Development of Optical Communications

presented by

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Data rate is growing.
Increase in internet traffic

Bit rate/sec @ Max.

20Gbps

40Gbps
Optical communication is the infrastructure for the present networks (and future).
Optical signals travels all around.

Let’s trace the development of optical communication technology.
Old days ....

Rocket

Signal lamp
Modern communication started with electricity

Wireless communication

Copper wired communication
Seeds of modern optical communication

Invention of laser (1960)

- high-frequency electromagnetic wave
- monochromatic light
- good directionality
possibility for high modulation rate
monochromatic

possibility for multi-channels

laser

prism

sun

directionality

efficient use of power
Space optical transmission using He-Ne laser

Not good enough for practical use
a trail to transmit light for a long distance

lens waveguide

*Impractical, of course.*
Semiconductor laser @ room temperature

first oscillation
Research activity was triggered by these innovations.
Optical fiber

Light propagates along fiber, being totally reflected.

\[ n_1 : \text{refractive index of core} \]
\[ n_2 : \text{refractive index of clad} \]
\[ (n_1 > n_2) \]
Why light is good for transmission?

Frequent answer: “Light is fast” ×
“traveling fast” ≠ “high data rate”

“Bits per second” has nothing to do with the traveling speed.
The main reason is

The propagation loss through fiber is quite low

- 0.2dB-loss @ 1km (transmittance = 95.5%)
- 2.0dB-loss @ 10km (transmittance = 63%)

On the other hand

Copper wire is lossy for high frequencies.
(ex. 10dB/km for 10MHz)
Optical communication has been developed, pursuing to fully utilize the low-loss property.

Transmission medium is the most important matter, generally speaking.

1st generation (0.8μm): first semiconductor laser
2nd generation (1.3μm): zero-dispersion
3rd generation (1.5μm): minimum loss
Light velocity in fiber is not unique

Mode-dispersion
Propagation velocity is different for different angles.

Chromatic-dispersion
Propagation velocity is different for different wavelength.
When velocity is different....... 

Pulse width broadens.

In case of a pulse train,

bit error
research effort

Combat with dispersion

◆ Single-mode fiber

◆ Chromatic dispersion is zero at 1.3μm, by chance.

2nd generation @ 1.3 μm
People wanted to use loss-minimum wavelength

- Laser emitting a single-wavelength

- Fiber with zero-dispersion at 1.5 μm (dispersion-shifted fiber)

3rd generation @ 1.5μm
furthermore

Combat with fiber loss

optical amplifier

signal light 1.55 μm

coupler

Erbium-doped fiber (several m – several tens m)

pump laser

1.48 or 0.98 μm

gain: ×1000 ~ 10000
Wavelength Division Multiplex (WDM)

great benefit of opt. amp.

transmitter ($\lambda_1$)
transmitter ($\lambda_2$)
transmitter ($\lambda_3$)
transmitter ($\lambda_4$)

receiver ($\lambda_1$)
receiver ($\lambda_2$)
receiver ($\lambda_3$)
receiver ($\lambda_4$)

simultaneous amplification
Increase in transmission capacity

- Increase in transmission capacity over time from 1970 to 2000.

Graph showing the increase in transmission capacity (Gbit/s) from 0.01 to 100 over 1970 to 2000, highlighting technological advancements.
Advanced Optical Networks

Optical Add/Drop

Optical Crossconnect
Advanced Optical Transmission