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DEPLOYING A CONTEXT AWARE SMART CLASSROOM

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Abstract

Context aware environments respond in a pseudo-intelligent manner depending on the identity of occupants, particular location, desired activity and specific time. The Context Aware Smart Classroom (CASC) is a classroom that responds to lecturers and student groups based on preset policies and the lecture timetable. The pervasive nature of personal mobile devices permits the investigation of developing low-cost location and identification systems that support development of a smart classroom. Material used during the teaching activity is distributed to students based on students' policies using WLAN, LAN or email. The smart classroom CASC uses a central scheduling system to determine the teaching activity.

In this paper we present CASCs' system design and results from the trial deployment. In particular we review the issues related to using low-cost solutions such as existing communications infrastructure for developing large scale environments. Finally we present the plans for ongoing development of the Context Aware Smart Classroom.

Keywords

Classroom Technology, Mobile Devices, Context, Smart Environments.

1. INTRODUCTION

The pervasive use of personal mobile phones and PDAs, with significant embedded computing power, provides an opportunity for developing truly smart environments in a cost-effective manner. In particular academic institutions can leverage the personal devices of students and staff, in association with standard communications infrastructure, to enable the deployment of smart classrooms. The availability of, Bluetooth-enabled, personal devices has been used as the core rationale for developing the Context Aware Smart Classroom (CASC) to investigate the ease with which a smart environment can be deployed within the School of Electronics and Communications Engineering (SECE) of DIT.

The CASC system extends ubiquitous computing into the realm of Smart Environments through the use of pseudo intelligent predictive decision making based on a set of rules. The CASC system is a classroom environment that reacts to users and the context of the situation. A lecturer walking into the room is identified by their Bluetooth device and this stimulates the activities of the smart classroom.

CASC has been developed to retrieve presentation notes for the particular lecture and display them on a projector in the room furthermore it will distribute the notes to students wirelessly, over a fixed LAN or by email.

The rest of the paper is organised in the following fashion. The purpose of this paper is to investigate the issues related to developing and deploying a smart environment in an academic environment. Section 2 presents background material in relation to context and smart environments that underpins the development of the CASC system and puts smart environments into perspective. A high level design of the system is presented in Section 3 and deployment approach for the system is discussed in Section 4. The results of the system are evaluated in section 5 and a final conclusion is then presented.

2. CONTEXT AWARE COMPUTING

“Context-aware computing is a mobile computing paradigm in which applications can discover and take advantage of contextual information (such as user location, time of day, nearby people and devices and user activity)” [1].

This concept has been around for over a decade and it is only the recent availability of suitable portable computing and wireless network resources that make it possible to implement such systems.

The term context is used to describe real world situations, and everything is said to happen in a certain context. This makes it difficult to define context in a precise manner for many different situations. In computing the term “context-aware” was introduced in [2] and was applied to location information that could enable software to adapt according to its location of use, the identities of nearby people and objects, and changes to those objects over time.

2.1 Location Aware Computing

Many context aware applications focus on location and these are described as location-aware computing applications [3, 4]. A key consideration in location-aware computing is the degree of accuracy required for a particular application and the accuracy that the technology can provide. Many situations do not require a high degree of accuracy such as with “locating a friend” solutions based on who is in a GSM cell. In the case of American legislation governing the location of a person making a 911 call, the requirement for positional accuracy of mobile phone systems is to be better than 50 meters for 67% of calls made [5]. This directive encouraged many mobile phone designers to considering the inclusion of GPS chipsets into their handsets.

There are many location-aware or location based applications such as museum guides [6] and tourist guides [7]. In these applications a variety of mobile and static technologies have been used to support the provision of environments that respond to users according to their location context. In these systems users choose voluntarily to use the system to get additional information.

2.1.1 Location Privacy

In developing smart environments, due regard to individuals' privacy is required to be considered. The ability to identify and track the location of specific individuals is covered by EU regulations and cannot be ignored. The collection of electronic location data requires to be protected under the EU data protection directive [8]. Article 6 of the directive demands that

“personally identifiable data are only collected for explicit and legitimate purposes, it must be accurate and up to date or else erased, it must be relevant and not excessive with respect to the purpose of collection and it must be stored for as long as necessary for the purposes for which the data was collected.”

Article 7 of the directive also requires “explicit consent or demonstration of necessity” to collect the data.

The preferred approach would be to have students opt-in to using the system and to permit tracking of their location for the purpose of providing enhanced services. Students would get up to date information, such as room changes and current material by opting into the system. Provision of sufficient enhanced services might be enough to encourage them to use the system.

An alternative approach to an opt-in policy is to ensure location data for specific individuals cannot be identified. Anonymity provided by use of pseudonyms could be used to ensure locations and identities are not correlated. This approach is not entirely secure, as when only a few individuals are within an area an observer may be able to identify individuals and their respective pseudonyms [9]. This alternative approach provides users with a degree of anonymity; however at some level the system would require to identify individuals in order to provide appropriate services and this would always be a point of concern.

2.2 Context Awareness

Location is an essential element in defining context but it is by no means the only aspect that needs to be considered. Context in computing terms involves a number of different aspects as identified in [4] a definition for context with 3 elements is presented:

1. *Computing context, made up of nearby computing resources, communications and communications bandwidth.*
2. *User context, such as the user's profile, location, people nearby and even the social situation.*
3. *Physical context, such as lighting noise levels, traffic conditions and temperature.*

To more completely define context for computing time was proposed as a fourth element in [1]:

4. *Time context, where user and physical contexts can be logged to provide a context history that can be useful in certain applications.*

These four particular aspects provide sufficient definition of context for the design and development of the context aware smart classroom. Context can be further categorised based on the specific situations under consideration.

2.2.1 Categories of Context

There are a number of categories of context such as environment, time, temperature or user identity. Location and identity are used to enable software to adapt to the people and objects that are nearby and also to how objects change over time [2]. In a similar manner, where and who one is, and what resources are available nearby, along with the social situation can be considered as in [4].

A suitable set of primary categories that coincide with the earlier definition of context are identified in [10]:

*“Identity: the identity of the relevant entities.
Location: the geographical position of relevant entities.
Activity: the activity or activities being performed.
Time: The period at which the entities perform the activity.”*

The category ‘activity’ is introduced as opposed to ‘environment’ on the basis that the word environment is used as a synonym for context.

These four primary types are sufficient to fully categorise a specific context, such as the temperature of a location at a particular time. These primary types can also be used as an index to determine secondary information, such as a phone number, which can be determined from the identity of an individual then be used as an index to a phone book.

2.3 Smart Environments

Smart environments are an extension of the ubiquitous computing paradigm. The core concept in ubiquitous computing is the ability of the technology to disappear and become invisible to users [11, 12]. In the ubiquitous computing paradigm, if a computer “*knows merely what room it is in, it can adapt its behaviour in significant ways without requiring even a hint of artificial intelligence*” [13].

Smart environments display a degree of autonomy, can adapt to changing situations and communicate with users [14]. The provision of intelligence automation enhances ubiquitous computing environments and provides the opportunity for additional features such as detection of anomalous behaviour. Devices can easily be controlled using existing communications infrastructures based on sensor information collected and in particular predictive decision making can be included in the capabilities of the smart environment [15]. These capabilities allow an environment to exhibit pseudo-intelligent behaviour and so be considered as a smart environment.

2.4 Smart Classrooms

The development of “*applications are of course the whole point of ubiquitous computing*” [16] similarly in developing smart environments an experimental methodology is used as identified in [17]. This approach has led to the development of a number of smart classrooms such as classroom 2000 [18] and eClass [19, 20] that were intended to reduce the workload of students. These systems automatically capture the lecture and make the material available on the web and this permits students to become more actively involved in the learning process during the class. The classroom 2000 and eClass research has targeted the capture and delivery of lectures using cameras and audio recording and supporting software infrastructure [17] to prepare notes for dissemination via the web.

The smart classroom CASC developed in this work focussed on making, real-time, context aware decisions based on information collected from the environment sensors, policies and rules of the smart classroom for the dissemination of material over WLAN, LAN or email during a class period.

3. SYSTEM DESIGN

The Context Aware Smart Classroom, CASC, was designed to react to changes in the environment according to rules preset in the system. A rules algorithm was designed to check information stored in local database tables and makes decisions based on current system context and preset policies. The prototype system implements two main rules:

What should happen when lecturer enters the room?
Which student should the notes transfer to and how?

The smart environment CASC has been developed that supports the delivery of course materials to students by lecturers according to the academic schedule. A block diagram of the key components of CASC is shown in Figure 1.

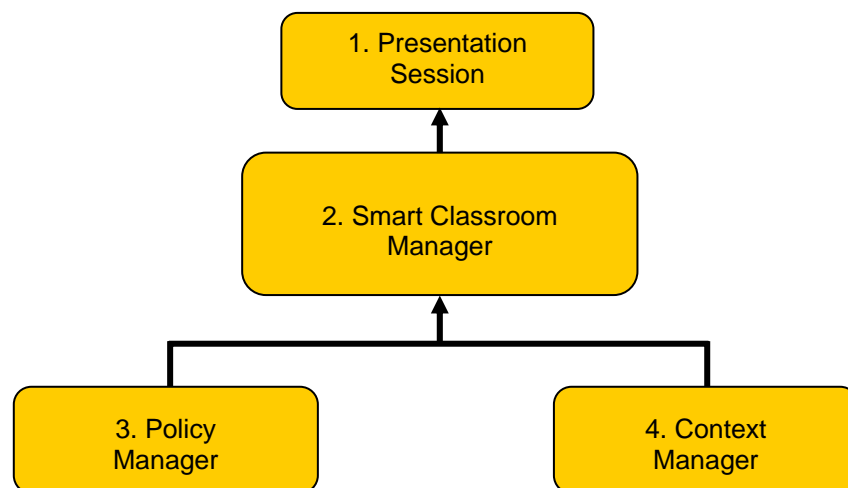


Figure 1: CASC Block Diagram

3.1 Presentation Session

The presentation session component is a client that resides on a local PC in the smart classroom that is responsible for locating the appropriate PowerPoint file and displaying it, starting at the appropriate slide.

3.2 Smart Classroom Manager

The core of the CASC system is the smart classroom manager that provides the adaptive behaviour based on a set of system rules. The manager collects the policy settings of the users and the current

context by connecting to appropriate database tables and is responsible for transferring material to students according to student specific policies.

3.3 Policy Manager

Students and lecturers can log into the system and modify their policies based on the set of options presented. The room operation is set by a room policy that can be modified by the lecturer and the CASC administrator. The notes policy is set by the lecturer and can be used to initiate a change of venue to ensure that appropriate facilities are available in a room.

- **Lecturer's policy:** This policy can request advance notification of lecture times and venues, which is mainly required if room venues are dynamically allocated. The policy informs the CASC client where to access notes, either from the lecturers' desktop machine, wirelessly from a PDA or a central server and they are then displayed on the room projector. The lecturer can set the distribution of material to those present or to all students of the class group.
- **Students' policy:** This policy enables the student to specify how the lecture material is to be transmitted, such as wirelessly to a laptop in the room, or sent to an email address. Also, this policy enables the student to remotely access the smart classroom and receive notes.
- **Room Policy:** The room policy allows the smart classroom to be used for a range of purposes such as a lecture, tutorial, or presentation. Based on the room policy being set as presentation a particular student may take on the role of the lecturer. The room policy ensures the correct activity, such as lecturer and student group, takes place in the appropriate room at the right time and date. CASC can send a message to lecturers or students who enter an incorrect room.
- **Notes Policy:** Certain lecture notes may require audio or DVD players and these options can be set by the lecturer. However a room with the appropriate functionality must be requested in advance of the lecture period. This permits the system to find a suitable room and give advance notice to students and the lecturer which room is available. A lecturer can set the notes policy to specify who receives the notes for each of the cases: when a student is present physically in the room; remotely signed in; or not present.

3.4 Context Manager

The context manager is responsible for collecting real-time data and storing the information into appropriate tables in a database for use by the smart classroom manager. The context manager relies on a Bluetooth monitoring daemon on the local computer for communicating with user devices.

- **Identity:** Users are identified through the MAC address of their personal devices. When users are added to the system specific device configuration information is also required to be added.
- **Location:** There are two location elements in the system, the smart classroom location and the location and tracking of individuals. The location of individuals is identified using the Bluetooth enabled personal devices and requires to determine if the user is inside the room. It is possible for CASC to change the room location and generate a Bluetooth broadcast to the appropriate student and lecturer that the venue has changed.
- **Activity:** An academic activity or event is defined in the central scheduling system database and requires a lecturer, class group, venue and activity such as a lecture or tutorial to be identified. The context manager connects to the central database and copies relevant schedules to a local database table for access by the smart classroom manager.
- **Time:** The start time of each activity and the duration is determined from the central scheduling system. This can be used by the smart classroom manager to send out reminders using Bluetooth or email to lecturers and staff in advance of lectures.

4. SYSTEM DEPLOYMENT

The prototype CASC system was deployed in room 4-040 of the School of Electronics and Communications Engineering (SECE) at DIT as shown in Figure 2. This room is a project laboratory and for the duration of the deployment evaluation, the room had to be equipped with a projector and a local PC. Currently in SECE, lecture theatres are equipped with LCD projectors and computers connected to the network to enable presentation of material and so CASC can easily be deployed in lecture theatres.

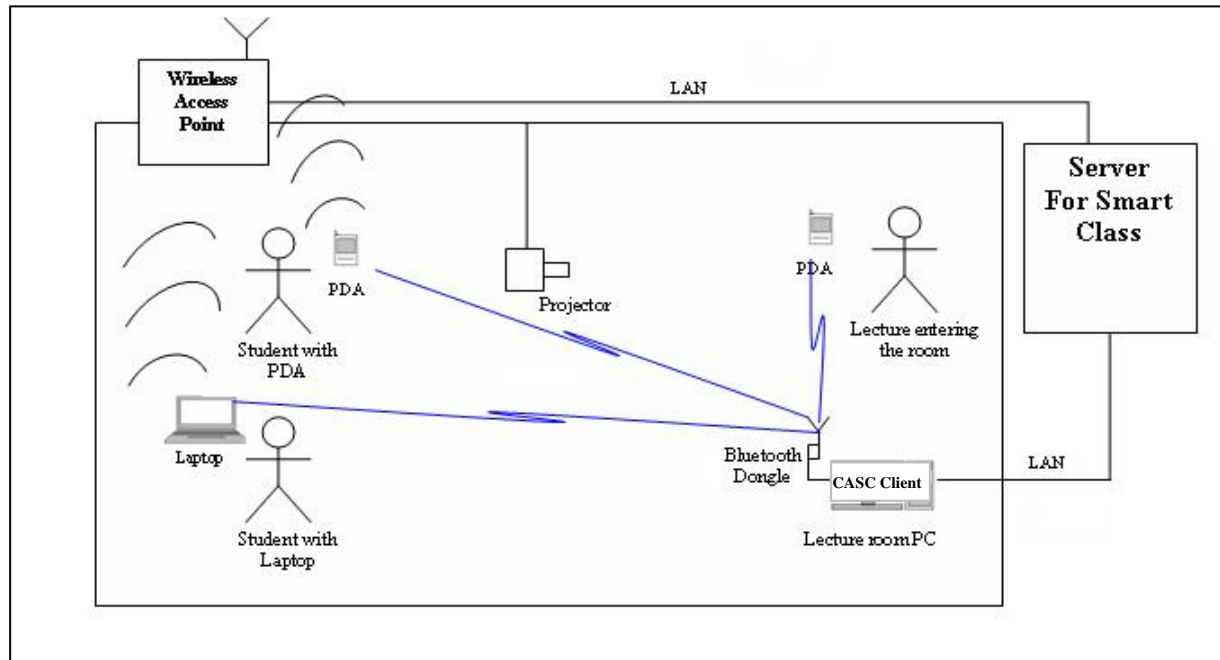


Figure 2: CASC System configuration

4.1 CASC implementation

CASC is a client-server architecture with a central server that manages the database tables, the Smart Classroom manager and its rules engine to provide predictive decision-making, and the Policy manager. Java was used as the core programming language for both client and server implementations with MySQL chosen as the database. The server system was implemented on a windows platform though any Linux operating system could be used. However the client machine had to be Linux as CASC uses a Linux API called BlueZ to manage the Bluetooth connections.

Prior to using the classroom manager of CASC the system needs users to register themselves and their devices and to input their preferences into the policy manager.

4.2 Registering Users

The CASC system requires users to register and opt-in to using the system. This ensures that individuals are aware and give permission to have their location tracked for the sole purposes of receiving lecture notes.

Users register using the registration applet as shown in Figure 3. In this screen shot a lecturer with the staff number L123456 is registered while for a student to register they require to select 'student' in the profile option at the bottom of the screen. The profiles contain a set of predefined policies that can be enabled or disabled using radio buttons in a separate applet.

The ID number is used to retrieve individuals' details from a database identity table that can be populated from the college Central Management Information System (CMIS), which has both staff and student records stored. For the prototype CASC, the identity numbers and tables were populated manually, though a link to the CMIS could easily be created.

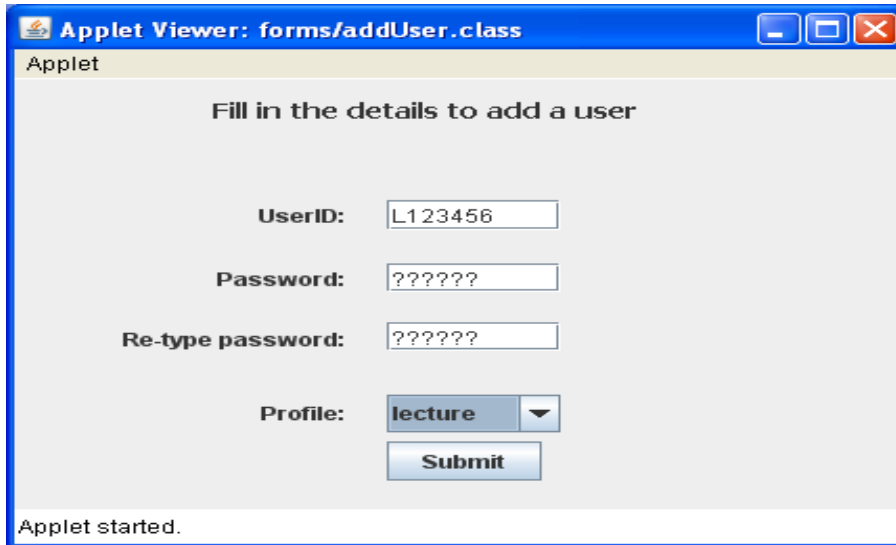


Figure 3: Registering a Lecturer

4.3 Registering a Device

Having added a new user with an appropriate profile, the user must register their Bluetooth enabled devices to permit CASC to track and identify them. This requires users to log into the system as in Figure 4 and then select the appropriate tab as in Figure 5.

In the prototype users are required to add the Bluetooth MAC address of their device, which is stored in the MySQL database along with user identity and their personal profile containing their preferred policy options.

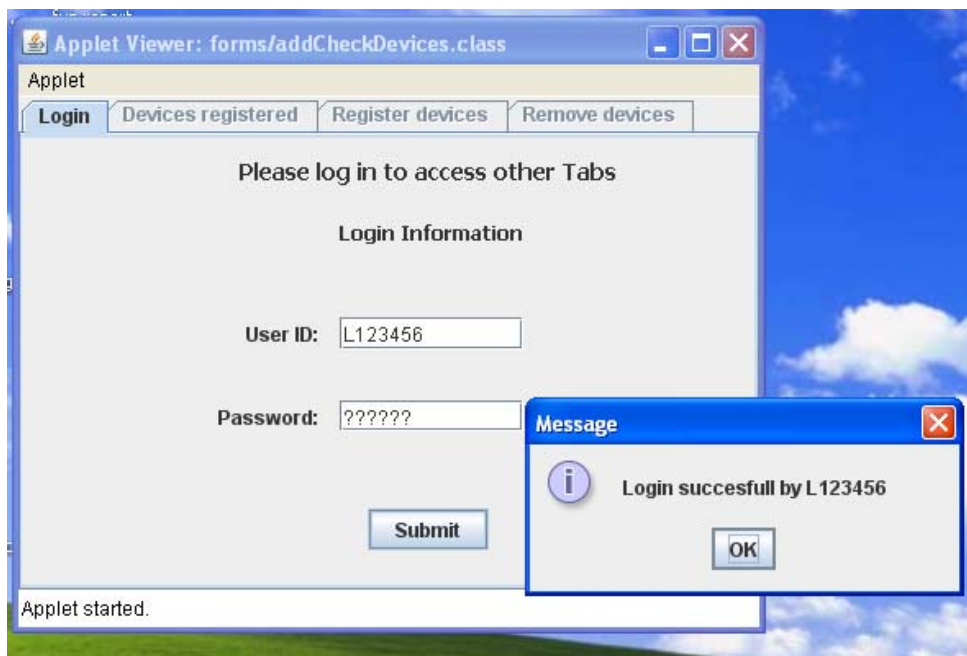


Figure 4: Logging into CASC

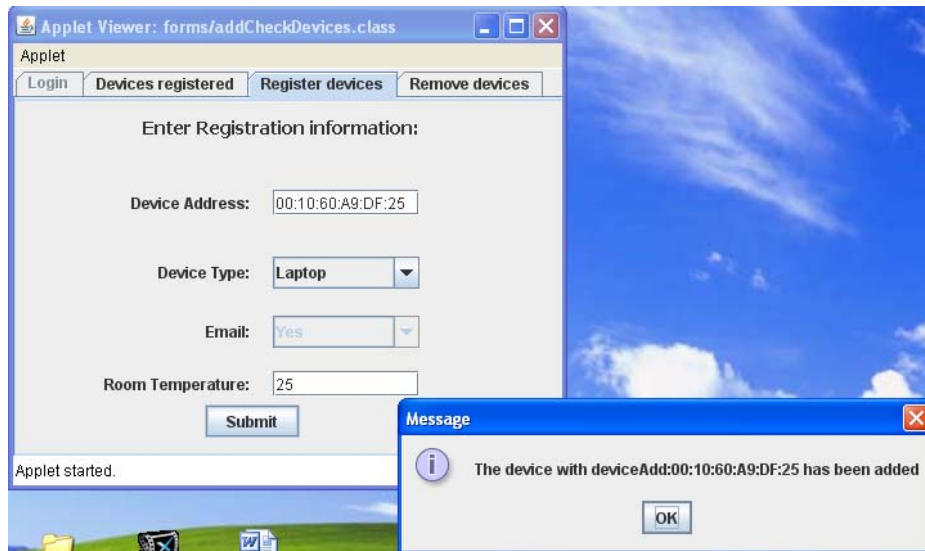


Figure 5: Adding a Personal Mobile Device

4.4 Managing the Classroom

The local classroom PC is used to run the CASC client, which is responsible for scanning for Bluetooth devices and for retrieving the presentation material for the lecturer. The scanning routine runs continuously and commences a scan every 30 seconds that will identify all Bluetooth devices in the neighbourhood and pass any information collected to the CASC server for the smart classroom manager.

The classroom manager determines if a lecturing event is to take place and updates the client on the current status for the particular room such as no class scheduled. On the arrival of a user, acting in the lecturer role, at the appropriate time the classroom manager will welcome the lecturer, retrieve the appropriate material and present the lecturer with options to commence from a specific slide, change to a different lecturer session or finish the session. On commencing the lecture, the CASC client will display the presentation material on the local PC, which is connected to the room projector as shown in Figure 6.

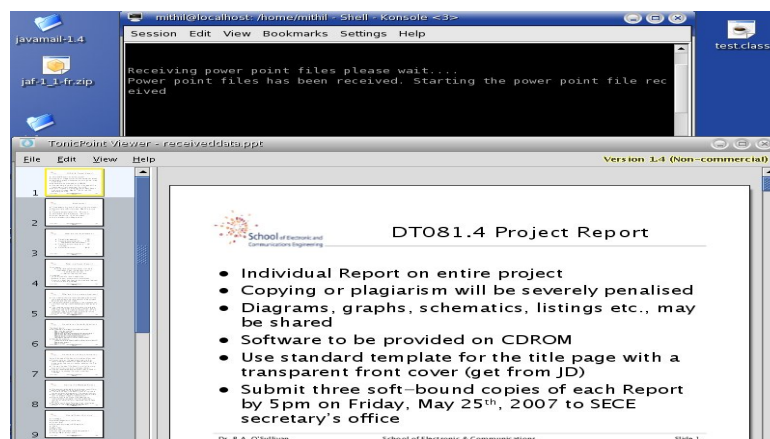


Figure 6: Notes Retrieved and Opened

The CASC client then identifies students via their personal devices and passes the information into the database on the server for the classroom manager to process. The classroom manager ensures the student is attending the correct lecturing event and retrieves their preference for distribution of notes. The material is then sent via the WLAN, LAN or email to the appropriate student device and the identity is added to a distribution table that is used to track who has received the notes. As students enter or temporarily leave and re-enter the room their devices will be scanned and added to the attendance table. To ensure that they only receive a single copy of the material a distribution table is maintained.

5. EVALUATION

The system was evaluated over a 4 week period with two lecturer roles and two simulated student groups in order to determine the usability of the system. From this deployment, the system was evaluated from a technical perspective and recommendations developed for future enhancements.

5.1 Deployment

The CASC system uses commonly available personal mobile devices supported by pervasive technologies such as Bluetooth, WLAN and LAN that make system deployment relatively simple and cheap to deploy in a real academic environment. The system is a client-server architecture that makes it easier to set up many smart rooms by adding the CASC client and a Bluetooth dongle to existing theatre or lecture facilities. User interaction is quite straightforward, using applets to setup database tables, although users are required to find the Bluetooth MAC address of their personal mobile devices. The CASC system effectively managed the retrieval, display and distribution of presentation material as intended.

5.2 System Limitations

The Bluetooth sensor occasionally scanned extra devices that were not inside the room. This problem depended on the actual positioning of the Bluetooth monitoring sensor. In the case of the local PC being positioned near the door Bluetooth devices outside of the room can be scanned. In this case a student identified as a member of the group would receive the material without attending the session. In the case that the PC was located at an external wall, away from the door, devices outside of the room were not identified by the system.

Performance issues, in terms of system response time, were identified in identifying and transferring material to students when the number of devices in the room was increased. This was due to the time required for Bluetooth to scan the room and collect each MAC address and was observed to take about 5 seconds per device to scan and identify the user.

5.3 Future Work

CASC requires assessment over a longer period of time to establish user acceptance and willingness to engage with the system. A longitudinal research approach will be undertaken that will gather qualitative and quantitative research material through interview and questionnaires of the users. Technical enhancements will be added to permit remote access to the classroom and to record the lecture in theatres with existing CCTV installations. An alternative approach to registering devices without the need for users to find their Bluetooth MAC address will be developed to permit ease of use by less technical users.

6. CONCLUSION

The purpose of developing the CASC system was to leverage existing technologies such as the personal devices of students and lecturers as Bluetooth tags to permit the existing communications infrastructure provided by WLAN, LAN and email to enhance the students experience in the classroom. The smart classroom manager was designed to automatically adapt to the behaviour of the room, based on the context, user policies and the core rules of the system. Bluetooth provided an acceptable solution to identifying users within the room although it occasionally identified users outside the room. The time for Bluetooth to identify each user raises concerns about the potential scalability of this identification technique. An alternative technique such as RFID tags in the student cards would probably improve performance and avoid mistaken identification. However this approach would require an RFID reader to be fitted at the doors of all smart classrooms and thus increase the cost and complexity of deployment. The CASC system operated as an effective demonstrator for the use of context awareness as a driver for creating a low-cost smart environment that can be developed using existing infrastructure and personal devices.

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