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DOHand: An ontology to support building services to exploit handover information in mobile heterogeneous networks

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Abstract — **The convergence of the internet infrastructures with the wireless networks and mobile devices has inspired the development of global ubiquitous networking platforms. The nomadic users can access services through heterogeneous network technologies using devices with interfaces for any one of them. The NGN – Next Generation Networking – will provide mechanisms to integrate the main technologies and to improve the user power in decisions which happen during handovers process. This work suggests the use of one ontology - DOHand - to support agents – users and/or applications – in these handover decisions. We believe that the normalization of information and the semantics provided by the ontology will ease management complexity and the integrated use of infrastructures by multiprovided services and enrich the users experience.**

Keywords – network management; ubiquitous computing; ontology; handover; user experience

I. Introduction

Ubiquitous environments provide high level of mobility which is characterized by heterogeneity of networking infrastructures and contexts. Such characteristics demands common vocabularies to gather semantic information about concepts on different networks and assist on representing networking contexts. These common vocabularies should support to gather precise information during handovers.

Handover is the process that occurs when a mobile terminal changes its attachment point to the Internet. Handovers can happen between systems using the same access technology or from different technologies.

Ubiquitous environments are based upon the idea that the users are highly mobile, hence the heterogeneity of networking infrastructures and contexts must be dealt with by the management. Let's imagine a mobile user watching a football match or having an audio chat through his/her PDA while going back home, after work. On the way home, this user will get a car ride till the train station; would travel by train up to a village; walk through a market for some last minute shopping for dinner and walk to finally reach home. In a NGN scenario, during the course of the session he/she could use several attachment points to the internet: corporate WLANs, mobile nets (GSM or UMTS), several public wireless networks, etc. Each time the user device changes the attachment point to the network, a handover occurs**.** Each handover can be a complex process, as many variables might change: access provider (and their policies on QoS, privacy, security, pricing), wireless technologies (GSM, UMTS, WiMax, WiFi), ecosystem in which the user is embedded (a tunnel, a traffic jam, darker or lighter environments, noisy places), etc. Obviously the ultimate requirement is that the quality of the user's enjoyment watching the video or chatting will not be significantly affected during the connection changes that the device will be subjected to.

In these circumstances, one demand from the management system is a common vocabulary representing semantic information about the basic concepts that the users, content providers and access providers could share so to exploit the various possibilities the environmental context offers, and in order to keep or improve the users experience during handovers. The use of well-structured set of semantic information and contexts can hide heterogeneity and complexity from the elements involved in the handovers allowing transparent and efficient switching between nets.

This work proposes the use of a Domain Ontology for Handovers (DOHand) in order to estructure managerial information in an abstract way. The ontology provides semantic meaning for common concepts that are essentials in an integrated and ubiquitous networking infrastructure management, easing the management of multi-provided services. Additionally, the ontology's instances must keep a network context model for context-aware applications, taking into account several aspects of the surrounding environment.

In Figure 1 we show an environment designed to illustrate such a complex communication platform. It is formed by corporate WLANs using WiFi technology, mobile network

using GPRS/GSM technology, WMAN using WiMax technology, WPAN using Bluetooth technology and, eventually, individual or community-owned wireless nets like mesh wireless networks. Such an environment has been set up as a Testbed at Cambridge University Computer Laboratory[1]. The user device attaches to access points that will provide access to the Internet through which it can reach content providers establishing a session. In our example, the user is attached to the Internet using a corporate WLAN. The nomadic users may need to switch between different technologies, based on attachment needs, current context, security and privacy concerns, or to optimize costs. In ubiquitous environments these access points' changes must happen seamlessly without disruption in their current session. In order to support seamless handover a common vocabulary and entities´ relations are structure in an ontology that should be centralized in a kind of Independent Register Profile (IRP); each entity involved on the integrated environment should carry this ontology (or part of it) as well as its own private ontology.

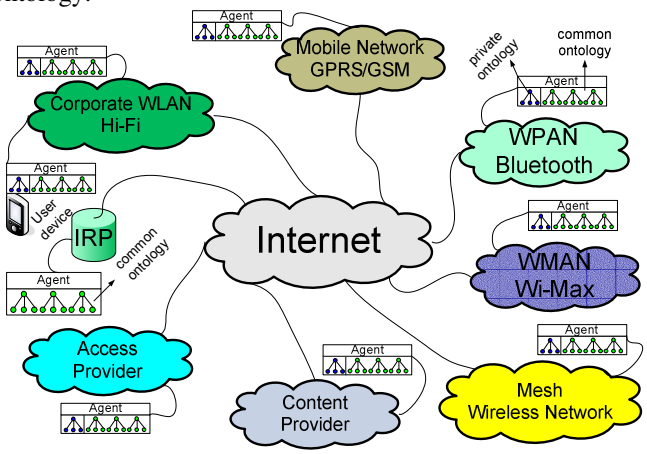

Figure 1 – Environment using the DOHand

This paper is organized as follows. Section II describes the handover types and their differences. In Section III we introduce the ubiquitous computing and how this work fits in this scenario. Section IV shows the definition of contexts which will be worked in this project and their classification. Section V describes some techniques to model context information and list advantages and restrictions of them. Section VI shows how we are using ontologies to support handover management. In Section VII we demonstrate how our ontology – DOHand – extends from the SOUPA framework and we conclude the paper in Section VIII.

II. HANDOVERS IN NEXT GENERATION NETWORKS

The handovers on IP networks do not have a management mechanism in the same way as cellular networks such as GSM. The handovers in cellular technologies are mobile-assisted, but the decision to perform a handover is network-controlled. Mobile IP has been designed for IP networks where the management of the network is distributed, with end users having as much control over the traffic as do the core entities in the network[2]. Handover on NGN should occur between two access routers on the Internet – IP network. The types of handovers can be classified from some views – Figure 2. From the *system view* the handover is classified as intra-system, i.e. when it occurs in the same access provider (same system) and inter-system otherwise. The *overlay view* is about the coverage and bandwidth, when a handover occurs from one network to another with different coverage and bandwidth it is classified as vertical – upward when it increases the coverage and upward when it decreases. Handovers at the same level are called horizontal. Related with the network access *technology view*, the handover is homogeneous for changes between access routers with the same technology and heterogeneous for different technologies. The complexity of the handover process management will increase with the number of different information to be managed, e.g. heterogeneous inter-system downward vertical handover. In this example, the providers (systems) are different - each one with its own policies, business model, infrastructure and interpretation of the managerial information – the technologies are not the same, the device interface must be switched without connection disruption and the bandwidth for the service will decrease.

In order to agree with NGN, the DOHand takes a different approach to the network-controlled model used by the cellular networks. The handovers should be client-based giving the empowerment to user devices during interfaces changes without connection disruption. The DOHand web server should provide a common vocabulary and the managerial information needed to providers to work together independently of technology, so minimizing the networking complexity and improving the user experience.

III. UBIQUITOUS COMPUTING

Mark Weiser introduced the area of ubiquitous computing (ubicomp) giving the vision of people interacting with the environments using computational resources that provide information and services when and where desired[3]. In ubicomp, the goal is that specialized elements of hardware and software, connected by wires, radio waves and infrared, become so ubiquitous that no one notices their presence.

Ubicomp is a challenge that affects all computer science. Three distinct perspectives attract interest of the researchers[4]:

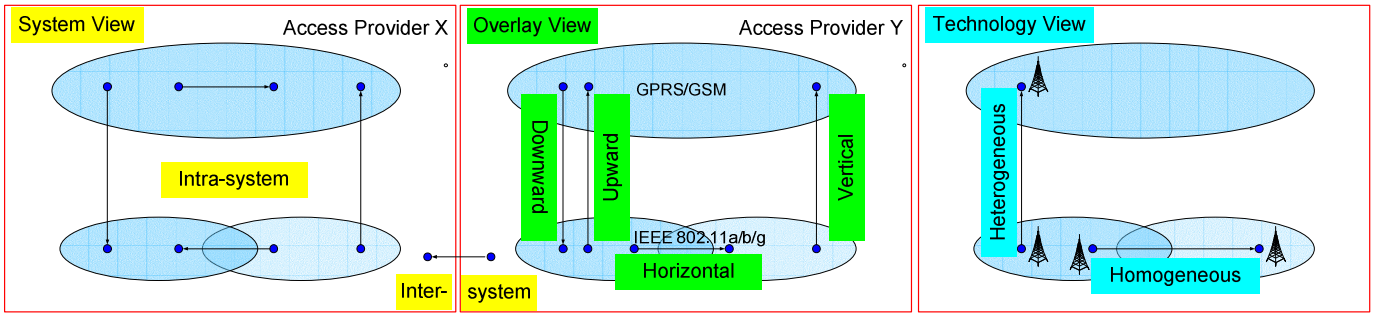

Figure 2 – Types of handovers

- ✓ The experience perspective – how people might share a world with ubiquitous computing environments.
- ✓ The engineering perspective – how architectural and network challenges impact on heterogeneous and dynamic nature of ubiquitous computing.
- ✓ The theoretical perspective – how concepts and rigorous models can capture the behavior of ubiquitous systems at varying levels of abstraction.

From the experience perspective the contextual information is used to understand and represent human activities. The nature and the role of the context will be determined by the real world concepts and activities that populate it. In order to present context to computational elements, and to exploit these representations on the improvement of user experience during handovers, the DOHand will describe the concepts and their meanings related with the system, user, application and infrastructure contexts.

From the engineering perspective, each provider has its own understanding of concepts; the DOHand provides a common interpretation to better information sharing between heterogeneous infrastructures. The model proposed may help the design of novel architectures to improve the user experience and the management of handovers.

From theoretical perspective, concepts and models may classify, represent and characterize the context. These models support the system to understand what is happening on its context and then adapt itself. However, there is a gap in ubicomp: a well-defined and common concept about context and its types does not exist, and how to extract and how to interpret the meanings (semantics) of the interactions between users and systems, and between systems is some that must be more exploited. The classification of contexts, proposed in session IV, helps the definition and a common understanding about the context concept. The ontology – DOHand – proposed in session VII provides a formal vocabulary based on a model representing information tied to explicit meaning. The ontology provides the abstraction need to hide management complexity.

Ubiquitous systems are context-aware in that they should be able to react and adapt their capabilities according to the available resources for service delivery and the rules that govern it. For instance, the situational status of the battery conditions could lead to a search for an energy-saving type of attachment (Bluetooth is much more economic than WiFi) or, depending on the situation, switch the processor to an energy saving mode. The analysis of the history of recent statistical patterns of usage, interactions and context can also be used to infer both current and future context[4]. In the case of our example, previous records from the user's route can hint on the possibilities which lies ahead in the way (a tunnel, for instance) and indicate certain mitigating measures (buffering of information for the video or a warning for the people involved in the chat).

IV. CONTEXT CLASSIFICATION

The literature usually reports and explains context as the user context, where developers use contextual information as a mean to represent the situation of a contextual entity. In order to decide which information is context, developers could use the following guidelines: "who" is the user, "where" is the user, "when" is the user, "what" is the user doing, "why" is the user doing that, and "how" the user is doing that[5].

However, there is more context than just the user one. Goularte [6], Schilit[7], Dix et al.[8], Chalmers[9] and Crowley et al.[10] (just to quote a few), built context-aware applications which use some characteristics that can be classified as belonging to infrastructure, system, domain or environment.

Due to the huge diversity of characteristics, it is not trivial to define contexts and, neither, the boundaries between the involved entities. In spite of these difficulties, we have defined a logical boundary which establishes context information's scope. In doing so, accurate taxonomies and domain ontologies can be modeled to drive our work.

Our approach is based on the classification proposed by Goularte [6, 11, 12]. According to that work, context can be classified in System context, User context, Application context and Infrastructure context, which, in turn is a composition of Network, Device and Service contexts – Figure 3. Applications may use infrastructure in two ways: 1) when applications are running on user's devices (PDAs, Laptops, tablets, etc.); 2) when applications use some other infrastructure device

(routers, servers, access points, etc.) and services (e-mail, proxies, web-servers, etc.) to realize tasks. Communication services between user's devices and services are offered by the network (e.g. WLAN, GPRS, and Internet).

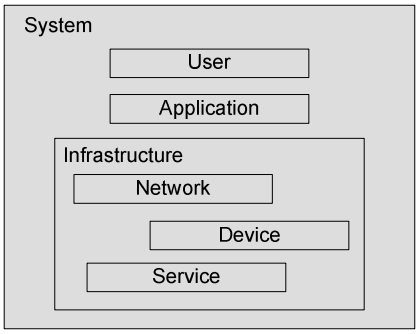

Figure 3 – Components of System Context[11]

Based on this classification, ontology-based models can be developed in order to characterize system context elements. These models can be implemented in an appropriate language (see section V) allowing to represent a contextual entity, to share information, and to preserve and to infer semantic relationships.

V. TECHNIQUES TO MODEL CONTEXT INFORMATION

In this session we describe and list the advantages and restrictions of some techniques that have been used to model context information and domain concepts as key-value pair, markup language, object-oriented language, topic maps and ontologies.

A. *Key-value Pair*

This technique uses a simple data structure to represent context information which is modeled by pairs of one key that identifies the context attribute and of an associated value to that key as illustrated in Figure 4. In this example, there are three keys: date, time, location and their following values "after December first", "9 a.m. to 2 p.m.", and "Trafalgar square". The action "Handover to tower X from Provider A" is associated with this context.

Category	Example
Date	After December first
Time	9 a.m to 2 p.m.
Location	Trafalgar square
Action: Handover to tower X from Provider A	

Figure 4 – Example of key-value pair

Advantage: because of its simplicity, it is used by operational systems to store environment variables. Examples of context-aware systems that use key-value pair to represent context are Context-Toolkit [13] and CXMS (Context Management System) [14].

Restriction: there is no hierarchy between the attributes and, despite of its simple use and manipulation, it is not possible to create more sophisticated structures that permit complex algorithms to retrieve context information.

B. *Markup Language*

This technique uses XML (eXtensible Markup Language) and RDF (Resource Description Framework) to model context information. The main characteristic of XML is been a hierarchical structure that contains tags with attributes and values. This approach has been used to model user profile and devices. One example is the CSCP (Comprehensive Structure Context Profile) [15]. The use of this technique aims to define a common and extended vocabulary to represent context information and domain concepts.

Advantage: XML and RDF ease the information sharing because they are broadly accepted standards.

Restriction: the semantic provided by the language constructors is poor to permit elaborated inferences [16].

C. *Object-Oriented*

The technique to model context information using object-oriented paradigm (OO) aims to use properties as encapsulation, inheritance and reusability to deal with the context dynamism [17].

Advantage: The context retrieval and processing is provided by well-defined interfaces.

Restriction: the context information is hard-code and its maintenance is not simple.

D. *Ontology*

Ontology represents a formal description of concepts and relationships. It is a very promising instrument for modeling contextual information due to their high and formal expressiveness and the possibilities for applying ontology reasoning techniques[17].

Advantage: The ontology should support the simple addition of new context elements and relations.

Restriction: the maintenance of rules associated with concepts and context information is not a trivial activity when there are many rules.

VI. THE DOHAND ONTOLOGY

There are many types of ontologies and their classification can consider various dimensions, like shallow *versus* deep, upper *versus* domain, formal versus informal, and regular *versus* irregular. Ontologies also can be classified in terms of their formalism, type of domain represented, and expressiveness[16]. However, the classification mostly accept is related with the ontology function/purpose, and it is divided into three levels[18]: *upper* ontology, *domain* ontology and *application* ontology.

The upper ontology describes generic and abstract concepts that address – in a general way and at a high level – a huge

number of domains. Specific concepts to domains are not included, but upper ontologies can be imported to specific domain ontologies that will specialize, this set of general concepts, in more specify vocabularies related with the area as networking, engineering, medicine, etc. Examples of upper ontologies are SOUPA[19], OpenCyc[20], and SeCoM[21]. The domain ontology describes a formal, shared understanding of a particular domain enabling the description of explicit semantics that can be used by humans and by systems to aid in information exchange and integration[22]. Examples of domain ontologies are OntoSec[23] and DOHand[24]. The application ontology will treat a specific problem in a domain; it generally imports domain ontology and has more specific vocabularies for the treated problem, e.g. an ontology that describes incidents of delay in handovers from our domain ontology for handovers management.

An ontological representation defines semantics independent of the reader/agent (human or software) and context. The use of ontologies has several advantages:

Interoperability. Ontologies provide a shared understanding of a domain, in our case the ubiquitous networking infrastructure domain. In this way the concerns about the structural and semantic heterogeneity of different infrastructures can be solved. Structural heterogeneity happens when different networking infrastructures store and manipulate their data in different manners. Semantic heterogeneity involves intended meaning and management of information and its service relationships. Ontologies provide an effective means for explicating implicit design decisions and underlying assumptions at networking infrastructure management decision time. This makes it easier to reason about the intended meaning of the information interchanged between two or more providers.

Machine processability. Ontologies provide a formalization of shared understanding which allows machine processability and it forms the basis for the Semantic Web, which is itself based on using ontologies to improve the quality of content with formal semantics[25]. This will enable the implementation of networking infrastructures management agents to reason about the services and carry out more intelligent tasks on behalf of the infrastructures.

New level of services. The explicit representation of the semantics of data through ontologies will enable the providers to reach agreements between them and with the users with a qualitative new level of services, such as *verification, justification,* and *gap analyses*. The ontology axioms and rules provide the verification service, e.g. an agent can use axioms and rules to discovery the equivalent resource in other provider to give the necessary functionalities for the service interoperability. Justification refers to the generation of descriptions of the inference process to humans, i.e. how a result was inferred. A gap analysis – in this case – is a set of information about network management limitations to help the ontology extensibility and adaptability.

The DOHand ontology will be encoded into files using the OWL[16] (Web Ontology Language), which is the prime language created for the Semantic Web. OWL is incorporated on the Protégé tool[26], which is a widely used environment to design and develop ontologies.

Ontologies provide constructs – class, property and individual – used as building blocks to describe relationships and to model explicit semantics[27]. The ontological class concept is related to the object class concept in object-oriented programming (OOP) and tables from Relational Databases Management Systems (RDBMS). Similarly, individuals are instances of one class that will group them by similar properties, like objects in OOP and records in RDBMS. Examples of classes in our work are "provider", "service", and "device"; and their correspondent individuals can be "XPTO provider", "e-mail service", and "PDA device". The ontological property concept associates attribute/value pairs with instances. A property is an association that relates an instance to a value. Examples of properties that we use are "provider name", "service type", and "IP device". In addition to describing classes, properties and individuals, it is necessary to create relationships between them. The inter-concept relationships include "is an instance of" – individual to class – "has value for" – individual to class – and "restrict" – between classes and properties. Other capabilities are used to include semantic relationships within classes, properties and individuals; these capabilities are synonymy, antonymy, hyponymy, and meronymy relations.

VII. DOHAND AS SOUPA EXTENSION

A particular preoccupation on this work is to follow established or emerging standards in its implementation. The DOHand ontology will import the upper ontology SOUPA [19] – Standard Ontology for Ubiquitous and Pervasive Applications – to model the user and application contexts. SOUPA model divides the system in *core* ontologies (upper ontology) and *extension* ontologies (domain ontology and/or application ontology). SOUPA Core defines wide range terms and relationships that are of general use for different ubiquitous applications. The Core uses modular component vocabularies to represent intelligent agents with associated beliefs, desires, and intentions, time, space, events, user profiles, actions, and policies for security and privacy. SOUPA Extension defines vocabularies for specific types of applications. We understand that, for our ontology, the core ontology will take care of the common vocabulary related with user and application contexts which will be used by all the entities belonging to the ubiquitous environment. Figure 5 shows a diagram of core ontologies and their associated relations.

The "Person" ontology defines typical vocabularies for describing the contact information and the profile of a person. "Policy" and "Action" ontologies are concerned with security and privacy concepts for policies. Policy is a set of rules that is specified by a user or a computing entity to restrict or guide the execution of actions. "Agent" and "BDI" ontologies were designed to give to both computational entities and human users the capabilities of agency, which is characterized by a set of mentalistic notions such as knowledge, belief, intention, and obligation. When the goals, plans, desires, and beliefs of different agents are explicitly represented in the ontologies, this information can help independently developed agents to share a common understanding of their "mental" states, helping them to cooperate and collaborate. The explicitly represented human user's mental states can help computing agents to reason about the specific needs of the users in a ubiquitous environment[19]. The "Time" ontology defines a set of concepts for expressing time and temporal relations. They can be used to describe the temporal properties of different events that occur in the physical world. The "Space" ontology is designed to support reasoning about the spatial relations between various types of geographical regions, mapping from the geo-spatial coordinates to the symbolic representation of space and vice versa. Events are event activities that have both spatial and temporal extensions. "Event" ontology can be used to describe the occurrence of different activities, schedules, and sensing events.

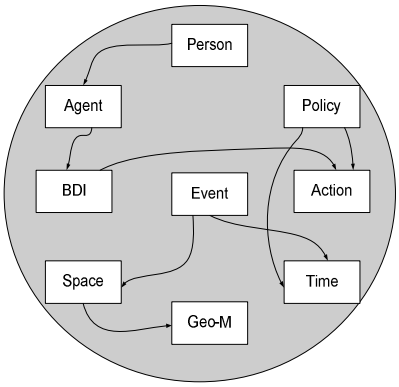

Figure 5 – SOUPA Core[19]

The DOHand ontology will incorporate the SOUPA Core and create an extension for the handover process. Figure 6 describes the new extension and their relationships.

The "Handover" is the main entity at the extension part; the handover process starts with actions governed by policies or by agent beliefs, desires, and intentions. The result is an event characterized for a change on the Internet attachment point. The handovers is associated with a person (user) that has a device to establish a session with a service. A service is a facility (a video streamer, a voice channel or a game connection) which a content provider offers, during a session, to a user/person through an access provider. One entity can offer both access and content at the same time. In the course of enjoying a service, the user seamlessly roams through a net of access providers. Context information, gathered by positioning sensors and other sources from the user device or by any other related service, can be used both by user device and business device to frame Security and Privacy issues. Positioning information can also be used for the definition route patterns used for one user, which could lead to better pricing strategies for the user. Some sort of SLA is signed between all the entities involved in order to offer to the user some parameters by which they can measure his/her Quality of Experience while using the system.

The Web Ontology Language (OWL), used to develop the ontologies in SOUPA and to extend the DOHand, permits the construction of complex and necessary relationships between terms in order to correlate the business with the management processes, e.g. making business with context information. This capability permits a better exploration of new possibilities derived from the positioning and context awareness technologies.

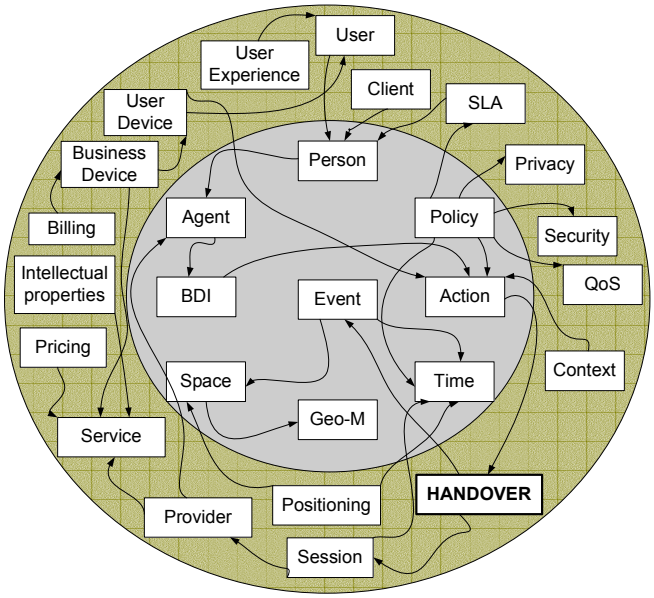

Figure 6 – DOHand extension on SOUPA Core

A. Description of the DOHand Classes

The key issue here is the possibility that the information in the Ontology can be shared by several entities involved in providing the services, in a service-oriented way. Parts of the ontology will be distributed between the following Profile registers: Access Provider, Content Provider, the User Device, and the Business Device.

The following classes are thought to be needed to manage the seamless roaming of a user connected to a service (for

instance a video server) and using several access providers on the way.

User/Person. This class extends from SOUPA Person ontology. It contains the profile of the user (name, address, age, etc), as well as the information needed for authentication;

Client. This class extends from SOUPA Person ontology. It informs who bought the service and/or signed the SLA. Usually, the client and the user will be the same person, but a client can be e.g. an organization and the users its employees;

User Device. This class defines the way the user access the net. Capabilities parameters (screen, network adapter, bandwidth, sensors, etc) are important information for the proper running of the service;

Business Device. This class is the provider's counterpart of the User Device. It is responsible to gather information from the different entities to form the knowledge necessary for the continuity and improvement of the business;

Access & Content Provider. This class presents information about the provider which is given the access to the user and/or about the provider who are offering the content. The information here must be rich enough to allow for the identification of good routes and to troubleshooting eventual access incidents. The user must have the information needed to access the perception of quality of individual providers;

Service. This class presents information about services which are in the portfolio of providers, with are the characteristic (QoS, privacy, security) needed for its run. Data regarded to intellectual properties of the content are stored in here;

Session. This class stores information about the period of time a user is connected to a provider's network for accessing a service;

User Experience. This class contains information about the user's experience on using the system. It will be managed by the user and by the providers in a shared way;

QoS. This class informs the parameters for keep the desire quality of service during the service delivery.

SLA. Information about the Service Level Agreement signed with the user and access and/or content provider;

Positioning. This class is aimed at providing information on the localization of the user, as well as for the history of his/her roaming. Eventually this kind of information can be shared with other positioning-based services (see the context class). The patterns of tracing of a service could give valuable provisioning information for capacity management;

Context. The positioning is not the only contextual information important for the user's navigation. Environmental data (who is around, is the user indoors or outdoors or in a car? is it cold or warm, is it a public place? which kind of device is used?) can be useful for definition of sensitive services, regarding privacy, for instance;

Security. This class contains information about the way the provider deals with security. It can contain the restrictions derived from the providers Security Policy and the terms agreed on the SLA. It should also present relevant information so that the security profile can be mapped when the user crosses borders of domains;

Privacy. This class contains personal information about the user (preferences, agenda, etc). It will be managed by the user;

Pricing. This class contains the prices offered by the providers related to services.

Billing. This class presents information on the total costs of the recent connections/access made by the user session. Eventually, it could be used with the **pattern of tracing** capabilities from the class positioning to optimise costs.

Intellectual Property. This class informs the intellectual property rights (IPR) related to the accessed content.

Handover. This class contains the changes made from one access point to another in the Internet. The handovers types are related to different systems, domains, technologies, bandwidths and coverage.

B. The use of the DOHand

The scenario described in *session I*, where a mobile user moves in a ubiquitous environment, is a good example to show how the DOHand can support the handovers management. The user watching a football match is using his/her PDA to establish a session with the content provider through an access provider both connect to the Internet. All the entities (content provider, access provider and user device) are sharing manageable information in order to keep a good user experience and to respect the policies (e.g. privacy and security) in the service provision. The user changes his/her attachment points many times, forcing his/her PDA to execute handovers. These handovers occur between different providers and technologies that must share all relevant information to execute a seamless change. The DOHand should be the framework containing the common vocabulary with the manageable information and the policies agreements. Additionally, the handovers´ history – DOHand and instances – should be logged in knowledge base available for providers and third parties. These entities should use the knowledge base to improve the users experience and the handovers management, and to aggregate value to services.

VIII. Conclusions

The ontologies will determine a common and agreed vocabulary of terms to be used during the design of new services in the communications industry, improving the deployment and the exploration in the added value chain. The provider or a group of providers should use the DOHand to unify in a structured manner the integration of the access networks, subscriber profiles, applications and data. This new arrangement should reduce network management complexity

both in terms of service support and delivery. There is a tendency for giving more control to users in their choices and interaction with the net[4]. The ontologies' information shared on the ubiquitous networking infrastructure should avoid a better user role on controlling their interaction with the net and having more choices, both in terms of connectivity and the services.

Acknowledgment

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References

[1] P. Vidales, G. Mapp, F. Stajano, and J. Crowcroft, "A Practical Approach for 4G Systems: Deployment of Overlay Networks," in *First International Conference on Testbeds and Research Infrastructures for the DEvelopment of NeTworks and COMmunities (TRIDENTCOM'05)*, 2005, pp.:172 - 181.

[2] L. B. Patanapongpibul, G. Mapp, and A. Hopper, "An End-System Approach to Mobility Management for 4G Networks and its Application to Thin-Client Computing," in *ACM SIGMOBILE Mobile Computing and Communications Review*, 2006.

[3] M. Weiser, "The computer for the 21st century," *Scientific American,* pp. 94-104, 1991.

[4] D. Chalmers, M. Chalmers, J. Crowcroft, M. Kwiatkowska, R. Milner, E. O'Neill, T. Rodden, V. Sassone, and M. Sloman, "Ubiquitous Computing: Experience, Design and Science," Grand Challenge web site, UK 2006.

[5] R. Goularte, M. d. G. C. Pimentel, and E. d. S. Moreira, "Context-Aware Support in Structured Documents for Interactive-TV," *Multimedia Systems, Springer,* vol. 11, n.4, pp. 367-382, 2006.

[6] R. Goularte, E. d. S. Moreira, and M. d. G. C. Pimentel, "Structuring Interactive TV Documents," in *ACM Symposium on Document Engineering*, Grenoble, 2003, pp. 42-51.

[7] W. N. Schilit, "A System Architecture for Context-Aware Mobile Computing," in *Graduate School of Arts and Sciences* Columbia: Columbia University, 1995, p. 144.Doctoral Thesis.

[8] A. Dix, T. Rodden, N. Davies, J. Trevor, A. Friday, and K. Palfreyman, "Exploiting Space and Location as a Design Framework for Interactive Mobile Systems," *ACM Transactions on Computer-Human Interaction,* vol. 7, pp. 285–321, September 2000.

[9] D. Chalmers, "Contextual Mediation to Support Ubiquitous Computing," in *Imperial College of Science, Technology and Medicine* London: London University, 2002, p. 279p.Doctoral Thesis.

[10] J. L. Crowley, J. Coutaz, G. Rey, and P. Reignier, "Perceptual Components for Context Aware Computing," in *4th international conference on Ubiquitous Computing*, Göteborg, Sweden, 2002, pp. 117 - 134.

[11] R. Goularte, "Personalização e adaptação de conteúdo baseadas em contexto para TV Interativa," in *Instituto de Ciências da Computação* São Carlos: Universidade de São Paulo, 2003.Doctoral Thesis.

[12] R. Eisinger, M. G. Manzato, and R. Goularte, "Devices Descriptions for Context-Based Content Adaptation," in *Third Latin American Web Congress - LA-WEB*, Buenos Aires, 2005, pp. 121-129.

[13] A. K. Dey and G. D. Abowd, "A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-Aware Applications," *Human-Computer Interaction,* vol. Volume 16, pp. 97-166, 2001.

[14] A. Zimmermann, A. Lorenz, and M. Specht, "Applications of a Context-Management System," in *CONTEXT*, 2005.

[15] A. Held, S. Buchholz, and A. Schill, "Modeling of Context Information for Pervasive Computing Applications," in *6th World Multiconference on Systemics, Cybernetics and Informatics*, Orlando, Florida, USA, 2002.

[16] L. W. Lacy, *OWL: Representing Information Using the Web Ontology Language*: Trafford, 2005.

[17] M. Baldauf, S. Dustdar, and F. Rosenberg, "A Survey on Context-Aware Systems," *Journal of Ad Hoc and Ubiquitous Computing,* 2004.

[18] N. Guarino, "Understanding, Building, and Using Ontologies: A Commentary to "Using Explicit Ontologies in KBS Development",by van Heijst, Schreiber, and Wielinga," *International Journal of Human and Computer Studies,* vol. 46, pp. 293-310, 1997.

[19] H. Chen, F. Perich, T. Finin, and A. Joshi, "SOUPA: Standard Ontology for Ubiquitous and Pervasive Applications," in *First Annual International Conference on Mobile and Ubiquitous Systems: Networking and Services (MobiQuitous'04)*, 2004, pp. pp. 258-267.

[20] D. B. Lenat, "CYC: A Large-Scale Investment in Knowledge Infrastructure," *COMMUNICATIONS OF THE ACM,* vol. Vol. 38, No. 11, pp. 33 - 38, November 1995.

[21] R. F. Bulcão Neto and M. G. C. Pimentel, "Toward a Domain-Independent Semantic Model for Context-Aware Computing," in *La-WEB: Latin American Web Conference*, Buenos Aires, 2005.

[22] L. Stojanovic, J. Schneider, A. Maedche, S. Libischer, R. Studer, T. Lumpp, A. Abecker, G. Breiter, and J. Dinger, "The role of ontologies in autonomic computing systems," *IBM Systems,* vol. 43, 2004.

[23] L. A. F. Martimiano and E. d. S. Moreira, "An Owl-based Security Incident Ontology," in *8th International Protégé Conference*, Madri, 2005.

[24] R. M. P. Vanni and E. d. S. Moreira, "Management of Services in Ubiquitous Environments: using ontologies for dealing with quality-of-service," in *7th Annual Postgraduate Symposium. The convergence of telecommunications, networking and broadcasting*, Liverpool, 2006, pp. 196-200.

[25] G. Antoniou and F. v. Harmelen, *A Semantic Web Primer*: Massachusettts Institute of Technology (MIT) Press, 2004.

[26] Protègè, "http://protege.stanford.edu/," 2006.

[27] D. L. McGuinness and F. v. Harmelen, "OWL Web Ontology Language Overview - W3C Recommendation, http://www.w3.org/TR/owl-features/." vol. 2006, 2004.

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