Perceptually Enabled and User Centric IMS Architecture: The ADAMANTIUM Project

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Abstract

The predominant candidate for current trend of multimedia services convergence with mobile/fixed networks and broadcast-interactive applications is the IP Multimedia Subsystem (IMS). IMS entails novel business opportunities for pioneering and emerging multimedia services, such as IPTV and VoIP video call applications. However, this strong commercial interest on this promising convergent IMS environment is balanced by the lack of efficient user/customer-centric network management mechanisms. ADAMANTIUM proposes an IMS-compatible Multimedia Content Management System (MCMS) focused on performing dynamic cross layer adaptation for optimization of the user experience in terms of perceptual quality for IPTV and VoIP services. This multimodal management system will be applied in an integrated and coherent way along all the network layers and delivery-chain nodes based on a user/customer-centric approach rather than a typical engineering one. Towards this, the proposed management system will make use of advanced IMS-compatible PQoS and NQoS monitoring and adaptation mechanisms across the network delivery-chain, enhancing in this way the current IMS management functions by providing perceptual awareness to them.

Keywords: IMS, PQoS, VoIP, IPTV, Video.

1. Introduction

The convergence of multimedia services with mobile/fixed networks and broadcast-interactive applications is creating new demands for high quality and user-responsive service provision management. To face the challenges of defining and developing the next generation of ubiquitous and converged network, together with the respective service infrastructures for communication, computing and media, the industry has launched various initiatives in order to design the reference network architecture and standardize the various modules/interfaces that are necessary for delivering the expected services.

The predominant candidate for this convergence is the IP Multimedia Subsystem (IMS) [1-2], which was originally defined by the 3GPP for next-generation mobile networking applications based on Session Initiation Protocol (SIP) as the basic common signalling protocol. It is a specification framework that introduces the functional and network elements, as well as service platforms and the respective architecture, which enable real multimedia convergence on an IP–based infrastructure.

The IMS infrastructure creates novel business opportunities for new and emerging multimedia services, such as Voice over IP (VoIP) (e.g. voice/video call) and Internet Protocol TV (IPTV) (e.g. Live multicast IPTV or Video-on-demand) services. However, this strong commercial interest in the IMS environment is hindered by the lack of efficient user-centric network management mechanisms, which will dynamically adapt/optimize network traffic policy to maximize perceived user satisfaction. One of the visions of future mobile communication networks is that services will be sold in a consumer mass market based on the provision of content that meets various perceptual quality requirements (e.g. video and/or voice quality). There are numerous approaches to this marketing model, but the most important is the Perceived Quality of Service (PQoS) concept [3-4] because it provides a direct link to user-satisfaction. Today, IMS does not provide perceptual management solution for multimedia services that optimizes the delivered PQoS. On the contrary, all the existing management mechanisms (e.g. Traffic prioritization and classification etc.) are only network-oriented and perform efficient management without considering the perceptual impact of the applied traffic policies.

ADAMANTIUM project proposes an innovative IMS-compatible Multimedia Content Management System (MCMS) focused on performing a dynamic cross layer adaptation for the optimization of the user experience in terms of the delivered PQoS level for IPTV and VoIP services– two of the most important multimeda services with the potential to create significant wealth for Europe. This multimodal management system will make use of advanced IMS-compatible PQoS/NQoS monitoring and adaptation mechanisms across the network delivery-chain, thereby significantly enhancing the current IMS management functions by providing necessary perceptual awareness capability.

The rest of the paper is organized as follows: Section 2 presents the ADAMANTIUM concept, while Section 3 discusses the overall proposed ADAMANTIUM architecture. In Section 4 the ADAMANTIUM MCMS is presented, Section 5 describes a relative case scenario and finally Section 6 concludes the paper.

2. The ADAMANTIUM Concept

An overview of the proposed PQoS-aware MCMS concept is depicted in Figure 1. On the left, a multimedia service provision full cycle from content creation, content transport (via core and access networks) to content consuming is shown (from top to bottom). On the right, MCMS interacts with each element in the service provision chain via real-time monitoring and adaptation/control mechanisms to achieve end-to-end Perceived Quality of Service (PQoS) maximization. As shown in the figure, real-time monitoring provides important information, includes from source (e.g. content dynamics), core/access network (e.g. network/link QoS) and terminal (e.g. delivered PQoS). Cross-layer adaptation includes service layer adaptation (e.g. source/terminal coding parameters and FEC), network layer adaptation (e.g. traffic policies) and link layer adaptation (e.g. service classification), and is controlled by an intelligent action engine within the MCMS system.

The PQoS-aware dynamic cross layer adaptation will be performed according to

- The monitored PQoS degradation at the end-user terminal device, which is also the triggering event for the initiation of the adaptation procedure
- The time varying conditions of the Access and Transport network
- The type of the delivered service (i.e. Voice and/or Video for VoIP and IPTV applications), and
- The content dynamics (i.e. Action movie/Talk show or High/Low dynamic conversation).

Towards this, at the Service/Multimedia Server the proposed MCMS module will be able to monitor and adapt the encoding parameters (e.g. bit rate, spatial and temporal resolution, encoding scheme structure) and the respective streaming/packetization schemes (e.g. packet size, hinted encoding for streaming optimization, streaming protocol,).

At the Core/Transport Network Operator, a DiffServ/MPLS policy mechanism is considered, which is capable of treating the incoming traffic according to the respective DiffServ/MPLS marking and classification rules applied by the edge routers. The MCMS, depending on the nature of the delivered service (i.e. Video and/or Voice for IPTV or VoIP), its dynamics level (High or Low) and the perceptual importance of the respective traffic packets (e.g. some packets are perceptually more important than others due to the interdependency of the encoded multimedia service) will perform the appropriate DiffServ/MPLS Marking at the edges of the transport network.

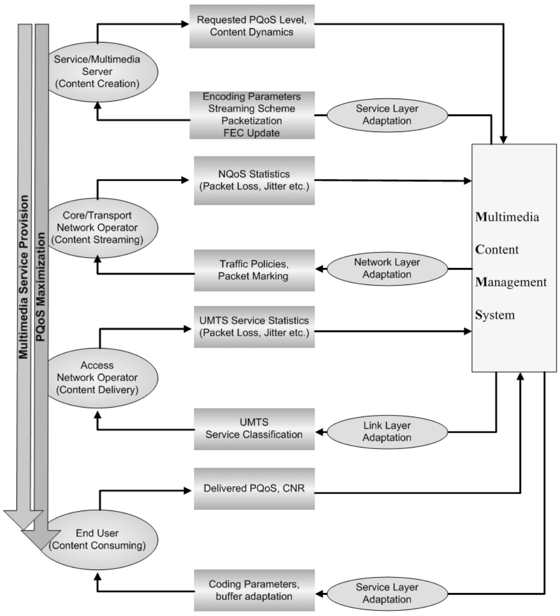

Figure 1: Conceptual diagram of the ADAMANTIUM MCMS for optimizing the user experience

At the access network, a UMTS technology is considered, where the MCMS is able via the GGSN to perform traffic policy adaptations to the incoming traffic (i.e. the service bearers) by exploiting the UMTS service classes (e.g. background class, media class etc.). This service prioritization provides specific QoS constraints to the adapted service, which in turn cause perceptual enhancement and therefore improvement of the user experience. Moreover, the MCMS will be able to monitor near real time traffic statistics for the access network that will be further processed by the MCMS for defining the optimal adaptation action for PQoS optimization.

Finally, at the end-user equipment, except from the monitoring of the delivered PQoS level and the Carrier-to-Noise Ratio (CNR), adaptation actions at the service level are considered, which enhance the robustness and the error resilience of the streaming service.

3. The Overall Architecture of ADAMANTIUM Project

Figure 2 depicts the overall architecture of ADAMANTIUM project. It comprises of:

- The ADAMANTIUM MCMS Module, which is the main project entity and focuses on monitoring the network statistics (i.e. core, access, terminal), the service generation (i.e. Media Server Resource Function (MSRF), VoIP terminals) and the service perceptual level at the end-user terminal in order to define and apply an optimal cross layer adaptation action across the delivery network chain and media lifecycle (i.e. service generation node, core network, access network and end-user terminal) for maximizing the user satisfaction.
- The ADAMANTIUM Multimedia Server and Resource Function (MSRF), which is an IMS-based MRF module with an additional fourfold responsibility:
  - The IPTV service generation, session management and service streaming.
  - The VoIP service session management and signalling.

- o The monitoring of the spatial and/or temporal content dynamics along with the selected encoding/streaming parameters
- o The adaptation, according to the MCMS commands, of the IPTV encoding parameters and/or the respective FEC value.

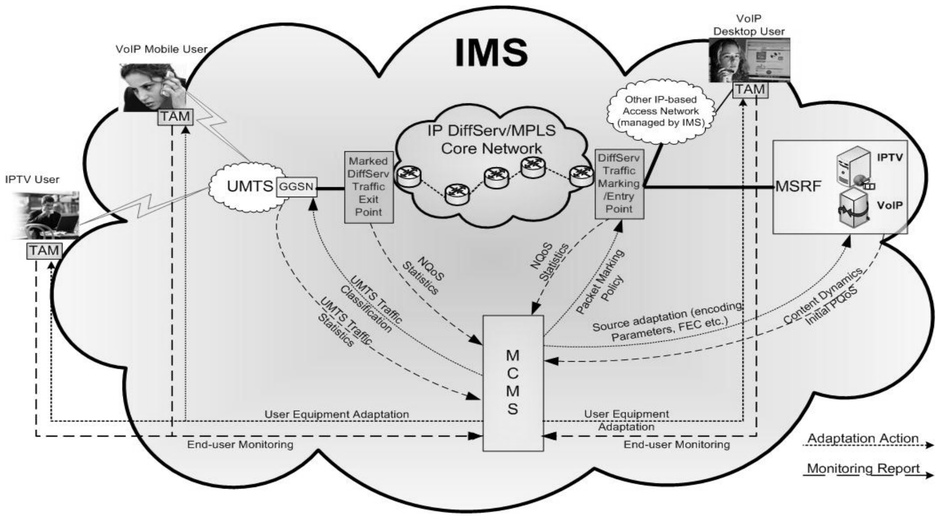

Figure 2: The overall architecture of ADAMANTIUM project.

- § An IP Core – DiffServ/MPLS Compatible Transport Network
  ADAMANTIUM project considers a DiffServ/MPLS-enabled core network for the delivery of the requested multimedia service. ADAMANTIUM will develop IMS and MCMS compatible modules and interfaces for the packet marking and traffic monitoring at the edges of the DiffServ/MPLS traffic network.

- § The UMTS Access Network
  At the access side a UMTS access network is considered, which provides service/bearer classification mechanisms for providing QoS constraints on the delivered service type (e.g. video, voice, data, etc). ADAMANTIUM project exploits these classification mechanisms of the GGSN in its sophisticated PQoS-aware cross layer adaptation procedure with scope the perceptual optimization of the delivered service

- § The ADAMANTIUM Terminal Adaptation Module (TAM).
  At the PQoS-enabled user terminals (e.g. 3G mobile handset, SIP voice/video phone (hardphone or softphone), PDA) a TAM will be integrated, which enables the terminal's interaction with the appropriate interfaces/modules of the MCMS.

There are two functions associated between the MCMS and the TAM of the PQoS-enabled user terminals:

- § Adaptation function: according to the control command/parameters received from the MCMS, the PQoS-enabled user terminal adapts on the fly its VoIP/Videocall codec, encoding bit rate or mode, packetization scheme and jitter buffer size, aiming at end-to-end perceived quality improvement.
- § Monitoring function: reporting delivered PQoS (e.g. MOS score for voice and video) and relevant terminal parameters (e.g. codec type, bit rate, encoding mode, packetization parameters) to the MCMS module. These parameters are obtained by the TAM interface, which is implemented in the terminal device.

4. ADAMANTIUM MCMS

The MCMS is the central entity of the proposed PQoS-aware and user-centric ADAMANTIUM IMS architecture that will seamlessly communicate with the already existing IMS modules and interfaces. Thus, MCMS will be fully IMS compliant, composed of modules based on IMS signalling for communication, processing and interaction with the rest IMS modules and interfaces. Figure 3 depicts the overall architecture of the proposed MCMS within the IMS-native components, their signalling relations and interactions.

According to figure 3, the IMS Application Servers (AS) for IPTV and VoIP applications are hosted within the Media Resource Function (MRF), which executes IMS applications and services by manipulating SIP and SDP signalling for interfacing with other systems. ADAMANTIUM project considers that MRF and AS modules are combined into a signle entity, which will be called as Media Server Resource Funtion (MSRF). The MSRF, besides being a media server, provides mechanisms for bearer-related services such as conferencing or bearer transcoding, through a controller (MRFC) and a processor (MRFP) in compliance with the MCMS decisions.

The HSS (Home Subscriber Server) is the master user database that supports the IMS network entities that are actually exploited by the CSCF modules for handling the calls/sessions. The HSS contains the subscription-related information (user profiles), performs authentication and authorization of the user, and can provide information about the physical location of user.

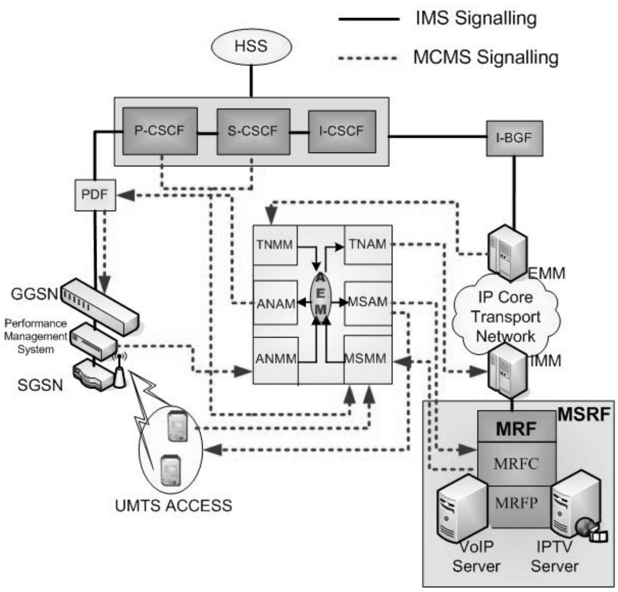

Figure 3: The ADAMANTIUM MCMS and NGN IMS architecture

The control layer of the IMS infrastructure consists of nodes for managing call establishment, management and release, which are called Call Session Control Functions (CSCF). The CSCF inspects each SIP/SDP message and determines if the signalling should visit one or more application servers en route to its final destination. More specifically, the CSCF is a distributed entity comprised of three different components:

- The Proxy CSCF (P-CSCF), which acts as the entry point for any service invocation within IMS and grants appropriate access rights after successful user authentication. The P-CSCF is tasked to relay session and media related info through Diameter protocol to the Policy Decision Function (PDF) when the operator wants to apply Service Based Local Policy (SBLP). Based on the received information the PDF is able to derive authorized NQoS information that will be passed to the GGSN when SBLP is applied.

- The Interrogating CSCF (I-CSCF) acts as a topology-hiding gateway between the P-CSCF and the S-CSCF, by determining the S-CSCF or the AS to which an end-user should register. I-CSCF is a contact point within an operator's network for all connections destined to a subscriber of that network operator. The I-BGF (Interconnection Border Gateway Function) will be also used as gateway to IP networks, providing NAT and Firewall functions;
- The Serving CSCF (S-CSCF) is responsible for key routing decisions as it receives all the User Equipment (UE)-originated and UE-terminated sessions and transactions. Therefore it is also responsible for handling registration processes, maintaining session states and storing the service profiles.

The ADAMANTIUM MCMS architecture will be based on a central decision module, the Action Engine Module (AEM), responsible for taking optimal adaptation decisions based on the monitoring of network and perceptual statistics, gathered by IMS-based (preferably SIP/SDP-based) monitoring and adaptation modules. Afterwards, the AEM exploiting theoretical mapping frameworks between NQoS and PQoS will process all the selected statistics and define a perceptually optimal cross layer adaptation action.

More specifically, for monitoring purposes the following modules are considered:

- Multimedia Service Monitoring Module (MSMM)

The MSMM performs monitoring of the service session through the P-CSCF and S-CSCF modules of the IMS. This is the only module of the MCMS that is activated when a service is requested; whilst all the rest remain in idle mode until the active adaptation procedure starts. Then, the MSMM, except from simply informing the MCMS for the liability of the service, monitors the PQoS and CNR values at the end-user mobile terminal device through the TAM of the terminal device, while at the service generation site, the content dynamics and the encoding parameters are also monitored.

- Transport Network Monitoring Module (TNMM)

The TNMM module is used during the dynamic cross layer adaptation procedure for monitoring network statistics like packet loss, jitter, delay etc. at the DiffServ/MPLS core transport network. Towards this, the appropriate External Marking Modules (EMM) interface will be developed and integrated at the egress edge router of the core transport network for enabling interaction and communication with the TNMM of the MCMS.

- Access Network Monitoring Module (ANMM)

The ANMM module monitors the UMTS access network statistics, based on the exploitation of historical data, which are updated in near real time by the UMTS performance management system at frequent time periods.

For adaptation purposes, ADAMANTIUM considers the following modules, through which the optimal adaptation actions for PQoS optimization are applied:

- Multimedia Service Adaptation Module (MSAM)

The MSAM performs adaptation actions at the end-user terminal device and at the service generation entity (i.e. the MSRF for IPTV services or the end-user terminal for VoIP applications) relative to the decoding (i.e. buffer scheme) and encoding (bit rate, packetization etc.) parameters, as well as FEC value adaptation towards enhancing the error resilience of the delivered service

- Transport Network Adaptation Module (TNAM)

The TNAM applies the adaptation actions to the DiffServ/MPLS-enabled core transport network through the Internal Marking Module (IMM), which will be developed and integrated at the ingress router of the core network. The IMM receives the adaptation actions from the TNAM and translate them to DiffServ/MPLS compatible commands, which are finally applied by marking appropriately the incoming traffic.

- Access Network Adaptation Module (ANAM)

The ANAM applies the adaptation actions, decided by the AEM of the MCMS, to the UMTS access network through the IMS PDF module. The PDF in turn applies them at the GGSN by performing service bearer classification in order to improve its QoS characteristics and therefore enhance the delivered PQoS level.

5. Case Scenario

Considering a requested multimedia service at a specific PQoS level by an ADAMANTIUM mobile terminal (i.e. mobile handset with TAM integrated), the first contact point within the IMS infrastructure is the P-CSCF module, which relays the services session. Then the P-CSCF interacts with the MSMM of the MCMS messages based on IMS protocols, reporting the request of the specific service. Since a session has been established for the specific service, the P-CSCF communicates with the S-CSCF, which maintains the service session and informs the MCMS about the session viability. This idle mode of the MCMS is essential for its scalability abilities, because during this operating mode, resources are not consumed. The MCMS simply monitors through the S-CSCF that the service session remains active, awaiting the reception of a PQoS-degradation alarm from the end-user terminal, indicating poor perceptual quality and therefore bad user experience.

During the service session, at the end-user mobile handset through an ultra light software application, the PQoS level and the CNR values are internally monitoring in real time, along with the duration that the measured PQoS is below a specific perceptual threshold. The intelligent PQoS-aware mobile handset when monitors a PQoS degradation in conjunction with bad signal reception (i.e. High CNR value), then the TAM of the mobile handset will not trigger a PQoS alarm to the MCMS, because this perceptual degradation is possibly caused by poor signal reception due to the location of the user. If PQoS degradation below a specific perceptual threshold and for given duration is observed at the PQoS-aware intelligent end-user terminal in conjunction with low CNR value (i.e. good reception, showing that the cause of the PQoS degradation is NQoS-related), then a PQoS alarm is triggered through the TAM interface of the terminal back to the MSMM, which till that moment passively monitors the session. Then, the idle mode of the MCMS for the specific session is terminated, which means that the dynamic cross layer adaptation procedure is initiated and all the monitoring and adapting modules of the MCMS are activated for the specific session. For all the rest on-going sessions, which do not face PQoS degradations, the MCMS continues to operate in idle mode, reassuring minimal resources consumption and enabling large-scale scalability abilities for MCMS.

Once the MCMS has been switched to active mode, the current QoS relative statistics across the network delivery chain (i.e. from the core and access network) are reported to MCMS via the ANMM and TSMM modules. Also, reports from the encoder about the coding parameters, the content dynamics of the multimedia service, the current FEC scheme (if applies) and the decoding prameters at the terminal (i.e. buffer scheme) are reported to the MCMS via the MSMM. If VoIP session is considered, then the MSMM monitoring takes place at both the end-user terminals that participate in the session, where the voice/video is encoded and decoded at the sender and receiver terminal respectively. All the collected statistics will be further exploited by the MCMS, through a sophisticated processing procedure and a decision algorithm in the MCMS AEM.

After the monitoring phase of the network statistics across the delivery chain has been completed, the adaptation phase is following. This is performed through the adaptation action modules of the MCMS (i.e. the MSAM, TNAM, ANAM) and may include adaptation of the encoding parameters, the packetization schemes or the FEC scheme in order to enhance the error resilience of the multimedia service, along with DiffServ/MPLS and UMTS traffic policies through more QoS-sensitive traffic/service classes. Towards this, the AEM will process all the received statistics by the ANMM, TNMM and MSMM in

order to define the adaptation actions across the network delivery chain, aiming at the optimization of the NQoS, which will lead to maximization of the user satisfaction and the delivered PQoS level, without altering the total service traffic of the bearer. The AEM shall be able to take QoS control decisions based on an advanced mechanism/algorithm (e.g. such as neuronal, genetic programming or expert system), taking into account multiple and interrelated PQoS theoretical models, which will be researched and developed by the ADAMANTIUM project. Moreover, since the ADAMANTIUM project aims at the commercial exploitation of the developed systems, special considerations will be taken during the definition of the intelligent decisions taken by the AEM, in order to ensure fast and seamless optimization of the user experience. Towards this, the communication and interaction of the AEM with the rest monitoring and adaptation modules of the MCMS will be based on present IMS protocols (e.g. SIP/SDP), in order to maintain compatibility with the NGN IMS infrastructure.
Regarding the traffic adaptation by the TNAM at the DiffServ/MPLS core transport network, it must be clarified that the respective MCMS do not have direct access to the core network traffic mechanisms and its routers in order to apply the relative adaptation command per hop. On the contrary, the traffic marking and adaptation is performed only at the entry point of the core transport network (i.e. ingress router), which means that since the core transport network is DiffServ/MPLS enabled, its management mechanisms recognise the marked packets and classifies them accordingly. Similarly, the collection of the NQoS statistics through the EMM is performed indirectly by monitoring the traffic at the exit point of the network (i.e. egress router).

6. Conclusions

ADAMANTIUM, being harmonized with market needs, will create the conditions for a new generation of media technologies, providing significantly higher performances through PQoS-aware dynamic cross layer adaptation techniques in the IMS infrastructure. By enhancing the existing IMS purely engineering management techniques with intelligent and flexible cross layer adaptation methods, ADAMANTIUM will offer higher performance at the provision of a new generation of media services (i.e. IPTV and VoIP/videocall over IMS).

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References

[1] M. Poikselka, G. Mayer, H. Khartabil, A. Niemi, “The IMS IP Multimedia Concepts and Services”, Wiley, 2006.

[2] G. Camarillo, M. A. Garcia-Martin “The 3G IP Multimedia Subsystem”, Wiley, 2004.

[3] H. Koumaras, A. Kourtis, D. Martakos, J. Lauterjung, “Quantified PQoS Assessment Based on Fast Estimation of the Spatial and Temporal Activity Level”, Multimedia Tools and Applications, Springer Editions, 34(3), 355-374, Sep. 2007

[4] H. Koumaras, F. Liberal, L. Sun, “PQoS Assessment Methods for Multimedia Services”, Chapter contribution in "Wireless Multimedia: Quality of Service and Solutions", Editors Dr. Nikki Cranley, Dr. Liam Murphy, IGI Global Pub. (Under Publication)