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Efficient Streaming in Future Internet

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Abstract. The Future Internet is not envisaged to be simply a faster way to go online. What is expected to fundamentally change the way that people use the Internet is the ability to produce, and seamlessly deliver and share their own multimedia content. In this paper, we introduce and analyse innovative architecture components to offer media scalable content delivery, increasing the robustness, enriching the PQoS and protecting the content from unauthorized access over heterogeneous physical architecture and P2P logical overlay network topologies. Technology pillars in which the system is based are described: i.e. Multi-layered/Multi-viewed content coding, Multi-source/multi-network streaming & adaptation, content protection and lightweight asset management.

Keywords. Multi-layered/Multi-viewed content coding, SVC/MVC, MDC, Multi-source/multi-network streaming & adaptation

Introduction

The Future Internet is expected to fundamentally change the way that people use the Internet: i.e. the ability to produce, and seamlessly deliver and share their own multimedia content. We expect that in a few years everyone will be multimedia content producer (by publishing digital pictures, video recordings, smart home surveillance, etc.), multimedia content mediator (by storing/forwarding streaming content) and multimedia content consumer (digital television, video on demand, mobile broadcasting and alike). In this context, we consider the Future Internet as a dynamic and distributed environment, which enables new services and seamless, scalable and trusted multimedia content delivery, increasing the robustness and resiliency, enriching the PQoS both within the network and/or at the end-user terminal.

The first step to introduce seamless content distribution is to take advantage of the sufficient uplink capacity that most access technologies typically offer. Individuals may operate as content creators and service providers by distributing their personal content including but not limited to video streams. Moreover, novel "follow me" like services may be introduced, where the home-based equipment may operate as service mediator

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and content forwarder and a subscriber may consume personalised streaming services, properly adapted to network characteristics/conditions and his mobile phone/PDA capabilities, while on the move.

However, the major envisaged potential of the Future Internet is shown in Figure 1 by introducing trusted Peer-to-Peer (P2P) overlay topologies and cloud computing in the broadband, heterogeneous architecture. This is also compatible with the increasing and expanding WiFi community networks architectures. In this case, services may be offered not only by centrally located media streaming servers, but by groups of end-user devices, acting as distributed content repositories. Given content protection and management is in place, network operators and service providers may offer value-added streaming services with remarkable PQoS, while avoiding the nightmare of network scaling and the expenses in network infrastructure upgrades, as the content (at least the most popular one) and the network resources (traffic load) may be distributed and thus balanced to a large number of peers. Moreover, individuals may produce their own (real-time) content and make it publicly available to a larger audience, without having to rely on a specific, expensive networking infrastructure. In this environment, video streaming scalability, resilience and PQoS may be exponentially increased, as not only multiple-networks, but also multiple-sources may stream video segments, enriching the content on-the-fly either at the network and/or at the end-user terminal.

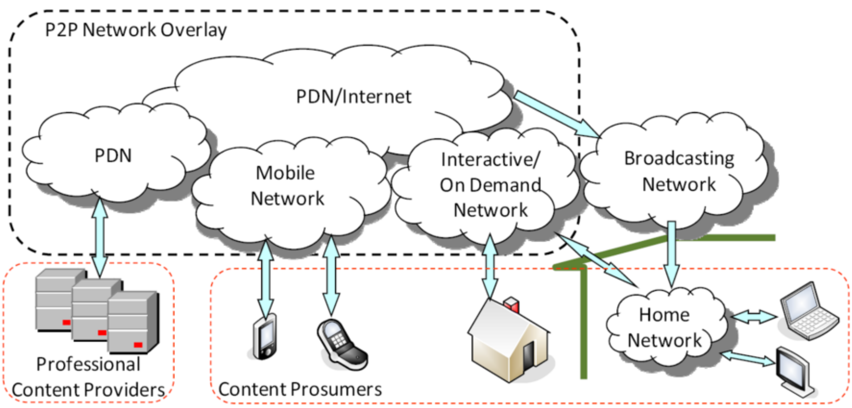

Figure 1: The proposed Future Internet logical network architecture

In order to realize the above service provisioning scenarios, a number of issues have to be considered and tackled. Advanced scalable and multiview video coding, knowledge of the network conditions, innovative cross layer optimization, real-time service adaptation, on-the fly PQoS enrichment, content protection are some of the issues that have to be solved. In this paper, we highlight and analyse the main pillars and introduce technologies and solutions that could be applied in the envisaged seamless content delivery in the Future Internet network evolution. The work is mainly based on the outcomes of the projects OPTIMIX[2] and SEA[3].

[2] The OPTIMIX project (INFSO-ICT-214625) focuses on studying innovative solutions enabling enhanced video streaming in an IP based wireless heterogeneous system, based on cross layer adaptation of the whole transmission chain.

[3] The SEA project (INFSO-ICT-214063) offers a new experience of seamless video delivery, maintaining the integrity and, wherever applicable, adapting and enriching the quality of the media.

1. Proposed Network Architecture Innovations

Advanced coding schemes like Scalable Video Coding (SVC), Multi-View Coding (MVC), Multi-Description Coding (MDC) 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, in order to meet all proposed innovative features, the media delivery service architecture should be content aware and have knowledge of the access technologies as well as to the utilised end-user device capabilities and characteristics. The Future Internet network architecture has to provide the relative adaptation functionalities to seamlessly support the majority of terminals. It should be able to support terminal mobility, including service continuity, between different (radio) access technologies, or maintaining and supporting the same capabilities of access control (authentication, authorization), privacy and charging when moving between different (radio) access technologies. IP service continuity should be maintained, i.e. the network should hide the impact of mobility events to the end user and the IP application(s), i.e. the service can continue without user intervention or special application support to mask the effects of a mobility event.

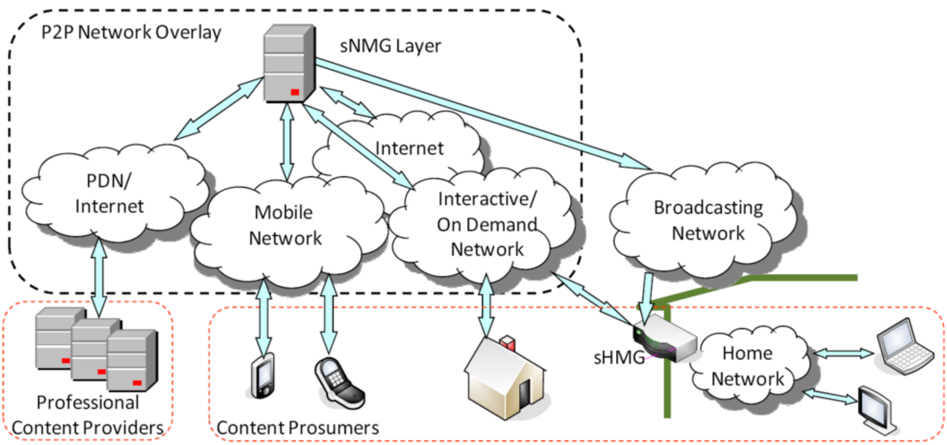

Figure 2: Proposed Content Delivery Network Architecture

In case of building a 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 optimization would certainly need knowledge of the network conditions/characteristics. In order to overcome this problem, wherever applicable in the proposed Future Internet architecture, we introduce intelligent media/ network aware entities. These could be new nodes of the foreseen network architecture or enhanced nodes for new network installations. In the first case, we propose two MANE types: a) streaming Home Media Gateway (sHMG), located at the edge of the extended home environment and b) streaming Network Media Gateway (sNMG). The sNMG could form a layered approach, while the sHMG could be considered as end nodes. Figure 2 summarizes these considerations, while Figure 3 provides a mapping of these MANE nodes to the 3GPP Service Architecture Evolution (SAE) network topology.

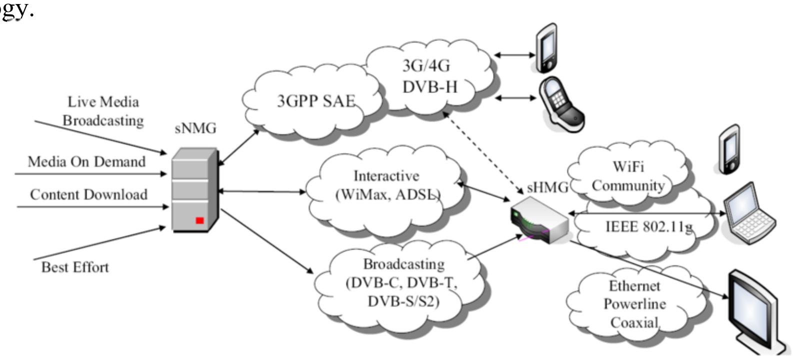

Figure 3: Mapping of proposed MANE to the SAE architecture

The proposed MANE nodes will support the intelligent, seamless content distribution. They will offer functions like network and terminal awareness, content enrichment and content protection. In the longer term, they may be integrated on Internet Multimedia Systems (IMS) as define by ETSI TISPAN. They will offer multimedia storage, dynamic content adaptation and enriched PQoS by dynamically combining multiple multimedia content layers from various sources. Moreover, as they will have knowledge of the underlined networks, they will provide information on the network conditions/characteristics, which will be utilised by the Cross Layer Control (CLC) mechanism and adapt the multimedia streams to the next network in the delivery path. This will be extremely important in case of a low bandwidth, but guaranteed QoS mobile networks and in the broadband, but best effort P2P topologies.

2. Key Technology Pillars and Trends

For the introduction of novel services and new business models, including efficient, resilient, enriched Perceived QoS (PQoS) and seamless content delivery over the future Internet, apart from the network architecture, we expect that key-content pillars should be introduced. Some of them are summarized in this section:

- ***Multi-layered/Multi-view personalised content coding.*** In order to maximize video portability, scalability and error resilience across a number of heterogeneous terminals, we propose the H.264 Scalable Video Coding (SVC) as the major encoding standard. The concept of Multi View Coding (MVC) is to allow for different views of video streaming without drastically increasing the data rate for the media delivery.

- ***Multiple Description Coding (MDC).*** Future Internet should provide for inherited mechanisms for resilient content distribution. One method that could be applied is the Multi Desription Coding (MDC) approach.

- ***P2P video streaming.*** The Future Internet should address P2P challenging topics including: a) peer retrieval optimization and b) application of proper coding techniques. Another important topic will be the distribution of multiple views over a P2P overlay and optimization of the visual quality and PQoS via exploitation of advanced source coding techniques (SVC, MVC, MDC).

- **Cross Layer Control (CLC) and Optimisation.** Existing CLC provide significant improvements in the PQoS under specific networking and transmission conditions. However, none is directly applicable to the Future Internet concept, as the terminal will not necessarily know the actual physical layer infrastructure. Especially in the case of P2P topologies, the physical infrastructure may even be an arbitrary, timely varying combination of links belonging to different networks.

3. Cross Layer Signaling Architecture for Adaptive Transmission

The Future Internet should be able to provide seamless media delivery within heterogeneous networks and terminals with dynamic scalability across the whole delivery chain. Local adaptation within a single system layer has proven not to be the most efficient way to achieve dynamic scalability. At the same time, cross-layer adaptation and controlling among different layers has been studied very extensively recently and it has proven to give better performance and better adaptivity than the traditional techniques. However, these studies quite commonly neglect the delivery and signaling of cross-layer information within and between entities. An efficient signaling architecture is crucial for the success of cross-layer adaptation and controlling and due to these issues, we propose an end-to-end architecture for cross-layer signaling.

3.1. The OPTIMIX Cross Layer Solution

The cross-layer and end-to-end signalling solution used in OPTIMIX system is based on Triggering Framework introduced in [1]. In this architecture, the triggering framework is used for transferring cross-layer signals both locally, that is, between entities located on the different layers of the local protocol stack, and remotely, between entities in different network nodes (i.e. the mobile station, the server, and the base station). Together with the IEEE 802.21, Media Independent Handover (MIH) Services, standard, it provides an end-to-end solution for cross-layer signalling. This architecture is illustrated in Figure 4 and more detailed description of the proposed architecture is given in the following sections.

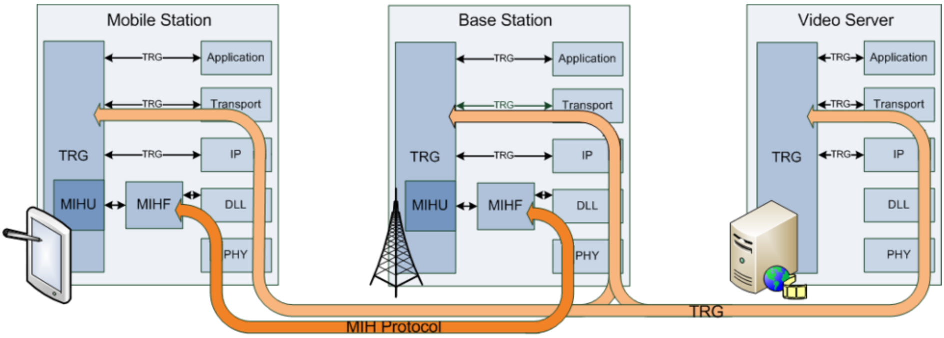

Figure 4: OPTIMIX Cross-layer Signalling Architecture

3.1.1. Low-level cross-layer signaling - IEEE 802.21

The IEEE 802.21 working group has published the first standard to facilitate heterogeneous handovers in January 2009. It provides three main services - command service, information service, and event service - to collect information from links and networks in range, and to initiate IEEE 802.21 assisted seamless network changes. Despite the main target of the standard, the provided services offer usage also beyond handovers, which are capitalized on and experimented in our architecture. For instance, event service enables receiving timely and consistent information about current link conditions. This information can be used, for instance, to trigger mechanisms to accommodate the current video stream to the varying link conditions, without executing a handover in the first place after the video quality start degrading.

The main entity of IEEE 802.21 framework [2] is called MIH Function (MIHF), which interfaces with the local link layers and MIH User (MIHU). MIHU is a common name for an entity having all logic and intelligent related to the usage of the information available through IEEE 802.21. IEEE 802.21 allows peer-MIHF entities to register with each other and exchange messages using MIH protocol. This way, for instance, MIHF on a Base Station (BS) can subscribe for a particular set of events from the Mobile Stations (MSs) it is affiliated with and monitor the link conditions of each MS separately. This is the main usage of IEEE 802.21 in our signaling architecture; to provide timely low layer events from MSs to BSs in a lightweight and fast way over Layer-2 communication. Since upper layer events (Layer-3 and above) and end-to-end communication are out of scope of IEEE 802.21, IEEE 802.21 does not contend with Triggering Framework in the architecture but collaborates [3].

3.1.2. Signaling between network elements - Triggering Framework

The central functional element of Triggering Framework is Triggering Engine (TRG) that manages the cross-layer signalling between the different entities. The strength of TRG is in its generic nature: the TRG offers generic socket or SOAP based interfaces for the collection and dissemination of cross-layer information and formats the information as *triggers* with a predetermined but flexible structure: ID, type, and value. Each trigger can be identified through a unique ID that also defines its source, that is, the entity that produced it (e.g. the video streaming application, L3 mobility management software, or a WLAN NIC). The different triggers produced by one source can be differentiated based on the type field of the trigger. Finally, the actual cross-layer information is carried in the value field. The structure of the value field is not fixed by TRG specification, and it thus can be used for carrying virtually any kind of feedback information that is useful for the trigger consumers within the system.

In addition to its role as a trigger collector and distributor, TRG provides trigger management and processing services in terms of access control, trigger filtering, and temporary storage for the triggers. Besides these operations, TRG remains agnostic to the contents of the triggers and additional entities need to be introduced into the system to perform more advanced trigger processing functions such as the trigger aggregation.

Our signalling system uses the cascaded TRGs feature of Triggering Framework [4] to enable end-to-end signalling. TRG cascading means that TRG running in a network node is capable of receiving triggers from TRGs located in other nodes of the system. The video streaming server is thus capable of receiving feedback information from all remote streaming clients connected to it via Triggering Framework. In this type of remote triggering, the triggers coming from different nodes are distinguished based on; for example, the IP addresses of the source nodes.

3.1.3. Cross-layer feedback messages and data aggregation

Although Triggering Framework allows using filters (to limit the value range of interest) in the subscriptions, the feedback message exchange will cause overhead for the total network traffic. The amount of message exchange could easily become enormous if each information source (e.g. streaming application, mobility manager software) will send a trigger every time something changes in the status of the source and especially when numbers of clients with similar functionalities will do the same. In order to mitigate the feedback overhead, we have developed a client-side aggregation mechanism for Triggering Framework. The proposed trigger aggregation bundles multiple triggers into a single trigger, which is periodically sent to the consumers subscribed to it. Aggregated triggers enable trigger consumers to subscribe triggers of their high interest with strict filters and still get information about the values of these triggers periodically. For example, the Network Media Gateway can subscribe to a single aggregated trigger which includes information from the application, transport and physical layers of an MS and use this for adaptation purposes.

3.2. The SEA Cross Layer Solution

The cross-layer and end-to-end signalling solution used in SEA system is based on MPEG-21 approach [5]. However, signalling has been adapted to follow the IETF (SDP [6] and RTSP [7]) approach. Taking into account the SEA architecture, the SEA network nodes and the final terminal capabilities (ranging form laptops to mobile phones) [8], within SEA we adopt a general adaptation network architecture as shown in Figure 5. In this view, we assume that in the path from the Content Provider (including content prosumers) to the terminal, we may have N+1 Adaptation Engines (AE). Each engine is responsible for adapting the video stream to the next network in the path i.e. AE_i adapts the video stream to the characteristics/capabilities of Network *i*, always taking into account the final terminal capabilities and user requirements.

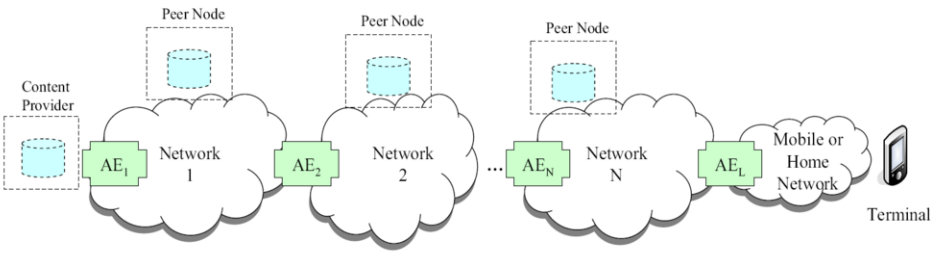

Figure 5: SEA Adaptation network architecture

As the adaptation options may be limited, some adaptation engines may perform stream adaptation, or some of them may just forward (relay) network, streaming, terminal or user characteristics to the next AE along the connection path. It is important to note however, that the last adaptation engine will also have the responsibility to terminate the adaptation in case the terminal is not able to handle it. For example in case of P2P streaming, the terminal may not be able to handle the required extended buffering and streaming reconstruction, and this functionality may be handled by the *Last Node AE* (AE_L). For simplicity reasons, we'll assume that the AE_L will always terminate the adaptation process, reconstruct the streamed video according to the terminal needs, and then stream the re-constructed video to the terminal[4]. Moreover, the AE_L will be responsible for streaming A/V content optimised for the end-user's terminal and access connection. Taking into account the above architecture we may summarize a number of scenarios, as follows.

The architecture of Figure 5 is further analysed in Cross Layer Adaptation and Control functional nodes as shown in Figure 6. It has to be noted, that the AE_L which is the Adaptation Engine of the *Last Node,* while the SEA Media Node may be realised/ instantiated as either a sNMG or a sHMG node.

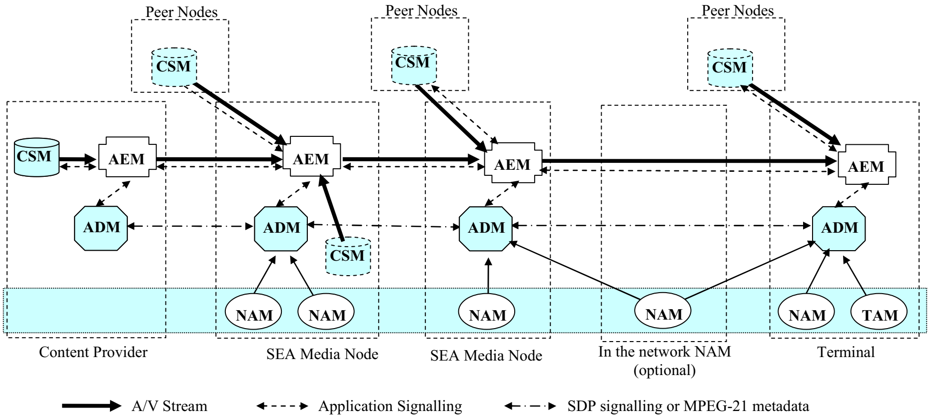

Figure 6: Cross Layer Modules communication

The major CLC nodes in SEA are the Adaptation Decision Module (ADM) and the Adaptation Execution Module (AEM), which offer the following functionality:

- **Adaptation Decision Module (ADM):** This module is able to decide if and what adaptation has to take place. Based on a multi-criteria decision framework, and network and terminal capabilities sensing, ADM will allow tuning of the encoding/streaming parameters, optimizing the end-to-end rate, the distortion image quality and the resilience strategies at the application layer, as well as information regarding the connecting terminals.
- **Adaptation Execution Module (AEM)**. This module is the context aware module, which actually performs the A/V handling. AEM functions include dropping or combining SVC layers or MVC views and initiating MDC distribution over different paths.

The ADM and the AEM modules will be located on all intelligent SEA Media Nodes i.e. the Content Provider node, the sHMG, the sNMG and the terminal. It should be noted that the "Content Provider" maybe a professional content provider; however user generated content is going to be the wide majority in the future scenarios. Thus, content provider may be considered as the initial content server, supported by a P2P

[4] In case the terminal is able to handle the adaptation process itself, we can assume that the AE_L is collocated at the terminal.

network. Additionally, based on the business model, the ownership of the nodes and the capabilities of the terminal, three supporting entities may also be defined:

- **Content Storage Module (CSM).** This module is utilised to store or cache the A/V content segments (layers, views, descriptions). It may act as an A/V server or a peer node in a P2P environment supporting on-the fly content enrichment.
- **Network Awareness Module (NAM):** This module has knowledge of the physical characteristics of the network (multiple access, QoS classes, coverage). Moreover, it may be able to measure or probe network parameters e.g. number of users, available bandwidth, etc. This module may be located at all intelligent SEA nodes. Moreover, it may be optionally located in the network, providing additional information which is directly retrieved by the network nodes.
- **Terminal Awareness Module (TAM):** This module is located at the user terminal and has knowledge of the physical characteristics of the terminal (display, network interfaces, processing power, decoding capabilities). Moreover, it may be able to measure parameters at the terminal e.g. CPU load, battery life, free storage space, and network conditions e.g. SNR, BER, etc.

3.2.1. The SEA adaptation engine architecture

Within SEA we assume that the received stream may be SVC (base layer with or without enhanced layers), MVC (with a number of views), MDC encoding different types of video (e.g. SVC base layer, MVC), P2P video chucks (either used as transport where P2P is unaware of the video format that it is carrying or the P2P network is aware and gives different priorities to the different chunks) and a number of their combination. Thus, a more detailed view of the Adaptation Engine is shown in Figure 7.

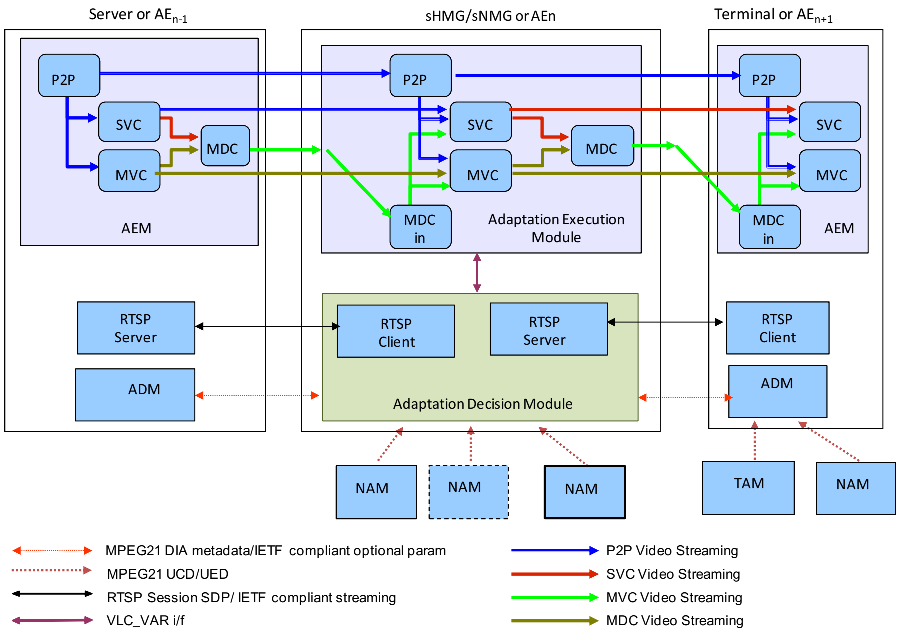

Figure 7. Adaptation Engine Architecture

As shown in Figure 7, in a first layer the NAM/TAM modules provide input to the ADM module. In a second layer, the ADM modules communicate horizontally to exchange information and make decisions. It is important to note that each ADM is making a decision for the network that will follow, while in VoD cases this information is propagated to the ADM modules that are closer to the Video Server. In a third level, the ADM communicates with the AEM to perform the content adaptation.

4. Conclusions

In this paper, we have introduced and analysed two innovative approaches (OPTIMIX and SEA) to offer media scalable content delivery, increasing the robustness and enriching the PQoS over heterogeneous physical architecture and P2P logical overlay network topologies. The OPTIMIX approach faces the problem in a more general network centric approach, while the SEA approach a more service oriented approach. Yet, the combination should be considered as an evolutionary step towards Future Media Internet.

5. Acknowledgment

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References

[1] J. Mäkelä and K. Pentikousis: *Trigger Management Mechanisms*, Proc. of the IEEE International Symposium on Wireless Pervasive Computing (ISWPC'07), 5-7 February 2007, San Juan, Puerto Rico.
[2] IEEE 802.21 WG. *IEEE Standard for Local and Metropolitan Area Networks. Part 21: Media Independent Handover Services*. IEEE Std 802.21-2008, 2009
[3] E. Piri, T. Sutinen, J. Vehkaperä. *Cross-layer Architecture for Adaptive Real-time Multimedia in Heterogeneous Network Environment*. In Proc. European Wireless 2009, May 2009, Aalborg, Denmark
[4] M. Luoto and T. Sutinen: *Cross-layer Enhanced Mobility Management in Heterogeneous Networks*. In Proc. of the International Conference on Communications, Beijing, China, May 2008.
[5] MPEG-21, *Digital Item Adaptation, FCD*, ISO/IEC JTCI/SG29/WG11 N5845, 2005
[6] M. Handly, V. Jacobson and C.Perkins, “SDP: Session Description Protocol”, IETF RFC 4566, July 2006, http://tools.ietf.org/html/rfc4566
[7] H. Schulzrinne, A. Rao, R. Lanphier: "Real Time Streaming Protocol (RTSP)", IETF RFC 2326, April 1998, http://tools.ietf.org/html/rfc2326
[8] SEA consortium, “D4.1: Cross layer control, adaptation modelling and metadata specification,” 30 September 2008, http://www.ist-sea.eu/Public/SEA_D4.1_SYN_FF_20080930.pdf