COMMUNICATIONS SCENARIOS FOR INFOSTATION-BASED ADAPTABLE PROVISION OF M-LEARNING SERVICES

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

Abstract: This paper presents an adaptable InfoStation-based multi-agent system, which facilitates mobile eLearning (mLearning) Service Provision within a University Campus area. A horizontal view of the network architecture is presented. A description of the mLecture service is detailed, highlighting how the different entities interact in order to facilitate the service within the four main communications scenarios. Approaches to the implementation of the system are also considered.

Keywords: InfoStations, intelligent agents, multi-agent system, CC/PP, UAProf.

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 focus on the main communication scenarios of service provision and show how the different components of the network architecture collaborate to facilitate one particular service, namely the mLecture service. We emphasize the service's ability to adapt to the changing environment/context including the change of the mobile device and/or the change of the access network/InfoStation.

The rest of the paper is organized as follows. Section II presents briefly the InfoStation-based network architecture. Section III illustrates the mLecture service provision outlining sample interactions between system entities following the four main communications scenarios. Section IV outlines some implementation issues, and 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 around a University Campus (Ganchev, Stojanov et al. 2004; Ganchev, Stojanov et al. 2006; Ganchev, Stojanov et al. 2006). The InfoStation paradigm is an extension of the wireless Internet as outlined in (Adaçal and Bener 2006), where mobile clients interact directly with Web service providers (i.e. InfoStations). 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.

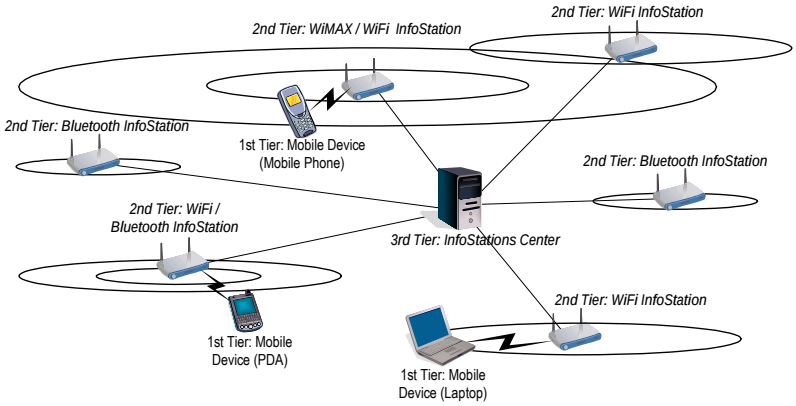

Figure 1. The 3-tier InfoStation-based network architecture

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 way of delivering the service to each user according to his/her current individual location and mobile device's capabilities (specified in the user profile). The InfoStation maintains an up-to-date repository of all profiles and eContent. The InfoStations themselves maintain cached copies of all recently used user profiles and user service profiles, as well as a local repository of cached eContent.

In the following section we describe the provision of one particular service, the mLecture service, in more detail.

III. mLecture Service

The multi-agent approach to the structuring of the system is adopted as most suitable. In order to facilitate flexible and adaptable service provision, the intelligent agents, residing within each of the three tiers of the system architecture, must interact so as to satisfy in the 'best' possible way any user requests they might encounter. The following are outlines of a number of scenarios that take place during the mLecture service provision. The mLecture service allows students to gain access to lectures content through their mobile devices. However, first this content must be adapted and customized according to the capabilities of the current user device, current access network constraints and the user preferences.

For instance, the user mobile device may be limited in its capabilities to play video content in which case video components will be sent in a format that best suits the device, or they may be simply omitted. The user may choose to access the full capabilities of the mLecture service later, when using a device with greater capabilities (e.g. a laptop). This service adaptation is used to address the shortcomings of some low-end mobile devices while still delivering the services.

Indeed a change of device is only one of a number of scenarios that could take place during the service provision. Due to user mobility (e.g. moving between geographically intermittent InfoStation cells) and device mobility (e.g. switching between devices) the following four main communications scenarios are possible:

- No change;
- Change of user mobile device;
- Change of InfoStation;

- Change of InfoStation and user mobile device.

Within each of these scenarios, the initial interactions between the entities remain the same. We utilize the "Composite Capabilities / Preference Profile" (CC/PP) as the uniform format for the implementation of the user profiles. The Master Profile repository in the InfoStation Center contains descriptions of all registered user devices, i.e. their capabilities and technical characteristics. During the initial AAA procedure, the user's Personal Assistant sends as parameters the make and the model of the user device. An agent working on the InfoStation (or the InfoStation Center) reads the corresponding device's description from the repository and according to this, selects the 'best' format of the lecture content, which is then forwarded to the user. However a problem arises when a user uses a non-registered device as s/he might receive the lecture content in unsuitable format. Thus the users need first to register any new mobile device they want to use within the system. In this case, during the initial AAA procedure the Personal Assistant sends a full description of the user device's capabilities towards the InfoStation Center. The manager agent on the InfoStation registers the user in its local Virtual Address Book and updates user/service profiles, before forwarding the user request onto the InfoStation Center. A Profile Agent within the InfoStation Center (updates and) analyses the user profile stored in its Master Profile Repository. The Service Agent, in collaboration with the Profile Agent, creates a list of services applicable to the user and makes a service offer to the Personal Assistant, which displays this to the user. If the user chooses the mLecture service, s/he then specifies the desired lecture content. The InfoStation checks if it has the most up-to-date version of the desired lecture content (in the format that best suits the user) in its local repository of cached eContent. If so, it forwards the lecture content onto the user. On the other hand if the InfoStation does not have the lecture content in the required format or most up-to-date version of the lecture content, it will forward on the user request to the InfoStation Center. The InfoStation Center, having already received the make and the model parameters, retrieves the device description from its central CC/PP repository, and adapts the selected lecture content to the format which best suits the user device's capabilities, access constraints and user preferences. This adapted lecture content is then forwarded onto the user. The Charging & Billing Module (within the Business Support Domain of the InfoStation Center) also monitors which formats are utilized to access the content, as each format may have minor differences in costs associated with it.

'No Change' Scenario

Figure 2 illustrates the straightforward provision of the mLecture service within the system. If the InfoStation can fulfil the user service request (i.e. the required lecture content's format that best suits the current user context is available at the InfoStation), the lecture content is forwarded onto the user.

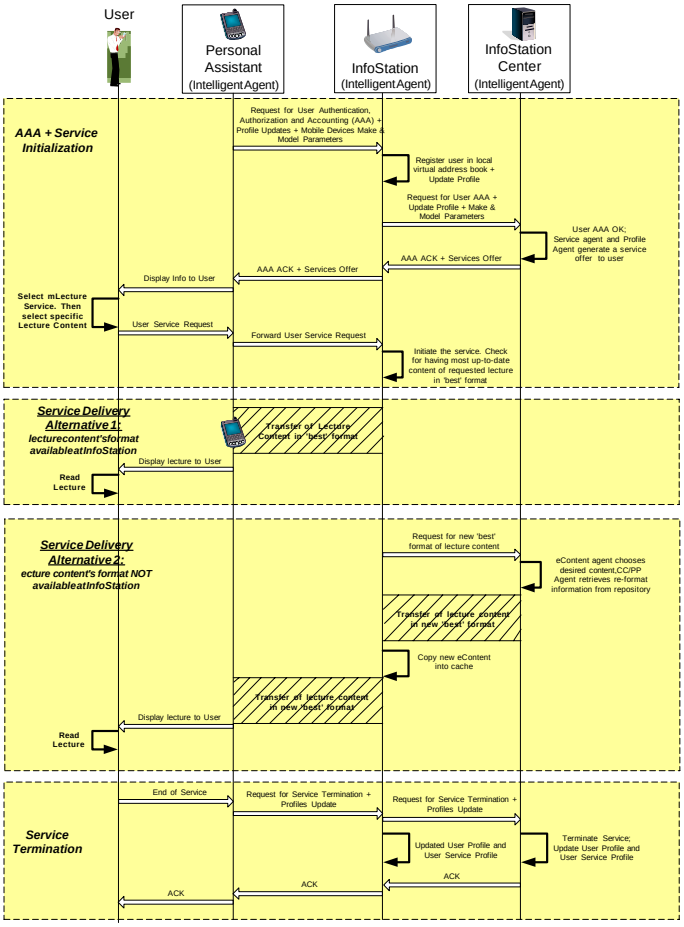

Figure 2. Sample interaction between entities involved in *mLecture* service provision in the 'No Change' Scenario

However if the InfoStation is unable to meet the demands of the user, the request is forwarded onto the InfoStation Center. Here the eContent manager chooses the required/best format of the content (from the repository) and in conjunction with the CC/PP agent reformats the content and transfers the adapted eContent onto the user's Personal Assistant. The InfoStation will store a copy of this re-formatted lecture eContent in its cache, in case if another user requests the same lecture. Once the service is terminated, the user profile and the user service profile are updated within the InfoStation and InfoStation Centre so as to reflect any mLearning work done by that particular user (e.g. intermediate tests at the end of each section of the lecture used to control the user knowledge and choose the level of the next section to be presented to the user).

'Change of Device' Scenario

Due to the inherent mobility of this system, it is entirely possible that during mLearning service provision, the user may shift to another mobile device (e.g. switch to a device with greater capabilities). By switching to a device with greater capabilities, the user may experience a much richer service environment and utilize a wider range of resources. Figure 3 depicts the case where the user switches from a PDA to a laptop, whilst utilizing the mLecture service. In this case, the users Personal Assistant sends a notification of device change to the InfoStation, detailing the make and model parameters of the new device. Then InfoStation checks its cache for

the required/best format to suit the capabilities of the new user device. If the new format is available, the InfoStation immediately forwards this formatted content onto the user's Personal Assistant.

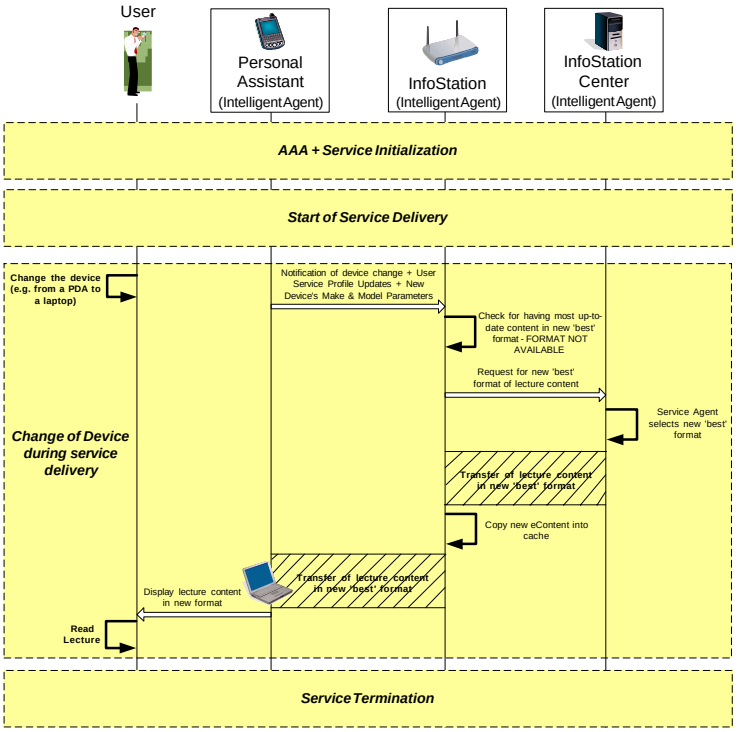

Figure 3. Sample interaction between entities involved in *mLecture* service provision in the 'Change of Device' Scenario

If however, the InfoStation does not have the new required/best format of the lecture, it requests this from the InfoStation Center, which will retrieve it from its eContent repository.

'Change of InfoStation' Scenario

Within the InfoStation paradigm, the connection between the InfoStations themselves and the user mobile devices is by definition geographically intermittent. With a number of InfoStations positioned around the campus, the users may pass through a number of InfoStation cells during the service session. This transition between InfoStation cells must be completely transparent to the user, ensuring the user has apparent un-interrupted access to the service.

The following Figure 4 illustrates the entity interactions involved in the transition between InfoStations. As the user mobile device moves from the coverage area of an InfoStation, the Personal Assistant requests user de-registration from the local Virtual Address Book of the InfoStation. The Personal Assistant also requests one last user service profile update before leaving the coverage area of the current InfoStation. The InfoStation de-registers the user, updates the cached profile, and forwards the profile update to the InfoStation Center to make necessary changes in the Master Profile Repository.

Meanwhile the user continues reading through the lecture content (and completing the intermediate tests at the end of lecture's sections). The Personal Assistant monitors the users progression through the lecture and

intermediate tests. When the user arrives within the coverage area of another InfoStation, the AAA and the service re-initialization procedure takes place first. After updating the user service profile, the newly requested sections of the lecture (if any) will be delivered to the user according to the level reached/justified by him/her in the intermediate tests completed while out of range of the InfoStations.

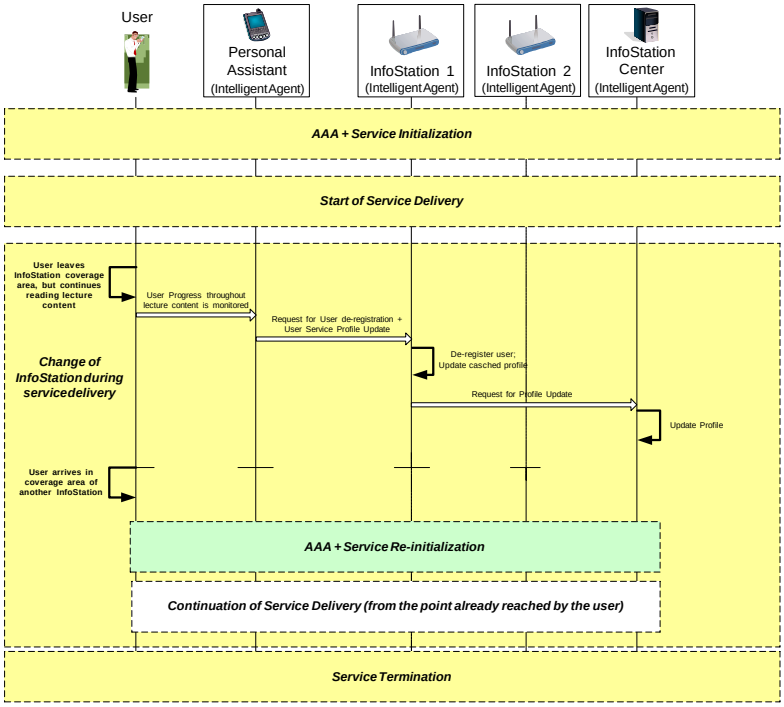

Figure 4. Sample interaction between entities involved in *mLecture* service provision in the 'Change of InfoStation' Scenario

'Change of Device & InfoStation' Scenario

We have outlined the separate instances where the user may switch his/her access device or pass between a number of InfoStation cells during a service session. However a situation may arise where the user may change the device simultaneously with the change of the InfoStation. The following Figure 5 illustrates the entity interactions, which occur in this scenario.

Both procedures for device change and InfoStation change (as described in the previous two subsections) could be considered as automatic procedures, independent of each other. Hence each of these may be executed and completed at any point inside the other procedure without a hindrance to it. The two alternatives are shown in Figure 5.

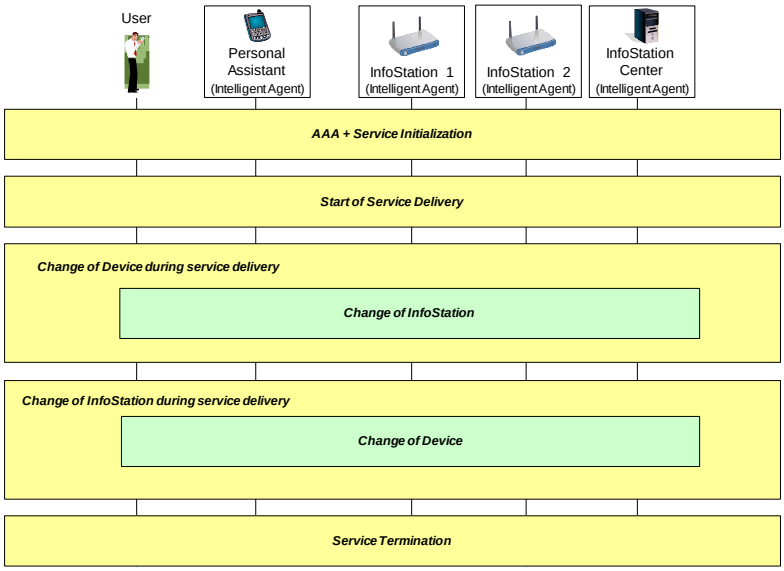

Figure 5. Sample interaction between entities involved in *mLecture* service provision in the 'Change of Device & InfoStation' Scenario

IV. Implementation

For the implementation of the User Profile and User Service Profile, which are integral to the facilitation of fully adaptable services, we have opted to use the uniform format "Composite Capabilities/ Preference Profile" (CC/PP) (Kiss 2006). This format is platform-independent and is based on the Resource Description Framework (RDF) (Manola and Miller 2004) and is recommended by the World Wide Web Consortium (W3C). 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. Basically when a specific user / mobile device submits a request to use a certain service, the source of that service (i.e. the InfoStation or the InfoStation Centre) 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. As we have illustrated in the previous section, the user may change devices a number of times during a service session, so by customizing and tailoring the services (and their content) 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 Personal Assistant.

The User Agent Profile (UAProf) (OMA 2006) specification is a concrete implementation of the CC/PP developed by the Open Mobile Alliance (OMA). This specification builds upon WAP 2.0 (WAP, 2007) and facilitates the flow of capability and preference information 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. Components are grouping mechanisms for attributes, therefore in essence, a CC/PP or UAProf profile is organised as a structured set of attributes and value pairs.

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, model number, 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.
- *Application Preferences:* attributes relating to the browser application on the device, e.g. browser name-version, content types accepted by browser, markup languages, scripting languages supported etc.
- *WAP Characteristics:* attributes relating to the WAP capabilities of the terminal, e.g. WAP version, WML script libraries, supported WAP applications.

The different entities within the system can use this capability and preference information 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 a lecturer or a student etc. Specific groups may be allowed access to different resources related to the service.

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 service allowing students to gain access to lectures content through their mobile devices has been described. The entity interactions involved in facilitating this service during the four main communications scenarios have been detailed. The process of adapting and customizing the mLecture 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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