Enhancing IMS to Support Content-Oriented Networking

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What about content?

- Multimedia traffic is significant and continuously growing – This is well known.
- Content is stored at multiple locations
  - Traditional CDN and transparent web caching
  - Distributed in-network caching at routers, base stations, relay nodes
    - Advances in storage capacity and processing power enable networking elements to cache large contents.
    - Mobile network and telecom operators are deploying their own CDNs and interconnecting them.
- A multimedia content object, e.g. a video clip, can have many representations: coding format, resolution
But today’s mobile networks and Internet were built to interconnect computing nodes and devices (terminals, servers, etc.), not well suited for content retrieval

- Packet transporting based on the host’s IP address
- As a result, users identify and access multimedia content based on “where is it stored”,

However...as a user, I care about the content itself, not where it is stored.

- desire that the content delivered to me:
  - matches my device’s operating conditions
  - with proper format/resolution
  - at the best available quality
• Locate, route, and deliver content based on the content itself, not on its storage location => **Content-Oriented Routing**
  – decouple contents from hosts at the networking level and retrieve the content by its name or ID
  – a clean-slate redesign of the Internet architecture

• Enable scalable and efficient content access => higher QoE
  – In-network caching to optimize bandwidth
  – Content delivery from the best location(s)
  – Free application and service developers from reinventing application-specific delivery mechanisms
IP Multimedia Subsystem (IMS)

- Developed by 3GPP and TISPAN
- Standardized framework for delivering IP multimedia services.
- Enables end users to access a wide range of services and applications via a *common control plane* regardless of network access technology
- Allows the network to control the services,
- Creates a form of fixed-mobile convergence for next generation networks (NGNs)
IMS Architecture

- client-server model
- device centric
- no adequate mechanisms to support content-oriented functionality

• Horizontal control layer: a good foundation that can be enhanced to support “content-oriented networking”
  - Flexibility to negotiate data plane protocols and content format
  - Potentially achieve the same scalability, security, and performance as the clean-slate architecture.

Application Plane
- Application Servers
- DNS/ENUM
- HSS
- S-CSCF
- P-CSCF
- I-CSCF

Control Plane
- P-CSCF: Proxy Call Session Control Function
- S-CSCF: Serving-CSCF
- I-CSCF: Interrogating-CSCF
- HSS: Home Subscriber Server
- PDF: Policy Decision Function
- A-BGF: Access Border Gateway Function
- IBCF: Interconnect Border Controller Function
- SBC: Session Border Controller
- I-BGF: Interconnect Border Gateway Function
- A-GW: Access Gateway
- P-GW: Packet Gateway
- MRFC: Media Resource Function Controller
- MRFP: Media Resource Function Processor
- ENUM: Telephone Number Mapping
- DNS: Domain Name System
• **Content Name Resolution Handler (CNRH):** Map content object name or ID (OID) to location (URL or host IP address)

**CNRH Implementation Choices:**
- Co-located or integrated with enhanced S-CSCF
- Implemented as application server
- Enhance DNS/Electronic Number Mapping System (ENUM) with CNRH functions
Enhancement of IMS

• Each content object is assigned a unique ID
  – decouple the content identity from its network locations
  – facilitate automatic content location resolution
  – enable interconnection or peering of content service networks to reach more contents, more types/formats of a content object, and more resources

• User agents and IMS network control entities interact for locating and accessing a content object by its OID instead of URL or host IP address
  – CNRH maps the requested content OID to URL/host IP address or more general delivery directive
  – Initiate, negotiate and control content retrieval session
  – route the control messages within and across network domains.

• Network elements (base stations, eNodeB, gateways, routers) cache and publish the cached/hosted content objects via enhanced IMS SIP signaling and CNRH
  – Enable more efficient and scalable content delivery (caching to optimize bandwidth, deliver content from the best location(s) along the best path(s), load balancing, improved latency and QoE)
Content Naming

- **Flat OID**
  - Hash of a public key + label or hash of the content data
  - Self-certifying, persistent, unique
  - Need mapping between human-readable name and flat OID, Difficult to aggregate

- **Hierarchical OID**
  - Similar to encoded URL
  - Prefix-based aggregation: aggregate hierarchical OIDs with the common prefix for scalability
    - The effectiveness of aggregation reduces as content objects are replicated at multiple locations
    - “suffix hole”: a host may not have all the content objects for a given prefix.
  - Name may become misleading if the location domain changes

- **Type-Length-Value (TLV) encoded OID**
  - consist of a set of variable-size information elements (IE)
  - each IE encoded as a TLV
  - hierarchical or peer relationships
  - location independent and flexible
  - E.g. `organizationTLV-authorTLV-categoryTLV-titleTLV-formatTLV-segmentationTLV`
A content server/cache publishes its content objects
- Using enhanced SIP messages
• User agent (UA) initiates content retrieval
Network Services Enabling

• Networks can insert middle boxes to provide services and control content access
  – Session control function (SCF) controls enhanced media resource function (eMRF) to manipulate content data, e.g. stream mixing, advertisement insertion, transcoding, etc.

• SIP messages between SCF, CRNH, content cache/server go through the IMS CN subsystem even if not indicated on the sequences.
• SCF queries CNRH

- SIP messages between SCF, CRNH, content cache/server go through the IMS CN subsystem even if not indicated on the sequences.
• Multiple CNRHs form a DHT ring
  – Map content object IDs to CNRH node ID in hash space
Cross-Domain Content Peering
Inter-Domain Content Routing Example

- CNRHs form hierarchical tree with peered links or hierarchical DHT
  - maps to the Internet hierarchy

Inter-domain SIP messages between CNRHs go through eIBCF/eSBC to enforce security and inter-domain policies.

- Content PUBLISH propagates up along the hierarchy and among peers
- Each CNRH maintains the location information of all the content objects published in its descendants and peers
  - Mapping of OID to next-hop CNRH/address and distance/cost to the host of this content copy
- Content request/INVITE is routed to the closest copy
• Standardization Aspects
  – Content Naming
  – IMS architecture enhancement for content awareness
  – CNRH
  – SIP signaling enhancement
  – Interconnection of networks

• Standardization Bodies
  – ETSI TISPAN, 3GPP, IETF

• InterDigital will continue developing new technologies and contributing to the standards.
Thank You!