

Future Internet Assembly - Stockholm

Future Content Networks: Emerging Evolutionary and Future Visionary Approaches

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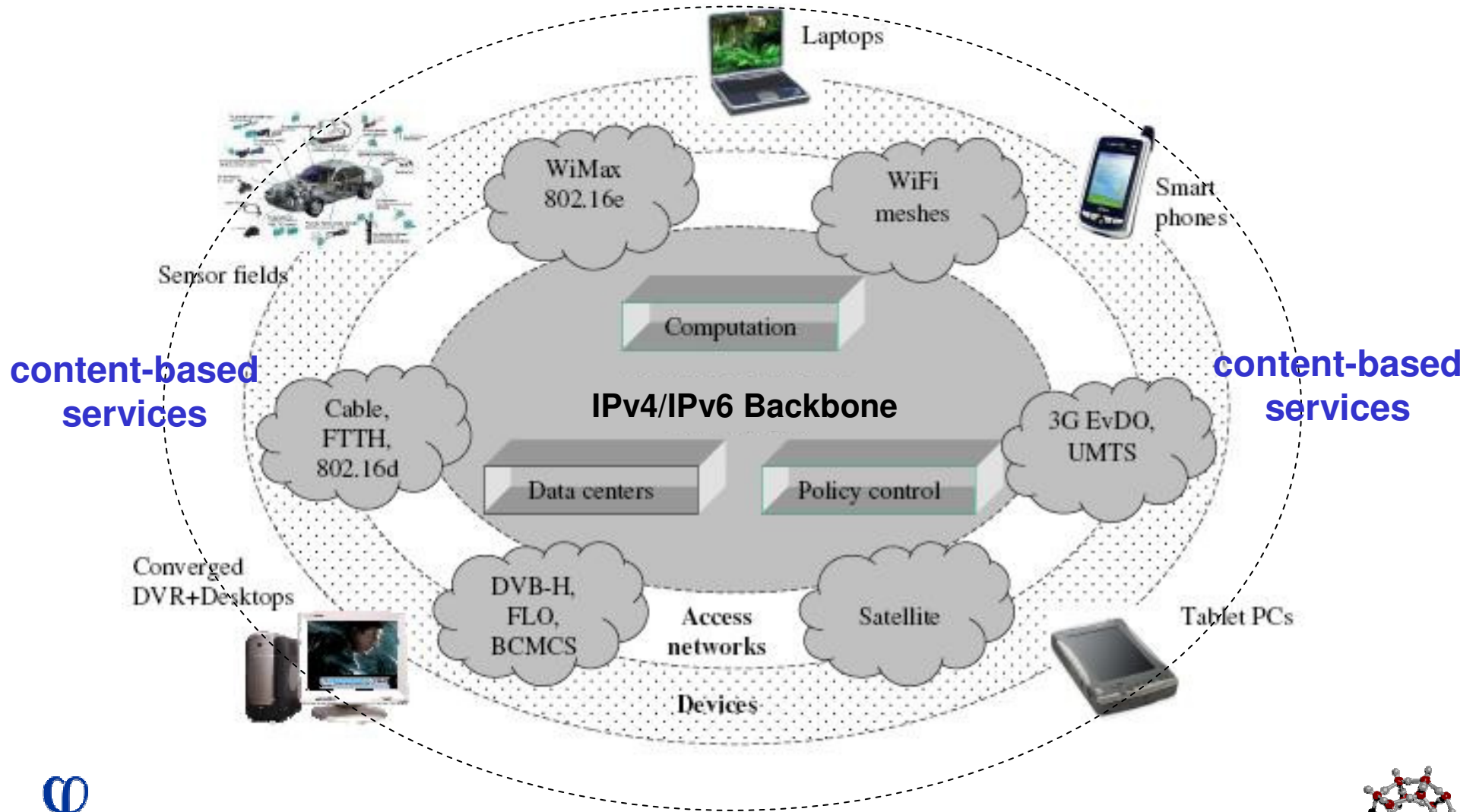
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Internet-based Content

- The Internet plays a central role in our society
 - Work and business, education, entertainment, social life, ...
- The vast majority of interactions relate to content access
 - Media aggregators (e.g. YouTube, GoogleVideo)
 - P2P overlays (e.g. BitTorrent, eMule)
 - Content Delivery Networks (e.g. Akamai, Limelight)
 - Social Networks (e.g. Facebook, MySpace)
 - Photo sharing sites (e.g. Picasa, Flickr)
 - Emerging immersive interactive applications
- User-generated content is expected to proliferate
- New approaches are required to cater for the explosion of video-based content and for creating novel use experiences
- **Solution space: evolutionary and visionary approaches**

The Emerging Content-based Internet



Future Content Networks (FCNs)

- Given the massive emergence of video content and the fact the Internet was not originally designed for that, new architectural approaches are being investigated
- **Evolutionary approaches**: these operate in the application/service layer and start from previous content-delivery architectures
 - More traditional view of FCNs
- **Visionary approaches**: these operate across layers, from the network layer upwards, and change the fundamental naming and addressing assumptions of IP
 - Visionary & Revolutionary view of FCNs => Content-Centric Networks
- **Content-Centric Networks (CCNs)** are emerging as a hot research topic worldwide



Evolutionary Future Content Networks

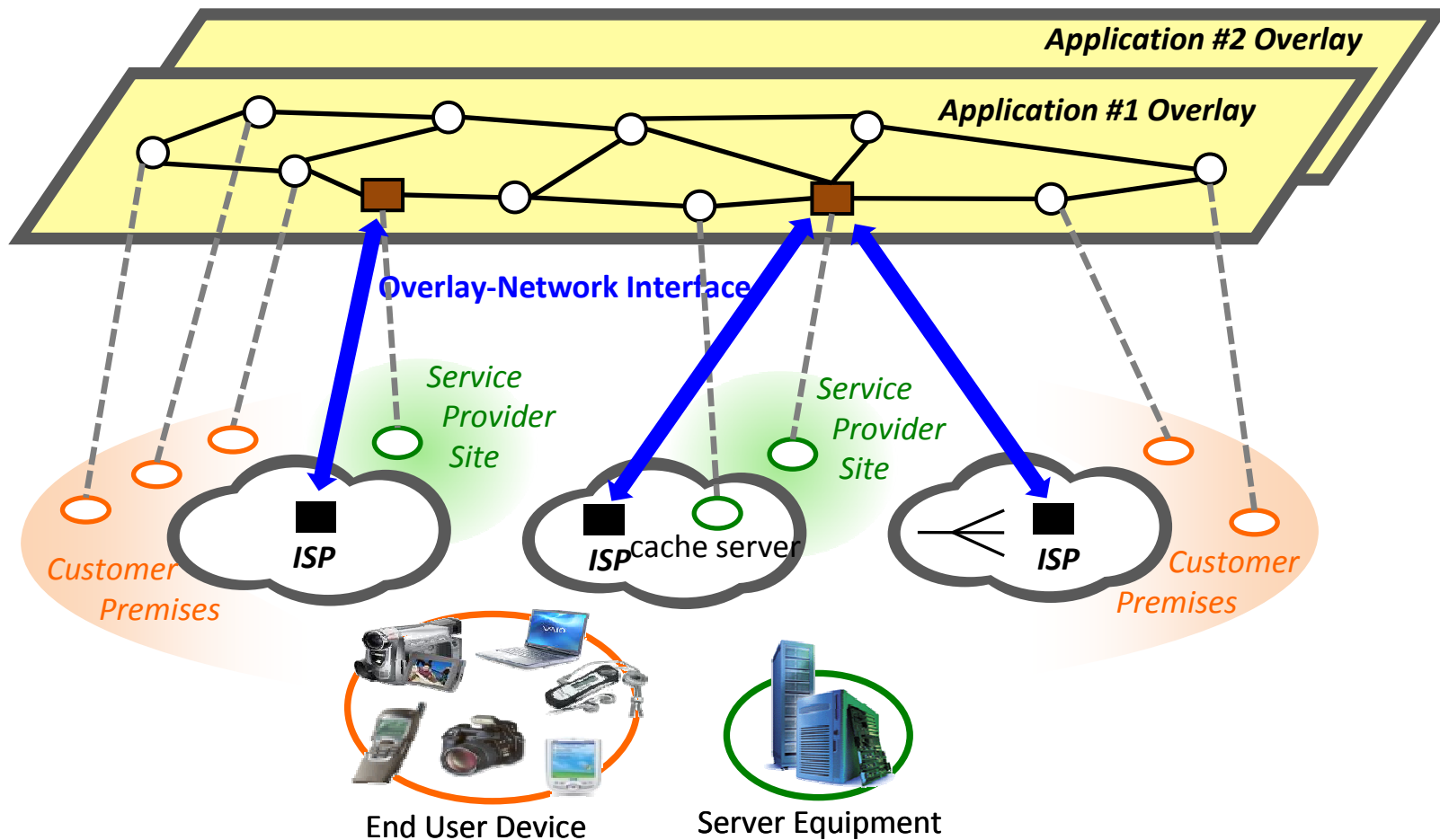
- Evolutionary (overlay) FCN approaches have originated from the fact that the current Internet does not support:
 - Inter-domain Quality of Service (QoS)
 - Inter-domain Multicast
 - Anycast
- **Content Distribution Network (CDN) approaches:** pioneered by Akamai, they support an anycast model by choosing the most appropriate content replica to maximise QoS/QoE
 - Overlay location approach, uses a network-level shortest path between the content server & consumer
- **Peer-to-Peer (P2P) Approaches:** started from file sharing, they stream video through overlay nodes
 - Overlay location and streaming approach, overlay delivery path can be different to (network) shortest path between server & consumer

Evolutionary FCNs (cont'd)

- A number of EU FP7 projects have been / will be looking at the evolution of content delivery architectures based on optimised overlay networks in different P2P variations
 - Running projects: [NAPAWINE](#), [P2P-NEXT](#), [TA2](#)
 - About to start: [DIOMEDES](#), [OCEAN](#), [OPTIBAND](#), [SARACEN](#) (call 4)
- A number of other projects will be looking at multidisciplinary approaches with cross-layer optimisation from both a content and network perspective
 - Evolutionary as they do not require radical network changes
 - About to start: [COAST](#), [ENVISION](#), [ALICANTE](#) (call 4)
- A key aspect in emerging evolutionary approaches is the coordinated overlay and network optimisation (e.g. P4P)

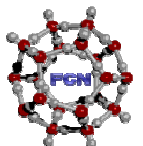
Coordinated Overlay-Network Operation

content producers & consumers, transcoding gateways, NAT gateways, caches, storage & processing power servers, application & overlay control coordinators, etc.



Visionary Content-Centric Networks

- Visionary CCN approaches have originated from the fact that most of the Internet interactions are user-to-content instead of host-to-host
 - Also from the well-known limitation of the current Internet in which address and identity are the same
- User-to-user communication has similar properties with user-to-content access, given users are identified by IDs
 - Voice or video communication between humans can be thought as bi-directional real-time generated content
- Relevant approaches propose native routing based on IDs instead of network addresses
 - Easy support for multicast, mobility and possibly privacy
 - Some also treat name resolution and routing together

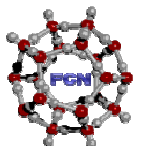


Background and State-of-the-Art on Visionary Content Centric Networks

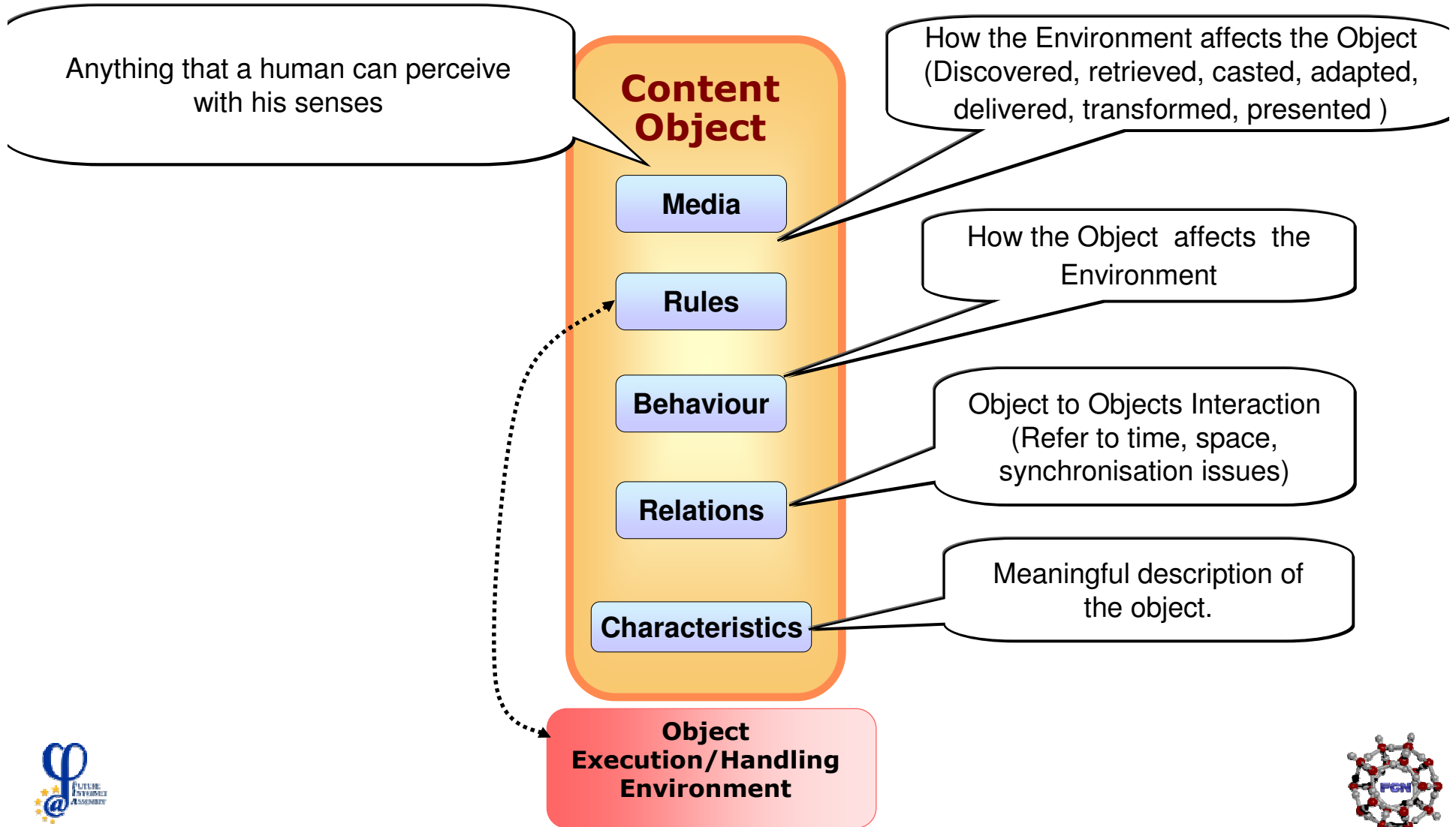
- As early as 2002, Stoica et al (Berkeley) proposed the **Internet Indirection Infrastructure (I3)** in which routing is based on IDs with rendezvous-based communication
 - Sigcomm 2002, most CCN architectures today adopt ID-based routing
- In 2004, Balakrishnan et al (MIT-Berkeley) proposed a **3-Level Name Resolution**: user-id to service-id, service-id to endpoint-id and endpoint-id to network address
 - Sigcomm 2004, today's locator-ID separation is a simplification of this
- In 2006, Caesar et al (Berkeley) proposed the **Routing on Flat Labels (ROFL)** approach which does not split identity and location but get rids of location for direct ID-based routing
 - Sigcomm 2006, superseded by the DONA approach of the same group

Background and SoA on Visionary CCNs (cont'd)

- In 2007, Kooponen et al (Berkeley) proposed the **Data-Oriented Network Architecture (DONA)** in which name resolution and routing are combined, based on IDs
 - Sigcomm 2007, key influence on emerging CCN architectures today
- In 2009, Jokela et al (Ericsson) proposed the **Line Speed Pub/Sub Inter-Networking (LIPSIN)** approach which employs an Internet-scale pub/sub approach for content access
 - Sigcomm 2009, emanated from the EU FP7 project PSIRP
- In 2009, Jacobson et al (Xerox Parc) – confirmed speaker for FIA Valencia - proposed the **Networking Named Content (NNC)** approach which treats content as a network primitive and retrieves content directly by name
 - CoNEXT 2009, to be tested by FP7 instead of US NSF projects



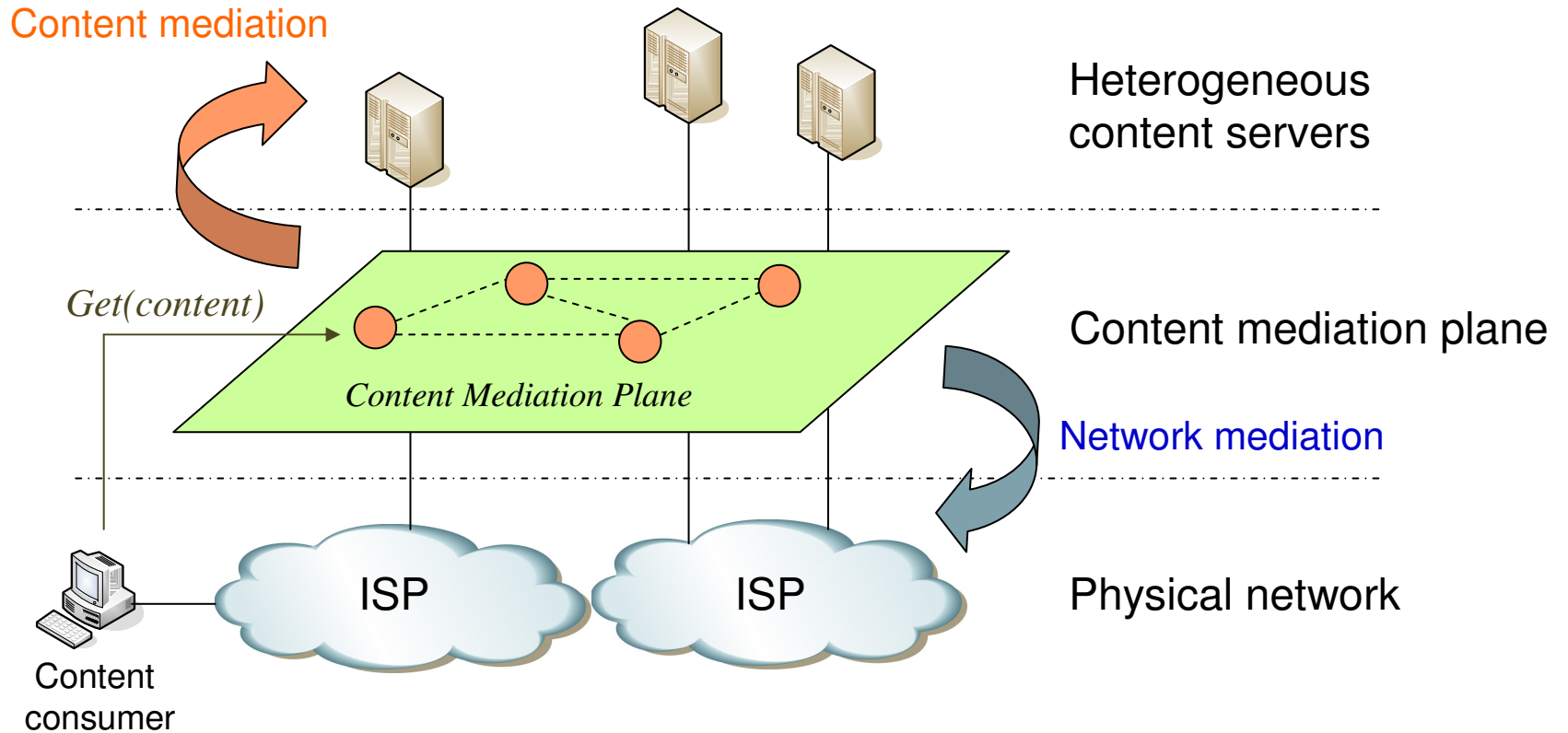
Autonomous Layer-Less Object Architecture (ALLOA)



Visionary CCN Projects

- A number of EU FP7 projects have been / will be looking at visionary and multidisciplinary content-centric architectures, combining content search, access and routing
 - Running projects: [PSIRP](#), [4WARD](#) (more network-oriented bias)
 - About to start: [COMET](#), [I-SEARCH](#) (call 4)
- A number of other projects are expected to start from call 5, focusing on future networking and self-management aspects
- A key aspect in emerging visionary content-centric approaches is the unification of content resolution / access and routing
 - The network can be thought of as providing a native [Content Mediation Plane](#)

Content Mediation Plane Approach



- The content mediation plane can be implemented in a revolutionary manner, directly in network routers

Summary

- Both **evolutionary** and **visionary / revolutionary** approaches for Future Content Networks
 - Evolutionary ones use different P2P variations with cross-layer optimisation – overlay & network coordination
 - Visionary ones propose multidisciplinary research on architectures that integrate native routing based on content and user IDs instead of network addresses
- Content-Centric Networks are right in the heart of the Future Internet, a driving force in FIA and visible to end-users, applications and services
 - Potential CCN cluster to be discussed
- Content-Centric Networks + Future Internet => **Future Media Internet**
- **Europe is in a unique position to make impact!**



Thank you for your attention!

This talk was supported by the EMANICS
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