Context-Aware Multimedia Services in a Pervasive Environment- The Daidalos Approach

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ABSTRACT

There is a clear trend towards making multimedia applications context-aware so as to customize them by taking into account any collection of information which may be relevant, such as e.g. user location. However, current multimedia services are dominated by IMS, which is seen as a service platform that uses the SIP protocol to access all services that the Internet can provide. In this paper, we describe the Daidalos approach on making IMS based multi-media services context-aware. We also demonstrate, how generic sensor networks can be integrated into the context management system of our platform thus enabling sensor network detected events to influence behavior of context-aware multimedia applications.

Categories and Subject Descriptors

C.2.4 [**Distributed Systems**]: Distributed applications

General Terms

Management, Design.

Keywords

Pervasiveness, Context-awareness, Service Management, Sensor Network Integration.

1. INTRODUCTION

The proliferation of multimedia capable mobile devices such as novel multimedia enabled cellular phones or PDAs has encouraged users to consume multimedia content and services while on move. However, selecting and enabling the presentation of the most appropriate content for the given device is rather complicated due to the vast amount of multimedia data available and the heterogeneity of systems available. Tools are required and being developed to enable automatic discovery and presentation of multimedia content. Context information can be used to guide the tools and systems in selecting the proper content and format for a given user at a certain time, place and under a specific context.

There is a clear trend towards making applications context-aware so as to take into account any collection of information about an entity such as its location, the surrounding temperature or anything else which may be relevant to it. This requires that various elements of the global context are captured or sensed and combined together to form a picture of the global context. In addition, information that shall be distributed or processed needs to be matched with the context in order to tailor the delivery towards the contextual information. As more and more small and powerful multimedia devices penetrate the environment, pervasive multimedia services seem to be not far away, which give the user the freedom to create, compose, discover, access and adapt multimedia services on a variety of devices, best suited for the given service. Along this direction, sensor networks are expected to penetrate our daily life capable of sensing the environment and thus the user context. However, several issues remain to be solved to address proper collection of contextual information from a variety of sensors and use this contextual information to exploit it for truly pervasive and context aware multimedia experience.

These trends call for a flexible application development and management environment, which enables rapid development of context-aware multimedia applications and management of multimedia services in such pervasive environment. However, in the area of telecommunications network providers and operators, current multimedia services are dominated by IMS (IP-based multimedia subsystem), which provides end-to-end multimedia conversational services on IP layer. On a long term perspective, IMS is seen as a service platform that uses the SIP protocol to

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access all services that the Internet can provide and users will access IMS through a variety of network technologies and terminals, usually combining several of them at the same time. Therefore, it seems natural to see IMS as an enabling platform which needs to be augmented in a modular way to support not only pervasive multimedia services of the future but also to define mechanisms to interact with sensor networks that can provide contextual data as input for making the multimedia service as context-aware as possible.

The key contribution of this paper is the Daidalos (www.ist-daidalos.org) context-aware multimedia service architecture that augments IMS in order to make it context-aware to provide novel context-aware multimedia services in a pervasive environment. It includes mechanisms to access sensorial data as part of contextual information. It is composed of core IMS components and augmented by several enhanced components that comprise a distributed service enabler plane and a server plane. Integration of any sensor network is achieved through a dedicated wireless sensor network proxy that decouples sensor network specific protocols and procedures and interacts with the context management system in the distributed service enabler plane. The system, while leveraging key IMS infrastructure, provides the user with powerful tools to rapidly create, compose, discover, access and adapt context-aware multimedia services.

The paper is structured as follows. In chapter 2, we describe how the IMS platform is extended in a modular way to enable context-awareness. Chapter 4 describes, how sensor networks can be integrated into our platform by treating sensor network detected events as context changes. Chapter 5 presents the pervasiveness of such extended IMS and how context is handled in more detail.

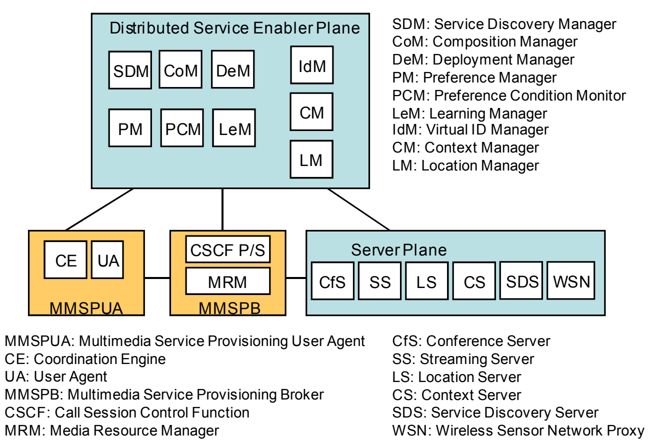

Figure 1: Daidalos Context Aware IMS Platform

2. Context Aware Multimedia Service Provisioning and Management Architecture

The Daidalos context-aware multimedia service architecture (Figure 1) is build upon a distributed service enabler layer, interacting with IMS, in order to make IMS applications pervasive and context aware. Management features such as Personalization, Learning, Context, Service Discovery, Service Composition and Security and Privacy are incorporated in this layer. These atomic management features may be distributed among different servers (application enabling servers) where the user terminal also is seen by the applications as an "enabling server". This type of architecture improves scalability when compared with IMS. The architecture is based on the following components:

- Pervasive Services Management (PSM): The PSM is composed of Service Discovery Manager (SDM), Composition Manager (CoM), and Deployment Manager (DeM) and is responsible for managing the discovery, filtering, composition, deployment and lifecycle of services. DeM controls the initiation, execution and termination of the various different types of services and the platforms upon which they run, thereby abstracting the low level details of services such as OSGi, Bluetooth and Web services. CoM builds the service based on discovery and composition in a single service logic. SDM is involved in starting the context-aware service discovery process, contacting the Service Discovery Server (SDS), in the case of a centralized discovery, or directly Service Provider Servers (SPSs) in the case of decentralized discovery.
- Preference Manager (PM), Preference Condition Monitor (PCM) and Learning Manager (LeM): PM manages user preferences (such as "when in lecture theater, switch-off ringtone and vibrate only") and is responsible for storing and retrieving preferences, evaluating their conditions to determine actual preference values (or outcomes), resolving conflicts between the outcomes and delivering outcomes to services that request them. PCM is responsible for monitoring context conditions affecting preferences and requesting PM to re-evaluate the preference and deliver the new "preference outcome" to the services that use the preference. A Preference Outcome is the actual value of a preference e.g. preference network = Wifi, GSM etc. LeM main functionality is to continuously analyses user interaction with service enabler layer and 3rd party services, learn the behavior of the user and create new or edit existing preferences inferred from learned behaviour. LeM thus records user action and stores this in a history database. Once a new service event is received, Context Management system is queried to retrieve a number of context attributes that could be affecting this action. This record is stored in a database and will be processed later. Sophisticated data mining algorithms are used to infer any new preference information from these user history records. This information is then passed to the PM to be integrated with the rest of the user preferences. Therefore, the system could learn that a given user prefers at certain places certain network types and installs those network preferences to be used by lower layers to automatically trigger handovers.
- Identity Manager (IdM): manage user identity and privacy. Each user has a set of virtual identities (VIDs), each one associated with a given profile. A VID may be distributed among different providers. Only the user knows his complete user profile which is used to uniquely identify the user while protecting the user's identity and privacy.
- Context Manager (CM): CM manages the collection and storage of context information on any entity, including services and users, which are identified through the VID [1]. Context can be collected from many sources such as sensor networks or other components within a system (as for example from IMS components as the Multimedia Service Provisioning User Agent (MMSPUA) and Multimedia Service Provisioning

Broker (MMSPB)). Any component in our system can subscribe for those context events that they are interested in. A component using the CM can subscribe for context events relating to these entities. Similar to [2] and [3], we merge sources from service discovery and further context information to select services and resources. However, we utilize an operator perspective and extend existing approaches with federation mechanisms and integration into the IMS framework. Moreover, we provide advanced search and reasoning [4][5] mechanisms for exploiting context information.

- Location Manager (LM): determines location of nodes utilizing Radio Frequency (RF) information to provide, together with the Location Server, a database assisted positioning solution. The current location will be determined by the Location Server, which works together with the context server to provide location information as part of global context data. This enables location based services such as "invite all users to a conference that are currently within Room 5A343".

The components in the Distributed Service Enabler plane provide third-party APIs, complementing the context-aware service management interfaces provided by the MMSPUA, MMSPB and Server Plane with the context and preferences management features presented above. The MMSPUA and MMSPB main functionality maps directly to the IMS architecture.

- Multimedia Service Provisioning User Agent (MMSPUA): is responsible for negotiation of multimedia session control, including setup, modification and teardown, with other MMSPUAs and MMSPBs. It is located on the client and its functionality includes management of SIP signaling and RTP for corresponding flows, QoS (de)allocation, retrieval and sending of authentication data, and notification of all context-related multimedia specific events to interested entities.
- Coordination Engine (CE): coordinates actions from users' applications with the invocations on both the SIP stack and the media stack taking into account the preferences and the context information given by the Distributed Service Enabler plane.
- Multimedia Service Provisioning Broker (MMSPB): represents a set of components that includes IMS Call Session Control Functions (CSCF - Proxy, Interrogating and Server) to set-up IMS calls that may require network resource reservations or the involvement of additional network elements such as Application Servers, gateway elements, and so on.
- Media Resource Manager (MRM): maps codecs into network parameters depending on the user profile and coordinates the invocations to other resource admission control components for QoS assurance (i.e. multi-technology QoSBrokers not shown in the picture). It provides support for session and terminal mobility in a fixed-mobile converged environment.

Finally, the Server Plane encompasses the whole set of servers and databases needed to support above explained architecture. In the picture only the main ones are represented (i.e. conferencing server(s), streaming server(s), location server(s), context server(s), wireless sensor network (WSN) proxy to allow sensor network information is transferred to context management data and service discovery servers (s)).

3. Sensor Networks as Context Sources

Sensor networks are an important source of context that is expected to have an impact on the behavior of multimedia services by raising awareness of situational context that cannot be inferred from location. The combination of multiple sensor network data will enable the inference of richer contextual information. To apply a rule such as "if in meeting, redirect the call to the answering machine" requires the combination of e.g. location data ("location" = "meeting room") and other sensors (such as e.g. voice activity detection) in order to infer that a given person is currently participating in a meeting. Therefore, based on results from [6, 7], we provide the possibility to integrate data from multiple sensor networks in the form of context information. In this way, the internal details of sensor network specific protocols and entities are hidden and decoupled as much as possible from context management.

The model is the following> Each sensor reports data to (or can be queried by) a specific aggregator node, preconfigured at each sensor. This allows establishing security relationships between aggregator nodes and individual sensors thus protecting the integrity and confidentiality of the reported measurements. Aggregator nodes are organized into a hierarchy. Aggregators communicate with sinks, which again have security relationship with aggregator nodes. Sink nodes are responsible to communicate (push, pull or push/pull model) aggregated measurements to the outside world or store recorded data.

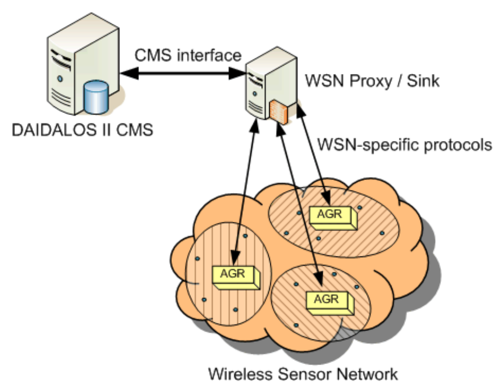

Figure 2: Daidalos WSN/Context Management Integration

A WSN Proxy, which may be co-located with the sink, serves as integration point between the Context Management System (CMS), which is comprised of context manager and context server and the WSN. That is, the WSN Proxy registers as one or more context sources (either one source that represents the aggregated values or multiple sources, each representing different derived metric or different sensors) with the context management system using the CMS Interface [8]. It is required that the CMS must be able to configure each registered context source with parameters such as sample rate, context type monitored, value thresholds, etc. This is because the context management system incorporates mechanisms that detect non-conformant behaviour of the WSN. For example, it checks that reported measurement lie inside certain thresholds, and will refuse to accept data that is reported in too short intervals.

The WSN proxy translates between the CMS side and the WSN by translating the involved protocols according to the semantics of each message. This function is important as it effectively decouples the internal operation and the topology of the WSN from the CMS; the CMS uses the standard Daidalos interface, while the proxy communicates with the sensors using WSN-specific protocols. Furthermore, the representation of time is likely to differ between the Daidalos system and the WSN; while Daidalos makes use of absolute time (e.g. number of seconds that have passed since a specific point in time), a WSN may operate based on relative time, e.g. "epochs". Moreover, the proxy can provide a number of additional functions, such as an administrative interface, statistics gathering, performance tuning, and isolation of security infrastructures.

It should be noted here that the WSN proxy is a single point of failure in this architecture. That is, if the WSN proxy is, for any reason, not available, then the entire sensor network is no longer reporting to the CMS. This potential deficiency can be overcome by adding redundant proxies and by an appropriate failover mechanism.

4. Pervasive IMS and Handling of Context

The distributed service enabler plane enables IMS based services to become pervasive. The PSM can use such services and manage their registration, their selection for use for a particular purpose, the composition of several individual services into a composed service, and the deployment and lifecycle of such a composed service [9]. A composed service can consist of components that are specifically selected to match the context and personal preferences of a user. It can be recomposed to reflect changes in the context trigger e.g. through sensor network detected events pushed through the WSN proxy into the CMS or/and personal preference changes of the user, or resource availability changes, thus adapting to environment and context. An IMS based service to become pervasive must provide information that allows it to be discovered, composed and deployed. This includes information about purpose, interfaces provided, parameters required, etc. This information is supplied through a service ontology such as OWL-based Web Service Ontology (OWL-S).

The core IMS-based elements (MMSP-UA and MMSP-B) can both act as context source ("Bob wants to talk to me") and consumer by retrieving context information ("Bob is busy"). Furthermore, they can subscribe for outcomes that are driven by preferences and context changes. Therefore, implementing a rule such as "when in meeting, redirect all calls" can thus be realized very easily. Another example is that the sensor network could detect that you are entering a very noisy environment. Such context change could trigger the MMSP-UA to switch to an audio codec that is optimized for such environment. All our IMS-based elements implement session mobility support, which enables a dynamic redirection of multimedia streams to different devices, based on device capabilities to optimize user experience. With the integration with context management, both terminal and network initiated session mobility can be triggered by changes in preferences and context (either totally or partially, e.g. based on the virtual identity, preferences and context information as location, the video stream of a audio-video session may be switched automatically to a bigger screen when a user using his "teacher" VID arrives to a class-room),. Finally, the virtual identity concept allows selecting a user identity automatically based on preferences and context ("When entering office room, used BoB@Work VID"), and the correspondent profile uploaded wherever needed.

5. Related Work

Several novel developments are related to context-awareness in general. Regarding context-aware multimedia systems and services, recent trends consider mostly the location and time as part of the context. Contextual information can be weaved into the process of Authoring, Annotation, Retrieval, Adaptation, Personalization and Delivery of Multimedia Content. As an example, location can be used as context information to deliver most appropriate multimedia information (such as a video, a multimedia presentation or a commercial) related to the current location of the user. Examples are location and context aware museums or tour guides such as [10], [11]. Location and time can also be used to annotate multimedia content or clips during their creation. Contextual information can then be used to tag and store the data as well as being used during the retrieval process. Several projects such as Meaning [12], Context Watcher [13], or Lifeblog [14] automatically associate such contextual metadata with media captured on cameraphones. When it comes to presentation of the multimedia content, device characteristics and bandwidth information can be used as contextual information to adapt the multimedia content to the device and network capabilities, as e.g. done within the MPEG-21 framework and contextual extensions [15]. Regarding more interactive multimedia services such as IPTV or video on demand (VoD), contextual information can be used to personalize the content and much work needs to be done to correctly estimate the context for proper personalization in order to enrich the streamed content by adding more information (such as personalized advertisements) or adapting the presented information taking into account user context [16]. Finally, location information is also used as context source in pervasive multimedia games. Here, context service management models and components are used to manage game related events and delivery of related multimedia data [17].

The upcoming IP multimedia system (IMS) will be an important platform in providing and delivering rich multimedia services to users. With the merge of internet world and telecom world, IMS is expected to be a dominant platform for deploying multimedia services to any IP based system. Making IMS context aware will enable radically new context aware personalized multimedia services. Naturally, user preferences should be considered in order to maximize the user satisfaction with the received service experience. In IMS, rudimentary contextual information is available such as presence [18] or coarse granular location information. Presence is considered an IMS enabling service that may be used by all other services. However, for truly pervasive and context aware applications based on IMS, the intrinsic IMS contextual information is not enough. Therefore, general context can be retrieved from external context management systems and linked into the IMS similar to what we propose in this paper. In [19] authors have proposed to use an external Context Management Service to retrieve context information about users, the places at which they are, and about other users. However, our proposal significantly extends those concepts. It links in much richer context information gathered through general sensor networks integrated to the context management system. Context management system is bundled together with a full fledged enabling platform that provides support for preference management, context inferring mechanisms and allowing to wrap such context aware multimedia service into a container to make it discoverable, composable and adaptable.

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