

Cloud Transport System Innovations

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January 18, 2020 invited presentation in the
IEEE ComFutures symposium of the **2020 PTC**.

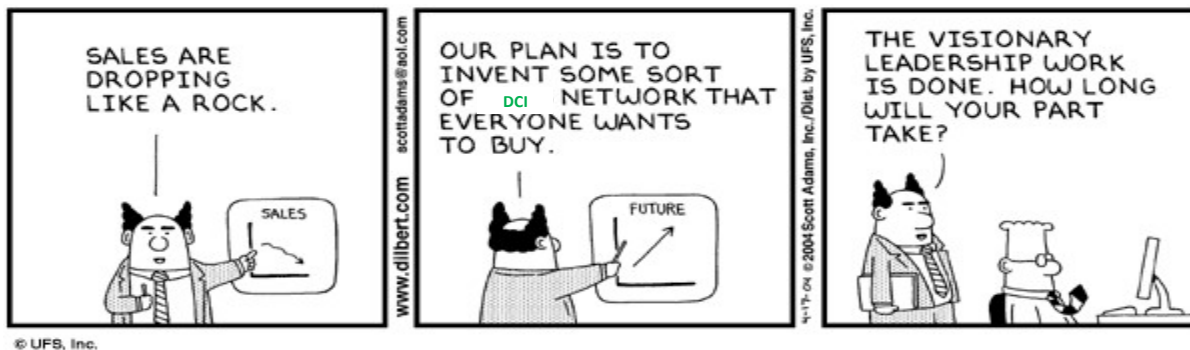


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The Importance of DCI Networks – “Executive Summary”

Reference: L. Paraschis oif2015.083 plenary Jan. 2015

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



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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



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Acknowledgement of Many Insightful Interactions

- ...with many colleagues at Infinera, industry and academia, including A. S. Sadasivarao*, S. Syed*, J. Rahn*, P. Kandappan*, P. Dale, D. Welch, M. Mitchell, B. Lu, G. Nagarajan, G. Rizzelli, V. Vusirikala, T. Hofmeister, A. Vahdat, J. Gaudette, M. Filer, R. Kannan, D. Pitt, K. Tse, R. Doverspike, A. Willner, V. Chan, and at IEEE and OSA events...
- *Disclaimer: This acknowledgement is NOT suggesting that these individuals have necessarily endorsed this presentation. Any errors are sole responsibility of the author.*



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Cloud has evolved to a Dedicated Massive Global Network Infrastructure

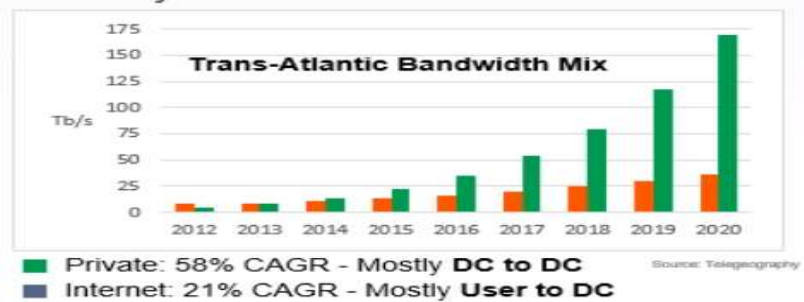
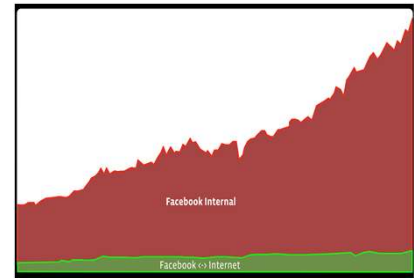
Reference: Bikash Koley, Google, OFC 2016, Najam, Facebook OFC 2016, and Google OFC 2018 and ECOC 2018 plenaries



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



Intra-datacenter Bandwidth Growth

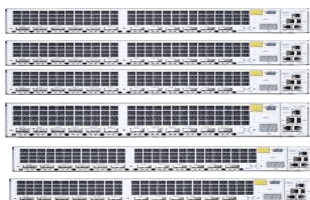
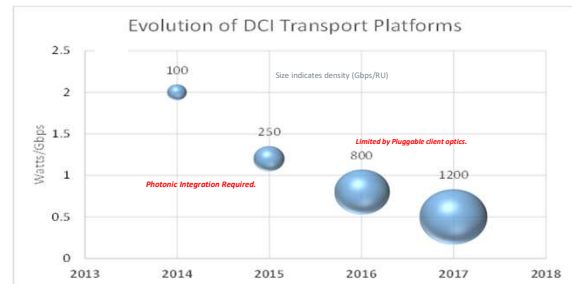


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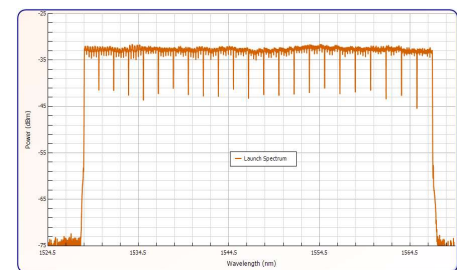
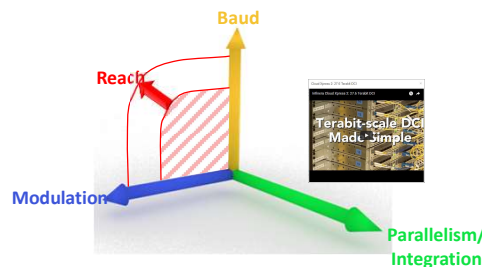
Cloud optimized Transport System Evolution

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**.

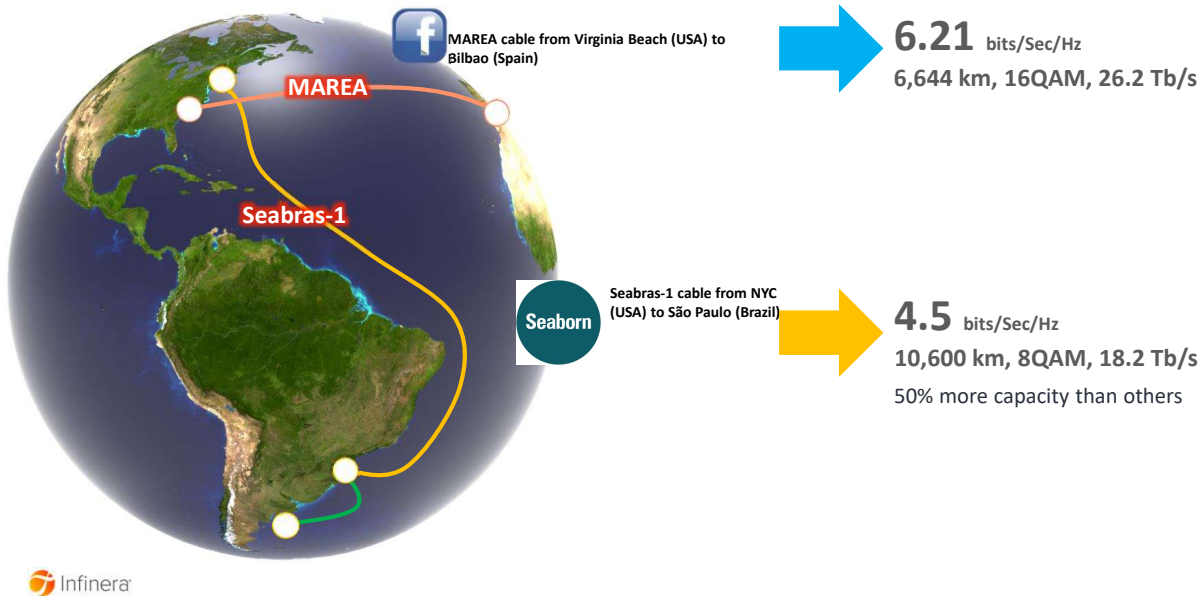


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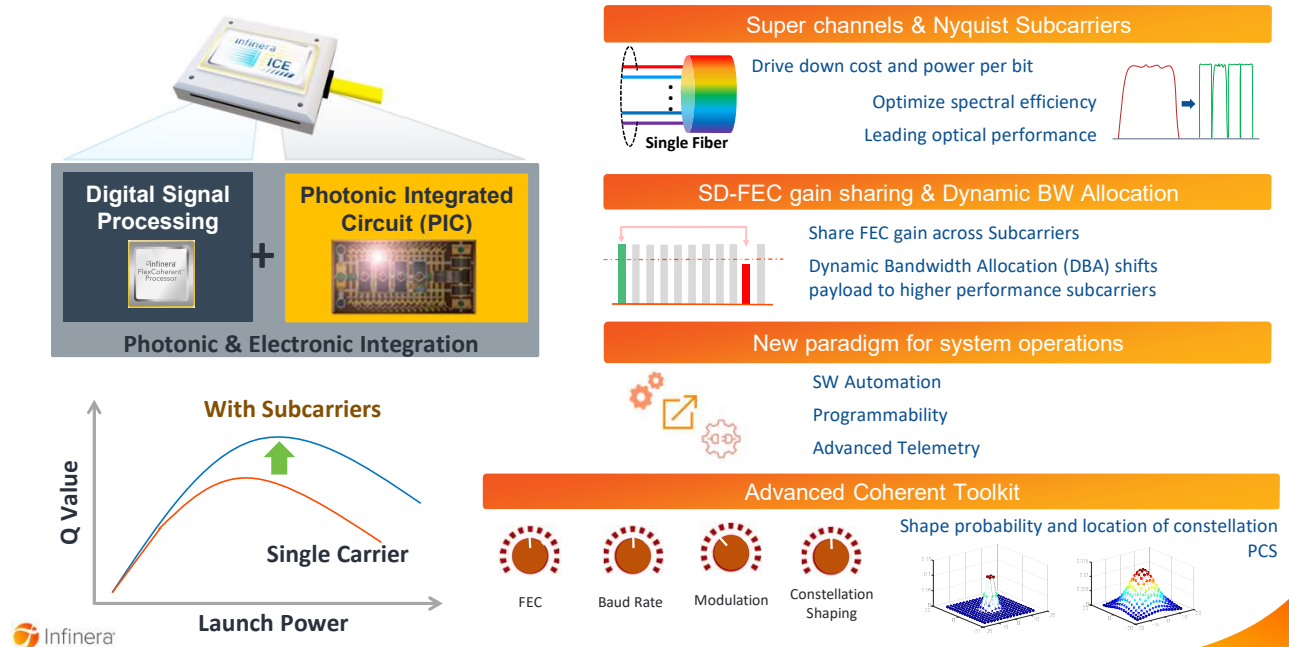
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DCI Physical layer innovation: Record Breaking Spectral Efficiency



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Maximizing Reach x Capacity: Enabling Technologies



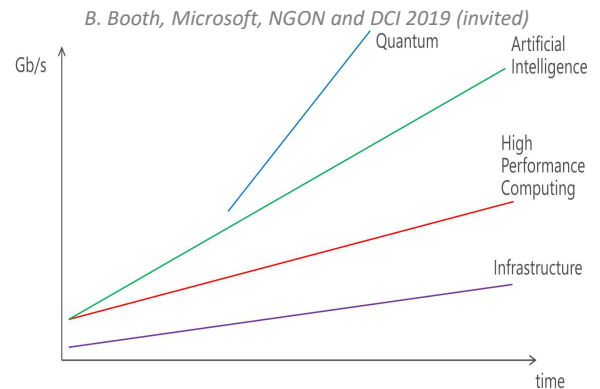
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Cloud increased important and future bandwidth demands

“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*

...

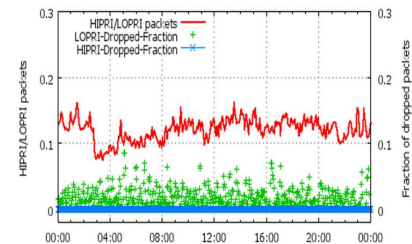
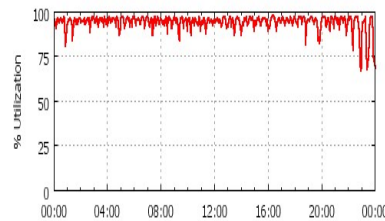
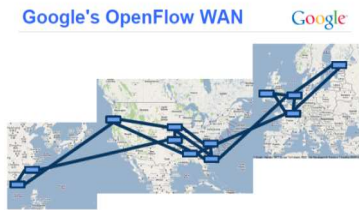


Next-Generation DCI Transport Innovations

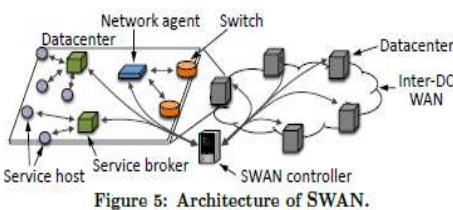
- How best to **lower power per b/s**, while still getting as close as possible to **Shannon Limit**?
- How best to achieve **Open Transport Architectures**, and **System Disaggregation**, while **advancing operation simplicity** at the Shannon Limit?
- How best to enhance **SW automation**, **extensibility**, **management abstraction** and **analytics**, and how much Network **Optimization** (and Traffic Engineering)?

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



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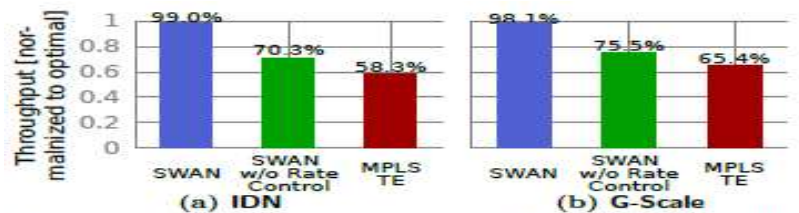


Figure 12: SWAN carries more traffic than MPLS TE.

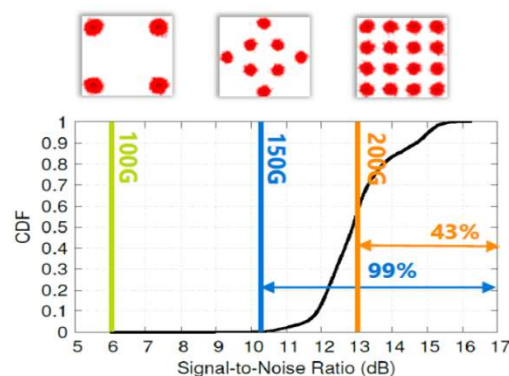
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Example of DCI Optical Transport Analytics and Optimization

M. Ghobadi, Microsoft, OFC 2016

LH BVT case study

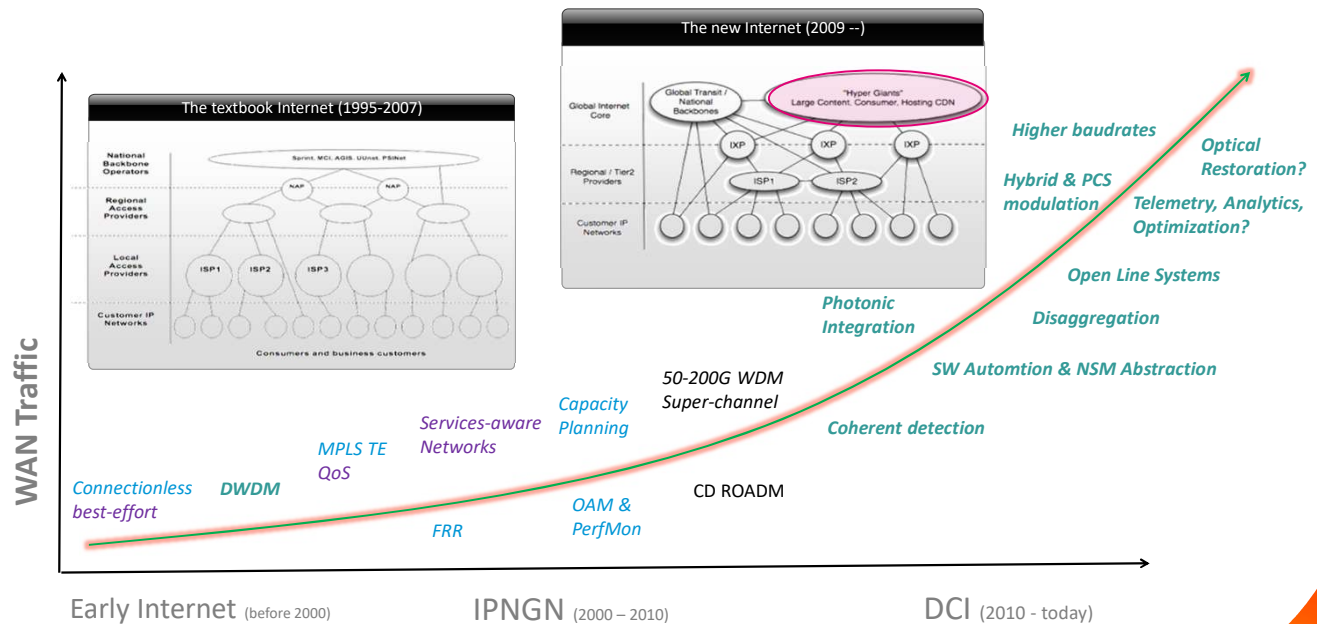
- Polled Q-factor of deployed 100G DP-QPSK for 3 months
- Observed Q → CDF of SNR
- Assumed BVT with modes:
 - QPSK at 100 Gb/s
 - 8QAM at 150 Gb/s
 - 16QAM at 200 Gb/s
- Findings
 - 99% addressable w/8QAM
 - 43% addressable w/16QAM
 - 70% net capacity gain possible



OFC 2016, paper M2J.2, Evaluation of Elastic Modulation Gains in Microsoft's Optical Backbone in North America, M. Ghobadi

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DCI Transport Innovations Summary



References for further reading

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- A. Shaikh et al., "Vendor-neutral Network Representations for Transport SDN", in OFC (2016), and A. Shaikh, "Multi-vendor Streaming Telemetry", and M. Birk, "Open Platforms for Optical Innovation", in OFC, (2018).
- V. Dangui, "Key Enablers of Automated Optical Networks", and M. Machacek, "Network Monitoring for Cloud", in OFC (2018), and M. Rizzi, "Automation of Optical Provisioning on Multi-Vendor Metro Optical Platforms", in OFC (2017).
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- L. Paraschis et al., "Innovations in Inter Data Center Transport Networks", Chapter 17 in Optical Fiber Telecommunications VII, Elsevier, ISBN 978-0128165027 (2019).