Island Community Wireless Networks

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Abstract

This paper presents a basic design and principles of an IP-based WLL for bridging Digital Divide in rural areas. Three principles are presented:

1) Use of Wireless LANs,
2) Cost-effective Sharing of an Internet Access Link among Wireless LANs, and
3) Volunteers' network basis. Some consideration on the network cost is also presented with our medical information infrastructure project for isolated islands in Kagoshima prefecture, Japan.

1 Introduction

At the APEC TEL22 meeting, KDDI presented the activity of ITU-D FG-7, which discusses a possible use of ISM band Wireless LAN as WLL in rural and under-served areas in the world. The related presentations were followed at APEC TEL 23 as well as APEC TEL 24 meetings on the results of the field experiments done by KDDI R&D Labs., Inc. during the last several years in this technological area.

In this paper, we presents a joint project with the related technology to establish the medical information infrastructure, and to improve the quality of telemedicine for people in the Amami Islands, a remote district of Kagoshima prefecture of Japan. This project has the followings objectives: to build up the telemedicine system with less running costs that is sustainable and easy to be accepted by residents in the islands, not to resort to conventional type of big projects depending on state-of-art medical equipment, and to contribute to the practical telemedicine for establishing cooperation among doctors as well as relationship between doctors and patients.

2 The Telemedicine in the Southern Islands of Kagoshima Prefecture

The remote islands of Kagoshima prefecture, Japan, are counting over 25 in all (Figure 1). Among them, in the major islands with a population of 1 000 and over, there are hospitals medically in place with beds for inpatients, equipment for operations, and doctors assigned by medical schools for a short time period, maximum a few years. These dispatched doctors are said to have various medical challenges: insufficient communications among doctors in terms of the treatment policies as well as the diagnostic precision especially when such accurate techniques as interpretation of radiogram are needed. They are also said to have anxieties about scarce opportunities to acquire new knowledge and information in this field. As for smaller islands with a population of 100 to 200, since there are no staffs dedicated to medical care, the residents have to go to a hospital in their major island by boat when coming down with a disease. Even today, there would be practically no actual measures to support emergency medical services if the sea route was shut off.

Figure 1 – The Amami Islands

Derived from: The Times Atlas of the world, 7th Edition 1985

In Figure 1, the red circle with a radius of 100 km surrounds the Amami Islands, our field experiment area. Especially we are concerning the two major islands, the Amami-Oshima and the Kakeroma-Jima, and the two smaller islands such as the Yoro-jima and the Uke-Jima. Fugure 2 shows the population trends in these islands for the last 40 years. These islands are getting severely depopulated because more and more young people are deserting them for cities. The medical care for the aged is another serious problem in these areas.

3 An Overview of Telemedicine in Japan

In Japan, the applied research on medical science with Internet technology started in about 1993. That includes "X Terminal-applied In-hospital Information System" by Kaihara et al.[1], Electrocardiogram Image Reference System over Networks by Ohe et al. [2], SGML Specialized for Medical Application by Yoshiwara et al.(MML: [3]), "Comprehensive Support System for Cancer Treatment" by Mizushima et al. [4], and Comprehensive Health Care Management System with E-mails by Nakagawa et al.[5] [6].

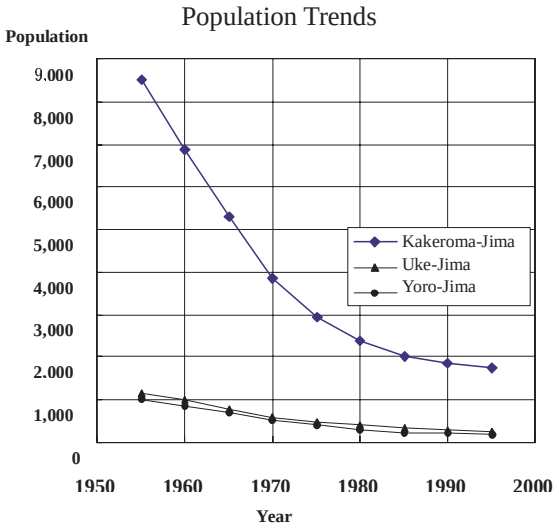

Figure 2 – The population trends in the Three Islands

Currently, most of designed systems as in-hospital information systems are ordering systems for examination or medication, have mainframe computers as a core of database, have dedicated terminals with less flexibility. Recently, an in-hospital information system with TCP/IP as a transmission method has developed, which is an attempt to build an ordering system and an electronic medical record system [1]. The system with multi-media functions such as TV phones and graphic monitors has not developed yet. Hospitals are now equipped with NTSC monitors at every corner, and intensive care units, or ICUs, are equipped with simple TV phones using NTSC monitors and intercoms by a ratio of one per a bed. Moreover, intercoms are ready at bedside for each patient in hospital wards and directly connected to so-called nurse stations. Hard wiring for this kind of peer-to-peer facility is said to make a part of equipment expenses at constructing hospitals.

The Figure 3 shows an example of telemedicine equipment for collaboration between doctors in primary medical zones and ones in a secondary medical zone. This system is based on the scenario that:

1) exacerbation which matters at primary medical zones or clinics in remote islands in this case, and/or emergency CT images in such a case as a sudden exacerbation are transmitted to a specialty facility through a network,
2) the results of examination by medical specialists are received through the network, and
(3) finally the medical decision is made by the on-the-spot doctor.

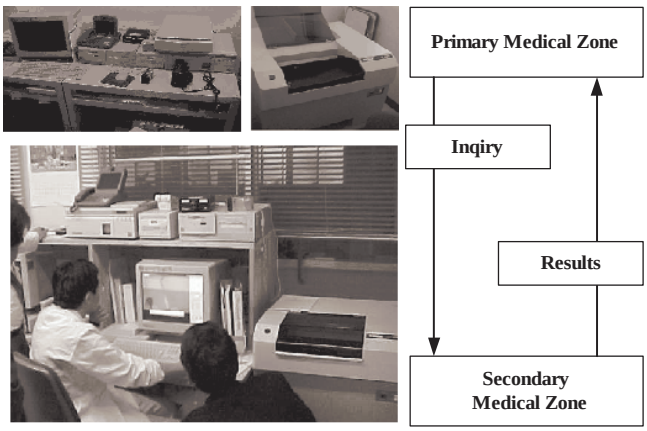

Figure 3 – Example of telemedicine equipment for collaboration between doctors

The rate of operation of this type of system is not so high, because clinics in remote islands are equipped with a certain level of

medical instruments in many cases and also because an interpretation of radiogram about especially problematic cases for diagnosis is asked to a specialist. On the other hand, there are some arguments that judging only by frequency in use should not be done because the system could contribute to the accuracy of diagnosis and the standardization of diagnostic criteria by specialists.

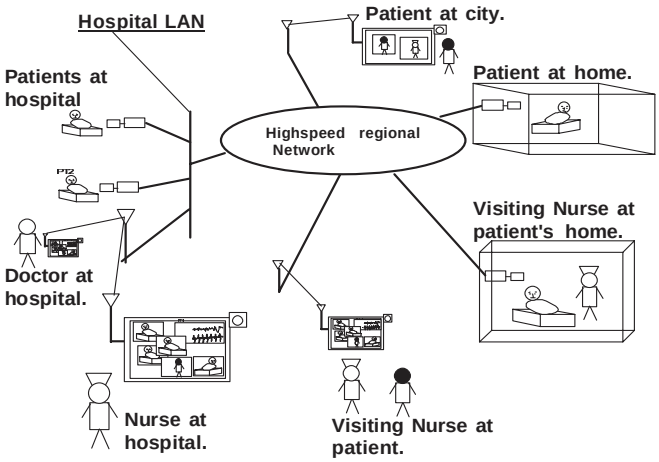

Figure 4 – Regional medical collaboration model with PDAs or mobile computers

Nakagawa, Okamura et al. contrived a regional telemedicine model making use of mobile computers for remote medical treatment (Figure 4).[7] The model accommodates the assumption that the communication demand by the regional care model is approximately the same amount of the communication between patients and medical staffs in general wards and the communication occurs at most about once every two hours. There are two other assumptions that TV phones based on personal computers are used as a means of communication and telemetory for serious cases are conducted through the networks. Table 1 reflects these assumptions and shows frequency being adaptable for the model and basic values to estimate communication demand.

Table 1 – Estimated bandwith based on normal media and occurrence possibilities of doctor-to-patient communications

Estimated Bandwidth at Real Implementations

Possible Bandwidth for Video Image from PC Terminals = 180kbit/s

nv, small: (160 × 120dots × 16bit × 10 frame/sec)

Tr (const) = (180 + 32 + 16 × 3) × 3 + 16 × 3 = 828 kbit/s

Tr (TV-phone) = (180 + 32) × 40/120 = 70.7 kbit/s

Mean total network requirement = 898.7 kbit/s

Simulated Network Traffic at a ward

Network traffic requirement (kbit/sec)	%frequency
< 900	69
900-1 200	28
1 500 <	
Simulated network traffic requirement = 925 ± 152 (kbit/s)	

As described above, if every household in remote islands is equipped with multimedia information terminals and information infrastructure in the whole island is replaced with personal computers, the traffic generated by each terminal is estimated to exceed 1.5 Mbit/s for about 3% of the whole diagnoses. Since the maximum TCP/IP transmission speed of commercially available IEEE 802.11b type wireless LAN systems is about 5.5 Mbit/s, these products are suitable for Doctor-to-Patient Communication Model as shown above.

What is the most serious issue for the information infrastructure in remote islands is communication costs. Especially, the distance of the area from Kagoshima City to the Amami-Oshima Island measures up to about 250 km, and that between every two islands measures about 100 km at maximum. It is very expensive to get high speed communication links in these islands. Therefore, during the short period of some large-scale communication projects with advanced medical equipment, satisfactory services could be provided, but could not be sustainable. As a result, still usable machines could be left uncared-for after the projects

because of communication cost issues. We propose the use of IP-based WLLs in rural areas and their operation model in the next several sections.

4 Policy of Rural Area Service

To construct the access networks for the rural people, we come to the conclusion to divide Internet access networks into 2 separate management domains: Commercial ISPs and volunteers' networks. For the saving of public Internet access charge, a single public Internet access link should be shared among several volunteers' networks even though that access link is a satellite link. One of the most important aims of volunteers' networks is to gather enough traffic to maintain that public Internet access link.

Before going into the details, we'll make a precise definition of "Rural area." In our presentation, "Rural area" is defined as the area before the dawn of Internet Service where communication demand exists to some extent but ISP is commercially infeasible. The situation is similar to that of the Internet in 1980s.

Use of carriers' services for intranets is a contradictory approach, that is, it is an area where a commercial ISP service is infeasible. If we use those services, there will be too heavy communication charges for small municipal corporations. When the fund is exhausted, the network will be died. Why not use the Internet business model in 1980s, that is, a volunteers' network? The cost of construction and maintenance is greatly reduced by using ISM Band Wireless LAN and AX.25 (TCP/IP link over the ham radio) in each volunteers' network.

5 Cost-effective Sharing of an Internet Access Link among Wireless LANs

Communication Research Laboratory has been promoting an APEC APII project for the last several years, where they use bi-directional satellite links to construct their networks between Asian research institutes. [8] It has been widely discussed that a satellite link, especially bi-directional satellite Internet service, is suitable for rural areas. This service uses a small & low cost VSAT terminal with a 75 cm antenna, and has high speed down stream and 150 kbit/s up stream. But thinking of the communication charge of such a satellite link, you'll find it is also infeasible. For the saving of public Internet access charge, a single public Internet access link should be shared among the people in the volunteers' network, or even among several volunteers' networks as shown in Figure 5.

Think of the fact that one of the most important aims of volunteers' networks is to gather enough traffic to maintain that public Internet access link.

Volunteers' network is the key to the sustainable solution. What is a volunteers' network? It's a network of the people, by the people, for the people, where a part of users are also network operators, that is, that network is operated by volunteers, themselves. For this reason, there must be active people in the target area, who are very keen to the Internet access. Their aspiration and perspiration is the basis of volunteers' network.

ODA should supply network facilities and network seminars for these operators since the acquired skills will be the basis of the IT Industry in the future.

From this standpoint, we are going to start a joint project between the Wireless LAN WLL project and the APII project driven by Communications Research Laboratory aiming at the wide area IP service.

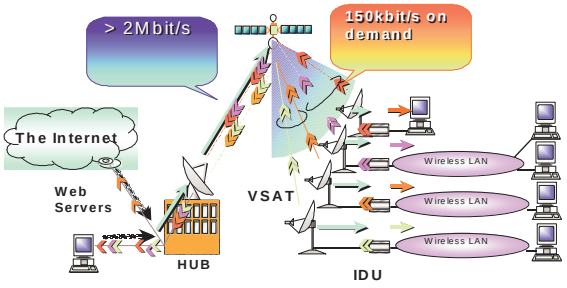

Figure 5 – Cost-effective sharing of an Internet access link among wireless LANs

6 ISM band wireless LAN

There are two possible technologies for rural area community networks. One is ISM Band Wireless LAN, which can serve 2-11 (18) Mbit/s communication service within 1-20 km from the base wireless station. The

other technology is AX.25, a TCP/IP link over the ham radio, which can serve 9.6-19.2 kbit/s communication service within around 100 km from each other.

Wireless LAN is similar to the Internet from the point of Best Effort Service. There are several advantages. There is no need for the license for the network operation. Since we can use cheap consumer products (IEEE 802.11, 11b), the maintenance cost is very inexpensive and parts are easy to buy even in the rural areas. The main disadvantages are as follows. Effective throughput per user decreases according to the number of users. The unlicensed band means that there is some interference from other systems or users. This makes it difficult to use the required frequency exclusively. (Quality of Service Problem)

To verify the model discussed at ITU-D FG-7, 3 field trials have been conducted by KDDI R&D Labs., Inc. for the last several years:

1) Kamifukuoka CityLAN Project
2) TAO School Internet Project
3) Inter-island Network Project in the Amami Islands

7 Kamifukuoka city lan project: field trial #1

The place, Kamifukuoka City, for the field trial #1 is a very small city in the suburbs of Tokyo. In a wireless service, it is commonly notified that a wider service area from each base wireless station, or cell size, reduces the service cost per user. However, a wider cell size contradicts the effective use of wireless band, and it includes more users and more variety of users. This means that different applications and different traffic patterns are involved and it is very difficult to maintain the quality of service.

Our solutions are as follows:

1) Use 4 crosswise setting directive antennas as shown in Figure 6,
2) Introduce different subnetworks (layer 3 management) to reduce the number of broadcasting frames, considering that traffic pattern of schools is different from that of individuals. The peak of the former case is in the daytime, and the latter in the night.

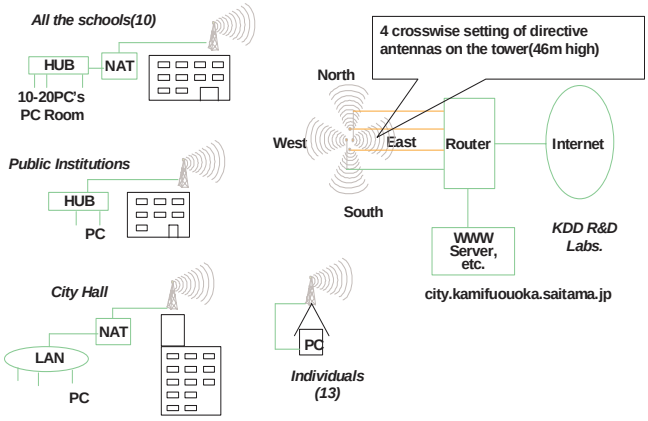

Figure 6 – The network structure of Kamifukuoka

Just set a tripod in a porch like Figure 7. It is much easier than a CS/BS antenna to install.

Figure 7 – Setting up an Antenna on a Veranda

As for the setting on top of the school, the stand is put to be proof against the wind at a speed of 60 m/sec.

With this wireless LAN, we verified that even MPEG-4 like broadcasting is possible. We demonstrated the MPEG-4 multicasting for the children's assembly in Kamifukuoka City, using the software, PrimeCast, developed by KDDI R&D Labs., Inc.

Figure 8 shows that a 16-86 times faster access link will be provided in a cheaper price after 2.5 years from the installation, comparing with a traditional leased line Internet access.

If we use it in the Japanese environments, a single cell service with an access charge of US$90/month can provide a comparable QoS service to that of current Japanese ISPs.

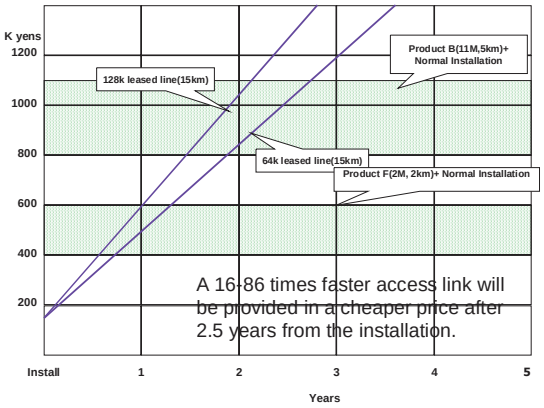

Figure 9 – Self-management networks v.s. carrier-based networks

8 Tao school Internet project: field trial # 2 (CFO-SS Wireless net. in Ota City)

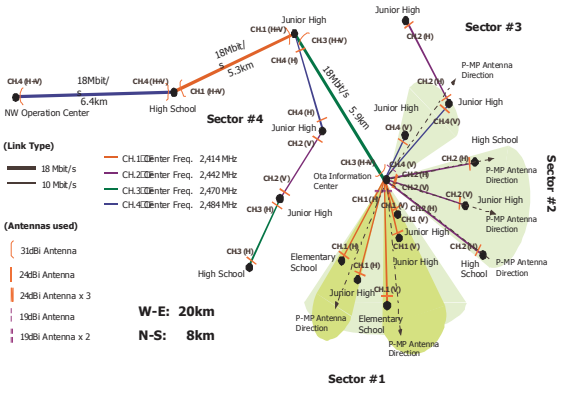

Figure 10 – TAO School Internet project: field trial # 2 (CFO-SS wireless net. in Ota City)

The multiple wireless base stations are used in Ota City in TAO School Internet Project, where TAO is the Japanese public institution for advanced telecommunication technologies. Ota is a rather big city, whose population exceeds 200 000. We use the CFO-SS10A/18 developed by KDDI R&D Labs., Inc. [9]. They can use to set up a long distant 10 Mbit/s or 18 Mbit/s link in this project as shown in Figure 10.

9 Inter-Island wireless LAN network project in the amamis: field trial # 3

The last experiment is a project of Kagoshima Univ. & KDDI R&D Labs. It again has aims to evaluate a Long Reach CFO-SS 10/18 Wireless, and the possibility of IP network for tele-medical experiments. We call this project as Southern-cross project since the Amamis, the targeted area, are semi-tropical islands in Japan [10].

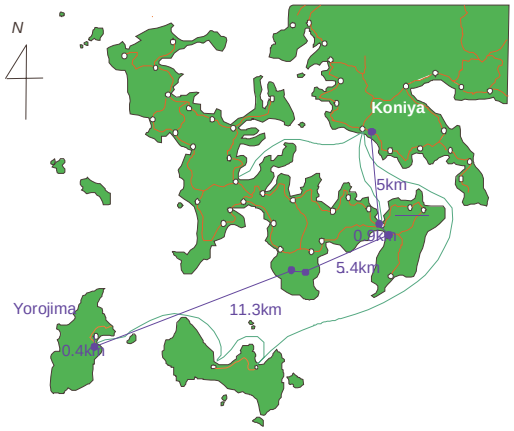

Figure 11 – Inter-Island wireless lan network project in the amamis: field trial # 3

As shown in Figure 11, 5 WLL links are used for the communication between doctors at Koniya Hospital in a main Amami island and a nurse at a clinic in the Yoro-Jima island. There is no doctor in the Yoro-Jima Clinic. Koniya Hospital is connected to Kagoshima University via an ISDN link.

Figure 12 – Inter-Island TV Meeting via primesession between a doctor in Koniya Hospital and a nurse in Yoro-Jima Clinic

Doctors can examine patients from a remote location such as Koniya Hospital or Kagoshima University using a MPEG-4 live transmission system (PrimeSession) over wireless LAN links[11]. Aiming at a community network, we also extend the use of this system as tele-educational system, since the transfer speed of this system is far more faster than required. Schools and community halls in separated islands are interconnected by CFO-SS links with a university, and lectures by professors are transmitted through the network.

As for the 11.3km long reach experiment, the CFO-SS10A with a 19dBi antenna shows the Bit Error Rate of less than $1x10^{-8}$ and the throughput is 3.7~4.2 Mbit/s.

10 AX.25: TCP/IP link over the Ham Radio

The other promising technology in rural areas is AX.25. AX.25 is an X.25 like data communication protocol for the ham radio. It has been developed since 1984, and is used as a Layer 2 link for IP networks. In AX.25 communications, each node consists of an antenna, a transceiver, a TNC (Terminal Node Controller), and a PC (Linux or Windows). As shown in Figure 13. As for the commercial products, they are long reach 100km communication media but slow. Typically the speed is less than 19.2 kbit/s. However some experimental TNC supports 768 kbit/s. With AX.25, some Japanese radio amateurs succeeded to communicate with even those in Brazil.

TNC (Terminal Node Controller)

PC & Transceiver

430MHz Beam Antenna

Figure 13 – Examples to be Required for AX.25 communications

11 Conclusions

We presented 2 management domains for Internet access: a commercial ISP domain and a volunteers' network. We'd like to insist that connectivity is more important than speed.

To reduce the construction and maintenance cost, the use consumer wireless products is preferred. The model discussed at ITU-D FG-7 is verified thought the results of our 3 field experiments

Another consideration for sustainability of the networks is to use a single public Internet access (ISP) link shared among several volunteers' networks. If these are satisfied, the network operation is sustainable and the acquired skills among those people will promote the IT culture in the areas to the next step.

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