



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)

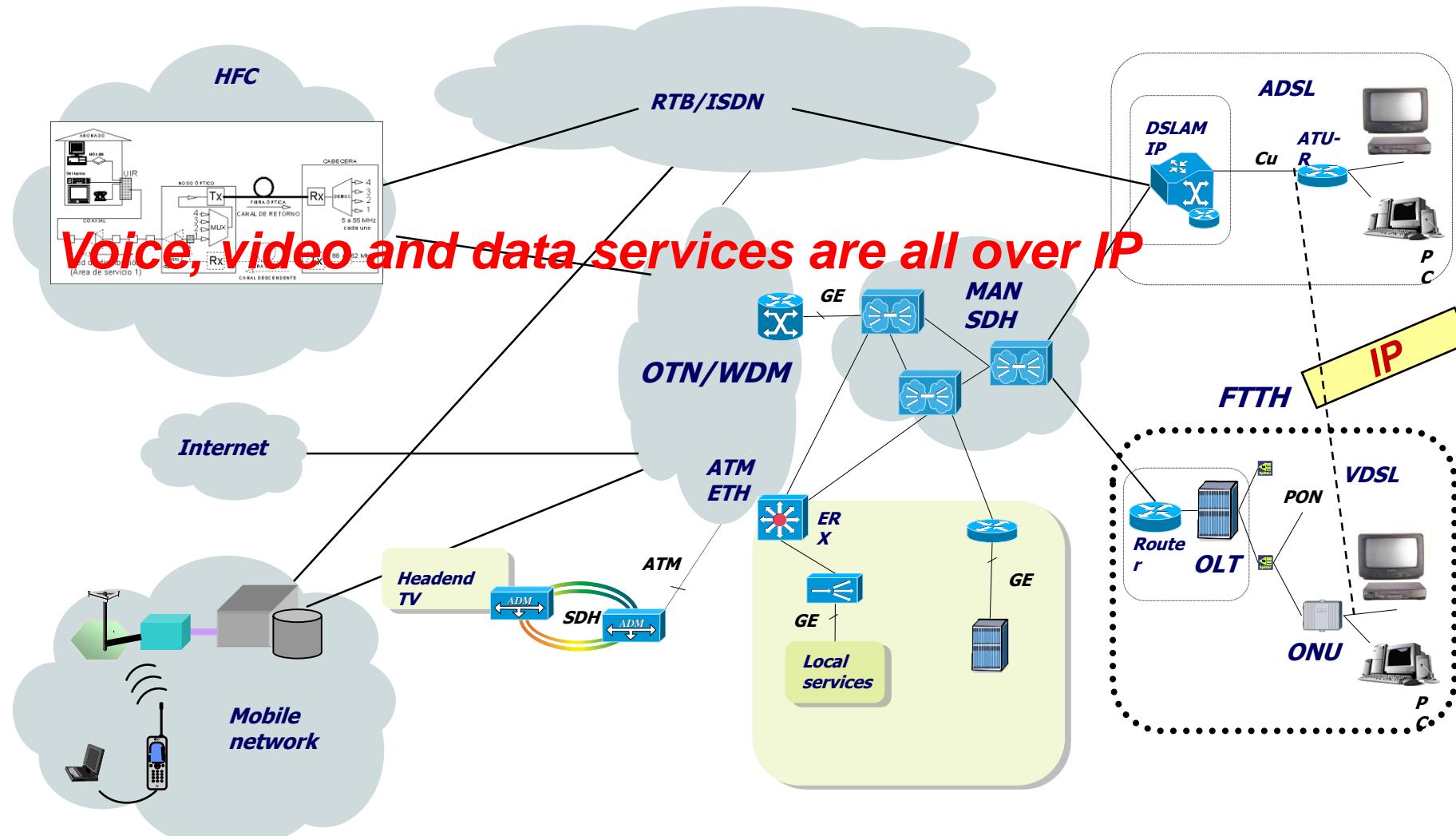
- ✓ What did we do last week (on September 16)?
 - We introduced the course
 - Launched the first Panel session
 - Launched the first set of questions
 - We started Chapter I: Review of the statistical figures provided by ITU:
 - ICT facts and figures

September 23, 2020 (ii)

- ✓ What did we learn/review/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

* Internetworking, Interoperable/International Network
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Internet became the Public Network



September 23, 2020 (III)

- ✓ What did we learn/review/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/review/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

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/review/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 (III)

- ✓ What did we learn/review/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 GMPLS¹: The control plane technology installed in current Backbone transport networks

¹⁾ GMPLS: Generalized MultiProtocol Label Switching

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

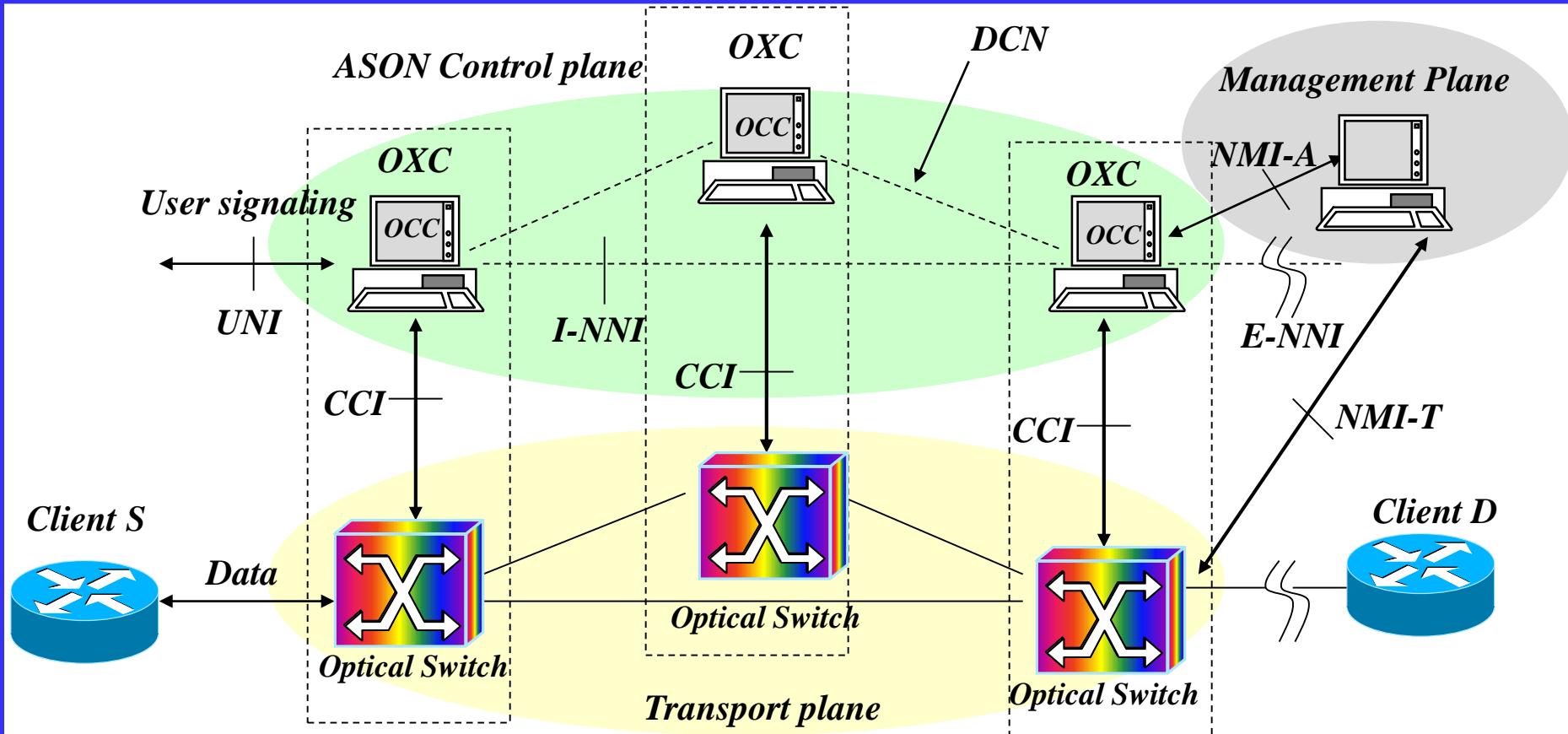
October 7, 2020 (II)

- ✓ 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

OCC: Optical Connection Controller

NMI-A: Network Management Interface for ASON Control Plane

UNI: User to Network Interface.

NMI-T: Network Management Interface for the Transport Network

NNI: Network to Network Interface

DCN: Data Communication Network

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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. Jordí Perelló)
 - Introduce SDN¹ the Emerging technology for implementing the control plane of the future networks
 - Introduce the OpenFlow Architecture
 - Introduce the NFV² concept
 - Start with the third item of Chapter 2
(Lecturer: Dr. Fernando Afgraz)
 - SDN on Optical Networks and Data Centers: Two case studies

¹) SDN: Software Defined Networking

²) 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 ATNEA: 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. Jordí Perelló)
 - Introduced SDN¹ the Emerging technology for implementing the control plane of the future networks
 - Introduced the OpenFlow Architecture
 - Introduce dthe NFV² 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

¹) SDN: Software Defined Networking

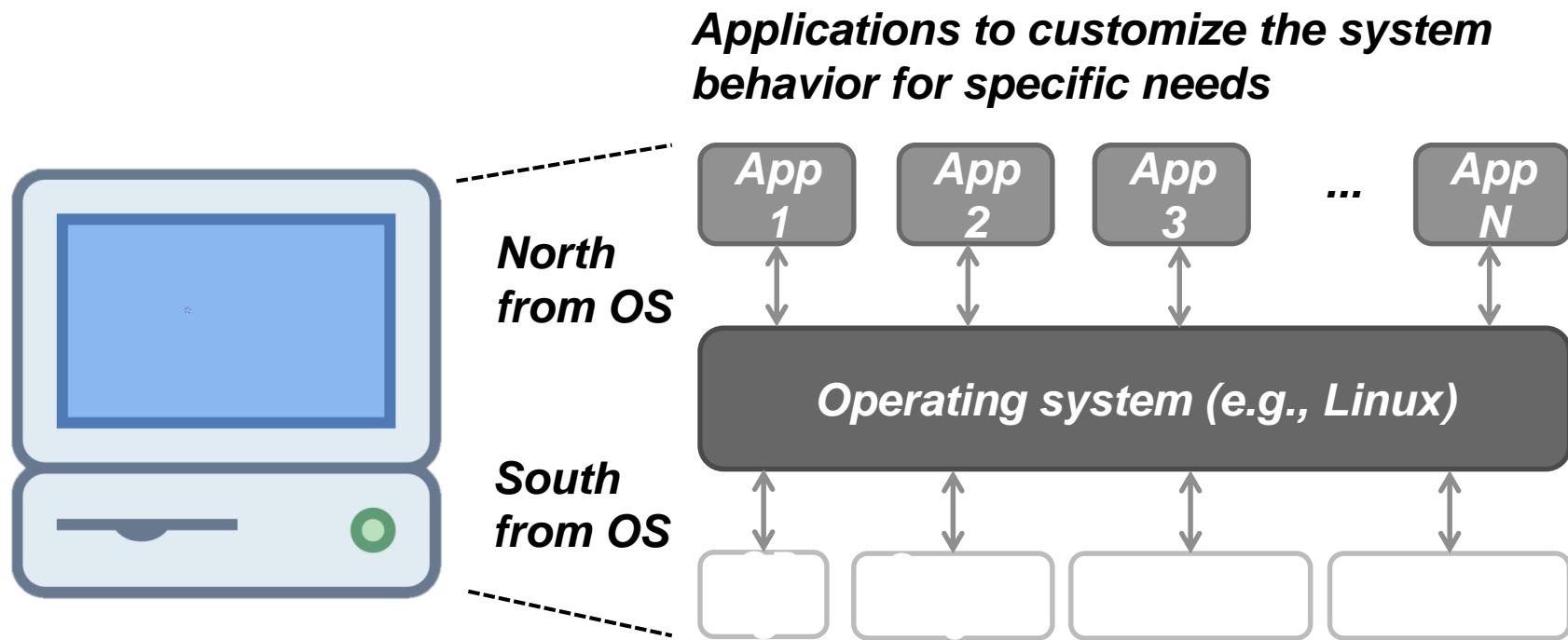
²) NFV: Network Functions Virtualization

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

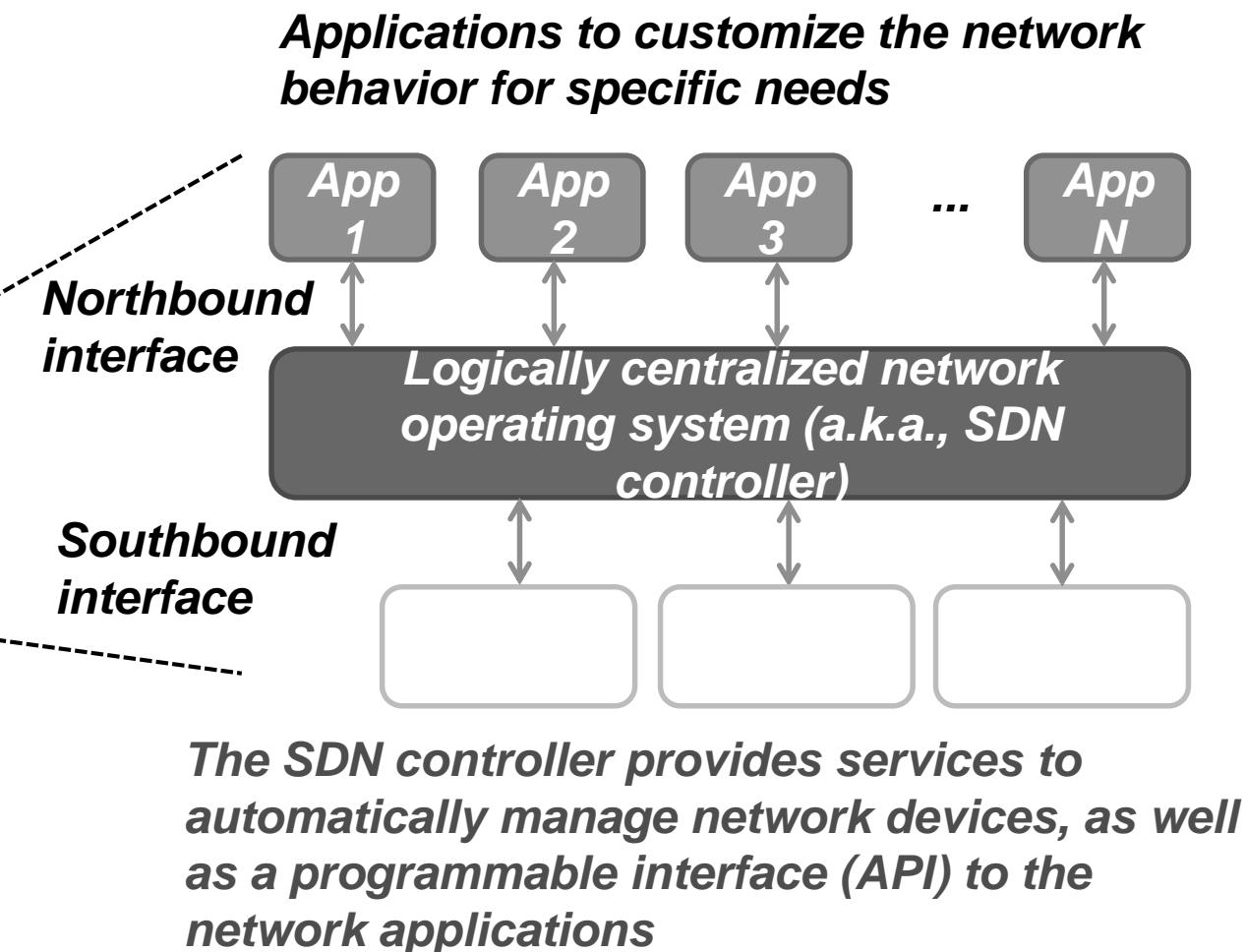
- The computer operating system model can be drawn in three basic layers: hardware, operating system and applications



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 (III)

- ✓ 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 1st. 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, Lauréline Le Godec, Axel Washington)
 - 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, Dinis Falcão Leite Moreira, Francesc Roy Campderros, Juan Pablo Royo Sales)
 - Solutions to secure the 5G system
 - <https://www-sciencedirect-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 (III)

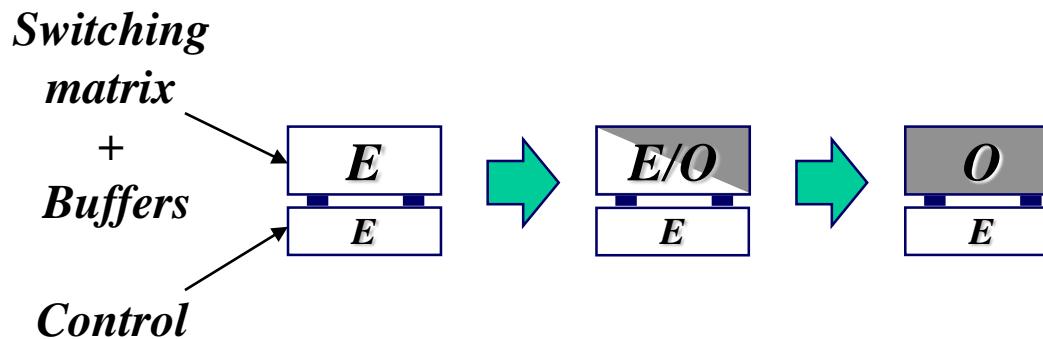
- ✓ What did we learn/refresh/understood? (cont.)
 - About the tutorial paper on ASON, we learned/debated about:
 - The issues to operate the core transport networks in Internet
 - The main mechanisms and requirements for enabling the ASON architecture
 - Which are also applicable to new schemes, such 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 (IV)

- ✓ 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), with Cc to me, if you have doubts
 - Play with the Erlang B calculator
 - Erlang B Calculator
 - A free online Erlang B calculator, which can be used to estimate how many lines are needed in the trunk groups of a network, once the traffic that will be offered to the target system is known. This is specifically for Circuit Switching Networks
 - 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

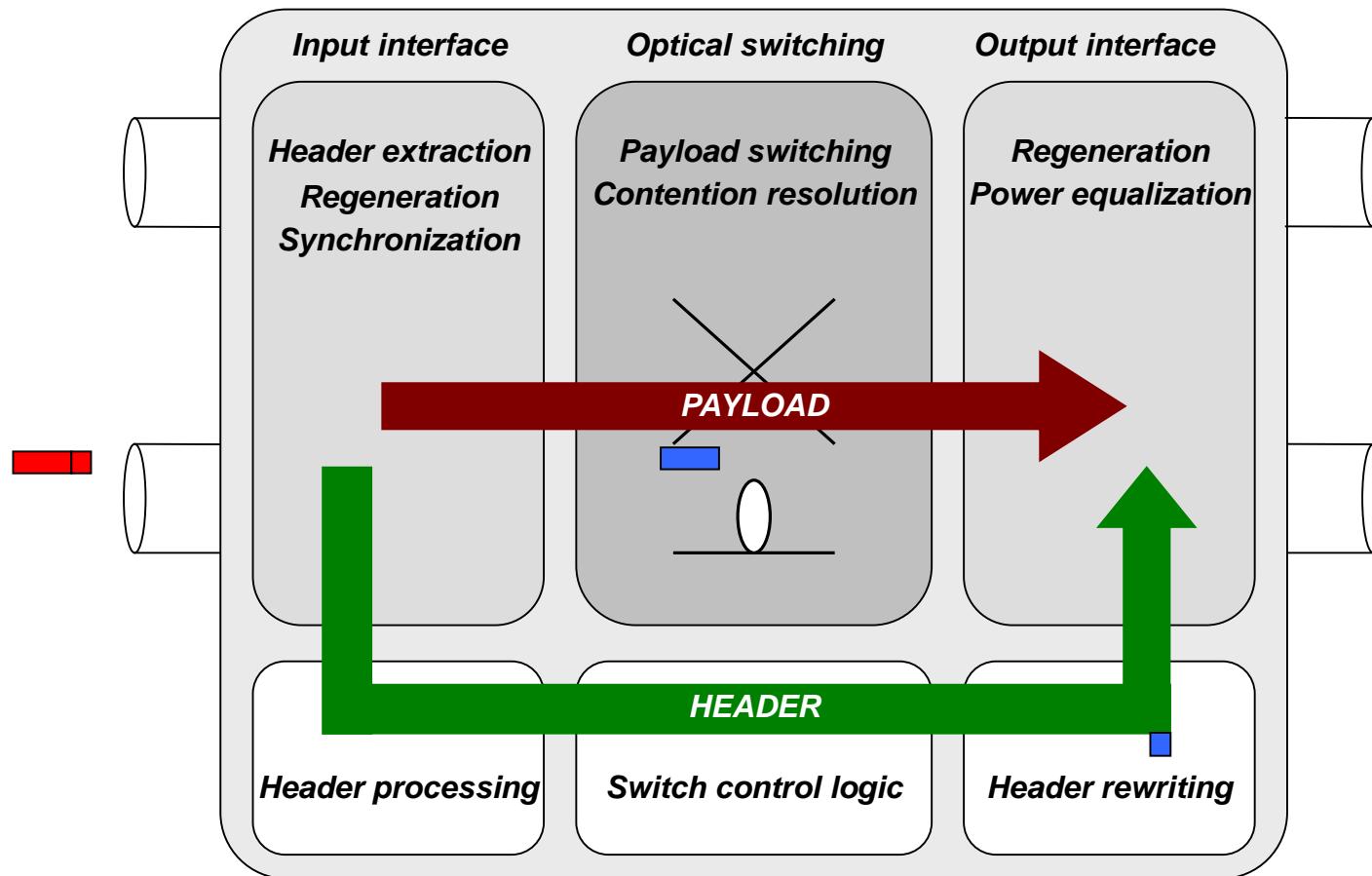
	Elec	Elec-Opt	Opt
Sw. Capacity	low	medium	high
Complexity	high	medium	low
Memory Dim.	high	high	low
Transparency	no	no	yes

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

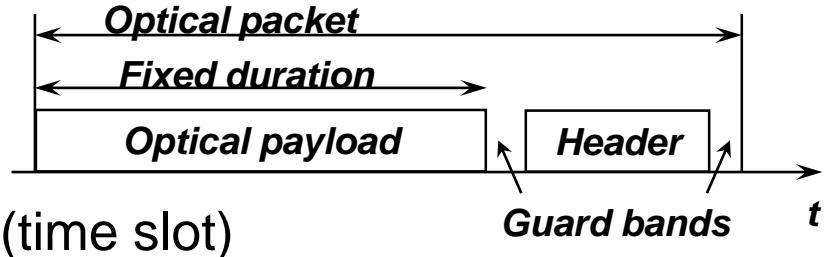
<i>Dimension</i>	<i>Space</i>	<i>Time</i>			<i>Wavelength</i>	
<i>Function</i>	<i>Switch</i>	<i>Mux</i>	<i>Syn/Asyn</i>	<i>Storage</i>	<i>Mux</i>	<i>Conv.</i>
<i>Electronic</i>	●	●	●	●	●	●
<i>Optical</i>	●	●	●	●	●	●

Optical Packet Switching operation

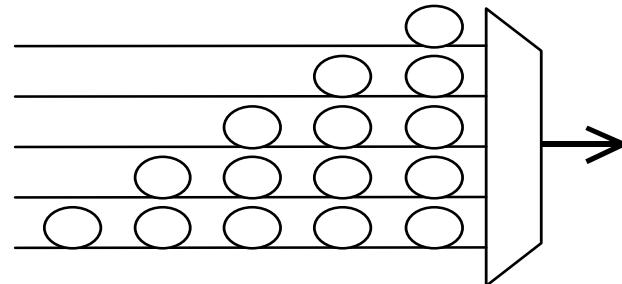


Optical Packet Switching operation

- 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 (V)

- ✓ What will we do today?
 - Start with Chapter 3 (Lecturer: Prof. Pere Barlet)
 - Traffic Monitoring and Analysis
 - Internet Measurements: Algorithms and Challenges

October 28, 2020 (i)

- ✓ What did we do last Wednesday (October 21)?
 - Reviewed the concept of Optical Packet Switching (OPS)
 - Started Chapter 3 (Lecturer: Prof. Pere Barlet)
 - Traffic Monitoring and Analysis
 - Internet Measurements: Algorithms and Challenges

October 28, 2020 (II)

- ✓ What did we learn/refresh/understood?
 - We reviewed the concept of Optical Packet Switching (OPS)
 - OPS networking was a top research topic some years ago. Nevertheless, the attention of the scientific community to this topic strongly reduced due to the evolution of WDM networking technology (moving from rigid fixed-grid to flexi-grid), which leaded to the Flexible or Elastic WDM (optical) networks
 - Two papers on Elastic Optical Networks for those who want to learn more about it:
 - <http://www.enggjournals.com/ijet/abstract.html?file=17-09-03-022>
 - <https://ieeexplore.ieee.org/abstract/document/6824237>

October 28, 2020 (III)

- ✓ What did we learn/refresh/understood?
 - About Traffic Monitoring & Network Measurements, we learned that
 - It is crucial for network operation and management
 - Estimation of traffic volume, type, topological distribution
 - Traffic engineering, network planning, BW management, QoS provisioning
 - Fault diagnosis, troubleshooting, performance evaluation
 - Accounting, billing, security...
 - It is important for networking research
 - Design and evaluation of protocols, applications, etc.
 - Traffic modeling and characterization (for network devices performance evaluation, analytical or by simulations)

October 28, 2020 (iv)

- ✓ What did we learn/refresh/understood?
 - We also learned that traffic monitoring/measuring is (another) scalability problem
 - The more the traffic demand grows, the more difficult is capturing the whole traffic
 - The more the network bitrate increases, the more challenging is computing the data captured in real time
 - Resort to sampling is commonly needed
 - Due to that, a gap between the obtained traffic measurements and its accuracy (accurate estimate traffic measurements) can appear
 - Some algorithms and techniques helping to reduce such a gap
 - Proper sampling techniques
 - Bloom Filters
 - Direct Bitmaps
 - Bitmaps over Sliding Windows (Timestamp and Countdown vectors)
 - Count-Min Sketch data Structures

October 28, 2020 (V)

- ✓ What will we do today?
 - Continue with Chapter 3
 - Traffic Monitoring and Analysis in SDN based networks
(Lecturer: Dr. José Suárez)
 - Traffic Measurements in SDN environments
 - Traffic Classification in SDN environments
 - Privacy and security implications on the Internet: Web tracking
(Lecturer: Ismael Castell, PhD student)
 - Launch the third set of questions
 - Devoted to the first part of Chapter 3 on Traffic Monitoring and Analysis
 - Deadline for posting the questions in ATENEA: November 4 (10:00 am.)
 - Evaluation period: From November 4 to November 11 (11:00 am.)
 - Launch the third Panel session
 - On the Self-similar Nature of Ethernet Traffic
 - Scheduled by November 11, to be chaired by Group #4

October 28, 2020 (Vi)

✓ What will we do today?

• Important!

- The assessment period for the 2nd. set of questions has been extended until today at midnight
- The first midterm exam is next Wednesday (November the 4th.)
 - If in person, at room A5-103, from 10 to 11:30 am.
 - If virtual, I will send you a message through Atenea

November 11, 2020 (I)

- ✓ What did we do in our last lecture (October 28)?
 - We concluded the topic on Traffic Monitoring and Analysis:
 - We had Dr. José Suárez who gave a lecture on "Traffic Monitoring and Analysis in **SDN based networks**" dealing with
 - Traffic Measurements in SDN environments
 - Traffic classification in SDN environments
 - We started a new topic about the dangers and risks of the use of Internet
 - Ismael Castell (PhD student) introduced the privacy and security implications on the Internet talking about
 - Web tracking: Definition, mechanism and antidotes
 - We launched the third Panel session
 - On the Self-similar Nature of Ethernet Traffic

November 11, 2020 (II)

✓ Notice

- The topic on dangers and risks of the use of Internet **will continue** in the class of November 25 with a lab session on:
 - Fighting Cyber Crime: An application of network analysis
 - Ransomware, network scanning, and general use of exploits and vulnerabilities
 - Practical look at malware behavior from a network perspective
 - Exercises on the offensive side of things using a virtual hacker lab
 - To be given by a special guest:
 - Prof. Jens Myrup Pedersen (University of Aalborg)

November 11, 2020 (III)

- ✓ What did we learn/refresh/understood?
 - We learned
 - How to perform Flow-level traffic aggregation in SDN environments
 - How to perform sampling in SDN environments
 - How to classify the traffic, in particular web traffic, in SDN environments
 - Different ways of tracking our activity in Internet
 - Several methods to counteract them and preserve our privacy

November 11, 2020 (IV)

- ✓ What will we do today?
 - Run the third Panel
 - "On the Self-similar Nature of Ethernet Traffic"
 - Evaluation period: Starts today and will last until November 18 (11:00 am.)
 - Continue with Chapter 3 dealing with "Inter-domain Routing" scalability and security issues
 - lecturer: Prof. Albert Cabellos

November 11, 2020 (V)

✓ Important notices

- The deadline for evaluating the third set of questions is extended until **today at midnight**
- The deadline for delivering the report on todays panel paper is extended until **today at midnight**
- Next week, I will start going through your exams. This week I could not do it because I had to prepare an exam for another course I'm giving
 - At first glance, the result of the exam is quite good

November 18, 2020 (i)

- ✓ What did we do in the last lecture (November 11)?
 - We run the third Panel
 - "On the Self-similar Nature of Ethernet Traffic"
 - Prof. Albert Cabellos gave his lecture on the "Inter-domain Routing". He discussed about:
 - The inter-domain routing protocols, in particular the case of BGP (Border Gateway Protocol) concerning to
 - The BGP Scalability problem
 - The BGP Security problem

November 18, 2020 (II)

- ✓ What did we learn/refresh/understood?
 - We again learned that:
 - Networks are becoming faster than computers, which creates Internet scalability problems
 - For the network monitoring (traffic capturing and analyzing)
 - Due to the Inter-domain routing function (BGP)
 - After all we have discussed about Network Monitoring, we should have learned that the most relevant to find out is:
 - What network users do?
 - What is happening to the network?
 - How traffic load the network?

November 18, 2020 (III)

- ✓ What did we learn/refresh/understood?
 - Can we answer these questions?
 - The main purposes (applications) of Network Monitoring are Traffic Classification, Anomaly Detection and Traffic Characterization.
Why is each of these applications useful for?
 - Traffic classification is useful for determining what network users do
 - Troubleshooting or Anomaly Detection is useful for determining what is happening in the network
 - Traffic Characterization allows for synthetizing the statistical behavior of the network traffic
 - Let us put an example to illustrate each of case:
 - Controlling users behavior, Engineering the network (network dimensioning & planning), Billing and Charging...
 - Is the network fully or partially attacked? Is the network (connectivity, devices, etc.) failing? Is there a too high BER or too low S/N?...
 - How traffic load the network? How new network devices and protocols will perform under realistic traffic conditions?...

November 18, 2020 (IV)

- ✓ What did we learn/refresh/understood?
 - We also learned that:
 - The main causes of BGP scalability problems are the procedures of Reachability advertisement and Multihoming
 - We refreshed the concept of Peering
 - This concept already appeared in one of our introductory videos... who has watched it?

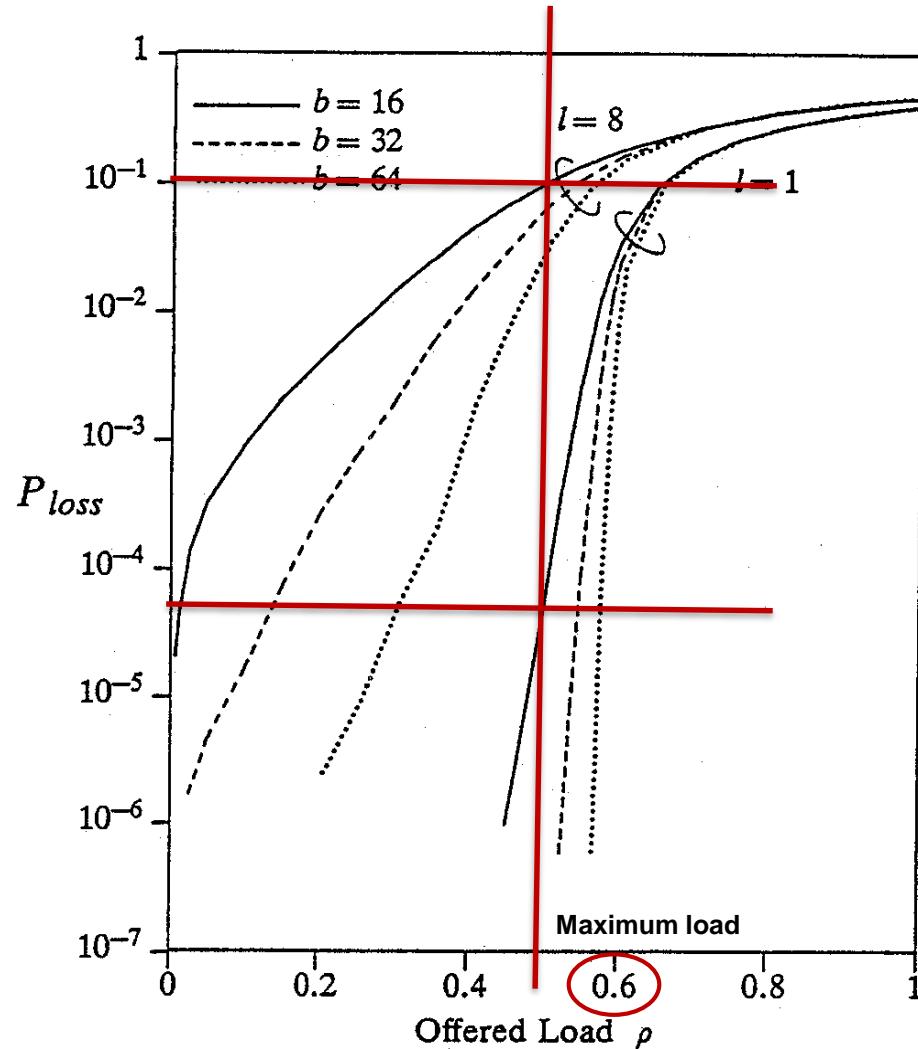
November 18, 2020 (V)

- ✓ What did we learn/refresh/understood?
 - Then, Albert went to the BGP security issues, and we learned that
 - BGP was not designed with security in mind. So then, BGP introduces critical security threats, namely:
 - Prefix Hijack
 - Path Hijack
 - Route Leak
 - Current solutions to fix such a security threats are
 - Resource Public Key Infrastructure (RPKI)
 - BGP-SEC
 - More advanced solutions
 - Decentralized Distributed Infrastructure (DII) and beyond

November 18, 2020 (VI)

- ✓ What will we do today?
 - Complete the discussion of the paper "On the Self-similar Nature of Ethernet Traffic" with
 - An example of the importance of traffic characterization for the performance evaluation of network devices
 - Continue with Chapter 3 dealing with the "Recursive Internet Architecture" (RINA)
 - Invited Lecturer: Prof. Jordí Perelló

Impact of burstiness



P_{loss} vs. ρ for ordinary input-buffered scheme.

November 18, 2020 (VI)

- ✓ What will we do today?
 - Complete the discussion of the paper "On the Self-similar Nature of Ethernet Traffic" with
 - An example of the importance of traffic characterization for the performance evaluation of network devices
 - Continue with Chapter 3 dealing with the "Recursive Internet Architecture" (RINA)
 - Invited Lecturer: Prof. Jordi Perelló

November 18, 2020 (VII)

- ✓ About RINA?
 - The problem:
 - Internet needs to continuously be updated, how to do this?
 - Evolutionary solutions:
 - "Put patches in the IP network
 - Example: To cope with the BGP security problem (discussed in class by Prof. Cabellos)
 - Disruptive (clean state) solutions:
 - Designing a brand new architecture for the IP network
 - Content Centric Networking
 - RINA (today's lecture by Prof. Perelló)
 - The Technical Report of Group #4 will also illustrate us about this topic...

November 18, 2020 (VIII)

✓ Today we will also:

- Launch the fourth set of questions
 - Devoted to inter-domain scalability and security problems, and RINA
 - Deadline for posting the questions in ATENEA: November 25 (11:00 am.)
 - Evaluation period: From November 25 to December 2 (14:00 pm.)
- Launch the fourth Panel session
 - Towards the Internet of 2030
 - Scheduled by December 9, to be chaired by Group #1
- Notice:
 - The period for evaluating the report on the paper of the third panel has **been extended until today midnight**

November 25, 2020 (i)

- ✓ What did we do in the last lecture (November 18)?
 - Prof. Jordi Perelló taught us about RINA: "Recursive Internet Architecture"

November 25, 2020 (II)

- ✓ What did we learn/refresh/understood?
 - In summary we learned:
 - The basics about the RINA architecture
 - Supported by the DIF (Distributed IPC¹ Facility) concept. A single repeating layer, hence the recursivity of RINA
 - The naming and addressing scheme for RINA
 - Which considers: Application names, Node addresses and Interface addresses (Point of Attachment (PoA) addresses)
 - How RINA supports application-specific QoS
 - Based on the Quantitative Timeliness Agreement Multiplexer (QTA-Mux) scheduling Policy
 - Also, will give us the opportunity to review the concepts of "Policing" function and traffic "Shaping"
- Next Wednesday

¹) Inter Process Communication

November 25, 2020 (III)

- ✓ What will we do today?
 - Finish with Chapter 3, on dangers and risks of the use of Internet, today we will deal with:
 - Fighting Cyber Crime: An application of network analysis
 - Ransomware, network scanning, and general use of exploits and vulnerabilities
 - Practical look at malware behavior from a network perspective
 - Exercises on the offensive side of things using a virtual hacker lab
 - Special guest:
 - Prof. Jens Myrup Pedersen (University of Aalborg)
 - Research areas: Cyber security, network security, network planning.
 - Other interests: Internationalization and digitization of education. Sustainability in engineering education. Problem Based Learning.

December 2, 2020 (I)

- ✓ What did we do last Tuesday (November 25)?
 - We had a special guest, Prof. Jens Myrup Pedersen (University of Aalborg, DK), who gave us a lecture on:
 - Fighting cyber-crime with a network analysis application
 - Case based introduction on the Internet security risks
 - Concepts: Penetration testing and network scanning.
 - Practical session: "Think like a hacker". Exercises on the offensive side of things using a virtual hacker lab

December 2, 2020 (II)

- ✓ What did we learn/refresh/understood?
 - From the talk we learned that:
 - The network capabilities can be used for malicious purposes
 - Strategic (political strategy, for instance)
 - cyber-crime (own profit)
 - The motivation for these actions are either for obtaining
 - Power
 - Money
 - Strategic information (knowledge)
 - Two key words for fighting against malware:
 - Traffic Monitoring and analysis
 - Network Protection

December 2, 2020 (II)

- ✓ What did we learn/refresh/understood?
 - During the lab you learned to be a hacker, which is the best way to fight against them
 - First, you did some exercises using **Wireshark**
 - for doing Network penetration tests
 - for doing Network Scanning
 - Then, you practiced with **nmap**
 - to find out which other computers are in your network
 - to find out the other computers operating system
 - to identify web servers
 - to detect if username and passwords are unencrypted
 - to catch username and password of other users
 - ... and more challenges

December 2, 2020 (iv)

- ✓ What did we learn/refresh/understood?
 - In summary...
 - *it is easy to get somebody's login data through the Internet. So then, it is important to create consciousness in regular users of this fact*

December 2, 2020 (V)

- ✓ To do list from the class done on November 18
 - Review the concepts of "**Policing**" function and traffic "**Shaping**" concerning to the QoS provisioning

November 25, 2020 (II)

- ✓ What did we learn/refresh/understood?
 - In summary we learned:
 - The basics about the RINA architecture
 - Supported by the DIF (Distributed IPC¹ Facility) concept. A single repeating layer, hence the recursivity of RINA
 - The naming and addressing scheme for RINA
 - Which considers: Application names, Node addresses and Interface addresses (Point of Attachment (PoA) addresses)
 - How RINA supports application-specific QoS
 - Based on the Quantitative Timeliness Agreement Multiplexer (QTA-Mux) scheduling Policy
 - **Policer/Shaper (P/S) modules** for intra-flow contention, allowing operations such as flow data rate control, inter-packets pacing, quality degradation, etc.

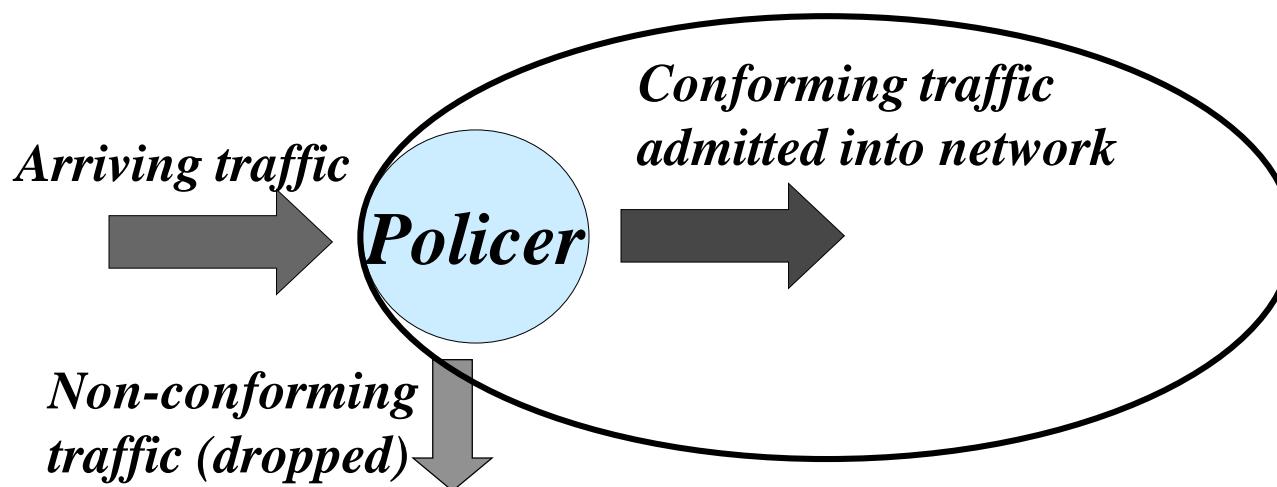
¹) Inter Process Communication

Resource Reservation

- To guarantee any QoS, **network resources** can be reserved in advance
 - Types of **network resources** likely to be reserved
 - Bandwidth
 - Buffer space
 - There are two types of reservation procedures:
 - Static (manual)
 - Dynamic, which requires the use of signalling
 - In any case, there is a need of establish a “**contract**”(*)
 - *According the values of the traffic parameters, the network provide the necessary resources to cope with the QoS required. Committing not to overcome the delay, jitter, loss bounds of that application*
- ***SLA:** The more you pay, the better is the contract you can obtain

Traffic Policing

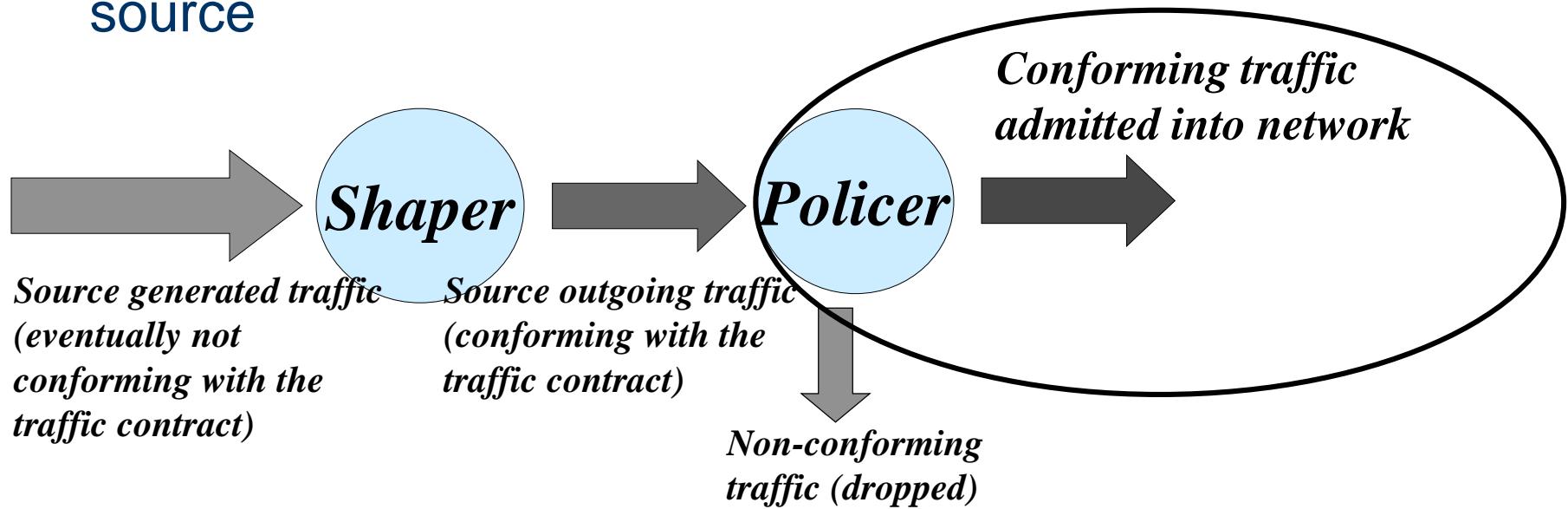
- Users violating the traffic **contract** can jeopardise the QoS of other connections
- The network must protect well behaving users against such traffic violations
- All entering traffic is therefore subject to policing
- Policing functions are deployed at the edge (entry) of the network



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Traffic Shaping

- The source can **shape** its traffic prior to sending it to network so it does not violate traffic **contract**
- **Traffic shaping** consists then of altering the traffic characteristics of a given flow, before being sent by the source



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December 2, 2020 (VI)

- ✓ What will we do today?
 - We will do Chapter 4, mainly dealing with two interesting topics:
 - Energy oriented Internet: Energy consumption and Energy efficiency in Internet
 - Multilayer Resilience Networks: Failure recovery mechanisms for (Optical) Transport Networks
 - Notice:
 - The period for evaluating the fourth set of questions has been extended until today midnight
 - I will finish to grade the 1st. midterm this week...

December 9, 2020 (I)

- ✓ What did we do in the last lecture (December 2)?
 - We did the Chapter 4, dealing with the following two topics:
 - Energy oriented Internet: Energy consumption and Energy efficiency in Internet
 - Multilayer Resilience Networks: Failure recovery mechanisms for (Optical) Transport Networks

December 9, 2020 (II)

- ✓ What did we learn/refresh and hopefully understood?
 - First, we understood the Energy problem in general and the Energy problem for the particular case of ICT
 - ICT presents a "vicious cycle": Watts \Rightarrow useful Work \Rightarrow produces Heat, which requires Cooling \Rightarrow PUE (Power usage Effectiveness) > 1 , can reach 2, current values for PUE in Data centers are around 1.2
 - We Knew the Energy-oriented Internet paradigm, which refers to the combination of Energy-Efficiency and Energy-Awareness, with green energy sources, in a sustainable and holistic¹ systemic approach
 - To understand this paradigm, we put our attention in Géant 2 (the European Academic Network)
 - We reviewed some results of a Case Study: Application of different constrained RWA algorithms (MinPower, MinHG and MinCost) to the Optical Network supporting Géant 2

¹) Holistic: Characterized by comprehension of the parts of something as intimately interconnected and explicable only by reference to the whole

December 9, 2020 (III)

- ✓ What did we learn/refresh and hopefully understood?
 - Then, we learned that network failures (cable/fibre cuts and equipment failures), which are a headache for network operators, can be overcome using different recovery strategies to be deployed in the network infrastructure
 - Recovering from failures is a trade-off between costly (protection mechanisms) and time consuming (restoration mechanisms)
 - Since the Internet network infrastructure is multilayer, recovery strategies have to deal with multiple layers
 - Simple escalation strategies among layers are available, but dynamic multilayer recovery is the way
 - Integration of IP and optical networks under a common control plane (supporting ASON) offers the opportunities and challenges related to survivability
 - Possible technologies to be used: GMPLS, SDN, KDN...

December 9, 2020 (IV)

- ✓ What will we do today?
 - Run the the fourth Panel session: Internet of 2030
 - That will be chaired by Group #1
 - Start the Chapter 5 on New Networking Paradigms
 - Invited lecturer: *Prof. Albert Cabellos*, who will present the Knowledge Defined Networking paradigm, the Graph Neural Network technique and some research problems where to apply this technique
 - Launch the fifth set of questions:
 - Two questions have to be proposed, one about Energy Internet Oriented and the other about Multilayer Resilience Networks
 - Deadline for posting the questions in ATENEA: December 16 (11:00 am.)
 - Evaluation period: From December 16 to December 23 (at midnight)

December 16, 2020 (I)

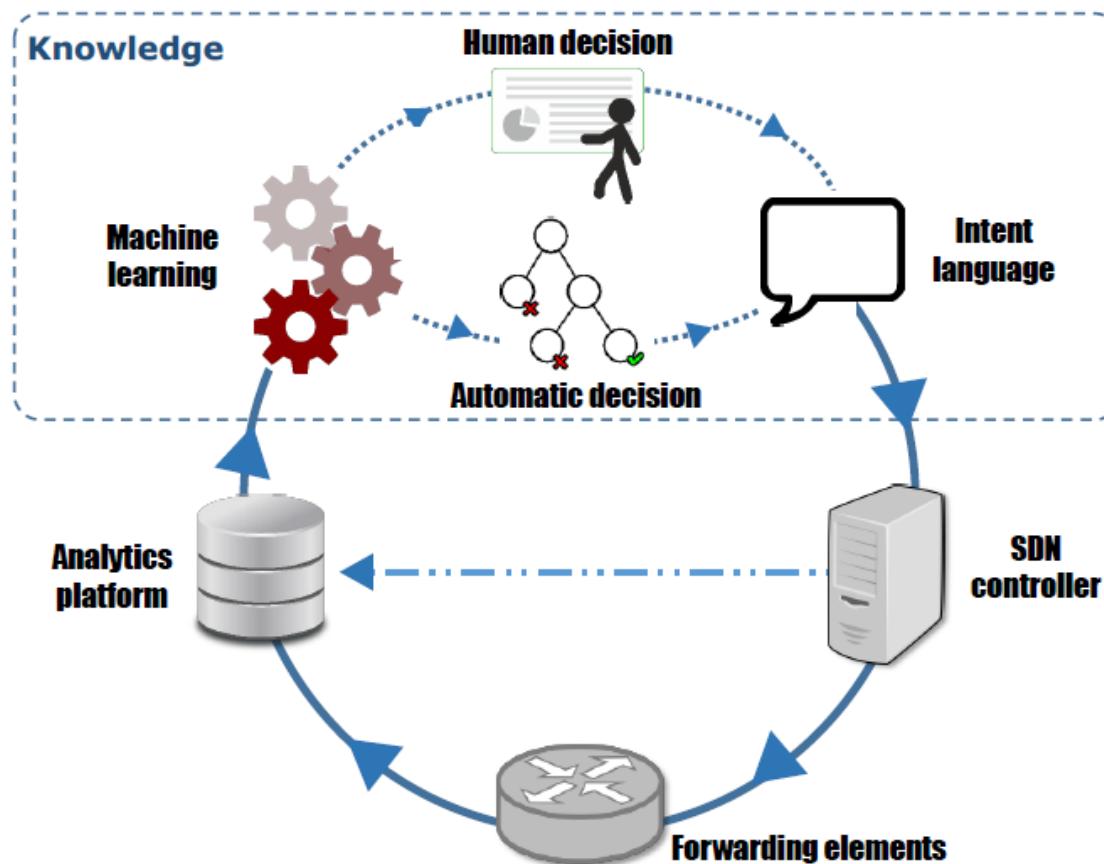
- ✓ What did we do in the last lecture (December 9)?
 - Run the fourth Panel session on the Internet of 2030 proposed by Huawei
 - Started Chapter 5 on New Networking Paradigms
 - Prof. Albert Cabellos introduced the Graph Neural Network and Knowledge Defined Networking concepts

December 16, 2020 (II)

- ✓ What did we learn/refresh/understood?
 - We learned about the existence of
 - The KDN (Knowledge Defined Network) concept. Consisting of introducing of a Knowledge Plane where to apply Machine Learning techniques to enhance the Networking features
 - Those of the Control Plan (in line dynamics), e.g., routing, resource allocation, resource optimization, congestion detection, etc.
 - Those of the Management Plan (off line dynamics), e.g., network planning, load estimation, etc.
 - Deep Reinforcement Learning concept. (Deep Learning + Reinforcement Learning). Artificial intelligent algorithms for self-driving networks
 - E.g., optimization of routing algorithms (routing based on QoS/QoE requirements)

December 16, 2020 (III)

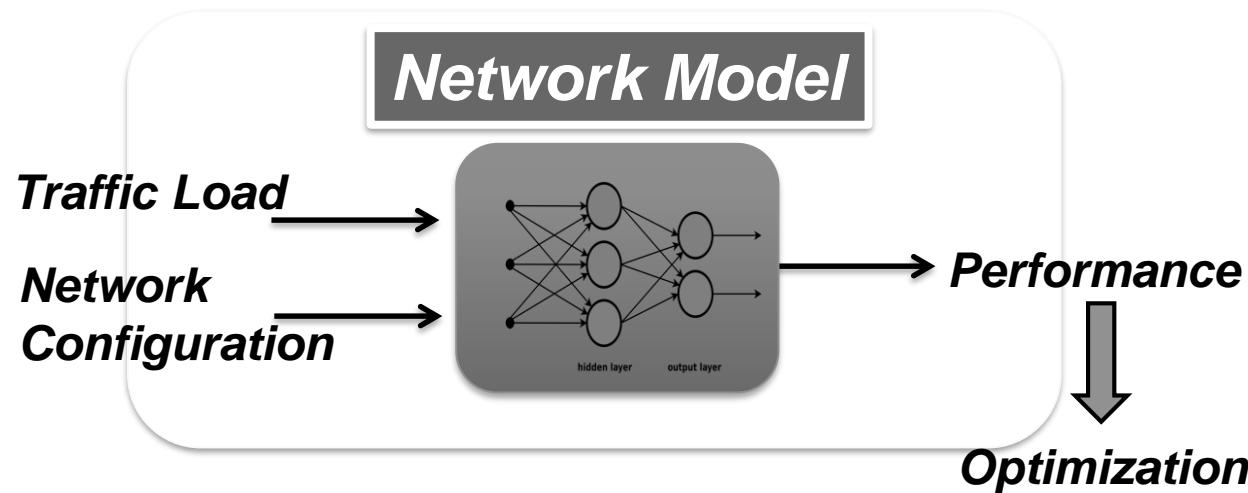
- In summary, the KDN model can be used either off line (open loop) and inline (close loop)...



December 16, 2020 (IV)

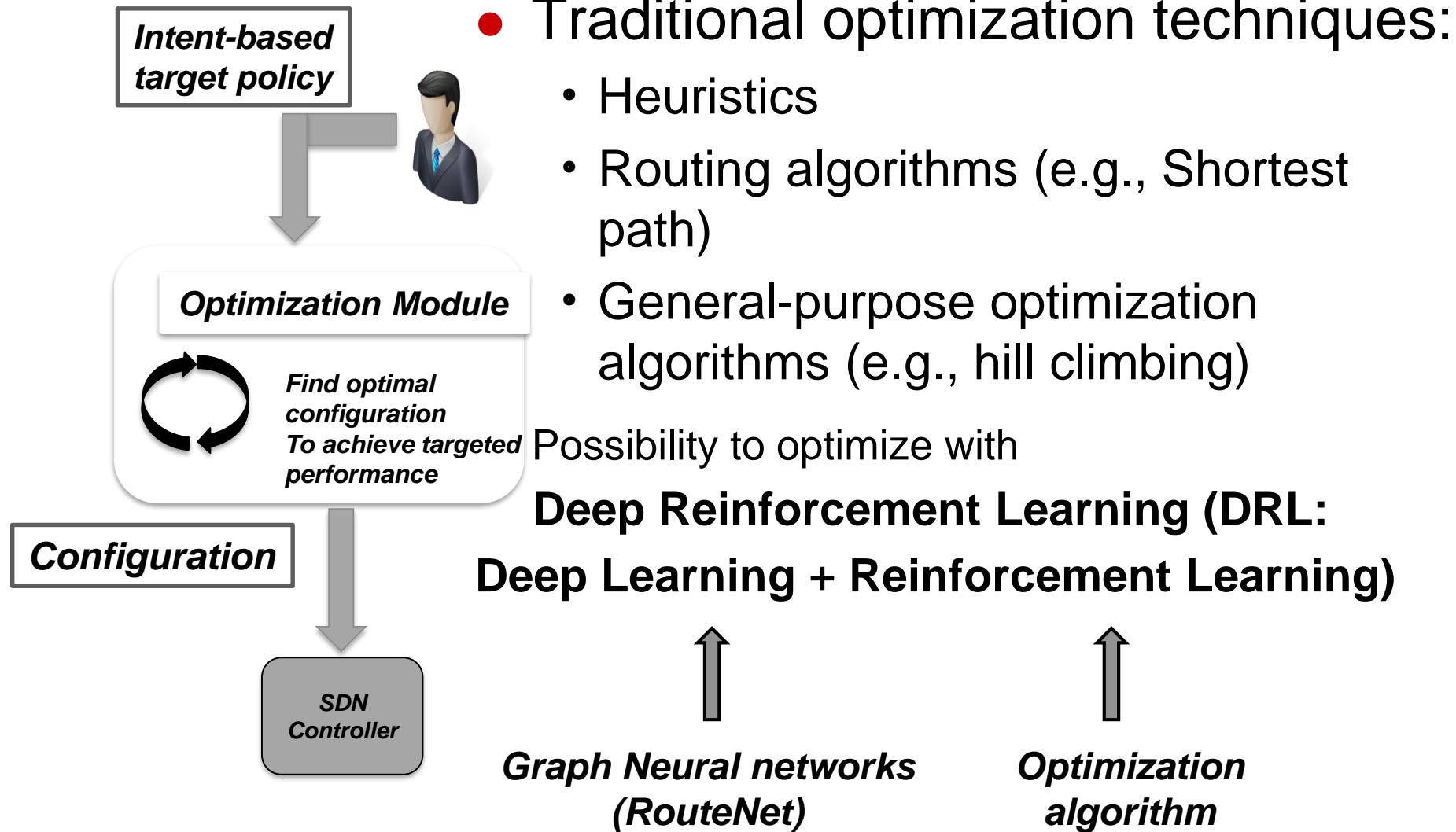
- ✓ What did we learn/refresh/understood?
 - We also learned:
 - That there are three ways for modeling a network we want to study to see how it behaves (evaluate the performance) to then optimize, namely:
 - Analytically, which usually does not work because of the number of assumptions that requires
 - By simulation, which works, but the more complex is the network, the higher is the computation time required. This makes it unpractical for complex networks
 - Using Neural Networks (Machine Learning), which based on building a "Digital Twin" of the network and learn from it. The obtained knowledge teach us about the network performance we were looking for... **here is where Graph Neural Networks techniques are useful**

Network Modeling: The Digital Network Twin



- Three main approaches
 - Computational Models: Simulation
 - Analytical Models: Queueing Theory
 - Our approach:
 - *Graph Neural Networks*

Network Optimization



December 16, 2020 (V)

- ✓ What will we do today?
 - Finish Chapter 5 on New Networking Paradigms
 - Invited Lecturer: Dr. Sergí Abadal, who will talk about Graphene-enabled Wireless Communications at the nanoscale, and its applications to
 - Networks-on-chip
 - Reconfigurable metamaterials (if time)

December 16, 2020 (Vi)

✓ Notices

- Progress meeting on the Technical Report status: December 21 to 23
 - Reply my mail to set-up an appointment
- On December 24, I will be launching the sixth (last) set of questions:
 - Requesting to prepare 2 questions with their correspondent solutions, one about KDN and GNN, and another about Graphene-enabled Wireless Communications
 - Deadline for posting the questions in ATENEA: January 13, 2021 (11:00 am.)
 - Evaluation period: From January 13 to January 20, 2021 (at midnight)
- Deadline for submitting the last version of the Technical Report: January 11, 2021, before midnight

December 16, 2020 (VII)

- ✓ Next year activity (January, 2021)
 - January 13 (Wednesday), from 15 to 18 pm.
 - Technical Reports presentation : Groups 2 and 3
 - Classroom: A6-105
 - January 20 (Wednesday), from 15 to 18 pm.
 - Technical Reports presentation of Groups 4 and 1
 - Classroom: A6-105
 - January 22 (Friday), from 15 to 18 pm.
 - Second midterm exam
 - Classroom: A6-105