

SCALABLE CONTENT DELIVERY OVER P2P CONVERGENT NETWORKS

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ABSTRACT

This paper describes an innovative system and its architecture to offer media scalable content delivery, increasing the robustness and resiliency, enriching the PQoS both within the network and/or at the end-user terminal, while protecting the content from unauthorized access over heterogeneous physical architecture and P2P logical overlay network topologies. The system is focused on different convergent networks including broadcasting, interactive/on demand bidirectional networks and mobile networks, and mesh P2P logical overlay topologies. This system is based on three technology pillars: Multi-layered/Multi-viewed content coding, Multi-source/multi-network streaming & adaptation, content protection and lightweight asset management. In addition, the applicability to IPTV over P2P convergent networks is described to demonstrate the system usefulness to offer commercial services.

Index Terms— *Multi-layered/Multi-viewed content coding, SVC/MVC, Multi-source/multi-network streaming & adaptation, content protection, asset management*

1. INTRODUCTION

In the future media environment flexible and reliable network structures to provide end-to-end content delivery to any device and over any network, which can offer seamless media scalability and adaptation along with a lightweight content management and protection, are a key technology of interest for the media industry.

These new service architectures are needed to offer a new experience of seamless video delivery, maintaining the integrity and wherever applicable, and adapting and enriching the quality of the media across the whole distribution chain.

In order to propose a solution to this objective, this paper will describe a complete system and its architecture to offer media scalable content delivery[1], which can increase the robustness and resiliency, enriching the PQoS both within the network and/or at the end-user terminal, while protecting the content from unauthorized access over heterogeneous physical architecture and P2P logical overlay network topologies.

The system described in the paper is focused on different convergent networks, including broadcasting networks e.g. terrestrial (DVB-T), satellite (DVB-S/S2), cable (DVB-C), interactive/on demand bidirectional networks (e.g. xDSL, WiMAX), mobile networks (e.g. 3G/4G, GERAN, UTRAN, DVB-H). The system covers also mesh P2P logical overlay topologies [4] which are expected to be present in many network architectures for media delivery.

For the introduction of novel services and new business models, the system is based on three key-content delivery pillars:

- a) Multi-layered/Multi-viewed content coding.
- b) Multi-source/multi-network streaming & adaptation.
- c) Content protection and lightweight asset management.

These three technology pillars are combined in the proposed architecture to produce the result of a seamless structure to provide AV services to any platform and any device using overlay network topologies.

This paper describes the ways to combine the mentioned technology pillars in the system architecture to produce the result of a media scalable delivery network architecture with the elsewhere mentioned features of robustness and resiliency, enriched PQoS, lightweight content management and protection, etc.

The rest of the paper is organised as follows. It will describe in section 2 the architecture key parts for this scalable content delivery. Section 3 contains the technology pillars of the proposed solution. In section 4 the applicability to IPTV over P2P delivery services is described. Section 5 contains the conclusions.

2. ARCHITECTURE FOR SEAMLESS CONTENT DELIVERY

To build a novel architecture for seamless content delivery it is needed to find the network elements and advances in content coding, distribution and protection which can accommodate the different system parts in a single robust solution.

First of all, the advanced coding schemes will facilitate video distribution with enriched QoS, especially in case of high-end multi-modal terminals able to receive and reconstruct multiple video streams segments (i.e. layers,

views, descriptions). However, home terminals or low-cost mobile terminals may be only capable for decoding at a particular bit-rate or may be only feasible to correctly display up to a particular image resolution.

Thus, on the one hand the media delivery service architecture should be content aware and have knowledge of the access technologies as well as to the end-user device capabilities and characteristics. On the other hand it should support terminal mobility, including service continuity, between different (radio) access technologies.

The service architecture upon the described variety of access networks, it is desirable to have as much information and adaptation at the lower layers (up to the network layer) as possible, along with scalability functionality coming with the media codec. Certain functions such as content caching in the network, content adaptation and cross-layer optimisation would certainly need knowledge of the network conditions/characteristics. In order to overcome this problem, wherever applicable in the Fig.1 architecture, it introduces intelligent media/ network aware nodes.

A Media Aware Network Element (MANE) is defined as a network element, such as an application layer gateway that is capable of parsing certain aspects of the RTP payload headers or the RTP payload and reacting to the contents and modifies session signalling. In the proposed architecture two MANE types will be introduced: a) seamless Home Media Gateway (sHMG), located at the edge of the extended home environment and b) seamless Network Media Gateway (sNMG) at the edge of the 3GPP Service Architecture Evolution (SAE).

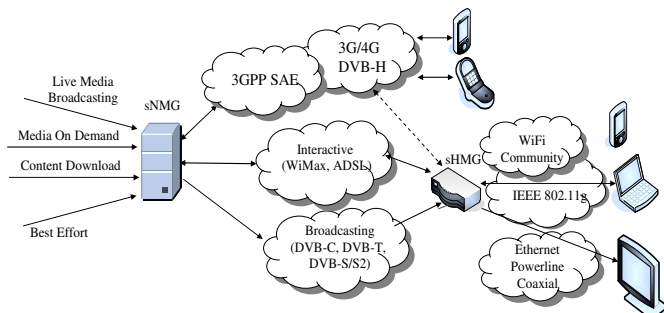


Fig. 1 Network elements and interfaces

As it could be found in Fig. 1, the sHMG will be the gate to the extended home environment and aims to interconnect various access networks (e.g. DVB-T, DVB-S/S2, xDSL, WiMAX) and indoor networks (e.g. WiFi, Ethernet, Powerline, ZigBee). Moreover, it will be an interconnection/relay node for the WiFi public community. Various broadband streams will be received (Dx), and then distributed in the multimedia home devices or stored locally. In parallel, a number of streams will be retrieved, adapted and sent/relayed (Ux) to terminals located inside or outside the house.

Another innovation to provide on-the-fly enriched PQoS, is that sHMG will be able to offer multimedia content adaptation and caching/storage functions to the service provider and the community. The storage capabilities of the sHMG will be divided in two partitions. One partition will be allocated to the user, where personal/private content will be located. This content will be distributed on user demand and under user permissions, assent and will to support P2P communications. Another partition will be allocated to the service provider and/or the community network, and will be utilised as temporal cache. A/V content files, layers or segments will be stored and indexed there, adapted and retrieved/relayed on remote (guest) users or subscribers' request.

In this way, not only a "follow me" service will be available, where the user will be able to receive services and retrieve content remotely, adapted to the network and the terminal that he/she is currently located, but P2P (super)distribution and load balancing will also be feasible. Of course, as the uplink (e.g. ADSL) connection may be flimsy, the owner of the sHMG will have priority over other users.

Similarly to the sHMG, sNMG will be located at the edge of the 3GPP Service Architecture Evolution (SAE) network. sNMG will interface the service providers with the multi-radio access terminal, b) the multi-RAT network and c) the IP network that interconnects the sNMG with the sHMG and the home terminals. In the longer term, sNMG may be integrated in an IMS element, or the sNMG functionality may be overloaded on an IMS.

The sNMG will provide for the network content reconstruction and forwarding, thus enriching the delivered content quality. Within sNMG, only service provider data will be stored as local cache. However, sNMG will have the capability to identify the terminal processing, decoding, networking and display capabilities, and based on user preferences and contract may initiate streaming video adaptation or reconstruction (thus in the network QoS enrichment) before forwarding to the end user.

3. KEY TECHNOLOGY PILLARS

The system is based in 3 technology pillars which combined in the described architecture will cover the system goals. In the paper length it is not possible to cover all the aspects of the proposed technology pillars but the adaptation and need for the system architecture will be properly covered.

The first technology pillar of this system is the Multi-layered/Multi-viewed content coding[2][3]. For the proposed architecture it is considered the evolution of H.264 SVC (Scalable Video Coding), H.264 MVC (Multi View Coding)[2][3] and their emerging standards, as the major foreseen content delivery technologies over heterogeneous networks, multiple terminals and large audiences. SVC will offer layered temporal/spatial/quality

content scalability, whereas MVC will introduce a truly personalised video delivery experience by allowing the user to select among the different views embedded in a single video stream. Future truly free-view point applications will become available by adding depth information to MVC coded sequences.

Secondly the multi-source/multi-network streaming & adaptation is needed for a on-the fly content adaptation, inherited resiliency and enriched PQoS by dynamically combining different content layers, views and representations of the same resource (video stream) transmitted from multiple sources (different servers or peers in case of P2P streaming) and/or received over multiple diverse paths or networks. Reconstruction of the content segments may take place either within the network (offering transparent streaming to low-end terminals) or at the end-user terminal in case multi-network connectivity is available. Cross-network adaptation and cross-layer optimization especially in P2P overlay topologies, will offer traffic adaptation (load balancing to avoid network flooding) and optimal use the available resources (bandwidth).

The third pillar is the content protection and lightweight asset management as new business models for large scale content distribution. This lightweight content management and protection will be facilitated side-by-side to a proper content protection and asset management mechanism. Personalised content protection on-the fly will be offered in the extended delivery environment, covering not only the legacy content creation chain in a Digital Rights Management (DRM)-like approach, but also the private multimedia content, which may be soon the major content category. Adaptation of the content protection and rights management solutions for new media in P2P networks is key for commercial applications. Protection of the content is another key area of the solution: if the data traffic is distributed over peers, should be protected for reasons of privacy and security.

The combination of the mentioned elements should be covered in the applicability to content delivery services such as IPTV over P2P. In the next section the application of the network elements and the technology pillars to IPTV P2P services is described.

4. APPLICATION TO IPTV OVER P2P SERVICES

Several services can be developed on top of this architecture and one example can be found in the IPTV over P2P networks that can demonstrate the feasibility and utility of the proposed architecture as in Fig. 2. An innovative P2P IPTV-like application efficiently combine and utilise all described multimedia technological advances, and can validate the mentioned concepts and optimization of the platform behaviour.

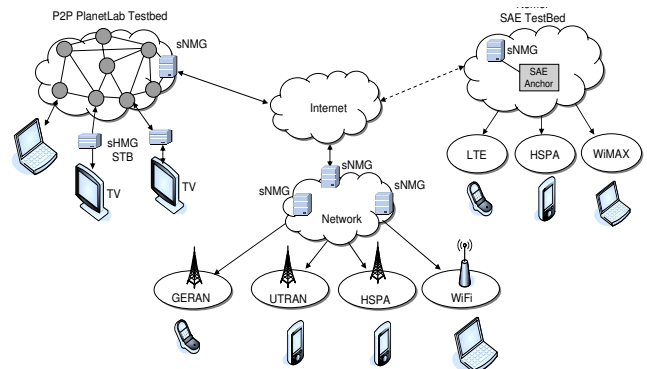


Figure 2: IPTV over P2P network test architecture

This architecture consists of an IPTV-like client/server video streaming application with seamless content distribution functionality which is connected to a P2P network testbed (left part of the Fig.2). The video server produces H.264/SVC and H.264/MVC encoding streams, and is used also for storage and distribution. Then is added the MDC (Multi-Description Coding, MDC) which will facilitate video distribution with enriched QoS, especially in case of high-end multi-modal terminals able to receive and reconstruct multiple video streams segments. This server should also provide content protection and encryption, including key negotiation and rights management with the end-users, which should go across the MANEs. sNMGs provide the interconnection through the different elements of the system and the different heterogeneous networks. Other functionality provided by the MANEs are “added functionalities” such as “follow me” capability, forwarding the streaming content to a mobile terminal, roaming capability in a multi-RAT environment, etc.

Especially, the utilisation of combined SVC and MDC technologies seems particularly suitable for the P2P scenario. MDC has been identified as one of the most efficient distribution method, when the packet loss rate is significant and the network allows for path diversity transmission. This may be exactly the case especially in P2P real time delivery scenarios, where the media data may reach the client via different best-effort connections. Many methods to generate MDC have been proposed [5]. These methods, although providing good performance, they are incompatible with video coding standards. Moreover, traditional MDC schemes do not encompass simple tuning mechanisms, so as to adapt on varying network/user conditions.

Recently, novel MDC schemes compatible with international coding standard and allowing tuning of the redundancy have been proposed. In particular, rate distortion optimization approaches have proven to be very effective in the analysis and the design of MDC techniques. In the proposed architecture, MDC will be combined with

SVC/MVC coding for enhanced resilience of multi-networked and P2P video distribution.

A huge gain is expected if the video data are not considered as ordinary data chunks, but organized in a succession of descriptions and/or layers, optimized from the point of view of the video playout. In fact, in critical transmission situations, e.g. a streaming node disconnects suddenly or thousands of users request the same content simultaneously, the peers may want to resort to lower quality, skipping refinement layer packets but not experiencing an abrupt service break down.

Tree-based P2P overlays implement a tree distribution graph, rooted at the source of the content. In principle, each node receives data from a parent node, which may be the source or a peer. If peers do not change too often, such systems require little overhead, since packets are forwarded from node to node without the need for extra messages. However, in high churn environment, the tree must be continuously destroyed and rebuilt, a process that requires considerable control message overhead. As a side effect, nodes must buffer data for at least the time required to repair the tree, in order to avoid packet loss. Mesh-based overlays implement a mesh distribution graph, where each node contacts a subset of peers to obtain a number of chunks.

Every node needs to know which chunks are owned by its peers and explicitly “pulls” the chunks it needs. This type of scheme involves overhead, due in part to the exchange of buffer maps between nodes and in part to the “pull” process. Thanks to the fact that each node relies on multiple peers (as opposed to just one parent) to retrieve content, mesh based systems offer good resilience to node failures.

On the negative side they require large buffers to support parallel pulling and chunk store and forwarding (clearly, large buffers are needed to increase the chances of finding the right chunk).

5. CONCLUSIONS

This paper introduces a novel approach to the architectures for seamless content delivery in convergent networks involving heterogeneous devices. This architecture has a clear applicability to IPTV services based on P2P logical overlay network topologies.

Although the paper describes a theoretical approach to the problem, the architecture is being implemented (see [4]) and the technologies described in the paper are expected to be developed for a complete end-to-end system functionality to be tested in a P2P environment (PlanetLab). This implementation and experimentation will offer a full validation for a commercial exploitation of the proposed solution.

6. REFERENCES

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