Si Photonics

Lecture 1: Introduction

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Lecture 1: Introduction

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● Goals

- Basic of optoelectronics
- Si photonic devices and integrated circuits
- Trends in Si photonics research

● Prerequisite

- Basic knowledge in EM waves, semiconductor physics, optoelectronics

Lecture 1: Introduction

- Topics to be covered
  - Introduction
  - Review of EM waves: Reflection/Transmission, Interference, Diffraction
  - Dielectric waveguides
  - Si photonic devices: Waveguide devices, Modulators, Photodetectors
  - Summary presentation of research papers

- Reference Book

"Silicon Photonics Design: From device to Systems" by Chrostowski and Hochberg

- Lecture notes available in LearnUs before class

- Class Schedule

  - Tuesdays (D603): 11:00-11:50 am ➔ Homework due, Discussion on homework
  - Thursdays (D407): 1:00 – 2:50 pm ➔ Lectures with homework problems

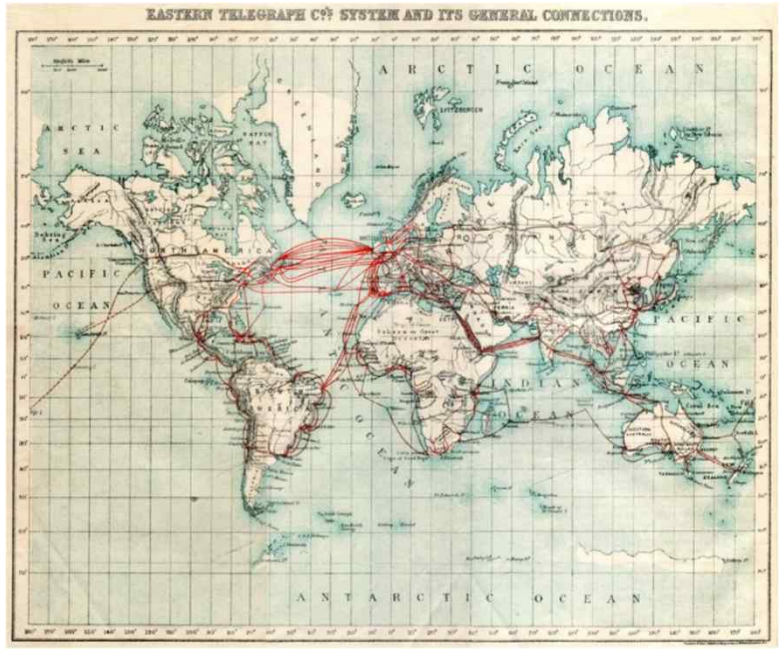
Lecture 1: Introduction

- Grades
  - Attendance: 40%
  - Homework: 40%
  - Class participation: 10%
  - Journal Paper Review Presentation (in English): 10%

Lecture 1: Introduction

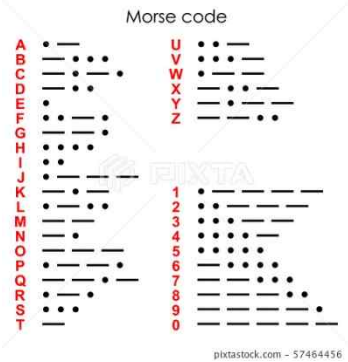
- Why Si Photonics?
- Why Photonics?
- Why Photonics for Communication?
- (Very Brief) History of Wireline Communication

- Telegraph



(1901)

Morse code



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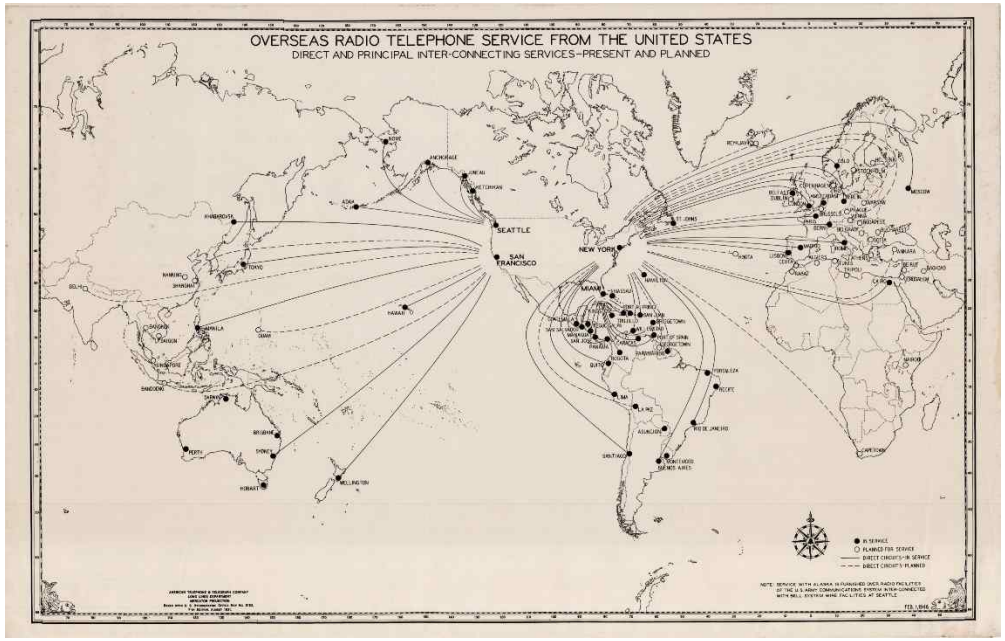
Lecture 1: Introduction

- Telephone

Alexander Graham Bell
making long-distance call
from New York to Chicago in 1915

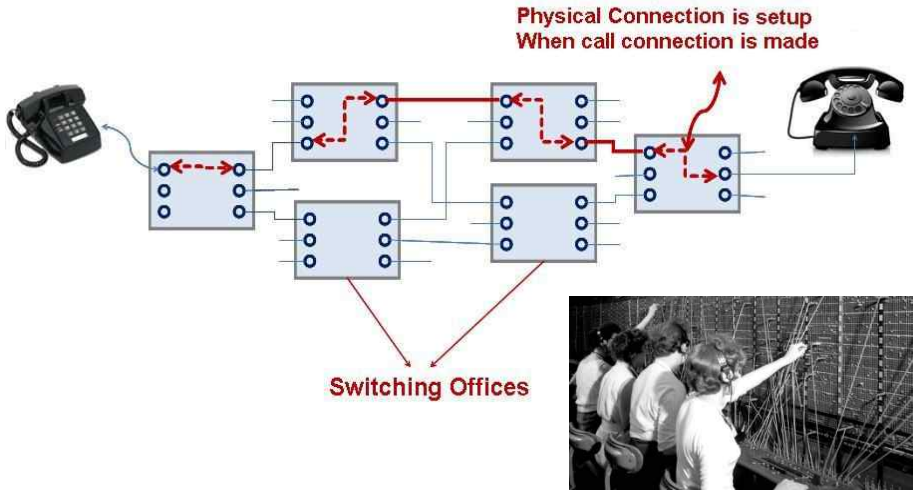


AT&T International Telephone Service Network in 1946

Lecture 1: Introduction

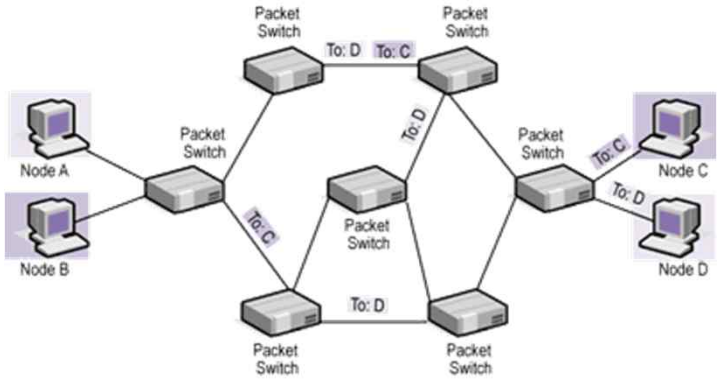
Telephone Network

(PSTN: Public Switched Telephone Network)



Internet

(TCP/IP: Transmission Control Protocol/Internet Protocol, 1983)



PSTN	TCP/IP
Voice (Data)	Data (VoIP)
Circuit switching	Packet switching
Dedicated path	No dedicated path
Cost based on distance and time	Cost **not** based on distance and time

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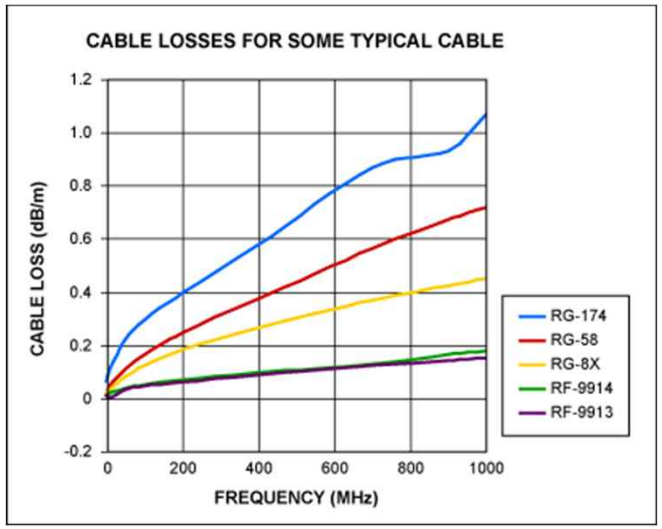
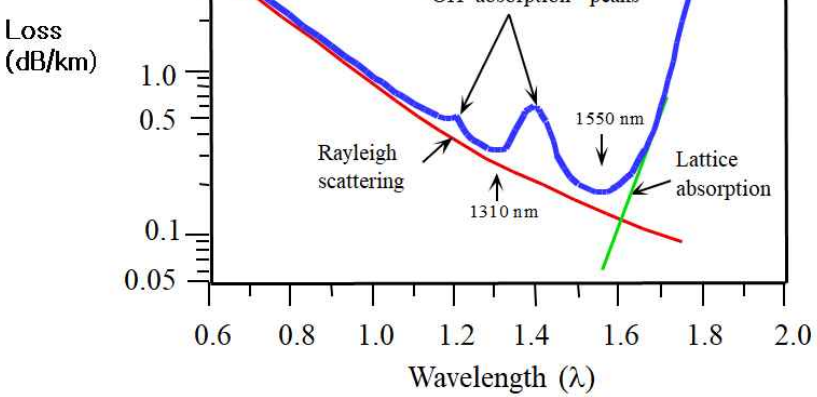
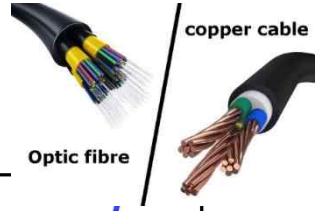
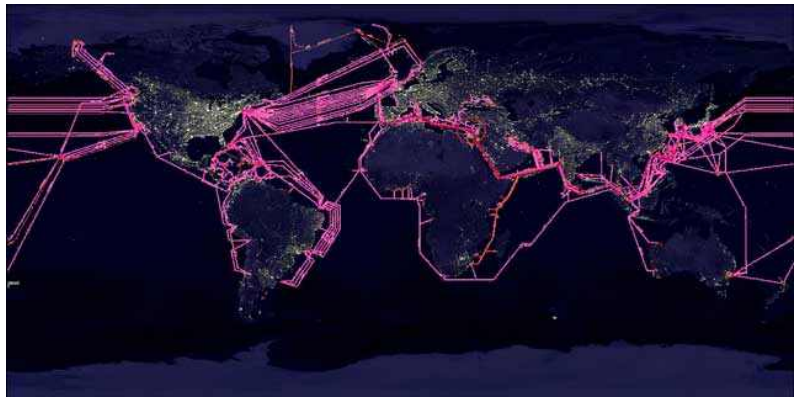
- Transmission Medium: Electrical Wire ➔ Optical Fiber









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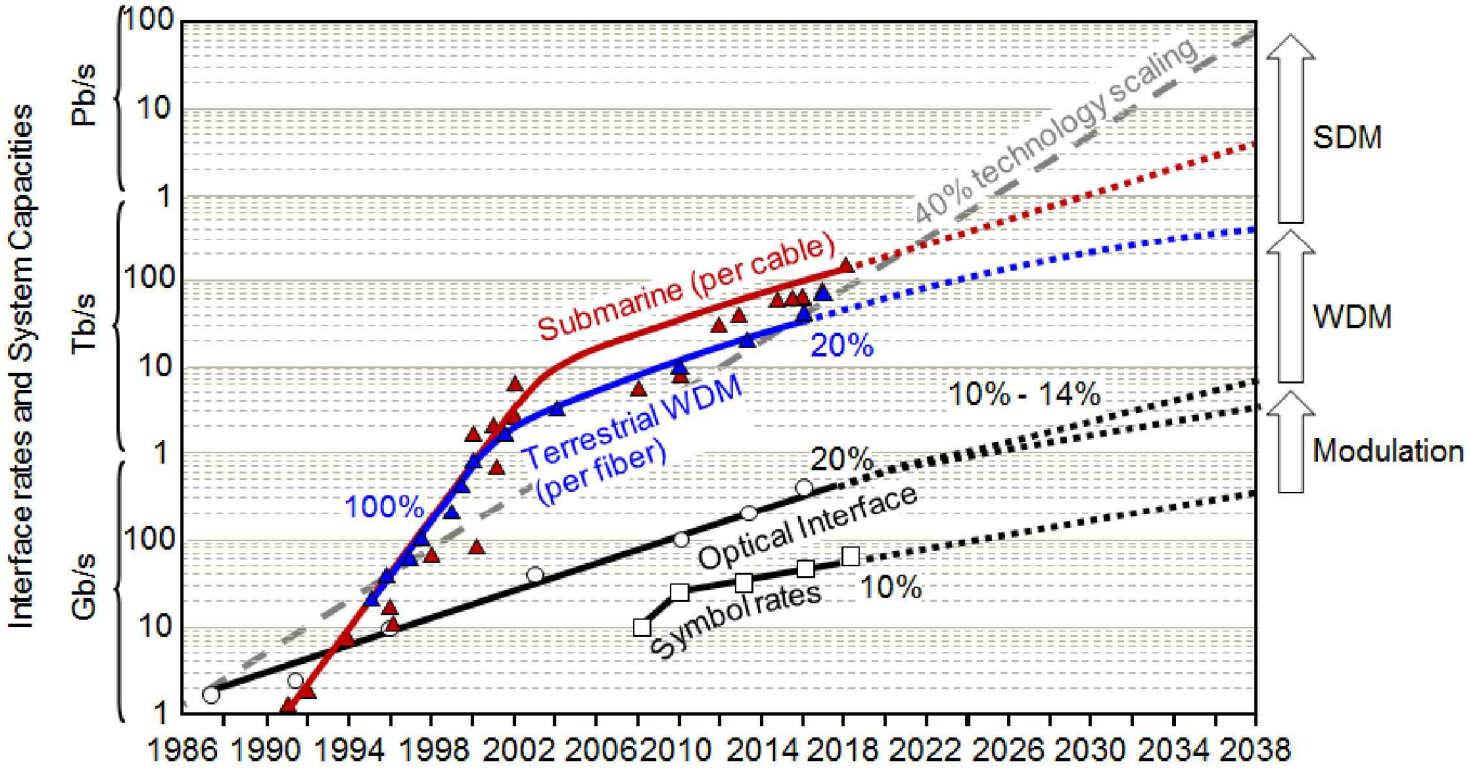
- Optical Communication Transmission Capacity



(Winzer et al, Opt. Express 2018)

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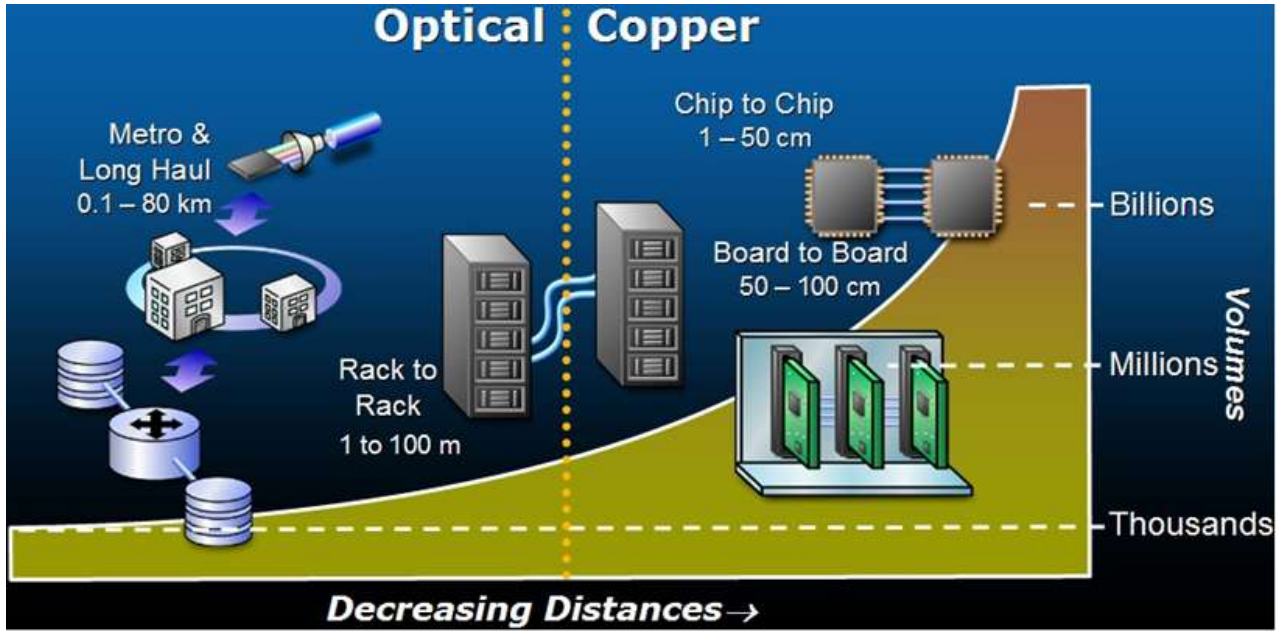
- Volume vs Distance



(Intel)

Long-distance applications

- Technology development driven by telco operators with regulation by government

- Much larger market potential for shorter distance applications if ***demands are sufficient***

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- Demands for Data

2020 ➔ 2021

On-line purchase: $1.1M ➔ $1.6M

FB Messengers/WhatsApp: 59M ➔ 69M

Views on Twitch: 1.2 M ➔ 2 M

Tiktok: 1,400 ➔ 5,000 downloads

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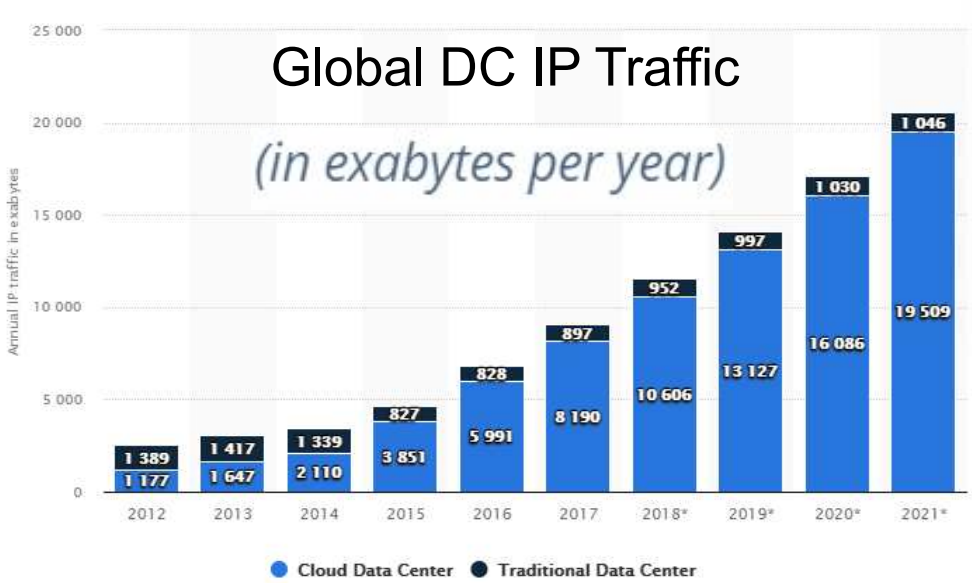
- Need to Store, Process, *Interconnect* Big Data

Google Data Center



(Statista 2021)

Growth much faster than that of telecommunication

➔ Sufficient demands for short distance optical interconnect

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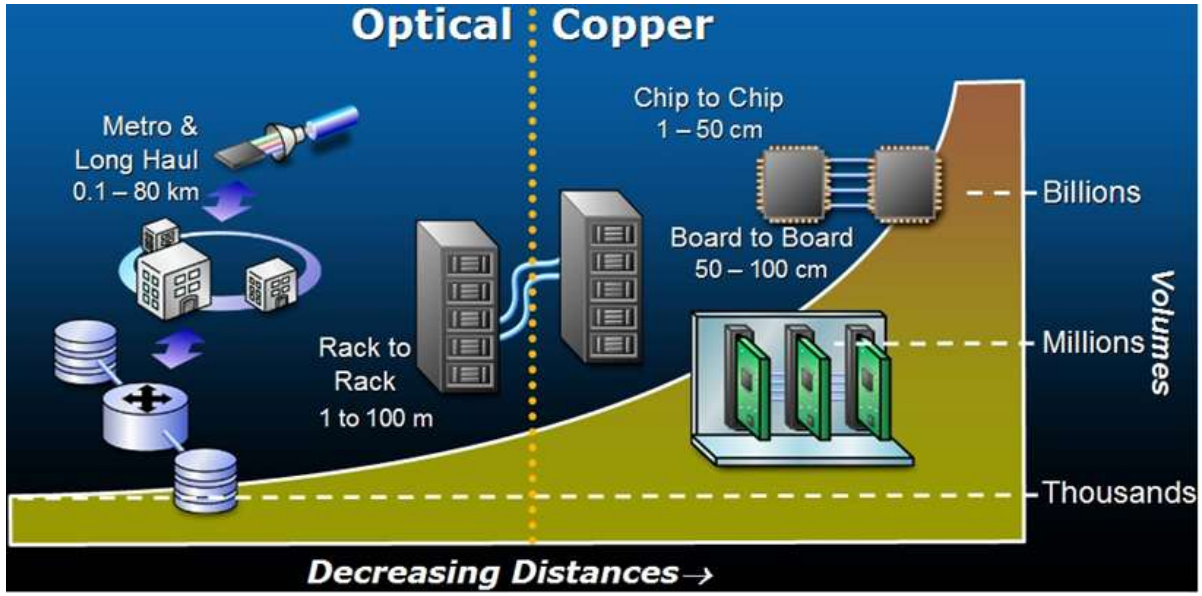
- Volume vs Distance



(Intel)

- Sufficient demands for short distance optical interconnect

Requirements:

High performance (data rate)

Mass production and cost

Energy efficient

CMOS technology for photonics?

➔ Si photonics

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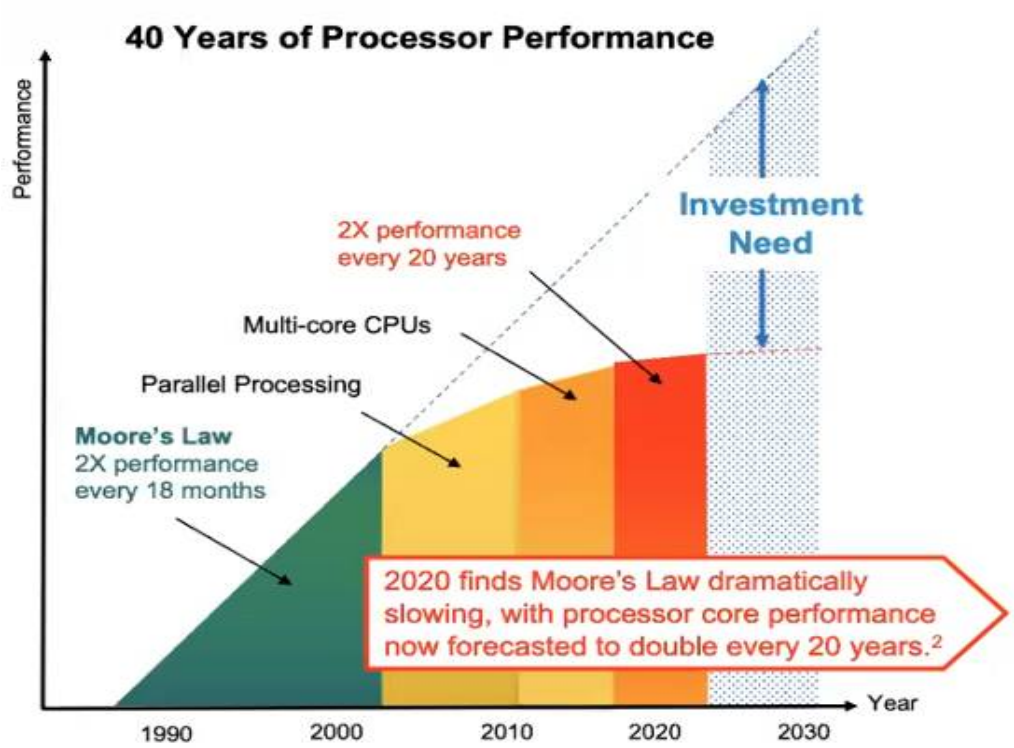
- Why semiconductor companies are interested in optical interconnect?



(Broadcom)

What technology can close the gap?

➔ **Connectivity**

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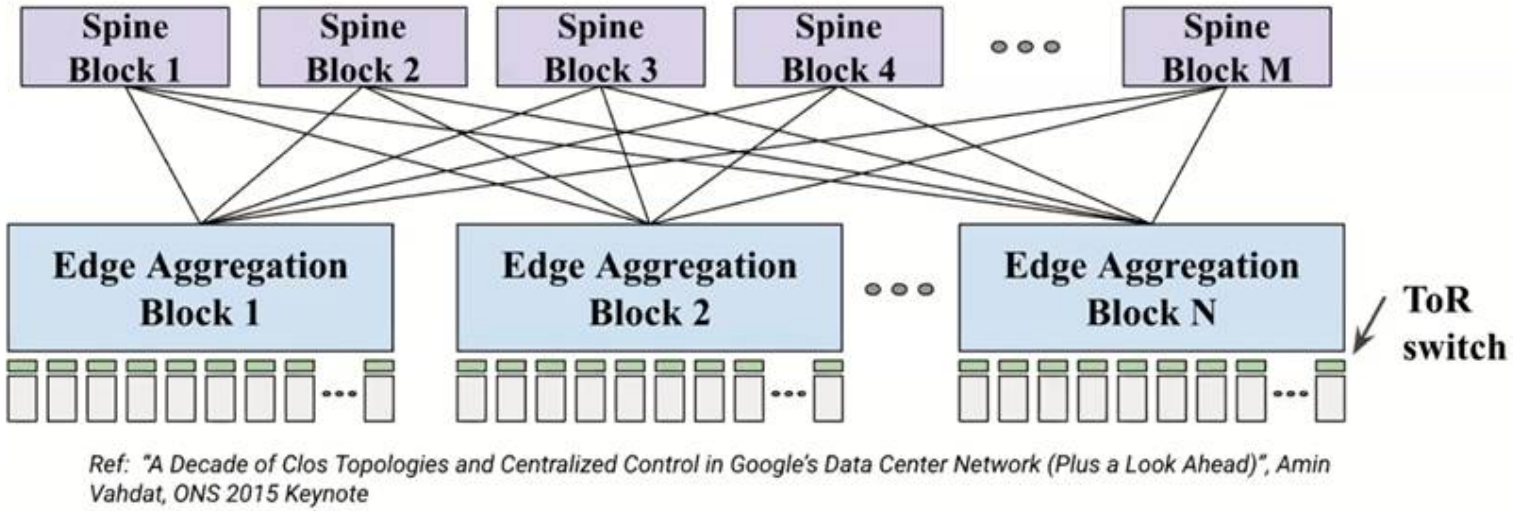
Data Center Architecture



Ref: "A Decade of Clos Topologies and Centralized Control in Google's Data Center Network (Plus a Look Ahead)", Amin Vahdat, ONS 2015 Keynote

(Google)

➔ Switch bandwidth and power consumption are the key performance metric

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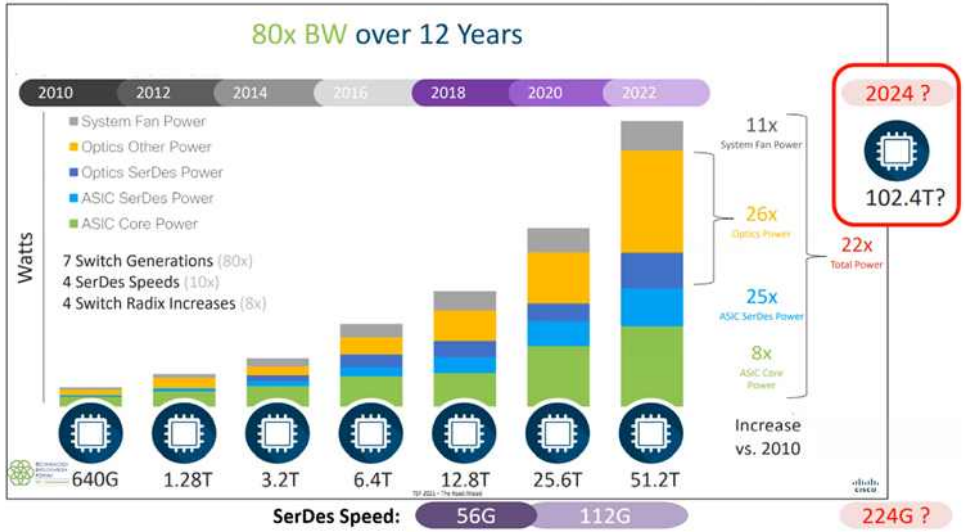
- Evolution of Cisco Switch Performance

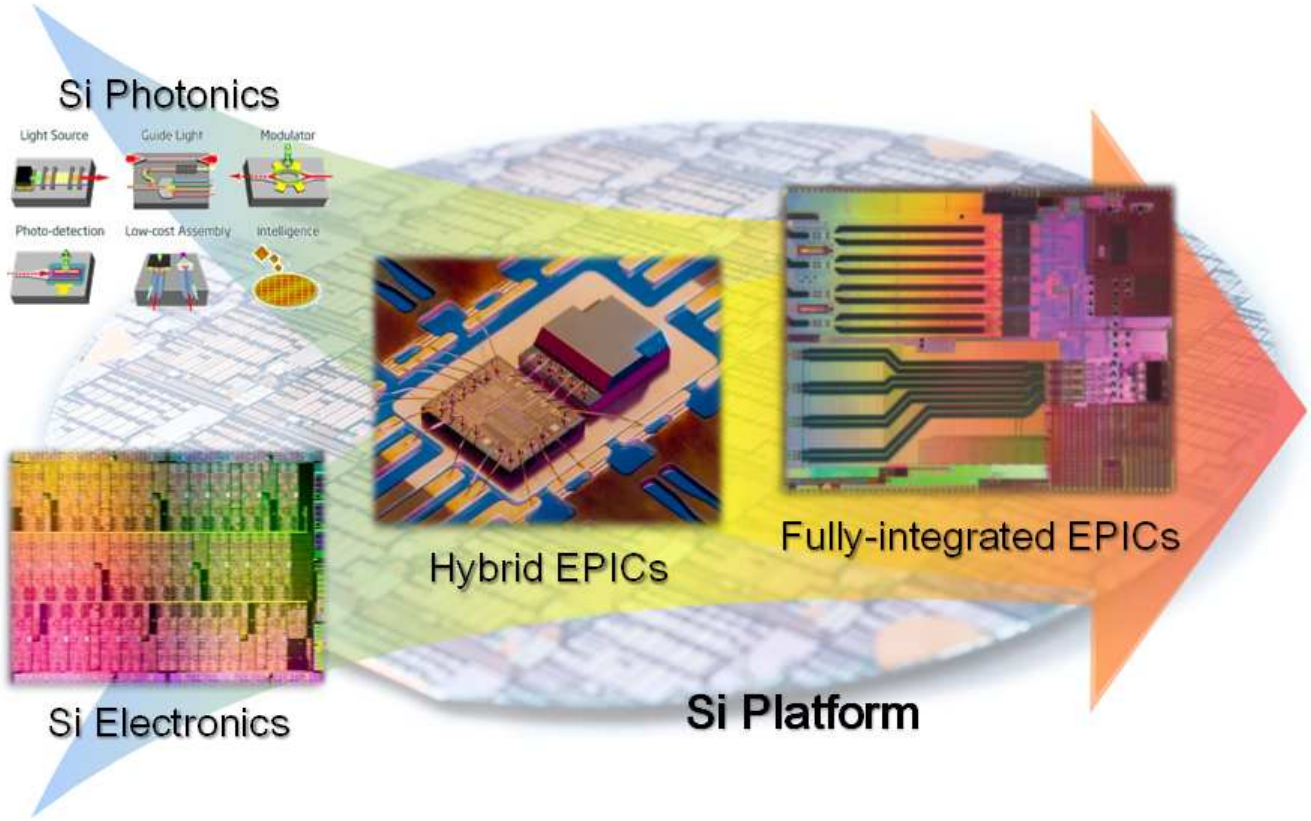


- Switch bandwidth performance has been continuously increasing
- Power consumption is also continuously increasing
- Interconnect power increases most significantly

CMOS-compatible high-performance interconnect solution with small-size and energy efficiency

➔ Si Photonics

Si Photonics



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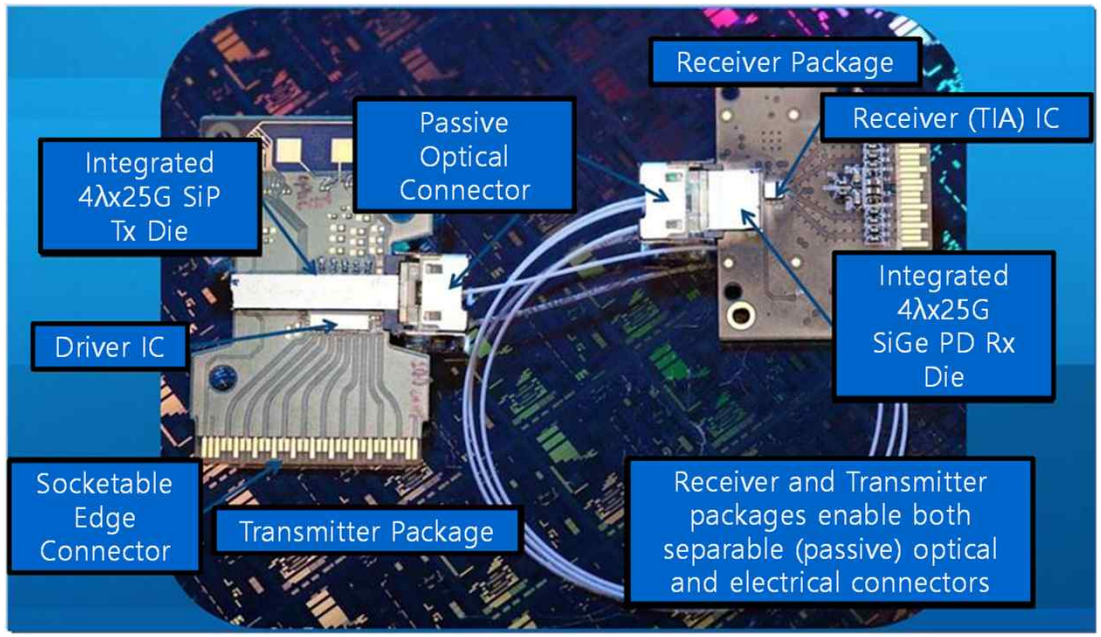
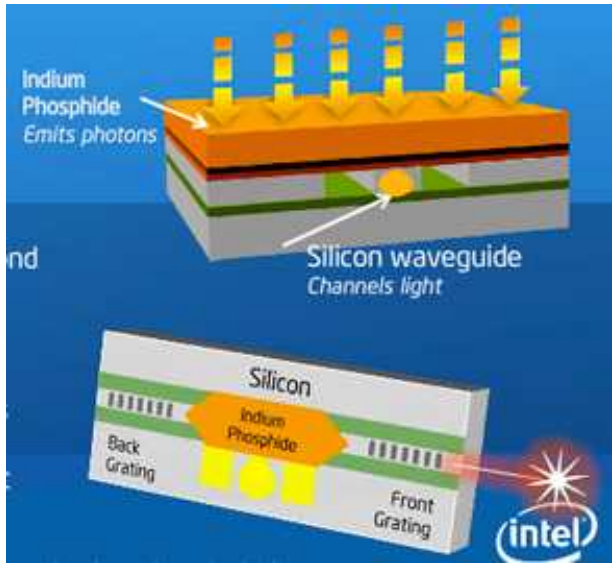
Intel : 100G PSM4, 100G CWDM4 TRx for intra DC interconnect





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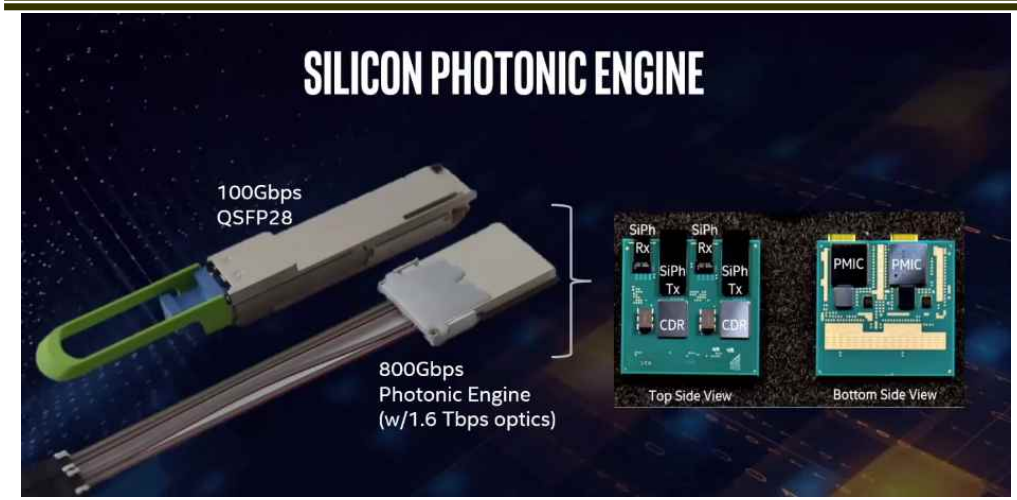
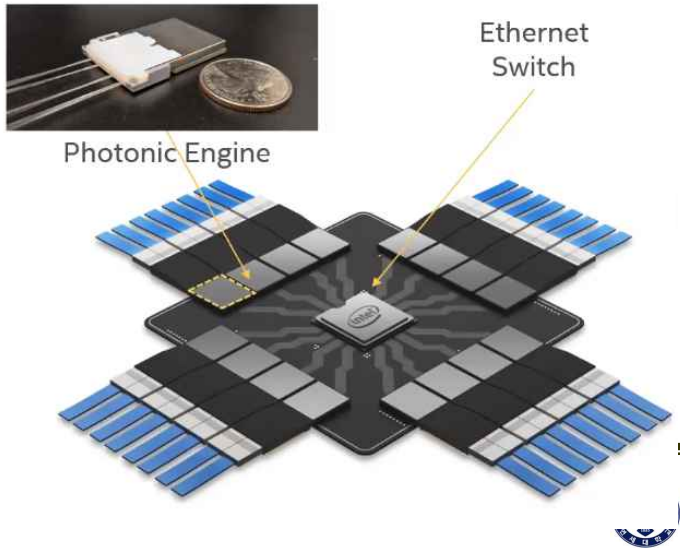


Si Photonic Engine + 12.8 Ethernet Switch

Intel ← Barefoot

Cisco M&A
← Ligthwire, Luxtera, Acacia

Nvidia ← Mellanox



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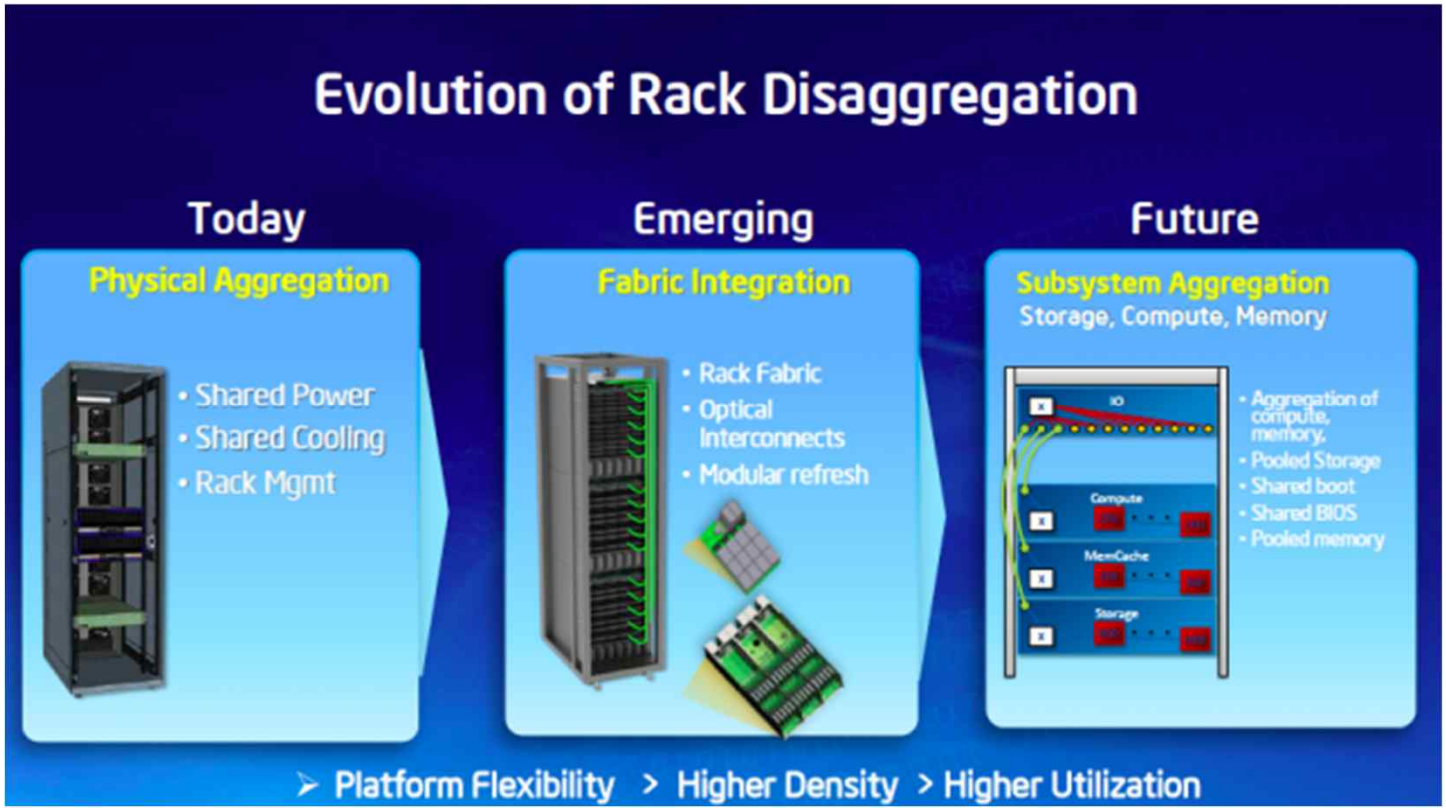

Connectivity will control the entire system architecture

Optical interconnects based on Si Photonics is the solution