

Xarxes de computadors II

Actividad complementario: presentaciones

Davide Careglio

Presentaciones

- ▶ 9 matriculados
 - ▶ 3 grupos de 2 personas y 1 grupo de 3
 - ▶ 15/17 minutos por grupo + 3/5 debate
 - ▶ 22 de Diciembre
 - ▶ Participación obligatoria a todas las presentaciones
 - ▶ Se evalúa también la participación en los debates
-
- ▶ **Calendario**
 - ▶ **Antes del 8/12 enviar un correo con el tema elegido y los grupos**
 - ▶ **Entregar límite de la presentación por correo es el 21/12 a las 23.59**

Presentaciones

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-
- ▶ Criterios de evaluación
 - ▶ 1 nota común para todo el grupo sobre el contenido de la presentación
 - ▶ 1 nota individual sobre como se ha presentado
 - ▶ Dominio del tema: sabe realmente de lo que habla?
 - ▶ Capacidad de síntesis: ha dicho realmente algo sustancial en sus minutos?
 - ▶ Exposición ordenada: el hilo argumental tiene realmente un hilo?

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 qué 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)
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- ▶ Material de backup (n)

Temas presentaciones

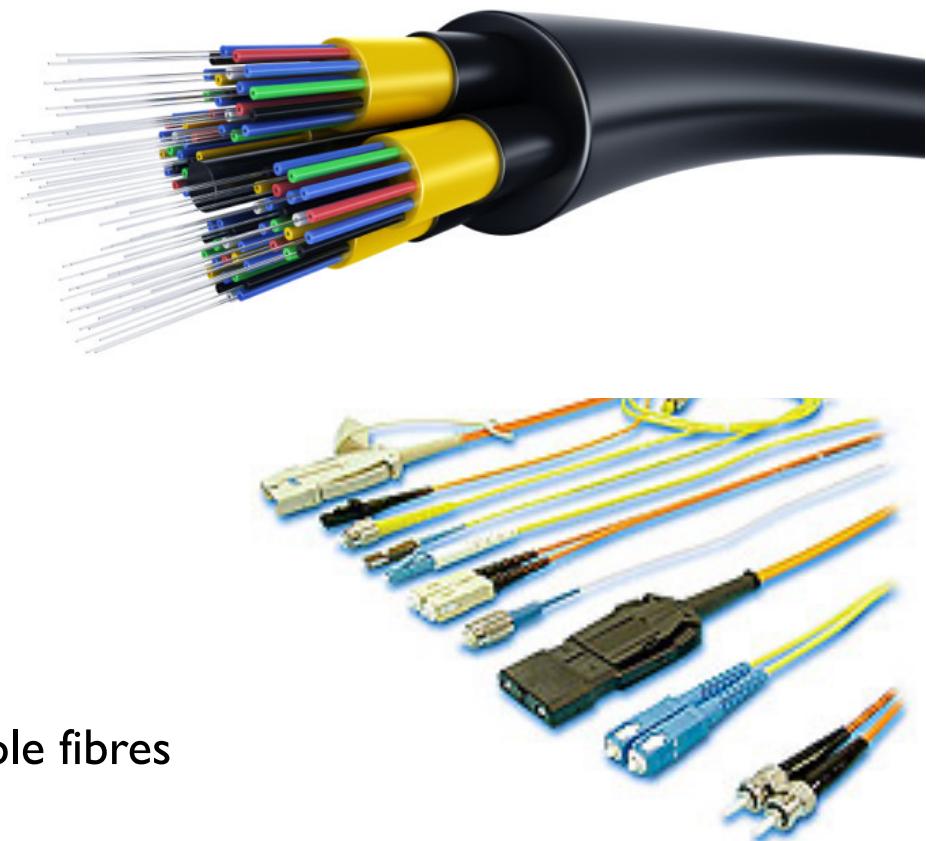
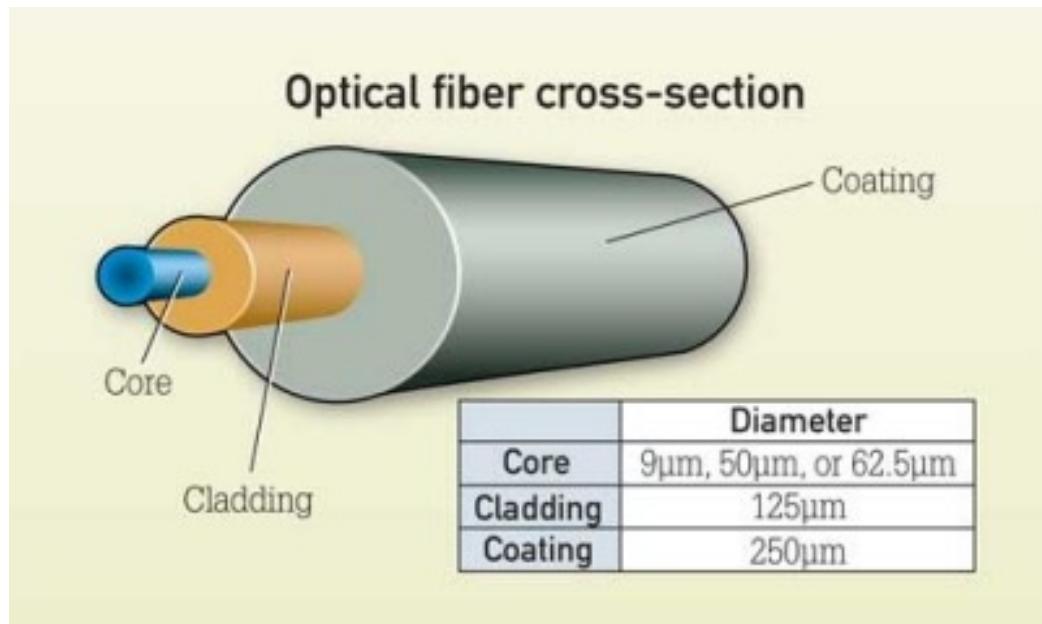
- ▶ Debe ser un tema actual de investigación
- ▶ De libre elección pero claramente relacionado con los conceptos y temas explicados en XC2
- ▶ Ejemplos
 - I) Alternativas a IP: ICN, RINA, etc.
 - 2) Protocolos de encaminamiento en redes ópticas (flexibles, multi-núcleo, etc.)
 - 3) Mejoras del BGP
 - I) Overlay (VXLAN, LISP, BIER multicast, etc.)
 - 2) Compact routing
 - 3) Greedy geometric routing
 - 4) Sostenibilidad en Internet
 - I) En redes locales
 - 2) En redes troncales
 - 5) Redes programables SDN
 - 6) Virtualización de funciones de red NFV
 - 7) Machine Learning / Cognitive / Artificial Intelligence

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Optical fibre

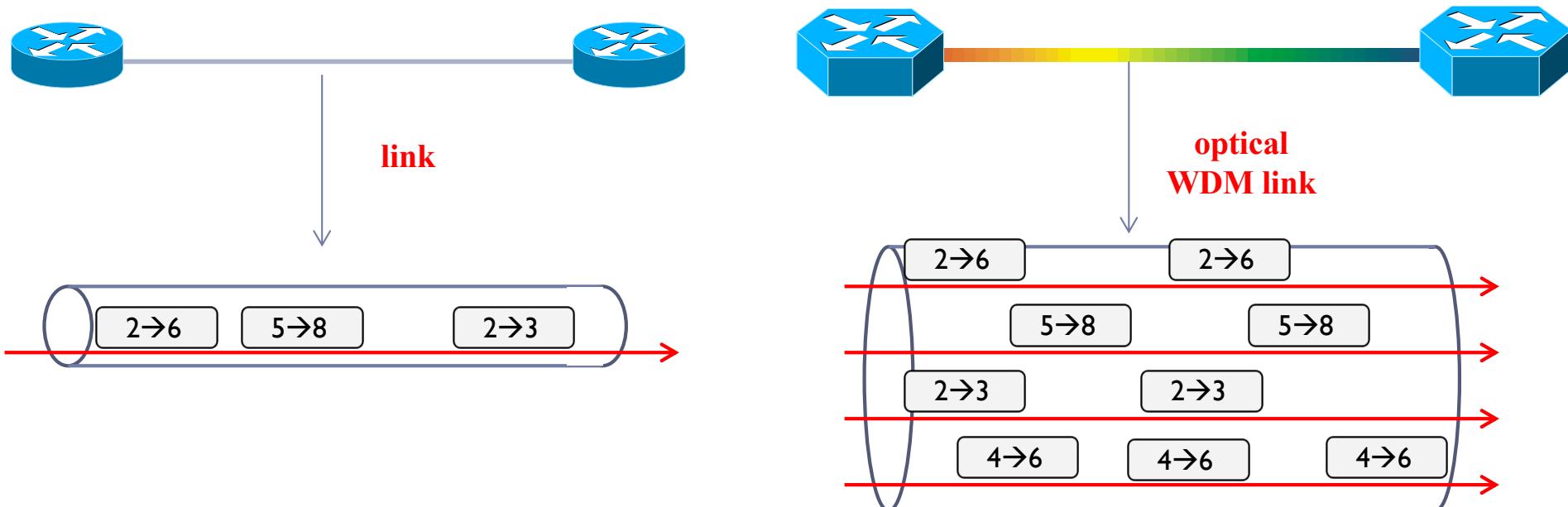
▶ Fibra óptica y conectores



- ▶ 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)

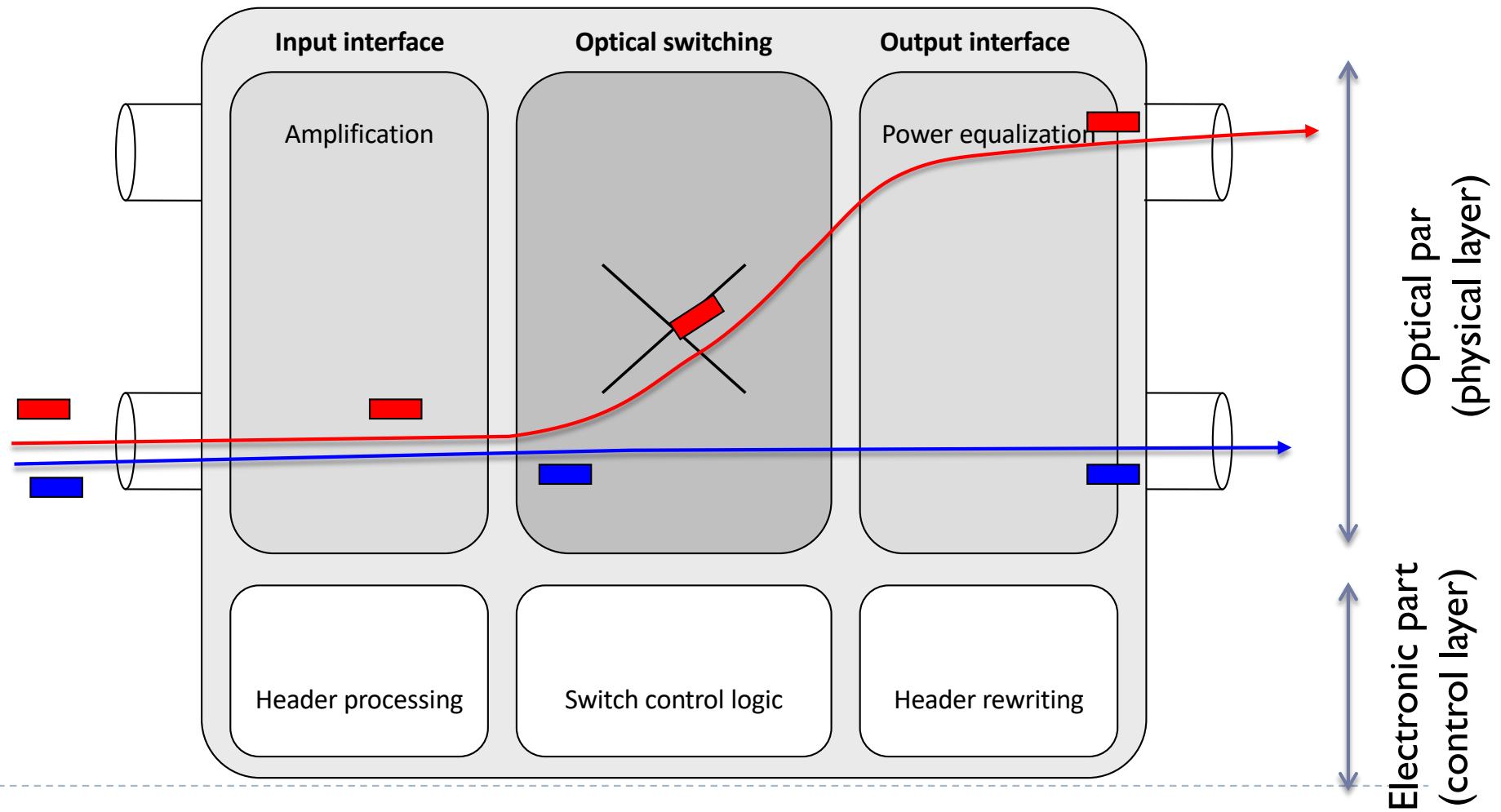
Scenario

- ▶ 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)

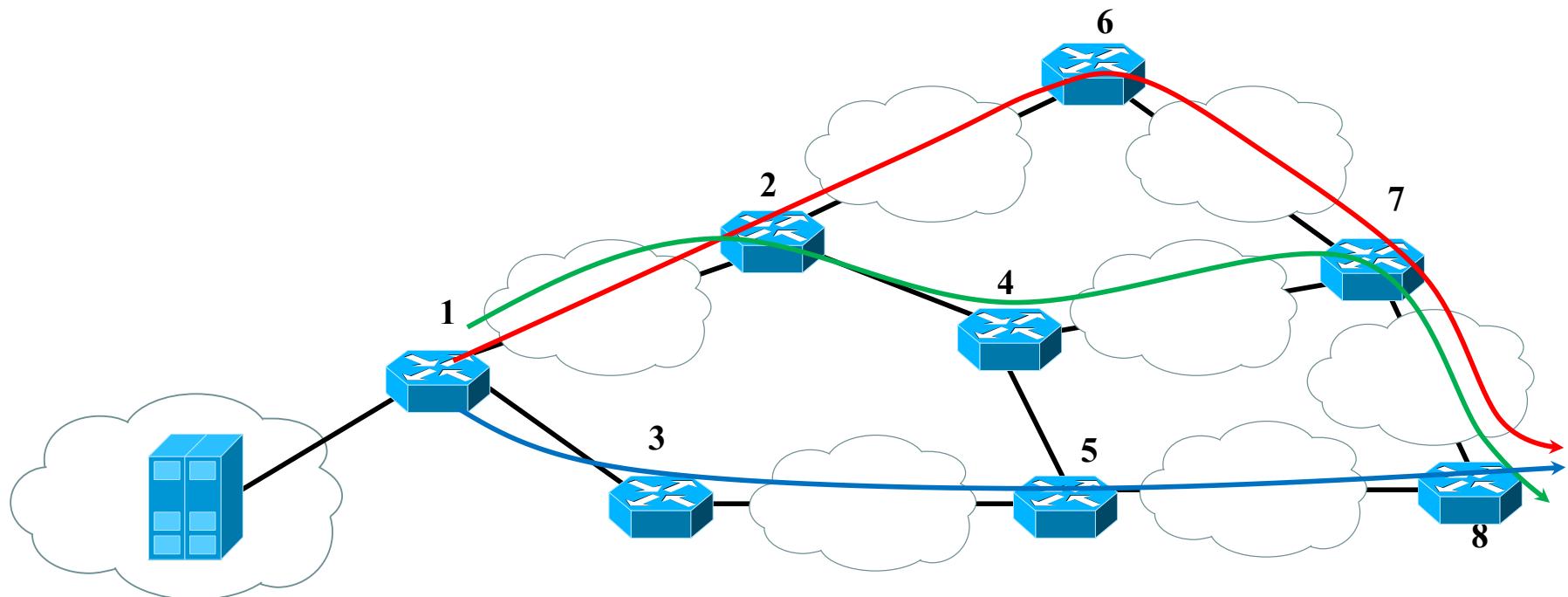
- ▶ Packets flow through the nodes without any change
- ▶ The path inside the node is almost fix and determined in advance



Problem formulation (1/4)

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**

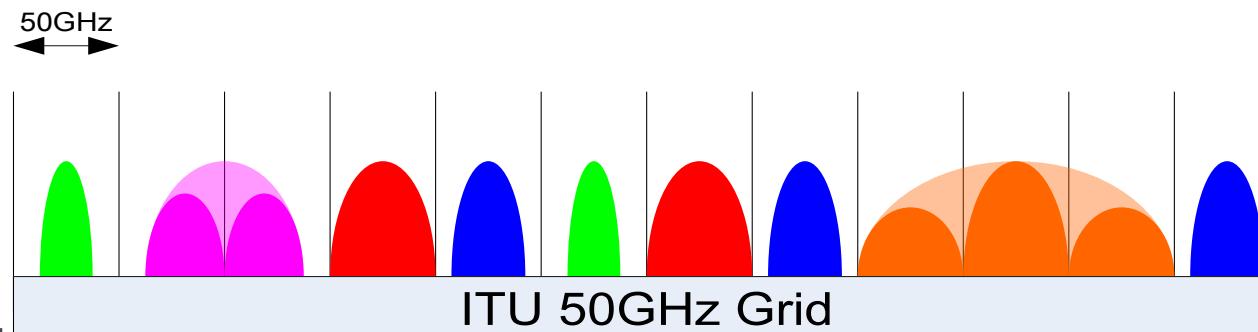


RWA solution

- ▶ 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

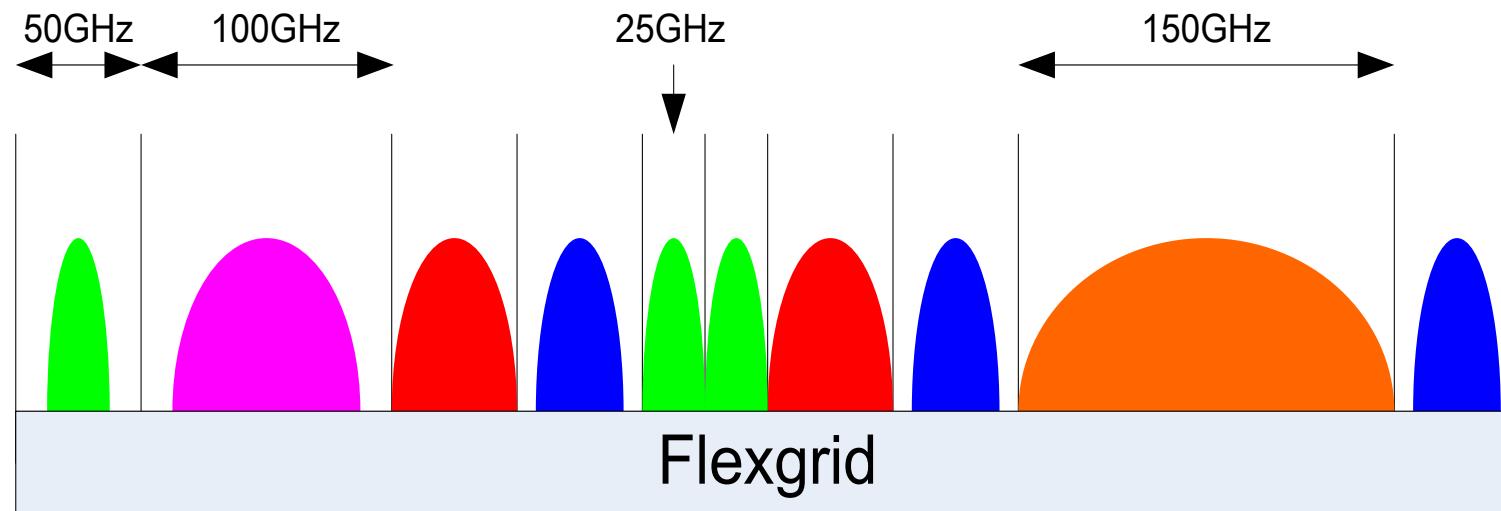
- ▶ 100 Gbps is expected to meet operator needs in the short to medium term, but traffic growth will lead to mixed line rates including 400 Gbps and 1 Tbps in the long term
- ▶ Existing DWDM systems are inflexible in two distinct ways:
 - ▶ The transponder has a fixed bit rate – for example of 10 Gbps 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



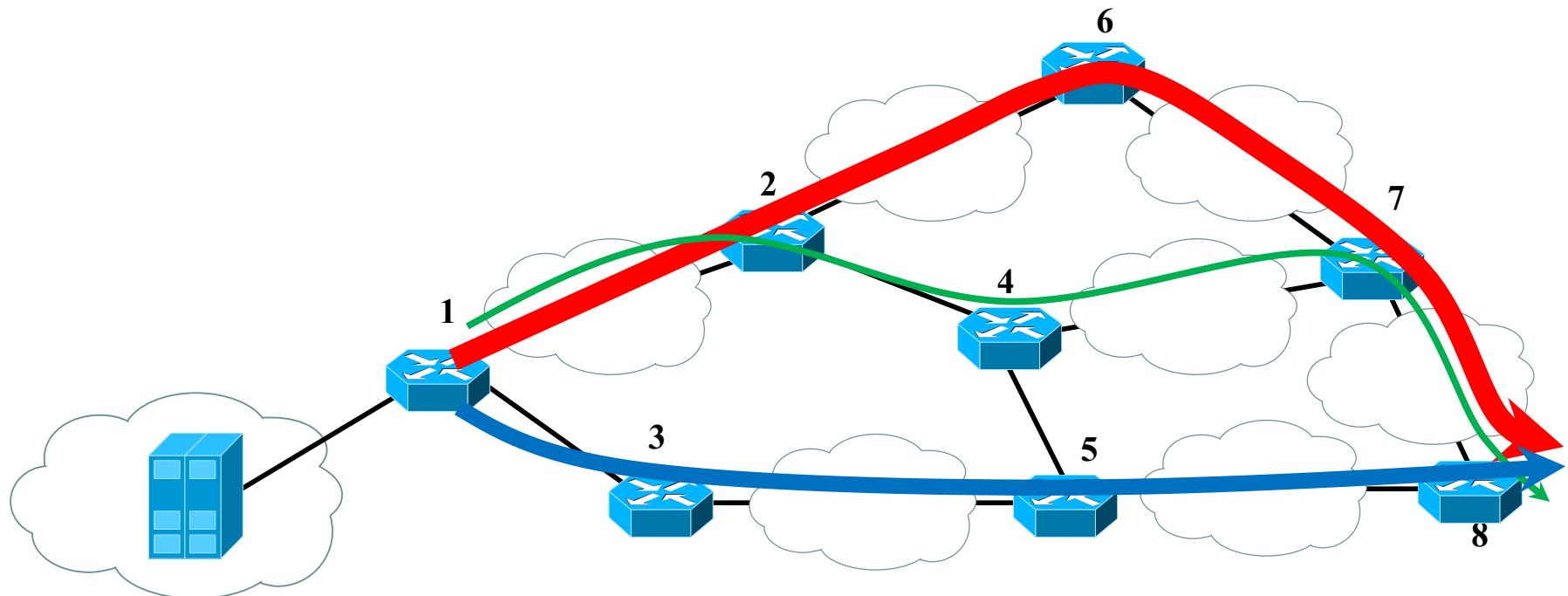
Flexible Optical Network

- ▶ 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

Flexible Optical Network

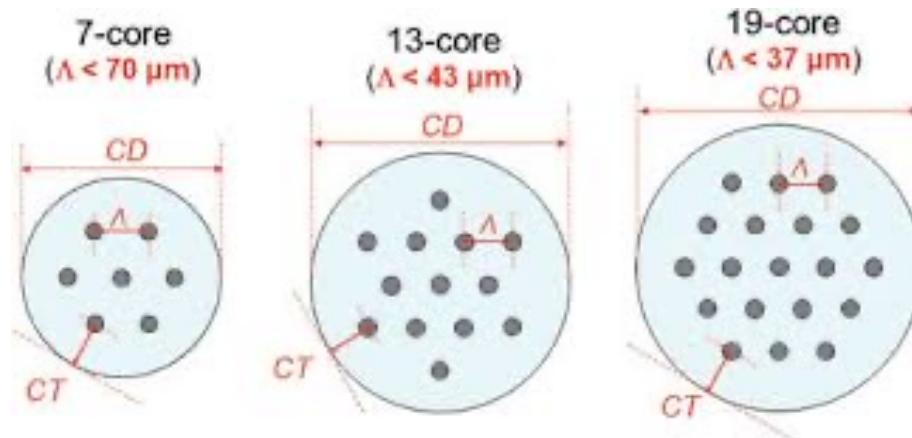
the RSA problem

- ▶ 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

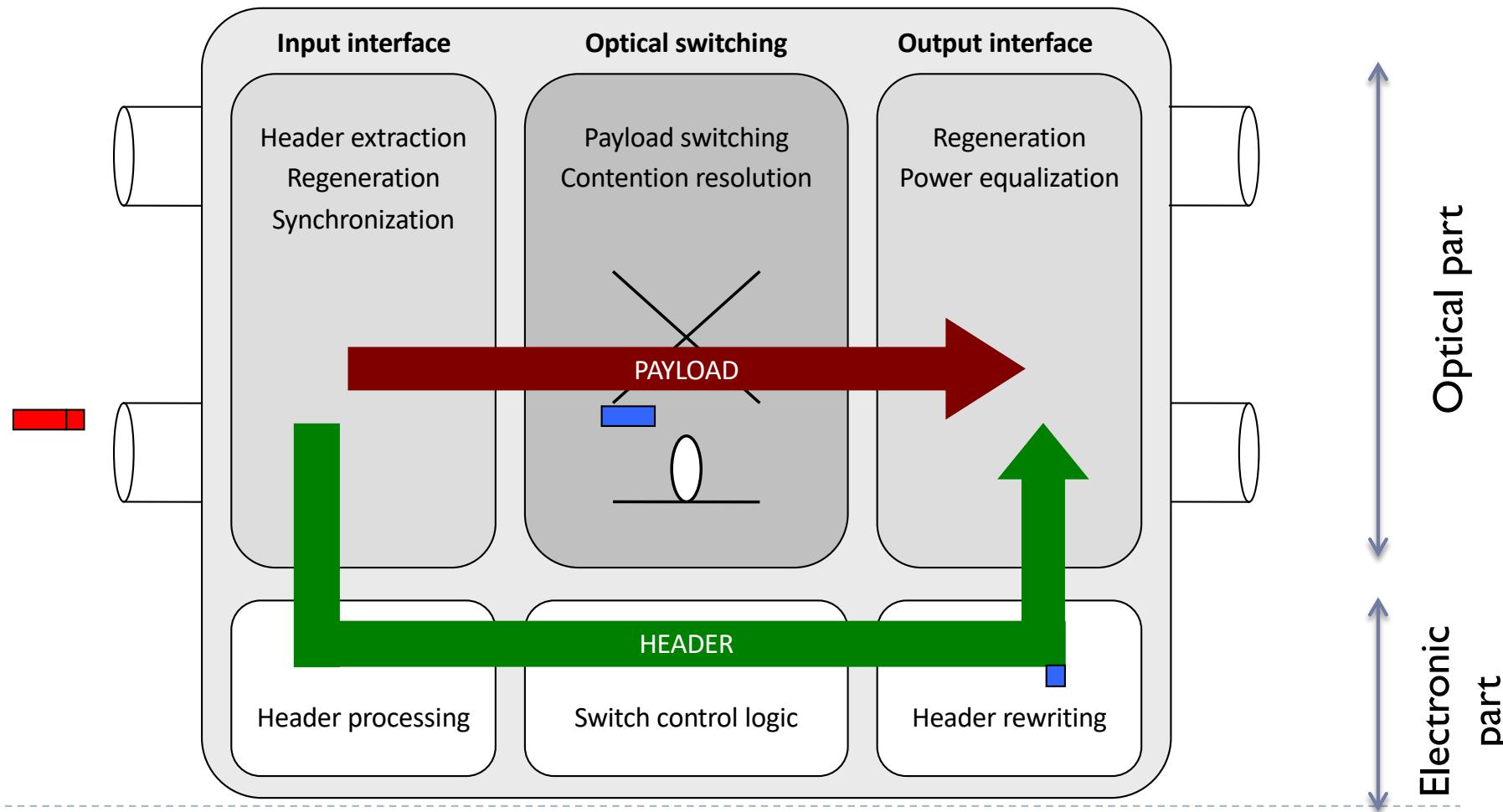
- ▶ One single cladding but multiple cores



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

Optical packet switching

- ▶ Implementation of conventional Internet packet switching techniques in the optical domain
- ▶ The path of the packets through the node is determined packet by packet



Optical packet switching

▶ Problems

- ▶ There is no optical RAM for buffering the optical packets
 - ▶ Slow light
 - ▶ Fiber Delay Lines
 - ▶ No buffering at all
- ▶ Optical switching at the ns scale
- ▶ Wavelength converters to change the wavelength of the optical packets

▶ Now some interest for data center interconnection networks

- ▶ Low latency
- ▶ High throughput
- ▶ High flexibility
- ▶ High bandwidth dynamics

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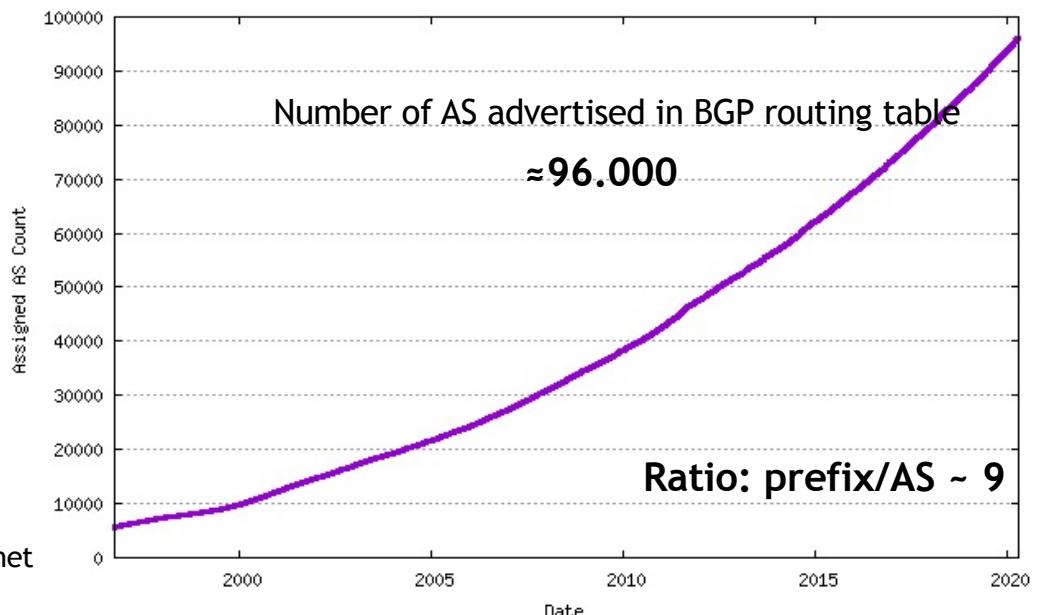
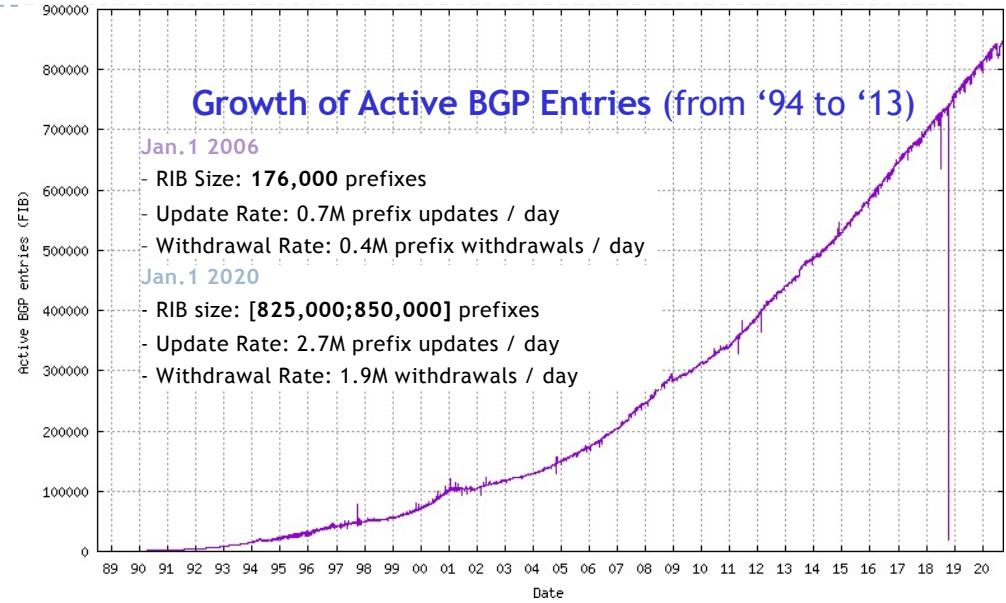
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Current situation (1 / 2)

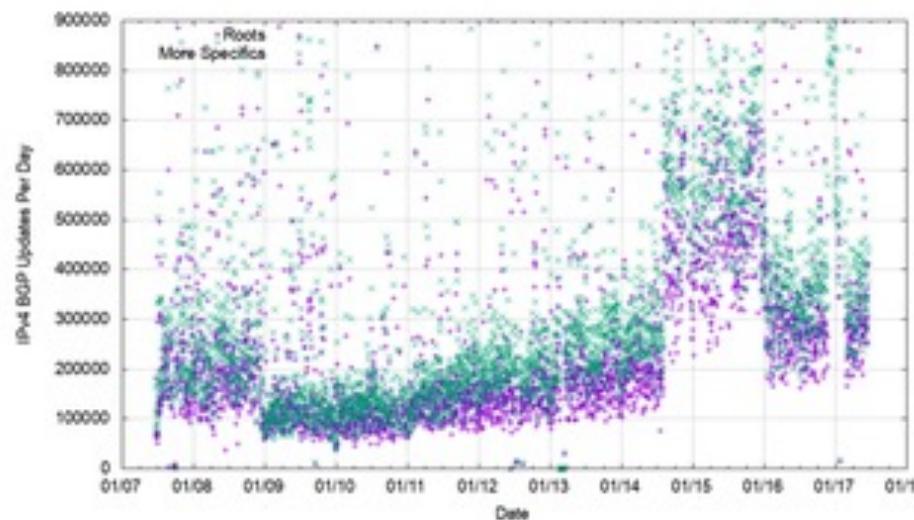
- ▶ Traffic
 - ▶ Traffic volume (per month): Exabytes
 - ▶ Traffic growth rate: 50% (+/- 5%) per year
- ▶ Routing tables size
 - ▶ Growth rate: 15%-25% per year
 - ▶ Number of active RT entries: 830k (202')
- ▶ Autonomous Systems (AS)
 - ▶ Growth rate: 10% per year
 - ▶ Number of advertised AS: 96k (2020)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



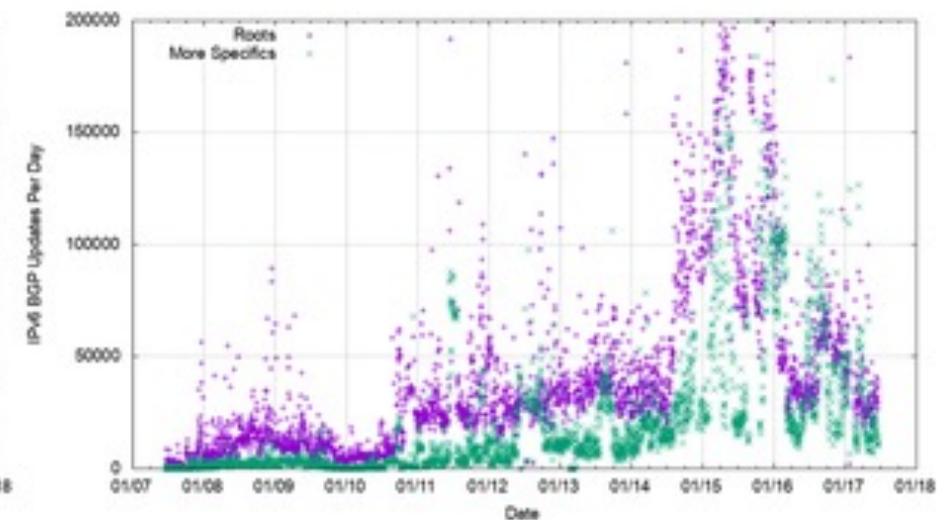
Source: BGP Routing Table Analysis Reports - <http://bgp.potaroo.net>

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

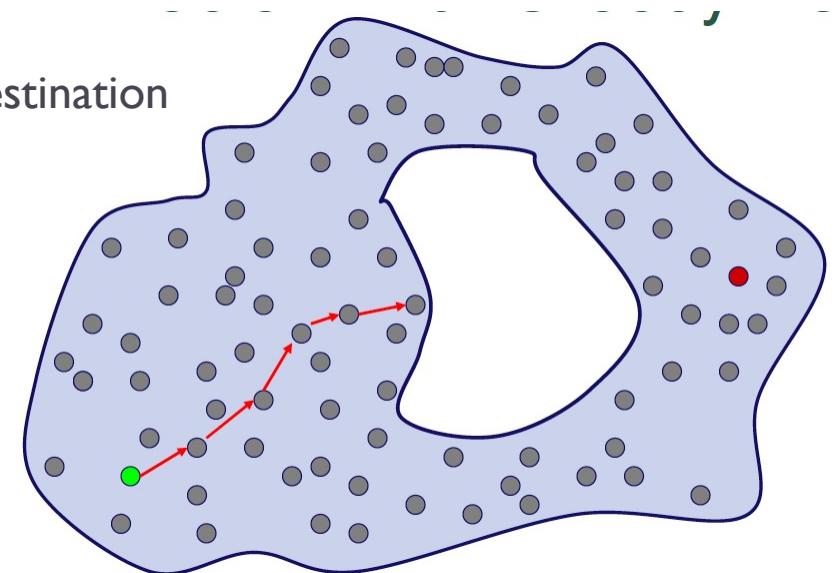
- **Updatefull:** Internet topology graph embedding into hyperbolic plane (requires full view topology graph)
- **Updateless:** graph constructed from hidden hyperbolic space yielding to scale-free topologies

Recursive InterNetwork Architecture

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

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)



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)

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

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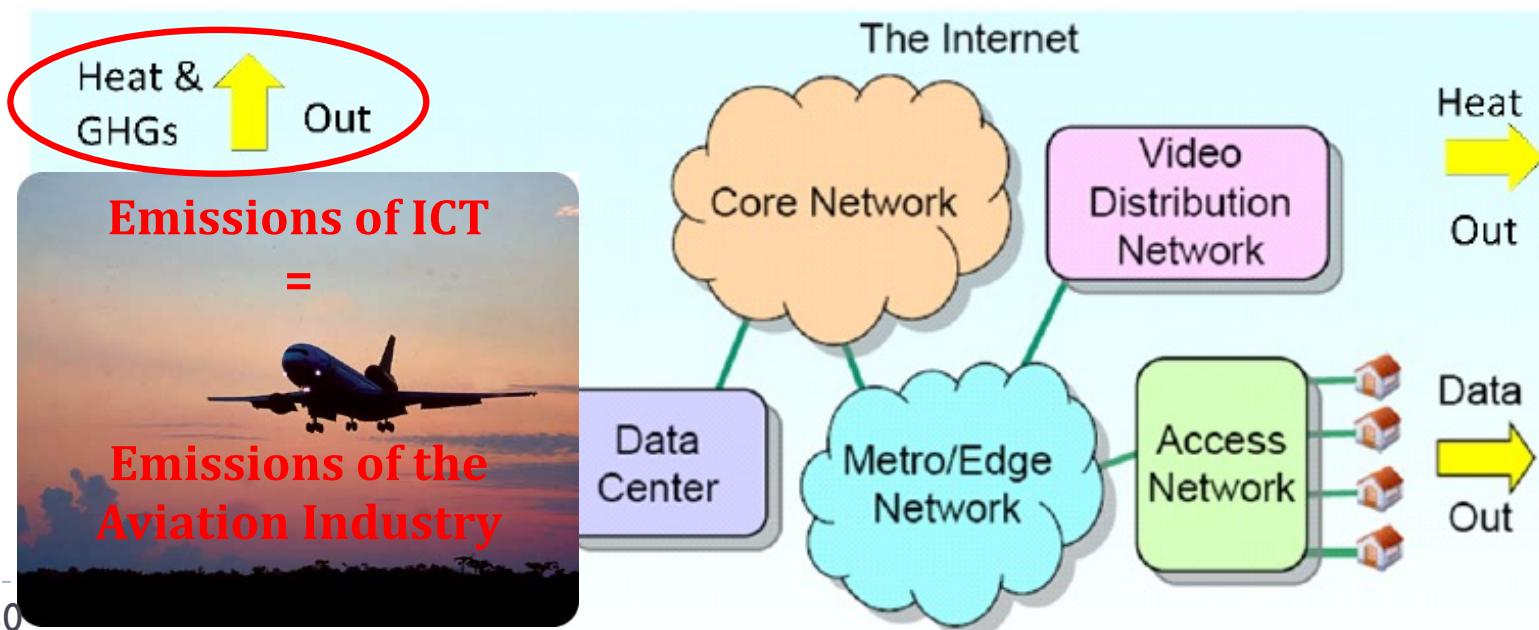
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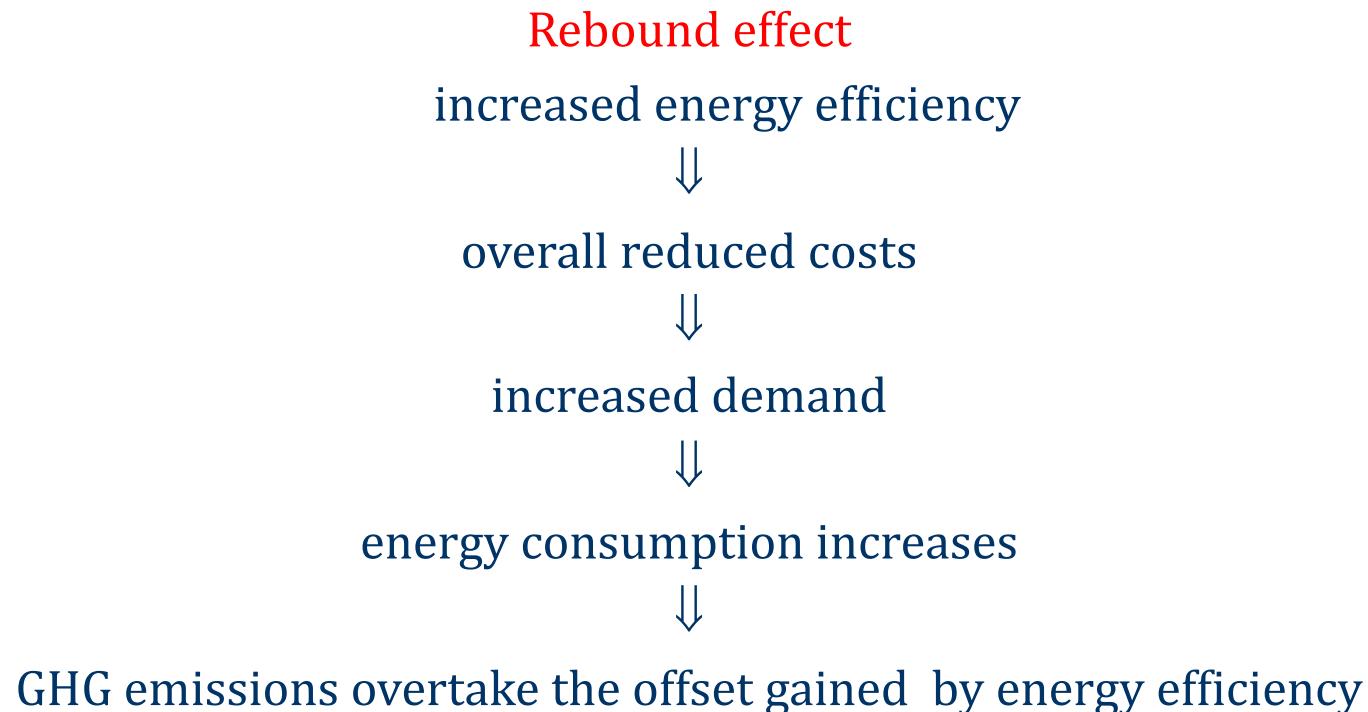
Sostenibilidad en Internet

- ▶ 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 CO₂, 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?



Problem formulation (2/2)

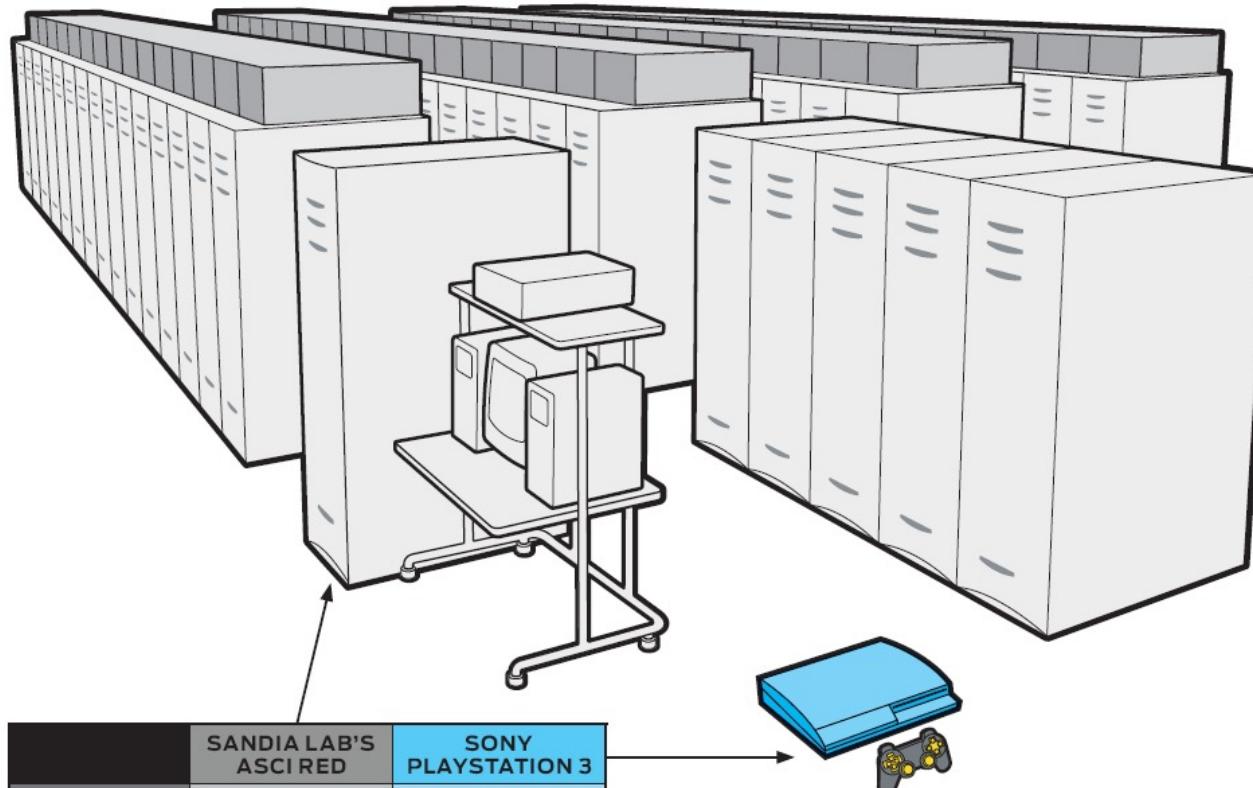
- ▶ **Energy-efficiency**
 - ▶ refers to a technology designed to reduce the equipment energy consumption without affecting the performance, according to the do more for less paradigm. Such solutions are usually referred to as eco-friendly solutions.
- ▶ **Energy-awareness**
 - ▶ refers to an intelligent 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 (CO₂ 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 |

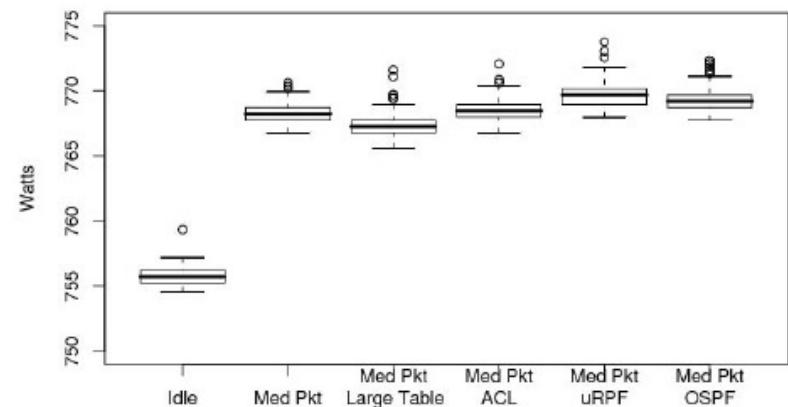
*For GPU; CPU adds another 0.2 teraflops

Examples

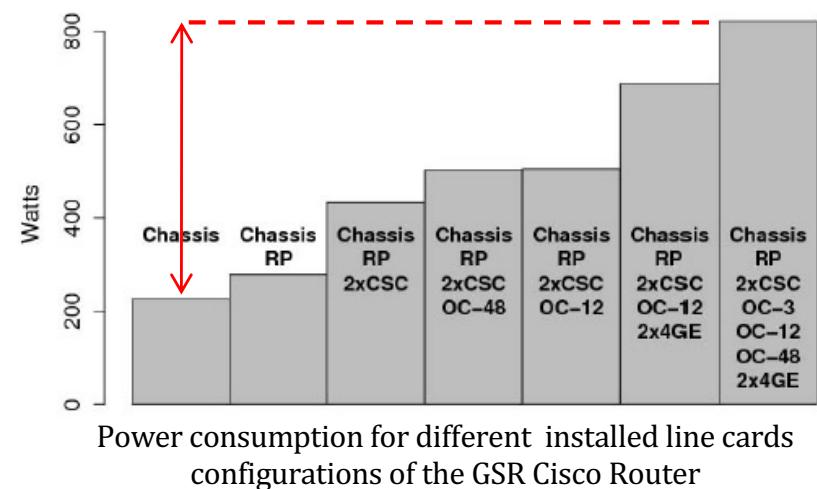
Energy-awareness

- ▶ 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



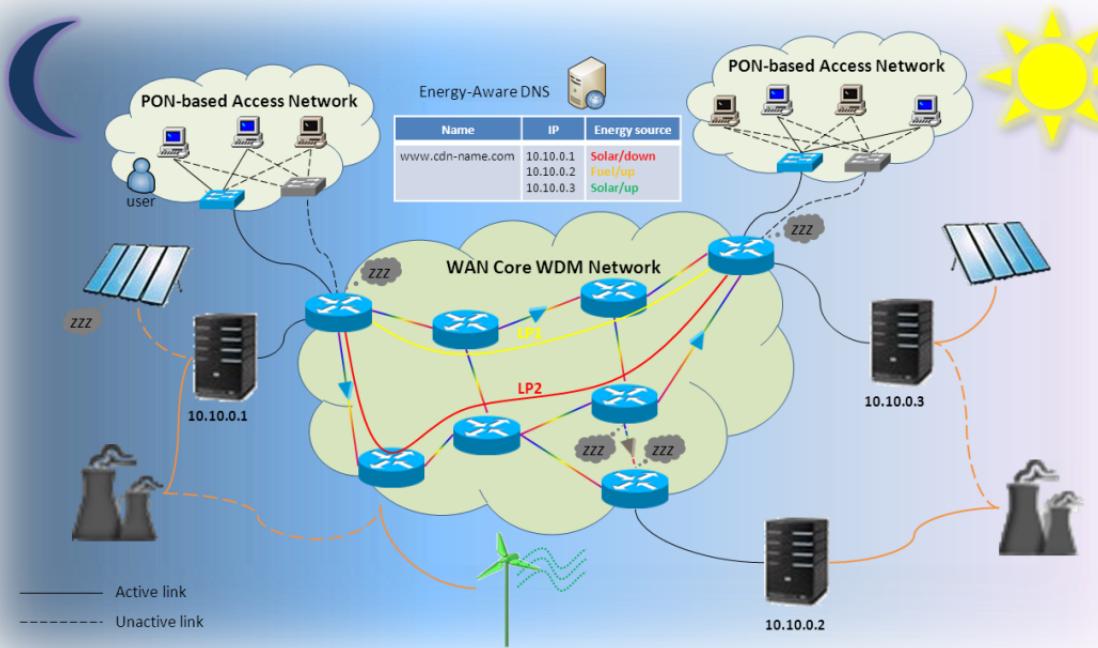
- ▶ But power consumption of base system is less than 50% of full configuration
- ▶ Focus on energy-aware architectures that can adapt their behavior, and so, their energy consumption, to the actual traffic loads



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

Bibliography

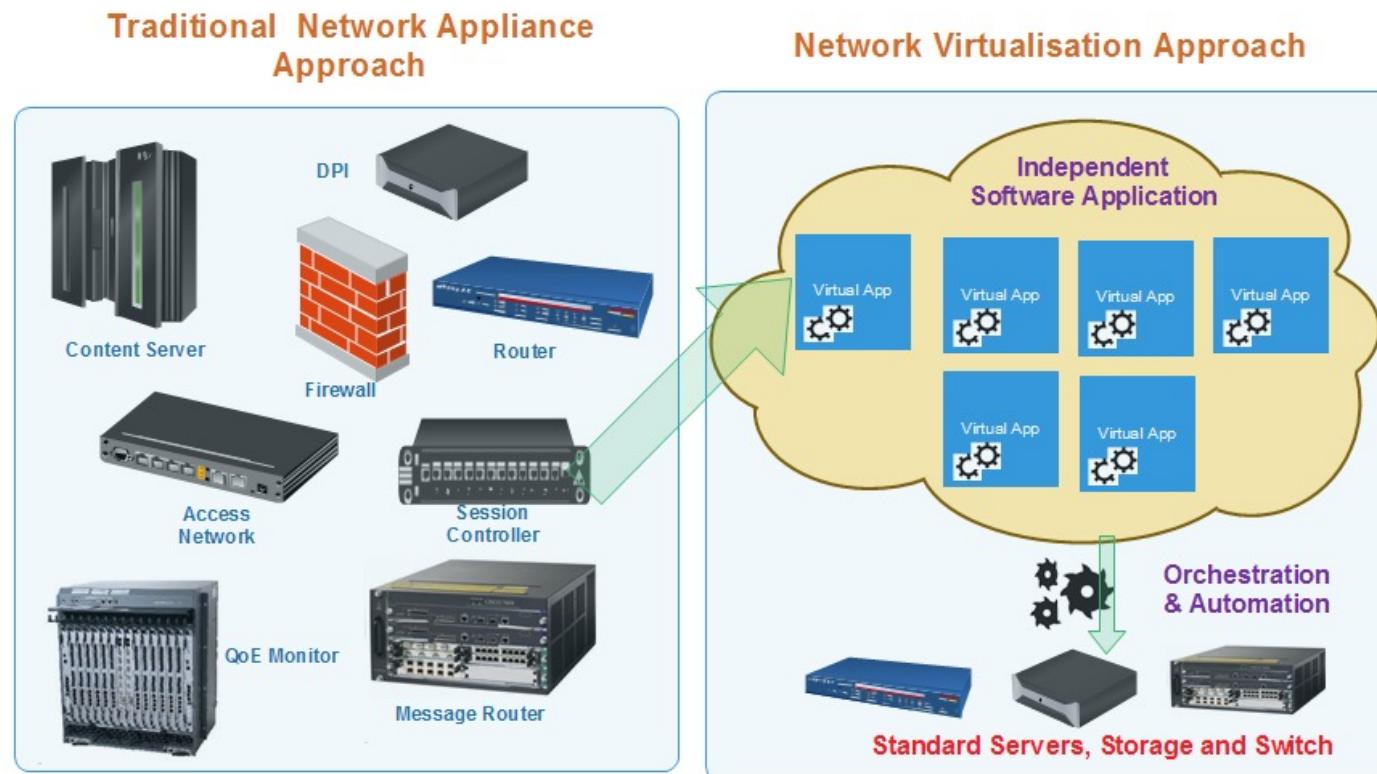
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- ▶ New recent journal: IEEE Transactions on Green Communications and Networking

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Network Function Virtualization (NFV)

- ▶ Virtualised Network Functions in the Cloud
- ▶ Instead of installing and maintaining 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



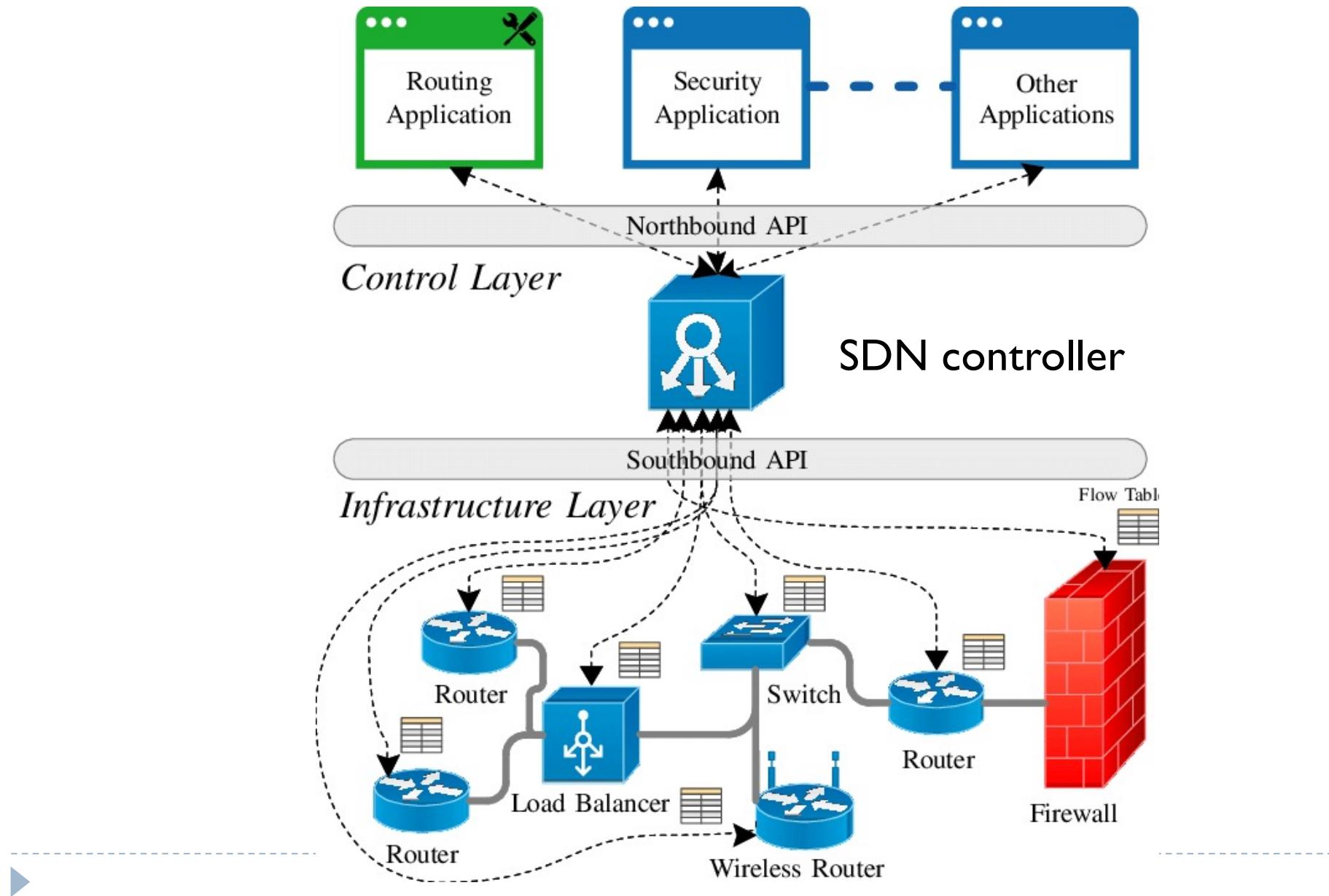
- ▶ Source image: Techplayon - <https://www.techplayon.com/network-function-virtualization-nfv-architecture/>

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

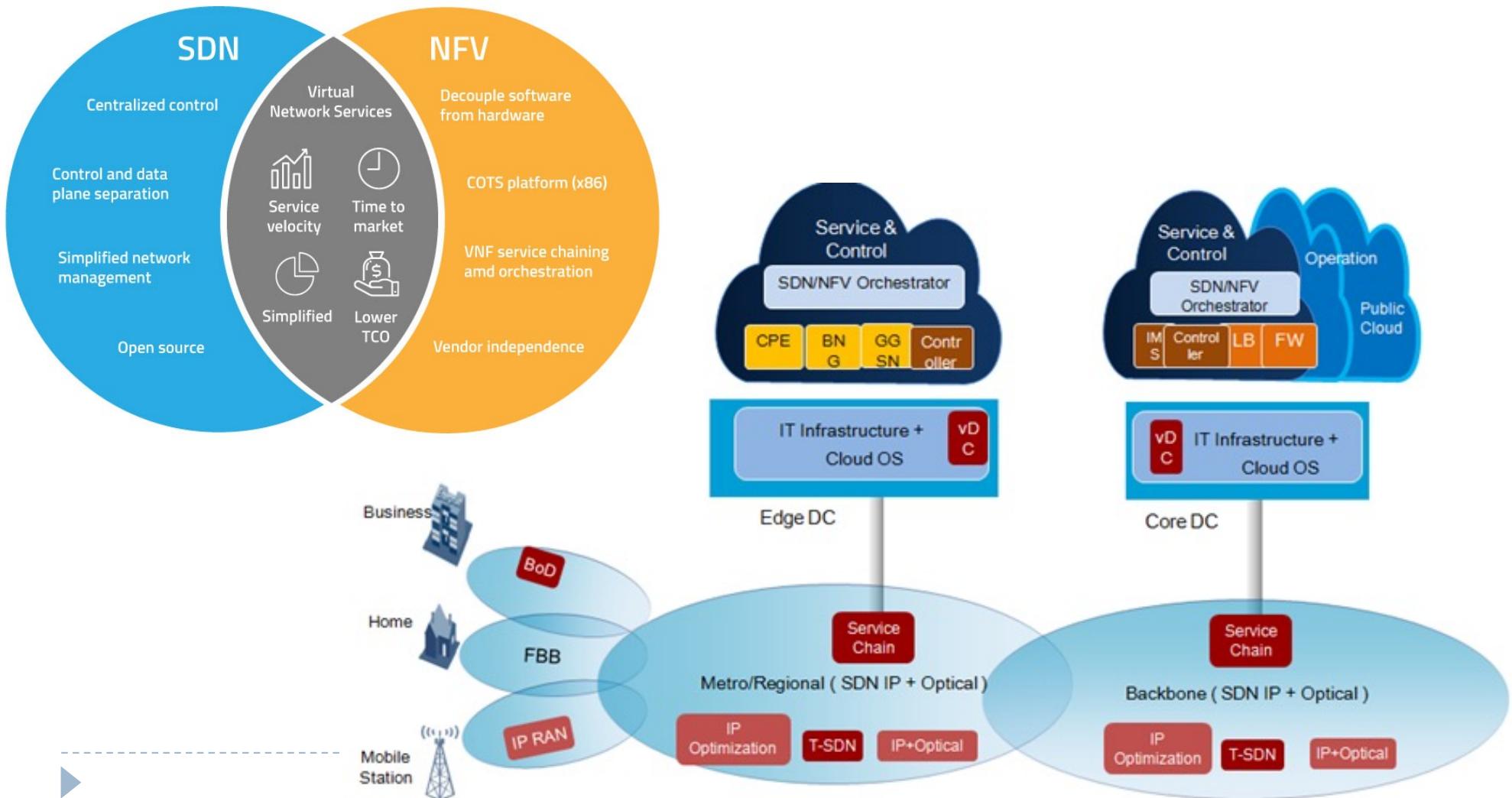


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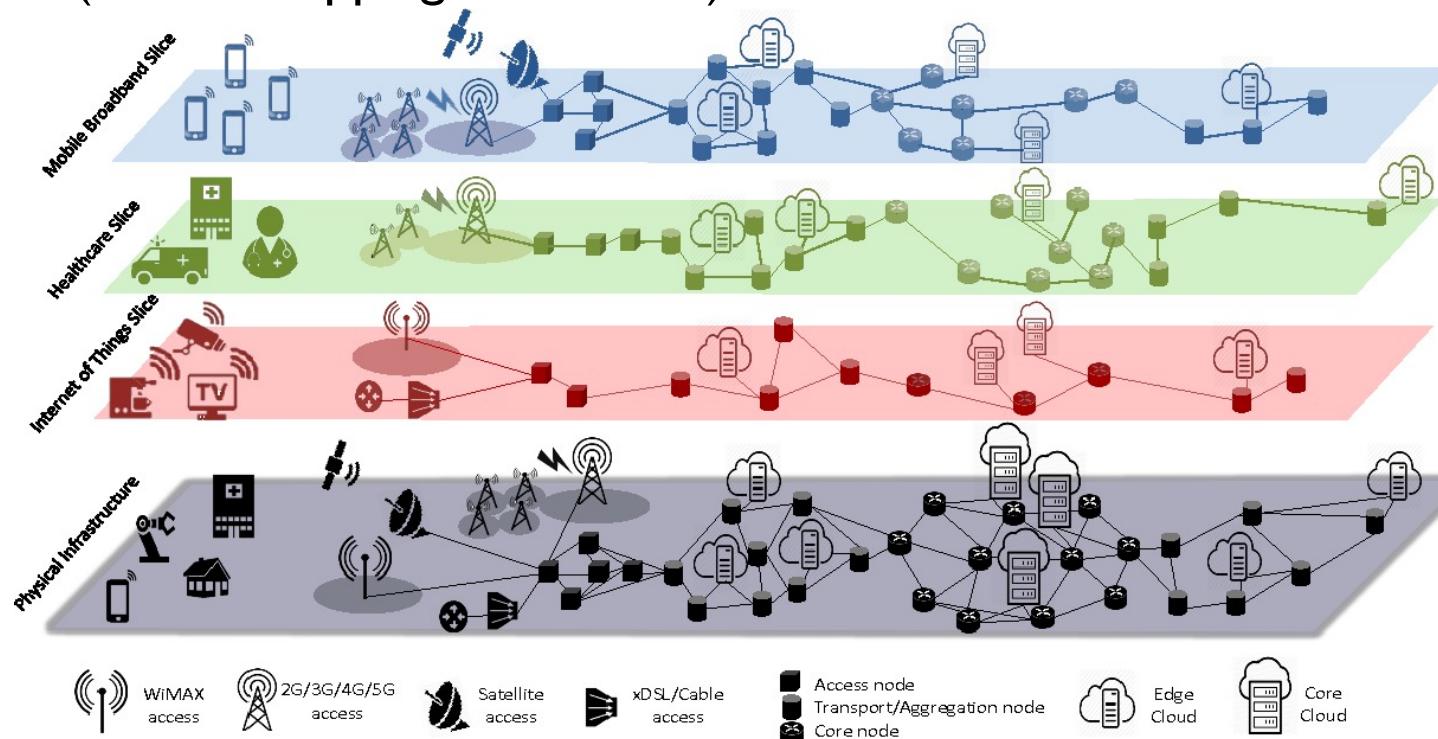
SDN/NFV

- ▶ 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



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) Alternativas a IP: ICN, RINA, etc.
 - 2) Protocolos de encaminamiento en redes ópticas (flexibles, multi-núcleo, etc.)
 - 3) Mejoras del BGP
 - 1) Overlay (VXLAN, LISP, BIER multicast, etc.)
 - 2) Compact routing
 - 3) Greedy geometric routing
 - 4) Sostenibilidad en Internet
 - 1) En redes locales
 - 2) En redes troncales
 - 5) Redes programables SDN
 - 6) Virtualización de funciones de red NFV
 - 7) Machine Learning / Cognitive / Artificial Intelligence

Xarxes de computadors II

Actividad complementario: presentaciones

Davide Careglio

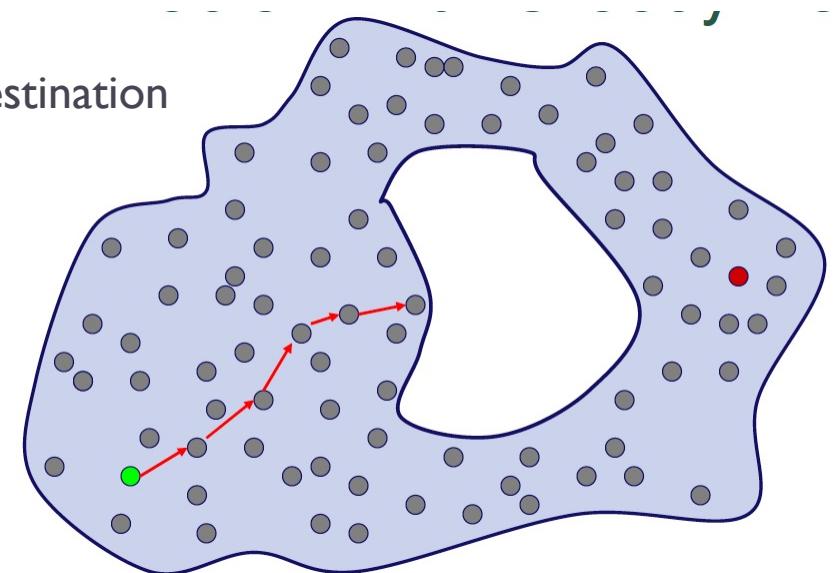
Xarxes de computadors II

Material de backup

Davide Careglio

Geometric routing

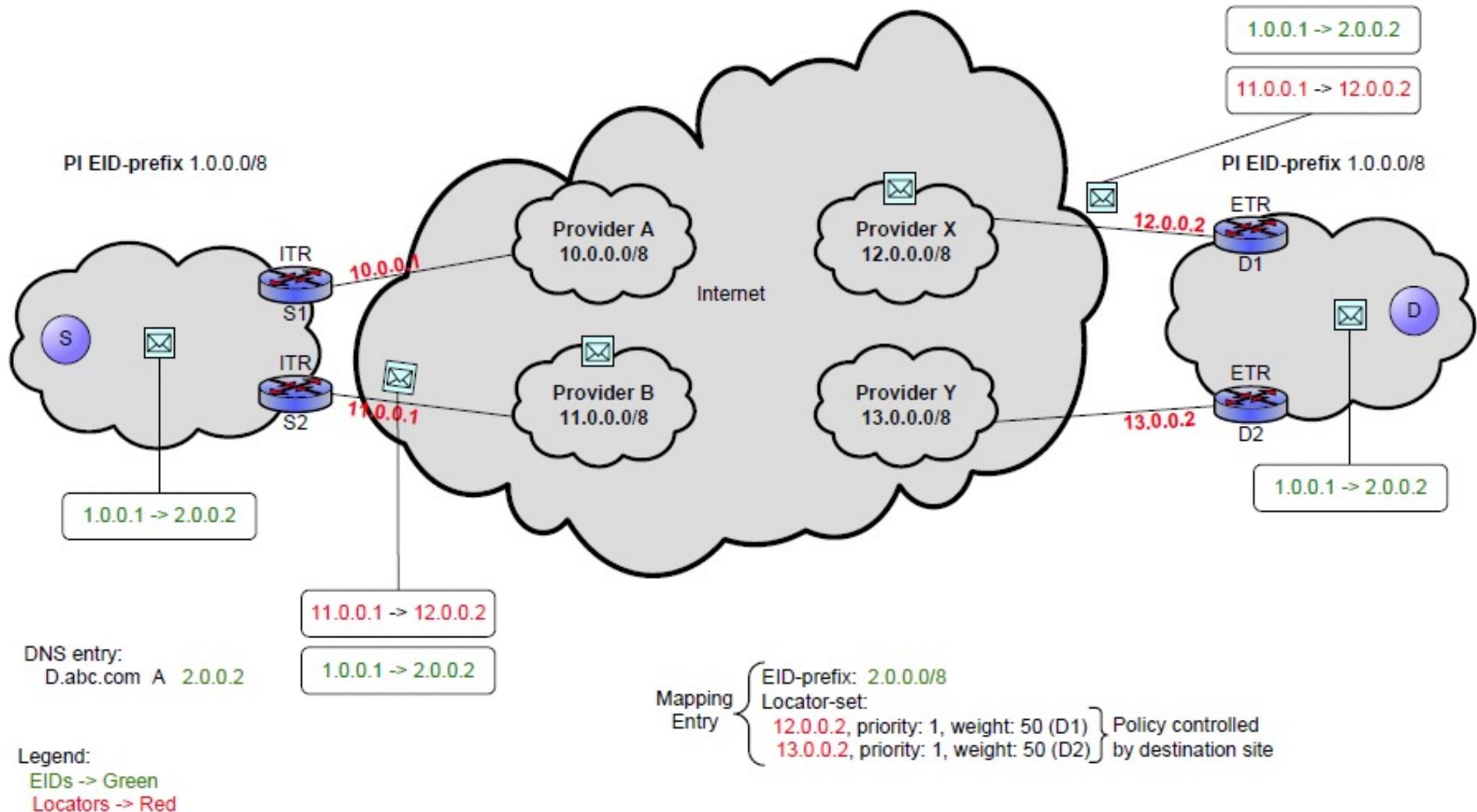
- ▶ **Principle**
 - ▶ relies on geographic position information
 - ▶ source sends a message to the geographic location of the destination instead of using the network address
- ▶ **Requirements**
 - ▶ each node determines its own location
 - ▶ source is aware of the location of the destination
 - ▶ 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)



LISP

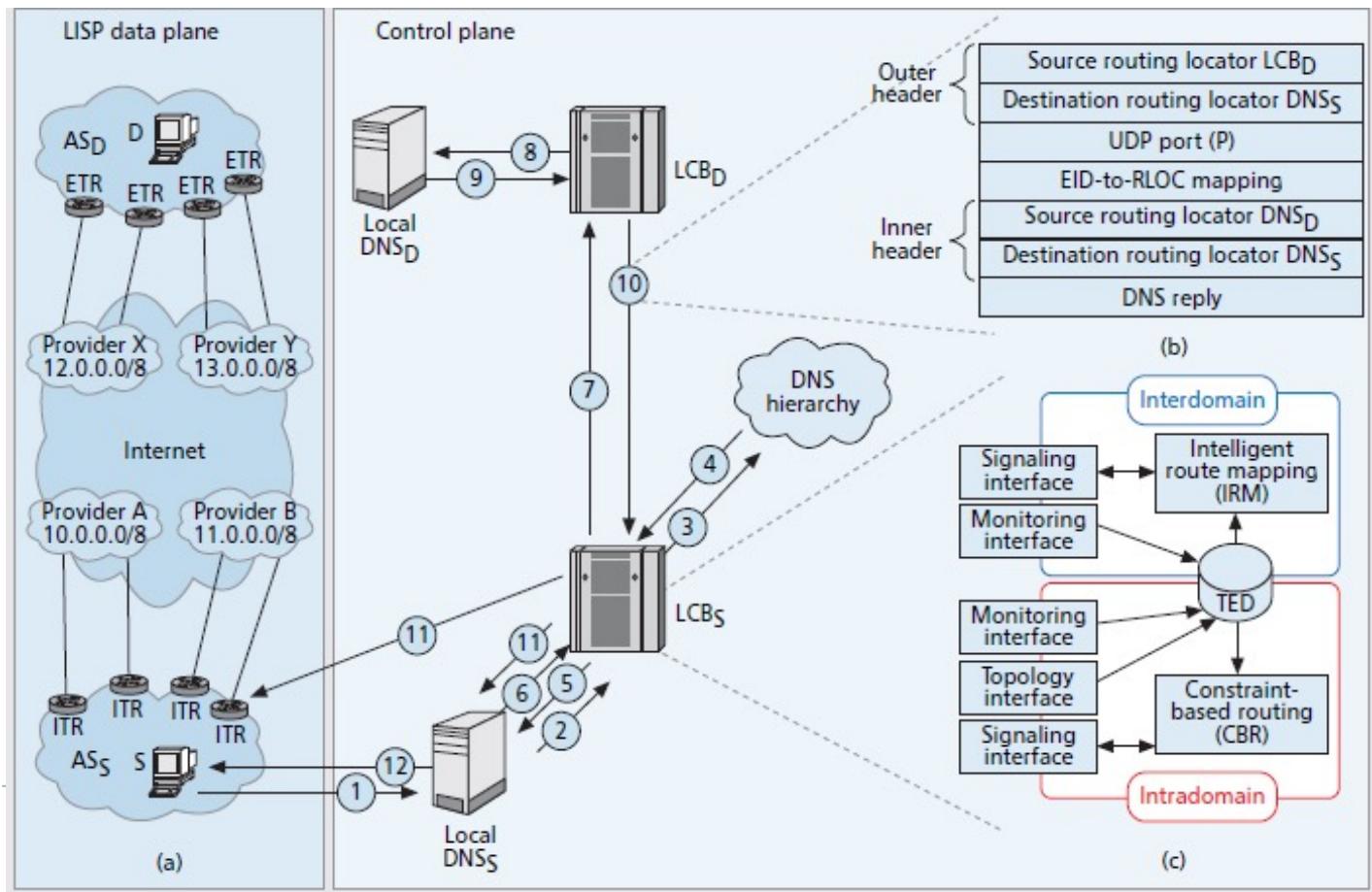
- ▶ The IP addresses currently used by endhosts play two complementary roles
 - ▶ **Identifier role:** the IP address identifies (with port) the endpoint of transport flows
 - ▶ **Locator role:** the IP address indicates the paths used to reach the endhost. These paths are updated by routing protocols after each topology change
- ▶ LISP: Locator/Identifier Separation Protocol
- ▶ IETF proposal
- ▶ Define a router-based solution where current IP addresses are separated in two different spaces:
 - ▶ Endpoint Identifier (EID): identify end-host, non-globally routable
 - ▶ Routing Locator (RLOC): Internet core address space, globally routable

LISP



LISP

- ▶ Requires an additional distributed database of EID-RLOC mappings
- ▶ Proposal
 - ▶ Obtaining and configuring the corresponding mapping during the DNS resolution process for the destination EID



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)

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

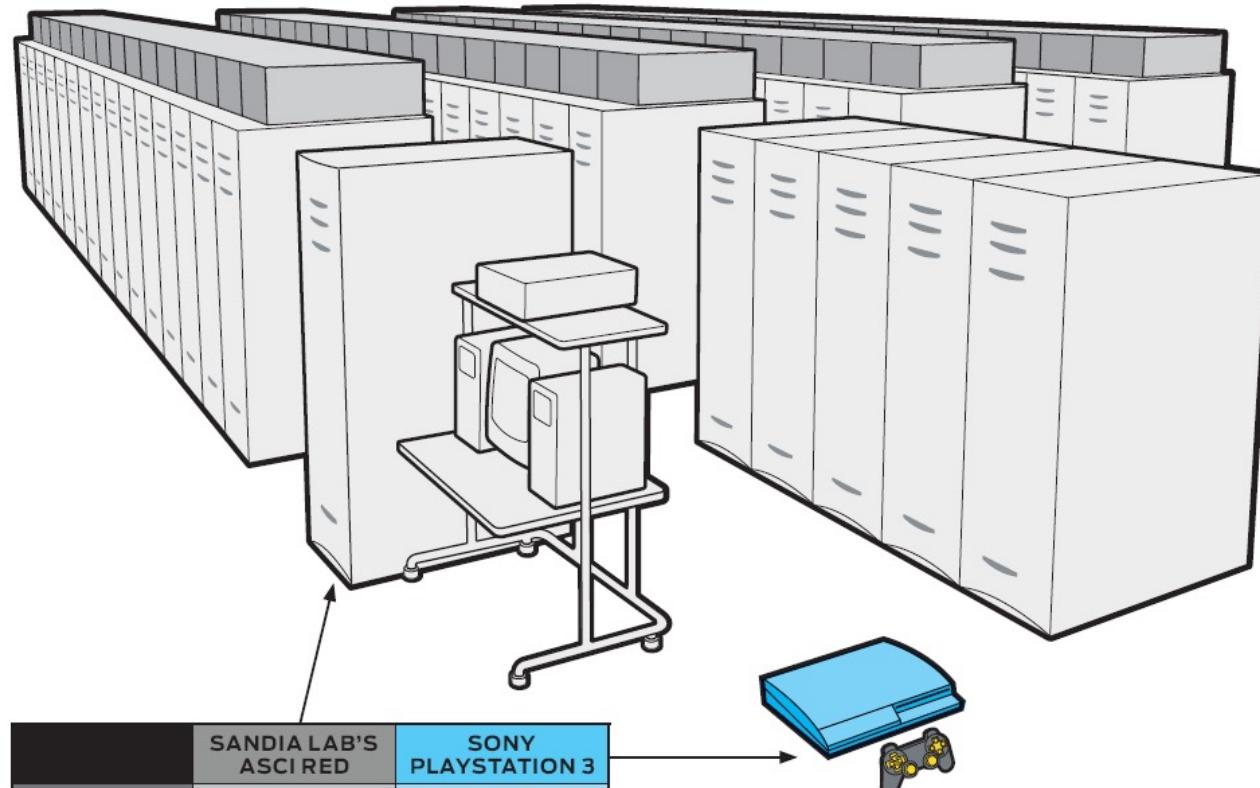
▶ Challenges

- ▶ 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

Examples: energy-efficiency

- ▶ Doing more with less

SUPERCOMPUTER VS. GAME CONSOLE



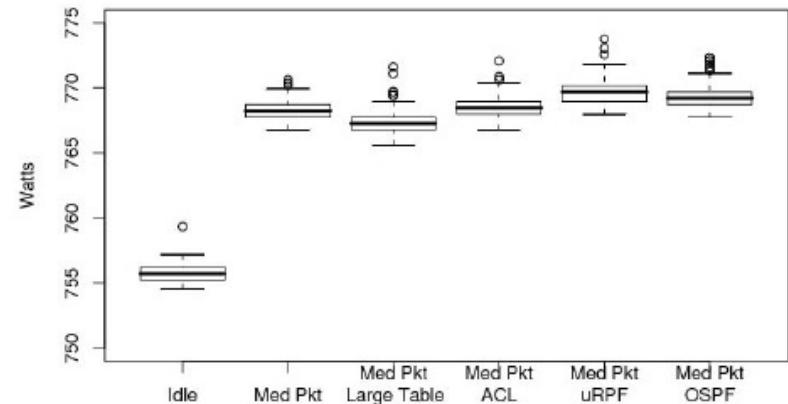
| | SANDIA LAB'S ASCI RED | SONY PLAYSTATION 3 |
|----------------------|--------------------------|-----------------------|
| DATE OF ORIGIN | 1997 | 2006 |
| PEAK PERFORMANCE | 1.8 teraflops | 1.8 teraflops* |
| PHYSICAL SIZE | 150 square meters | 0.08 square meter |
| POWER CONSUMPTION | 800 000 watts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

*For GPU; CPU adds another 0.2 teraflops

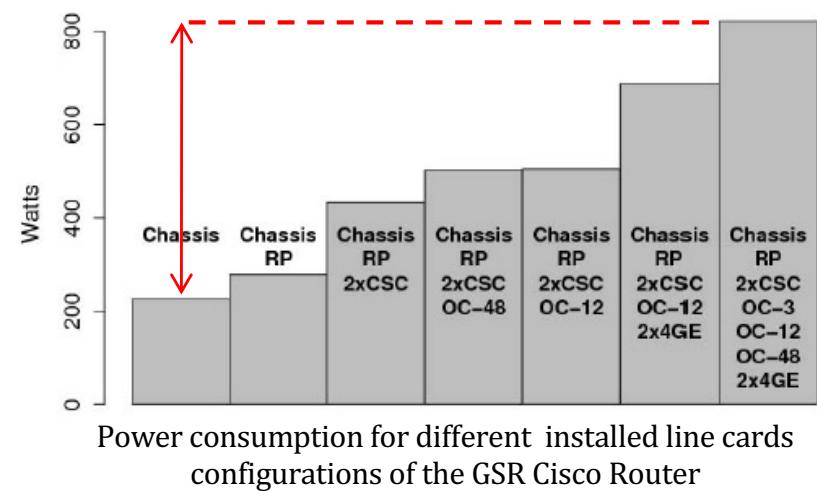
Examples: energy-awareness (1/3)

- ▶ 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

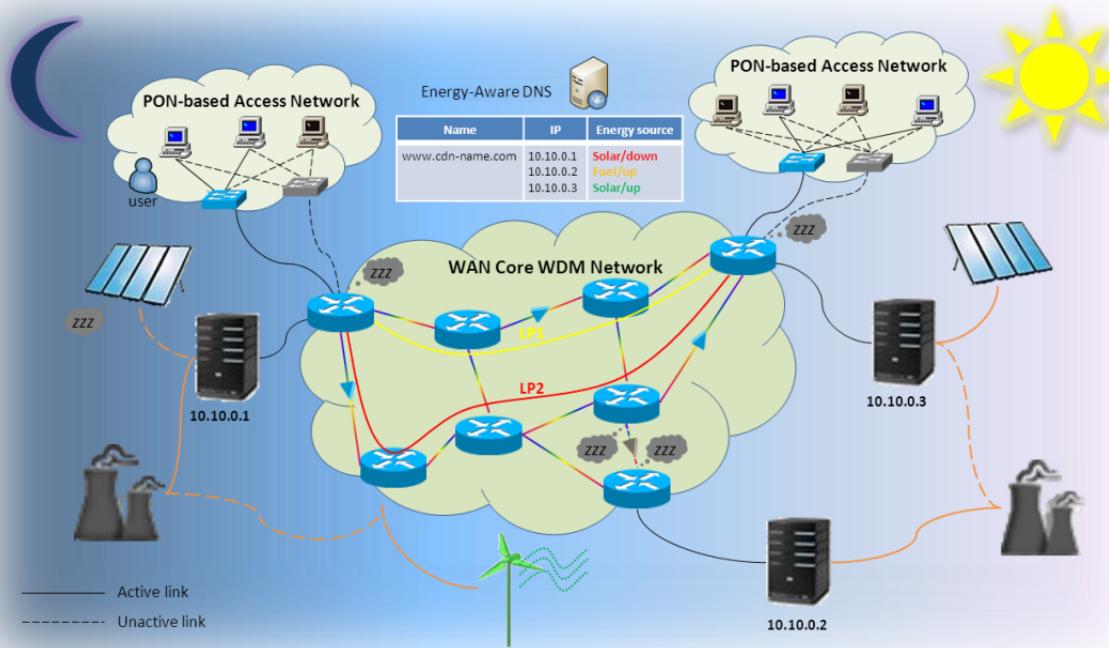


Examples: energy-awareness (2/3)

- ▶ **Sleep-mode**
 - ▶ switch-off or downclocking interfaces or devices when not used
- ▶ **Two initial proposals for Ethernet line cards**
- ▶ **Adaptive Link Rate (ALR)**
 - ▶ dynamically modify the link rate according to the real traffic needs
- ▶ **Low Power Idle (LPI)**
 - ▶ transmission on single interface is stopped when there is no data to send and quickly resumed when new packets arrive

Examples: energy-awareness (3/3)

- ▶ 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