A Study on the Seamless Monitoring over the Wireless LAN and the Public Cellular Network for a Portable Patient Monitoring System

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Abstract

As information technologies are developing, the improvement of the quality of life becomes worldwide issues. Especially, to improve the quality of life of a patient suffering intermittent diseases, in addition to the some portable equipments for measuring, analyzing, and notifying the status of the patients, methods of communication for seamless transmission of the measured data over to the remote site, such as an emergency center or a hospital, are required. In this paper, we address a seamless transmission of patient monitoring data such as ECG from a moving patient to a remote site, wherever the patient may be. We divide the whole environments into two wireless communication environments: an indoor one based on WLAN and an outdoor one based on CDMA cellular network in which the patient is assumed to move anywhere. We develop algorithms, implement them on a PDA-based hardware platform, and show some of the results for handover between the two environments in addition to the data transmission for each of the two environments.

Key words : handover, WLAN, CDMA, seamless monitoring

I. INTRODUCTION

As the information technologies such as Cellular, WLAN, TV, PDA, etc., are developing, the improvement of the quality of life and well-being of human become worldwide issues. Especially, the issues of the improving the quality of life of old people and patients suffering intermittent diseases such as stroke, or epilepsy have been widely accepted as a new research area. For these people to work and enjoy their lives, they should be equipped with some devices and systems that they can be treated properly in case of emergency. To do so, some portable devices that can monitor them continuously are needed [1]. In other words, such devices can measure data such as ECG or EEG, and send them to a remote site such as an emergency center or a hospital to check the states of the patients. In addition to these, for the remote site to receive the data always, some communication methods of sending the data seamlessly are required.

In this paper, we consider a seamless monitoring of a patient through both Wireless LAN and CDMA public cellular network. We consider the data transmission over each of the environment as well as the handover between the two environments. The organization of this paper is as follow. After an introduction of the problem that we address in this paper, we present the overview of a WLAN environment and a CDMA cellular net work. Then we consider the transmission of data at the two environments and the handover between these two environments. Finally, we present the hardware platform used for implementation and show some of the results.

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II. SYSTEM ORGANIZATION

A. Overall Scenario

Fig. 1 shows the overall scenario of the patient monitoring system. In this scenario, patients are assumed to suffer intermittent diseases, such as stroke, epilepsy, etc., but who are willing to work, move, and enjoy every day life. Since the occurrences of the diseases of these patients are unpredictable, constant monitoring, analysis, and notification are essential. To enable these, first of all, sensors should be small enough to wear. As we can see in this figure, moving patients are equipped with various portable biosensors that can measure the bio data continuously. Some examples are ECG, EEG, EMG, SpO2, etc. These data are collected in a device such as a PDA and are analyzed or sent to remote sites, when necessary. In remote sites, there is an emergency center or a hospital and is constantly receiving data from various patients via wireless or wired network and checking the status of the patients. If some emergency situation occurs, then the center or hospital does something for the patient to recover from the emergency situation such as sending an ambulance or noticing emergency to people or hospital nearby.

The wireless communication environments to be considered in this paper are also shown in Fig. 1. In this figure, the patients are assumed to be moving around the two different environments: the indoor environment and the outdoor environment. In the indoor environment, including home or office environment, the main communication method is assumed to be the Wireless LAN. The WLAN becomes very popular in most indoor environments recently and is as fast as 10 Mbps, 54 Mbps, or 100 Mbps and is as reliable as the wired LAN inside the area. Also, once the infrastructure has been set up, then the cost for maintenance and usage is very cheap. The weak point of the WLAN, however, is that it usually does not have enough coverage and does not support handover normally.

In the outdoor environment, the main communication method is the public cellular services. Among these are the IS-95 CDMA or the CDMA2000 in Korea and CDMA, GSM, DCS-1800, etc., elsewhere. These networks have advantages that they are accessible from anywhere. It has a nationwide coverage and can be reached from anywhere, i.e., outdoor as well as indoor. The communication over to the foreign country is possible through roaming. There are several weak points, however. The one is that, if we want to send large or constant streaming data, the cost may become huge. The other problem is that the speed of the transmission is limited, and is about 10 to 14.4 kbps in the IS-95 or 144 kbps in the CDMA 2000, which are much lower than 11Mbps or 54 Mbps of WLAN. And the practical speed may be lower than the nominal values. Also, the link

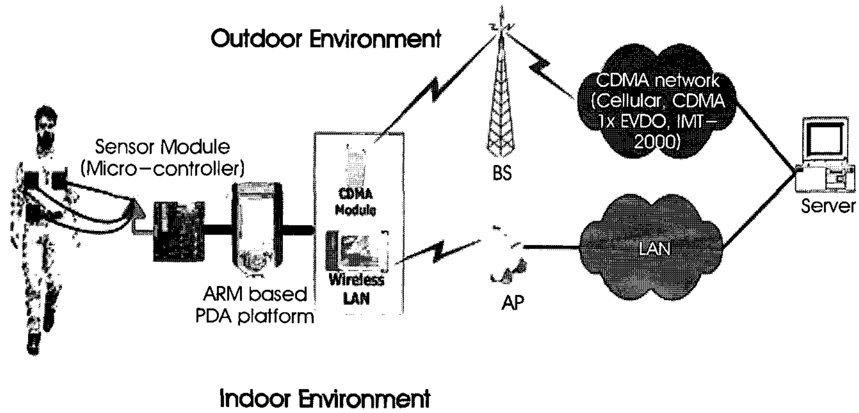


Fig. 1. Overall scenario of the communication environments.

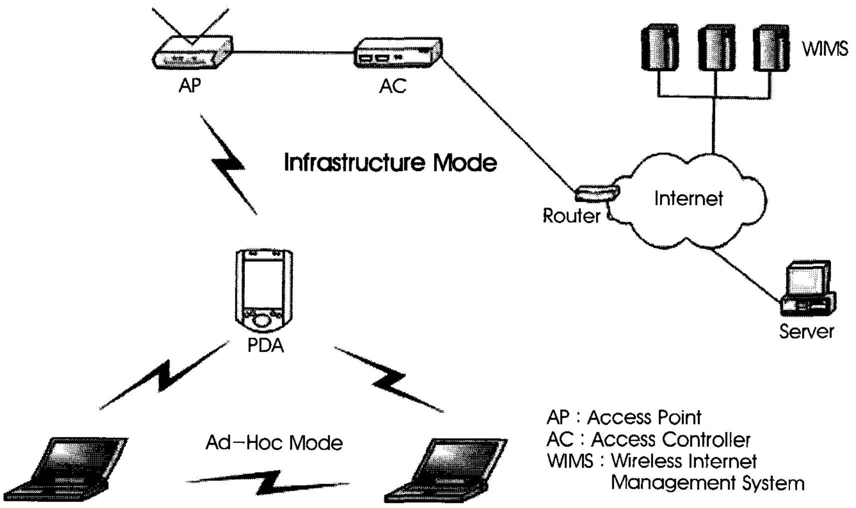


Fig. 2. Overall view of wireless LAN network

quality varies from place to place and so it can be bad in some places. This can cause errors during transmitting data and as well as a high traffic in the course of retransmitting the error packets. These limitations, however, are expected to be resolved in a near future since it is expected that the speed will increase rapidly as new cellular services such as CDMA 2000 1X EVDO, IMT 2000, etc., are deployed.

B. Overview of the WLAN Network

In the indoor environment, we have assumed that the data are transmitted via WLAN. Basically the WLAN is constructed by attaching base stations called APs (Access Point) to the existing wired LAN. In the WLAN network, we can communicate in two different modes [2-4]. The one is the Ad-Hoc mode, in which both the data source and the server are in the same network. The other mode is the Infrastructure mode, where the data source and the server are not in the same network so that the data are sent through at least one public network [2-5]. Fig. 2 shows two kinds of Networking in the WLAN.

In this paper, we consider only the 'Infrastructure mode'. In this mode, the data collected at the clients are sent to a nearest AP (Access point) and eventually sent to a server at a remote site via public LAN. The WLAN works to the standard IEEE 802.11b, and uses CSMA-CA [2-7].

C. Overview of a Cellular CDMA Network

In the outdoor environment, the main communication method is the public cellular network. Fig. 3 shows an simplified diagram of the CDMA Network [8,9]. As we can see in this figure, the data collected at the PDA are sent to the BSC (Base Station Controller) via the nearest BS (Base Station) or BTS (Base Transceiver Station) through a CDMA modem. The data that come into the CDMA network direct to a RAS (Remote Access Server) for TCP/IP communication whereas the voice goes to the MSC (Mobile Switching Center). There are two protocols for connecting the Internet through telephone [10]. One is the PPP (Point to Point Protocol) and the other is the SLIP (Serial Line Internet Protocol). Since the PPP is said to be more efficient than the SLIP in terms of stability and flexibility in communication, we use the PPP to the RAS and TCP/IP to the remote Server. To use the PPP on a CDMA Network, it must pass through a user certification process on the RAS (Remote Access Server) that is prepared by the mobile company. After finishing the certification process, TCP/IP based data communication is ready to transmit through the IS-95C channel.

III. SENDING DATA OVER TO THE WLAN AND A CELLULAR NETWORK AND HANDOVER BETWEEN THEM

To send data over to the network, some processes are needed. In this section, we consider these processes including registration, connection, and the handover between the two communication environments.

A. Registration

To begin the communication, the first thing to do is the recognition of the service area and the acquisition of the channel called the registration. Between the CDMA network and the WLAN, we put a higher priority on the WLAN because the cellular network is accessible from anywhere. In sensing which service area the patient is in, the most important criterion is the signal strength (SS) from the APs. The patient is constantly monitoring the signal strength, analyzes the current state, and takes action accordingly.

Power on

When the power is on, then the client automatically enter into an initialization process. In the initialization process, both the client and the remote server prepare two independent ports:

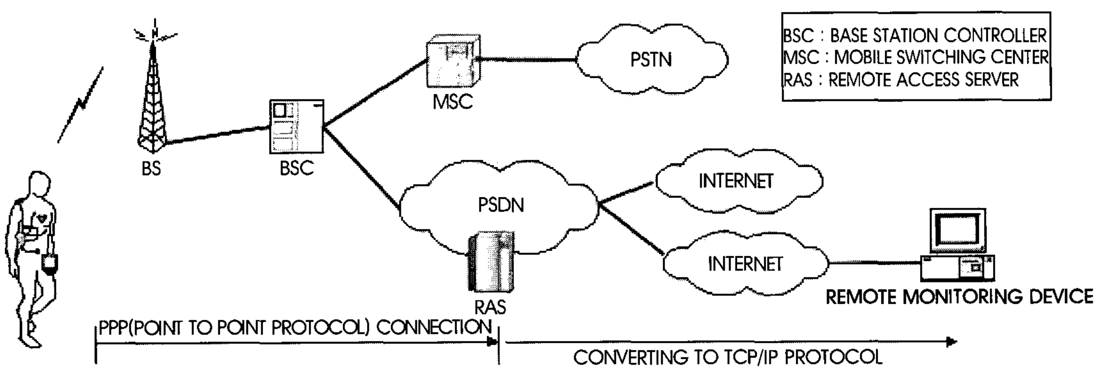


Fig. 3. OVERALL STRUCTURE OF THE CDMA NETWORK

one for the WLAN (Port A) and the other for the Cellular Network (Port B). If connected, then the transmission through WLAN is achieved through Port A and the transmission through the cellular network is achieved through Port B. Since each environment uses the dedicated ports, the client can send data to each communication environment freely and also the remote server knows whether the client is in the WLAN service area or not. Then, the client checks the signal strength from the AP. If the SS is nonzero, then the client begins to open the WLAN port. If not, then the client opens the CDMA port.

Procedure for Establishing a Connection over WLAN

If the measured SS is greater than 0 and if the client does not have a connection over the WLAN, then it needs to establish a connection to the remote server. Fig. 4 shows the procedure for establishing a connection over the WLAN.

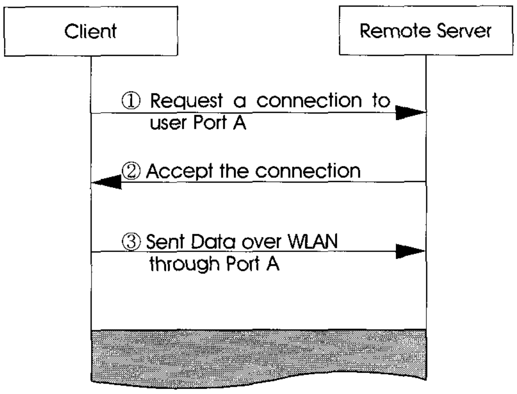


Fig. 4. Procedure for establishing a connection over the WLAN.

The explanation of each procedure is as follows.

① The client requests a connection to the remote server using Port A.

② If the client requests a connection to use Port A, then the server knows that the user is now in the service area of the WLAN and send an acceptance notice for the request.

③ If the client receives the acceptance notice from the server, then the client begins transmission of the data to the remote server through the WLAN using Port A.

Procedure for Establishing a Connection over the Cellular Network

While transmitting the data in the WLAN area, if the SS becomes 0, then it can be said that the client moves out from the WLAN area and is no longer possible to maintain the connection. In Fig. 5, we show the procedure.

① The client sends a request for connection to the CDMA network by dialing numbers.

② If the RAS in the CDMA network receives the request, then it request authentication data to the client through.

③ Then the client sends necessary data including ID and password, etc.

④ When the authentication process is over, then the RAS sends complete message to the client and the remote server.

⑤,⑥ If the client receives the notice of the acceptance from the remote server, then the client retransmits data over the cellular network through Port B.

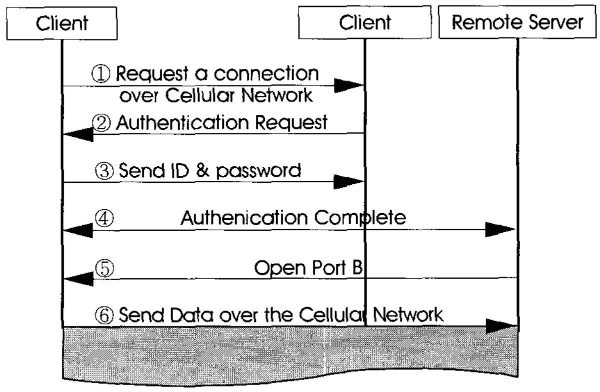


Fig. 5. Procedure for establishing a connection over the cellular network

B. Handover

As soon as the connection is established, the mobile client begins to send data over the WLAN or the CDMA cellular network. At the same time, the client measures the signal strength of the signal coming from the AP into the device. For example, if the client is in the WLAN area and if the SS becomes 0, there are two possible situations. The one is that the client is moving from the WLAN service area out into a no-service area. The other situation is that it is already outside of the WLAN service area. In the latter case, since we can think that the connection to the RAS has been already established, the client keeps sending data through the CDMA cellular network. In the former case, the server initiates the registration process to establish the connection and then send data through CDMA network [12]. The cases when the SS value is bigger than 0, can happen in two occasions. The one is when the user is about to cross the boundary of the WLAN service area and move out of the WLAN service area. The other is that the users are in WLAN service area already and its processes are summarized in Fig. 4.

If the client moves out of the service area of WLAN and crosses over the boundary of the service area, then the flow of the data may be stopped and lost its track. To prevent this, we must continually monitor whether the client is inside the service area and, in case the object leaves the service area, we must switch to the cellular network, i.e., the handover. The switch between the two communication modems can be implemented by software. The criteria for the handover is also SS. Fig. 6 shows the flow chart of an algorithm for the handover between the two communication environments.

A detailed explanation of the procedure is as follows.

① If the SS checked is larger than 0, the client is in the WLAN service area. In this case, the next step is to check whether the client has a connection to the cellular network.

② If the client still has a connection to the cellular network, then it has just moved inside the boundary of the WLAN area or powered up the device. In this case, the client disconnects to the RAS immediately, closes Port B, and begins transmission of data through Port A over the WLAN.

③ If the client does not have a connection to the CDMA network, then it means that the client is transmitting data over the WLAN and everything is normal. So, it goes to the next step.

④⑤ If the SS is 0, then the client is out of the WLAN area and checks whether it has a connection with the cellular network.

⑥ If the client has a connection to the CDMA network, then it has moved just out of the WLAN area and the client transmits data to maintain the connection to the CDMA network.

⑦ If the client has not been connected to the CDMA network already, then it is the time when the client just moves out of WLAN area. As the RAS connection program is executed automatically, the transmission of data is achieved through CDMA network and port B.

Ⅳ. IMPLEMENTATION AND RESULTS

A. Hardware Platform

The hardware platform implemented in this paper is as follows. The client, i.e., the developed portable patient monitoring system, is a PDA of which the model name is a Compaq iPAQ 5450 that has a built-in WLAN modem and is shown in Fig. 7. Basically, the device is equipped with an ECG, a temperature, and a SpO2 sensors (not shown). On the right side, the ECG probes and a temperature sensor are shown. The sensor data are sent to the ECG sensor module, located in the lower center. In this senor module, the analog ECG data, the temperature data, and the SpO2 data are transformed into digital data and sent to the PDA via RS-232C serial port. These data are produced constantly but the overall data rate is about several kbps and can be classified as the low-speed constant data. The PDA has basic processing ability. First of all, the data from the sensor module has been displayed on the screen of the PDA. Also, these data can be processed so that the features can be extracted and from the features, the current status of the patient, such as normal, in stroke, fainted, disconnected, etc., may be determined. The PDA has two ways of sending data over a remote site; one is the WLAN and the other is the CDMA cellular network. The CDMA modem is attached to the PDA on a cradle.

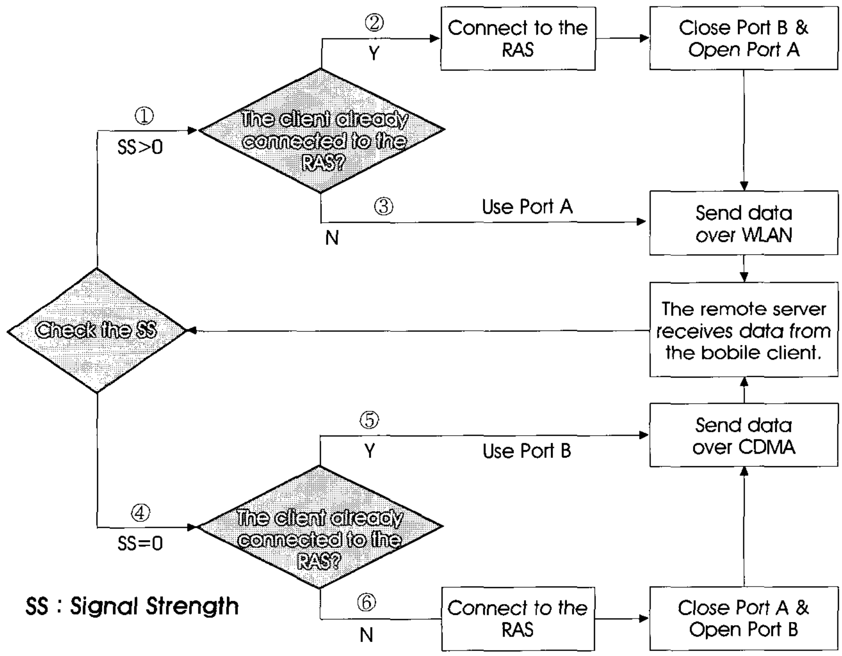


Fig. 6. Procedures for the handover

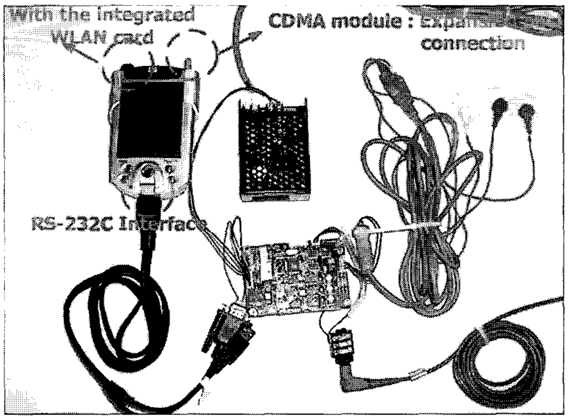
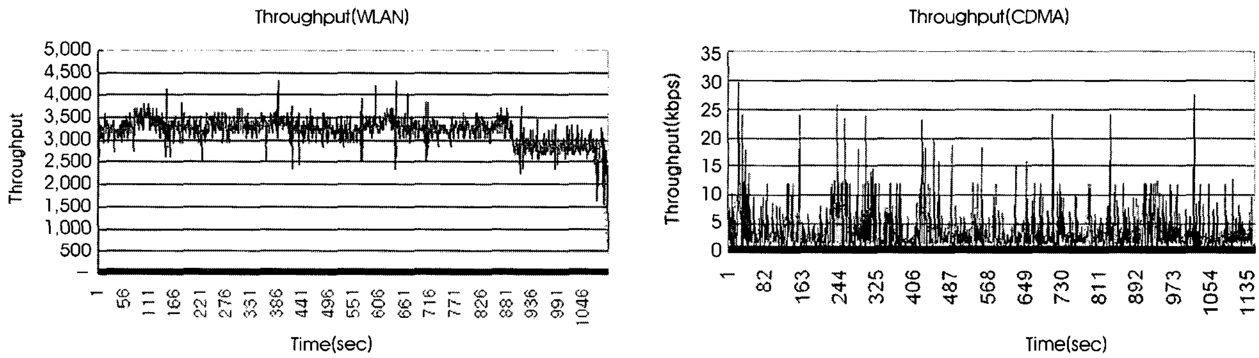


Fig. 7. Developed portable patient monitoring system

The PDA uses PocketPC 2002 as an OS. The PDA related software are developed through the embedded Visual C++3.0 and Platform Builder. For the server side, a Windows2000 Server as Server OS and Visual C++6.0 are used for the development of the server related programs. The program for monitoring the strength of signal is developed through the NDIS (Network Driver Interface Specification) and the SDK (Software Development Kit).

B. Result of Transmission through each Environment

In the WLAN environment, the speed and quality of the communication is very good, so there is hardly a problem. However, in the CDMA communication environment, relatively long transmission delays happen occasionally. (Since the data are transmitted through TCP/IP, they are transmitted without an error.) These delays are not fatal in general, since eventually the data will be transmitted without any loss, but may cause inconveniences. For this reason, monitoring is possible in the remote area to examine and analyze the data. To analyze the data transmitted over each communication environment, we captured all the packets transmitted over the WLAN and the CDMA network using the command 'WinDump' and analyzed them.



(a) WLAN (b) Cellular (CDMA)

Fig. 8. Throughput

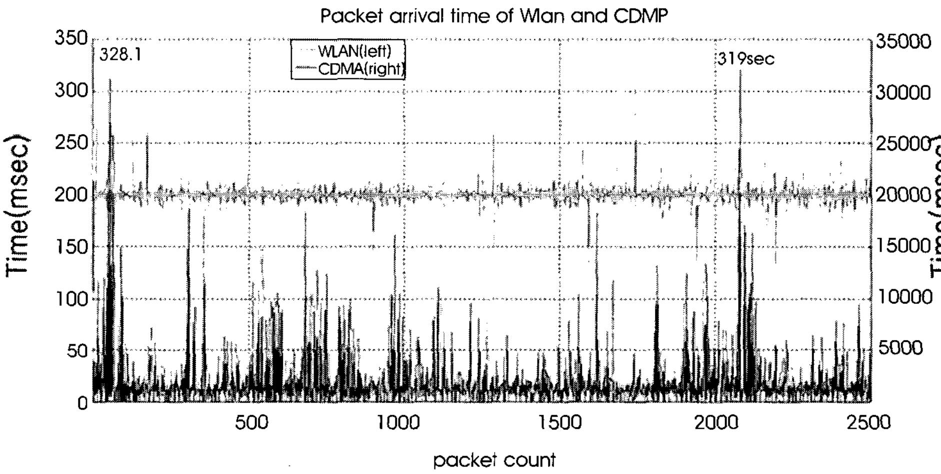


Fig. 9. Packet Arrival Time

Fig. 8 is the measured throughput of each network. In the figure, the dotted (red) lines are a moving average of the throughput. The moving average is calculated at every 10 seconds for WLAN and 20 seconds for CDMA. In Fig. 8 (a), the moving average is nearly constant for the WLAN and the throughput does not vary much at near the average value. This is due to stability and high-speed data transmission rate. On the other hand, in Fig. 8 (b), the throughput in CDMA varies much because expiration of packets due to timeout appears frequently so that the retransmission occurs that cause of burst data. The average throughputs in the WLAN and the CDMA network are 3.195 (Kbps) and 3.787 (Kbps) and are nearly the same. The minimum throughputs for the WLAN and the CDMA network are the same as 512 (bps). The maximums are, however, about 4.3 (Kbps) in the WLAN and 31.2 kbps in the CDMA, which are quite different. The reason why the maximum throughput of the CDMA network is much bigger than that of the WLAN is because of the unstable link state of CDMA network. So there can be the interval that maximum bandwidth in CDMA network is tempo- rarily much larger than in the WLAN.

Fig. 9 is a picture of an interval distribution of arrival time for received 2,500 packets. The averages are 200 (msec) for WLAN and 1.8(sec) the CDMA network. The packet arrival time for WLAN network did not exceed 328(msec), but for the CDMA network arrival time for some cases reach even 31.9 (sec). In this case, the received packet size is about 1550-byte.

One of the important factors in the mobile environment is the operation time of the mobile devices in connection with the battery. In this system, the operation time is about the 2 hours, which is not long for seamless monitoring. But, we hope that this problem of the short operation time will be solved as the new kinds of energy efficient batteries as well as processors and sensors are developed and replaced.

C. Handover

Fig. 10 is a graph of the sequence number of packets before, during, and after the handover where the client moves from the WLAN area to the CDMA area. Normally the sequence number increases linearly, with the slope proportional to the transfer rate. For the WLAN, the shape of the graph looks like a continuous straight line. On the other hand, in the CDMA cellular network, we see that the graph is composed of discrete points. This phenomena comes from the fact that the link quality of the CDMA is not uniform.

Between these two time intervals, there is a short interval where no data are sent. During this interval, the handover occurs and takes about 10~15 seconds. Basically, this is due to the connection time to the RAS in the CDMA network and is a typical phenomenon during the hard handoff. For seamless transmission, we can circumvent this problem by backing up the data that are to be transmitted during the transition time and send them after the connection is re-established.

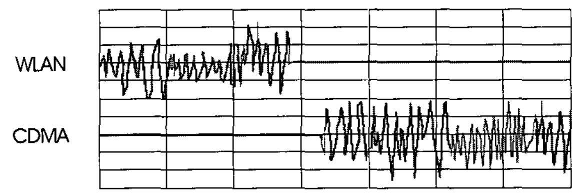


Fig. 11. Received data at the remote server

Fig. 11 shows the final data received at the remote server. As we can see in this picture, the handover function is implemented successfully at the mobile client and the data are sent seamlessly.

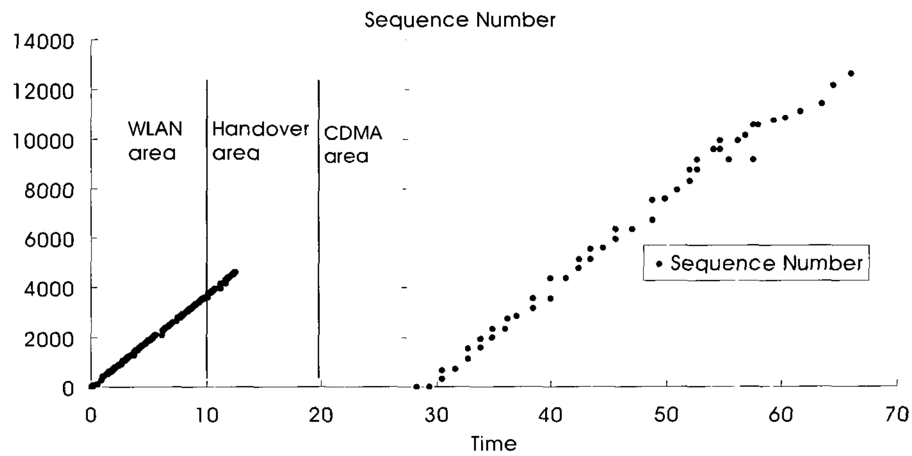


Fig. 10. A graph of the sequence numbers before, during, and after the handover.

V. CONCLUSION

In this paper we addressed the hard handover for the seamless transmission of the data from a mobile patients. We divided the whole environments into the indoor and the outdoor environments. The main communication methods for the indoor environment would be the WLAN and the method for the outdoor environment is the CDMA public network. The WLAN has a better link quality and much faster than the CDMA environment, in general. However, the WLAN has not been deployed fully and the system itself does not support the handover. On the other hand, the CDMA public cellular network has an advantage that it can be reached from everywhere and support handover but has several disadvantages that we need to pay expenses for the service and the link quality varies much from place to place.

The hardware platform developed for the moving client is composed of a PDA and two modems, one is for WLAN and the other is for the CDMA. To send data seamlessly to a remote site, we developed algorithms for transmitting data in each environment and for switching between the modems for handover. We found that basically the handover works well although there are some transition time when the data were not sent to the remote site. This problem, however, is expected to be solved if we implement a better scheme such as soft handover, which is one of the possible future works. Others may be the implementation of the error checking and correcting schemes as well as compression schemes for reliable communications. Also, other handover schemes, for example handover from the WLAN to the bluetooth, etc., are to be developed. Also, the data should be re-adjusted to meet the appropriate format to send over the mobile environments and as well as the existing biomedical data format such as HL7 [13].

We expect that the WLAN will be deployed rapidly in offices, homes and even the outdoor near office buildings or public places such as parks, hospitals, universities, etc. Also, the public cellular services have their own evolution schedules so that they will improve dramatically. We think that it is inevitable to coexist both the WLAN and the CDMA cellular network in the Wireless communication market for some time and the quality of services will imp- rove. So, we expect that the results can make a remarkable contribution to improve the quality of human lives.

REFERENCES

[1] J. H. Hong, et al, "*Development of a Body Area Network for Ubiquitous Healthcare: An Introduction to Ubiquitous Biomedical Systems Development Center*", Journal of Biomedical Engineering Research, Vol. 26, No. 5, pp.331-336, Oct. 2005.

[2] ETSI, "*Requirements and Architectures for Interworking between HIPERLAN/2 and 3rd Generation Cellular Systems*", 2001.8.

[3] IEEE 802.11f-D3.1, "*Draft-Recommended Practice for Multi-Vendor Access Point Protocol Across Distribution Systems Supporting IEEE802.11 Operation*", April.2002.

[4] IEEE 802.11a, "*Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High- speed Physical Layer in the 5GHz Band*", 1999.

[5] C. Rigney, et al., "*Remote Authentication Dial In User Service (RADIUS)*", IETF RFC 2865, June. 2000.

[6] J. Ala-Laurila, J. Mikkonen, J. Rinnemaa, "*Wireless LAN access Network Architecture for Mobile Operators*", IEEE Communications Magazine, Vol. 39, No.11, pp.82-89, Nov. 2001.

[7] ANSI/IEEE std.802.1D, "*IEEE Standard for Information technology Tele-communications and Information exchange between systems Local and metropolitan area networks-Common Specification-Media access (MAC) bridge*", 1998.

[8] H. Kim, et al., "*Principles of IMT-2000 Mobile Communications*", Jin Han Publishing Company.

[9] ETRI TR 129 061, "*Digital cellular telecommunications system (phase2+) (GSM); Universal Mobile Telecommunications System (UMTS); Packet Domain; Interworking between the Public Land Mobile Network(PLMN) supporting Packet Based Services and Packet Data Networks*" 1999.

[10] W. Richard Stevens, "*TCP/IP Illustrated, Volume 1*", Addison Wesley, 1994.

[11] Wooshik Kim, Wan Jin Ko, HyangDuck Cho, and Miae Woo, "*A Study on the Seamless Transmission of an Uplink Constant Streaming Data over Wireless LANs and Cellular Networks*", ICOIN, LNCS 3391, pp.874-883, Jan. 31-Feb.02, 2005.

[12] Noerpel and Y. Lin, "*Handover Management for a PCS Network*", IEEE Personal Communication, Vol.4, No. 6, pp.18-24, 1997.

[13] J. Choi et al, "*Design and Implementation of HL7-based real-time data Communication for Mobile Clinical Information System*", Journal of Biomedical Engineering Research, Vol 26, No. 2, pp.65-73, 2005.