Experiment of Internet-based Tele-medicine in Amami Rural Islands

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Abstract

Although many tele-medicine experiments have been conducted, the project reported here takes different approach. Equipment specifically developed for medical use has often been introduced in previous tele-medicine projects. This project aims to evaluate how common products and technologies of the Internet can be utilized in tele-medicine applications. Our experiments show that products such as Wireless LANs and video-telephony over Windows PCs can be utilized for tele-medicine in rural islands. Useful observations on the promotion of Internet based tele-medicine are also presented.

1. Introduction

There are distinctive characteristics of 2.4 GHz wireless LAN systems, i.e., 1) no radio-wave license, 2) little degradation by weather conditions and 3) tolerance of interference required. With these features, 2.4 GHz wireless LAN systems have become widely used to build networks in self-governing communities and/or public institutions, i.e., private networks. Wireless LAN systems are particularly suitable for networks in rural areas where there is little radio interference and sufficient line-of-sight between antennas.

In rural areas, the development of education, transportation, welfare and so forth has been hindered due to the small size of the population. The development of telecommunications has been similarly hampered. Therefore, the exploitation of wireless LAN systems is considered useful for promoting Internet technology in rural areas. The system is cost-effective, easy to install and effective.

Current Internet-based consumer products, e.g., Windows PC and LAN, should be used rather than introducing dedicated equipment developed for tele-medicine, education, etc. Such dedicated equipment is often too difficult to operate. Internet and PCs are used everyday for office work in clinics and schools, and the use of those PCs for tele-medicine and tele-education as well should be increased.

We conducted a tele-medicine experiment in a joint research project among Setouchi Town of Amami Ohshima Islands, Faculty of Medicine of Kagoshima University and KDDI R&D Labs [1]. This paper presents the background of the project in Section 2, describes network and systems in Section 3, and reports results of the experiment in Section 4. The paper mainly focuses on considerations of tele-medicine application whereas technical details are presented elsewhere [2] [3].

2. Backgrounds and Area of the Experiment

The experiment was conducted in islands of Setouchi Town, which is located in the southern part of Amami Ohshima Islands, as shown in Fig.1. The islands are located about 2 hours flight and then a 1 and a half hour drive from Tokyo. The majority of people live in Ohshima Main Island (the top right in Fig. 1), and Kakeromajima (Kakeroma Island, the middle) holds the second largest population. There is a frequent ferry service (almost hourly) between Ohshima and Kakeromajima for approximately 20 minutes.

Figure 1. Wireless LAN network composed of 5 tandem links to connect rural islands
On the other hand, only a half daily ferry service (a ferry comes one day and departs the next day) is operated between Yorojima (Yoro Island, the bottom left) / Ukejima (Uke Island, the bottom middle) and Ohshima. That ferry may be cancelled during typhoons (several times per year), which often last for several days.

Doctors are resident only in the Setouchi Clinic located in Ohshima, where beds and medical devices are equipped. Nurses became resident in Yorojima and Ukejima about three years ago, before which doctors only visited occasionally to provide medical treatment. This project was initiated taking the opportunity of nurses’ assignment to Yorojima and Ukejima.

Yorojima has 89 families of 159 people with 49% of senior citizens (citizens of more than 65 years old). Ukejima has 110 families of 208 people with 53% of senior citizens, at present. Compared to the Japanese average of 14%, rural islands maintain a high percentage of senior citizens [4]. Each island has one school, a combined elementary and junior high school, which has only about 10 pupils.

![Yorojima island clinic and wireless LAN](image)

### Figure 2. Yorojima island clinic and wireless LAN

#### 3. Network and Systems

**Wireless LAN network**

The experimental tele-medicine network is composed of five tandem wireless LAN links, as shown in Fig.1. At each relay point, an Ethernet hub interconnects two devices, whereby constructing completely a layer 2 network. The longest wireless link of this network is 11.3 km between Kakeromajima and Yorojima. Wireless LAN equipment used in this network is not compatible with IEEE802.11b, but is CFO-SS10A developed by KDDI R&D Labs [3]. This wireless LAN equipment is aimed at supporting point-point communication particularly for long distance applications.

Three clinics of Setouchi (doctors), Yorojima (nurse) and Ukejima (nurse) Islands are directly connected to this wireless LAN network. In addition to clinics, the network also supports three schools of Kakeromajima, Yorojima and Ukejima. IEEE802.11b-compatible equipment is used for connecting schools to the network, where distance is relatively short, i.e., 300 to 1000 m. Figure 2 shows Yorojima Clinic as well as installed wireless LAN equipment.

**VPN among clinics**

Since the network has to support commodity applications as well, i.e., schools and village centers (planned), traffic and data among clinics should be secured. In order to make tele-medicine communication secure, VPN (virtual private network) equipment is introduced among clinics. LANs of each clinic are securely connected through VPN as shown in Fig. 3. Portable PCs, as explained later in Section 4.2, can access PCs within clinics’ LANs after the establishment of a VPN connection between PCs.

![VPN among clinics for securing tele-medicine](image)

**Figure 3. VPN among clinics for securing tele-medicine**
PC-based video-telephony

This tele-medicine experiment is based on video-telephony operated over Windows PC. Since PCs have become popular in clinics for doctors and nurses, it is assumed that PC softwares/tools are more friendly and usable than equipment specifically developed for tele-medicine. Doctors and nurses use PCs for their routine work everyday, and can simply initiate video-telephony software when it is needed.

The video-telephony software experienced in this network is QM (Quality Meeting) developed by KDDI R&D Labs [3]. The QM supports an MPEG4-based coding with various enhancements, among which the following are evaluated for tele-medicine:

- Resilience for errors specific to wireless LANs, e.g., miss-order of packets, duplication of packets.
- Flexible rates from ISDN dial-up to LANs, i.e., 16-4096 kbps of video, up to 30 frames/sec, up to 640x480 pixels/picture, and 16-256 kbps of audio.
- Capturing a still image at the remote end, by which low-compressed clear image can be obtained.

The video-telephony software is also implemented in three schools for video-based meetings and dialogues between teachers and pupils. Since there has been close interaction among these schools, video-telephony can be easily utilized by them.

Figure 4. Fluctuation of delay caused by 5 tandem wireless LAN links

4. Experimental Results

4.1 Some technical results

The network provides approximately 4 Mbps throughput as maximum between Setouchi Clinic (doctors) and Yorojima/Ukejima (nurse) Clinics, which is sufficient for video-telephony and other applications. One interesting characteristic observed in the network is fluctuation of delay between two end-points. Round trip time varies in a very short period. Figure 4 shows the response time that TCP acknowledges, where 50-400 ms round-trip time is observed. This is due to a tandem connection of wireless links whose transmission is based on a half duplex mode of CSMA/CA (Carrier Sense Multiple Access / Collision Avoidance). Applications over wireless LAN need to accommodate this delay variation. Further technical results of the experiment are presented in [3].

The following are some pragmatic know-how obtained for construction of IP networks in rural areas:

- A self-generating plant within the island provides electric power in Yorojima/Ukejma Island, so its voltage is not stable. It is useful to prepare power stabilization equipment and particularly portable PCs that normally equips a battery.
- Due to the frequent occurrence of typhoons, equipment is affected by thunderstorms. A lightning arrester is mandatory.
- An antenna suffers significantly from salty sea breezes and must be replaced more often than in normal installation.

Figure 5. A doctor using video-telephony over Windows PC for medical care

4.2 Considerations on tele-medicine

This section presents considerations arising from the experiment on how to utilize Internet technologies for tele-medicine.

Ethernet LAN is better than a router network

One notable outcome of the experiment is that Ethernet LAN itself is very useful for office work among clinics. Directories, files and printers are shared among clinics. For example, nurses at Yorojima/Ukejima Clinic can send reports directly to a printer of Setouchi Clinic, which doctors can receive immediately. An Excel file
containing the medical history of patients can be easily shared between nurses and doctors.

Since there is only a half-day ferry service between Yorojima/Ukejima and Setouchi Clinics, PCs connected via Ethernet LAN make clinical work significantly more effective and productive.

**Video-telephony over Windows PC is useful**

Video-telephony is mainly used between Setouchi (doctor) and Yorojima/Ukejima (nurse) Clinics, as well as between Yorojima and Ukejima for exchanging information between nurses. It is also used between Kagoshima University and Yorojima/Ukejima. Since only ISDN dial-up is available between Kagoshima and Yorojima/Ukejima, video-telephony of QM is set to 64 kbps of video and 32 kbps of audio, whereas 384 kbps of video and 64 kbps of audio is a normal operation between Setouchi and Yorojima/Ukejima. QM accommodates these rates by its parameter files, hence users need not manipulate rates explicitly and can use video-telephony with the same unified interface.

Since PCs themselves are already employed in clinics, there was no specific training needed for doctors and nurses. They use PCs everyday, and initiate video-telephony when necessary. They can use video-telephony in parallel with other tasks such as reviewing a history file, still images previously captured, and so on (See Fig. 5.).

**Even digital camera pictures are useful**

Although the resolution of digital cameras is far inferior to that of professional medical equipment, they can be utilized where ferries operate infrequently. As an example, a nurse may take pictures of patients at his/her home using a digital camera, and store them on PC. A doctor can check those pictures afterwards and make a diagnosis if further treatment, e.g., sending him/her to Setouchi Clinic, is necessary.

When a patient comes to Yorojima/Ukejima Clinic, a doctor can use QM and take still pictures by remote control. Those pictures are stored in the local (doctor’s) PC in standardized jpeg format (See Fig. 6.).

**Preventive medicine rather than clinical medicine**

Since Yorojima and Ukejima have populations of only 159 and 208 respectively, there are few medical injuries on the islands. For this reason, preventative medicine is more important than clinical medicine. Considering the high rate of senior citizens, healthcare is a major issue in rural areas.

Remote lectures were conducted by a dentist on how to care for teeth, using QM via ISDN dial-up from the dentist’s clinic in Kagoshima City. There is no dentist in Yorojima/Ukejima Islands. The scene is shown in Fig. 7. The dentist knew how to operate PCs and learnt QM within a few minutes. Since the dentist is so busy and does not have time to go to rural islands, a remote lecture is a good tool in preventive medicine.

This lecture was followed by a non-smoking lecture, for which pupils and their parents attended with the cooperation of Yorojima elementary and junior high school. In order to promote preventive medicine in rural areas, schools may play important roles as a center of the community.

This situation in rural areas provides another rationale for use of Internet-based equipment and tools rather than specialist equipment developed for tele-medicine. Since specific injuries and diseases are rare in rural areas, it is difficult to familiarize a nurse with specialist equipment. A nurse cannot become fully familiar with the use of such equipment.
specialist equipment if it is needed only once per several months, or year. On the other hand, doctors and nurses will be able use Internet technologies everyday as handy, friendly and personal tools.

Portability is important in tele-medicine

Senior patients are usually unwilling to attend clinics, even more so in rural islands. An important task for nurses in Yorojima/Ukejima is making home visits to senior patients, and to determine if there have been any unusual situations. This activity is another aspect of preventive medicine.

It would be useful if video-telephony were also available at patients’ homes. Installation of a wireless LAN device in every home would be expensive, so a portable PC with a wireless LAN was introduced in the experiment. A base station is set up at Yorojima Clinic, which covers the whole residential area of the island. IEEE802.11b compatible wireless LAN is used for this purpose. Figure 8 shows such a scene of a nurse (left) visiting a patient (right) who communicates with a doctor via video-telephony.

5. Conclusions

Internet technologies, instead of professional medical equipment, are useful and effective for supporting medical care in rural islands. Common products and applications such as wireless LANs, video-telephony over windows PC, digital cameras, etc. can be fully utilized to support tele-medicine. The experiment has also revealed some important considerations on the use of Internet for tele-medicine: 1) Ethernet LAN is better than a router network, 2) video-telephony over Windows PC is useful, 3) even digital camera pictures are useful, 4) preventive medicine is essential rather than clinical medicine, and 5) portability is important in tele-medicine.

In Japan, there are more than 200 islands where people live. Among them, about 150 islands have less than 1000 population, and about 80 islands have less than 300 people. About 60 islands have no clinic, i.e., the situation there is far worse than on Amami Ohshima Islands [5]. The penetration of Internet technologies to those islands provides the opportunity to improve medical care. Doctors and nurses are willing to use Internet technologies for medical care as handy, friendly and personal tools. It is hoped that the result of this experiment will help advance medical and healthcare in rural islands.

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