Transport and Networking: Future Internet Trends

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Acknowledgement

This overview presentation is based on several public documents and different authors' and groups work: Future Internet , conferences public material, research papers and projects, overviews, tutorials, etc.: (see Reference list).

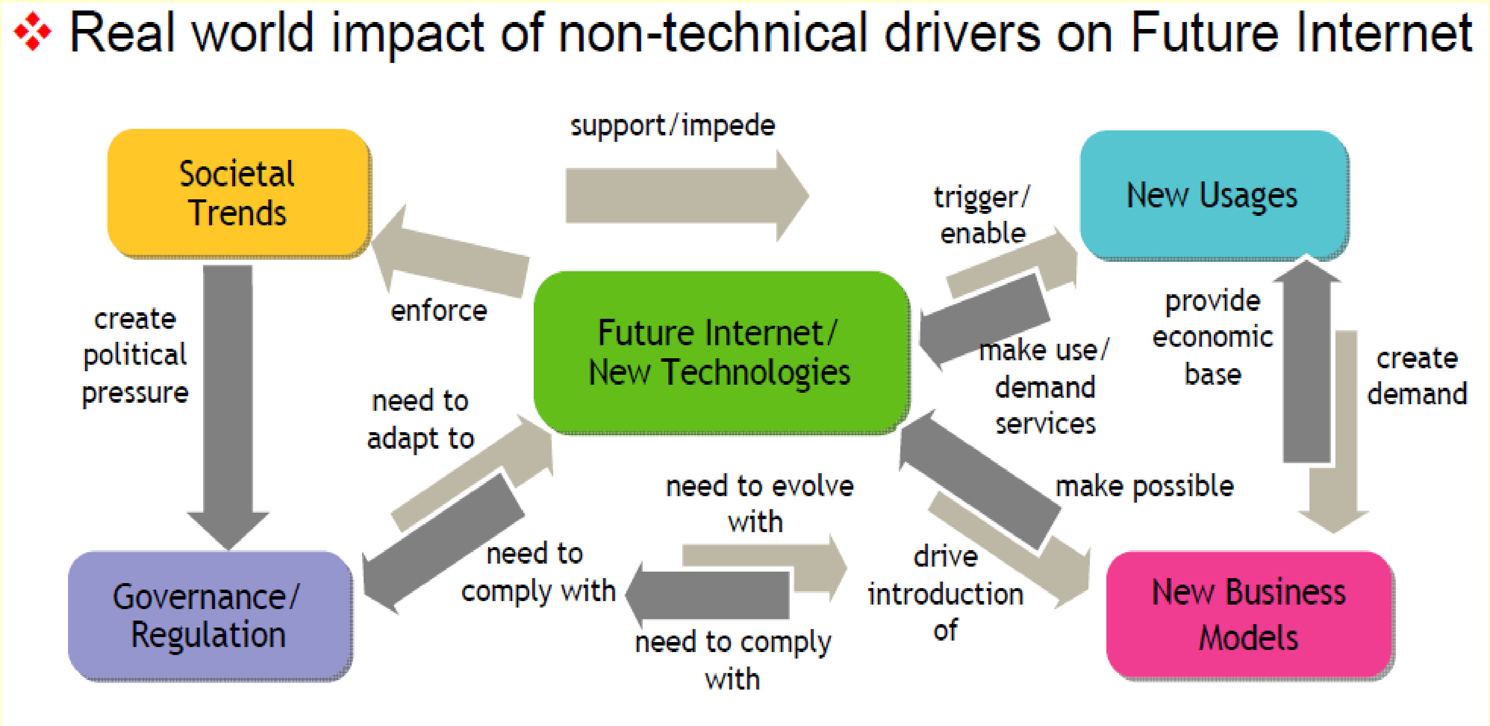
CONTENTS

CONTENTS

1.Introduction

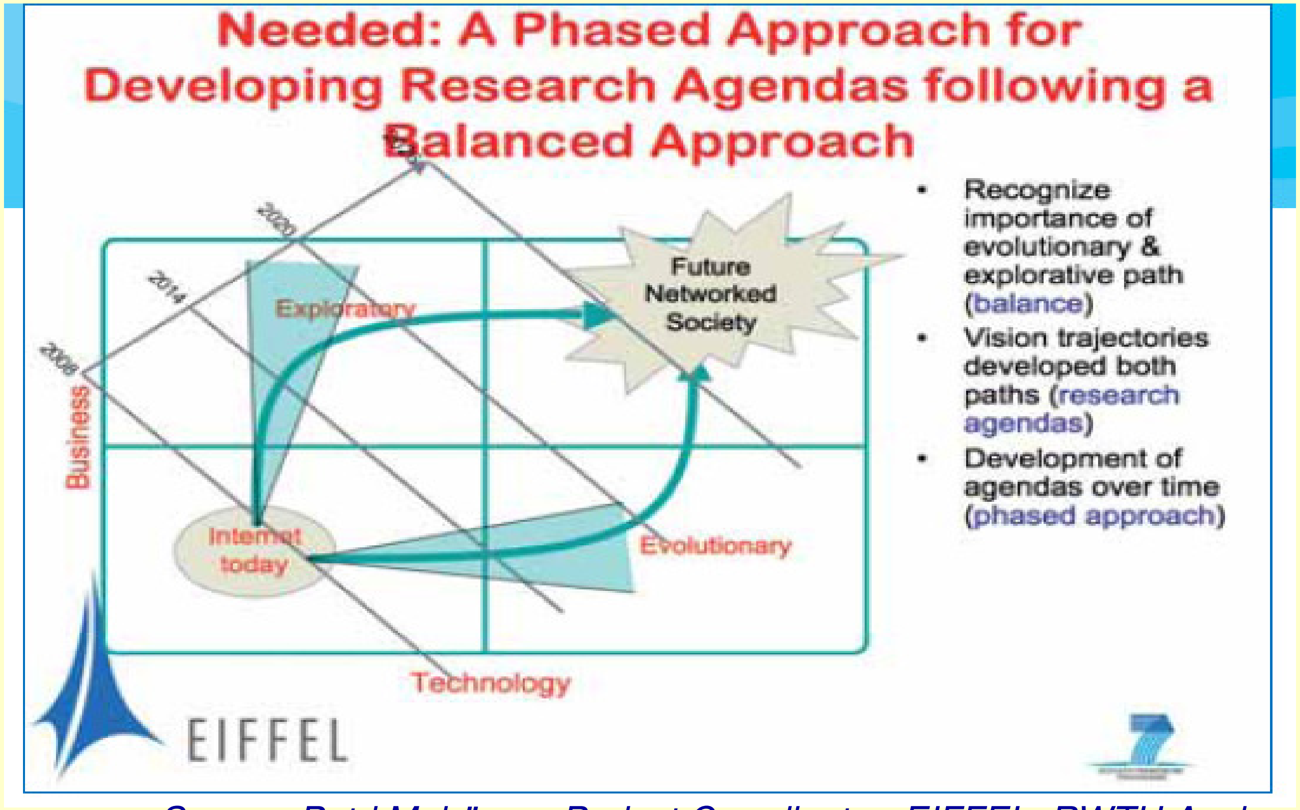
Why this talk ?

- **Future Internet challenges** - to solve the current Internet limitation and ossification (flexibility, management, security, QoS, adaptation to new services needs, mobility, etc.)
- **Many factors influencing the development:** Social, Economic and Environmental Challenges
  - *Source: Future Internet – Towards Research Challenges – 07 APRIL 2009, http://www.future-internet.eu/fileadmin/documents/prague_documents/FI*



1.Introduction

- **Evolutionary approach**
- **Clean slate approach**
- **Intermediate solutions**
- **Transport layer and network layer are supposed to be changed**



Source: Petri Mahönen, Project Coordinator, EIFFEL, RWTH Aachen University" Evolved Internet Future for European Leadership (EIFFEL)", FI Conference, Bled, 2008

1.Introduction

- Traditional TCP/IP stack
- Single architectural plane (Data, Control, Management)
- IP – best effort- simple very flexible, dynamic
  - Connectionless
  - No guarantees
  - Agnostic w.r.t services and applications
  - High success (40 years)
- Transport layer
  - Main protocols:TCP (CO), UDP(CL)
- Application layer
  - Supposed to solve all problems unsolved by L3, L4
- IP Addressing
  - Identity and location- included in IP address → problems

CONTENTS

2. Information/Content Centric Networking

- **ICN/CON/CCN/CAN/NDN….**
  - recent significant attention of the research community and also industry and operators
  - propose **some fundamental changes** for TCP/IP networking
    - claiming several advantages in the perspective of Future Internet
  - **Terminology**
    - Not standardised, different (overlapping) semantics…
      - ICN/CCN - Information/Content Centric Networking
      - CON - Content Oriented Networking
      - DON - Data Oriented Networking
      - CAN - Content Aware Networking
      - NDN - Named Data Networking
    - **Related terminology:**
      - SON – Service Oriented Networking
      - NAA- Network Aware Applications
    - **Examples of ICN/CON Projects**
      - EUROPE : PSIRP, 4WARD, PURSUIT, SAIL, …
      - USA: CCN , DONA , NDN, …

2. Information/Content Centric Networking

- Example : Content Centric Networking
  - Relevant proposal in the area
  - Why CCN ? : Current networks **evolve mainly to content distribution and retrieval**
- *Source: Van Jacobson Diana K. Smetters James D. Thornton Michael F. Plass, Nicholas H. Briggs Rebecca L. Braynard, Networking Named Content, Palo Alto Research Center, Palo Alto, CA, October 2009*

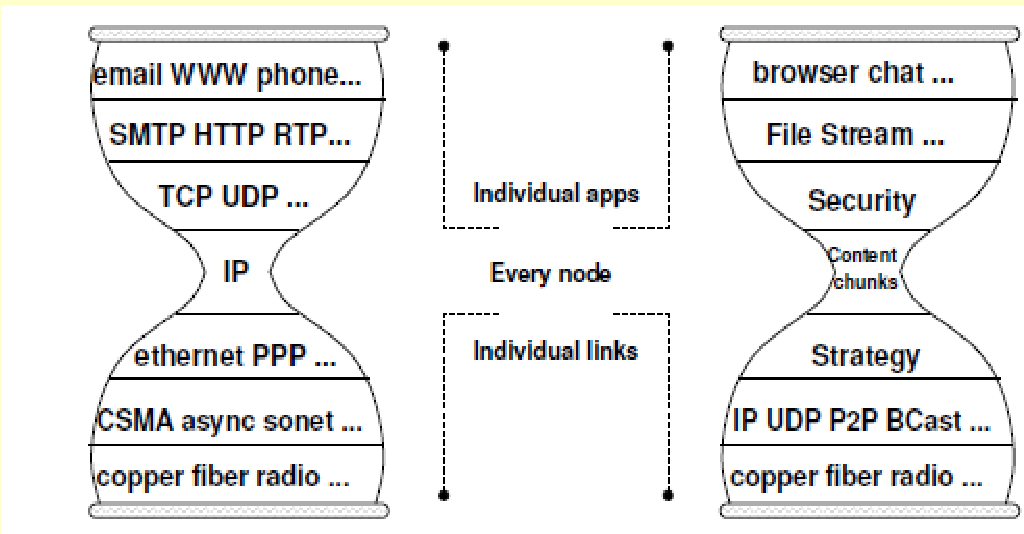
- **CCN Concepts**
  - Traditional networking : connections based on hosts locations
  - CCN proposes changes : ***where*** to ***what*** *.*
  - **Content treated as a primitive**
    - *decoupling location from identity, security and access*
    - *retrieving content by name*

  - ***Routing named content*, **(derived from IP), allows,*(claimed by authors),* to achieve *scalability* security and performance

2. Information/Content Centric Networking

CCN concepts (cont'd)

CCN proposes new "thin waist" of the Internet: IP → to chunks of named content



Traditional TCP/IP stack → **Original picture CCN**

Source: Van Jacobson Diana K. Smetters James D. Thornton Michael F. Plass, Nicholas H. Briggs Rebecca L. Braynard, Networking Named Content, Palo Alto Research Center, Palo Alto, CA, October 2009

Application	Applications: browser chat, file stream:
	Security
	Content chunks
	Strategy
	P2P, ..
TCP, UDP, …	UDP
IP	Intra-domain routing:OSPF, .. Inter-domain routing: BGP, ... (placed here to show their role)
Data link	Any Layer 2
Physical Layer (wireline, wireless)	Any PHY

Alternative view of CCN stack (if it run on top of IP)

2. Information/Content Centric Networking

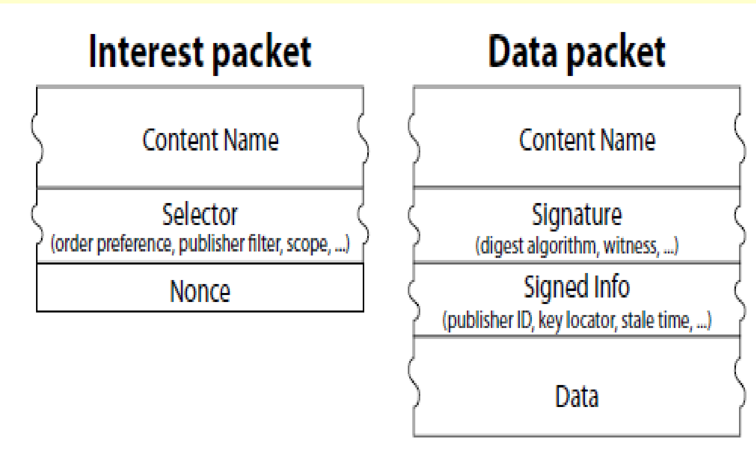
CCN Concepts (cont'd)

- CCN specific features- different from IP
  - **Strategy and security: new layers**
  - can use multiple simultaneous connectivity (e.g., Ethernet, 3G, 802.11, 802.16, etc.) due to its simpler relationship with layer 2.
  - **Strategy layer**
    - *makes dynamic optimization* choices - to best exploit multiple connectivity under changing conditions
  - **Security Layer**
  - *CCN secures the content objects* rather than the connections over which it travels *(this is to be discussed more..)*
    - avoiding many of the host-based vulnerabilities of current IP networking

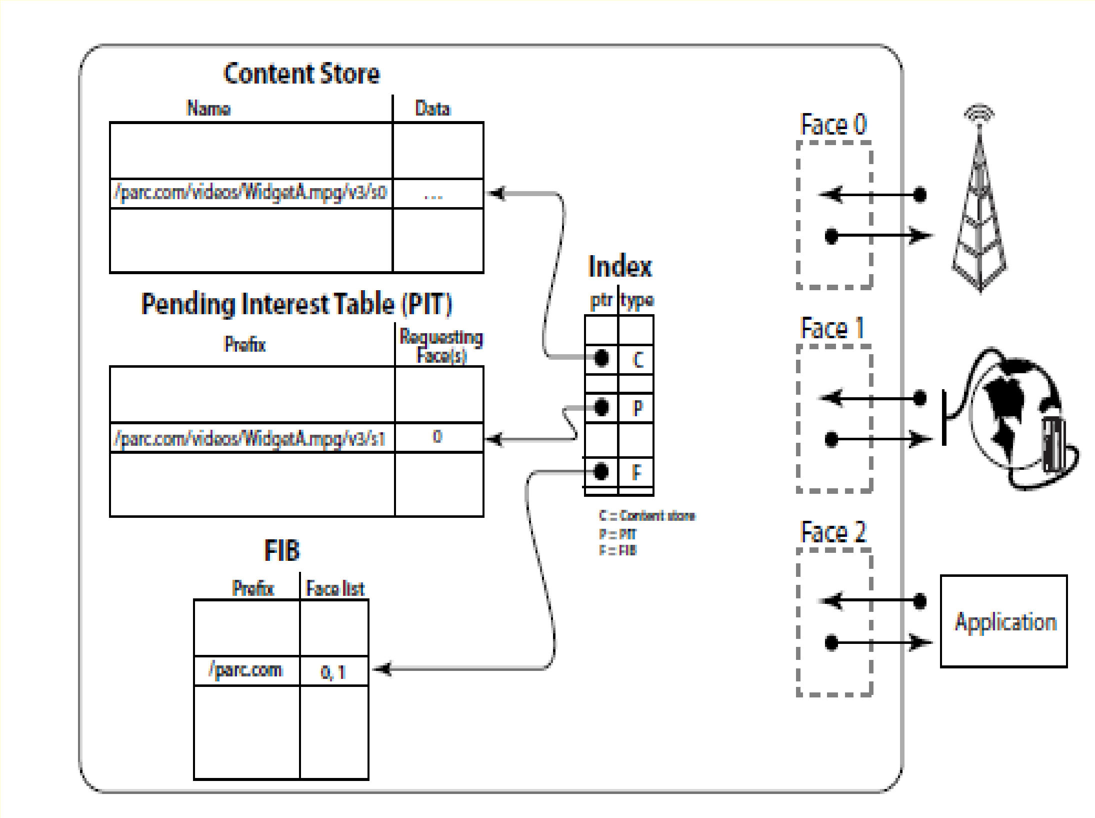
2. Information/Content Centric Networking

- **CCN packets (original paper)**

CCN Forwarding Engine Model (See Reference)



CCN Packet types



Source: Van Jacobson Diana K. Smetters James D. Thornton Michael F. Plass, Nicholas H. Briggs Rebecca L. Braynard, Networking Named Content, Palo Alto Research Center, Palo Alto, CA, October 2009

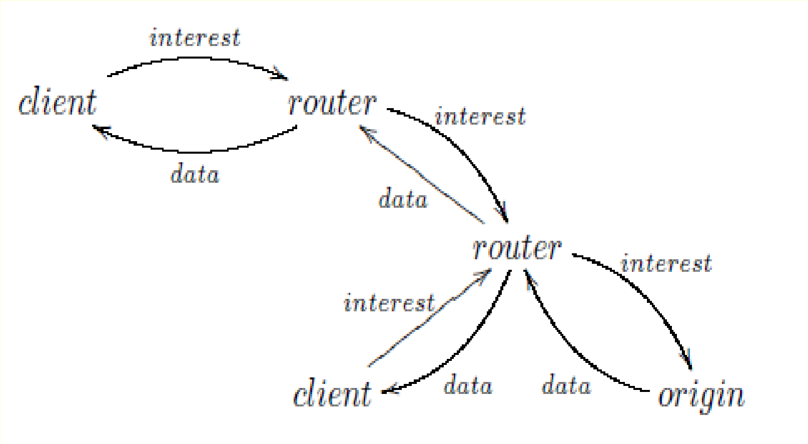
2. Information/Content Centric Networking

CCN operation: high level description

- The content producers advertise their content objects
- The nodes store the interfaces from where content can be reachable
  - Some "forwarding tables" are filled
- The consumers *broadcast* their ***interest*** for some ***content***
- Any node hearing the ***Interest*** and having stored the required content can respond with ***Data* packet**
- *Data* are returned as a response to an interest only and consumes this *interest (1-to- 1 relationship Interest-Data)*
- Multiple nodes interested in the same content may share the Data Packets: CCN is naturally multicast enabled
- Network nodes can perform caching- CDN similar functions

Content characterisation:

Data 'satisfies' an Interest if the *ContentName* in the *Interest Packet* is a prefix of the *ContentName* in the *DataPacket*



2. Information/Content Centric Networking

- **CCN Still open questions**

  - What significant benefits does ICN designs offer?
  - Are ICN designs the best solution to achieve those benefits?

  - Is the current technology prepared to introduce soon these changes?
    - Apparently not yet….
  - Seamless development possible?
  - Scalability issues
    - Network nodes store information objects and not locations
    - Number of info objects is much greataer than number of locations
  - High processing tasks for routers
  - Less support from the industry
  - …..?

CONTENTS

3. Software Defined Networking

- **SDN architecture**
  - Important concept: **Control and data planes are decoupled**
    - Increase flexibility (any SW in the control plane – independent on the switch/routers vendor solutions embedded in network devices)

    - OpenFlow protocol proposed for communication between planes
      - **Open Networking Foundation** (ONF- non-profit industry consortium) → OpenFlow I/F specifications for SDN
    - Network intelligence is more centralized
      - better and also flexible control of the resource management (good for QoS control)
      - overall image of the system in the control plane
      - programmability of the network resources
    - Underlying network infrastructure is abstracted from the applications

3. Software Defined Networking

- **SDN architecture (cont'd)**
- SDN + OpenFlow I/F(first standard) advantages:
  - *high-performance, granular traffic control* across multiple vendors' network devices
  - *centralized management and control* of networking devices improving automation and management
  - *common APIs abstracting the underlying networking* details from the orchestration and provisioning systems and applications;
  - *flexibility:* new network capabilities and services with no need to configure individual devices or wait for vendor releases
  - *programmability* by operators, enterprises, independent software vendors, and users (not just equipment manufacturers) using common programming environments
  - *Increased network reliability* and *security* as a result of centralized and automated management of network devices, uniform policy enforcement, and fewer configuration errors.

3. Software Defined Networking

- **SDN Architecture (cont'd)**
- SDN + OpenFlow (first standard) I/F allow for:
  - *more granular network control* with the ability to apply comprehensive and wide-ranging policies at the session, user, device, and application levels
  - *better end-user experience* as applications exploit centralized network state information to seamlessly adapt network behavior to user needs
  - *protects existing investments* while future-proofing the network

  - **With SDN, today's static network can evolve into an extensible service delivery platform capable of responding rapidly to changing business, end-user, and market needs.**

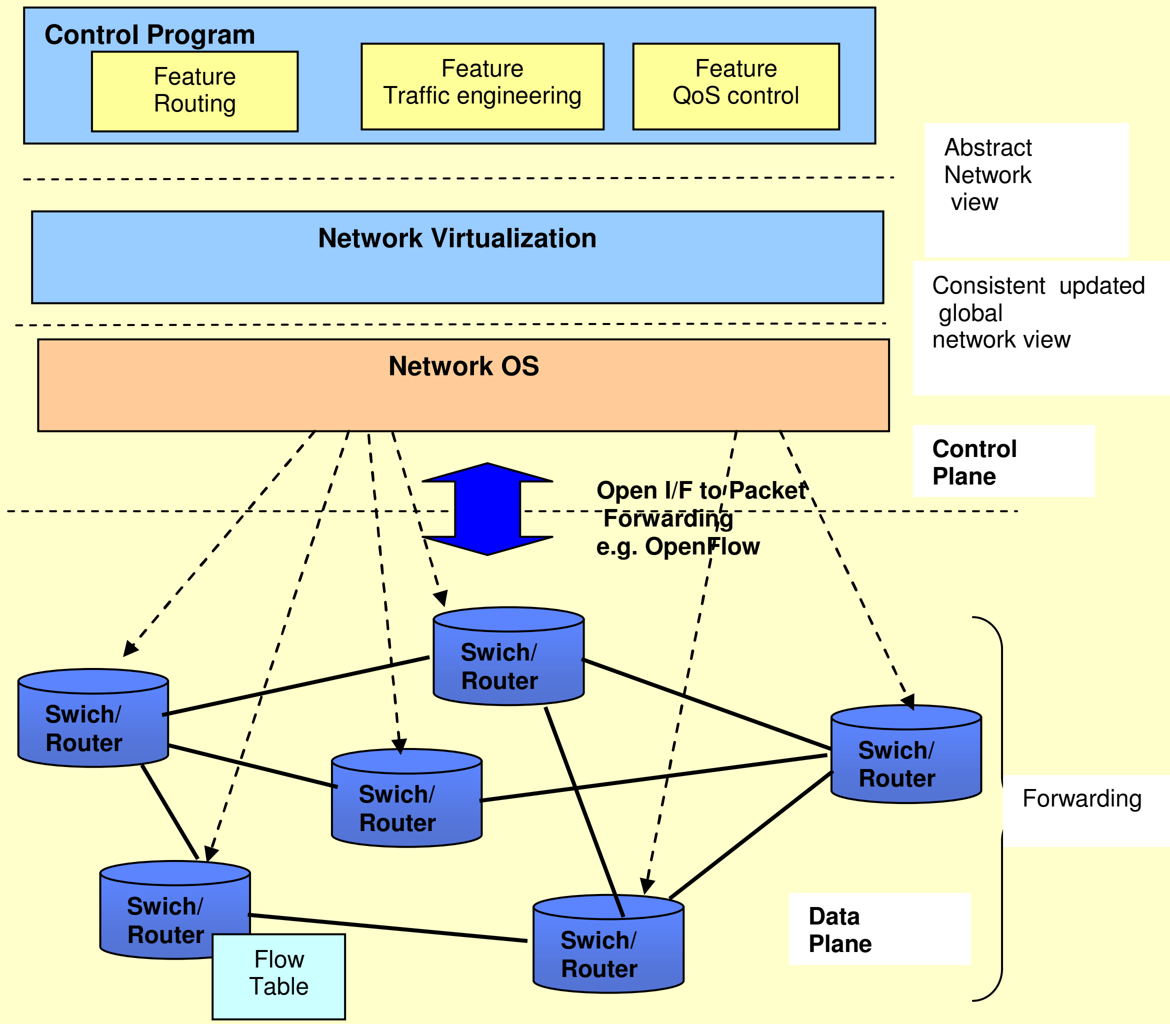
SDN short history

- 2008: Software-Defined Networking (SDN) : NOX Network Operating System [Nicira] ; OpenFlow switch interface [Stanford/Nicira]

- 2011: Open Networking Foundation (72 members) : Board: Google, Yahoo, Verizon, DT, Msoft, F'book, NTT ; Members: Cisco, Juniper, HP, Dell, Broadcom, IBM,…..

3. Software Defined Networking

- **SDN Architecture**
- **Network OS:**
  - Distributed system that creates a consistent, updated network view
  - Executed on servers (controllers) in the network
  - Examples: NOX, ONIX, HyperFlow, Floodlight, Trema, Kandoo, Beacon, Maestro,..
- Uses forwarding abstraction in order to:
  - Collect state information from forwarding nodes
  - Generate commands to forwarding nodes



3. Software Defined Networking

- **SDN Architecture**
- **Advantages**
- **Centralization allows:**
  - To **alter network behavior in real-time** and faster deploy new applications and network services (hours, days, not weeks or months as today).
  - network managers can flexibility to **configure, manage, secure, and optimize network resources via dynamic, automated SDN programs** (not waiting for vendors) .

- APIs make it possible to implement
  - common network services: **routing, multicast,** security, access control, **bandwidth management, QoS, traffic engineering,** processor and storage optimization, energy usage
  - policy management**,** custom tailored to meet business objectives
    - Easy to define and enforce consistent policies across both wired and wireless connections on a campus.
- **Manage the entire network** through intelligent orchestration and provisioning systems.

3. Software Defined Networking

- **SDN Architecture**
- **Advantages (cont'd)**

- ONF studies open APIs to promote multi-vendor management:
  - possibility for **on-demand resource allocation, self-service provisioning,** truly virtualized networking, and secure cloud services.
- SDN control and applications layers, business apps can operate on an **abstraction of the network**, leveraging network services and capabilities without being tied to the details of their implementation.

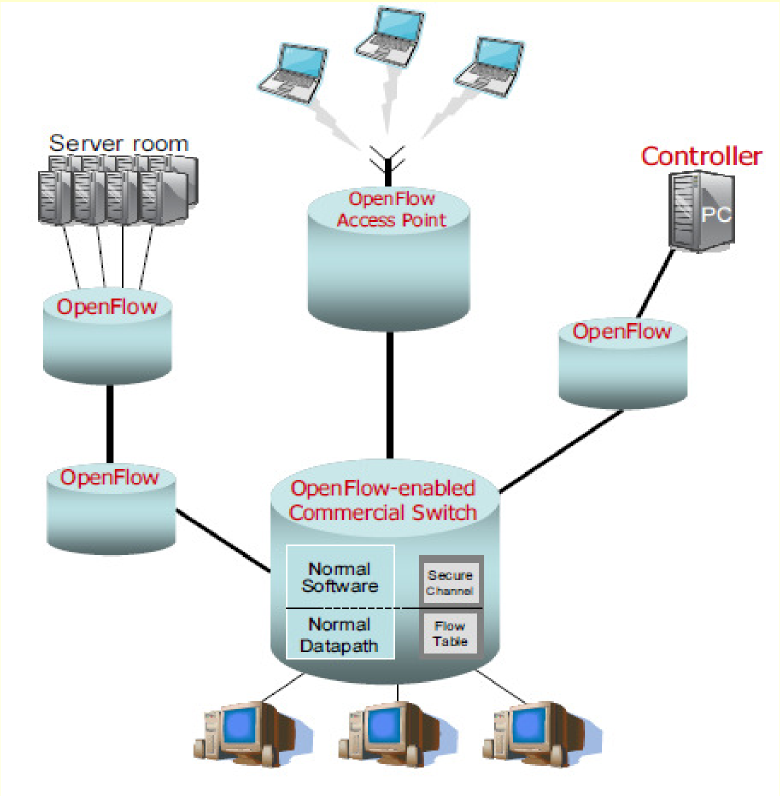
- SDN :
  - the network itself is not so much "application-aware" as "application-customized" and applications not so much "network-aware" as "network-capability-aware"
  - different approach w.r.t.ICN/CON/CCN
  - Question: these two technologies could cooperate?
    - Some recent answers: yes!

3. Software Defined Networking

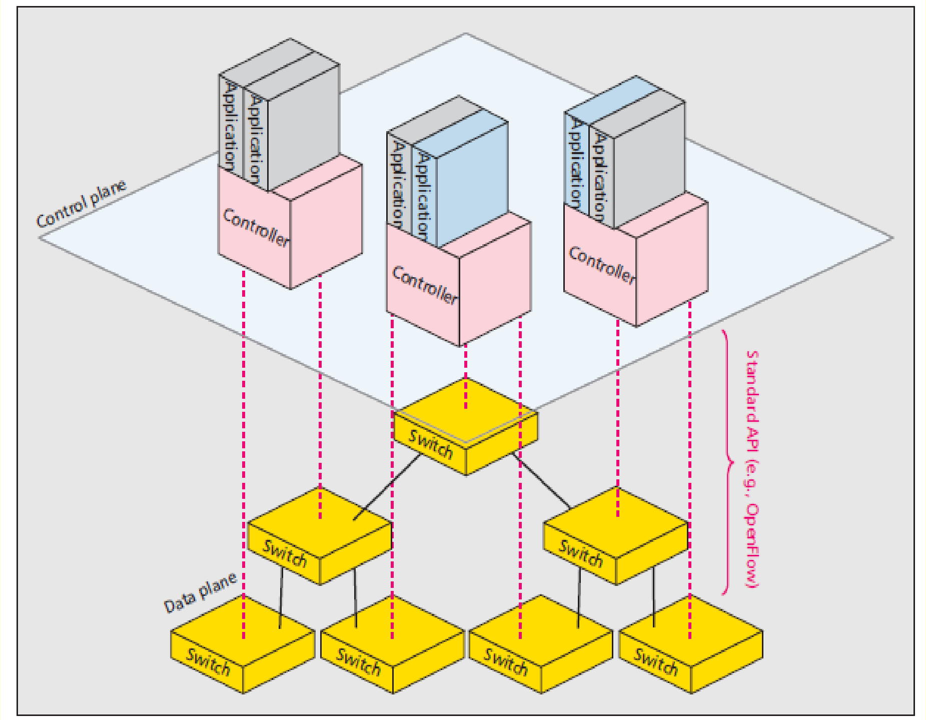
- **OpenFlow protocol**
- **first SDN standard** communications CPI-DPI I/F
- allows direct access to the Fwd.Plane of network devices (switches and routers), both physical and virtual (hypervisor-based).
- **network control is moved out of the networking switches** to logically centralized control software.
- **specifies basic primitives** to be used by an external SW application to program the Fwd.Plane (~ instruction set of a CPU would program a computer system)
- uses the ***concept of flows*** to identify network traffic based on pre-defined match rules that can be statically or dynamically programmed by the SDN control SW.
- **allows IT to define how traffic should flow through network** devices based on parameters such as usage patterns, applications, and cloud resources
- allows the **network to be programmed** on **aggregated** or **per-flow** basis
  - provides – if wanted- extremely granular control, enabling the network to respond to real-time changes at the application, user, and session levels

3. Software Defined Networking

- **OpenFlow Protocol (cont'd)**
- *Source Ref1: "OpenFlow: Enabling Innovation in Campus Networks"- Nick McKeown, Tom Anderson, Hari Balakrishnan, Guru Parulkar, Larry Peterson, Jennifer Rexford, Scott Shenker, Jonathan Turner*



Ref1: Example of a network of OpenFlow-enabled commercial switches and routers.



Solving the scalability: several controllers

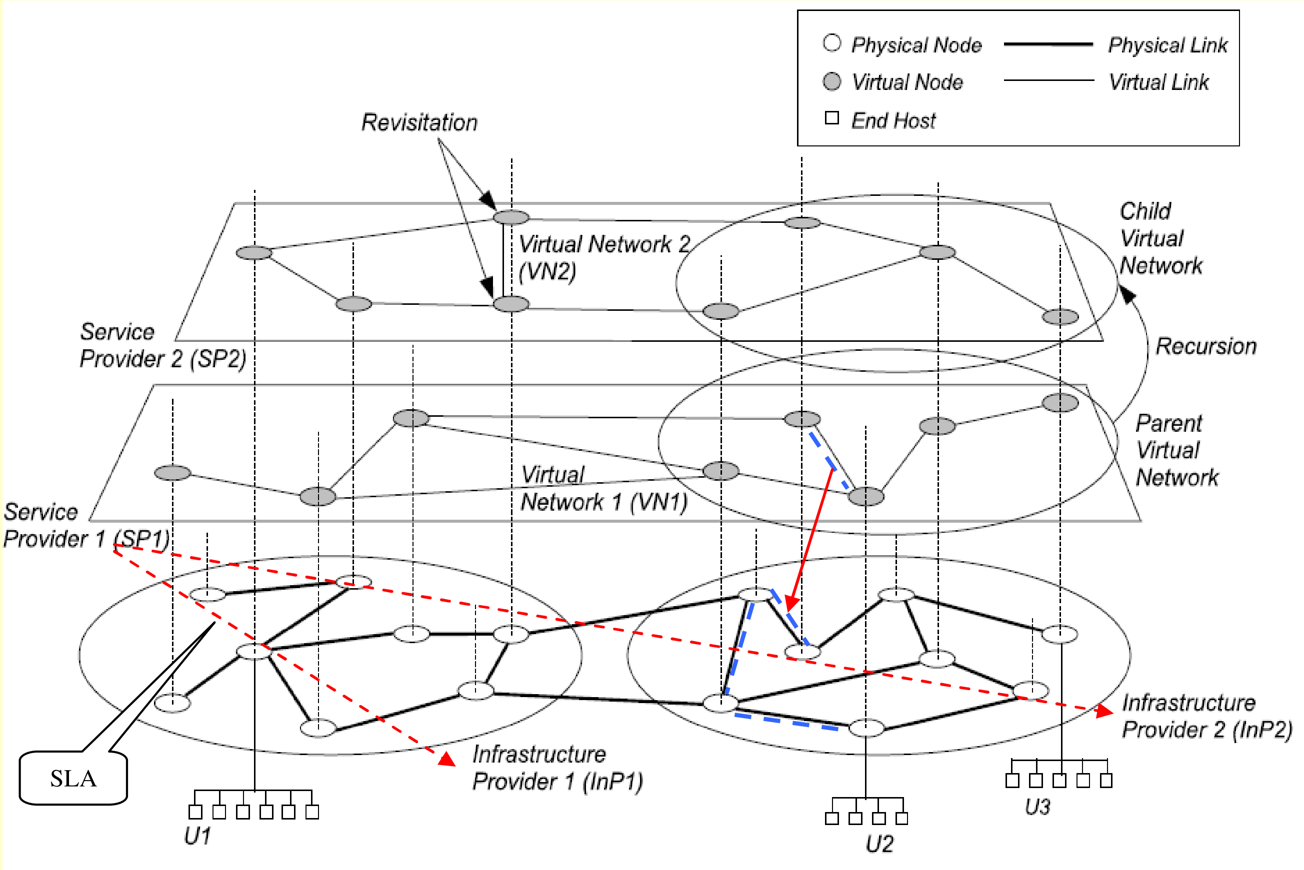
Source: S.Hassas Yeganeh, A.Tootoonchian, and Y.Ganjali,
On Scalability of Software-Defined Networking,
IEEE Comm. Magazine • February 2013

CONTENTS

1. Introduction
2. Adapting network layer to content: Information/Content Centric Networking
3. Decoupling Data and Control Planes : Software Defined Networks
4. **☞ Flexibility: Virtualization**
5. XaaS: Cloud computing
6. Telecom (ITU-T) solutions
7. Conclusions

4. Virtualization

- Main tool to slicing the hosts/nodes and network
- Largely applied in FI proposals
- Dynamic customized and isolated slices



Dynamic customised

VNets, Vpaths,

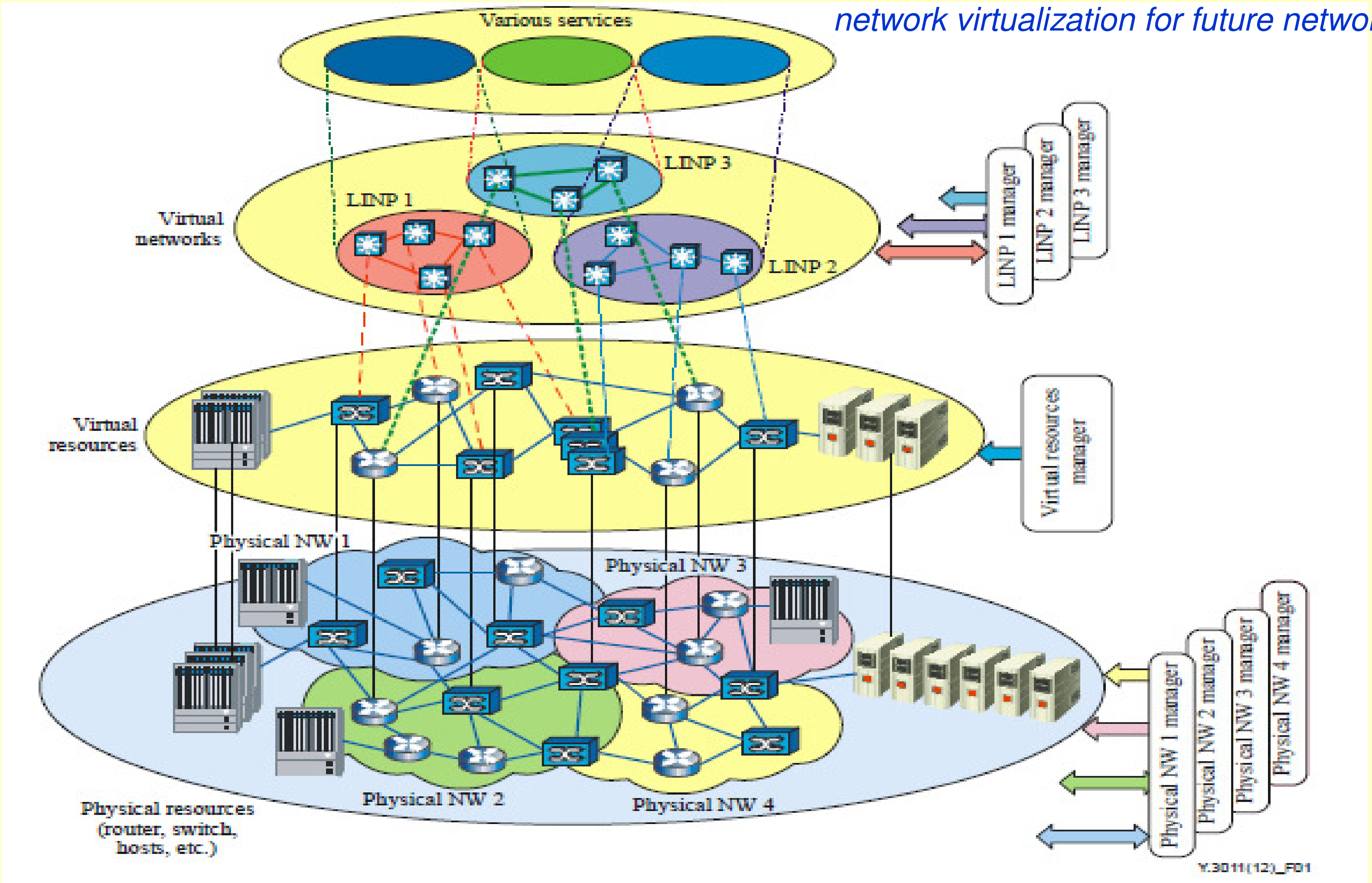
unicast /mcast/P2P

Source: N.M. Chowdhury and R.Boutaba,
A Survey of Network Virtualization, University of Waterloo, Technical Report: CS-2008-25, 2008

4. Virtualization

- ITU-T vision on virtualization

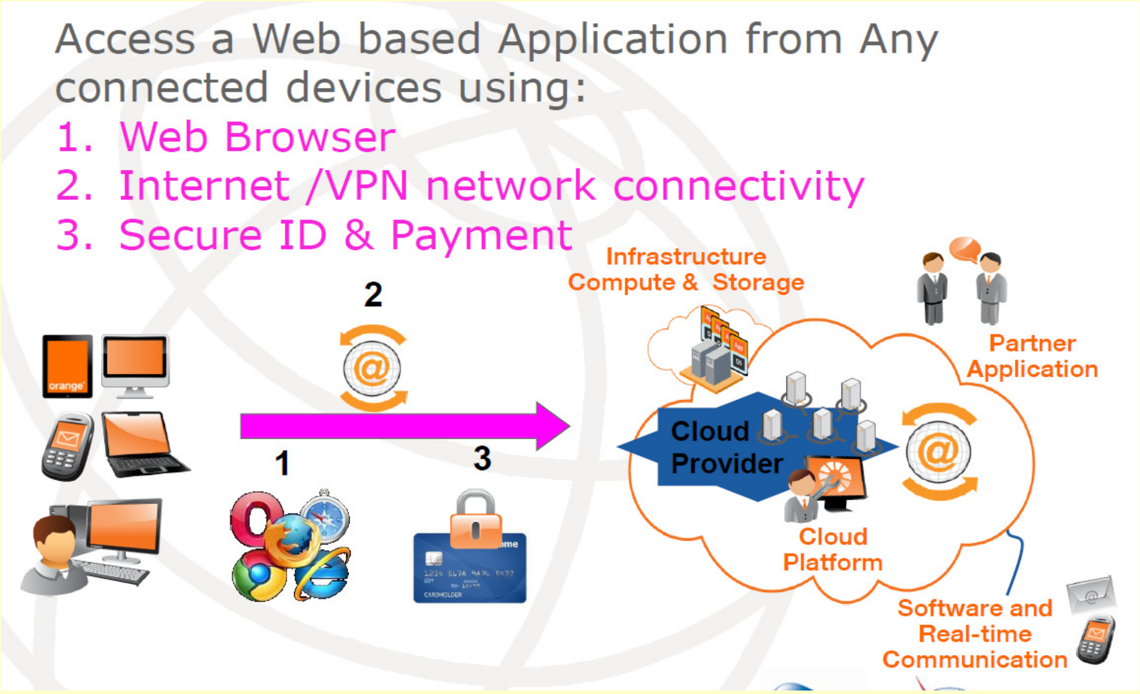
Source: ITU-T Y.3011: Framework of network virtualization for future networks



CONTENTS

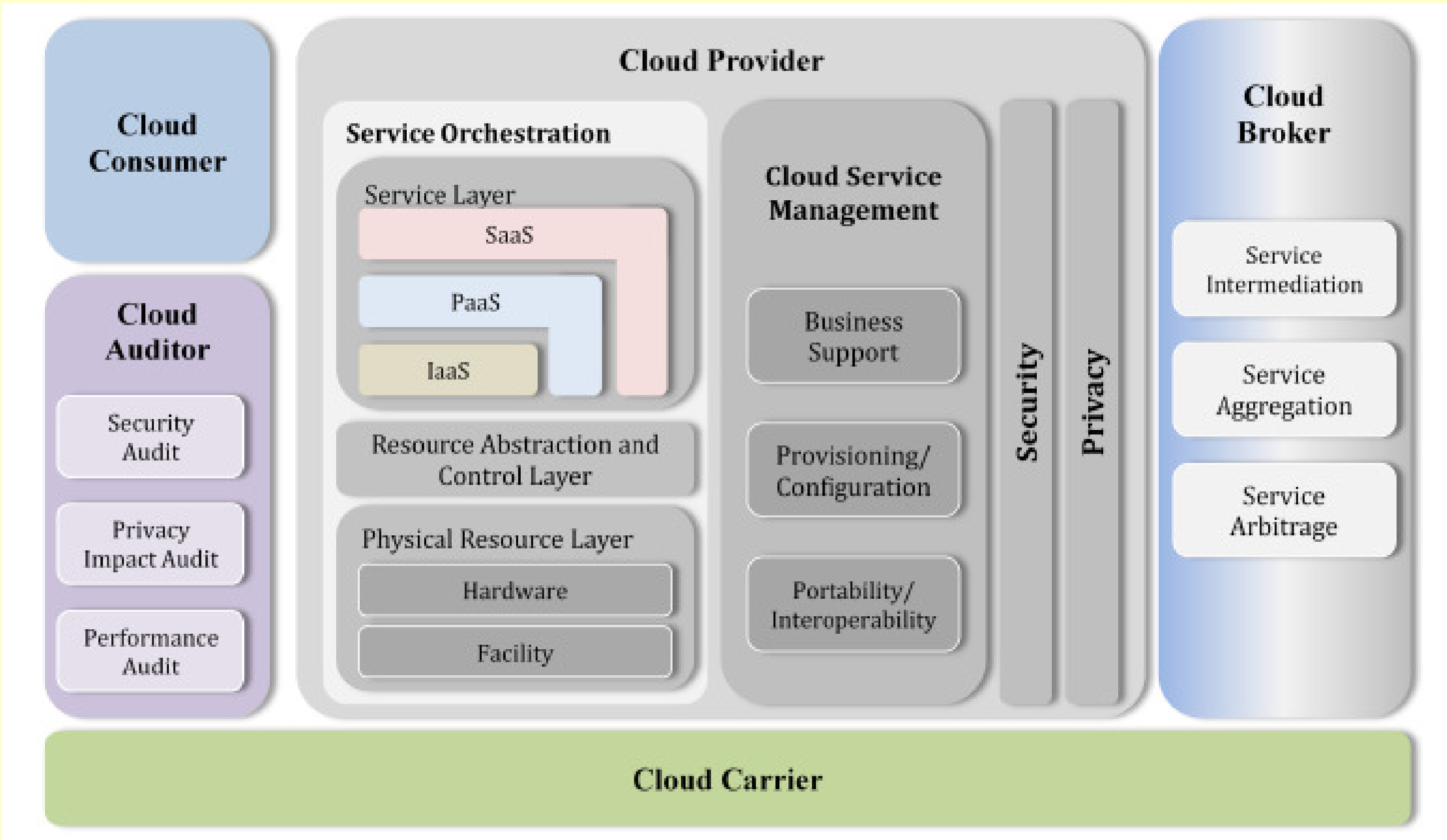
5. Cloud Computing

- **High level view of cloud computing**
- **Cloud model (source: National Institute of Standardization - NIST)**
  - five essential characteristics ; three service models; four services models
  - *Source: P.Mell , Ti.Grance, The NIST Definition of Cloud Computing, Special Publication 800-145, Rec. of the National Institute of Standards and Technology , 2011*
  - *Source: F.Liu, J.Tong, J.Mao, R.Bohn, J.Messina, L.Badger and D.Leaf, Rec. of the National Institute of Standards and Technology, NIST "Cloud Computing Reference Architecture", Special Publication 500-292 , 2011*



4. Cloud Computing

- **Cloud model**
- NIST cloud computing reference architecture



4. Cloud Computing

- **Cloud model**
- **Cloud Characteristics**
  - On-demand self-service
  - Broad network access
  - Resource pooling (storage, processing, memory, network bandwidth, etc.)
  - Rapid elasticity (for provisioning/releasing resources)
  - Measured service (automatically control and optimize resource utilization)
- **Cloud services**
  - **NIST:**
    - Software as a Service (SaaS).
    - Platform as a Service (PaaS).
    - **Infrastructure as a Service (IaaS)**
  - ITU-T (defined additional services)
    - **Network as a Service – NaaS**
    - Communication as a Service- CaaS, etc.

Transport and network layer - involved

- **Deployment model**
  - Private cloud ; Community cloud; Public cloud; Hybrid cloud

4. Cloud Computing

- **Cloud model**
- NIST cloud computing reference architecture
- **Five entities/actors**
  - **Cloud Consumer :**a person or organization that maintains a business relationship with, and *uses service* from, *Cloud Providers*
  - **Cloud Provider:** a person, organization, or entity responsible for *making a service available* to interested parties
  -
  - **Cloud Auditor:** a party that can conduct *independent assessment* of cloud services, information system operations, performance and security of the cloud implementation
  - **Cloud Broker:** an entity that *manages the use, performance and delivery of cloud services, and negotiates relationships* between *Cloud Providers* and *Cloud Consumers*
  - **Cloud Carrier:** an *intermediary* that provides *connectivity and transport of cloud services* from *Cloud Providers* to *Cloud Consumers*.

4. Cloud Computing

- **ITU-T vision on cloud computing**
- **Telecommunication centric Cloud Ecosystem, cloud services and use cases**
- **Cloud service**: A service that is delivered and consumed **on demand at any time**, through **any access network,** using **any connected devices** using cloud computing technologies
- **Cloud Ecosystem**
  - **Cloud Service Provider (CSP):** An organization that provides and maintains delivered cloud services:
    - Provider of SaaS ,CaaS, PaaS, IaaS, NaaS
    - Inter-cloud Provider: Inter-cloud peering, Inter-cloud service broker, Inter-cloud federation
  - **Cloud Service User (CSU)** A person or organization that consumes delivered cloud services (Consumer, Enterprise, Governmental/public institution)
  - **Cloud Service Partner (CSN)** A person or organization that provides support to the building of the service offer of a CSP: Application developer, Content provider, SW provider, HW provider, Equipment provider, System integrator, Auditor

- *Source: ITU-T: Focus Group on Cloud Computing ; FG Cloud TR Version 1.0 (02/2012) Part 1: Introduction to the cloud ecosystem: definitions, taxonomies, use cases and high-level requirements*

4. Cloud Computing

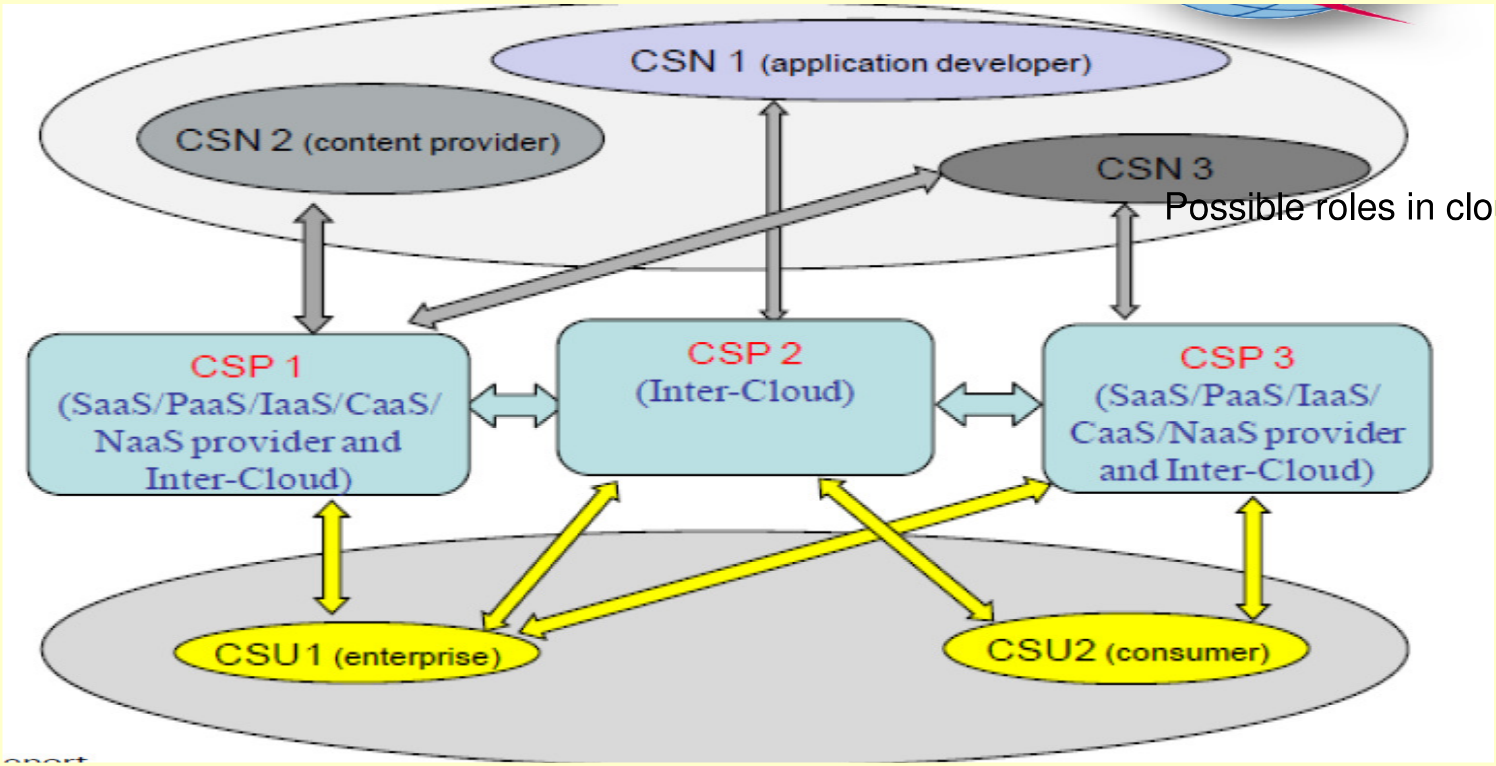
- **ITU-T vision on cloud computing**
- **New types of Cloud Services (ITU-T)**
  - **Communication as a Service - CaaS** : real-time communication and collaboration services
  - (VoIP, A/VC), collaborative services, unified communications, e-mail, instant messaging, data sharing (web conference)
  - **Network as a Service – NaaS** : transport/connectivity services intra and/or inter-cloud network connectivity services.
  - **Managed Internet** (guaranteed speed **,** availability, etc.) virtualized networks (VPNs), coupled with cloud computing services, flexible and on **demand bandwidth**

	Desktop as a service	Flexible and extended VPN	Service delivery platform as a service	Bandwidth on demand	Cloud communication centre
IAAS	✓				
PAAS			✓		
NAAS		✓		✓	
CAAS			✓		✓
SAAS			✓		✓

Map of cloud services to cloud-service categories – ITU-T

5. Cloud Computing

- **ITU-T vision on cloud computing**
- ITU-T Cloud computing functional reference architecture

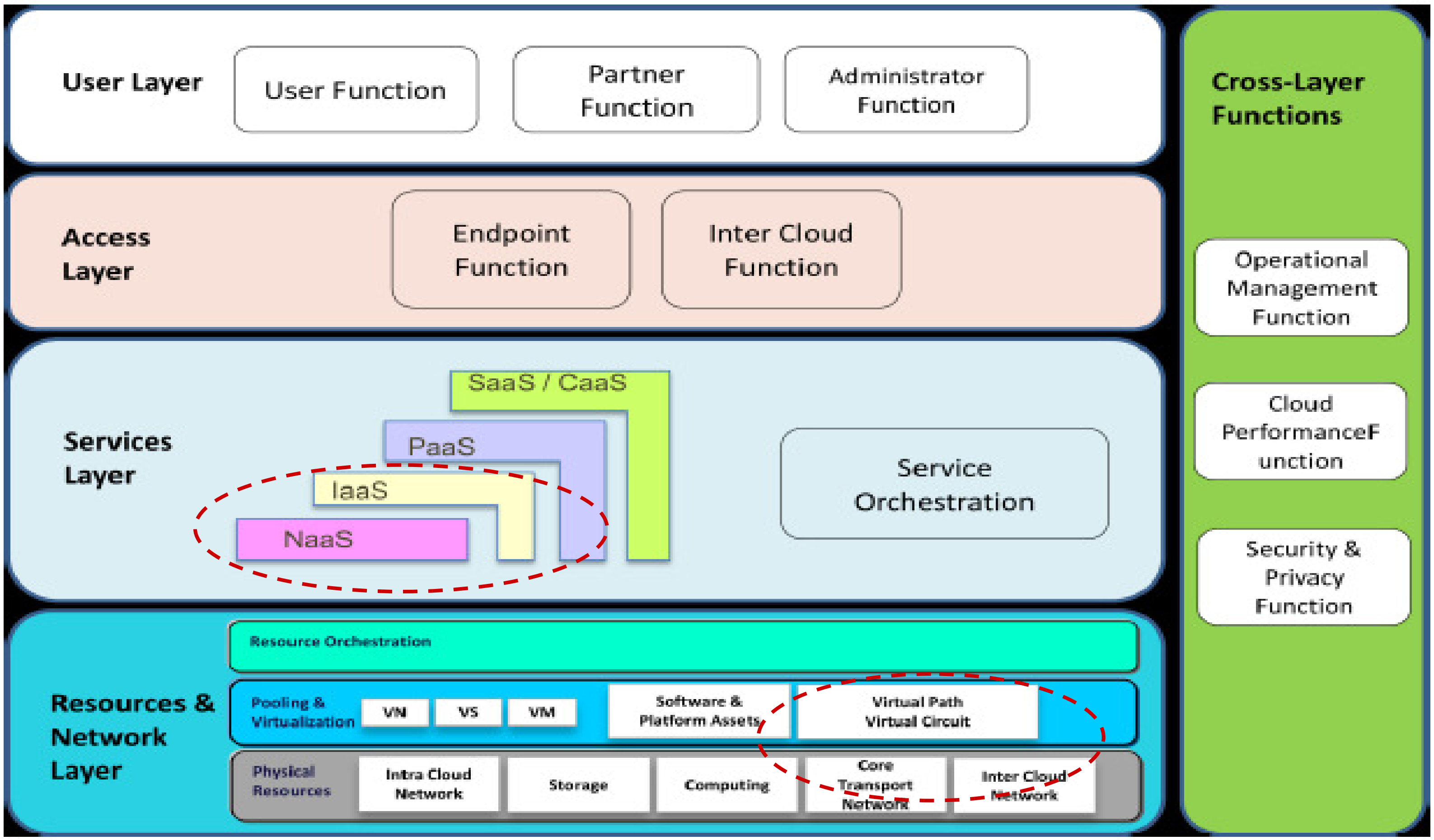


Possible roles in cloud scenario

Source: ITU-T Focus Group on Cloud Computing Technical Report

5. Cloud Computing

- **ITU-T vision on cloud computing**
- ITU-T Cloud computing functional reference architecture



5. Cloud Computing

- **ITU-T vision on cloud computing**
- **ITU-T Cloud computing functional reference architecture**

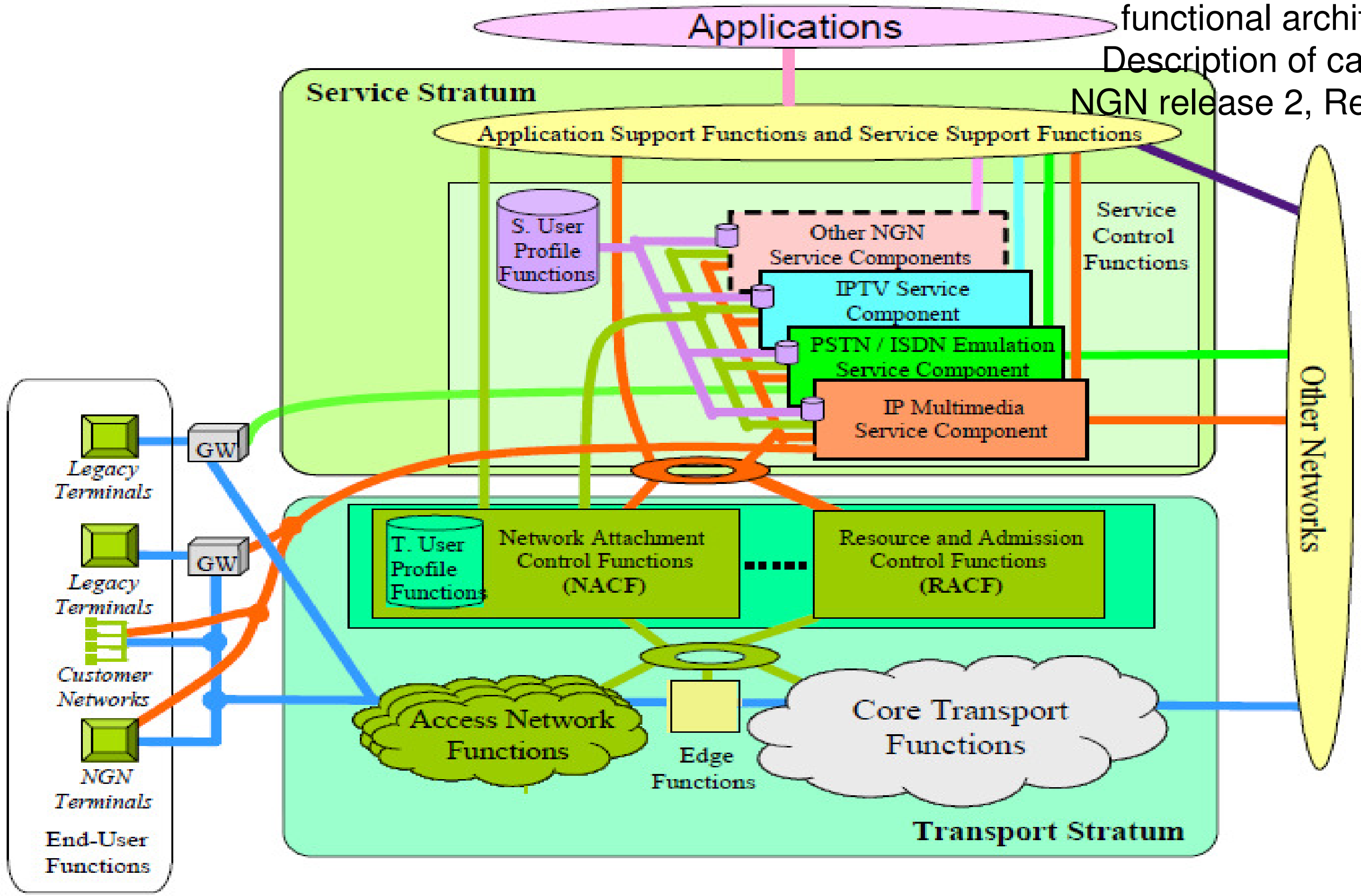
- **Access layer**
  - Endpoint : controls cloud traffic and improves cloud service delivery
  - Inter Cloud: addresses delivering any cloud service across two or more CSPs
- **Services layer**
  - Service Orchestration: is the process of deploying and managing “Cloud Services“
  - Cloud Services: provides instances (and composition) of CaaS, SaaS, PaaS, IaaS & NaaS
- **Resources & Network Layer**
  - Resource orchestration
  - Pooling Virtualization: compute, storage, network, software & platform assets
  - Physical resources

CONTENTS

6. ITU-T solutions

- **Next Generation Network Architecture**

Y.2007 NGN– Frameworks and functional architecture models, Description of capability set 1 of NGN release 2, Recommendation ITU-T, 2010



* NOTE – Gateway (GW) may exist in either Transport Stratum or End-User Functions.

CONTENTS

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4. Flexibility: Virtualization
5. XaaS: Cloud computing
6. Telecom (ITU-T) solutions
7. ☞ **Conclusions**

7. Conclusions

- New architectures and technologies are proposed for FI – affecting the network and transport layers
- **Information/Content Centric Networking**
  - Revolutionary approach (change classic networking paradigms)
  - Strong information/content orientation
  - Still not developed in the industry
  - Many open research issues
- **Software Defined Networking**
  - Evolutionary approach
  - Separation Data Plane – Control and Management plane + Centralization
  - Flexibility
  - Much more support in the industry
- **Virtrualization: nodes, links**
- **Cloud Computing**
  - Data Centers offering flexible network/transport services
    - IaaS, NaaS
  - Strong support in the industry
- **Future Internet: - probably will be combinations of such technologies**

- **THANK YOU!**
- **Questions ?**

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