ACCESS AND TRANSPORT NETWORKS
Introduction

Elissar Khloussy, Steinar Bjørnstad   TTM4105 2022

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ACCESS AND TRANSPORT NETWORKS
Introduction

0. introduction

- course staff

- course content

- learning outcome

- lectures and tutorials

- learning methods

- learning materials

- assignments

Reference groups needed: E-mail Stud.Ass. responsible

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Course Staff

Course responsible (Faglærer)
- Norvald Stol (Norvald.stol@ntnu.no)

Course lecturers (Forelesere)
- Elissar Khloussy (elissar.khloussy@ntnu.no)
- Steinar Bjørnstad (steinar.bjornstad@ntnu.no)
- (E-mail communication preferred)

Teaching assistant responsible
- Kalpanie (kalpanie.mendis@ntnu.no)

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Course Content

The course has focus on concepts and technologies which are used in:

- **Wireless Access Networks**
- **Optical Access and Transport Networks**.

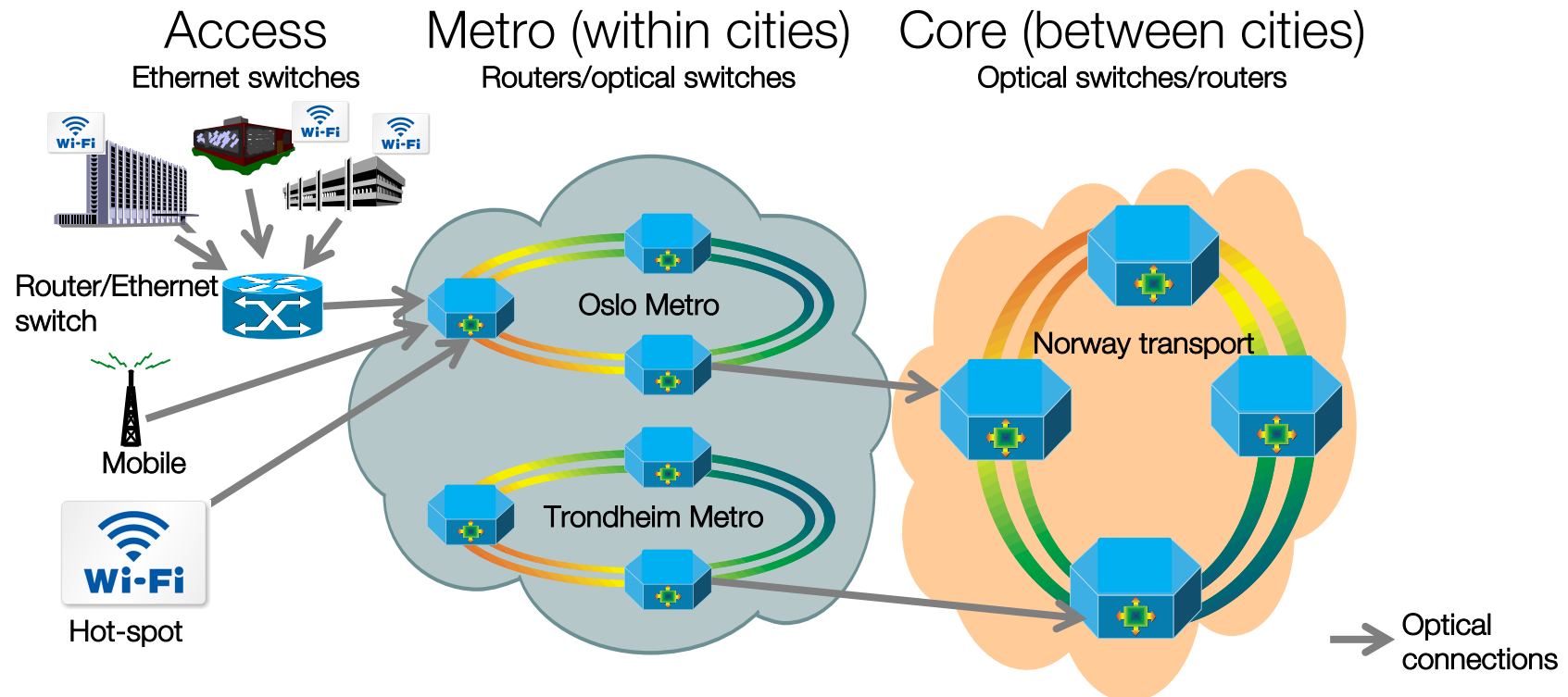| |
|:---|
| **General** |
| **Wireless Access** |
| **Optical Networks** |

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- <u>Access network</u>: Connects end systems to the first ISP (or Telecom) router on the path from the end system

- <u>Metro network</u>: Consists of components and links that perform data switching between the access points.

- <u>Transport network</u>: Consists of components and links that perform data switching between the metro networks and other transport networks. National and international connections.

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Course Content

General:

- Architecture and functions of communication networks

- Capacity and transmission characteristics of different mediums

- Application (services) examples and their requirements of Quality of Service

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<div style="border:1px solid; background:#cfe4e7; text-align:center;">

Course Content

</div>

Access networks

- Radio as communication medium

- Frequency band, Modulation, Multiplexing, Antennas, Coverage, Propagation,…

- Approaches to address the wireless channel impairments

- Medium Access Control

- Wireless Local Area Network & Wireless Personal Networks

- Cellular networks

- Fixed communication medium (characteristics, availability)

- Fiber based access and its applications, active/passive FTTH

- Optical network components

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Transport Networks

- Optical switching (ROADM, WSS)

- Control and traffic management

- Protection switching and survivability

- Optical Transport Networks (OTN)

- Carrier Ethernet

- Research topics in optical communication

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Knowledge

- To understand which components, functions and principles are required for the realization of optical networks and wireless access

- To gain inside into a selection of the most used wireless and optical network technologies

Skills

- To be able to reuse ideas, technologies and components of previous networks to build new networks

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Learning Methods

For the complete training course:

- **On Wednesdays there will be live lecturing in GL-KH KJL 2 from 12:15 - 14:00**

- **There will be quizzes or lectures on Wednesdays in GL-KH KJL 2 from 15:15 - 17:00**

- **There will be two assignments, the first will be available after the second lecture, but introduction is given in week 39.**

- **On Fridays the Teaching Assistants will be available for questions from 14:15 - 16:00 in GL-GEL EL5.**

- **Questions can be asked during the lectures.**

- **Lectures will not be streamed or recorded.**

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Lectures, Forum and Assignments

General: (Elissar and Steinar)	**week 34**
Course introduction and overview	**week 34**
Important background knowledge topics	**week 35/36**
Wireless transmission	**week 37**
Multiplexing & Medium Access control	**week 38**
WLAN & Bluetooth	**week 36**
Optical Networks (Steinar)	**week 39**
Optical components and transmission	**week 39**
Optical access networks	**week 40**
Cellular networks	**week 41**
Optical circuit switched networks	**week 42**
Guest lecture	**week 43**
Carrier Ethernet	**week 43**
Optical Transport Networks (OTN)	**week 44**
Optical network management/	**week 44**
Optical Protection switching	**week 45**
Guest lecture	**week 46**
Review of curriculum/	**week 46**
Information about exam	

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Learning Material

Optical network syllabus based on:

- Selected articles

- Lecture slides

Wireless network syllabus based on:

- Books:

- *Mobile Communication*, by J. Schiller

- *Wireless Communication Networks and Systems*, by C. Beard & W. Stallings

Blackboard:

Blackboard is the place to find information and course material

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> There will be two assignments

For both assignments there will be groups of three students
Follow announcements on blackboard

Assignment1: Access Networks

- **Design of Wireless and optical access network**

- **Setting: The company you work would like to deploy an network.**

- **YOU are the network specialist and is given the design task.**

- **Key topics in access networks are covered**

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> ## Assignments

Assignment2: Designing networks

- **Design of optical network and wireless networks**

- **Setting: The company you work would like to deploy a network.**

- **YOU are the network specialist and is given the design task.**

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Grading

- **Assignment 1:** **Required to pass**
- **Assignment 2:** **Required to pass**
- **Written Exam:** **100%**

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What are the key benefits of optical fibre communication?

- Is it fast or slow?
    - How do we define fast and slow?
- Is it expensive?
- Is it a thick cable?
- Is it susceptible to electromagnetic interference?

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Optical fibre, characteristic

- Large bandwidth (theoretical 50 THz)

- Low attenuation (0,2 dB/km at 1550nm)

- Physical size beneficial, light and thin, simplifies installation

- Splicing and mounting connectors more complex

- Immune to electromagnetic interference

- Environmentally friendly material (sand!).

- Easy to break

Where in the network is fiber currently being used?

- Within houses?

- Connecting buildings/houses?

- Connecting cities?

- Connecting countries?

- Connecting continents?

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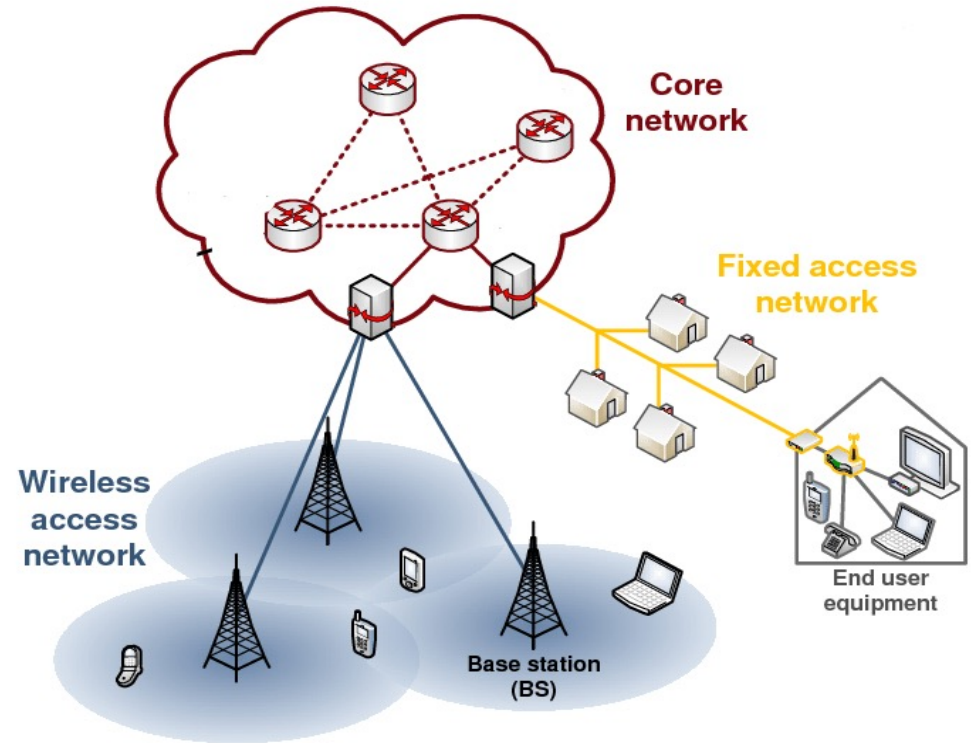
Access Networks

- Examples:
  - Home access: DSL, Cable, FTTH
  - Enterprise access: Ethernet
  - Enterprise and Home Access: WiFi
  - Wide-area wireless access: 3G, LTE, 5G

- Wireless is increasingly prevalent!
  - Health, IoT, Smart Home, Vehicular Networks, …
  - Challenge: To provide high-quality high-speed wireless access services

How Do Wireless and Wired Networks differ?

- Wireless is less reliable. Increased bit error rate due to:
    - ➤ Obstacles between Tx and Rx
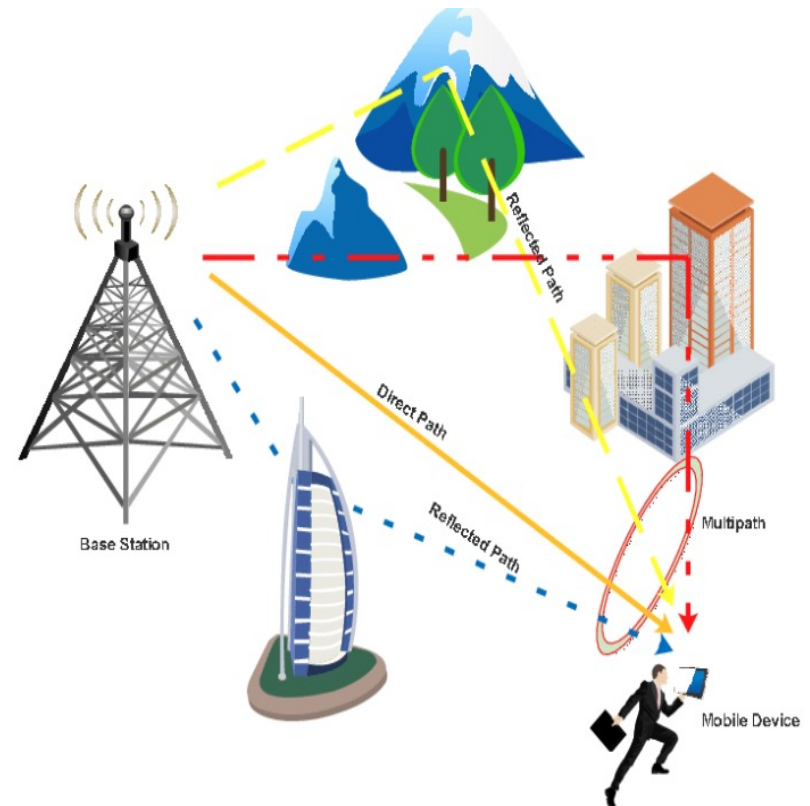   - ➤ Interference
- Multi-path propagation
    - ➤ Signal bounces on surfaces
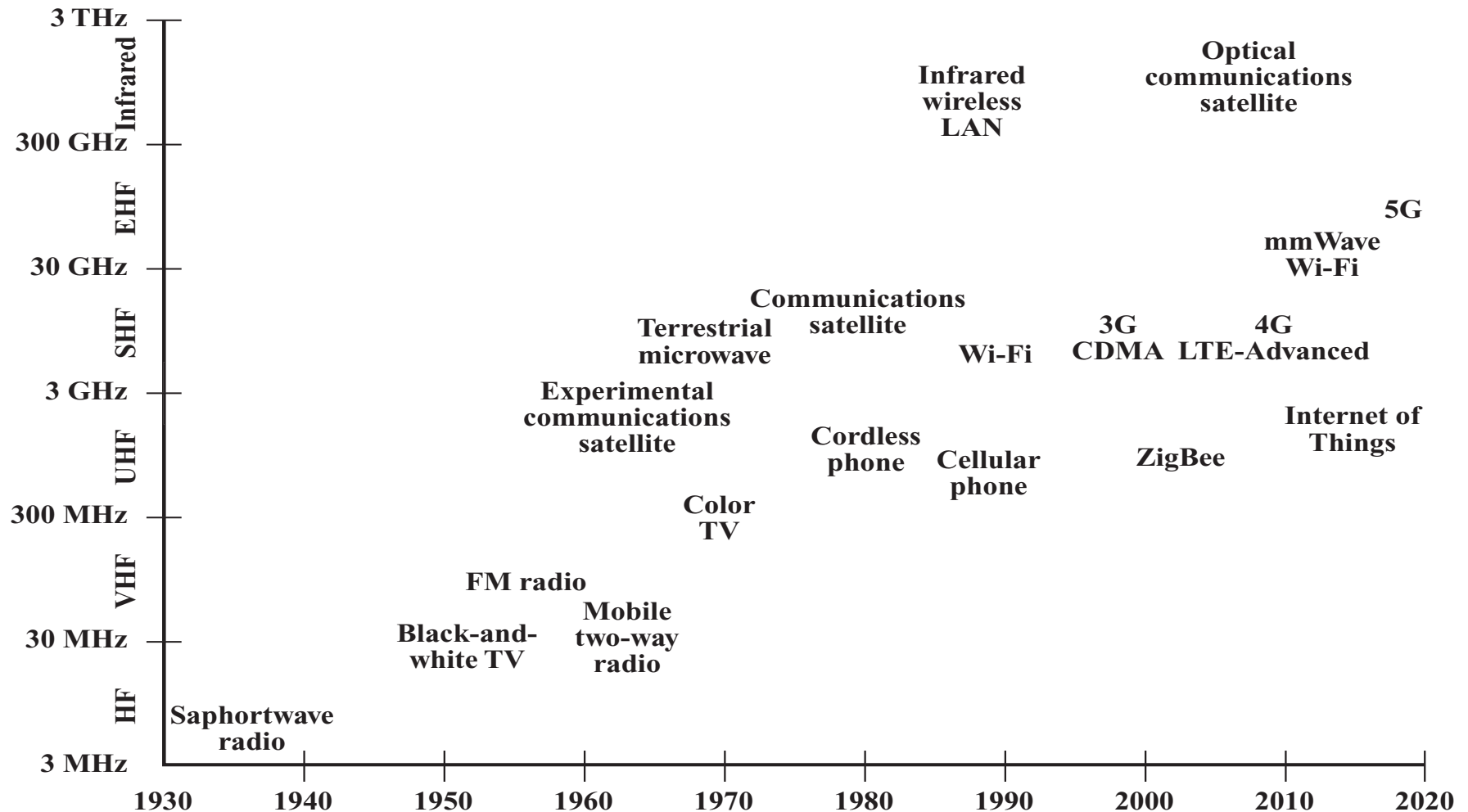   - ➤ Can be destructive or constructive
- Mobility
    - ➤ Affects the quality of the transmission
    - ➤ Worst case: outages
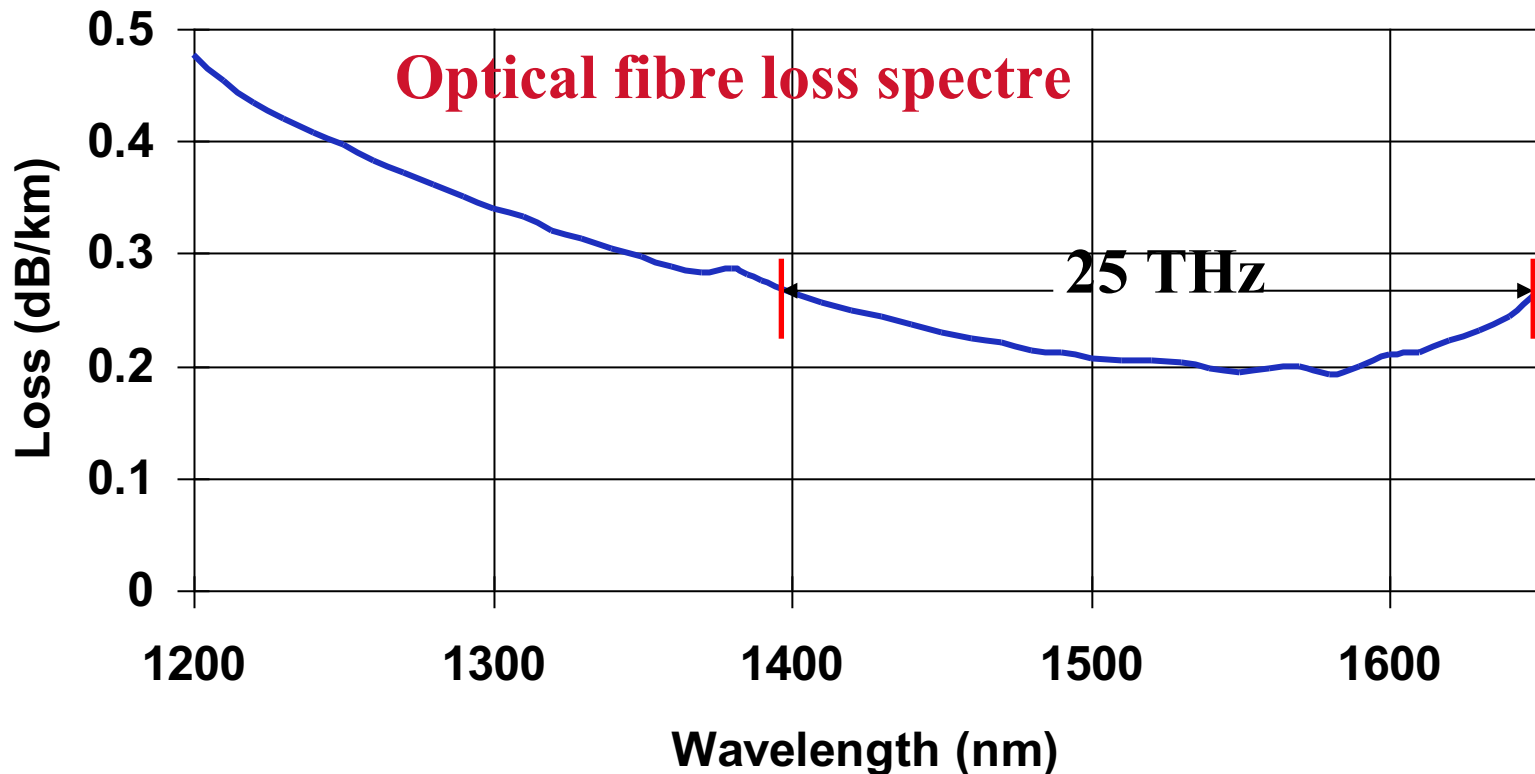
Milestones in Wireless Communications

Main Challenges in Wireless Communications

- Attenuation or Signal Loss
  - ➤ The farther they travel, the more wireless signals begin to lose their strength

- Always shared medium
  - ➤ How do you coordinate access to the medium?

- Security
  - ➤ The broadcasting nature of the wireless transmission makes the transmitted information vulnerable

- Resource and spectrum utilization
  - ➤ The spectrum suitable for wireless communications is becoming increasingly scarce, which motivate the exploration of new spectrum bands
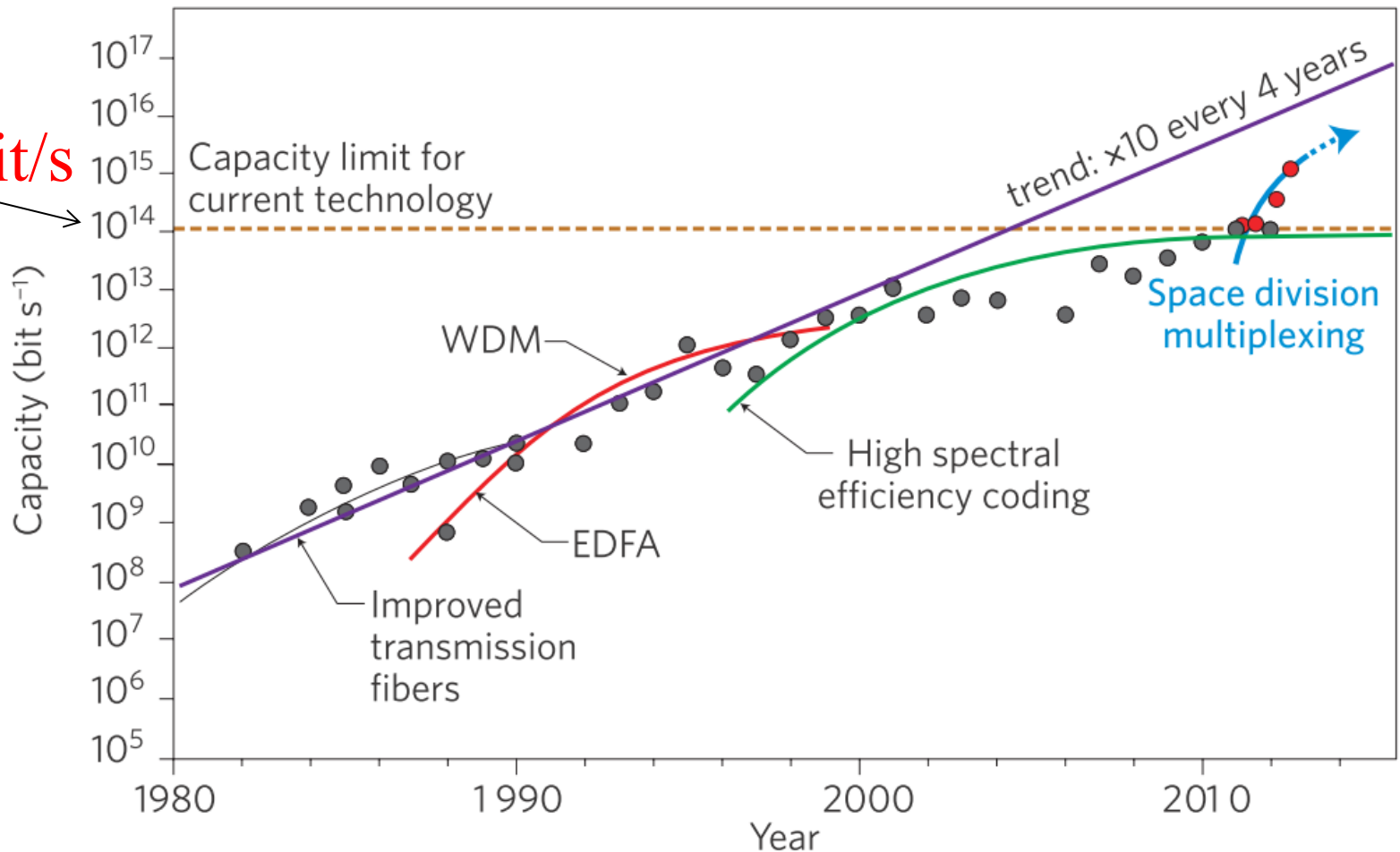
Optical fibre has unique properties

- 25 THz bandwidth available with low loss
- Enables Terabits of bandwidth over thousands of kilometers

Optical fibre loss spectre

25 THz

Loss (dB/km)

0.5
0.4
0.3
0.2
0.1
0

1200   1300   1400   1500   1600

Wavelength (nm)

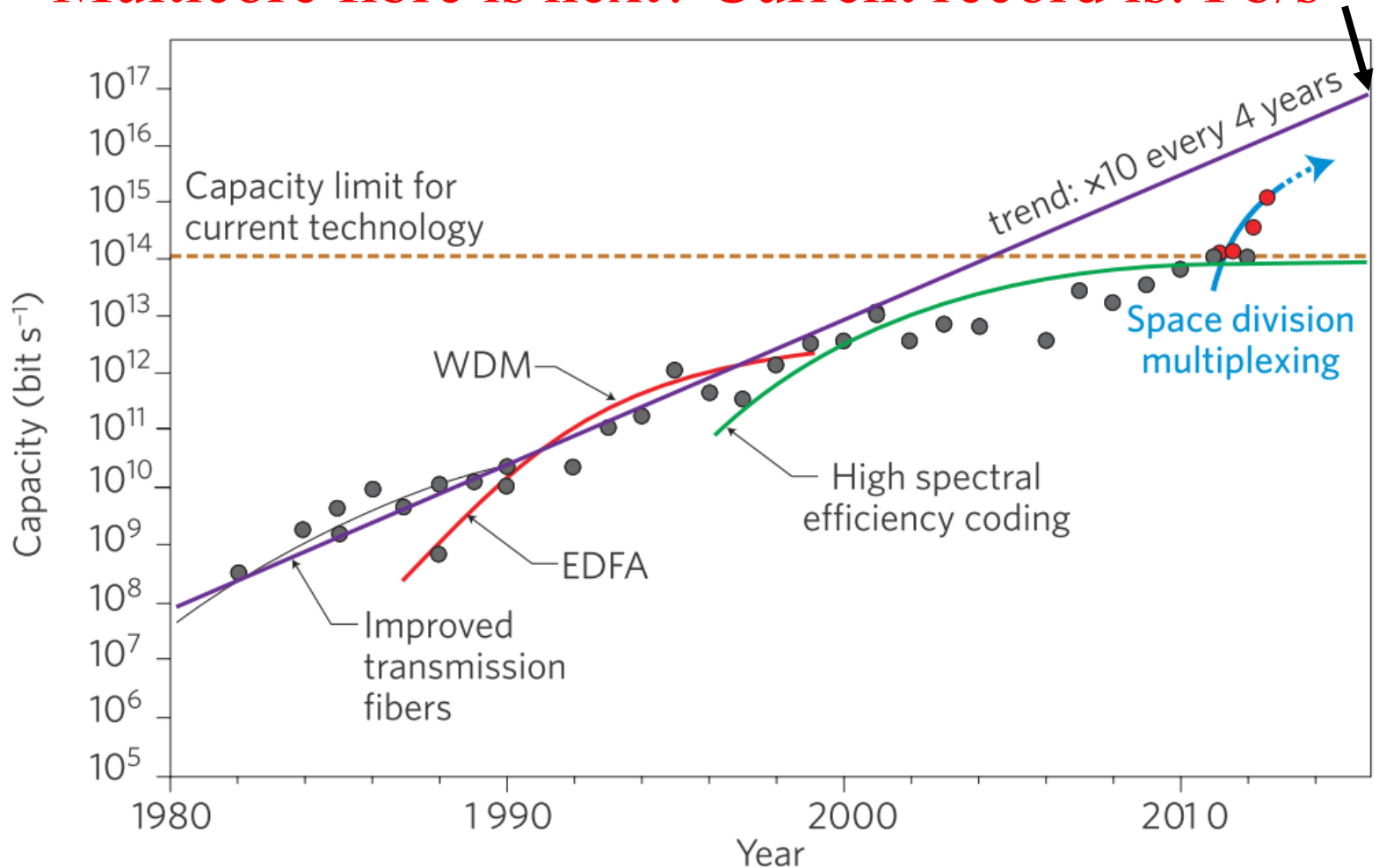# Transmission capacity in optical fiber (lab)

100Tbit/s

Transmission capacity in optical fiber (lab)

Multicore fibre is next? Current record is: Pb/s

Future Wireless Systems Requirements

Many technical challenges are to be addressed in order to <u>satisfy stringent requirements</u> for future wireless systems:

- Very high spectral efficiency
- Very low latency
- Massive device connectivity
- Very high achievable data rate
- Ultra-high reliability
- High throughput
- Diverse quality-of-service
- Energy efficiency
- Cost reduction
- …

Major factors	6G	5G
Peak data rate	> 100Gb/s	10[20] Gb/s
User experience data rate	> 10Gb/s	1Gb/s
Traffic density	> 100Tb/s/km^2	10Tb/s/km^2
Connection density	> 10million/km^2	1million/km^2
Delay	< 1ms	ms level
Mobility	> 1000km/h	350km/h
Spectrum efficiency	> 3x relative to 5G	3~5x relative to 4G
Energy efficiency	> 10x relative to 5G	1000x relative to 4G
Coverage percent	> 99%	About 70%
Reliability	> 99.999%	About 99.9%
Positioning precision	Centimeter level	Meter level
Receiver sensitivity	< −130dBm	About −120dBm

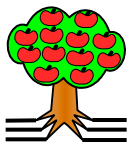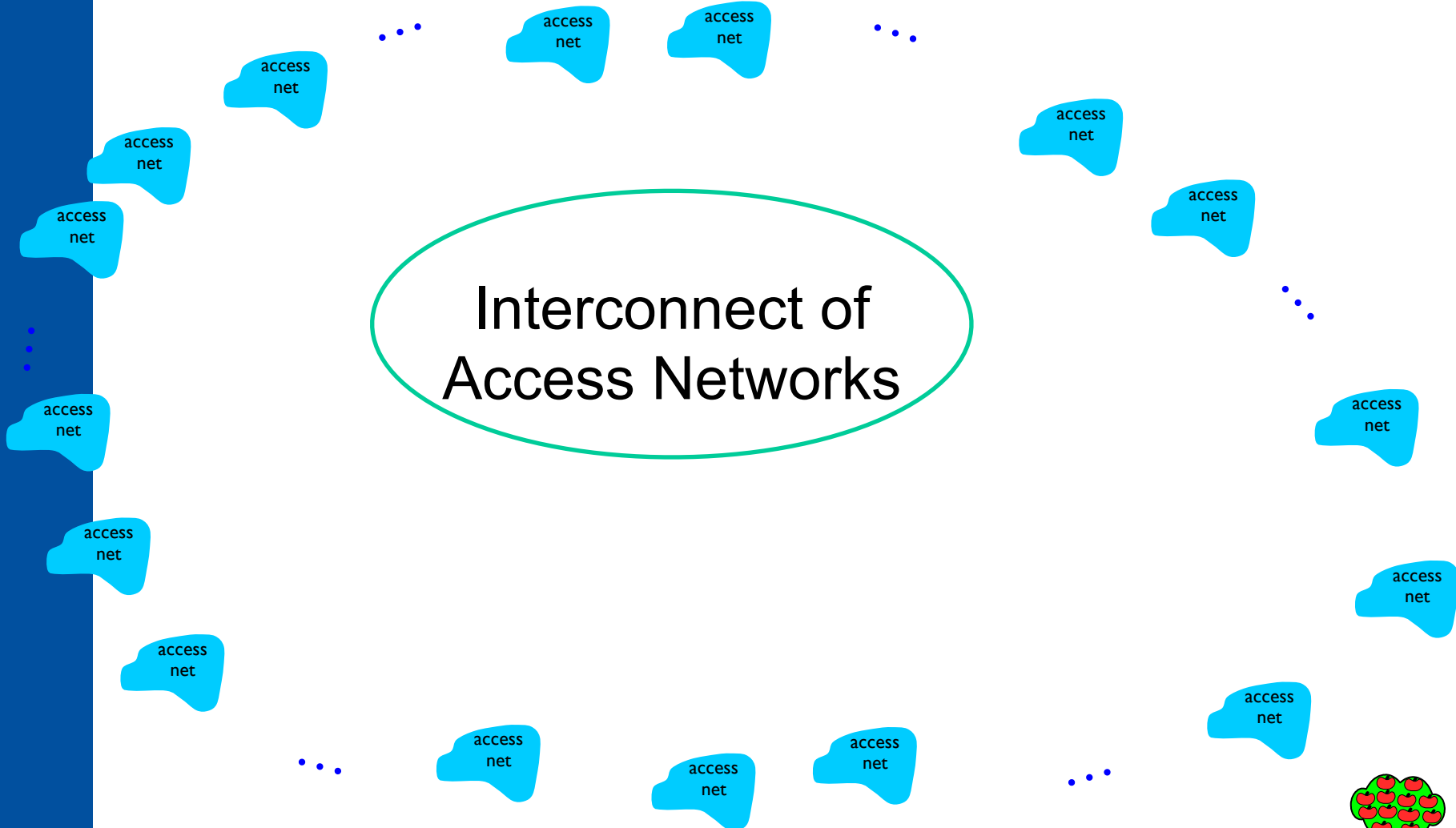**TABLE 1. Possible capabilities of 6G in comparison with 5G.**

A taste of optical core and access networking
Why optical networks?

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Core Networks

Interconnect of Access Networks
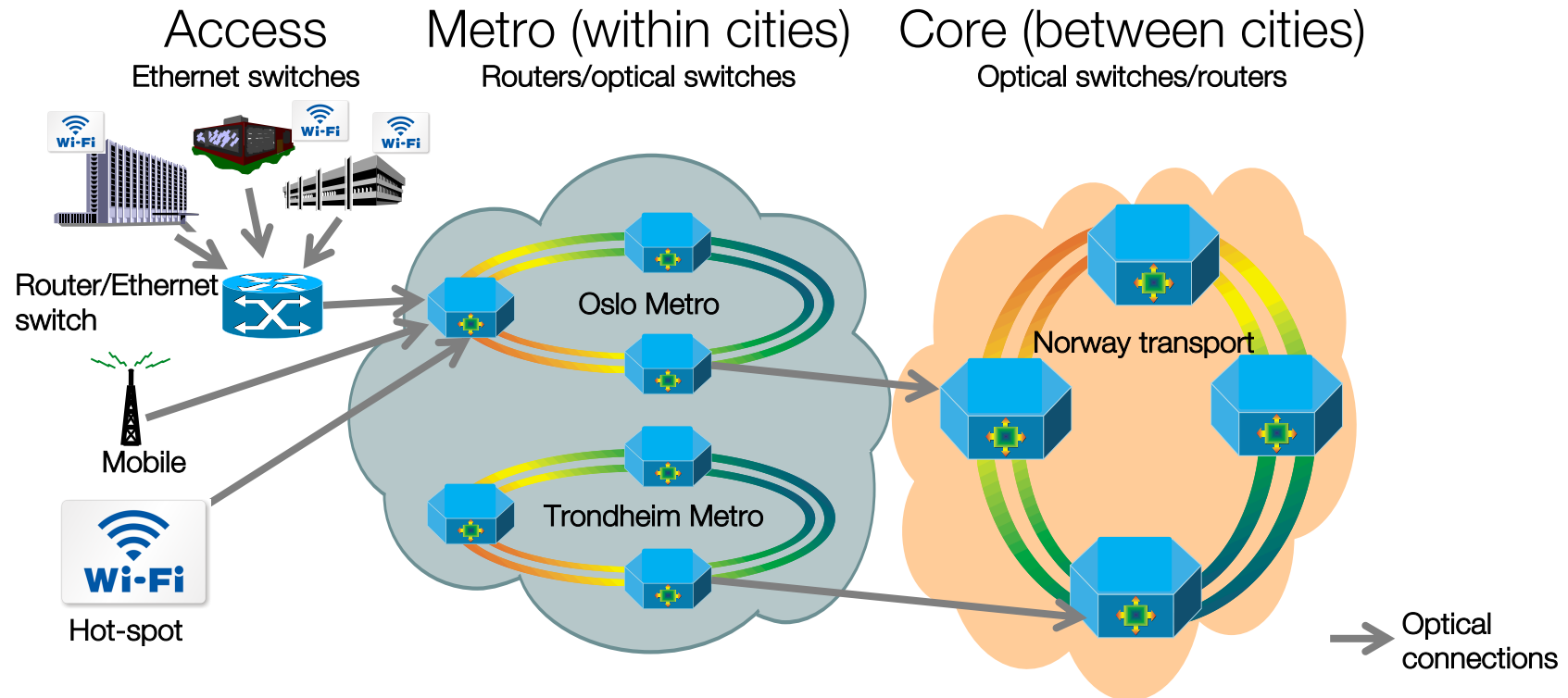
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Access
Ethernet switches

Metro (within cities)
Routers/optical switches

Core (between cities)
Optical switches/routers

Router/Ethernet switch

Mobile

Hot-spot

Oslo Metro
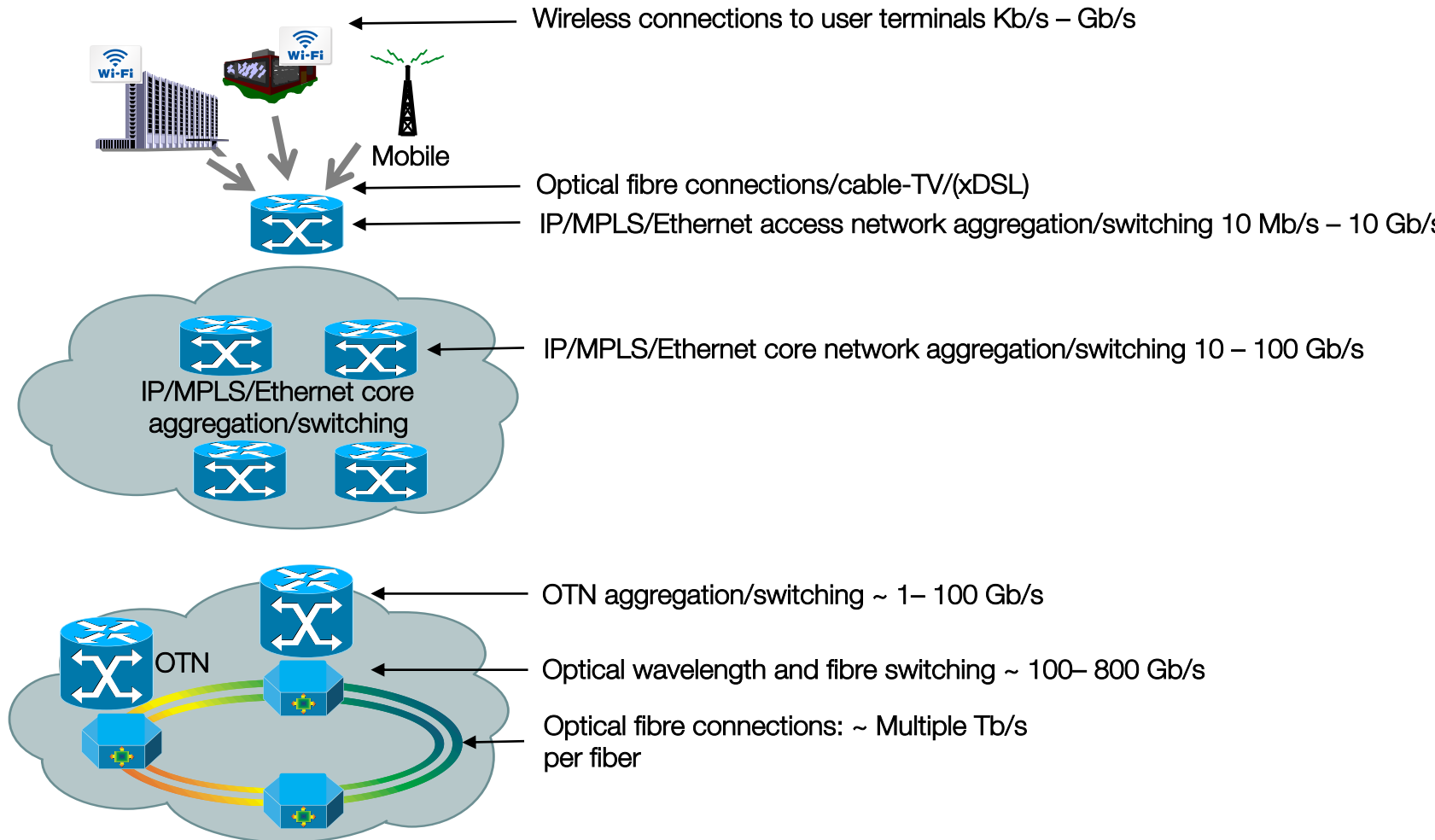
Trondheim Metro

Norway transport

Optical connections

- <u>Access network</u>: Connects end systems to the first ISP (or Telecom) router on the path from the end system

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Wireless connections to user terminals Kb/s – Gb/s

Mobile

Optical fibre connections/cable-TV/(xDSL)

IP/MPLS/Ethernet access network aggregation/switching 10 Mb/s – 10 Gb/s

IP/MPLS/Ethernet core aggregation/switching

IP/MPLS/Ethernet core network aggregation/switching 10 – 100 Gb/s

OTN

OTN aggregation/switching ~ 1– 100 Gb/s

Optical wavelength and fibre switching ~ 100– 800 Gb/s

Optical fibre connections: ~ Multiple Tb/s per fiber

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Core Networks - Key Technologies

- Multiplexing

- Switching
  - Known as layer 1 and 2 in protocol stack

- Routing
  - Known as layer 3 in protocol stack

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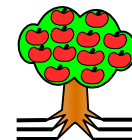
Tampnet business areas

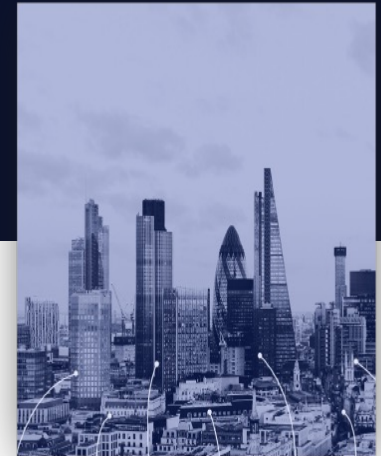We deliver unparalleled connectivity for your business critical operations.
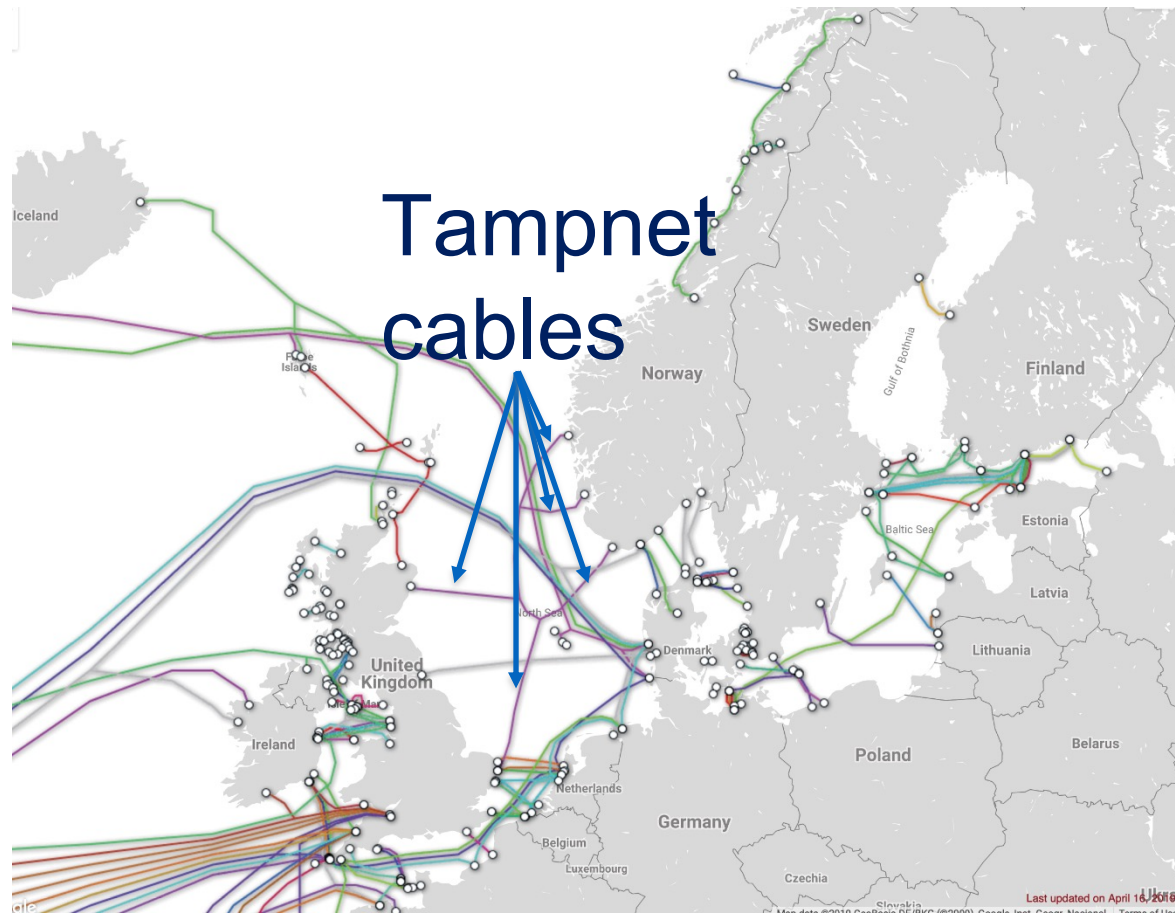
Oil & Gas

Offshore Wind

Maritime

International Carrier

Redundant fibre connectivity is key

Tampnet: Cables to England and Scotland with multiple fibres pairs: 20 Tb/pair

Tampnet cables

tampnet

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Optical Telecom networks

From long distance transport to 5G radio access network

Market drivers optical networks

- Fibre to the Home (FTTH)
  - Video applications (E.g. Netflix)
- Mobile networks
  - Increased density of mobile base stations
  - Fibre to the base-station
- Datacenter communication
  - Between datacenters
  - Datacenter to customers
  - Connecting the datacenter to Internet