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Software Defined Systems for Management of Ubiquitous Communications and Services - How and What to Virtualize and Programme

Current State and Key Challenges

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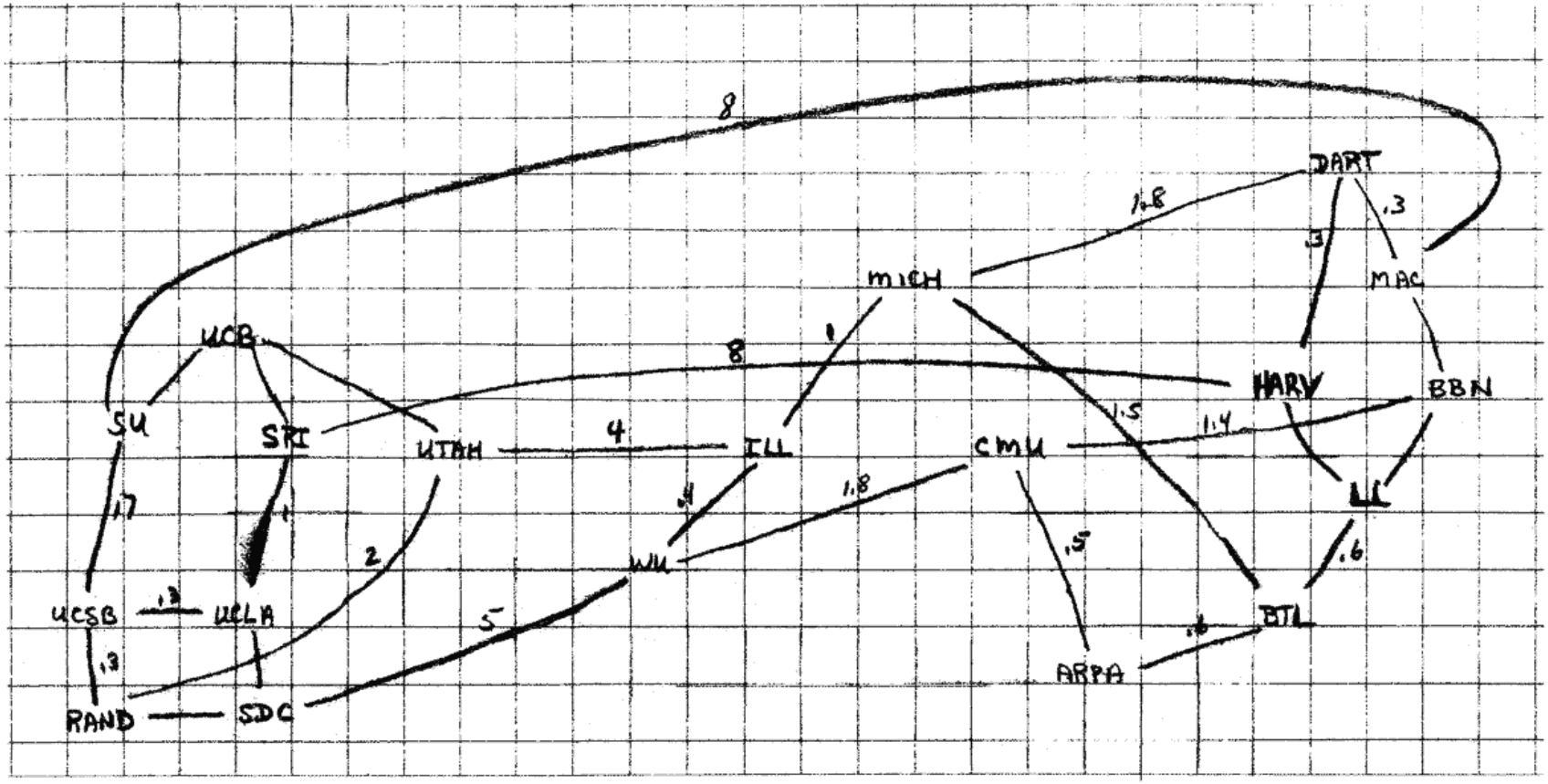
Contents

ARPAnet Plan – late 1960s

Rough sketch by Larry Roberts



Internet 1973-74

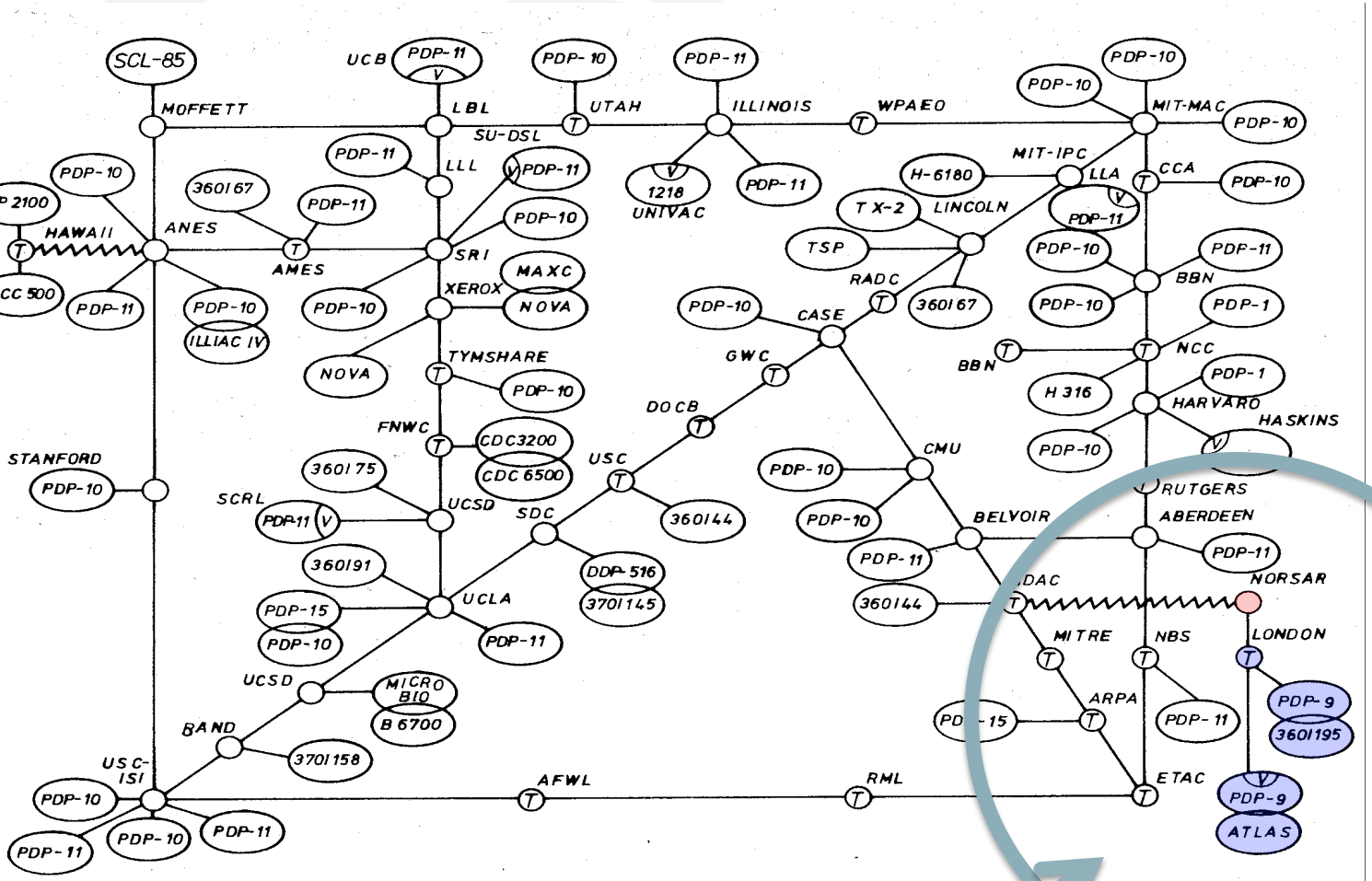


Abb. 4 ARPA NETwork, topologische Karte. Stand Juni 1974.

UCL connected in July 1973 to ARPAnet

Current Internet

- The Internet as a ***connectivity platform*** plays a central and vital role in our society
  - Work and business, education, entertainment, social life, …
- Victim of its own success, suffering from ***ossification***
  - Innovation meets natural resistance (e.g. no IPv6, no mobile IP, no inter-domain DiffServ, no inter-domain multicast, etc.)
- Services such as P2P, IPTV, Cloud services, emerging services, pose new requirements on the underlying network architecture. ***OPEX costs are up to 90%***
- Big growth in terms of the number of inter-connected devices but ***slow growth in new services***

Key Changes in Internet - History

- Changes were possible when the Internet was still an academic research network (i.e. until 1993 when the WWW turned it to a commercial)

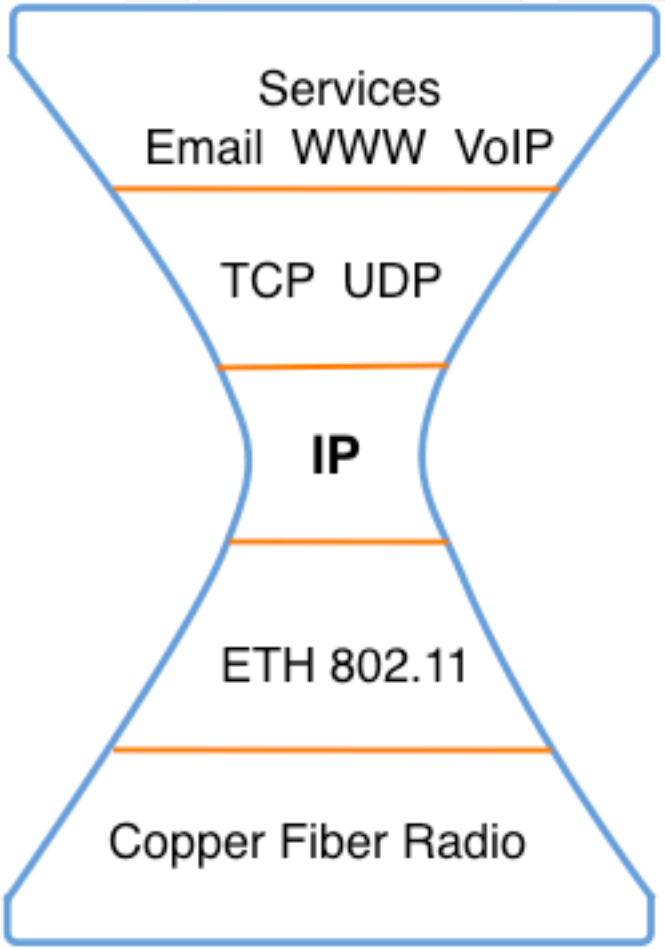
- Inter-network that underpins the “information society”

- Key changes in that period were the following: 1982 DNS, 1983 TCP/IP instead of NCP, 1987 TCP congestion control, 1991 BGP policy routing, 1991 SNMP

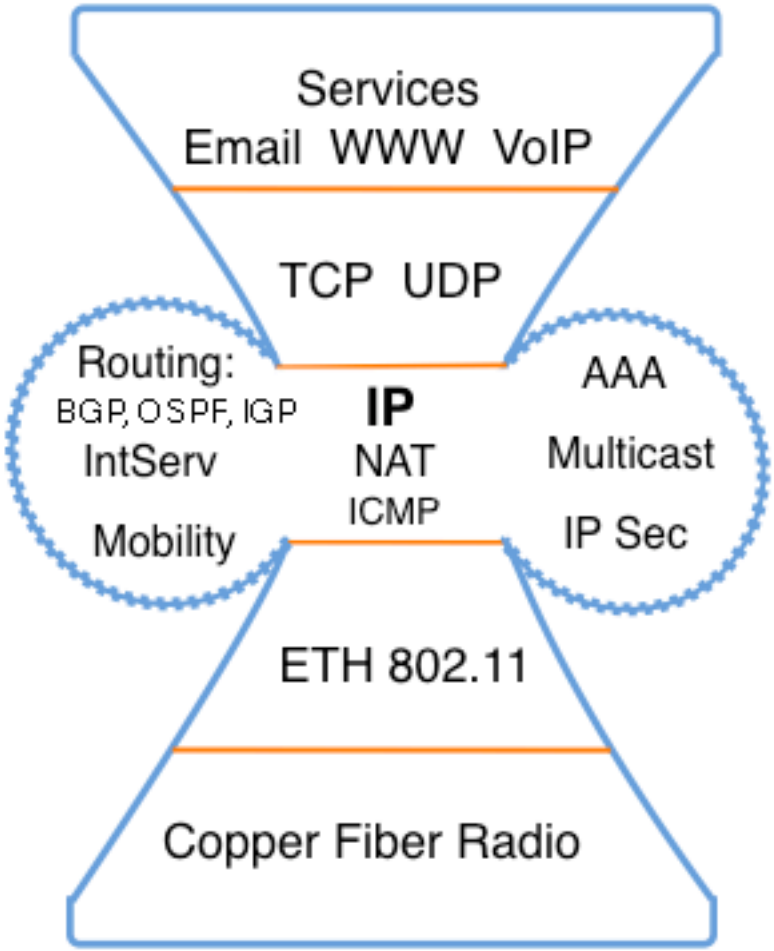
- No significant changes since then apart from MPLS which has been deployed in addition to plain IP

- Research efforts towards the Future Internet: ***evolutionary & clean-slate approaches, autonomic management, Internet softwarization***

Internet Hour-glass Model



Data Plane



Control Plane

Some current systemic limits

- Networks are becoming both a connectivity and service execution environment

→Work towards a service and management aware connectivity infrastructure

- 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:

→

- 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

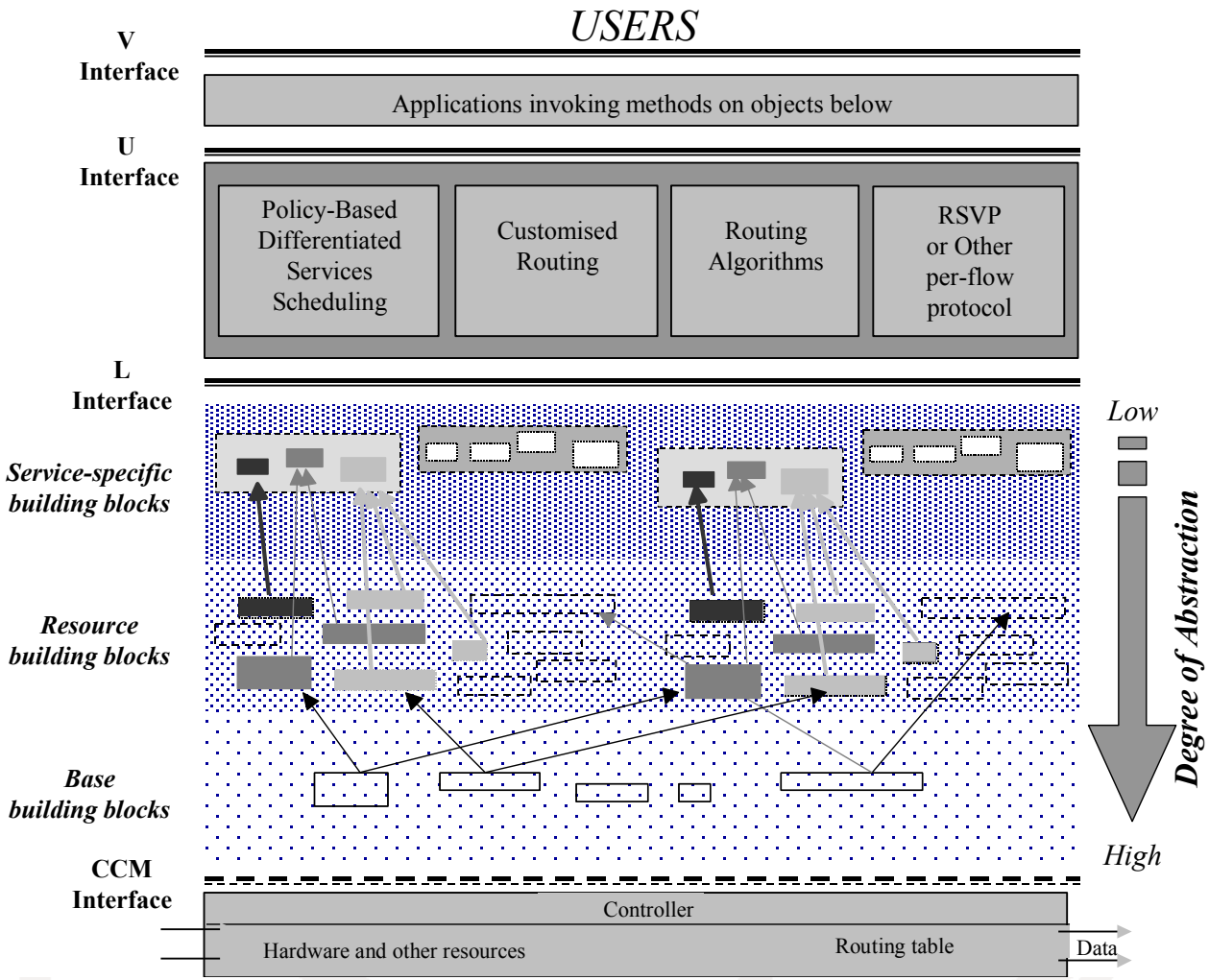
How to Change

Approaches:

- Parallel Internets; Progressive changes; "Cleaner" slate and evolutionary
- Network of networks → system of coordinated service networks
- Virtualization of resources (Computation, 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

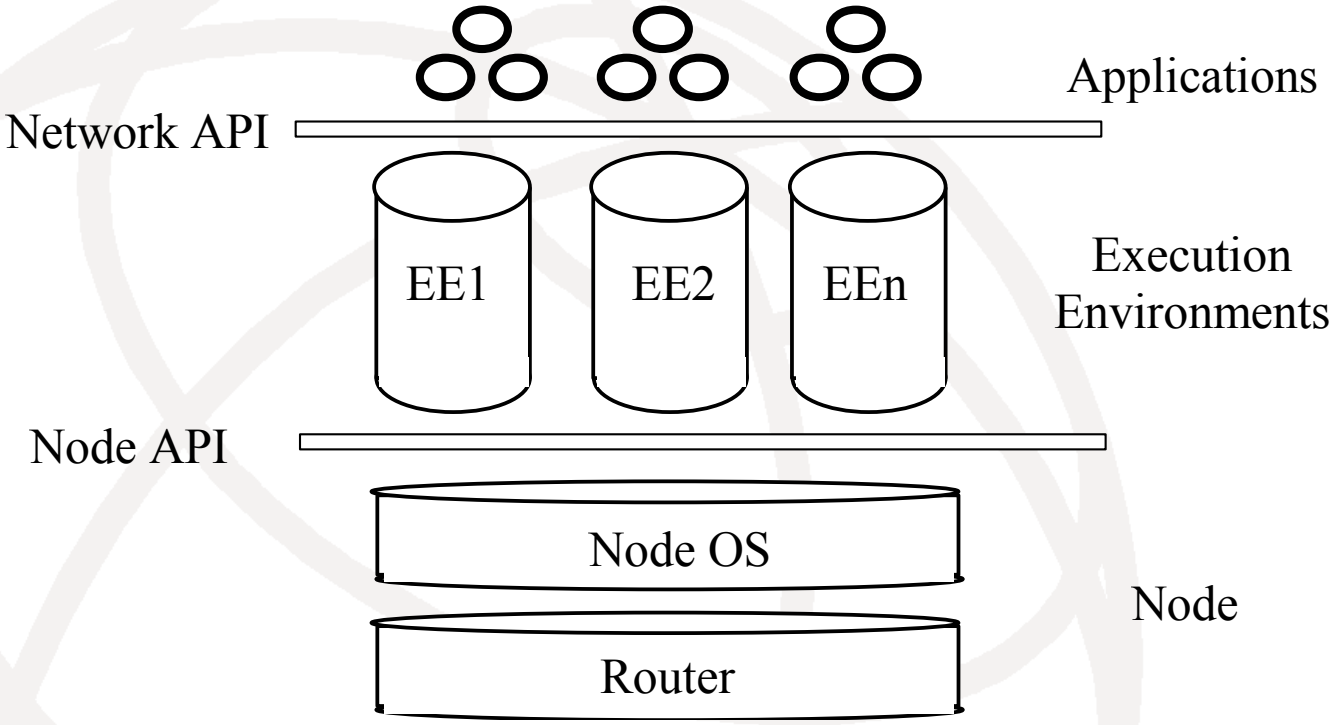
Contents

P1520 Reference Model –Application Programming Interfaces [i.e. Dynamic Service Chaining (Service Deployment Concept)~ 2004]



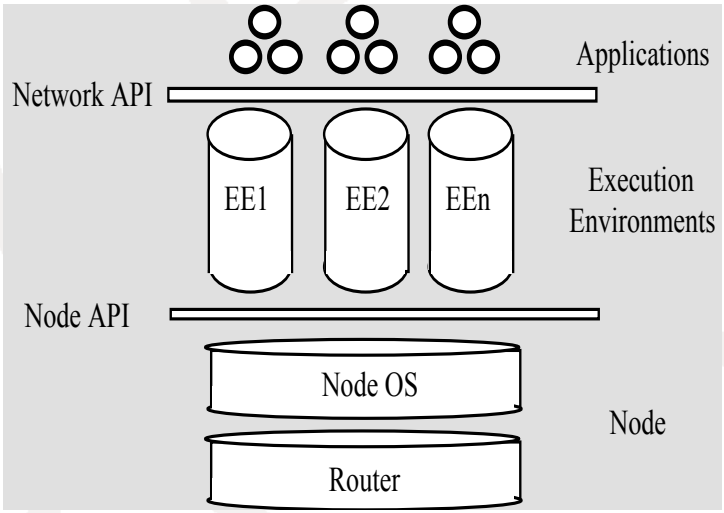
Remarks: 1. P1520 has no hosting environment(s) for the network services → dynamic service chaining and the evolution of network virtualization from data centers into carrier networks do not come without their own challenges.

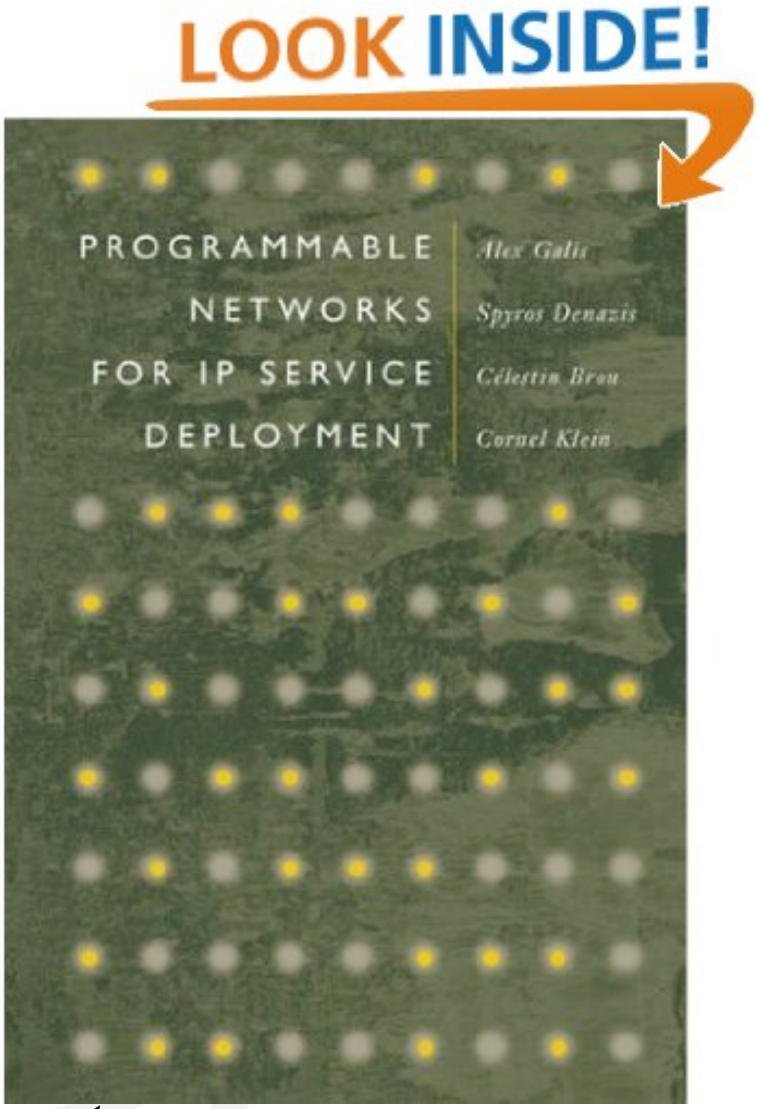
Programmable Network Model (~ 2005)



Remarks: 1. No interest in “low level” programming the network;
2. Virtualisation of networks via programming of networks
3. Extremely hyperactive network which would be difficult to manage
→ Needing programming network services (instead of re-architecting the network and OSs for every service)

SDN Evolution - Conceptual Networked Systems





SDNs Architecture

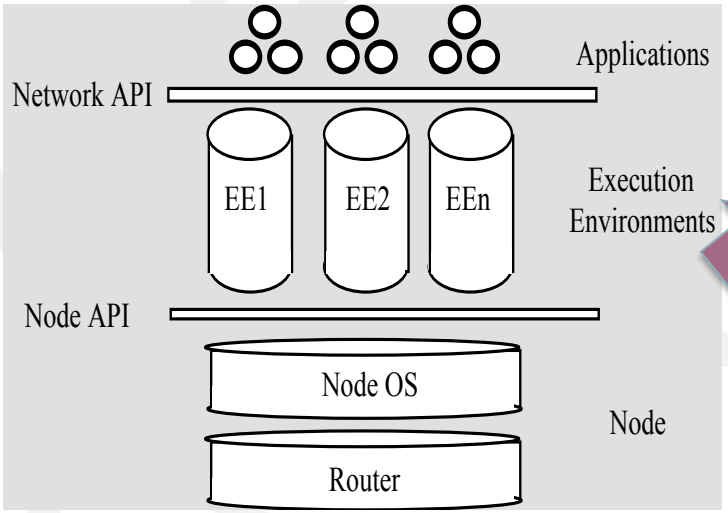
Connectivity & Computation Infrastructure

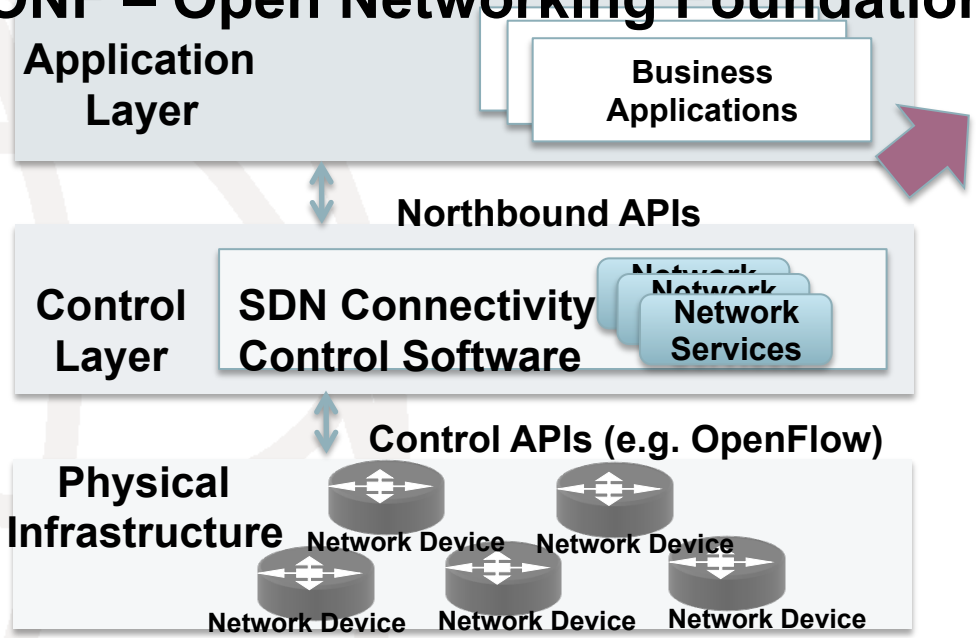
Status in the early *2000+*

(active & programmable networks)

SDN Evolution - Conceptual Networked Systems

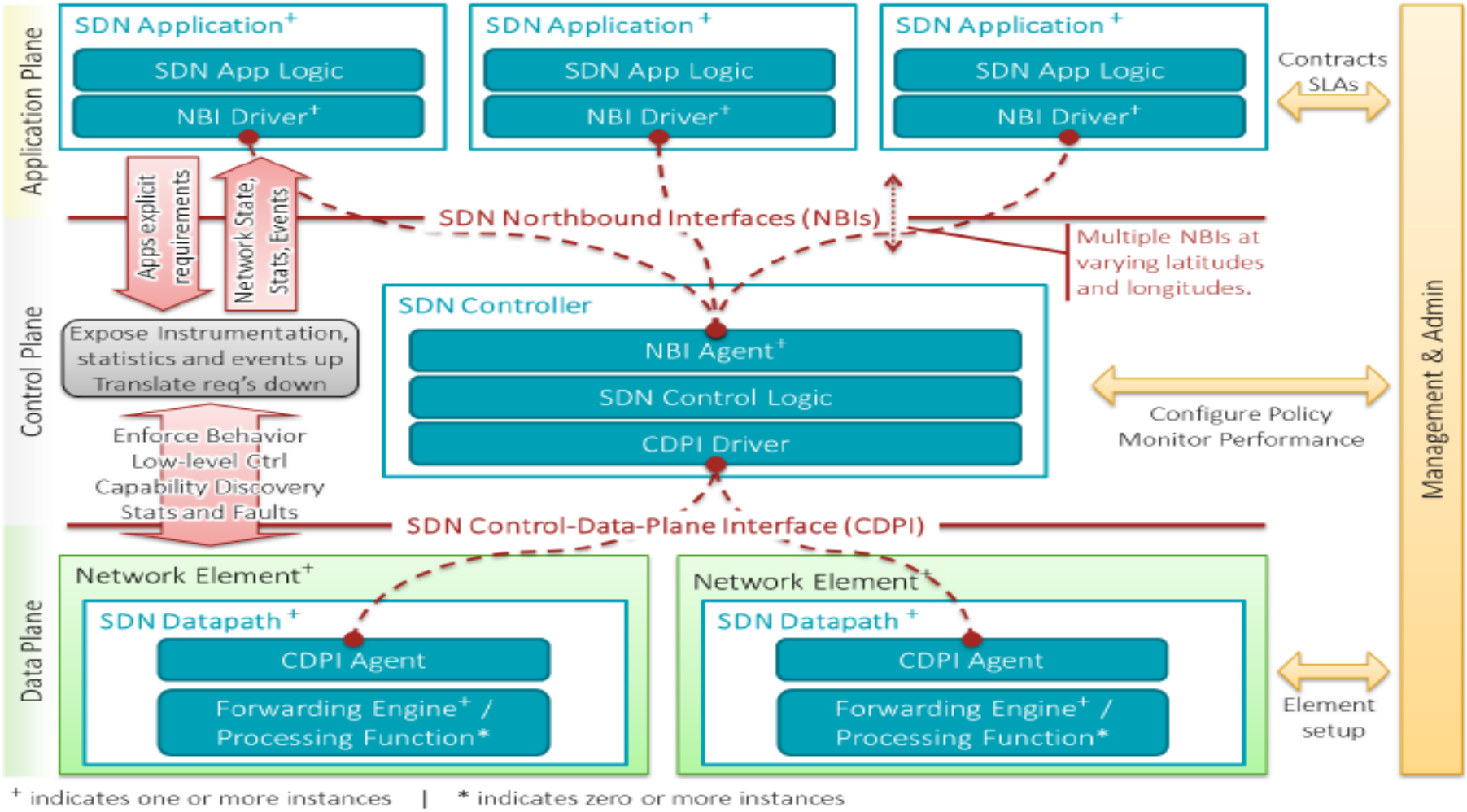
SDNs Architecture
Connectivity Only Infrastructure
Status in the *2010+*
(ONF – Open Networking Foundation)





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

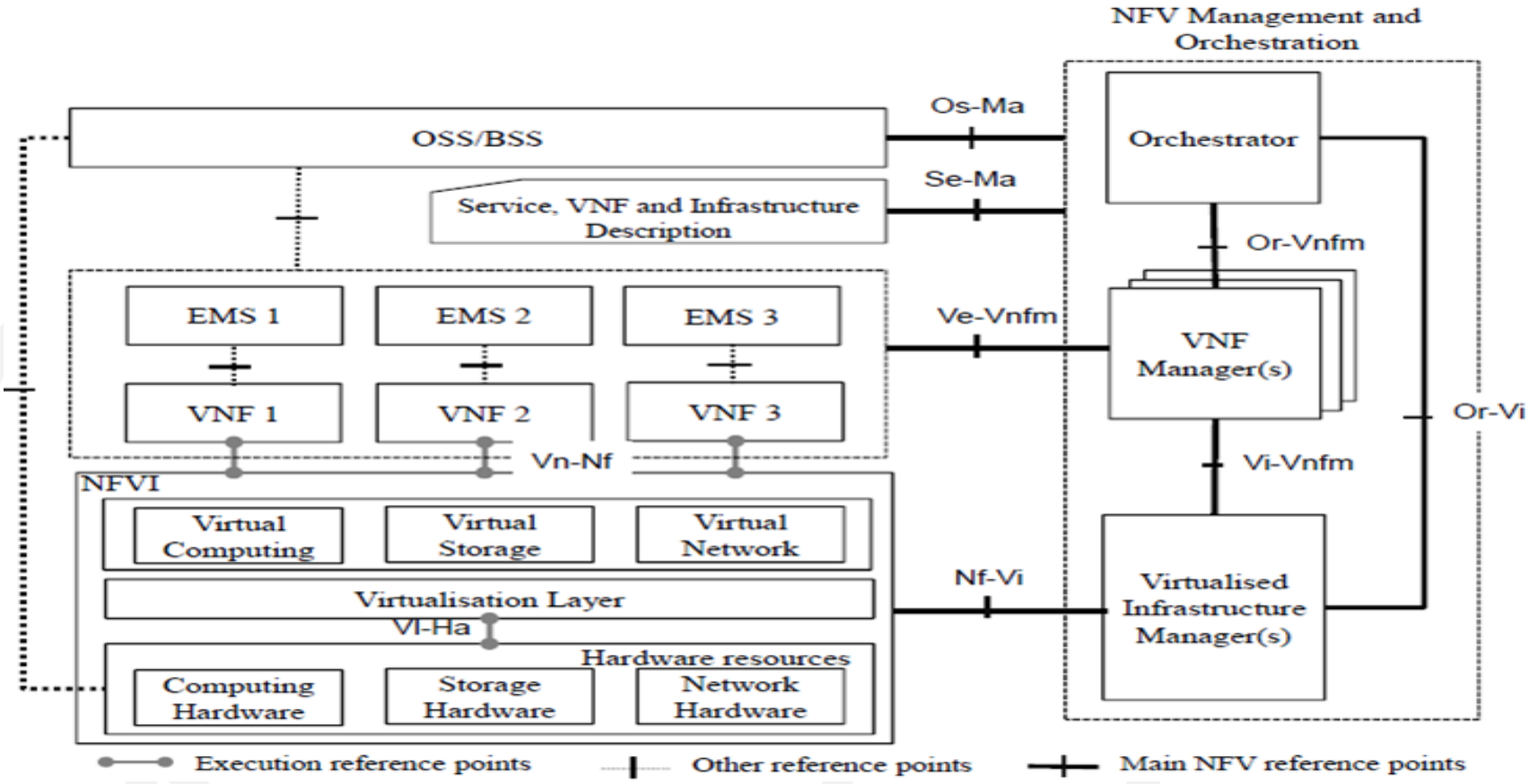
SDN Architectural Model (Source ONF ~ 2014)



Remarks: 1. industry acceptance of management & control & data planes decoupling

2. underdeveloped service & management planes

NFV Architectural Model (Source ETSI ~ 2014)



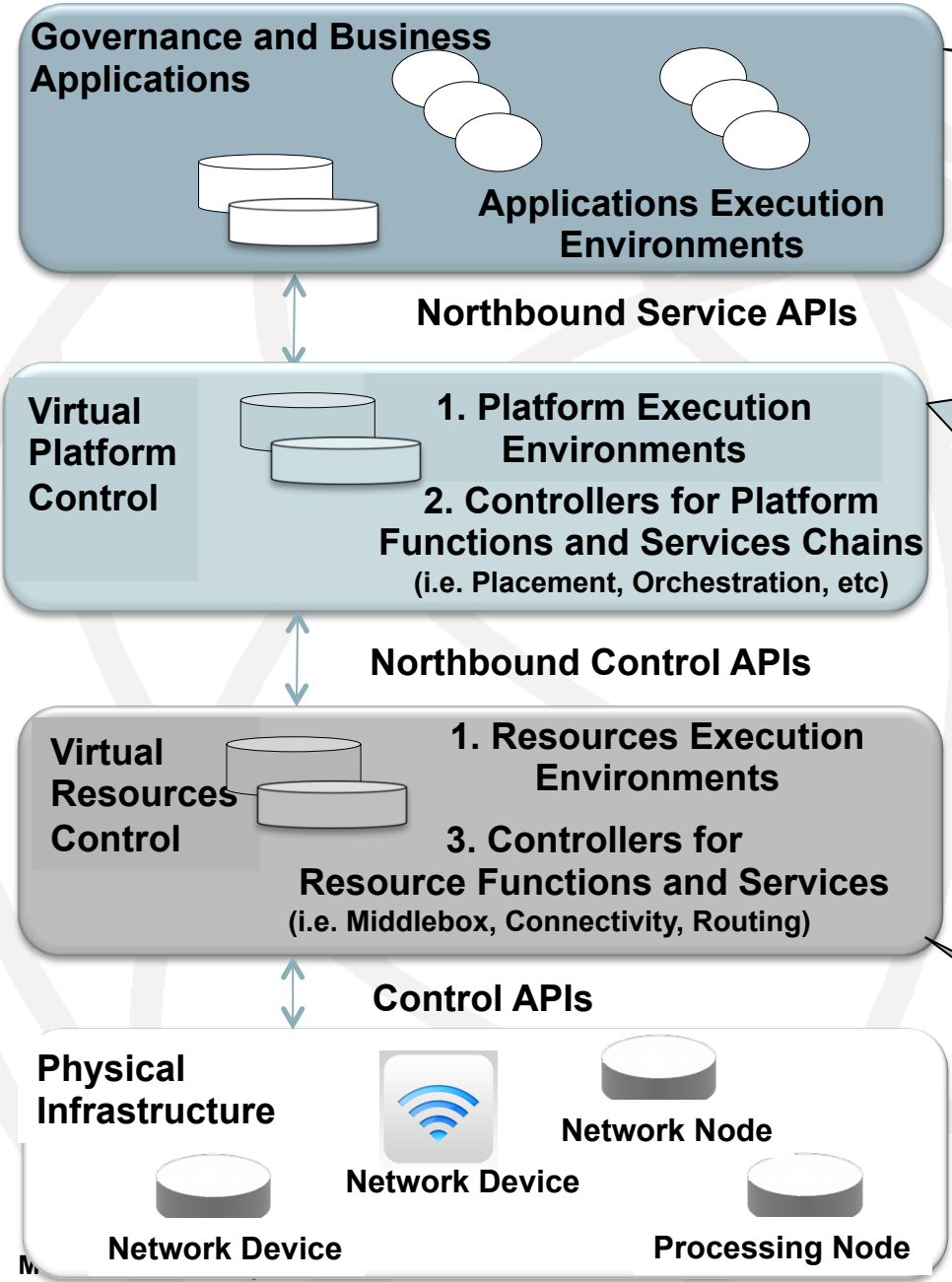
Remarks: 1. Virtualisation of some network appliances / middleboxes based (network) functions

→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)

Contents

Software Defined Network (Revised) Model (~ 2014)

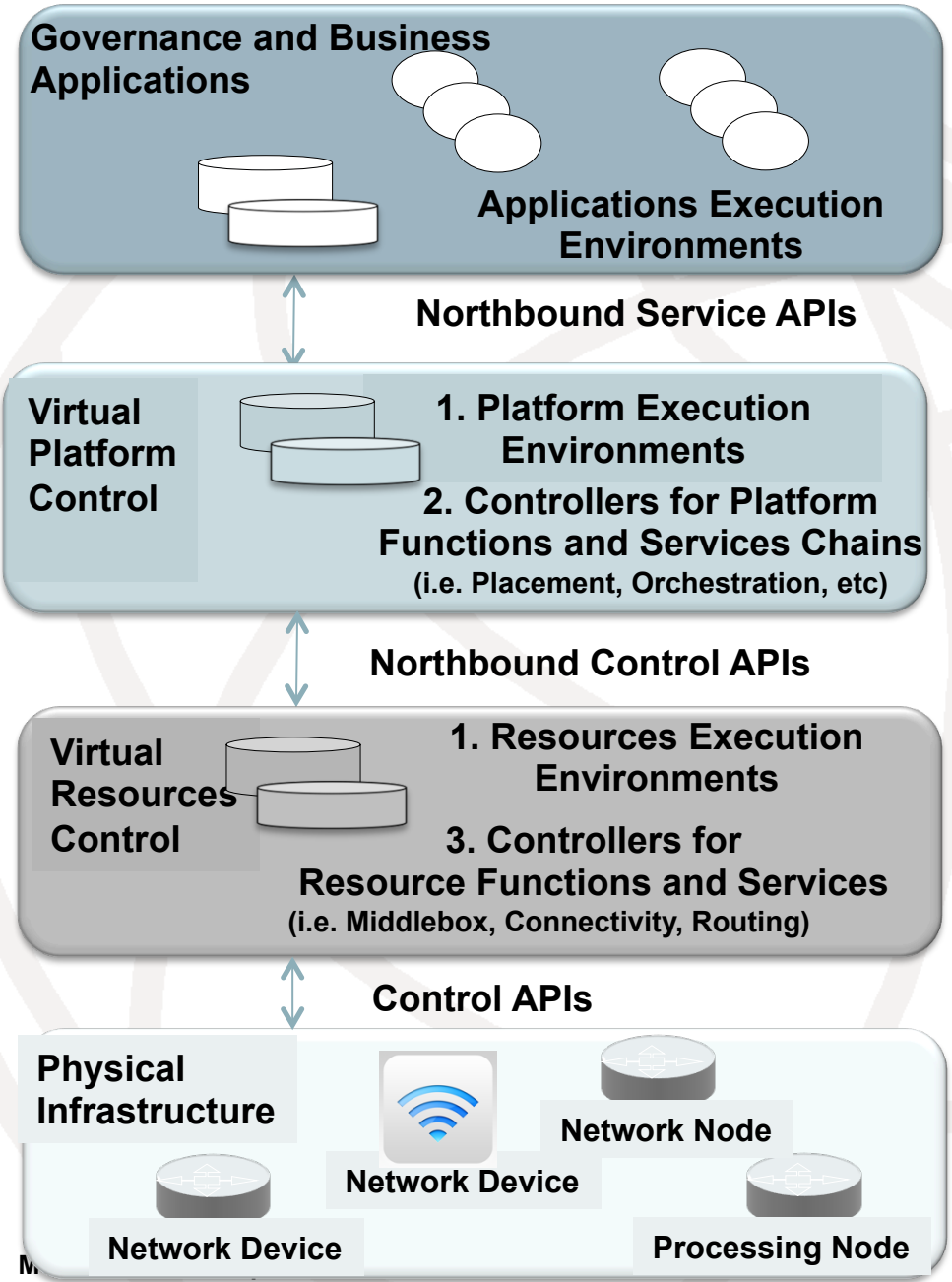


Governance, Service Orchestration, Deployment, execution, global manifest

- Dynamic networked environments that combine virtual networks with virtual compute nodes within the same topology
- Control Elements for Resources & Integrated Virtualisation, Networked hypervisors
- Rapid VMs movements, Virtual networks • Control Elements for VMs
- Creation of groups of VMs, Orchestration, multi goal optimisation, Resources Virtualisation Functions, Virtual Machines management (QoS, rapid movement, monitoring, federation) , VMs Information Base, Service-awareness Enablers, Execution Environments Management, Network Services, Self-management Functions, VPEX Management

- Control Elements for Resources & Integrated Virtualisation,
- Networked hypervisors
- Rapid VMs movements, Virtual networks

Software Defined Network (Revised) Model (~ 2014)



Key Challenges – Future Networking Systems

Network and Computing Operations

- Performant and Safe Network Execution environments
- Programmability methods and mechanisms in Future Networks and Services
- Service programmability and service manifests

Control Mechanisms

- wireless environments
- wireline environments

System Hosting Architecture & Models

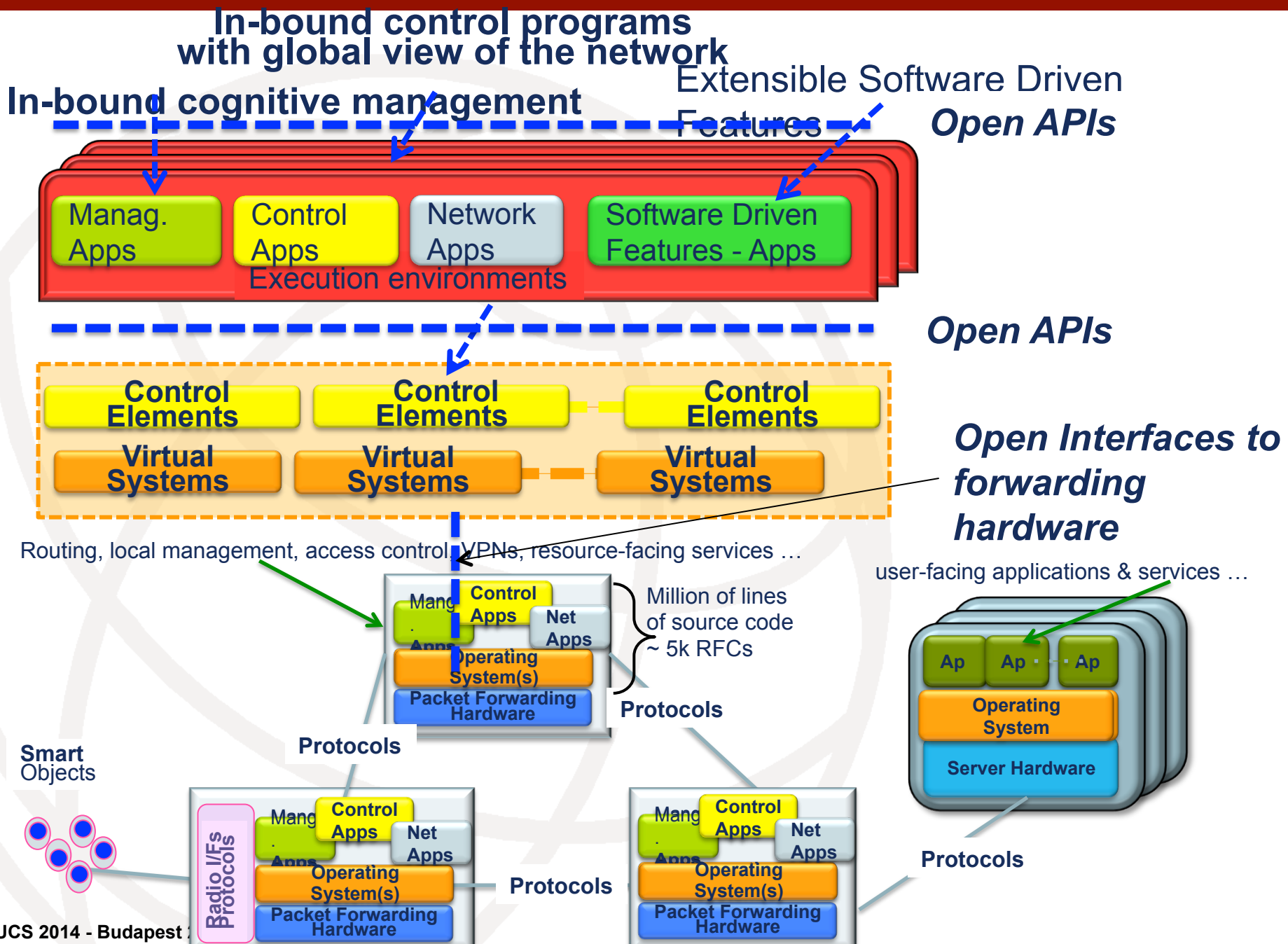
(Autonomic) Management and Orchestration

- Optimised allocation and orchestration of resources
- Unification, Adaptive and Autonomic Methods and Systems
- Energy management and optimisation
- Security and Safety and Scalability

Interoperability and federation

- Authentication for service modules
- Mechanisms and methods for communication and programmability of service modules

Softwarization of Networked Systems



Future Networks - 12 Design Goals

① (Service Diversity) FNs should accommodate a wid traffic and support diversified services

② (Functional Flexibility) FNs should have flexibility to support and sustain new services derived from future user demands

③ (Virtualization of resources) FNs should support virtualization so that a single resource can be used concurrently by multiple virtual resources.

④ (Data Access) FNs should support isolation and abstraction FNs should have mechanisms for retrieving data in a timely manner regardless of its location.

⑤ (Energy Consumption) FNs should have device, system, and network level technologies to improve power efficiency and to satisfy customer's requests with minimum traffic

⑥ (Service Universalization)FNs should facilitate and accelerate provision of convergent facilities in differing areas such as towns or the countryside, developed or developing countries

FNs - 12 Design Goals (Cont.)

⑦ (Economic Incentives) FNs should be designed to provide sustainable competition environment to various participants in ecosystem of ICT by providing proper economic incentives

⑧ (Network Management) FNs should be able to operate, maintain and provision efficiently the increasing number of services and entities.

⑨ (Mobility) FNs should be designed and implemented to provide mobility that facilitates high levels of reliability, availability and quality of service in an environment where a huge number of nodes can dynamically move across the heterogeneous networks.

⑩ (Optimization) FNs should provide sufficient performance by optimizing capacity of network equipments based on service requirement and user demand.

11 (Identification) FNs should provide a new identification structure that can effectively support mobility and data access in a scalable manner.

12 (Reliability and Security) FNs should support extremely high-reliability services

Future Networks : Objectives Vs. Design Goals

Objectives

Design Goals

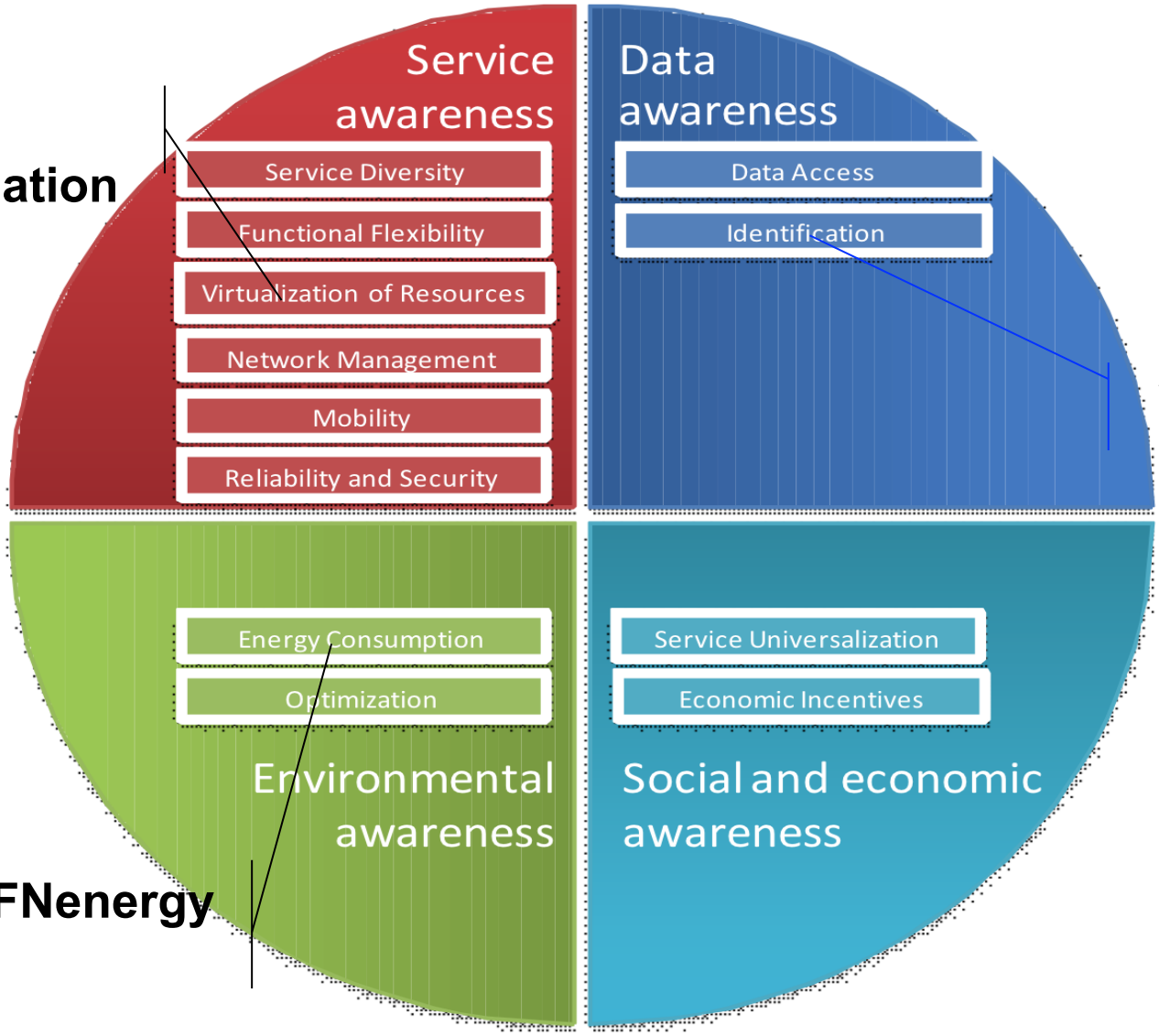
Technologies - achieving the design goals

- **Virtualization of Resources (Network Virtualization)**
  - Enables creation of logically isolated network partitions over shared physical network infrastructures so that multiple heterogeneous virtual networks can simultaneously coexist over the shared infrastructures; it allows the aggregation of multiple resources and makes the aggregated resources appear as a single resource
- **Data/Content-oriented Networking (Data Access)**
- **Energy-saving of Networks (Energy Consumption)**
  - Forward traffic with less power
  - Control device/system operation for traffic dynamics
  - Satisfy customer requests with minimum traffic
- **In-system Network Management (Network Management)**
- **Distributed Mobile Networking (Mobility)**
- **Network Optimization (Optimization)**
  - Device / System / Network level optimization (Path optimization, Network topology optimization, Accommodation point optimization)

Future Networks : Objectives Vs. Design Goals

Y.3001 - FNobjectives&designgoals

Y.3011 - FNvirtualisation



Y.3031 - IDconfig

Y.3021 - FNenergy

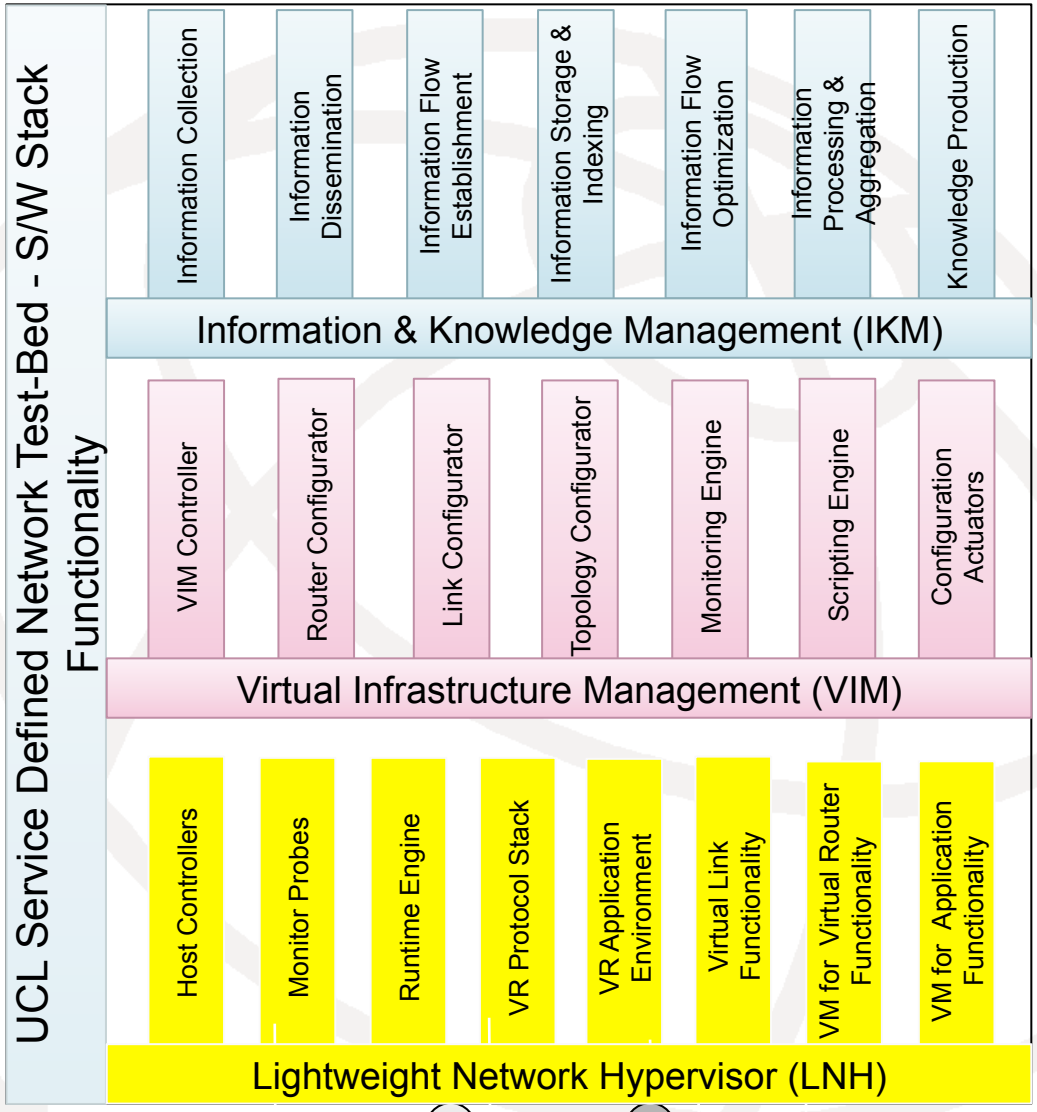
Contents

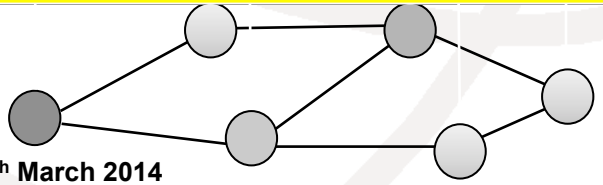
Service Defined Systems - Open Source TestBed

- **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.**

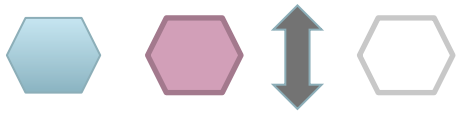
- The main elements include:
  - **A virtual environment** using hybrid resources (e.g. network & computation resources)
    - **A New Network Hypervisor**
    - **Various Placement engines**, for placing virtual elements
    - **A mechanism to setup experiments** for network functions
    - **Autonomic 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



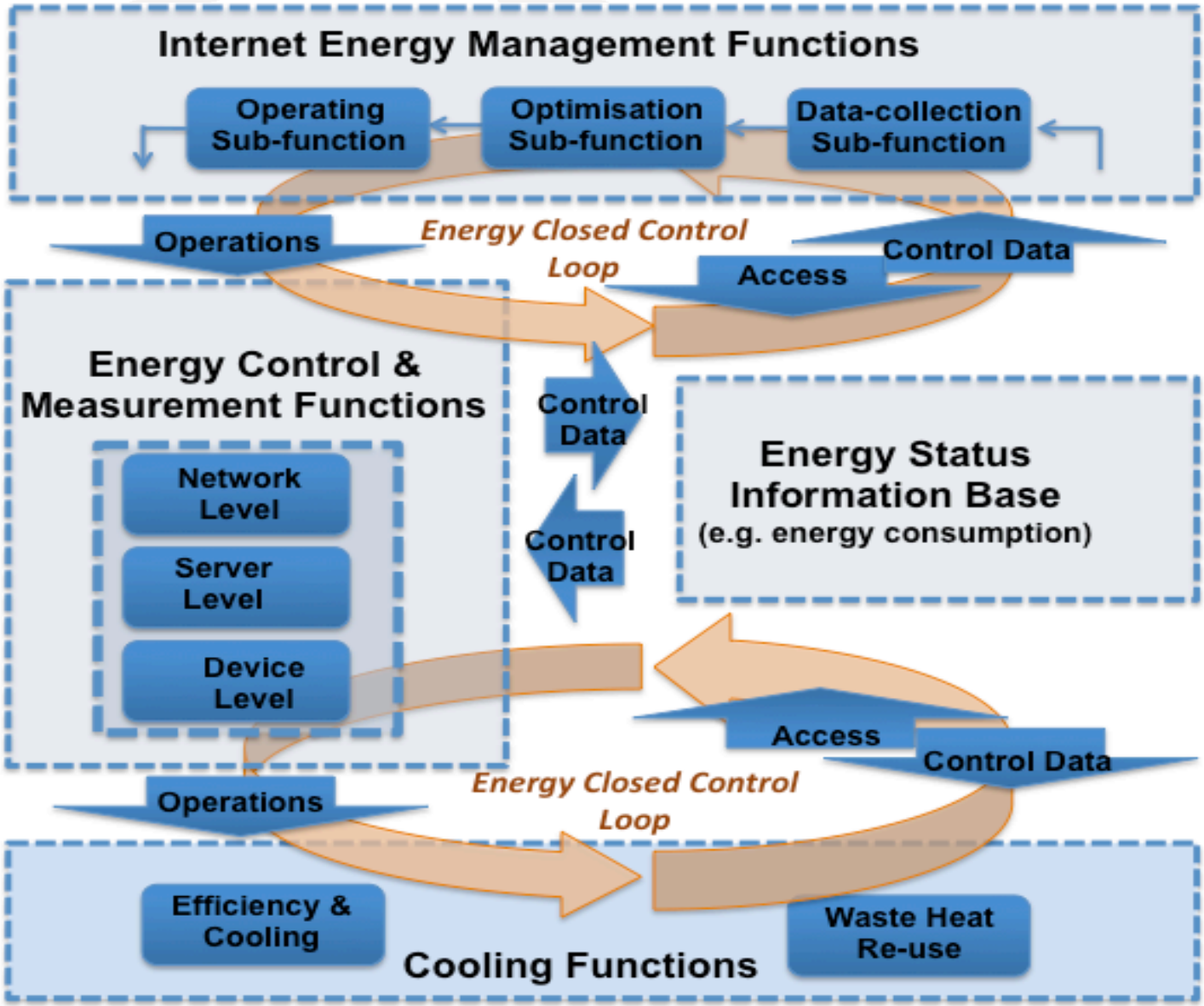
Platform to Manage Information / Knowledge in the Virtual Infrastructure (i.e., collection, dissemination, storing, optimisation, aggregation, information flows establishment / optimization)

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

Energy Management



Contents

Concluding Remarks

Future Networks including 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**

Some Relevant References

- Galis, A., Denazis, S., Brou, C., Klein, C.–"**Programmable Networks for IP Service Deployment**" ISBN 1-58053-745-6, pp 450, June 2004, Artech House Books, http://www.artechhouse.com/International/Books/Programmable-Networks-for-IP-Service-Deployment-1017.aspx
- Y.3001 ITU-T recommendation – "**Future networks: Objectives and design goals**" – July 2012 @ http://www.itu.int/rec/T-REC-Y.3001-201105-I
- A. Galis et al., "**Softwarization of Future Networks and Services – Next Generation SDNs**" @ Proc. of IEEE SDN4FNS'13, Trento, Italy, Nov. 2013 @http://sites.ieee.org/sdn4fns
- IEEE Open Access White Paper –"**Software-Defined Networks for Future Networks and Services - Main Technical Challenges and Business Implications**" –Feb 2014 @ http://sites.ieee.org/sdn4fns/whitepaper/

Thank You