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Indoor Ad Hoc Proximity-Location Sensing for Service Provider Selection

VICTOR AZONDEKON barbeau@scs.carleton.ca
Département de génie électrique et de génie informatique, Université de Sherbrooke, 2500 boul. de l'Université, Sherbrooke, QC, Canada J1K 2R1

MICHEL BARBEAU
School of Computer Science, Carleton University, 1125 Colonel By Drive, Ottawa, ON, Canada K1S 5B6

RAMIRO LISCANO
Mitel Networks, 350 Legget Drive, P.O. Box 13089, Kanata, ON, Canada K2K 2W7

Abstract. There are protocols that can be used by mobile clients to discover service providers in foreign networks to which they get attached, e.g., SDP of Bluetooth and SLP of IETF. These protocols do address service discovery, but do not address the selection of a service provider among a set of candidates according to a physical proximity of the client and service provider. The goal of the research described in this paper is to integrate proximity-based selection mechanisms to service discovery protocols. We present in this paper protocols that allow nomadic clients to discover and select service providers according to physical proximity.

Keywords: service discovery, service location, ad-hoc location sensing, protocols, networks, client–server

Introduction

Service discovery protocols enable service providers to advertise capabilities to potential clients, while also providing to clients and service providers a means for entering into relationship. Service Location Protocol (SLP) by Guttman et al. [4], Jini of Sun Microsystems [13], Bluetooth's Service Discovery Protocol (SDP) of Bluetooth Special Interest Group [2], Salutation of The Salutation Consortium [15], and Universal Plug and Play (UPnP) of Universal Plug and Play Forum [16] are protocols addressing service discovery. They are all likely to discover many service providers, which are relatively useless to a client at a given time by virtue of his/her inability to determine the appropriate service provider to use. This could be due to physical inaccessibility of a service provider (problematic in the case of a printing service provider) or the inability to determine its relative physical location (problematic in the case of a desktop telephone that can handle forwarded calls).

The solution to the issue is not simply a matter of being able to map the service providers to their geographical location. For instance, let us consider a client looking for a desktop telephone for call forwarding purposes. The client does not understand location information and is unaware of its exact location, i.e. he/she is a visitor with no maps. For the purpose of the selection according to close proximity, information about the geographical location of a service provider is not usable in the selection process. What is relevant is the relative location of the client with respect to a service provider. The detection of the existence of line of sight between the client and a service provider is a more useful piece of information as it confirms physical proximity, in indoor environments.

This issue is even more relevant in wireless networks where Radio Frequency (RF) is used as a medium for communications. RF can traverse physical obstacles. This presents problems for service discovery and selection according to physical proximity. All service providers within communication range are discovered. This inevitably includes service providers located in other rooms, on other floors or in other buildings. Being inaccessible, a large number of them are useless.

The problem addressed in this paper is the selection of service providers according to physical accessibility and relative location.

In this article, we propose an integration of a proximity-location sensing protocol to service discovery protocols. It allows a client to select a service based on its physical proximity. Two approaches are presented, one that can leverage one-way infrared communications and another that requires two-way infrared communications. The approach is said ad hoc because no infrastructure is required.

The rest of this paper is organized as follows. In section 1, we review related work. Section 2 discusses existing service discovery protocols. Section 3 describes the two proximity-location sensing service selection protocols we have created. In section 4, we review an implementation of the protocols. Finally, the conclusion is given in the last section.

1. Related work

Work related to ours is about indoor location sensing systems for mobile nodes (e.g., devices, people or processes) using infrared, RF or ultrasound. Location sensing technologies are addressing the needs for tracking, for example, people, inventory and baggage. We review work addressing location sensing. Work about using infrared for ad hoc communications is also related to ours and discussed afterwards.

Hightower and Berriello [6] have published a review about location systems. Their paper does a good job at identifying the characteristics of location systems, namely, physical versus symbolic location, absolute versus relative location, localized versus distributed computation, accuracy, scalability, recognition and cost. A system can sense either the physical location or symbolic location of a node. The physical location refers to latitude, longitude and altitude. A symbolic location refers to a place such as a building, a highway or a room. A physical location can be translated to a symbolic location if maps are available. A sensed location can be absolute or relative. Absolute location sensing requires a common reference framework. In contrast, with relative location sensing each node has its own reference framework. An absolute location can be translated to a relative location, through transformations of coordinates from the absolute framework to the relative framework. The process of sensing the location can be localized to the mobile node. It means that it can receive signals and information from its environment, but it is not transmitting any data. This is useful for location hiding and privacy. Otherwise, it is distributed and the computation of a location is the result of cooperation between non co-located entities. The accuracy of a location system can refer to a numerical value (e.g., within a certain distance) or to a symbolic concept (e.g., within a room). Scalability refers to the coverage and the number of nodes that can be handled by a location system. Recognition is a feature that enables association of an identity to a located node (e.g., a phone number, an owner name). The cost can be estimated in terms of installation and maintenance expenditures, time or space.

In addition to these seven properties, location systems can be classified according to whether they are for indoor or outdoor use and whether an infrastructure has to be put in place (e.g., network of sensors, databases) or not. In that latter case, the system is said ad hoc location sensing. In addition, every location system has limitations. For example, all systems using infrared or RF are subject to interference, including ours.

The GPS is a widely used location system. It locally computes a physical and absolute location within accuracy as good as one meter. Its scale is the entire earth. It does not recognize the identity of nodes. It relies on a multi-billion dollars infrastructure of satellites. It is a location system basically designed for outdoor use because signals from satellites are blocked by walls and roofs. It can, however, be extended for indoor use with the installation of GPS repeaters in buildings.

Exact Location Identification, of Sinha and Das [12], is another type of location system for outdoor use. It is an infrastructure consisting of a master and base stations. Triangulation is used to find the physical absolute location of identified mobile nodes. The computation is distributed because messages are exchanged between the mobile nodes and based stations. Exact Location Identification is a feature that can be added to a cell phone network, which determines the scale and mitigates the deployment cost. The system works well in the absence of signal reflection; otherwise the accuracy is considerably affected. Hereafter, we focus our attention on location systems for indoor use.

In the Active Badge location system of Want et al. [18], electronic badges periodically send using broadcast infrared their unique identity. A network of sensors receives the signals and reports locations of badges to a central database. An absolute symbolic location is computed. Computation is distributed and with an accuracy of a room. Identities of nodes are recognized. The infrastructure of the Active Badge location system can be deployed within a building, which represents a significant initial investment.

As in the Active Badge location system, in the Active Bat location system of Harter et al. [5] there are wearable electronic badges. RF is used to trigger the ultrasound transmitters in the badges. According the authors, the accuracy of their system is better (nine cm versus the size of a room). The exact locations of people (wearing active badges) and pieces of equipment (tagged with active badges) within an organization can be tracked with this system. Cricket is another location system along those lines, by Priyantha et al. [9]. It is also ultrasound based, but less costly and less accurate.

It is worth discussing the use of RF signal strength for the purpose of physical location sensing. Two such location systems are RADAR, by Bahl and Padmanabhan [1], and SpotON, by Hightower et al. [7]. RADAR uses an 802.11 infrastructure wireless local area network and scene analysis or triangulation. SpotON is an ad hoc location sensing system. In contrast to the other approaches, RF location-sensing systems are probabilistic. Foundation work has been done by Seidel and Rapport [11].

All the aforementioned work about location sensing relies on the deployment of an infrastructure, except for SpotON. Our approach is of the ad hoc location sensing type. It does not require networks of sensors. It is distributed. Clients and service providers cooperate to sense proximity. It computes a symbolic relative location in a distributed manner. In contrast, SpotON computes a physical location. In our system, identities of nodes are recognized. Coverage of our location sensing system is limited to a room, which in this case is an exploited property. The installation of an infrastructure is not required, only infrared transceivers in nodes are needed. Several types of the personal digital assistants, laptops, notebooks and printers come with an installed infrared transceiver. Considering that, the cost is extremely low. In contrast, SpotON needs special hardware and calibration. Our approach requires neither special hardware nor calibration.

The Smart-Its Friends proximity-location sensing technique is worth mentioning, by Holmquist et al. [8]. Devices are equipped with movement sensors and transceivers. The following heuristic is used. Two devices are considered in proximity if the recent movement to which they have been subject are the same. When a movement is sensed by a device, it is sent using broadcast along with the identity of the device. The transmission is received and compared by other devices with their own sensed movement.

Work leveraging infrared communications for the purpose of face-to-face contacts between users has inspired us, in particular the Meme Tag project of Borovoy et al. [3]. A meme tag is an electronic name tag used to collect memes during meetings of people. A meme is an idea or an opinion expressed as short text. This meme tag uses the Infrared Data Association (IrDA) communication protocol to exchange memes during face-to-face contacts.

2. Service discovery protocols

Service discovery protocols play a key role in mobile and wireless networks. They provide to the mobile nodes a functionality that enables them to advertise and discover service providers. There is a number of existing service discovery protocols. These include Jini of Sun Microsystems [13], Service Location Protocol by Guttam et al. [4], and Service Discovery Protocol of Bluetooth Special Interest Group [2]. They are discussed in more detail in the sequel.

2.1. Jini

Sun Microsystems has developed a distributed service-oriented architecture called Jini for the Java programming environment. It runs above RMI (TCP and IP). Service providers can represent hardware devices, software programs or a combination of both. They are all accessed in a uniform manner. Service providers look for and register offers with lookup servers. Registration means uploading, in a lookup server, a service object and values of descriptive service attributes. Clients look for services by contacting the lookup servers and sending requests with conditions on service attributes. When requests can be granted, service objects are downloaded in the clients. They serve as local proxies to the remote service providers.

Jini can work without lookup servers by using a technique called peer lookup. With the peer lookup approach, the clients request particular services by sending messages called identifications. Registration messages are returned directly by the service providers to the clients, which hence get the service object and service attributes.

2.2. Service Location Protocol

The Service Location Protocol (SLP) is a service discovery protocol designed for IP networks. It runs above UDP. SLP defines three types of agents: User Agent (UA), Service Agent (SA) and Directory Agent (DA). UAs are clients, SAs are service providers and DAs are repositories of service advertisements.

The flow of interactions in SLP is as follows. DAs advertise their presence to UAs or SAs with the Directory Agent Advertisement (DAAdvert) message. SAs respond to this message using the Service Registration (SrvReg) message to register service offers. A service offer consists of a URL and values of descriptive attributes. A URL is a service access point (SAP) to a service provider, in other words it provides all the information required to establish a communication.

UAs send using unicast the Service Request (SrvRqst) message to DAs, which respond with the Service Reply (SrvRply) message. A SrvRply message contains one or several URLs. UAs can communicate directly with the SAs, which are discovered by sending the SrvRqst message using broadcast. The SAs may reply with the SrvRply message or the Service Agent Advertisement (SAAdvert) message.

SLP is used in enterprise networks, but to the best of our knowledge it has not yet been augmented with mechanisms to select service providers according to close physical proximity.

2.3. Bluetooth's Service Discovery Protocol

The Service Discovery Protocol (SDP) provides a means to client applications for locating available server applications, and learning about their characteristics, on Bluetooth ad hoc networks. In contrast to Jini and SLP, the IP protocol is not involved.

A flow of interactions is pictured in figure 1. A SDP client sends using unicast a SDP Request message to a SDP server. The SDP server maintains a list of service records that describe the characteristics of services, i.e. descriptive attributes. There is a maximum of one SDP server per Bluetooth device (there is no SDP server on a Bluetooth device that acts as a client only). The server returns a SDP Response message

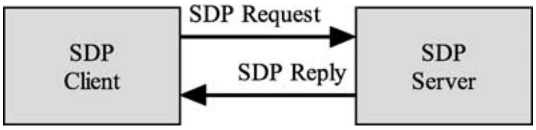

Figure 1. SDP Client-server Interaction.

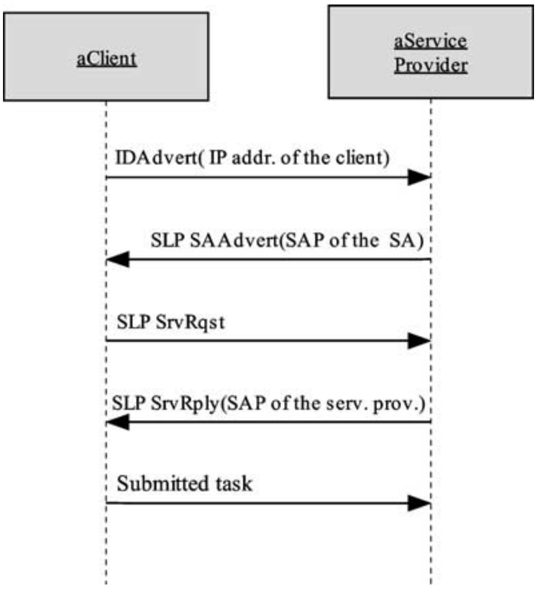

Figure 2. The IDAdvert protocol.

to the client. A client must open a separate connection to the service provider in order to use the service.

3. Proximity-location sensing service selection protocols

Service discovery protocols can be augmented with close proximity-location sensing elements. To this end, we define two protocols that exploit infrared communications, namely the IDAdvert and SetIrdLink protocols. We show how they can be integrated to SLP.

3.1. The IDAdvert protocol

This IDAdvert protocol uses one-way infrared communications from clients to service providers. Each client must have an infrared transmitter and each service provider must have an infrared receiver. Clients and service providers must be attached to a common network and support a service discovery protocol. Hereafter, it is assumed that SLP plays that role. Figure 2 pictures a sequence diagram for this proximity-location sensing service selection protocol.

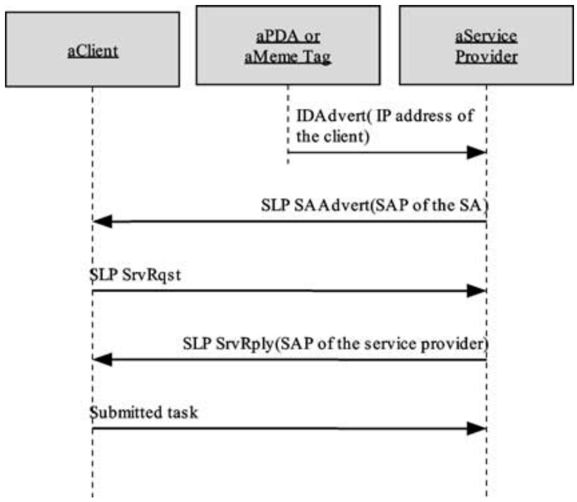

Figure 3. The IDAdvert protocol with distributed functionality on the client side.

Possibly triggered by an human action, the client sends to the service provider the IDAdvert message using infrared. IDAdvert contains the IP address of the client. This message is received only if there is line of sight and close proximity between the client and service provider. Reception of the IDAdvert message triggers the SLP SA on the service provider. SLP operates over the common network. Upon reception of the IDAdvert, the service provider replies with a SLP SAAdvert message. Hence, the SAP of the SA is communicated to the client.

Upon reception of the SAAdvert message, the client sends a unicast SLP SrvRqst message to the service provider, which replies with a SLP SrvRply message containing a SAP and descriptive attributes of the service provider. The client then submits its task to the service provider using the SAP.

An alternative scenario is pictured in figure 3. A separate device, such as a Personal Digital Assistant (PDA) or Meme Tag, transports the IP address of the client, has an infrared transmitter and sends the IDAdvert message on behalf of the client. Apart from that, the rest of the scenario is as in figure 2.

3.2. The SetIrdLink protocol

The SetIrdLink protocol uses two-way infrared communications. The clients and service providers must have infrared transceivers. They must be attached to a common network and support a service discovery protocol. It is assumed that SLP plays that role. Figure 4 pictures a sequence diagram for this proximity-location sensing service selection protocol.

Firstly, a client sends, using broadcast, a SLP SrvRqst message to gather a list of SAPs of service providers attached to the network. SLP operates over the common network. A number of service providers reply with the SLP SrvRply message. In figure 4,

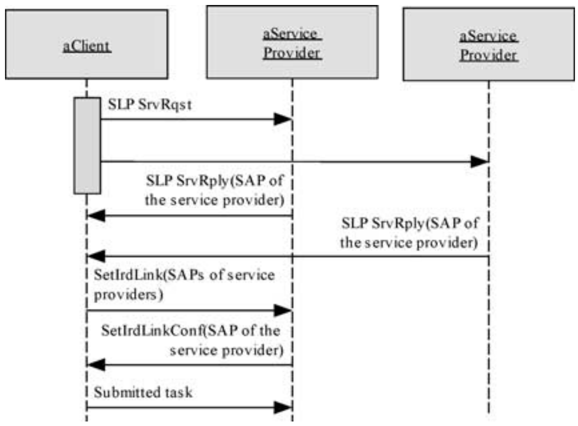

Figure 4. The SetIrdLink protocol.

two service providers return a SrvRply. Each one contains the SAP of a service provider. One of them is *near* while the other is *far*.

To assess physical proximity, the client sends through its infrared transceiver the Set Infrared Link (SetIrdLink) message. It contains a list of the SAPs of the service providers that were obtained with the SrvRply messages. Since infrared is capable of only line of sight and short distance communications, only the near service providers (the ones within infrared reach) receives the SetIrdLink message and replies with a Set Infrared Link Confirmation (SetIrdLinkConf) message. The SetIrdLinkConf message contains the SAP of a service provider. The client then submits its task to the service provider.

An advantage of this protocol is that the entity advertising the service (e.g., a SA) and the service provider (participating in the infrared communications) do not have to be neither co-located nor synchronized during the discovery and selection process.

4. Implementation

A primary interest in developing these proximity-location sensing protocols is to facilitate the registration of mobile users for location-based communication applications like follow-me, presence-enabled communications and hot desking. A follow-me application forwards a user's communication requests to devices that are located near its location. Presence-enabled communication applications notify users of the availability, location, status and contact information of any services and persons that are willing to commence a communication session with the user. Hot desking allows employees without permanent office locations to register with a particular office environment and have all their communication requests forwarded to the devices in that particular office.

User registration is commonly done by accessing a registrar server using a client application. In our case there is a presence and availability service that mobile users can register their location and contact information with. When a user of the system registers

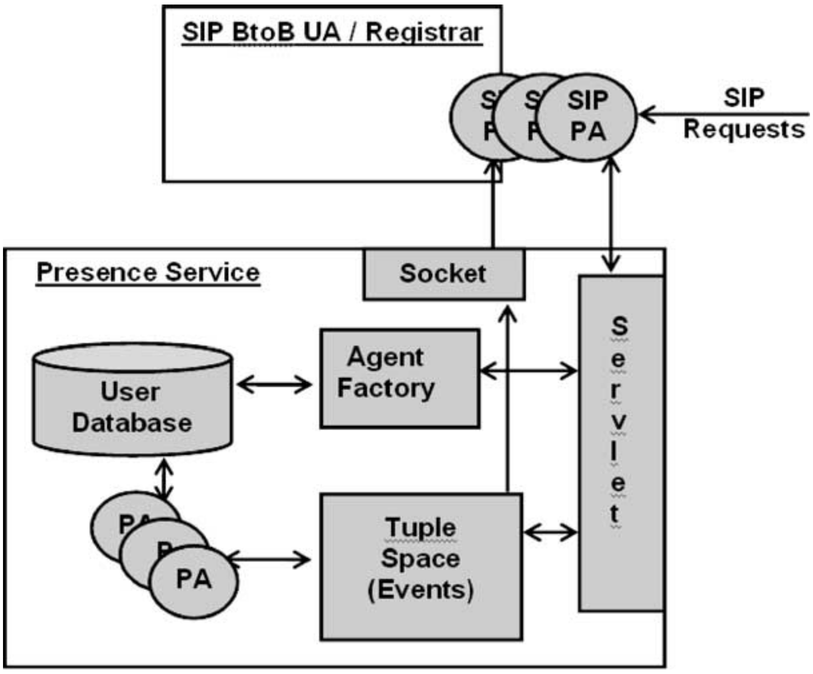

Figure 5. Components of the presence service.

its new location with the presence framework all other users subscribed to watch this particular user's availability will be notified of the new location and contact address information for the user.

This presence framework is compliant with the SIMPLE presence specification, of Rosenberg et al. [10], and leverages the Session Initiation Protocol (SIP) Register method as a way for users to specify that they are available. Figure 5 shows the basic components of the presence framework.

The SIP Register method, a type of SIP Requests, contains contact information that is stored in the SIP Presence Agents (PAs). This contact information is sent to users that have successfully subscribed to the user's availability. The contact information defines a communication service and is similar to that used by SLP. There is no particular service defined for telephony by the SLP standard. We have adopted the telephony Uniform Resource Identifier (URI) specification based on the RFC 2806 by Vaha-Sipila [17]. This URI is used to specify the SAP in the SLP service specification. An example of a telephony service definition is shown below:

```
service : telephony : PBX/E164/4567;
          phone-context =' +16135922122'
```

This example defines the telephony family service and in particular a PBX service. The protocol is the E164 format and the address is extension number 4567. The telephony URI also defines a *phone-context* that is required by the E164 telephone numbering due

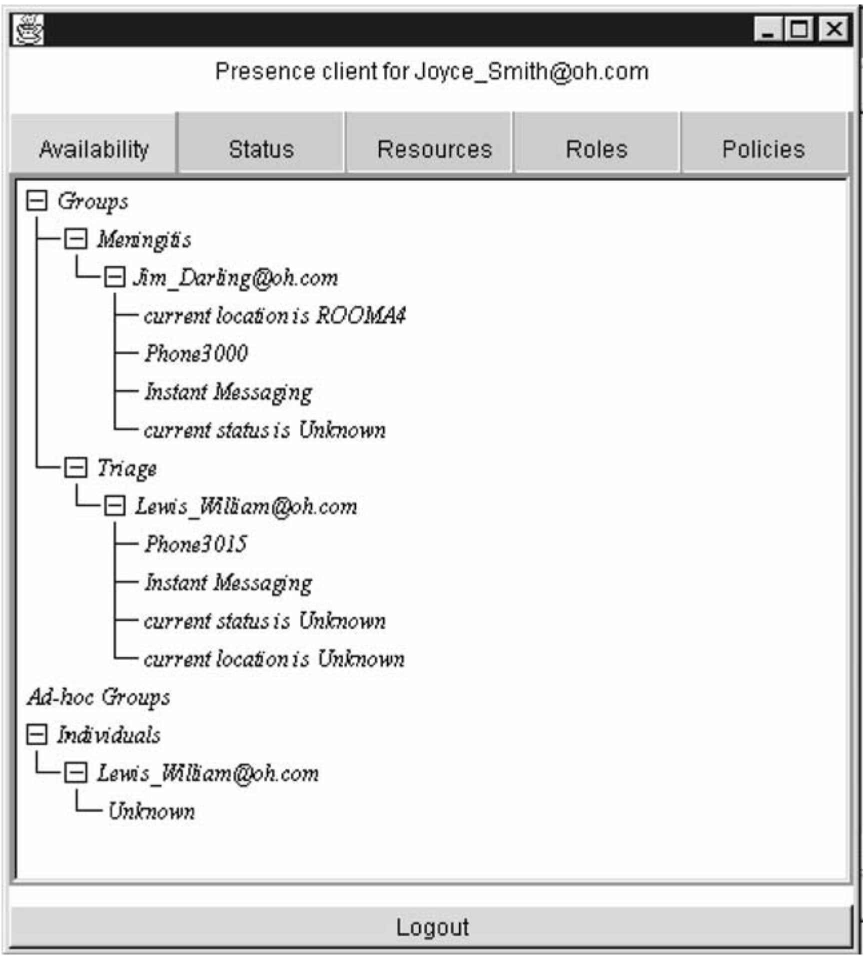

Figure 6. Presence client interface.

to the worldwide inconsistencies of telephone numbers. This service information is sent as contact information by the presence service.

A typical client window on our presence service looks like the one in figure 6. It presents to the user the availability of other persons that (s)he has subscribed to. For each person location, contact services and its activity are presented.

The IDAdvert and SetIrdLink proximity-location sensing protocols are used to acquire form a phone set its service and register this as the contact information in the presence server. The scenario implemented is one where a user visits a lab where (s)he would like to be available for voice conversations through a particular phone in the lab. These phones are equipped with ports that support IrDA communications with personal digital assistants (PDAs). The flow of discovery messages is pictured in figure 7 for the IDAdvert protocol. Messages are relayed to the phone over an Object Exchange (OBEX) protocol. Message types are identified by OBEX file types. In our case, a task

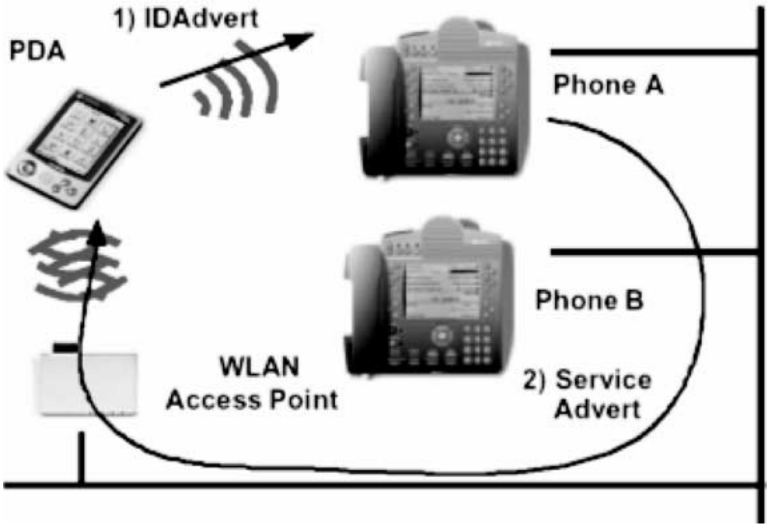

Figure 7. The IDAdvert protocol in action.

Figure 8. IrDA enabled phone set.

in the phone services SLP message that are received via OBEX requests. This task is an SLP service agent registered as an OBEX service routine. We see a user interacting with the phone in figure 8.

The mobile user has a PDA enabled with both IrDA and RF communications. For this particular implementation a Palm OS PDA is used. It supports a Bluetooth LAN access profile that can open a PPP connection to the network.

In order leverage the IDAdvert association protocol, a presence client has been developed which integrates both the IDAdvert protocol with the SIP SIMPLE protocol. The user has a window where (s)he can input its name and trigger the sending of the

IDAdvert message to the phone via IrDA. On reception of this message, an association firmware on the phone set sends a SAAdvert message to the application on the PDA. After the PDA application has acquired the telephone's SAP it extracts the telephone URI and uses it in a SIP Register message. In particular this information is coded in the contact information of the registration message.

Note that in this example the PDA application does not actually use the SAP that it receives from the telephone, but it extracts the service information to send it to the presence service. This of course is due to the fact that the user is not actually trying to communicate using the telephony service, but (s)he is setting up the contact information for the presence service instead. This emphasizes the importance in understanding and standardizing service descriptions across applications.

The SetIrdLink protocol was not implemented to work on the actual phone set due to the phone sets inability to do two way OBEX communications. The SetIrdLink protocol was implemented to execute on a PDA but it was configured to communicate via an infrared receptor connected to a PC.

Implementation challenges

We originally built the SLP and SetIrdLink protocols on a PDA using Java 2 Micro Edition (J2ME) of Sun Microsystems [14]. We soon discovered limitations of the J2ME that are difficult to overcome. The first and foremost is J2ME's inability to handle broadcast and multicast of a datagram. We therefore use unicast to request for services. Secondly, is the inability of J2ME to specify the file name of an object when using the beamSend method of the Spotlet class on the Palm. The telephone sets use a predefined name that needs to be specified and that cannot be done so using beamSend. In order to solve this shortcoming of beaming, we have implemented the same protocols in the C language and we are using the existing infrared beaming capabilities on the telephone set.

5. Conclusion

Service discovery and selection according to physical proximity play an important role in networks. They let mobile users, who have no clear understanding of their environment, find service providers that are physically close and accessible. We have reviewed a number of existing service discovery protocols. None of them offers a native support for proximity-location sensing of service providers. This problem has received no attention in the past.

We have addressed this problem for the first time and developed two protocols, namely IDAdvert and SetIrdLink, which augment service discovery protocols; such has SLP, with proximity location sensing selection. The limited range and line of sight requirement of infrared communications are exploited. The IDAdvert protocol uses one-way infrared communications to trigger transmission of service advertisements, using the common network. Its advantage is simplicity. The SA and the service provider need to be synchronized or co-located. With the SetIrdLink protocol, service providers are discovered first using the common network then physical proximity is confirmed using two-way infrared communications. Its advantage is that the entity that advertises the service provider (the SA) and the entity that participates in the infrared communication (the service provider) are asynchronous and can be distributed.

In comparison to other location systems, our location system is ad hoc, for indoor use and subject to interference and congestion because we use infrared and RF. A symbolic and relative location (i.e. within the same room) along with an identity are computed in a distributed manner.

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Victor Azondekon has a M.Sc.A. from Département de Génie Electrique et de Génie Informatique, Université de Sherbrooke, 2002. His research topic is service selection in networks.

Michel Barbeau has a Ph.D. in computer science from Université de Montreal, 1991. He is currently a Professor in the School of Computer Science at Carleton University (Ottawa). His main research interests are telecommunications protocols and software engineering for telecommunications protocols with a focus on the following areas of application: pervasive computing, mobile and wireless networks and satellite telecommunications.

Ramiro Liscano Ramiro Liscano has a Ph.D. in systems design engineering from University of Waterloo, 1998. He is currently a Senior Research Engineer with the Strategic Technology Group at Mitel Networks (Ottawa). He is also an Adjunct Professor at Carleton University (Ottawa) and Dalhousie University (Halifax). His research topics are ad hoc communications, service specification and discovery, context-based presence and awareness, policy management and call processing protocols.