Softwarization of 5G Network and Service Infrastructures

Current State, Upcoming Trends and Key Challenges

Prof. Alex Galis
http://www.ee.ucl.ac.uk/~agalis/
Communications and Information Systems Group
Department of Electronic & Electrical Engineering
University College London,
United Kingdom

A view point on 5G Networks

View point: 5G Networks qualities

Citius, Altius, Fortius **(Olimpic motto - Latin for "Faster, Higher, Stronger")**

- **High / ever higher performant connectivity converged wire and wireless environments (i.e. 'everything is connected' paradigm)**

Flexibilis **(Latin for 'flexibility')**

- **Service execution environments & programmable infrastructures (i.e. enable networks to support a new range of applications - 'computation for everybody' paradigm)**
- **Softwarization and in particular (Self) Software Management and Control would represent nearly 99% of the new 5G Networks & Services functionality**
- **Significant reduction in management complexity and in costs of operations (i.e. OPEX)**

H/W + S/W → virtualization, cloud architecture, flexibility, openness, programmability, automation

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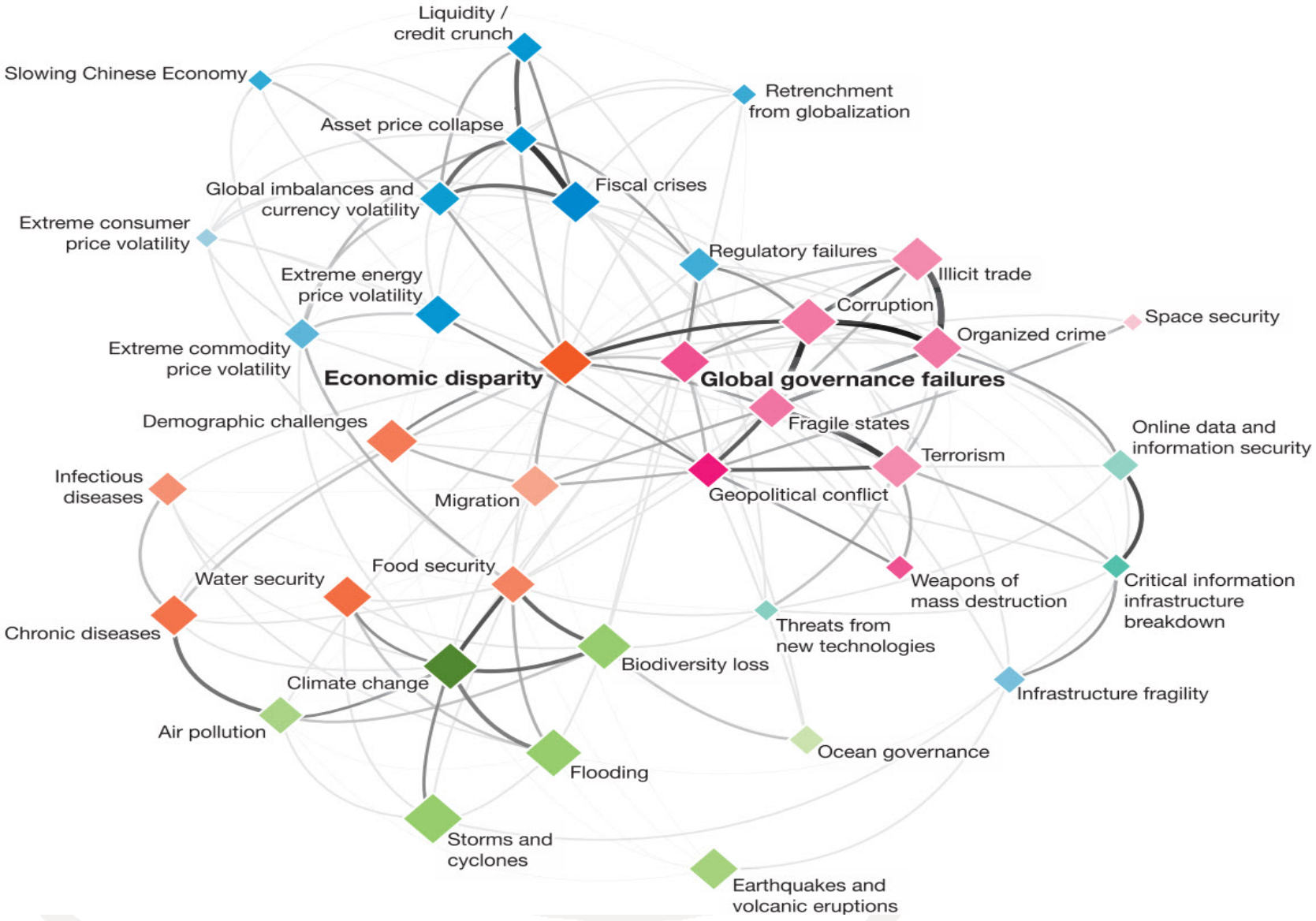
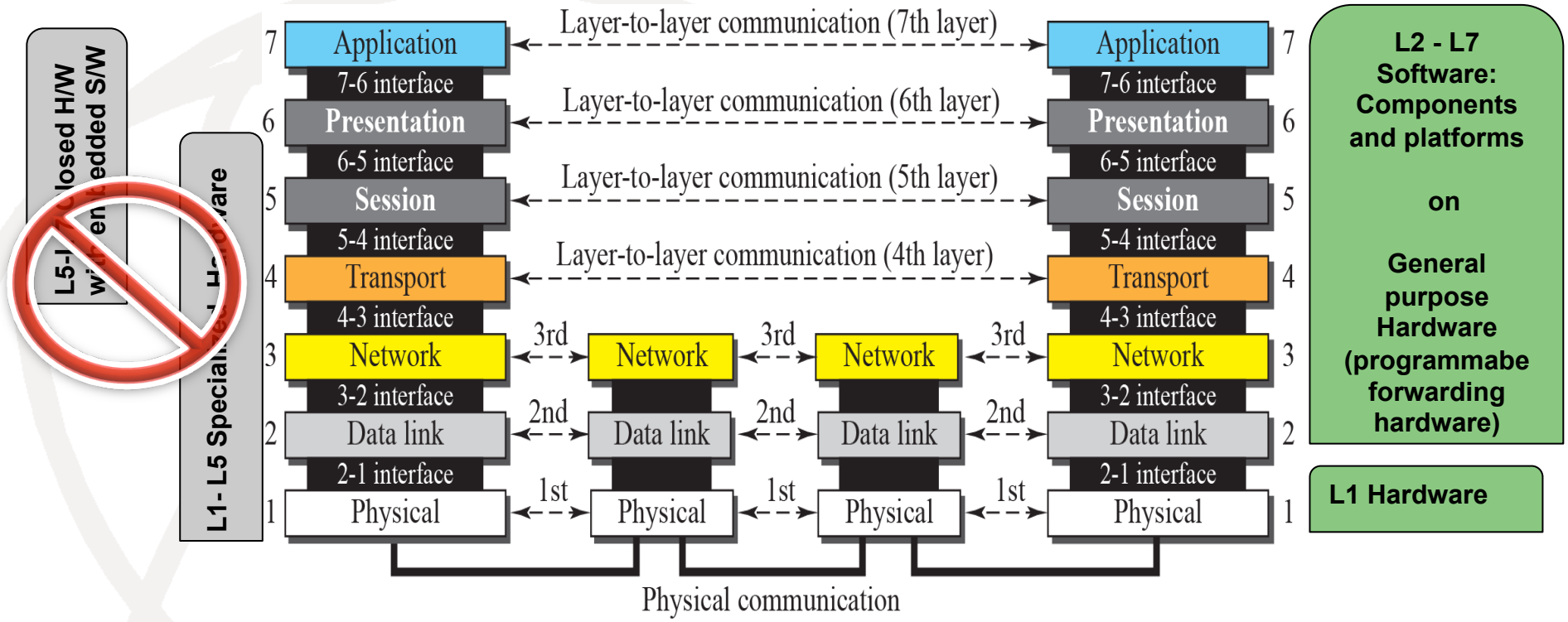
General: UCL is ranked fifth in the world's top universities by the QS World University Rankings (2014) and number 20 in the Shanghai Ranking of World Universities (2014); Only 2 other European Universities (i.e. also from the U.K.) are ranked higher. UCL connected in July 1973 to ARPAnet.

A highly joint with interdependencies World and moving towards hyper connectivity



Systemic interdependencies of the socio-economic variables of the highly connected world (i.e.: reference: World Economic Forum)

Softwarization - A Trend



Processing Computation

Storage

Connectivity Bandwidth

How best to manage and use physical resources (connectivity, computation, storage, big/small data), virtual resources, network functions and service …

Some current systemic limits & trends

- Networks are becoming both a connectivity and service execution environment

→Work towards a service and management aware connectivity infrastructure

- Wireless/wire network equipment and/or resources virtualisation; Computation, storage and connectivity Virtualised separately (but not in an integrated way);

→ Work towards a flexible and cost effective integrated virtual infrastructure with elastic usage and sharing resources

- Silos and disparate systems with limited extensibilities which created a segmentation of networking & computation

→ Programmability: dynamic and autonomic activation of network and service functions

- Need for Software driven / enabled features (in NFV era – build differentiated competitiveness)

→

- Programmability and Elasticity
- Integrated Virtualisation of Connectivity Storage and Processing Resources
- In-Network Management
- Service awareness
- Energy awareness
- Content awareness
- Knowledge awareness
- Economic awareness
- Extensibility with new features
- .....

Drivers for Change

- **Disappearance of the 'End-host only' concept** (i.e. edge networks; new nodes : sensors, mobile devices;)
- **Lack of in-system management** (i.e. information, decision, implementation – closed control loops for realizing management requirements)
- **Trustworthy User / Network / Service (**i.e. end-host protocols can and are altered → many security issues)
- **Best effort service delivery**
- **No explicit media & content handling**
- **Size & Costs:**
  - N X 10^9 connectivity points - status: reaching maturity and maybe some limits
  - N X10^5 services /applications - status: fast growing
  - N X10^3 Exabyte's content - status: fast growing
  - Cost structure: 80% (→90%) of lifecycle costs are operational and management costs - status: reaching crisis level
- **Ossification:** reaching crisis level
  - A lot of missing and interrelated features; missing enablers for integration and orchestration of Nets, Services, Content, Storage
  - Substantial barriers to innovation with novel services, networking systems, architecture and technologies

How to Change

Approaches:

- Parallel Internets; Progressive changes; “Cleaner” slate and evolutionary
- Network of networks → system of coordinated service networks
- Virtualization of resources (Computation, Wire/ Wireless Networks, Services, Content, Storage)
- Programmability at all levels
- Increased self in-management as the means of controlling the complexity and the lifecycle costs
- Softwarization of Internet

Softwarization means ....

- Migration of “advance and new intelligence” towards the End-Users
- Enabling ICT ecosystems, by addressing socio-economic “problems” (i.e., the fabric of Society);
  - lowering the threshold for new Players to enter the edge arena;
  - new forms of competition / collaboration among Players; new value chains
- Integrating deeply cloud resources with wireless / wire networking resources:
  - build up of connectivity, processing and storage resources
  - distributed virtual platforms executing any network function and networked services (i.e. L4 - L7 or full L2 - L7) as “applications” (on Virtual Machines, dynamically allocated, moved and managed on general purpose Hardware);
  - Blurring the distinction between the “Network” and what connects to it. Most devices, machines, smart things, cars, robots…would /could act as nodes (at the edge) providing the End-Users with “any services”.
- For operators
  - convergence of IT and Networks nodes and systems / … a plethora of de Facto Standards
  - development of high-skill jobs for mastering the software.
  - potential significant reductions of CAPEX and OPEX / big impact on operations processes
- Availability of programmable forwarding hardware (optical & radio devices) – support for control software

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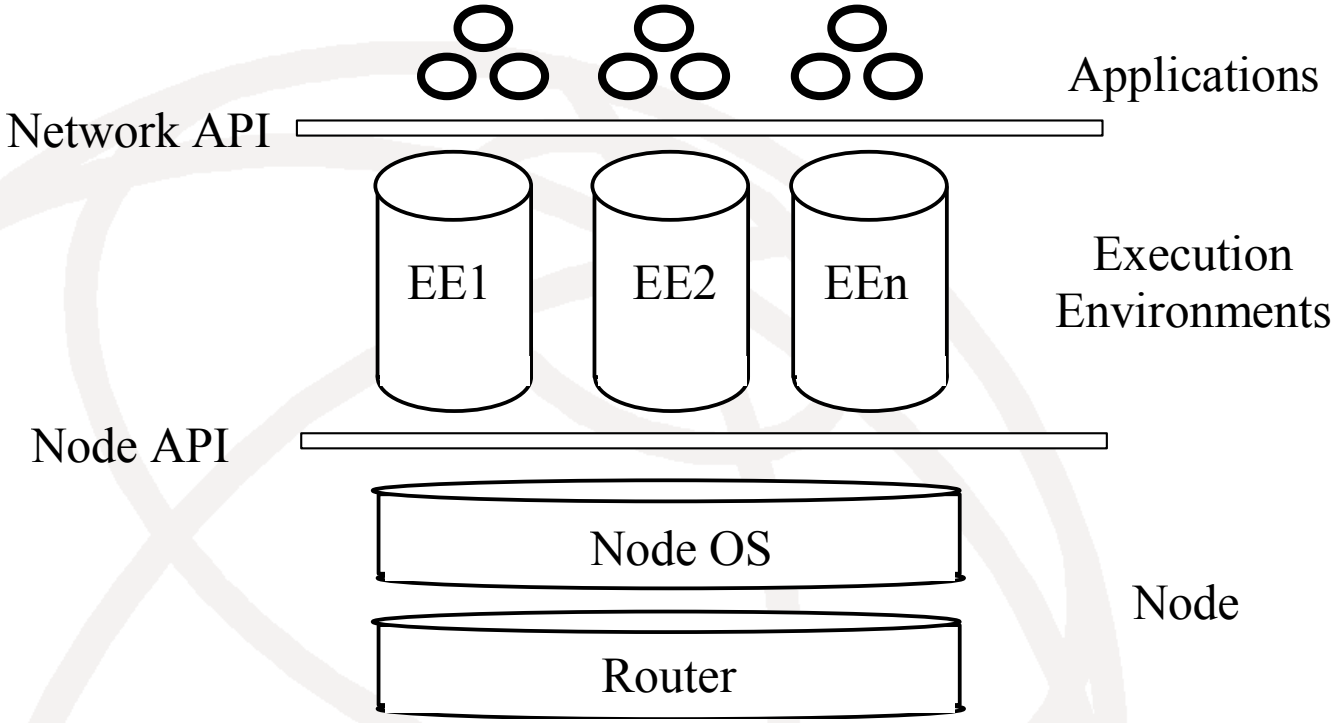
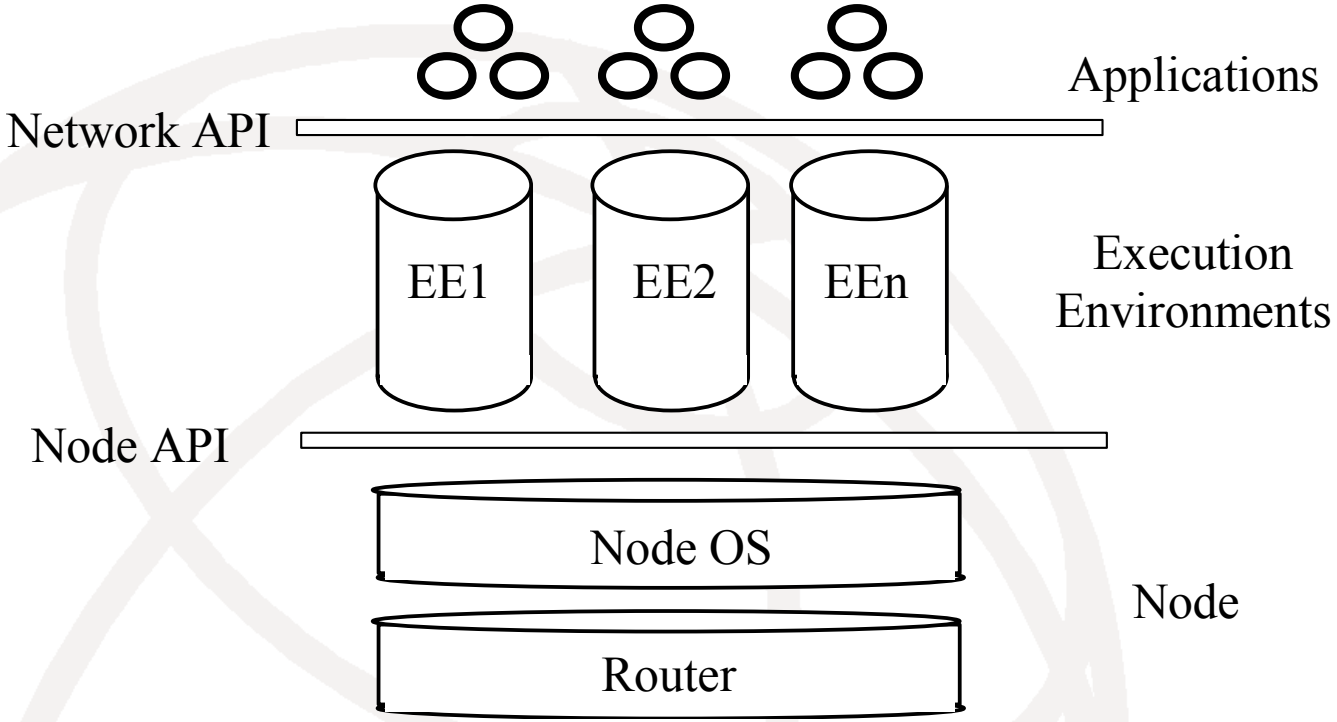
Programmable Network Model (mid 1990s – late 2000s)



Remarks: 1. Dynamic programming refers to executable code that is injected into the network element in order to create the new functionality at run time. Two programming models:

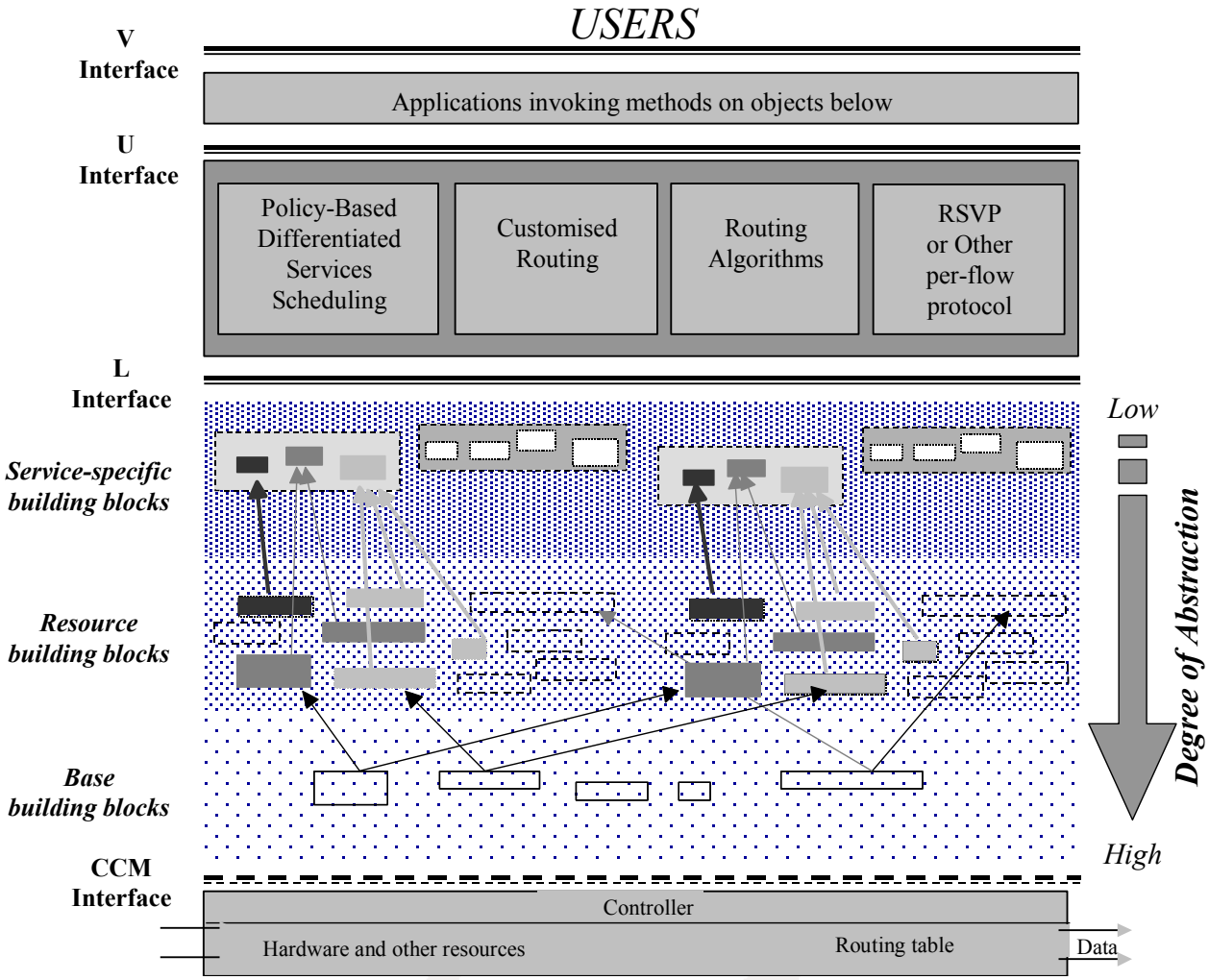
- The capsule model, where the code to execute at the nodes was carried in-band in data packets. Capsules envisioned installation of new data-plane functionality across a network, carrying code in data packets and using caching to improve the efficiency of code distribution.
- The programmable router/switch model, where the code to execute at the nodes was established by out-of-band mechanisms. Programmable routers placed decisions about extensibility directly in the hands of the network operator.

Programmable Network Model (mid 1990s – late 2000s)



Remarks: 2. No interest in "low level" programming the network;
3. Virtualisation of networks via programming of networks
4. Extremely hyperactive network which would be difficult to manage
→ Needing programming network services (instead of re-architecting the network and OSs for every service)

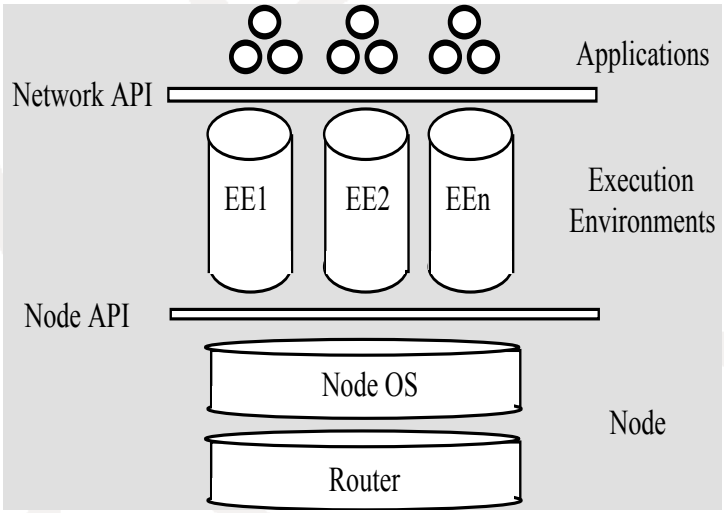
P1520 Reference Model –Application Programming Interfaces [i.e. Dynamic Service Chaining (Service Deployment Concept)~ 2005]

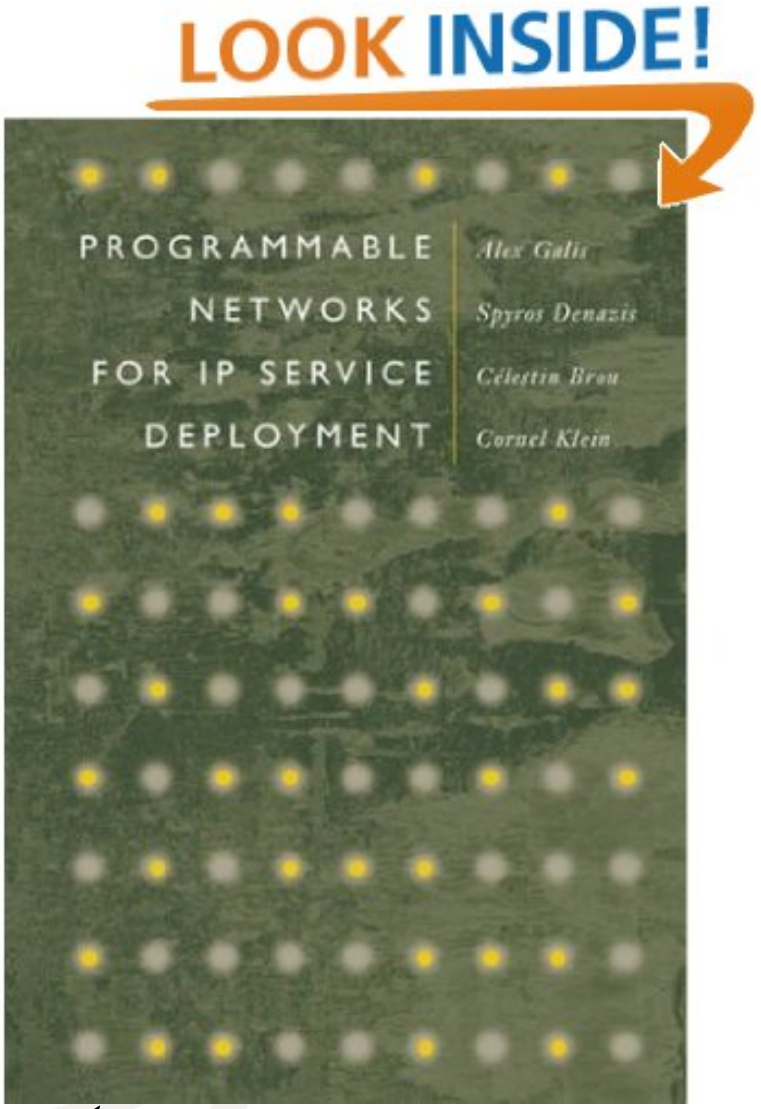


Remarks: 1. motivation behind Service control and programmability came from the observation that monolithic and complex control architectures could be restructured as a minimal set of layers, allowing the services residing in each layer to be accessible through open interfaces—providing the basis for service creation (composition and chaining)

Remarks: 2. P1520 has no hosting environment(s) for the network services → dynamic service chaining and the evolution of network virtualization from data centers into carrier networks do not come without their own challenges

SDN Evolution - Conceptual Networked Systems





SDNs Architecture

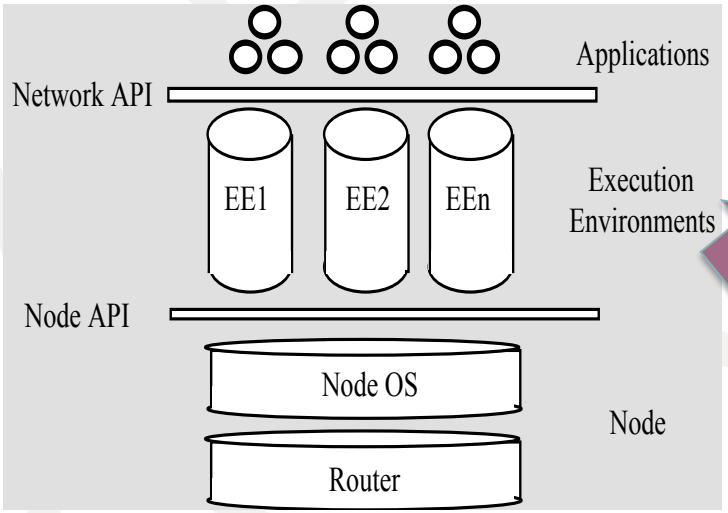
Connectivity & Computation Infrastructure

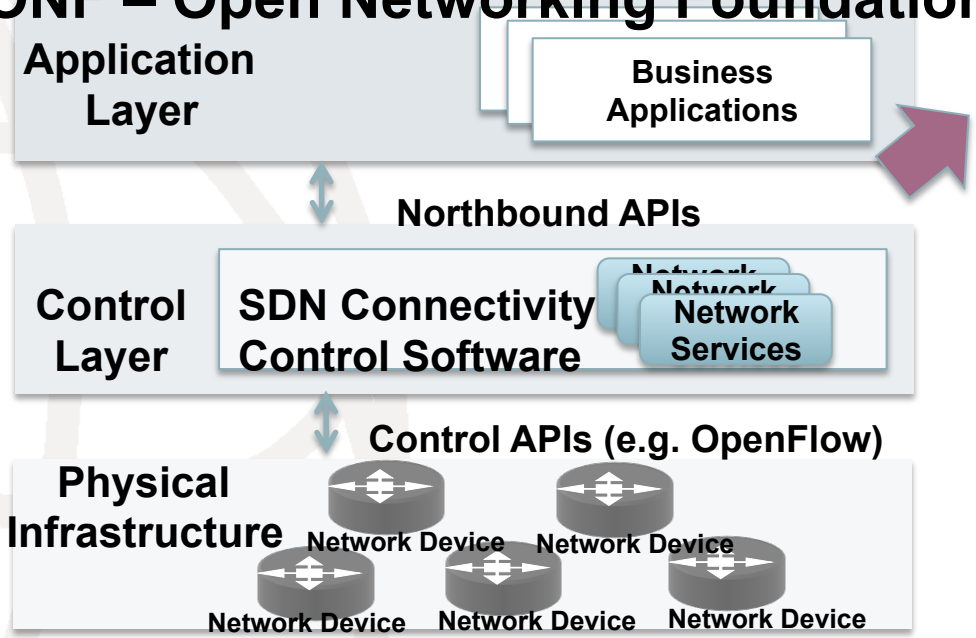
Status in the early *2000+*

(active & programmable networks)

SDN Evolution - Conceptual Networked Systems

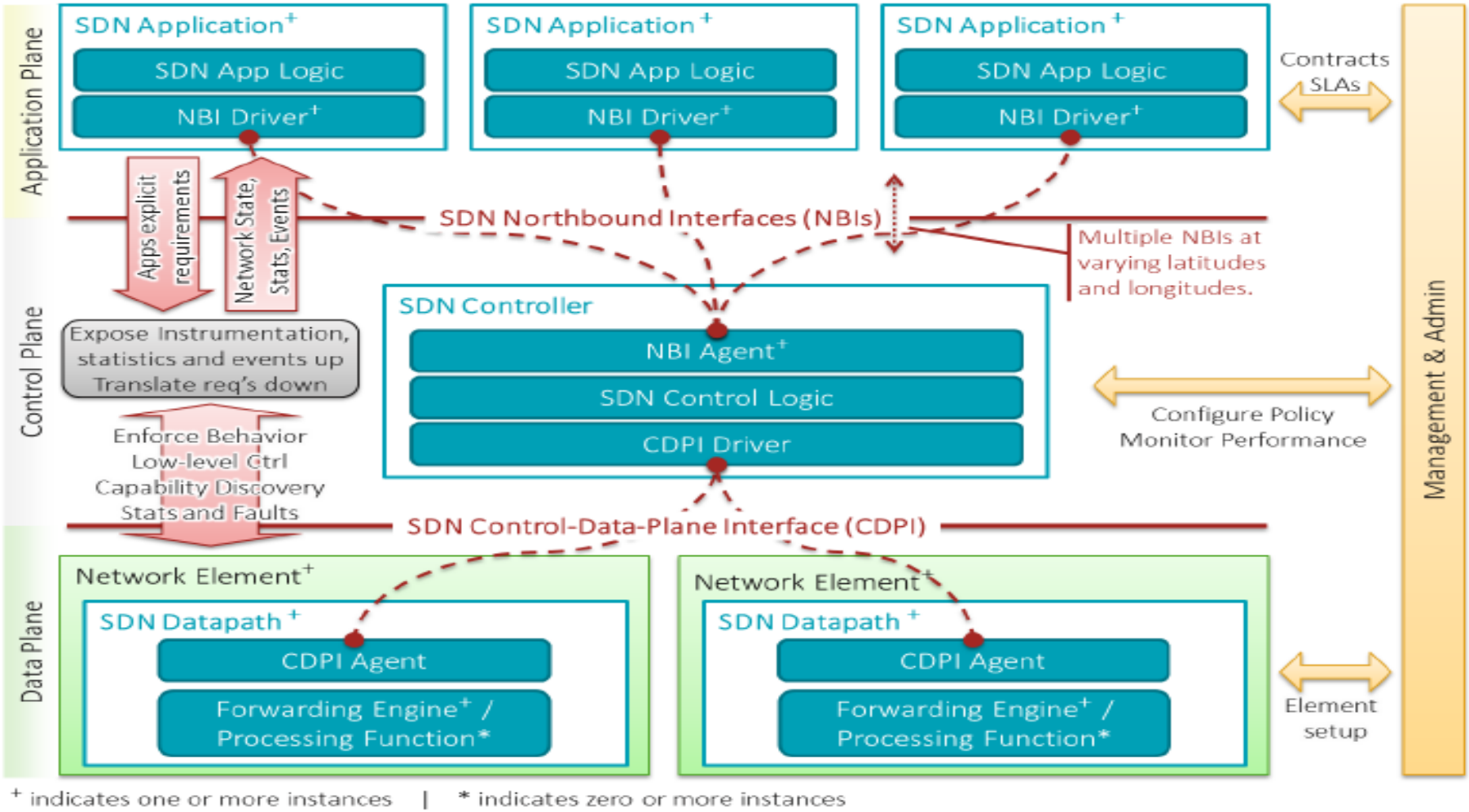
SDNs Architecture
Connectivity Only Infrastructure
Status in the *2010+*
(ONF – Open Networking Foundation)





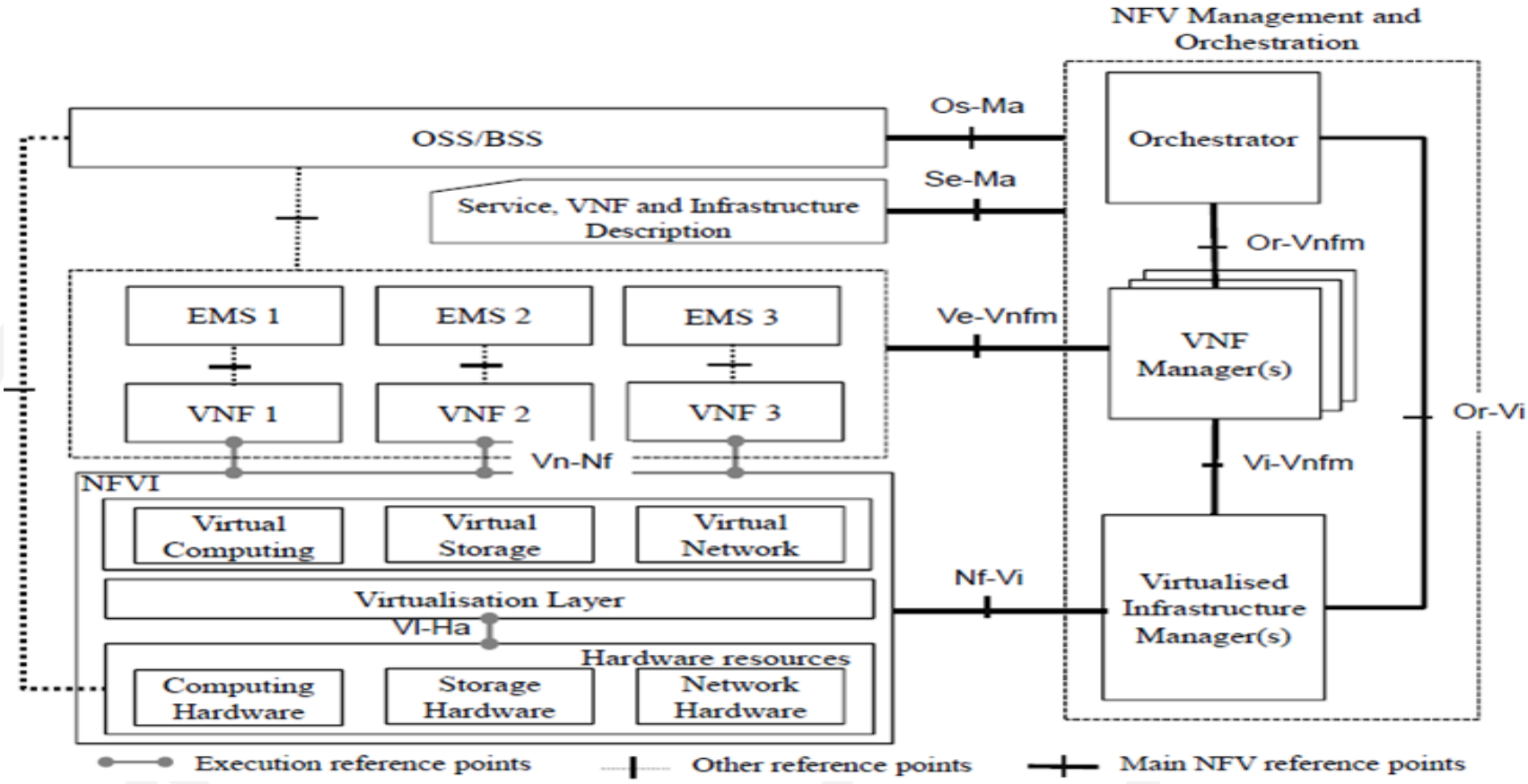
SDNs Architecture
Connectivity & Computation Infrastructure
Status in the early *2000+*
(active & programmable networks)

SDN Architectural Model (Source ONF ~ 2014)



Remarks: 1. industry acceptance of management & control & data planes Decoupling; 2. underdeveloped service & management planes

NFV Architectural Model (Source ETSI ~ 2014)



Remarks: 1. Virtualisation of some network appliances / middleboxes based (network) functions

→Retrofitting programmability of networks / services means substantial architectural changes

→ Needing programming network services (instead of re-architecting the network functions and OSS for every service)

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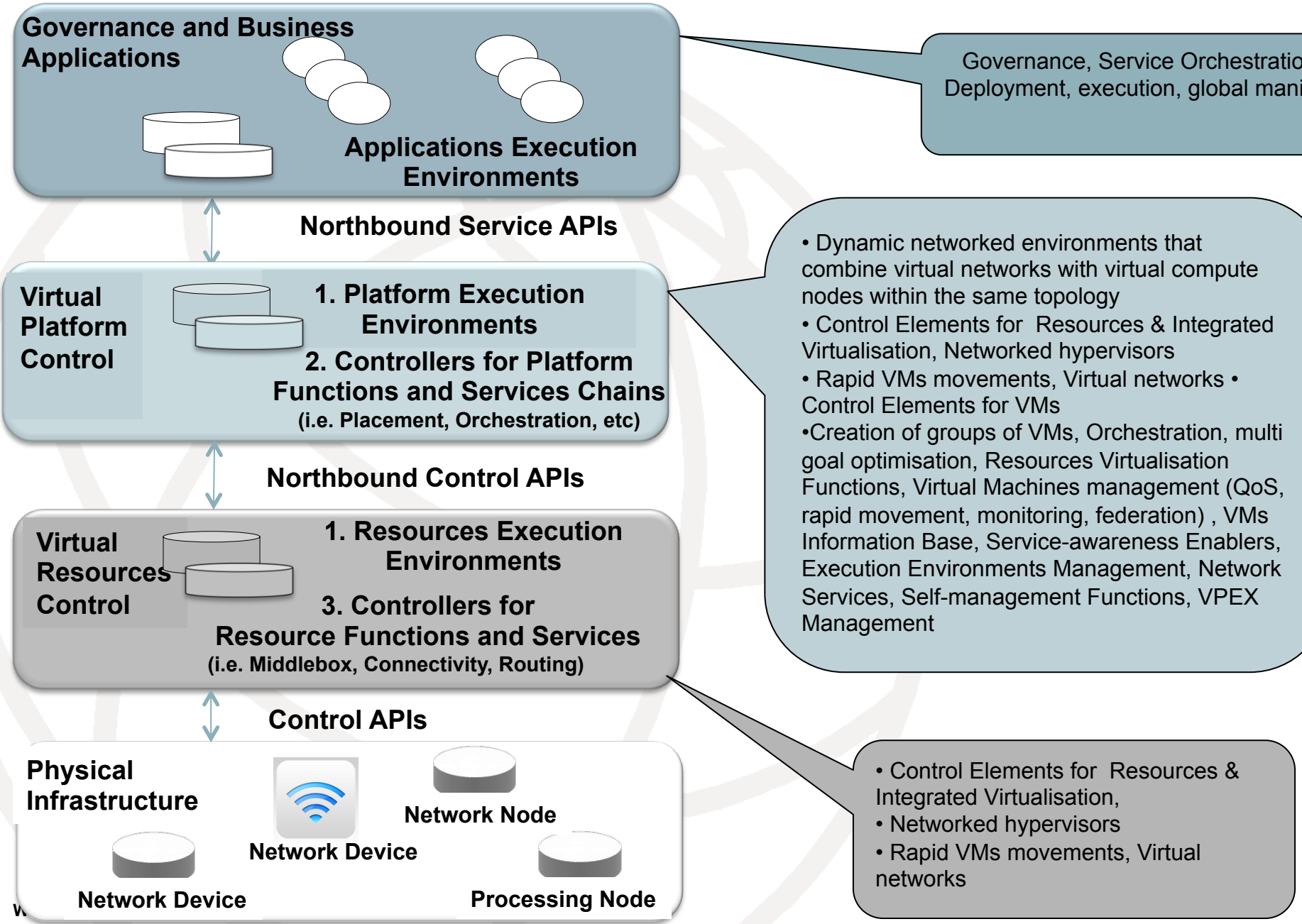
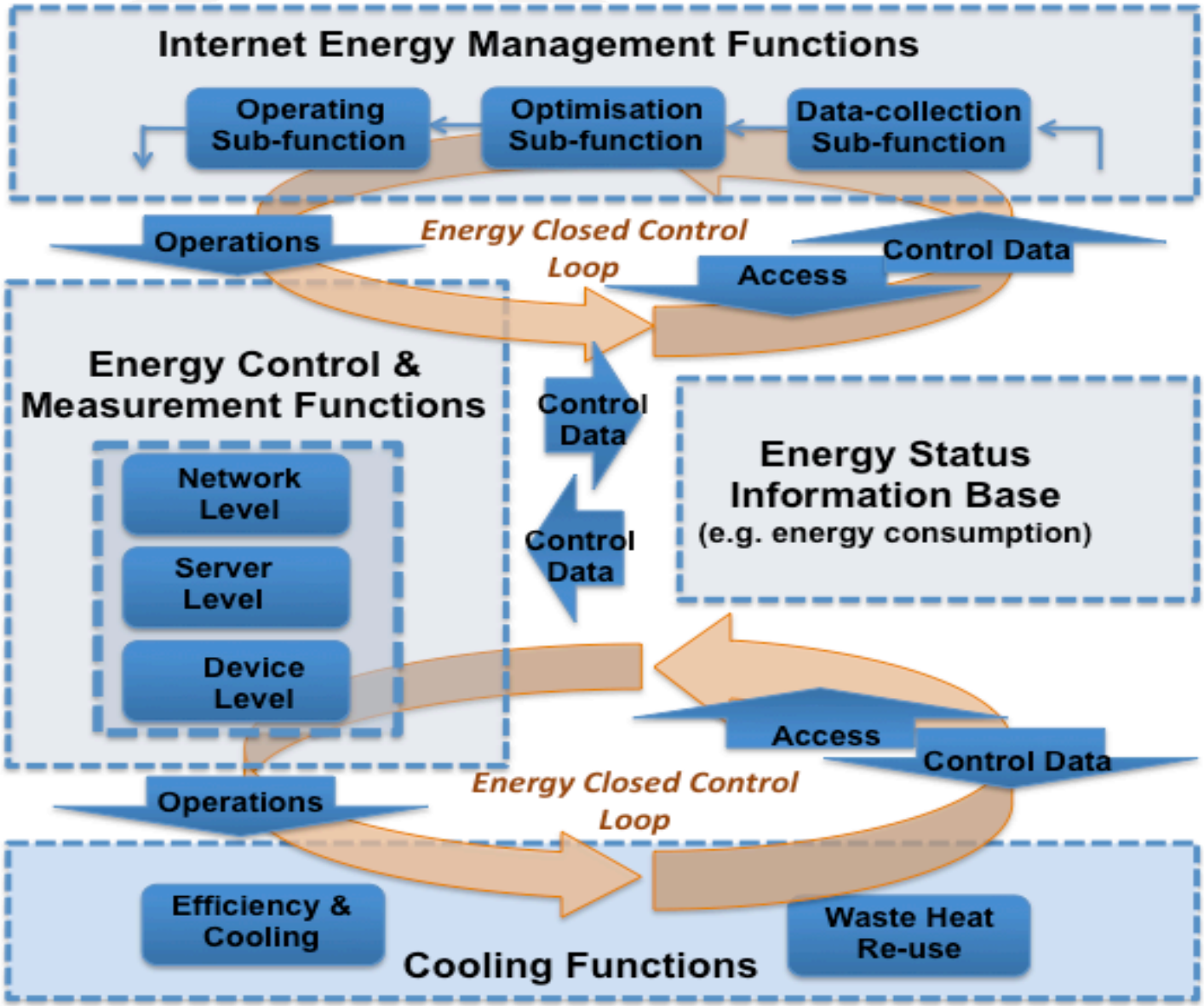
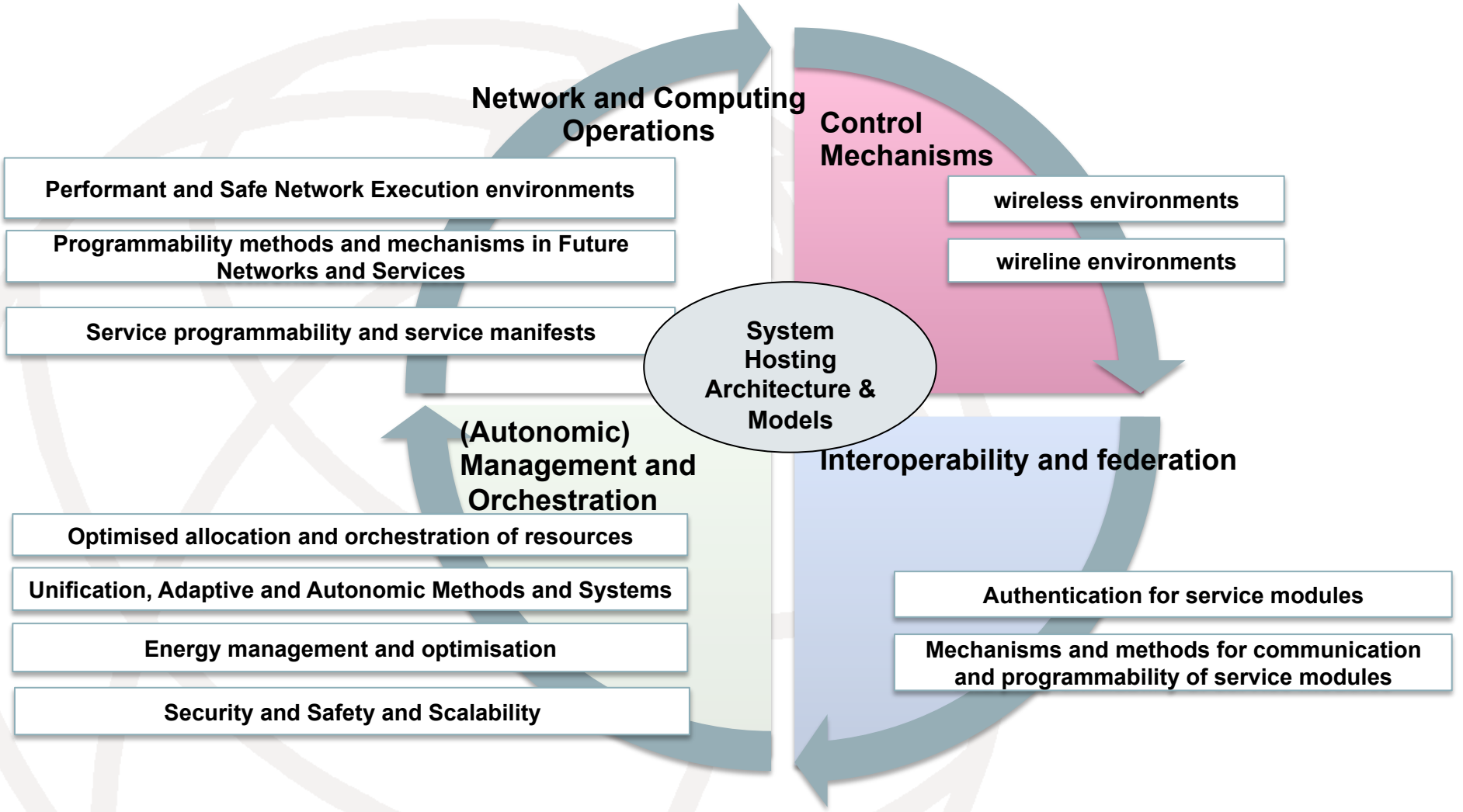
Full Network Softwarization (Revised) Model (~ 2014)



Energy Management



Work Challenges – Future 5G Networking Systems



Viable 5G Networking architectures accommodating 'change/flexibility' and 'Faster, Higher, Stronger' requirements

Contents

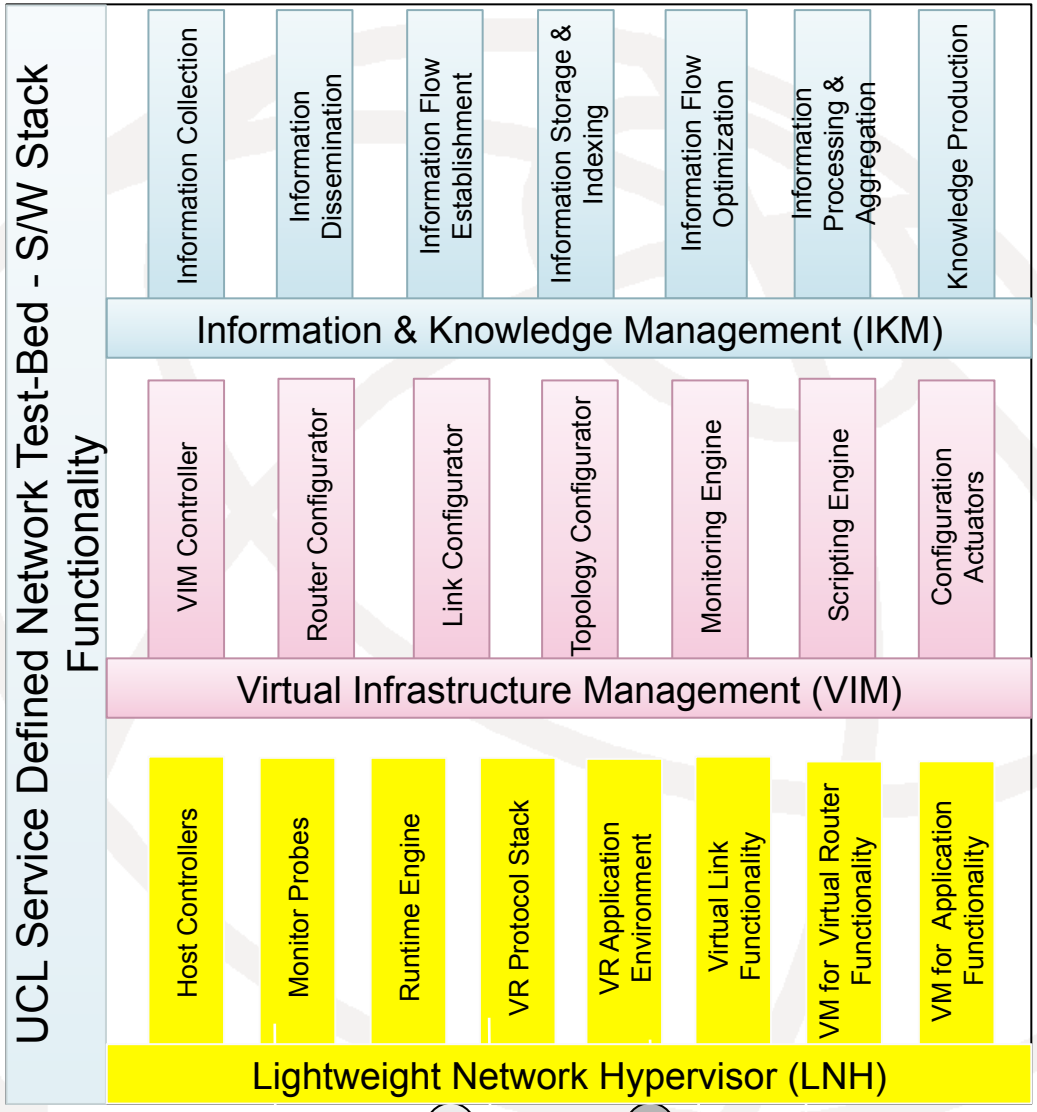
1. External drivers
2. Towards Network Softwarization – remarks & lessons from the past
3. Toward a new Network Model
4. Early Developments @ University College London
5. Conclusions

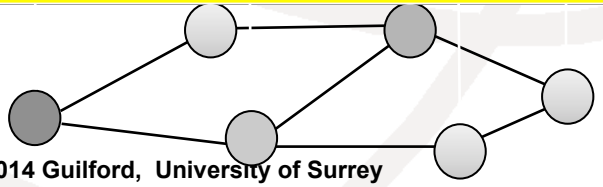
Service Defined Systems - Open Source TestBed

- **It is composed of platforms and systems that are Open Source and are actively under development (http://clayfour.ee.ucl.ac.uk).**
- **It allows us to build distributed dynamic networked environments that combine virtual networks with virtual compute nodes within the same topology.**

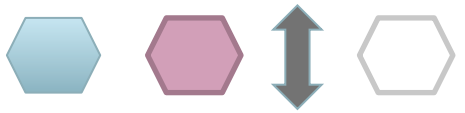
- The main elements include:
  - **A virtual environment** using hybrid resources (e.g. network & computation resources)
    - **A New Network Hypervisor**
    - **Various Placement engines**, for placing virtual elements
    - **A mechanism to setup experiments** for network functions
    - **Autonomic Management tools** for the above systems
    - **Monitoring Framework** for the above systems
    - **Information system & platform** specific to the above platforms

Service Defined Networks – UCL Open Source TestBed





Client Management Applications / Network Services



Platform to Manage Information / Knowledge in the Virtual Infrastructure (i.e., collection, dissemination, storing, optimisation, aggregation, information flows establishment / optimization)

Platform to Manage the Virtual Infrastructure - Dynamic networked environments that combine virtual networks with virtual compute nodes within the same topology (i.e., creates, monitors, configures, manages virtual networks & runs VIM scripting applications)

Management of Network VMs (i.e., creates, monitors, configures and runs VMs for the network: virtual routers, virtual links & VR applications)

Physical Hosts

IEEE SDN Initiative

- IEEE SDN Initiative (http://sdn.ieee.org)
- 1st IEEE Conference on Network Softwarization (sites.ieee.org/netsoft/) 13-17 April 2015 London

1st IEEE Conference on Network Softwarization (NetSoft 2015)

IEEE SOFTWARE DEFINED NETWORKS

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IEEE NetSoft 2015 at UCL on 13-17 April 2015

Conference Overview

Bridging Networking with IT

Software-Defined Networks (SDN), Network Function Virtualization (NFV), and Software-Defined Clouds could be seen as different expressions of an overall transformation trend, which is deeply impacting and bridging Telecom and IT industries. This trend is also transforming several other Industries, in using *"softwarization"* to optimize costs and processes and in bringing new values in infrastructures. In particular, SDN, NFV and network programmability are creating the conditions to reinvent network and cloud architectures, accelerate service deployment and facilitate infrastructure management. Accordingly, the theme of **NetSoft 2015** is *"Software-Defined Infrastructures (SDI) for Networks, Clouds and Services"*.

Conference Venue

***IEEE NetSoft 2015** will be held at:*

UCL

University College London
London, UK

on 13-17 April 2015

Registration coming soon

Important Dates

- **15 December 2014:** Papers submission deadline
- **15 February 2015:** Papers acceptance notification
- **9 March 2015:** Papers - final camera ready submission and author registration
- **13-17 April 2015:** Date of Conference

Theme of the Conference

Software-Defined Infrastructures for Networks, Clouds and Services

Call for Papers

NetSoft 2015 Call for Papers is now available

Please **click here to view the Call for Papers** (PDF, 262 KB).

Concluding Remarks

5G Networks are both a connectivity and service execution environments

Softwarization and in particular (Self) Management and Control would represent nearly 99% of the new Networks & Services functionality !!!

Why now:

- **Virtualisation and programmability are cost effective and operational**
- **Continuous demands for large number of software features and qualities**

Thank You