Context-Aware Multimedia Distribution for Multiparty Communications

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Abstract. The increasing attractiveness of multimedia group communications forces Mobile Operators to provide more useful services and to evolve their networking technologies to effectively distribute rich-media content to mobile communities. Context information shall have a highlight role on next generation networks when dealing with communications' groups such as the ones target by MBMS and E-MBMS systems. Users' situation information shall be used to increase the system effectiveness while augmenting the user experience. This paper proposes a convergent context-aware architecture where IMS is used to convey context information and to control MBMS and E-MBMS multimedia channels allowing Mobile Operators to easily offer innovative services over efficient networks.

Keywords: Context, IMS, MBMS, E-MBMS.

1 Introduction

The growing popularity of multimedia group communications requires evolved networking technologies to provide rich-media content to groups of users in the most effective way. Mobile TV services have already proved to be a great commercial success and, following the Web 2.0 trend, it is expected an avalanche of user-generated content to be shared over large mobile communities.

The 3GPP has specified Multimedia Broadcast Multicast Service (MBMS) to enable broadcasting and multicasting packet data in Universal Mobile Telecommunications System (UMTS) networks to large user groups. Furthermore, the Evolved Packet System (EPS) specification has evolved MBMS (E-MBMS) in order to provide broadcast connections over the EPS architecture.

Mobile Operators need to offer even more innovative and personalized services if they want to maintain their market supremacy. They need to have a preponderant role in the social network world and they can't throw away the Mobile TV opportunities. To achieve this objective, Mobile Operators can make use of context information in

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order to provide tailored services to their clients. The definition of context, in a broad sense, might be considered as the set of information used to improve the system efficiency. Therefore, context-aware systems process context information in order to perform their tasks in a more accurate way. They collect context information to become aware of their environment and can act in response intelligently.

Mobile Operators already use location-based information to deliver selected content to their clients. But context may have an emphasized role when dealing with communications' groups such as the ones target by MBMS and E-MBMS systems. It might be used to define groups that demand the same content and to optimize multimedia content delivery to mobile communities. Mass media distribution has no room to network wastes. Therefore, context information shall be used to increase the system effectiveness while augmenting the user experience.

Since the target traffic is multimedia, it makes sense to expect some interactions with IP Multimedia Subsystem (IMS). 3GPP Release 5 brought IMS into play as a controlling subsystem for IP traffic in UMTS networks. It was developed to provide multimedia services over different access technologies. But IMS can also be evolved to convey context information allowing context-awareness in MBMS and E-MBMS systems and simultaneously manage multiparty bearers over unicast, multicast and broadcast connections.

This paper introduces an integrated context-aware MBMS and IMS architecture making possible to intelligently manage multimedia multiparty content distribution. It makes use of IMS to transport context information and to manage MBMS and E-MBMS channels. Furthermore, it improves MBMS and E-MBMS systems by adding context-awareness on their decisions making possible to have personalization services on multiparty communications. This innovative architecture is for sure a promising opportunity for new business models around Mobile TV and Web 2.0 services, allowing an intelligent and efficient content sharing within mobile communities. Context-aware multimedia content distribution might be the famous killer applications that Mobile Operators are still looking for.

2 Related Work

The increase popularity of multimedia group communications has need of advanced networking technologies to efficiently make available rich-media content to mobile communities.

The IST C-MOBILE project has defined converged, multi-bearer service architecture for supporting broadcast and multicast services [1]. It has used IMS as a common control layer to converge heterogeneous multicast and broadcast access networks. The main requirement was to enable the delivery of multimedia content to a group of IMS users over MBMS bearers. This work was reported in [2].

The study carried out in [3] presents potential multicast and broadcast technologies convergence and discusses the issues and challenges in moving towards the next generation network vision from the viewpoint of evolving MBMS.

In [4], it is proposed a generic integrated architecture which not only supports MBMS but other broadcast and multicast delivery technologies like DVB-H and WiFi. Moreover the research aims to work in line with the next generation network architectures conforming to the standardizing bodies like 3GPP, TISPAN and IETF.

Following the same direction, enhanced signalling procedures for an effective IMS and MBMS integration was presented in [5] supporting the provisioning of multimedia sessions to mobile communities.

In [6], it is proposed an architecture for IPTV services over IMS-based next generation networks enabling the delivery of converged multimedia services over unicast, multicast, and broadcast transmission modes following the approaches from ITU-T and TISPAN.

The studied carried out in [7] led to the definition of an architecture for future environments bridging the gap between the content production and communication infrastructures, able to operate across different networks.

The integration between IMS and MBMS was also considered under 3GPP Release 8 study item named “Enhancements to IMS Service Functionalities Facilitating Multicast Bearer Services”. The idea behind was to have multicast bearers supporting IMS-based applications leading to radio and core network savings by mean of resources sharing. As stated in [8], IMS users and Content Providers may use the multicast bearers for delivering multimedia content simultaneously to a group of subscribed users.

In [9] was specified a centralized approach for the use of IMS to initiate and control MBMS user service allowing their deployment as IMS services. Although the use of IMS for controlling MBMS bearers there is still a clear separation of MBMS user services and other packet switch streaming services following a centrically trend.

The use of context in mobile networks is nowadays a hot topic. Its usage makes possible to have personalized services being efficiently transmitted to mobile communities.

SENSEI is a FP7 IP intending to design an open architecture that addresses the scalability problems for a large number of globally distributed wireless sensor and actuator networks devices by making available the required network and information management services to allow reliable and accurate context information retrieval and interaction with the physical environment [10]. As stated in [11], it introduces a set of interfaces allowing Applications and Services to access real world information.

PERSIST is a FP7 STREP aiming at developing Personal Smart Spaces (PSS) that will be capable of learning and reasoning about users, their intentions, preferences and context [12]. The PSS shall have the capability to extend and enhance as the user meets other smart spaces. In [13] is presented the overall design of the main components supporting the operation of Personal Smart Spaces.

The FP7 ICT C-CAST project aims at evolving mobile multimedia multicasting to exploit the increasing integration of mobile devices with our everyday physical world and environment [14]. In [15] it is defined an architecture to support complete context management functionality along with service components like group management and content selection. The work carried out in [16] defines a framework to collect sensor data, distribute context information and manage efficiently context aware multiparty data distribution.

In [17] it is addressed the impact of context, sensors and wireless networks in the telecommunications field. Several scenarios are proposed highlighting the possible synergies between the defined areas.

The work carried out in [18] proposes an evolution for the session management functionality to support multiparty sessions having context information triggering the creation, modification and teardown of multimedia sessions.

A hierarchal group management framework is proposed in [19] making possible to manage transcoding based groups. It was demonstrated that specifically in an MBMS environment, there is an advantage for using more efficient codecs, by subgrouping multicast groups based on supported codec, as they become widely available in the network.

The authors of [20] propose a context-aware multiparty architecture, able to support context from the user, network, sessions and surrounding environment in future multiparty mobile communications. They defend sub-grouping of content-based service groups, making possible to have the same service session delivered using different codings of the same content, to adapt to the current network, users, session and environment context.

The detection and distribution of context is being already envisaged by some standardization initiatives. In [21], it is presented the functional architecture for machine-to-machine communications. Additionally, the procedures flows for an effective communications are here described. However, this draft is in a very early stage being the work planned for future development.

3GPP has presented a technical report in [22] aiming at identifying potential requirements to facilitate improvements in machine-to-machine communication. The study has investigated the needed standards improvements to provide network operators with lower operational costs when offering machine-to-machine services. Moreover, the technical specification in [23] is detailing the service requirements for network improvements for machine type communications. A technical report is being carried out to evaluate the outcomes of this spec [24].

3 Context in MBMS and E-MBMS

This paper proposes the use of context information to improve MBMS and E-MBMS services and simultaneously to optimize the system efficiency.

3.1 Context-Awareness

MBMS and E-MBMS manage mobile clients that can be associated based on their situation. Depending on users' context, such as environment, profile, network, different content can be offered to groups of mobile users. Additionally, the users' surroundings can also be used to get more refined service provision phases leading to a better resource usage.

The work carried out in [25] defines context as the information used to characterize the situation of entities. And situation is defined in [26] as the state of a context at a certain point (or region) in space at a certain point (or interval) in time, identified by a name. A situation can be compared to a snapshot taken by a camera where it captures the momentary profile of the context attributes. In [27] it is defended that context-aware software shall adapt taking into account the user location, the collection of nearby people and objects, the accessible devices, as well as changes to those objects over time. Taking a broad view, a system can be considered context-aware when it makes use of context information to adjust its behavior. Consequently, a context-aware system uses context information to effectively perform its jobs. Fig 1 presents the context-aware system life cycle.

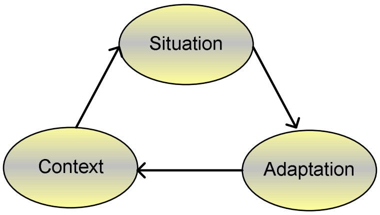

Fig. 1. Context system phases

3.2 Enhancing MBMS and E-MBMS with Context Information

The work here presented proposes the use of context information by MBMS and E-MBMS systems to provide more useful services over optimized networks. User situation information shall be handled by applications making possible to offer personalized contents to groups of mobile clients. Moreover, this valuable information shall have impact on the decisions done by resource management entities related with network usage.

MBMS and E-MBMS have to be improved to turn into a context-aware system. For that, they need to have mechanisms to collect context information from different context sources. Besides, they can have aggregator functionalities to obtain higher level information more accurate to their requirements. Finally, context-aware systems require reasoning processes to derive the user situation. Based on that, MBMS and E-MBMS systems should be adaptable to increase their effectiveness.

Context shall affect both user and bearer service functionalities. But, depending on the scenarios, different levels of awareness can be incorporated leading to different degrees of adaptation. The information about users' situation can be used to select the most appropriated content to mobile clients. Whenever a new content becomes available, applications can select the group of users having interest on it and they should trigger the setup of the session. Depending on the application, different context sources can be utilized and different types of interactions might be applied.

The MBMS and E-MBMS session management entities shall also make use of context information. The session parameters can be adapted taking into account the users' context. For instance, the codec selection might be affected by users' situation. If the user is in a noisy environment, a lower powerful codec might be selected since the client will not be able to enjoy all audio characteristics. Additionally, if the client is running, the video subtitles might be removed because the user will not be capable of reading them. But context can be also helpful on the radio access. As an example, different power schemes can be applied depending on the users' location leading to an improved coverage control. Moreover, the transmission modes could dynamically exchange from point-to-point to point-to-multipoint or vice-versa.

3.3 MBMS and E-MBMS Adaptation

The work presented in [28] state that the main goal of a context-aware application or service is to be able to modify its behaviour in response to a context change. For services that target mobile communities the challenges include personalized multimedia content distribution to groups of users while guaranteeing an effective network resource usage. These apparently contradictory requirements can be worked out by splitting the group of users that has subscribed the same service into several subgroups based on users' context. Each subgroup will include all users in similar situation leading to collections of mobile clients getting the same content with the same format sharing the network resources. Consequently, MBMS and E-MBMS systems shall dynamically adapt their behavior based on users' context leading to improved services over optimized communication bearers, as described in Fig 2.

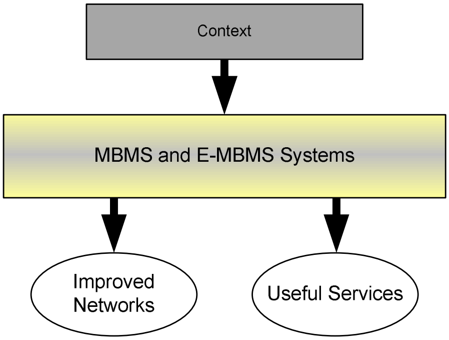

Fig. 2. Context-aware MBMS and E-MBMS systems

MBMS and E-MBMS aim at distributing multimedia content to groups of users. In that sense, context-aware MBMS and E-MBMS systems shall start by choosing mobile clients predisposed to receive a specific content. When a new content is published applications shall make use of reasoning mechanisms to select from the list of subscribed users the ones willing to receive the multimedia data based on users' situation and the content description. Users' situation can include network status, user location, movement information or even any type of personal information. Given that there is an infinite set of context information. Applications should narrow down the context data by deciding on the ones that are useful for the service. Additionally, the content description includes the tags describing the content subject. As an example, if the content is described as Aveiro weather information, clients at Coimbra should not be disturbed. But of course there are situation in which all users should be announced. For instance, if the service is promoted by Chelsea Football Club, all supporters should be informed about the final premier league results. Applications shall use reasoning mechanisms to build a new group based on both user context and content metadata information. Consequently, from the subscribed users' list it shall be created a dynamically polished group encompassing users with higher probability of buying the content and from this group a subset shall be created encompassing the ones that really have bought the service.

When the session is about to start, it is needed to setup the channels to distribute the multimedia content to interested users. In heterogeneous environments, users in a group can be served by different access networks and user equipments will for sure have different capabilities. Future MBMS and E-MBMS context-aware services shall be capable of providing unicast, multicast and transmission modes, independently of the radio access technology, reinforcing the next generation networks' convergence vision. As a result, users shall be grouped based on the wireless links and on the selected transmission mode. Each multicast connections encompasses users intending to receive the same content. But the content made available might be distributed using different content formats in order to match terminal capabilities. Furthermore, environment conditions might trigger the use of different codecs. For instance, users driving a car cannot experience high fidelity audio due to the noisy surroundings. Therefore, context-aware systems might reduce the audio quality saving network resources. One other possible scenario is to have the multimedia quality dependent on the content. Manchester United fans could be interested in receiving Rooney videos with maximum audio and video qualities. Consequently, the groups should also be split in different content formats subgroups. It is important to note that each group might be dynamically adapted since users' contexts are always changing. Therefore, they can be updated every time based on users' situations change.

4 Managing Context-Aware MBMS and E-MBMS Systems with IMS

This paper presents an enhanced and integrated architecture having new interfaces, protocols and functionalities in order to control the bearers used to deliver multimedia content to a converged core network.

3GPP Release 5 brought IMS into play to provide multimedia services over different access technologies. The main gains of having this additional subsystem are threefold: IMS may provide Quality of Service (QoS) in the user plane since it is aware of the service requested by the user; knowing the exact service, operators may also improve their charging schemes for multimedia sessions; finally, IMS allow integrating different services offering more and improved services to the customers. IMS is a system based on the IP protocols defined by IETF. 3GPP adopted Session Initiation Protocol (SIP) protocol to manage multimedia sessions. As a consequence, SIP becomes the protocol used to setup, modify and tear down multimedia sessions over UMTS and EPS networks.

4.1 MBMS and E-MBMS Session Management with IMS

IMS system was designed to deal with point-to-point connections. For services involving groups of users receiving the same information this limitation may become a drawback. Because IMS only supports unicast transmission there is a waste of resources when data is to be delivered to a group of users. On the other hand, there are MBMS and E-MBMS systems. They were brought in by 3GPP to broadcast and multicast data on UMTS and EPS networks to user groups. They make possible the unidirectional transportation of information from a single source to many receipts. A new entity was presented under Release 6 and evolved for EPS systems during Release 9. This new entity is the Broadcast Multicast Service Centre (BM-SC). The roles of BM-SC are related with MBMS user service provision and delivery. The BM-SC provides service announcements for multicast and broadcast MBMS user services. It makes available to the Gateway GPRS Support Node (GGSN) and MBMS Gateway (MBMS GW) the transport of associated parameters, such as QoS, and it is in charge of initiating and terminating multicast and broadcast resources. The BM-SC sends MBMS data taking into account the integrity and confidentiality protection of the information. The user services are mainly based on streaming and content download. All the MBMS and E-MBMS session management procedures are made by means of specific signaling bypassing the IMS control system. When looking into IMS and MBMS, it becomes clear possible synergies between both systems: IMS for controlling sessions using SIP signalling and MBMS for delivering data through its multicast and broadcast bearers. Having multicast and broadcast services controlled by IMS entities, content providers may send multimedia content to user groups saving network resources due to the gains achieved when using point-to-multipoint bearers. Additionally innovative services can easily be developed using IMS well defined interfaces with the application service layer.

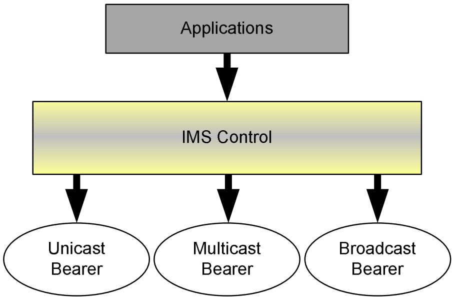

Fig. 3. IMS for controlling MBMS services

4.2 Context as IMS a Service

A Context Service (CxS) can be described as a service that makes available context information to context-aware systems. Depending on the service, the information made available can be simple sensor data, such as the room temperature. But context can also be more complex information based on heterogeneous context sources, such as users' mood or users' intentions. CxS can offer statically information, such as terminal capabilities, or it can provide more dynamic information based on sensors' networks, services' states or network status. Furthermore, different CxS can collect similar context information, but they might provide different results depending on their associated logic. CxS shall be capable of collecting context information from different sources of context data. The data can be filtered to select valid context information. Additionally, it shall go over fusion processes making possible to obtain reliable values through the integration of similar data sources. Context information can even be aggregated by combining diverse sources of information to get higher level context data. Finally, reasoning mechanisms enable to conclude about users' situation by applying logical rules over collected context information.

Context Producers (CxP) are entities that make available context information. CxS makes the bridge between CxP and context-aware systems, which play the role of Context Consumers (CxC), since they use the information to increase their efficiency. Therefore, CxS shall collect context information from context sources, they can manage it and finally they make it available to context consumers.

IMS can easily be extended to convey context information. SIP language already has specific signaling messages that make possible to transport users' situation information. The work here presented proposes context services as IMS services that instead of delivering multimedia content make available context information to context-aware systems. This can be seen in Fig 4.

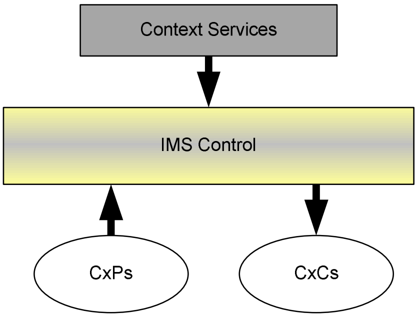

Fig. 4. Context as an IMS service

5 Context-Aware Multimedia Multiparty Distribution

This paper aims at detailing an architecture for future context-aware converged networks. Starting from the logical framework, all functional entities and respective interfaces are defined.

The architecture introduced in Fig 5 allows personalizing services targeted to mobile communities and, simultaneously, it let an efficient multimedia content distribution saving network resources. The architecture is described below.

Application Plane. The Application Plane is the place where users' applications take place putting forward value-added service to mobile clients. They make use of the enablers' capabilities offering to the end-users personalized services over unicast, multicast or broadcast channels. It also provides logical context services.

Service Enabler Plane. Here are defined several enablers playing the role of MBMS user and bearer service functionalities. Also, a context enabler is introduced. These service enablers are presented below:

Session Management Enabler (SME). The Session Management Enabler is the main contact point to the end-user being the signalling procedures here managed. It is the SME that receives the messages for activating the services and it is also the SME that sends invitation messages when sessions are about to start. SME also maps service groups into network groups in order to allow users to enjoy the same content but using different formats. Furthermore, the appropriate address allocation shall also be done within the SME based on the bearer selection and information coming from the network.

Service Announcement Enabler (SAE). This enabler provides advertisements to subscribed end-users identifying the service and the content, but not network related parameters. Interested users should use the Service Announcement information to activate the service. Whenever the session is about to start, the network related parameters shall be distributed inside the Service Description Protocol (SDP) carried out by the invitation done by the application to the end-users.

Security Enabler (SE). The Security Enabler took some of the security function roles of the BM-SC. It shall be responsible of service protection by limiting the access of multicast data to subscribed users. The SE is in charge of MBMS keys distribution to authorized users in order to provide integrity and confidentiality protection of MBMS data. The UE may register at the SE for key distribution and key updates. Note that while the BM-SC performs key distribution and data ciphering, the SE should only deal with managing the security keys, relaying the data ciphering for media processors.

Membership Enabler (ME). The Membership Enabler holds up group management functionality within the IMS core. It is in charge of creating, modifying and deleting user groups based on subscription information for each specific service. The user authorization for service activation is here managed.

Content Management Enabler (CME). The Content Management Enabler provides interfaces to Content Providers allowing content publishing. A web front-end shall be used to allow CP to describe the incoming data. The submitted information should then be used by the application to schedule new sessions and to trigger the announcement of the service. It is within the CME that the content identification shall be carried out by assigning it a unique identifier.

Associated Delivery Enabler (ADE). This enabler is responsible for performing the associated delivery procedures. It provides post-delivery file repair mechanisms for MBMS File Download services. Furthermore, it will allow content reception reporting on both File Download and Streaming services. Regarding the download delivery method, the report will be used to inform about the complete reception of the files, while in the streaming delivery method, the report will convey statistics on the stream. It is during the Service Announcement phase that the respective delivery parameters are made available to mobile terminals.

Context Enabler (CE). CE shall support context services by managing context providers and consumers interactions. Different applications will use different reasoning mechanisms to derive users' situation based on context information. The CE shall be the common component to all context services. It is responsible for the context publishing made by CxP and for the context subscription carried out by CxC. Furthermore it shall be in charge of context information flow between end-points for all interaction types, namely the ones done by request, periodically or based on specific events.

Control Plane. This layer encompasses the core IMS elements, such as the Proxy (P), the Serving (S) and the Interrogating (I) Call Session Control Function (CSCF), which remain with the standardized functionalities. But in order to make possible using IMS to control MBMS services, some improvements are required on the Media Resource Function (MRF). The MRF Controller (MRFC) needs to be enhanced in order to cope with streaming and file download services. In [1] it is proposed the name of Media Delivery Function Controller (MDFC) for the evolved MRFC. The MDFC maintains the MRFC functionalities whereas it stills controlling the media resources based on the information received from the AS via SIP protocol. Based on requests coming from the AS, the MDFC should set up the processors for unicast, multicast and broadcast connections. Additionally, it must assure a reliable data distribution through the use of Forward Error Correction schemas. Finally, the content shall be ciphered to assure communication confidentiality.

Delivery Plane. The MRF Processor (MRFP) has the capability of being a media stream source for multimedia announcements. Furthermore, the MRFP is enabled to make media processing, such as transcoding and media analysis. In order to deal with MBMS services, the MRFP shall be extended. Such as the MRFC, the MRFP shall also be evolved in order to cope with both streaming and download services. Additionally FEC and ciphering procedures shall run here. The new name proposed in [1] is Media Delivery Function Processors (MDFP). Each MDFP has media processing capabilities. The enhanced MRFP, the MDFP, shall have the ability of receiving data from a content provider and relay the content to a set of subscribed users using unicast, multicast or broadcast channels. The MDFP stills performing transcoding, but now the transcoding shall be done in real time for some streaming services or may be performed asynchronously for File Download sessions. Therefore, the MDFP shall receive the content from a content provider over the Mb interface by means of a unicast channel. The data shall then be ciphered and processed according the type of media needs and, finally, shall be reliable distributed using unicast bearer over the Mb interface or using a multicast or broadcast channel throughout the Gi interface.

Access and Transport Plane. The Access and Transport Plane includes heterogeneous radio access and the core network with QoS and mobility support. In order to support different type of access networks, an abstraction layer is mandatory to provide all specific radio access network signalling. In that sense, it is here considered a network based control layer that links the service primitives to network specific signalling for channel management. Network Specific Signalling (NSS) is the layer that hides network specificities. It takes the control plane role and, consequently, it is used to setup, modify and release the bearers, based on the requests received from the enablers' stratum. For the MBMS and E-MBMS cases, NSS will allow multicast and broadcast channel management being connected to the UMTS and EPS networks in order to manage the MBMS and E-MBMS channels.

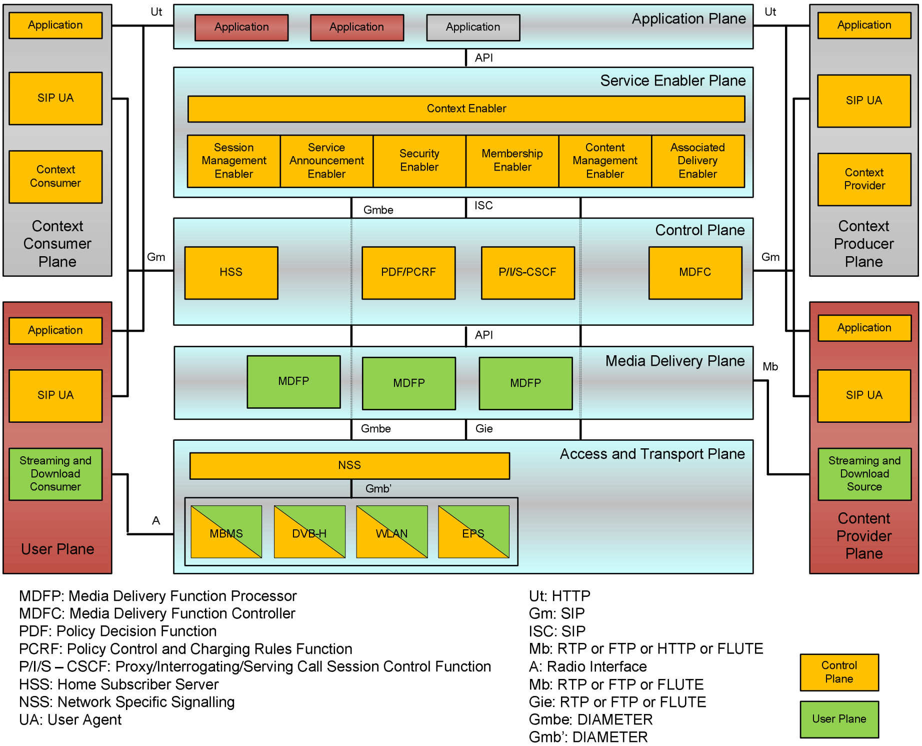

Fig. 5. Context-aware integrated architecture

6 Conclusions

This paper has presented a context-aware architecture for advanced MBMS and E-MBMS systems on next generation networks. Context information enables mobile systems to adapt their actions taking into account context changes, leading to more useful services offered over effective convergent networks. The architecture here introduced made use of IMS to transport users' situation information and to control the MBMS and E-MBMS multimedia channels. This novel architecture is for sure a promising opportunity for new business models around Mobile TV and Web 2.0 services allowing an intelligent and efficient content sharing within groups of mobile users.

References

1. http://c-mobile.ptinovacao.pt/
2. C-MOBILE, Deliverable 4.4, Evaluation Results of Enhanced Core Network Elements (April 2008)
3. Santos, J., Gomes, D., Sargento, S., Aguiar, R., Baker, N., Zafar, M., Ikram, A.: Multicast/Broadcast Network Convergence in Next Generation Mobile Networks. Computer Networks 52(1), 228–247 (2008)
4. Zafar, M., Baker, N., Fuchs, M., Santos, J., Ikram, A., Sargento, S.: IMS – MBMS Integration: Functional Analysis & Architectural Design. In: 16th IST Mobile and Wireless Communication Summit, Budapest, Hungary (July 2007)
5. Pinto, F., Knappmeyer, M., Al-Hezmi, A.: Signalling for IMS and MBMS Integration. In: 17th ICT Mobile and Wireless Communications Summit, Stockholm, Sweden (June 2008)
6. Al-Hezmi, A., Magedanz, T., Jaen Pallares, J., Riede, C.: Evolving the Convergence of Telecommunication and TV Services over NGN. International Journal of Digital Multimedia Broadcasting (October 2008)
7. Gomes, D., Pinto, F., Gonçalves, J., Aguiar, R.: IP based Content Delivery over Next Generation Networks. International Journal of Internet Protocol Technology, IJIPT (October 2008)
8. 3GPP TR 23.847 V1.0.0 (February 2007), Study on Enhancements to IMS Service Functionalities Facilitating Multicast Bearer services (Release 8)
9. 3GPP TS 26.237 V8.4.0 (December 2009), IP Multimedia Subsystem (IMS) based Packet Switch Streaming (PSS) and Multimedia Broadcast/Multicast Service (MBMS) User Service; Protocols (Release 8)
10. http://www.ict-sensei.org/
11. SENSEI, Deliverable D3.2, Reference Architecture (January 2009)
12. http://www.ict-persist.eu/
13. PERSIST, Deliverable D3.1, Detailed design for personal smart spaces (March 2009)
14. http://www.ict-ccast.eu/
15. C-CAST, Deliverable D12, Specification context casting service enablers, context management and context brokering (June 2009)
16. C-CAST, Deliverable D13, Specification of context detection and context-aware multiparty transport (June 2009)

17. Aguiar, R., Gomes, D.: Quasi-omniscient Networks - Scenarios on Context Capturing and New Services through Wireless Sensor Networks. Wireless Personal Communications 45 (June 2008)
18. Antoniou, J., Pinto, F.C., Simoes, J., Pitsillides, A.: Supporting Context-Aware Multiparty Sessions in Heterogeneous Mobile Networks. ACM/Springer Mobile Networks and Applications, MONET (2010)
19. Zafar, M., Fuchs, M., Baker, N.: Supporting Transcoding-based Multicast Groups. In: 15th International Conference on Telecommunications, St. Petersburg, Russia (2008) (paper accepted)
20. Antoniou, J., Christophorou, C., Neto, A., Sargento, S., Pinto, F.C., Carapeto, N.F., Mota, T., Simoes, J., Pitsillides, A.: Session and Network Support for Autonomous Context-Aware Multiparty Communications in Heterogeneous Mobile Systems. International Journal of Handheld Computing Research, IJHCR (2010)
21. Draft ETSI TS 102 690 V<0.1.2> (January 2010), Technical Specification Machine-to-Machine communications (M2M); Functional architecture
22. 3GPP TR 22.868 V8.0.0 (March 2007), Study on Facilitating Machine to Machine Communication in 3GPP Systems (Release 8)
23. 3GPP TS 22.368 V1.1.1 (November 2009), Service requirements for machine-type communications, Stage 1 (Release 10)
24. 3GPP TR 23.888 V0.2.1 (January 2010), System Improvements for Machine-Type Communications (Release 10)
25. Dey, A.K.: Understanding and Using Context. Personal Ubiquitous Computing 5(1), 4–7 (2001)
26. Zimmermann, A.: Context Management and Personalisation, PhD Thesis, University of Aachen (2007)
27. Schilit, W.: A System Architecture for Context-Aware Mobile Computing. PhD Thesis, Columbia University (1995)
28. Baker, N., Zafar, M., Moltchanov, B., Knappmeyer, M.: Context-Aware Systems and Implications for Future Internet. In: Future Internet Conference, Prague, Czech Republic (2009)