urban areas) installation of a fibre access network.

Risk of creating de-facto monopoly

Can vertically-integrated operators support the diversity fostered by 5G??

Open access

Benefit from fast dynamics and innovation brought by fully open market
Access network virtualisation

- **Virtual Network Operator (VNO)**
  - Operate, control, and manage its own virtual networks
  - Run/Re-design customized protocol in its own virtual networks
  - Provide specific and customized service through its own virtual networks
  - VNO saves deployment cost of network infrastructure

- **Infrastructure Provider (IP)**
  - Own and maintain physical networking resources
  - Enable physical resource virtualization and carry out the virtualization
  - Provide virtual resource controlling API to VNP/VNO
  - InP gets revenue from resource leasing

**Source:** Alcatel-Lucent


**BroadBand Forum SD-351, Analysis of Fixed Access Network Sharing (FANS), Jun. 2015**
Summary of requirements

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Requirements enabled by consolidation, service multiplexing, multi tenancy

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Is SDN **the glue** to enable true access/metro convergence?

Promises full programmability through open and standardized interfaces (e.g., web server APIs)

“Softwareization” is key to tackle the complexity and dynamic requirements of a converged access/metro infrastructure

AT&T DOMAIN 2.0 – SDN-based multi-service multi-tenant platform
AT&T CORD – Central Office Re-architected as Datacentre

OLT as white-box switch

Source: white paper Central Office Re-architected as Datacentre (CORD), onosproject.org
SDN enabling innovation and convergence

- SDN speeds up research on control plane integration...
  - DISCUS-IDEALIST-STRAUSS control plane integration


- Access/metro re-architected as a data centre
  - Flat LAYER Two Large-scale Network (FLATLANd)

Bristol is open
Conclusions Vision
Content-focused business models

Move from the current model:

To a service-driven model:

Example: Amazon Kindle 3G
End-to-end ephemeral network

Aggregated services

Virtualized service-oriented network

Heterogeneous Infrastructure

Request: Services
Response: Aggregated Services

Application-oriented service provisioning
Ephemeral network connection

Brokerage of pool of virtualized network resources
SDN orchestration

Heterogeneous physical layer
Networks without borders

(Open) questions

• How much fonthaul will we need?
  – Will front-hauled small cells really displace simpler Wi-Fi or Li-Fi?

• Will access SDN stand the challenge of gluing together apps and networks to enable true access/metro convergence?

• If the appetite is all for being a virtual operator, who will maintain the physical infrastructure?
  – Back to state-owned infrastructure?
  – Or can a content-focused model pour enough revenue into the physical infrastructure?

• Full open access vs. vertical integration?!?
Thank you for your attention!

Prof. Marco Ruffini
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Architectural changes

**Access/Metro centric architectures:** keep the traffic in the metro and avoid the core as much as possible.
Indeed already a well **consolidated trend**..
Some of the issues addressed

- Narrowband (Tuneable) Filter
- Circulator
- Connector
- Splice
- EDFA
- MUX

80 channels US/DS interleaved in C-band with EDFA SOA amplification for other bands

Low-cost tunable laser
Low-cost SiP tunable filter

512- Total Split

FPGA prototype of LR-PON ONU

Burst-mode receiver with FEC and differential range

40G Bit interleaved protocol downstream

Coherent 100G point-to-point overlay channel

Optional day 1 WDM mux/demux

FPGA prototype of LR-PON OLT

Dual-homed protection

Stand-By: M/C Node

OLT

P2P
many fibre pairs

Access

Mux/Demux

ONUs/ONTs

Access Node Controller

IP/MPLS service node (SP1)

MPLS Access switch

IP/MPLS peering points (Internet)

IP/MPLS peering points (other NGNs)

Access elements

Core elements

SP elements

Core Network Controller

Network Orchestrator

non-blocking single sided optical space switch

Duct routes out of Metro node to other nodes

Flexgrid WSS Line Interface

In-band

Grey clients

Alien lambdas

Core Network

Controller

Transponders/regenerators

ADD/DROP

MPLS Access switch

MPLS Core switch

IP/MPLS service node (SPn)

IP/MPLS peering points (Internet)

IP/MPLS peering points (other NGNs)

DISCUS Multi-service Metro-Core Node
Flat optical core

For further decreasing electronic packet processing

- Optical reach feasible

- Limitation in number of nodes in flat core due to mesh explosion ➔ concept of optical island

- Economical viability requires traffic between nodes to be above a given threshold

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<tr>
<th>Signal</th>
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