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E-mail addresses for editorial correspondence: <rfcalvo@ati.es>, <nicolet@acm.org> or <rcarniel@dgt.uniud.it>

E-mail address for advertising correspondence: <novatica@ati.es>

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* This monograph will be also published in Spanish (full issue printed; summary, abstracts and some articles online) by NOVÁTICA, journal of the Spanish CEPIS society ATI (Asociación de Técnicos de Informática) at <http://www.ati.es/novatica/>, and in Italian (online edition only, containing summary abstracts and some articles) by the Italian CEPIS society ALSI and the Italian IT portal Tecnoteca at <http://www.tecnoteca.it>.

Dissemination of Popular Data in Distributed Hot Spots

Mehmet Yunus Donmez, Sinan Isik, and Cem Ersoy

We developed an information delivery system, namely WIDE (Wireless Information Delivery Environment), on client-server architecture using IEEE 802.11b infrastructure. WIDE aims to deliver popular information services to registered mobile clients in WLAN (Wireless Information Local Area Network) hot spots. We present the proposed system architecture, related delivery mechanism and communication protocols. We also give a brief overview of the mechanisms required for secure and reliable communication over a WIDE system.

Keywords: Hot Spots, Wireless Information Delivery, Wireless LANs

1 Introduction

With the emergence of battery-operated, low-cost, portable computers such as Personal Digital Assistants (PDAs) or laptop computers equipped with wireless communication peripherals, people now have the ability to access data stored on information servers, on demand and at any time and place, even while they are on the move. The capability of accessing data on air satisfies people's information needs as well as providing them with a competitive advantage. The dissemination of wireless information to huge numbers of mobile clients has also been beneficial for service providers. Naturally, information delivery to mobile clients has become a broadly studied subject as a result of the continuing advances made in telecommunications, interconnectivity and mobile computing.

The delivery of wireless data may depend on various factors regarding the geography of the information, time and space constraints, and user characteristics. Some information, for example emergency messages, must be delivered anytime, anywhere, and need to be distributed by cellular systems offering ubiquitous coverage. Many other types of information can tolerate discontinuous service provision. It may be preferable for certain information to be received only in the areas where it is relevant. Other information, which is relevant everywhere, may not be urgent, and it may be preferable for it to be received later if receiving the information immediately is more costly than waiting. Some information is relevant to a single user, some to a small group, some to many people.

The Infostation project [1] was a reflection of the discontinuous data delivery concept over WLANs (Wireless Information Local Area Networks), which uses IEEE 802.11b as its underlying communication technology. An Infostation can be defined as a *wireless hot spot* providing a high bandwidth radio link for data services. It was initially introduced by Frenkiel et al. [2] and also has been studied by DATAMAN Laboratory [3] in Rutgers University, USA, and by WICAT (Wireless Internet Centre for Advanced Technology) [4] in the Polytechnic University, Brooklyn, USA. This work, by DATAMAN Laboratory, centres on Infostations at the MAC layer to enable drive-through data reception, whereas WICAT studies walk-through and sit-through data reception scenarios by concentrating only on the application layer.

The design of a similar system and a 'proof of concept' prototype is presented in this paper, under the auspices of the Computer Networks Research laboratory (NetLab) of the Computer Engineering Department of Bogazici University, Turkey, using MAST (Mobile Applications and Services Testbed) [5] infrastructure to deliver course related data services to students.

2 WIDE System

Inspired by the Infostation concept, we proposed a client/server system, namely WIDE (Wireless Information Delivery Environment), which aims to deliver popular or

Mehmet Yunus Donmez is a PhD student at *Bogazici University*, Computer Engineering Department, Istanbul, Turkey, where he obtained his MSc. degree in Computer Engineering. He is currently a research assistant at Bogazici University. His research interests are wireless networks and content delivery systems, along with QoS and multicasting issues in MANETs.
<donmezme@boun.edu.tr>

Sinan Isik is a PhD student at *Bogazici University*, Computer Engineering department, Istanbul, Turkey, where he obtained his MSc. degree in Computer Engineering. He is a research assistant at Bogazici University and his research interests are wireless networks, especially QoS and multicasting issues in MANETs.
<isiks@boun.edu.tr>

Cem Ersoy received his BSc. and MSc. degrees in electrical engineering from *Bogazici University* in 1984 and 1986, respectively. He worked as an R&D engineer in NETAS A.S. between 1984 and 1986. He received his PhD. in electrical engineering from Polytechnic University in 1992. He is currently a professor in the Computer Engineering Department of Bogazici University. His research interests include performance evaluation and topological design of communication networks, wireless communications and mobile applications. He is a Senior Member of IEEE.
<ersoyu@boun.edu.tr>

Figure 1: A Typical WIDE Client.

personal information services to registered mobile clients in distributed wireless hot spots. The system design includes protocols that use IEEE 802.11b WLAN technology to distribute data within isolated coverage areas in a reliable and secure manner.

WIDE can be likened to gas stations or ATM (Automatic Teller Machines) devices, which are to be found in locations where there is an appropriate user density, and where users drive or walk through the service area quickly when accessing the service before taking the 'product' away for later consumption. Similarly, in WIDE, as users pass through the system's coverage area, the most recent version of the subscribed information services will be automatically downloaded to their mobile terminals without any user intervention. And, unlike gas stations, customers do not need to stop to receive data.

WIDE may be used to deliver general information services such as education, entertainment and shopping. Specifically, in an exhibition centre, WIDE could deliver detailed information to visitors about the objects on the stands or, in a shopping-mall, it could deliver information about products and price to customers. In a campus environment, as a student passes through the hot spot of a department building with his PDA or laptop computer, the system could download a wide range of potentially useful information. This information could include the most recent data about course locations, course announcements, course web pages and course notes as well as events in the building and on campus. As the student walks out of the building and arrives at the café, information relevant to that environment, such as administrative, departmental, student club and cultural organization announcements, are delivered to the user, as well as newspaper articles, e-books, etc. A typical WIDE client is shown in Figure 1.

3 Design Principles of WIDE

The WIDE system should be constructed on top of existing protocol layers and should be compatible with TCP/IP (Transmission Control Protocol/Internet Protocol). The design of the WIDE system should also meet some basic requirements. First of all, clients of WIDE must be authenticated by the system before accessing any services. For this purpose, a secure authentication mechanism and a global security mechanism should be employed in WIDE so that WIDE system network packets are only identified and processed by WIDE components.

The transfer of any information services and their updates must be effected in such a way as to require little or no human-computer interaction and has to be completed as clients pass through the wireless coverage area of a server. A publish/subscribe mechanism must be designed to create a user profile for each WIDE system client. Client subscriptions to information services are recorded in their user profiles and clients will automatically receive any updates of information services with the help of their user profiles.

As the system offers popular information services, the design should be based on data broadcasting, or, more precisely, data multicasting, in order to ensure scalability and an efficient use of the wireless channel.

The protocols included in the system must be designed with battery energy conservation in mind, and should also satisfy the reliability requirements of the wireless medium. The residence time of a client in the coverage area can be very short which may lead to an incomplete data transfer. The completion of any incomplete data transfer should be handled by the system infrastructure using some recovery and error correction mechanisms. In addition, the protocols for data transfer should be designed in such a way as to allow the coexistence of other communication traffic on the wireless channel.

4 WIDE System Architecture

WIDE system has three main components. These components are clients, data delivery servers and a server controller. A system client is called a WIDE Client (WIC), and is a battery operated handheld or laptop PC with the necessary equipment to provide wireless connectivity to system's servers via IEEE 802.11b WAPs, known as WIDE Access Points (WIAPs). The system's servers are called WIDE Servers (WIS) and are responsible for preparing and delivering information services to clients. The information services available for delivery to clients are assumed to be stored on a local disk on each WIS. The delivery management information such as service identifier, class, version, name and location on the local disk is recorded in a database called WIDE Server Database (SDB). WIDE system architecture is shown in Figure 2.

A component called WIDE Cluster Controller (WICC) maintains and manages the system management database known as WIDE Cluster Controller Database (CCDB) which consists of a number of tables: user authentication table, server information table, user profile table and information services table.

In a WIDE system, each WIS communicates with the WICC through the WIDE LAN. The communication between a WIS and a WIC is established via a WIAP. There can be one or more WIAPs connected to a WIS, but a WIAP can only be connected to one WIS. We define the Service Area (SA) of a WIS as the geographical area covered by the WIAPs that are connected to a WIS.

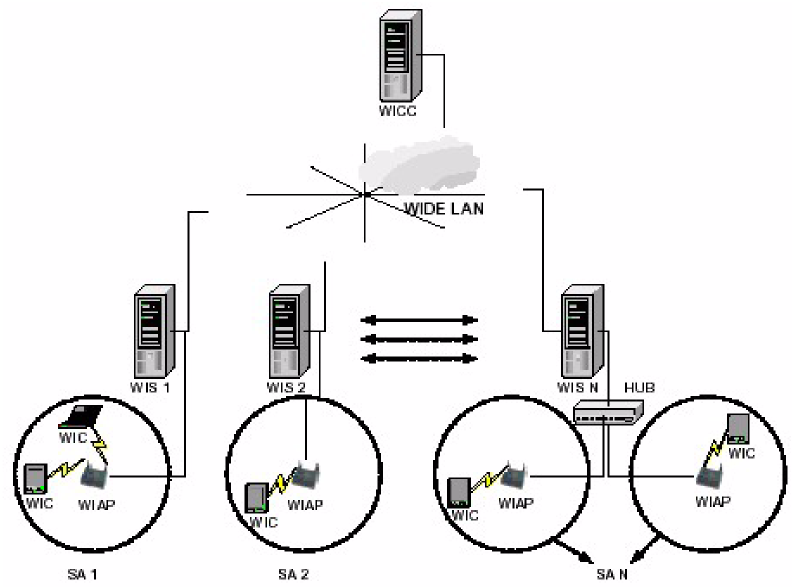

Figure 2: WIDE System Architecture.

4.1 Communication Protocols in WIDE

The system is designed on top of an Internet Protocol (IP) stack. Since WIDE's clients are mobile, they may roam into the service area of different servers, which are likely to be in different subnets. DHCP (Dynamic Host Configuration Protocol) may be used as a valid addressing of clients in service areas. Here, WIS or another server may be configured as a DHCP server.

In a WIDE system, WIC-WIS communication is constructed on top of UDP (User Datagram Protocol), since TCP does not support broadcasting and multicasting. IP unicast is required for control messages concerning only the clients they are sent to or initiated from. An IP broadcast mechanism is employed on the server to send control messages that concern all clients in the service area. An IP multicast mechanism is used to transfer data simultaneously to multiple users who are interested in that information.

For WIS-WICC communication TCP protocol is used. Control messages concerning the administrative databases of the system are transferred between these two components,. However, these messages are crucial for system integrity and therefore we have to ensure that they reach the recipient.

4.2 WIDE Communication Design

Communication between a WIS and WICs takes place in cycles called Communication Cycles (CCs). In each CC there are specific time periods in which certain tasks are performed. These time periods, called Index Broadcast Periods (IBP), Reception Preparation Periods (RPP), Data Periods (DP), Authentication Periods (AUP) and Request Periods (RQP), sequentially follow each other in this order in time. DP is also divided into time slots, which are called communication slots (CS). Figure 3 shows the timing diagram of a CC.

A client entering a server's service area sends its authentication request to the WIS in an AUP in order to be able to receive service from the system. WIS sends the response to the authentication request in the AUP of a subsequent CC.

Clients' requests for subscription to information services or requests for unsubscriptions are transmitted to WIS in RQPs. In addition, retransmission requests for information services whose packets are missed, and polling requests for information service updates on the user profile are also transmitted to WIS in RQPs. WIS sends the corresponding response messages to WIC in the same RQP.

A scheduler running in WIS determines which data to transmit during each CC and prepares the index. The scheduling of

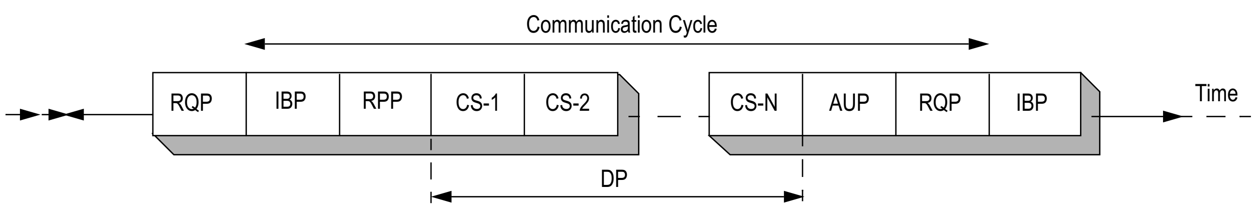

Figure 3: Timing Diagram of a CC.

an information service in a WIS requires at least one WIC in the SA of that WIS who has already subscribed or has just subscribed to that service. If a WIC has just subscribed to that information service or a retransmission is requested for that service from a WIS due to incomplete reception, then that service is queued for delivery. In addition, if a WIC has made an authentication or polling request and if there is a more recent version of that information service than the one recorded in the user profile of that WIC, then that service is also queued for delivery. At the time of delivery, the service appears on the index.

When a WIC is within the SA of that WIS, it listens to the index sent on IBP to see which information services are offered by the WIS during that CC. This index message also informs the clients interested in the information service about the multicast transmission group and the version of the data to be transmitted. Each multicast group is coupled with a CS in a DP. An application programme running on WIC examines the index and determines whether there are any available items of interest by examining the user profile on the mobile terminal. If items of interest are available, the WIC performs the necessary operations such as joining the announced multicast group and preparing the buffers to receive an information service in the RPP. Information services are delivered to WICs in the form of fixed size packets. Data packets of each item announced for that CC in the index are delivered in the corresponding CS in a DP. Consequently, WIC will receive data packets of the interested service from the multicast group joined.

4.3 Mechanisms of WIDE System

Publish / Subscribe Mechanism: Subscription to information services is provided by a publish/subscribe mechanism in the WIDE system. The list of information services offered by the system is called the Table of Contents (TOC), which is also offered as a service. In WICs, a user interface is provided to display the local copy of the TOC to users. Figure 4 shows the TOC GUI (Graphical User Interface) on a PDA client. Users may create a subscription request anytime and anywhere with the help of this user interface. Subscription requests are transmitted automatically to WICC via a WIS when WICs roam into the SA of that WIS. A local and a remote list of subscriptions are kept in WIC and WICC respectively. The remote subscription list is kept as a user profile for each WIC. Similarly, if a user no longer wants to receive or update a service, he can create an unsubscription request. The entry for the service that the user wants to unsubscribe from is deleted from the corresponding user profile.

Reliable Data Delivery Mechanism: Messages initiated by a WIC must be acknowledged by the WIS. These messages are the request messages related to information services. A WIC must be sure that its requests are received by the WIS and that they are being processed in the system. If acknowledgement messages for information service requests are not received, then the request is repeated in the next request period. Similarly, if acknowledgement messages for authentication requests are not received, then it repeats its requests in the next authentication period after the timeout.

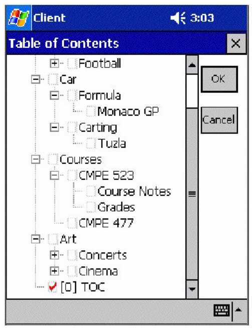

Figure 4: Local Copy of the Table of Contents on a PDA Client.

We chose to employ a reliability mechanism which uses a mixture of carousel [6], erasure code and Automatic Retransmission Request (ARQ) [7] techniques. Before the data packets of an information service are transmitted, data packets are encoded using a Forward Error Correction (FEC) technique called erasure codes, in which the reception of any k packets out of $k+m$ transmitted packets is sufficient for reliable reception [8]. After this phase, packets are numbered in sequential order. Numbering helps the WIC to track the packets and to discard any duplicates caused by the carousel mechanism. Actual data is obtained after decoding when enough packets are received for FEC. If the received number of packets is not sufficient, the missing packets can be captured in the next carousel cycle, if there is one. If there are still missing packets to be captured, then an ARQ request is prepared by the WIC to request the retransmission of that information service.

Security Mechanism: Symmetric-key encryption schemes are used to provide security in the WIDE system. These encryption schemes have low complexity and high data throughput, providing fast and power-efficient processing [9]. The contents of each packet exchanged between WISs and WICs are encrypted with a key, which is only known by the endpoints of the communication and WICC. Each component in the system has a different key. The WICC key is known by all the WICs in the system. The headers of each packet initiated from a WIS are encrypted with the WICC key to be identified by each WIC in the service area. The payload parts of these packets are encrypted with the WIS key, which acts as a service key. The WIS key is acquired by WICs at the end of user authentication operations. User authentication is accomplished in WICC by comparing the user password encrypted with the WIC key in the authentication request message with the corresponding one in the user authentication table.

WIS and WICs entering into a communication should identify each other. We use time stamping for each packet passed between WICs and WISs. Each party in communication checks the time stamps of the messages received from other parties, and keeps the last received time stamp for each different party. Packets which have time stamps earlier than or equal to the last encountered time stamp are discarded. Additionally, a two way challenge-response mechanism is applied to all requests and responses. WIS announces a challenge for AUP and RQP in start probes. WIC puts the response of that challenge together with its own challenge in the request message. In the notification message, WIS sends the response of challenge in the request message back to WIC. This mechanism ensures that the responding party is actually the one that is expected to respond. There are distinct challenge functions in both WIC and WIS known by each other. If the response sent to the initiator of a challenge is the same as the result of the challenge function of the responding party, then that packet is recognized as a WIDE packet.

5 Implementation of WIDE Prototype

We implemented a WIDE prototype delivering services in a campus environment. The components are implemented using Microsoft Visual C++ 6.0 and Microsoft Platform Software Development Kit (SDK) for Visual C-++ 6.0. For full functionality, our WIC prototype is designed to run on laptop computers equipped with Windows 98 Second Edition or later operating systems. WIS and WICC prototypes run on desktop computers with a Windows 2000 Family operating system. In addition, we have a WIC prototype with partial functionality that runs on a Toshiba E740 PDA with Pocket PC operating system.

6 Conclusions and Future Works

WIDE is a data delivery system which aims to offer popular information services to mobile clients using a distributed hot spot WLAN infrastructure. We have summarized the requirements of the system and outlined the system architecture. The protocols on which WIDE is built are discussed and the details of the communication design between components of WIDE are described. We also briefly present the mechanisms required for reliable and secure communication and data delivery. The initial prototype of WIDE client is implemented for Windows 98 SE or later platforms, while the PDA version of WIC prototype must be improved to have full functionality.

Scalability and robustness of the WIDE system are not a feature of the current design. The primary goals of the current implementation were to prove the usefulness of the system in a moderate-sized environment such as a university campus and find out the pros and cons of the current architecture. Our future goal is to improve the architecture in terms of scalability and robustness. For this purpose, we plan to add backup authentication and profiling services to the current design, which will enable the system to operate under heavy loads without any dramatic effect on performance.

We plan to give location-based information services to clients, and therefore we need to know the physical location of the client. We aim to integrate WIDE with WLAN Tracker [10] and give location based information services. Currently WIDE offers file delivery services, but in the future the system can be improved so as to give streaming and upload services such as music and video streaming, plus e-mail transfer requiring special coding and security issues.

The charging for services in WIDE is another issue. Since file delivery is carried out using UDP packets, charging cannot be on a per-byte or per-packet basis, but could instead be based on the number of information service updates on the user profiles. The type of service provided could be another criterion for charging. For dynamically changing services such as web page subscriptions or e-mail transfers, charging could be on a weekly or monthly basis.

Readers interested in further details about system design and preliminary performance evaluation results can refer to [11].

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