



# The Content Mediation Approach Towards Future Information-Centric Networks

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# Key Challenges in Information-Centric Networks

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- **Content naming**: names/IDs should be location independent and searchable / accessible in a unified manner
  - Should scale to billions of content entries
- **Combined name resolution and routing**: routing by name/ID directly to the content copy (or user in the return path)
  - First proposed by the Data-Oriented Network Architecture (DONA)
- **Network-awareness**: resolving and delivering content based on the current state of network & content server
  - Performance optimisation and management within the network
- **Content replication/caching in routers**: the difference between routers and servers will tend to diminish
  - In-network torrent-based caching

- **Growing proliferation of Internet content**, both user-generated but also through companies seeing business opportunities
  - Users websites, social networks (Facebook, MySpace, etc.), photo sharing sites (Picasa, Flickr, etc.), pre-recorded media aggregators (YouTube, GoogleVideo, etc.), content delivery networks (Akamai, Limelight, etc.) or P2P networks
  - Companies such as Blockbuster, Netflix, Apple, etc. sell content and other content businesses are expected to proliferate
- **Users currently need to know the content location *a priori* and search for it through the relevant intermediary**,
  - global content search and direct access are *fragmented*
- **Content delivery simply uses the best-effort shortest path** dictated by the Internet routing architecture
  - Relevant resources may be strained, impairing the user quality of experience despite the potential existence of other resources

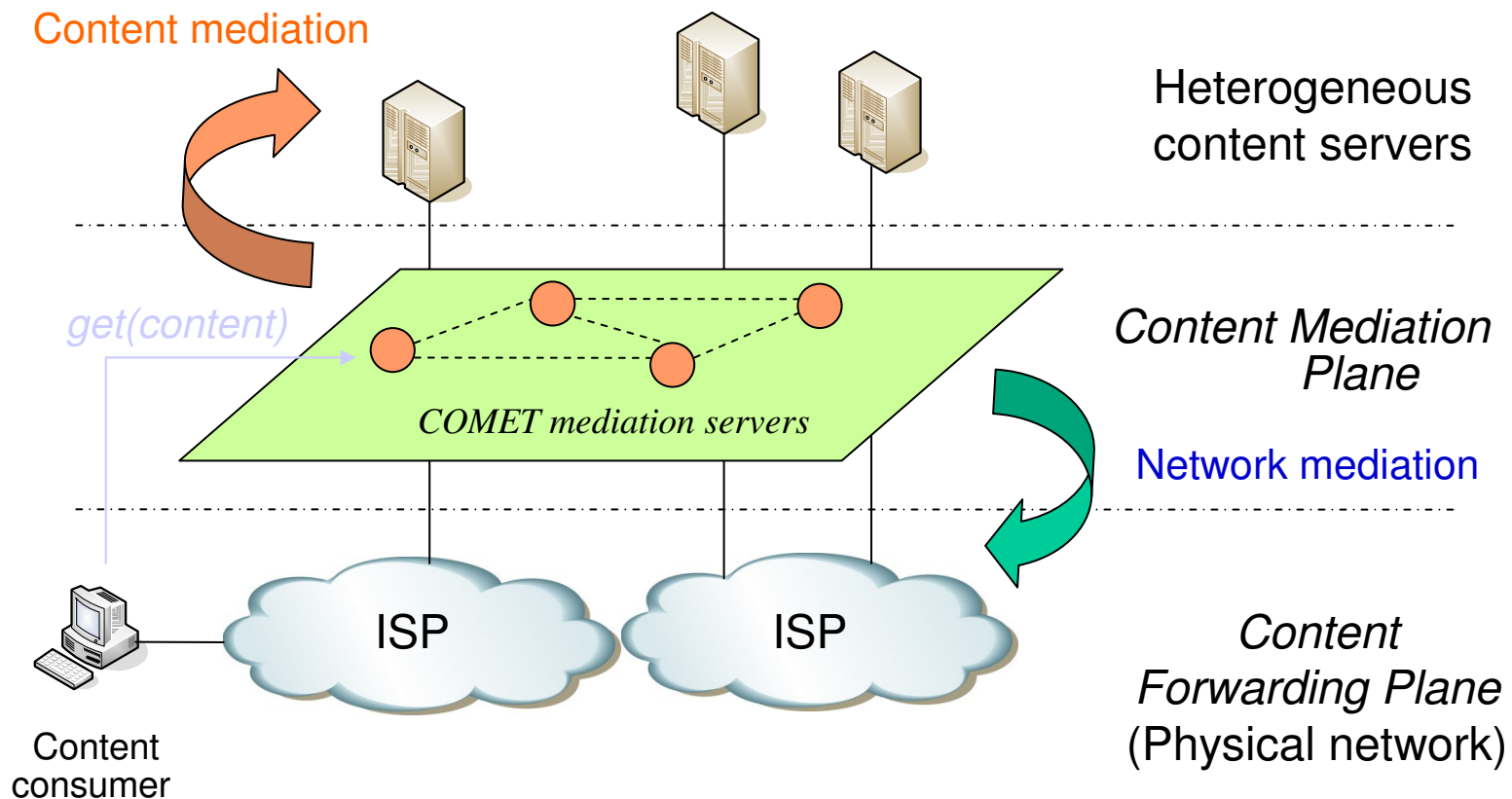
# Top-level Objectives

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- **COMET aims to provide a unified interface for content access whatever the content characteristics are:**
  - temporal nature (pre-recorded or live),
  - physical location (centralised or distributed),
  - interactivity requirements (elastic or real-time)
- **It also aims to apply the most appropriate end-to-end transport strategy for content delivery:**
  - By mapping the content according to its requirements and user preferences to the appropriate network resources
    - Best quality of experience (QoE) for end users
  - All different types of content distribution will be supported:
    - *Unicast, Anycast, Multicast, P2P-delegated*

# The Content Mediation Plane

- The Content Mediation plane combines content resolution and access:
  - Locating content according to delivery requirements (content mediation)
  - Delivering it using the most suitable resources (network mediation)



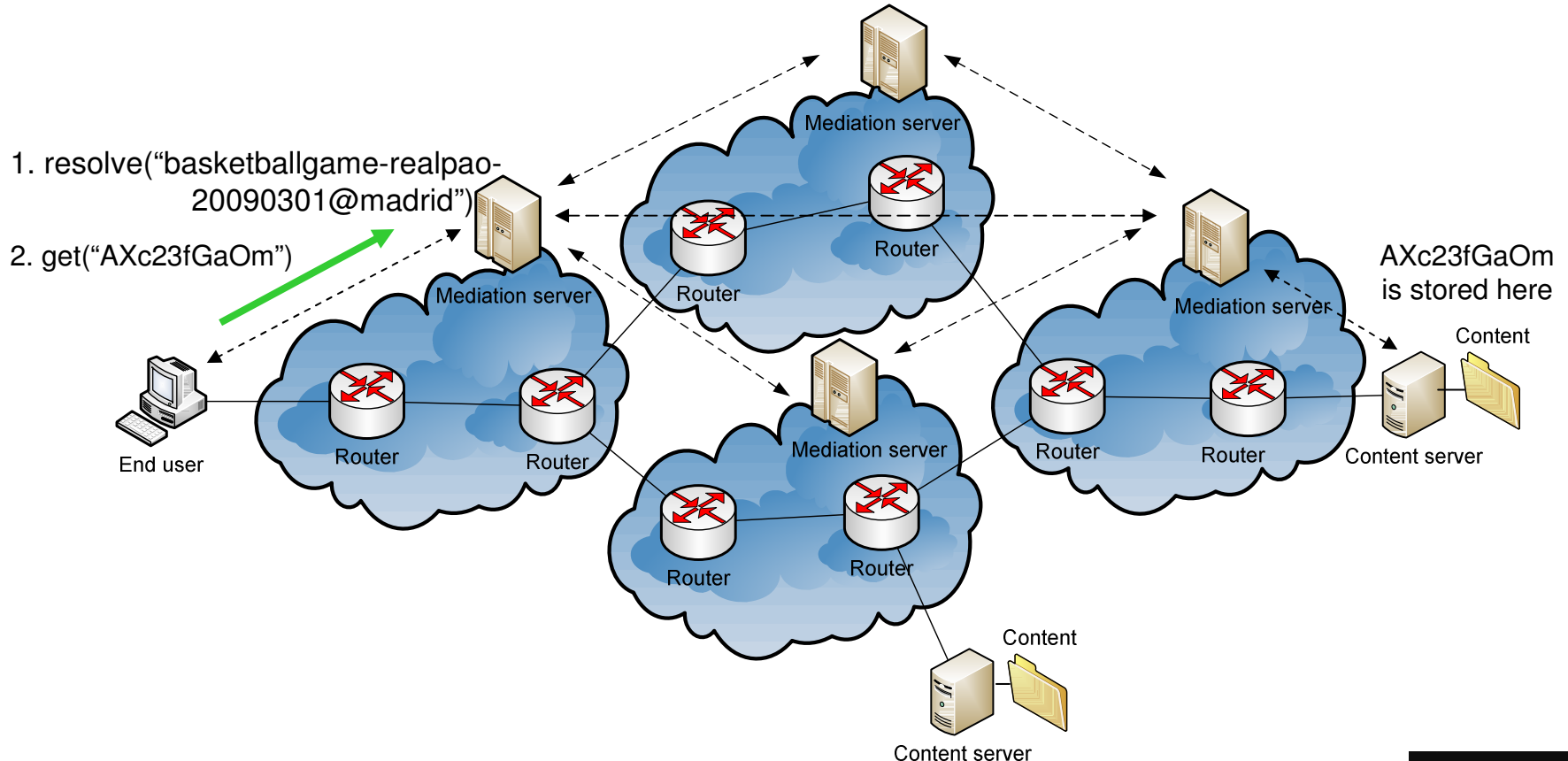
# Detailed Objectives

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- Investigate a **content and network-aware architecture that is intermediary and location-independent**
- Investigate the issues behind a **content resolution and access plane of *massive scale*** and consider different approaches for its realisation
- Specify **protocols and interfaces** to the content mediation system **for content resolution, content publishing and content indexing**
- **Consider network awareness in the content mediation plane** and investigate current Internet-based and evolutionary traffic management and routing schemes to provide the adequate QoE
- Examine the **possibility of native network-level routing based on content and user identifiers** instead of network addresses, aligning the project's work and contributing towards Future Internet efforts

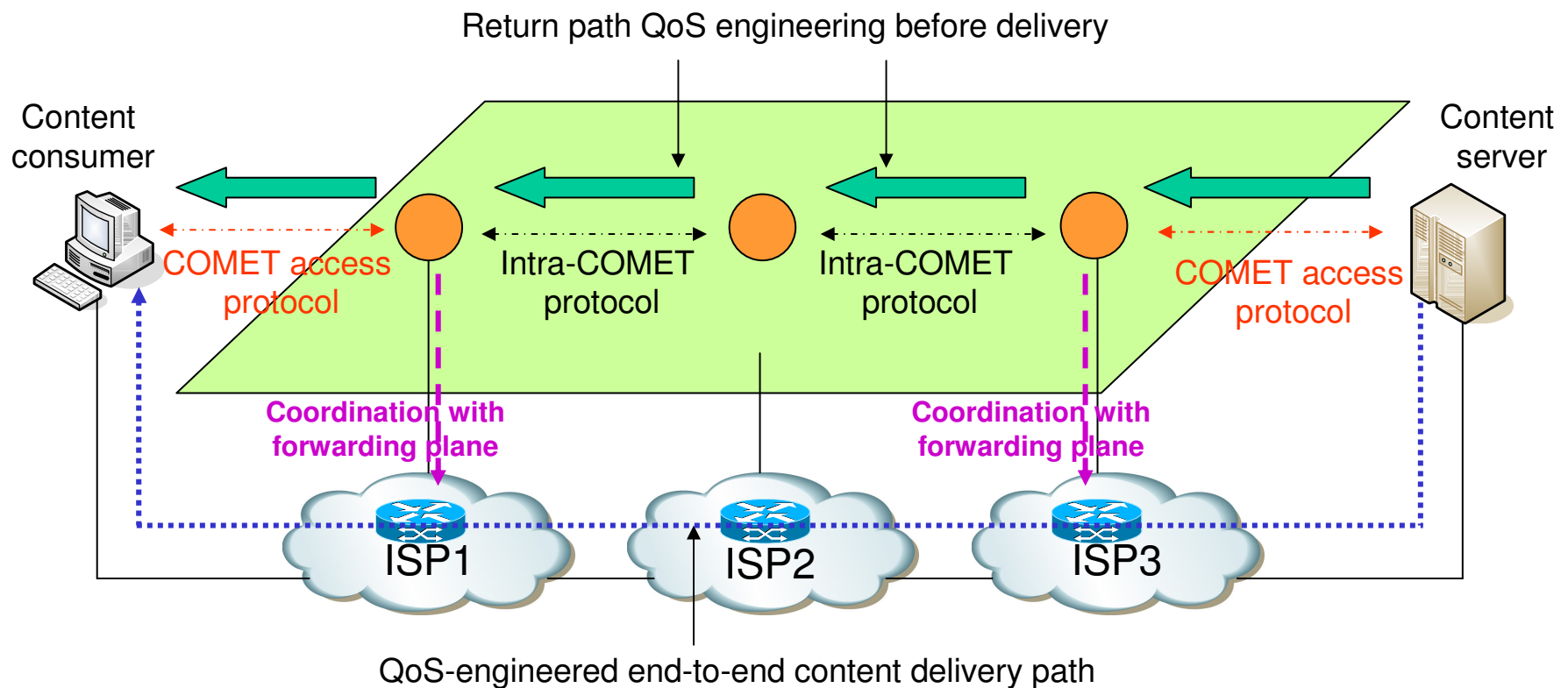
# COMET<sup>o</sup> Example Deployment Architecture

- Content name or alias resolution to content ID and content access through the content ID
- Chaining of the request through COMET servers until the right copy is found based on both the state of the network and of the holding server(s)
- ID-based routing supports mobility, privacy and network-independence



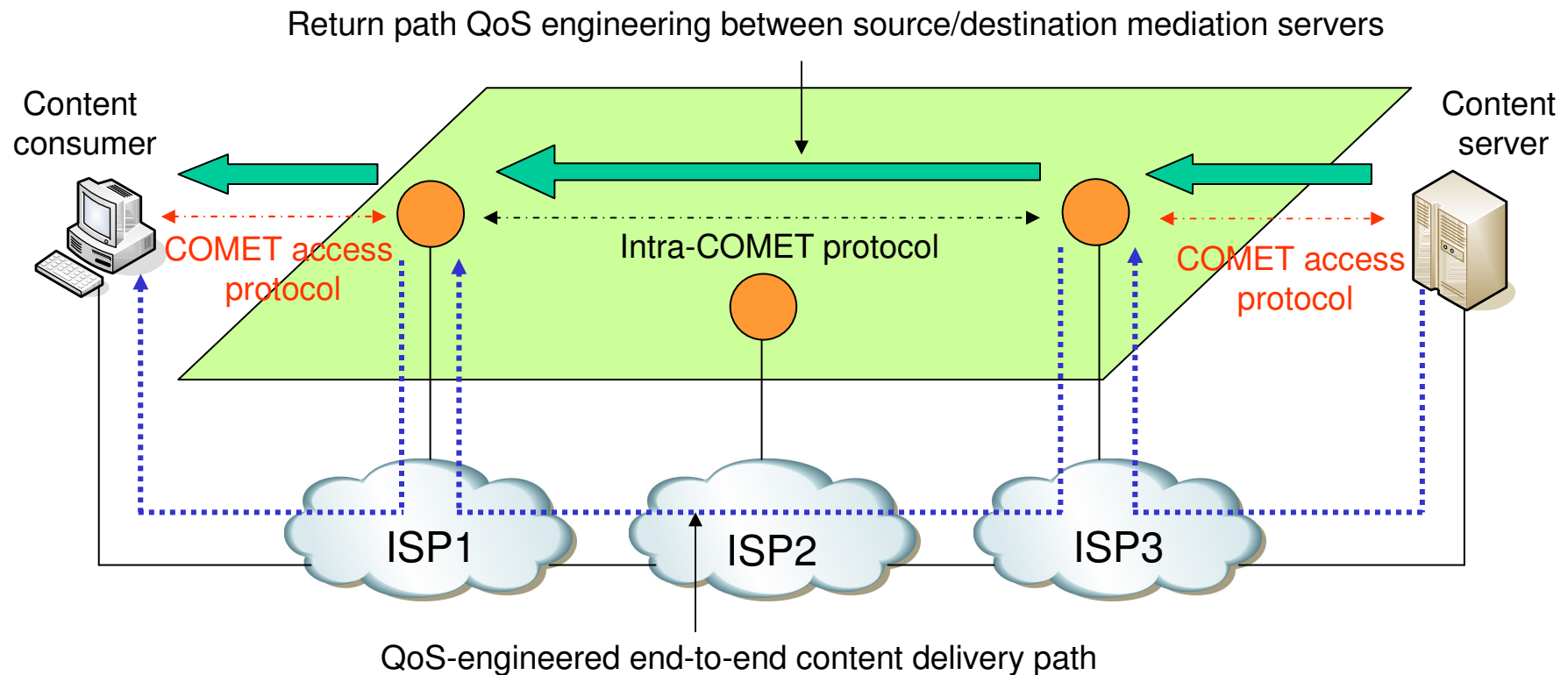
# Address-based Content Delivery

- The consumer/user passes its network (i.e. IP) address in the request
- The mediation servers potentially “prepare” a content-aware return path according to the content and user QoS requirements
- Content is delivered using that path via native network-level routing
- This approach does not cope well with user (and also server) mobility
- Ties well with incremental deployment and evolutionary approaches



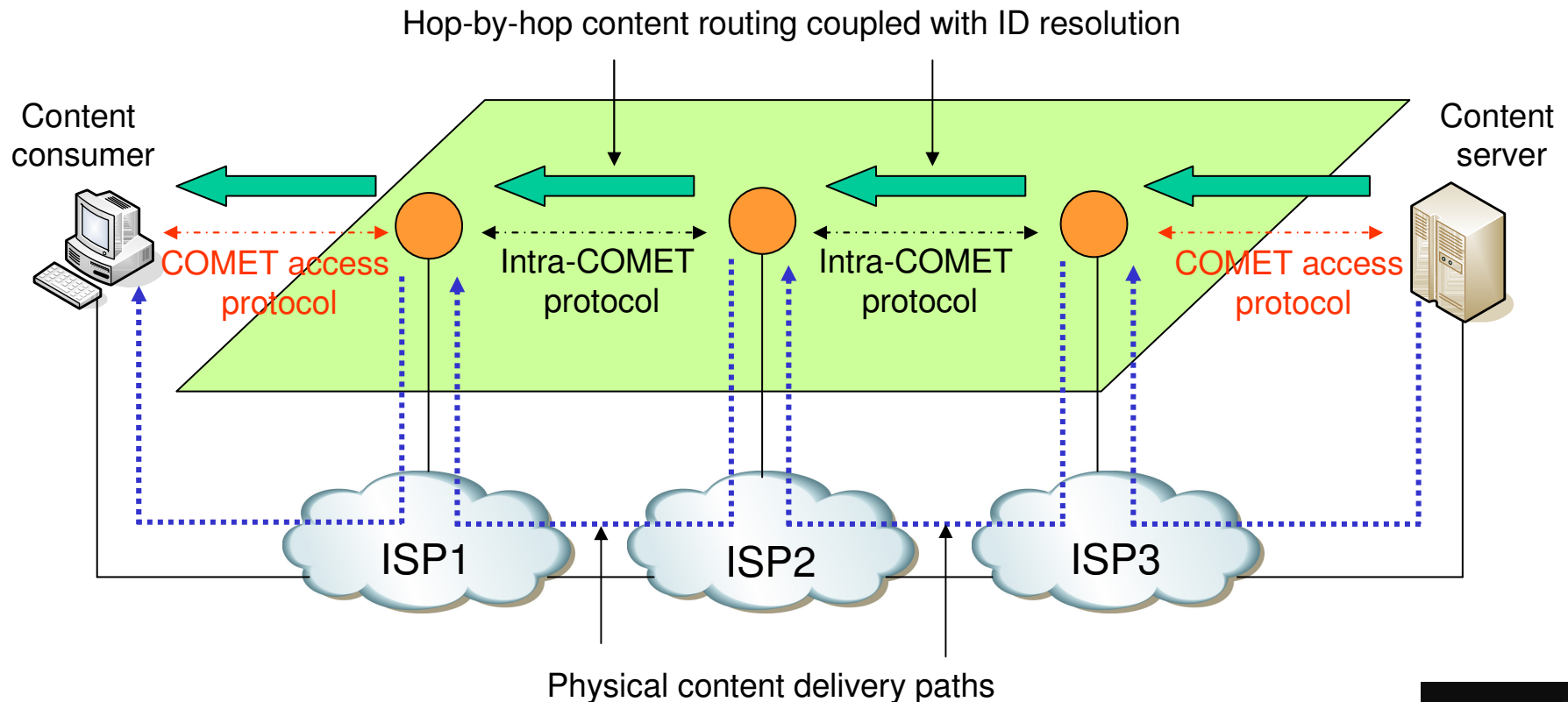
# COMET ID-based “Edge-to-Edge” Content Delivery

- The consumer/user passes its ID and resolution takes place first, resulting in a network (i.e. IP) address
- The host and destination servers “prepare” a content-aware path between them according to the content and user QoS requirements
- Content is delivered via the “home” content mediation servers for the content server and consumer, supporting mobility, privacy and network independence



# Full ID-based Content Delivery

- Consumer/user ID resolution is combined with content delivery, using server-to-server or “content-aware router-to-router” communication until the content consumer
- Content-aware routers (which may also cache content) can be introduced gradually in an evolutionary / semi-revolutionary approach
- In the extreme approach, every router will be content-aware possibly using direct ID-based routing – a radical Future Internet approach



# COMET<sup>•</sup> Content Mediation Plane Organisation

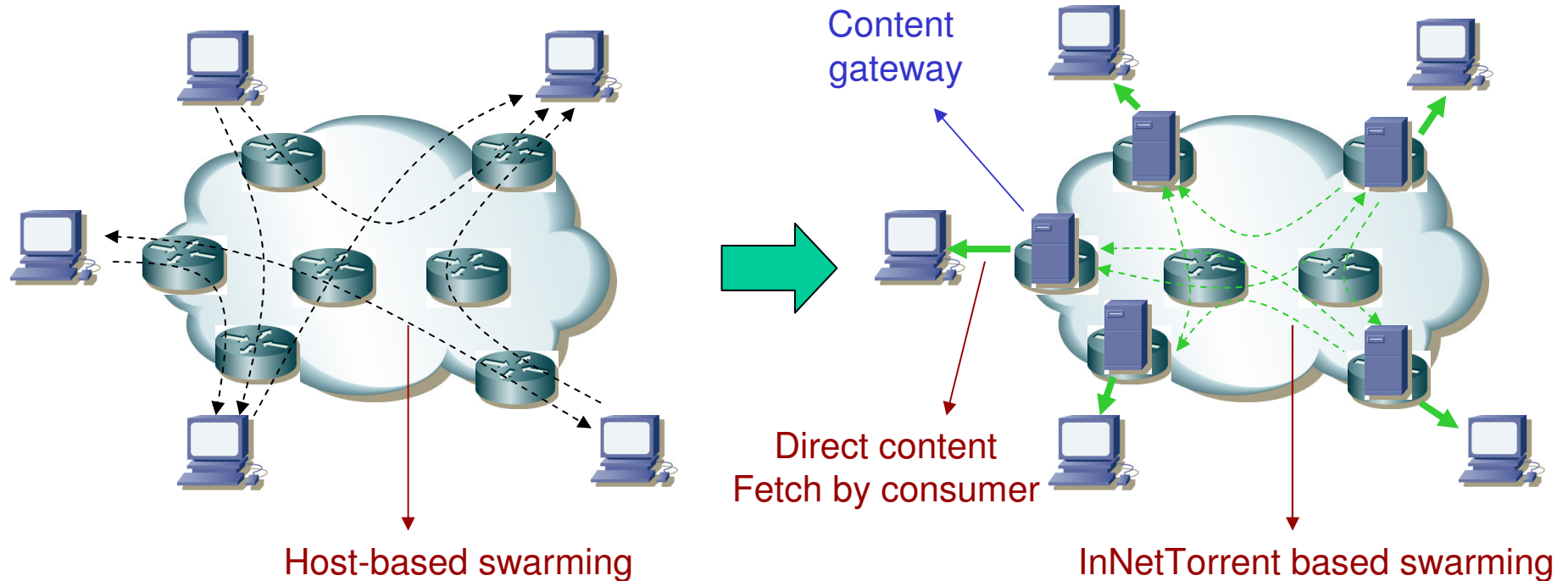
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- User and content names will be **flat** and **self-certifying** in order to be location independent and also support the resolution process
- **Search** functionality should be supported for resolving names/IDs based on content properties (external search engines could also be used)
  - Search is not a key aspect of COMET but of other FP7 projects
- The use of content & user IDs can support **mobility** (when the user or content moves), **privacy** (as users will be able to introduce filters to control access back to them) and can also exploit **multi-homing**
- The **architecture** and **technology** of the mediation plane is a **key challenge** for COMET and, due to the expected large scale and strong location transparency, hierarchical approaches may not be suitable
  - Potential technologies can be publish/subscribe approaches, data-oriented network principles, DHTs, other
- An **application-layer based mediation** plane provides fast deployment time and is evolutionary but a native **network-layer based mediation plane** could be the heart of a Future Internet Architecture

- Content delivery may use a “better-than-best-effort” service
- **Explicit path routing** (tunnelling / LISP / MPLS) and **overlay routing** can be used to circumvent congested shortest paths
  - Monitoring information on path status needs to be available in the mediation plane and gathering this in a scalable manner is a key issue
  - Potentially similar issues to QoS-enabled Resilient Overlay Networks (QRON)
- **DiffServ** may be used but as there is no inter-domain agreements yet, per-domain mediation servers may configure edge routers along the return path with the required service class mappings
- **Parallel Network Planes / Internets** as proposed by the AGAVE project may be also used, supported e.g. by MPLS and multi-topology routing, with per-domain mediation servers “harmonising” planes as above
- More radical multi-path routing approaches may be used, allowing user control & selection - **Edged Controlled / User Selected Routing**
- Finally, revolutionary approaches based on **native ID-based routing** for the Future Internet will also be considered
  - QoS awareness and scalability / efficiency are key issues

- **Current P2P approaches:**
  - Each peer fetches content from multiple partners (end hosts)
  - Routers only do the job of routing/forwarding the traffic – no “memory” of the content passing through
- **Key issues:**
  - Difficult to control P2P traffic created by end users due to the non-cooperative/selfish peer behaviours
  - High churn due to unexpected user departures
  - Trust issues in peer partner selections
  - Incentive to contribute / free-riding issues
  - P4P/Alto only a start and does not solve all the problems
- **Fundamental problem – “non-cooperation” between:**
  - P2P overlay and the underlying network
  - Peers themselves (e.g. local decision on departures)

# In-Network Torrent-based Caching



- **Content-aware routers (with storage capability) at the network edge perform network-aware content swarming on behalf of content consumers**
- **Major functions of content-aware access routers:**
  - “Transient” memory for supporting live-media buffering functions as well as “long-term” storage if necessary
  - **Swarming taking into account network resource conditions**

# **COMET** Key State of the Art Related to COMET

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- **Data-Oriented Network Architecture:** combined name resolution and routing based on IDs
  - UC Berkeley 2007
- **Network Planes and Parallel Internets:** service differentiation based on differentiated routing
  - EU AGAVE 2007
- **Networking Named Content:** content a network primitive with in-network content caching
  - Van Jacobson 2009
- **Internet Indirection Infrastructure:** ID-based routing with rendezvous-based communication
  - UC Berkeley 2002

- COMET encompasses two key aspects:
  - Locating content according to delivery requirements (content mediation)
  - Delivering it using the most suitable resources (network mediation)
- In its simplest form, the Content Mediation Plane can be seen as a content-oriented enhancement of the Domain Name System
- In its medium guise, the Content Mediation Plane uses IDs in the return path and can support mobility, privacy and exploit multi-homing
  - In both cases above, network-awareness is supported in addition to best-effort delivery through various mechanisms of increasing sophistication
- In its most advanced, radical guise, the Content Mediation Plane uses IDs for native routing in content-aware routers
  - In-network Torrent-based caching a possibility
  - Potentially incremental deployment leading to a radical information-centric Future Internet
- **COMET takes a cross-layer multi-disciplinary approach towards the Future Information-Centric Internet**