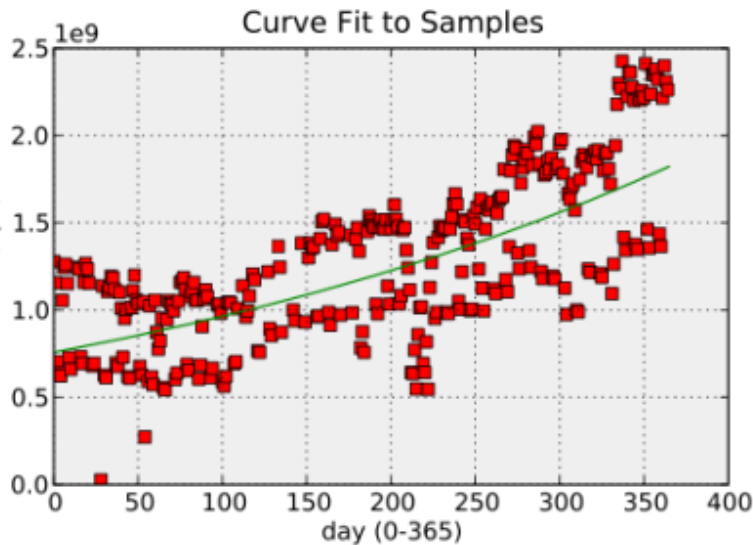# Beyond 100GbE: How Datacenter Interconnects Drive Demand for Higher Speed

Vijay Vusirikala, Bikash Koley and Paulie Germano
Network Architecture, Google

Outline

- Demand Drivers

- Google Views on
  - Rate
  - Reach
  - Temperature range
- Lessons from 40G/100G

Global IP traffic growth

Internet Observatory Report

Curve Fit to Samples

(a) Example AGR Calculation

CAGR: 44%

MINT Study

CAGR: 50%

http://www.dtc.umn.edu/mints/home.php

Cisco Study

CAGR: 40%

http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360_ns827_Networking_Solutions_White_Paper.html

Global Internet Traffic is growing at 40%-50% year-over-year rate

Moore's Law as REAL Driver for BW Demand

CPU Transistor Counts 1971-2008 & Moore's Law

HDD STORAGE DENSITY — STORAGE DEVICE PRICES
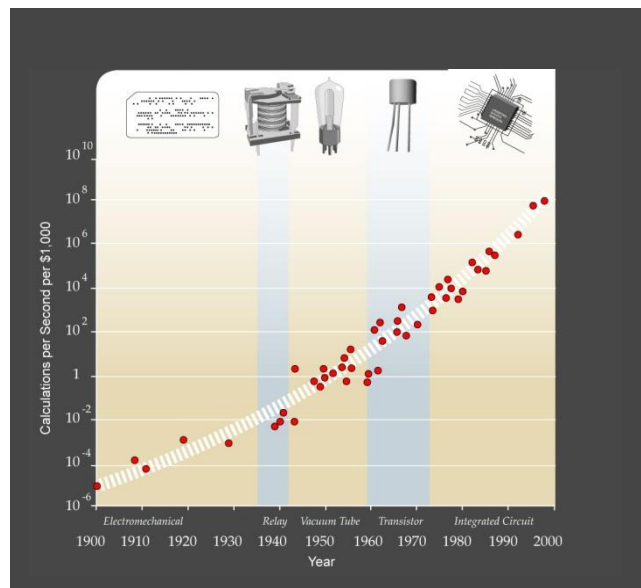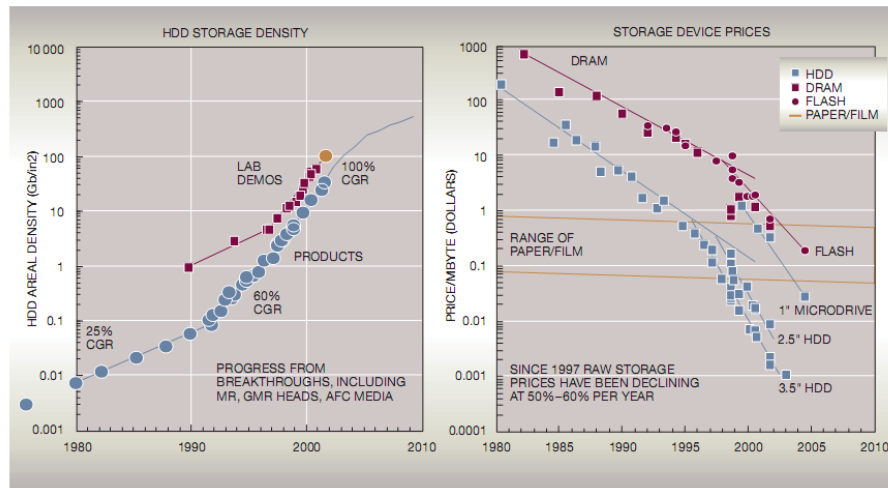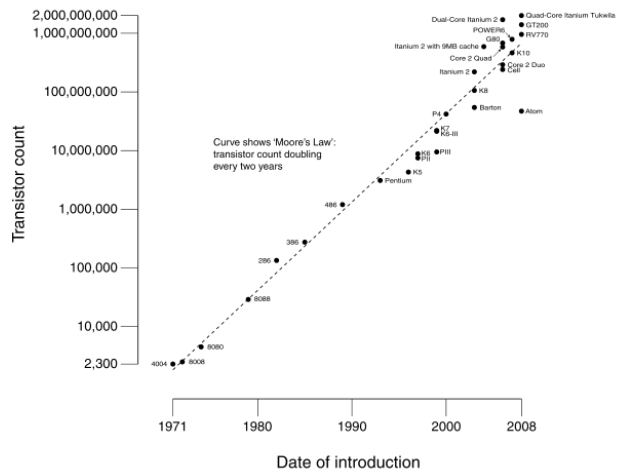
~ 60% per year improvement in compute power/storage density

~ 60% per year increase in inter-compute BW demand

*Morris, Truskowski, IBM Systems Journal, Vol 42, No 2, 2003*

Warehouse-Scale Computer Interconnects

- Large number of identical compute systems

- Interconnected by a large number of identical switching gears

- Can be within single physical boundary or can span several physical boundaries

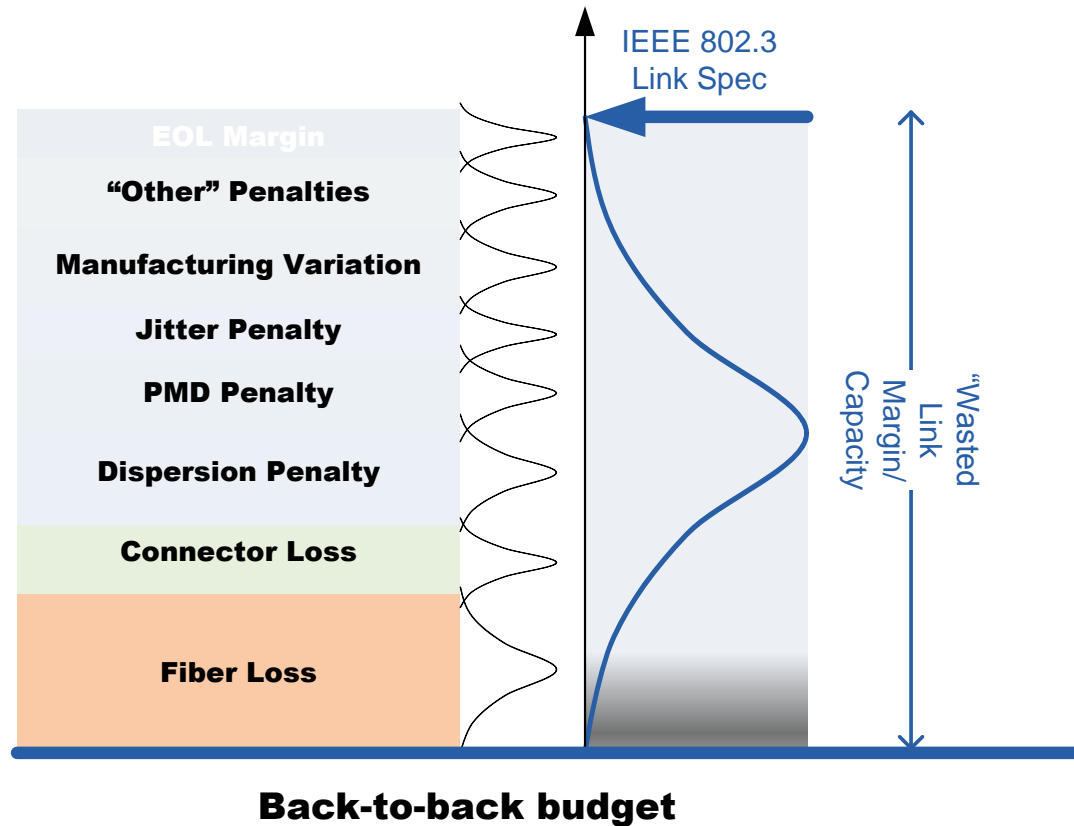- Interconnect length varies between few meters to hundreds of kms
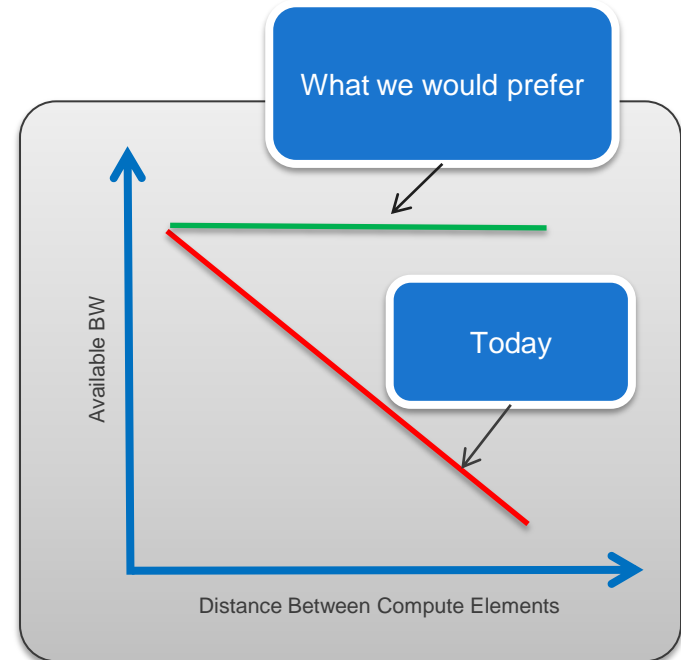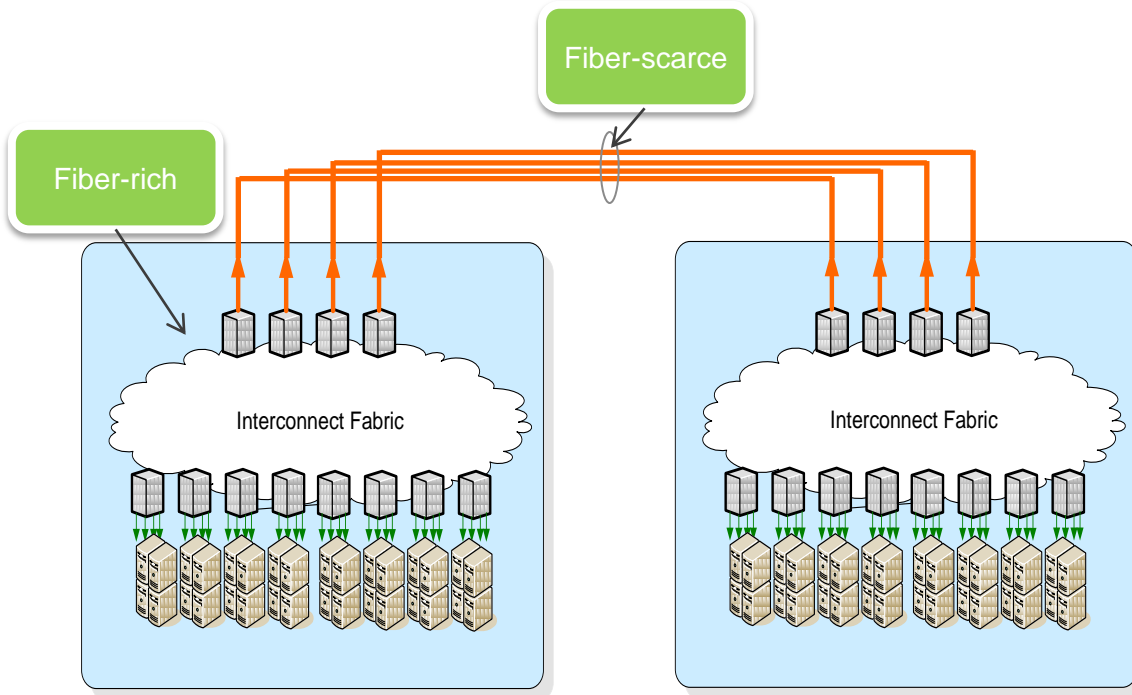
Is Ethernet Speed Keeping Up?
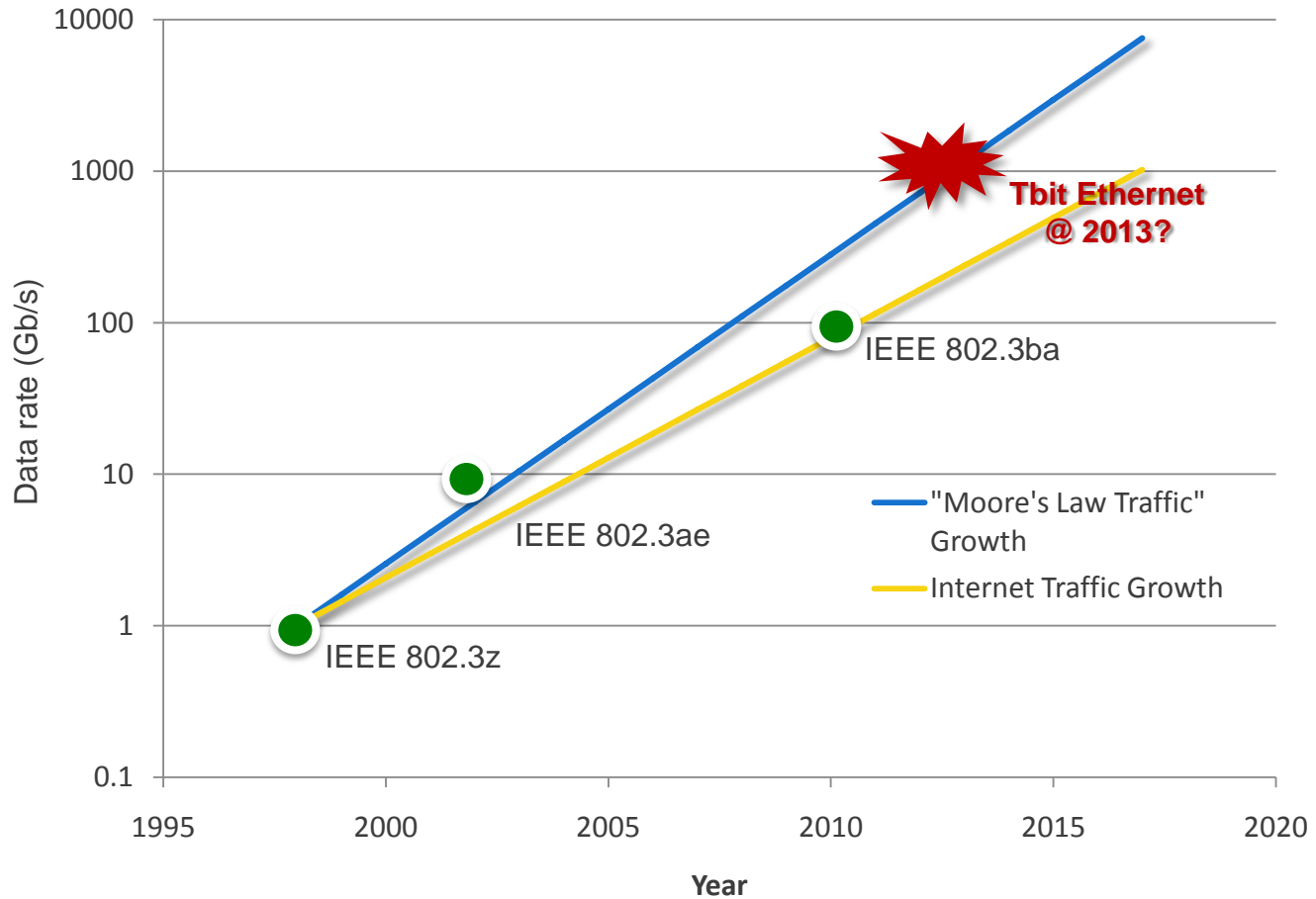
Beyond 100G: What data rate?

- 400Gbps? 1Tbps? Something "in-between"? How about all of the above?

- Current optical PMD specs are designed for absolute worst-case optical penalties, worst-case temperature and 15 year aging margin

- **Significant capacity is untapped within the statistical variation of various penalties**

IEEE 802.3 Link Spec

"Wasted Link Margin/ Capacity"

EOL Margin

"Other" Penalties

Manufacturing Variation

Jitter Penalty

PMD Penalty

Dispersion Penalty

Connector Loss

Fiber Loss

Back-to-back budget

Rate Adaptive 100G+ Ethernet?

- There are existing standards within the IEEE802.3 family:
  - IEEE 802.3ah 10PASS-TS: based on MCM-VDSL standard
  - IEEE 802.3ah 2BASE-TL: based on SHDSL standard
- Needed when channels are close to physics-limit : We are getting there with 100Gbps+ Ethernet
- **Shorter links ≡ Higher capacity**
- **Applications need to be aware of the available BW: MAC layer messaging**
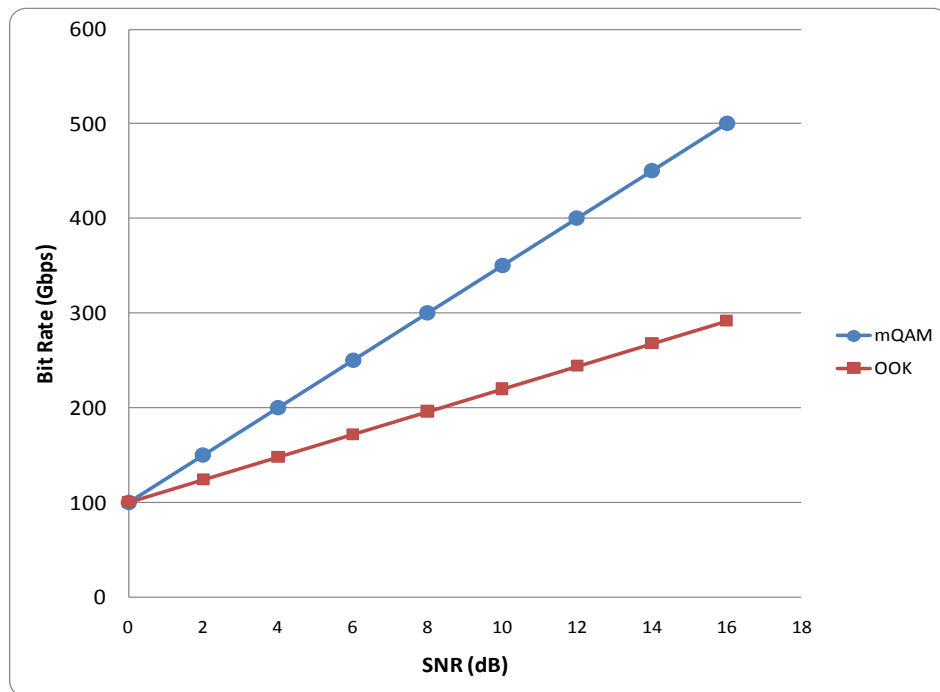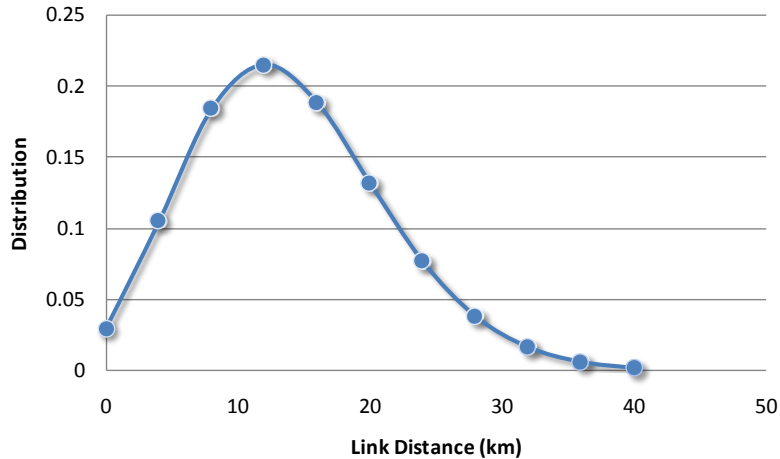

- **How to get there?**
  - High-order modulation
  - Multi-carrier-Modulation/OFDM
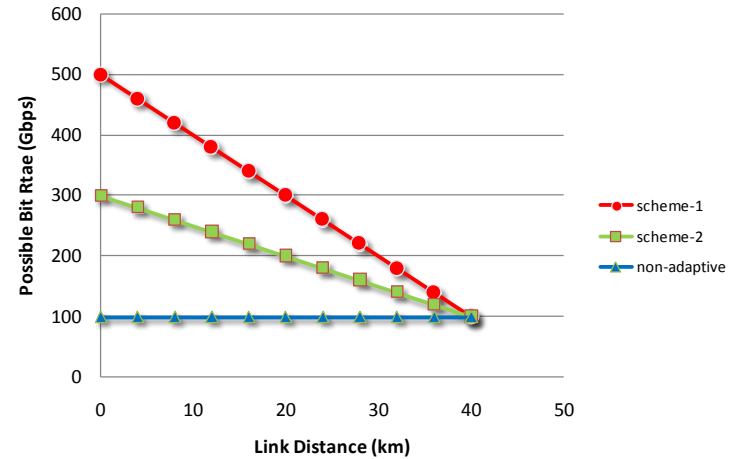 - Ultra-dense WDM
  - **Combination of all the above**
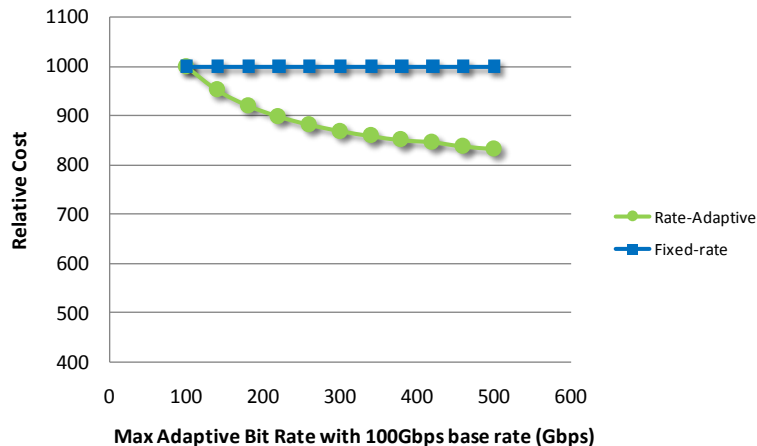
Is There a Business Case for Variable Rate?

Example Link Distance Distribution

Example Adaptive Bit Rate Implementations

Relative Cost of 100T Capacity

- **Cost of aggregate capacity for large number of "metro" links could be significantly lower with adaptive-rate Ethernet with a base-rate of 100G but capable of speeding up for shorter distance/ better link quality**