

# ***FINe: Future (Inter)Net(works)***

The day by day of the course:

What we did

What we learned

What we will do today

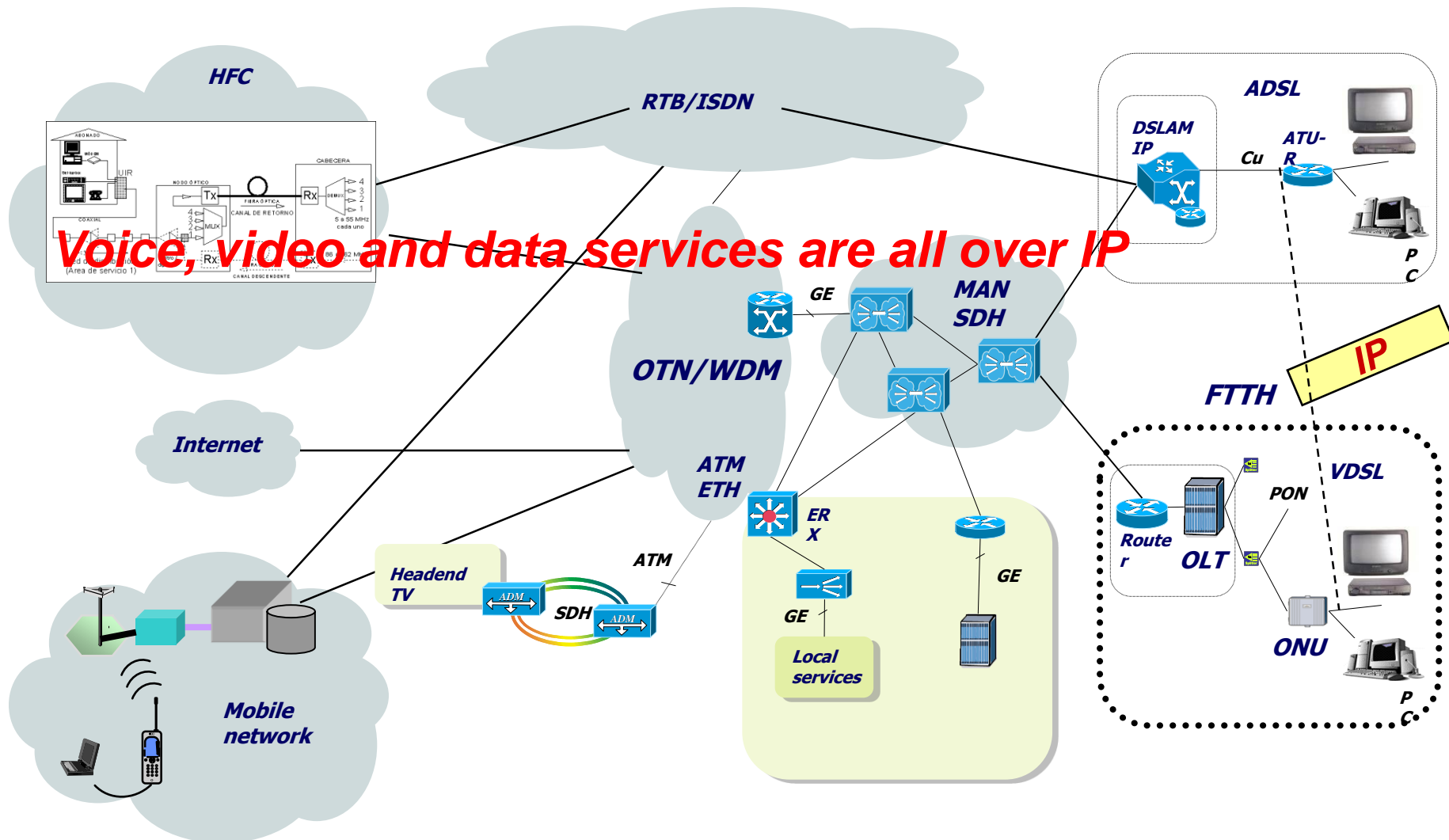
# September 23, 2020 (i)

- ✓ What did we do last week (on September 16)?
  - We introduced the course
  - Launched the first Panel session
  - Launched the first set of questions
  - We started Chapter 1: Review of the statistical figures provided by ITU:
    - ICT facts and figures

September 23, 2020 (ii)

- ✓ What did we learn/revise/understand?
  - We learned what to do for passing the course
  - We revised the concept of Internet\*:
    - The Layer 3 (IP) being the glue for interconnecting different network technologies
      - An IP network is packet switched
      - An IP network is connectionless
      - The IP packet is the universally accepted format for transporting data (either PDUs or streaming)
      - The Backbone (Transport) Network is usually connection oriented, and is in charge of transporting IP packets from source to destination

# Internet became the Public Network



September 23, 2020 (ííí)

- ✓ What did we learn/revise/understand? (cont.)
  - Revising the statistical figures provided by ITU, we knew that:
    - Internet usage keeps growing, but barriers lie ahead
      - Lack of ICT skills a barrier to effective Internet use
      - Most of the offline population lives in least developed countries
      - The digital gender gap is growing in developing countries
    - Mobile-broadband subscriptions continue to grow strongly
      - Computers no longer needed to access the Internet at home
    - Bundled mobile broadband prices, compared with the PPP\$ (Purchasing Power Parity) of 2019
      - Broadband still expensive in LDCs
    - Almost the entire world population lives within reach of a mobile network

# September 23, 2020 (iv)

- ✓ What did we learn/revise/understand? (cont.)
  - We learned about the existence of...
    - Two organizations providing the main Internet standard documents, namely ITU and IETF
    - CIS (Commonwealth of Independent States), a very powerful political and economic organization, in the orbit of the United Kingdom, whose head currently is the Queen of UK (Elizabeth II)
      - [https://en.wikipedia.org/wiki/Commonwealth\\_of\\_Nations](https://en.wikipedia.org/wiki/Commonwealth_of_Nations)

# September 23, 2020 (V)

- ✓ What will we do today?
  - Continue with Chapter 1: Review of the statistical figures provided by:
    - Mary Meeker in her 2019 Internet Trends report
  - Explore one of the main concerns of the EU in the ICT arena:
    - Joining efforts to shape the Digital Single Market...
  - Go through the Networking Infrastructure models, in particular, commons versus private
    - Lecturer: Roger Baig

# September 30, 2020 (i)

- ✓ What did we do last week (on September 23)?
  - Review the statistical figures provided by:
    - Mary Meeker in her 2019 Internet Trends report
  - Explore the main concerns and active policies of the EU in the ICT arena
    - Technology that works for people
    - A fair and competitive digital economy
    - An open, democratic and sustainable digital society
    - Europe as a global digital player
  - The lecture on Infrastructure models, commons versus private (Lecturer: Dr. Roger Baig)



# September 30, 2020 (II)

✓ What did we learn/revise/understand?

- From the Mary Meeker's 2019 Internet Trends report, we knew that:

- The number of Internet users comprises more than half the world's population, *but Internet user growth is slowing*
- E-Commerce continues to gain share vs. physical retail, *but growth rates are slowing*
- Global innovation & competition continue to drive product improvements
  - New types of usage & monetization - especially in areas of digital video, voice, wearables, on-demand + local services & traditionally underserved markets
- Internet advertising growth is solid & innovation is healthy, *but there are areas where customer acquisition costs may be rising to unsustainable levels*
- The rapid rise of gathering digital data is often core to the success of the fastest growing & most successful companies of our days
- As Internet systems become increasingly sophisticated, data-rich & mission critical, so has the opportunity for cyber attacks
  - *We are in a new era of cyber security where technology issues are increasingly intermixed with international diplomacy & defense*

September 30, 2020 (ííí)

✓ What did we learn/revise/understand?

- We learned that the European Digital Strategy is focused in the development, deployment and uptake of digital technologies to achieve:
  - A real difference to enhance people's daily lives
  - A strong and competitive economy that masters and shapes technology in a way that respects European values
  - A frictionless single market, where companies of all sizes and in any sector can compete on equal terms, and can develop, market and use digital technologies, products and services at a scale that boosts their productivity and global competitiveness, and consumers can be confident that their rights are respected
  - A trustworthy environment in which citizens are empowered in how they act and interact, and of the data they provide both online and offline
  - A European way to digital transformation which enhances our democratic values, respects our fundamental rights, and contributes to a sustainable, climate-neutral and resource-efficient economy

# September 30, 2020 (iv)

- ✓ What did we learn/refresh/understood?
  - With Roger Baig, we went into the concepts of property and management for the Internet/network infrastructures
    - We learned that the dominant models for building and managing the telecommunication infrastructures are three:
      - Public
      - Public-private partnerships (PPP)
      - Private
    - We discussed about the opportunities of an alternative model: The Commons

# September 30, 2020 (v)

✓ What will we do today?

- Run the first panel
  - Panel chaired by the members of Group #2
- First item of the Chapter 2 (Lecturer: Prof. Josep Solé-Pareta):
  - Review the Transport Network Concept
  - Review the Control Plane Concept
  - Review GMPLS<sup>1</sup>: The control plane technology installed in current Backbone transport networks

<sup>1</sup>) GMPLS: Generalized MultiProtocol Label Switching

October 7, 2019 (víl)

✓ What will we do today?

- Run the first panel
- First item of the Chapter 2 (Lecturer: Prof. Josep Solé-Pareta):
  - Review the Transport Network Concept
  - Review the Control Plane Concept
  - Review GMPLS<sup>1</sup>: The control plane technology installed in current Backbone transport networks
- Second item of Chapter 2 (Lecturer: Prof. Jordi Perelló):
  - Introduce SDN<sup>2</sup> the Emerging technology for implementing the control plane of the future networks
  - Introduce the OpenFlow Architecture

<sup>1</sup>) GMPLS: Generalized MultiProtocol Label Switching

<sup>2</sup>) SDN: Software Defined Networking

October 7, 2020 (i)

- ✓ What did we do last Tuesday (September 30)?
  - Run the first Panel on:
    - Democratizing the Digital Economy
  - Start with Chapter 2:
    - Review the Transport Network Concept
    - Review the Control Plane Concept
    - Introduced MPLS and GMPLS: The control plane technology installed in current Backbone transport networks

October 7, 2020 (ii)

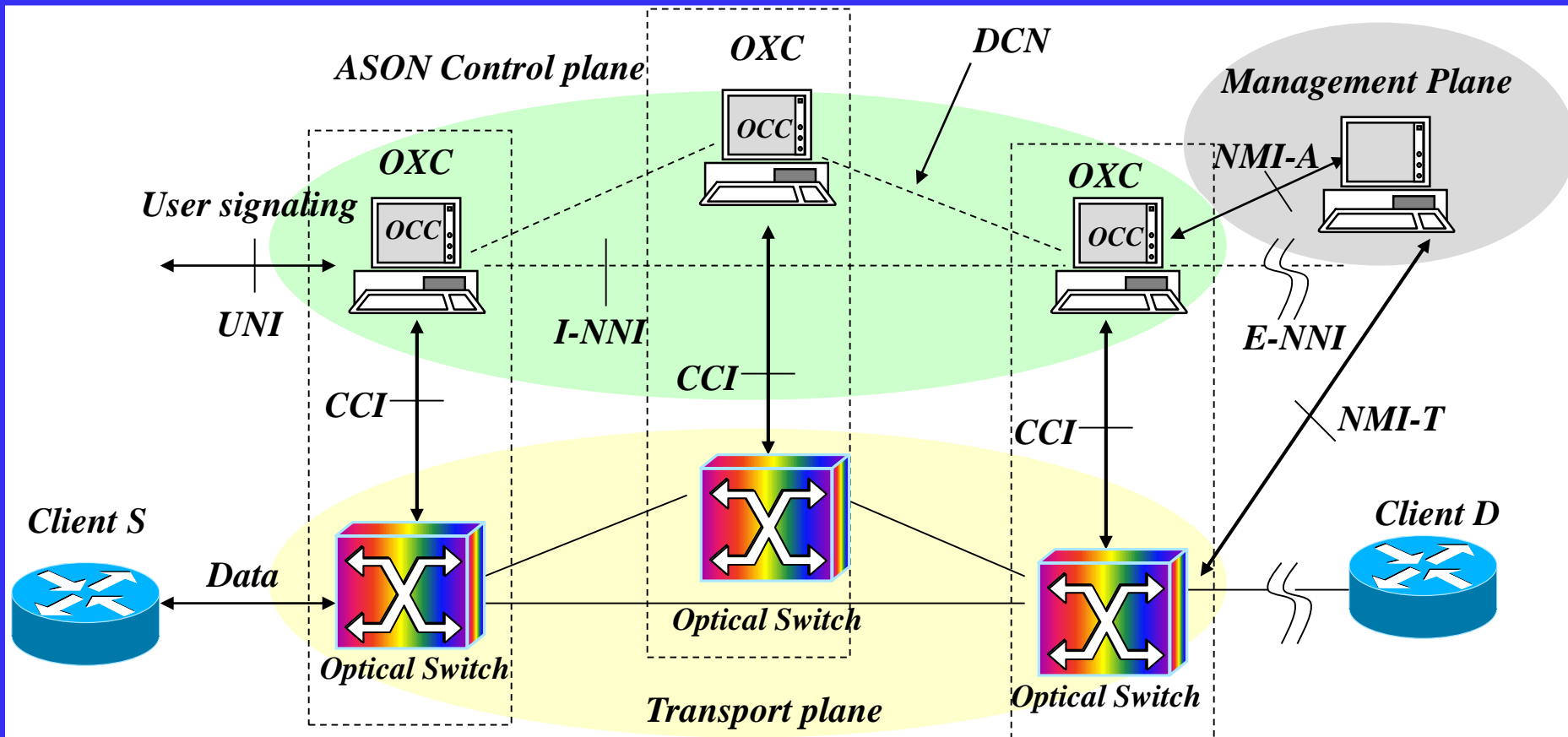
- ✓ What did we learn/refresh/understood?
  - From Evgeny's Morozov talk we learned how accumulation of power over user data by giant tech companies will lead to very difficult problems
    - Promises by big tech companies are lies
    - Their behavior just enhances their profit
    - Companies control what and how we access information
  - Potential solutions:
    - Subscription-based: not clear
    - Competition-based: not clear
    - Legal framework to regulate access to data: difficult, since depend on governments... they usually react at the last minute
    - Educating and informing well the people. Also difficult, but seems the most effective

October 7, 2020 (iii)

- ✓ What did we learn/refresh/understood?
  - About the Transport Networking technology existing below Internet, we knew that
    - Its features are key for a fast and reliable transport of the IP traffic
    - It uses Optical transmission and switching
    - It is Circuit-Switched based, *currently supporting flexible Bw allocation*
      - A Tutorial on the Flexible Optical Networking Paradigm: State-of-the-Art, Trends, and Research Challenges:  
<https://ieeexplore.ieee.org/abstract/document/6824237>
- We learned the main elements of an ASON architecture



# ASON architecture



CCI: Connection Control Interface

NMI-A: Network Management Interface for ASON Control Plane

NMI-T: Network Management Interface for the Transport Network

DCN: Data Communication Network

OCC: Optical Connection Controller

UNI: User to Network Interface.

NNI: Network to Network Interface

OXC: Optical Cross Connect.

# October 7, 2020 (iv)

- ✓ What did we learn/refresh/understood?
  - We introduced the MPLS protocol, and we learned that
    - It allows for *traffic engineering*, QoS provisioning, tunnelling, etc.
    - Its generalization (GMPLS) is the Control Plane standard protocol installed in the Core of current transport networks

# October 7, 2020 (v)

- ✓ What will we do today?
  - Second item of Chapter 2  
(Lecturer: Prof. Jordi Perelló)
    - Introduce SDN<sup>1</sup> the Emerging technology for implementing the control plane of the future networks
    - Introduce the OpenFlow Architecture
    - Introduce the NFV<sup>2</sup> concept
  - Start with the third item of Chapter 2  
(Lecturer: Dr. Fernando Afgraz)
    - SDN on Optical Networks and Data Centers: Two case studies

<sup>1</sup>) SDN: Software Defined Networking

<sup>2</sup>) NFV: Network Functions Virtualization

# October 7, 2020 (VI)

- ✓ What will we do today?
  - Launch the second panel session
    - On a Tutorial paper on ASON *Automatically Switched Optical Networks*
      - Deadline for posting the report in ATENEA: October 14 (11:00 am.)
      - To be run on October 14 and Chaired by Working Group #3
      - Evaluation period: From October 14 to October 21 (11:00 am.)

# October 14, 2020 (i)

- ✓ What did we do last Tuesday (October 7)?
  - Second item of Chapter 2  
(Lecturer: Prof. Jordi Perelló)
    - Introduced SDN<sup>1</sup> the Emerging technology for implementing the control plane of the future networks
    - Introduced the OpenFlow Architecture
    - Introduce dthe NFV<sup>2</sup> concept
  - Started the third item of Chapter 2  
(Lecturer: Dr. Fernando Afgraz)
    - SDN on Optical Networks and Data Centers: Two case studies
  - Launched the second panel session
    - On a Tutorial paper on ASON Automatically Switched Optical Networks

<sup>1)</sup> SDN: Software Defined Networking

<sup>2)</sup> NFV: Network Functions Virtualization

# October 14, 2020 (II)

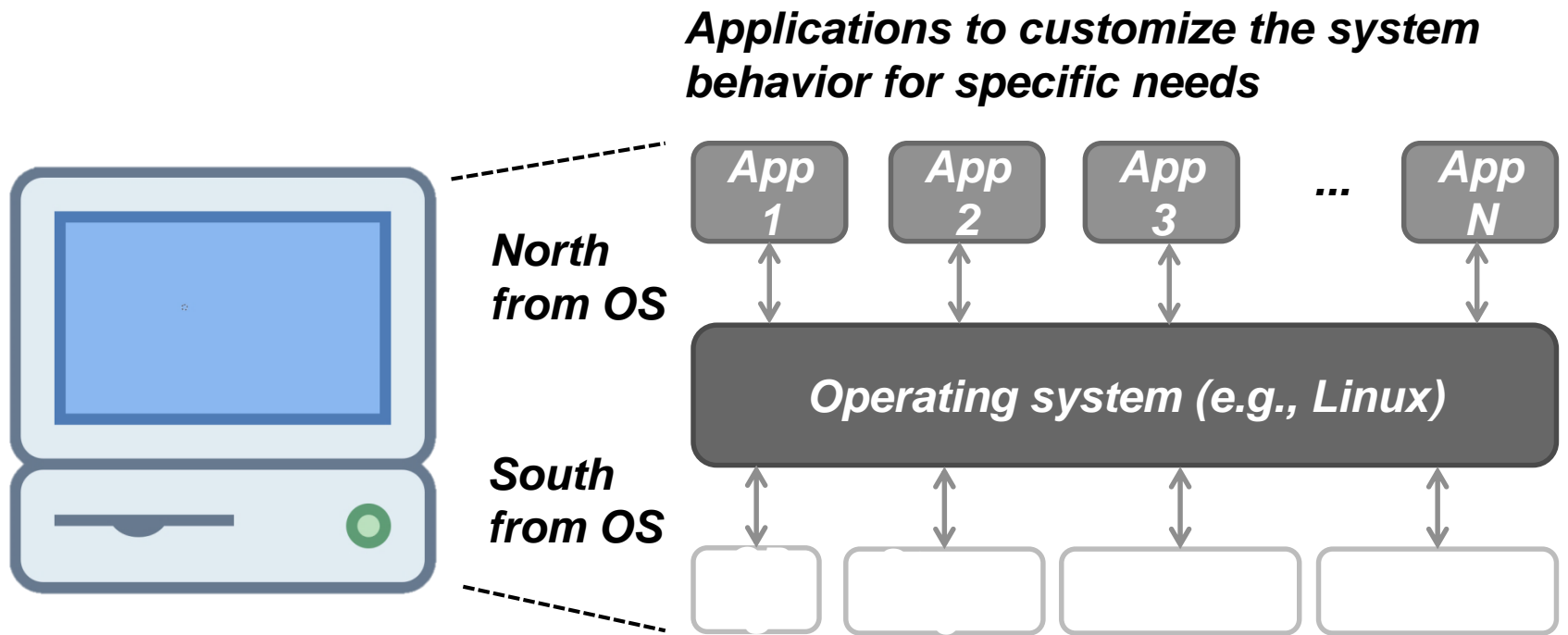
## ✓ What did we learn/refresh/understood?

- About SDN and OpenFlow

- *SDN aims to counteract some limitations current networks operation*
  - Problematic vendor-specific configuration procedures
  - Inconsistencies of distributed control protocols
  - ...
- *SDN can be seen as an analogy of a computer OS, but operating over a network domain*
- *OpenFlow is the most widely used standard protocol for communicate the SDN controller and the Network Devices*
  - Initial OpenFlow main goal was to make Ethernet networks, which are native connectionless, able to operate in connection oriented mode.
  - ... as MPLS do with IP networks

# ***SDN in analogy with a computer OS***

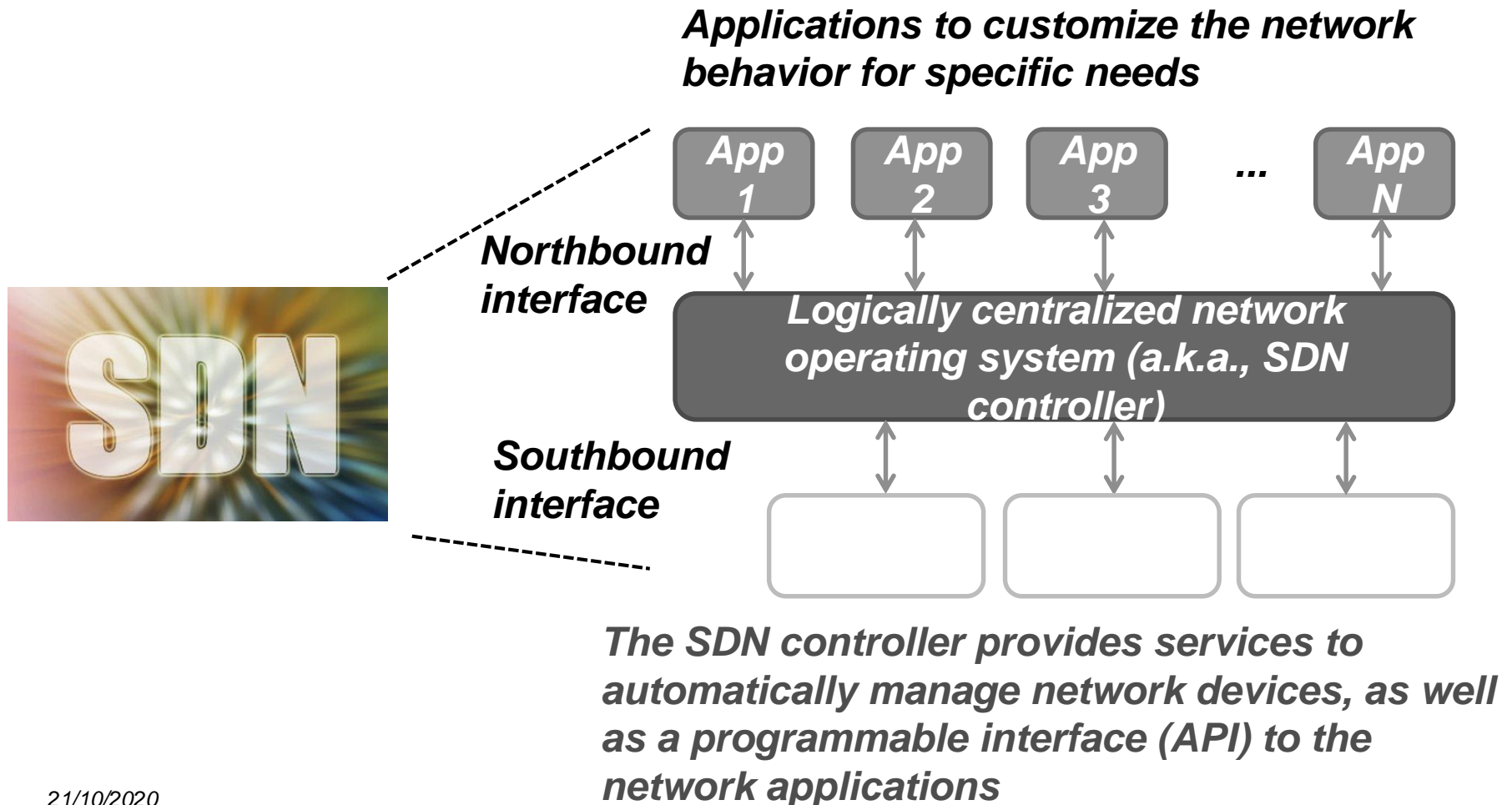
- The computer operating system model can be drawn in three basic layers: hardware, operating system and applications



***The OS can be seen as a middleware permitting applications to access HW resources, based on policies***

# ***SDN in analogy with a computer OS***

- Similarly, the SDN model can also be split into 3 different layers:





# October 14, 2020 (ííí)

✓ What did we learn/refresh/understood?

- About NFV

- NFV consists of replacing specialized network appliances (like firewalls, load balancers, routers, etc.) with software running on VMs
- SDN and NFV complement each other:
  - VNFs running on VMs in different servers can be connected over an SDN network to build an end-to-end service chain
  - Orchestrator is then required to coordinate both SDN and NFV

- That the LIGHTNESS project was about designing a novel interconnection network architecture for *intra* data center network (DCN)

- Based on both Optical Circuit Switching and Optical Packet Switching technology
- Leveraging SDN and OpenFlow solution/specs

# October 14, 2020 (iv)

- ✓ What will we do today?
  - Finishing the third item of Chapter 2  
(Lecturer: Dr. Fernando Afgraz)
    - SDN on Optical Networks and Data Centers: Two case studies
  - Run the second panel session
    - On a Tutorial paper on ASON Automatically Switched Optical Networks
    - Erlang B Calculator
  - Launch the second set of questions
    - Devoted to Chapter 2
      - Deadline for posting the questions in ATENEA: October 21 (11:00 am.)
      - Evaluation period: From October 21 to October 28 (11:00 am.)
  - Technical reports assignment (tentative)

**Note:** I have extended the assessment period for the 1<sup>st</sup>. set of questions until midnight, today

# October 14, 2020 (v)

## ✓ Tentative assignment of the technical reports

### • TOPIC for Group#2:

(Group members: David Carrera Casado, Laur line Le Godec, Axel Wassington)

#### – Can GDPR protect the privacy rights of citizens?

- <https://gdpr-info.eu/>

- <https://ec.europa.eu/info/law/law-topic/data-protection>

### • TOPIC for Group#3:

(Group members: Ayoub Bellouk, D n s Falc o Le te Moreira, Francesc Roy Campderros, Juan Pablo Royo Sales)

#### – Solutions to secure the 5G system

- [https://www.sciencedirect-](https://www.sciencedirect-com.recursos.biblioteca.upc.edu/science/article/pii/S138912861830817X)

- com.recursos.biblioteca.upc.edu/science/article/pii/S138912861830817X

# October 14, 2020 (VI)

- ✓ Tentative assignment of the technical reports
  - TOPIC for Group#4:  
(Group members: Paulina Jedrzejewska, Julien Labarre, Adrian Manco Sanchez, Jorrit Wolfgang Palfner)
    - Towards the 6G Network era: New IP architecture
      - <http://jultika.oulu.fi/files/isbn9789526226842.pdf>
      - <https://www.oulu.fi/6gflagship/>
  - TOPIC for Group#1 (sponsored by DAMM):  
(Group members: M Ros Gauthier, Kacper Szymula, Mar Vidal Segura)
    - Augmented traceability for food or its state (inclosing nanosensors inside the food / drink). Also applicable to control the beer fermentation process?
      - <https://www.rentokil.com/blog/five-examples-iot-food-supply-chain/>

# October 21, 2020 (I)

- ✓ What did we do last Tuesday (October 14)?
  - Finished with Chapter 2
    - Second case study: a SDN-based control plane and an Orchestration plane for provisioning coordinated IaaS (Lecturer: Dr. Fernando Afgraz)
  - Run the second panel session
    - On a Tutorial paper on ASON Automatically Switched Optical Networks
      - Evaluation period was until today at 11:00 am. → extended until midnight!
  - Launched the second set of questions
    - Devoted to Chapter 2
      - Deadline for posting the questions in ATENEA: October 21 (11:00 am.)  
→ extended until midnight!
      - Evaluation period: From October 21 to October 28 (11:00 am.)
  - Assigned the topics for doing the Technical Reports to the different working groups of the course
    - Date for the appointment? Pending for groups 2 and 4

# October 21, 2020 (II)

- ✓ What did we learn/refresh/understood?
  - While the LIGHTNESS project was about designing a novel interconnection network architecture for *intra* data center network (DCN)
    - Based on both Optical Circuit Switching and *Optical Packet Switching* technologies
  - The COSIGN project was about a novel architecture with a SDN-based control plane and an Orchestration plane for provisioning coordinated *IaaS*
    - We learned that Data Centers Orchestrator can provide network and IT virtualization allowing service programmability and complex service provisioning. The so called Virtual Data Center (VDC) provisioning
      - VDCs emerged as a service to cope with the multi-tenancy requirements faced by the DC operators

October 21, 2020 (ííí)

- ✓ What did we learn/refresh/understood? (cont.)
  - About the tutorial paper on ASON, we learned/debated about:
    - The issues to operate the core transport networks in Internet
    - The main mechanisms and requirements for enabling the ASON architecture
      - Which are also applicable to new schemes, such as SDN
    - The benefits of using ASON architecture
      - Matching client-network operator needs (BW on Demand Service plus resource optimization)
      - Easy network operation
      - Facilitate network reliability
      - ... among others

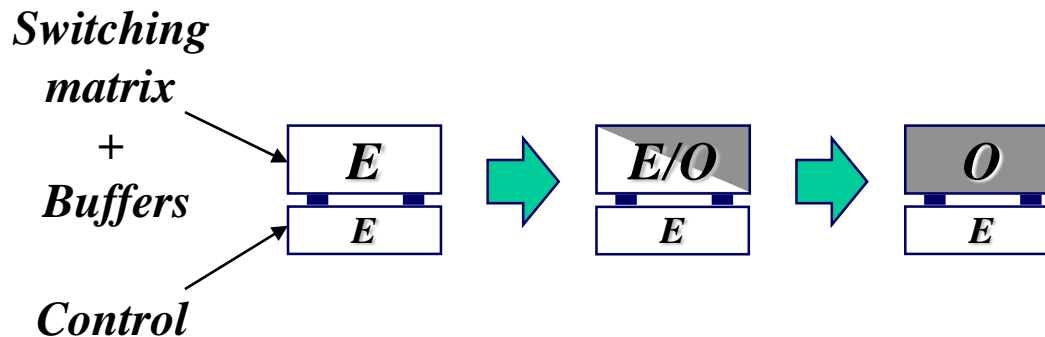
# October 21, 2020 (ííí)

- ✓ To do list from the pass class
  - Review the last slides of Fernando's presentation on
    - Providing 5G services over an optical infrastructure
    - ... and send an e-mail to Fernando ([agraz@tsc.upc.edu](mailto:agraz@tsc.upc.edu)), with Cc to me, if you have doubts
  - Play with the Erlang B calculator
    - Erlang B Calculator
  - Review the generic slides on Optical Packet Switching of the pass version of the diary of the course



# Packet Switching vs. Optical Packet Switching

- Electronic to optical packet switching evolution:















- Optical Packet Switches main characteristics:
  - Both switching matrix and buffers are optical
  - Bit rate independent payload (transparent bit rate)
  - Headers still processed electronically

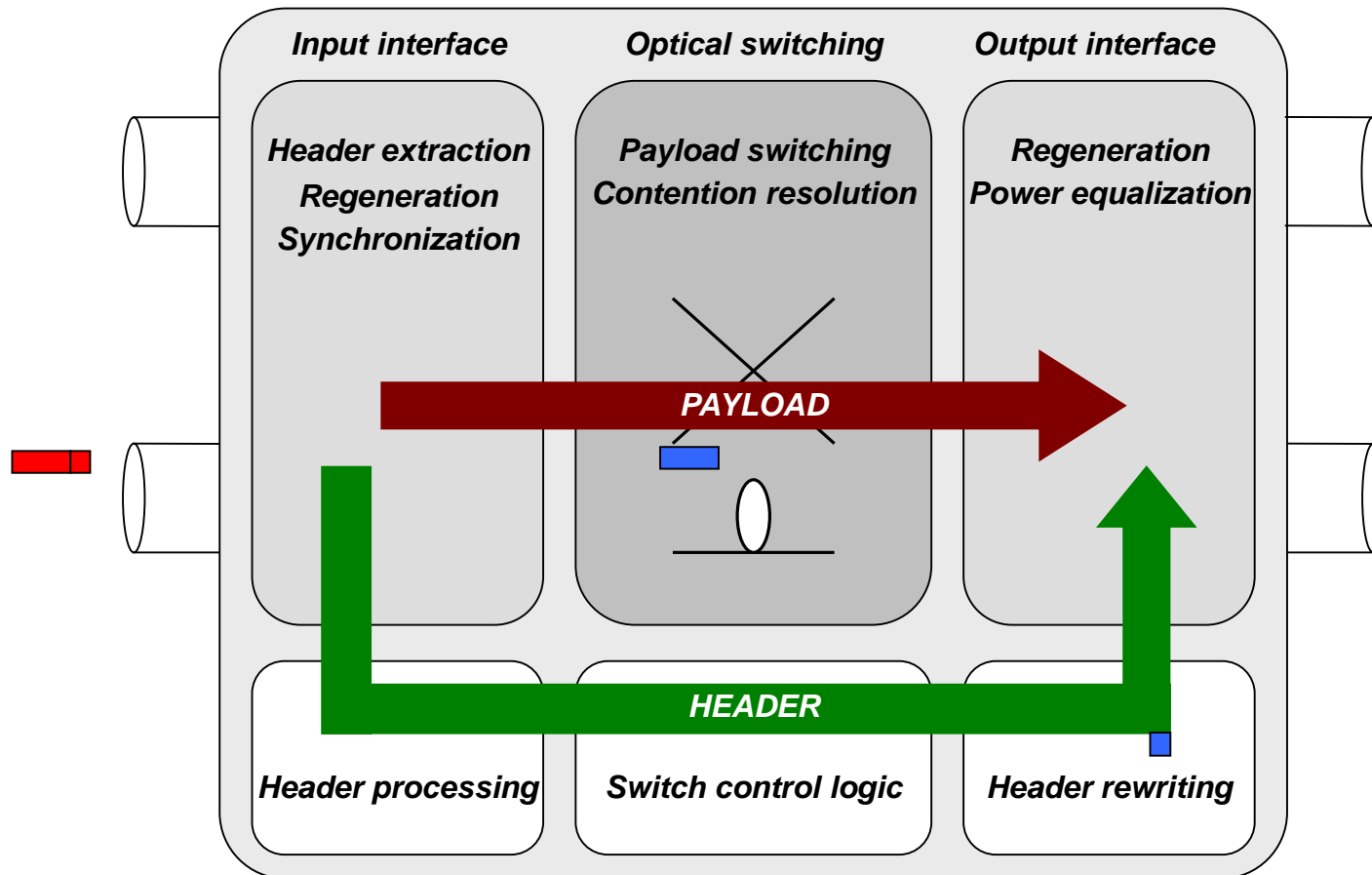
|              | Elec | Elec-Opt | Opt  |
|--------------|------|----------|------|
| Sw. Capacity | low  | medium   | high |
| Complexity   | high | medium   | low  |
| Memory Dim.  | high | high     | low  |
| Transparency | no   | no       | yes  |

# Packet Switching vs. Optical Packet Switching

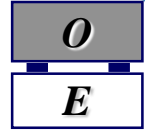
- Electronics are reacting to fill the opto-electronic capacity GAP:
  - > 1 Tbps throughput is reachable
- Photonic technology is also evolving fast
  - Solves the opto-electronic capacity GAP
  - Three dimensions: Space, Time, Wavelength

| <i>Dimensio</i>   | <i>Space</i>  | <i>Time</i>   |   |   | <i>Wavelength</i>   |   |
|-------------------|---|---|---|---|---|---|
| <i>Function</i>   | <i>Switch</i>   | <i>Mux</i>  | <i>Syn/Asyn</i>   | <i>Storage</i>  | <i>Mux</i>  | <i>Conv.</i>  |
| <i>Electronic</i> |  |  |  |  |  |  |
| <i>Optical</i>    |  |  |  |  |  |  |

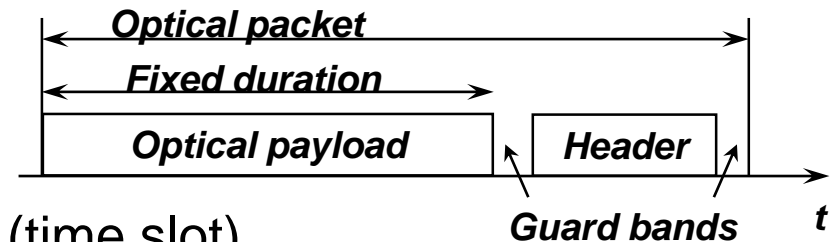
# ***Optical Packet Switching operation***



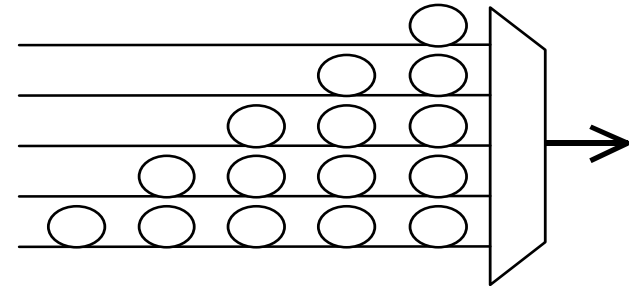
# Optical Packet Switching operation



- Optical packets:
  - Electronic header
  - Optical transparent payload (time slot)
    - *Because what is switched are very short light beams*



- Optical buffers? Fiber delay lines



# October 21, 2020 (iv)

- ✓ What will we do today?
  - Start with Chapter 3 (Lecturer: Prof. Pere Barlet)
    - Traffic Monitoring and Analysis
      - Internet Measurements: Algorithms and Challenges
  - If time, continue with Chapter 3 (Lecturers: José Suárez)
    - Traffic Monitoring and Analysis in SDN based networks
      - Traffic Measurements in SDN environments
      - Traffic Classification in SDN environments