New Networking Technologies Support for Media-oriented Applications

Eugen Borcoci

University POLITEHNICA Bucharest,
Eugen.Borcoci@elcom.pub.ro

InfoSys 2012 Conference, March 24-29, 2013 Lisbon

Acknowledgement

The **overview (State of the Art) part is compiled**, 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).

The **ALICANTE –project case study- part -** as an example of content/media – oriented architecture is presented with permission of the ALICANTE Consortium.

This work is supported by **ALICANTE FP7 IP Project 248652: "MediA Ecosystem Deployment Through Ubiquitous Content-Aware Network Environments", 2010 – 2013.**

Motivation of this talk

- **Content and media** oriented communications (+ social networks) are forecasted to produce a high percentage of the global Internet traffic (more than 90% - estimated in 2015)
  - New challenges for networks:
    - Offer appropriate support for different kind of services
    - Offer different degrees of quality of services/experience (QoS/QoE) assured on demand for the end users
    - Business models : more complex, with several actors
      end users may play single or combined roles as information/content consumers but also content or services providers.

  - Future Internet challenges - to solve the current Internet limitation and ossification
    - **Evolutionary approach**
    - **Clean slate approach**
    - **New trends**
      (ICN/CCN) Information/Content Centric Networking, (CON) Content Oriented Networking, (CAN) Content Aware Networking, …

      Software Defined Networks→ Sofware Defined Internet Architectures

      Cloud computing

      Combinations

Motivation of this talk (cont'd)

- **This tutorial**
  - **Summary overview of some recent architectures and technologies, studied in research groups but also developed in the real market, capable (among other features) to more efficiently support the media applications and services**
- **Topics**
  - **Media oriented architectures**
  - **Software Defined Networks (SDN) architecture**
    - Control and data planes are decoupled
    - Increase flexibility
    - E.g. - OpenFlow protocol for communication between planes
    - Attractive also for media-oriented apps/services
    - 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.

Motivation of this talk (cont'd)

- **Topics**
  - **Content/information oriented/centric networking**
  - propose to significantly (revolutionary) change the traditional approach
    - by decoupling the content and location at network level
    - creating the possibility for media objects to be directly leveraged in network nodes
  - **Cloud computing**
    - **SaaS, PaaS, IaaS, NaaS**
    - **Infrastructure as a Service (IaaS) and Network as a Service (NaaS)**
      - **capable (among others), to efficiently serve the dynamic bandwidth and storage needs of the media and content oriented applications.**
  - **The above approaches : SDN/ICN/Cloud computing**
    - can be seen and developed as complementary
    - cooperating and supporting each other
    - aiming finally towards higher overall capabilities of the networked media systems
    - However some conceptual differences – to be more clarified- exist in these approaches

CONTENTS

CONTENTS

1. Media Oriented Architectures

- **Improvement proposed by FMIA group**
  - ***Source: Future Media Internet Architecture Reference Model***
  - *www.fi-nextmedia.eu /*
    - ***Content dynamic caching*** In-network:
      - efficiency increase
      - network nodes store content (routers, servers,gateways, data centres) – closer to the users
    - ***Content Identification***
      - routers could identify/analyse *content_type* and/or *content_objects* and process packets efficiently in terms of routing, forwarding, filtering, multiplication, etc.
    - ***Network topology & traffic knowledge***
      - the current best/better E2E path could be selected for data delivery, if knowledge about the network topology /traffic per link were known, by some other entities than the network ones only
    - ***Content Centric Delivery***:
      - more efficient content-aware delivery - based on the content name, if the content caching location, the network topology and traffic were known, rather than initial location of the content only
    - ***Dynamic Content Adaptation & Enrichment***: based on user preferences and user/network context

1. Media Oriented Architectures

- **Future Media Internet Architecture Reference Model**

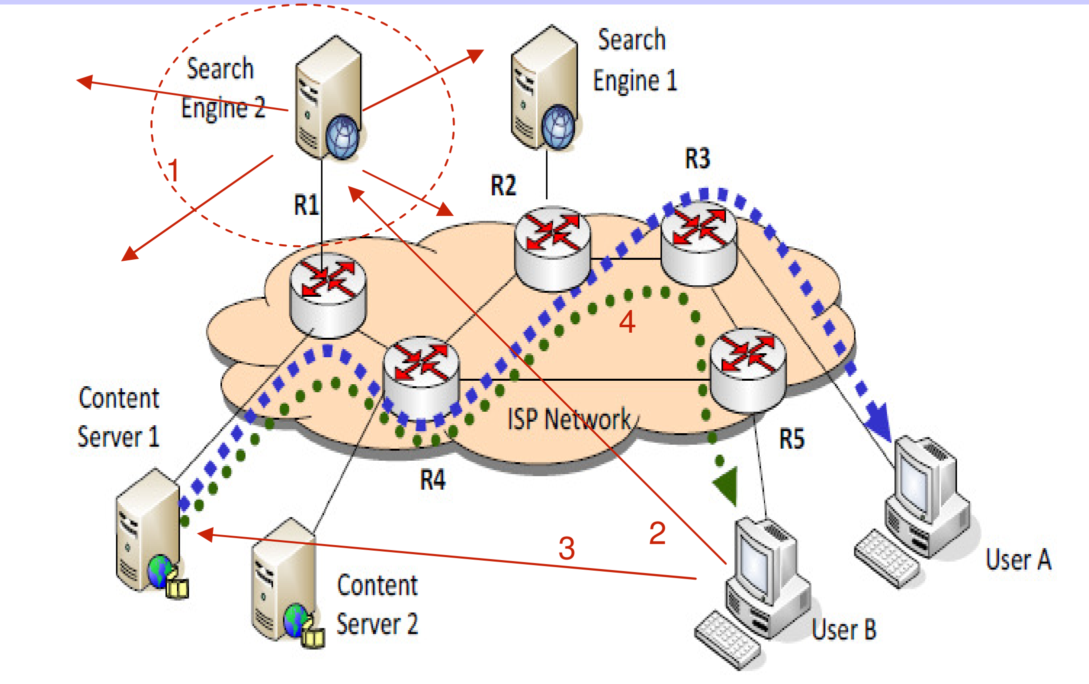
  - **FI Design principles (valid also for FMIA)**
  - Support flexible business models
    - multiple stakeholders can , open environment
    - encouraging innovation and participation without barriers
  - Open architectures and protocols
    - enable increased competition between providers (NP, SP, ..)
  - Users -> “prosumers”
  - Higher participation of individuals, communities and small businesses + and more established organizations

  - Incentives for CP/SPs to receive appropriate benefits for their contribution
  - FI :
    - sustainable network, flexible for evolution, development and extension -in response to market
    - scalable, available and reliable (resources versus cost)

1. Media Oriented Architectures

- **Source: Future Media Internet Architecture Reference Model**
  - www.fi-nextmedia.eu /
  - http://initiative.future-internet.eu/news/view/article/future-media-internet-architecture-reference-model-white-paper.html- 2011

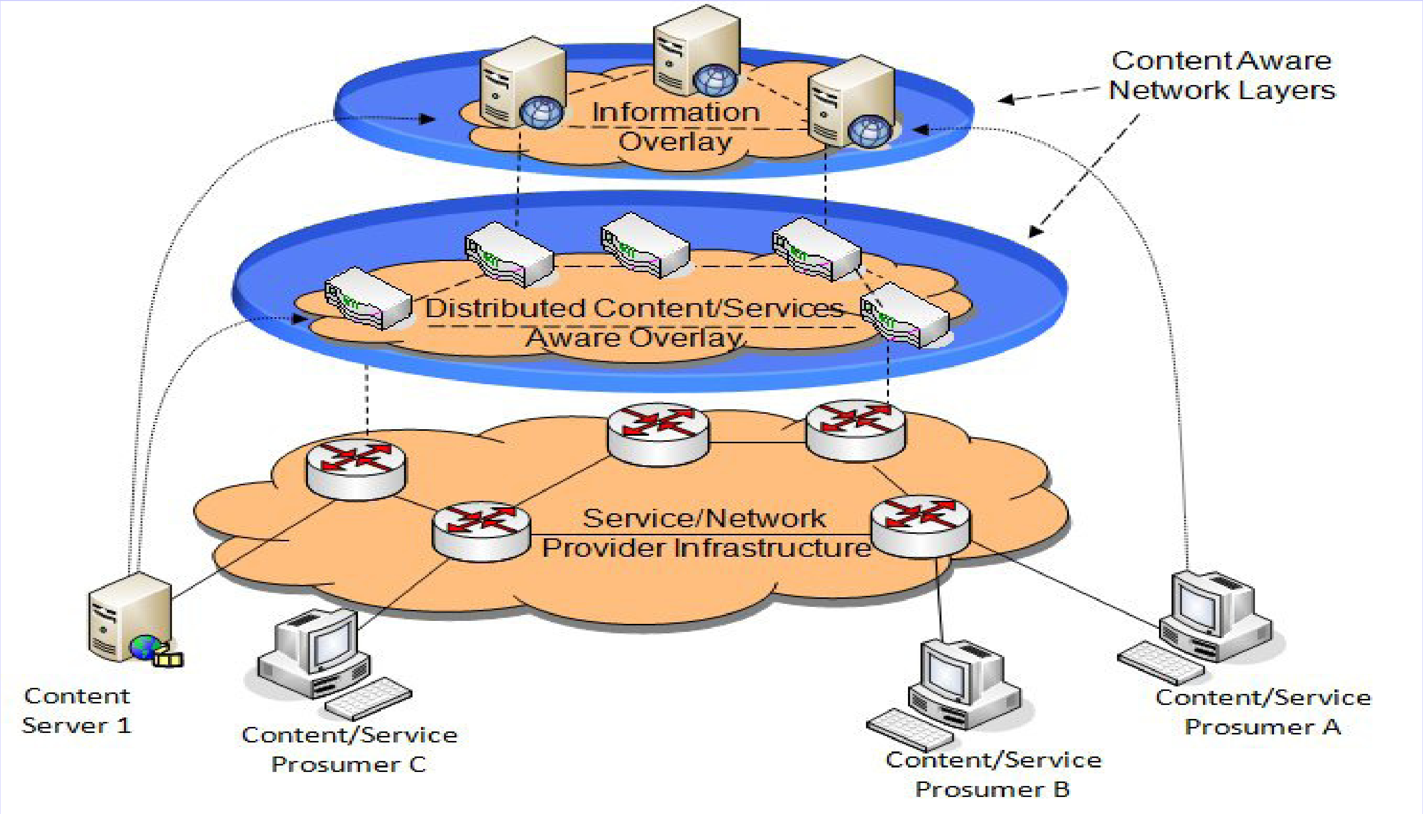
- **Current Internet limitations- related to content delivery**
  - *Components*
    - *Content Servers* or *Content Caches* (Content Provider or user generated content and services),
    - *Search Engines* (centralised or clustered)
    - *Network Nodes (Routers* - edge *and* core and, *Residential Gateways)*
    - *User terminals*
    - *Phases: 1-4 to get content*



Source: http://initiative.future-internet.eu/news/view/article/future-media-internet-architecture-reference-model-white-paper.html- 2011

1. Media Oriented Architectures

- **Source: Future Media Internet Architecture Reference Model**
  - www.fi-nextmedia.eu /
  - **High –level FMI Network Architecture- proposal**



1. Media Oriented Architectures

- **Source: Future Media Internet Architecture Reference Model**
  - www.fi-nextmedia.eu /

  - **High –level FMI Network Architecture (cont'd)**
    - nodes may belong to more than one layer

  - FMI deployment –still incremental
    - legacy network nodes will remain for a number of years;
    - architecture : backward compatible with current Internet deployment

    - ***Service/Network Provider Infrastructure***
      - Lower layers
      - Users can be "Prosumers"
      - Usually the owner is ISP/network provider
      - Limited functionality and intelligence nodes
      - Content will be routed, assuming basic quality requirements and if possible cached in this layer.

1. Media Oriented Architectures

- **Source: Future Media Internet Architecture Reference Model**
  - www.fi-nextmedia.eu /
  - **High –level FMI Network Architecture (cont'd)**
  - ***Distributed Content/Services Aware Overlay***
    - Content-Aware Network Nodes (edge routers, home gateways, terminals devices)
    - *Intelligent nodes* can filter content and Web services flowing through (e.g. via DPI, signalling processing),
    - identify streaming sessions and traffic (via signalling analysis) and provide qualification of the content.
    - information reported to the *Information Overlay*
    - *Virtual overlays* –at this layer - statically/dynamically constructed
      - specific purposes: content caching, content classification, indexing, network monitoring, content adaptation, optimal delivery/streaming
    - Content delivery modes; hybrid client-server and/or P2P
    - Nodes have information on the content and the content type/context that they deliver ➔ hybrid topologies may be constructed, customised for streaming complex media

      Scalable Video Coding (SVC), Multi-view Video Coding (MVC).

1. Media Oriented Architectures

- **Source: Future Media Internet Architecture Reference Model**
  - www.fi-nextmedia.eu /

  - **High –level FMI Network Architecture (cont'd)**

  - ***Information Overlay (IO)***
  - intelligent nodes/servers having distributed knowledge of
    - content/web-service location/caching
    - (mobile) network instantiation/ conditions (limited)

  - **Types of nodes:**
    - unreliable peers in a P2P topology
    - secure corporate routers
    - Data Centres in a distributed carrier-grade cloud network

  - Factors determining variation: actual network deployment and instantiation, the service scenario/requirements, service quality agreements

  - Content stored/cached : at the *Information Overlay* or at lower hierarchy layers.

  - *IO allows* awareness of the content/services location/caching and the network information
    - decision --> content optimally retrieved and delivered to the subscribers or inquiring users or services

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
  - **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?
    - Seamless development possible?
    - Scalability issues?
    - …..?

2. Information/Content Centric Networking

- **ICN/CON/CCN/CAN/NDN….**

  - **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 1: Content Centric Networking
- **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**
  - Current network **evolve mainly to content distribution and retrieval**
  - Traditional networking : connections based on hosts locations (need mapping *what* -> *where).*

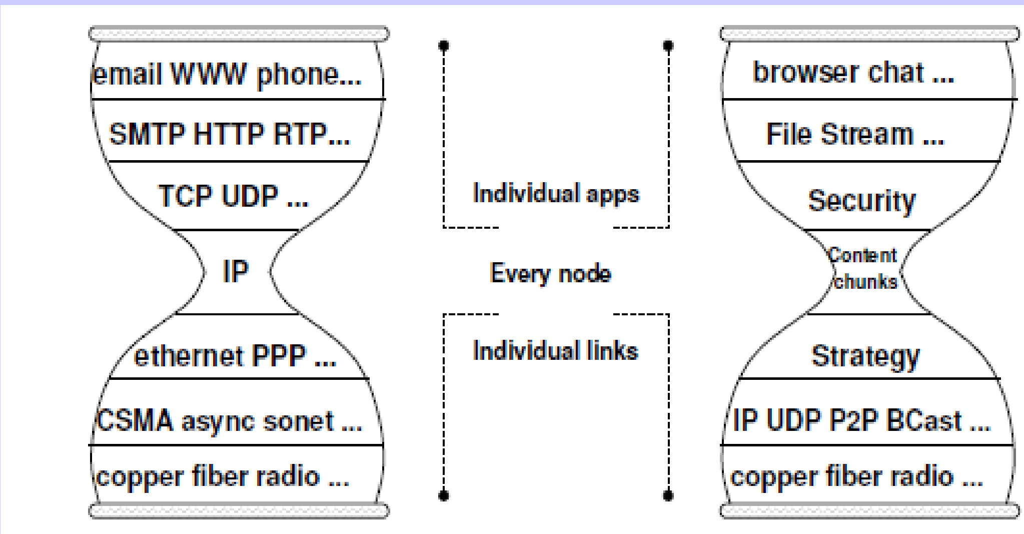
  - CCN: Content treated as a primitive – *decoupling*
    - *location from identity, security and access,*
    - *retrieving content by name*

  - *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**

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)

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 Concepts** (cont'd)
  - Most layers of the traditional stack have horizontal bilateral agreements/protocols (Node to node, end to end)
  - Network layer : the only one requiring universal agreement
  - **Why IP's success ?:**
    - simple (thin 'waist' of the stack)
    - flexible (dynamic routing)
    - Any L4 on it
    - Any L2 under it: Low demand from L2: stateless, unreliable, unordered, best-effort delivery.
  - **CCN's "network layer" is claimed to be similar to IP**
    - it makes fewer demands on L2,
    - (+): CCN *can run on top of anything,* including IP itself.

2. Information/Content Centric Networking

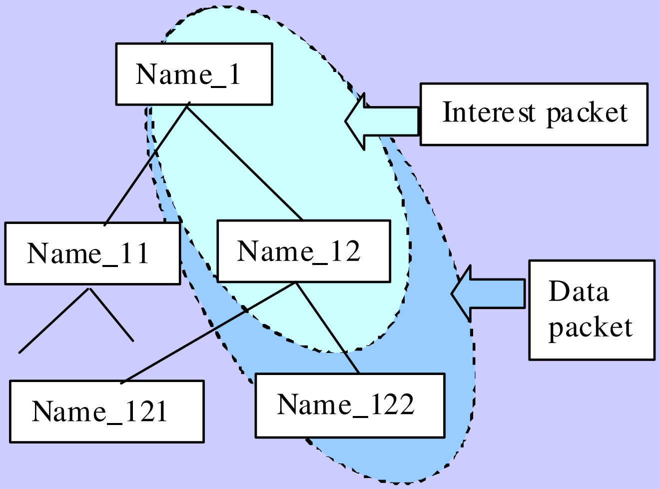
- **CCN Concepts (cont'd)**
  - CCN specific features- different from IP
    - **Strategy and security: new layers**
    - can use multiple simultaneous connectivity (e.g., Ethernet, 3G, 802.11, 802.16, etc.) due to its simpler relationship with layer 2.
    - **Strategy layer**
      - *makes dynamic 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 Concepts (cont'd)

- CCN Naming
  - CCN names :opaque, binary objects composed of some (explicitly specified) number of components
  - Hierarchical structure of names => the above prefix match is equivalent to
  - *Data_Packet* is in the *name subtree* specified by the *Interest_Packet*

  - Similarity with hierarchical structure of IP addresses ((net, subnet, ..)
  - Name prefixes can be context dependent
    - e.g. *"This_building/this_room*"



Interest (Name_1/Name_12)

Data (Name_1/Name_12/Name_122)

CCN Concepts (cont'd)

- **CCN 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

- **Real-time interactive communication in CCN**
- **Q: Can it be done?**
- **Example VoIP:** main problem: how to request a content which does not exist yet??
  - *Solution:Source: Van Jacobson, Diana K. Smetters, Nicholas H. Briggs, Michael F. Plass, Paul Stewart, James D. Thornton, Rebecca L. Braynard, VoCCN: Voice-over Content-Centric Networks*

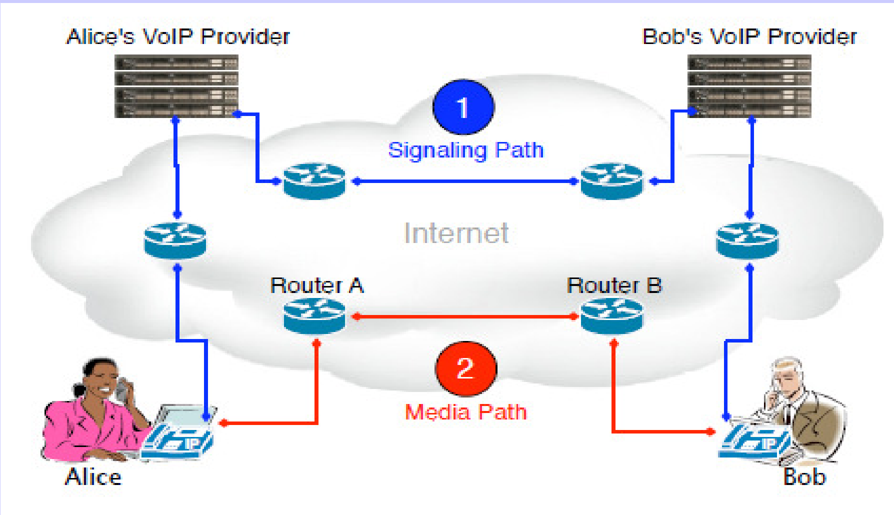


Figure 1: Voice-over-IP data flows

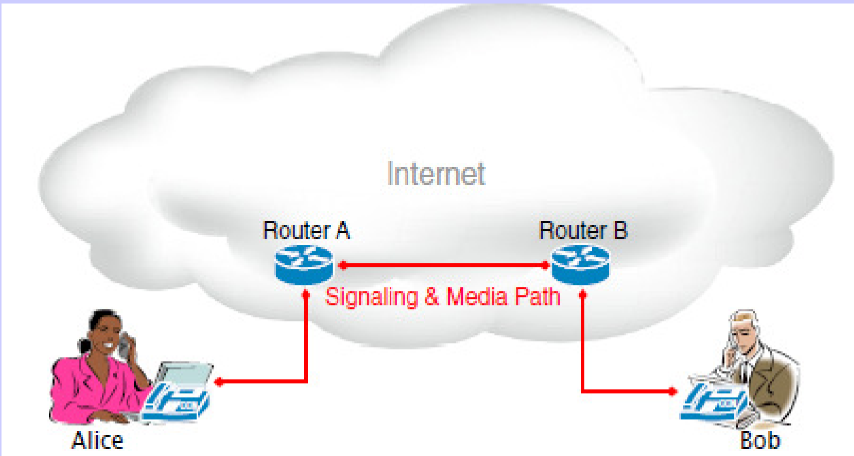


Figure 2: Voice-over-CCN data flows

2. Information/Content Centric Networking

- **Real-time interactive communication in CCN**
- **Q: Can it be done?**
- **Example VoIP (cont'd) :**
  - **Summary of solution**
  - 1. Define a rendez-vous mechanism to allow signalling between caller and the calee
    - o initiate a call, the caller's phone must be able to request a connection with the callee, and get a confirmation response
    - This requires the callee's phone to offer a service contact point.
    - To translate the original procedure (based on location address) into a CCN model, *on-demand publishing* is defined
      - the ability to request content that has not yet been published, route that request to potential publishers, and have them create and then publish, the desired content in response
  - 2. Define a way to transition from this initial rendezvous to a bi-directional flow of conversational data
  - For details see: *VoCCN: Voice-over Content-Centric Networks*

CONTENTS

3. Software Defined Networking

Introduction

- Recent industry/research effort resulted in new approaches:
  - **Software- Defined Networking (SDN)** – aiming to transform networking architecture
  - **Open Networking Foundation** (ONF- non-profit industry consortium) → OpenFlow I/F specifications for SDN

- **SDN architecture major characteristics:**
  - the *Control Plane (CPl)* and *Data Planes (DPl)* are decoupled
  - network intelligence and state are logically centralized
  - underlying network infrastructure is abstracted from the applications.

- **Promises for enterprises and carriers** :
  - higher programmability opportunities, automation, and network control
  - enabling them to build highly scalable, flexible networks
  - fast adapt to changing business needs

- *Source: Software-Defined Networking: The New Norm for Networks ONF White Paper April 13, 2012*

- *Note: after many years of strongly looking for completely distributed control approach in TCP/IP architecture- now a more centralized approach is proposed ….*

3. Software Defined Networking

- **Introduction (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

Introduction (cont'd)

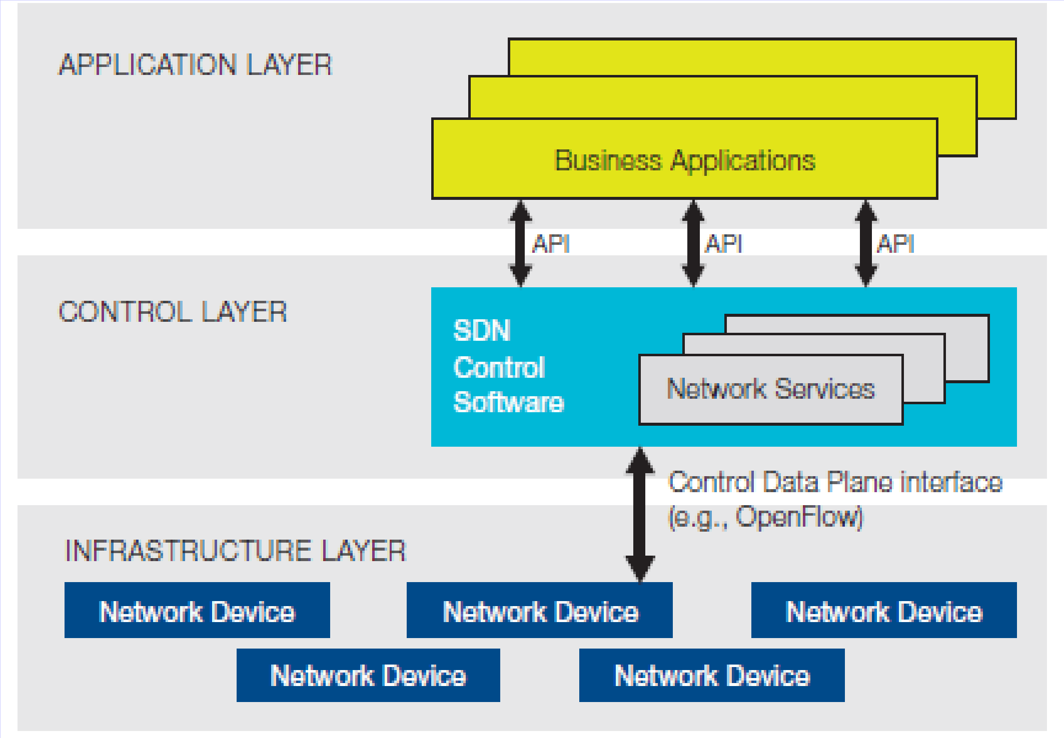
- SDN + OpenFlow (first standard) I/F allow for:
  - *more granular network control* with the ability to apply comprehensive and wide-ranging policies at the session, user, device, and application levels
  - *better end-user experience* as applications exploit centralized network state information to 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,…..

SDN Architecture

- **Principles**
- **Evolutionary architecture**
- CPI and DPI are separated
- Network intelligence is (logically) centralized in SW -based SDN controllers, which maintain a global view of the network.
- Execute CPI SW on general purpose HW
  - Decoupled from specific networking HW
  - CPI can use use commodity servers
- DPI is programmable
- Maintain, control and program data plane state from a central entity



- The architecture defines the control for a network (and not for a network device)
- The network appears to the applications and policy engines as a single, logical switch.
- This simplified network abstraction can be efficiently programmed

3. Software Defined Networking

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

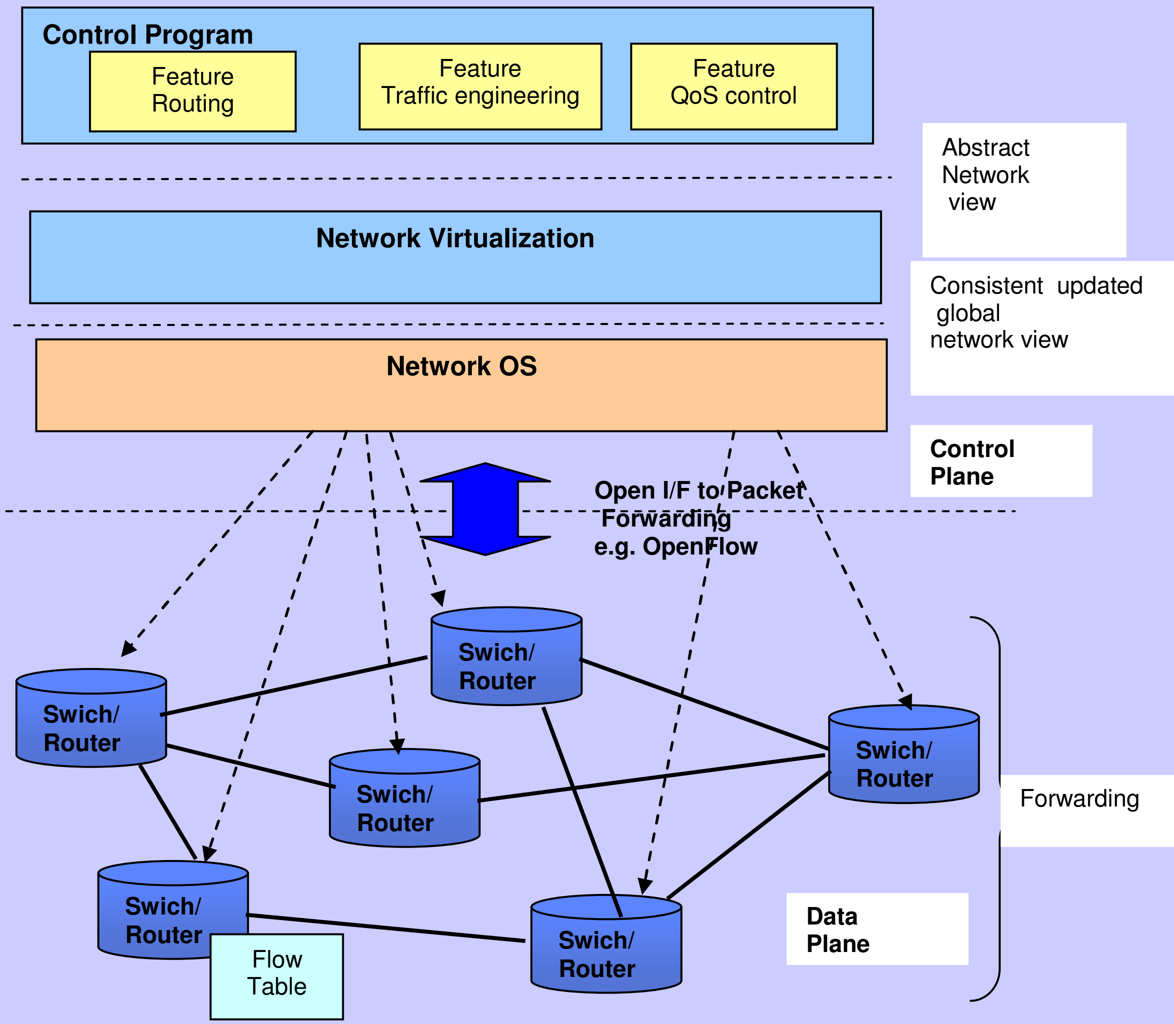
- **SDN Architecture (cont'd)**
- **Advantages**

- 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 not so much "application-aware" as "application-customized" and applications not so much "network-aware" as "network-capability-aware"
  - different approach w.r.t.
  - Information/Content Centric Networking
  - Content aware Networking

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

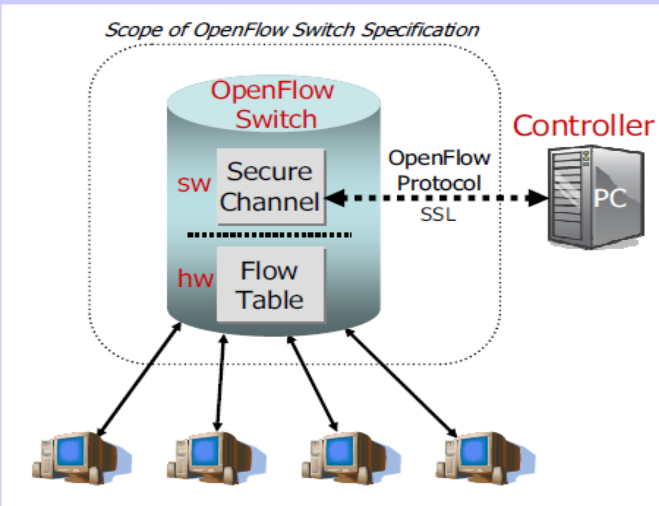


3. Software Defined Networking

- **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).
- allows to move network control 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

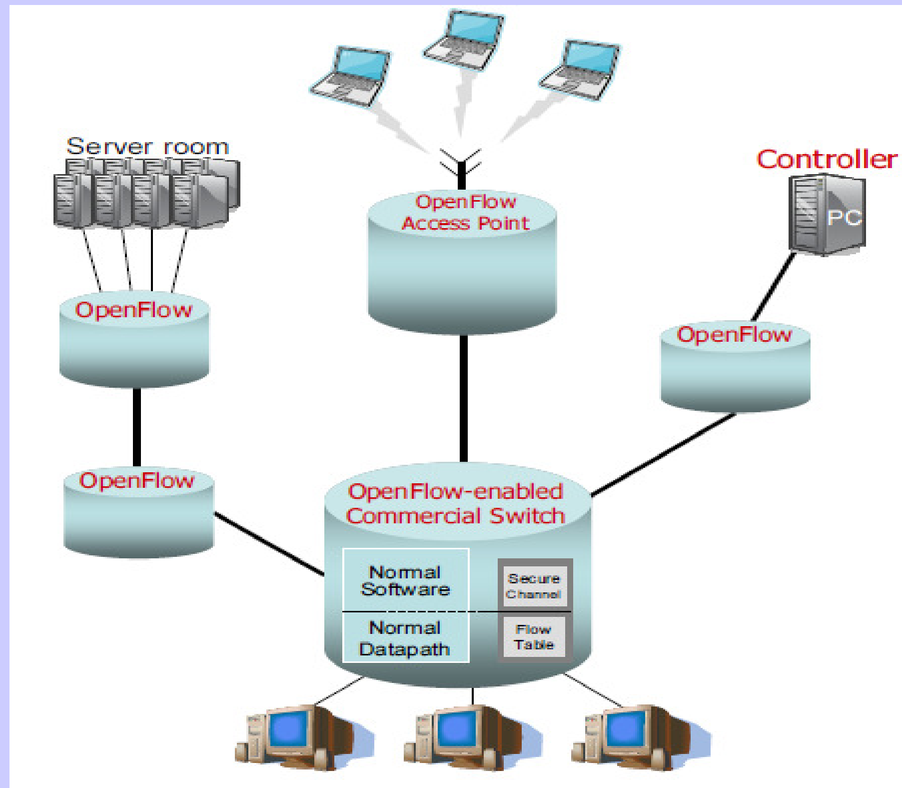
- **OpenFlow (cont'd)**
- *Source Ref1: "OpenFlow: Enabling Innovation in Campus Networks"- Nick McKeown, Tom Anderson, Hari Balakrishnan, Guru Parulkar, Larry Peterson, Jennifer Rexford, Scott Shenker, Jonathan Turner*



Ref1: Figure 1: Idealized OpenFlow Switch. The Flow Table is controlled by a remote controller via the Secure Channel.

In	VLAN	Ethernet			IP			TCP	
Port	ID	SA	DA	Type	SA	DA	Proto	Src	Dst

Table 1: The header fields matched in a "Type 0" OpenFlow switch.



Ref1: Figure 2: Example of a network of OpenFlow-enabled commercial switches and routers.

OpenFlow (cont'd)

- *Source Ref2: OpenFlow Switch Specification, V 1.3.0 (Wire Protocol 0x04) June 25, 2012*

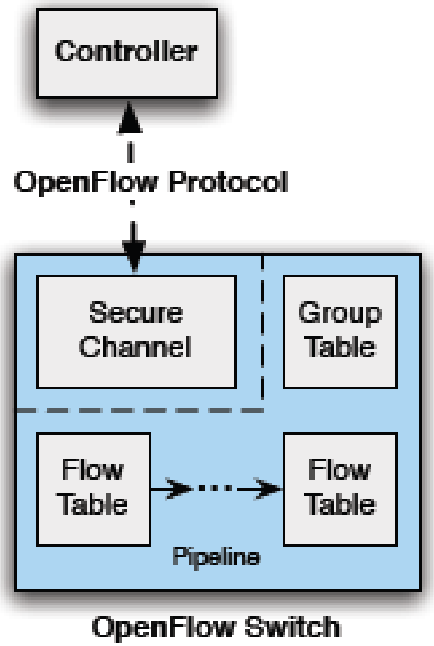


Figure 1: Main components of an OpenFlow switch.

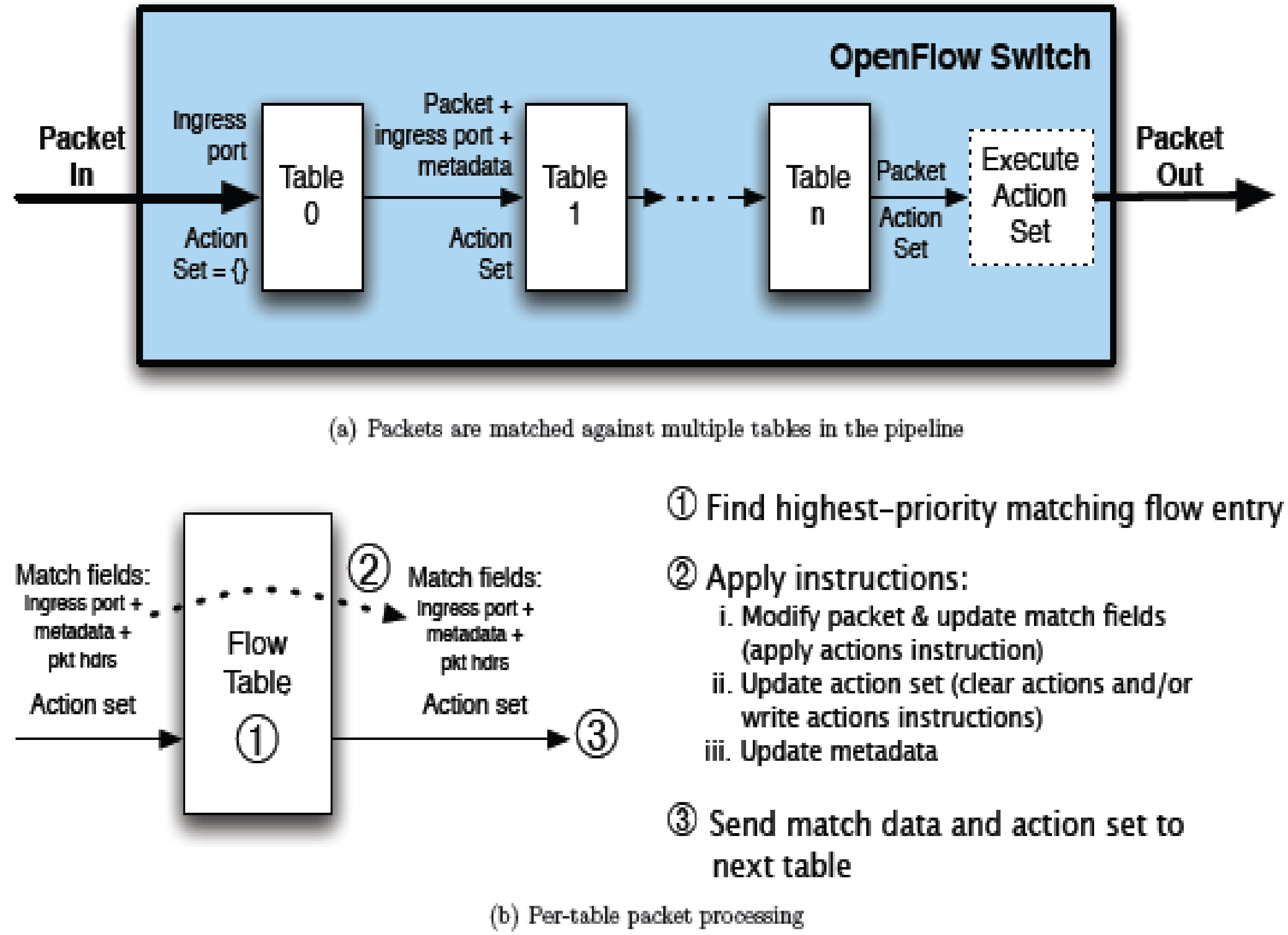
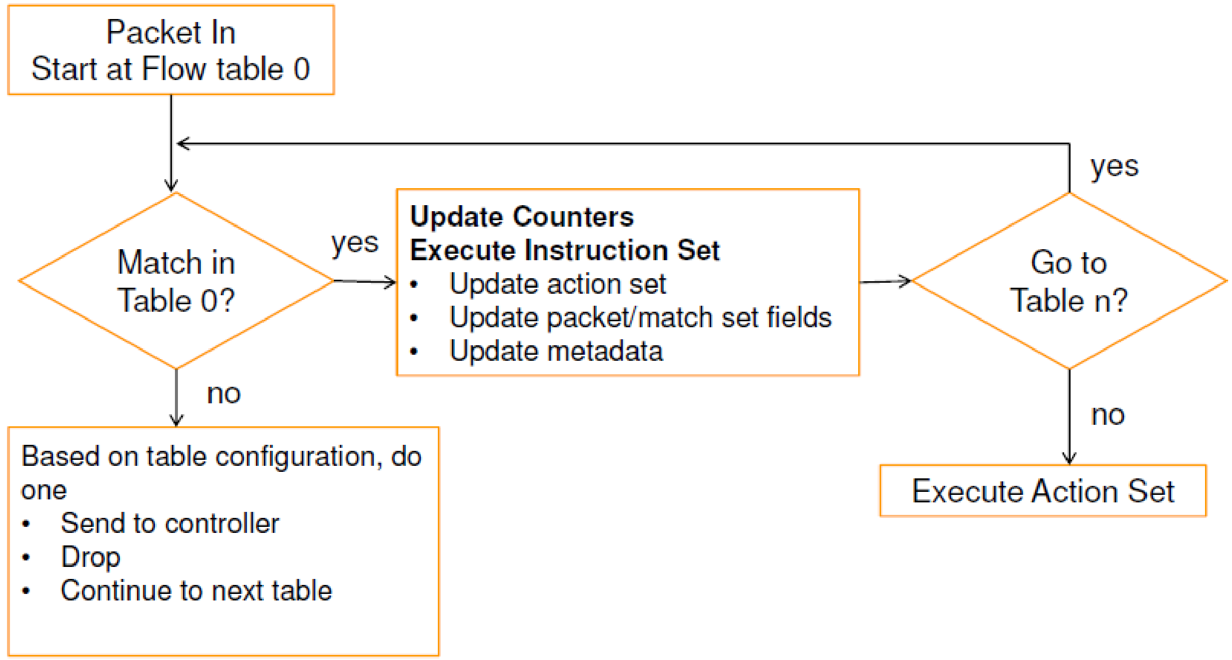


Figure 2: Packet flow through the processing pipeline

- **OpenFlow**

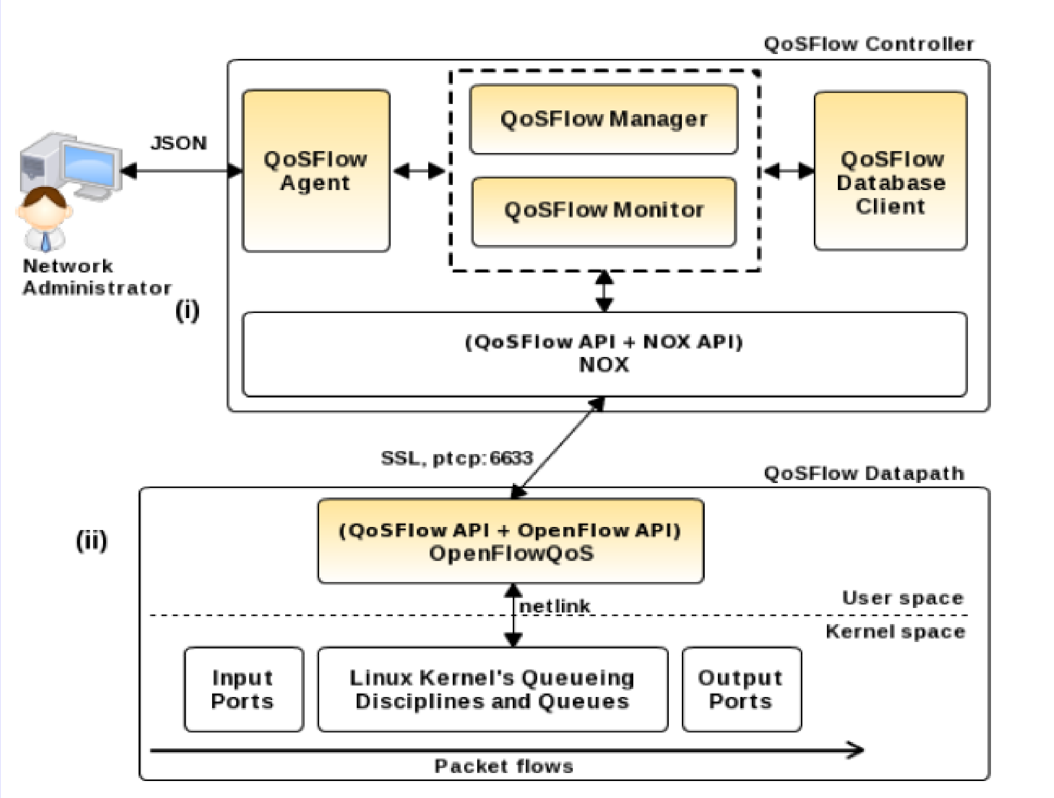


* Figure From OpenFlow Switch Specification

3. Software Defined Networking

- **SDN support for Media and QoS**
- **Example 1**
  - Source: A.Ishimori, F.Farias, I.Furtado, E.Cerqueira, A.Abelém "Automatic QoS Management on OpenFlow SDN" http://siti.ulusofona.pt/aigaion/index.php/attachments/single/362
- **Architecture**

- NOX based QoSFlow controller
- NOX- responsible for managing, monitoring actions , controling signalling messages
- New QoS primitives added to OF
  - There is defined a new group of control messages and functions able to manage QoS resources on DPI
  - They can be invoked by a component running a application with QoS aspects over the OF switches.



3. Software Defined Networking

- **SDN support for Media and QoS**
- **Example 1 (cont'd)**
  - **Architecture**
  - **QoSFlow Controller**
    - **QoS Agent** : communication module between admin. management tool and the other two QoS Flow components
    - By using JSON interface, the agent is able to receive policies, manage or monitor commands coming from a third party administrator application.
    - **QoSFlow monitor and manager** components, - to monitor and manage the QoS of OpenFlow domains.
      - these modules run just after the decision of QoSFlow Agent.
      - i.e. the agent chooses the right component to be used depending on the action sent by the network admin.
  - Four **new OpenFlow actions** are defined - to configure network nodes
    - class, filters, qdisc (queue disciplines) and QoS statistics
    - **DB-QoSFlow** : support for monitoring and management schemes, enabling
      - querying, inserting, removing or updating of registered information from resources in the DB

3. Software Defined Networking

- **SDN support for Media and QoS**
- **Example 1 (cont'd)**
- **QoSFlow Datapath**
  - The QoSFlow data path component (OpenFlowQoS) creates all low-level actions on the switch ports, and it is based on the original Openflow datapath (the current implementation lacks QoS functions).
  - OpenFlowQoS allows OF to get all the required primitives to run management commands created by either the administrator's tool or through header packet information
  - In QoS mgmt. tool, the actions are processed in the QoSFlow Agent.
    - When receiving those actions, it checks the type (mgmt. or monitoring) of the received requests in order to select the procedure to be done (QoS control message and action)
    - This new message is automatically sent to OpenFlowQoS through NOX.

3. Software Defined Networking

- **SDN support for Media and QoS**
- **Example 1 (cont'd)**

- Types of problems that can be solved by using QoSFlow to maximize the usage of network resources.
  - Limit total bandwidth to a known rate
  - Limit the bandwidth of a particular user, service or client
  - Reserve bandwidth for a particular application or user
  - Manage oversubscribed bandwidth
  - Allow equitable distribution of unreserved bandwidth

- QoS policies can be defined in QoSFlow
  - allow the admin to manage a network domain
    - mapping of configuration models in a low level
  - scaling the management of hundreds of entities and the control behavior with E2E features.

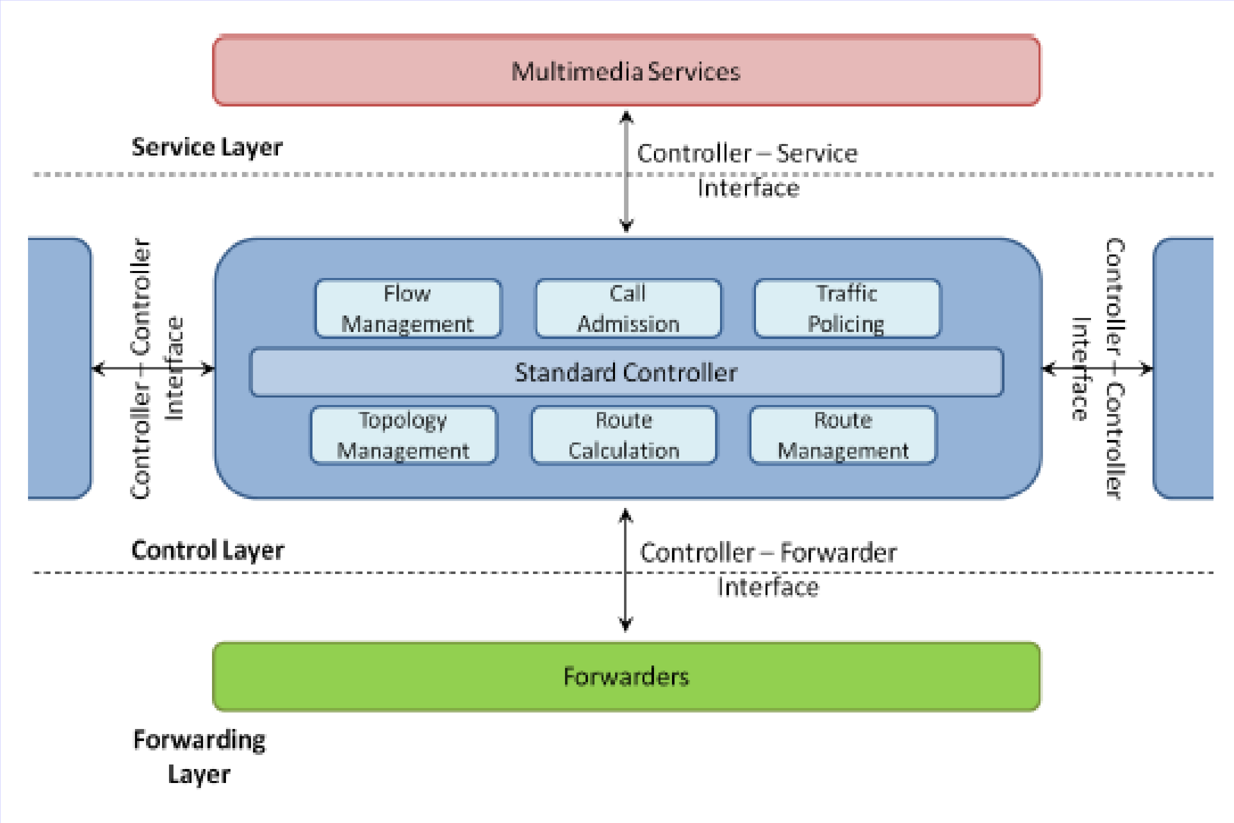
- **SDN support for Media and QoS**
- **Example 2**
- ***Source:*** *H.E. Egilmez, S. T.Dane, K. T Bagci , A. M.Tekalp, "OpenQoS: An OpenFlow Controller Design for Multimedia Delivery with E2E Quality of Service over SDN"*
  - *Signal & Information Processing Association Annual Summit and Conference (APSIPA ASC), 2012 Asia-Pacific, 3-6 Dec. 2012*

- An OpenQoS, novel OpenFlow controller is proposed : design for multimedia delivery with E2E QoS support
- Approach based on QoS routing : the routes of multimedia traffic are optimized dynamically to fulfill the required QoS
- Performance are measured of OpenQoS over a real test network and compared with the performance of the current state-of-the-art, HTTP-based multibitrate adaptive streaming
- The experimental results show that OpenQoS can guarantee seamless video delivery with little or no video artifacts experienced by the end-users
- In OpenQoS the guaranteed service is handled without producing adverse effects on other types of traffic in the network.

3. Software Defined Networking

- **SDN support for Media and QoS**
- **Example 2**

- **Architecture**
- A new prioritization scheme is proposed based on
  - dynamic QoS routing for QoS flows (multimedia traffic) while other flows (data) remain on their shortest path
- Approach different from the current QoS architectures since neither resource reservation nor priority queuing (i.e. rate shaping) is used
  - advantage : the adverse effects of QoS provisioning on non-QoS flows, such as packet loss and latency, are minimized



3. Software Defined Networking

- **SDN support for Media and QoS**
- **Example 2**
- **Architecture**

- Topology management- topology information collection
- Route management: determines the availability and packet forwarding performance
- of routers to aid the route calculation. It requires collecting the up-to-date network state from the forwarders on a synchronous or asynchronous basis.

- Route calculation: determines routes for different types of flows. Several routing algorithms can run in parallel to meet the performance requirements and the objectives of different flows.
  - input to this function: network topology ,route management information and the service reservations.

- Flow management: collects the flow definitions received from the service provider through the controller-service interface, and efficient flow management by aggregation.

- Call admission: denies/blocks a request when the requested QoS parameters cannot be satisfied (i.e. there is no feasible route), and informs the controller to take necessary actions.

- Traffic policing: determines whether data flows agree with their requested QoS parameters, and applying the policy rules when they do not (e.g. pre-empting traffic or selective packet dropping).

3. Software Defined Networking

- **SDN support for Media and QoS**
- **Example 2**
- **OpenQoS comparison with IntServ and DiffServ**

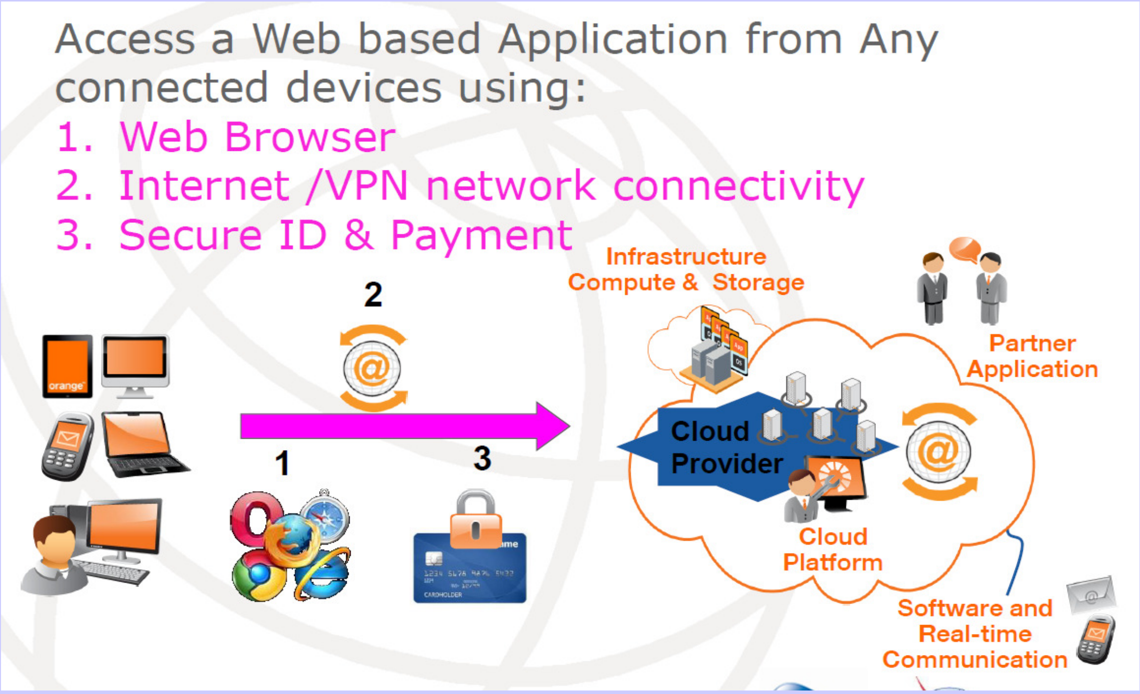
TABLE I
COMPARISON OF QOS ARCHITECTURES

	Flow Support	Type of Guarantee	Complexity	Effects on other flows	Mechanism
IntServ	Individual flows	Hard & end-to-end	High	High (due to reservation)	Resource reservation
DiffServ	Aggregated flows	Soft & hop-by-hop	Medium	Medium (priority queuing)	Scheduling, priority queuing
OpenQoS	Multiple flows	Soft & end-to-end	Low	Low (only based on routing)	Dynamic QoS routing

CONTENTS

4. 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*

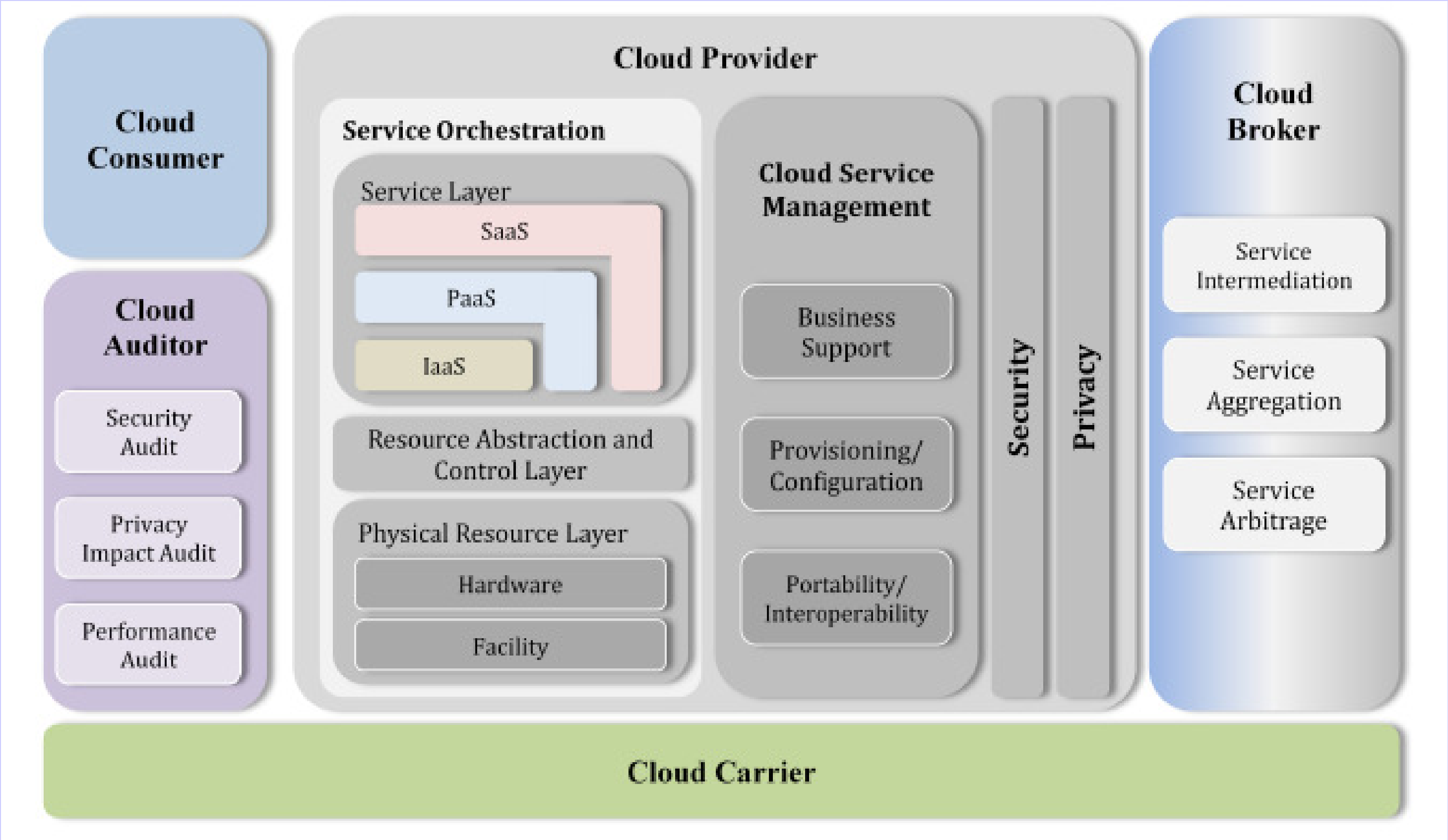


4. Cloud Computing

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

4. Cloud Computing

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

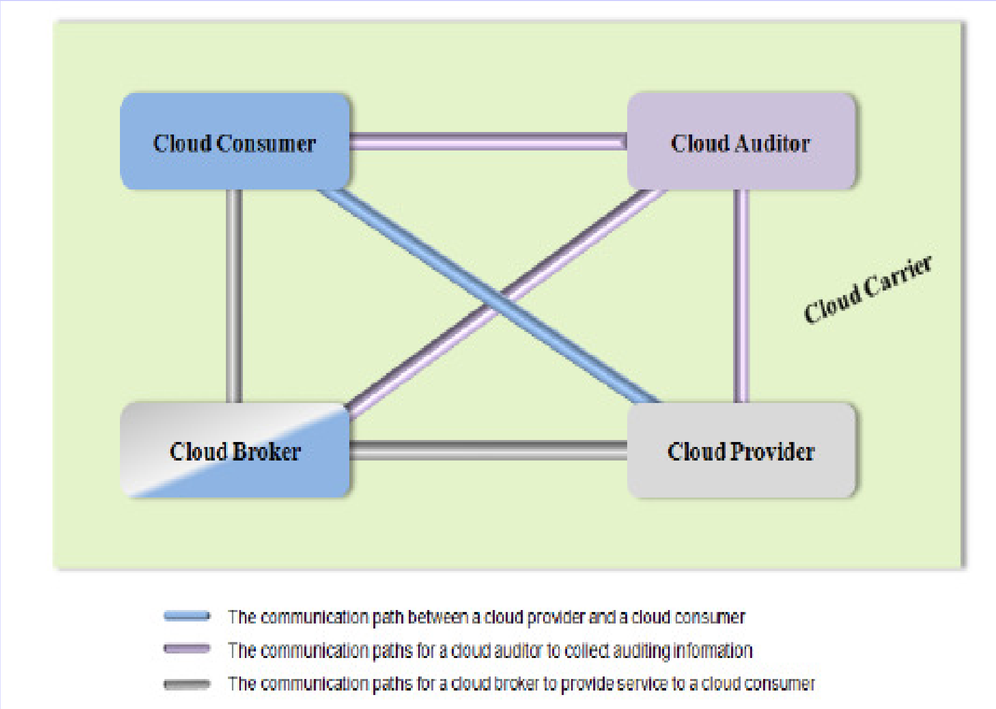


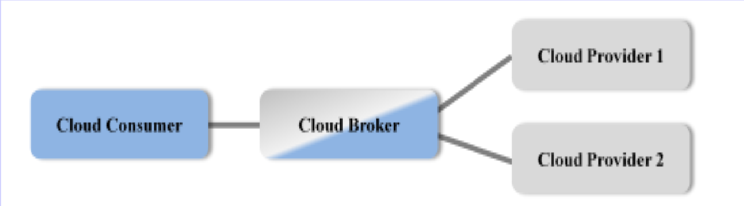
4. Cloud Computing

- **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*.

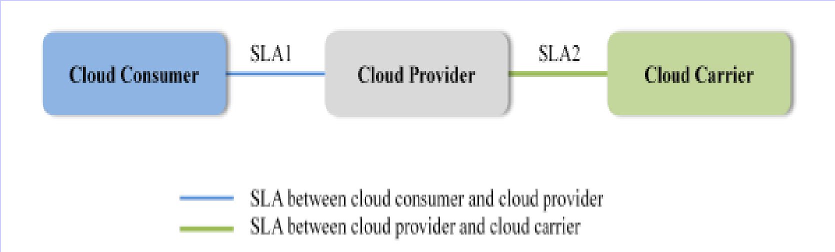
4. Cloud Computing

- **Cloud model**
- NIST cloud computing reference architecture
  - Interactions between the Actors

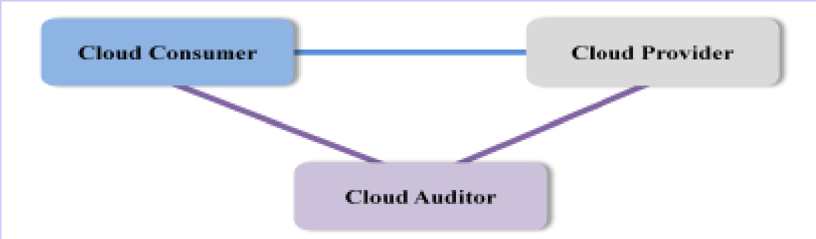




Use case Example 1: brokers



Use case Example 2: carriers



Use case Example 3 : auditors

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
  - audio/video communication 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

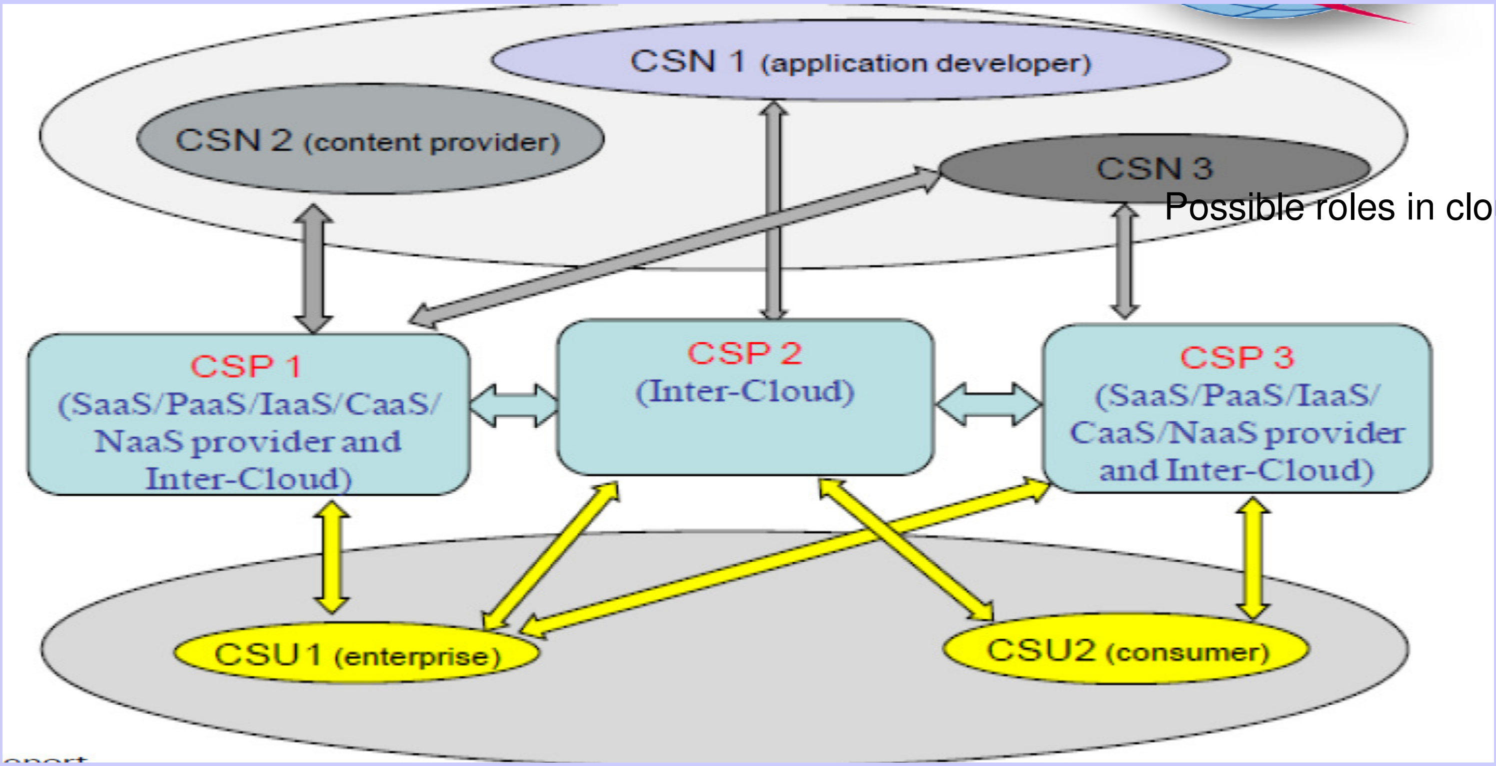
	Desktop as a service	Flexible and extended VPN	Service delivery platform as a service	Bandwidth on demand	Cloud communication centre
IAAS	✓				
PAAS			✓		
NAAS		✓		✓	
CAAS			✓		✓
SAAS			✓		✓

Can support media oriented applications and services

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

4. Cloud Computing

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

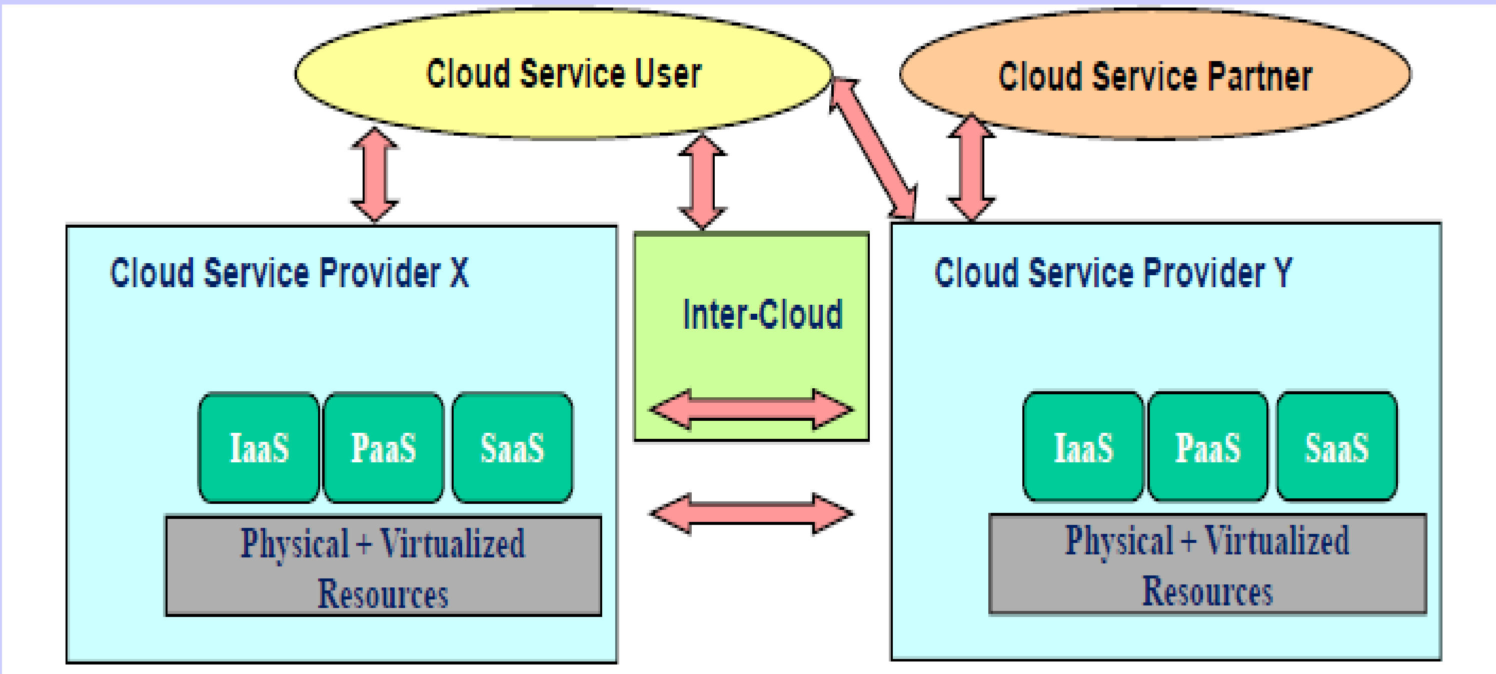


Possible roles in cloud scenario

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

4. Cloud Computing

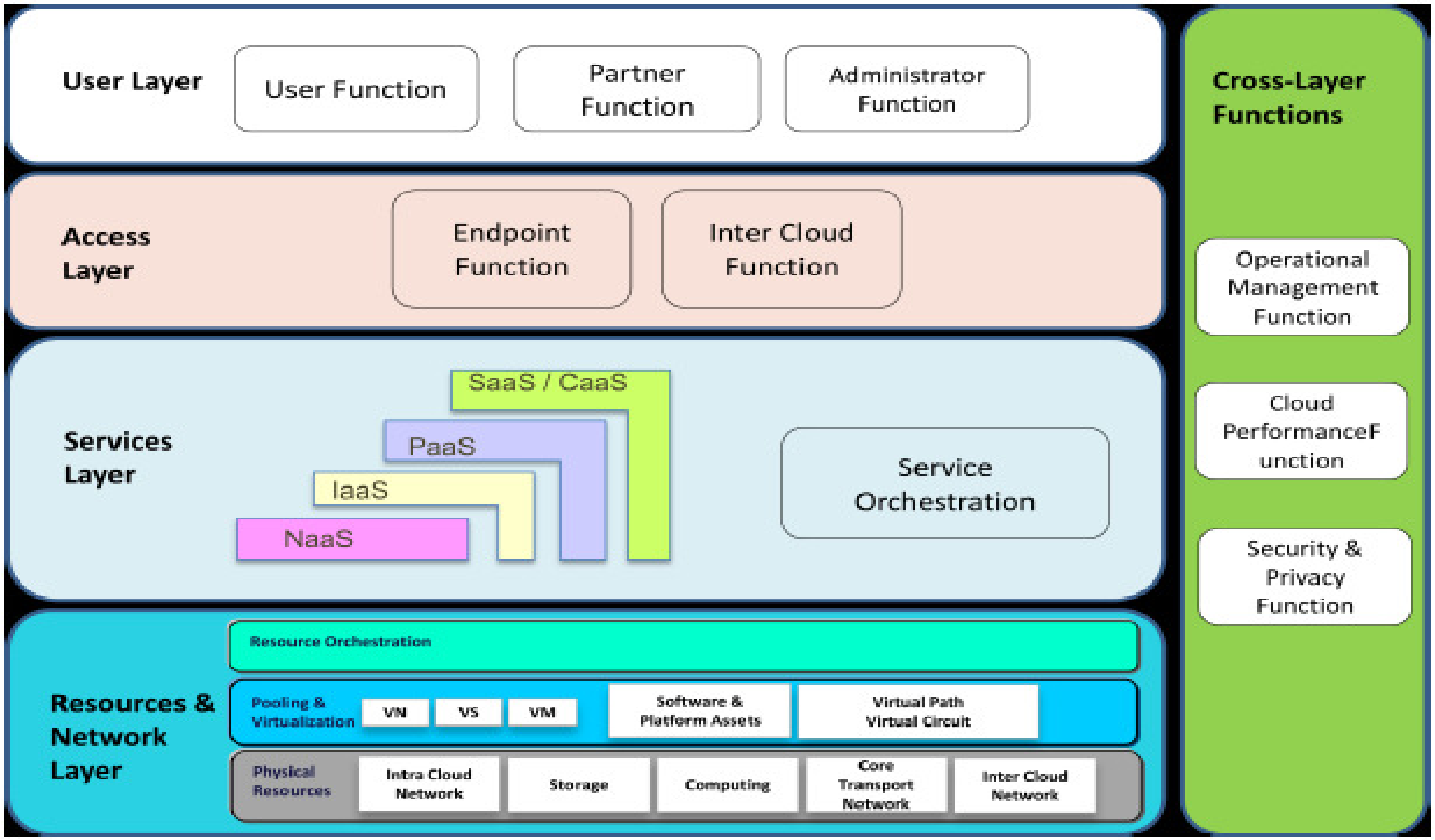
- **ITU-T vision on cloud computing**
- ITU-T Inter-cloud example



Source: J.CHAWKI, "Cloud Computing Standards: Overview and ITU-T positioning", ITU Workshop on "Cloud Computing" (Tunis, Tunisia, 18-19 June 2012)

4. Cloud Computing

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



4. Cloud Computing

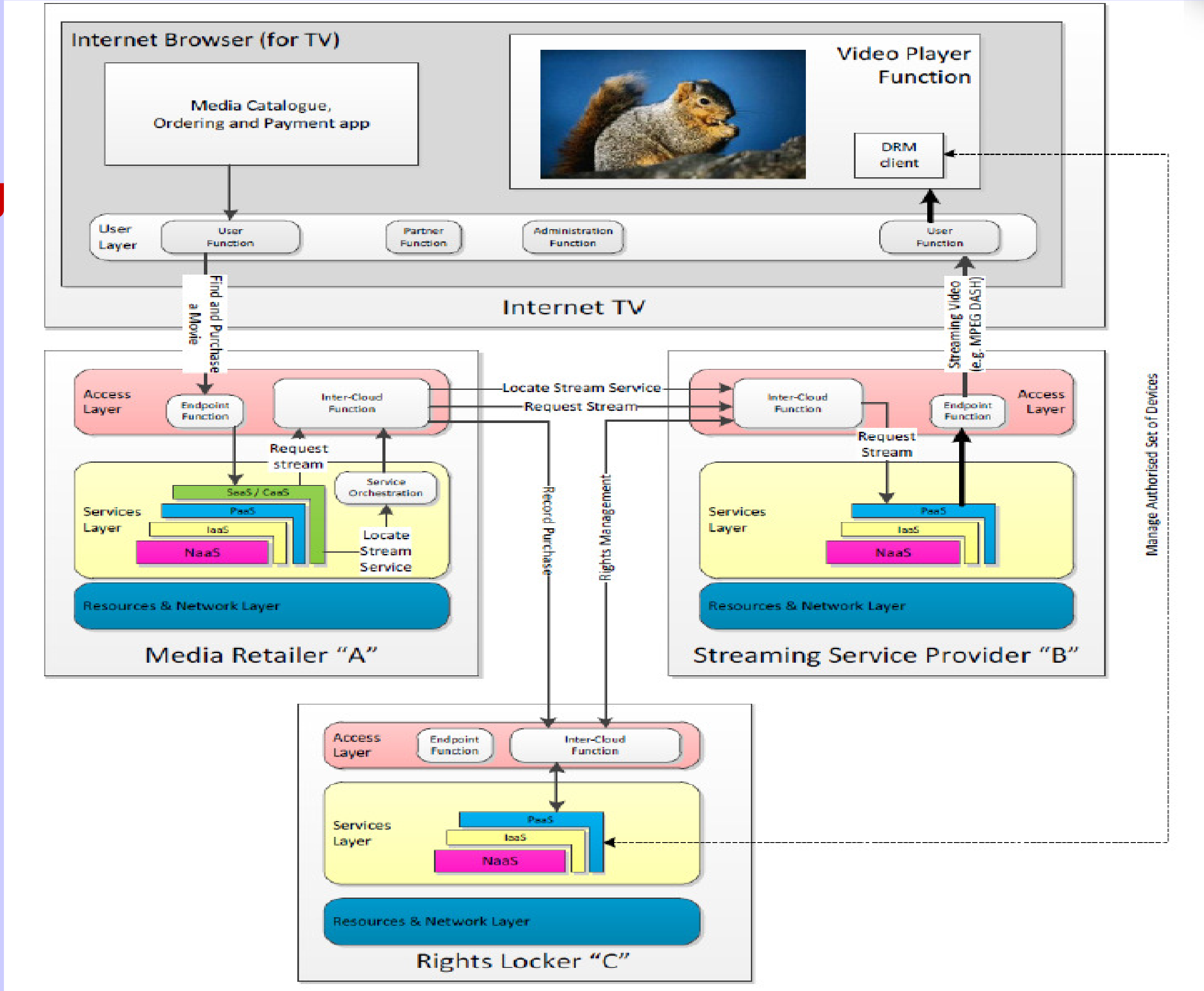
- **ITU-T vision on cloud computing**
- **ITU-T Cloud computing functional reference architecture**

- **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

4. Cloud Computing

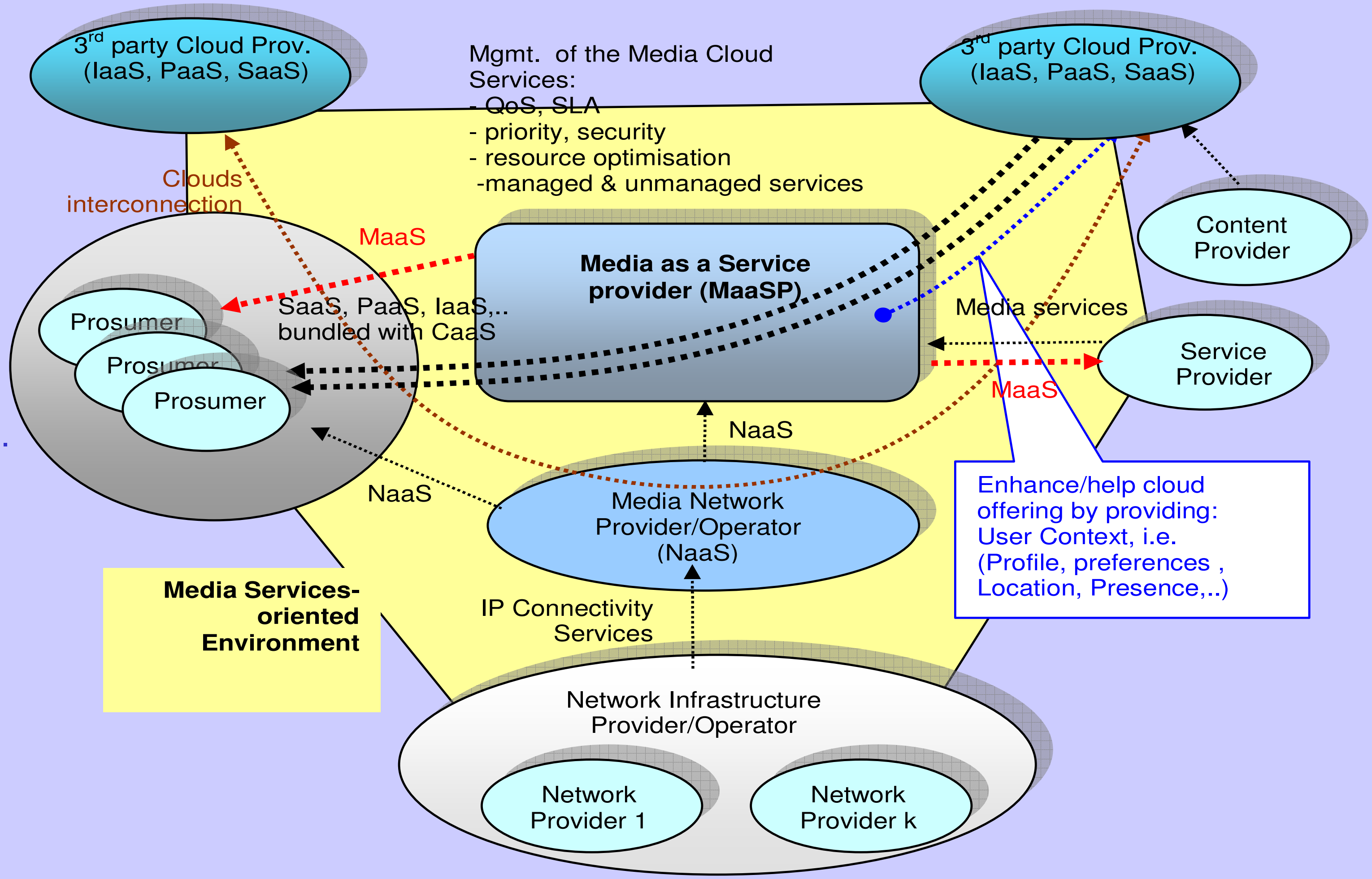
- **ITU-T vision on cloud computing**

- Example of Media Services Use case
  - Internet TV



4. Cloud Computing

- **Example of generic architecture using Cloud-type services for Media** Services support



CONTENTS

5. ALICANTE Project Solutions

- **ALICANTE**, 2010-2013, Integrated Project (IP): MediA Ecosystem Deployment Through Ubiquitous Content-Aware Network Environment- *FI oriented project*

- *http://www.ict-alicante.eu/*

- *19 European partners*
  - *Industry, SME*
  - *Operators*
  - *Universities*
  - *Research groups*

5. ALICANTE Project Solutions

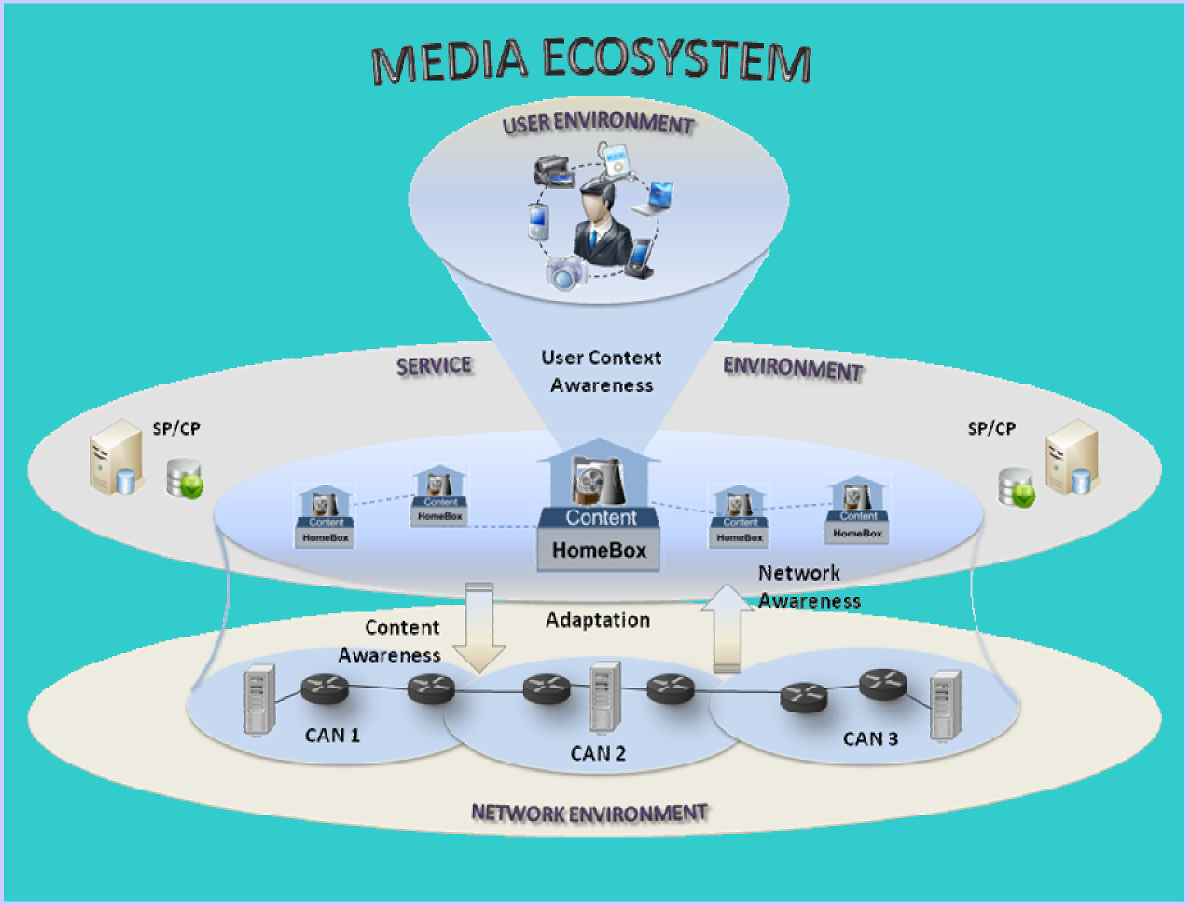
- **Networked Media**
  - **Content Aware Networking (CAN) & Network Aware Application (NAA)**
  - **Evolutionary architecture** for networked media systems
    - Middle-way between traditional Internet solutions and full ICN
- **ALICANTE general objectives**:
  - **End users**
    - Flexible access to MM services, consume, share, generate A/V content
  - **Providers** (high level services, connectivity services)
    - extend their services range of for large number of users
    - efficiently manage their high level services and /or network resources
  - Flexible cooperation between actors
  - Media services and network resources management in multi-domain, multi-provider environment
- **Novel virtual *CAN)* layer**
  - Content-Awareness delivered to Network Environment
  - Network- and User Context-Awareness to Service Environment
  - Different levels of QoS/QoE, security, etc. for media-oriented services
- **ALICANTE Architectural concepts are similar to SDN (but no OpenFlow implementation): decoupling Mgmt/Ctrl Plane and Data Pmale, Controllers, etc.**

5. ALICANTE Project Solutions

- **ALICANTE-** High level architectural view

- **Environments:**
- *User (UE)* : End-Users terminals
- *Service (SE):* Service and Content Providers
- *Network (NE)*, CAN Providers, Network Providers

"Environment ": groups of functions defined around the same functional goal and possibly spanning, vertically, one or more several architectural (sub-) layers.



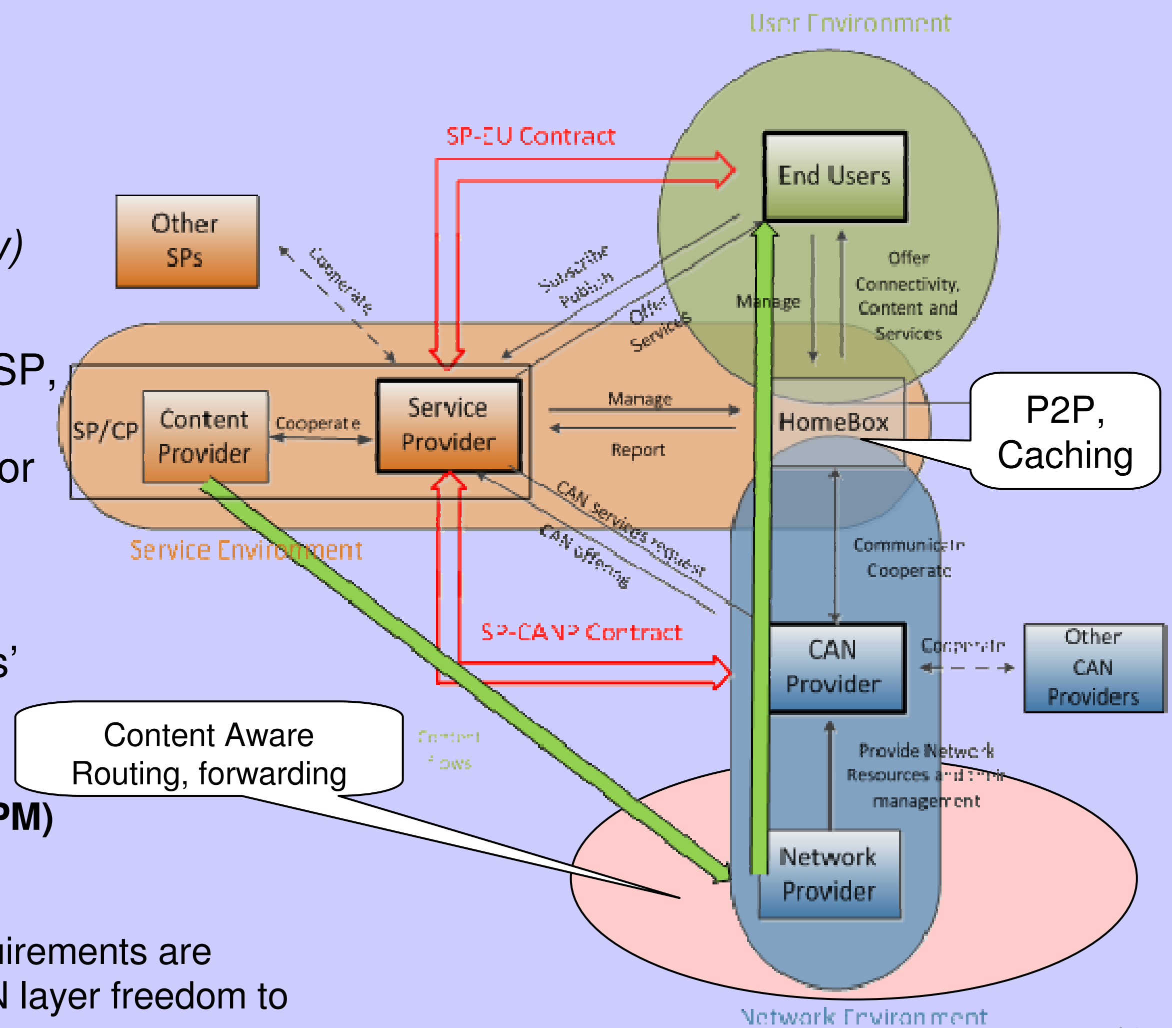
5. ALICANTE Project Solutions

Business Model

Business Actors:

- *End-User (EU)*
- *Content Provider* (CP)
- *Service Provider* (SP)
- *Network Provider* (NP)
- *CAN Provider (CANP) (new)*

Flexible Business Model : B2C, B2B, C2C and to consider new CAN features and service environment new capabilities



Cooperation, interaction:

- Single/aggregated roles of SP, CP, NP, ANP, C/SCs,
- Cooperation, via static and/or dynamic SLAs
- Distributed management
- Independent resource management of each actors' resources

Fully Managed Services (FM)
Partially managed Services (PM)
Unmanaged Services

- Include two point of views
  - Services: levels QoS requirements are
  - CANP: degree of the CAN layer freedom to perform autonomic actions

5. ALICANTE Project Solutions

- **ALICANTE architecture**
- Two virtual layers,
  - CAN layer for virtual connectivity services on top of the the core IP network
  - Home-Box layer- content delivery
- On top of the traditional IP Network layer, virtualising the network nodes in
- User Environment, seamlessly interacting with the underlying layers
- Service Environment, based on cooperation between the traditional SPs and End-Users (through their HBs)
- Combine resource provisioning at CAN layer with adaptation solution for the multimedia flow delivery over multi-domains
- Hierarchical Multi-layered monitoring sub-system at all defined levels: User, Service, Home-Box, CAN, Underlying network

5. ALICANTE Project Solutions

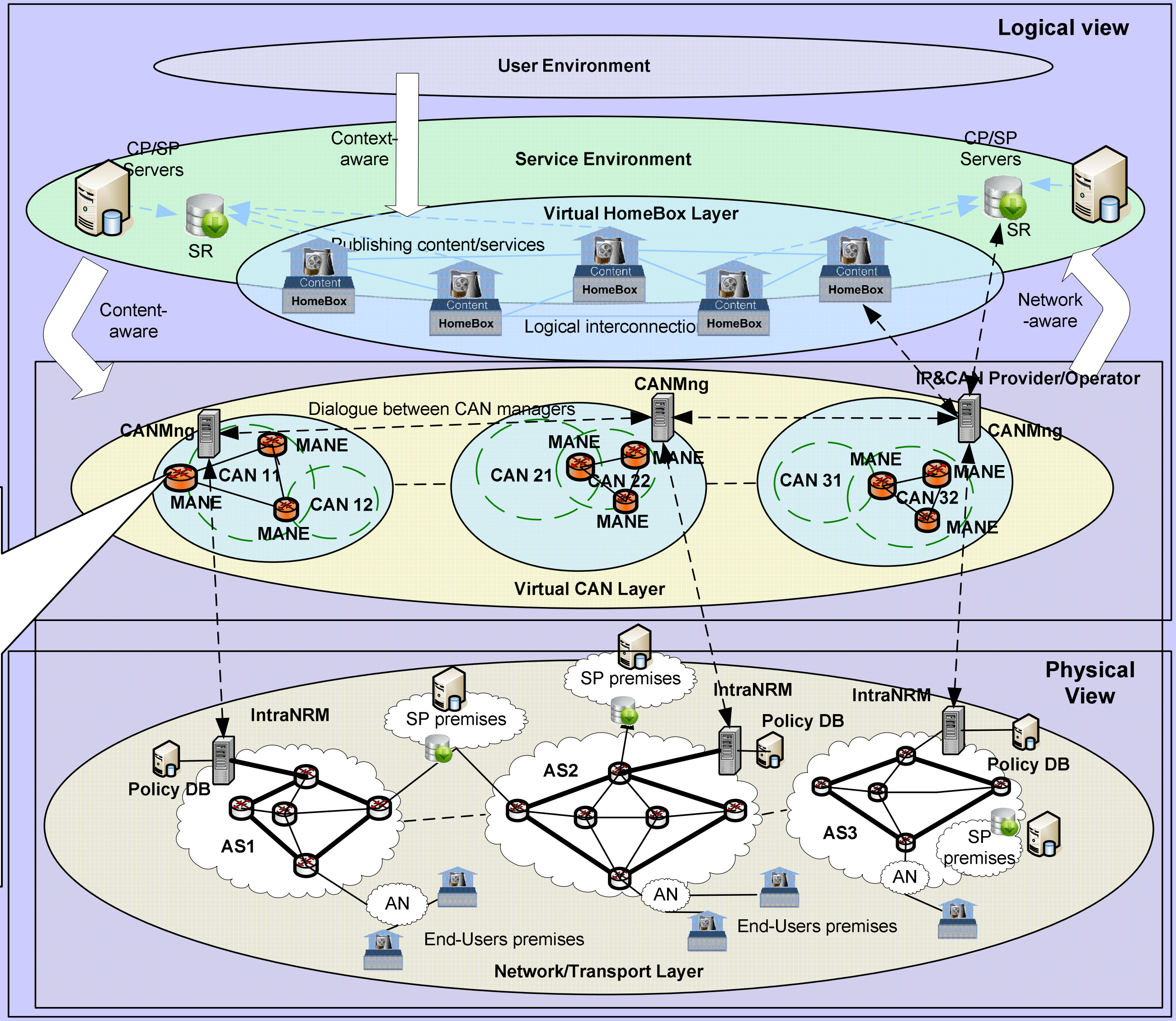
- ALICANTE Architecture
- *midle-way architecture* : *CAN/NAA* coupling, extendable both at service level and network/ transport level
- support integration
  - *vertical* (based on CAN/NAA) of high level services and connectivity ones,
  - *horizontal integration* on top of single or multiple-domain IP networks.
- network virtualization techniques is applied
  - to create parallel *content-aware virtual planes*
    - enriched in terms of functionality (due to content –awareness)
    - represented by *Virtual Content Aware Networks (VCANs)*
      - *Constrained routing and forwarding depending on content type*
    - VCANs spanning single or multiple IP domains

5. ALICANTE Project Solutions

- **Overall Architecture View**
  - User Env
  - Service Env
  - HB-layer
  - Net Env
    - CAN layer
    - Infrastructure layer

SDN similar architecture (w.r.t. Management and Control Plane separation

MANE – Novel ALICANTE router- Media Aware Network Element



5. ALICANTE Project Solutions

- ***Vertical and Horizontal Layering and functional splitting***
- ***Virtual Content-Aware Network (V)CAN* - layer**
  - Works on top of traditional IP network/transport layer
  - *Data Plane*
    - enhanced support for packet payload inspection, CA- processing and caching in network equipment
    - **improves QoS assurance via content-aware forwarding/routing**
    - increases network security level via content-based monitoring and filtering
    - 1:1, 1:n, n:m communications, P2P
  - *M&C Plane*
    - Distributed M&C: per domain CANMgr
    - Establish SLA/SLS between CANP and other business entities
    - Plan, provisioning, modifying VCANs in the form of parallel planes
  - The specific components of VCAN are the
    - Media-Aware Network Elements (MANE), i.e., the new CAN routers
    - CAN managers.
    - SDN –similar architecture

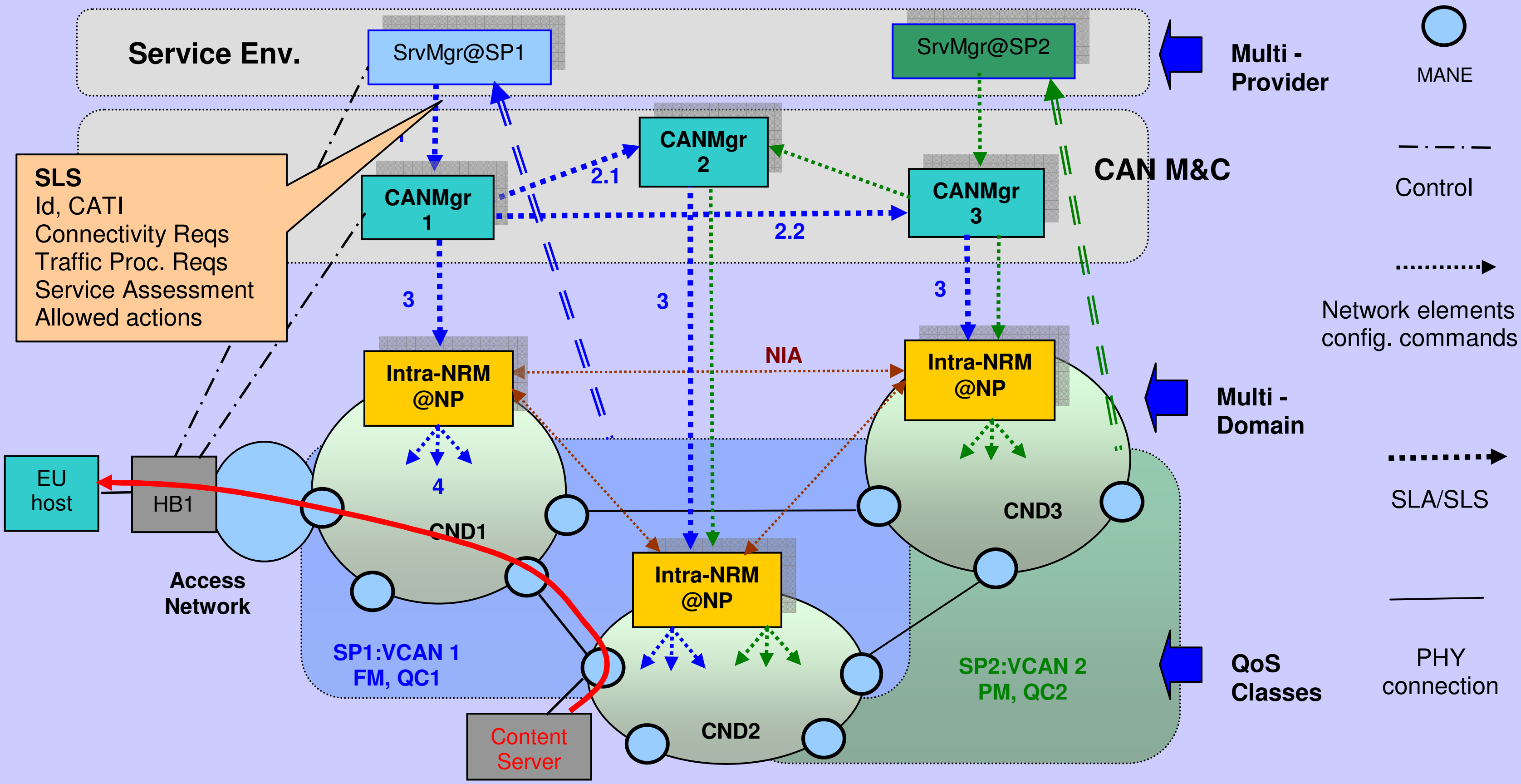
5. ALICANTE Project Solutions

- ***Vertical and Horizontal Layering and functional splitting (cont'd)***

- ***Intra-domain Network Layer***
  - Traditional network TCP/IP layer
  - **Data Plane**
    - Implements VCANs by process data flows in CA style in MANE
    - Makes use of traditional network technologies to assure QoS, availability of paths
      - MPLS, Diffserv, etc.
    - IP multicast
  - **M&C Plane**
    - Managed by the Intra-domain Network Resource Manager (IntraNRM)
      - Having full authority on the network nodes and domain configuration
      - Cooperating with CANMgr in order to negotiate and install VCANs
    - IntraNRM
      - establish Network Interconnection Agreements with other IntraNRMs
      - Establish SLA with CAN Manager

5. ALICANTE Project Solutions

- *SLAs and Interactions for VCAN establishments*



5. ALICANTE Project Solutions

- **Content Awareness and QoS at CAN Layer**
- CA is realized in three ways:
  - by concluding a SP - CANP SLA concerning different VCAN construction.
    - The content servers are instructed by the SP to insert some special Content Aware Transport Information (CATI) in the data packets.
  - SLA is concluded, but no CATI is inserted in the data packets (legacy CSs)
    - DPI packet inspection for data flow classification and assignment to VCANs
  - no SP–CANP SLA exists and no CATI.
    - The flows treatment can still be CA, local policy-driven at CANP and IntraNRM.

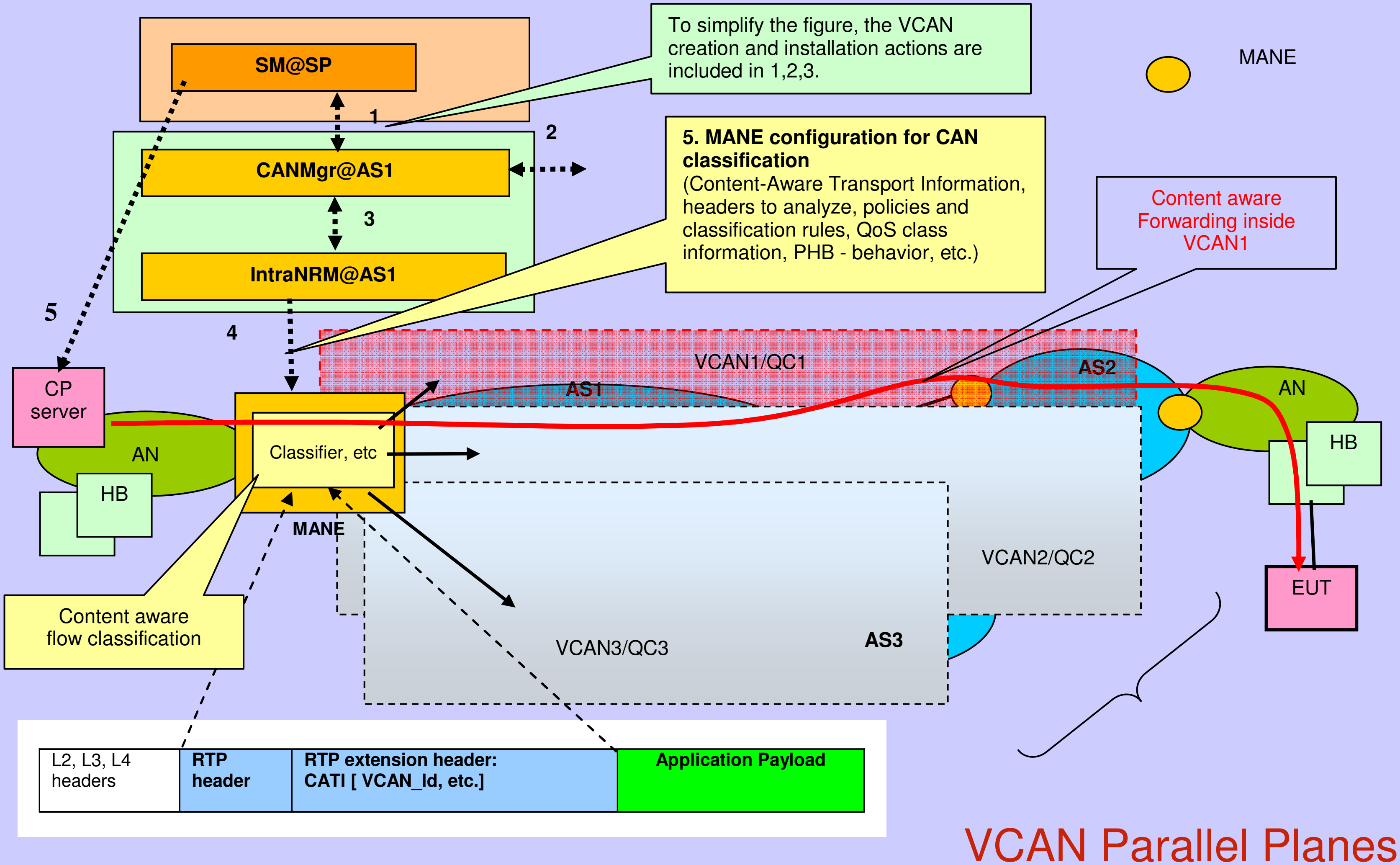
- The DiffServ and/or MPLS support splitting the sets of flows in QoS classes (QC) with a mapping between the VCANs and the QCs.

- Generally a 1-to-1 mapping between a VCAN and a network plane will exist.
- Several levels of QoS granularity for VCANs.

- The QoS behavior of each VCAN plane is established by the SP-CANP
- QoS classes (QC) :
  - meta-QoS classes ;
  - VCANs based on local QC composition
  - hierarchical VCANs based on local QC composition

5. ALICANTE Project Solutions

VCAN Parallel Planes setup



CONTENTS

6. Conclusions

- New networking technologies are proposed inside evolutionary and/or revolutionary architectures
- All of them have among objectives – to support media oriented applications
- **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
  - Centralization
  - Separation Data Plane – Control and Management plane
  - Flexibility
  - Much more support in the industry
- **Cloud Computing**
  - Data Centrers offering flexible services SaaS, PaaS, IaaS, NaaS, CaaS
  - Strong support in the industry
- Networking of the future ?-
  - probably combinations of these technologies

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

References

1. J. Schönwälder, M. Fouquet, G., Dreo Rodosek, and Hochstatter, I.C., "Future Internet = Content + Services + Management", IEEE Communications Magazine, vol. 47, no. 7, Jul. 2009, pp. 27-33.
2. C.Baladrón, "User-Centric Future Internet and Telecommunication Services", in: G. Tselentis, et. al. (eds.), Towards the Future Internet, IOS Press, 2009, pp. 217-226.
3. DG Information Society and Media Directorate, for Converged Networks and ServiceFuture Internet 2020, VISIONS OF AN INDUSTRY EXPERT GROUP, May 2009
4. G. Tselentis et al. (Eds.), Towards the Future Internet, IOS Press, 2009
5. Future Internet – Towards Research Challenges – 07 APR 2009, http://www.future-internet.eu/fileadmin/documents/prague_documents/FI_-_From_Functionalities2Challenges-09_04_08.pdf
6. Future Internet Initiatives, http://www.nessi-europe.com/Nessi/ (Networked European Software and sevices initiative)
7. Pavlou G., Towards a Service-aware Future Internet Architecture, Future Internet Assembly – Madrid, Dec 2008
8. A. Galis et al., "Management and Service-aware Networking Architectures (MANA) for Future Internet Position Paper: System Functions, Capabilities and Requirements",
9. Future Media Internet Architecture Reference Model, www.fi-nextmedia.eu /http://initiative.future-internet.eu/news/view/article/future-media-internet-architecture-reference-model-white-paper.html- 2011
10. Software-Defined Networking: The New Norm for Networks ONF White Paper April 13, 2012

References

11. D.Kennedy, Networks + Content, Eurescom, Bled 2008
12. The FP7 4WARD Project , http://www.4ward-project.eu/
13. Abramowicz,H. Introduction to BIRD WS,
14. M. Gritter and D. R. Cheriton. TRIAD: A New Next-Generation Internet Architecture. http://www-dsg.stanford.edu/triad/, July 2000.
15. A.Ghodsi, T.Koponen, B.Raghavan, S.Shenker, A.Singla, J.Wilcox, Information-Centric Networking: Seeing the Forest for the Trees, http://www.icsi.berkeley.edu/~barath/papers/icn-hotnets11.pdf
16. D. Kutscher, B.Ahlgren, H.Karl, B. Ohlman, S.Oueslati I.Solis, Information-Centric Networking— Dagstuhl Seminar — 2011
17. Niranth, NGSON Architecture and Service Oriented Networking,
18. J.Choi, Jinyoung Han, E.Cho, Ted Kwon, and Y.Choi,A Survey on Content-Oriented Networking for Efficient Content Delivery, IEEE Communications Magazine • March 2011
19. T. Koponen et al., "A Data-Oriented (and Beyond) Network Architecture," SIGCOMM '07, 2007, pp. 181–92
20. G. Pavlou, Information-Centric Networking: Overview, Current State and Key Challenges, http://www.ee.ucl.ac.uk/~gpavlou/, , IEEE ISCC 2011 Keynote

References

21. Van Jacobson, D.K. Smetters, J.D. Thornton, M. F. Plass, NH. Briggs, R.L. Braynard, Networking Named Content, Palo Alto Research Center, Palo Alto, CA, October 2009
22. J. Choi, J. Han, E.Cho, T.Kwon, and Y.Choi "A Survey on Content-Oriented Networking for Efficient Content Delivery"IEEE Communications Magazine, March 2011pp. 121- 127
23. Luis M. Correia, An Academic View on Business and Regulatory Issues on the Future Internet, http://www.4ward-project.eu/
24. A. Mitra, M.Maheswaran, Wide-Area Content-based Routing Mechanism, International Parallel and Distributed Processing Symposium (IPDPS'03), http://www.computer.org/portal/web/csdl/doi/10.1109/IPDPS.2003.1213447
25. Barani Subbiah Zartash Afzal Uzmi Content Aware Networking in the Internet: Issues and Challenges, suraj.lums.edu.pk/~zartash/publications/2001-06-ICC-Content.pdf
26. A.Carzaniga, A. L. Wolf, Forwarding in a Content-Based Network, www.inf.usi.ch/carzaniga/papers/cw_sigcomm03.pdf
27. P.Mell , T.Grance, The NIST Definition of Cloud Computing, Special Publication 800-145, Recommendations of the National Institute of Standards and Technology , 2011
28. F.Liu, J.Tong, J.Mao, R.Bohn, J.Messina, L.Badger and D. Leaf, Recommendations of the National Institute of Standards and Technology, NIST "Cloud Computing Reference Architecture", Special Publication 500-292 , 2011
29. Jamil CHAWKI, "Cloud Computing Standards: Overview and ITU-T positioning", ITU Workshop on "Cloud Computing" (Tunis, Tunisia, 18-19 June 2012)
30. M.CARUGI Cloud Computing technology in Telecommunication ecosystems and recent ITU-T standardization efforts, International Workshop "Innovative research directions in the field of telecommunications in the world" within ITU-ZNIIS ITTC joint project 21-22 July 2011, Moscow, Russia

References

31. ITU-T FG Cloud TR Part 2: Functional requirements and reference architecture
32. Editors: L.M. Correia and L.Lundgren, Going 4WARD Newsletter, 4WARD-Architecture and Design for the Future Internet May 2009, Issue No. 4
33. Subharthi Paul, Jianli Pan, and Raj Jain, Architectures for the Future Networks and the Next Generation Internet: A Survey
34. C.Tsilopoulos, G.Xylomenos, "Supporting Diverse Traffic Types in Information Centric Networks", *ICN'11*, August 19, 2011, Toronto, Ontario, Canada.
35. E.Borcoci, D.Negru, C.Timmerer, "A Novel Architecture for Multimedia Distribution based on Content-Aware Networking" Proc. of CTRQ 2010, Athens, June 2010, pp. 162-168 , http://www.ict-alicante.eu
36. M. Boucadair, P. Lévi, D. Griffin, N. Wang, M. Howarth, G. Pavlou, E. Mykoniati, P. Georgatsos, B. Quoitin, J. Rodríguez Sánchez, M. L. García-Osma, "A Framework for End-to-End Service Differentiation: Network Planes and Parallel Internets", IEEE Communication Magazine, Sept. 2007, pp. 134-143..
37. K.Cho, J. Choi, D.Ko, T.Kwon, Y.Choi, Content-Oriented Networking as a Future Internet Infrastructure: Concepts, Strengths, and Application Scenarios, http://mmlab.snu.ac.kr/~kdcho/publications/CON_CFI2008.pdf
38. S. Michel, K. Nguyen, A. Rosenstein, L. Zhang, S. Floyd, and V. Jacobson. Adaptive Web Caching: Towards a New Global Caching Architecture. Computer Networks and ISDN Systems, 30(22-23), 1998.
39. COntent Mediator architecture for content-aware nETworks, (COMET) http://www.comet-project.org/
40. Scalable and Adaptive Internet Solutions (SAIL), http://www.sail-project.eu/.

References

41. L. Popa, A. Ghodsi, and I. Stoica. HTTP as the Narrow Waist of the Future Internet. In Proc. of HotNets, 2010. http://bnrg.eecs.berkeley.edu/~randy/Courses/CS268.F08/papers/24_diffusion.pdf
42. HP SDN/Openflow Technology Solutions //h17007.www1.hp.com/us/en/solutions/technology/openflow/index.aspx?jumpid=in_r11652_us/en/openflow-114x110/solutions/banner
43. SDN Controller Product Fact Sheet: h17007.www1.hp.com/docs/interopny/4AA4-3881ENW.PDF
44. SDN for cloud providers and enterprises: http://h17007.www1.hp.com/docs/interopny/4AA4-3872ENW.pdf
45. SDN Technical White Paper http://h17007.www1.hp.com/docs/interopny/4AA4-3871ENW.pdf
46. "OpenFlow: Enabling Innovation in Campus Networks"- Nick McKeown, Tom Anderson, Hari Balakrishnan, Guru Parulkar, Larry Peterson, Jennifer Rexford, Scott Shenker, Jonathan Turner
47. OpenFlow Switch Specification, V 1.3.0 (Wire Protocol 0x04) June 25, 2012
48. A.Ishimori, F.Farias, I.Furtado, E.Cerqueira, A.Abelém "Automatic QoS Management on OpenFlow SDN" http://siti.ulusofona.pt/aigaion/index.php/attachments/single/362
49. H.E. Egilmez, S. T.Dane, K. T Bagci , A. M.Tekalp, "OpenQoS: An OpenFlow Controller Design for Multimedia Delivery with E2E Quality of Service over SDN" Signal & Information Processing Association Annual Summit and Conference (APSIPA ASC), 2012 Asia-Pacific, 3-6 Dec. 2012