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Combining Pervasive Computing With Social Networking for a Student Environment

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Abstract

Whereas social networking has become an essential part of computing today, pervasive computing is seen as a key component for future systems. However, these two paradigms are complementary in many respects – the former responsible for communication and interaction between people, the latter focused on interaction with devices and services in the environment surrounding the user. By combining these two different paradigms in an integrated and seamless fashion one may provide users with the advantages of each plus the power obtained from using them together. Thus one might combine personalization, context awareness, learning, access to a wide range of devices and services, etc., with the management and operation of communities of users. This is the goal of the SOCIETIES project. By building on recent developments in pervasive systems and mobile computing, a new type of system that combines pervasive with social networking functionality – Pervasive Social Networking (PSN) – has been developed based on cloud and mobile technologies. Implementation of the basic system is complete and as part of the evaluation of the system it is currently being used by a group of students in a real user trial. This paper focuses on the student aspect and describes the requirements gathering exercises conducted with students. It then describes the architecture of the final system developed to meet the requirements. It ends with a brief outline of the final trial.

Keywords: Pervasive systems, social networking, mobile computing, cloud computing, smart spaces, ubiquitous systems.

1 Introduction

As the environment surrounding the user becomes more complex, with growing numbers of intelligent sensors and devices, so systems are becoming better able to change their behaviour to meet the user's needs. The goal of

pervasive computing (Sun 2001) is to create an intelligent environment that provides support to the user in interacting with and managing these devices and services unobtrusively, without the user needing to be aware of and cope with the underlying communications and computing technologies. Driven by this important challenge, research in this area has followed a variety of different approaches with different objectives, and a growing number of prototypes have been created to test these. Examples include the Adaptive House (Mozier 2004), MavHome (Youngblood, Holder and Cook 2005), GAIA (Roman et al 2002, Ziebart et al 2005), Synapse (Si et al 2005), Mobilife (Strutterer et al 2007), Daidalos, Ubisec, etc.

On the other hand, social networking is a paradigm that has come into its own in a very short space of time. In recent years, online social networking has become one of the most significant trends in computer use, particularly through social network sites. In so doing it has significantly improved social connectivity between users and has opened up a whole new world of opportunities for exploiting the Internet. The unexpectedly rapid take-up of social networking services provided by systems such as Facebook, LinkedIn, MySpace, Bebo, YouTube, Flickr, etc., has transformed the way in which a large number of users use their systems, and takes up an increasing proportion of the time that the average user spends at his/her computer.

However, if these two different paradigms can be brought together and integrated seamlessly into a single system, there are significant benefits to be gained. The aim of the SOCIETIES project (Gallacher et al 2012) is to build on recent technical developments in these two areas to create such a system – a Pervasive Social Networking (PSN) system. This combines the strengths of pervasive systems with those of social networks to meet the needs of a wide range of different applications and users. Thus a PSN should enable the user to interact with devices in the environment, and communicate with other users either individually or as communities. Here a community is defined as a collection of participants who share some common characteristics or interests. In SOCIETIES a community may have its own criteria for membership, including the types of information that members are

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prepared to share and third party services they may have access to.

In order to test out these ideas, the system is being evaluated in a set of field trials by three separate user groups. The three different user groups selected for this purpose are:

(1) Students. The motivation behind this choice is that students are very adaptive and take to new technology very easily. They also serve as an independent group of volunteers who are not employed by any of the developers of the system nor will they receive any academic credit for participating in the trials.

(2) Disaster Management. A set of professionals who meet together annually to simulate large scale disaster scenarios will assess the usefulness of the platform in disaster management situations.

(3) Enterprise. A collection of workers from industry have been evaluating the usefulness of the platform for handling support for delegates at a conference. This part has now been completed.

This paper is concerned with the student user group consisting of Computer Science and Information Systems students from Heriot-Watt University. Engagement with this group began in late 2010 when students were involved in the development of key scenarios. These were used to drive further design phases including the extraction of requirements and use cases. Since then the development of the platform has progressed and on 23rd October it was subjected to a full user trial. In this trial 20 students were provided with a device containing a prototype PSN platform to trial over a period of six weeks and their use of this monitored during this period.

The next section provides a brief background. The derivation of requirements through storyboarding and the immersive environment is described in section 3 while section 4 provides a brief introduction to the platform. Section 5 gives a detailed view of the components of the platform. Section 6 provides a brief description of the final trial and section 7 concludes.

2 Background

2.1 Pervasive Computing

The goal of pervasive computing is to create an intelligent environment in which devices provide unobtrusive connectivity and access to services, thereby improving user experience and quality of life without the user needing to be aware of and cope with the underlying communications and computing technologies. In this environment, the world around us is interconnected as a set of pervasive networks of intelligent devices that cooperate with each other and autonomously collect, process and exchange information, in accordance with the context and preferences of the user.

Pervasive computing embraces a wide range of diverse applications, including those of mobile computing systems and services. Driven by the important challenges presented by pervasive computing (Zaslavsky 2002), research in this area has followed a wide variety of different approaches with different objectives in mind, and a growing number of prototypes have been created to test different combinations of these. These diverse efforts can be categorized in various ways. For example, a brief

summary of 29 software infrastructures and frameworks from a number of different projects is provided by Endres, Butz and MacWilliams (2005). This groups them into three main categories: Augmented Reality, Intelligent Environments and Distributed Mobile Systems.

Following a different way of grouping these developments, one major class of projects is that concerned with fixed smart spaces. A fixed smart space is a bounded physical environment filled with adaptive devices (such as lights, window shutters, etc.) that can be automatically managed to meet the needs of individual users. The main focus here lies in developing different forms of intelligent building, the most important of which is the Smart Home. This is motivated by the strong belief that pervasive technology can be used to provide safe and secure support for elderly and disabled citizens, which will facilitate their independent living and reduce the need for permanent carers or institutions. Besides covering the automatic control of devices providing lighting, temperature control, security, etc., the research has also extended to energy conservation in a smart building as well as a variety of intelligent appliances. Examples of systems of this type include the Adaptive House, MavHome, GAIA, Synapse, Ubisec (Groppe and Mueller 2005), etc.

Another major group has been that focused on mobile users with the aim of providing them with devices, networks and services to meet their needs wherever they may be. The location of the user plays a large part in the decision making process. The provision of support for mobile users and the problems associated with this, have been investigated in a number of research projects with corresponding prototypes developed to demonstrate and assess different approaches. For example, the European project Daidalos explored two separate architectures (Williams et al 2006), and developed prototypes based on each of these. By contrast, Mobilife focused on the issues of privacy and trust as well as on maintaining a "shared cognition" amongst groups of users. The project Spice (Cordier et al 2006) developed a platform for creating and executing mobile services.

The Persist project (Roussaki et al 2010) attempted to bridge the gap between these two classes of project by developing a prototype based on a Personal Smart Space (PSS) approach. This is a hybrid approach that can be used as a fixed smart space (taking advantage of sensor equipped buildings) as well as a mobile smart space that interacts with other surrounding fixed and mobile smart spaces (Papadopoulou et al 2010).

However, despite all the developments in this area, exploitation of these ideas has been slow.

2.2 Social Networking

In recent years, online social networking has become one of the most significant trends in computer use, particularly through social network sites. Using these sites, people can create accounts and connect digitally to friends, family, and others with ease. They can publicly share information and media about themselves and their lives, engage in chat with friends, form and join groups of users, and more. Certain sites, such as foursquare, add a location-based element to online social networking,

where users can check in to key locations and share their location details and histories with friends.

The popularity of social network sites is remarkable, and continues to grow. However, such sites are heavily geared towards networking in the digital realm. People have many real-world relationships that involve physical interaction to an extent that transferring them to a social network site is only somewhat useful. Even the aforementioned location-based services, while making some headway in bridging the physical-digital divide, are not exploiting the rich potential of real-world events and interactions to influence digital relationships and vice versa.

2.3 Combining the Two

The aim of the SOCIETIES project is to bring together the two different paradigms of pervasive computing and social networking to create a system that can benefit from both and from their combination.

In the case of pervasive computing the system enables the user to interact with devices in the vicinity. It monitors the user's actions and builds up a detailed history of these from which it can infer user preferences and user intent depending on the context of the user. These can then be used to assist the user by taking actions on the user's behalf when a relevant context is identified.

In the case of social networking the user controls the communications that he/she has with other users. This includes the information (text, pictures, etc.) that the user wishes to share, the other users who are allowed access to such information, and the access the user makes of other user's information. Communities (or groups) can be formed and within them subsets of information can be shared. And so on.

In combining the two the aim is to integrate the facilities of both. Thus the notion of monitoring user's actions and using learning techniques to identify patterns of behaviour, and hence user preferences and user intent, can be applied to personalising the user's interactions with social networking.

Moreover, a pervasive system can be in a very good position to detect apparent real-world relationships and communities, as well as the potential for new communities to be formed based on criteria such as shared interests, and to bring these into the digital realm. Thus it can be developed to identify potential new communities or existing ones that might be of interest to the user.

The use of context management within pervasive systems provides a rich source of context that can be exploited by a social networking system to provide a wider range of information with access controlled in a more context-dependent fashion. In turn the social networking systems can provide useful information on the user which can assist the pervasive system. By taking advantage of location information and social networking information on other users in the vicinity this can create opportunities for new applications in the future. However, all this must be done in the context of strict privacy controls to ensure the protection of user information.

3 Gathering Requirements

This section describes the requirements gathering exercises conducted with the students in preparation for the development of the SOCIETIES platform.

After a short introduction to the basic concepts of the SOCIETIES project, a combination of techniques (such as brainwriting, brainstorming and bodystorming) were performed with the students to identify scenarios that they felt were most useful or interesting for a PSN prototype to support. The feedback covered a wide range of situations from those that involved enhancing common practice to those that were novel. This exercise helped to identify the opportunity spaces for the PSN prototype in the everyday life of a group of student users.

This led to two preparatory user trials that took place in 2011. The primary objective of these trials was to record user response to an early low fidelity prototype of the proposed PSN system. The trials were carried out using two methodologies: *storyboarding* and *immersive environments*. Both techniques employ scenario based vision prototypes which serve the combined tasks of defining early design focus for developers and providing a site for evaluating user responses.

3.1 Storyboard Evaluation

The scenarios identified in the initial exercise were used to create a set of storyboard slides and an associated set of questions which were used to conduct a storyboard evaluation. Some fifteen first year Computer Science (CS) and Information Systems (IS) students took part in the session.

The storyboard slides detailed eight scenes that illustrated the SOCIETIES system supporting a student user in various situations. At key points during the slide presentations the students were asked multiple choice questions to gain their feedback on a concept that had just been presented. Each participant used a voting keypad to answer the multiple choice questions anonymously. The output from all keypads was captured on the session coordinator's laptop using voting system software.

A total of 19 questions were posed to the participants regarding the SOCIETIES concepts shown during the presentation of the storyboard slides. In this section, only the most significant questions and responses are presented in Table 1 although the entire result set is available by request from the project website (SOCIETIES project website).

| # | Question | Response | Percentage |
|-----|---|---|------------|
| S1 | Would you have joined a "Freshers" community if this functionality had been available to you when you began University? | Yes | 73% |
| | | Maybe | 13% |
| | | Only if the majority of other freshers had already joined | 13% |
| | | No | 0% |
| S2 | Would you have found it useful to be told where other "Freshers" community members preferred to eat? | Yes | 73% |
| | | Maybe | 13% |
| | | No, I'd rather discover such things myself | 7% |
| | | No, for other reasons | 7% |
| S3 | Would you like to be automatically added to a community (without being asked for confirmation) related to your degree course? | Yes | 73% |
| | | Maybe | 13% |
| | | No, I'd always like to be asked for confirmation first | 7% |
| | | No, for other reasons | 7% |
| S4 | Would you have any privacy concerns about sharing your music preferences at a proactive disco? | Yes | 13% |
| | | Maybe | 13% |
| | | No | 73% |
| S5 | Would you like services to be automatically started on your behalf if the system was sure they would be of benefit to you? | Yes | 13% |
| | | Maybe | 13% |
| | | No, I'd always like to be asked for confirmation first | 73% |
| | | No, for other reasons | 0% |
| S6 | Would you appreciate suggestions to introduce yourself to new individuals (who share common goals/interests/characteristics)? | Yes, if we share something in common | 53% |
| | | Yes, but only if we are significantly similar | 27% |
| | | No | 20% |
| | | Yes | 33% |
| S7 | Do you think such technology would have improved your initial experiences at University in terms of making new friends? | Maybe | 27% |
| | | No, I prefer to make friends the old fashioned way | 40% |
| | | Yes | 87% |
| | | No, for other reasons | 0% |
| S8 | Would you join job/task sharing communities if they were available? | Yes | 87% |
| | | Maybe | 13% |
| | | No | 0% |
| S9 | Would you like your device to predict your behaviour and make suggestions to you? | Yes | 47% |
| | | Maybe | 27% |
| | | No | 27% |
| S10 | Would you mind being monitored if it meant that the system could make better suggestions to you? | No, as long as the system kept my data private and secure | 60% |
| | | Maybe | 33% |
| | | Yes, even if the system kept my data private and secure | 7% |
| | | Yes | 67% |
| S11 | Would you find automatic organising and planning of daily meetings/events useful in daily life? | Yes | 67% |
| | | Maybe | 27% |
| | | No | 7% |

Table 1: Key results from the storyboard evaluation

3.2 Immersive Environment Evaluation

As with the storyboard evaluation, first year Computer Science and Information Systems students were invited to take part in the immersive environment evaluation. A total of thirteen students took up this invitation with each student being allocated a date and time for their individual immersive experience test which they attended alone. Each test took between ten and fifteen minutes to complete.

The immersive environment was erected in a test room and was designed to reflect physical locations that the students were familiar with such as University corridors and a meeting area. A number of devices were installed in the environment as interaction devices in accordance with the evaluation script. Figure 1 shows an aerial view of the immersive environment with hotspots and devices marked.

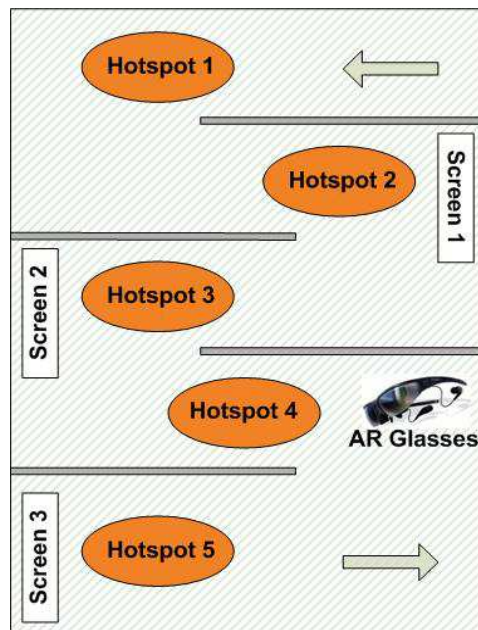


Figure 1: Aerial view of the immersive environment

Three screens acted as University advertisement screens that would show personalised content as the test participant walked past. The augmented reality (AR) glasses provided personalised content and other details in a more discrete fashion. An HTC smart phone acted as the participant's SOCIETIES device through which the trial participant could receive mock community alerts.

The controller was manipulated by the test coordinator to control and adapt the other devices within the environment appropriately. Several recording devices such as a camcorder and a dictaphone were also installed in the immersive environment to capture the reactions and feedback from participants. The immersive environment itself was a pathway through the various devices. The pathway was marked with five "Hotspots", each indicating a point where the participant would interact with a device or experience some SOCIETIES-like behaviour.

Each participant answered an average of 32 questions regarding the SOCIETIES concepts experienced within the immersive environment. The number of questions varied based on the decisions taken by participants during the immersive experience. In this section, only the most significant questions and responses are presented in Table 2 although the entire result set is available by request from the project website (SOCIETIES project website).

| # | Question | Response | Percentage |
|-----|--|-------------------|------------|
| 11 | Would you find information about the actions of other community members helpful to aid your own decision making? | Yes | 100% |
| | | No | 0% |
| 12 | Would you like it if screens around the University department displayed content specific to your interests when you walked past? | Yes | 100% |
| | | No | 0% |
| 13 | Are you ok with the University screens showing personal information (such as your name) in a public place? | Yes | 62% |
| | | No | 39% |
| 14 | Did you decide to join the community dedicated to one of your interests? | Yes | 100% |
| | | No | 0% |
| 15 | Would you still have joined the community related to your interests if you knew only 2% of your friends were members? | Yes | 92% |
| | | No | 8% |
| 16 | Would you find it useful to receive information (via AR glasses) on people you encounter in real life? | Yes | 92% |
| | | No | 8% |
| 17 | Did you decide to join the random "cardboard box artwork" community? | Yes | 31% |
| | | No | 69% |
| 18 | Would you find it useful to receive exam timetable information on the University screens? | Yes | 92% |
| | | No | 8% |
| 19 | Would you prefer the University screens to show course related info, personal info or both? | Course-related | 23% |
| | | Personal-Interest | 0% |
| | | Both | 77% |
| 110 | Did you decide to join the study group community related to one of your exams? | Yes | 100% |
| | | No | 0% |
| 111 | Would you still have joined the study group community if you knew only 2% of your friends were members? | Yes | 85% |
| | | No | 15% |
| 112 | If the study group community had requested your mobile phone number would you still have joined? | Yes | 62% |
| | | No | 39% |
| 113 | If the study group community had requested your location would you still have joined? | Yes | 77% |
| | | No | 23% |
| 114 | To minimise popups, would you allow the system to take decision on your behalf if it was 99% sure its decision | Yes | 77% |
| | | No | 23% |

Table 2: Key results from the immersive environment evaluation

3.3 Comparison of Results

When the first trial (Storyboard Evaluation) was conducted, the aim was to present a set of imaginative scenarios to the participants and obtain their reactions to these. In doing so we were not inhibited by the constraints of actually demonstrating these scenarios. The second trial was much more focused and constrained by what we could do in the short amount of time that the participants were engaged in the trial. Although this had the disadvantage of being less imaginative, it had the advantage of letting the student actually experience the phenomena first hand.

Although it was not our intention to compare the results of the two trials, it was noticeable that, while both sets of results showed a general positive attitude towards SOCIETIES concepts, the results obtained from the

immersive trial were in places more positive than those obtained from the storyboard trial.

In particular, this included:

(1) When queried about joining a community, in the storyboard trial participants indicated that this would depend on existing members whereas in the immersive trial they said it would not.

(2) In the storyboard trial participants did not like the idea of being automatically joined to any community whereas in the immersive trial there is evidence that automatic joining would be acceptable in certain cases.

(3) With regard to community information, in the storyboard trial most participants did not think community preferences would be useful whereas in the immersive trial all participants thought that this would be helpful.

(4) When asked whether they would like help in introducing them to other community members, most storyboard participants were unsure or against the idea whereas most immersive trial participants who used the AR glasses felt that this was really useful functionality.

(5) In the case of automatic behaviour, nearly all storyboard participants wanted to confirm before an automatic action was started whereas immersive trial participants were happy with some automatic actions on their behalf.

Thus, although it was not our intention to compare the two sets of results, especially since the number of participants is small, it did seem noticeable that, if participants actually experience the phenomena before being questioned about them, a slightly different result might be obtained compared to that obtained from a storyboard trial. In this case the results were more positive towards some of the concepts of a PSN platform.

4 SOCIETIES Platform

The requirements gathered from the three separate user groups were merged and an architecture derived that would provide the functionality needed to satisfy them. This architecture was based on the assumption that the main device with which the user interacts with the system is a smart phone. However, there may also be occasions when the user wishes to interact with the system via a laptop or PC. Whatever the case, since parts of the system require significant processing power, it has been assumed that the backend of the system resides in a cloud.

To simplify the architecture, it is divided into several layers, each of which incorporates various components and component blocks essential to the design of a PSN environment, as shown in Fig. 2.

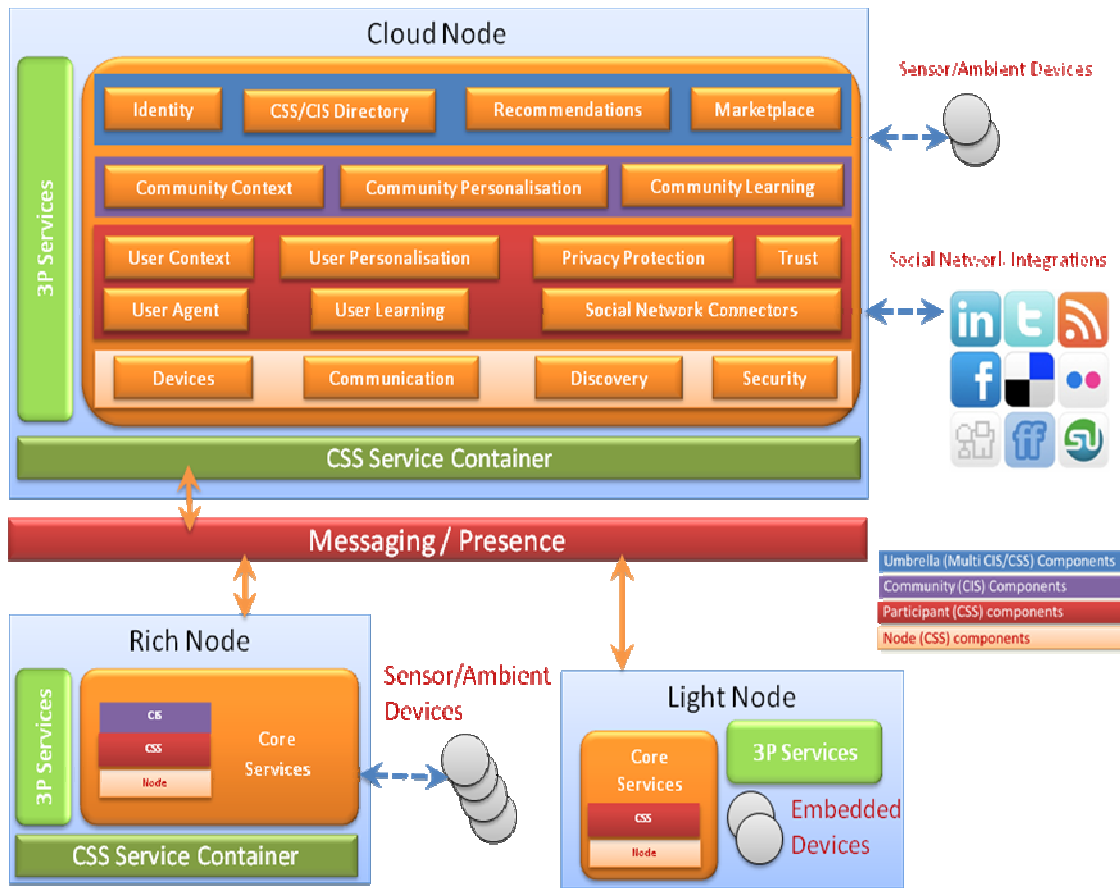


Figure 2: Architecture of the Societies Platform

Assuming that the main device with which the user interacts with the system, is a smart phone, we have based our implementation on an Android-based smart phone, although it is also possible to use other devices such as a notebook or laptop to interact with the system. Due to the more limited capabilities of a smart phone, the set of software components located on such a device is limited and provides minimum functionality. This is referred to as a Light Node. On the other hand a notebook or laptop may host most of the functionality of the system and is referred to as a Rich Node. In order to provide the full range of functionality on each type of node, both types communicate with a Cloud Node where most of the processing takes place.

Key to the system is the distinction between an individual user and a community of users. The different parts of the system that operate on behalf of a particular user are referred to as a Cooperating Smart Space or CSS. This represents a “smart space” of devices and applications that belong to that user. For example, the user may have both a smart phone and a laptop as well as several other smart devices. These together with the components in the cloud form a smart space for the user.

On the other hand, a community of users is referred to as a Community Interaction Space or CIS. When a community is formed, it is set up by a user through his/her CSS for a particular purpose. In general a community may have its own criteria for membership, including the types of information that members are

prepared to share with each other. A community may also have associated with it a set of third party services that members may have access to.

5 Layers of the Architecture

The architecture can best be viewed as a layered one in which the Cloud Node contains the full set of components whereas the Light Node contains a minimal subset of them and relies on the Cloud Node to do most of its processing.

The Rich Node is somewhere between the two in that it has a more substantial subset of the components, making it possible to do more processing on the node without the constant dependence on the Cloud Node although it does still rely on the Cloud Node for some (e.g. offline data mining of the history data).

The four layers of the architecture are as follows.

5.1 Node Components

At the lowest level one has the node components themselves and the software needed for them to communicate with each other (Communication Framework) and to discover one another (Discovery).

At the very minimum the user will have a Light Node in the form of a smart phone and a Cloud Node. The Communication Framework provides the means for these two to communicate with each other. More generally the user may have other devices which can connect to the

Cloud Node and these too may use the Communication Framework.

In addition security is an important component at this level. This is mainly responsible for access control.

5.2 Participant Components

This layer contains the largest part of the system. It includes the main components providing functionality for the individual user or CSS. These include:

5.2.1 User Context

Context plays a key role in pervasive systems. Information about the context of a user is captured and stored in a Context Management system. Some of this information may be entered directly by the user (e.g. interests), other information is gathered from sensors or other devices and needs to be updated regularly.

Sometimes different sources may be used to provide information for the same attribute. Location is a good example. Out of doors one may use GPS to provide accurate location information while when the user is indoors one might use RFID tags to locate him/her.

In the SOCIETIES platform a Context Management system is used that keeps track of a range of different attributes, and uses three different methods to keep track of user location.

5.2.2 Personalisation

Personalisation is concerned with the set of techniques that are used to adapt the behaviour of the system to meet the needs and preferences of an individual user. Basically this means that under certain conditions (in certain contexts) the system needs to take specific actions on behalf of the user. These may involve setting parameters for a third party service, selecting or initiating a service, responding to a request for the user's personal information, etc.

In the SOCIETIES platform this subsystem uses two very different approaches to determine when to take action and what action to take. The first is based on user preferences. These can be viewed as rules of the form:

IF a context arises THEN perform some action although in practice the process is more complex.

The second is referred to as User Intent and is based on sequences of actions that are performed by the user in particular contexts. Thus if the system detects that the user is part way through a known action sequence, it can predict what action to perform in the future provided a suitable context match arises.

In the SOCIETIES platform two different techniques are used for each of these two different approaches.

5.2.3 Learning

To build up a set of user preferences, one cannot expect the user to provide these manually. Instead the system monitors the user's actions plus the context in which they occur and uses this to "learn" the user's preferences.

Since two different techniques are used for handling user preferences in the SOCIETIES platform, two different styles of learning are required. The first technique used is based on a neural network and learning for this is straightforward. The second technique is based

on preference rules and a variation of the C4.5 algorithm is used. This is coupled with a confidence level indicator which provides a measure of the degree of confidence associated with a preference rule at any stage.

In addition to these the project is also experimenting with the use of a Bayesian Network to handle input from bio-sensors. Again learning is straightforward.

5.2.4 User Agent

With all these different techniques being used to predict actions for the system to perform on the user's behalf, an arbiter is required to select the most appropriate one. The User Agent is the component responsible for taking the outputs from these different techniques and deciding which to perform.

It is also responsible for communication with the user. Thus whenever the system decides to perform an action on the user's behalf, the User Agent informs the user and provides the user with an opportunity to reject this if the action is not what he/she wants. If the user does nothing, the system proceeds with the action.

5.2.5 Privacy

Protection of user privacy is essential in a system where the user's personal information may be shared with other users. In the SOCIETIES platform the Privacy component is responsible for providing the support to enable the user to manage personal information and its disclosure.

To determine what data attributes may be disclosed and to whom, the system uses the process of Privacy Policy Negotiation between the preferences of the user and the requests for data from third party services or communities. To determine in what form the data should be released, a process of obfuscation is employed. And to provide further protection to the user a system of multiple identities is used.

5.2.6 Trust

The decision to share information with another user or a third party service does rely to some extent on the degree of trust that the user has in the other user or the third party service.

As the number of contacts a user has and the number of third party services available to a user increases so the need for the user to assess the trustworthiness of these entities becomes increasingly important. The set of communities to which a user belongs can be used to provide support for the trust assessment mechanism.

5.2.7 Social Network Connectors

By enabling the system to connect to social network sites directly though the interfaces provided by the social network systems, the SOCIETIES platform can access information about users directly and provide this to the components of the system that might use it. In particular the communities within SOCIETIES can benefit from information on their members obtained from these sites, as can third party services.

In the current state of the system one can obtain information from social network sites but not write information to them.

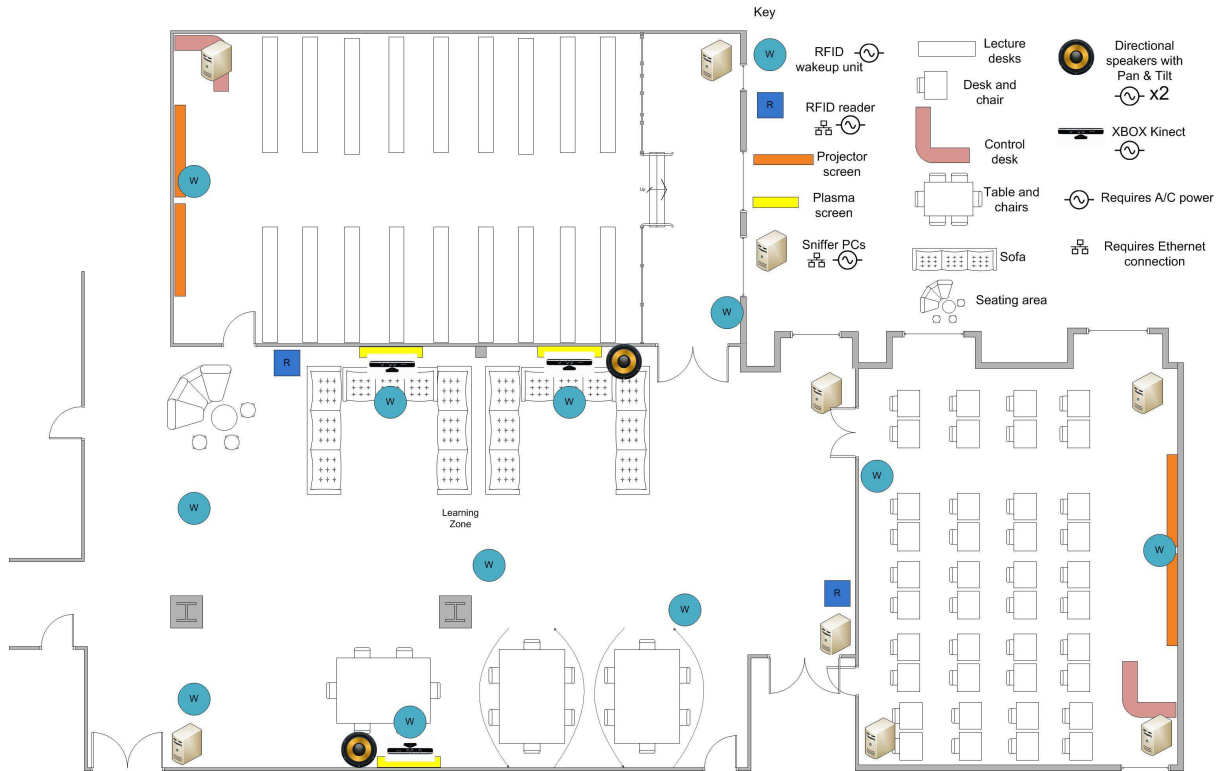


Figure 3: Set up of pervasive Learning Zone

5.3 Community Components

The Community Component Layer contains three components that provide functionality relating directly to communities. These are as follows.

5.3.1 Community Context

Just as the individual user has an associated set of context attributes pertaining to that user, each community may have context attributes associated with it that are derived from the attributes of its individual members.

An important example of a community context attribute is location. When a number of members of a community are gathered together, it may be useful for other members to know where this is taking place. Other community context attributes may be derived from mean or median values of the attributes of its members (e.g. average age).

5.3.2 Community Personalisation

Here the notion of a user preference has been extended to that of a community preference. This takes the same form as an individual user preference and hence can be used in the process of personalisation in the same way.

5.3.3 Community Learning

The SOCIETIES platform provides a mechanism for processing the individual user preferences of the members of a community to infer or “learn” the common preferences associated with the community. Each individual member can choose to inherit some or all of

these. This is particularly important for new members joining a community.

5.4 Umbrella Components

This layer lies outside the other three layers and provides functionality which applies to all CSSs/CISs. There are four components in this layer. These are:

- (1) CSS/CIS Directory – which provides typical directory services;
- (2) Identity – which controls the unique identities allocated to CSSs;
- (3) Recommendations – which recommends relevant existing or potential CISs to CSSs;
- (4) Marketplace – which provides access to third party services for users.

6 Full User Trial

The full user trial started on 23rd October and is scheduled to run for six weeks. A group of 20 student volunteers have been issued with RFID tags and smart phones (Samsung Galaxy SIII) loaded with the software for Light Nodes.

The main area where the system is being used is the Learning Zone in the School of Mathematical and Computer Sciences. This is an area adjacent to two main lecture rooms that is furnished with tables and chairs used by students for work and relaxation. This has been equipped with RFID wakeup units and readers, large plasma screens, XBOX Kinects, etc. as shown in Fig. 3. In addition we have two servers hosting the Cloud Nodes which contain the basic system as well as nine third party services.

7 Summary and Conclusion

Pervasive computing and social networking are two complementary paradigms which the SOCIETIES project aims to bring together to create a Pervasive Social Networking System. A system has been created involving a combination of mobile devices (smart phones and laptops), cloud computing and devices in the user's environment to provide the basic functionality required. In addition a number of third party services have been developed to run on this system. The system is currently being evaluated by three trial groups. This paper focuses on one of these groups, namely university students.

At the outset of the SOCIETIES project, a student demographic was identified, and this group has been involved in several activities, with the intention of capturing their requirements for such a system. Through this process they have also been exposed to ideas of pervasive computing and what the SOCIETIES system can offer them. By the time that the full trial began on 23rd October we believe that they had sufficient understanding to be able to make full use of the system.

Section 3 describes two exercises conducted with the students to establish requirements for the system. The first was a storyboard evaluation, the second an experiment with an immersive environment.

From the requirements from all three user trial groups the design for a PSN was derived and the architecture of this is described in section 4 with details of the components given in section 5.

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9 References

Cordier, C., Carrez, F., Van Kranenburg, H., Licciardi, C., Van der Meer, J., Spedaliere, A., Le Rouzic, J.P. and Zoric, J. (2006): Addressing the Challenges of Beyond 3G Service Delivery: the SPICE Service Platform. *Proc. Workshop on Applications and Services in Wireless Networks (ASWN '06)*.

Endres, C., Butz, A., and MacWilliams, A. (2005): A survey of Software Infrastructures and Frameworks for Ubiquitous Computing, *Mobile Information Systems Journal* 1:41-80.

Gallacher, S., Papadopoulou, E., Taylor, N.K., Blackmun, F.R. and Williams, M.H. (2012): Intelligent Systems that Combine Pervasive Computing and Social Networking. *Proc. Ninth International Conference on Ubiquitous Intelligence and Computing (IEEE UIC 2012)*, Fukuoka, Japan, 151-158, IEEE Computer Society.

Groppe, J. and Mueller, W. (2005): Profile Management Technology for Smart Customizations in Private Home

Applications. *Proc 16th International Workshop on Database and Expert Systems Applications (DEXA '05)*, 226-230.

Mozer, M.C. (2004): Lessons from an Adaptive House. In *Smart Environments: Technologies, protocols and applications*. Cook, D. and Das, R. Eds. 273-294.

Papadopoulou, E., Gallacher, S., Taylor, N. K. and Williams, M. H. (2010): Personal Smart Spaces as a Basis for Identifying Users in Pervasive Systems. *Proc. International Workshop on Ubiquitous Service Systems and Technologies (USST 2010)*, Xian, China, 88-93, IEEE CS Press.

Roman, M., Hess, C.K., Cerqueira, R., Ranganathan, A., Campbell, R.H. and Nahrstedt, K. (2002): Gaia: A middleware infrastructure to enable smart spaces, *IEEE Pervasive Computing* 1:74-83.

Roussaki, I., Kalatzis, N., Doolin, K., Taylor N. K., Spadotto, G., Liampotis, N. and Williams, H. (2010): Self-Improving Personal Smart Spaces for Pervasive Service Provision. In *Towards the Future Internet*, Tselentis, G., Galis, A., Gavras, A., Krco, S., Lotz, V., Simperl, E., Stiller, B. and Zahariadis, T., 193-203, IOS Press.

Si, H., Kawahara, Y., Morikawa, H. and Aoyama, T. (2005): A stochastic approach for creating context aware services based on context histories in smart Home. *Proc. 1st International Workshop on Exploiting Context Histories in Smart Environments, 3rd International Conf on Pervasive Computing (Pervasive 2005)*, 37-41.

SOCIETIES project website, <http://www.ict-societies.eu>

Strutterer, M., Coutand, O., Droegehorn, O. and David, K. (2007): Managing and Delivering Context-Dependent User Preferences in Ubiquitous Computing Environments. *Proc. International Symposium on Applications and the Internet Workshops (SAINTW '07)*.

Sun, J. (2001): Mobile ad hoc networking: an essential technology for pervasive computing. *Proc. International Conference on Info-tech & Info-net*, 316-321.

Williams, M. H., Taylor, N. K., Roussaki, I., Robertson, P., Farshchian, B. and Doolin, K. (2006): Developing a Pervasive System for a Mobile Environment. *Proc. eChallenges 2006 - Exploiting the Knowledge Economy*, 1695 - 1702.

Youngblood, M.G., Holder, L.B. and Cook, D.J. (2005): Managing Adaptive Versatile Environments. *Proc. 3rd IEEE International Conference on Pervasive Computing and Communications (PerCom '05)*, 351-360.

Zaslavsky, A. (2002): Adaptability and Interfaces: key to efficient pervasive computing. *Proc. NSF Workshop on Context-Aware Mobile Database Management*, 24-25.

Ziebart, B. D., Roth, D., Campbell, R. H. and Dey, A. K. (2005): Learning Automation Policies for Pervasive Computing Environments. *Proc. 2nd International Conference on Autonomic Computing (ICAC '05)*, 193-203.