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Implementation and Performance Evaluation of Mobile Ad hoc Network for Emergency Telemedicine System in Disaster Areas

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Abstract—**So far we have developed Emergency Telemedicine System (ETS) which is a robust system using heterogeneous networks. In disaster areas, however, ETS cannot be used if the primary network channel is disabled due to damages on the network infrastructures. Thus we designed network management software for disaster communication network by combination of Mobile Ad hoc Network (MANET) and Wireless LAN (WLAN). This software maintains routes to a Backbone Gateway Node in dynamic network topologies. In this paper, we introduce the proposed disaster communication network with management software, and evaluate its performance using ETS between Medical Center and simulated disaster areas. We also present the results of network performance analysis which identifies the possibility of actual Telemedicine Service in disaster areas via MANET and mobile network (e.g. HSDPA, WiBro).**

I. Introduction

IT is inevitable that many casualties and infrastructure damages(e.g. Network, Traffic, Electricity) occur in disaster areas[1]. Hence, it is important that the rescue of casualties and the recovery of infrastructure should be done as soon as possible. Emergency Telemedicine Service (ETS) is an efficient way to overcome the limitation of medical specialists, but it will be disabled by damage of network infrastructure in disaster areas.

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Although several papers have previously addressed the methodological issues concerning the various types of network currently available, but there are some limitations in economic and performance to provide actual services [2]-[8]. Very Small Aperture Terminal (VSAT) can be used as an emergency network in disaster areas because it provides communicating among wide areas possible [3]. VSAT, however, requires vehicle equipped with a huge antenna for communication. Thus, VSAT is not proper to apply ETS when the vehicle is difficult to access to disaster areas. Broadband Global Area Network (BGAN) communicates data using Inmarsat-4 Satellite. It is adequate to communicate medical date in disaster areas because of its portable size [4], it has high terminal price of US$5,000 and should pay around US$7.50/MB for data communication fee. Trunked Radio System (TRS) is cheaper and has wide coverage area up to 20~30 km which is better for emergency communication networks [5], but its bandwidth is around 36 kbps which is too slow to transmit multimedia data for telemedicine services.

To overcome these limitations, this paper applies Mobile Ad hoc Network (MANET) which combines Wireless LAN (WLAN) with mobile network. MANET is automatically configured by MANET management application (MMA) which is based on Windows XP, and MMA maintains connectivity and accessibility between Mobile Node (MN) and Backbone Gateway Node (BGN) in dynamic network topologies.

The rest of this paper is organized as follow: Section 2 briefly describes Ad hoc network configuration method on Windows XP, MANET routing algorithm, MMA, and experimental design. In Section 3, we evaluate the performance of ETS between MN in disaster area and Medical Center. Section 4 concludes this research.

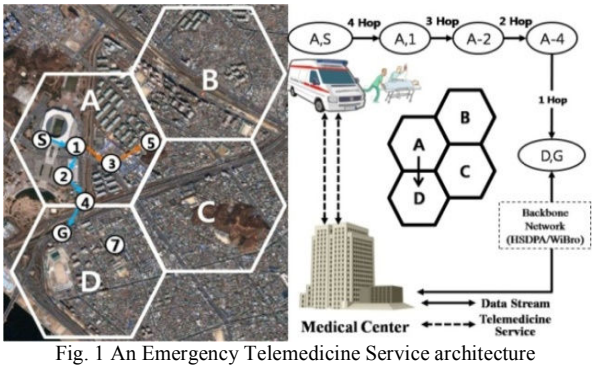


Fig. 1 An Emergency Telemedicine Service architecture in disaster areas

II. MATERIAL AND METHOD

A. Ad hoc Network Configuration

In Figure 1, MN at Area A, B, C and D should be equipped with not only Network Interface Card (NIC) for Ad hoc network based on WLAN, but also HSDPA or WiBro interface cards. WLAN is configured with same Service Set Identifier (SSID) for Ad hoc mode, and NIC has the own Private IP Address. HSDPA or WiBro is used by MN for BGN interface, and it should be allowed for other MNs to share the mobile network using the interface.

Basically, Windows XP discard the corresponding packets when the received packet's destination address is not same to its own address. Thus, only single-hop communication is available for Ad hoc mode on Windows XP. For multi-hop communication, MN should work as Relay Node (RN) like a router. For that reason, we modify the registry key value in the operating system for enabling the routing function, and MN certainly needs software which manages routing table. Then, MN is ready for multi-hop communication through MANET and mobile network [9].

B. Ad hoc On-Demand Distance Vector Routing Algorithm

We implement Ad hoc On-Demand Distance Vector (AODV) Routing Algorithm based on RFC3561 [10]. AODV is a reactive routing algorithm, and is an adequate method for dynamic network topologies. Fig. 2 shows the process of AODV. So, it is available by the process described in Fig.2 that MN not only establishes routing path to BGN, but also maintains and recovers its routing table.

If MN acts as source node, it generates 'Route Request (RREQ)' message and transit the message using flooding method. When it receives 'Route Reply (RREP)' message from one of relay node, the link between source node and BGN have established in MANET. Also MN acts as a relay node between source node and BGN. It relays control messages of AODV protocol or generates 'Route Error (RRER)' message when it happens to link failure on the routing path.

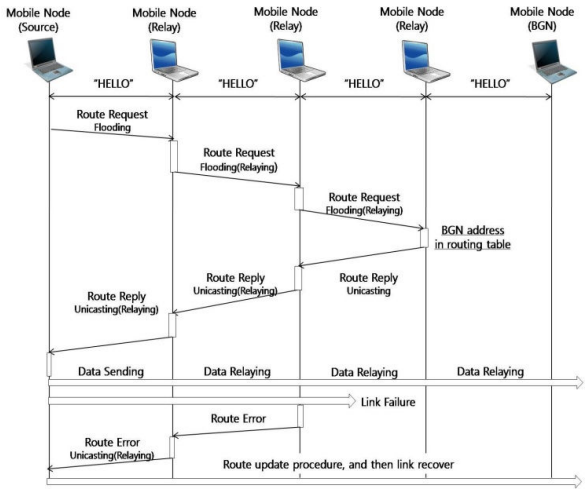


Fig 2. Sequence diagram for routing algorithm

C. MANET Management Application (MMA)

MMA is software with AODV to manage MN's routing table. It is developed using MFC with additional installation of Microsoft Platform SDK 2003 on Microsoft Visual Studio 6.0, and is independently executed with ETS. It functionally enables the backbone network connectivity for most of MNs in MANET [11]. Thus, MNs in MANET is able to use web browsing and socket communication.

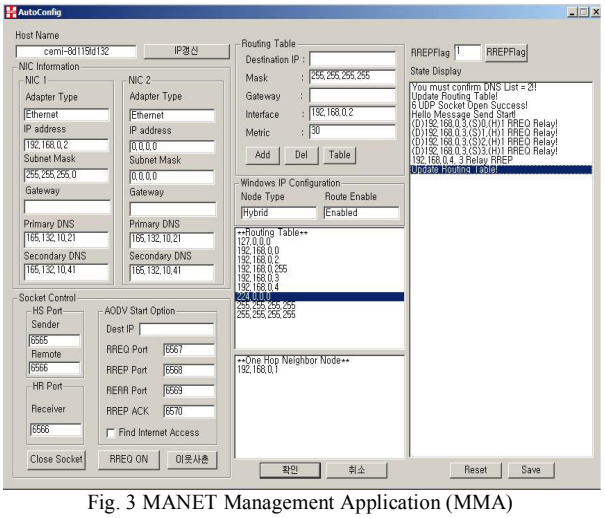


Fig. 3 MANET Management Application (MMA)

D. Emergency Telemedicine System (ETS)

So far we have developed Emergency Telemedicine System (ETS) which has several functions for telemedicine between a medical specialist and a remote patient. It is equipped with High-Quality Video transmission, bidirectional Video Conferencing, Chatting, DICOM viewer, Vital Sign Monitor, and file transmission for medical images [12], [13]. Since it is able to dynamically handle the throughput of ETS, it is capable of transmitting the multimedia medical data via heterogeneous networks.

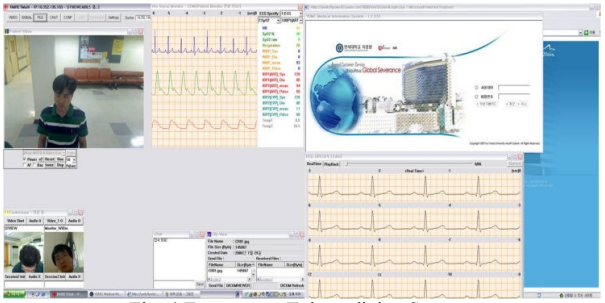


Fig. 4 Emergency Telemedicine System

E. Experimental Design

The computer in Medical Center using for remote medical specialists has a capacity of Intel Quad Core 2.4GHz CPU, 4GB RAM, and VDSL(Uplink: 10M bps/Downlink: 50Mbps). And mobile computers (Laptop, UMPC, etc) installed with MMA is used as MN which configures MANET. MN is running at Windows XP equipped with minimum of Core 2 DUO 2.0 GHz CPU, 2GB RAM. Each MN is equipped with WLAN and operates at IEEE 802.11

a/b/g/n mode. IEEE 802.11 b/g mode is selected because IEEE 802.11 a/n is not widely in use while it has better performance in data transmission.

MNs were located by the experimental network topology which was depicted in Fig.5, and each distance of among MNs was within 50m to 60m. One of MN was a BGN for a gateway of external network (e.g. HSDPA, WiBro).

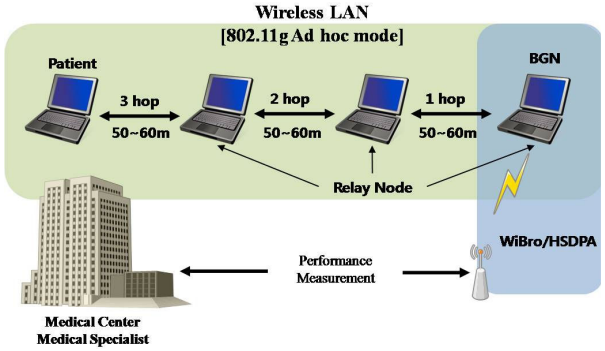


Fig. 5 Experimental network topology

Using ETS and MMA, MN for Patient was able to send multimedia medical data only MANET without WiBro and HSDPA. And we performed simultaneously network performance evaluation by means of Ethereal which is a packet analysis program.

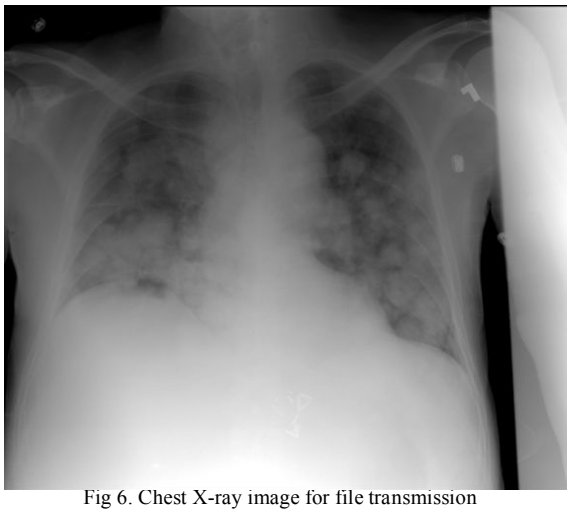


Fig 6. Chest X-ray image for file transmission

Fig 6 is a chest x-ray which is transmitted by ETS. The radiology image is formatted by JPEG with size of 200 KB, and has a resolution of 2048x2048 pixels. We assumed that the radiology image was obtained through patient in disaster area. Fig 7 describes Vital Sign Monitor which is embedded in ETS.

Also we expect that the Vital Sign Monitor will serve remote medical specialists with vital sign for clinical decision. The packet from Patient Monitor is combined with ECG, SpO2, Respiration, 2-channel IBP, EtCO2 wave. And it adds on the numerical parameter which is comprised of Heart Rate, SpO2, Non-invasive Blood Pressure, and Temperature. So, Vital Sign Monitor generates 1413 bytes packet every 1 second.

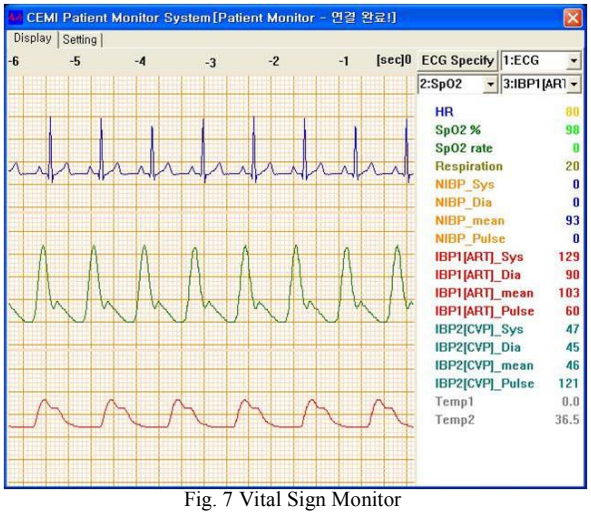


Fig. 7 Vital Sign Monitor

Video that capture the patient in disaster area has a resolution of 320x240 pixels. We generated the video considered with a capacity of mobile network. This paper consider that vital sign is most important. And the Quality of video is less important than other data in ETS. Thus, we setup MPEG4 codec that the video is compressed with data rate under 50kbps.

III. RESULTS

TABLE I
AVERAGE THROUGHPUT OF MEDICAL DATA

Average transmission rate of ETS	
Video	27.632 kbps
Vital Sign	13.8 kbps
File	101.3 kbps

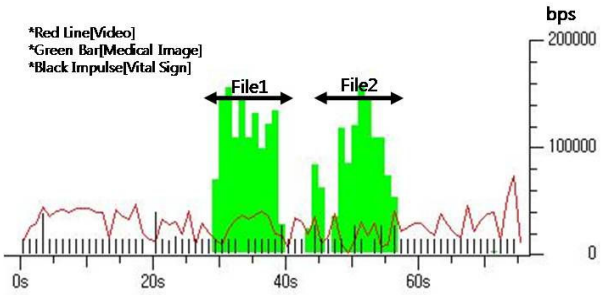
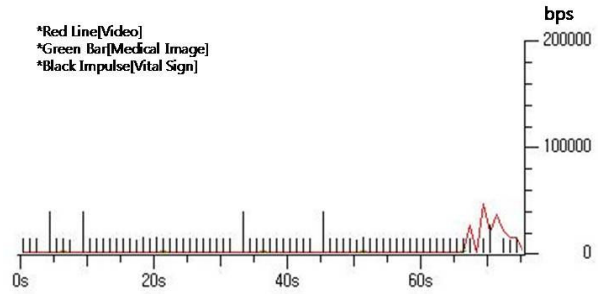


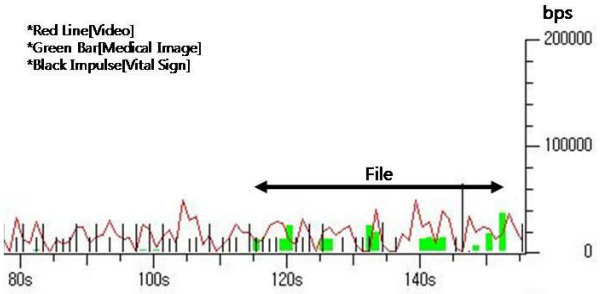
Fig 8. Performance of ETS when BGN uses WiBro

Fig 8 shows the result that BGN uses WiBro. Vital Sign is transmitted reliably when ETS sends simultaneously Video, Medical Image. Fig 9 (a), (b) describe the result that BGN uses HSDPA. Fig 9 (a) also describe that Vital Sign is transmitted reliably from patient in disaster to medical specialist in Medical Center when it was sent alone. In Fig 9 (b), however, because the transmission of Vital Sign, Video, and Medical Image at the same time, it causes burst error, packet loss, the increase of delay variance and RTT.

The experimental results presented in this paper show that WiBro supports average throughput of 73.4 kbps and HSDPA supports average throughput of 25.6kbps. We have already shown the uploading performance of WiBro and HSDPA



(a) Transmission of Vital Sign



(b) Transmission of Vital Sign, Video, and Medical Image

Fig 9. Performance of ETS when BGN uses HSDPA

linked with MANET. WiBro has capability to support uploading performance more than 952.8 kbps at 4 hop count. And HSDPA has capability to support uploading more than 32.2 kbps at 4 hop count [11]. According to [11], WiBro is still available to transmit contents of more enhanced multimedia data, but HSDPA transmits narrowly the experimental designed multimedia data. So, it is possible that BGN in MANET is able to adopt WiBro and HSDPA to backbone network interface.

IV. DISCUSSION & CONCLUSION

The purpose of this paper is to solve the problem that disaster areas could disable the primary network channel for data communications. We propose MANET linked with mobile network, and establish the temporary secondary network channel in disaster area by means of WLAN and MMA. MMA, installed in MN, is a program based on Windows XP, and embeds AODV which is one of reactive routing algorithm. Our proposed system establishes automatically the MANET and manages MN's routing table on dynamic network topology. When ETS is used in MANET with MMA, ETS will be able to use for Telemedicine Service, and the performance is decided by mobile network performance which BGN uses.

In this paper, however, we cannot find out the coverage of MANET because lack of MN's number. Due to Hidden Node Problem which is caused by IEEE 802.11 MAC protocol, the performance will decline in the increase of MN [14]. Basically, the MAC protocol for MANET should be needed to solve the problem.

In conclusion, this paper proposed methods for the establishment of MANET, and assessed the systems for Telemedicine Service. We also present the results of network performance analysis which identifies the possibility of actual Telemedicine Service in disaster areas via MANET and mobile network.

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