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Hui, Siu C;Fong, A C M;Lau, C T
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Unified personal mobile communication services for a wireless campus

Siu C. Hui
A.C.M. Fong and
C.T. Lau

The authors

Siu C. Hui and **C.T. Lau** are Associate Professors in the School of Computer Engineering at Nanyang Technological University, Singapore.

A.C.M. Fong is a Lecturer at Massey University, Auckland, New Zealand.

Keywords

Wireless technology, Mobile communications, Local area networks

Abstract

A wireless campus environment provides user mobility, as users are no longer tied to fixed locations to access the network. It also offers high network accessibility as network resources remain accessible after office hours. While existing communication applications can work in a wireless network, they are separate applications that often require different devices. This paper describes a personal communications system that integrates various services into a unified platform, providing a one-stop source for both information access and communication within a wireless campus environment.

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Introduction

A wireless campus environment can provide user mobility and service opportunities not possible with wired networks alone. Mobile personal communication services within such a wireless campus environment will enable students and academic staff to access information services and communicate with each other anytime, anywhere within the campus. These campus-wide wireless communication services may bring about new ways of distance learning and support the concept of learning anytime, anywhere.

Traditionally, the campus population uses conventional modes of communication such as internal mail and telephone to interact. They can also communicate electronically using services such as electronic mail (e-mail) (Hughes, 1998) and real-time online chat services such as Internet relay chat (IRC) (Oikarinen and Reed, 1993) or Microsoft's NetMeeting (Microsoft, 2001). While these existing applications can function in a wireless network environment, they are separate applications developed with a wired network model in mind. This paper describes a unified messaging service for personal communications in a wireless campus environment. It discusses problems and solutions associated with the implementation of a wireless campus environment. It also describes the development of "Personal Communicator", which is an easy-to-use Web-based application for unified messaging and secure online presence notification. Overall, this environment facilitates delivery of teaching materials and exchange of ideas among students and staff. The result is likely to be a more enriching learning experience for students.

The remainder of the paper is organized as follows. The next section describes the wireless campus environment in which our system operates. This is followed by a presentation of the system architecture for supporting wireless mobile communication services. The two major components in the architecture, namely unified messaging and secure online presence notification, are discussed in greater detail in subsequent sections. Next, the overall system user-interface and performance evaluation are presented, followed by a conclusion.

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Campus-Wide Information Systems
Volume 19 · Number 1 · 2002 · 27–35

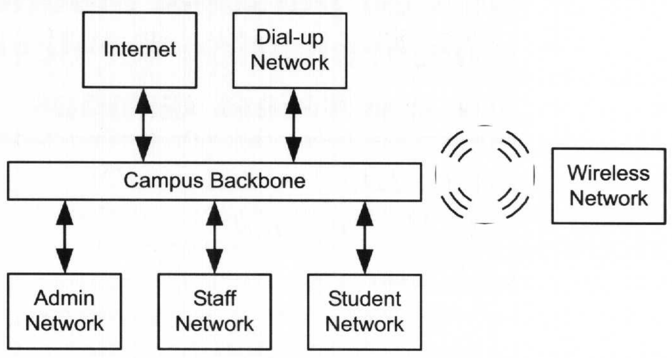
Wireless campus environment

The Nanyang Technological University's campus has installed a 100Mbps intranet network with a 2Mbps link to the Internet (CITS, 2001). The intranet has about 6,000 nodes spread across the buildings on campus. There are also about 300 56Kbps modem dial-up lines for remote access to the campus intranet. However, such massive network resources have limited utilization as access to the network has often been restricted by location and operating hours of computer rooms and laboratories.

A wireless local area network (LAN) (Geier, 1998) as an extension to the existing wired network backbone can provide higher accessibility and utilization of network resources. Using radio frequency technology, the wireless LAN transmits and receives data from one point to another over the air without relying on any physical wired connections. Thus, the wireless LAN supports user mobility and provides round-the-clock access to network resources. Also, the wireless network provides complementary network coverage as it is able to cover many more locations for network connections where in the past these were unreachable. A wireless LAN system can be installed easily without the need to pull cable through walls and ceilings. It also lessens the demand for space in setting up permanent computer clusters.

A wireless LAN typically supports a data rate between 2-10Mbps and a service range of several hundred metres. In a typical wireless LAN configuration, access points, which are essentially transceiver devices, connect to the wired network from fixed locations using standard cabling. Access points operate on the data link layer and are equivalent to network hubs in the wired domain. These access points receive, buffer, and transmit data between the wireless LAN and the wired network infrastructure. A single access point can support a small group of users and can function within a range of not more than a few hundred metres. By setting up access points all over the built-up areas of the campus, a wireless campus environment, as shown in Figure 1, is created for the university. The S$4 million campus-wide wireless network with 500 access points all over the entire 200 hectare campus provides wireless access for the whole university. Each access point covers a radius of about 30 metres. The network covers the university's hostels, lecture theatres, canteens, libraries, offices, meeting rooms and open areas.

Figure 1 Wireless campus environment



In recent years, the Internet has become an important communications medium, as it allows rapid transfer of information over a wide area. Therefore, besides integrating the wireless network to the existing campus intranet, the combination of wireless network technology and the Internet will provide many opportunities for enhancing mobile communication services for the campus community. In addition, it also enables academic staff and students to further exploit the rich repertoire of IT-based teaching and learning resources.

The reduction in size, weight and cost of notebook computers also make mobile personal communication services over the wireless campus environment more feasible at the users' end. These portable computing devices, featuring most of the necessary desktop computer's capabilities and applications, allow users to work anywhere and anytime. By using wireless LAN adapter PC cards, these computing devices can obtain wireless access transparently to the campus intranet and the Internet. Applications can thus be developed for these devices to support interactions among staff and students. These include services for accessing and sharing of information resources (e.g. teaching material), wireless messaging, real-time communication and remote learning (e.g. delivery of lectures over a distance).

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Campus-Wide Information Systems
Volume 19 · Number 1 · 2002 · 27–35

System architecture

Figure 2 shows the system architecture of the mobile communication service gateway. It consists of an information resource server (Chong *et al.*, 1999) that stores online lecture notes, tutorial assignments, and other information resources that can be accessed by staff and students, who have different levels of read/write privileges. These privileges are defined and managed by the University's Centre for Information Technology Services (CITS). This server combines with the server that provides administrative services for staff and students and the library's online public access catalogue (OPAC) server to form a complete online information resource center for the campus community.

The video streaming server (Chin *et al.*, 1998) provides support for real-time video streaming services. It supports both live broadcast of lectures and replay of previously recorded lectures. For live broadcast of a lecture, the session is captured by a video camera in lecture theatre and the audio-video stream is broadcast live over the network by the server.

For replay of previous lectures, the recorded lecture session is stored in digital video format and streamed at anytime and anywhere within the campus to any student who requests to review the lecture. To prevent network congestion, the number of users for video streaming service at any instance is limited. It can also be configured to suspend its operation during peak usage periods.

The wireless messaging server provides wireless unified messaging (Khuzadi, 1999) for e-mail, voicemail, fax, short message service (SMS) and paging. This unified approach is described in more detail in the next section. This is followed by a description of an open and secure protocol (Fong *et al.*, 2001) used by the online presence notification server to provide online presence information to online users and to act as a middleman for negotiation of real-time communication services such as instant messaging and text-based chat.

Unified messaging

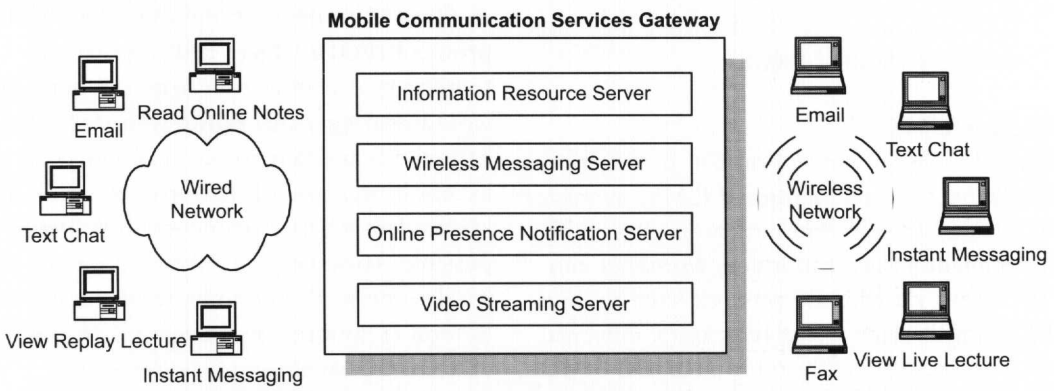
This section describes a unified messaging server in the context of a wireless campus environment.

Motivation

The Internet has traditionally been used as a textual messaging communication medium for electronic mail (e-mail) (Foo *et al.*, 1996; Hess *et al.*, 1998). Recently, it has also been used for real-time fax, voice and video communications (Chin *et al.*, 1998; Chong *et al.*, 1998). However, different equipment is needed in order to access the various communication services. The concept of unified messaging (Chong *et al.*, 1999) has been proposed for unifying various communication services into one single mechanism and a single user-interface, eliminating the need for multiple communication devices.

Unified messaging servers (UMS) such as JFax (JFax, 2001), 2bSURE (2bSURE, 2001), MessagePoint (Unified Messaging, 2001) and iPost Universal Messaging (Mediagate, 2001),

Figure 2 Mobile communication service gateway



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Campus-Wide Information Systems
Volume 19 · Number 1 · 2002 · 27–35

have been developed to support e-mail, fax and voicemail for users. These systems use the concept of a "universal inbox" (Hurwicz, 1997) for users to store and retrieve their messages. This allows different media components and messages to converge upon a single point of retrieval for the recipient and also provides a single point of message dispatch. UMS gives each of their users a single phone number, which can be used to receive fax, voicemail and pager messages. In these UMS, the e-mail system is typically used as the underlying transportation and messaging mechanism. Users are provided with an e-mail account, and the e-mail storage space then acts as the user's universal inbox. Therefore, UMS users can view their messages via e-mail client software or e-mail Web site. In addition, users may also retrieve their messages via other devices apart from the standard equipment. For example, users may listen to their e-mail via text-to-speech (TTS) on a telephone or view fax via e-mail software. Within the context of a single user-interface, the user can read, delete or store all types of messages. Users can also send outbound messages to various communications devices. This approach has many advantages:

- *Efficiency*. Users check one inbox rather than multiple e-mail accounts, fax machines and voicemail systems. The universal inbox may also eliminate delays in message reception that are due to infrequent checking by the user.
- *Ease of use*. Users only need to learn to interact with one interface.
- *Enhanced features*. Enhanced features can be incorporated into existing communication services. For example, through text-to-speech conversion, users could listen to their e-mail over the phone. Users can also be alerted to new incoming messages via their pager.

Wireless UMS

Figure 3 shows a wireless unified messaging environment. As in traditional UMS, messages can be sent via telecommunication devices to the recipient's universal inbox. Messages can also be sent via wireless network from mobile computing devices to the recipient's universal inbox or directly to telecommunication devices such as fax machine, pager or mobile phone. To do this, the sender needs to compose his message on his mobile computing device and deliver it via the wireless network to a unified messaging server connected to the Internet. When the message reaches the server, the server will format it to the standard transportation format and deliver the formatted message to the recipient's universal inbox over the Internet. If it is a fax message, short message or pager message, the server will direct it to the appropriate telecommunication device over PSTN.

When the recipient retrieves the received message, the unified messaging server will get the message from the universal inbox. The server then formats the message into an appropriate format and delivers it over the wireless network to the recipient's mobile computing device. Therefore, the user can retrieve messages from different media types such as e-mail messages, fax messages, voice messages and pager messages over the wireless network.

Special requirements and customization for the wireless environment

Although most of the existing e-mail systems can be extended to support wireless messaging via wireless network, they do not operate efficiently for wireless messaging services as all of them are designed for wired network. The use of e-mail systems for unified messaging implies that the different media data are sent as e-mail attachments for transportation. Since the bandwidth of wireless network is very limited, the problems on traditional e-mail systems have posed a challenging problem for supporting wireless messaging. In addition, most e-mail clients retrieve e-mail messages from the mailbox when the user logs onto the Post Office protocol (POP) (Rose, 1991) server. A temporary disconnection from the network would re-trigger this retrieval process. This situation is unlikely to occur in wired network except in the case of dial-up access to network via modem where disconnection is highly possible. However, it is likely to happen in wireless network due to its weak connectivity. Several techniques are developed to support efficient transmission of messages in wireless networks:

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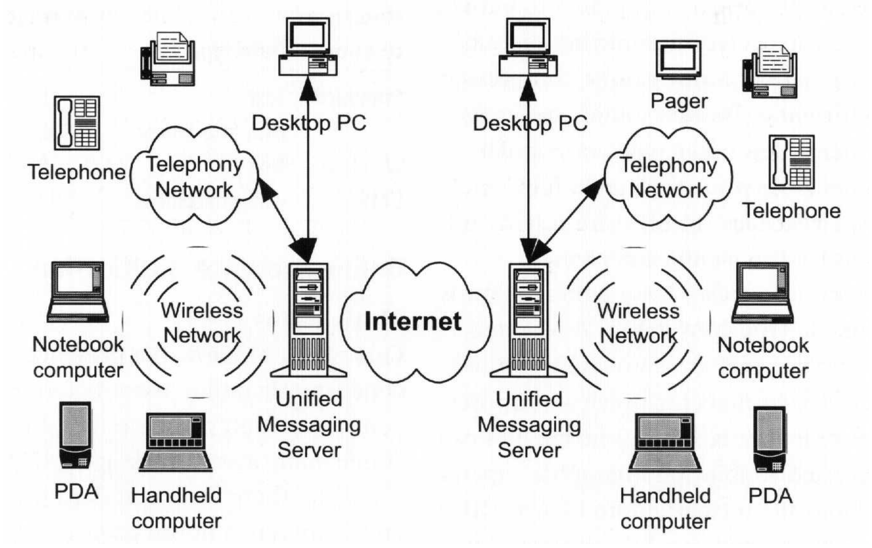
Campus-Wide Information Systems
Volume 19 · Number 1 · 2002 · 27–35

Figure 3 Wireless unified messaging support



- *On-demand retrieval*: upon login, the client software does not download all the messages from the user's message inbox into the messaging server. The user can view the sender's name and e-mail address, the subject title, the date and the size of each message residing in the message inbox before retrieval. This is particularly useful for mobile users, as they will not need to download messages that they would not want to read.
- *Message partitioning*: it is similar to the on-demand technique except that it applies to the components of each message. The user can selectively retrieve different parts of a message to view.
- *Content summarization*: the user can preview a summary of a message content before downloading it. Different summarization techniques exist (Goh and Hui, 1996). The technique adopted extracts the first 50 words of the text body. For completeness, it stops at the end of the sentence after the 50th word. This location-based technique is also popular among search engines for Web pages, where usually the first 100-250 words of the Web page are shown in the search result to give the user an idea of what the Web page contains.
- *Lossless compression*: this enables the original message (body and attachment) to be recovered following decompression. The ZIP compression algorithm (Gailly, 1999) is used as it is one of the most commonly used lossless compression algorithms and it is the only native compression algorithm supported in the Java programming language in which the system is implemented. Table I shows the results of compressing text files of various sizes using the ZIP algorithm.

In each test, 1,000 randomly sampled files of the same file type were used. For typical messages of several thousand bytes, a saving of 40 per cent or more can be achieved. Table II shows the results of applying the ZIP algorithm to other file types.

Table I Compression of text files of different sizes

File size (bytes)	1,000	10,000	100,000	1,000,000
Compressed size	585	4,532	37,530	337,626
Average saving (%)	41.5	54.7	62.5	66.2

Table II Compression of various types of files

File type		Average saving (%)
Audio	Au	24.2
	Wav	26.7
	Mp3	6.1
Image	Bmp	36.3
	Jpg	0.4
	Gif	1.7
Others	Exe	49.8
	Text	63.1
	Html	64.0

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Campus-Wide Information Systems
Volume 19 · Number 1 · 2002 · 27–35

The audio files tested were monaural data sampled at 8KHz, corresponding to human speech. As expected, files having the most redundancy (e.g. bmp) can be compressed most efficiently. Besides audio and image attachment files, other types of popular attachments such as executable files (exe) and hypertext files (html) were tested and found to lead to significant savings.

- *Attachment conversion*: lossy compression is used for file type conversion. Audio and image attachments are converted to more compact file formats for preview purposes. For example, bitmap (bmp) image files can be converted to joint photographic experts group (jpg) file format; audio files in RIFF Wave (wav) format can be converted into Sun Microsystem's audio (au) format.

Table III shows the results of file type conversion for 500 randomly sampled files for each file type. With file type conversion, lossy compression is used to significantly reduce bandwidth requirements.

Ultimately, the efficiency of data transmission must be measured to determine the usefulness of the system after all the above techniques are implemented. In the transmission efficiency test, Proxim's RangeLan2 (Proxim Inc., 2001) wireless LAN was connected to the backbone of the campus network. The test distance was 100m unobstructed path from the wireless network access point. The CPU of the Messaging Server was a Pentium II 400MHz machine, while the mobile computing device was a Pentium II 266MHz notebook. Two kinds of tests were conducted: one for plain text messages and another for messages with various types of attachment(s). In each test, 1,000 randomly sampled messages were used. The results are tabulated in Table IV, which illustrates that significant reduction in transmission time over the wireless link has been achieved with the wireless UMS.

Table III Size reduction from file type conversion

Conversion	Average saving (%)
Wav to au (8KHz mono)	90.9
Bmp to jpg	79.7
Gif to jpg	60.0

Table IV Transmission time via wireless link

Messaging system	Data type	Average size (Kb)	Transmission time (sec)
Standard	Text	8.6	0.237
	with attachment	192.3	7.322
Wireless UMS	Text	8.6	0.133
	with attachment	192.3	3.857

Online presence notification

Motivation

One needs to know the presence of other concurrently online users before real-time communication can be established with them. While many instant messaging (IM) systems are available, there is no standard protocol for online presence notification due to the proprietary nature of such systems. These systems generally have many security weaknesses such as anonymous messaging, message spoofing, account hijacking and authorization overriding because they depend heavily on client-side operations. An open protocol has been developed for online presence notification that also provides negotiation support for real-time communication services. The open nature of the protocol promotes interoperability, but demands higher levels of security than proprietary ones.

Implementation techniques

The two fundamental problems associated with online presence notification are Internet Protocol (IP) address resolution and security. Security is a major concern in any Web-based system, particularly with an open standard when program codes are made available to different parties. This section describes some solutions to these problems.

Within the standard Internet transmission control protocol/Internet protocol (TCP/IP) (Postel, 1981) suite, each host computer is identified by a unique IP address. In order to have point-to-point real-time communication, client software must be aware of the target party's IP address (Information Sciences Institute, 1981). Therefore, resolution of dynamic IP addressing is the central theme for providing online presence notification.

Figure 4 shows the exchange server approach for IP resolution adopted in this research. The

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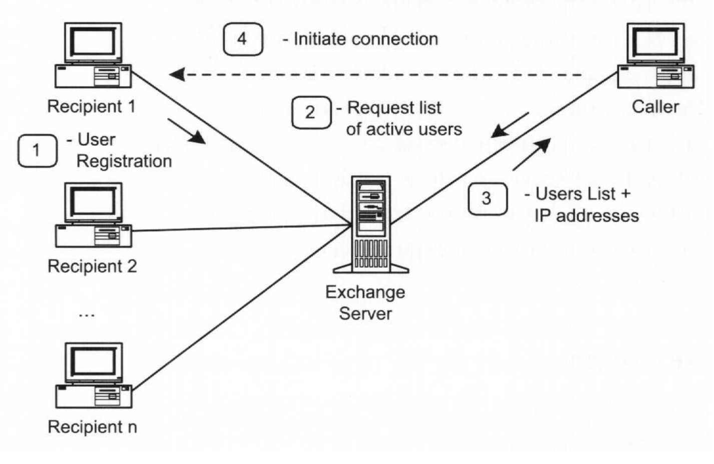
Campus-Wide Information Systems
Volume 19 · Number 1 · 2002 · 27–35

Figure 4 The exchange server approach for IP resolution



exchange server is a dedicated server that supports IP resolution by maintaining and managing the information of active, registered users. It acts as an exchange for finding and connecting users together. In order to ensure that the list of online users is up to date, the server periodically checks to ensure that each signed-on user is still online. This is necessary to cater for any abnormal disconnection from network of signed-on users. Unreachable signed-on users will be removed from the online user list and the relevant parties will be notified.

There are two major methods of handling online users list: public list and subscription list. A public list includes all current signed-on users so that they are visible to one another. In a subscription list, only authorized users will be notified of the online presence of the user. The public list organization allows more interaction to take place as signed-on users can view each other. However, such exposure reduces privacy and might also result in unsolicited interaction requests from strangers. The subscription list organization prevents such problems since only authorized signed-on users will be notified of the online presence of the user.

In addition, cryptography techniques (Schneier, 1996) can be applied to provide secure authentication and communication service negotiation in online presence notification systems. A hybrid approach (Fong *et al.*, 2001) that combines the convenience of public key encryption with the speed of conventional encryption has been used for the implementation.

Personal Communicator: unified system user-interface and evaluation

Unified interface

The Personal Communicator interface is a Web-based interface that integrates all the mobile personal communication services provided by the mobile communication service gateway for the wireless campus environment. It is a one-stop source for mobile personal communication services such as e-mail, voicemail, fax, instant messaging, text-based chat and other real-time services. In addition, the Personal Communicator allows access to other Web-based services such as viewing and retrieval of lecture notes, tutorial assignments and lab questions, and viewing of selected live lectures and past recorded lectures. It also provides access to administrative functions for both staff and students.

A Web-based solution is developed because Web browsers provide a convenient platform for accessing information. Users do not need to install any new software on their computer. In addition, users can also access the services via Web browsers from public computer terminals. In order to conserve the precious bandwidth for wireless network users, the Web-based Personal Communicator's interface is mainly text-based with graphics and audio-visual effects excluded to provide efficient services.

As shown in Figure 5, the Personal Communicator's menu provides a variety of

Figure 5 Personal Communicator

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mobile communication services. Under the "messaging" option, users can retrieve their e-mail, voicemail and fax messages. They can also view a summary of their mail content or preview the attachments. Users can also compose messages and send them as e-mail, fax, SMS or paging messages from the Personal Communicator. The "online" option provides information on the online presence of other users in their subscription lists. Users can then select from the list to send instant messages or to have real-time text-based chat with them. The "learning" option allows users to access online lecture notes, tutorial assignments and lab questions. The "lecture" option lets students view live or archived lectures. Finally, the "admin" option lets users access various administrative functions online. Students can register for subjects, check timetable, check seating arrangement for examinations, check examination results, book sport facilities and even inform the university office of any changes in personal particulars via the Web. For staff, they can also book tutorial rooms, apply leave and access student records.

System evaluation

Using the same test setup as for the efficiency test, various services were tested by 20 student users and the Personal Communicator was found to achieve an average score of 8.7 out of 10 in terms of user-friendliness, usefulness, relevance, availability and reliability. Data transmission throughput for the wireless link averaged more than 35Kbytes/s.

The single user test provides good performance results. However, multiple users performance test cannot be conducted due to current resource limitation. Detailed performance testing can only be conducted at the end of the year when the whole campus-wide wireless network becomes fully operational. In addition, the upcoming wireless LAN will be based on 10Mbits technology, which is expected to provide much better performance.

Conclusion

This paper has outlined the problems and solutions associated with providing mobile communication services via a wireless campus environment. These mobile communication services complement existing wired network applications and other teaching facilities to enable strategic exploitation of information technology for educational use. The integration of all these services into a unified Web-based interface as a one-stop client also provides enhancement to user experience.

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