Content-Aware Networking:
Future Internet Perspective

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Content-Aware Networking:
Future Internet Perspective

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1. Future Internet Challenges

- **Future Internet**
  - Internet has more and more a significant impact on all socio-economic and life aspects of the global society
  - Internet – became (some opinions) the ~5th power of the society
  - Many efforts to revisit/re-define the future directions of Internet (seen from different point of views):
    - Research groups, Academia, Industry, Standardization organizations, Governments, Users, ..
    - Still – there are many open FI issues, including discussion/revision of the basic concepts

1. Future Internet Challenges

- **However..**

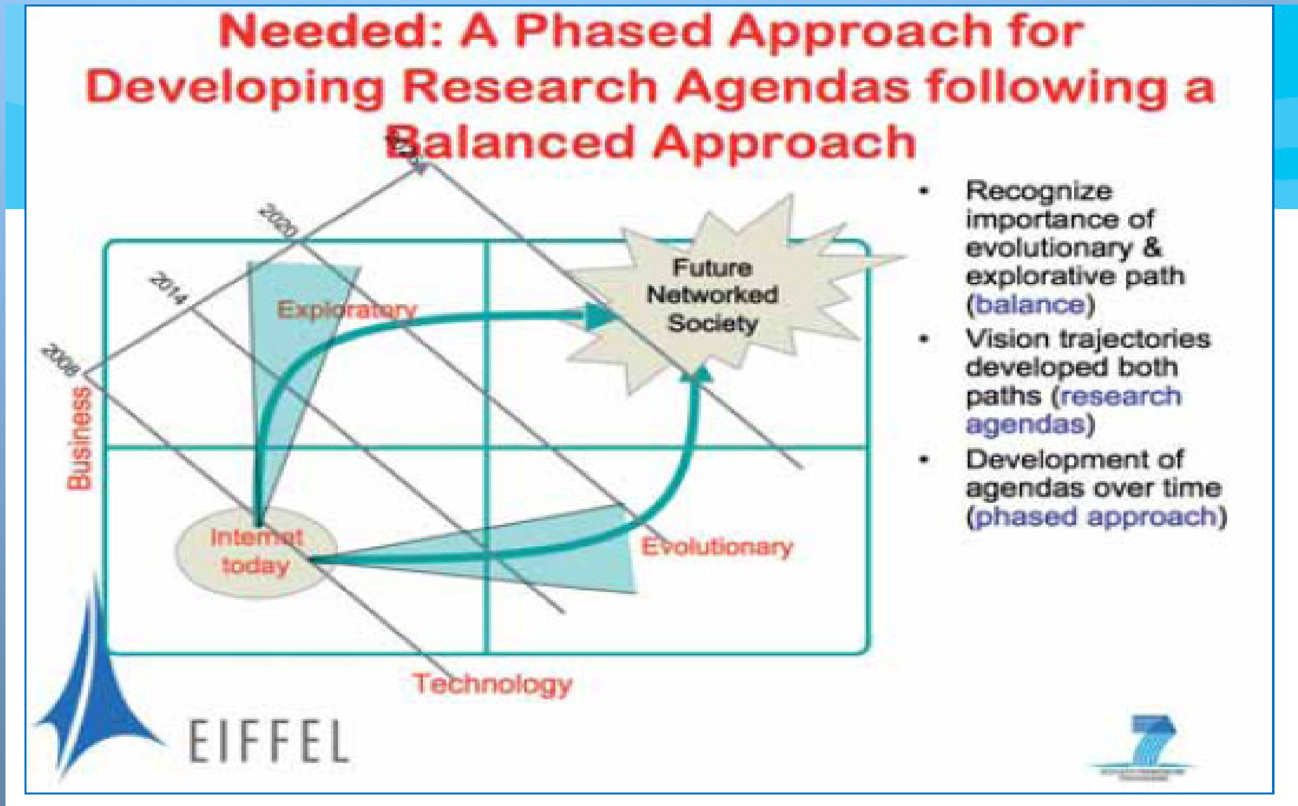
- Sample from IEEE Comm Magazine –July 2009:
  - *(many authors agree with that)*
  - "The term *future Internet* has gained a lot of interest recently"

  - "Several research funding organizations have decided to support the development of the FI; a growing number of research projects are being established."

  - "**There is, however, currently no agreement on what the technology of the FI will look like; nor is there agreement on what the goals of the various competing future Internet activities are…**
  - **"**
- **Partially this is true...**

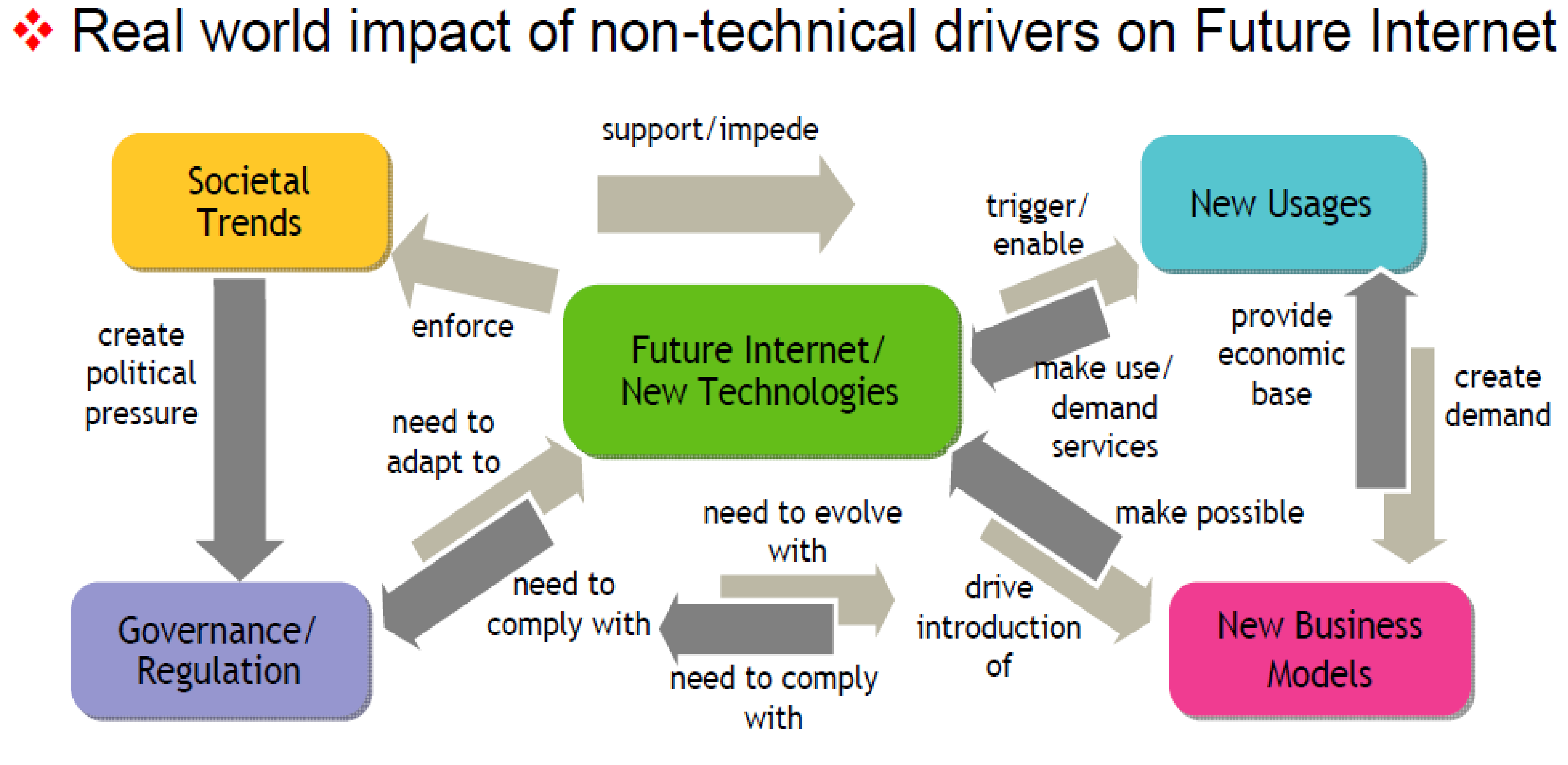
1. Future Internet Challenges

- **What is the way?**
  - **evolution? or clean slate approach? or something in the middle?**
  - **Source:** Petri Mahönen, Project Coordinator, EIFFEL, RWTH Aachen University“ **Evolved Internet Future for European Leadership (EIFFEL)”, FI Conference, Bled, 2008**



1. Future Internet Challenges

- **FI - Social, Economic and Environmental Challenges**
  - Future Internet – Towards Research Challenges – 07 APRIL 2009, http://www.future-internet.eu/fileadmin/documents/prague_documents/FI



1. Future Internet Challenges

- **Usage trends versus current Internet limitations**

Usage Trend	Technological limitations of the current Internet
Very high rate throughput, E2E	Many protocols not designed for ultra broadband scenarios
Ubiquitous good quality and cheap network access	Limited availability of high-quality optical wired networks and of bandwidth and quality offered by the wireless networks
Increasing mobility needs (micro, macro, terminal/ session, network mobility)	Initial Internet support has been conceived for fixed usages
Need for more *security* , and *trust* capabilities	Major limitation of the current Internet. Security and trust mechanism natively supported in service and network infrastructures.
Neeed for more *privacy* and *anonymity* capabilities	Currently: privacy by design. The awareness of these issues is somewhat underdeveloped in today's Internet users.
New services: VoIP, P2P, IPTV	Not enough and effective networking support, including QoS

Summary on Internet Evolution and Status (cont'd)

- Current trends versus limitations

Usage Trend	Technological limitations of the current Internet
User generated content and services	Service architecture enabling dynamic, secure and trusted service compositions and mashups- is still in the starting phase. No business models enough flexible
Novel human-computer interaction techniques	Reduced availability of cheap and compact sensor technology and advanced display technologies Basic Human-computer interaction
Universal connectivity,of devices, coupling of virtual world data with physical world information (RFID, sensors)	Network architecture itself scalability Non existing protocols for an optimal support device generated traffic Basic-only service architectures Not enough capability for service discovery
3D becoming mainstream	Imposes resource intensive usage of computing and networking platforms and standards - only partially available today
Negotiated management and control of resources, negotiated SLA's	Dynamic and predictive network management, infrastructure observability and controllability- objectives partially fulfilled

Summary on Internet Evolution and Status (cont'd)

- **Current trends versus limitations**

Usage Trend	Technological limitations of the current Internet
User is mainly interested in services and content- not in location	Need for content/service awareness, need for contentent centric Internet
Personalized services will become widespread on the FI.	Limited context awareness, lack of personalization tools, basic search capabilities
Computing and software as a network-centric service. This will give users freedom from dealing with backups and software updates, etc.	Currently many PCs exist, having installed a large number of different applications. This trend will probably come to an end.
More need for *Availability*, *reliability*, and *dependability*	Limited: various degree of offering these, depending on provider. Not enough maturity of distributed approaches to solve these.

1. Future Internet Challenges

- **FI = Content + Services + Management**
- (Source: *Schönwälder* ,j. et al. , IEEE Communications Magazine, July 2009)
  - **Management of FI services**
    - **Traditional management:** Out-of-band, added later
    - **FI management:** designed from start, in-band/out-of-band/mixture
  - **Service management - requirements**
    - Content and context as managed objects
    - Users acting as content or service providers
    - Personalization of services
    - Seamless access to services and session mobility
    - Enhanced security
    - Privacy of services and content, Identity and trust management
    - Distributed management (self-X management)
    - Context -, situation-, location-, aware services

1. Future Internet Challenges

- Source: D.Kennedy, Networks + Content, Eurescom, FI Conference, Bled 2008

- **CONTENT orientation- main trend !**

- The Future of Content delivery
  - Ability to aggregate/bundle and manage content
  - Need to have a close relationship between content producers/providers and networking
  - Need for flexibility, extensibility and capability to evolve
  - Need for distributed control and management (including autonomic)

  - Coupling between networks and content (new concept) seems to be necessary (not strong – to avoid destroying the layering)
  - The challenge: "can we cross the layers"?

- What's different about media now?
  - Trends and needs: combined services, high volume, high speed, high interactivity, spanning any geographic distances

1. Future Internet Challenges

- Source: D.Kennedy, Networks + Content, Eurescom, FI Conference, Bled 2008

- **Infrastructure capabilities: should evolve**
  - Mobile networks will support much greater bandwidth,
  - Fixed networks will support cooperation for mobility
  - Internet transport will become more reliable, available, guaranteed quality, better security, etc,
  - Multicast and broadcast technologies evolved (to support e.g. non-linear interactive IPTV)
  - Home networks will be much more powerful (and complex!)
  - Access networks are more powerful, should be more manageable
  - Core networks will be intelligent, efficient, optimised high capacity, low-latency transport structures
  - Seamless integration of home, car, office and other networks seems to happen sooner

1. Future Internet Challenges

- Source: D.Kennedy, Networks + Content, Eurescom, FI Conference, Bled 2008

- **Some Key Cross issues…**
- **Architecture for federating (network resources and user identity)**
  - Identity management
  - Resource consumption : monitoring & management
  - Service consumption : monitoring and management
  - Data logging for billing and costing
  - Data recording for lawful interception requirements

- **Application aware network (intelligent routing)**
  - How can the network identify "sensitive" traffic, what traffic should be treated differently,
  - Net neutrality is not useful when traffic is inherently different and has different transmission requirements.
  - *Note: this breaks the traditional approach on network layer role*

- **Open questions….**
  - How "Content/Service aware" should the Networks be?
  - How "Network sensitive" should the Services be?
  - Where should the user terminal limitations be handled?

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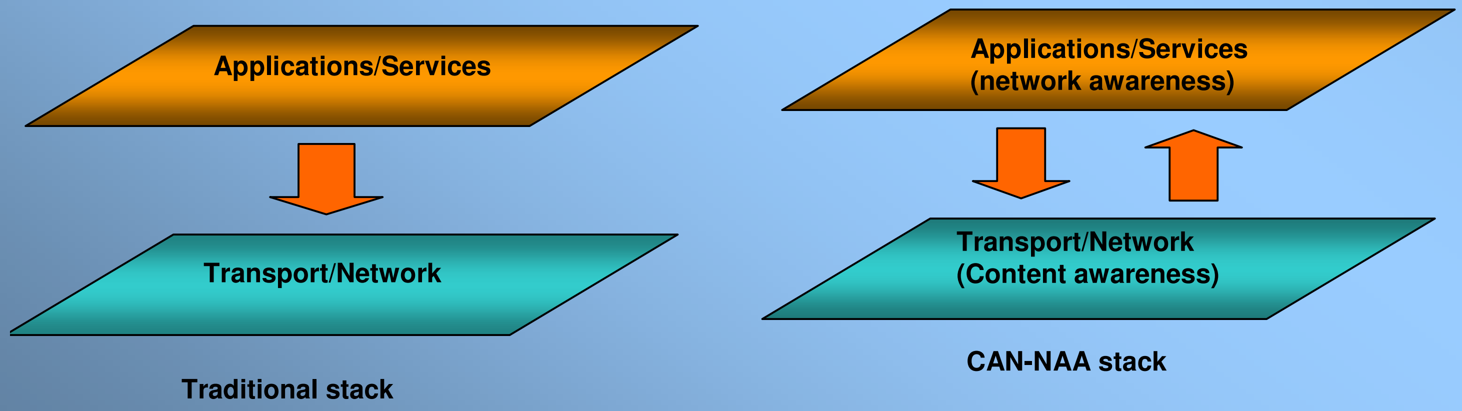
1. Future Internet Challenges
2. **Content Aware Networking**
3. Content Centric Networking
4. CAN/CCN and Virtualisation
5. Architecture examples: ALICANTE project
6. Conclusions

Content-Aware Network (CAN) and Network Aware Application (NAA) - Concepts

- **Current approach**: the way contents are generated, processed, and distributed are separated from the way they are transported
- Question: can one enable better interactions (content-network) but still preserving the architecture modularity?
- CAN : adjusting network resource allocation based on limited understanding of the nature of the content
- NAA: network-aware content processing : adjusting the way contents are processed and distributed based on limited understanding of the network condition



CAN- versus Content Delivery Networks (CDN)

- Source: wikipedia
  - (**CDN**) **delivery/distribution network** : system of computers containing copies of data, placed at various points in a network so as to maximize bandwidth for clients access to the data throughout the network
  - A client
    - accesses a copy of the data near to its location
    - opposed to all clients accessing the same central server, (avoid single server bottleneck)
  - *Content types :* web objects, downloadable objects (media files, software, documents), applications, real time media streams, and other components of internet delivery (DNS, routes, and database queries)

2. Content Aware Networking

- **CAN- versus Content Delivery Networks (CDN)**
- CDN
- The servers aggregate capacity is higher than the network backbone capacity -> impressive increase in the number of concurrent users
- Edge servers should be strategically placed -> decrease the load on interconnects, public peers, private peers and backbones
- CDN can optimally redirect the traffic to edge servers (optimize capacity per customer, provide views of real-time load and statistics, reveal which assets are popular, show active regions and report exact viewing details to the customers)
- **CDNs generally deliver content over traditional TCP/ UDP (no content awareness is supposed to exist in the network nodes)**
  - TCP throughput : impacted by latency , loss, ... -> need that CDNs place servers as close to the edge networks where users are

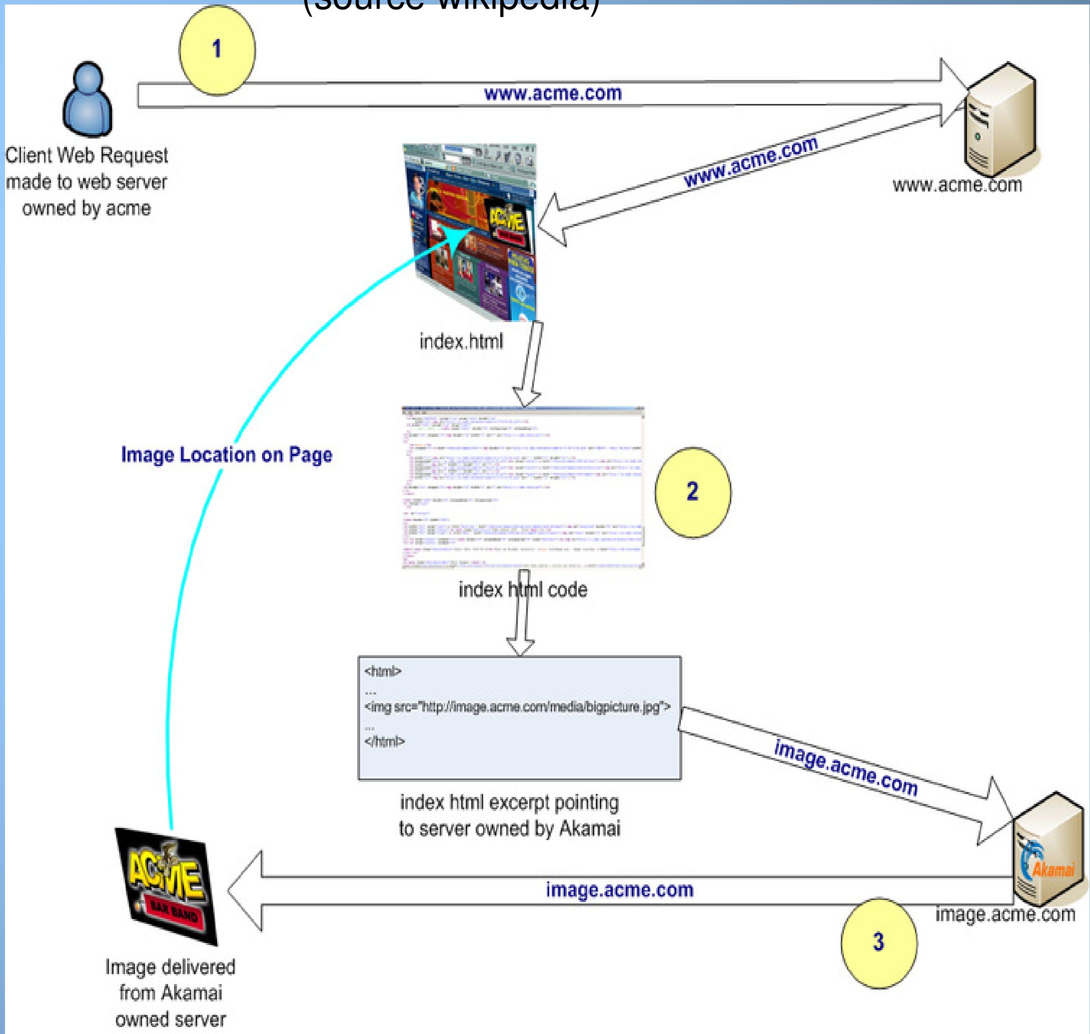
2. Content Aware Networking

- **CAN- versus Content Delivery Networks (CDN)**
- CDN
- CDN increased reliability: deliver HD quality content with high QoS , low costs and low network load
- CDNs can dynamically distribute assets to strategically placed redundant core, fallback and edge servers
-
- CDNs can have automatic server availability sensing with instant user redirection
- A CDN can offer 100% availability, even with large power, network or hardware outages
- CDN must provide usage details
  - since the usage logs are no longer available at the content source server after it has been plugged into the CDN
  - the connections of end-users are now served by the CDN edges instead of the content source

2. Content Aware Networking

- **CAN- versus Content Delivery Networks (CDN)**
- CDN Examples:
- **Free CDNs:**
  - Coral CDN,coBlitz (a subproject of CoDeeN), FreeCast, MediaBlog, PeerCast PPLive, PPStream, QQLive
- **Commercial CDNs:**
  - Akamai Technologies, Amazon CloudFront, CacheFly, CDNetworks (PantherExpress), Chinacache, Cotendo, EdgeCast Networks, Highwinds Network Group, Internap, Level 3 Communications, Limelight Networks, PEER 1, Windows Azure
- **Commercial CDNs using P2P for delivery**
  - BitTorrent, Inc., Internap, Octoshape, Pando, Rawflow, AT&T

Example : AKAMAI access
(source wikipedia)



2. Content Aware Networking

- CAN + NAA Concepts
  - **Content access is the dominant service requested by the users in today's and FI**
  - Current network layer (routing, transport) do not meet the needs of the content related services.
    - Network services are address-location based : traditional routing and forwarding (OSPF, BGP, ..)
    - The network – is neutral: it has no knowledge related to the content-type which it transport and about some optimisation possibilities
  - Examples:
    - 1. For a portal which may be served by several servers, the DNS may return IP addresses, of multiple servers with same domain name, in a round robin scheme,
    - Neither DNS nor network do not know which server (IP address) is closer and maybe less loaded , given a particular user request
    - **CAN could solve such problems**
    - 2. Content based routing and forwarding: the network
      - can route and forward different type of contents among different routes
      - and can reserve resources without the user or application level signaling

2. Content Aware Networking

- CAN + NAA Concepts (cont'd)
  - Architectures and technologies are needed - for converged and scalable networking and delivery of multimedia content and services
  - Maintaining the integrity and quality of media across media life cycle

  - CAN overlays existing IP infrastructure
  - It does what IP routers can't: filter, forward and transform inter-application messages/data based on their content
  - It moves (partially) application logic and business rules into the network
  - This helps customers to build a more intelligent infrastructure (one that identifies content) routes it efficiently and reduces latency.

  - **Service Provider (SP) Role**
    - Many enterprises build their own CANs,
    - Others focus on their core businesses and engage service providers to provide and manage them.
    - SPs are under pressure to offer more valuable services
    - Content-aware, application-enabled networks are helping them reach this objective
    - With only small capital investment, the networks offer the application-layer services their clients need—including market data delivery, network FIX, regulatory compliance or an extended middleware infrastructure.

2. Content Aware Networking

CAN + NAA Concepts (cont'd)

- Business model entities possible in a Content-based Internet **:**
- basic split:
  - Content-Based Service Provider (CSP)
    - locating a content, searching static contents to build a dynamic content, charging information, and content negotiation
    - CSP: e.g. Yahoo, AOL, etc.
  - Content Provider - actual creator or owner of the content
  - Content Consumer

- **Entity similar to CSP**
  - (High level) - Service Provider (HLSP) which offer and manages high level services but uses the content-based transport services from another entity (e.g Content Aware Network Provider - CANP)
  - HLSP and CSP roles can be merged

2. Content Aware Networking

CAN + NAA Concepts (cont'd)

- **Content Request Distribution**
  - Distributing the requests among servers (further than round robin scheme)
- *Centralised solution:*
  - front end unit to distribute the load
  - requires as much networking resources as collectively required by all nodes, (network bottleneck)
  - Commercial products: Cisco's LocalDirector, Connect-Control by Check Point, Locality Aware Request Distribution (LARD) scheme
- *Distributed solutions:*
  - an incoming content request can be received by any server in the cluster
  - servers have new inter-communication protocol to learn the status of other servers
  - each server will determine which other server is suitable (load, content type)
  - no bottleneck (front-end) but horizontal protocol overhead

2. Content Aware Networking

CAN + NAA Concepts (cont'd)

- **Content delivery /distribution**
- *Multicast content delivery examples*
  - Problem : to serve a static content to a group of users whose requests are received at different times at a content server.
  - Time slot multicast:
    - All users whose requests, for the same content, are received in the same time slot are served in a group
    - The server can create a multicast group and instruct them to join a new multicast group.
    - All users always receive the content from the beginning.
    - Trade-off is needed for selection of the length of the time-slot: waiting-time seen by users versus mcast efficiency
    - CAN approach can support such a service including offering of QoS customised CANs
- *Reliable multicast content distribution*
  - CANs for reliable multicast can be constructed to distribute contents between CSs within the domain of a web portal.
  - Reliable multicast can be used
    - - to push the content from the main server to all other edge servers
    - - to deliver any reliable content to a group of users

2. Content Aware Networking

CAN + NAA Concepts (cont'd)

Content aware routing and forwarding

- Content-based routing can be used to to direct the request to the most appropriate server (among several distributed at different IP addresses) with intelligence closer to the client.
  - Current DNS mapping based systems do not proceed like this
  - The server distribution may be non-overlapping or it may be complete duplication (often referred to as mirroring).
  - Variants:
    - routes are computed in traditional way but forwarding is choosing the most appropriate one based on content type analysis
    - the routes themselves are computed in a content-based style

2. Content Aware Networking

CAN + NAA Concepts (cont'd)

- **Location aware content services (LACS)**
  - They offer information about sites/environment "content" based on their location
  - The use of clients location is also helpful for content routing,
    - the I/F to a content aware DNS respond with the IP address of one of the distributed servers closest to the client
  - LACS are useful for a CSP to push contents to customers.
  - e.g. provide up to date info about a customer's environment (e.g traffic data in the visited zone)
  - Problems with providing LACS: no association of IP addresses with the physical location
  - Solution:
    - use of GPS or some other device and this location information is transmitted to the CSP.
    - CSP then processes the location information along with the requested content
    - contacts the content provider (CP) to retrieve the desired content
    - delivers it to the client, or redirects the client to the desired content

2. Content Aware Networking

CAN + NAA Concepts (cont'd)

- *Security aspects and CAN*
  - IP Security define ways to encrypt data between peer entities thus protecting integrity and privacy of the data
  - The use of IPSec is becoming popular in VPN based services
  - If IPSec is used between peer nodes, intermediate networking nodes no longer have access to the content carried inside an IP packet.
  - This is one of the reasons why CAN cannot be so easy feasible in the core of the Internet
  - However we can solve security issues in a CSP domain such as portal sites.
    - Content distribution involves Front End Servers (FES) and Back End servers (BES) where FES handles all the incoming content requests
  - Possible solution:
    - if CSPs want to use CAN techniques with IPSec, it is advisable that IPSec is terminated at the FES
    - Once FES decrypts and analyzes the content, it is easier to use CAN techniques to route, reserve and charge accordingly

2. Content Aware Networking

- Content-Aware Network: Example 1
- Content Routing Mechanism based on content tagging
  - Source: A. Mitra, M.Maheswaran, Wide-Area Content-based Routing Mechanism, International Parallel and Distributed Processing Symposium (IPDPS'03)

  - Wide area network environment
  - Content Clients, Content Servers distributed at the edge of a network

  - Clients are requesting content

  - The requests for content are steered by *content routers* (examining dest but also also *content descriptors – e.g.* such as URLs and cookies
  - In the current CDN, content routing is confined to selecting the most appropriate back-end server in virtualized web server clusters

  - The architecture: based on tagging the requests at ingress points
    - The tags incorporate several different content attributes and are used in the in the routing process.

3. Content Aware Networking

- Content-Aware Network: Example 1
- Content Routing Mechanism based on content tagging
- Wide-Area Content-based Routing Mechanism (cont'd)

  - Content-based routing architecture: *protocol independent content switching* (PICS).
  - Client and server sites – linked through an overlay -*virtual content network* (VCN)
  - The client and server sites connect to the VCN using GWs (called content-based routers).
    - *content edge routers* (CERs).-placed at the outer edge of the VCN first examine the content
    - VCN interior : *content-based switching routers* (CSRs)

    - the client or server sites can connect to the VCN, via multiple CERs (load balancing + preventing single-point failures)
    - CERs
      - are responsible for characterization and classification of content
      - encapsulate the incoming packets using a content header containing a content derived tag uniquely identifying a content within the VCN
    - The CSRs at the VCN's core steer the content requests from the ingress CER to the egress CER based on the tags in the content header
      - CSRs are Tag based switches that support a single forwarding component (i.e., algorithm for tag-based forwarding)

2. Content Aware Networking

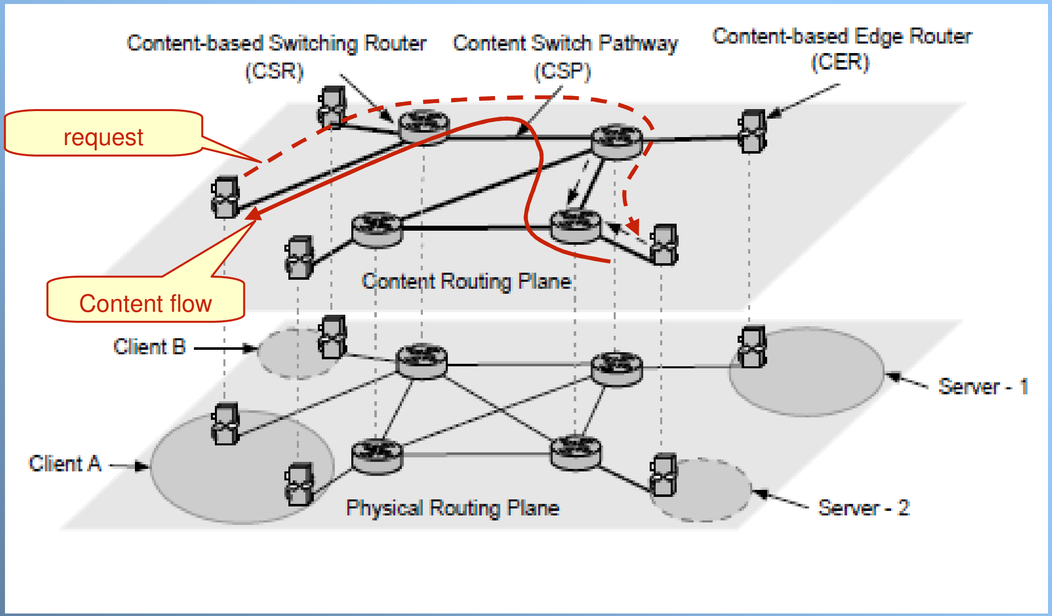
- Wide-Area Content-based Routing Mechanism (cont'd)
- Virtual content network
  - A content request arrives to a ingress CER
  - Ingress CER identifies the content and tag it

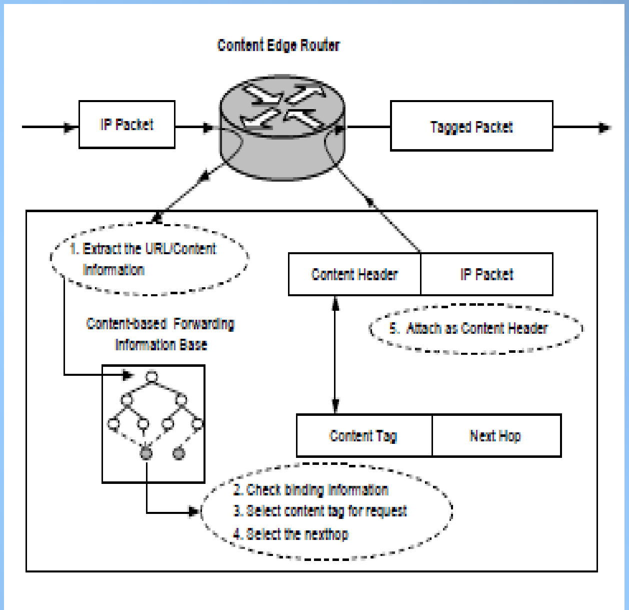
  - The CERs extract the content descriptors (e.g URLs, cookies, etc.) from the requests and use a *content-based forwarding information base* (CFIB) to determine the corresponding content derived tag, (content-to-tag bindings)
    - The tag is generated by a combination of content and policy information
    - CFIB is organized hierarchically based on the popularity of the content to enhance the scalability
    - The CFIB is reorganized periodically by the *content classification* process to reflect additions and deletions in content subscriptions

  - The content classification process leverages the properties of the content identified by the *content characterization* process
  - The content classification process uses the content attributes
  - to create *content equivalence classes* (CECs)
  - The IP packet is encapsulated with a content header at the ingress CER
  - and is restored by the egress CER

2. Content Aware Networking

- Wide-Area Content-based Routing Mechanism
- Virtual content network topology example
  - CSRs
    - maintain content based forwarding tables
    - do not have any content-to-tag binding information (they are tag switches)
    - assume that the appropriate tags are already created by the CERs.
    - use the content-based forwarding tables to steer the requests toward the appropriate server side CER.
- Note: the proposed technique is similar to MPLS where the LSP is replacing CSP





Source: A. Mitra, M.Maheswaran, Wide-Area Content-based Routing Mechanism, International Parallel and Distributed Processing Symposium (IPDPS'03)

2. Content Aware Networking

- Wide-Area Content-based Routing Mechanism
- Virtual content network topology example

  - Content characterisation
    - Process that identifies the content key attributes
    - Used to to generate content description and its resource reqs
    - A content profile is defined *a priori* to the routing process.
    - used to locate the content and also allows the routing protocol to infer those characteristics that directly affects the content delivery mechanism (e.g., bandwidth required for delivery, client QoS reqs.etc.).

  - Possible two distinct classes of attributes:
    - Structural class : their values are known prior to the routing process and can be used to create content description, a priori, which is then used to discover content on a network.
    - Semantic class: are initialized only at the time a request for the content is submitted and is used for accessing the content.
  - A combination of them decides the network resources to be allocated for a request

2. Content Aware Networking

- Wide-Area Content-based Routing Mechanism (con'd)
- Virtual content network topology example

  - Content characterisation:
  - **Physical:** size, version, modification date, ownership permissions, copyrights, author
  - **Name-based** filename, location name, URL, origin server name
  - **End data type:** HTML, cookies, scripts, audio/video
  - clips, text
  - **Popularity** temporal, spatial

  - **Access :** duration, streaming, non-streaming,
  - variable-bit rate, constant-bit rate,
  - adaptive-bit rate
  - **Quality of service** bandwidth, delay,
  - loss tolerance
  - **Document Type** static, dynamic

Content-Aware Network: Example 2

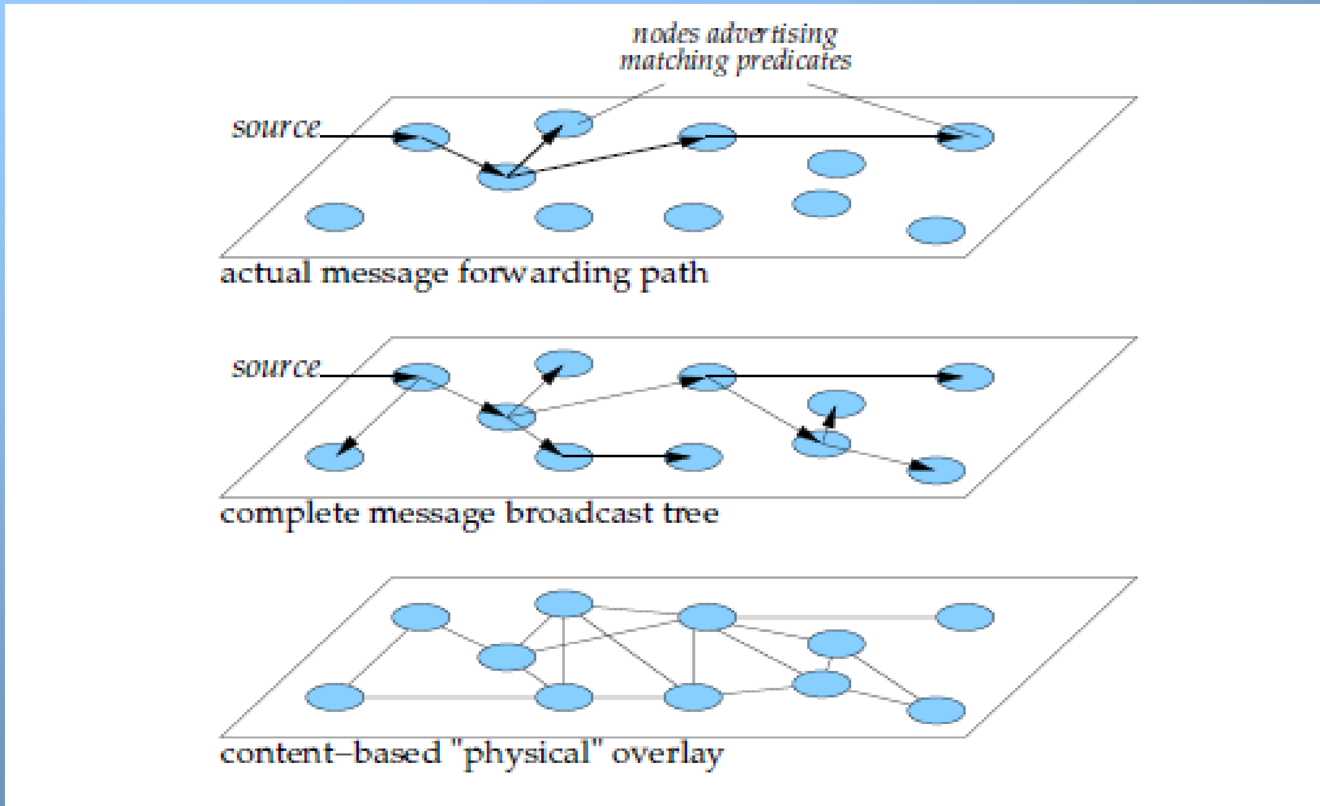
- Source: A.Carzaniga, M. J. Rutherford, A. L. Wolf, A Routing Scheme for Content-Based Networking, http://www.inf.usi.ch/carzaniga/papers/crw_infocom04.pdf

- Content-based communication service example: datagram, connectionless service, through a *content-based network*
- content-based network as an overlay point-to-point network.
- Routing in a content-based network
  - synthesizing distribution paths throughout the network
  - forwarding : determining at each router the set of next-hop destinations of a message

- Solution: ***combined broadcast and content-based (CBCB)*** routing scheme.
  - content-based layer over a traditional broadcast layer
  - The broadcast layer handles each message as a broadcast message
  - the content-based layer prunes the broadcast distribution paths, limiting the propagation of each message to only those nodes that advertised predicates matching the message

Content-Aware Network: Example 2 (cont'd)

- Network Overlay and High-Level Routing Scheme



- Source: A.Carzaniga, M. J. Rutherford, A. L. Wolf, A Routing Scheme
- for Content-Based Networking,
- http://www.inf.usi.ch/carzaniga/papers/crw_infocom04.pdf

2. Content Aware Networking

- **Content-Aware Network: Example 2 (cont'd)**

- A router runs two protocols :
  - a *broadcast routing* protocol
  - a *content-based routing* protocol.
-
- The broadcast protocol
  - creates a broadcast tree:
    - processes topological information
    - maintains the forwarding state necessary to send a message from each node to every other node.
  - There is a broadcast layer to execute broadcast tree construction
    - common broadcast schemes can be used maybe slightly modified
    - Implementation : global spanning tree protocol, per-source minimal-paths spanning trees, or reverse-path broadcasting.

3. Content Aware Networking

- **Content-Aware Network: Example 2 (cont'd)**
- The content-based protocol
  - processes *predicates advertised by nodes*,
  - maintains the forwarding state - to decide, for each router I/F whether a message matches the predicates advertised by any downstream node reachable through that interface.
- is based on a *dual push/pull* mechanism that guarantees robust and timely propagation of CB routing information

- **Message content**: structured as a set of attribute/value pairs, and a selection logical predicate (disjunction of conjunctions) of elementary constraints over the values of individual attributes
- Example: a message might have the following content
  - [class=alert, severity=6, device-type=web-server, alert-type=hardware failure]
- This content matches a selection predicate e.g. :
  - [alert-type=intrusion ^ severity>2 U class=alert ^ device-type=web-server]

CONTENTS

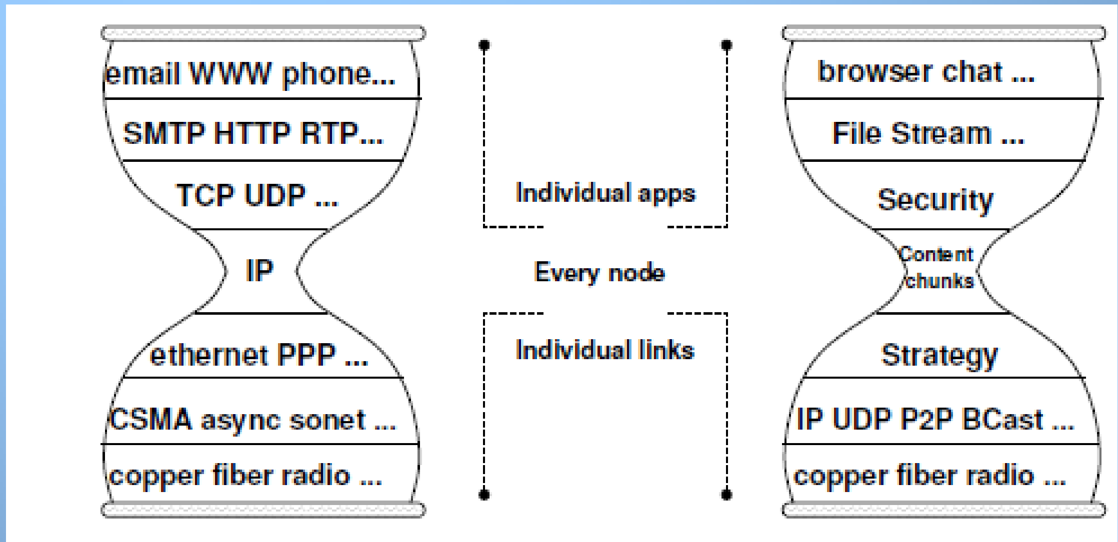
3. Content Centric Networking

- **CCN Concepts**
  - Current network evolve mainly to content distribution and retrieval
  - Traditional networking technology still uses connections based on hosts locations
  - Accessing content and services requires mapping from the *what* that users care about to the network's *where.*
  - CCN proposes to treats content as a primitive – *decoupling location from identity, security and access, and retrieving content by name*
  - *Routing named content*, (derived from IP), allows to achieve scalability, security and performance
  - New architectures are proposed to demonstrate new features of the CCN

3. Content Centric Networking

CCN concepts (cont'd) Example 1

CCN transformation of the traditional network stack from IP to chunks of named content



Traditional TCP/IP stack

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

3. Content Centric Networking

- **CCN Concepts** (cont'd)
  - Most layers of the traditional stack horizontal bilateral agreements/protocols (Node to node, end to end)
  - Network layer : the only one requiring universal agreement
  - IP's success:
    - It is simple (thin 'waist' of the stack)
    - flexible (dynamic routing)
    - Low demand from layer 2: stateless, unreliable, unordered, best-effort delivery.
  - **CCN's network layer is similar to IP**
    - it makes fewer demands on layer 2, giving it many of the same attractive properties.
    - (+): CCN *can be layered over anything,* including IP itself.

3. Content Centric Networking

- **CCN Concepts (cont'd)**

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

  - The strategy layer
    - *makes the fine-grained, dynamic optimization* choices needed to best exploit multiple connectivity under changing conditions
  - CCN
    - *secures content itself* rather than the connections over which it travels
    - thereby avoiding many of the host-based vulnerabilities that exist in IP networking

3. Content Centric Networking

- **CCN Concepts (cont'd)**
  - CCN node model
    - CCN communication is driven by the data consumers
    - CCN packet types
      - Interest packet (InP) ("Querry" for content)
      - Data (DP) (carry the actual content)

    - **How it works ? (high level description)**
      - The consumers broadcast their interest for some content
      - Any node which hears the *Interest* and has the required content can responbd with *Data* packet
      - *Data* are transmitted as a response only to an interest and consume this *interest (1-to- 1 relationship Interest-data)*

3. Content Centric Networking

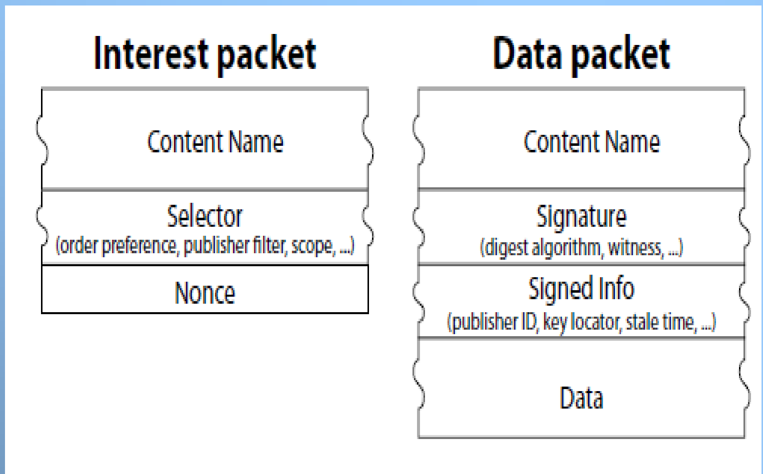
- **CCN node model (cont'd)**

  - Multiple nodes interested in the same content may share the Data packets: CCN is naturally multicast enabled

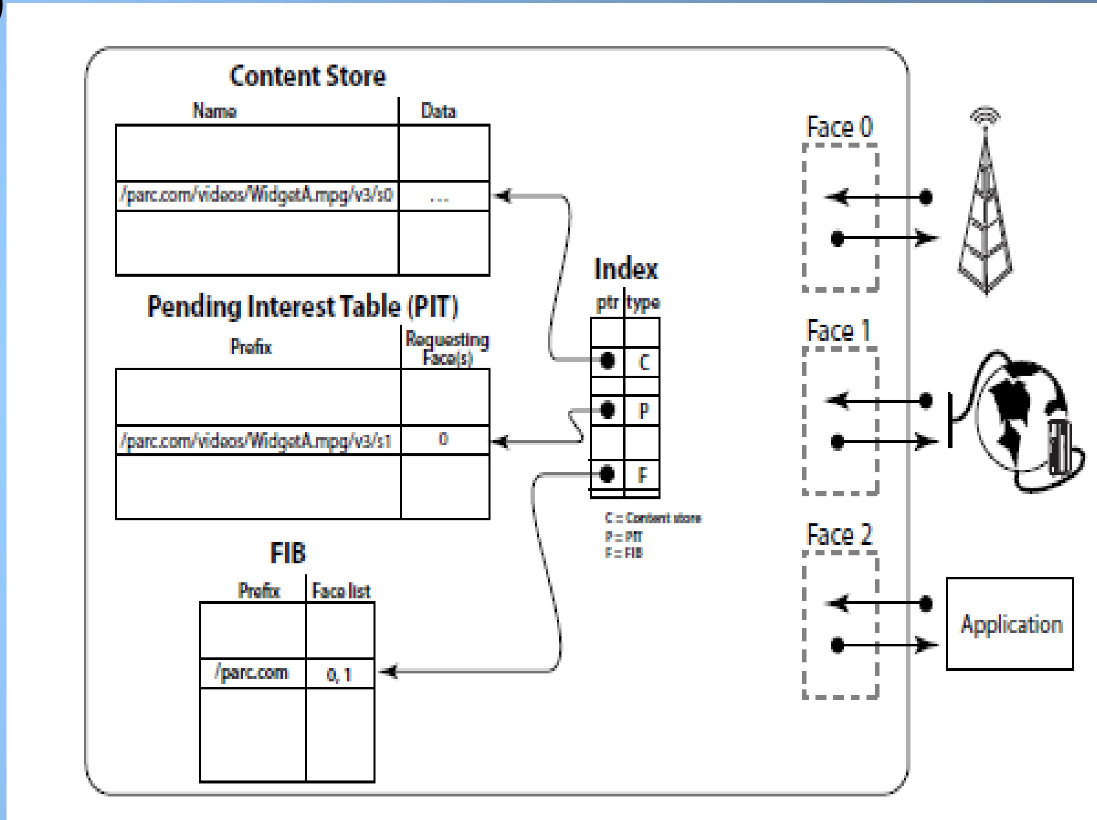
- Content characterisation:
  - Data 'satisfies' an Interest if the *ContentName* in the InP is a prefix of the *ContentName* in the DP
  - CCN names :opaque, binary objects composed of an (explicitly specified) number of components
  - Hierarchical structure of names => the above prefix match is equivalent to : the DP is in the *name subtree* specified by the InP
  - Similarity wit hierarchical structure of IP addresses ((net, subnet, ..)
  - Name prefixes can be context dependent (e.g. *"This building/this_room*")

3. Content Centric Networking

- **CCN node model (cont'd)**



CCN Packet types



CCN Forwarding Engine Model

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

3. Content Centric Networking

- CCN node model (cont'd)

- CCN Forwarding engine
  - FIB (Forwarding Information Base)
  - CS (Content Store – i.e. buffer memory)
  - PIT (Pending Interest Table)
  - FIB
    - used to forward an InP towards potential (sources)
    - Similar to IP FIB
    - But admits several I/Fs
      - multiple sources that can act in parallel
      - CCN is not limited to the spanning tree as in IP routing
  - CS
    - Same as buffer mneme in IP router
    - stores the DPs to be used in the future by other recipents (difference from IP router which forgets a packetbafter it has been forwarded)
    - It has a different replacement policy
    - Allows "caching" at every node – depending on its capabilities
    - Increase in perf for content delivery

3. Content Centric Networking

- **CCN node model (cont'd)**

- **CCN Forwarding engine**
- Pending Interest Table (PIT)
  - Stores the pending requests for content, i.e
  - It keeps track of InP forwarded upstream toward content source(s) so that returned Data can be sent downstream to its requester(s)
  - In CCN the routes are computed for INP packets only, (when they propagates upstream towards the data sources)
  - Each unsolved INP is stored in PIT (similar to RSVP reservation style) , so the DPs will be forwarded on the reverse (towards the requester(s) path when they come
  - Basic operation at a CCN node-
    - similar to IP node (router) done performing forwarding phase
  - Packet arrives on an I/F (InP or DP)
    - (note that in original source) these are named *faces* – as to emphasize their logical roles –an I/F can be in the same machine towards an application
    - Longest match look-up is performed based on its *ContentName*
    - Appropriate actions are done based on the result

3. Content Centric Networking

- **CCN node model (cont'd)**
- **Basic operation at a CCN node**
- **InP packet arrives**
  - Longest lookup is done on its ContentName
  - Priorities of the search: CS, PIT, FIB
  - If there is a DP in the Content Store that matches the InP
    - Then it will be sent out the I/F the InP arrived
    - Discard the InP (solved)
  - Otherwise: If there vis an exact match to to PIT,
    - then a new I/F is added to the pending list
    - And the InP is discarded (similar to IGMP working in multicast)
  - Otherwise: If a FIB matching is found
    - then the request (InP) is sent upstream towards the data source(s)
    - On nall I/Fs except the input I/F
  - If no match for InP then discard

3. Content Centric Networking

- **CCN node model (cont'd)**
- **Basic operation at a CCN node**
- **Data packet arrives**
  - DPgenerally follows the route back conforming the PIT information

  - Longest-match lookup is done at DP arrival on itsContent Name
  - CS match => DP is a duplicate, discard
  - PIT match (there can be more thatn one) =>
    - Data validation (security)
    - Data are added to the CS (caching)
    - Data are sent towards the pending entities (list in PIT)
    - The PiT- corresponding pending requests are solved (erased)

  - In CCN each new packet of data is sent only after a new interest is expressed
    - This approach is similar to TCP ACks(giving a new window to the transmitter) + Data packets
    - Senders are stateless, so retransmission if necessary is requested by the application (the strategy level has the task to determine the policies)
    - CCN has in such a way a flow control mechanism

4. CAN/CCN and Virtualisation

1. Future Internet Challenges
2. Content Aware Networking
3. Content Centric Networking
4. **CAN/CCN and Virtualisation**
5. Architecture examples: ALICANTE project
6. Conclusions

4. CAN/CCN and Virtualisation

- Network Virtualisation

- It is defined by decoupling the roles of the traditional Internet service providers (ISPs) into two independent entities
  - Infrastructure providers (InPs), who manage the physical infrastructure
  - Service providers (SPs), who create virtual networks (VNs) by aggregating resources from multiple InPs andoffer end-to-end services
- Such an environment will proliferate deployment of coexisting heterogeneous network architectures free of the inherent limitations of the existing Internet.

- In particular CAN networks and CCNs can be realised on slices of VNets

4. CAN/CCN and Virtualisation

- **Network Virtualisation**
  - **Historical perspective**
  - L1 VPNs
    - The layer 1 VPN (L1VPN) emerged from the need to extend layer 2/3 (L2/L3) packet switching VPN concepts to advanced circuit switching domains.
    - It provides a multiservice backbone where customers can offer their own services, whose payloads can be of any layer (e.g., asynchronous transfer mode [ATM] and IP).
    - each service network has an independent address space, an independent L1 resource view, separate policies, and complete isolation from other VPNs.
  - Layer 2 VPN
    - transport L2 (typically Ethernet) frames between participating sites
    - they are agnostic about the higher-level protocols, and consequently more flexible than L3VPN.
    - On the downside, there is no control plane to manage reachability across the VPN.

4. CAN/CCN and Virtualisation

- **Network Virtualisation**
- **Historical perspective**
- Layer 3 VPN
  - Is characterized by its use of L3 protocols in the VPN backbone to carry data between the distributed CEs
  - There are two types of L3VPNs.
    - **CE-based VPN** : the provider network is completely unaware of the existence of a VPN
      - CE devices create, manage, and tear down the tunnels between themselves.
      - Sender CE devices encapsulate the passenger packets and route them into carrier networks; when these encapsulated packets reach the end of the tunnel (i.e., receiver CE devices), they are extracted, and actual packets are injected into receiver networks.
    - **PE-based** the provider network is responsible for VPN configuration and management.
      - A connected CE device may have as if it were connected to a private network

4. CAN/CCN and Virtualisation

- **Network Virtualisation**
  - **Historical perspective**

  - **OVERLAY NETWORKS**
  - Logical network built on top of one or more existing physical networks.
  - The Internet itself started off as an overlay on top of the telecom network.
  - Overlays in the existing Internet are typically implemented in the application layer; however, various implementations at lower layers of the network stack do exist.

  - Overlays do not require or cause any changes to the underlying network. Consequently, overlays have long been used as relatively easy and inexpensive means to deploy new features and fixes in the Internet.

4. CAN/CCN and Virtualisation

- **Network Virtualisation- Example 1**
  - **Source : N. M. Mosharaf Kabir Chowdhury and Raouf Boutaba “Network Virtualization:State of the Art and Research Challenges”, IEEE Commm Magazine, July 2009**

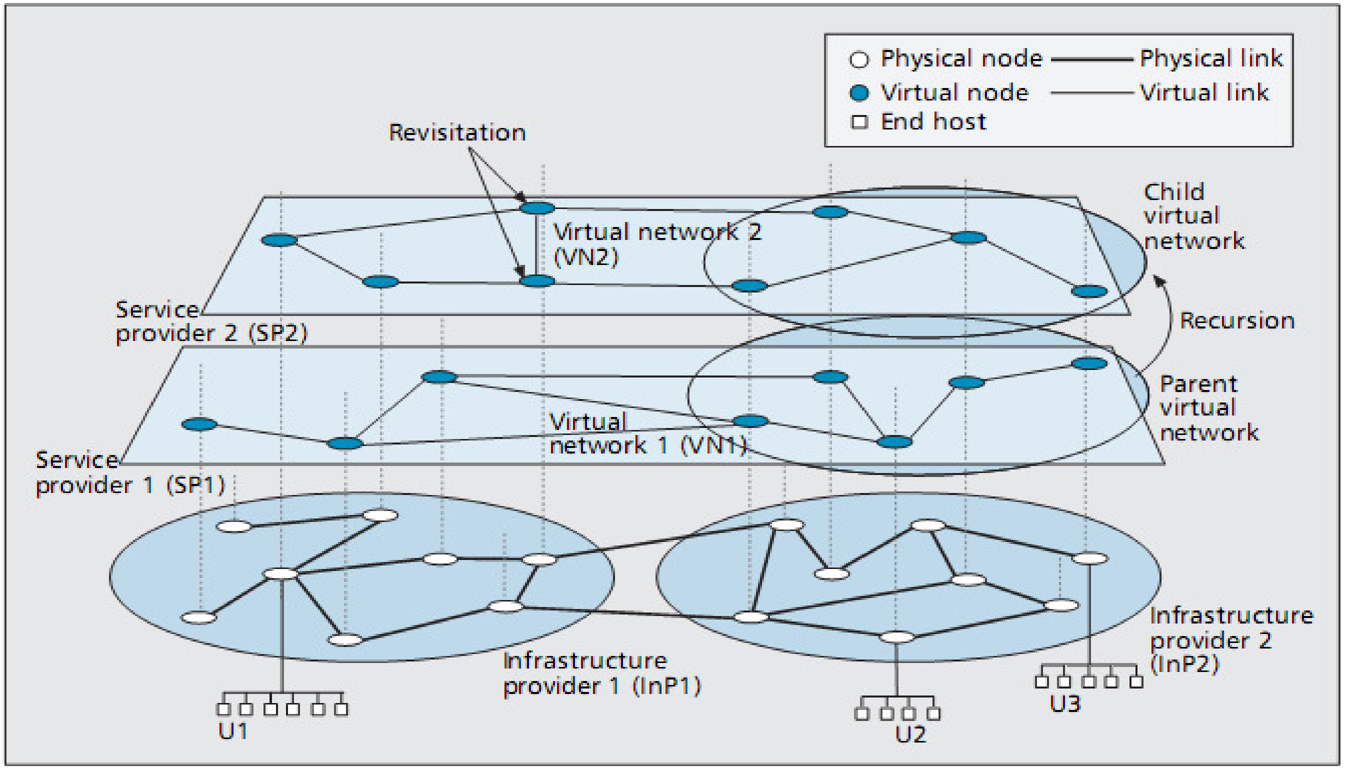
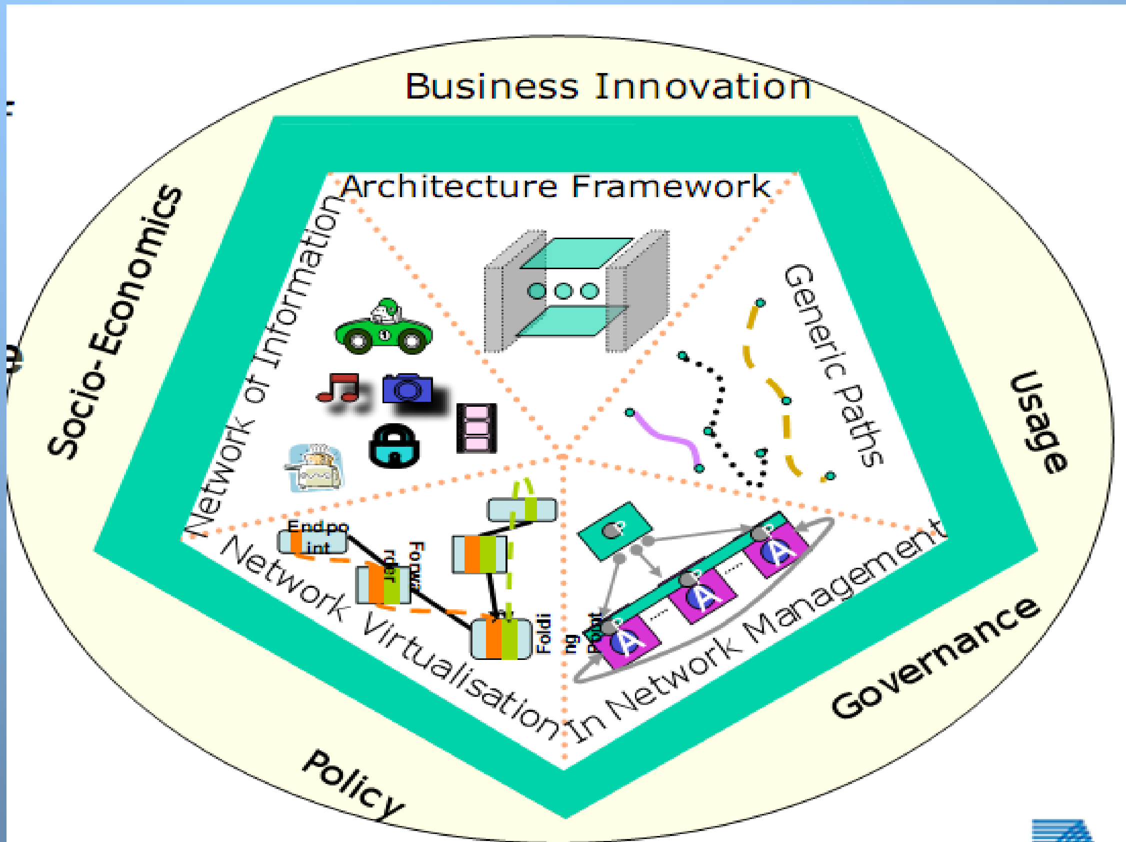


Figure 1. *Network virtualization environment.*

4. CAN/CCN and Virtualisation

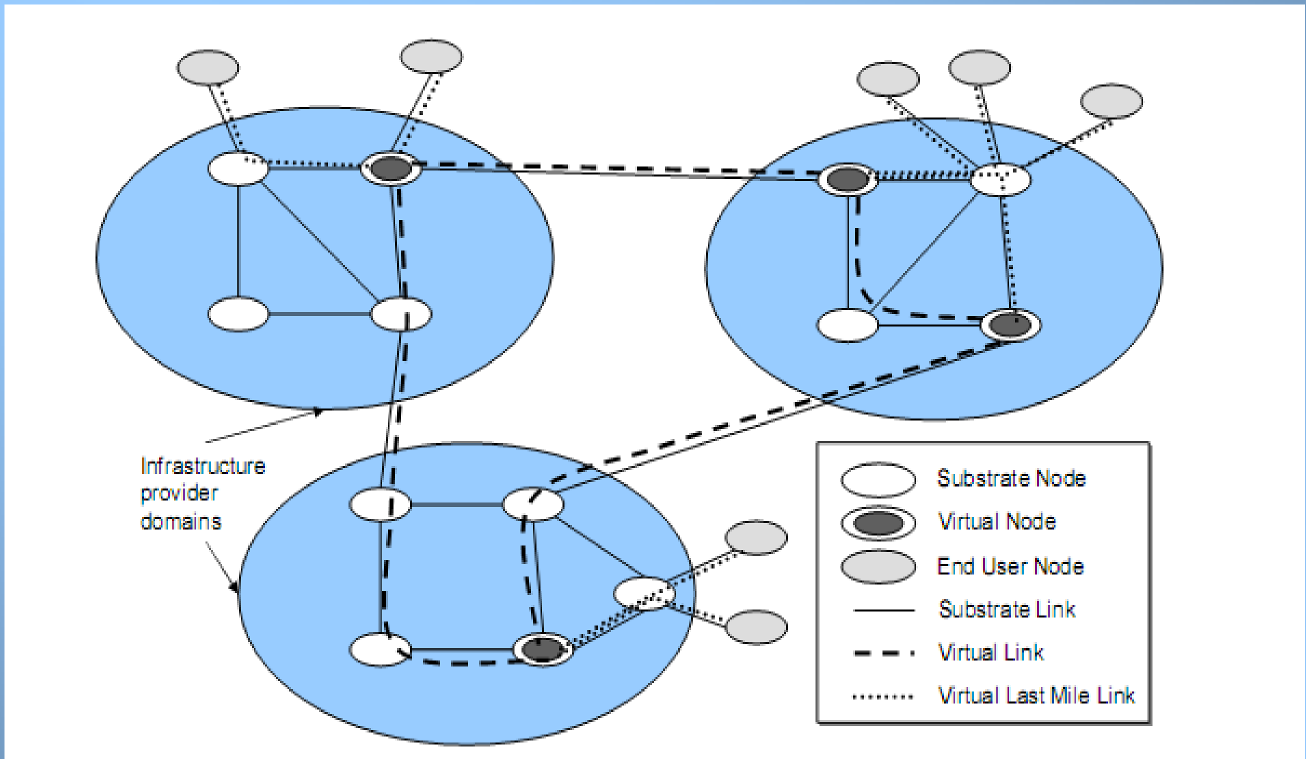
- Example of an European project using full virtualisation (Data Control and Management Plane):
- 4WARD A clean slate approach for Future Internet, FP7 IP Project (2008-2009)



Source: …Abramowicz,H. Introduction to BIRD WS, http://www.4ward-project.eu

4. CAN/CCN and Virtualisation

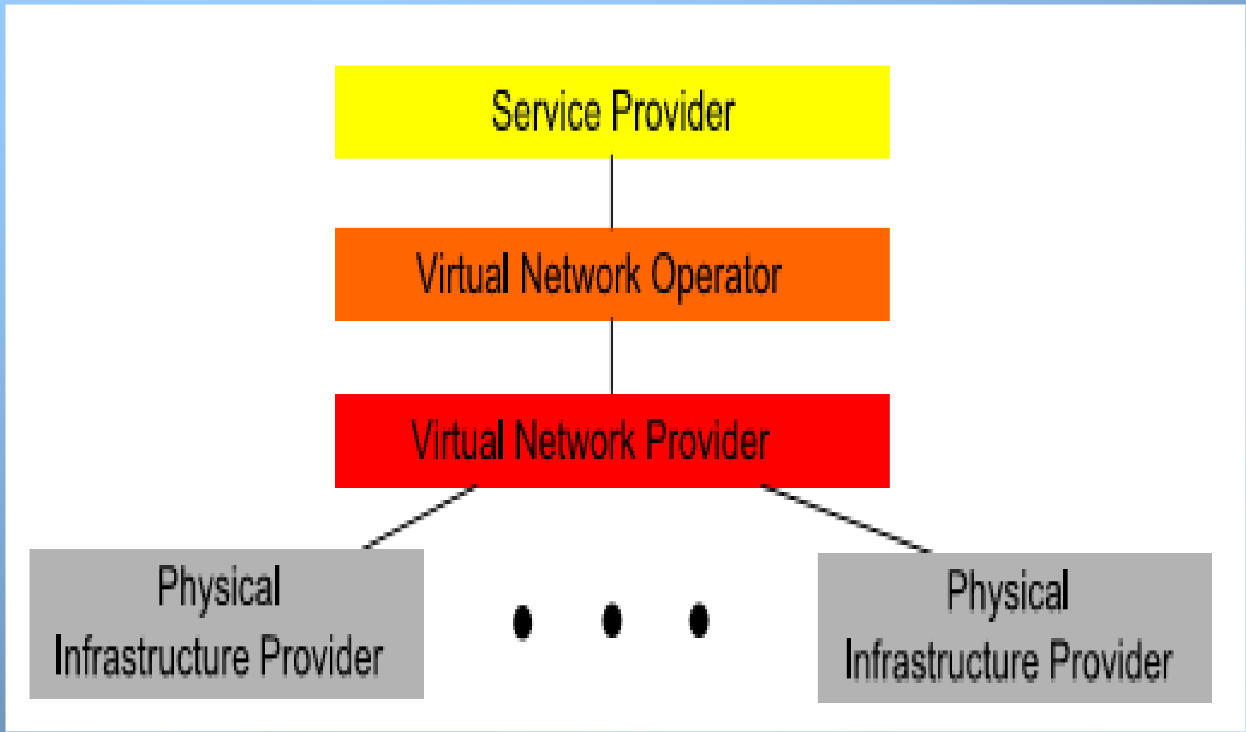
- **Example of full virtualisation**
- Overview of a virtual network topology and substrate networks



R.Bless, C.Werle, Control Plane Issues in the 4WARD Network Virtualization Architecture, Electronic Communications of the EASST Volume 17 (2009)

4. CAN/CCN and Virtualisation

- 4WARD Main approach : virtualisation
- New business entities needed:



Source: L.M. Correia and L.Lundgren-editors, *Going 4WARD Newsletter,* 4WARD- Architecture and Design for the Future Internet May 2009, Issue No. 4

4. CAN/CCN and Virtualisation

- 4WARD- Business entities

- **Physical Infrastructure Provider (PIP)** : owns and manages the PHY infrastructure (the substrate), and provides wholesale of raw bit and processing services (also known as slices), which support network virtualisation

- **Virtual Network Provider (VNP):** assembles virtual resources from one or multiple PIPs into a virtual topology

- **Virtual Network Operator (VNO)** initiate installation and then performs operation of a VNet over the virtual topology provided by the VNP according to the needs of the SP (realises a tailored connectivity service)

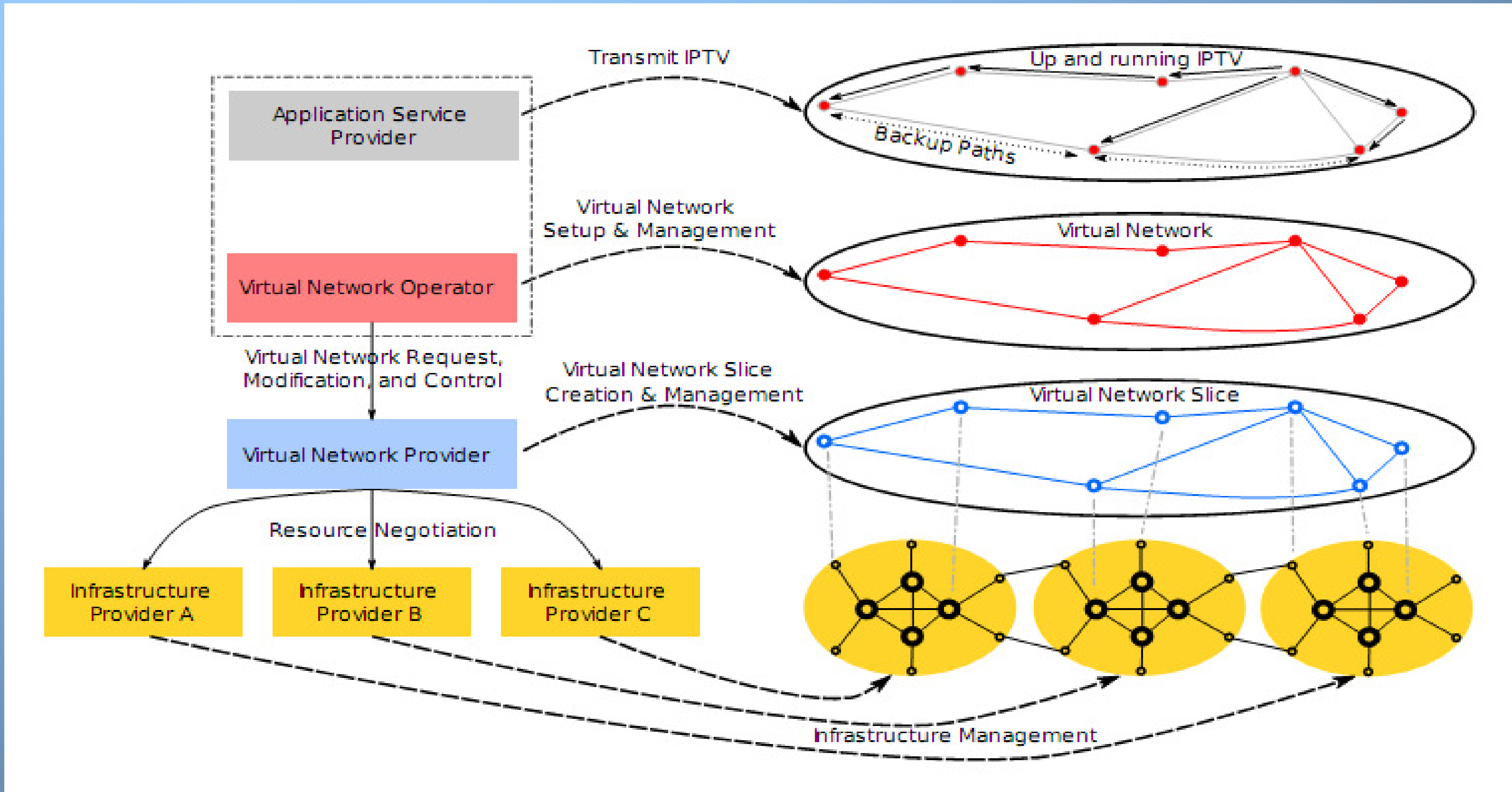
- **Service Provider (SP):** constructs, advertises and offers high level services to the customers/users

7. Other FI-oriented Architectures

- 4WARD- Business entities (cont'd)
- Service Providers (SP) use the VNets to offer their services
  - value-added services (SPs act as ASP)
  - or transport services (SPs act as NSP)
- VNP : new business role (it does not exist in today's economic structure)
  - enable the layer of indirection that virtualisation is providing.

  - Notes: The above roles must be understood as a technical concept, while:
    - a single business entity could perform more than one task, e.g., one company can be PIP and VNP at the same time
    - or VNP and VNO could coincide
  - The 4WARD separation concept allows VNets to have properties and guarantees not currently available in today's Internet.

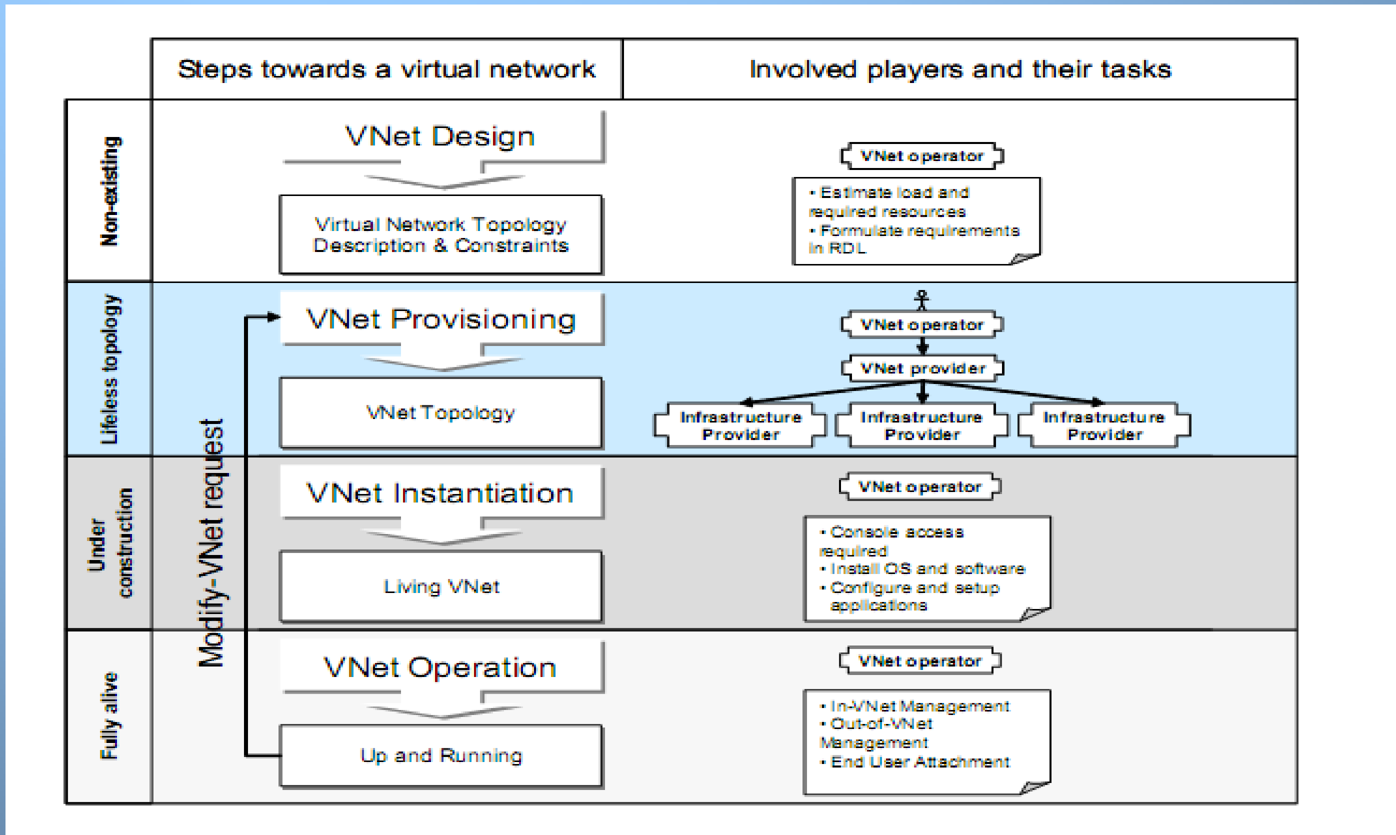
7. Other FI-oriented Architectures

- 4WARD- Business entities (cont'd)
- 

Source: R.Bless, C.Werle, Control Plane Issues in the 4WARD Network Virtualization Architecture, Electronic Communications of the EASST Volume 17 (2009)

7. Other FI-oriented Architectures

- 4WARD- Business entities (cont'd)
  - VNet Lyfe cycle overview



Source: R.Bless, C.Werle, Control Plane Issues in the 4WARD Network Virtualization Architecture, Electronic Communications of the EASST Volume 17 (2009)

CONTENTS

5. Architecture examples: ALICANTE project

- **ALICANTE, 2010-2013, Integrated Project (IP): MediA Ecosystem Deployment Through Ubiquitous Content-Aware Network Environment- *FI oriented project,*** *http://www.ict-alicante.eu/*

ALICANTE Partners

5. Architecture examples: ALICANTE project

- Applying new concepts (Future Internet – oriented) of
-
  - **Content Aware Networking**
  - **Network Aware Application**

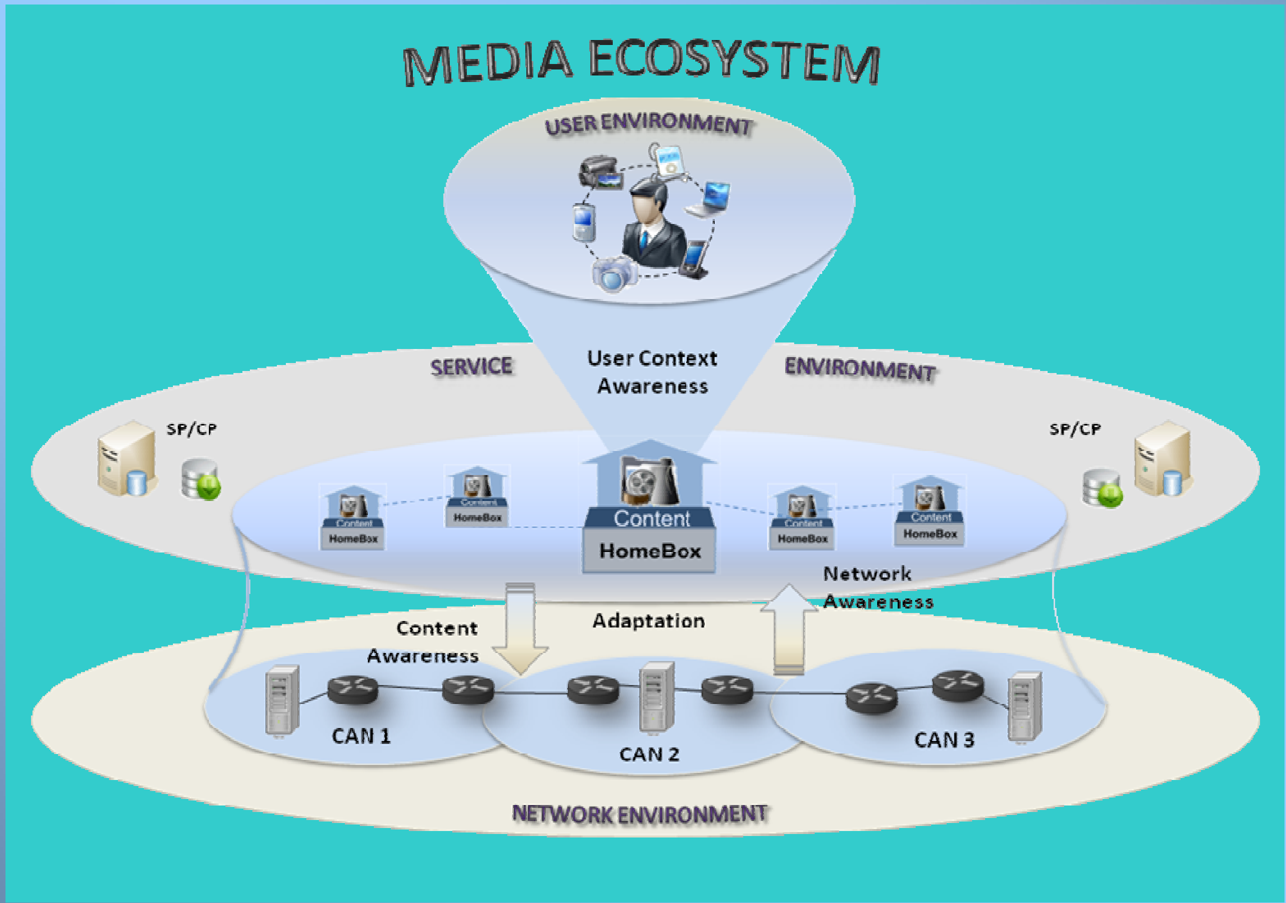
- Proposal of a novel virtual Content-Aware Network (CAN) layer
  - as a part of a full layered architecture
  - focused, but not limited to, on multimedia distribution with Quality of Services (QoS) assurance

- The overall system is based on a flexible cooperation between
  - providers,
  - operators and end-users,
  - enabling users to access the offered multimedia services in various contexts and also to become private content providers.

- Focus of this presentation :
  - the main concepts and architecture for the main virtual network layer (i.e., CAN)
  - exposing its role and interfaces among overall system layers.

5. Architecture examples: ALICANTE project

- **ALICANTE-** High level architectural view



5. Architecture examples: ALICANTE project

- ALICANTE concept:

- Provision of Content-Awareness to Network Environment
- Provision of Network- and User Context-Awareness to Service Environment
- Adaptation of services and content to the End-User for his best service experience
- ALICANTE objectives:
- Enabling users
  - to efficiently access the offered multimedia services in various contexts
  - to share and deliver audiovisual content

- Enabling providers (high level services, network)
  - To extend their range of services
  - To service large number of users
  - To efficiently manage their high level services and network resources

5. Architecture examples: ALICANTE project

- ALICANTE solution:
- On top of the traditional Network layer, virtualising the network nodes in two virtual layers, one for packet processing (CAN layer) and the other one for content delivery (Home-Box layer)
- Full User Environment, seamlessly interacting with the underlying layers
- Flexible Service Environment, based on cooperation between the traditional SPs and End-Users (through their HBs)
- Two level solution to fully support adaptation for the multimedia flow delivery over multi-domains
- Multi-layered monitoring solution at all defined levels: User, Service, Home-Box, CAN

5. Architecture examples: ALICANTE project

- **ALICANTE defines several environments:**
  - ***User Environment (UE)*, to which the End-Users belong;**
  - ***Service Environment (SE)*, to which the Service and Content Providers belong;**
  - ***Network Environment (NE)*, to which the Network Providers belong.**

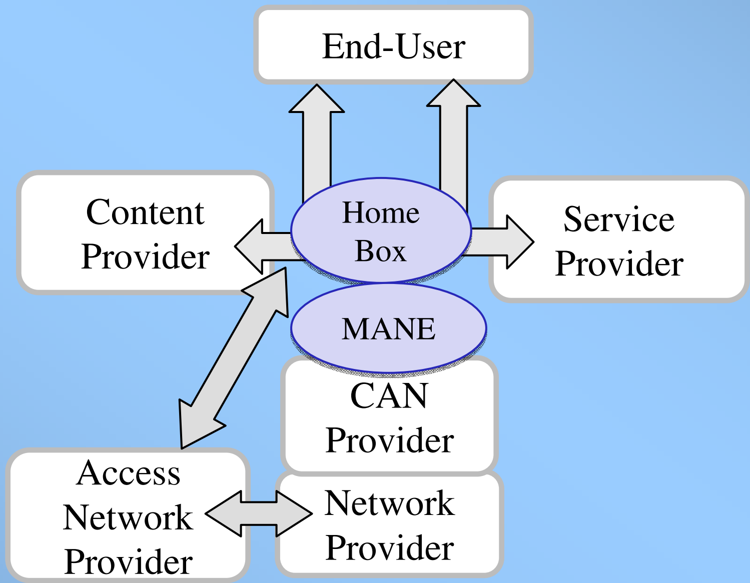
Environment : generic name to emphasize a grouping of functions defined around the same functional goal and possibly spanning, vertically, one or more several architectural (sub-) layers. (It has a broader scope, with respect to the term *layer*)

Business Actors:

- *Content Consumer* (CC) or *End-User (U)*
- *Content Provider* (CP)
- *Service Provider* (SP).
- *Network Provider* (NP)
- *CAN Provider (CANP)* is a new **ALICANTE** business

5. Architecture examples: ALICANTE project

New business models (BMs) flexible enough to include B2C, B2B, C2C and to consider new CAN features and service environment new capabilities



Business actors:

- Diversified single roles but also aggregated roles of SP, CP, NP, ANP, C/SCs, including incentive given to CCs in P2P Service Provider driven cases
- Cooperation between all actors involved, via appropriate static and/or dynamic SLAs
- Distributed management and independency of each actor in terms of managing its own resources

5. Architecture examples: ALICANTE project

ALICANTE business models evolution:

- By the internal ALICANTE business actors and telecom operators
- By external business actors, and in cooperation with other FP7 projects
- By evolution of BMs via successive evaluation of its efficiency in CAPEX/OPEX/ROI, during the project

- Exploitation models possible - based on ALICANTE's new business models
  - VoD distribution offered by CAN Provider with QoS guarantees through adaptation in MANE according to the overall User Context
  - IPTV Hybrid multi-domain multicast distribution offered by CAN Provider
  - ALICANTE's enhanced service personalization
  - Watch TV Anywhere at Any Time

ALICANTE new entities

MANE:

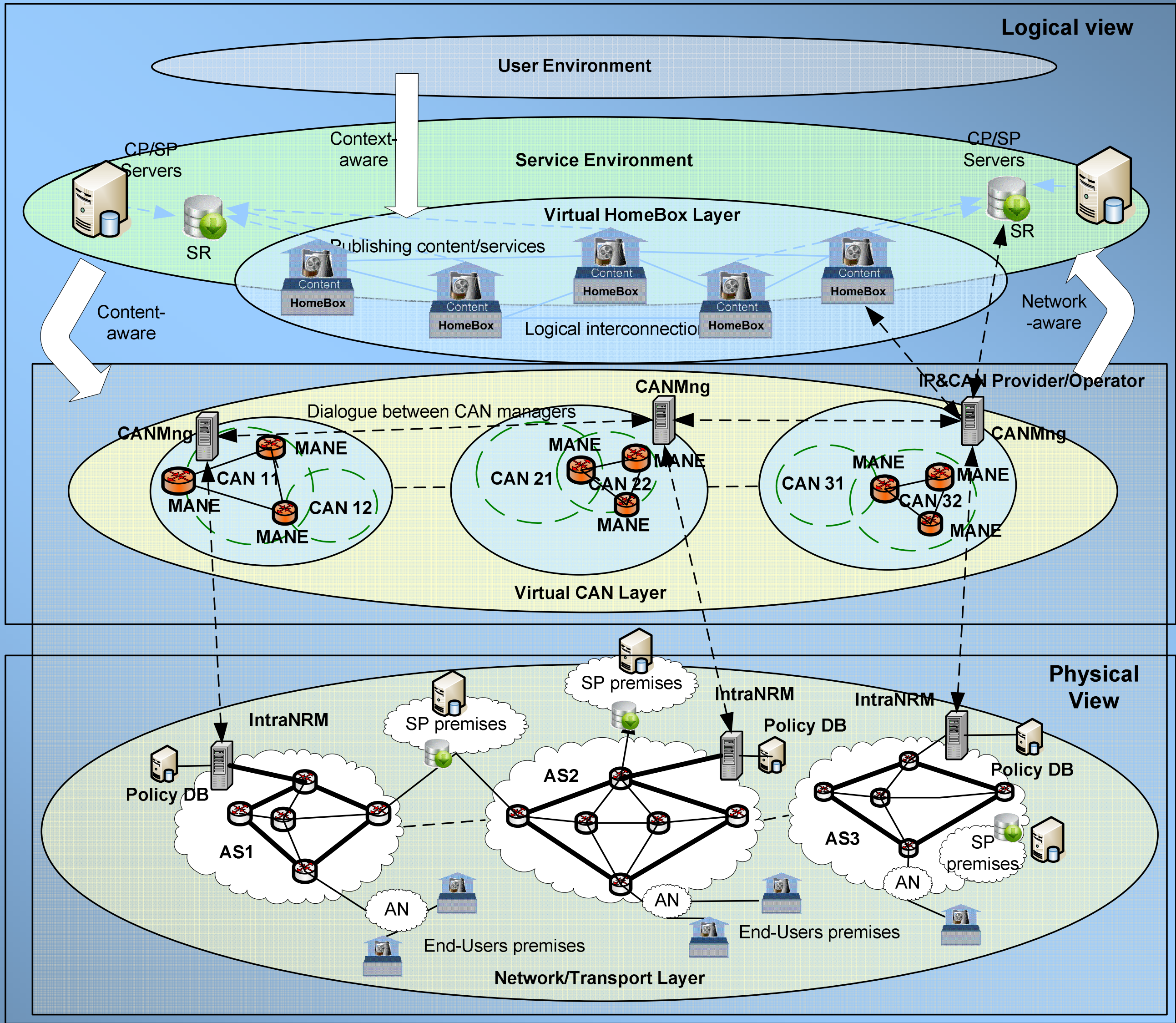
- Introduction of a new BM actor: CAN Provider
- CAN = enhanced capabilities to NP
- BM based on existing IP connectivity services + new offerings

Home-Box:

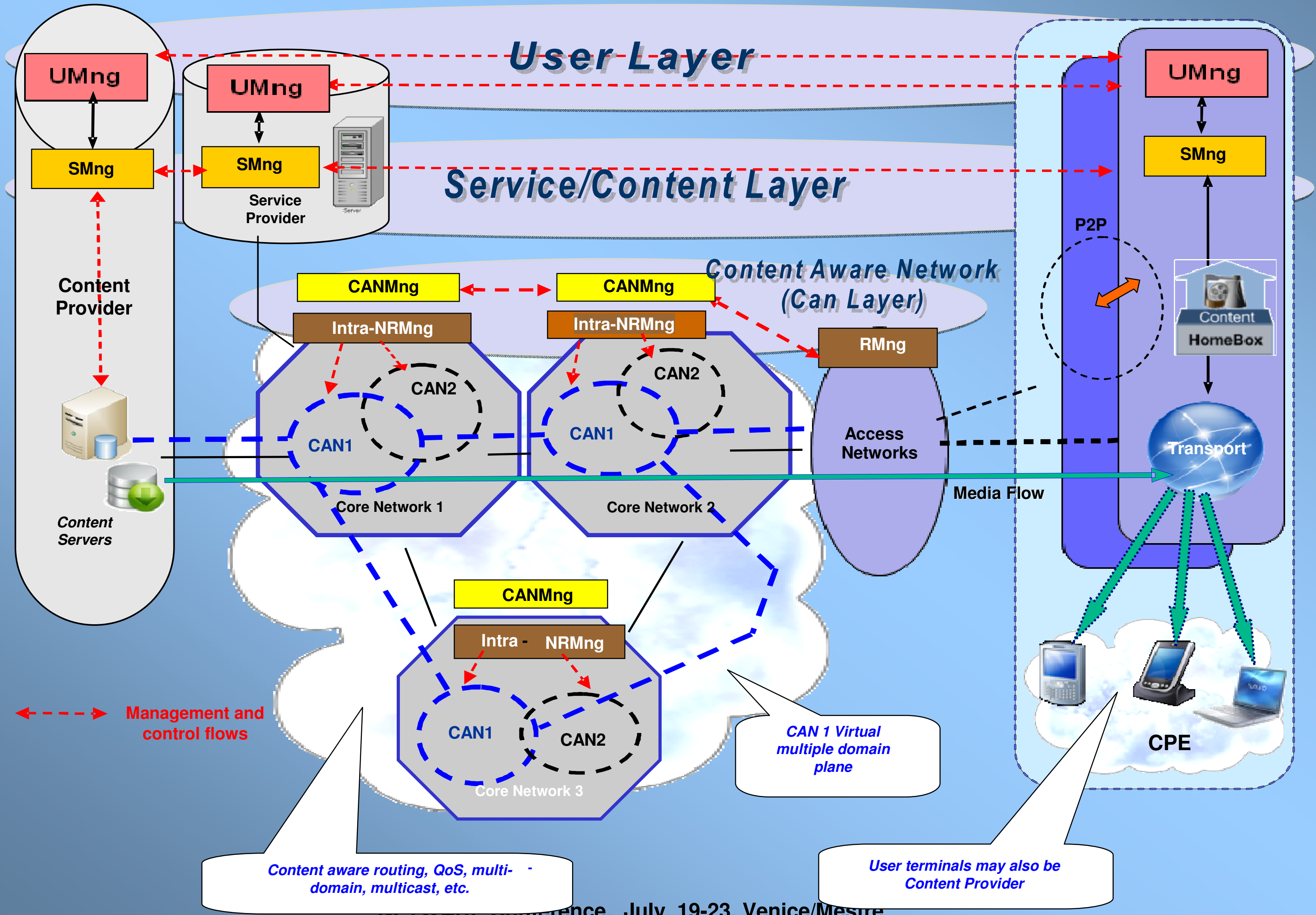
- Managed by SP, CANP, End-User
- Allows new BMs by giving End-User possibility to become CC, CP, CM
- New BMs by giving SP/CP multiple and efficient ways of distributing services and content

5. Architecture examples: ALICANTE project

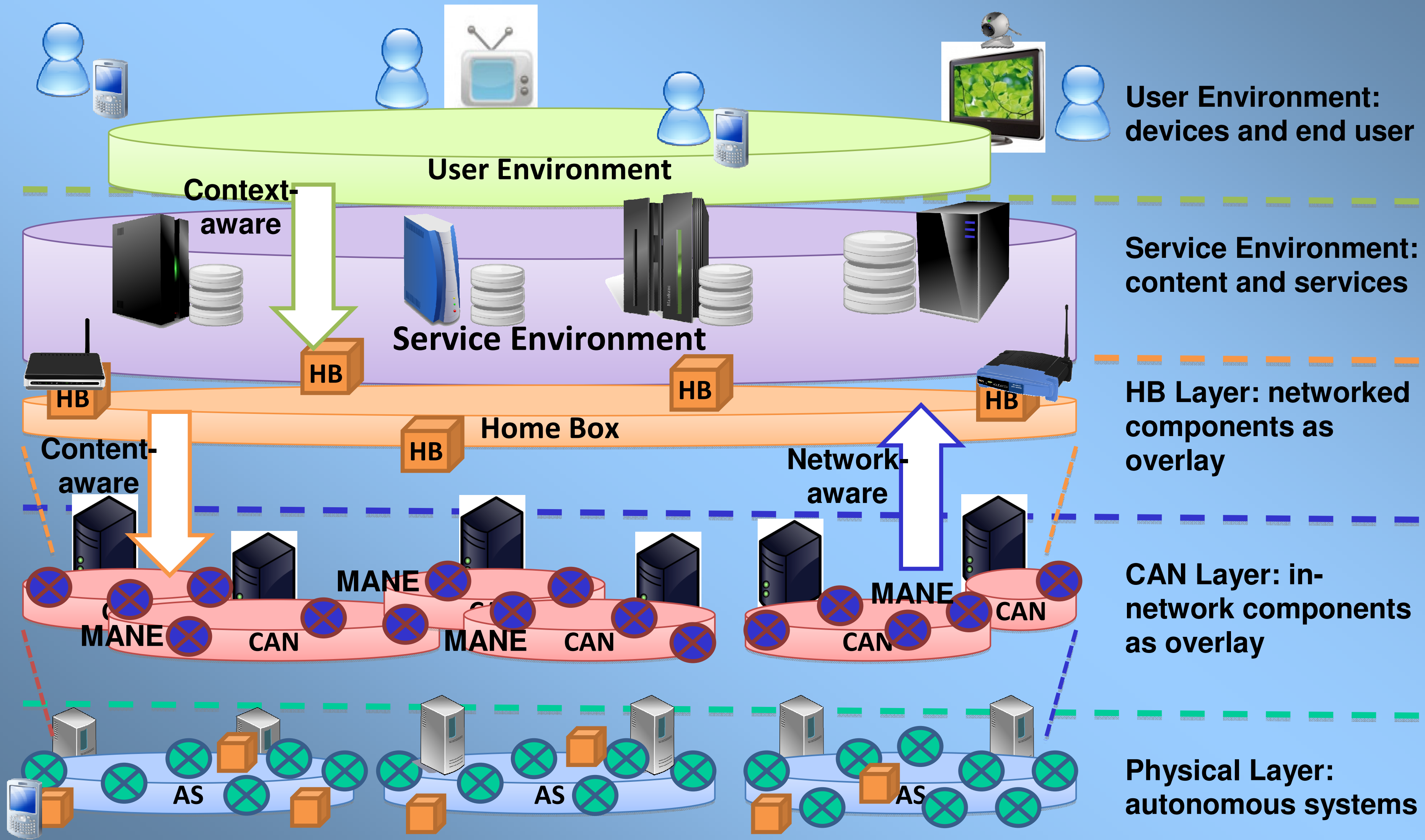
- **Overall Architecture**
  - **User Env**
  - **Service Env**
  - **HB-layer**
  - **CAN layer**
  - **Infrastructure layer**



5. Architecture examples: ALICANTE project



5. Architecture examples: ALICANTE project



5. Architecture examples: ALICANTE project

Architectural model

- **Scalability : important target while seen on several dimensions/ levels**
- **User and Service-Content layer:**
  - At management and control plane: Distributed per/entity; Aggregated and/or individual signalling
  - At data plane: P2P overlay inherent scalability; All HBs take part in the adaptation (done per class or individual) and distribution of content to other HBs
- **CAN and network layer:**
  - At management and control plane: distributed per/domain or per/entity; Aggregated and/or individual resource allocation
  - At data plane: Still push complexity at the edges; Network QoS procedures applied first and then adaptation if necessary

Architectural model (cont'd)
Scalability : important target while seen on several dimensions/ levels

Per/node entity model (e.g MANE):

- High performance algorithms for MANE (w.r.t packet inspection and fwd)
- Methods to reduce the amount of analysis task of packets (first packet of a flow- deep analysis, the rest- summarised processing)
- Policy-based management approach efficiency will be investigated for CAN configuration:
  - For better flexibility
  - To reduce the amount of processing tasks in the data plane by policy-based pre-configuring various CANs, where possible
- Cross-layer optimisation capabilities : CAN – HB powerful tool offered by the CAN and network aware applications approach

6. Architecture examples: ALICANTE project

- ***Hierarchy of Functions***
- New features inside the Network/Service/User Environments
- *At network level*:
- *applying CAN concepts*
  - network/transport intelligent content-aware processing (routing, dynamic adaptation, security, etc.) for existing and future emerging applications in a scalable, open and optimized way.
- *realizing distributed management and control*
  - customize the CANs as to respond to the upper layer needs, including 1:1, 1:n, and n:m communications,
  - efficient network resource exploitation at network provider level;
- *cross layer optimizations*
  - (CAN layer - upper layers), including P2P approach
  - optimization is possible due to network awareness capabilities of the upper layers

6. Architecture examples: ALICANTE project

Hierarchy of Functions (cont'd)

- ***At service/content level***
- *elaborating a new approach for the delivery of services*
  - HB : as a new element capable of advanced functionalities (service management and adaptation, user mobility, security);
- *creating a new virtual HB layer*,
  - virtually interconnected HB (distributed client/server mode or P2P mode)
  - capable of advanced provisioning of service/content;
- *dissociation of the roles (*in terms of service/content exploitation and delivery)
  - *Service/Content Providers capabilities*
  - *Home-Box layer role and capabilities*

- *enhanced services*:
  - *delivery* - through the servers or HBs, in various modes;
  - *discovery* - new type of component called *Service Registry (SR);*
  - efficient *management*;
  - *service composition* - Service Composition Engine for streaming media applications
- *achieving collaboration* with the User Environment and with the CAN layer

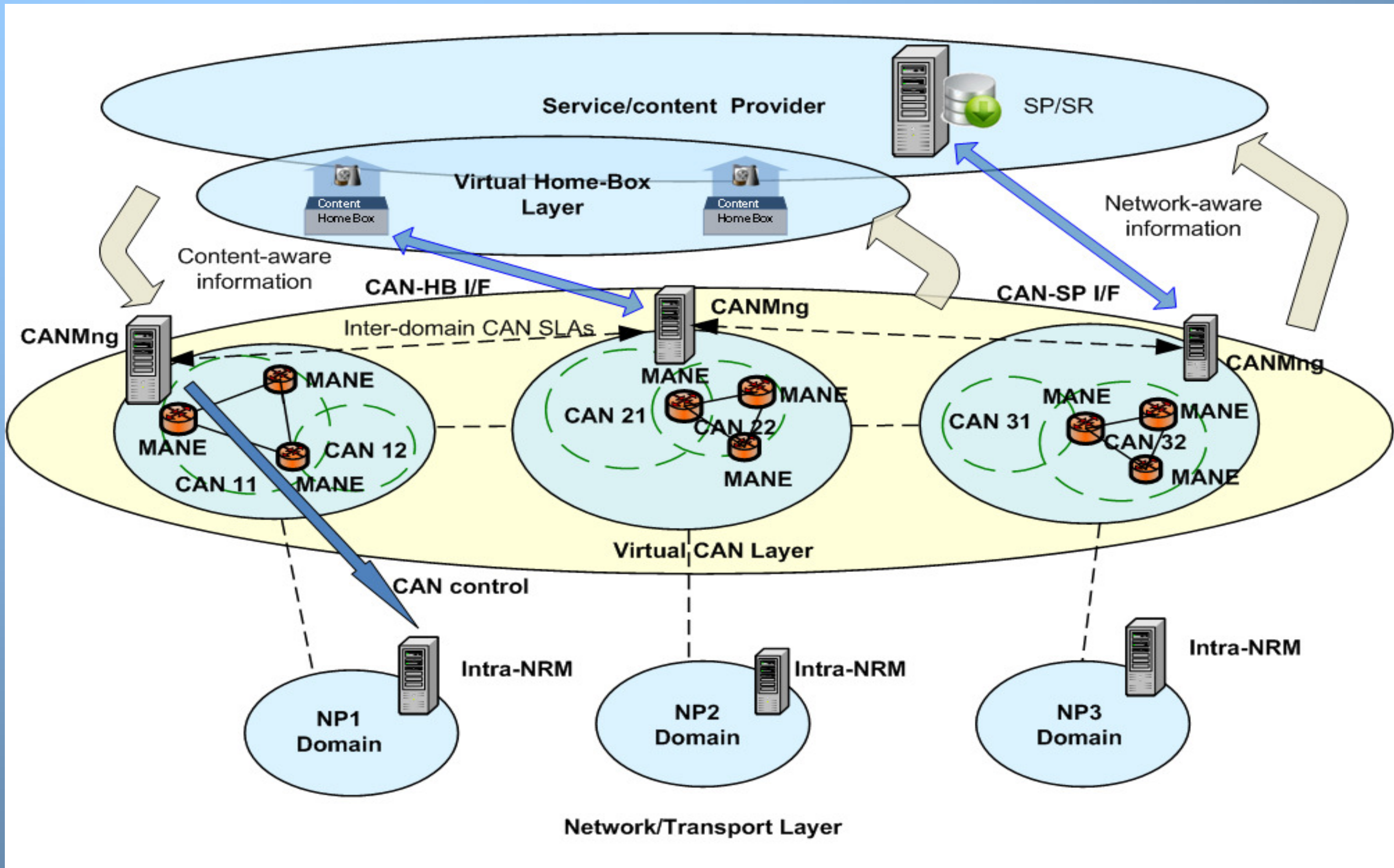
6. Architecture examples: ALICANTE project

Hierarchy of Functions (cont'd)

- **At user level**
- users can consume and/or generate content and exploit services delivered by components of the SE.
- *adding new dimensions* user may have several roles: Content and Service Consumer; Content and Service Provider; Content and Service Manager
- *elaborating a User Profile* : static and dynamic parameters of the user and his context
- *permitting any user* to access/deliver/manage any service/content on any device from anywhere and at any time
- *achieving efficient collaboration* with the SE, enabling user context-awareness

6. Architecture examples: ALICANTE project

- **Multi-domain CAN layer view**



5. Architecture examples: ALICANTE project

- ***Vertical and Horizontal Layering***
- ***Virtual Content-Aware Network (VCAN)***
  - an enhanced support for packet payload inspection, processing and caching in network equipment
  - developed over traditional IP network/transport layer
  - improves data delivery *via classifying and controlling messages in terms of content, application and individual* subscribers
  - improves QoS assurance via content-based routing and increases network security level via content-based monitoring and filtering.
  - The specific components VCAN are the
    - Media-Aware Network Elements (MANE), i.e., the new CAN routers
    - CAN managers.

5. Architecture examples: ALICANTE project

- ***Vertical and Horizontal Layering***
- ***Virtual Home-Box layer***
  - uses CAN services and network-aware information delivered by the CAN layer
  - HB inter-working with the User, Service, and Network Environments allows:
  - to elaborate network and context-aware appl. and deliver the necessary inputs to create CANs
    - adaptation, service mobility, security, and overall management of services and content are being assured at this layer
- ***Intra-domain Network Layer***
  - Traditional network TCP/IP layer
  - Managed by the Intra-domain Network Resource Manager
    - Having full authority on the network nodes and domain configuration
    - Cooperating with CANMng in order to negotiate and install CANs

5. Architecture examples: ALICANTE project

- ***Traditional Architectural perspective***
  - *Management*, *Control* and *Data Planes* (MPl, CPl, DPl) cooperating with each other.
- **Management and Control Interfaces:**
  - main management and control entity in the VCAN layer is the CAN Manager (CANMng)
  - Current solution: each network domain (AS) has a CAN Manager
  - **Interfaces of CAN Manager (vertical and horizontal)**
    - Dynamic, SLA/SLS based – plus negotiation protocol
    - **To the SE environment** : advertise, negotiate, construct CANs
      - help the establishing of connectivity relationships at Virtual HB layer based on, e.g., network related distance information
      - CAN at request of SE (provisioned)- guarantees
      - CAN established by the CANMng and advertised to SE- guarantees
      - CAN behqaviour versus individual flows- no guarantees
    - **to the lower network layer** (Intra-NRM) in order to negotiate CANs and request their installation.
    - **to other CANMngs** – in order to extend VCAN over several network domains

5. Architecture examples: ALICANTE project

- **The MANE/Content-Aware Network Router (CANR)**
  - intelligent network node.
  - Consider the content type in order to perform
    - appropriate processing (filtering, routing, adaptation, security operations, etc.)
    - according to the content properties (metadata, protocol field analysis) and also depending on network properties and its current status.
- **MANE basic set of functions :**
  - *Content-aware intelligent routing and forwarding*: based on results extracted from packet fields' analysis or content description metadata
  - *Content-aware QoS and resource allocation*
  - *Flow adaptation : e.g considering SVC codes*
  - *Specific Security processing*
    - Keep the traditional security procedures- plus specific treatment based on content type

6. Architecture examples: ALICANTE project

- **The MANE/Content-Aware Network Router (CANR)**
- **MANE basic set of functions :** (cont'd)

  - *Content-aware QoS and resource allocation:*
    - appropriate instances of CAN will be assigned to flows depending on the level of QoS guarantees and network status
    - the MANEs deduce the QoS requirements of different flows based on the flows content
    - MANE will assign the flows to the appropriate CANs
    - The CAN layer will monitor the current load CANs
    - The MANE will maintain an aggregated image of flows that they forward
    - Efficient resource allocation and/or load balancing –possible

- ***Architectural planes***
  - cooperating *Management*, *Control* and *Data Planes* (MPl, CPl, DPl)

- **Management and Control :**
  - CAN Manager (CANMng): main management and control entity
  - Current solution: each network domain (AS) has a CAN Manager

- **Interfaces of CAN Manager (V/H)**
  - Dynamic, SLA/SLS based – plus negotiation protocol

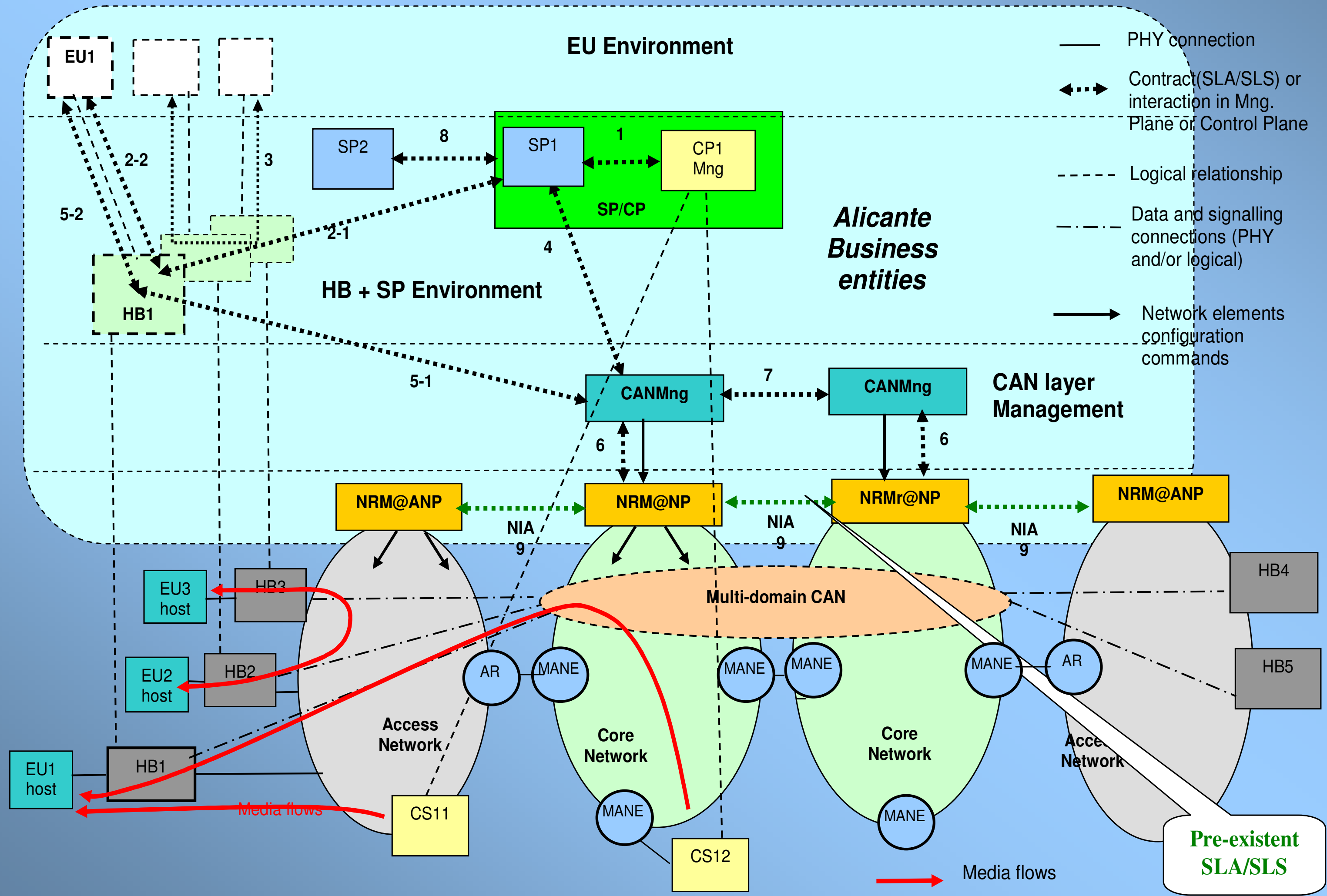
  - **To the SE environment** : advertise, negotiate, construct CANs
    - help the establishing of connectivity relationships at Virtual HB layer based on, e.g., network related distance information
    - CAN at request of SE (provisioned)- guarantees
    - CAN established by the CANMng and advertised to SE- guarantees
    - CAN behaviour versus individual flows- no guarantees

  - **to the lower network layer** (Intra-NRM) in order to negotiate CANs and request their installation

  - **to other CANMngs** –to extend VCAN over several network domains

  - **to HB** –to offer distance information for P2P communications

CAN layer in ALICANTE Environment: contracts/interactions



5. Architecture examples: ALICANTE project

- **Notations:**
- SP- Service Provider; HB- Home Box; EU End User; AR Access Router; BR- Border Router
- CS- Content Server; CPMng- Content Provider Manger; CANMng- CAN Manager (per-NP domain)
- NRM@NP – Intra-domain Network Resource Manager at Network Provider
- NRM@ANP- Network Resource Manager at Access Network Provider

- The management/control contracts/interactions can be of two types:
  - SLA/SLS – mid-long term contract on customer/provider basis , with some reciprocal commitments and/or guarantees offered by the provider
  - Ad-hoc interaction (like "session-based") to consume on fly content or use services (high level services or connectivity services) – without an SLA/SLS

5. Architecture examples: ALICANTE project

- **Management/control contracts/interactions**
  - ***SP- CANP*** – SLA/SLA through which SP requests to CANP
    - to provision new CANs (single or multi-domain ones)
    - to modify/remove existing CANs
    - to allow to CANP to inform SP about its capabilities to treat in CAN style (i.e differentiated) the media flow packets but without any guarantees
  - ***HB- CANP*** – (based on SLA or not) through which the HB could ask CAN services directly from CANP (without intermediation of SP- for instance in order to find distances between HBs)
  - ***CANP- NP*** - SLA/SLS through which the NP offers commits to offer resources to CANP. These data are topological and quantitative ones.
  - ***CANP-CANP*** –SLA/SLS through which a given CAN is extended upon several NP domains
  - **SLA/SLS for network interconnection agreements** (NIA) between the NPs or between NPs and ANPs

5. Architecture examples: ALICANTE project

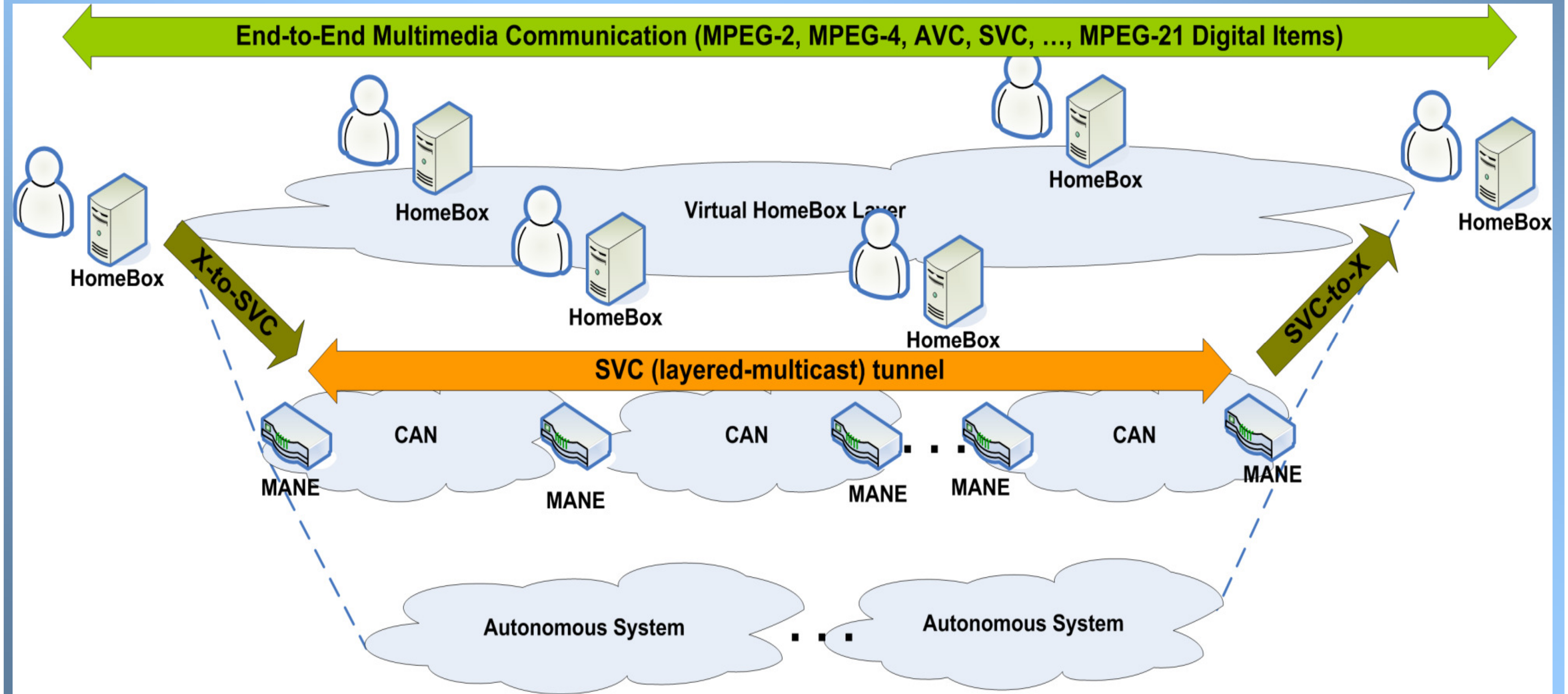
- **Management/control contracts/interactions**
  - ***SP-CP*** – SLA/SLS - to allow SP to *advertise, offer, negotiate and distribute* content produced by CP (the CP might be a traditional one or an EU), through high level services (this is not mandatory to exist in Alicante)
  - ***EU-SP*** in order to establish:
    - SLA/SLS to subscribe and later invoke to high level services offered by SP
    - SLA/SLS –to give the rights to SP to distribute content produced by EU
    - Ad-hoc interaction through which the EU try to consume content if currently available
  - ***SP-SP*** –SLA/SLS- concluded if SPs wants to cooperate in offering services

5. Architecture examples: ALICANTE project

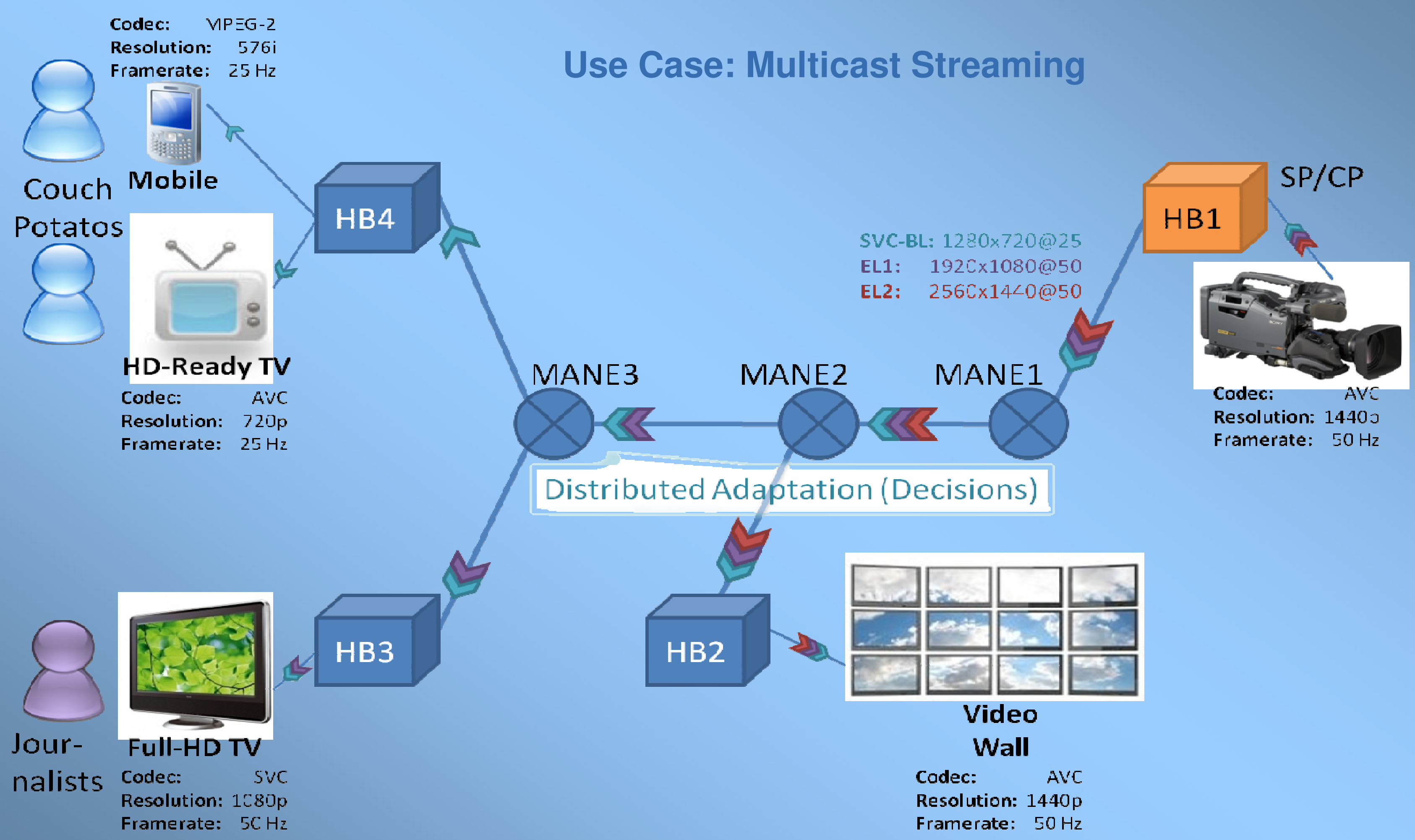
- **Summary of the Main challenges at CAN Layer**
  - Offer all above capabilities – content aware related
    - QoS, routing/forwarding, adaptation, security, caching,
  - While:
    - Keep the amount of per/packet processing as low as possible in order tu function at high line rate
      - E.g.:First packet deep analysis plus hash table techniques
    - Allow seamless development in the network
      - Primarily – they will be installed at core domain edges
    - Preserve the Intra-domain independency combined to offering capability to extend VCAN over multiple domains
    - Taking into account network dimensioning information provided by the IntraNRM when designing CANs

5. Architecture examples: ALICANTE project

- **Adaptation**: Key innovation in Alicante
- SVC tunnel with in-network adaptation
  - Better network resource utilization
  - Maintaining a satisfactory Quality of Experience for the end user

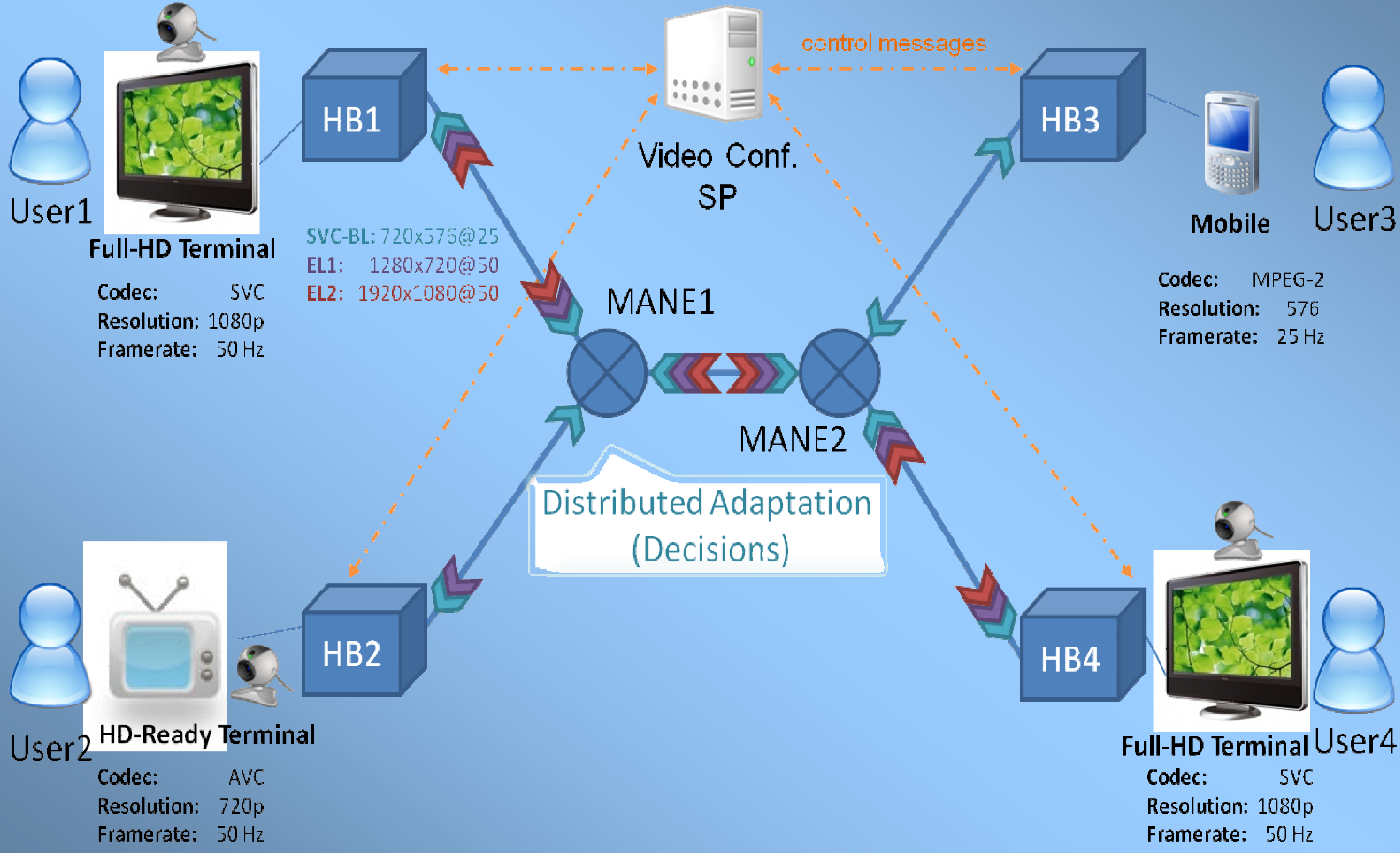


5. Architecture examples: ALICANTE project



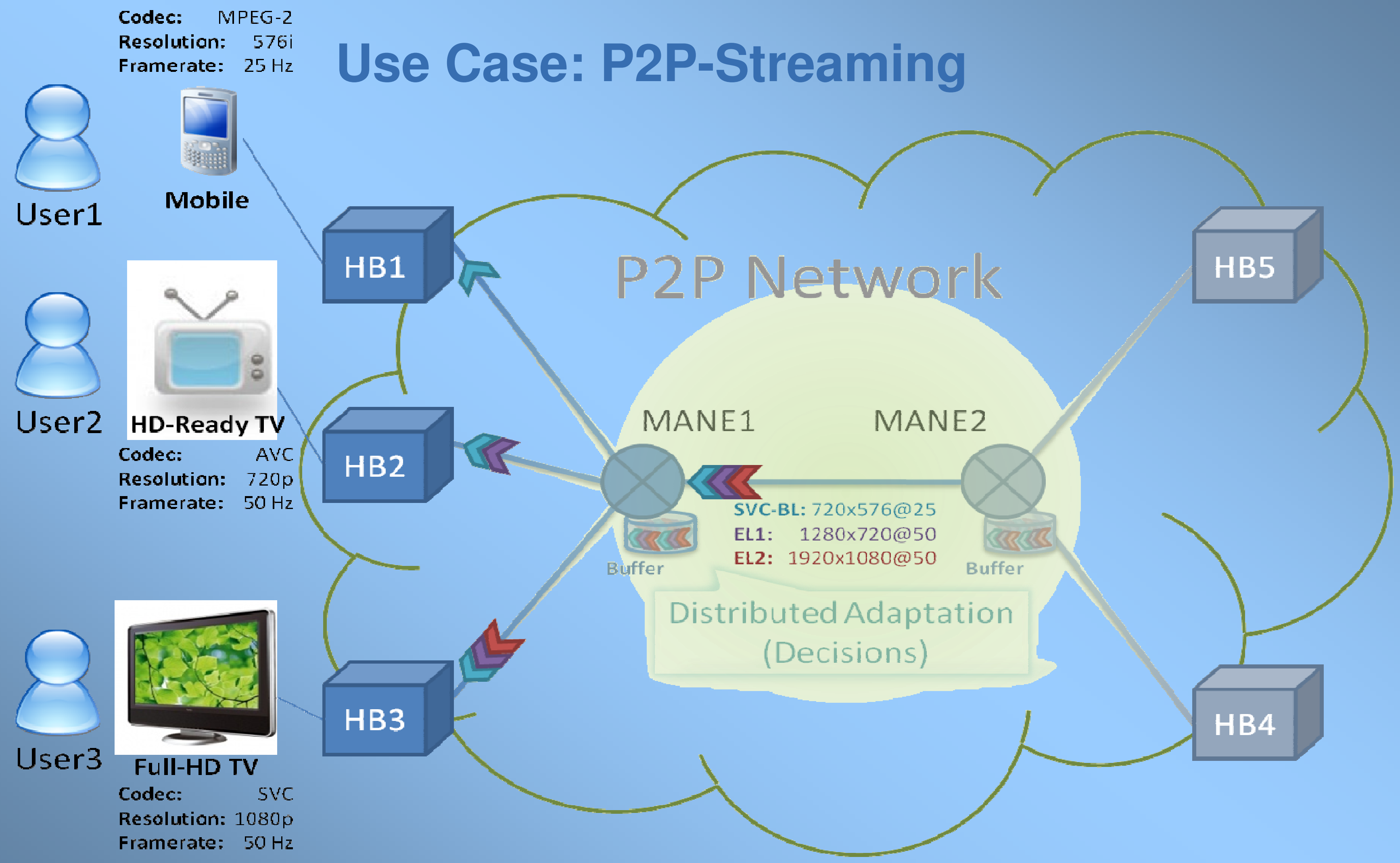
5. Architecture examples: ALICANTE project

Use Case: Video Conference

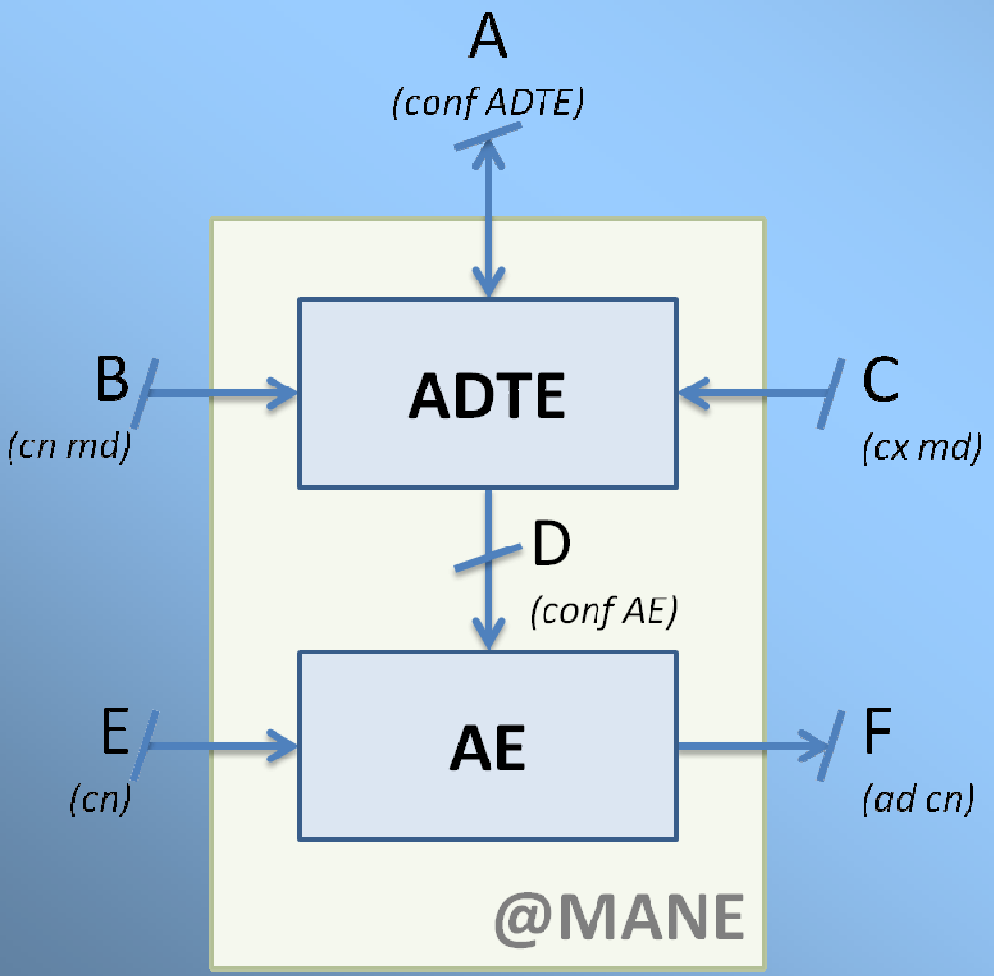


5. Architecture examples: ALICANTE project

Use Case: P2P-Streaming



Adaptation: Generic Architecture



Legend

A … configure ADTE (input/output)

B … content metadata (input)

C … context metadata (input)

D … configure AE (input/output)

E … content (input)

F … adapted content (output)

5. Architecture examples: ALICANTE project

Adaptation: Generic Architecture (cont‘d)

- Adaptation at the CAN layer (online)
  - MANEs only at edges of AS
  - CAN Monitoring available only in aggregated form
  - SVC scalability
    - Spatial: Multiple resolutions in ELs
    - Temporal: Multiple frame rates
    - SNR (Quality): Multiple bitrates
- Adaptation at the HB layer
  - X-to-SVC and SVC-to-X transcoding
    - SVC encoder/decoder, SVC-to-AVC & AVC-to-SVC
  - All scalability dimensions supported
  - Offline and real-time adaptation possible (at the SP/CP side)

5. Architecture examples: ALICANTE project

- Conclusions ALICANTE
  - New architecture oriented to
    - Content aware networking
    - and Network aware applications
  - Environment/layers: User, Service, Home-box, CAN
  - Horizontal and vertical cooperation between the CAN layer and upper layer
  - Combines the networking technology with adaptation methods
  - Allows multimedia oriented services to be developed in a flexible way
  - Multi-domain
  - Users as consumer and producers of content

CONTENTS

6. Conclusions

- **Still open questions:**
  - Preserve the current network neutrality?
  - Content aware networking- Network Aware Applications- traditional protocol stack modifications
  - Content Centric Networking- new paradigm for IP networking
  - Virtualisation – strong tool helping also CAN , CCN – still open to research
  - New business models are needed
  - Acceptance in practice of these new approaches ?

- Thank you !

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- Questions?