ADAPTATION FOR ASSIMILATION: THE ROLE OF ADAPTABLE M-LEARNING SERVICES IN THE MODERN EDUCATIONAL PARADIGM

Damien Meere, Ivan Ganchev, Stanimir Stojanov, Máirtín O'Dróma

Abstract: This paper presents an adaptable InfoStation-based multi-agent system facilitating the mobile eLearning (mLearning) services provision within a University Campus. The network architecture is presented, and the interactions between the various components within the architecture during mLearning service provision (mLecture, mTest) are presented. System implementation approaches are also considered, with particular attention paid to the creation of user profiles and service profiles for the personalization and contextualization of the presented services.

Keywords: InfoStations, Intelligent Agents, Multi-agent System, mLearning, CC/PP-UAProf, OWL-S.

I. Introduction

The InfoStation-based system described in this paper is established and operates across a University Campus area mainly for the purposes of the mobile eLearning (mLearning) process. It provides "many-time, many-where" wireless services accessible via mobile devices (cellular phones, laptops, personal digital assistants–PDAs) through geographically intermittent high-speed connections. In this paper we highlight the architecture underlying the provision of these services. We also discuss how the various components of the network architecture collaborate in order to facilitate the mLearning services provision in both blended and distance learning environments. Particular emphasis will be placed on the architectures ability to adapt and customize the services to meet the capabilities of the particular operating environment, as well as personalizing the service to suit a particular end user.

The rest of the paper is organized as follows. Section II presents briefly the InfoStation-based network architecture. Section III illustrates the mLearning service provision outlining sample interactions between system entities. Section IV outlines some implementation issues, in particular regarding the use of semantic web technologies in order to facilitate a personalized and contextualized learning environment through the creation of user profiles and service profiles. Finally Section V concludes the paper.

II. InfoStation-based Network Architecture

The following InfoStation-based network architecture provides access to mLearning services, for users equipped with mobile wireless devices, via a set of InfoStations deployed in key points across the University Campus [1-4]. Whilst within these isolated pockets, within range of an InfoStation, clients may access these localised and personalised mLearning services, in a "many-time, many-where" fashion through a geographically intermittent high speed connection. The InfoStation paradigm is an extension of the wireless Internet as outlined in [5], where mobile clients interact directly with Web service providers (i.e. InfoStations). The evolution in capabilities of, and resources available in modern mobile devices, has precipitated an evolution in the realm of eLearning. The following presented architecture serves to harness this communicative potential in order to present learners with a pervasive learning experience which can be dynamically altered and tailored to suit the learner. Due to the geographically intermittent nature of the connection to the InfoStations, it is necessary for intelligent agents to

operate also onboard the user mobile devices [6-8]. Acting as "Personal Assistants", these agents are able to function autonomously in order to satisfy any user service requests they may encounter, while in or out of contact with other agents (installed on the InfoStations and/or InfoStation Center). This agent autonomy allows the most efficient utilization of the InfoStation's high-rate intermittent coverage. The 3-tier network architecture consists of the following basic building entities as depicted in Figure 1: user mobile devices, InfoStations and an InfoStation Center.

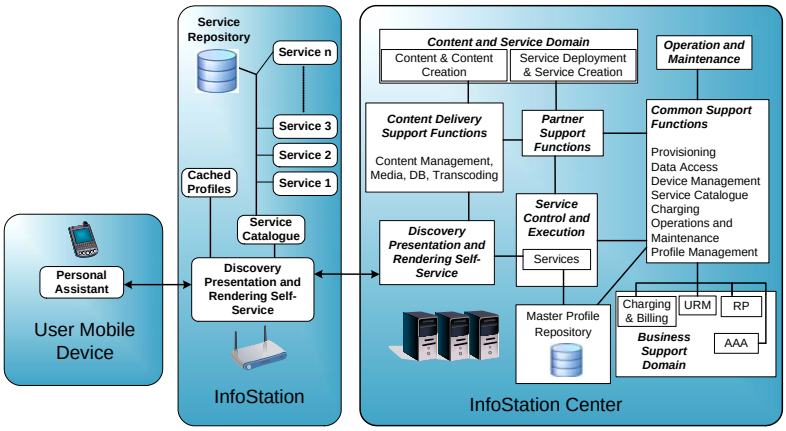

Figure 1. The 3-tier InfoStation-based network architecture with some entity components utilized from [9]

The users request mLearning services (from their mobile devices) from the nearest InfoStation via available Bluetooth (IEEE 802.15 WPAN), WiFi (IEEE 802.11 WLAN), or WiMAX (IEEE 802.16) connection. The InfoStation-based system is organized in such a way that if the InfoStation cannot fully satisfy the user request, the request is forwarded to the InfoStation Center, which decides on the most appropriate, quickest and cheapest method of delivering the service to each user according to his/her current individual location, current operating environment (mobile device's capabilities and wireless access constraints) and indeed the preferences of the particular user. The InfoStation Centre maintains an up-to-date repository of all profiles and eContent. The InfoStations themselves maintain cached copies of all recently used user profiles and service profiles, as well as a local repository of cached eContent. In the following section we describe the provision of a number of mLearning services.

III. mLearning Services

mLecture Service

The mLecture service exists as one of the core mLearning services within this system. Initially this service might be used as a supplementary aid to the traditional learning experience. In a traditional learning environment, it is often the case that a lecturer will make available various ancillary learning resources in order to aid the students understand the presented information. Usually this would consist of a set of notes to accompany the lecture. In this case, a lecturer could upload these learning resources (e.g. text, diagrams, images) pertaining to the lecture, or indeed supply a pod-cast or possibly even a video-cast of the lecture itself. This would greatly assist the student's assimilation of information. As students would be able to regulate the pace at which they proceed through the information and if necessary re-cycle back through the lecture. This ensures the material be more

accessible for learners of varying learning styles. Indeed for some time now, pod-casts have been utilized around the world in third level institutions to aid students.

The following, Figure 2, outlines the entity interactions that take place during the provision of the mLecture service. The purpose of this service is to allow students to gain access to lecture content through their mobile devices. The students can request material relevant to specific lectures, which is delivered to their mobile device. However, first this service is adapted and customized according to the capabilities of the user devices and the users own preferences (specified within user profiles). The user device may be limited to the utilization of a text and/or audio only, in which case if there are video components available they will be omitted. The user may choose to access the full capabilities of the service later, whilst using a device of greater capabilities (e.g. PDA, laptop). This trimming (adaptation) of the services is one way to address the shortcomings of some mobile devices, while still delivering the service.

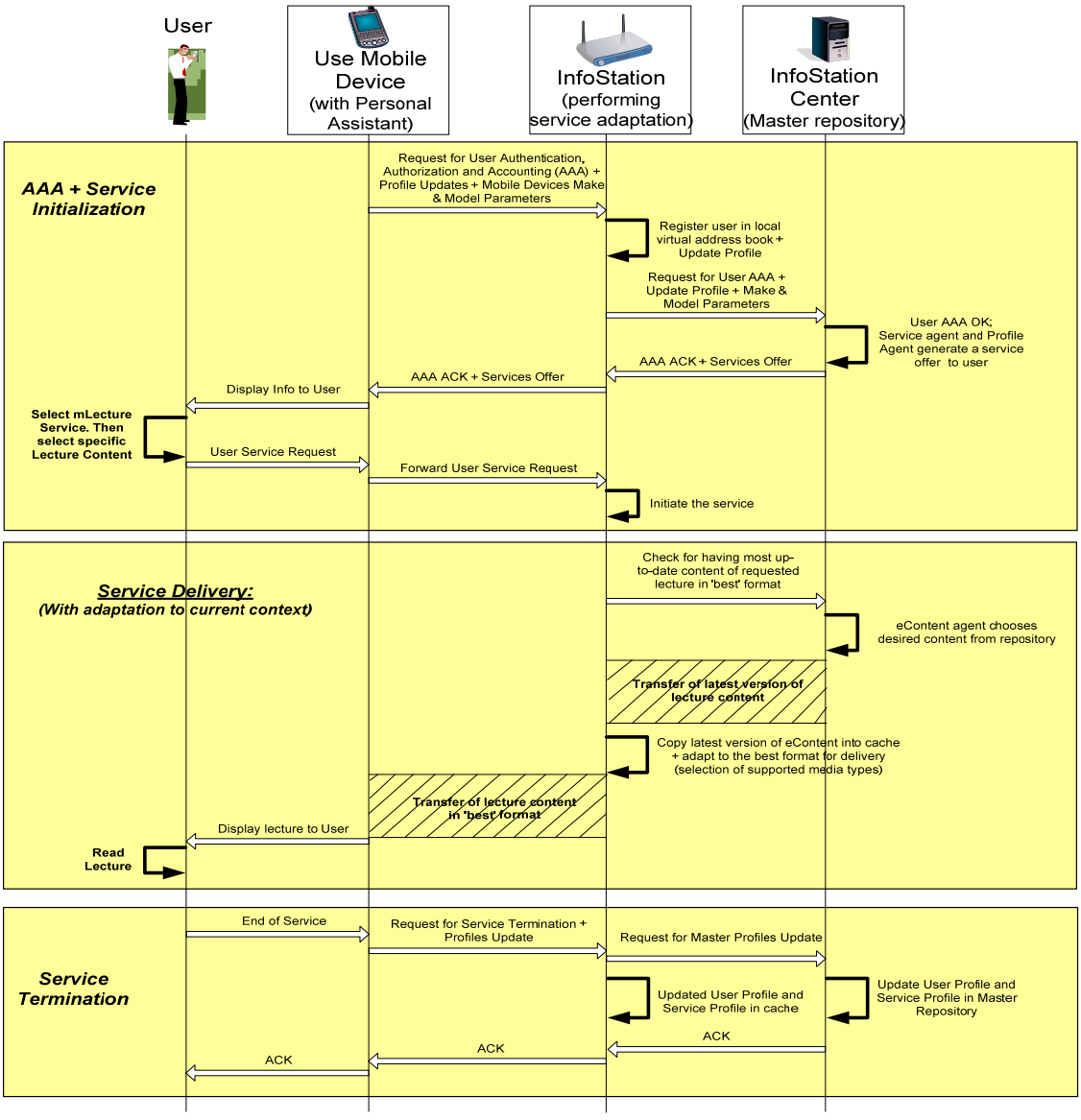

Figure 2. *mLecture* service provision

When the mobile user first enters within the range of an InfoStation, the InfoStation is initially concerned with the processing of the user's AAA request before subsequent selection of service. The InfoStation registers the user's details within its local repository and processes any necessary updates to the user profile and service profile. If an update is necessary, the InfoStation forwards the various profile updates to the InfoStation Center, which can in turn disseminate these updates throughout the InfoStation network. If the Local InfoStation has no record of the user, the user AAA request can be forwarded to the InfoStation Center, which processes the request and facilitates the InfoStation with the requisite profile information. Once the AAA procedure has been successfully completed, the user is presented with a list if available services. Let's assume that the service chosen is the *mLecture*. The PA forwards the users service request to the InfoStation, which first initiates the services and then checks with the InfoStation Center whether or not it has the most up-to-date cached version of the required mLecture. If not, the InfoStation Center sends back a full copy of the requested lecture to the InfoStation. The InfoStation examines the user profile and service profile and customizes the service accordingly. The users current device may not possess the capabilities to accessing the full range of media formats available as part of a service. For this reason, the InfoStation will adapt the service content to a format which 'best' suits that particular device (i.e. accounting for both the device and the access network) according to the specifications within the User Profile.

mTest Service

This service is crucial to the complete eLearning process. mTest provides a means to evaluate the students acquired knowledge and provides valuable feedback to students concerning their progress. mTest also allows the educator to shape the learning experience of the students, ensuring the student remains engaged in the correct material. Indeed the main benefit of using quizzes is the motivation of the students engagement in the material, without the stress of associated with traditional exams. By providing feedback on their progression, student can be made aware of how well they are assimilating the presented course content. Educators may also benefit from such information. By monitoring the progression of a group of students, the educator may actively modify their approach to conveying the course content and as such, optimize the performance of the group, and enhance the overall learning experience. Nowadays the line between mobile phones and devices such as PDAs and laptops has become so blurred that in some cases there really is little difference in terms of capabilities. As such, the mTest service must be capable of utilizing the full capabilities of the device on which it's being accessed. In addition, more advanced capabilities afford content developers the opportunity to be more creative in designing multimedia mTests. On low-level devices with limited capabilities, a simple text format can be adopted for the creation of the assessments. However on those devices capable of supporting multi-media, assessments may incorporate elements of text, images, sounds and even videos. All of which serve to actively engage students in the material being assessed, especially when utilized alongside the mLecture service.

The following sequence diagram, Figure 3, depicts sample interactions between entities involved in this service. As outlined previously, when a mobile user enters within the range of an InfoStation, the InfoStation registers the user's details within its local repository and processes any necessary updates to the user- and service profiles. If an update is necessary, the InfoStation forwards the various profile updates to the InfoStation Center, which can in turn disseminate these updates throughout the InfoStation network. If the Local InfoStation has no record of the user, the user AAA request can be forwarded to the InfoStation Center, which processes the request and facilitates the InfoStation with the requisite profile information. Once the AAA procedure has been successfully completed the user is presented with a list if available services. In this case the *mTest* service is chosen. Once

the user/student gains access to the service, s/he may choose a particular assessment. The PA on the user's mobile device forwards a service request on to the InfoStation, specifying the user's choices. The InfoStation in turn, having analysed the capabilities of the target device, discerns the optimal format in which to present the assessment. This service content is then made available to the PA.

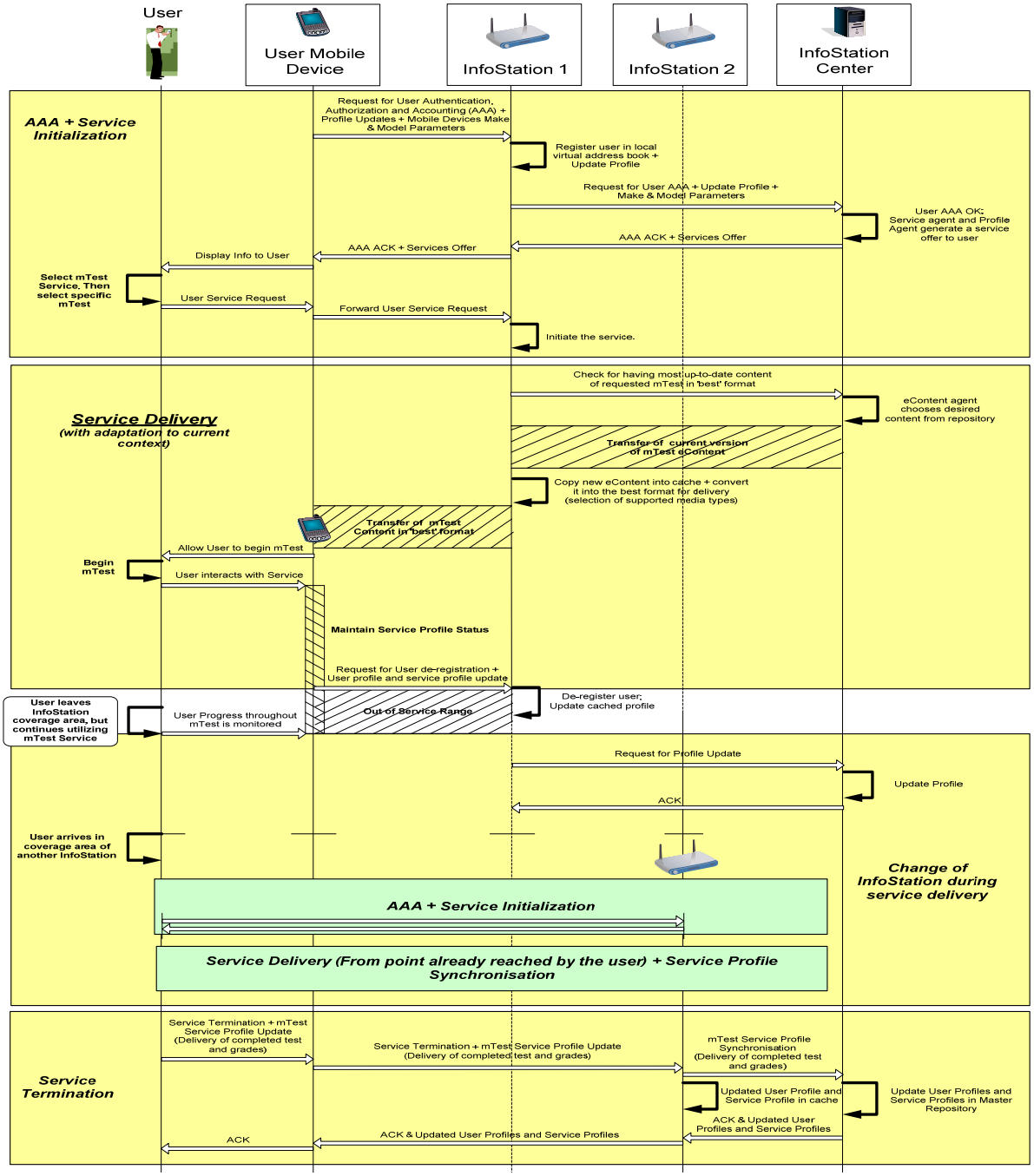

Figure 3. *mTest* service provision

As the student progresses through the test, his/her user profile is maintained to reflect this progress. Furthermore we consider the possibility for the student to do the test whilst on the move and out of range of an InfoStation. Due to the geographically intermittent nature of an InfoStation connection, the student's mobile device may leave the contact range of the initial InfoStation (InfoStation 1). However the PA facilitates the users continued

utilization of the service while at the same time maintaining the user profile. Thus the student may complete the test whilst outside the radio range of any InfoStation, with the user profile reflecting the student's progression through the material. InfoStation 1, the last InfoStation in contact with the PA, sends user profile updates to the InfoStation Center, ensuring it has the most up-to-date information. Once the PA eventually does enter back within range of an InfoStation (i.e. InfoStation 2), the PA will, after completion of the AAA procedure, forward on a user profile update which reflects the progress of the student through the test content, whilst out of range of the InfoStation network. These updates are disseminated through to the InfoStation Center so as to ensure all information across the system is up-to-date. To the user, this transition between InfoStations should appear seamless, with the user not experiencing any loss of service. Once the user has completed the mTest, the PA displays the results of the assessment to the user, providing valuable feedback on their own progress and performance.

IV. Implementation Issues

OWL-S: Service Profiles

We intend to implement the communication between the intelligent agents and the eServices by means of: (i) our own developed communications mechanisms (as explained in the example); and (ii) the standard Ontology Web Language (OWL-S) protocol [10, 11]. The OWL-S is a semantic web protocol that provides a set of constructs with which to create ontologies, which are machine understandable descriptions of the service. These ontologies enable agents to identify and interoperate with the various services. Using OWL-S, the ontology structure is divided into four separate sections, each dealing with a different aspect of the service:

- *Service Profile:* this advertises the abilities of the service (i.e. what it can do), in such a way as enable a service-seeking agent to determine if the service meets its requirements.
- *Service/Process Model:* this gives a detailed description of the operation of the service and tells a service user how and when to interact with a service (read/write messages). Essentially it outlines how to initiate the service, and what happens when a service carries out its purpose.
- *Grounding:* this provides details of how the agent can interoperate with a service (i.e. interact with the service).
- *The Service*: This simply binds the other elements together into a single entity which can be published and invoked.

When these separate elements are combined, they form an ontology/description that allows intelligent agents to discover, invoke, compose and monitor eServices. Agents utilize the information contained within the *Service Profile* to ascertain whether or not a service meets its requirements, and adheres to certain constraints such as security, and quality etc. The profile serves only to provide a description of the service to a registry. In this system, the InfoStation provides a user's PA with access to a registry of services. Here the user can examine the available service profile information to locate a particular relevant service. Once the user has selected a particular service, the profile has fulfilled its purpose and performs no other function. The *Process Model* provides the information necessary for the agent to use the service. The Process Model allows the agent to perform a more in-depth analysis of the service and its capabilities, and determine if it can be utilized. It informs the PA of how and when to interoperate with the service (read/write messages). The process model is not a program to be executed, but rather a specification of the methods in which a client must interact with a service in order for the desired outcome to be achieved. The Service/Process Model also allows agents to monitor the execution of tasks

performed by a service (or a set of services), and to coordinate the entities involved in the service execution. The *Service Grounding* details how agents can communicate with, interoperate with, and invoke a service. Specified within the grounding, are details pertaining to message formatting, transport mechanisms, protocols, addressing etc. When combined with the details outlined within the process model, all the information necessary for a PA to utilize a particular service is presented.

CC/PP-UAProf: Device and User Profiles

For the implementation of the User Profile which is integral to the facilitation of fully adaptable services, we have opted to use the uniform format "Composite Capabilities/ Preference Profile" (CC/PP) [12, 13]. This format is platform-independent and is based on the Resource Description Framework (RDF) [14, 15] and is recommended by the World Wide Web Consortium [16]. A CC/PP profile is basically a description of device capabilities as well as specific user preferences that can be utilized to guide the adaptation of service content delivered to that device. This adapted and personalized mLearning allows us to offer multimedia content and activities adapted to learners' specific needs and influenced by their specific preferences and context. So when a specific user / mobile device submits a request to use a certain service, the source of that service (i.e. the InfoStation) customizes and tailors the service content to meet the user preferences and the capabilities of his/her current mobile device. In essence, content is adapted to 'best' suit the individual user and the specific device at that particular time. Through the customization and tailoring of the services (and their content), they can be offered to users, independent of the type of mobile devices. This is an essential factor in this type of network, as user devices and preferences will be as varied as the users themselves. A CC/PP profile contains a number of attributes and associated values, which are used by the InfoStations to determine the most appropriate ('best') format of the resource to be delivered to the user's PA. The User Agent Profile (UAProf) [17-19] specification is a concrete implementation of the CC/PP developed by the Open Mobile Alliance [20]. This specification builds upon WAP 2.0 and facilitates the flow of capability and preference information (CPI) between the Personal Assistant, the InfoStation and the InfoStation Center. This specification defines this capability and preference information through a structured set of components and attributes. The following are the most useful components defined within the UAProf specification. However we could add our own additional components and attributes to better convey capability and preference information within our system:

- *Hardware Platform*: contains attributes that describe the hardware characteristics of the current user device, e.g. device type, input and output methods, screen size, color capabilities, image capabilities, device CPU etc.
- *Software Platform:* contains attributes relating to the operating environment of the device, e.g. operating system name-vendor-version, JVM version, audio & video codecs, Java enabled etc.
- *Network Characteristics:* attributes relating to the network capabilities of the terminal, e.g. bearer characteristics – latency, reliability etc.

The different entities within the system can use this CPI to ensure that the user receives service/content that is tailored for the environment in which it will be accessed. However, it is possible to even further customize the service to suit the preferences of the user. This is achieved through the extension of the CC/PP vocabulary. A CC/PP vocabulary defines the format or structure of the profile information, which is exchanged between a Personal Assistant and the InfoStation. While CC/PP and UAProf already define a number of components and attributes to describe the many different capabilities of the user device, we define a number of attributes relating to the user himself/herself, which could be used to further customize and enhance the service for that individual

user. The user preference components can specify anything from the user's name, the languages s/he speaks, user's age, location, and the format in which the user would prefer to receive information. Another important attribute within the user profile is to specify the role or job title of the user, i.e. whether the individual is an educator or a student etc. Specific groups may be allowed access to different resources related to the service. This is especially within a University environment, where students from different faculties may require access to different services. The following Figure 4 is an example of how a component and group of attributes relating to a particular user may specify vital information about that individual, which can be used to facilitate a higher degree of personalization and quality of service to users.

```
<prf:component>
<rdf:Description rdf:ID="UserPlatform">
  <rdf:type rdf:resource="http:// www.ece.ul.ie/trc/profiles/UAPROF/ccppschema-1#UserPlatform" />
<prf:Name>John Doe</prf:Name>
<prf:StudentID>0123456</prf: StudentID >
<prf:Faculty>ECE</prf:Faculty>
<prf:Course>Electronic Engineering</prf:Course>
<prf:Year>4</prf:Year>
<prf:Classes>
    <rdf:Bag>
            <rdf:li>CE4517</rdf:li>
            <rdf:li>CE4607</rdf:li>
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<prf:FYPTitle>Design and Implementation of an Animated Interactive Tutorial</prf:FYPTitle>
</rdf:Description>
</prf:component>
```

Figure 4. Example of a CC/PP User specific Component

Within this sample profile component, we can see some attributes which will prove essential in order to properly offer services to the most applicable users, and indeed adapt them to suit this particular user. In the given sample component, an attribute such as 'Faculty' can have a major bearing on the type of services being offered to a particular user. It is essential for these factors to be taken into account in order to avoid unnecessarily advertising irrelevant services to users.

V. Conclusion

The implementation of the adaptable InfoStation-based mLearning service provision within a University Campus has been outlined in this paper. The underlying network architecture has been detailed. The mLecture and mTest services, which provide a means to evaluate the students acquired knowledge and provide valuable feedback to students concerning their progress, has been described. The entity interactions involved in facilitating these services have been detailed. The process of adapting and customizing the service content according to the capabilities of the current user device, current access network constraints and the user preferences has also been outlined. The utilization of the Composite Capabilities/ Preference Profile" (CC/PP) format for the implementation of the User/Service Profiles, which are integral to the adaptation of the services, has been outlined. The benefits of using this format have also been considered.

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Authors' Information

Damien Meere – Researcher in the Telecommunications Research Centre in the University of Limerick, Ireland. He is currently pursuing his PhD. Damien.Meere@ul.ie

Dr. Ivan Ganchev – Dip. Eng. (honours), PhD, IEEE (SM.), IEEE ComSoc (SM.); Lecturer and Deputy Director of the Telecommunications Research Centre, University of Limerick, Ireland. He has served on the TPC of many international conferences including IEEE VTC, IEEE Globecom, IEEE ISWCS. Ivan.Ganchev@ul.ie.

Dr. Stanimir Stojanov – Dip. Eng. (Humboldt, Berlin), PhD (Humboldt, Berlin); Associated Professor, Chief of eCommerce Laboratory, and Head of Department of Computer Systems, Faculty of Mathematics and Informatics, University of Plovdiv, Plovdiv, Bulgaria. S.Stojanov@isy-dc.com

Dr. Máirtín S. O'Droma – B.E., PhD, C.Eng., FIEE, IEEE (SM); Senior Lecturer and Director of the Telecommunications Research Centre, University of Limerick, Ireland. He has served on the TPC of many international conferences including IEEE VTC2007Spring, IEEE ISWCS 2006 & 2007. Mairtin.ODroma@ul.ie