A Study of Wireless IP for Telemedicine

Yongguo Zhao, Yukako Yagi, Hiroshi Juzoji, Isao Nakajima

Nakajima Laboratory, Medical Research Institute
Tokai University, Boseidai, Isehara, Kanagawa, 259-1193, Japan
zyongguo@is.icc.u-tokai.ac.jp

Abstract

The movement of telemedicine to wireless and Internet Protocol (IP) based applications is imminent in the next few years. This migration from desktop platforms to wireless and mobile configurations will have a significant impact on future healthcare delivery systems and their globalization. Wireless and IP-based telecommunications networks will significantly enhance the current methodologies of telemedicine and telecare systems that are not possible with conventional telephony.

The aim of this paper is to propose and describe the design of a prototype wireless IP telephony system for telemedicine. It enables integrated voice and data transmission in a wireless and mobile environment. The preliminary results show that it is possible to provide stable IP connectivity for highly flexible medical services that are not possible with conventional telephony. This paper will present and analyze some of the technical problems and economic aspects associated with the implementation of wireless IP telemedicine system. Recommendations on future research directions will also be discussed.

Key words

wireless IP, telemedicine, IP telephony, Voice over IP, wireless broadband multimedia communications

1. Introduction

The recent advances in telemedicine applications are propelled by two converging trends: advances in enabling Internet and telecommunications technologies and the increasing demand for access to high-quality medical care irrespective of location or geographical mobility. Wireless telemedicine is a new and evolving research area that exploits recent advances in wireless telecommunications networks. Conventional telemedicine systems using public switched telephone network (PSTN) are already available for a doctor to deliver medical diagnosis and education remotely. Wireless and mobile systems provide further flexibility, wider coverage and new applications for telemedicine. For these reasons, the next step in the evolution of telemedicine will be wireless telemedicine systems, and the advantages in wireless and mobile telecommunications technologies will enable swift and better healthcare delivery, regardless any geographical barriers, and time and mobility constraints [1].

In the last couple of years, IP telephony has seen a tremendous surge in interest. Known as voice over IP (VoIP), it promises to deliver real-time, two-way, synchronous voice and data traffic over packet-switched IP-based networks [2]. Supporting telephony services over IP network is considered a promising trend in the telecommunications business. It has been increasingly used as alternatives to the traditional circuit-switched networks for carrying voice traffic [3]. IP-based networks represent the future trends towards convergence of the public switched telephone network (PSTN), mobile network, fixed wireless and the Internet in the communication industry. With the second-generation mobile networks shifting to IP platforms as the deployment of 3G systems, IP appears to have emerged as the unifying platform for all forms of communications [4]. Because IP technology uses network capacity more efficiently, it has the potential to provide reduced cost, greater flexibility, better manageability and enhanced services. The IP telephony technology can be extended to create limitless possibilities for the transmission of voice alone, or in combination with any other digitizable information. These features are essential for telemedicine to deliver integrated multimedia medical information to the underserved population or any other people in need.

IP telephony has reached a certain level of maturity in the technology area as well as in the market place. There already exist several protocols that aid in delivering the promise of IP telephony [5]. However, until recently, wireless and mobility issues have not been investigated in detail within the scope of IP telephony, and the main focus has been on fixed IP telephony systems [6]. In light of the current convergence trend of wireless communications and IP-based technology, we have proposed and tested a wireless access IP telephony solution for telemedicine applications. The solution combines a wireless router manufactured by Root, Inc. with an IP telephony system from OSI Plus Co., producing a scalable communications solution for healthcare institutions. In the following sections, we try to discuss and analyze the challenges and opportunities brought about by wireless IP telephony for the future healthcare delivery systems.

2. System design

The most important advantage of wireless IP telephony system for telemedicine is the integrated transmission of voice traffic, patients' images and demographic data. An independent wireless IP wide area network (WAN) has been proposed and tested for telemedicine applications. *Figure 1* illustrates an outline of the wireless IP telephony system for telemedicine.

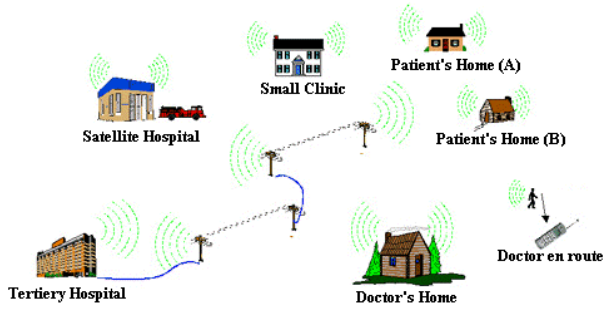

Fig. 1 Wireless IP telephony WAN for telemedicine

The wireless IP telephony system described in this paper is based on the integration of two advanced products: the RTB2400 wireless router and the IP Phone 323 software. The RTB2400 is manufactured by Root, Inc., a Tokyo-based R&D firm founded in 1993 (*Fig. 2*). IP Phone 323 is a software product of OSI Plus Corporation, a KDD subsidiary. The RTB2400 and IP Phone 323 have already been used in many applications independently. IP Phone 323 has been put into operation by several IP telephony carriers in the world, including KDD. The RTB2400 has been used to establish several wireless networks in Japan, including a wireless Intranet connecting medical facilities at the Itabashi Health Care Center in Tokyo.

Fig.2 RTB2400 wireless router manufactured by Root Inc.

The RTB2400 wireless router, which functions as a receive/transmit terminal as well as a repeater, provides circular coverage with a radius of 3km (5km using a uni-directional antenna) when configured in compliance with Japanese regulations on frequency use and maximum transmission power. If higher power is allowed the wireless reach can be much longer. The transmission speed of the RTB2400 router can reach 2Mbit/s with a TCP/IP platform. The entire IP-based wireless WAN covers an area with a radius of 15 km. The network topology adopts a flat connectivity between the scattering nodes (*Fig. 3b*). In contrast to the general-purpose wireless LAN which adopts a hierarchical connectivity (*Fig. 3a*), the topology of the wireless IP WAN for telemedicine allows several path options between the nodes to transmit voice and data traffic. This approach offers greater resiliency, more flexible node locations, and better traffic distribution than the ordinary wireless network topology. The network capacity has been exploited with improved efficiency. Since the wireless WAN is IP-based, it can be easily interconnected via a gateway with any public and dedicated networks, including intranets, Internet, PSTN, ISDN, and/or even a satellite link. Local, long-distance and international telephone/video conferencing can be carried out through the gateway connected to the public telephone networks or the Internet.

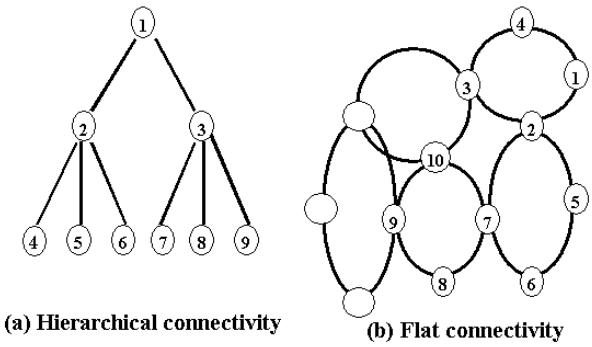

Fig. 3 Network topology of the wireless LAN

The wireless IP telephony system consists of multiple Client Stations managed and monitored by computers located at a Center Station. At the Client Station, the wireless router equipment consists of an antenna, a main unit, a junction unit, and interconnection cables. An IP telephony gateway is connected to the router equipment using a 10Base-T interface. The gateway contains two ports, each of which can be connected to a standard telephone set or a lap-top computer. The main Center Station houses a management server for the IP telephony network and an SNMP server to monitor the wireless router network. The IP telephony management server has the capacity to serve a large number of unit systems. Local Center Stations can be established at appropriate client sites. The minimum configuration requires to establish a network consists of two Client Stations and a Center Station. In terms of equipment, a minimal network requires at least three wireless routers and three IP telephony gateways, supporting between three and five telephone lines (including one at the Center Station).

IP Phone 323 is installed on a personal computer (PC) server. The software can respond flexibly to the needs of the network functions. Multimedia computers can be set up at each node to serve as the communication platform to integrate the voice and data traffic and transmit them through the wireless IP telemedicine system. If only voice communication is desired, a typical telephone set is enough. The equipment used at each site occupies limited space and can be loaded on an ambulance. The ambulance is then turned into a mobile Client Station. The system configuration is simple, expandable, and do not require too much capital investment.

3. Results and Discussion

3.1. Preliminary results

The wireless IP telephony system investigated in this paper provides voice communication as its basic service. Analog voice signals are converted into digital data, compressed, segmented into packets, added an IP address, and then distributed over the wireless IP network. On the receiving station, the compressed digital data are extracted and converted back into analog signals meaningful to humans [7]. Since the network system is based on IP telephony technology, normal PCs and other electronic devices that use TCP/IP can easily be operated on the current network. Internet telephony software can integrate the voice and data traffic over the computers. Thus multimedia communication services including data, video, audio and image transmission are provided through this wireless IP network. These multimedia functions can be used to enable medical consultation, health information services, distance education, and e-commerce.

The wireless IP telephony system has been tested in the field study. The Client Stations on the network were monitored at the Center Station. The parameters of the wireless routers could be reset from the Center Station as well. If a gateway experienced problems, the Center Station was signaled. In general, the connectivity and voice quality were fine in the trial.

3.2. Technical features

Some key aspects of the wireless IP telemedicine system are discussed below:

(1) The data transmission speed can reach 2Mbit/s with a TCP/IP platform. Such transfer rate is adequate for interactive multimedia communication.
(2) Since digital data is free from signal decay depending on transmission distance, the voice quality for long distance telecommunications is better than that of analog calls.
(3) Certain level of voice delay is generated by data compression and extraction.
(4) Multimedia data (such as images and video) and Fax can be integrated and transmitted along with the voice traffic.
(5) IP-based wireless connections are more easily established which allow users to talk to multiple parties simultaneously. The network size and functions can be expanded with flexibility.
(6) The network is easy to operate and maintain, and resilient against disasters and network outages.

3.3. Clinical benefits

The clinical benefits of such a wireless IP telemedicine systems lay in the following aspects:

(1) Prompt response to critical medical scenarios regardless of any barriers;
(2) Flexible and swift access to expert opinions and advice to the point of care and without delay and optimize the management of medical resources;
(3) Interactive medical consultation and communication links of medical images and video data in complete mobility and in global coverage and connectivity when through a gateway;
(4) Increased empowerment and management of medical expertise, especially in rural and underserved areas using the above technologies;
(5) Swift and better medical care delivery in emergencies and management of medical data in catastrophes or natural disaster circumstances where conventional communication links could be unavailable.

3.4. Cost analysis

Under the assumption of a total of 200 lines in the network, the initial investment for a wireless IP telephony system costs US$ 2,644 per line. This figure is higher than the reported cost of various rural communication systems ranges from US$500 to US$750 per line. However, these lower per-line costs are generally based on full utilization of large capacity networks. If a relative small network is proposed, for example 30 client terminals as in the case of telemedicine, the wireless IP telephony system is considered to be competitive.

As for communication cost, it has been generally accepted that IP telephony brings about cost saving for long-distance and international communication. We would like to illustrate this with an example. We assume that

C_a: Call charges for user A
C_b: Call charges for user B
I_a: Payment to Internet Service Provider (ISP) from user A
I_b: Payment to ISP from user B
P: Public telephone network charge for the call between A and B

If C_a, I_a, C_b, I_b, and P are variables, the function for comparing the charges between IP telephony and the conventional telephone calls is as follows:

$$g\{(C_a+I_a)+(C_b+I_b), P\}.$$

If the costs for communications line and ISP are fixed per month at the price schedule effective as of March 2001 (C_a=4,050 yen, I_a=1,950 yen, C_b=$19.95, I_b=$49.95, $1=120 yen), IP-based phone calls between Tokyo and San Francisco are cheaper than the conventional international telephone calls (6-yen/6-sec during the daytime, through KDDI or NTT) once the call time exceeds 240 minutes (4 hours) per month. This example suggests that IP telephony has the potential to generate cost-saving on telecommunication, especially for long-distance or international communication. Since the wireless IP telephony system discussed in this paper can be easily connected to any public and private networks, this feature will facilitate the deployment of telemedicine over a long-distance or in a global scenario, particularly for those international telemedicine programs in developing countries.

3.5. Future research directions

With the advent of 3G wireless system and the new IP version-6 (IPV6), the next few years will see the emergence of next-generation wireless and Internet telemedicine networks that will provide broadband health services over wireless networks [8]. Based on our preliminary study, we will further address the following issues in our future investigation:

(1) The mobility issues of the current wireless IP telephony system;

(2) The integration of 3G, IPV6 and signal processing technologies for selected telemedicine applications:
(3) The interconnectivity issues with various public and private networks, as well as with the bio-medical data collecting devices.
(4) The performance and reliability issues and economic analysis of the wireless IP telephony system in different healthcare scenarios.

4. Conclusions

The current evolution of the next generation of Internet and mobile communication technologies will have a crucial impact on the movement of telemedicine to the Internet platform and migration of the technology from the conventional desktop configuration to the wireless and mobile area. In this paper, we have proposed and tested a prototype wireless IP telephony system used for telemedicine applications. It demonstrates that the healthcare and medical community could benefit from the latest advance in telecommunication and information technologies. The research introduced so far is the first phase in our development of wireless IP telemedicine system.

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