Xarxes de computadors II

Actividad complementaria: presentaciones

Davide Careglio, Marc Ruiz

Evaluación

- Tres componentes
  - Evaluación continuada de la teoría (NT)
  - Laboratorio (NL)
  - Actividad complementaria (AC)
- Nota Teoría (NT)
  - Primer parcial (C1) a mitad del curso
  - Segundo parcial (C2) al final dl curso
  - NT = 50% C1 + 50% C2
- Nota Laboratorio (NL)
  - Media de los 5 minicontroles (NL)
  - NL = (Lab 1 + Lab 2 + … + Lab 5) / 5

Nota final (NF)

NF = 60% NT + 25% NL + 15% AC

- Actividad Complementaria (AC)
  - Nota grupo sobre el material de la presentación (NG)
  - Nota individual de la presentación oral (NI)
  - AC = 50% NG + 50% NI

Actividad complementaria

- Profesor
  - Una clase a finales de abril dedicada a la investigación actual sobre los temas tratados en teoría
  - Clase enfocada también en la competencia transversal "Sostenibilidad y compromiso social"
  - Al final de esta clase se propondrán algunos temas

- Alumnos
  - Hay que formar grupos de 2/3 personas, elegir uno de los temas presentados o elegir un tema diferente pero claramente relacionado con XC2
  - Al cabo de 3 semanas (final de curso), cada grupo tendrá que entregar una presentación (mínimo 14 paginas, máximo 25) sobre el tema investigado
  - Hacer una presentación pública de 15 minutos máximo
  - Al acabar la presentación se abre un turno de preguntas/debate donde deben participar todos los demás alumnos

- Evaluación
  - Material preparado, presentación y participación en las preguntas/debate

Presentaciones

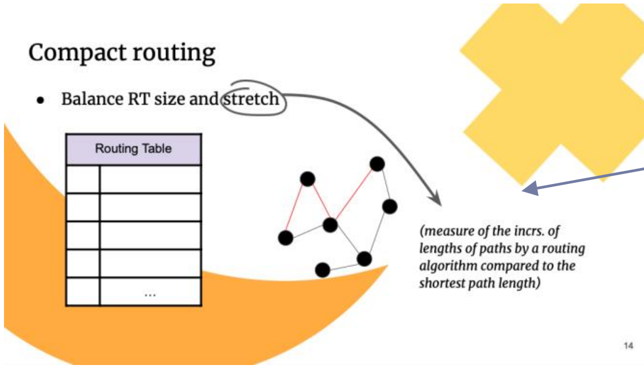
- 19 matriculados (18 se han presentado al primer control)
  - 9 grupos de 2 personas
- 15 minutos por grupo + 3/5 debate
- Presentaciones: 15 y 17 de Diciembre
- Participación obligatoria a todas las presentaciones
- Se evalúa también la participación en los debates

- **Calendario**
  - **Antes del 24/11 entregar por Racó un fichero con los nombres, el tema elegido y el día de presentación**
  - **<u>Entregar limite de la presentación por Racó es el 14/12 a las 23.59</u>**

Presentaciones

Criterios	Peso	Bien 8,1 - 10	Regular 4,1 -8	Mal 0 – 4
Formato	5%	Se utiliza un buen formato de presentación, número de paginas, índice y notas para explicar cada diapositiva.	Faltan algunas cosas, hay más de un 20% de páginas sin notas explicativas.	Se ha usado un formato incompleto, no hay notas explicativas.
Referencias	10%	Las referencias consultadas se incluyen al final y se enumeran a lo largo de la presentación	No se indican referencias a lo largo de la presentación, pero la lista se incluye al final.	Se han incluido menos de 4 referencias al final de la presentación.
Contenido	35%	El contenido es excelente, buena abstracción del tema y la presentación es clara y concisa.	El contenido es aceptable, se entiende, pero hay mucha información poco útil.	El contenido es pobre, no se entiende, es escaso y redundante.
Presentación	35%	Claro, conciso y comprensible; formas adecuadas (voz, ritmo, colocación, gestión de la audiencia), ajustadas al tiempo disponible. Contesta a las preguntas. Coordinación entre los miembros del equipo.	La explicación se entiende, pero es complicada. Formas aceptables, pero no controladas. Problemas en la resolución de dudas. Poca coordinación en el equipo.	El público no puede entender la explicación. No mantiene formas. No se sabe responder a preguntas. No hay coordinación en el equipo.
Participación	15%	Optima participación en los debates, formulación de preguntas con criterio.	Participación en los debates y formulación de preguntas.	Poca o nula participación. Formulación de preguntas sin sentido.

Presentaciones



Diseño claro, coinciso, atrae el interés

Número de página

Pero, no hay notas explicativas

Les Xarxes Definides per Programari (SDN) ofereixen una gran varietat d'aplicacions i casos d'ús en diferents àmbits. A continuació, es presenten alguns exemples destacats:

1. Centre de dades virtualitzat: En un centre de dades virtualitzat, les Xarxes Definides per Programari (SDN) proporcionen una solució flexible i escalable per gestionar la connectivitat de les aplicacions i els recursos de xarxa. Mitjançant un controlador SDN, es crea una capa d'abstracció que permet la creació de xarxes virtuals lògiques (VLANs) que s'executen sobre la infraestructura física compartida.

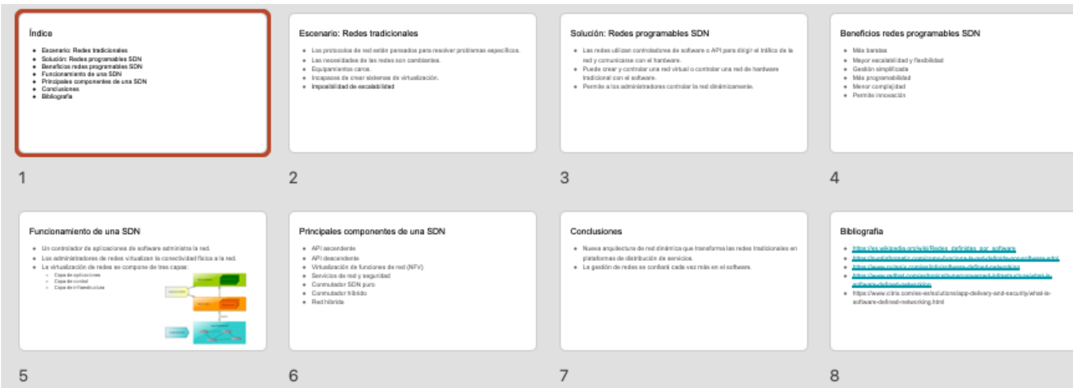
   En aquest escenari, el controlador SDN actua com a punt central de control per a totes les decisions de commutació i encaminament. Les polítiques de xarxa, com

No hay referencia del origen de las figuras

Número de página

Hay notas explicativas

Presentaciones

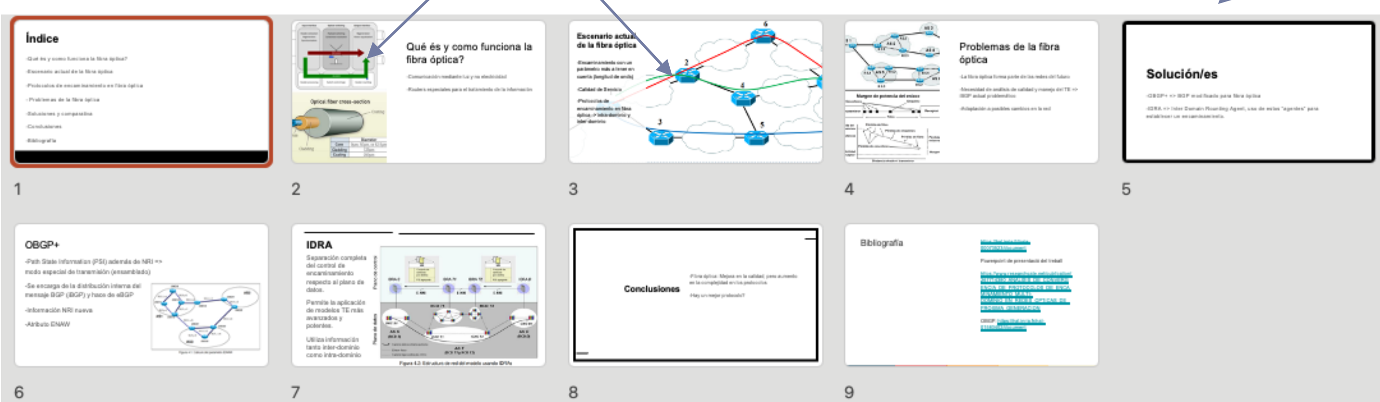


8 páginas en total

Mayoría es texto
Una figura, sin referencia del origen
No hay diseño
No hay número de página

No hay diseño
No hay número de página
Bibliografía antigua (ya no es investigación)

Uso de imagenes de mi misma presentación sin referenciarlo



Estructura

- Portada: introducción de los miembros del grupo y del tema a tratar (1)
- Índice de la presentación: de que se va a hablar y en que orden (1)
- Escenario: presentación del entorno que se va a tratar (1/2)
- Tema/problema: identificación del problema/tema concreto dentro del entorno anterior que se va a tratar (1/2)
- Solución/argumentación: descripción de la o las soluciones (4/5)
- Comparativa: entre las soluciones presentadas y con otras alternativas (2/3)
- Conclusiones y líneas futuras (1)
- Bibliografía (1)

- Material de backup (n)

Temas presentaciones

- Debe ser un tema actual de investigación
- De libre elección pero claramente relacionado con los conceptos y temas explicados en XC2
- Ejemplos

1) Alternatives to IP: ICN, RINA, etc.
2) Routing protocols in optical networks (flexible, multi-cores, etc.)
3) Improving BGP
4) Sustainable Internet
5) Software Defined Network (SDN) / Network Function Virtualisation (NFV)
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7) Quantum networks and communication
8) 6G networks

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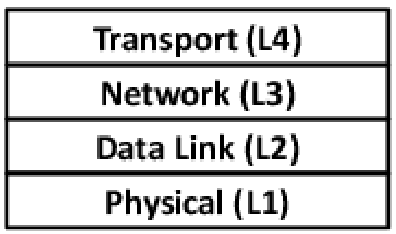
Alternativas a IP

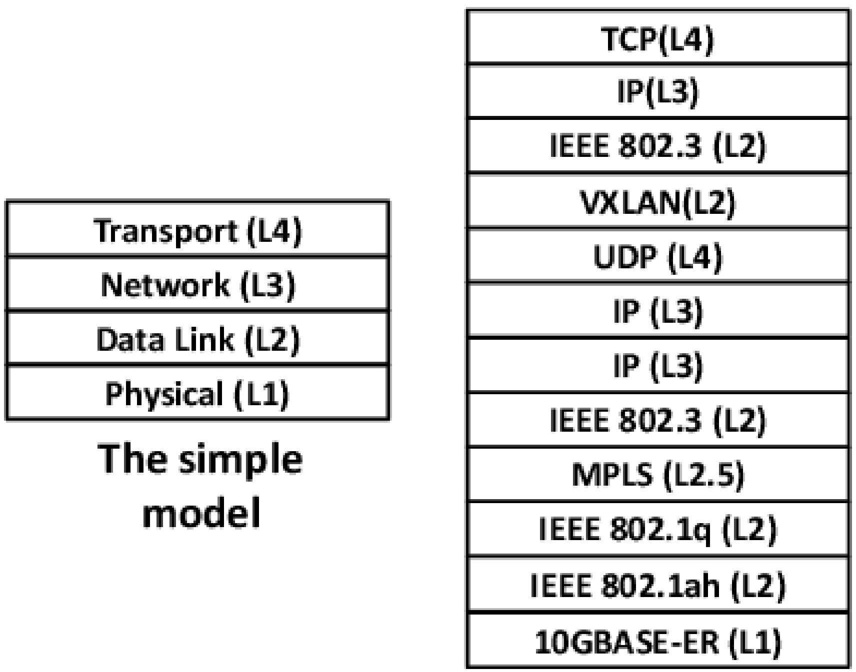
- ¿Por que?
  - Idea inicial



The simple model

Alternativas a IP

- ¿Por que?
  - Realidad

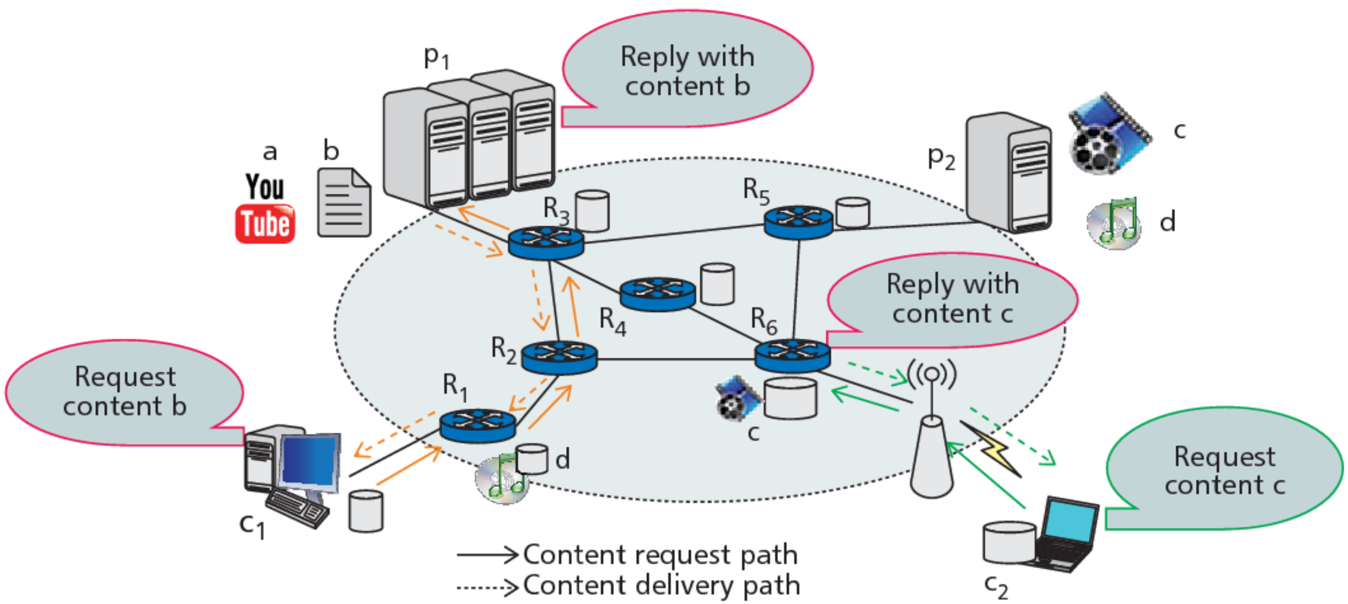


The simple model

The complex reality (just an example)

Alternativas a IP
Information Centric Networking

- Based on content rather than @IP/locators



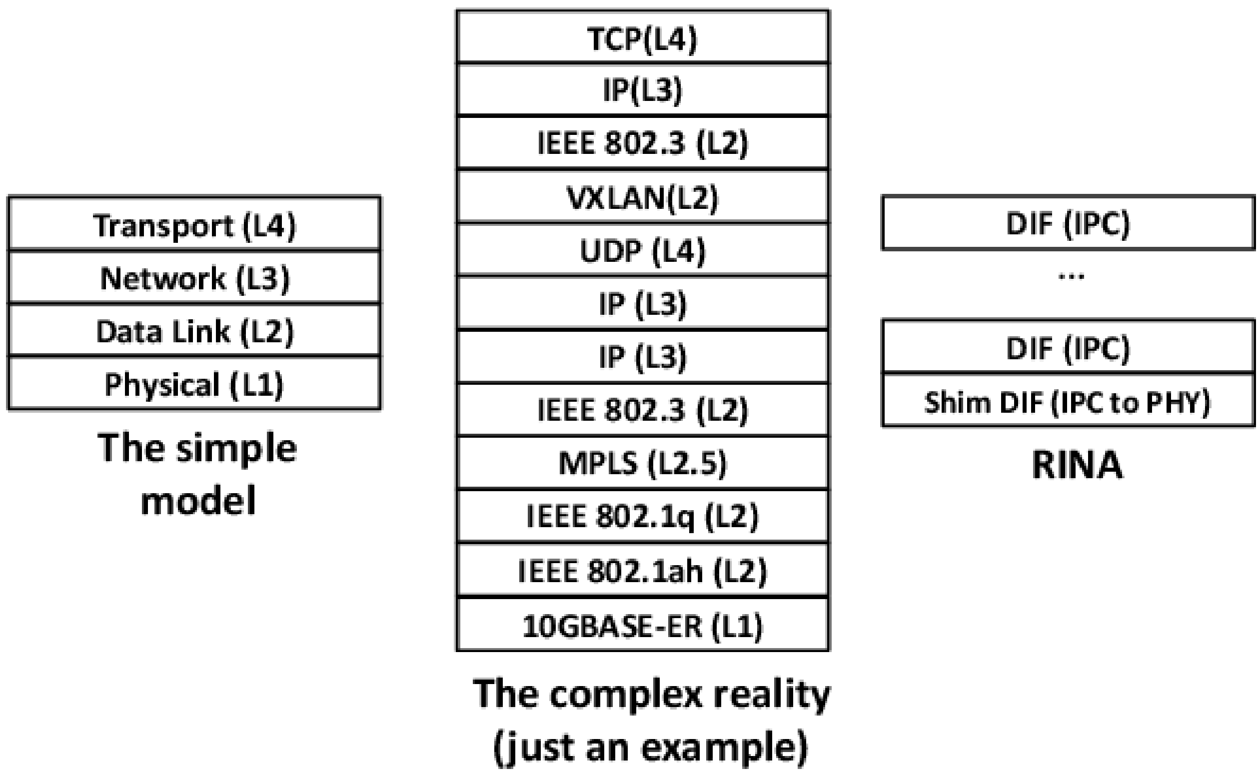
  - Users send content requests
  - Routers keep temporary copies of the contents
  - Routers deliver contents from own copies or from other trusted sources

Fuente imagen: M. Amadeo *et al.*, "Information-centric networking for the internet of things: challenges and opportunities," in *IEEE Network*, vol. 30, no. 2, pp. 92-100, March-April 2016, doi: 10.1109/MNET.2016.7437030

Alternativas a IP

Recursive Internetwork Architecture

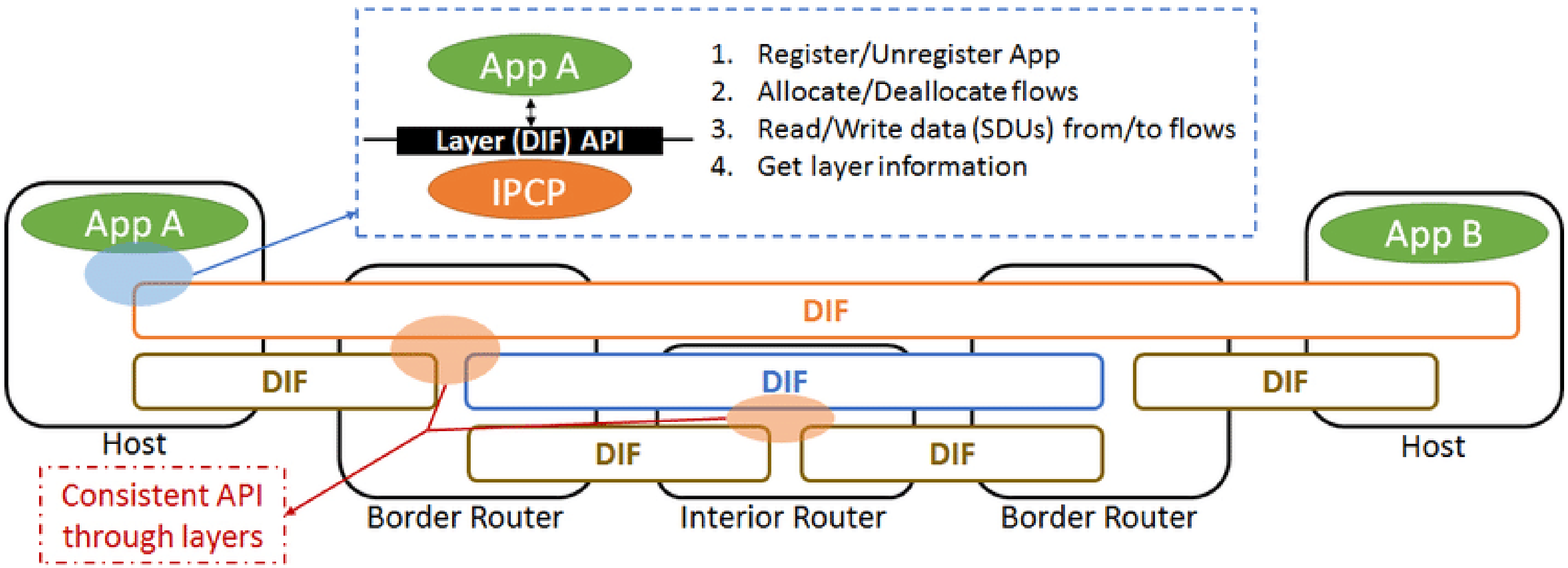
- One single layer called DIF that can be recursively used with different scopes
- Communication inside a DIF is performed by InterProcess Communication (IPC)



Alternativas a IP

Recursive Internetwork Architecture

- One single layer called DIF that can be recursively used with different scopes
- Each DIF is programmable with different policies (routing, addressing, authentication, security, etc.)



- Secure by design
- Computer networking is just Inter-Process Communication

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- Amadeo, Marica et al. "Information-centric networking for the internet of things: challenges and opportunities." IEEE Network 30 (2016): 92-100.
- https://datatracker.ietf.org/rg/icnrg/about/
- John Day, *Patterns in Network Architecture: A Return to Fundamentals*, Prentice Hall, 2008, ISBN 978-0132252423
- Vincenzo Maffione, Francesco Salvestrini, Eduard Grasa, Leonardo Bergesio, Miquel Tarzan, "A Software Development Kit to exploit RINA programmability", ICC 2016, doi: 10.1109/ICC.2016.7510711.
- https://i2cat.net/recerca/5g-iot-rina-recursive-internetwork-architecture/?lang=ca

- Estas referencias, como las que vendrán a continuación, son solo puntos de partida, una o más significativas sobre la tecnología.
- Vuestra tarea es buscar referencias significativas, sobre todo las más recientes, para conocer el estado actual.

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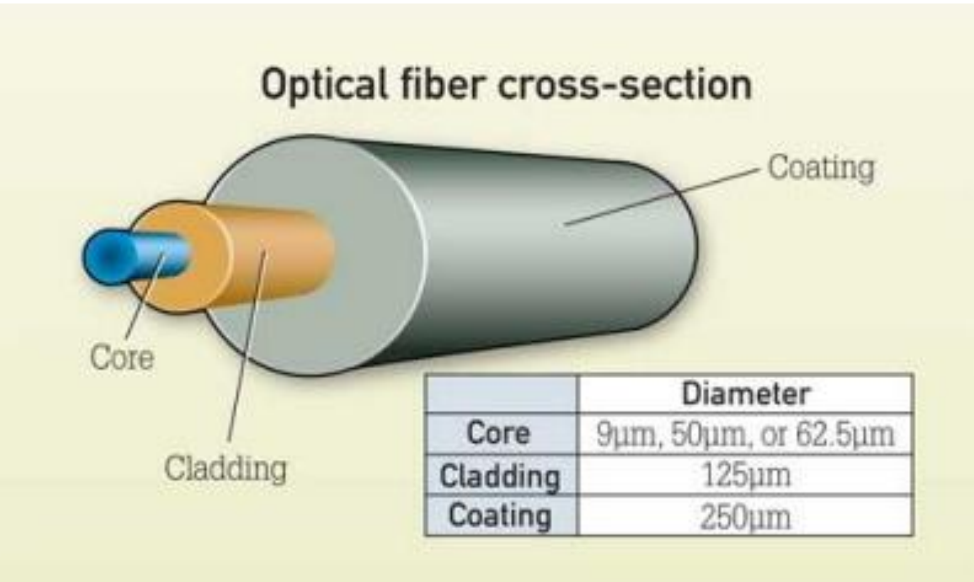
Optical fibre

- Optical fibres and connectors

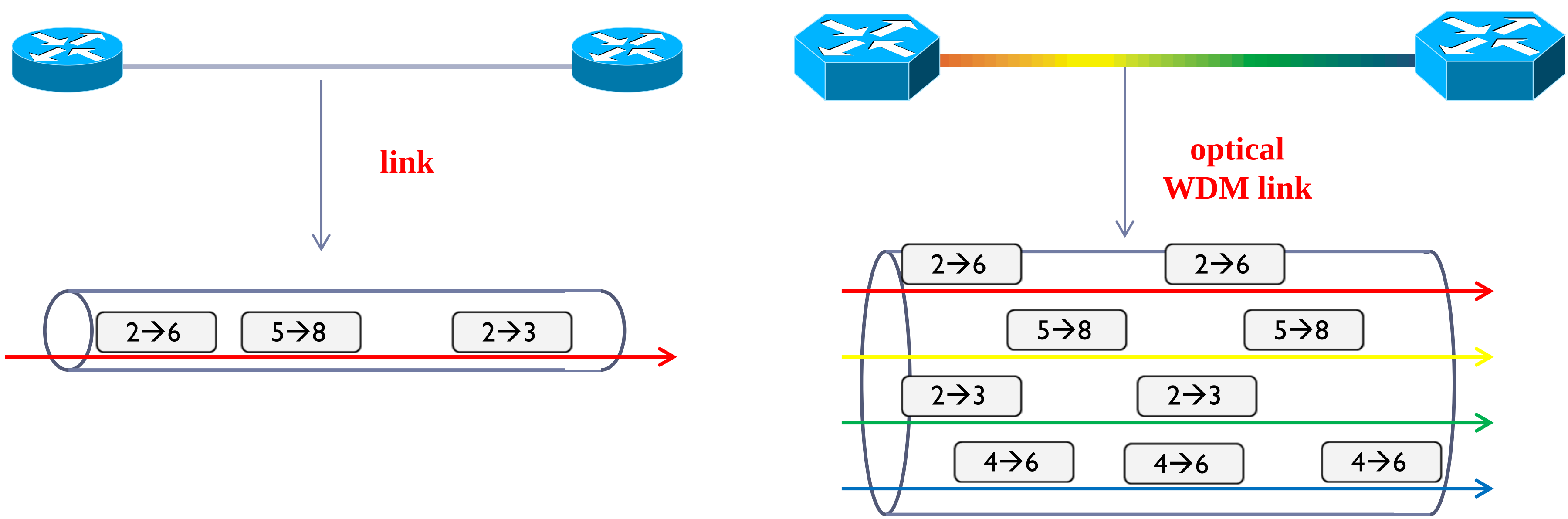


	Diameter
Core	9µm, 50µm, or 62.5µm
Cladding	125µm
Coating	250µm

- The outer jacket may contain one or multiple fibres
- The plastic coating protects the fibre
- The cladding keeps the optical signal in the fibre
- The core is where the optical signal passes
  - Cladding and core are silicon (it is not a conductive medium, there is no electricity)

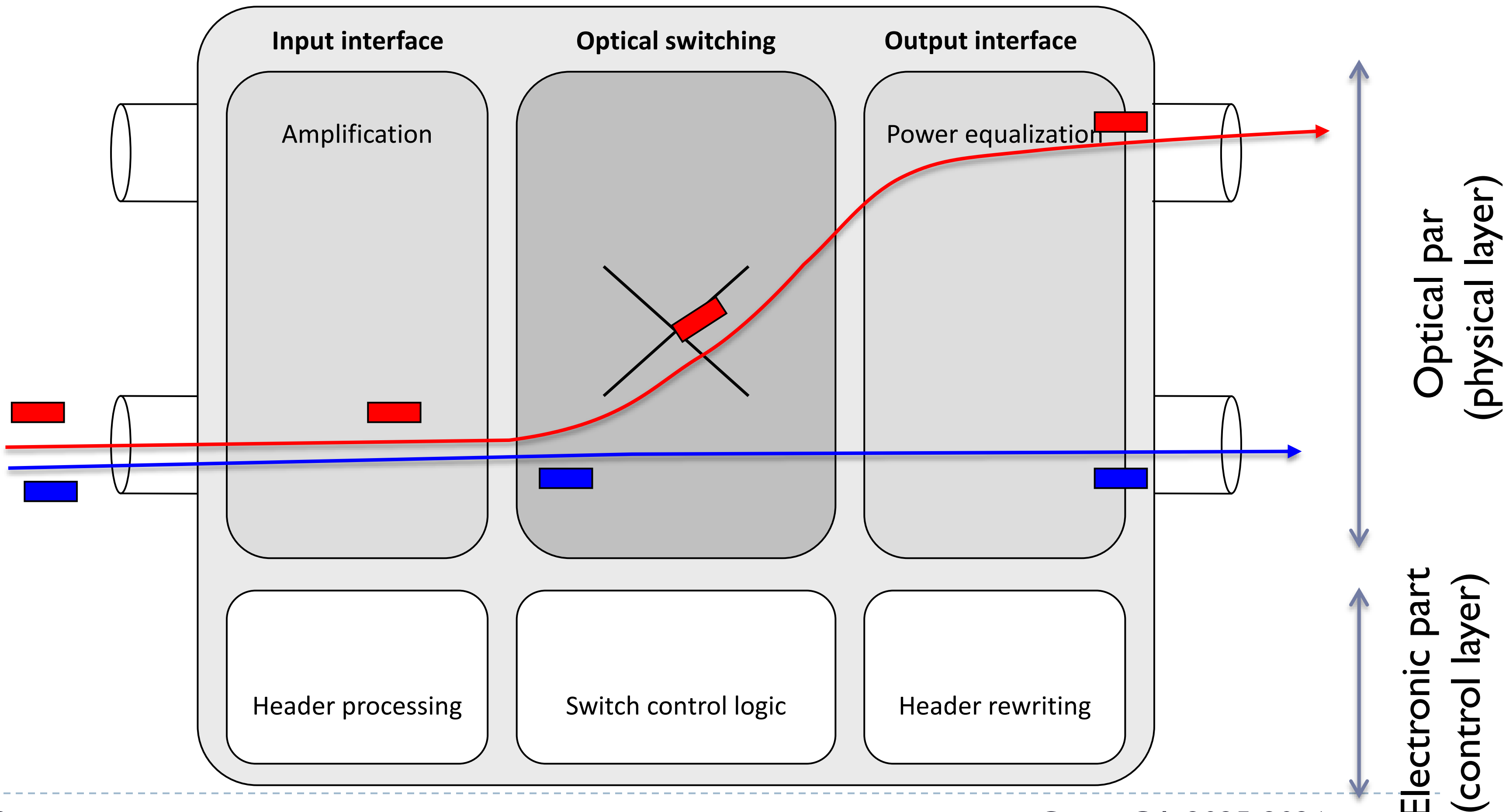
Scenario

- Optical networks
  - very high capacity
  - possibility to transmit many signal at the same time at different wavelengths (80–160 wavelengths per fiber) -> Wavelength Division Multiplexing (WDM)
  - the bitrate of each wavelength can be: 2.5, 10, 40, 100, 400 Gbps



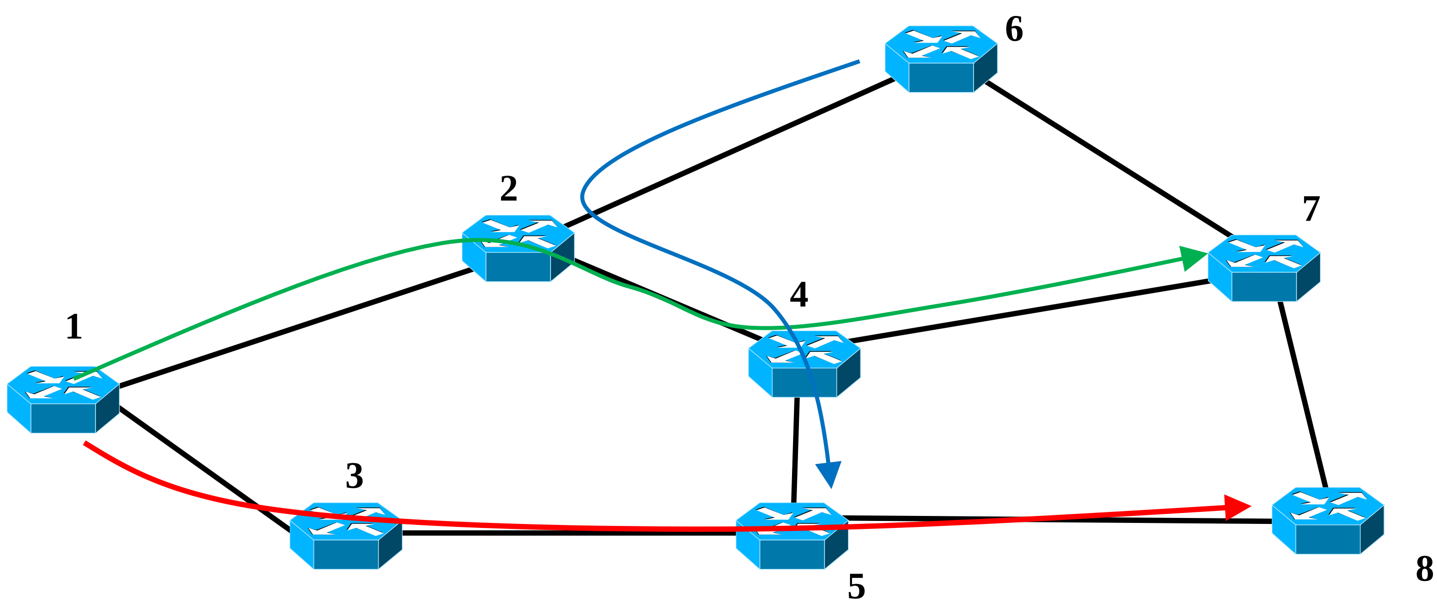
Optical router (ROADM or WXC)

- Packets flow through the nodes without any change
- The path inside the node is almost fix and determined in advance



Problem formulation
the RWA problem

- The problem becomes a Routing and Wavelength Assignment (RWA) problem since it requires
  - selection of the path between source and destination
  - selection of the wavelength at each link from source to destination
  - the resulting path + wavelength is called **lightpath**



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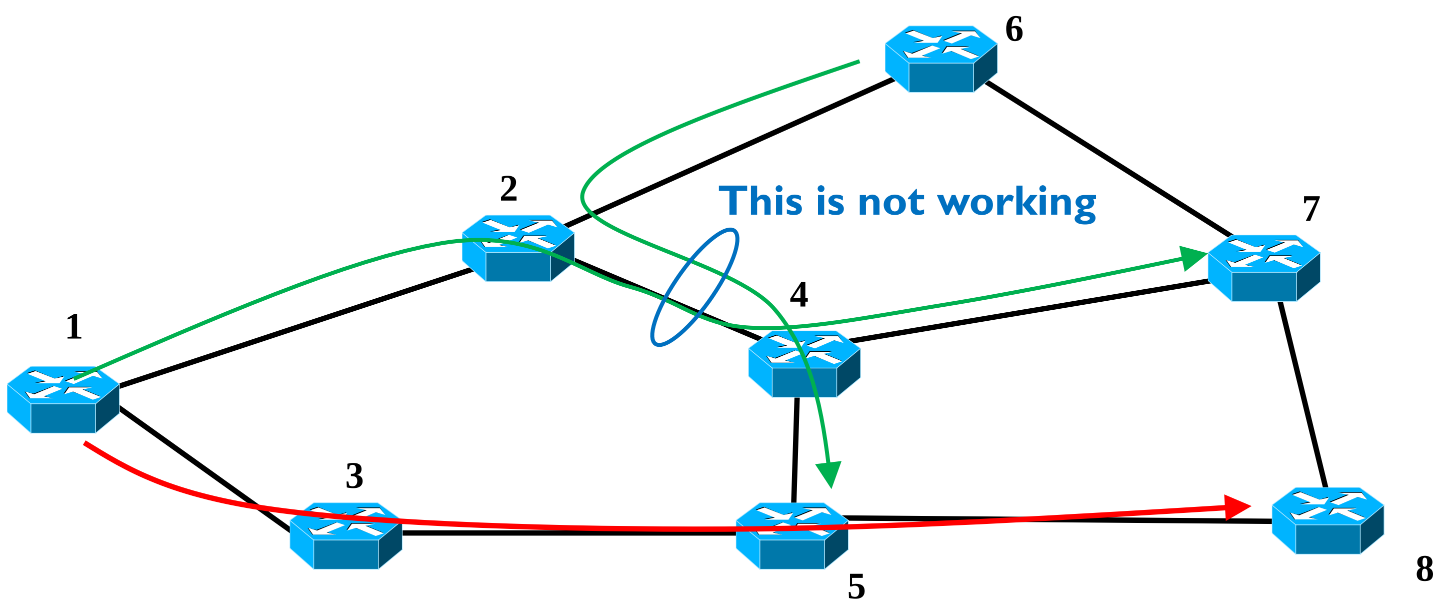
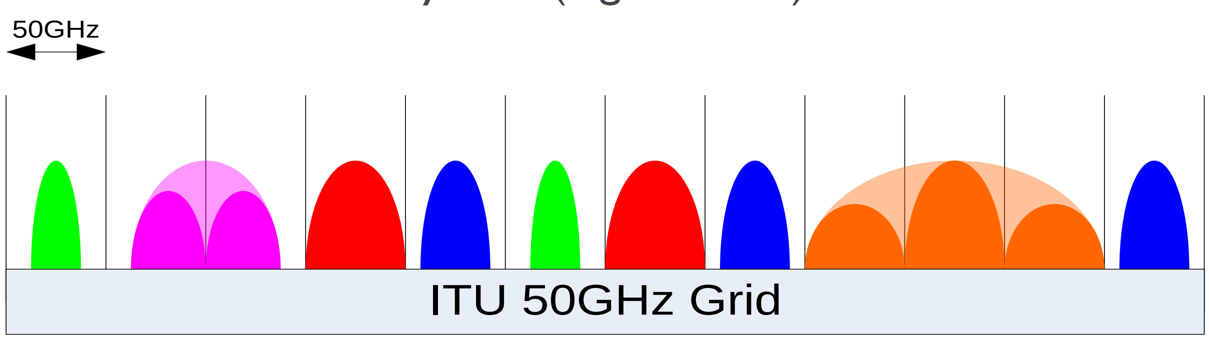


RWA solution

- RWA is NP-complete
- Apply approximate algorithms
- Decouple the routing and the wavelength assignment into two sub-problem
  - find optimal routing paths (by means e.g. of optimization technique)
  - apply simple wavelength assignment solutions like first-fit

WDM but

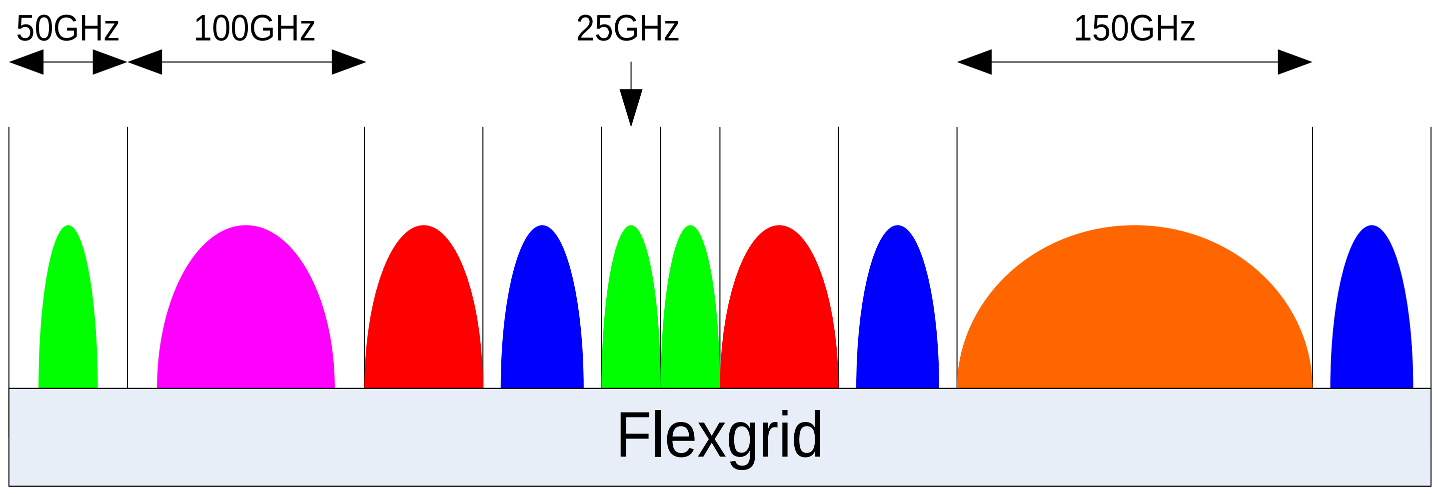
- 100 Gbps is expected to meet operator needs in the short to medium term, but traffic growth will lead to mixed line rates including 400 Gbps and 1 Tbps in the long term
- Existing DWDM systems are inflexible in two distinct ways:
  - The transponder has a fixed bit rate – for example of 10 Gbps or 40 Gbps.
  - The spectral width of each wavelength signal cannot extend beyond the fixed ITU grid width used in the system (e.g. 50 GHz)



  - Large bandwidth demands will have to be divided up so that they can be carried over the fixed grid
  - This results in a highly inefficient use of the network capacity

Flexible Optical Network

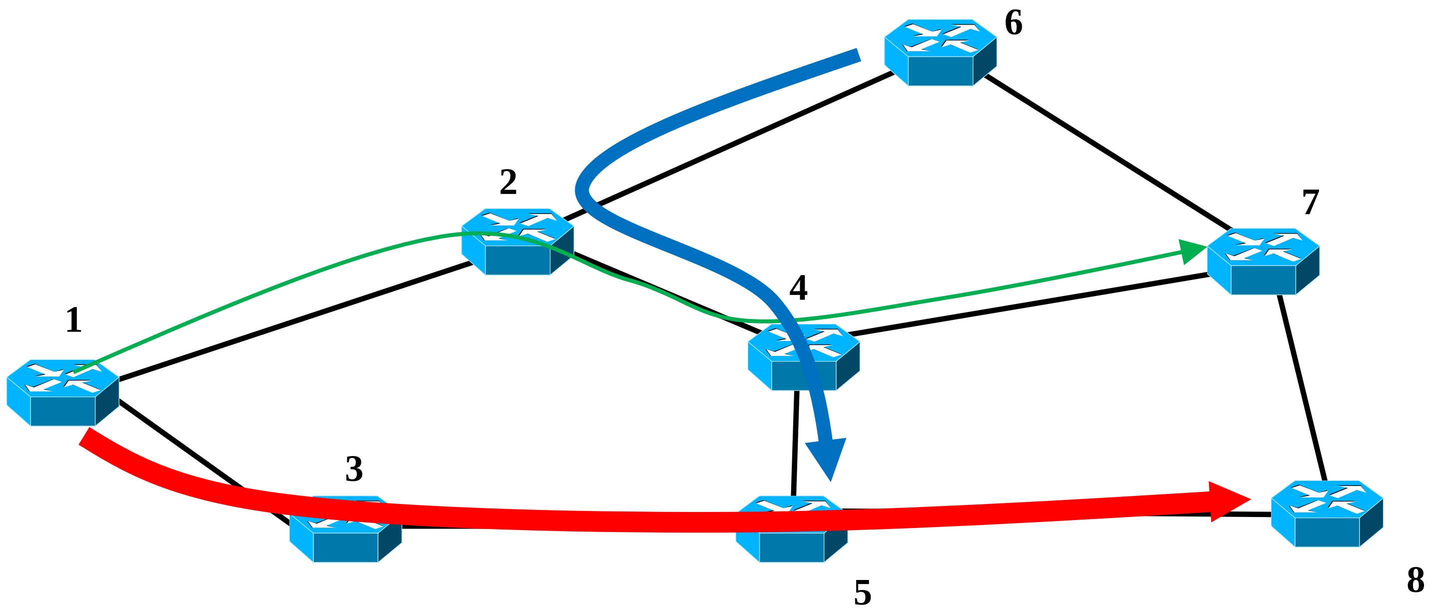
- An elastic optical transport network based on a combination of Bandwidth Variable Transponders and Flex-grid might enable a more flexible optical spectrum use
- Grid boundaries could be set in the most appropriate place



Flexible Optical Network

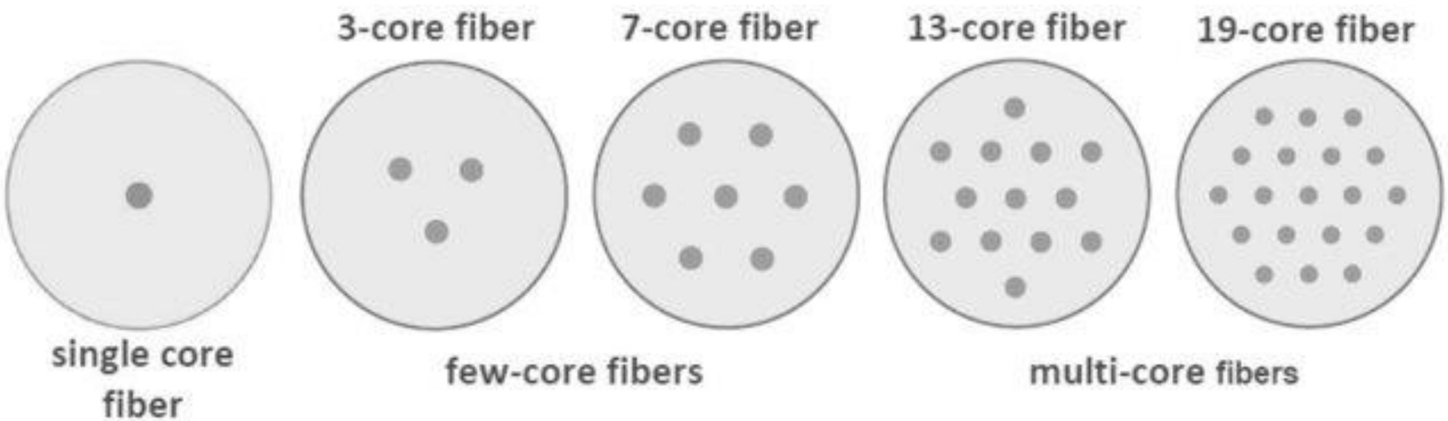
- The routing problem becomes a Routing and Spectrum Assignment (RSA) problem
- Determine a route and a spectrum width subject to
  - Spectrum continuity constraint (i.e., the same slots must be used in all the links of the path)
  - Spectrum contiguity constraint (i.e., the slots must be contiguous in the spectrum)
- As RWA, RSA is NP complete
  - Apply approximate algorithms
  - Decouple the routing and the spectrum assignment into two sub-problem

- The problem becomes a Routing and Spectrum Allocation (RSA) problem since it requires
  - selection of the path between source and destination
  - selection of the spectrum width from source to destination



Multi-core fibres

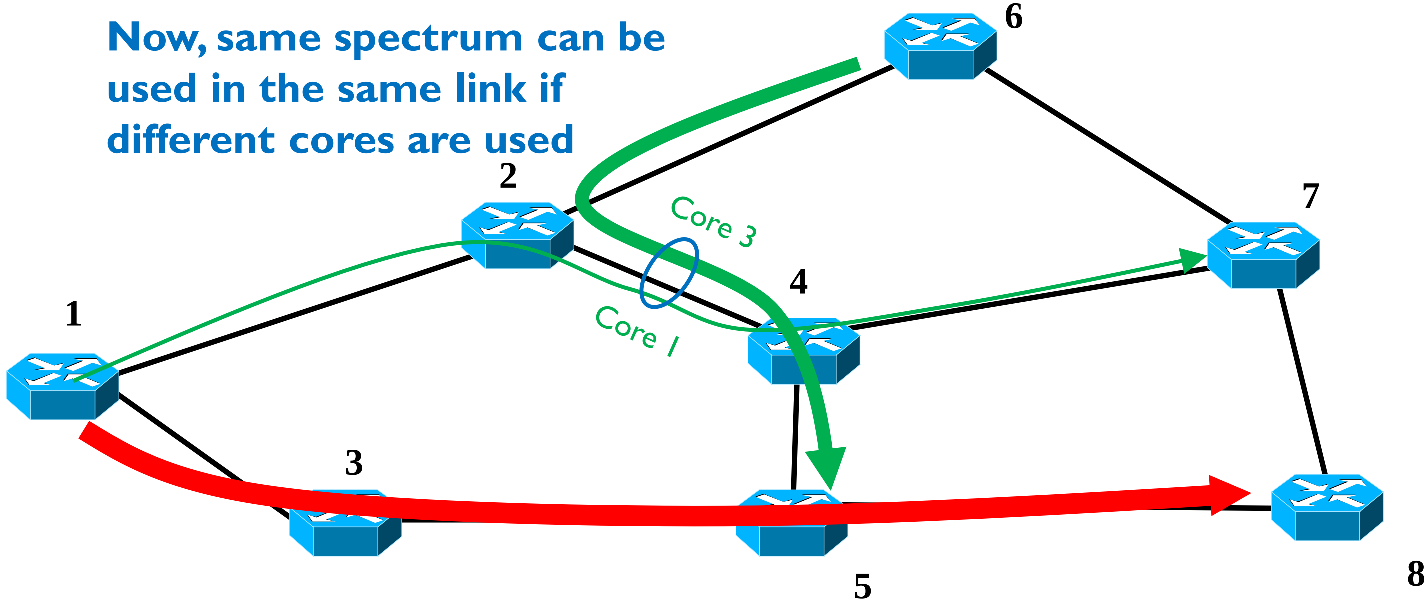
- One single cladding but multiple cores



- Besides route and spectrum, multi-core fibres introduce a third dimension: the space
- The problem becomes a routing, spectrum and core assignment (RSCA) problem

Multi-core fibres

- The problem becomes a routing, spectrum and core assignment (RSCA) problem



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- O. Pedrola, A. Castro, L. Velasco, M. Ruiz, J. Fernández-Palacios, D. Careglio, "CAPEX study for a multilayer IP/MPLS over FlexGrid optical network", IEEE/OSA Journal of Optical Communications and Networking, vol. 4, no. 8, pp. 639-650, August 2012, ISSN: 1943-0620.
- Hideki Tode and Yusuke Hirota, "Routing, Spectrum, and Core and/or Mode Assignment on Space-Division Multiplexing Optical Networks", IEEE/OSA Journal of Optical Communications and Networking, vol. 9, no.1, Jan. 2017.
- F. Yan, W. Miao and N. Calabretta, "OPSquare: A flat DCN architecture based on flow-controlled optical packet switches", IEEE/OSA J. Opt. Commun. Netw., vol. 9, no. 4, pp. 291-303, 2017.
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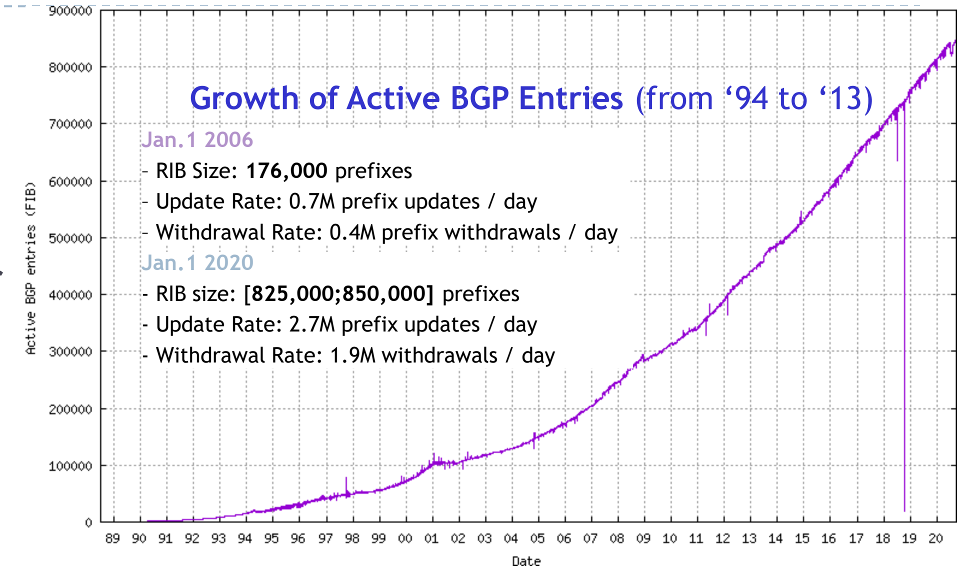
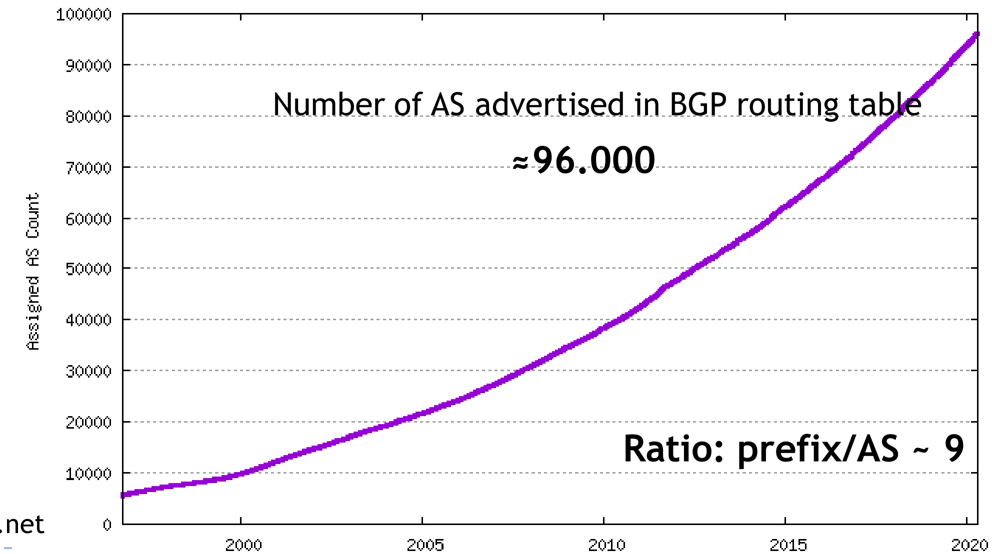
Current situation (1/2)

- Traffic
  - Traffic volume (per month): Exabytes
  - Traffic growth rate: 50% (+/- 5%) per year
- Routing tables size
  - Growth rate: 15%-25% per year
  - Number of active RT entries: 830k (202')
- Autonomous Systems (AS)
  - Growth rate: 10% per year
  - Number of advertised AS: 96k (2020)
- Average AS-path length: steady ~3.4

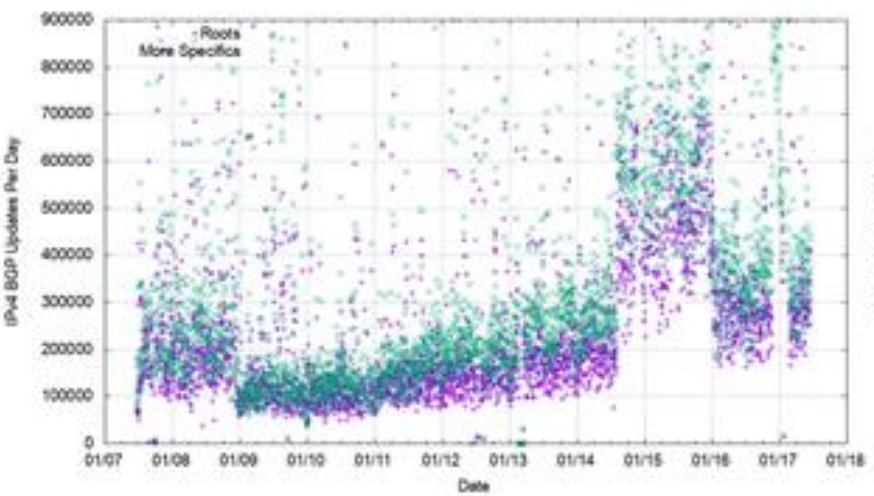




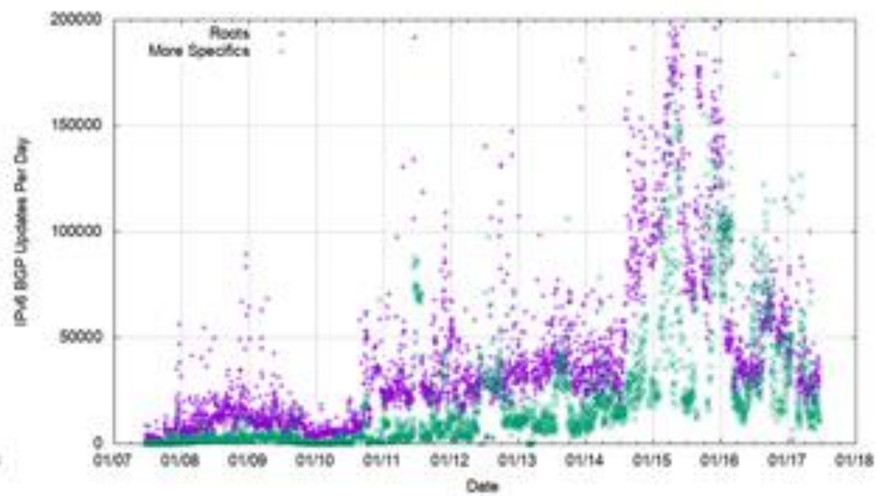
Source: BGP Routing Table Analysis Reports - http://bgp.potaroo.net

Current situation (2/2)

- Dynamics BGP updates (routing convergence)
  - Between Jan.2007 and Jan.2018: prefix update and withdrawal rates per day are continuously increasing
  - Average: 3-4 per sec. – Peak: over 1.000.000 per day.



IPv4



IPv6

Source: RIPE labs - https://labs.ripe.net/author/gih/bgp-more-specifics-routing-vandalism-or-useful/

Solutions space: evolutionary vs. revolutionary

Short-term solutions

- Geographical routing
- Overlay routing such as **LISP, SDN**

Compact Routing

- **Name dependent schemes**: e.g. TZ scheme, BC scheme, etc.
- **Name independent schemes**: e.g. Abraham scheme

Name routing

- **Information-centric network**
- **Content-centric network**
- **Named-data network**

Greedy Geometric Routing

- **Updatefull**: Internet topology graph embedding into hyperbolic plane (requires full view topology graph)
- **Updateless**: graph constructed from hidden hyperbolic space yielding to scale-free topologies

Recursive InterNetwork Architecture

- **Radical change of the Internet architecture:** The problem is in the Internet protocols

Compact routing

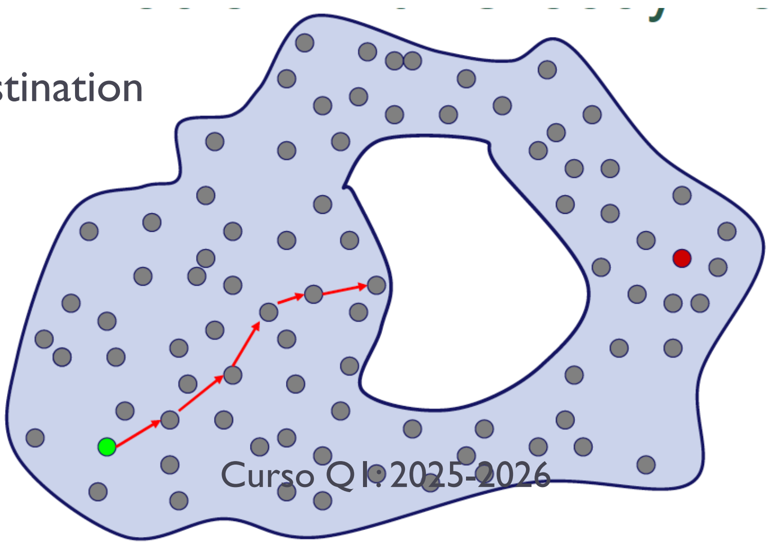
- Compact routing algorithms make RT sizes compact by omitting "some" network topology details such that resulting path length increase stays small

- Principle
  - given coherent full view of the network topology build routing algorithm that balances efficiently trade-off between stretch and size of RT

- Compact routing scheme
  - stretch bound by constant: does not grow with the network size
  - RT sizes scale sub-linearly: at most of the order of n bits of routing information stored per RT (per node)
  - may increase the communication cost (i.e. increase the number of control messages)

Geometric routing

- Principle
  - relies on geographic position information
  - source sends a message to the geographic location of the destination instead of using the network address
- Requirements
  - each node determines its own location
  - source is aware of the location of the destination
  - with this information a message can be routed to the destination without knowledge of the network topology or a prior route discovery
- Routing decision
  - forward to the neighbor that is nearest to the destination
- Problem
  - can get stuck at a local minimum (i.e. it is not able to find a global optimal solution taking only local decision in a conventional plane)



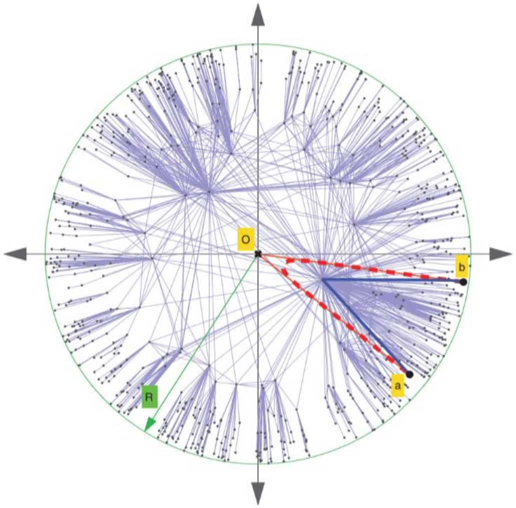
Greedy routing

- Principle of greedy
  - follow the **problem solving heuristic** of making the locally optimal choice at each stage with the hope of finding a global optimum
  - only information necessary for greedy routing to operate: coordinates of local node, its neighbors, and message destination

- Application to greedy routing
  - find the shortest paths between nodes
  - routing is performed in the dark (i.e., no routing update messages are exchanged, no knowledge of the network's global topology)
  - use the particular geometric properties of the topology to facilitate the packet routing process while keep its efficiency robust even under dynamic network conditions

- Requirement
  - require the embedding (mapping) of the network topology into an Hyperbolic plane
  - in an Euclidean (classical) plane an optimal solution cannot be found using greedy routing

Greedy routing



- Approach
  1. Build an hyperbolic space underlying the Internet topology
  2. Specify node distribution and inter-connection as a function of the hyperbolic distance between nodes
  3. Perform greedy routing in such setting

- Challenges
  - Develop technique to compute the AS/routers coordinates in the underlying hyperbolic space
    - Embedding of newly added nodes not always possible without changing coordinates of all network nodes
    - Each node shall be able to autonomously compute its hidden hyperbolic coordinates based solely on information locally accessible
  - Determine dependency of greedy routing algorithms on topologies properties

References

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  - R. Kleinberg, J. Kleinberg, "Isomorphism and embedding problems for infinite limits of scale-free graphs", 15th ACM-SIAM SODA, Jan. 2005
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  - M. Boguña, F. Papadopoulos, D. Krioukov, "Sustaining the Internet with hyperbolic mapping", Nature Communications, vol. 62, no. 1, 2010
  - Sulyok, B., Palla, G. Greedy routing optimisation in hyperbolic networks. Sci Rep 13, 23026 (2023). https://doi.org/10.1038/s41598-023-50244-8

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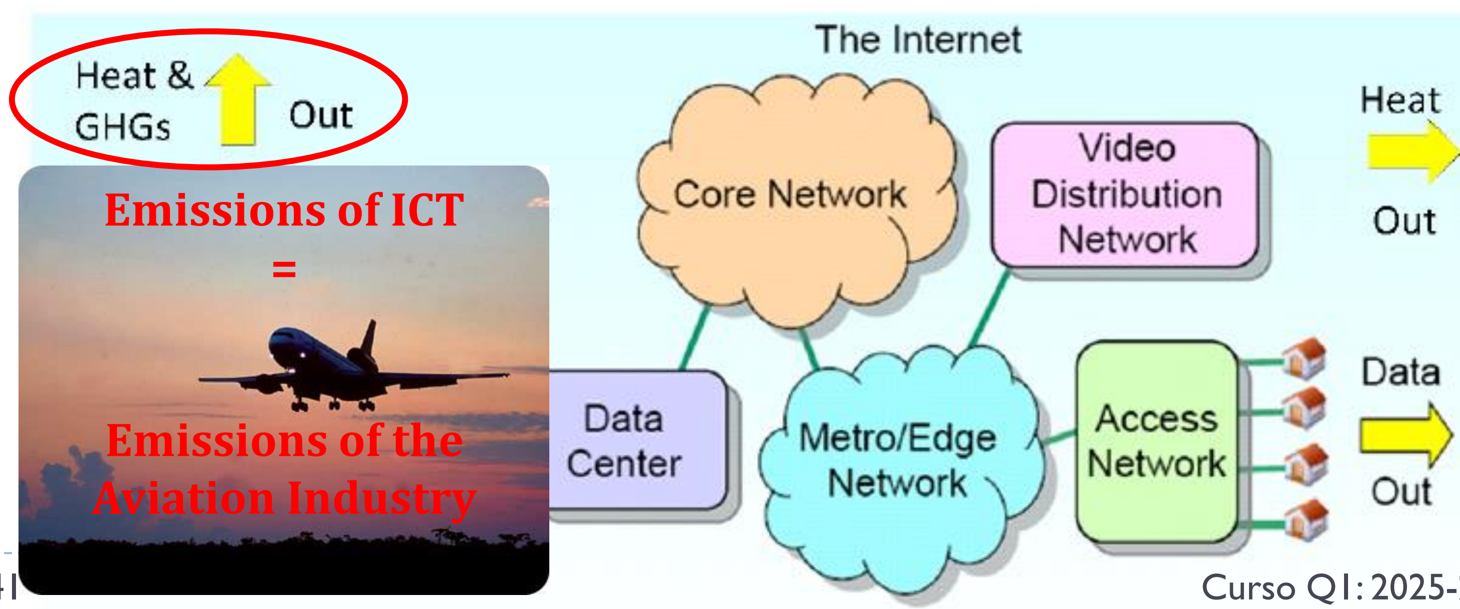
Sostenibilidad en Internet

- ICT consumes two times energy
  - Powering devices
  - UPS + Cooling (HVAC, Heating Ventilation and Air Conditioning)
- Energy consumption means GreenHouse Gases (GHG) emissions
  - Climate changes, global warming & dimming, pollution
  - Major contributors to the GH effect:
    - water vapor, carbon dioxide CO_2, methane, ozone, nitrous oxide, chlorofluorocarbons



Problem formulation (1/2)

- Define protocols, algorithms, architecture, devices, etc. able to reduce the overall energy consumption
- BUT pay attention to the rebound effect
  - i.e. do we really reduce GHG emissions increasing the energy efficiency?

Rebound effect

increased energy efficiency

$\Downarrow$

overall reduced costs

$\Downarrow$

increased demand

$\Downarrow$

energy consumption increases

$\Downarrow$

GHG emissions overtake the offset gained by energy efficiency

Problem formulation (2/2)

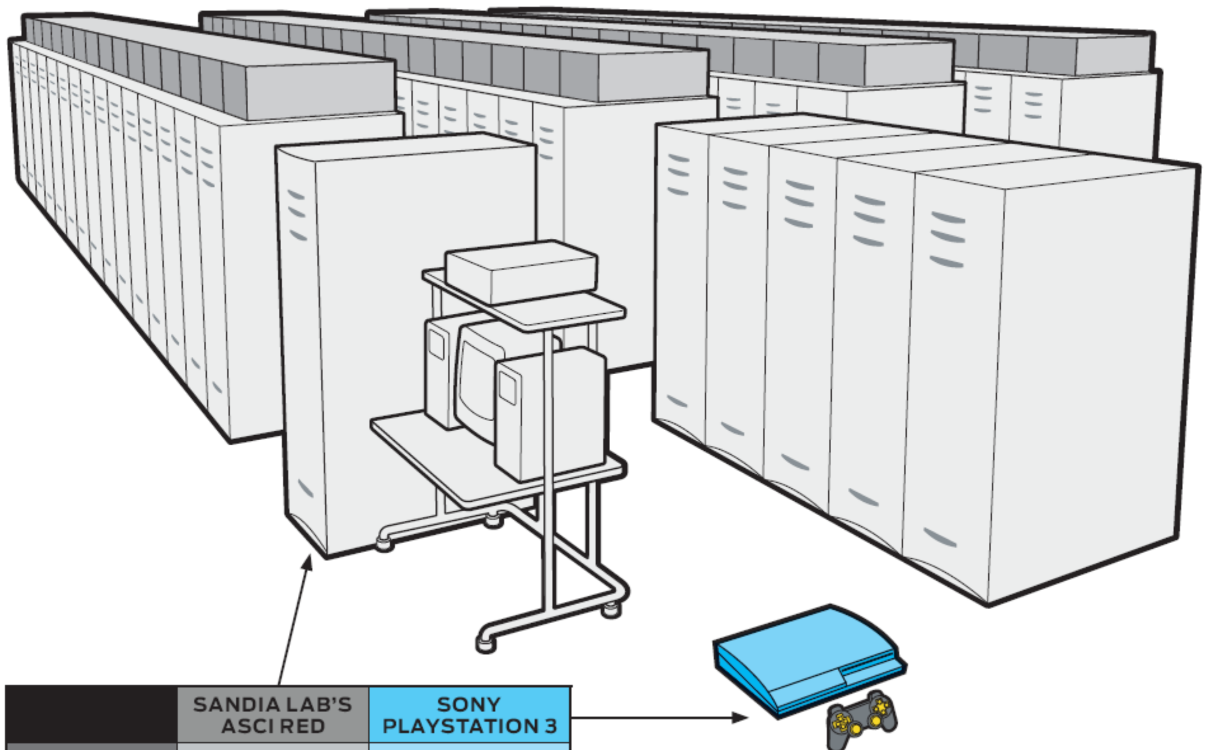
- Energy-efficiency
  - refers to a technology designed to reduce the equipment energy consumption without affecting the performance, according to the do more for less paradigm. Such solutions are usually referred to as eco-friendly solutions.
- Energy-awareness
  - refers to an intelligent technology that adapts its behavior or performance based on the current working load and on the quantity and quality of energy that the equipment is expending (energy-feedback information). Usually referred to as eco-aware solutions.

- Energy-oriented Infrastructures
  - Energy-Efficiency + Energy-Awareness
  - Consider Energy as an additional constraint
  - Consider Type of Energy (dirty or renewable) as an additional input
    - Solar (thermal + photovoltaic), Aeolian, Hydropower & Tidal, Geothermic, Biomass (CO_2 emissions)

Examples
Energy-efficiency

- Doing more with less

SUPERCOMPUTER VS. GAME CONSOLE

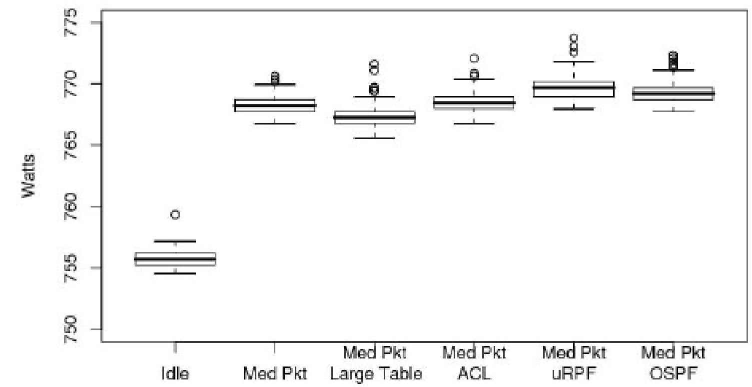


	SANDIA LAB'S ASCI RED	SONY PLAYSTATION 3
DATE OF ORIGIN	1997	2006
PEAK PERFORMANCE	1.8 teraflops	1.8 teraflops*
PHYSICAL SIZE	150 square meters	0.08 square meter
POWER CONSUMPTION	800 000 watts	<200 watts

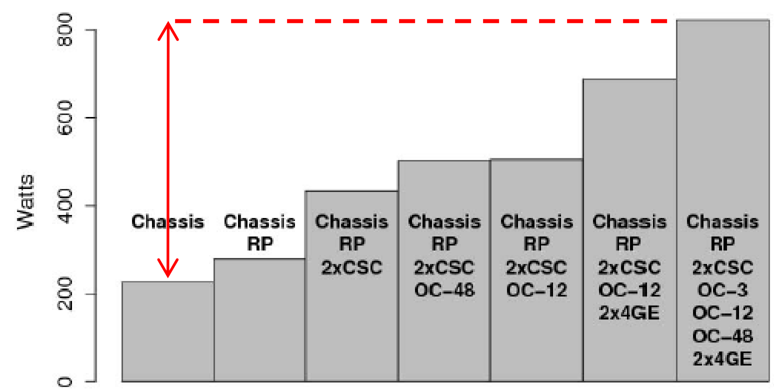
* For GPU; CPU adds another 0.2 teraflops

Examples
Energy-awareness

- Current router architectures are not energy-aware
  - The difference between idle and heavily loaded router vary only of 3% (25 W on 750 W)
  - Energy consumption is a function of capacity and not use



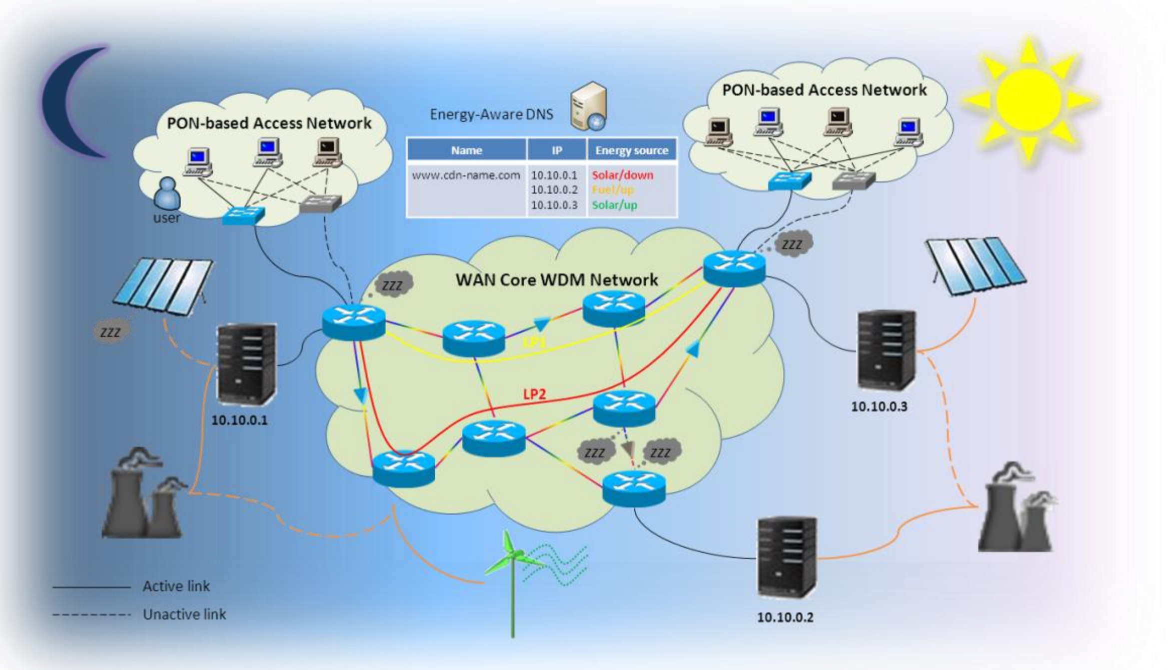
- But power consumption of base system is less than 50% of full configuration
  - Focus on energy-aware architectures that can adapt their behavior, and so, their energy consumption, to the actual traffic loads



Power consumption for different installed line cards configurations of the GSR Cisco Router

Examples
Energy-oriented Internet

- Consider the type of energy in network decisions



- Energy-aware OSPF-TE extension
  - disseminate information on the type and amount of energy used in each router
- Use such information in routing algorithm decisions

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- New recent journal: IEEE Transactions on Green Communications and Networking

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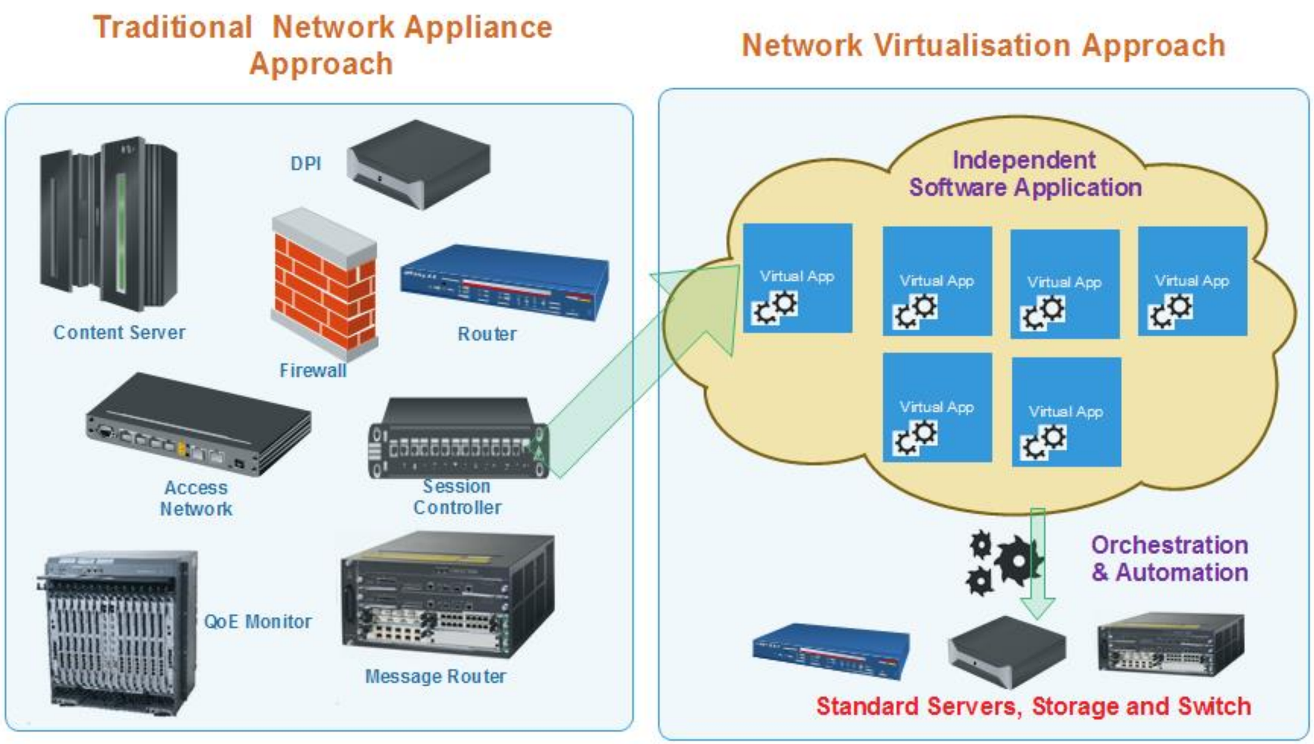
Network Function Virtualization (NFV)

- Virtualised Network Functions in the Cloud
- Instead of installing and maintain costly physical hardware to perform given functions, we can use VM in DCs and use software functions
- Examples: firewall, load balancer, NAT/PAT, mobile nodes

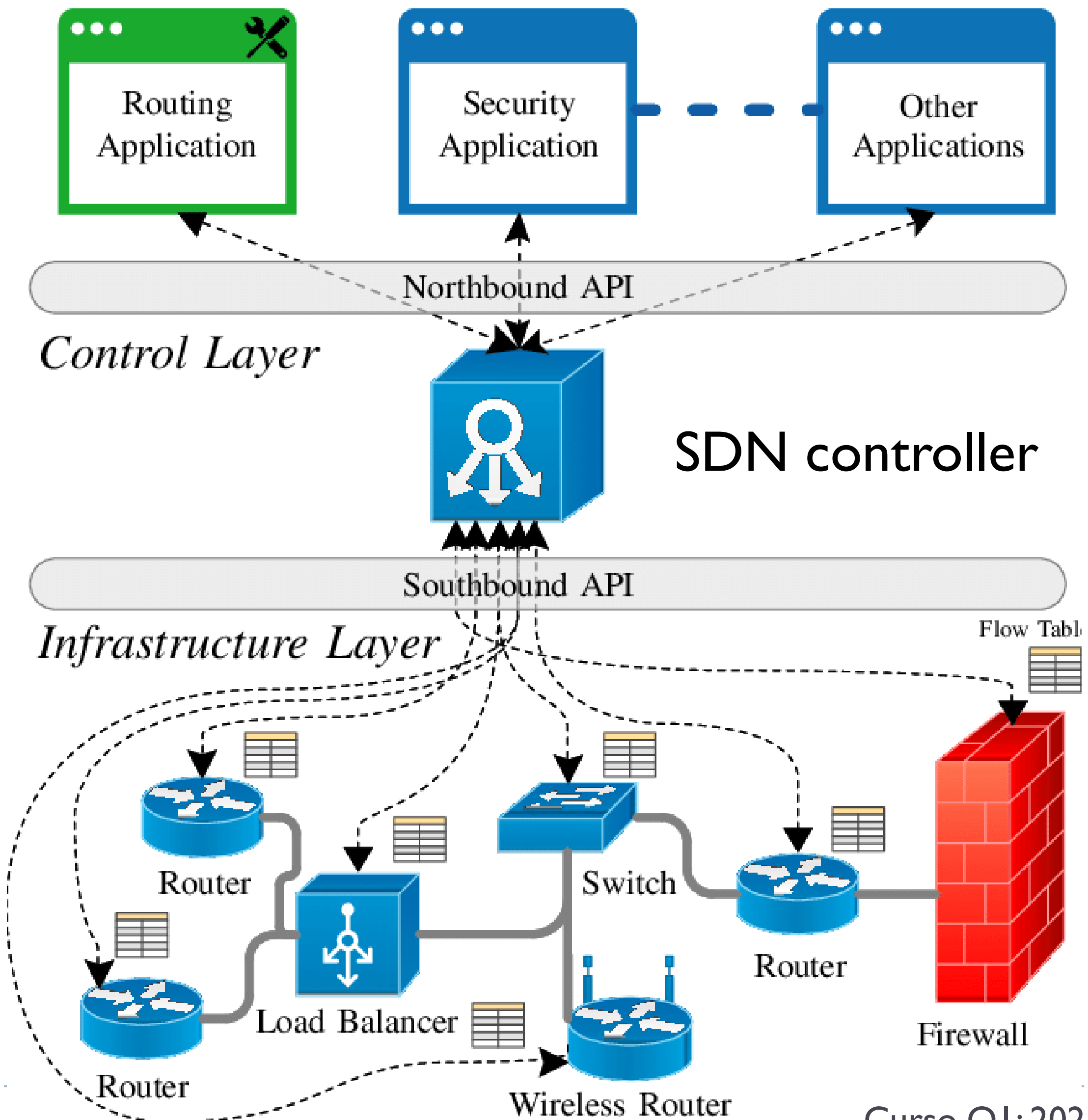


Source image: Techplayon - https://www.techplayon.com/network-function-virtualization-nfv-architecture/

Software Defined Networks (SDN)

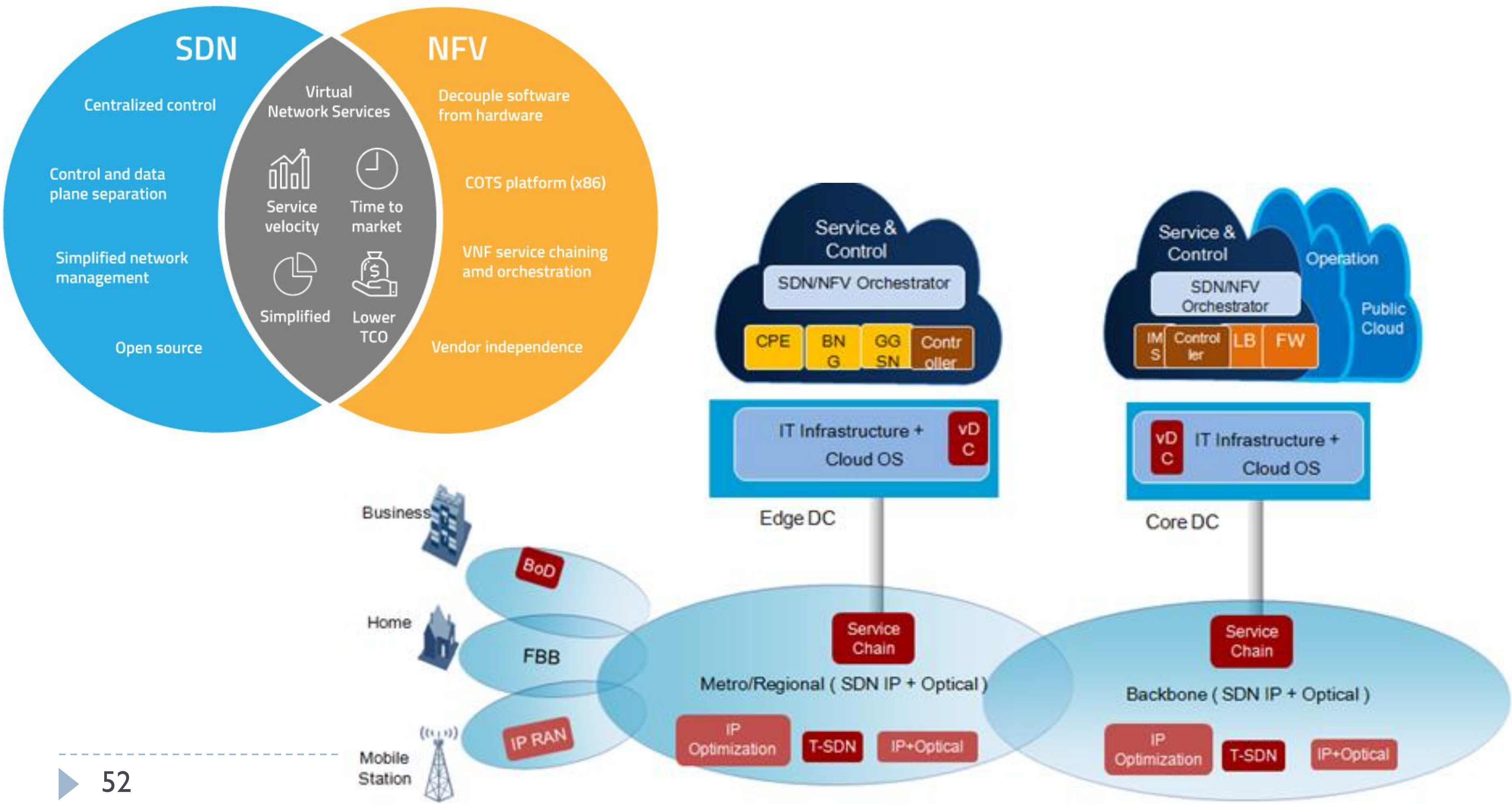
- The network equipment and their configurations/behaviours are controlled via software
- Instead of having to enter and configure each device with its own (usually proprietary) OS/GUI, a centralised platform is used
- This SDN platform allows the configuration (usually through a GUI) of the entire infrastructure in an easy way, independently of the peculiarity of each device
- The proprietary commands of each device are converted and abstracted (simplified) through the SDN platform

Software Defined Networks (SDN)



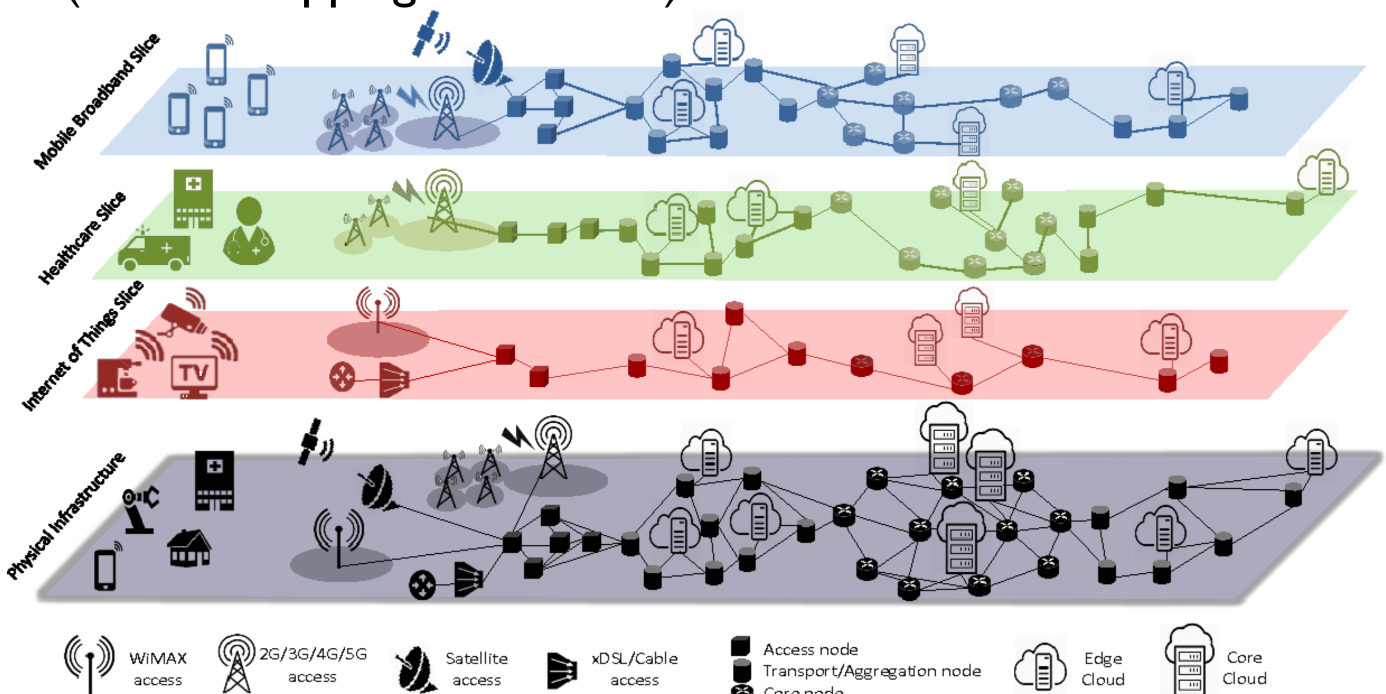
SDN/NFV

- The combination of both is the main driver today in Internet architecture



SDN/NFV

- Today, the main focus is on achieving a coordinated operation of entities at different infrastructure to support the automated orchestration of end-to-end services
- Such services needs to be deployed on shared resources and needs to be isolated (not overlapping each other) → network slice



 Source image: J.Ordoñez-Lucena et al., "Network Slicing for 5G with SDN/NFV: Concepts, Architectures, and Challenges·, IEEE Communications Magazine, viol. 55, no. 5, May 2017

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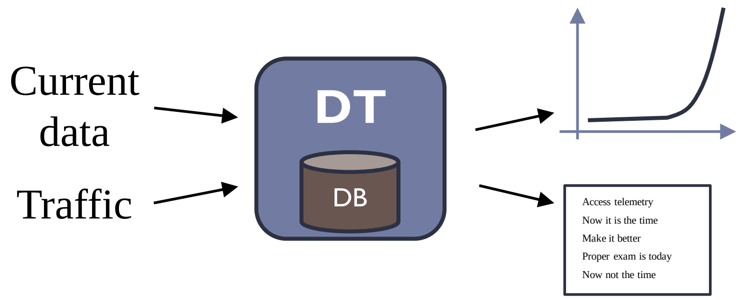
Digital Twin

- Digital representation of a real-world asset to improve collaboration, information access, and decision-making
- A combination of simulation technology and data (gathered from network telemetry, historical records, and so on)
- A virtual (software) twin of a physical object, a process or combination of them
- In network, a digital twin could be: a network device, an application, a network segment, an entire infrastructure, etc.

Digital Twin

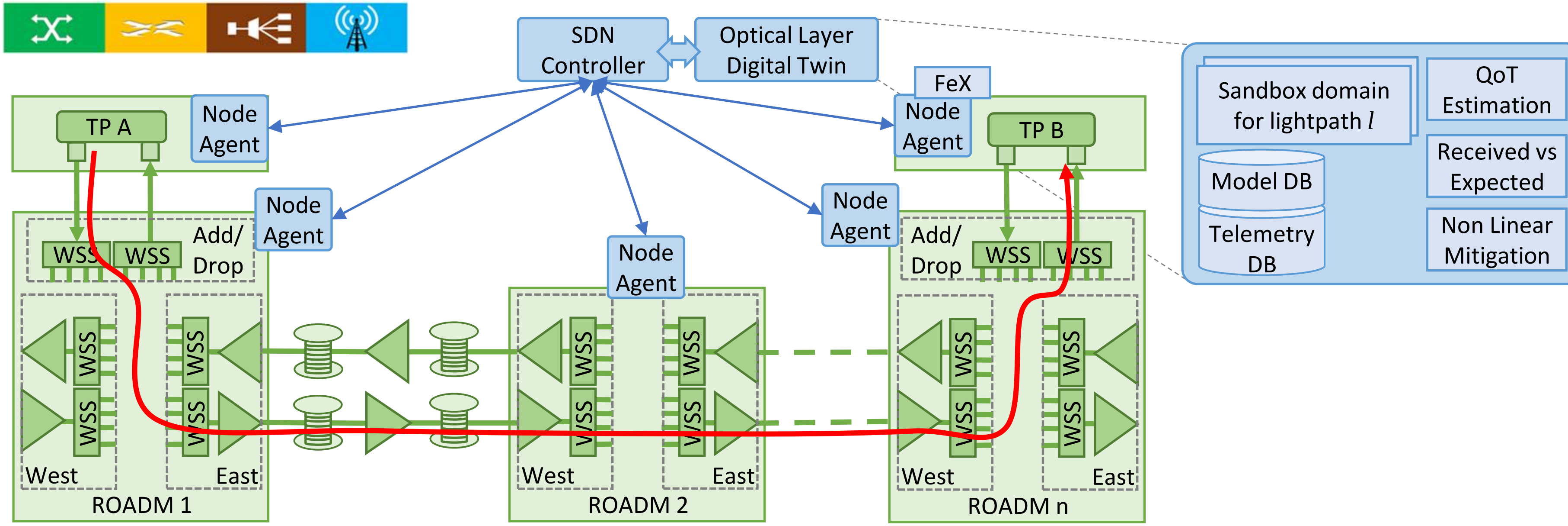
- A digital twin can be created using
  - Markov chain
  - Queueing modelling
  - Stochastic modelling
  - Machine Learning / Deep Learning
  - Graph Neuronal Networks
  - Fluid dynamics

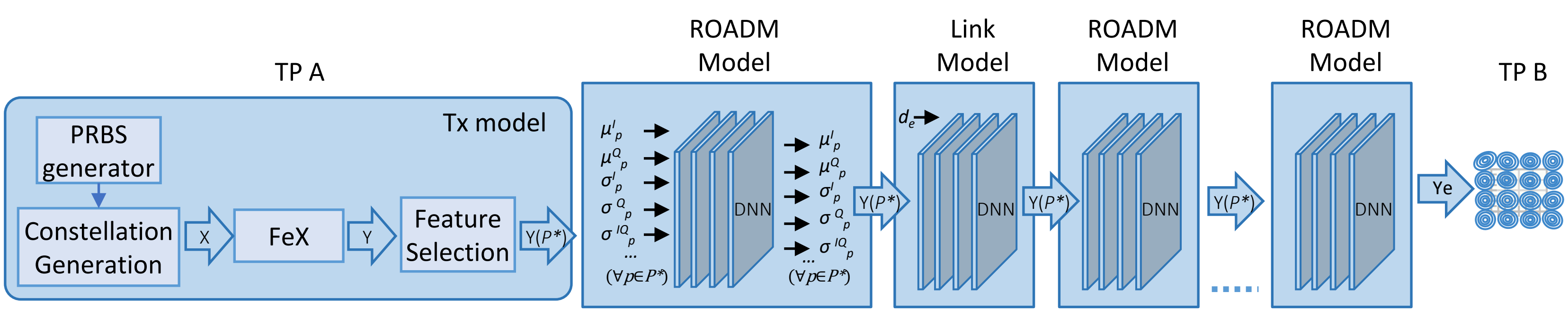


- The objective in networks is
  - Predict the performance of a new state in simulation before deploying it in the real network
  - Discover service degradation
  - Optimise the use of the network resources identifying specific management actions to improve overall network performance

Optical Layer DTs

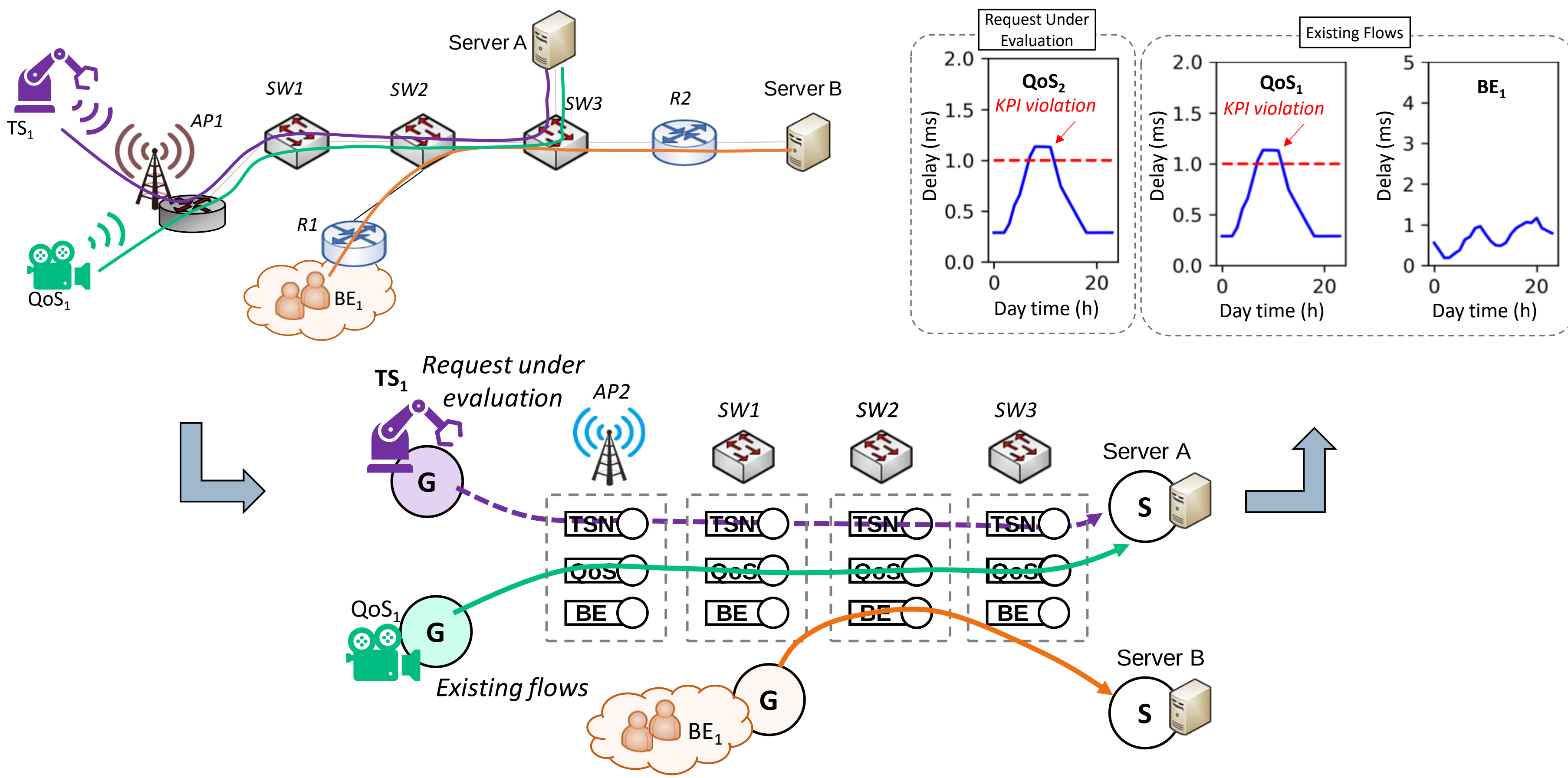
https://www.season-project.eu/





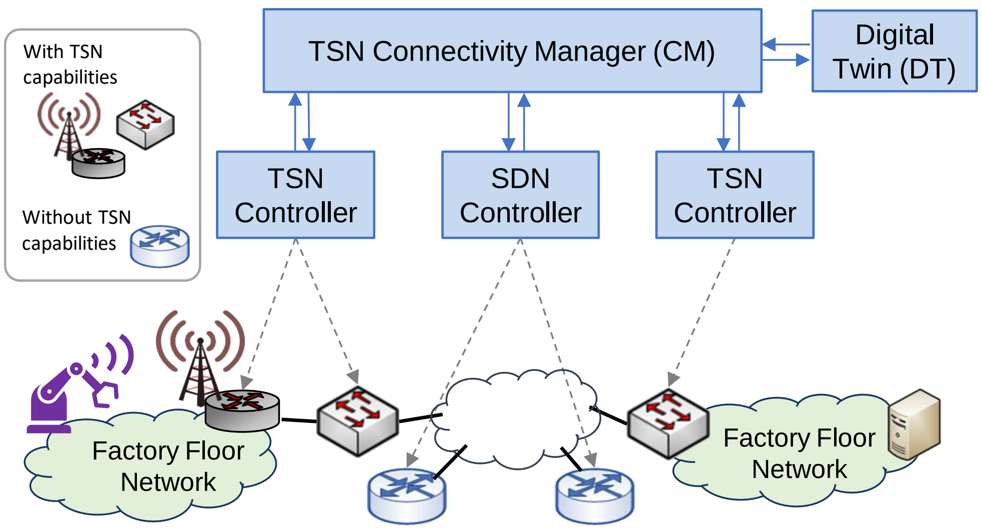
Packet Layer DTs

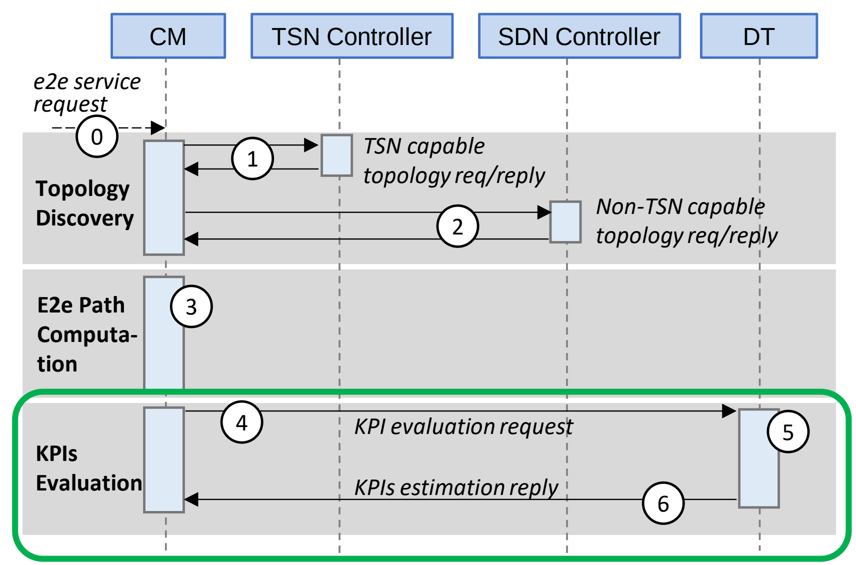
https://predict-6g.eu/



Time Sensitive Networks

https://predict-6g.eu/





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AI in networking

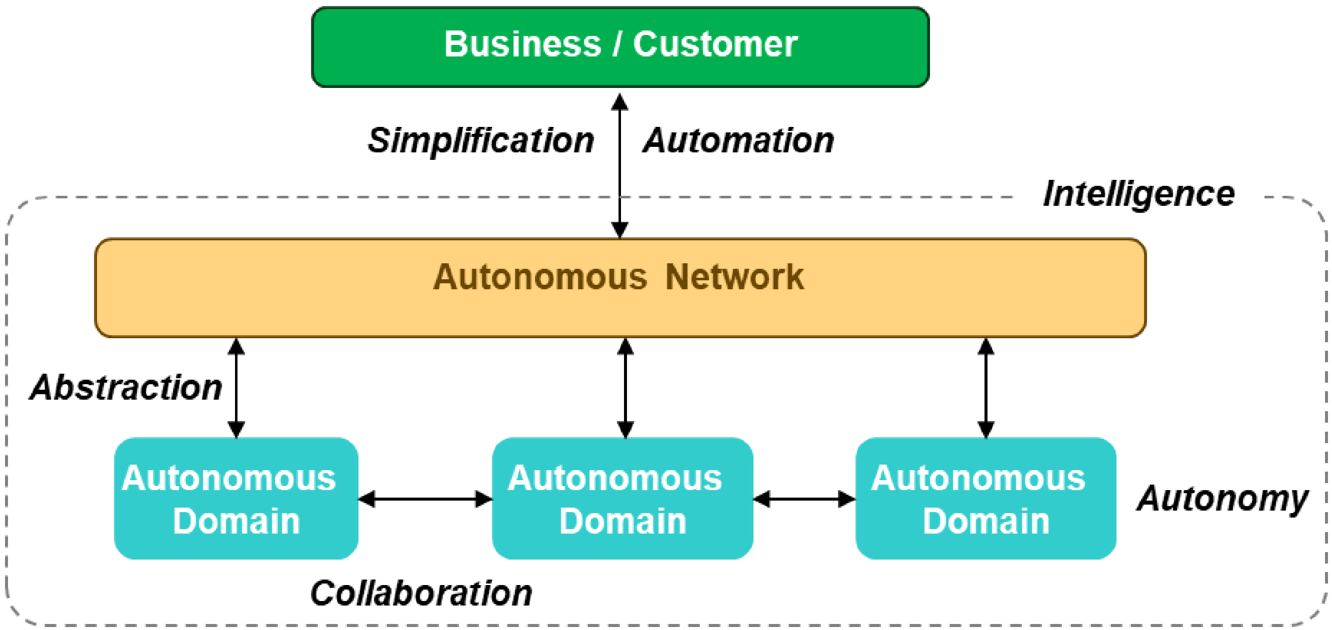
- Artificial Intelligence (AI) is not a "new" science
  - The term AI was coined in 1956
  - But neural networks for instance already existed since 1943
- Current new wave of AI is due to
  - Accessibility to powerful computers
  - Availability of big data from sources including e-commerce, businesses, social media, science, and government
  - Improved AI approaches and its implementation algorithms
- Networking is not an exception in this new AI era
  - Network telemetry provides a huge volume of data in real time
  - SDN provides a centralised decision-making process

AI in networking

- Network automation
  - Identification and classification of devices on the network
  - Deployment and management of optimised network policies
  - integration of zero-trust security solutions
- Network-health benchmarks
  - Long-term variations in performance trends
  - Telemetry: Identify anomalies, eliminate false positives, suggest remediation actions
- Predictive analytics
  - Anticipate events of interest such as failures or performance issues
- Lifecycle management
  - Verify that all devices have the latest software updates/upgrades
  - Look for potential vulnerabilities in device configuration

Autonomous Network Paradigm

- An Autonomous Network consists of a simplified network architecture, virtualized components, **automating agents**, **intelligent decision engines** which present self-dynamic capabilities with the goal to create **intelligent** business and **network operations** based on the concept of **closed-loop controls**.



Autonomous Networks, supporting tomorrow's ICT business, ETSI White Paper, nº 40, 2020

Autonomous Network Levels

"Autonomous Networks: Empowering Digital Transformation For The Telecoms Industry," TM forum White Paper

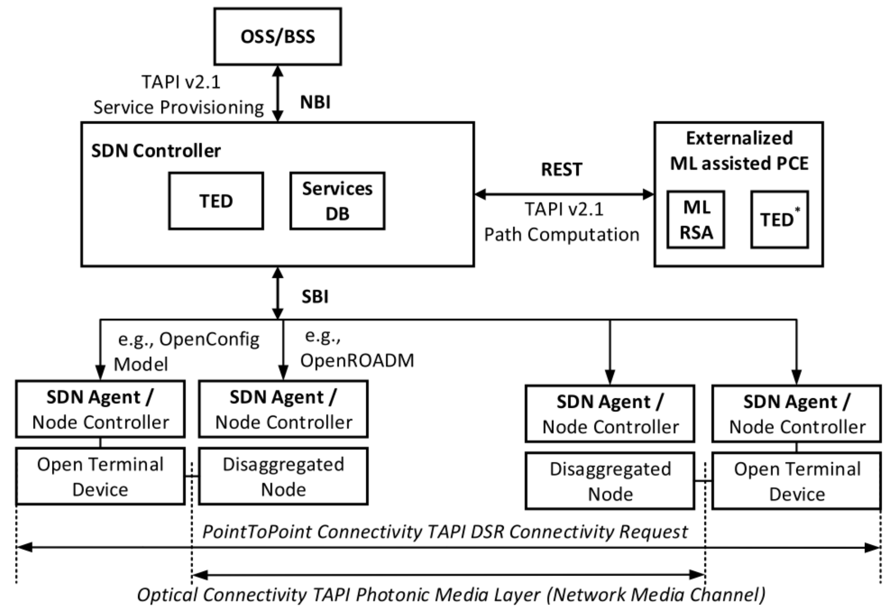
Autonomous networks levels

Level Definition	L0: Manual Operation & Maintenance	L1: Assisted Operation & Maintenance	L2: Partial Autonomous Network	L3: Conditional Autonomous Network	L4: High Autonomous Network	L5: Full Autonomous Network
Execution	P	P/S	S	S	S	S
Awareness	P	P	P/S	S	S	S
Analysis	P	P	P	P/S	S	S
Decision	P	P	P	P/S	S	S
Intent/Experience	P	P	P	P	P/S	S
Applicability	N/A	Select scenarios				All scenarios

P: Personnel, **S:** Systems

AI-based routing algorithms

- AI helps the system to continuously learn from new data (telemetry) and improve its performance over time
- By analysing past routing data and outcomes, the system can identify patterns, optimize routing decisions, and enhance overall efficiency
- For instance
  - ML/DL or Reinforcement DL can assist PCE in calculating paths
  - AI-based algorithm can prepare network resource in advance and make room for new paths

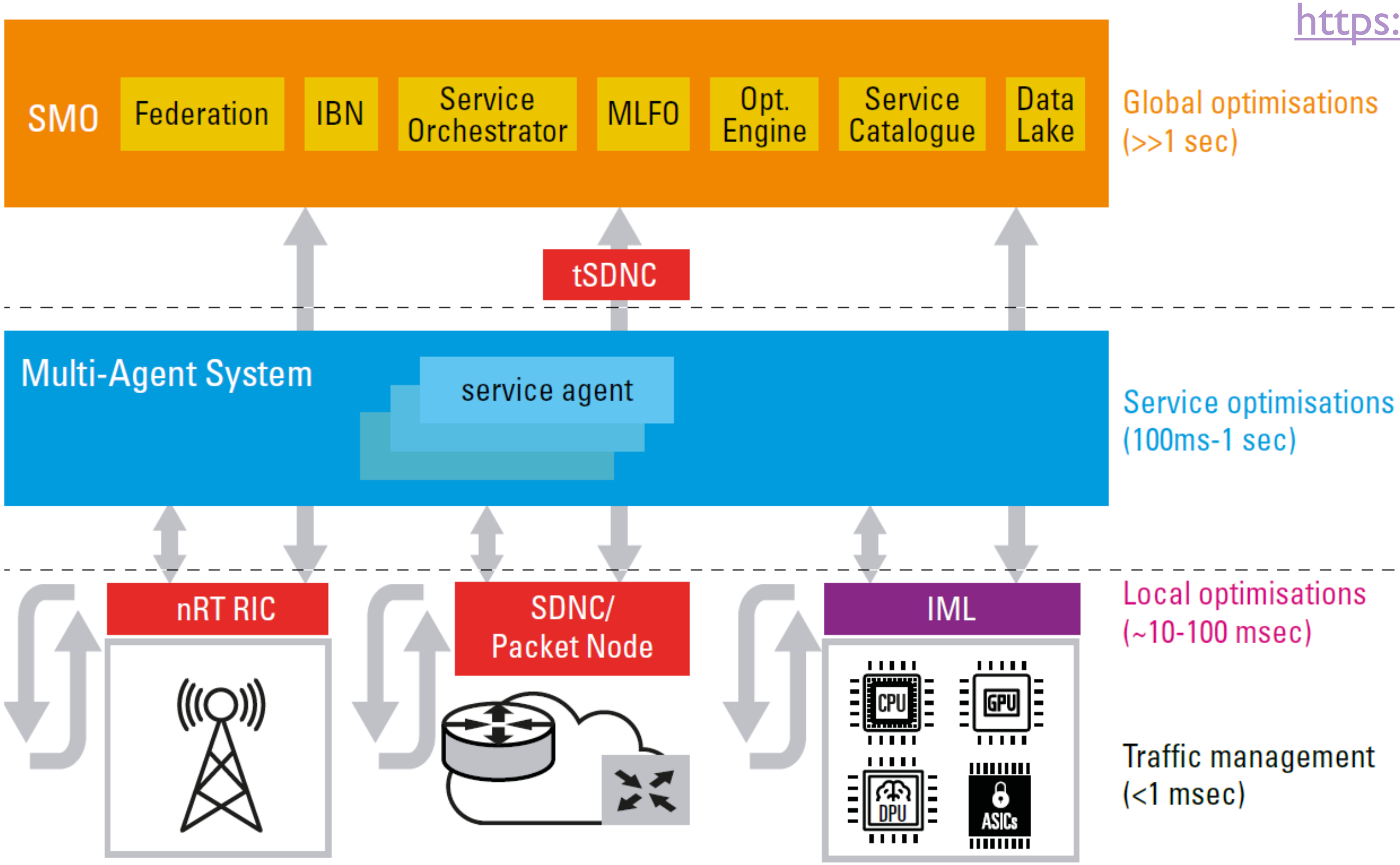


Fuente imagen: C. Hernández-Chulde, et al. "Experimental evaluation of a latency-aware routing and spectrum assignment mechanism based on deep reinforcement learning," J. Opt. Commun. Netw. 15, 925-937 (2023)

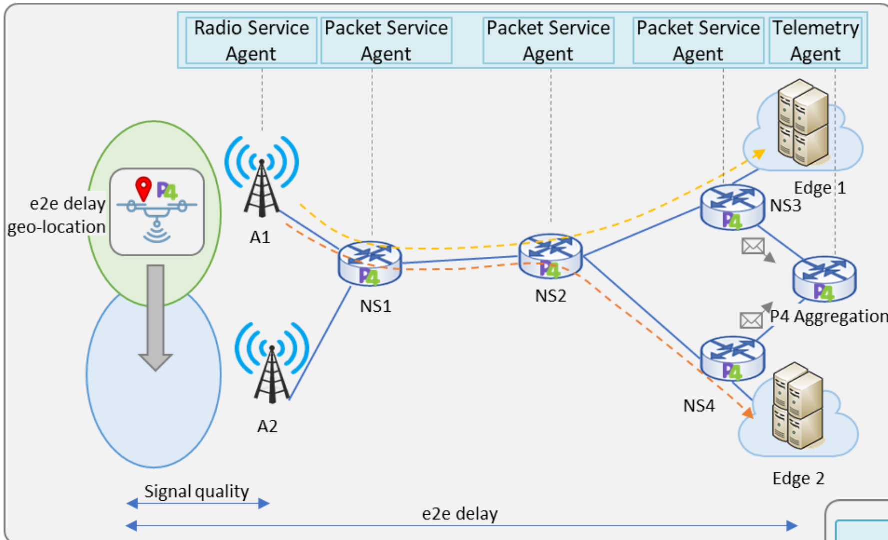
Multi-Scale Intelligent Control Loops

›DESIRE6G‹

https://desire6g.eu/



Multi-Agent Systems



DESIRE6G

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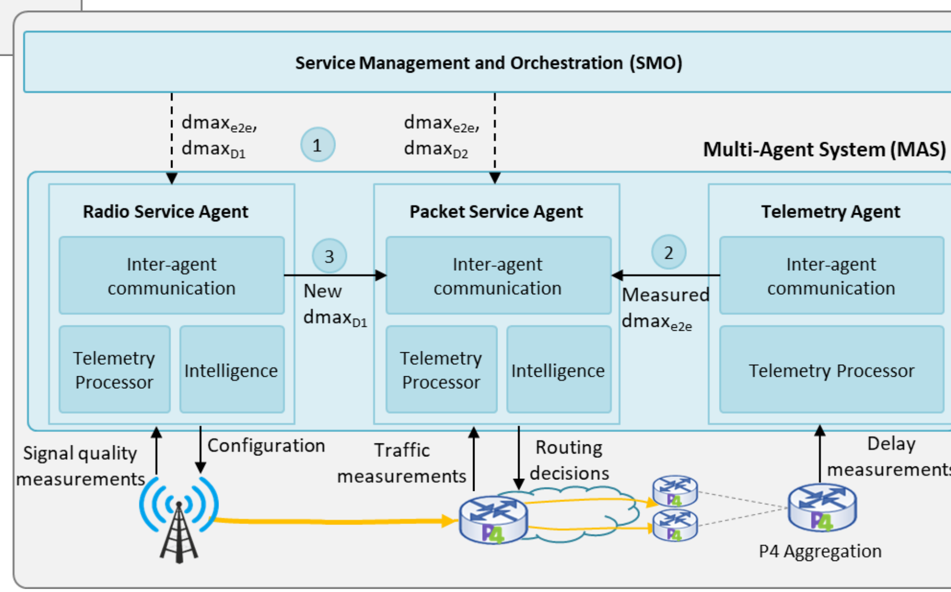

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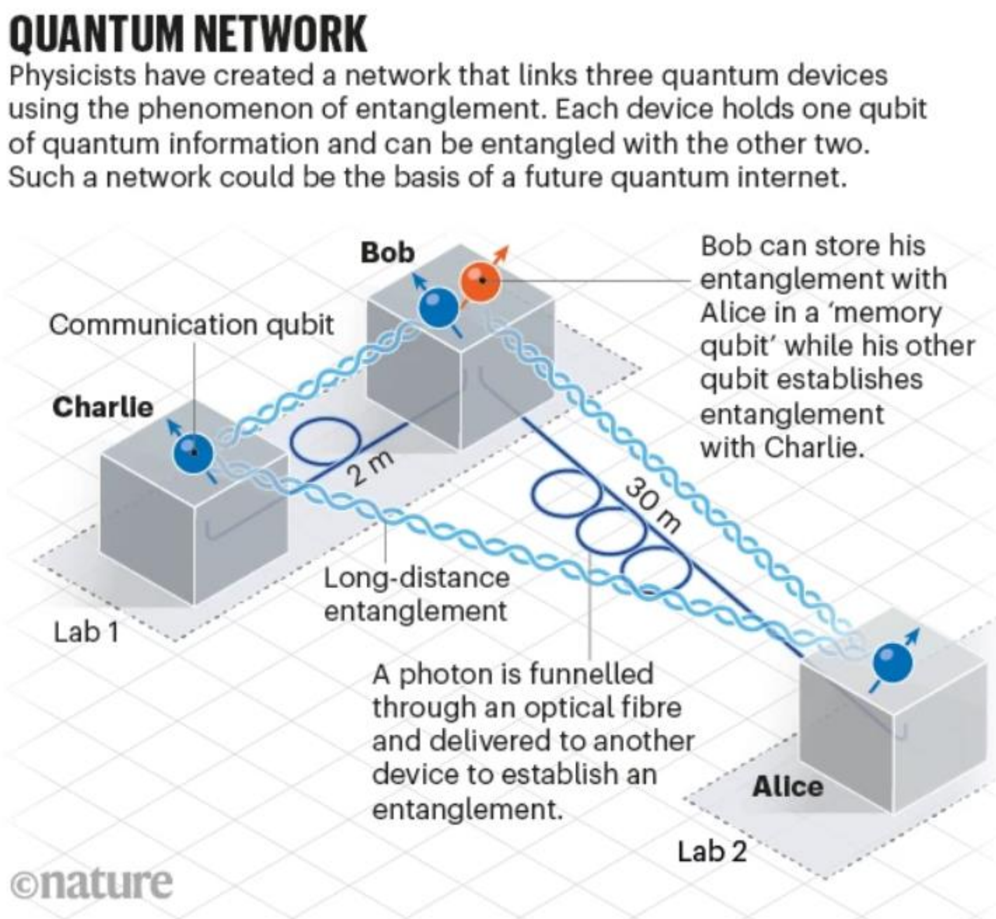
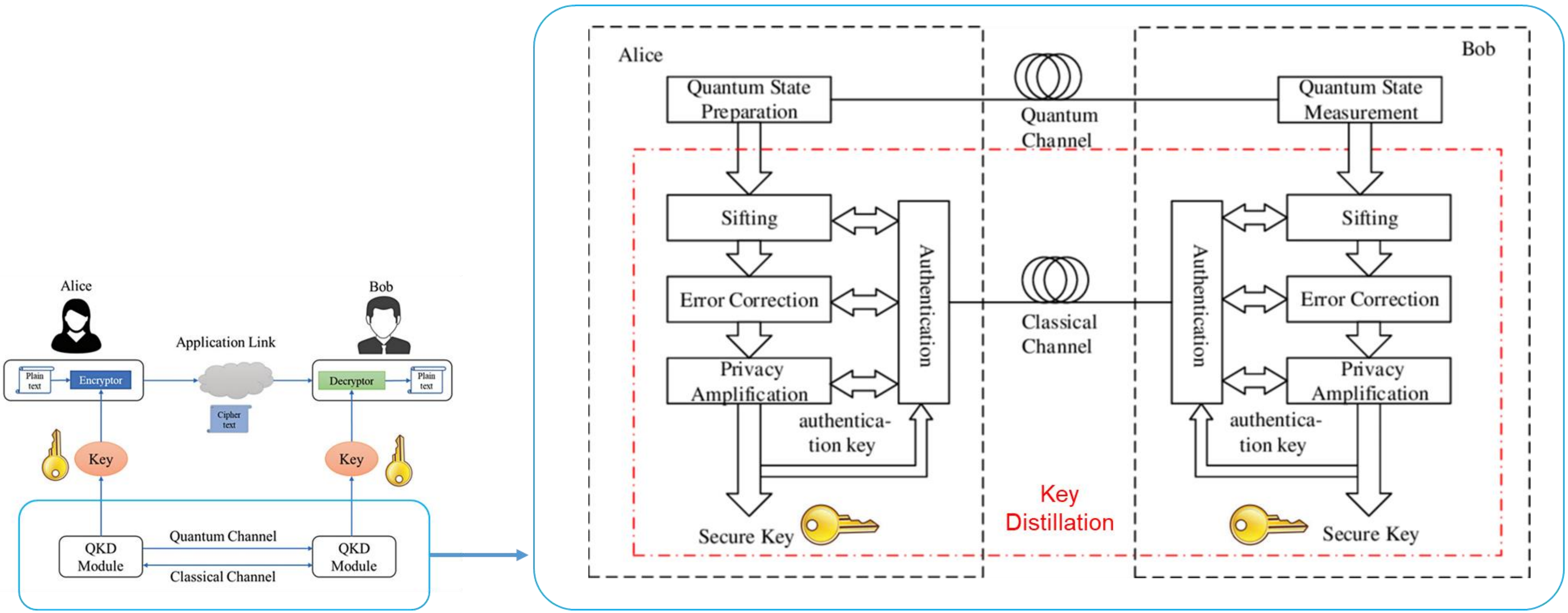
Quantum networks and communication



Fuente imagen: https://www-nature-com.recursos.biblioteca.upc.edu/articles/d41586-021-00420-5, acceso Noviembre 2024

Quantum Key Distribution



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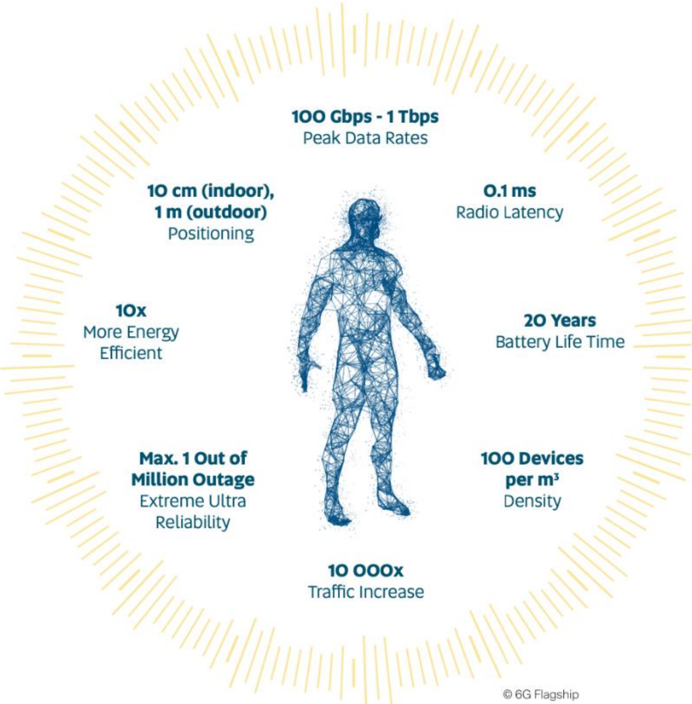
6G networks

- Definition of the objectives and specification
- New types of communication with different required performance
- Starting point: https://www.6gflagship.com/white-papers/



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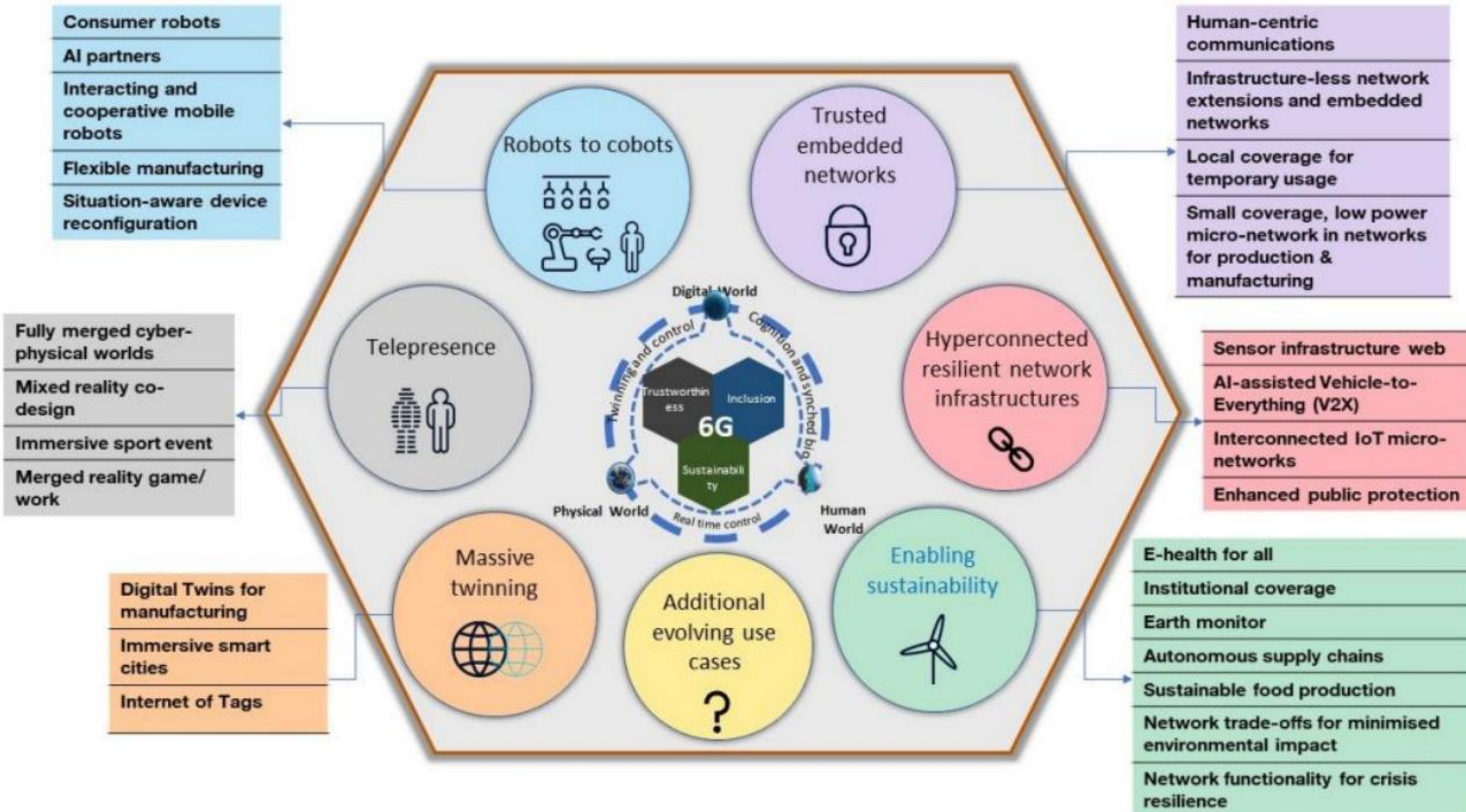
6G Use Cases



Source: https://hexa-x.eu/category/use-cases/

Reference Research Projects

https://www.b5g-open.eu/

https://www.season-project.eu/

https://desire6g.eu/

https://www.allegro-he.eu/

https://predict-6g.eu/

https://copernico.upc.edu/

Xarxes de computadors II

Actividad complementaria: presentaciones

Davide Careglio, Marc Ruiz