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CONTEXT-AWARE SERVICE ADAPTATION MANAGEMENT

Abdelhak Attou
Centre for Communication Systems Research
University of Surrey
Guildford, United Kingdom

Klaus Moessner
Centre for Communication Systems Research
University of Surrey
Guildford, United Kingdom

ABSTRACT

Technology is paving the way for ubiquitous services. However, the delivery environment is characterized by its complexity which emanates from the diversity in end user terminals and networking infrastructures. Hence, adaptation is vital to the portability and personalization of the ever increasing content and services offered to users. This paper proposes a context-aware Adaptation Manager architecture for adaptation management. The architecture aims to analyse the service delivery context to determine the required adaptations in order to enable efficient ubiquitous accessibility and personalization to the user situation and preferences. This paper presents technologies which have been identified useful for this purpose and how they are applied to deliver the functionality of the Adaptation Manager architecture, including ontology, OWL-DL, SWRL, reasoning and XSTL.

I. INTRODUCTION

Mobile devices such as PDAs, smart phones, handheld computers and notebooks have entered almost every part of life. These devices or network appliances [1] are networked via an infrastructure of heterogeneous access technologies ranging from fixed such as the Internet, LAN, ISDN and Cable TV to wireless and mobile such as Bluetooth, WiFi, WiMAX, GSM, GPRS and UMTS. In such complexity, a crucial enabler to services portability and personalization is content and service adaptation especially for future complex multimedia-rich services. A service in the context of this paper is a layer above content that may embody functionality and deliver multiple content items to the user in a specified manner. For example news, hotel booking, tourist guide, streaming and shopping services such as EBay. Adapting a service would in most cases involve adapting the content it delivers. To overcome compatibility issues, multiple content and service versions, each targeted at a specific delivery environment, can be authored statically. This approach, termed static adaptation [2], is impractical in terms of development and maintenance costs and its inability to cover all platforms and user preferences. The inadequacy of static adaptation prompted research towards dynamic adaptation.

This paper introduces a context-aware Adaptation Manager (AM) as a central entity in the content and service Adaptation Management Framework (AMF) defined as part of the Mobile VCE Core 4 Removing the Barriers to Ubiquitous Services [3] Project. The AM aims to provide a fully context-aware dynamic service adaptation and personalization according to the delivery context which includes device characteristics, available user peripherals, network properties and state, user situation, user preferences, natural environment characteristics and service and content descriptions. The AM controls the adaptation process and calculates an adaptation decision plan to manipulate the content and alter the service delivery with the aim to render them to the applicable delivery context and tailor them to the user preferences and likings. This paper does not investigate transcoding techniques or the actual adaptation operations. It rather investigates how mechanisms including those of the Semantic Web can be used to facilitate efficient context-aware adaptation management.

The paper is structured in 6 sections. Section 2 briefly surveys relevant research. Section 3 introduces the proposed Adaptation Management Framework and specifies where the AM fits. Sections 4 and 5 present AM requirements and architecture. Finally, section 6 concludes and briefly discusses evaluation criteria.

II. RELATED WORK

Content and service adaptation has been investigated by several research efforts and its significance was established. Reference [4] presents the state of the art in visual content analysis and adaptation for multimedia communications. Reference [5] presents a comprehensive survey of video transcoding architectures and techniques. However, this paper deals with adaptation management aspects such as in systems presented in [1], [6-13] and [21]. As one of the early systems in this respect, IBM proposed an extension to content servers [1] to adapt web content to client devices with varying capabilities. The system selects the best fit content version from a multimodal and multi resolution representation hierarchy of multimedia content to suit the user device and network characteristics. Although the system dynamically assesses user devices and their access network, it chooses from a statically authored content version and only adapts for resolution and modality. A decision engine is proposed in [6] to dynamically calculate an adaptation decision based on device capabilities, network characteristics, content description and the user perception of quality. The adaptation process starts with the pre-processing phase prior to receiving user requests where user preferences and different quality parameters of multimedia contents are analysed, quantified and represented in a score tree. Upon receiving a request, the user device, network and content descriptions are analysed and matched against the scores represented in the score tree to choose the appropriate set of content quality parameter

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values. Motorola Labs demonstrated how a museum visitors guide service can adapt its content to mobile users in Motorola's History museum according to the visitor's preferences, interests, location within the museum, display resolution and accepted modalities of their devices [7]. According to the user location, the system retrieves relevant content from the museum database and converts it to an XML intermediary format according to the user device, network and preferences. The Intermediary format is converted to the appropriate mark-up such as WML, XHTM, *etc*. The adaptation proxy presented in [8] adapts web documents to mobile devices to facilitate viewing and navigation by decomposition and segmentation. The Xadaptor presented in [9] adapts HTML pages for users based on their device characteristics and preferences described in XML. A rule-based approach is employed for page content adaptation and fuzzy logic is used for modelling user satisfaction levels with resizing HTML forms such as tables, labels and buttons.

The ISO MPEG group introduced the Digital Item Adaptation (DIA) standard [10] as part of the MPEG-21 [11] framework. DIA aims to assist multimedia content adaptation to different storage, transition and consumption environments by providing standard metadata enabling the description of terminals, networks, users and consumption environments characteristics. DIA only provides description tools, using the tools for adaptation is left to implementers. Examples of research based on DIA are presented in [12, 13]. MPEG-21 is based on XML which is efficient for syntax definition but limited in semantic definition.

The surveyed research provides solutions with limited context-awareness. Emphasis is on communication system context (Device, network and content), an inadequate set of user preferences or context parameters were considered in latest projects. The performed adaptation is often uni-dimensional, i.e. focusing on a particular target such as device display. Moreover, context representation and modelling is based on XML which ensures syntax enforcement but lacks formal semantics. Extensibility to new context types and interoperability with frameworks implementing different description standards is limited.

However, The aim of this research is to extend service/content adaptation to context beyond device, network, content characteristics and user preferences to cover user characteristics (such as physical impairments, detailed user preferences, user activity if available, *etc.*), surrounding environment characteristics (such as noise and illumination levels), surrounding objects (such as other available user peripherals or public devices), adaptation operations profiles and adaptation restrictions such as digital rights. Another target is efficient co-ordination between several adaptation operations to adapt at different planes. Hence, several "dimensions" of adaptations are considered to meet several targets such as preserving memory and battery life, coping with network bandwidth, adjusting colours for user eyesight impairments, removing, summarizing and restructuring according to the user situation and preferences. This research is investigating efficient semantic context description mechanisms to better understand the user situation and preferences and hence optimize the quality of the adaptation decisions, thus, Semantic Web technologies are considered. Interoperability with the existing widely deployed standards and the extensibility of the system to support new context types are targeted features.

III. Adaptation Management Framework

The proposed AMF [3] aims to achieve efficient context-aware adaptation to enable true ubiquitous access and tailoring of services and content to best suit the user situation and preferences. For example, modifying a banking service as to deliver confidential information such as account balance as text instead of audio if the user is in a shopping centre, or extract key video frames and summarize text of a sport service if the user is in a hurry or only interested in highlights.

Fig. 1 shows that the AMF mediates between two complex heterogeneous environments; user environments from one side and content and service providers from the other side.

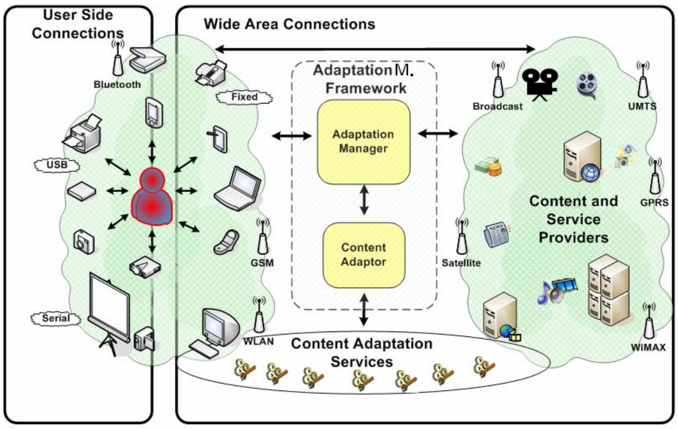

Figure 1: Adaptation Management

The AMF shall make the complexity of each side transparent to the other and bridge the gap between complex and heterogeneous user environments, advanced multimedia-rich services and content and service adaptation techniques offered by adaptation services. The AMF has two main components, the AM that manages adaptation and invokes other framework components and the Content Adaptor (CA) that discovers adaptation services and collects and maintains their profiles. Adaptation services can reside in different locations in the network and can be offered by content/service providers or specialized adaptation servers according to a service agreement. The AM adaptation decisions are executed by the CA which selects the best adaptation services according to their QoS parameters and costs. A simple AM deployment scenario is being part of a user environment (Fig. 2 C) to enable accessing content or services with other user terminals such as diverting a video streaming service to a larger display or adapting contents to satisfy certain storage requirements for later access. The AM can be deployed in content and service servers (Fig. 2 B), which gives them control over how their services or content are handled, or deployed as a proxy server (Fig. 2 A) In the last two scenarios, the AM receives adaptation requests from user environments as well as content/service providers

IV. AM Requirements

System requirements were identified by means of user scenarios. User scenarios are short descriptions that represent

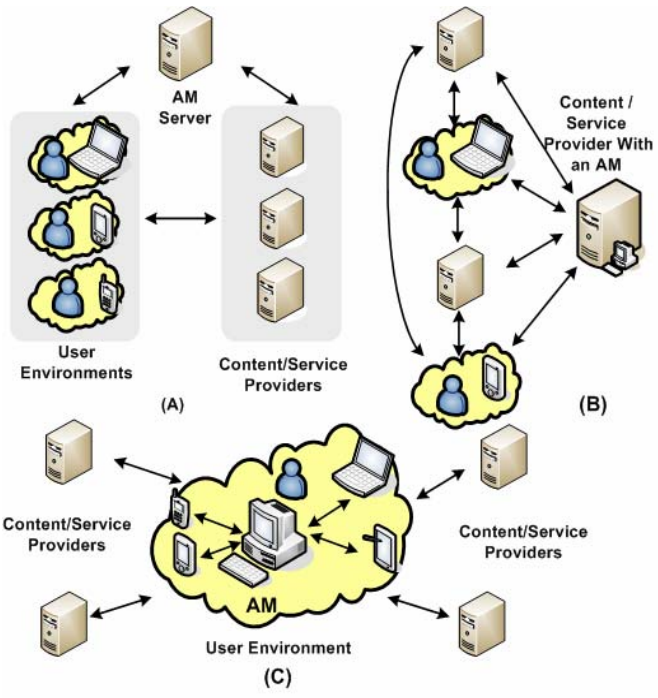

Figure 2 : Adaptation Manager Deployment Scenarios

possible patterns of system use. Key scenarios analysis shows that for the AM to provide efficient context-aware adaptation, the following requirements have to be met:

1) *Functional requirements*

- Collect user context from user environments as well as content and service descriptions from their providers. This research does not investigate context sensing methods; the aim is efficient context representation and inference for accurate adaptation decisions.
- Provide mechanisms to extract features from services or content if their descriptions are not available or inadequate.
- Format context to the AM context representation format as context profiles from different user environments are likely to be semantically and syntactically heterogeneous due to the existence of several context description and metadata standards.
- Interact with the Content Adaptor to acquire adaptation operation profiles. An adaptation operation may be resolution reduction, text summarization, language translation, video key frame extraction, transcoding, *etc.*
- Provide mechanisms to handle incomplete and inconsistent context input as context often suffers from such problems.
- Determine the best fit service version and how that affects service content according to the adaptation context
- Identify services with strict response time requirements as to give them higher priority.
- Plan adaptation in achievable steps as it is unlikely that one adaptation operation would be sufficient.
- Enforce user privacy policies and maintain content and service digital rights.
- Identify the importance of different parts of a service, parts may be removed, summarized or restructured.
- Inform users what outcome from the adaptation process and feed them back with intermediary results if possible.

2) *Non functional requirements*

- Process context semantics efficiently in order to optimize adaptation decisions and hence provide the user with the best experience that is as close as possible to the experience provided by the original content/service version and according to their preferences.
- Ensure acceptable response time for adaptation requests. This requirement varies for different types of services.
- The system deals with simultaneous adaptation requests in a concurrent fashion. The AM needs to ensure fair resource allocation and acceptable overall performance at high demand times.
- Support different context description standards and allow extensibility, otherwise the system faces interoperability issues.

V. AM Architecture

In order to satisfy AM requirements, the architecture as shown in Fig. 3 has been defined. The main AM entities are:

Adaptation Gateway: this is the interface to the AM. It defines protocols by which the AM can be requested. For each adaptation client an adaptation session is created. An adaptation client can be a device from a user environment or a service or content provider. Clients may request adaptation, cancel or inquire about an existing request. The message translator entity resolves requests for the appropriate AM function to be invoked; it also translates AM results to the appropriate message format.

Context Provider: The role of the CP is to gather contextual information and format it to a suitable format. Two components are defined to achieve this functionality:

The *Context Extractor* uses different extractors and parsers where possible (depicted by E in Fig. 3) to extract content and service descriptions or information about service structure if not provided or if inadequate.

Context Formatter: Context input is most likely XML based. The AM also uses an XML based context description approach which is explained below. The input context is formatted using one of the transformers (depicted as T in Fig. 3) which use XML Stylesheet Language Transformation (XSLT) tools. XSLT can transform an XML document into another XML document. To support other context description standards, a corresponding XSLT is wrapped in a Transformer entity and added to the Context Formatter;

hence, AM extensibility to other formats and standards is simple and easy.

Knowledge Base (KB): The KB is the adaptation domain ontology (ADO) plus adaptation rules. It captures a formal definition of the adaptation domain to which the delivery context is mapped by the Context Formatter using the appropriate Transformer, for example the MPEG-21 DIA transformer that formats DIA environment description profiles and maps them to the KB. In order to achieve an efficient semantic description, different knowledge representation mechanisms were studied. Ontology is found to be a very powerful knowledge representation scheme which has received widespread acceptance and application in different fields [14]. Ontologies formally define objects and relationships between them in a domain. OWL-DL , a subset

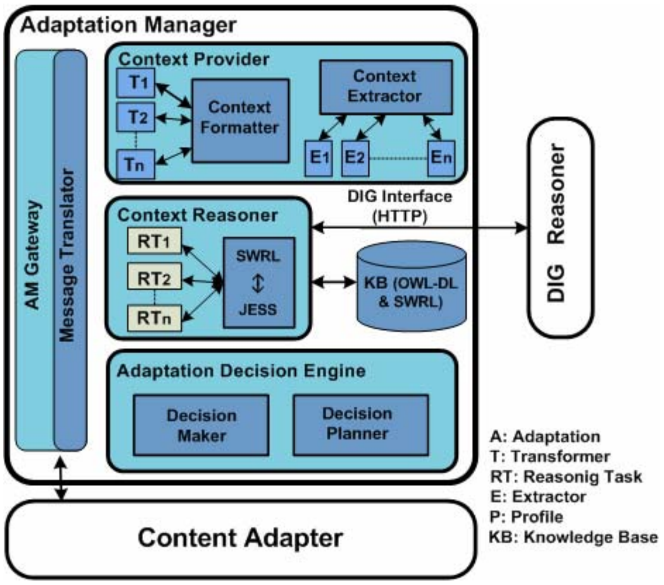

Figure 3: Adaptation Manager Architecture

of OWL , is chosen as the ontology language because it is defined in accordance with the Artificial Intelligence powerful technique for knowledge representation formalism: Description Logics (DL) [15]. The ADO borrows terms and vocabulary defined by DIA MPEG-21 and MPEG-7 because of their maturity and wide acceptance by the multimedia community. The Context Provider transforms raw context to formatted context in the form of OWL-DL profiles (Fig. 4). These profiles represent instance ontologies that describe the environment that originated the adaptation request, i.e. describing particular instances such as a User possessing a PDA and a Nokia N70 Phone and requesting an online Shopping Service to be adapted to their N70 Device. The instance ontology imports the adaptation domain ontology in order to allow the system to identify the semantics of individuals (such as Nokia and N70) and terms (such as the User, Device and PAD). Instance ontologies form part of the knowledge base temporarily while the request is being processed. The Semantic Web Rule Language (SWRL)[1] is used with the ontology to define rules using ontology constructs such as if 'Device' D has limited 'Storage' G then change coding format and reduce quality of images and videos delivered by 'Service' S. Device, Storage and Service are ontology constructs in this example i.e. defined as classes in the ADO. Ontology and OWL-DL allow easy and efficient extension of the ADO to new context types.

Context Reasoner: The role of this entity is to refine adaptation context to understand more about the user situation, the nature of the service and content, what the user wants and the restrictions that apply. The quality of the refinement process affects the accuracy of the adaptation decisions. The CR maintains user privacy policies and digital rights management and applies them to the adaptation process. The CR interacts with the knowledge base, maintains a connection to a DIG (Description-logic Implementation Group) reasoner [15] and has a JESS-SWRL rule engine. Each reasoning request for an adaptation is processed as a Reasoning Task (depicted as RT in Fig. 3). The CR employs two types of reasoning for each RT in order to analyse the delivery context as accurately as possible: rule-based reasoning using the JESS-SWRL engine and ontology reasoning using a DIG reasoner. The JESS-SWRL engine applies SWRL rules to contextual information using the Java Expert System Shell (JESS) [16] which implements the Rete algorithm known for its efficiency [17]. Rule-based reasoning is used to complement ontology reasoning and overcome its limitations [18]. DIG reasoners such as Racer[2] and Pellet[3] reason on knowledge stored in ontology to identify inconsistent instances and infer hidden dependencies and relationships. The CR refines context and defines the decision input parameters which in turn are fed into the Adaptation Decision Engine (ADE) to make adaptation decisions (Fig. 4).

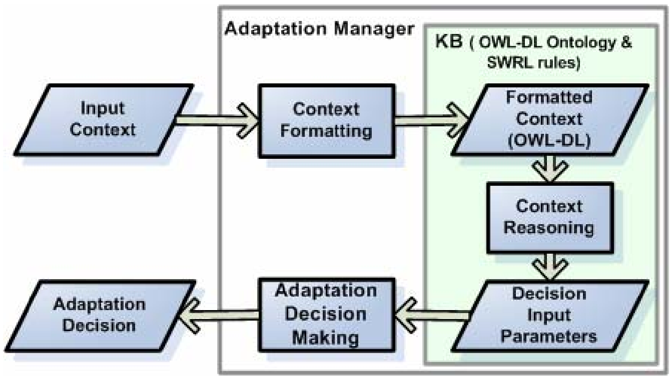

Figure 4: Context Processing Stages

The Protégé[4] and Jena[5] Java APIs can be used to implement the CR.

[1] http://www.w3.org/Submission/SWRL/
[2] http://www.sts.tu-harburg.de/~r.f.moeller/racer/
[3] http://pellet.owldl.com/
[4] http://protege.stanford.edu/
[5] http://jena.sourceforge.net/

Adaptation Decision Engine (ADE): the role of the ADE is to make adaptation decisions and plan them according to the refined context. Two components provide this functionality, the Decision Maker and the Decision Planner. The Decision Maker feeds decision input parameters into the decision making mechanism and makes adaptation decisions that represent the best fit content\service version. Decisions determine which parts of the service or content to be removed, summarized, translated or restructured to specific targets such as display, battery preservation or personalization. Decisions on specific content elements such as a video file are used by the Content Adaptor as adaptation hints. Using the available adaptation operation profiles, the Decision Planner composes a plan of achievable steps to ensure the feasibility of executing the adaptation decisions [19]. Efficient decision making and planning mechanisms need to be defined. Applicability of decision support technologies such as fuzzy logic [9] and Neural Networks need to be closely studied.

VI. Conclusion

Content and service adaptations are significant enablers for a new user experience in complex ubiquitous communication situations. To be able to adapt the required content, as well as the service delivery and presentation to the needs and likings of the user (and the capabilities of the equipment used), reliable mechanisms for adaptation of services and content have to be available. The Adaptation Manager introduced in this paper provides one significant part of such an adaptation framework, other parts, including content adaptors and context information provision complement this. Making the right decisions for an adaptation relies mainly on the available context information and the quality of the decision making processes. The architecture discussed in this paper helps to ensure the quality of both. Regarding system evaluation, criteria which need to be observed in particular are: response time, resource occupation and usability. The system has to ensure that delay caused from service adaptation and personalization is justified and does not affect the user experience in an undesirable manner. The mechanisms being employed are process intensive in addition to the concurrency requirement, thus there need to be measures to ensure reasonable resource occupation even when deployed in a powerful machine. An important evaluation criterion is the accuracy and relevance of adaptation decisions and hence user satisfaction with the adapted service/content. Other features such as stability and robustness are important especially to deal with load and incomplete input.

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