Cloud Transport
System Innovations

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The Importance of DCI Networks – “Executive Summary”

Cloud and DCI is the biggest Network Evolution of the last 10-15 years,
since the Internet IP/MPLS Network evolution in early 2000.
Outline

- Summarize the importance of Cloud in the Transport Network Evolution
- Review the significant current Cloud optimized System Innovation
- Identify some key emerging Cloud Transport Innovations
- Conclusions & Discussion

Acknowledgement of Many Insightful Interactions

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- Disclaimer: This acknowledgement is NOT suggesting that these individuals have necessarily endorsed this presentation. Any errors are sole responsibility of the author.
Cloud has evolved to a Dedicated Massive Global Network Infrastructure


Google global Inter-DC Backbone, B4 (above) separate from Internet Backbone B2 (below)

Cloud optimized Transport System Evolution

Reference: L. Paraschis Invited ECOC 2019 Data Center Symposium Tuesday, Sept. 24, 2019

- **Routing simplification & WDM sophistication.** High throughput packet transport & Coherent WDM today exceeding with 6+ b/s/Hz Trans-Atlantic

- **Modular** small stackable system scaling; with multiple Tb/s per RU at sub-Watt per Gb/s, leading to power limited capacity per rack, and increased value of PIC.

- **Open** (Linux based) OS with APIs, Open Line systems and Open Transport architectures.
DCI Physical layer innovation: Record Breaking Spectral Efficiency

- **MAREA cable from Virginia Beach (USA) to Bilbao (Spain)**
  - 6.21 bits/Sec/Hz
  - 6,644 km, 16QAM, 26.2 Tb/s

- **Seabras-1 cable from NYC (USA) to São Paulo (Brazil)**
  - 4.5 bits/Sec/Hz
  - 10,600 km, 8QAM, 18.2 Tb/s
  - 50% more capacity than others

Maximizing Reach x Capacity: Enabling Technologies

- **Super channels & Nyquist Subcarriers**
  - Drive down cost and power per bit
  - Optimize spectral efficiency
  - Leading optical performance

- **SD-FEC gain sharing & Dynamic BW Allocation**
  - Share FEC gain across Subcarriers
  - Dynamic Bandwidth Allocation (DBA) shifts payload to higher performance subcarriers

- **New paradigm for system operations**
  - SW Automation
  - Programmability
  - Advanced Telemetry

- **Advanced Coherent Toolkit**
  - Shape probability and location of constellation
  - PCS

- **Photonic & Electronic Integration**
  - Photonic Integrated Circuit (PIC)
Open DCI Transport and multi-vendor Automation
Reference: L. Paraschis Invited ECOC 2018 Tuesday 2 pm

- Disaggregation and Openness to break vendor lock-in and enable faster network innovation
- Open APIs to decouple functions
- Multi-vendor and multi-domain SDN for fully automated network operations

→ Industry effort to enable seamless e2e operations within new open ecosystem

Extensible Transport NOS = main need for Open, Automation, Analytics
Reference: A. Sadasivarao et al OFC 2019 Demo Zone March 4, 2019 M3Z.1

- Programmable Network Element Management with Model Driven and Declarative Configuration
  - NETCONF YANG data models for configuration
  - GRPC streaming of PM data
  - Osquery Instrumentation to depict a 3rd party software agent on the NE

- Analytics
  - Timestamped PM data archived and visualized on PNDA, Splunk or Prometheus
Cloud increased important and future bandwidth demands

“cloud” is now core of our society! ... and will be growing even more!!

- 40% on Internet, 65% on Facebook...
  
  Deutsche Telekom AG, P. Lothberg, OIF, 8-MAR-2016

- by 2021, 94% of compute to be in cloud data centers... cisco, cloud index 2019

...
DCI packet transport Traffic Engineering!... Will it also extent to Optical?

L. Paraschis, ECOC 2013, DCI Tutorial

MSFT and GOOG - ACM SIGCOMM’13 References of SDN-based Traffic Engineering

Example of DCI Optical Transport Analytics and Optimization

M. Ghobadi, Microsoft, OFC 2016

LH BVT case study

- Polled Q-factor of deployed 100G DP-QPSK for 3 months
- Observed Q → CDF of SNR
- Assumed BVT with modes:
  - QPSK at 100 Gb/s
  - 8QAM at 150 Gb/s
  - 16QAM at 200 Gb/s
- Findings
  - 99% addressable w/8QAM
  - 43% addressable w/16QAM
  - 70% net capacity gain possible
DCI Transport Innovations Summary

The textbook Internet (1995-2007)
- OSPF
- BGP
- MPLS

The new Internet (2009-)
- 5G
- 3GPP
- OAM & PerfMon
- Coherent detection
- DWDM
- CD ROADM

Early Internet (before 2000)
- Connectionless best-effort
- MPLS TE
- QoS
- FRR
- OAM & PerfMon

IPNGN (2000-2010)
- Services-aware Networks
- Capacity Planning
- OAM & PerfMon

DCI (2010-today)
- Super-channel
- 50-200G WDM
- CD ROADM
- Photonic Integration
- OAM & PerfMon
- Disaggregation
- Higher baudrates
- Hybrid & PCS modulation
- Optical Restoration?
- Telemetry, Analytics, Optimization?
- Open Line Systems
- SW Automation & NSM Abstraction

References for further reading

• A. Sadasivarao et al., “High Performance Streaming Telemetry in Optical Transport Network”, in OFC 2018, and
• A. Sadasivarao et al., “Demonstration of Advanced Open WDM Operations and Analytics, based on an Application…”, in OFC 2019.
• A. Sadasivarao et al., “Demonstration of Extensible Threshold-Based Streaming Telemetry for Open DWDM Analytics and Verification” in OFC 2020.