SVEUČILIŠTE U ZAGREBU
Fakultet elektrotehnike i računarstva

Master Programme
Computing

Advanced Architectures of Telecommunication Networks

Ac. year 2022/2023

Evolution of Fixed Networks

Communication networks

- Communication network
- Telecommunication n.
- Fixed n.
- Mobile n.
- Public n.
- Private n.
- Special n.
- Corporate n.
- Satellite n.
- Telephone n.
- Data n.
- Cable TV n.
- Computer n.
- N. with channel switching
- N. with packet switching
- N. with beam commutation
- Integrated Services Digital Network - ISDN
- Broadband ISDN - B-ISDN
- Signaling n.
- Synchronization n.
- Controller n.
- Local n. - LAN
- Metropolitan n. - MAN
- wide area network - WAN
- Commutation n.
- Transmission n.
- Core n.
- Access n.
- Transport n.
- Synchronous digital hierarchies - SDH
- Optical (photonic) n.
- All-optical n.
- Internet
- Personal area n.
- Controller Area Network (CAN)

Standardization

- 1865. First International Convention on Telegraph Traffic
- 1885. First International Convention on Telephone Traffic
- 1936. International Telecommunication Union (ITU)
- 1945. **ITU** >> UN agency (Geneva)
- 1956. CCITT (Consultative Committee for Telephony and Telegraphy) within the ITU
- CCIR (Consultative Committee for Radio)
- 1993 ITU is transformed into sectors:
  - **ITU-T** (telecommunication)
  - ITU-R (radio)
  - ITU-D (development)

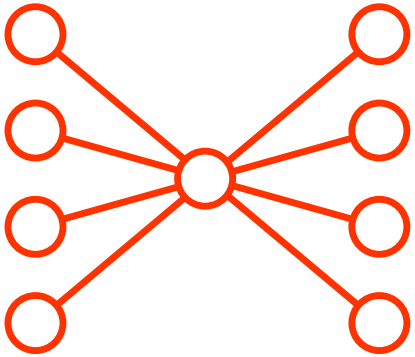
Standardization in Europe

- 1959. CEPT (European Conference on Public Administration and Telecommunications)
- 1988. **ETSI** (European Telecommunication Standards Institute)

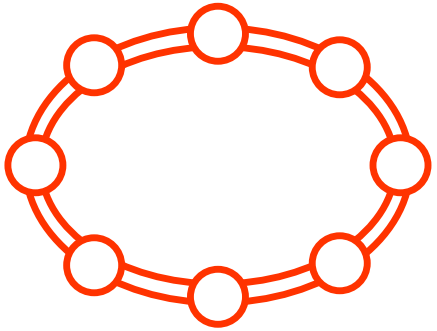
- Other standards: IEEE, ISO, ANSI,…

Basic topologies

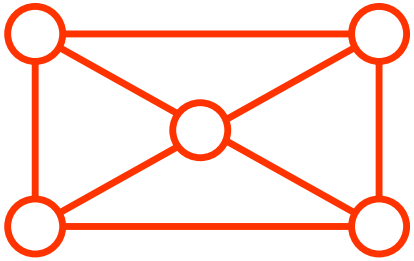
Star



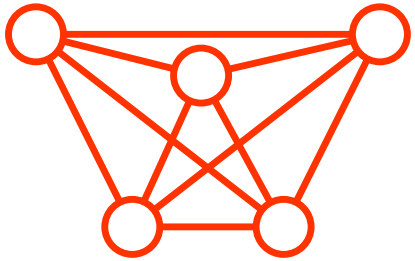
Ring



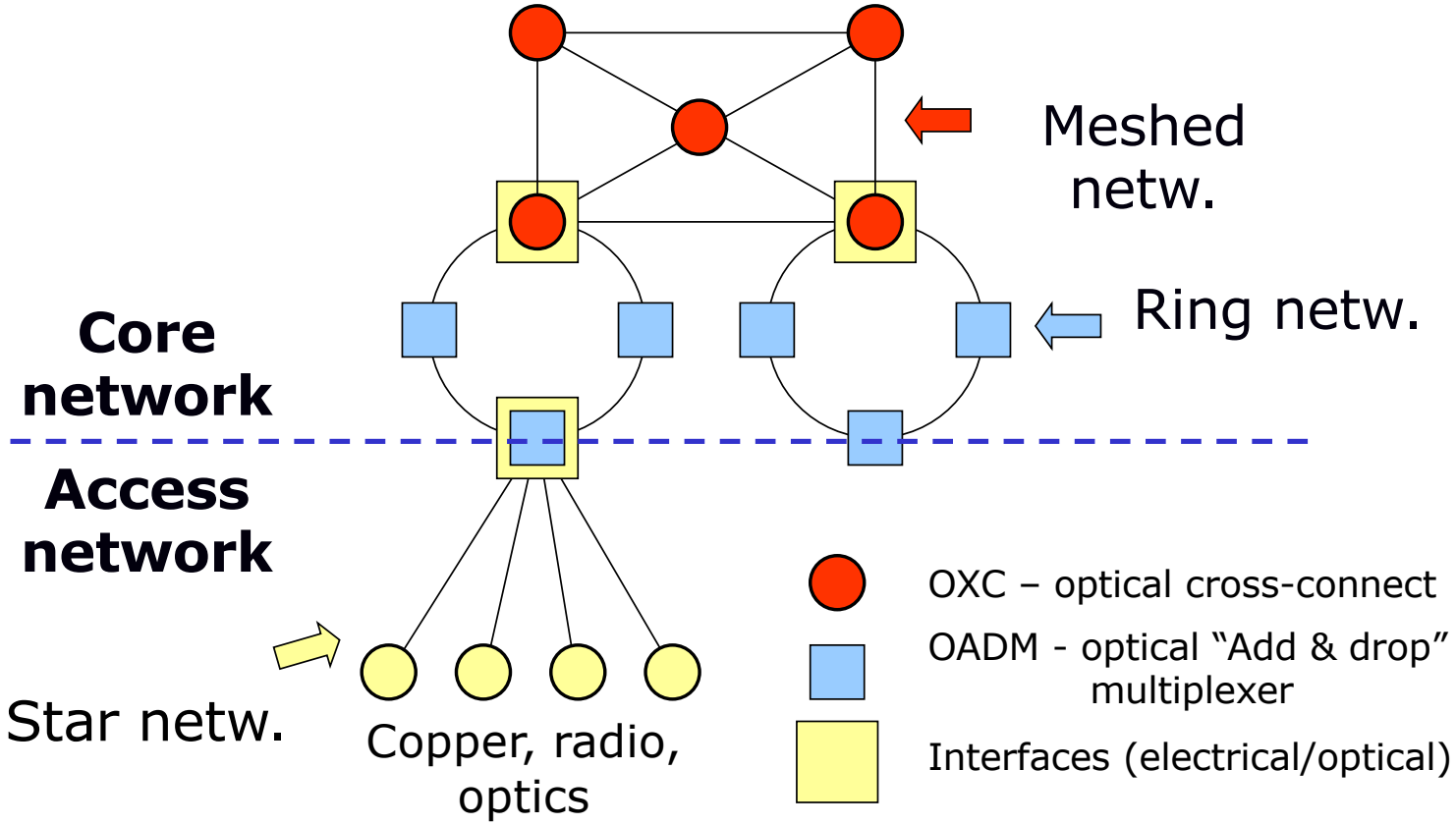
Meshed network



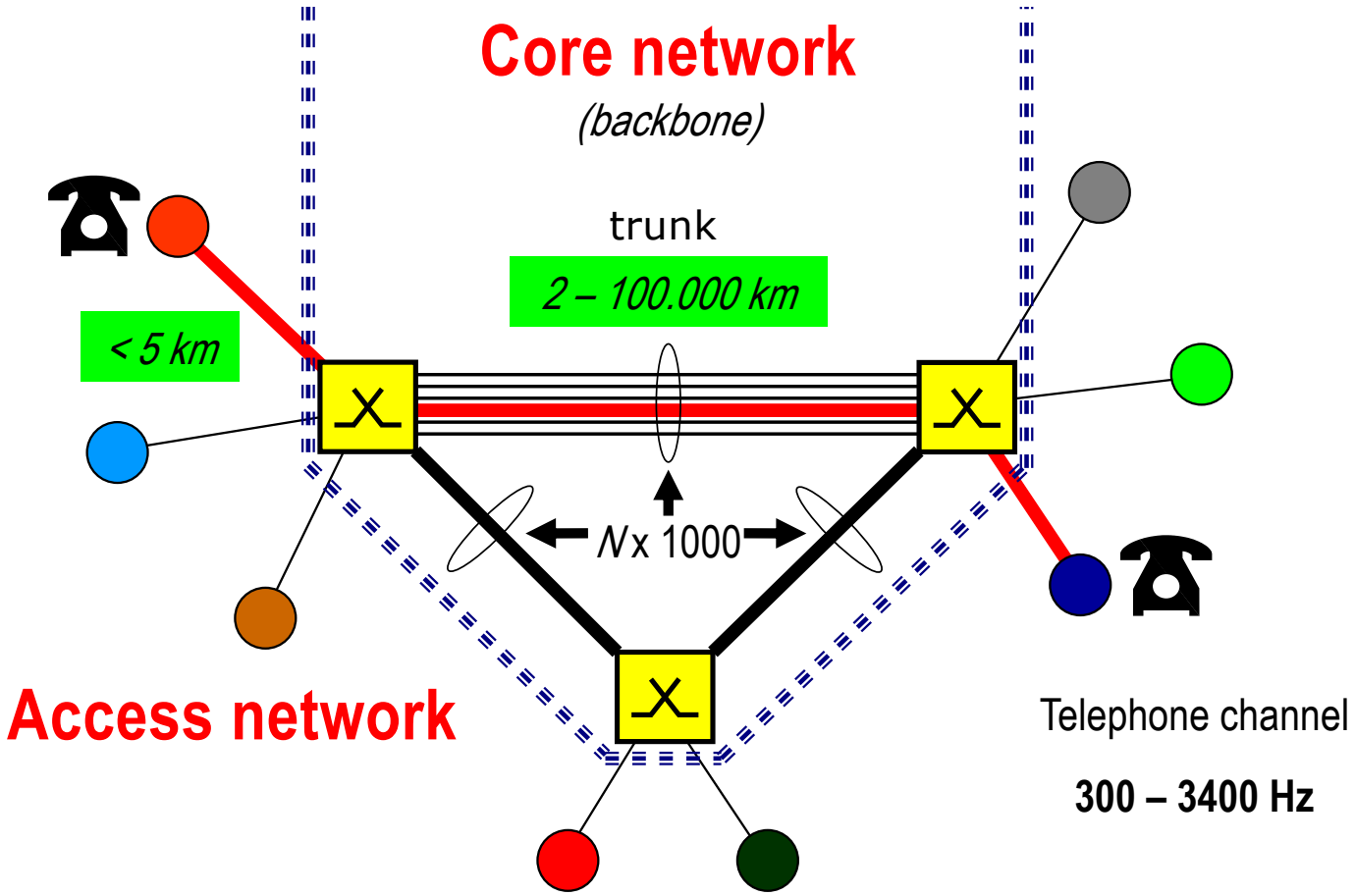
Fully meshed network



Basic network topologies



Evolution of (fixed) PSTN



Core network

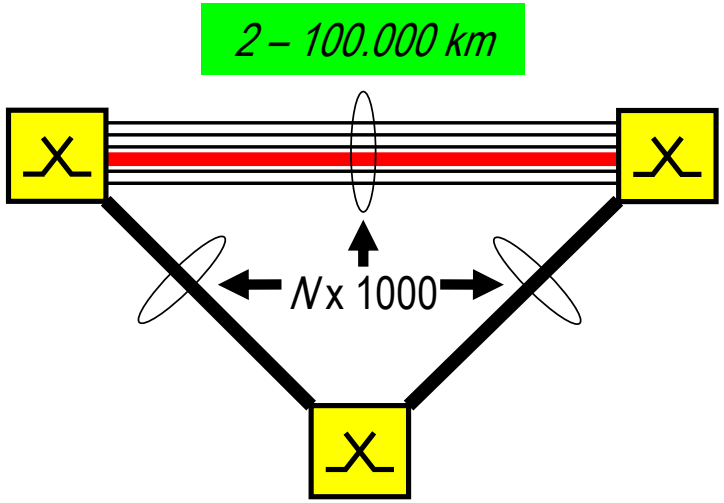
Problems…

Line length and signal degradation → solution: **signal regeneration** (amplification, shaping and time recovery)

(3R – re-amplification, re-shaping, re-timing)

Number of lines → solution: **multiplexing** (multiple connection utilization)

Propagation time → possible solution: optical cable instead of satellite connection

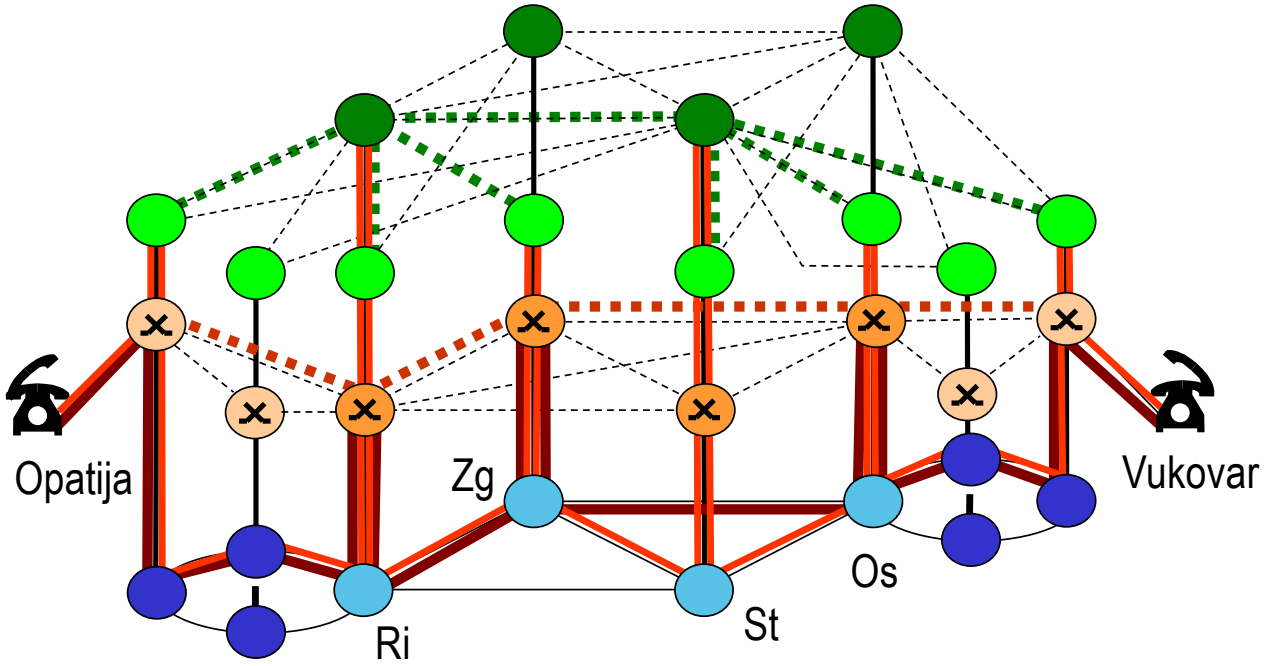


Zagreb - New York

Optical cable
8.000 km, 200.000 km/s
Delay: **40 ms**

Satellite
min 2 x 36.000 = 72.000 km, 300.000 km/s
Delay: **240 ms**

Network layers – PSTN example



Signalling network

Switching network

Transmission network

Time to establishing connection = time to process + propagation time → ***n* x ms**

- Local switch
- Transit switch
- Cross-connect (DCC)
- ADM
- Signallization point (**SP**)
- Signal Transfer Point (STP)

Network layers – IP example (history)

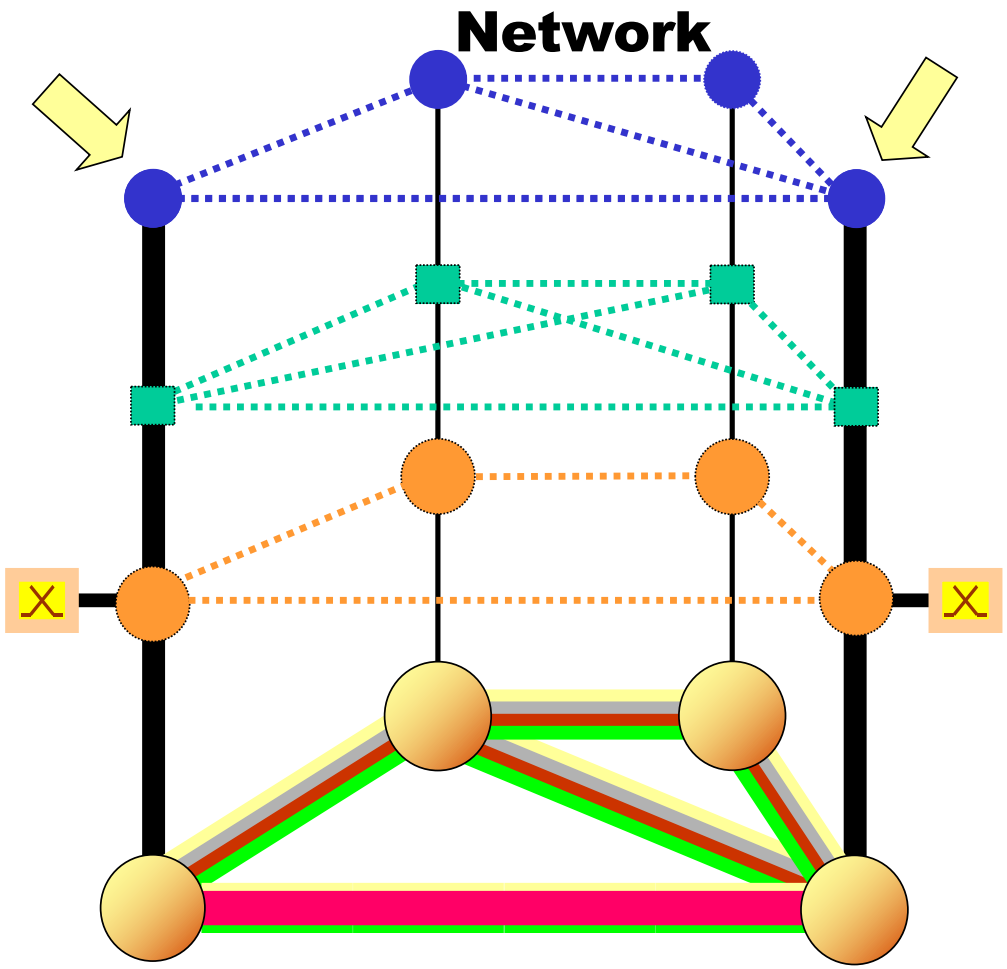
Services

IP / Internet

Asynchronous transfer mode (ATM)

Synchronous Digital Hierarchy SDH/SONET

All-optical network



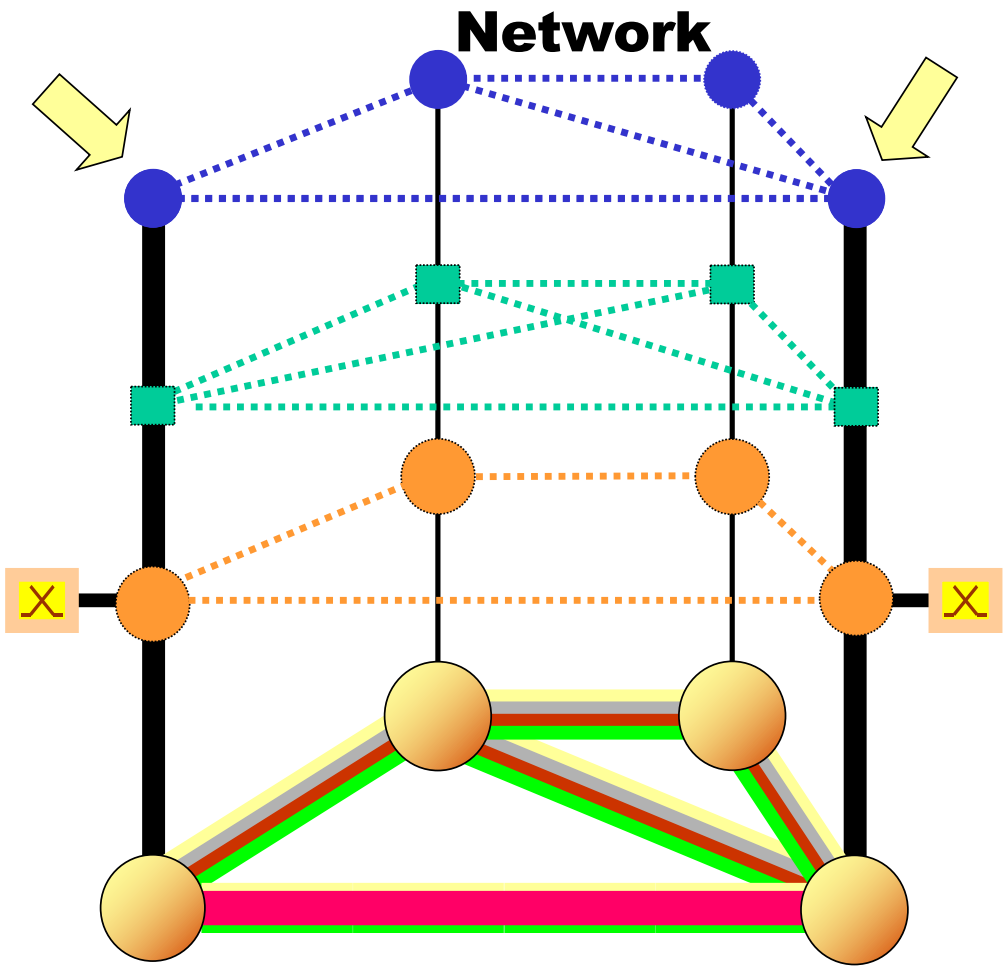
Network layers – IP example (today)

Services

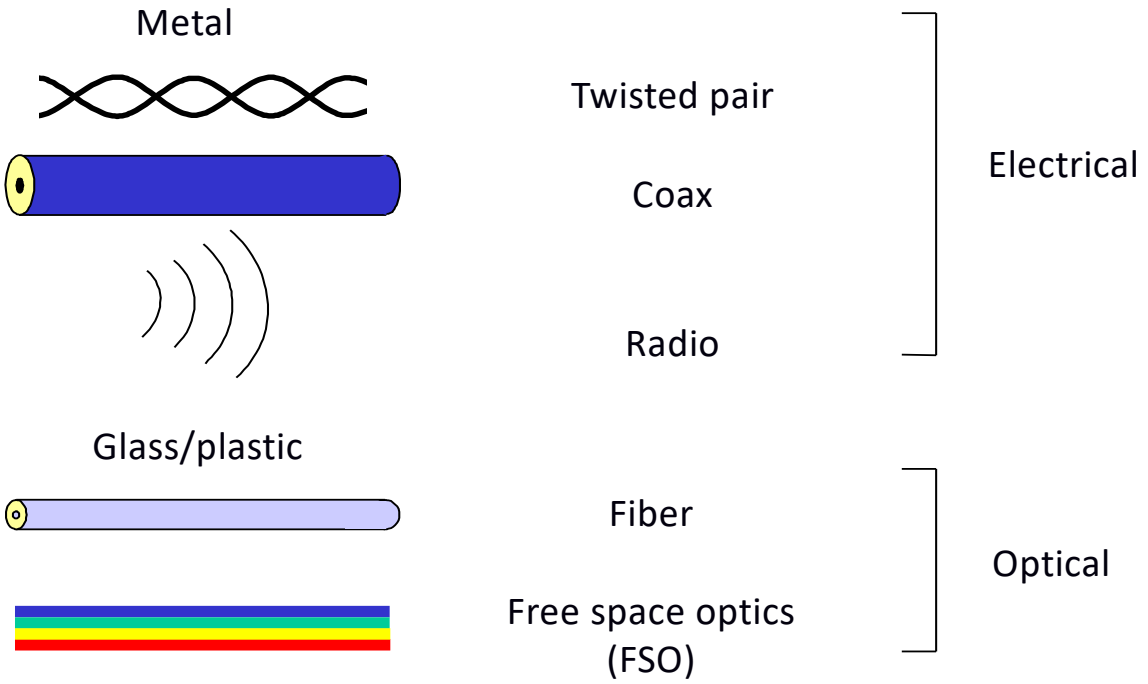
IP / Internet

(Generalised) Multiprotocol Label Switching (GMPLS/MPLS)

All-optical network



Medium

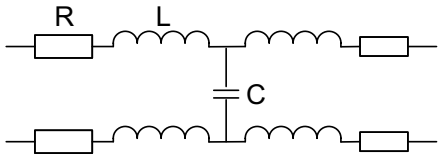

Metal
Twisted pair
Coax
Radio
Electrical
Glass/plastic
Fiber
Free space optics
(FSO)
Optical

Digital transmission - electrical

↑ Full signal regeneration (**3R**)
  unlimited range
↑ Quality of transmission
↓ High attenuation (a ~ $\sqrt{f}$) → shorter lines
  limited transfer speed
↓ Limited circuitry speed ~40 (100) GHz

Low pass filter example

(remember Information Theory and channel capacity!)



Digital transmission - optical

↑ Wide frequency spectrum → **huge capacity potential**

↑ Low attenuation → longer lines → **low price per channel**

↓ Only 2R regeneration **limited** range

transfer speed × distance = const.

10 Pbit/s x km

1 Tbit/s x 10.000 km

10 Tbit/s x 1000 km

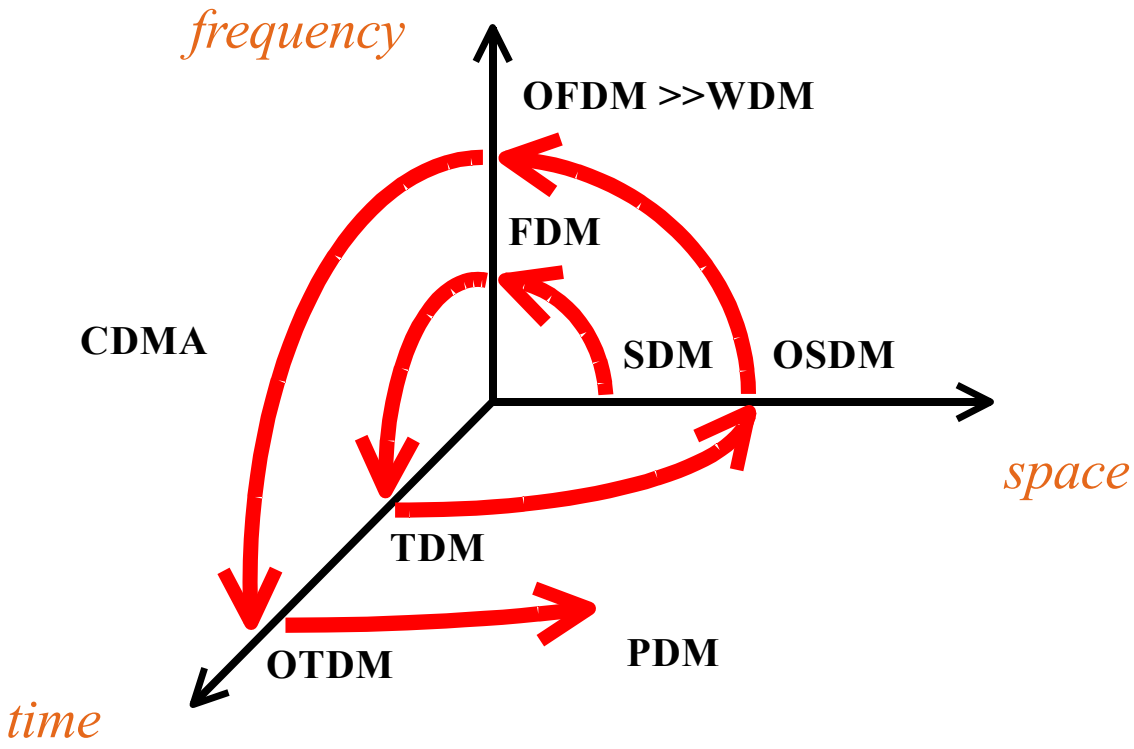
Optical vs. electrical

- There is no wiretapping between the threads.
- There is no radiation in the environment.
- Immunity to (static) electromagnetic interference (EMI), radio frequency interference (RFI), electromagnetic pulse (EMP), extreme environmental conditions (temperature variations, volatile liquids and gases).
- Light weight
  - application in airplanes, satellites, cars, ships
- Easier to transport, install and maintain.
- Security and secrecy for military applications.
- Longer lifespan - lower costs in the long run.
- Electrical insulator (no sparks, no grounding)
- The ubiquitous source of material - sand

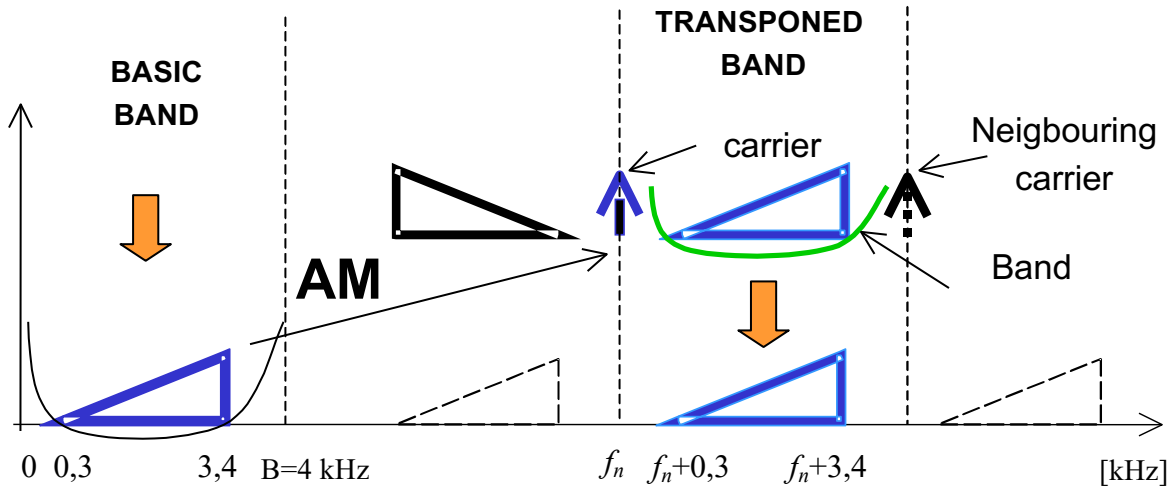
Multiplexing

- (*optical*) *space division multiplexing* - **(O)SDM**
- (*optical*) *frequency division multiplexing* – **(O)FDM**
  wavelength division multiplexing - **WDM**
- (*optical*) *time division multiplexing* - **(O)TDM**
- *code-division multiple access* - **CDMA**
- *polaristion division multiplexing* - **PDM**

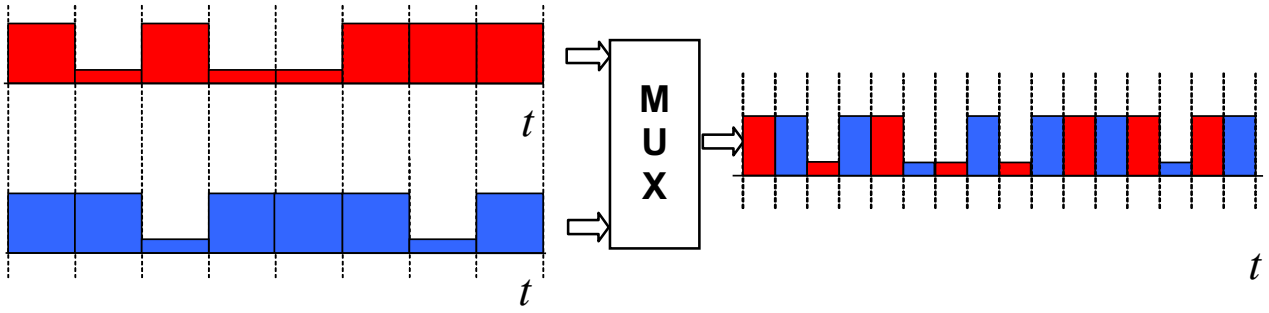
Multiplexing



FDM - Frequency Division Multiplexing



TDM - Time Division Multiplexing



B

B – speed - capacity

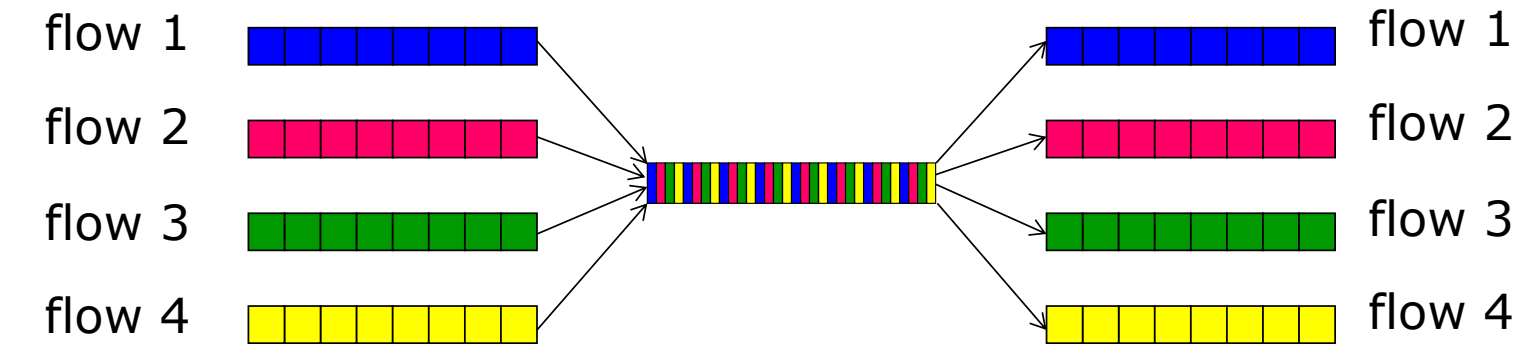
2B

Multiplexing bit by bit

Multiplexing char by char

1 bit or one char (8 bit)

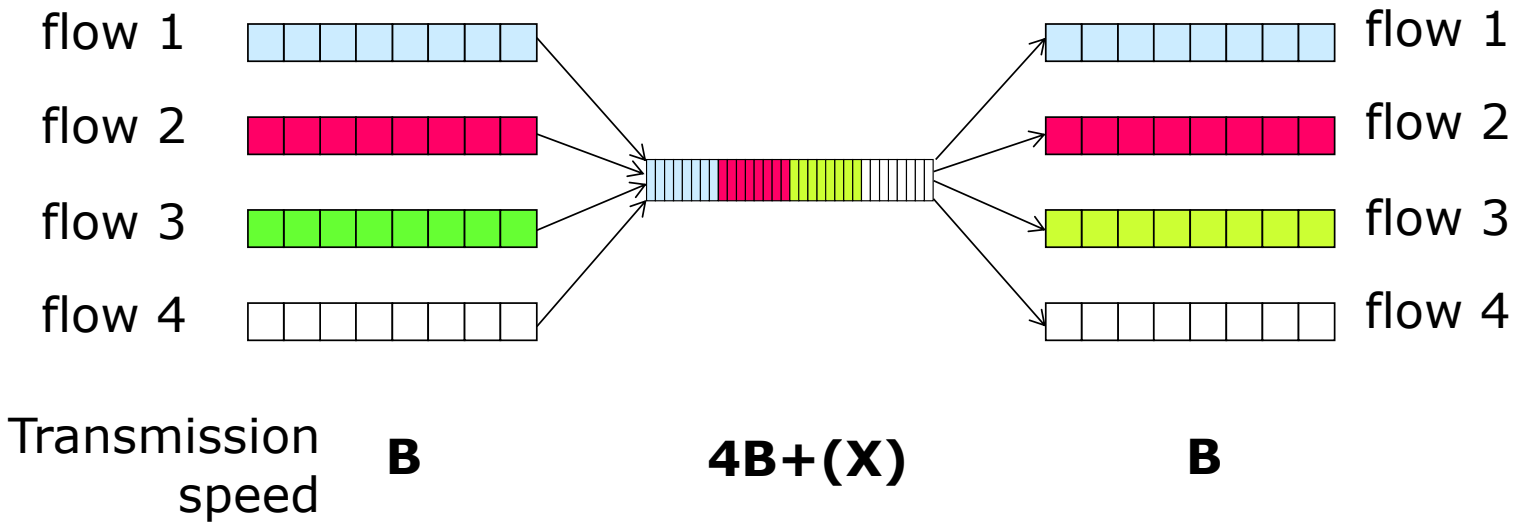
Bit by bit multiplexing



Transmission speed	**B**	**4B+(X)**	**B**

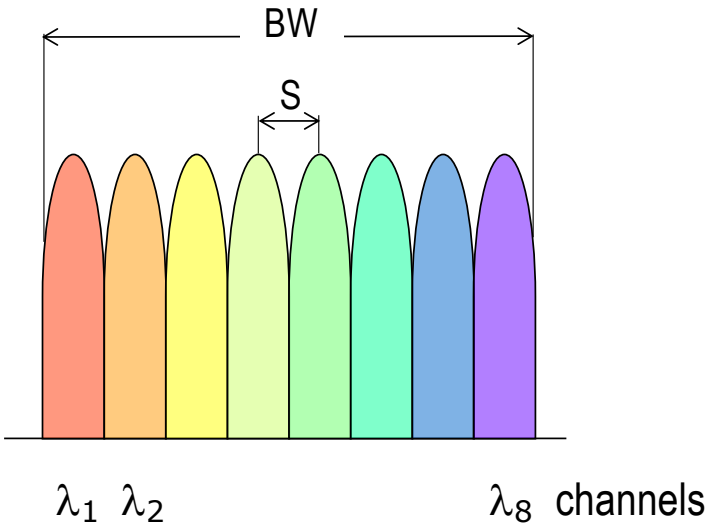
X – additional trans. speed due to frame synchronization

Channel by channel multiplexing



X – additional trans. speed due to frame synchronization

WDM – Wavelength Division Multiplexing



BW – frequency band, bandwidth

S – distance between wavelengths

1,2 Tbit/s
10 Gbit/s / λ
DWDM - 160 λ S < 1 nm
CWDM - 16 λ S = 20 nm

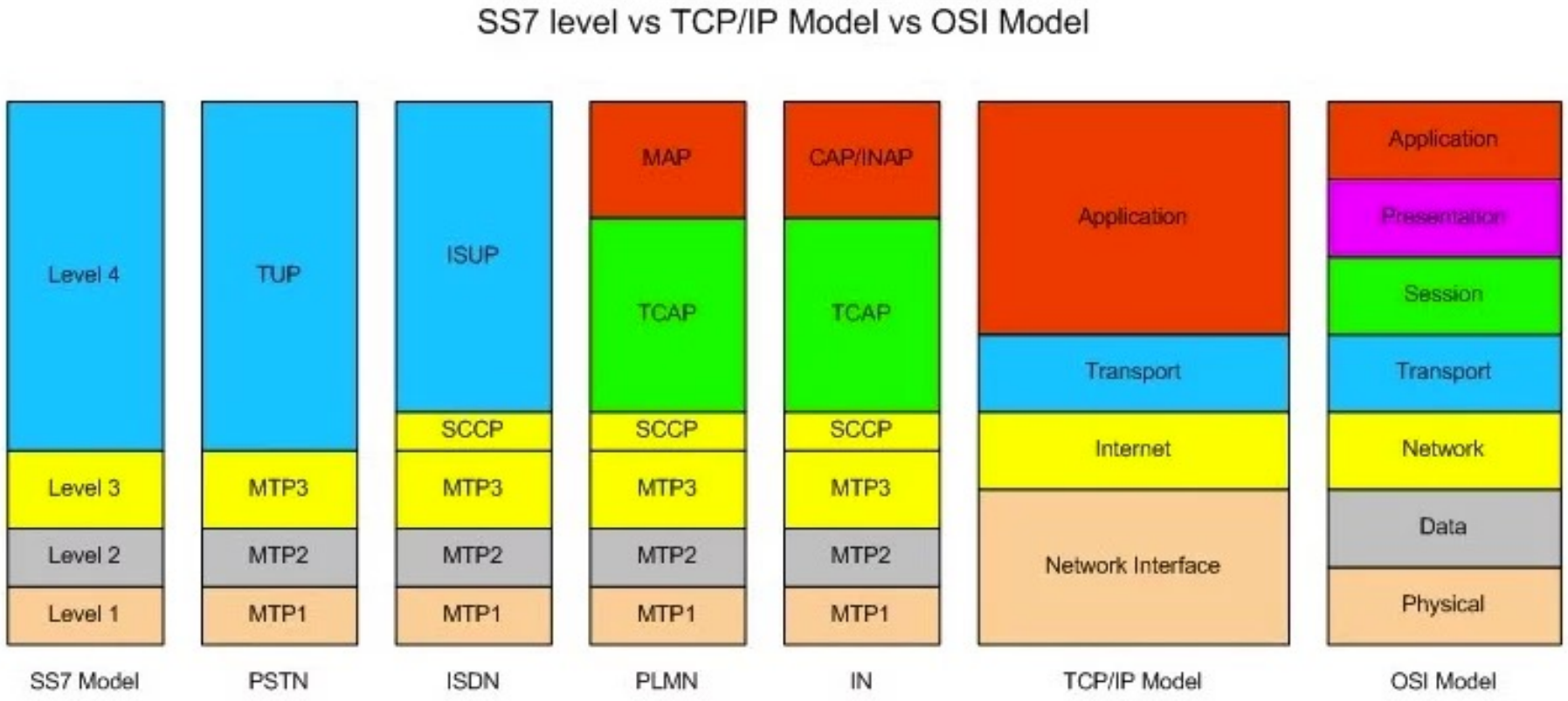
WDM – Wavelength Division Multiplexing
DWDM – Dense Wavelength Division Multiplexing
CWDM - Coarse Wavelength Division Multiplexing

Signalling

- Common Channel Cignaling (CCS)
  - separate path for signalling!

- Common Channel Signaling System no. 7 - (CC)SSno7
  - Used for telephone calls – set up and tear down
  - SMS!
  - Also in 5G
  - Weaknesses – later lectures

Signalling – how does SS7 "fit" OSI and other models?



MTP - Message Transfer Part (1 - physical, 2 - data link layer, 3 - network)
SCCP – Signalling Connection Control Part
TCAP – Transaction Capabilities Application Part
MAP – Mobile Application Part

TUP – Telephone User Part
ISUP – ISDN user Part
BISUP – Broadband ISDN User Part

https://www.poplabtelecom.com/free-introduction-to-ss7-protocol-stack-in-2021/

3R regeneration

1R: Re-amplification

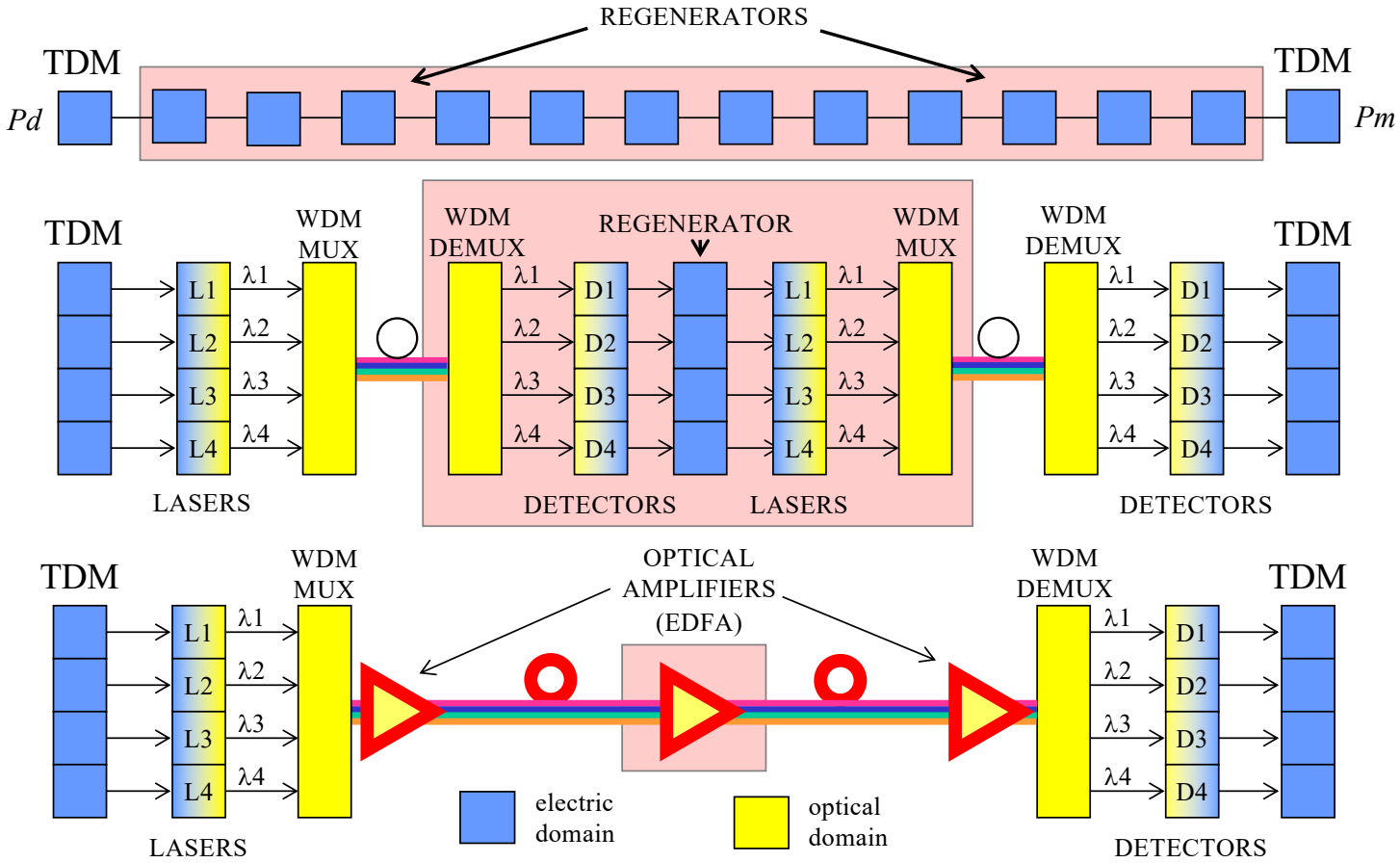
2R: 1R + Re-shaping

3R: 2R + Re-timing

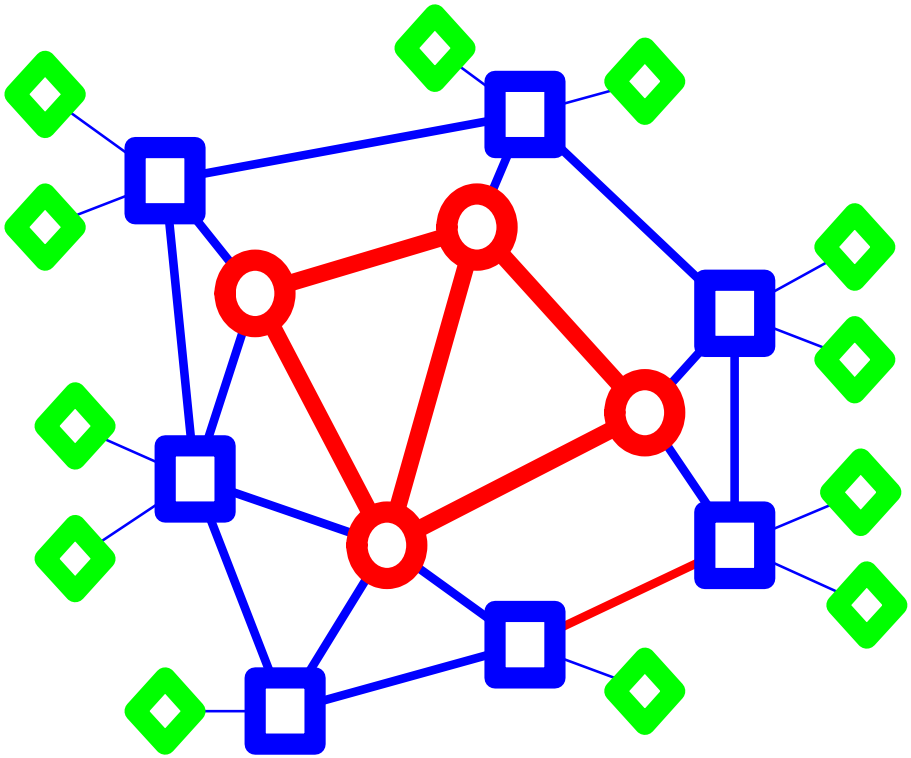
3R – regeneration in electric realm

2R – regeneration in optical realm

Digital link evolution



Transport network



Optical node
Channel, packet or burst switching

Edge switch
Terabit router

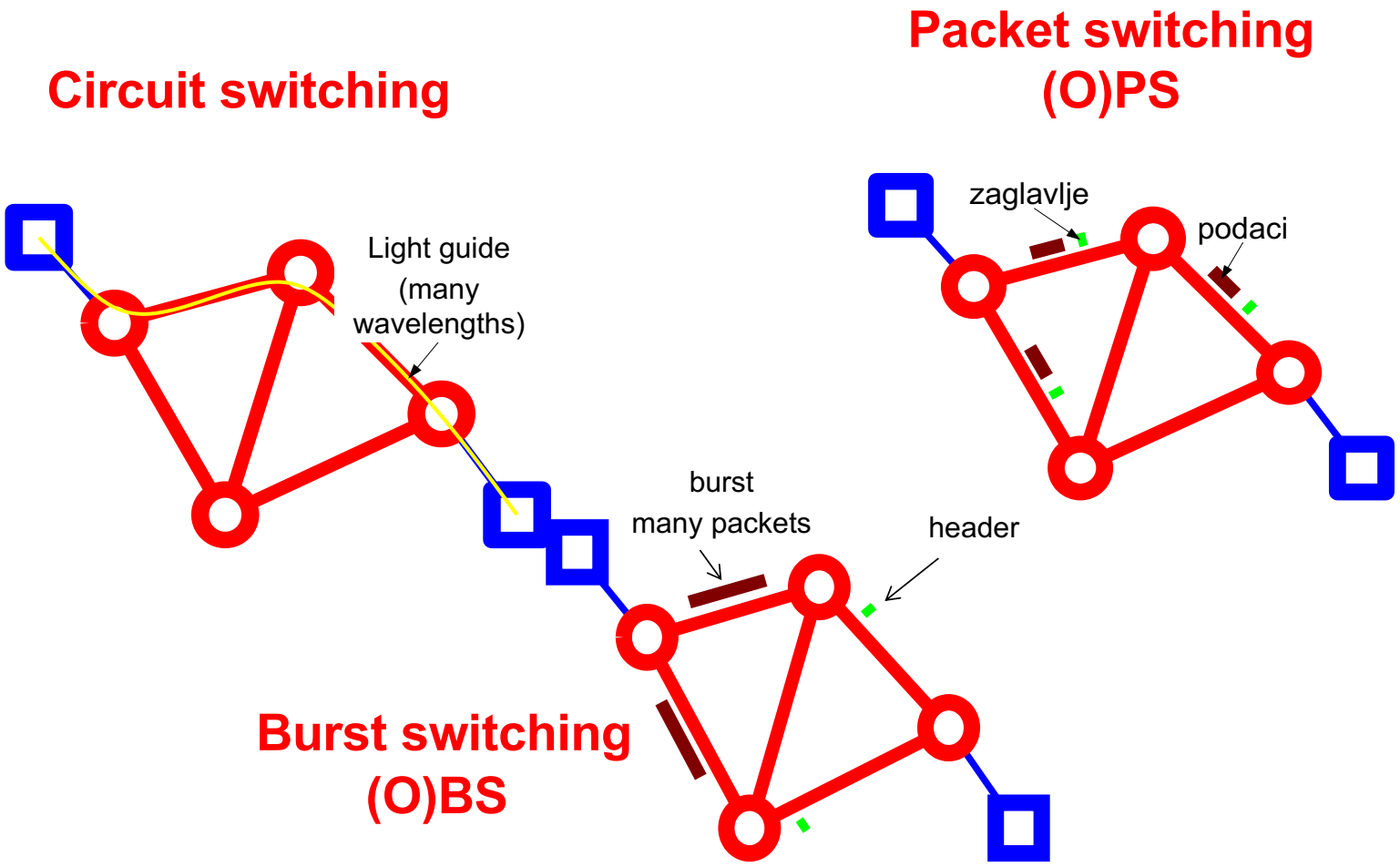
Access router (Gbit)

Optical links **WDM**

Electrical links (copper)

Optical links – point-to-point

Comparison of switching methods



Software defined networks

- Idea: (re)programmable and reconfigurable hardware to enable more agile approach to network configuration and management
- Central control
- Based on open standards and vendor neutral!
  - OpenFlow

- https://sdn.systemsapproach.org/

To conclude

- This was a brief overview
- You will get much more info on most of these topics during further lectures

- Next lecture
  - Optical networks basics