Video Services in Information Centric Networks: Technologies and Business Models

A. Difino, R. Chiariglione and G. Tropea

***Abstract*—Information Centric Networking (ICN) is an emerging communication paradigm in which information is stored and retrieved based on its "name". It can be seen as moving away from a host-based to a content-based communication model. The CONVERGENCE project has developed a comprehensive ICN solution integrating network and middleware, glued together by a unified, interoperable container called Versatile Digital Item (VDI). The paper describes the implementation called Video Centric Networking – Publish/Subscribe (VCN-PS) and shows that ICN can be realistically implemented and made accessible to applications in popular devices, and can thus be considered as a viable medium-term alternative to other multimedia delivery technologies. The paper also checks the ability of VCN-PS to support business models for video streaming services.**

***Index Terms*—Dynamic Adaptive Streaming Information Centric Networking, Internet Protocol, Middleware, Publish/Subscribe**

I. Introduction

CONSIDERING the premises – a network born for connecting computers and later to transport hypertext information using the HTTP protocol – Internet has been quite successful in responding to the expanding needs of its users, as demonstrated by the wide range of different formats used today in an ever growing number of multimedia data. Video data, e.g. MPEG standards like AVC [13] and, shortly, HEVC [28] take an increasingly lion's share of the global traffic and the amount of streamed bits is growing by the day. Among the different protocols used to transport data formats, of particular interest for the short term is Dynamic Adaptive Streaming over HTTP (DASH) [29] that uses HTTP to transport on demand segments of audio and video at different levels of quality – and hence of bitrate – to cope with unpredictable bandwidth variations from source to destination.

Additionally, content replication at appropriate network locations is an effective strategy to cope with the unpredictable mismatch between source and destination in terms of bandwidth availability over long distances. The relevant logic is currently implemented in such overlay networks as Peer-to-Peer (P2P) Networks [1] and Content Distribution Networks (CDN) [2]: P2P leverages self-organised, adaptive, and fault-tolerant distribution among peers by retrieving fragments of information from selected available peers, while CDNs redirect requests for web resources to appropriately located caches using mechanisms such as DNS-based redirection.

The paradigm shift represented by both solutions is to move away from a host-based to a content-based communication model: URIs and DNS names are interpreted in a way that allows accessing cached copies of information units in the network.

Information Centric Networking (ICN) is an emerging communication paradigm in which information is stored and retrieved based on its "name" or identifier, without relying on point-to-point (client-server) communication primitives. It can be seen as a move towards incorporation of the above issues into the network layer, with the promise to overcome some of their existing shortcomings. In ICN each information unit, when stored, is individually identified at an appropriate granularity level so that it can be retrieved by simply using the identifier, as opposed to retrieving from a logical location whose physical addresses are provided by the Domain Name System (DNS). In other words ICN does not require an additional level of indirection, from identifiers to logical or physical content locations, being able to directly "route-by-name" requests to the "closest" copy of the content.

Since the Xerox PARC CCN [3] and the NSF funded Named Data Networking (NDN) [4] projects, ICN has benefitted from European Commission funded Framework Program 7 R&D investments in different projects such as 4WARD [5], PSIRP/PURSUIT [6], SAIL [7], and COMET [8].

Section 2 lists the main requirements for generic ICN Publish/Subscribe. Section 3 details the main technology choices adopted by CONVERGENCE, an FP7-funded ICN project [9]. Section 4 describes the peculiarities of video pub/sub in ICN based on the comprehensive ICN solution based on the combination of CCN for the network part and a range of technologies specified by such MPEG standards as MPEG-7, MPEG-21 and MPEG-M for the middleware part. The middleware is glued together by a unified, interoperable container named Versatile Digital Item (VDI), a specialisation of the MPEG-21

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Angelo Difino was with CEDEO.net, Via Borgionera 103, I-10040 Villar Dora (TO), Italy. Currently he works as an independent consultant (email: angelo.difino@gmail.com).

Riccardo Chiariglione is with CEDEO.net (email:riccardo@cedeo.net).

Giuseppe Tropea is with CNIT, Italy, (email: giuseppe.tropea@cnit.it)

Digital Item [16]. This paper also provides novel contributions toward a user-friendly publish/subscribe of audio-visual content streamed using the DASH format natively embedded in the CONVERGENCE ICN, implemented as a running platform accessible from the web called Video Centric Networking – Publish/Subscribe (VCN-PS). VCN-PS proves that ICN features can be realistically implemented and made accessible to applications in such popular devices as the Mac PC, and can thus be considered as a viable medium-term alternative to CDNs for the delivery of multimedia content. Section 5 analyses business models for video services in ICN using the operational video platform WimTV [10] mapped to VCN-PS. Section 6 draws conclusions and identifies future work areas.

II. Requirements for Generic Information-Centric Publish/Subscribe

In this section we will make an analysis of requirements that a generic (content-agnostic) ICN PS system shall support, by using results published in the literature.

A. Network Layer Requirements

- **Caching** is the functionality whereby the ICN knows where to find the information element that has been requested. As a subscriber's request can be satisfied with data coming from any source holding a copy of the object, ICN requires that publisher- and subscriber-neutral caching be natively part of ICN. Objects can be replicated, distributed without owner control.
- **Security and privacy** is the functionality whereby the source may sign and protect an information element so that other entities, e.g. network elements and consumer devices, can verify its signature and hence its integrity and authenticity, because publishers and subscribers are decoupled in space and time, and the source can control access to it, because the network has visibility of the information elements.
- **Information transport** is the functionality providing reliable, and congestion- and flow-controlled transport of information elements from one or more sources to a receiver, including support for caching, multi-path and disruption tolerance.
- **Routing** is the functionality of
  - *Name-based forwarding*: forward on names, using a specific routing protocol;
  - *Name resolution*: resolve names to data objects, leveraging underlying forwarding and routing infrastructure;
  - *Congestion control and QoS.*

B. Middleware Layer Requirements

Publish/Subscribe is the functionality, dealing with descriptions (Publish) and queries (Subscribe) of information elements, whereby an ICN user can

- Request content that satisfies certain criteria. In a publication the following data should be provided: the issuer, the descriptions, the names of those to be notified when a match occurs etc.
- Make known that content with certain features has been stored on the ICN. In a subscription the following data should be provided: the issuer, the query, the names of those to be notified when a match occurs etc.

Please note that both subscribe-first/publish-later and publish-first/subscribe-later models have to be supported.

C. Joint Requirements

Content Identification is the functionality whereby each information element, down to the appropriate granularity level, must be identified uniquely and unambiguously. This involves two main sub-requirements:

- Information elements should be identified at the application level;
- The syntax of the information element identifier should support scalability since ICN should be able to cope with an extremely large number of information objects.

Therefore the naming/addressing architecture should be designed to allow an information element identification that is global, provides efficient lookup, is scalable to objects possibly numbering quadrillions, and is able to deal with node and information object mobility.

D. Meta-Requirements

The following requirements are of general "trans-layer" interest:

- The availability of metrics that make it possible to evaluate implementations in a consistent manner;
- The existence of business, legal and regulatory frameworks, including incentives and novel business models to engage relevant stakeholders;
- The ability to deploy ICN incrementally, e.g. to gradually migrate without obliterating existing IPv4/v6 infrastructure.

To fully satisfy the above (and broader) requirements, the CONVERGENCE project ended-up developing a reference layered ICN architecture where layers are operated independently and glued by the notion of VDI and its identification scheme. The outline is provided by *Figure 1* where three different kinds of ICN device, namely CoNet, a network node, CoSec, a security node, and Peer, or user device, are required.

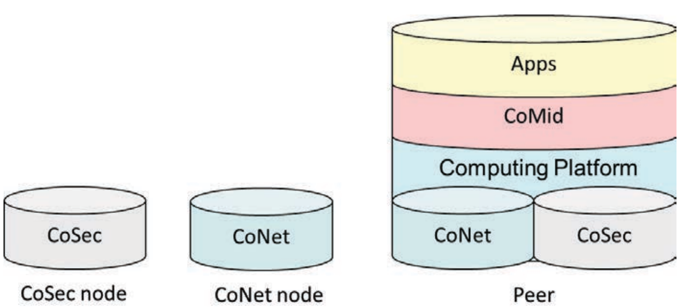

Figure 1: CONVERGENCE devices

CoNet node is a device running the ICN stack of functionalities only, including caching, routing-by-name and securing of network data objects, while CoSec is a device responsible for handling the majority of cryptographic protocols and security related tasks.

Peer is a layered device whose layers are:

1. Computing Platform that includes computing resources and operating system interfaces able to run concurrently CoNet and CoSec implementations;
2. CoMid a middleware with API interfaces to the underlying ICN functionalities;
3. Apps that includes applications offering VCN-PS to humans or higher-level machine users.

Figure 2 depicts the architecture from a distributed point-of-view. The functionalities at the computing platform level of each device are collectively distributed across an Infrastructure level. Special devices that only run CoNet (core network routers) or only run CoSec (specialised security servers) are referred to as nodes. Devices that additionally run the CoMid are referred to as peers. The middleware is **distributed across all peers**: however, some of them can be more specialised in providing certain services, some of them (typically devices for end-user but also for service providers) will additionally run CONVERGENCE-compliant applications.

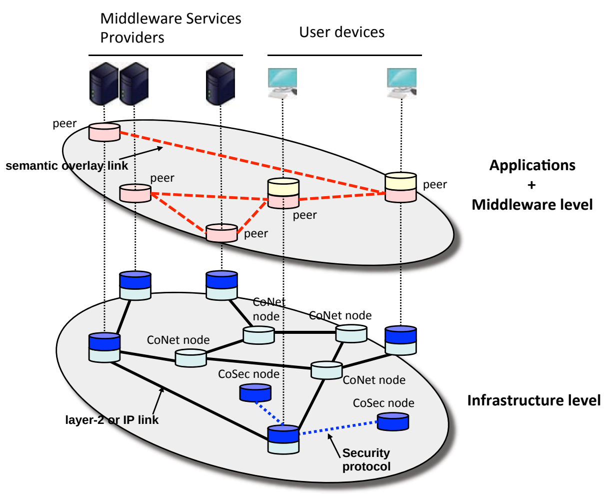

Figure 2: Distributed view of the CONVERGENCE architecture

CoMid peers exchange messages with peer entities of a semantic overlay. CoNet nodes are connected via physical or traditional IP links and communicate over the ICN. CoSec nodes talk using distributed, specialised security protocols.

III. TECHNOLOGIES AT THE HEART OF CONVERGENCE

A priori there is no obligation to rely on standards but the specification of a complete information-centric system is such a huge undertaking that it is preferable to be able to tick out some problem elements by relying on the technical consensus achieved by standards groups in selected technology areas, particularly when these are tightly connected with the special information type called media.

A suite of International Standards developed by MPEG, namely the Multimedia Service Platform Technologies (MPEG-M), provides technology support to CONVERGENCE architecture.

The CONVERGENCE extension of the MPEG-M architecture [23] represented in *Figure 3* includes:

- An intermediate Tool layer between the MXM Layer and the Application Layer. Tools include reusable code for applications;
- New southward APIs for ICN (CoNet) and Security (CoSec).

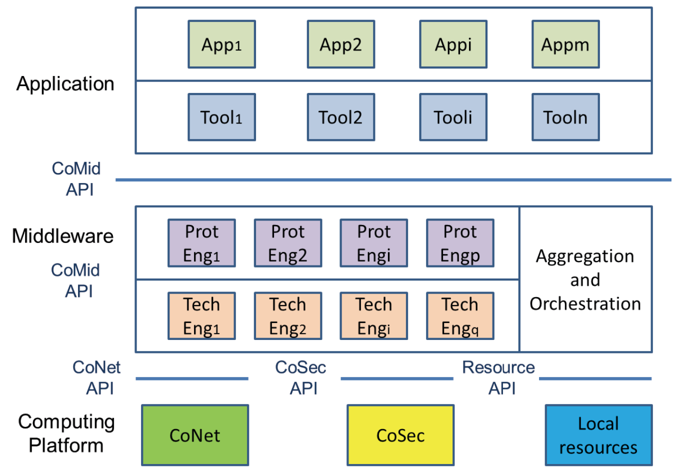

Figure 3: MPEG-M based CONVERGENCE ICN Architecture

When an Application calls the API defined in part 2 of MPEG-M [24], to access the MPEG Extensible Middleware (MXM), different possibilities exist:

1. The App calls just one local Technology Engines (TE). A TE is a module providing defined functionalities, such as a Media Framework to play a video. Part 2 of MPEG-M defines some high level APIs and provides placeholders to define new ones. Part 3 of MPEG-M [25] provides software implementations of a range of TEs released with a Berkeley Software Distribution (BSD) licence;
2. The App calls a chain of local TEs. This TE serialization is called "Technology Orchestration";
3. The App calls just one Protocol Engine (PE). A PE is an implementation of an Elementary Service (ES) such as Create Licence which in turn calls just one or a sequence of local or remote TEs. Part 4 of MPEG-M [26] defines a set of ESs and the corresponding PEs;
4. The App calls a chain of PEs. Part 5 of MPEG-M [27] defines a machine-readable representation of the PE workflow that represents the "Service Aggregation" implied by the sequence of PEs.

Figure 4 shows an Application calling the PEa→PEb→PEc Aggregated Service and where PEa calls just one TE, PEb calls 3 Orchestrated TEs and PEc calls 2 Orchestrated TEs. Typically a special TE called Orchestrator drives the sequence of TEs to accomplish the goal.

A. Resource Identification

In the following the term Resource indicates information primarily intended for human-consumption. Versatile Digital Item (VDI) is the CONVERGENCE-defined data structure that includes:

- VDI Identifier
- Resource Identifier
- Metadata describing Resources or query on Resources
- Licence expressing what rights are given to a User to act on Resources on what conditions
- Event Report Requests (ERR) to instruct a Peer to issue an Event Report (ER) to specific users/peers in the event certain actions (e.g. play or store) are performed on a resource etc.

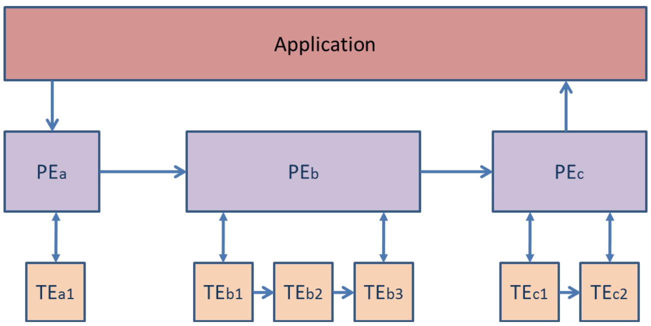

Figure 4: MPEG-M Aggregation and Orchestration

CONVERGENCE has further defined 3 types of VDI

1. R-VDI (Resource VDI) carrying resource (e.g. a video) identifier and other data
2. S-VDI (Subscription VDI) carrying the query and other data
3. P-VDI (Publication VDI) carrying the resource description and other data.

A VDI created by the CONVERGENCE Middleware receives a unique and persistent Identifier. Please note that it is useful to be able to place a semantic link between a VDI and one or more than one VDI, e.g. in case a VDI is "superseded" by a new version of it or a new independent VDI appears that has some connection with the existing VDI. CONVERGENCE Ontology Services lets users establish such links.

B. Resource Classification

The CONVERGENCE Core Ontology (CCO) allows for a semantic organisation of peers in a virtual overlay network of "topics" built on the basis of users' interests in the different types of published content [11]. Note that

1. *Figure 5*, an example of fractal organisation of topics, shows that a peer typically belongs to more than one topic, depending on which resources users are interested in;
2. All P-VDIs and S-VDIs related to a certain Metadata are stored in some Peers of that fractal;
3. In general more than one peer populates a topic, to accommodate the fact that some peers may be off when access to them is needed.

C. Resource Publication and Subscription

Peers are endowed with the embedded ability to

- Perform matches between P-VDIs and S-VDIs that are stored on them;
- Communicate any match found to the specified users/peers depending on licences and ERRs;
- Remove S-VDIs and P-VDIs whose validity date has expired from the tables from the topic.

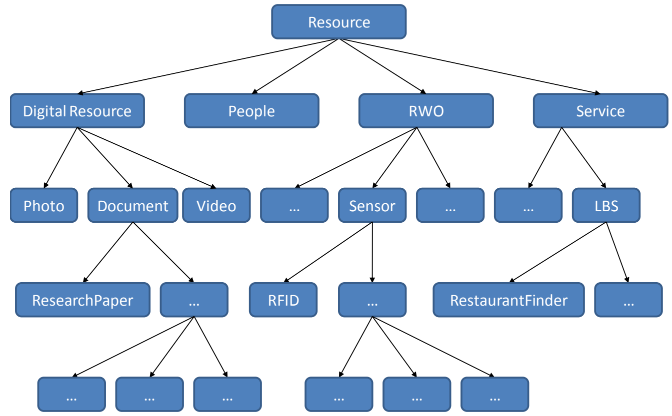

Figure 5: Topics

Figure 6 depicts how Publish/Subscribe works in CONVERGENCE.

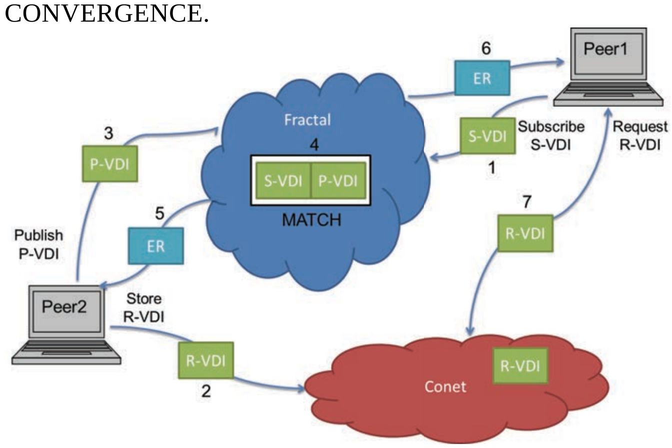

Figure 6: Publish/Subscribe in CONVERGENCE ICN

This is the sequence of steps:

1. Whenever a user (on Peer1) subscribes to receive a Resource with particular features, a description of its interest will be created as an S-VDI and will be injected in the Overlay (step 1);
2. When another user (on Peer2) wants inform a particular class of Users that a Resource has been created, an R-VDI will be created that includes Resource description and will be Stored on CoNet (step 2);
3. A description of the features of the media will be created as a P-VDI and injected in the same Overlay topic (step 3);
4. Behind the scene, a Peer dedicated to the particular class of Resource will eventually match the publication with the subscriptions previously injected (step 4);
5. If a match is detected, Peer2 and the Peer1 are notified back about the match (steps 5 and 6);
6. Peer1 User can now retrieve the R-VDI that includes the Resource previously stored on CoNet (step 7).

With reference to Figure 6 this is the complete walkthrough:

1. Peer1
   a. Creates S-VDI

   b. Subscribes S-VDI
2. Peer2
   a. Creates R-VDI
   b. Stores R-VDI
   c. Stores Resource
   d. Creates P-VDI
   e. Publishes P-VDI
3. PeerN (the peer hosting the relevant topic)
   a. Finds Match between Peer1's S-VDI and Peer2's P-VDI
   b. Notifies Peer1 and Peer2
4. Peer1
   a. Retrieves R-VDI
   b. Retrieves Resource

IV. Peculiarities of Video Pub/Sub in ICN

This section focuses on the peculiarities of the Middleware and Application layers for video streaming in a DASH-based environment. The focus is on a complete implementation of a specialised ICN for handling and distributing video content in a consumer-friendly manner. The last section will discuss the described VCN-PS can be used to support the WimTV video service.

The VCN-PS solution has been designed to enable a user of an ICN application to perform the functions listed in Table 1, which represent a subset of the functionality requirements capturing the fundamental need of a Publish/Subscribe ICN application.

Please note that in the following

1. Words beginning with a capital letter will refer to terms with defined semantics;
2. The term data structure will refer to the specifically defined XML structure conveying information related to a Resource.

Table 1: VCN-PS requirements

#	Requirement
1	Create a data structure containing
1.a	Identifier of the data structure
1.b	Identifier of the Multimedia Resource it refers to
1.c	Metadata describing the Multimedia Resource it refers to
1.d	Rights available to a User and conditions to be satisfied for using the Multimedia Resource
1.e	Requests to report Resource-related Events
2	Encrypt parts of the data structure
3	Sign the data structure
4	Verify the authenticity of a data structure or Multimedia Resource
5	Establish links of a data structure with other data structures (e.g. a previous version)
6	Optionally make a package of the data structure and the Multimedia Resource it refers to
7	Subscribe to a set of Multimedia Resource attributes by providing a query and a request to report to identified Users any match of the Subscription with a Publication
8	Publish information about a Resource Stored on the ICN by providing appropriate Metadata and a request to report to identified Users any match of the Publication with a Subscription
9	Interface to Store (put) and Retrieve (get) data from ICN indicating the data Identifier

These requirements are largely met by two suites of International Standards developed by MPEG group and listed in Table 2, namely: Multimedia Content Description Interface (MPEG-7) and Multimedia Framework (MPEG-21).

Table 2: MPEG-7 and MPEG-21 standards for VCN-PS

Req.	Title	Std	Acronym	Ref.
1	Digital Item Declaration	21	DID	[16]
1.a	Digital Item Identification	21	DII	[17]
1.b	Digital Item Identification	21	DII	[17]
1.c	Simple Metadata Profile	7	SMP	[14]
1.d	Rights Expression Language	21	REL	[20]
1.e	Event Report	21	ER	[22]
2	Intellectual Property Management and Protection Components	21	IPMP	[19]
5	Related identifier types	21	DII	[18]
6	MPEG-21 File Format	21	MP21FF	[21]
7	MPEG Query Format	7	MPQF	[15]

A. *Implementation*

The scenario in *Figure 6* has been implemented as depicted in *Figure 7*.

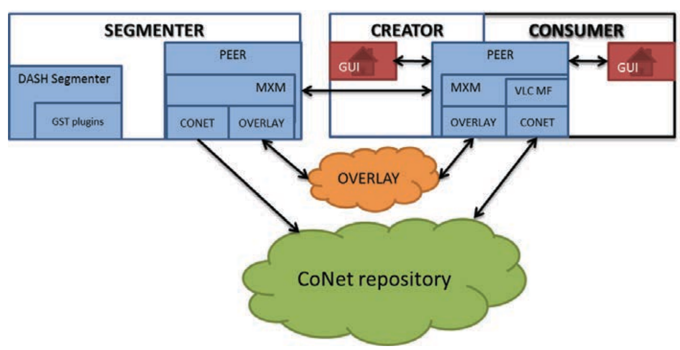

Figure 7: An implementation of VCN-PS

In *Figure 7* two Peers are depicted:

1. A Peer with the Creator and Consumer functionalities. Both share CoMid with 3 Engines highlighted because of their relevance to this paper: CoNet TE to Store/Retrieve data from ICN, Overlay TE to subscribe S-VDIs and publish P-VDIs and VideoLAN (VLC) [30] based Media Framework TE to play DASH-streamed videos from CoNet;
2. A Peer with the functionality of DASH segmenter. This has a CoMid instance that does not include the Media Framework TE and has additionally an internal engine (DASH Segmenter) that chops a video into DASH segments.

The walkthrough described in this section covers the same scenario presented above, adding more details about the video streaming capabilities of the system. Resource retrieval the is achieved using a similar approach as in [12]. Since video is delivered in DASH format, it is simply identified by an HTTP URI inserted in the R-VDI (*Figure 8*). The DASH segments and Media Presentation Descrip-tion (MPD) are stored in CoNet. The HTTP URI contains a dummy common prefix followed by the real name of the video to enable the consumer to forward the HTTP request to Conet (*Figure 9*).

```
<mpegm-didl:DIDL>
…
  <mpegm-didl:Component>
    <mpegm-didl:Resource mimeType="video/mp4"
      ref="http://www.ict-convergence.eu:9080/convergence/FerraraBalloonFestival_1350451738512.mpd"/>
  </mpegm-didl:Component>
…
</mpegm-didl:DIDL>
```

Figure 8: R-VDI fragment with MPD URI

```
<MPD
  xmlns:xsi="http://www.w3.org/2001/XMLSchema"
  xmlns="urn:mpeg:DASH:schema:MPD:2011"
  xsi:schemaLocation="urn:mpeg:DASH:schema:MPD:2011"
  profiles="urn:mpeg:dash:profile:isoff-main:2011"
  type="static"
  minBufferTime="PT3.0S">

  <BaseURL>http://www.ict-convergence.eu:9080/convergence/</BaseURL>
  <Period start="PT0S">
    <AdaptationSet bitstreamSwitching="true">
      <Representation codecs="avc1"
        mimeType="video/mp4"
        width="1024" height="576" startWithSAP="1"
        bandwidth="438272" minBufferTime="3000">

        <SegmentBase>
          <Initialization
sourceURL="FerraraBalloonFestival_1350451738512_438272.mp4"/>
        </SegmentBase>

        <SegmentList duration="3">
…
</MPD>
```

Figure 9: MPD fragment containing the dummy common prefix

The DASH segmentation related operations are covered by an ad-hoc remote service invoked by Creator to chop the video in DASH segments and to store the segments and its MPD in CoNet. As soon as this set of operations is concluded, Creator proceeds as usual: store the R-VDI (with the MPD URI inside) on CoNet and inject P-VDI in Overlay.

As highlighted above, whenever a match occurs, the consumer peer receives an ER that includes the R-VDI identifier. Consumer can now retrieve that R-VDI from CoNet using the Resource URI inside the ER. Therefore the MF engine can use the MPD URI to render the video, with the help of an HTTP proxy that forwards the HTTP request to ICN get operation. When the MPD and/or its segments are retrieved, they are forwarded back to the MF engine that presents the information.

This is the detailed walkthrough:

1. Consumer
    a. Creates S-VDI
    b. Subscribes S-VDI to Overlay
2. Creator sends video to Segmenter Service
3. Segmenter Service
    a. Segments video
    b. Stores video segments and MPD to CoNet
4. Creator
    a. Polls Segmenter until it is notified that video segments and MPD have been stored to CoNet
    b. Creates R-VDI
    c. Stores R-VDI
    d. Creates P-VDI
    e. Publishes P-VDI
5. PeerN (hosting the relevant topic)
    a. Detects match between S-VDI and P-VDI
    b. Notifies Consumer
6. Consumer
    a. Retrieves R-VDI
    b. Extracts the MPD URI
    c. Via MXM MF VLC Engine, request the MPD
    d. HTTP PROXY intercepts the request and forwards it to ICN
    e. The MPD is returned to MXM MF VLC Engine, which starts to request DASH segments
    f. HTTP PROXY intercepts the requests and forwards them to ICN

Currently VCN-PS includes the MXM engines listed in the following *Table 3*.

Table 3: MXM engines in VCN-PS

Engine name	Function	Engine type
convergence-conetTE	CoNet	TE
convergence-eventReportTE	Event Report	TE
convergence-matchTE	Match	TE
convergence-metadataTE	Metadata	TE
convergence-overlayTE	Overlay	TE
convergence-vdiTE	VDI	TE
mxm-digitalitemTE	Digital Item	TE
mxm-mediaframeworkTE	Mediaframework	TE
mxm-metadataTE	Metadata	TE
mxm-createcontentPE	Create Content	PE
mxm-identifycontentPE	Identify Content	PE

V. Business models for video services in ICN

In this section we explore the suitability of ICN to support the video streaming business by taking as WimTV, a platform supporting the activity of a plurality of interacting businesses, a case study, The platform is conceptually represented in *Figure 10*.

In WimTV a User can

1. Import Resources and relevant Metadata (including Rights and payment terms) to his digital locker (MyMedia)
2. Export Resources out of MyMedia (if export rights are available)

3. Post videos to his WebTV (MyStreams) for End Users to stream
4. Post videos to the marketplace (MyShop) for Buyers to assess and possibly acquire
5. Issue calls where User declares his availability to acquire specific content at specific conditions (MyCalls) that he can then, depending on Licence terms, post on MyShop or MyStreams, or export
6. Upload content with the specific value of "advertisement"
7. Get rights to content from another User's MyShop and post it on his Web TV.

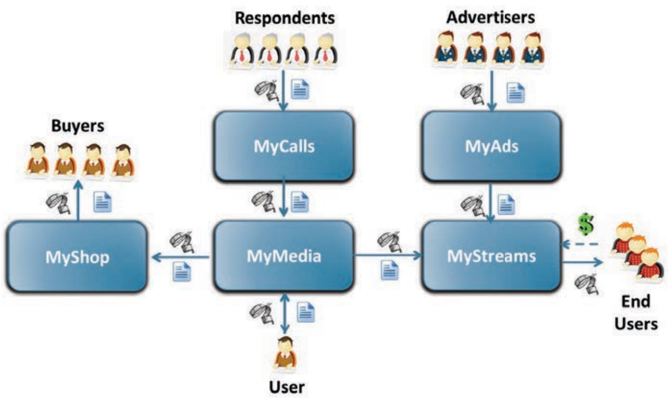

Figure 10: The WimTV model

All videos are stored on the WimTV server and can be referenced (e.g. streamed). Every time a User gets rights to a content item this is recorded by the WimTV server application.

In today's internet, video services are regularly based on a large servers managed by service providers. End users access the server, make their selection and the selected video is streamed to them.

VCN-PS offers new ways to look at networked video services but their precise mapping is a matter for discussion. How this can be done in ICN is the purpose of an analysis that is based on the following assumptions:

1. Videos are stored in ICN as clear-text or encrypted form;
2. R-VDIs are stored in ICN along with video Identifier, Metadata, Licence describing the rights granted to the principal (i.e. the licensee) and ERRs containing the names of the entities to be notified when video is played;
3. P-VDIs are posted on the overlay with search-friendly Metadata, Licence describing the match rights granted to the overlay and ERRs containing the names of the entities to be notified when match is found;
4. R-VDIs are injected on the overlay with Queries, Licence describing the match rights granted to the overlay and ERRs containing the names of the entities to be notified when match is found.

Table 4 shows how an operation (of the Function column) of a WimTV User (in the User type column) can be mapped to ICN steps (the Action column).

Table 4: MPEG-7 and MPEG-21 standards for ICN

Legend: GU=Generic User CP=Content Provider
SP=Service Provider AD=Advertiser

Function	**User type**	**Action**
Import to MyMedia	GU	Create and Store R-VDI
Export from MyMedia	GU	Create and Store R-VDI
Post to MyStreams	SP	Create and Store P-VDI
Search MyStream	GU	Create and Store S-VDI
View MyStream	GU	Get R-VDI
Post to MyShop	CP	Create and Store P-VDI
Search MyShop	SP	Create and Store S-VDI
Get Resource	SP	Get R-VDI
Post to MyCall	SP	Create and Store S-VDI
Respond to MyCall	CP	Create and Store P-VDI
Provide Ads	AD	Create and Store P-VDI
Look for Ads	SP	Create and Store S-VDI
Get Ad	SP	Get R-VDI

NB1 "Create and Store R-VDI" may be executed separately on the VDI and the Resource or on a file that includes both VDI and the Resource. Obviously P-VDI and S-VDI do not involve Resources.

NB2 The Middleware provides support to a wide range of business relationships, e.g.
1. Metadata to describe videos
2. Licence to describe the rights to videos, but also what the Overlay can actually do
3. Event Report Requests to notify which Users

NB3 The VDI can be extended to convey additional information regarding payments, a key enabler of WimTV value chains.

It is clear that a blind use of ICN features would probably make business differentiation rather difficult. Fortunately some options exist to achieve differentiation, e.g.

1. **Use of two-layered Metadata**. The first is common to all businesses and the second is proprietary. This would make matching between P-VDI and S-VDI work well only for a particular Service Provider
2. **Use of Licences** to provide clear benefits to only to subscribers to a particular Service Provider. Of course this requires that Peers have a sufficiently high level of security
3. **Use of proprietary ontologies**. A Service Provider bases its offer on proprietary ontologies that allow effective tagging and searches
4. **Use of VDI creation services**. A service provider offers a VDI creation service. The structure of the VDIs is such that R-VDI licences allow video retrieval only by principals recognised by the SP.
5. **Use of private overlay**. The Service Provider manages a private overlay that performs matches between Publishers and Subscribers in case Peers do not offer sufficiently high security.

VI. Conclusions and Future Work

Introduction of ICN offers clear benefits to network operators because they are able to recover certain functions (P2P and CDN) that are currently implemented as overlay by other operators. The current competitive environment and the abundance of network infrastructure may also offer P2P and

CDN operators the opportunity to become ICN operators themselves.

This paper has presented the standards-based CONVERGENCE Middleware that provides a rich set of functionalities for application developers and a complete implementation of the key video-oriented ICN Publish/Subscribe functionality called VCN-PS. The MXM Middleware is available as BSD OSS from http://mxm.wg11.sc29.org/download/check-out-the-source-code/java/.

A summary analysis of how VCN-PS can be applied to the existing WimTV video platform has shown that exploitation of VCN-PS is possible and that there is ample room to specific optimisations for the provisioning of meaningful personalisation of video service business.

The next steps in this research will include 1) making VCN-PS robust, 2) adding new functionalities, 3) deploying an experimental ICN, 4) implementing parts of the WimTV platform for actual operation on ICN and 5) furthering the business model analysis.

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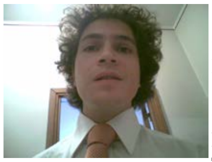
IX. Biographies

Angelo Difino
Angelo received his Computer Science degree from Università di Torino, Italy, in December 2000 and in 2005 he also got the degree in Computer Science Engineering from Politecnico di Torino. He started to work in the research lab of the telecommunication Italian company, Telecom Italia Lab, onpersonalization and user profiling activities. He contributed to several international standards: MPEG, SIP and FIPA. He spent last 6 years working on a startup and on a consulting agency about Multimedia technologies and Metadata descriptions, having the lead on the CEDEO.net contributions on Italian and European research projects.

Riccardo Chiariglione
Riccardo graduated in Science of Communication from Turin University. He worked on his final year project at Hill&Knowlton, London, UK, and sDae, Madrid, Spain (interships), where he started to investigate the Digital Media domain. Since June 2005 Riccardo has been working at CEDEO.net as Digital Media Analyst, developing a series of studies and analysis in the field of Digital Media. Riccardo focuses on the evolution of Digital Media environment and is currently involved in the User-Generated-Content and Social Networking areas.



Giuseppe Tropea
Giuseppe received his Laurea Degree in Informatics Engineering (spec. Computer Systems) from University of Catania, Italy, in October 2002. Since 2006 he is with Consorzio Nazionale Inter-universitario per le Telecomunicazioni (CNIT), inside the DIS-CREET, MOMENT and CONVERGENCE European projects, dealing with privacy protection in digital services and obfuscation of sensible IP traffic data by means of semantic, ontology-bases approaches. He is active in the MOI (Monitoring Ontology for IP traffic) ETSI Industry Specification Group and in MPEG-21 and MPEG-M. His research interests include routing protocols, neural networks, software modeling, semantic ontologies and natural language parsers, as well as data mining and GIS applications.