Linking between Personal Smart Spaces

Sarah Gallacher, Elizabeth Papadopoulou, Nick K. Taylor,
M. Howard Williams, and Fraser R. Blackmun

School of Maths and Computer Sciences, Heriot-Watt University,
Riccarton, Edinburgh, EH14 4AS, UK
{S.Gallacher,E.Papadopoulou,N.K.Taylor,
M.H.Williams,F.R.Blackmun}@hw.ac.uk

Abstract. One approach to the development of pervasive systems is based on the notion of Personal Smart Spaces (PSSs). A PSS is implemented as an ad hoc network and may be either fixed or mobile. When one PSS encounters another, communication is established between them. This may be used to alert one user to the presence of another, or a fixed smart space to the presence of a mobile user. There is considerable potential for applications using this type of functionality and it could become an important component of pervasive systems in the future. However, one problem with this is that it is difficult to detect when one PSS is close enough to another to be relevant. The Persist project has built a pervasive system based on PSSs and investigated the problems of their interaction in order to demonstrate this functionality. This paper discusses the problem of proximity and attempts to address it.

Keywords: Pervasive systems, smart spaces, ubiquitous systems, inter-PSS communication.

1 Introduction

One of the key objectives of a pervasive system is to provide support to enable the user to interact easily with and control the myriad of devices in the environment surrounding him/her. Many different researchers have been engaged in finding solutions to different aspects of this problem, and from this research two main approaches have emerged. The first is focused on fixed smart spaces which support users while they are present in the space; typical of this type of system is the Smart Home (e.g. Adaptive House [1], MavHome [2], GAIA [3], Synapse, Ubisec [4], etc.). The second approach is focused on the mobile user and provides support wherever he/she may go. Examples of this type of system include Daidalos [5], Mobilife, Spice, etc.

A novel approach to the development of pervasive systems is based on the idea of a Personal Smart Space (PSS) - this was developed in part to bridge the gap between fixed and mobile pervasive systems. It is based on the use of ad hoc networks as a means of communication within a PSS and for interactions between different PSSs.

The PSS approach has a number of advantages. One of these is the possibility of using the detection of another PSS to trigger particular actions. For example, when one mobile PSS encounters another which it recognises, it could alert the user to the

P. Sénac, M. Ott, and A. Seneviratne (Eds.): MobiQuitous 2010, LNICST 73, pp. 401–408, 2012.

presence of the other user (by name and/or other details). Similarly, when a mobile PSS comes within range of a fixed PSS, the fixed PSS may respond appropriately.

The PSS approach and some of the challenges and new functionality that it offers, have been investigated in the Persist project, a European research project funded under Framework Programme 7. Within Persist a pervasive system has been developed based on PSSs. This system has been demonstrated at several conferences and the open source code of the platform is available to download from the Sourceforge website [6]. In the course of developing this pervasive system one of the problems that was encountered, was the difficulty in detecting when one PSS is close enough to another to be considered relevant and the appropriate action triggered. This paper is concerned with this problem and attempts made to address it.

The next section provides a brief overview of the notion of Personal Smart Spaces while section 3 describes two scenarios used to demonstrate the functionality discussed. Section 4 discusses the issue of how close a PSS needs to be, to be relevant. Section 5 considers the problem of determining proximity and attempts to address this. Section 6 concludes.

2 Personal Smart Spaces

Fixed smart spaces suffer from the problem that while they provide support for the users who occupy them, when a user leaves such a space, the support provided disappears. The net result is that one will end up with "islands of pervasiveness" within which fully functional pervasive services are provided, but outside of which there is limited (if any) support for pervasive features. Although research has also been carried out on systems to support mobile users, the problems here are somewhat different and these two types of system are generally quite independent of each other.

The notion of a Personal Smart Space [7] was introduced to integrate fixed smart spaces and mobile systems in a clean and consistent fashion. The result is that the user will have a degree of pervasive support at all times, which is enhanced by additional functionalities provided by other PSSs whenever these are sufficiently close to the user.

A Personal Smart Space may be defined as "the set of services that are running or available within a dynamic space of connectable devices where the set of services and devices are owned, controlled, or administered by a single user or organisation". More specifically, a PSS must have the following three essential properties:

(1) A PSS must have an "owner". From the above a PSS consists of a collection of devices and services that are owned, controlled or administered by a single user or organisation and that work together on behalf of the person or legal entity that owns it. As such it forms a pervasive subsystem on behalf of its owner. From the point of view of personalisation it maintains a set of preferences of the owner that are used to personalise the behaviour of the PSS and its services, and, by extension, services from another visited PSS, subject to group conflict resolution on those preferences (where two different PSSs have different requirements for the same service at the same time), both proactively and by reacting to changes in the environment.

(2) A PSS may be mobile or stationary. If a PSS is owned by a person, its physical boundary will move around with the user whereas a PSS associated with a building (e.g. railway station, airport, hospital) will be stationary. Both types of PSS have exactly the same architecture but differ in the devices and third party services that they offer. In the case of the mobile user the preferences are those of the user who owns it; in the case of a stationary PSS (e.g. office, railway station, etc.) they are those of the organisation or user (in the case of a smart home) that owns it.

(3) A PSS must be able to identify and interact with other PSSs. By using an ad hoc network, a mobile PSS can interact with other mobile PSSs or with a stationary PSS to exchange information or access services. Access to information and services is governed by a set of rules defining admissibility to the PSS. A simple example of mobile-stationary interaction is when a mobile PSS enters the railway station and asks the station PSS for platform information.

In addition to these three characteristics, a PSS must also possess the general properties that are normally associated with a pervasive system. These include:

(4) A PSS must be context-aware, personalisable and adaptable.

(5) A PSS must be capable of pro-active behaviour.

(6) A PSS must be capable of self-improvement by learning from the user's interactions.

(7) A PSS must provide appropriate measures to protect the privacy of the user.

Thus a PSS can be realised as an ad hoc network which may interact with the networks of other PSSs when these are encountered. This has the advantage of not requiring any fixed infrastructure to be provided by Internet Service Providers or Mobile Network Operators, although it is able to take advantage of infrastructure when it is available. Thus users can deploy their own personal smart spaces, populating them with their mobile and fixed devices.

3 Two Scenarios

The prototype platform developed within Persist has been used to demonstrate the usefulness of this approach in a variety of scenarios. For this paper, two of these scenarios have been selected to illustrate the problem that is being addressed here.

3.1 Memory Support

The first scenario is a hypothetical case in which a PSS may be used in the future to provide memory support to users. The scenario is as follows:

"Arthur sometimes has difficulty remembering people's names. When he is in town, Arthur meets his old friend Bill. Arthur's PSS identifies Bill and tells Arthur Bill's name through his earpiece while displaying relevant information about Bill to help trigger his memory."

For this demonstration two PSSs are used. In Arthur's PSS text to speech generation is used to provide the information discreetly to him (through an earpiece).

We have also experimented with special spectacles to display information to the user although the technology available at this stage is not yet suitable for this.

3.2 Personalised Advertisement

The idea of personalised advertisements targeted at the user as he/she approaches a particular shop has been used by various researchers, e.g. [8, 9]. For our purposes the following scenario was used:

"As Jack approaches the Shopping Mall, the Shopping Mall PSS detects Jack's PSS, and from what is known about Jack's interests, it displays a personalised message to Jack on one of its large screens, alerting him to a special offer that is relevant to his interests."

Again two PSSs are used – in this case a mobile PSS owned by Jack and a fixed PSS in the shopping mall, hosting an advertising service that uses a large screen.

4 Problem of Detecting Proximity

Both of the scenarios in the previous section depend on one of the fundamental ideas underpinning the notion of the PSS, namely that when one PSS approaches another, the two establish communication between themselves. This is essential both for basic operation of the PSS as well as for the additional functionality they provide.

The way in which this is realized is through ad hoc networks. Thus when one PSS comes within range of another, an ad hoc network connection is established between them. The two can then exchange information. This includes an identifier that identifies the PSS – Digital Personal Identifier (DPI) – as well as advertisements, advertising the services that each is prepared to share with the other.

In the case of the memory support scenario, when Arthur's and Bill's PSSs come within range of each other, they will send out their DPIs on the ad hoc network. A third party service for memory support in Arthur's PSS checks whether it recognizes the new DPI and, if it does so, it relays the appropriate information to Arthur via a text to speech conversion package or interface to the special glasses.

A similar situation applies to the advertisement scenario. Again both PSSs identify each other. A third party service running in the shopping mall PSS recognizes Jack and directs an appropriate personalised advertisement to the large screen which it controls.

However, one problem with these two scenarios and with other similar ones in which one PSS is alerted to the presence of another is that of determining when a PSS is close enough to be "relevant". Different factors affect this decision and, in general, the problem is non-trivial. In our investigation we have focused on the distance between the PSSs although one may argue that this will also depend on other contextual factors such as the density of other PSSs around them and their directions of travel relative to each other as well as personal factors such as the relationship between the owners of the two PSSs and the need for them to communicate. However, these additional factors will not be addressed here.

Consider some typical cases:

(1) In the case of the memory support scenario Arthur and Bill need to be close enough to be within "greeting" distance of each other – say 10 metres.

(2) However, suppose that Arthur had agreed to meet Bill and was looking out for him. In this case one would want the third party service to alert Arthur when Bill was within "approaching" distance – say, 50 metres.

(3) In the case of the advertisement scenario Jack needs to be close enough to the screen to have his attention drawn to it. This "viewing" distance may be between, say, 5 and 20 metres depending on the screen size.

(4) If, instead of a shopping mall, Jack was hurrying to the station to catch a train, he might want to establish communication with the station PSS as early as possible to determine whether the train is on time and what platform it is leaving from. This "early contact" distance will be the limit at which the two PSSs can join in an ad hoc network.

Besides these four cases there are obviously others that need to be considered in the future. However, this research did not take this further but instead focused on the problem of separating distance as described in the next section.

5 Problem of Determining Proximity

Besides the complex problem of determining when one should alert one PSS to the presence of another, there is another problem – that of determining when one PSS is close to another. Within the Persist project the issue of proximity has been investigated in depth, utilising techniques such as indoor locationing (Ubisense) and outdoor locationing (GPS) to identify PSS locations and determine distances between them [10],[11]. However, this work is reliant on the availability of locationing infrastructure and hence cannot provide proximity information when such infrastructure is not available. In contrast, the PSS must be capable of providing pervasive support even outside areas of infrastructure support to fulfill the aim of the PSS acting as a bridge between islands of pervasiveness.

To address this problem, two solutions were considered involving ad-hoc network connections with no dependency on external infrastructure beyond the PSS device itself. The solutions, testing and results are described below.

5.1 Using Wireless Network Alone

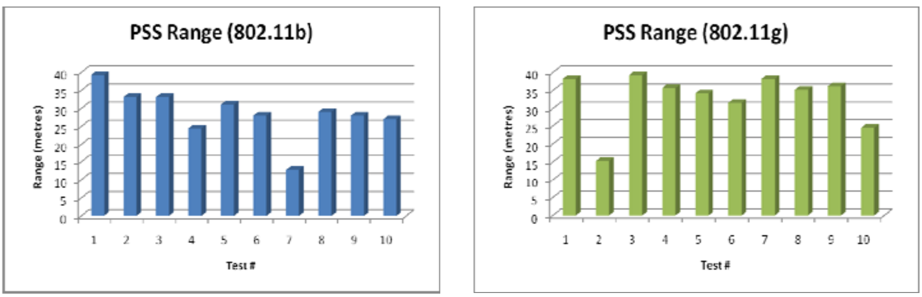
Initially a simple ad-hoc wireless connection was used to determine proximity. The act of one PSS connecting to an ad-hoc network alerted the other PSSs already on the ad-hoc network that another PSS was close by. However, since different wireless technologies are available, with different ranges, a quantitative analysis was performed to investigate the PSS range over different wireless technologies. Specifically the 802.11 protocols *b* and *g* were utilised for inter PSS communications to investigate their utility for identification of PSSs in close proximity.

Two laptops were used, each acting as a mobile PSS. Each device ran the latest release of the PSS platform under Windows XP. An ad-hoc wireless network was created between the two devices and they were configured with static IP addresses.

For the first set of tests, both devices were configured to use the 802.11b protocol. The PSS platform was launched on each device and one was left stationary while the other was moved away until communication between the two was lost. The distance between the two was then recorded. This process was repeated 10 times with the mobile PSS moving in different directions through the test building each time. For the second set of tests the same process was followed with the devices configured to use the 802.11g protocol.

For the first 10 tests with 802.11b the PSS range lay between 13m and 39m. This variance in range was due to the interference (from walls, floors, etc.) experienced at different locations in the test building. The average PSS range across the 10 tests using the 802.11b protocol was 29m.

For the second 10 tests with 802.11g the PSS range lay between 15m and 39m. Again the variance was due to interference but the average PSS range across the 10 tests was slightly higher than the first set of tests, at 33m. The test results are shown graphically below.



(a) (b)

Fig. 1. Graphs showing the PSS range (in metres) using (a) the 802.11b and (b) the 802.11g wireless LAN protocols

The results show that there is a small difference between the PSS ranges using the wireless b and g protocols. On average the PSS range was wider when using the 802.11g protocol. However, the PSS ranges for both sets of tests are comparable.

Thus, in general, the distance at which one PSS detected another was quite large, and this was suitable for recognition at the limit. However, there was little difference between the two protocols.

5.2 Using Bluetooth in Addition to Wireless

The alternative approach that we investigated, was to use a combination of Bluetooth and ad hoc wireless connection. The aim here was to use the wireless network to establish a connection between two PSSs and hence to determine when they are at the limit with respect to one another. Then the Bluetooth connection could be used to determine when the two PSSs are close to one another.

Although much work has been done on the problem of using Bluetooth with mobile phones for proximity detection (e.g. [12], [13]), its use in more general situations is less straightforward. In particular, two problems were encountered:

(1) Suppose that a Bluetooth connection is established between two PSSs and then one moves out of range of the other with the result that connection is lost. If subsequently the two PSSs come back within range of each other, some operating systems do not provide the functionality to re-establish the connection automatically. Initial testing with Windows highlighted that, although a Bluetooth enabled peripheral device such as a keyboard or mouse can automatically reconnect without issue, there was no option provided for automatic re-establishment of other Bluetooth connections due to pre-configuration of their Bluetooth drivers for security reasons. The Linux OS does allow for Bluetooth connections to automatically reconnect; however, after much effort it became apparent that the task is non-trivial. After initially establishing a TCP IP persisted connection over Bluetooth, network interfaces on the laptop devices would fail to re-establish themselves after losing connection with each other, resulting in non-deterministic reconnection behaviour.

(2) Suppose that a PSS has established an ad hoc wireless connection with more than one other PSS, then if it now finds a Bluetooth connection with one of these, there is no simple way of determining to which PSS the Bluetooth link belongs. Ideally the Bluetooth advertisement should contain some means of identifying the PSS – the most obvious being the related DPI. This would allow other PSSs to perform mappings between DPIs and Bluetooth Ids.

6 Summary and Conclusion

The notion of a Personal Smart Space (PSS) provides a useful approach for building pervasive systems which combines the fixed smart space and the mobile one. One consequence of this approach is that it also provides a basis for additional functionality to identify other PSSs in the near environment and raises the possibility of a range of new types of services based on the interactions between PSSs. This may be one mobile PSS encountering another, or a mobile PSS encountering a fixed one. This paper is concerned with some of the issues around providing this functionality.

In the Persist project a pervasive system has been developed based on PSSs. This system has been used to demonstrate a number of scenarios, in particular in relation to new services. This paper describes two of these. The first is concerned with memory support for recognising people, but could be used in a range of different types of situations, including support for people in the early stages of dementia, partially sighted or blind users, users at large meetings, conferences, conventions, etc. The second relates to recognising passers-by to target personalised advertisement towards them. This too could be used in a variety of other applications to support users in smart buildings.

For these applications it is necessary to determine when two PSSs are in close proximity. This paper is focused on one aspect of this, namely that of the separating distance between two PSSs. Other factors that should also be considered include contextual factors such as the density of other PSSs around them and their directions of travel relative to each other as well as personal factors such as the relationship between the owners of the two PSSs and the need for them to communicate.

Section 5 discusses the problem of determining the proximity of another PSS without relying on additional infrastructure. Two approaches were tried but, although the research is still only at a very preliminary stage, only one was found useful. The problem of determining when a user is nearby (say, within the same room or within 10 metres) remains an issue. It is hoped that this will be further studied in the Societies project.

Acknowledgments. This work is supported by the European Union under the FP7 programme (Persist and Societies projects) which the authors gratefully acknowledge. The authors wish to thank all colleagues in the Persist project developing Personal Self-Improving Smart Spaces. However, it should be noted that this paper expresses the authors' personal views, which are not necessarily those of the Persist consortium. Apart from funding these two projects, the European Commission has no responsibility for the content of this paper.

References

1. Mozer, M.C.: Lessons from an Adaptive House. In: Cook, D., Das, R. (eds.) Smart Environments: Technologies, Protocols and Applications, pp. 273–294 (2004)
2. Youngblood, M.G., Holder, L.B., Cook, D.J.: Managing Adaptive Versatile Environments. In: 3rd IEEE Int. Conf. on Pervasive Computing and Communications (PerCom 2005), pp. 351–360 (2005)
3. Román, M., Hess, C.K., Cerqueira, R., Ranganathan, A., Campbell, R.H., Nahrstedt, K.: Gaia: A middleware infrastructure to enable active spaces. IEEE Pervasive Computing 1, 74–83 (2002)
4. Groppe, J., Mueller, W.: Profile Management Technology for Smart Customizations in Private Home Applications. In: Andersen, K.V., Debenham, J., Wagner, R. (eds.) DEXA 2005. LNCS, vol. 3588, pp. 226–230. Springer, Heidelberg (2005)
5. Williams, M.H., Taylor, N.K., Roussaki, I., Robertson, P., Farshchian, B., Doolin, K.: Developing a Pervasive System for a Mobile Environment. In: eChallenges 2006 – Exploiting the Knowledge Economy, pp. 1695–1702. IOS Press, Amsterdam (2006)
6. PSS platform open source, http://sourceforge.net/projects/psmartspace
7. Crotty, M., Taylor, N., Williams, H., Frank, K., Roussaki, I., Roddy, M.: A Pervasive Environment Based on Personal Self-improving Smart Spaces. In: Gerhäuser, H., Hupp, J., Efstratiou, C., Heppner, J. (eds.) AmI 2008. CCIS, vol. 32, pp. 58–62. Springer, Heidelberg (2010)
8. Apple's iAd, http://www.independent.co.uk/life-style/gadgets-and-tech/news/how-apples-new-iphone-brings-minority-report-a-step-closer-to-reality-1940723.html
9. Digital Signage Promotion Project, http://www.google.com/hostednews/afp/article/ALeqM5iDd1xzYx7CaahlxkLnvo4Xtcksug
10. Frank, K., Robertson, P., McBurney, S., Kalatzis, N., Roussaki, I., Marengo, M.: A Hybrid Preference Learning and Context Refinement Architecture. In: PERSIST Workshop on Intelligent Pervasive Environments, AISB 2009, Edinburgh, pp. 9–15 (2009)
11. Khider, M., Kaiser, S., Robertson, P., Angermann, M.: A Novel Movement Model for Pedestrians Suitable for Personal Navigation. In: ION NTM 2008, San Diego (January 2008)
12. Kostakos, V., O'Neill, E., Penn, A., Roussos, G., Papadongonas, D.: Making sense of urban mobility and encounter data. ACM Trans. CHI (2010) (to appear)
13. Yoneki, E., Hui, P., Crowcroft, J.: Visualizing community detection in opportunistic networks. In: 2nd Workshop on Challenged networks (CHANTS), Montreal, Canada (2007)