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Mobile Phones as Learning Instruments: mLearning Service Provision within an InfoStation-based Multi-Agent Environment

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Abstract. With the continuing evolution of modern handheld mobile devices, an opportunity has arisen for a more comprehensive integration of these devices into educational environments. Over the last decade, the common mobile phone has developed into a terminal incorporating a massive amount of functionality, with these devices now operating as media players, web access, personal organisers etc. Indeed virtually every student has access to a mobile phone of some description. With this experience students have developed an extensive tacit knowledge of operating these devices that for the most part, is left untapped. Indeed in many class rooms, students are encouraged to turn these devices off. However these devices could alternatively be used to enhance the overall learning experience of the students. The system presented in this paper seeks to incorporate mobile devices into the spheres of learning, and utilize the assimilated tacit knowledge of students. The ongoing development of a context-sensitive InfoStation-based architecture, tasked with supporting the provision of mobile information services within a University domain, is outlined. These services are designed to complement the traditional educational paradigm, providing an enhanced blended learning experience for students.

Keywords InfoStations; intelligent agents; multi-agent systems; context-sensitive mLearning; WURFL; JADE-LEAP.

1. Introduction

Throughout the last decade, mobile phones have continued to evolve and develop, to point where now, these devices can offer the functionality comparable to that of desktop computers. They can operate as personal organisers, facilitate access to email accounts, provide web access and indeed perform the role of a media player. Indeed the more high-end devices facilitate access to application stores, which enable a person's mobile phone to take on huge range of capabilities, bound only by the personal preferences of the user. In recent years there have been some efforts made to utilize these devices within the educational domain. However for the most part, in most classrooms, mobile devices are viewed as an impediment to learning. Of course, mobile phones have been such a major part of modern student's lives, that they have developed an extensive tacit knowledge of working with these devices. By harnessing this pre-existing knowledge, these devices represent a huge opportunity to enhance the educational practices. Indeed in the proper circumstances, these mobile technologies can be utilized to enhance the participatory nature of education as in [1], where the lecturer interacts with the students through their mobile phones, soliciting responses, and assessing the students assimilation of the presented material.

The system presented here seeks to incorporate user mobile devices, facilitating a blended learning experience, where a number of mobile eLearning (mLearning) services, supplement the traditional learning paradigm. Access to these services and resources is facilitated through intelligent wireless access points (InfoStations), located at various places throughout the University campus. This mLearning system, previously detailed in [2-6], provides "anytime, anywhere, anyhow" access to learning objects, which can be adapted to suit both the user, and the device utilized to access the learning material. In this paper we will detail the multi-agent architecture of these InfoStations, detailing the main components which collaborate within the various strata of this system, to facilitate intelligent service provision. Particular emphasis is placed on the system's ability to not only adapt to the heterogeneous nature of operating environments, inherent to this type of wireless access architectures, but also adapt in order to facilitate services based on the personal context of the user.

The rest of the paper is organized as follows. Section II presents global view of this InfoStation-based network architecture, highlighting the tiered nature of the system. Section III presents this enhanced system architecture, outlining the main components involved in service provision, highlighting, in particular, the context-awareness and the personalization of service delivery through the utilization of user-, device- and service profiles. Within Section IV, the utilization of profile information for the effective adaptation of service and service content is examined, detailing how the system harvests and adapts to changing contextual information. In Section V we discuss the benefits systems such as this can provide within the educational domain, in particular as a supplementary service to the traditional lecture experience. Finally, Section VI concludes the paper.

2. InfoStation-based Network Architecture

This InfoStation-based network architecture is gears towards facilitating access to mLearning, and other supplementary services, for users equipped with mobile wireless devices. This access is facilitated through a set of intelligent wireless access points, or InfoStations, situated at key locations throughout the University campus. This InfoStation paradigm is an extension of the wireless Internet as outlined in [7], where mobile clients interact directly with Web service providers, in this case the InfoStations. This architecture has been designed to operate across three tiers, as depicted in Figure 1, which encompasses the user mobile devices, the InfoStations, and a central InfoStations Centre.

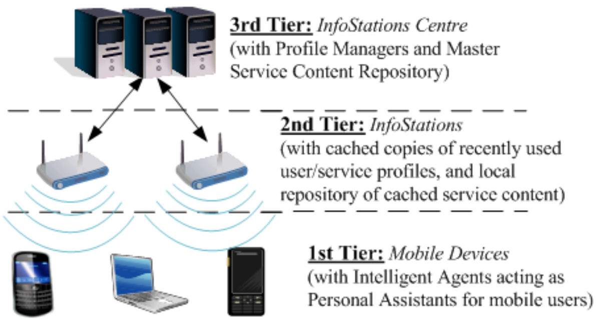

Fig. 1: The 3-tier InfoStation-based network architecture.

The evolution in capabilities and resources available in modern mobile devices has precipitated an evolution in the realm of eLearning. The presented architecture harnesses this communicative potential in order to present learners with a pervasive learning experience which can be dynamically altered and tailored to suit the learner. As the clients move throughout the campus, passing within range of the InfoStation network, they may access various contextualised and personalised mLearning services and resources distributed throughout the system architecture. By incorporating this existing stratum of equipment, not only are we saving on the need to supply the students with devices necessary to access the services and resources, but we are also tapping into the user's own tacit knowledge of operating the mobile devices.

Due to the inherent mobility support of the system, entities operating within each of the tiers must have the capability of operating autonomously to complete their own objective whilst out of contact with the other tiered entities. It is for that reason that the system has adopted an agent-oriented approach, where intelligent agents operate throughout each tier of the system. Agents can gather information and accomplish tasks without the requirement for interaction with the user or other agents. While the entire system has the appearance of a multi-agent system, both the InfoStation and InfoStation Centre themselves, each take the form of a multi-agent system in their own right. As has been detailed previously [8, 9], the implementation of this multi-agent environment is facilitated through the utilization of the Java Agent DEvelopment (JADE) [10, 11] framework developed by Telecom Italia Lab (TILAB). This software framework facilitated the creation of this multi-agent system, through the provision of a predefined set of services and management tools in addition to the runtime library and agent programming library.

Onboard the user mobile devices, agents acting as “Personal Assistants” (PAs), function autonomously in order to satisfy any user service requests they may encounter, whilst in or out of contact with other agents (installed on the InfoStations). The agents operating onboard the InfoStations operate to fulfil any user requests for *local* services and resources, i.e. those stored within a particular InfoStation. The localised quality of these services and resources is particularly important within an educational domain, as InfoStations housed within various departments of an educational institution can serve to facilitate services relevant to just those individuals within a localised domain (e.g. Electronics, Languages, Library [12]). However, the system is organised in such a way, that if the user makes a request for a service or resource beyond the localised scope of a particular InfoStation, these requests may be forwarded on to the InfoStation Centre. This *global* functionality is shared across the entire system of InfoStations. This is particular useful when taking into account the device mobility supported by the system. Various scenarios have been envisaged [13] whereby a service session may begin with a user request being handled by one InfoStation and later fulfilled by another, e.g. as the mobile user/device moves throughout the campus between the service area of various InfoStations. This interoperation is overseen by the InfoStation Centre, which in itself maintains up-to-date repositories of all profiles, service content and resources.

3. InfoStation Multi-Agent Environment

Work has been undertaken and discussed previously concerning the multi-agent architecture of the InfoStations [2, 9, 14]. As previously mentioned, the InfoStations and the InfoStation Centre themselves exist as a network of interoperating agents and services, with the agents fulfilling various essential roles necessary for system management. Within this multi-agent environment, the agents communicate by passing ACL messages (FIPA’s [15] Agent Communication Language [16]). Figure 2 highlights the main components necessary to ensure continuity to the service provision, i.e. support for the continuous provision of services and user sessions in the case of scenario change [13] or resource deficiency. Also illustrated within this diagram are the components which serve to facilitate a level of context sensitivity and personalization to the presented services. The mechanisms by which the services achieve this context sensitivity are dealt with in more detail in Section IV.

While the agents can operate autonomously within their own environments, to facilitate the users with access to the various services housed within a particular InfoStation, a connection must first be established. This process begins with the Scanner agent, which continuously searches for mobile devices / PA agents, and initializes communication between the PA and the agents in the InfoStation multi-agent environment. On receipt of a call-for-proposal (CFP) ACL message, the Scanner Agent extracts information from the “UserDefinedHeaders” of the incoming ACL message regarding the context of the requesting device. This information can be passed on to the Scenario Manager agent who monitors and manages changes to the operating environment within which the services will be delivered (i.e. change in access device). In the event of a significant change of service environment, this agent gathers the new capability and preference information (CPI) via the Scanner agent, and in conjunction with the Query Manager agent and the Content Adaptation agent, it facilitates the dynamic adaptation of the service content to meet the new service context.

The role of the Connection Advisor agent (CAA) is to gather a list of service applicable to the user. The information required to generate this list is garnered from the headers contained within the received service request. Information needed for the filtering is stored in local DB4O [17] databases. This CAA gathers a list of the classes, based on the course and year of study of the user, as specified in the ACL request headers, then examines the user credentials, querying them against a DB4O database of users. If the user’s credentials pass this Authentication, Authorization and Accounting (AAA) procedure, the CAA gathers a list of services, applicable to the user, based on courses they study. Once a list of applicable services has been collated, the CAA passes on the filtered service list to the Connection Initiator agent, which takes on the task of initiating a connection with the PA onboard the mobile device.

The Content Adaptation agent essentially performs the role of an adaptation engine, which takes in the profile information provided by the Profile Processor agent, and executes the requisite adaptation operations on the service content (e.g. converting content to another quality, image resizing etc.). The process through which content is adapted to the context of both the user and the device is dealt with in greater detail in Section IV. The tasks undertaken by the Content Adaptation agent, the Scenario Manager agent and the Profile Processor agent, enable the system to dynamically adapt to changing service environments, even during a particular service session. Once the connection to a particular service has been initialized and the service content adapted to the requisite format, the Connection agent facilitates the transfer of the information to the user mobile device.

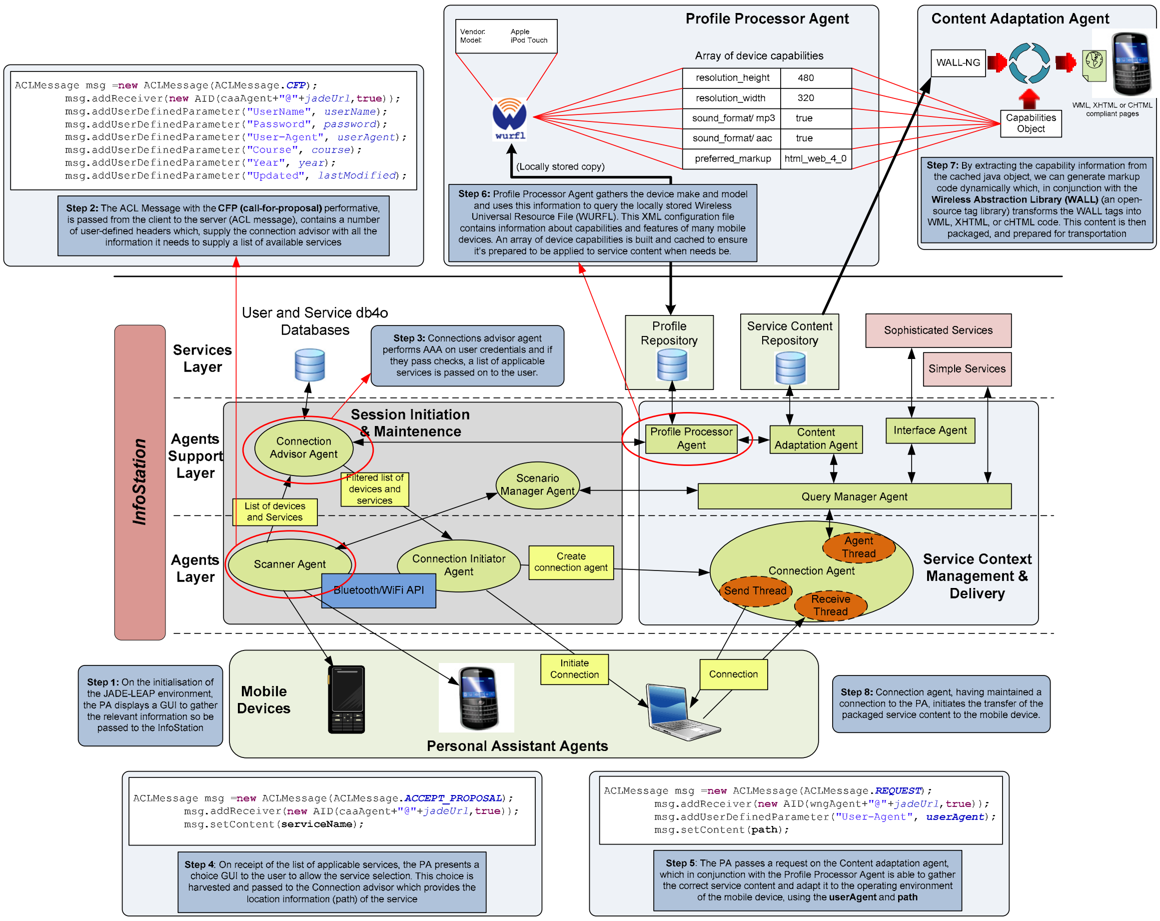

Fig 2: The enhanced InfoStation architecture

4. Context-Aware Service Adaptation

One of the fundamental elements of this system is the facilitation for service context-sensitivity and personalization. Due to the entirely heterogeneous nature of the environments within which services are to be delivered, i.e. the huge variation in the capabilities of the user devices, it is necessary for service content to be adapted to meet the constraints within these environments. However, within an educational domain, it is also necessary to take the context of the user into account when adapting the presented services. To facilitate this personalization and contextualization, capability and preference information (CPI) must be passed between the mobile devices and service providers, i.e. between the PA and InfoStation / InfoStation Centre.

The process of gathering this CPI is undertaken by the PA, which through a number of GUI's, solicits information such as the user's username, password, course and year of study, and of course the make and model of the mobile device they are utilizing to access the InfoStation-based services. This information is passed from the PA to the InfoStation within the headers of an ACL CFP message. The Connection Advisor Agent (CAA) utilizes this information to generate a list of applicable local services. First it performs the AAA procedure to ensure that the user has provided the correct credentials. If the credentials pass these checks, the CAA examines the course and year of study of the user and queries a DB4O database containing the details of all classes within each year of each course. The result of this query is a list of all classes being undertaken by the user. Within a separate DB4O database is an up-to-date list of all the services housed locally within the InfoStation. Contained within the records of each service is a listing of the modules to which this service applies. By querying the list of the student's modules against the list of available services, a list of services directly applicable to that particular user is generated. By ensuring that users are only advertised services which apply to them, we minimize the chance to users receiving unnecessary services (i.e. engineering student receiving Law-oriented mLecture services). An ACL Proposal message carries this list to the PA, which enables the user to select the service they wish to access. Once a particular service has been selected, the user's selection is placed in an ACL Accept-Proposal response message.

Within the InfoStation's multi-agent architecture, the CAA waits for a request from the PA. On receipt of the user's service request, the CAA examines the headers of the ACL message discerning the make and model of the access device, which is enough to generate a user-Agent string, used to gather the capabilities of the device. In order to facilitate this functionality, the Wireless Universal Resource File (WURFL) [18] was incorporated into the system. This XML configuration file, containing information about capabilities and features of a vast multitude of mobile devices enables the CAA to utilize a simple user-Agent string, to generate a directory of the capabilities and features of any device that the system may encounter. Of particular interest is the supported mark-up, which identifies the preferred content format of that particular device. Also incorporated into the CAA is the Wireless Abstraction Library by Luca (Passani)- Next Generation (WNG) [19]. This library enables the creation of service content in one mark-up and facilitates the rendering of this content as in WML, XHTML MP or CHTML automatically. The CAA requires only information about the device, and the user's chosen service, to render content dynamically to suit the access device. Not only does this benefit the users, as the content they receive is dynamically tailored to suit them and their access device, but the content developers need only generate their content in one format, and the system can adapt it accordingly to each service request.

5. Enhanced mLecture

The core goal with the implantation of this system was to facilitate the delivery of services which would serve to supplement and enhance the traditional learning experience. Since the advent of mobile phones as a truly pervasive element within the lives to many students, for the most part, these devices have been viewed as a hindrance to learning. It is only in recent years where these technologies have begun to be embraced by the educational community, in particular though the incorporation of podcasting, or indeed the use of online collaboration and learning environments such as Moodle [20] and Sakai [21]. However in the case of actual lecture delivery, these technologies have often been used to supplement teaching after the fact. The system discussed in this paper seeks to enable the utilization of mobile technology to enhance the delivery of educational content to students. In [1], Kinsella describes the utilization of mobile phones to interact with large classes over SMS. However, within our system, the mLecture service can be utilized to harvest feedback from large classes. Utilizing an InfoStation based in the lecture theatre, the class can be presented with questions, which the students could answer and send back (without a SMS charge) via the PA installed on their mobile devices. This enables the lecturer to gauge the student's assimilation of the material, and if necessary, dynamically alter the direction of the class to ensure an optimal learning experience for the users. This process would also encourage the continued attendance of the students, enabling the lecturer to measure attendances during the lectures. Of course the main use of this mLecture service is facilitating the users with "anytime, anywhere, anyhow" access to the lecture content, aiding a more continuous learning experience.

6. Conclusions

Within this paper we presented a global view of the InfoStation-based network architecture, highlighting in particular the tiered nature of the system. Also discussed were the main components which comprise this architecture, in particular those which facilitate the system's context-awareness and service personalization, utilizing user-, device- and service profiles. The utilization of this profile information for the effective adaptation of services and service content was examined, detailing in particular how the system harvests and adapts to changing contextual information. Finally, how this system and the services it supports may supplement and enhance the traditional learning experience was outlined.

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