Progress of Wakkanai Experimental Community Network Project

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Since 1999, CRL and Wakkanai Hokuseigakuen College have conducted a research project on implementation of wireless community network in Wakkanai, the northernmost city of Japan. The city is suitable for experimental field of wireless self-supporting network because of sparse population. However weather condition, i.e. high wind and heavy snow, is hard for wireless network. This paper introduces 5 years detailed progress of the project.

Keywords
Community network, Wireless LAN, Optical beam network, Wakkanai city, School internet

1 Introduction

The Wakkanai Experimental Community Network Project is a collaborative research project that began in 1999 in Wakkanai City, Hokkaido, the northernmost city of Japan. This project was designed to study the technical difficulties involved in the implementation of a wireless community network consisting of wireless equipment not requiring user licenses, including low-power data transmission systems (referred to below as "wireless LANs") and laser optical-beam networks. The project was also aimed at establishing a basis for developing applications that make use of the advantages of broadband communication in large, sparsely populated areas. This paper presents the progress and achievements of this project over the course of five years. The report is constructed as follows: Section **2** explains the background at the outset of the project, Section **3** discusses the goals of the project, Section **4** describes the five-year progress of the project, Section **5** provides details regarding the configuration of the Experimental Network, Section **6** summarizes the achievements of the project, and Section **7** comments on the remaining challenges.

2 Background at the outset of the project

Wakkanai Hokusei Gakuen College (referred to below as "Wakkanai Hokusei") was established in 1987 as a junior college. It is now a four-year college consisting of a single department: the Department of Integrated Media within the Faculty of Integrated Media. Since its establishment, the college has devoted particular effort to promoting information-processing education, including training programs for UNIX system administrators. In 1995, Wakkanai Hokusei established wireless LAN connections to two prefectural high schools in Wakkanai (Hokkaido Wakkanai High School and Hokkaido Wakkanai Shoko High School). Wakkanai Hokusei thus very early on recognized the potential of applying wireless technologies to a community network, and has since devised a number of unique techniques in accomplishing this aim [1].

Meanwhile, the Communications Research Laboratory (the "CRL") was searching for new uses for the Wakkanai Radio Observatory located in the urban area of Wakkanai. The CRL recognized that the implementation of a community network was a research topic that could be assessed even from remote locations. One of the authors (Takizawa), at the time a member of the Network and Information Systems Office of the CRL Planning Division, proposed a collaborative research project between Wakkanai Hokusei and the CRL. The two parties agreed to conclude a contract to form a field study on the implementation of a community network mainly based on wireless links, in a large, sparsely populated area under severe natural conditions. On October 14, 1999, the President of the CRL visited Wakkanai City to deliver a lecture entitled “The Future of Information Media” to the general public of Wakkanai (Fig.1). The CRL then began preparing equipment for the project at the Wakkanai Radio Observatory and other locations.

Fig.1 Lecture by former Director Takashi Iida of the CRL (At Wakkanai Hokusei, October 14, 1999.)

3 Goals of the project

Wireless LAN mainly uses ISM-band (2.4-GHz band) radio waves to connect personal computers within a local area, which could extend up to several tens of meters, to the network infrastructure. However, communication is possible between access points several kilometers apart using wireless LAN equipment equipped with external antennas approved under the Technical Regulations Conformity Certification protocol. Further, laser-beam network equipment allows for communication between locations up to approximately one kilometer apart with bit rates ten to twenty times faster than IEEE 802.11b standard wireless LANs (11 Mbps). This sort of equipment does not require user licenses. Anyone can install these systems and use them immediately.

To construct a fast network infrastructure, fiber-optic cables are the standard choice. However, new fiber optic equipment entails significant installation and maintenance costs that increase with distance, including the costs of poles and ground rent. ADSL is a possible alternative but performs poorly when the target location is far from telephone stations. Thus, it is logical to conclude that connection via wireless systems—including wireless LANs, laser optical-beam networks, and relay systems—offers cost advantages when implementing a fast network infrastructure in large, sparsely populated areas. Accordingly, many projects are currently underway throughout Japan involving the construction of community networks using wireless equipment. One example may be found in the “Experimental Development of a Rural Multimedia System” projects (for instance [2]) of the Telecommunications Advancement Organization of Japan (the “TAO;” now integrated within the National Institute of Information and Communications Technology, or “NICT”).

In terms of climate, Wakkanai City is not only a cold, snowy area but it is also one of the windiest areas in Japan due its geographical disposition facing the Soya Strait. As such, the natural environment is extremely severe. The effects of the cold, snow, and winds on antennas and radio conditions cannot be ignored in a high-frequency wireless network using the 2.4-GHz band or lasers. Thus, the project established as one of its goals verification of the practicability of establishing a wireless network in such a severe natural environment. Many of the large, sparsely populated areas in Japan are in Hokkaido, Tohoku, and Hokuriku, all with plentiful snowfall. The findings of this project were hoped to serve as a reference in promoting the acceleration of community network installation throughout Japan.

The project was planned to progress as follows. In the first phase, several organizations in the city were to be connected with wireless equipment, forming the "Wakkanai Experimental Community Network" (referred to below as "the Experimental Network*"). The second phase was to involve the development of applications to run on the constructed Experimental Network. The organizations to be connected to the Experimental Network were to have public use and would also function as test beds for application development. With these factors in mind, junior and senior high schools in Wakkanai were selected as target organizations.

The Experimental Network was constructed as shown in Fig.2 as result of this collaborative research. Wakkanai Hokusei serves as the main hub station, connecting three senior high schools, five junior high schools, and Wakkanai Radio Observatory (unmanned operations beginning in June 2003).

The purpose of the project was not simply to construct a community network. The intention was to facilitate advanced and practical experimental research in view of next-generation IT technologies (such as IPv 6) and to establish flexible designs enabling dynamic response to the sudden alteration of pathways that are inevitable within a wireless network. Care was also taken to ensure that the connected schools would have a sense of active participation in the experiment from the start of network construction, as opposed to passive use of a given community network. To achieve this aim, Wakkanai Hokusei provided network administration training to teachers in the connected schools, as described in Section **5**. These sorts of activities in the implementation of a community network contribute significantly to the improvement of IT skills in

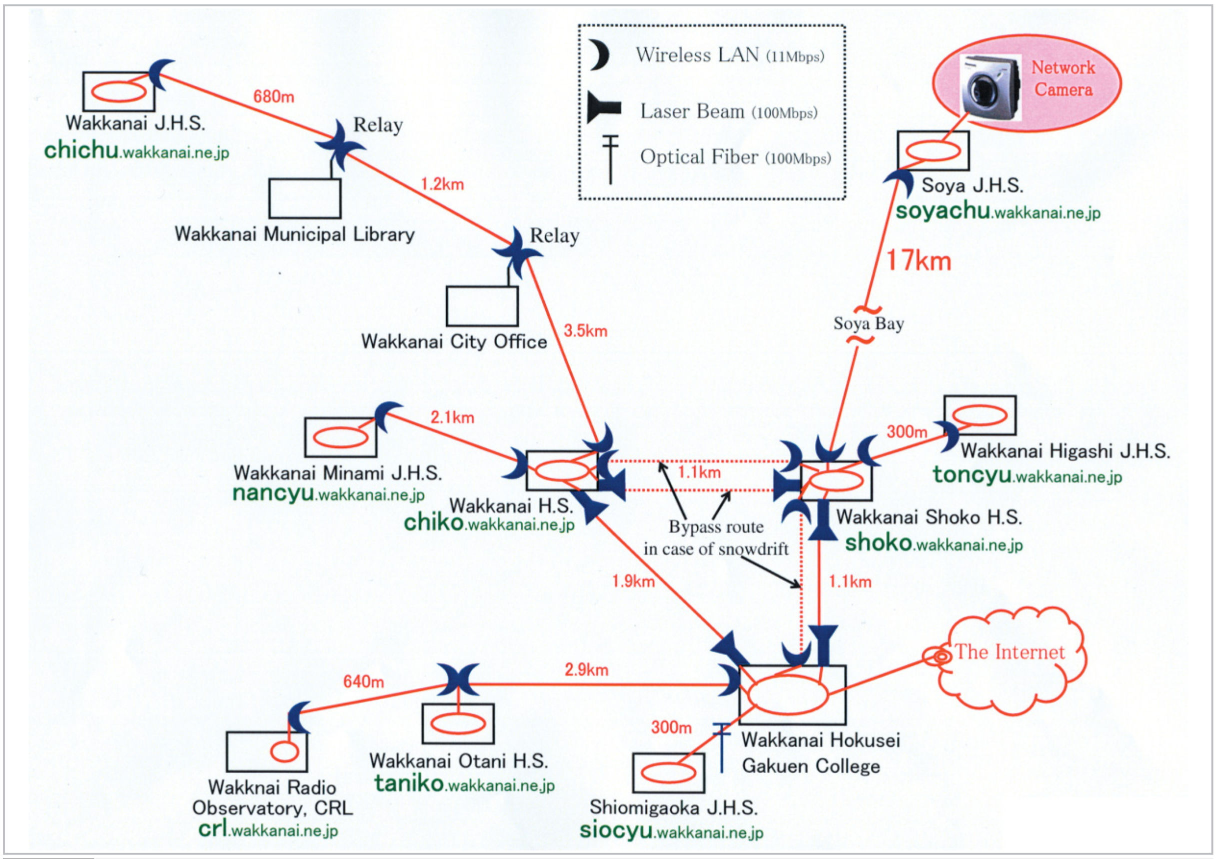

Fig.2 *Connection diagram of the Wakkanai Experimental Community Network (March 2004)*

* Those involved in the project generally referred to the Experimental Network as the "3K Net," the three Ks standing for "Koiki (large area)," "Kaso (sparsely populated)," and "Kakoku-na shizen-kankyo (severe natural environment)."

primary and secondary education. One of the authors (Takizawa) co-edited a textbook to train "Joho" teachers, a new resource for information technology education in senior high schools [3], leading to the inclusion of a number of comments on this project.

4 Progress of the project

4.1 Progress in 2000

4.1.1 Reinforcement within the Wakkanai Hokusei organization

In April 2000, directly after the start of the project, Wakkanai Hokusei became a four-year college, leading to improvement in the specialized skills of the students who participated in the project.

4.1.2 New connections

On June 29, 2000, the Soya District Office of Education, a local agency of the Hokkaido Prefectural Board of Education, designated two prefectural senior high schools, namely, Wakkanai High School and Wakkanai Shoko High School, as project participant schools. This designation clarified the roles within the project of these two schools, which had been connected with wireless LANs since 1995 through Wakkanai Hokusei's independent network activities. The collaboration of the Wakkanai City Board of Education was also secured under the project, clearing the way for connection of the junior high schools in Wakkanai to the network.

After these preparations, the project proceeded to connect each of the city junior high schools to Wakkanai Radio Observatory and the network via wireless LAN.

(1) Between Wakkanai Radio Observatory and Wakkanai Hokusei

Wakkanai Radio Observatory is located in a low-lying depression out of direct view of Wakkanai Hokusei. Wakkanai Otani High School, a private high school, is situated between these two locations, and it became clear that relaying via the roof of the gymnasium at the high school would allow for communication between the observatory and Wakkanai Hokusei. With the cooperation of Wakkanai Otani High School, a set of relay antennas was installed to this end. Figure 3 shows the relay antennas installed on the gymnasium of the high school. The distance between Wakkanai Radio Observatory and Wakkanai Otani High School is approximately 640 m, and the distance between the high school gymnasium and Wakkanai Hokusei is approximately 2.9 km. Yagi antennas were used at the high school and college connected. The antenna at Wakkanai Radio Observatory was installed indoors, near a window on the second floor of the office building. Figure 4 shows the Yagi antenna installed outdoors at Wakkanai Hokusei, pointing toward Wakkanai Otani High School. At this stage, only the

Fig.3 *Relay antennas installed on the roof of the gymnasium of Wakkanai Otani High School. The antenna on the left is for connection with Wakkanai Hokusei and the antenna on the right is for connection with the Wakkanai Radio Observatory.*

Fig.4 *Yagi antenna installed outdoors for the wireless LAN to Wakkanai Otani High School (Wakkanai Hokusei)*

relay antennas were installed at Wakkanai Otani High School, without implementing the network in the school. Due to CRL security policy, the Experimental Network was not connected to the CRL's own LAN.

Because the Experimental Network extended to the Wakkanai Radio Observatory, a web server was installed at the observatory specifically to present general aspects of the project, with a portal site opened to the public in March 2001 (http://www.crl.wakkanai.ne.jp/).

(2) Between Wakkanai Higashi Junior High School and Wakkanai Shoko High School

The wireless LAN was extended to Wakkanai Higashi Junior High School, approximately 300 m from Wakkanai Shoko High School, with the latter already connected to the wireless network extending from Wakkanai Hokusei. The Wakkanai Shoko High School placed an antenna in its observatory and Wakkanai Higashi Junior High School placed a planar antenna near a window in a classroom. Figure 5 shows the antenna installed at Wakkanai Higashi Junior High School, facing Wakkanai Shoko High School.

Fig.5 *Planar antenna installed indoors for the wireless LAN to Wakkanai Shoko High School (Wakkanai Higashi Junior High School)*

(3) Between Wakkanai Minami Junior High School and Wakkanai High School

As Wakkanai Minami Junior High School is located just behind the Wakkanai Radio Observatory, it seemed desirable to connect this high school to the wireless LAN via the Wakkanai Radio Observatory. However, for convenience in network management, the junior high school was connected to the LAN via Wakkanai High School, which was already connected via Wakkanai Hokusei. A planar antenna was selected for the Wakkanai Minami Junior High School, installed indoors near a classroom window.

(4) Between Shiomigaoka Junior High School and Wakkanai Hokusei

Shiomigaoka Junior High School is located directly adjacent to the grounds of Wakkanai Hokusei, with no third-party property between the two. Based on calculations showing that it would be less costly than purchasing and installing wireless network equipment, fiber-optic cables were installed on poles situated between the two organizations, providing connection at a transmission rate of 100 Mbps. Figure 6 shows the cables connecting the two organizations.

Fig.6 *Fiber-optic cables connecting Wakkanai Hokusei (center) and Shiomigaoka Junior High School (to the left beyond the frame of the photograph)*

During this period, a "Community Network Committee" was organized, including the Director of the Wakkanai Radio Observatory, representatives from Wakkanai Hokusei, Planning and Coordination Division, Municipality of Wakkanai, the Wakkanai City Board of Education, and headmasters of the connected schools, to conduct various negotiations between the connected organizations. The committee held three meetings: on August 22, 2000, December 18, 2000, and March 21, 2001.

As the number of connected organizations increased, Wakkanai High School and Wakkanai Shoko High School started to play the roles of hub stations, which demanded reinforcement in the links to Wakkanai Hokusei. Thus, the wireless LAN equipment (1.5 Mbps) installed by Wakkanai Hokusei in 1995 was replaced by laser-beam network equipment, both between Wakkanai Hokusei and Wakkanai High School and between Wakkanai Hokusei and Wakkanai Shoko High School. Figures 7 and 8 show the laser-beam network equipment installed at Wakkanai Hokusei. The CRT display shown in the photograph is the monitor used to adjust the laser beam.

Fig.7 Laser-beam network equipment for connection to Wakkanai High School (Wakkanai Hokusei)

Fig.8 Laser-beam network equipment for connection to Wakkanai Shoko High School (Wakkanai Hokusei)

4.1.3 Providing services open to the public

In June 2000, the All-Hokkaido High School Basketball Championship was held at several locations, including Wakkanai Shoko High School. As a demonstration of the Experimental Network, the games were covered live on the Internet, an achievement reported in the local newspaper [4].

4.2 Progress in 2001

4.2.1 Beginning to provide information

As the Experimental Network was operating smoothly, Wakkanai Higashi Junior High School and Shiomigaoka Junior High School established websites in March 2001 and began uploading information introducing their schools to the Internet; these activities were also reported in the local newspaper [5].

4.2.2 Clarification of the CRL organization

In April 2001, the CRL was reorganized as an incorporated administrative agency, and the radio observatory was eliminated from the organization. The Emergency Communications Group of the CRL Information and Network Systems Division thus determined to take charge of this project on behalf of the CRL, with the establishment of a clear organization to promote the project. At the same time, the project schedule was fixed: the experiment was slated to end at the end of March 2003, and after one year of follow-up, collaborative research was to end in March 2004, five years from the start of the project.

4.2.3 Observation of correlation between network performance and meteorological data

To verify the practicability of a wireless network under cold, snowy, and windy conditions, it is important to study the general correlation between meteorological and network conditions. Thus, to observe the correlation between network performance and meteorological data provided by the Wakkanai Local Meteorological Observatory, in November 2001 the project began to use Meteor i-NET, an Internet data service provided by the Japan Meteorological Business Support Center (JMBSC). By connecting to a server at the JMBSC, a user can download quasi-real-time meteorological data, including surface observations and AMeDAS data. The results of these correlation observations are discussed in ***6.2.1*** in detail.

4.2.4 Extension to Wakkanai Junior High School

In August 2001, Wakkanai Junior High School was newly connected to Wakkanai High School by wireless LAN. Wakkanai Junior High School is the only school among the connected organizations located in the central section of Wakkanai City and is out of direct view of Wakkanai High School. Thus, relay equipment was installed at Wakkanai City Hall and at the City Library. Only relay equipment was used; no network was installed at these two locations.

4.2.5 Appeal and reputation of the project

Around this time, the project started to attract public attention for its grass-roots implementation of a community network with wireless equipment. Accordingly, mass media, such as local television news, began reporting on the project with increasing frequency [6] [7]. Wakkanai Hokusei was also awarded the Hokkaido Telecommunication Conference Chairman's Award during the Information and Communications Month (May 15–June 15), 2001, for its contributions in the implementation of the Experimental Network.

4.3 Progress in 2002

4.3.1 Extension to Wakkanai Otani High School

In March 2002, Wakkanai Otani High School was connected to the Experimental Network. The link was branched via the relay equipment already installed on the school gymnasium to connect Wakkanai Radio Observatory and Wakkanai Hokusei. Connection to a school building approximately 100 m away was provided by wireless LAN.

4.3.2 Countermeasures against snowdrift

Correlation observations in relation to meteorological data that began in fall 2001 showed that the link between Wakkanai Hokusei and Wakkanai High School, which was provided by a laser-beam network system over a particularly long distance (1.9 km), was frequently disconnected due to snowdrift and similar causes. Thus, beginning March 2002, the connection for Wakkanai Hokusei, Wakkanai High School, and Wakkanai Shoko High School was triangularly duplexed via laser-beam network and wireless LAN. This provided means to bypass the connection route dynamically using OSPF in the case of snowdrift. Figure 9 shows the two sets of laser-beam network equipment (each pointing toward Wakkanai Hokusei and Wakkanai Shoko High School) and two wireless LAN antennas for the backup link installed in Wakkanai High School. Details are discussed in **6.2.**

Fig.9 *Duplex network equipment installed at Wakkanai High School: two sets of laser beam network equipment (for connection to Wakkanai Hokusei and Wakkanai Shoko High School) and two wireless LAN antennas for the backup link*

4.3.3 Workshop on the collaboration research

From July 2 through July 4, 2002, project participants from the CRL and Wakkanai Hokusei held a "Collaboration Research Workshop" at Wakkanai Hokusei (Fig.10). Eight people participated in the workshop: from the Emergency Communications Group of the CRL Information and Network Systems Division, the CRL Planning Division, and Wakkanai Radio Observatory. The workshop included presentations and discussions by students from Wakkanai Hokusei, a tour of the connected organizations, and discussions with the Planning and Coordination Division, Municipality of Wakkanai.

Fig.10 *Collaboration Research Workshop (from July 2, 2002 through July 4, 2002, at Wakkanai Hokusei)*

A large fire had taken place in the central part of Wakkanai City, involving the total destruction of 23 buildings on June 29, just before the opening of the workshop. The participants also visited the site of the fire.

4.3.4 Presentation of the project on CRL open-house days

On August 2 and 3, 2002, the CRL held open-house days at its headquarters in Koganei City, Tokyo, with the activities of the project displayed in the exhibition, with many attendees showing interest in the prospect of long distance communications based on wireless LANs (Fig.11).

Fig.11 *Display at the open-house exhibition (August 2 and 3, 2002, CRL Headquarters)*

4.4 Progress in 2003

4.4.1 Information and Communications Symposium in Wakkanai

On May 15, 2003, the "Information and Communications Symposium in Wakkanai" was held, cosponsored by the Hokkaido Bureau of Telecommunications, the Information and Communications Month Promotion Council, the Hokkaido Telecommunication Conference, and Wakkanai City Government. One of the authors (Kanayama) served as a panelist, introducing the project's activities. On May 16, a videoconference experiment was performed between Shiomigaoka Junior High School and Wakkanai Junior High School. However, due to malfunction of the PC router kernel and the implementation of multicasting, which will be discussed in ***6.2.2***, it was necessary to use IP tunneling with the DVMRP.

4.4.2 Extension to Soya Junior High School

In spring 2002, regulations concerning low-power data communication systems were eased, allowing for antenna gain of up to 12.14 dBi [8]. As a result, nominal 16-km products became available without the need for a user license. Thus, In July 2003, project members attempted a direct connection over a distance of approximately 17 km between Soya Junior High School and Wakkanai Shoko High School (Fig.12). From the Wakkanai urban area in the direction of Cape Noshappu to Soya Junior High School in the direction of Cape Soya, a connection was established over the Soya Bay with no problems. Soya Junior High School is the northernmost junior high school in Japan, located just before Cape Soya. In 2003, the network infrastructure commercially available to the public in the local area of the school had been limited to 64-kbps ISDN services. This link thus established a permanent connection to and from the northernmost part of Japan at a transmission rate enabling conveyance of video. Live video taken by the network camera installed in the school's observatory were continuously exhibited (Fig.13); again, these achievements

Fig. 12 *Parabolic antenna installed at Soya Junior High School for long distance wireless LAN*

Fig. 13 *Screen shot of video images taken by the network camera installed in the observatory of Soya Junior High School (Cape Soya at upper-right corner)*

were documented in a related trade paper [9].

During the CRL open-house days on August 1 and 2, 2003, a well-received demonstration took place in which visitors could operate the network camera at Soya Junior High School from CRL Headquarters via Internet (Fig.14).

The connection to Soya Junior High School completed the first phase of the experiment—i.e., the implementation of the Experimental Network.

5 Configuration of the Experimental Network

Each organization (node) connected to the Experimental Network is treated as a sub-domain in the Wakkanai Hokusei campus LAN (wakhok.ac.jp). In May 2001, Wakkanai Hokusei changed the Experimental Network part of the LAN to a double-domain network and the nodes were assigned to apparently independent domains expressed as XXX.wakkanai.ne.jp as viewed from the Internet. (Here, XXX indicates a sub-domain name that varies from one node to another.) All nodes are located within the firewall of the Wakkanai Hokusei LAN except for the respective web servers, the settings for which are made to allow access from external networks by port forwarding. Each node can be reached in accordance with application of the Wakkanai Hokusei policy regarding global addresses. One of the authors (Kanayama) is also one of Wakkanai Hokusei's network administrators, and thus was in a position to

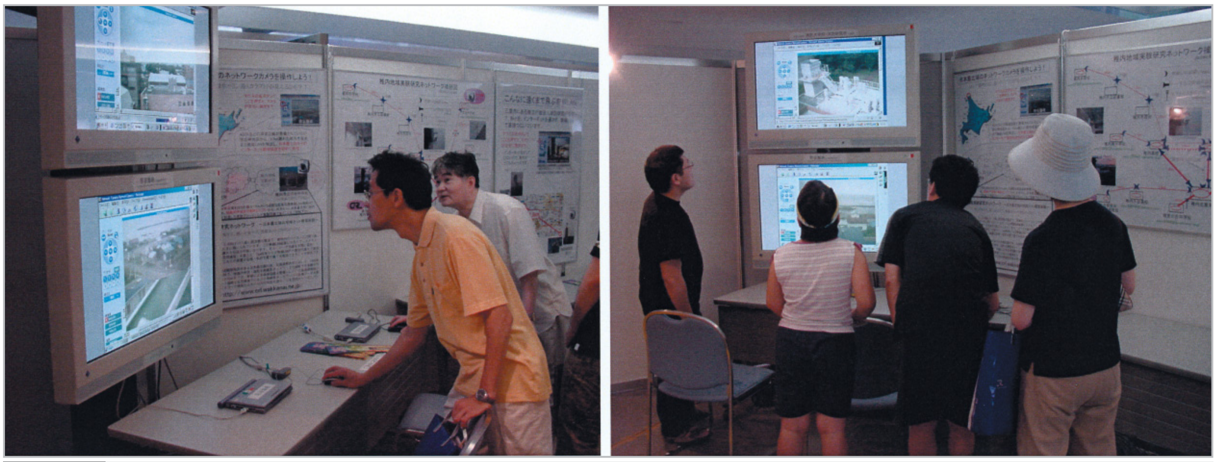

Fig. 14 *Display at the open-house exhibition (August 1 and 2, 2003, CRL Headquarters)*

design the Experimental Network out of Wakkanai Hokusei's LAN such that these two networks were treated as equivalent. However, it was decided that the Experimental Network should temporarily remain within the Wakkanai Hokusei LAN until each node could independently handle the functions of network management. Today, when the nodes demand more services, the Experimental Network can respond flexibly.

Each node is assigned to an independent sub-domain. Wakkanai High School and Wakkanai Shoko High School are hub stations, each with several personal computers (PCs) constituting a network. Other organizations (junior high schools and Wakkanai Radio Observatory) are terminal nodes, each with a single PC equipped with network server functions. At least single global IP address, with netmasks of 28 bits, is assigned to each PC. For routing purposes, the Experimental Network is composed of private addresses as well. The private addresses of the Experimental Network are designed to maintain consistency with those of the Wakkanai Hokusei intranet. (Wakkanai Hokusei's private address is 10.0.0.0/8, while the Experimental Network's private address is 10.17.0.0/16.) This design will allow for extremely convenient modification of the network in the future, when the nodes of the Experimental Network and Wakkanai Hokusei become treated as equivalent network components. When B Flets service of NTT becomes available in Wakkanai, this design will also allow a VPN (Virtual Private Network) connection between the nodes and Wakkanai Hokusei using B Flets, and it will also be easy to control routing between the wireless network and B Flets. In any case, the gateway PCs of the Experimental Network are currently placed within the Wakkanai Hokusei intranet routing. Thus, viewed from the Internet, the network features double-wall structures with independent firewalls for the connected organizations based on their own policies, within the firewall of the Wakkanai Hokusei campus LAN.

Figure 15 represents a selected section of the Wakkanai Hokusei network structure as it relates to the Experimental Network.

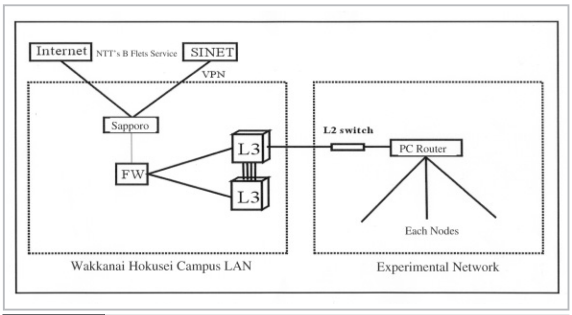

Fig.15 *Schematic diagram showing the connection between Wakkanai Hokusei LAN and the Experimental Network*

Ordinary PCs equipped with the FreeBSD OS are used for all routing in the Experimental Network. Of course, special-purpose routers could also be used. However, more flexible routing using PCs was selected, in consideration of the possibility of performing experiments into new routing methods and multicast routing. Fortunately, branching within the Experimental Network can be handled by the PCs. Nevertheless, it should be noted that the actual installation conditions require a variety of techniques: for example, low-band wireless LANs are handled within a single line in the hub stations based on VLAN technology allowing for the presence of two networks within structures that are physically the same but logically different. For this reason, an L2 switch that can handle VLAN and an exclusive routing PC are placed at each of the two hub stations (Wakkanai High School and Wakkanai Shoko High School). The PC itself handles the VLAN tag. Figure 16 shows

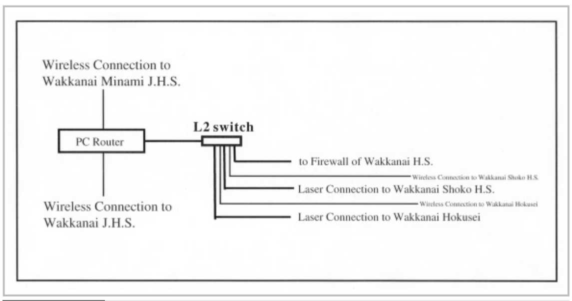

Fig.16 *Schematic diagram of the internal network within Wakkanai High School*

the network at Wakkanai High School, one of the hub stations.

Due to its dependence on laser and other wireless equipment (as discussed later), a practical problem in the Experimental Network arises in maintaining the links between the hub stations at Wakkanai High School, Wakkanai Shoko High School, and Wakkanai Hokusei. To solve this problem, project members settled on the use of wireless LANs and redundant connection to other schools. Thus, double lines connect these three organizations, as explained in ***6.2.2***. Due to the cable routing in each of the schools and other reasons, equipment details differ among the organizations—including line concentration and the VLAN relay—but the logical structure is basically the same at Wakkanai Shoko High School and at the remaining stations. The only difference is that Wakkanai Shoko High School is connected to Soya Junior High School 17 km away, and linked to Wakkanai Higashi Junior High School within a close range, via wireless LAN.

The basic design is the same for all nodes. In the junior high schools, a single PC provides the functions of a firewall, an NAT box, a mail server, a web server, and a DHCP server. Administration of these servers is in theory the responsibility of each node, but Wakkanai Hokusei was at first delegated with this role. Wakkanai High School and Wakkanai Shoko High School participated in a collaborative connection experiment set up by Wakkanai Hokusei before the start of the project. Thus, Wakkanai Hokusei took responsibility for administration at first, but now the high schools themselves are responsible for administration. As a matter of course, Wakkanai Hokusei has provided assistance to these high schools, including training for administrators. The equipment was also gradually upgraded and expanded from a configuration similar to those of the junior high schools described above to a more extended configuration with separate server functions. The lessons of this experience led to the application of the same approach to the junior high schools. Some of these junior high schools are now, initiating independent administration. In this sense, another significant effect of the Experimental Network can be seen in the growth within each organization, both in terms of human resources and in terms of network equipment.

Another characteristic of the node design is that the server PC is always installed in the staff room or in the principal's office to control the existing internal network of each node. As the two high schools joined the network earlier, they have grown internally since the installation of the servers, improving their internal networks. However, the junior high schools already had PC rooms or staff-room networks when they were connected to the Experimental Network. These networks might have been insufficient in terms of external connections and each had a different configuration. Nevertheless, each school had some form of existing network. It has been suggested that one of the reasons behind the success of the project is that the Experimental Network was planned to integrate (or simply proved capable of integrating) these internal networks, as opposed to being designed as an external entity. Of course, it was fortunate that the project received the full cooperation of the City Board of Education. In any case, as discussed above, the node for each junior high school was designed as shown in Fig.17.

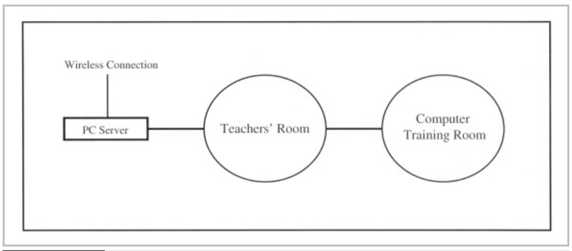

Fig.17 *Schematic diagram of the internal network within each of the junior high schools*

As Soya Junior High School, the most distant of all sites, already had ISDN network facilities before connection to the Experimental Network, and as the stability of the wireless link was unknown, the firewall settings were adjusted to switch the network automatically to Flets ISDN connection in the event of failure in the wireless link.

6 Achievements

6.1 Comparison with similar community networks

6.1.1 Kamifukuoka Wireless LAN Project

The KDD Research and Development Laboratories (now KDDI R&D Laboratories) hosted an experimental project conducted in Kamifukuoka City of Saitama Prefecture from December 1999 through to July 2000. Eleven schools and ten to twenty individuals participated in this project. The experiment also included multicast broadcasting. However, this was a simple broadcast experiment without actual multiple routing due to the experimental configuration, with the wireless equipment installed on a central steel tower. The experiment was also limited in terms of the range of communication to and from the steel tower, a range constituting a circular area with a diameter of approximately 3 km.

6.1.2 Community Network in the town of Wajiki, Tokushima Prefecture

The Shikoku Bureau of Telecommunications hosted a study group investigating the use of small-scale wireless systems for community networks, and this group subsequently conducted an applied experiment. This was a relatively early experiment and is thus considered a pioneer study. ROOT Inc. developed the equipment used in the experiment. At the outset, the equipment was based on NetBSD, although it has now evolved to form an exclusive unit (the content appears still to be based on NetBSD). As a result of this development, the equipment can in theory handle wireless routing. On the other hand, the unit is committed to certain preset purposes and it would be difficult to compare various routing algorithms and to introduce multicast routing. Nevertheless, it stands as a tried-and-tested special-purpose unit and has been introduced in different areas in Japan (including the Taisei Town in Hokkaido, Aomori City, and Matsuyama City). This unit is also used in the current project for the connection between Wakkanai Shoko High School and Soya Junior High School.

6.1.3 Maebashi City Educational Information Network

The Maebashi City Educational Information Network began as a service based on the Advanced Educational Network Model Project (supported by the former Ministry of Education, Science, Sports and Culture and the Ministry of Posts and Telecommunications) in 1999. Network connection extended to 20 schools, (elementary, junior high, and senior high), as well as to the Children's Center, with 1.5-Mbps wireless links, and to 12 additional elementary schools and one other organization via a 0.5-Mbps link. Approximately 30 organizations continue to be involved, with elementary and junior high schools as the main participants. One particular characteristic of the endeavor is that the "Gunma Internet Volunteers for Education" (GIVE), a volunteer based organization, provides most of the network design and support. This project is similar to the current project in many aspects. However, research in the former case is still mainly for the purpose of education.

6.1.4 Advanced Educational Network Model Project

As discussed above, Maebashi City established a network based on this model project, supported at inception by the former Ministry of Education, Science, Sports and Culture and the Ministry of Posts and Telecommunications. Other examples of independent network implementation based on this project include Shizuoka City, Hamamatsu City, and Setagaya Ward in Tokyo, in all of which 10 to 20 schools were connected via laser (with physical speeds of 155 Mbps). Other examples have involved the use of satellite communications. All 30 models of this example employ different methods.

6.1.5 Naruto University of Education

Naruto University of Education is independently connected to two local junior high schools via laser (100 Mbps), but the details of this system are not currently available, including the purpose of the project.

6.2 Experiments and discussion of laser and wireless LAN networks

6.2.1 Meteorological conditions and connection ratio

From the start of the project, snowfall was expected to influence the laser connections. In a multicast experiment performed in the first spring, dense fog rendered communication impossible for a time, which raised concerns about the issue of snowfall. Figure 18 plots the daily connection ratio from February 28, 2001 to March 21, 2001. Here the connection ratio is defined as the ratio of reply packets to sent packets when five 64-byte ICMP packets are transmitted per minute. As shown in the Figure, the connection conspicuously failed on March 4 and March 7.

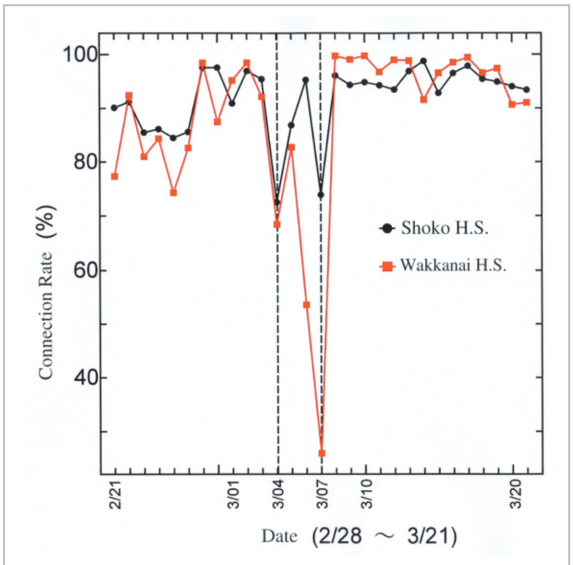

Fig.18 *Connection ratios of the laser beam network*

Figures 19 and 20 plot the weather conditions and the connection ratio on these two days with the same time axis. The weather data plotted include wind speed, range of visibility, and snowfall observed at the Wakkanai Local Meteorological Observatory. Unfortunately, the observatory is near Wakkanai City Hall, which is approximately four kilometers from the observation point for measuring the

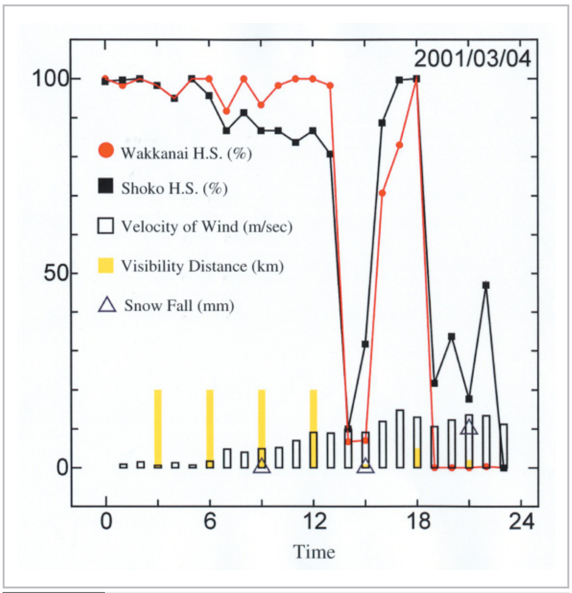

Fig.19 *Connection ratios and meteorological conditions (March 4, 2001)*

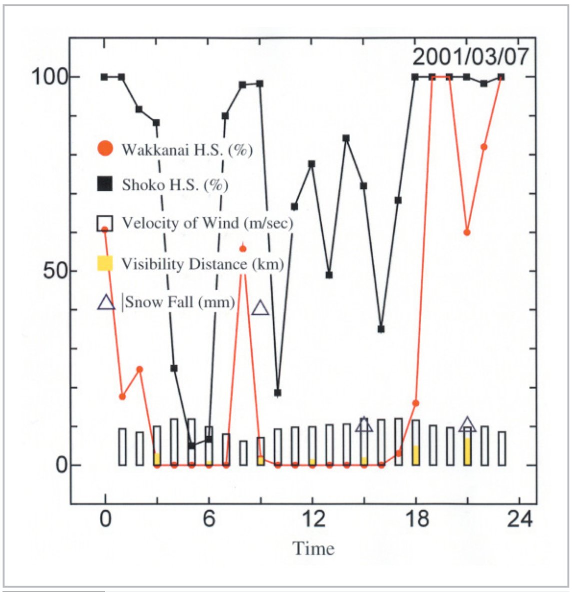

Fig.20 *Connection ratios and meteorological conditions (March 7, 2001)*

connection ratio (Fig.2). Wind speed has a significant effect on conditions in a snowstorm, specifically in terms of the range of visibility. This is due to the fact that the snow is consistently powdery, with ground temperatures of approximately -10℃, after the beginning of winter and before early spring. This renders the effect of snowfall on the range of visibility largely dependent on the presence or absence of wind. Even when there is no snowfall, snow accumulated on the ground sometimes acts like falling snow as the winds stir up the loose snow. This phenomenon is referred to as snowdrift. Thus, snowfall and wind speed were considered important weather factors at the start of the experiment, and the correlation between these weather conditions and the connection ratio was taken into consideration. It should be noted that the weather data obtained from the Meteor i-NET service was provided in a unique format. A reading tool was provided; nevertheless, it was extremely inconvenient and a new tool was developed for use in the project. In Fig.18, the connection ratio for communication to Wakkanai High School is indicated in red and the ratio for Wakkanai Shoko High School is shown in black.

As previously indicated in Fig.2, while the distance between Wakkanai Hokusei and Wakkanai Shoko High School is approximately one kilometer, the distance between Wakkanai Hokusei and Wakkanai High School is twice as far, at approximately two kilometers. Considering that energy loss for wireless LANs or laser transmission is proportional to the square of distance and that direct visibility is proportional to distance (assuming constant snowfall), the difficulty in connection between Wakkanai Hokusei and Wakkanai High School is estimated to be over three times that of communication between Wakkanai Hokusei and Wakkanai Shoko High school. Figure 19 shows that the connection ratio dropped rapidly before 13:00, recovered after 17:00 for a time, but deteriorated again. Here note that snowfall at 15:00 was 0 mm according to the weather data, but this is probably an anomaly relating to the location of the observation point; a certain extent of snowfall and simultaneous wind were considered to be the causes of disconnection at this stage. Next, Fig.20 clearly shows the difference between conditions at Wakkanai High School and Wakkanai Shoko High School. The weather data at 9:00 shows that there was a considerable amount of snowfall from morning to noon, but it appears that snowfall generally decreased later, as shown in the accumulation of 10 mm between 9:00 and 15:00. Reflecting these weather conditions, the connection to Wakkanai Shoko High School recovered to approximately 50 % of full performance, while the connection to Wakkanai High School remained at 0 %. Even more interestingly, the connection generally recovered between 15:00 and 21:00 in spite of the fact that snow accumulation during this period was the same as in the previous observation. These results indicate that snowfall had already decreased to a low level at around 15:00 in the afternoon but that snowdrift occurred as a result of the morning snow and winds of approximately 10 m/s. The range of visibility data also reflects this state: the range was substantially below one kilometer but then recovered to approximately one kilometer by 21:00.

Based on this data, the laser connections between Wakkanai High School, Wakkanai Shoko High School, and Wakkanai Hokusei were improved to allow for combined use with wireless LAN. Figure 21 shows the weather data and connection ratio measured on one day the following year, with the improved network. A constant snowfall of approximately 10 mm was observed all day, but the figure clearly shows that the connection ratio for the laser link varied due to the wind. On the other hand, no significant changes were noted in the wireless LAN connection in spite of these conditions. Weather factors such as snowfall also influence wireless LANs to a certain extent; however, the conditions surrounding the communication equipment influence the connection far more than snowfall or rainfall between the two locations connected. For example, in the Wakkanai Hokusei experiment performed before the current project, the wet snow in the early spring covered the front side of the planar antenna and completely blocked the connection. Similar problems also occurred in this experiment. As planar antennas often present these sorts of problems, they were always installed indoors in the early stage of the experiment, with connection established through a window. Nevertheless, at Wakkanai Higashi Junior High School, the window was covered with snow, which

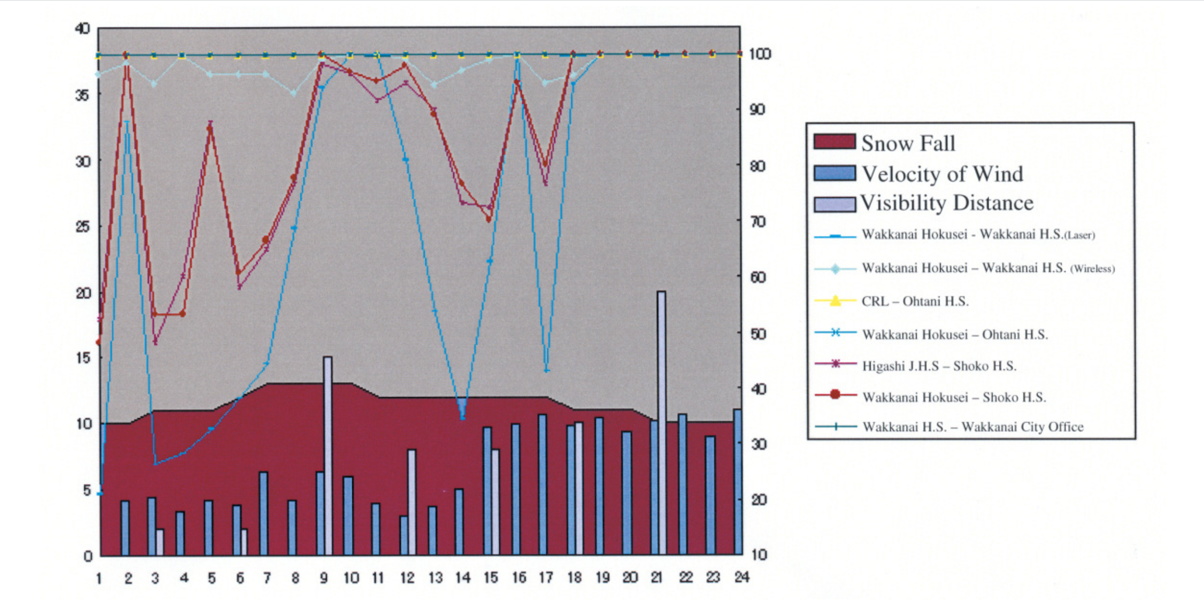

Fig.21 *Connection ratios between various sites and weather data*

blocked the connection. This adhesion of snow does not often occur in heated rooms with human activity. However, at Higashi Junior High School, the equipment was installed in an infrequently used room due to physical restrictions stemming from the connection to the hub station at Wakkanai Shoko High School. Later, the main antenna path for the wireless LAN was changed, with a switch from planar antennas to Yagi antennas; with these changes these interruptions seldom occur, even when the antennas are installed outdoors. This is the reason for the apparent synchronization of the data for the wireless LAN connection between Wakkanai Higashi Junior High School and Wakkanai Shoko High School and the data for the laser connection between Wakkanai Hokusei and Wakkanai Shoko High School. In any case, the data reveals that the wireless LAN is relatively resilient, even with snowfall, and that no problem arises if the connection route is switched to wireless LAN when the laser connection fails.

A technical problem remained in switching the connection from laser to wireless LAN safely and quickly. To effect this automatic switching, dynamic routing with OSPF (Open Shortest Path First) protocol was introduced in the connections between Wakkanai Shoko High School, Wakkanai High School, and Wakkanai Hokusei, as described in ***4.3.2***. However, OSPF protocol also changes the route after detecting a period of disconnection. Consequently, the disconnection must be quickly detected, but there was a concern that such a quick detection system would misidentify a temporary recovery as an ongoing connection, leading to detection errors. An initial experiment was therefore performed to shorten the detection time. However, the PC in use was not capable of handling these settings, and it became evident that the OS would hang when these settings were forced. This verification was thus unfortunately abandoned.

As discussed, there are various problems in establishing countermeasures for winter-related challenges. Nevertheless, it is important to note that a fast network has been maintained generally well throughout the year. There is no other example in Japan of successful stable operation of a network that supplements the weaknesses of laser connection with a practical network using inexpensive equipment such as wireless LANs. Figure 22 shows the connection ratio during three months in the spring of 2002. The figure clearly shows that the laser connection also operates relatively stably around April, in contrast to February or March, when blizzards are frequent.

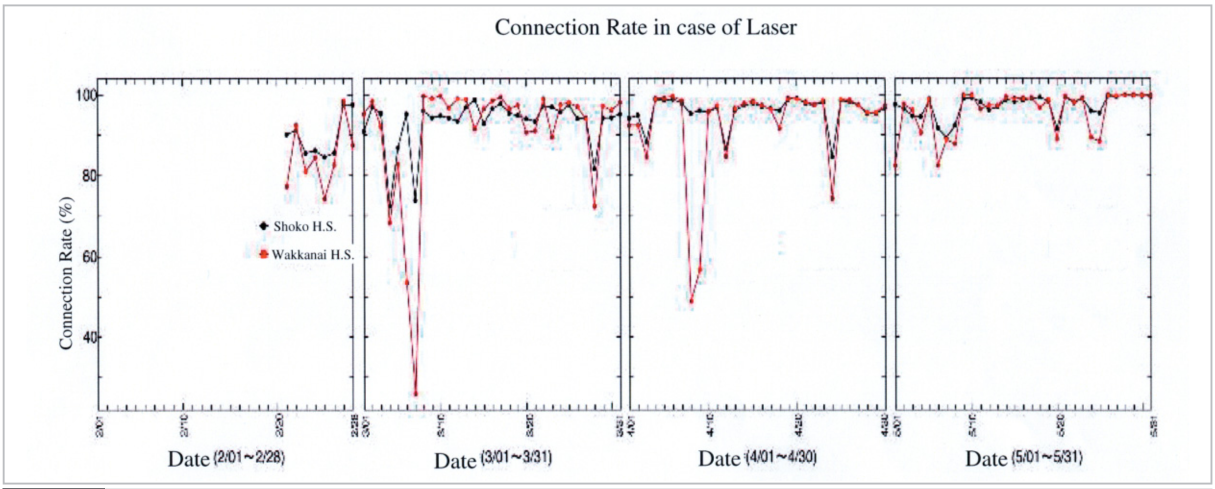

Fig.22 *Connection ratios from February 21, 2002 through to May 21, 2002*

6.2.2 Duplex design with laser and wireless LAN

As discussed in **4.3.2** and **6.2.1**, the connection routes were duplexed with laser and wireless LAN to address winter-related problems in laser communications. The significant points of this duplex design were as follows.

The three sites to be duplexed were Wakkanai Hokusei, Wakkanai Shoko High School, and Wakkanai High School. Taking the maximum bandwidth between these sites into consideration, it was estimated that 200-Mbps communication would be required at each site with full operability of the laser connection. In view of various technical experiments envisioned with this Experimental Network—including multicast and IPv6 applications—equipment such as the dedicated L3 switch would obviously be insufficient. It was therefore determined to introduce routing via PCs as in the connection points of the various nodes. At the same time, in consideration of the bandwidth requirements and also in light of heavy multicast use (IPv4 and IPv6), the lines would have to be separated; though this was not completely feasible due to the limitations of the node equipment, at least a logical separation was necessary. As a result, a router PC equipped with a PCI-X bus and Gigabit NIC was selected to secure bandwidth, and an L2 switch with a Tagging VLAN function was included in the design to ensure separation. Figure 23 shows a conceptual diagram of the design. Of course, the PC router must be able to control Gigabit Ether and it must also be able to handle VLAN directly. Fortunately, BSD was updated at this time to support VLAN, with operation confirmed in preceding experiments. However, the OSPF and multicast functions were not sufficiently supported at first—it was not until near the end of the project that the duplex lines began to operate as designed.

6.2.3 Remaining challenges

The remaining challenges include a number of problems arising at the start of the project that were known from similar experiments, and other problems that still remain unaddressed. This section outlines the problems that could not be studied during the course of the project.

As the authors were not specialists in meteorology, the study of the correlation between the meteorological data and the connection ratio was in a sense insufficient. In particular, few existing studies are available concerning various snowfall-related problems in wireless LAN or laser communications, and thus collaboration with specialists is indispensable. When one of the authors (Kanayama) delivered a lecture at Wakkanai Local Meteorological Observatory, a meteorologist offered a number of suggestions, which unfortunately could not be incorporated into this study. Specifically, we had limited our focus to snowfall, but snowfall was measured every six

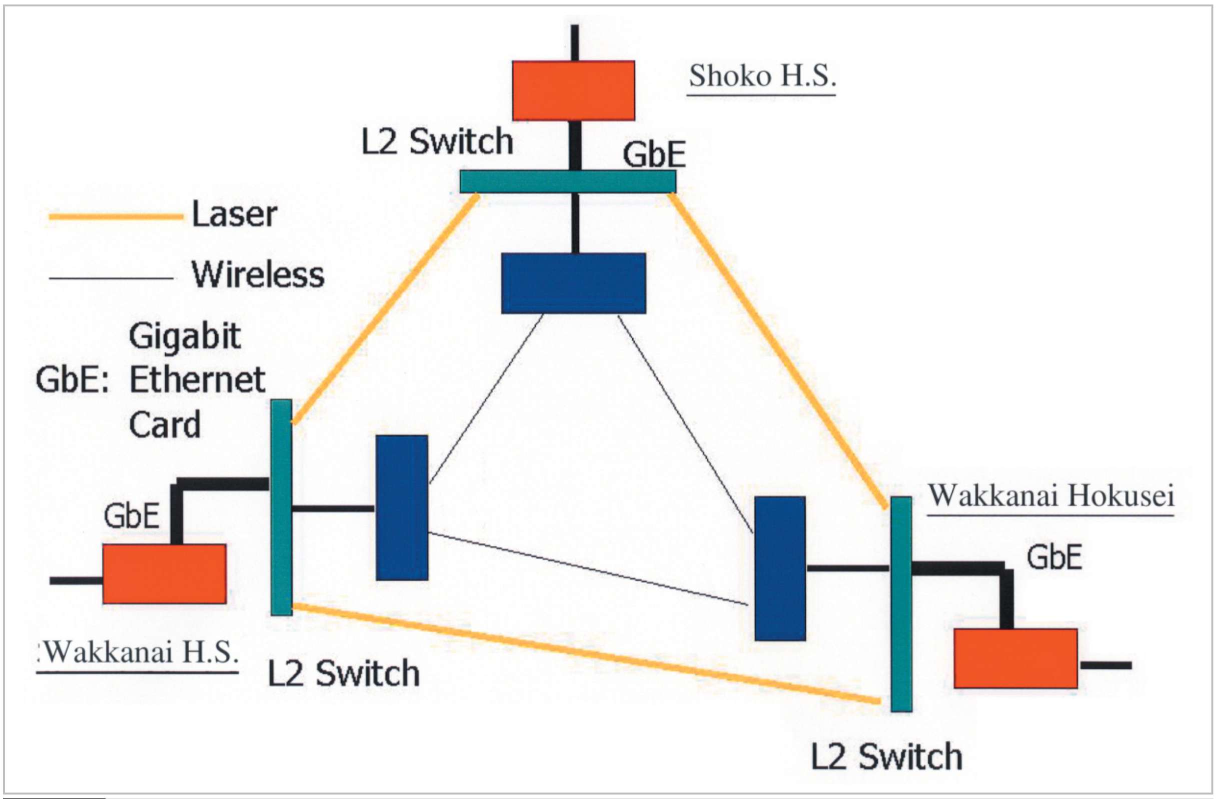

Fig.23 Duplex design

hours, which was not sufficiently frequent for comparison of the data with the connection ratio. On the other hand, rainfall was measured quite precisely, with some snowfall data included in the rainfall data. Of course, this led to the problem of distinguishing between rainfall and snowfall, but the meteorologist mentioned above pointed out that actual earth-surface temperatures could be used to make this distinction. Hence it may be possible to draw new conclusions about the connection ratio based on the three-fold correlation among rainfall, earth-surface temperature, and wind speed. We have not performed these analyses but data is plentiful and we hope to study this problem in the future.

A second problem was found in the duplex design, which unexpectedly hampered network operation with respect to the OS kernel, as noted earlier. The authors' assessments in this respect might have been too optimistic. Nevertheless, the network has at last begun to operate stably, and multicast and other experiments can now be performed. Connection via PC router has advantages in terms of flexibility, but stability in this case inevitably pales in comparison with that of a dedicated router. The current design was selected in accordance with the purposes of the experiment, but it cannot be denied that this decision caused a certain degree of inconvenience among the participants.

6.3 Low-latitude auroral observation

When the project began in 1999, the number of sunspots was at a maximum. Accordingly, continuous image monitoring of low-latitude auroral development was proposed. A network camera was installed at Wakkanai Hokusei for automatic imaging of the north sky in the direction of the Soya Strait at constant intervals at night, with data stored within the server. Basic tests and operational experiments were thus performed in the provision of this data to the public over the Internet.

6.4 Experiments at Wakkanai Radio Observatory

With the rapid growth in email using PCs and portable phones, a so-called "digital divide" developed between those who were communicating via email and those who were not. In response, to provide an easy means for those uncomfortable with information-technology equipment to enter into the world of email communication, an experimental email-to-voice conversion system was installed at the Wakkanai Radio Observatory as an application experiment over the Experimental Network.

This system is based on "Mail Carrier," developed by Railway Information Systems Co., Ltd. for groupware mail systems, modified to operate using SMTP. The system was installed on an Internet mail server constructed in Windows NT, providing functions to read text aloud through voice synthesis and to identify users based on caller ID and DTMF (touch-tone) signals. In this system, the user calls in to listen to the voice-synthesized content of emails delivered to the user's mail server account (a pull-type service). When an email arrives with a certain flag, the experimental system immediately calls the target user; the user can then listen to the content of the email (a push-type service). Registered user telephone numbers may also be modified by phone.

This system differs from the synthetic voice functions implemented in client e-mail software for the visually impaired in that here the voice function is implemented on the mail server. The system offers an advantage in that the user does not need to have access to hardware such as a PC or even a specific portable phone, but instead can listen to the email by calling the server from a home or public telephone.

We prepared this system and solicited applications during the Wakkanai Radio Observatory open-house days in the summer of 2001. However, not a single person applied. Meanwhile, portable phone e-mail services, including those provided by i-mode, were rapidly spreading throughout society, nearly resolving the digital divide issue, which had been the motivation for the development of this system.

A server-side service such as this one is considered more effective when used as a convenient means of recording text-based information via telephone and email than when it is applied as personal e-mail voice-synthesis service. A case of the former use might be seen, for example, in the event of rain on the occasion of a school excursion; the teacher in this case would send an announcement as to whether or not the excursion is postponed, notifying the system from his or her PC via e-mail on the morning of the excursion. Parents and guardians could then call the system to hear the announcement.

6.5 Evaluation by connected organizations

In considering the achievements of this project, the evaluations of the participating schools connected to the Experimental Network play an important role. With the cooperation of the BSNetwork Corp., a feedback survey was thus conducted from February 2004 to March 2004 for the five junior high schools newly connected under the project, with the teachers in charge of network administration in these schools as the respondents. The questions concerned use of the network in and out of class, frequency of use, the relationship between the weather and connection failures, the management of the school LAN, and other comments. Table 1 shows the results of the survey.

According to the survey, the schools showed a tendency to use the network more as a tool to collect information than as a means to provide information. It also became clear that the schools did not use the mail server function installed on the router PC but instead relied on web mail services. The task of supporting the schools in their use of the Experimental Network to provide information thus remains to be addressed. Use of the network between the connected schools, e.g. for remote classes, also has yet to be established. These problems should be studied in connection with application development, considered as the second phase of the project.

Table 1 *Results of the feedback from connected junior high schools*

	Use in class	Use out of class	Frequency of use	Relationship between connection failure and weather	Management systems	Comments and requests
Wakkanai Junior High School	All students from first to third grade use the network.(Assignment problems are also distributed via e-mail.)	Teachers use the network to search for information. They use web mail systems provided by Yahoo! and others and do not use the email program in the Experimental Network domain.	Every day	Bad in blizzards. However, the conditions are improving every year. There were virtually no problems in 2003. It stopped due to construction work at Wakkanai High School along the route. The students also are aware of the applicable conditions and the possibility of disconnection in blizzards.	A teacher takes charge. The teacher also identifies problems. However, management by three administrators will begin in 2004.	1. We do not know how to operate the FreeBSD OS of the router PC. We would like to request an instructive seminar. 2. The link was fast, which was good. 3. It will be better with a backup link. 4. We want to use the network as a place for students to build and present common content. We appreciate the on-site seminars by Wakkanai Hokusei.
Wakkanai Higashi Junior High School	Used in IT classes in Industrial Arts and Homemaking or in Comprehensive Learning (third grade). Learning through Investigation projects in Social Studies (first grade), extracurricular activities, etc.	Teachers search the web.	Used intensively when necessary according to the progress of the class and three times a week for extracurricular activities.	No good in blizzards. It once stopped in fine weather in summer (possibly due to the construction work at Wakkanai Shoko High School).	A teacher takes charge. We call Wakkanai Hokusei for help when there's a problem.	We received great assistance from Professor Kanayama and the students in his laboratory. We hope that this assistance in equipment and human resources will continue. The student council hopes to have meetings with students in other schools through video conferences or a similar method.
Wakkanai Minami Junior High School	Used in Learning through Investigation projects in Social Studies and Science, IT classes in Industrial Arts, extracurricular activities, etc.	Teachers search the web.	25 class hours per year.	The network failed in blizzards the year before last but no disconnection occurred in winter of last year.	Three teachers take charge of managing the network and solving problems.	1. We're hoping for a stable connection. 2. We cannot operate the router because of the FreeBSD OS. 3. We weren't familiar with the sub-domain system. We don't understand how to use it. 4. We would like to conduct activities such as video conferences.
Shiomigaoka Junior High School	All grades use the network in Learning through Investigation projects in Social Studies, simulation of spatial figures in mathematics, Comprehensive Learning, self-study preliminary survey for school trips, etc.	Teachers search the web. Some teachers use the email program in the Experimental Network domain.	Three times or more per weak and approximately every day from October through March.	(Inapplicable due to the use of fiber-optic connection)	Two teachers take charge of managing the network and solving problems.	The connection fails too often. It is not reliable. On some occasions, the class could not move forward. We have to consider using other connection alternatives, such as ADSL.

The frequency of use was generally high in all of the schools, which indicates that the Experimental Network can serve as an indispensable classroom tool. This is the source of the concern regarding the stability of the connection in many schools. One of the authors (Kanayama) currently responds to connection malfunctions at the user's request, either personally or with the assistance of the students in his laboratory. The survey nevertheless indicates that the establishment of a management system is urgently required. With the expansion of the Experimental Network, the number of organizations connected to the network increased, and it appears the Experimental Network should now move from its basic experimental phase to an operational phase, equipped with a responsive management system. However, except for Soya Junior High School, the four schools are located in Wakkanai urban areas, where inexpensive commercial connection services are available, which will gradually temper the need to rely on the Experimental Network. The cost of ensuring stable operations should certainly be taken into account when considering the future role of the Experimental Network.

As for the relationship between the weather and connection failure, although the connection was unstable at first, a gradual tendency toward stability has been noted. As discussed in ***6.2.2***, we know that the modification to the connection between the three hub stations (Wakkanai Hokusei, Wakkanai High School, and Wakkanai Shoko High School) made in 2002 to modify the network to a triangular and duplex configuration was particularly effective. As the vulnerability of the wireless LAN network to bad weather is no longer considered a problem even at Soya Junior High School, where the conditions are the most severe, this issue does not now appear to merit much concern.

Regarding the management system and other comments, we noted an unexpected number of complaints that the teachers could not operate the router PC with the FreeBSD OS. This indicates that the schools are eager to take charge of administration of the router PC. The early concern relating to raising awareness among users not as passive subjects but as active participants in the implementation of the Experimental Network thus seems to have been addressed. In the future, it will be necessary to consider providing FreeBSD education to the administrators at each school and also to examine the possibility of constructing the router with an OS that is easier to manage than FreeBSD.

7 Future challenges

The equipment used in the Experimental Network will remain in use for experiments to be performed after completion of the collaborative research project between the CRL and Wakkanai Hokusei. This section will discuss the challenges that will remain within the future Experimental Network.

7.1 Challenges related to experiments

As discussed in ***6.2.2***, the duplex system has at last begun stable operation, and it is now possible to perform experiments to determine the most appropriate multicast routing algorithm. These experiments have usually been performed within stable networks and have already provided a certain number of conclusions. However, the findings may be different for this network, which is why this experimental system is particularly interesting. At the same time, these experiments are important in the evaluation of new multicast routing algorithms to be used in IPv6 or other novel environments.

7.2 Challenges related to the facility

The wireless LAN equipment now used in the Experimental Network is mostly based on the IEEE802.11b standard. Replacing the equipment with devices compliant with the IEEE802.11g standard should improve the network specification speeds from 11 Mbps to 54 Mbps without the need for antenna replacement.

Although the initial goals were achieved in the first phase of the project regarding the extension of the Experimental Network, it is worthwhile to consider further extension to nearby islands in the future, as the project has specialized in these sorts of large, sparsely populated areas. For example, Rishiri Island, which is in direct view of Wakkanai City, is an interesting candidate area. Survey results indicate that Motorola's 5-GHz wireless equipment can be used to connect to Rishiri Island, though this equipment requires a user license and thus certain formalities will be necessary. On the other hand, there has been some indication that ADSL services will also begin on Rishiri Island in 2004, in which case, it may be wise to target another site, such as Rebun Island. Still, since it is unlikely that services such as ADSL will be provided in all areas of Wakkanai and that isolated schools will always remain out of reach of these services, the importance of network implementation using wireless equipment—and the corresponding significance of the Experimental Network—will not diminish.

7.3 Relationship with other projects

When the current project began, inexpensive Internet connection available in Wakkanai had reached the ISDN (64 kbps) service level. This alone gave value to the fast network through Wakkanai Hokusei for the schools involved. Later, development plans for a local municipal government intranet and for the board of education's School Network began to progress. The Experimental Network thus must be able to be positioned effectively with respect to these municipal and educational networks.

The Wakkanai City Regional Intranet Infrastructure Development Project has implemented a network connecting three hub facilities—City Hall, the Board of Education, and the Health and Welfare Center—in addition to 23 other facilities. Wakkanai City executed the first phase of the project in 2000, with a grant provided by the former Ministry of Posts and Telecommunications, and initiated the second phase of the project in 2002 on its own. By 2005, the city will conduct the third phase of the project, consisting of the development of the city backbone fiber-optic network; the connection of 30 public municipal facilities, five elementary schools, and four junior high schools; and the development of 17 public access terminals. The junior high schools included in the third phase of this project are already connected to the Experimental Network. Wakkanai City is aware of the existence of the Experimental Network, having reported on the activities of the Experimental Network in the context of efforts toward community computerization in Wakkanai [10]. However, the relationship has yet to be clarified between the Experimental Network and the network to be constructed in the third phase of the project. Collaboration between grass-roots and government activities is traditionally somewhat difficult. Nevertheless, it will be a good idea to make arrangements with Wakkanai City concerning the future use of the Experimental Network, to avoid the waste of double or triple investment in public development. On the other hand, five years after the start of the project, the equipment used in the Experimental Network has begun to complete its useful service life. Already several devices have broken down in the course of the project, and the light sources for the laser equipment should be replaced. In considering the use of the Experimental Network in the future, the cost of updating the equipment should also be taken into account. Given this background, we have begun discussions with Wakkanai City and other parties regarding the future of the Experimental Network and the sharing of costs in the event of failure, for example.

Meanwhile, all of the public high schools in Hokkaido are already connected to an independent public school network developed by the Hokkaido prefecture. This network is nevertheless unpopular among users, and both Wakkanai High School and Wakkanai Shoko High School now mainly use the Experimental Network. However, the spread of other fast services such as B Flets in Wakkanai would inevitably reduce the significance of connecting the junior high schools to the Experimental Network, as already noted. Yet the Experimental Network has already earned a significant local reputation, and a physical departure from the network will not immediately entail full abandonment. At the same time, construction of a framework that will involve a certain degree of participation in the network centered at Wakkanai Hokusei seems possible, even if the participating schools are independently connected to new networks.

7.4 Application experiments

The multicast broadcast experiment remains as a future problem that has not even begun to be addressed. This experiment was one of the targets of the project, under the assumption that the network would be used for community television or for remote learning systems. According to the plan, video cameras and MPEG servers were to be installed in the connected schools, with broadcasting to be performed via the MPEG4 multicast broadcast server at Wakkanai Hokusei. This system was viewed as a potential communication tool between the connected schools, to be used as a means to exchange information among teachers as well as students. Some schools connected to the network have constructed a number of video projects, which we believe could be used as broadcast content.

The impediments to this experiment to date have been discussed in ***6.2.2*** above, and these problems have been resolved. On the other hand, policy and operational guidelines for data delivery remain as future challenges; a meeting should be organized to consider and determine an approach to these issues.

7.5 Stable operation of wireless LAN

The feedback from the schools connected to the Experimental Network indicates no strong correlation between weather and the connection stability. However, the connection stability of 2.4-GHz band wireless LANs is known to depend on the amount of moisture on the antenna. Wet snow will adhere to the antenna, absorbing radio waves and reducing sensitivity. Even when the snow is not on the antenna element itself but instead adheres to the antenna cover, some effect is inevitable. It is windy in Wakkanai and the wind stirs up the snow. While the temperature is generally low in Wakkanai, and wet snow is only infrequently observed, when wet snow does fall, the collected snow often freezes, forming a surface for the adhesion of further snow. Thus installation of the antenna entails a thorough evaluation of location and disposition.

A 2.4-GHz band wireless LAN is also limited in the number of available channels, and radio interference has also been recently observed in the urban areas of Wakkanai. The main causes of this problem can likely be traced to the wireless routers introduced into homes with the spread of broadband, inter-building business communications, and wireless services initiated through ISP. Wireless LANs that do not require a user license are not limited in terms of number of users and thus this trend is expected to continue. When using a wireless LAN in backbone routing, it may be necessary to consider other frequency bands with less interference (for example, the 5-GHz band, conforming to IEEE802.11a standards) as alternatives.

Another problem may be seen in the occasional unaccountable hanging of the wireless LAN equipment currently in use. Some variation in this phenomenon has been noted, but most of the devices have been confirmed to hang. In many cases, resetting the power allows recovery of the connection. In networks such as the Experimental Network that extend over a large area, relay equipment is required; this equipment is installed in locations often difficult to access for maintenance—for example, in unpopulated areas or in high locations. In such cases, resetting the equipment leads to delays in recovery. It may be necessary to consider introducing a mechanism to reset the power in the course of network traffic monitoring, or to reset power automatically at least once a day.

7.6 Toward advanced experiments

As already mentioned in several sections, the current Internet will soon have to accommodate the introduction of IPv6. This is due to the current global situation in which, for better or worse, the number of available IP addresses has become critically low. Now the Internet faces a situation that could be described as a new north-south problem. Even in the U.S., which enjoys a great number of IPv4 addresses and where users saw little urgency in implementing IPv6, the government network has stipulated the introduction of IPv6 within a clear time frame, with moves toward implementation expected to accelerate. Japan is relatively eager to implement IPv6, and IPv6 connections are now possible within many ISPs. However, IPv6 itself still offers numerous possibilities in terms of development and the discovery of unexploited characteristics. As already discussed, many of the routers in the Experimental Network are PC routers, designed to enable free experimentation in connection with these new technologies. We intend to introduce IPv6 into the Experimental Network in conjunction with the development of a new version of the IPv6 protocol.

At the same time, a group headed by one of the authors (Kanayama) is beginning connection experiments using MPLS (Multi Protocol Label Switching) in collaboration with universities and organizations in Hokkaido (NORTH BOREO: Network Organization for Research and Technology in Hokkaido / Broadband Orbit of Research and Experiment Opportunity [11]). MPLS has evolved as a layer-2.5 technology in terms of logical hierarchy, and is conceptually independent of the IP, designed based on historical lessons in the improvement, development, or failures of ATM. MPLS is thus expected to solve the load issue in IP routing. Due to these characteristics, the relationship between MPLS and IPv6 also poses a significant challenge for the future, and the project is expected to be extending beyond the initial experimental phase.

8 Conclusion

The environment surrounding information and communication networks evolved significantly during the five years of the Wakkanai Experimental Community Network Project. In urban areas, ADSL and FTTH have spread rapidly, and broadband use is now common, even in homes. The government's introduction of the e-Japan Priority Policy Program and the School Internet Project supported by the Ministry of Education, Culture, Sports, Science and Technology and the Ministry of Internal Affairs and Communications are two examples within the current movement promoting information and communication networks nationwide. On the other hand, it is as difficult as ever to use broadband services in large, sparsely populated areas. The cost advantages of a self-maintaining network implemented by wireless equipment, as demonstrated in the current project, have probably not decreased. In the future, it will be important to apply the findings of this project in the implementation of other community networks.

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References

1 Noriyo Kanayama, "Development and Operation of an Educational Community Network using Wireless LAN", Proceedings of the IPSJ Autumn General Conference, 3H-3, 1998.

2 Hitomi Ohmichi et al., "Community Network using Low Power Wireless System, Proceedings of the 2001 IEICE General Conference, D-9-26, Mar. 2001.

3 Ken'ichi Sakaguchi et al (Eds.), "The Textbook to Train Teachers for Information Technology Education in Senior High Schools", ISBN 4-501-53680-2, pp.156-157, Tokyo Denki University Press, Feb. 2004.

4 "Inter-Hokkaido High Schools Basketball Games - Relay Broadcasting on Computer Network", Hokkaido Shimbun, Jun.23, 2000.

5 "Wakkanai Higashi Junior High School Released New Website, and Shiomigaoka Junior High School also Has a Plan", Nikkan Souya, Mar.29, 2001.

6 "Friday Spot", NHK TV, May 18, 2002.

7 "Good Morning Report", NHK TV, May 25, 2002.

8 "Second Generation Low Power Data Communication System / Wireless LAN System", ARIB Standard STD-T66 ver.2.0, Association of Radio Industries and Businesses of Japan, Mar. 2002.

9 "Wireless LAN System for Cold and Snowy Area -CRL Founds an Experimental Facility in Wakkanai City", Nikkei Sangyo Shimbun, Aug.1, 2003.

10 Kazuhiro Hyugaji, "Regional Informatization Report Vol.47, Regional Informatization of Wakkanai City", Info-Communication Journal, Vol.19, No.11, pp.26-28, Ministry of Internal Affairs and Communications, Nov. 2001.

11 Norikatsu Ooishi, "NORTH boreo MPLS -Network Organization for Research and Technology in Hokkaido / Broadband Orbit of Research and Experiment Opportunity", http://www.north.ad.jp/boreo/north-boreo-mpls_plan.pdf.

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Theory of Network