NerveNet Architecture and Its Pilot Test in Shirahama for Resilient Social Infrastructure

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SUMMARY From past experience of the large-scale cutoff of existing networks as a result of the East Japan Great Earthquake and tsunamis, and from previous research on stabilizing ad hoc networks that lack control mechanisms, we have strengthened the resilience of NerveNet. NerveNet was originally designed and developed as an access network for providing context-aware services with the use of sensors and actuators. Thus, at present, it has the capability to enable resilient information sharing and communications in a region even if access to the Internet is impossible in emergency situations. NerveNet is composed of single or multiple base stations interconnected by a variety of Ethernet-based wired or wireless transmission systems. A network is formed using line, star, tree, or mesh topology. Network and data management works in each base station in a distributed manner, resulting in the resilience of this system. In collaboration with the town of Shirahama in Wakayama prefecture in Japan, we have been conducting a pilot test with the NerveNet testbed. The test includes nine base stations interconnected by 5.6-GHz Wi-Fi and Fixed Wireless Access (FWA), providing tourists and residents with Internet access. In the future, we expect that not only NerveNet but also other novel technologies will contribute to solving social problems and enriching people’s lives.

Key words: resilient network, disaster, multihop network, mesh network, ad hoc network

1. Introduction

The East Japan Great Earthquake and subsequent tsunamis on March 11, 2011, badly damaged lifelines such as roads, water, gas and electric power supply, including communication networks. Approximately 29,000 cellular base stations were damaged [1]. Optical fibers, metal cables, and telephone lines were cut. These failures made it impossible for people in the quake areas to obtain, upload, or share information about the safety of their families, locations of refuges, damage to the above-mentioned lifelines, need for food and medical supplies at each refuge, and so on, since they could not access application servers on the Internet. People in other regions, including Tokyo, were also unable to make prompt phone calls owing to the limitations of call acceptance to avoid a large-scale breakdown of telephone networks. In order to initiate prompt rescues and evacuations and to minimize the amount of secondary damage, regional information sharing and communications should be vital and should never be lost.

This motivated us to upgrade a regional network system called NerveNet to a disaster-resilient information sharing and communication system. NerveNet was originally designed and developed in 2008 as an access network for providing context-aware services with the use of sensors and actuators [2]–[7]. Since 2011, under a project led by the Ministry of Internal Affairs and Communications to strengthen information and communication networks, we have conducted R&D to upgrade NerveNet and verified its scalability and stability using a large-scale test bed of approximately 30 base stations constructed on two campuses of Tohoku University, Sendai, Japan [8].

Thus, the upgraded NerveNet came to provide a robust network and application services without depending on the server system in a core network or the Internet. In 2014, our R&D entered its next phase as we started operating NerveNet deployed in real environments at several sites. Since January 2014, we have been operating a pilot network of four base stations for disaster prevention in the town of Onagawa, Miyagi, Japan. We have also been operating a nine-base-station network for disaster prevention deployed in the town of Shirahama, Wakayama, Japan, since May 2015, and a six-base-station network installed between the metropolitan city of Phnom Penh and a village in a rural area in Cambodia since March 2016.

This paper describes an overview of the architecture and mechanism of NerveNet. Then, we discuss a field experiment in the town of Shirahama and show some results. We also mention use cases and summarize NerveNet in contrast to related works.

2. Architecture

2.1 Problems and Approach

The key feature of NerveNet is that it adopts distributed architectures for provisioning application services as well as networking. This is a paradigm shift from conventional client-server architecture for application services and the centralized control and management architecture in a tree-topology network structure.

As current communication infrastructures including mobile phone (cellular) networks and public Wi-Fi access networks are built on conventional telephone-based networks, they are shaped like trees. Tree-topology networks use centralized control and management. Although treetopological networks are economical, they are weak against failures. Damage to a branch affects the leaves below the branch. Figure 1 illustrates images of current and proposed...
network architectures. Failure A on a link between a cellular base station (BS) and its radio network controller (RNC) renders clients unable to communicate with each other even if they belong to the same BS that is working without any damage since the BS loses control and management by RNC and core network (CN). Failure B on a link between a CN and an RNC would cause the same damage to much more clients in general.

Data communication networks and the Internet have mesh shapes because routers are interconnected. Although they are tolerant to failures in transporting data, there is a weakness in providing application services continuously and stably. Clients need to communicate with application servers on remote data networks or the Internet; otherwise, most applications will not work. Failure A or B, therefore, as pictured as two dotted arrows in black between clients and servers, disables clients from connecting to servers for enjoying application services. In summary, this client-server or point-to-point architecture in an application layer is weak to failures on the communication route and in overloads of servers.

NerveNet has distributed structures for networking and providing application services. It has the capability of configuring at least one communication route between any base stations on a network in any shape including tree and mesh. Interworking computing functions at each base station result in a distributed application service platform. A certain level of computing for a web server, SIP proxy, id/locator resolution, and database can be performed on each base station within NerveNet. These distributed architectures make both networking and application services tolerant to failures, allowing us to continue enjoying certain services even while unable to access remote networks and the Internet. Three arrows in black on the right figure express that there are communication routes between clients and servers on the Internet and the access network even if there are several failures on links. This feature, in-network processing, could also help NerveNet provide low-latency services to clients.

The other characteristic is the provision of fast multihop Ethernet-frame transmission over a layer-2 network in any shape. Given a communication request between any two users at different base stations, NerveNet assigns one of multiple virtual LANs to the communication. If the virtual LAN suffers from a link disconnection or a failure of a base station on the route, the communication will be handed over to another virtual LAN.

The features of NerveNet introduced in this section would be effective in improving resilience and robustness of current communication networks including mobile phone networks. Since NerveNet is a LAN-based network, it could be applicable to future mobile phone networks.

2.2 Physical Architecture

A NerveNet network system consists of several base stations that are interconnected by wired or wireless transmission systems. Figure 2 shows an example of a base station and three pairs of an antenna and a radio transceiver each. A base station consists of an intelligent Virtual LAN (VLAN) switch featuring Power over Ethernet (PoE) capability and a CPU board with flash storage devices (Compact flash card and SD card) and a RAM disk. A customized Linux OS runs on the CPU board, and several distributed server and database systems run on the OS. A base station provides information-sharing application services to mobile terminals in a stand-alone manner.

When base stations are interconnected, each base station automatically detects and recognizes its neighbors and begins to cooperate with them. Thus, individual base stations merge into one system in an autonomous and distributed manner, working as a regional cloud platform that provides functions of resilient networking, name/address resolution, distributed storage, database, and processing. To enable a base station to work in a stand-alone manner, all server functions including DHCP, DNS, and SIP are embedded into it in a customized fashion to cooperate with others. NerveNet works as a stand-alone network system. It also works as a...
Fig. 3  Flexibility in configuring a network using a variety of transmission systems.

backhaul to the Internet when one or more base stations are connected to the Internet.

A variety of Ethernet-based wired and wireless transmission systems can be used to interconnect base stations. This flexibility in configuration is an advantage.

A typical transmission system we use is Wi-Fi, as shown in Fig. 2. A 5.6-GHz system is better than 2.4 GHz owing to interference. Optical and metal Ethernet, Fixed Wireless Access (FWA) systems, satellite systems, or unmanned aerial vehicles (UAVs) having radio relay functions can be used as well (see Fig. 3). End devices can be connected to a base station via wired Ethernet or Wi-Fi if a Wi-Fi access point is connected to the device port. Any other wireless systems that can transport Ethernet frames can be used as well. A typical set of base stations including several Wi-Fi transceivers consumes 50 W or less, enabling operation by only solar power when necessary. There are three variations in the shape of base station: portable outdoor, outdoor, and indoor.

2.3 Overview of Software Architecture

NerveNet system functions are divided into two service platforms: network and application. These are illustrated in Fig. 4 and summarized in Table 1. The former includes functions of layer-2 VLAN switch control, reliable flooding, fast flooding, neighborhood link sensing, topology monitoring, and management. The latter includes functions of node id and locator (IP address) resolver; service id and node id resolver; several services such as a web server, DHCP, and SIP proxy; distributed on-memory database management system (DBMS); distributed DBMS synchronization service; terminal association management; and P2P communication support service.

2.4 Network Service Platform

The Network service platform provides routing, switch management, and flooding functions. The entire network is managed from one PC called the Network Manager (NM) [7]. An NM needs to be connected to a base station only when network configuration is necessary (when a network is created or the network topology has changed). When an NM is attached to a base station, it can collect the state information of all connections between base stations. Next, it calculates the overall network topology. It then calculates multiple VLAN tree routes with a certain base station as its root; this is repeated for all base stations.

As a result, a configuration file including multiple VLAN tree routes with a certain base station as its root; this is repeated for all base stations.

Table 1  Functions of base station service platform.

<table>
<thead>
<tr>
<th>Application service platform</th>
<th>Network service platform</th>
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<tbody>
<tr>
<td>IP address allocation (DHCP)</td>
<td>VLAN switch control</td>
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<tr>
<td>Name resolution (DNS)</td>
<td>Multiple VLAN path maintenace and path selection</td>
</tr>
<tr>
<td>Peer-to-Peer communication (SIP Proxy)</td>
<td>Traffic control and management</td>
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<td>Distributed database system</td>
<td>Reliable flooding and multicasting</td>
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<td>Distributed server system(Apache)</td>
<td>Autonomous link sensing and path switching</td>
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<tr>
<td>Database synchronization service</td>
<td>Multihoming</td>
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<tr>
<td>Terminal association management service</td>
<td>Network virtualization (L2 tunneling)</td>
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the Ethernet frame of the IP packet, and transmits it to the VLAN switch.

The frame goes to BS2. The VLAN switch of BS2 just switches it to BS3 based on its VLAN tag, and then it reaches BS3. The BS3 control unit receives the IP packet and forwards it to the destination terminal. When BS1 detects the link disconnection between BS1 and BS2, it autonomously updates the route to BS3 from VLAN 1 to VLAN 2 without any control by the NM. This autonomous and distributed route-switching mechanism brings resilience to failures.

2.5 Application Service Platform

One key of NerveNet is a distributed on-memory database management system (DBMS). It has two databases for system management and for user application. They are automatically synchronized among base stations immediately through a fast/reliable flooding technique. The system management database is used to share control information such as terminal IP and association information that is necessary to resolve the ID and locator for the mobile terminals. The user application database can be accessed using smartphone applications through the NerveNet Application Framework (NNAF). NNAF is software on smartphones that provides services such as ID/locator resolution, user presence, P2P communication, and group-cast data exchange using the user application database of the framework changes, the framework sends a push notification to the related application. Since the NNAF has a distributed DBMS locally as well. Messaging applications work with the local user application database of the NNAF. When a user types a message into this application, the message is stored in the user application database of the NNAF. Since the NNAF automatically synchronizes the data to the distributed DBMS on the base stations, the data are finally synchronized with all user application databases on the base stations and the smartphones’ NNAF. When the user application database of the framework changes, the framework sends a push notification to the related application. Since the user application database scheme is generalized, application developers can define the container of the data format to be synchronized through this database.

Another example of an application that involves a user application database of distributed DBMS is messaging. NNAF has a distributed DBMS locally as well. Messaging applications work with the local user application database of the NNAF. When a user types a message into this application, the message is stored in the user application database of the NNAF. Since the NNAF automatically synchronizes the data to the distributed DBMS on the base stations, the data are finally synchronized with all user application databases on the base stations and the smartphones’ NNAF. When the user application database of the framework changes, the framework sends a push notification to the related application. Since the user application database scheme is generalized, application developers can define the container of the data format to be synchronized through this database.

It would be better if not only the NerveNet-specific applications introduced here but also popular applications available on the Internet such as SNS would be provided even in emergencies. If it is possible, however, NerveNet could provide not the full but a part of an application only if it has an application service proxy function, mirroring data on the master server on the Internet. This is an interesting, technical issue.

3. Field Experiment in the Town of Shirahama

3.1 Town of Shirahama

The town of Shirahama in Wakayama Prefecture is located on the Pacific coast, as mapped in Fig. 6. It has a population of approximately 22,000, but a large number of tourists (approximately 3 million a year) come for sightseeing and recreation. More than 70,000 tourists from abroad visited in 2015. The town, on the other hand, must prepare for natural disasters such as typhoons and earthquakes. In particular, it has to prepare for megascale earthquakes and tsunamis predicted by the Japanese government to take place in the Nankai Trough off the Pacific coast. Wakayama prefecture announced in 2013 that a tsunami of several to 20 meters
is predicted along the coast of the town, as shown in Fig. 7. This motivates the town to demand a system that ensures the safety of residents and tourists.

3.2 Goal

The town government of Shirahama and NICT agreed to collaborate on a resilient network in December 2014, and started to prepare a field experiment of NerveNet in the town. The goal is to make clear the effectiveness and sustainability of NerveNet in ordinary and emergency situations. It will be necessary to collaborate with local authorities, organizations, residents, and tourists. A “Shirahama model” is expected to be found. This is a useful reference for other regions that are similar to Shirahama with regard to location, topography, types of disasters, etc.

3.3 Setup of Experimental Network

We deployed nine base stations in the region, configured a NerveNet in May 2015, and started a field experiment. The geographical arrangement of the network is shown in Fig. 8. Eight base stations are in the town, and another is positioned in the neighboring city of Tanabe. The eight base stations in the town are located at Shirahama Town Hall, Shirahama Hamayu Hospital, open-air hot-spring bath Shirasuna, Minakata Kumagusu Museum, three hotels (hotel A, B, and C), and Senjo-jiki. One is at the Wakayama Prefectural Information Exchange Center “Big-U” in Tanabe city. This base station is approximately 5 km away from Hotel A. The base stations and their antennas and transceivers are installed on the top of each building, as shown in Figs. 9 and 10.
Fig. 10 Three Wi-Fi antennas and transceivers for mesh links at (top) Hotel A and (bottom) at Hotel B for user access from the beach.

A commercial FWA system at 4.9 GHz (IEEE802.11j) is used for the link between Big-U and Hotel A. Wi-Fi transmission systems in the band of 5.6 GHz (IEEE802.11a in W56 band) are used for the other 15 links. The longest distance is approximately 2.5 km between Minakata Kumagusu Museum and Senjo-jiki across the sea. Figure 11 shows the configurations for the speed and channel of each Wi-Fi link, and the allocation of the layer-2 switch port for each base station. A channel of 11 channels in the W56 band is assigned to each link to avoid as much interference as possible. A connection speed of W56 links is set to either 6 Mbps or 54 Mbps depending on distance.

To improve resilience, the network has two routes to the Internet. BS1 at Shirahama Town Hall is connected to NTT’s Internet access service “FLETS,” while BS12 at Big-U is connected to the Internet through the Wakayama Prefectural Information Highway “Kinokuni e-net.” Wi-Fi access points for user access operated in the bands of both 2.4 GHz and 5 GHz are also installed to provide users with the access to this network as well as to the Internet. Wi-Fi is available at five locations: the museum, beach “Shirarahama” area (covered from Hotel B and open-air spring-bath buildings), Shirahama Town Hall, the hospital, and the Senjo-jiki area. The SSID is “Shirahama-Beach-WiFi.” In particular, we tried to cover the entire beach of “Shirarahama” with our Wi-Fi signals to accept a large number of users on the beach in season. Four commercialized outdoor Wi-Fi access points installed at Hotel B (see the bottom of Fig. 10) and at the open-air spring bath successfully cover most of the beach, as illustrated in Fig. 12. A total of 2560 users can be online simultaneously with these access points according to its catalog specification for the maximum number of users.

3.4 Applications

The experimental network provides four applications to users (Fig. 13). The first is Internet access. The second is geolocalized data access on a web server at each base station. Potentially, we can present different content and different applications to users at different base stations without using power-consuming GPS positioning. In the experiment, we provide a shelter map around the connecting base station (left side of Fig. 14). The “Kokodake BBS” is also provided (right side of Fig. 14). Tourists can leave their notes
as a footprint for their tour, and will be able to use this as a footprint for missing people in case of emergency. The notes can be read only at the same base station. The third and fourth applications are intranetwork voice calls and intranetwork messaging using dedicated application software for smartphones, as described in Sect. 2.5. The software was developed but has not been released to users at present.

3.5 Results

Since field experiments are still ongoing and we cannot damage the network on purpose or stop its operation, we have not obtained all of our results. Thus, only some of them are presented here.

Figure 15 shows that more than 10,000 users have registered with the network in the one year and four months since May 2015. The bottom of Fig. 15 indicates that during every summer in July and August, the daily number of registered users increased because summer is the tourist season.

The daily number of users accessing the Wi-Fi of the four base stations shown in Fig. 16 also increased during the same season. There were two spikes (on July 30 and August 10) because there were fireworks displays at the beach. There were peaks in the daily number of registered users on the same days, as shown in Fig. 15. The average daily access to the four base stations in total in the most recent year is approximately 800.

Figure 17 shows the received signal strength indicator (RSSI), or received power, of the Wi-Fi link between BS10 and BS11 observed at BS11. This link is approximately 2.5 km long. It is the longest among all the Wi-Fi links except for the FWA link between BS2 and BS12. The antenna gain at both sides is 18 dBi. The physical transmission speed is set to 6 Mbps. The observed average RSSI was $-77.18$ dBm with variations of approximately $\pm 10$ dBm.

The theoretical RSSI, on the other hand, can be calculated as follows. We assume that transmitted power at BS10 is 13 dBm, the mismatch loss is 5 dB, and the height of the antenna above sea level at Museum BS10 and Senjo-jiki. BS11 is at 16–17 m and 7–8 m, respectively, taking into account variations caused by ebb tides.

Since the link is across the sea, we apply a two-ray ground path-loss model to the propagation loss, obtaining
a theoretical RSSI of $-78.5\,\text{dBm}$ with variations from $-67$ to $-90\,\text{dBm}$ depending on the antenna height on both sides. Considering additional shadowing effects of trees and buildings in the Fresnel zone, the observed results are considered to be reasonable. The recommended minimum RSSI for the 6-Mbps mode of IEEE80211a is $-82\,\text{dBm}$, and when the RSSI dips below the roaming threshold ($-85\,\text{dBm}$) for a certain period, a disassociation and reassociation process occurs. Link disconnection may occur occasionally considering the observed RSSI. During the same period from January to June 2016, the average and maximum frame error rate of the link observed at BS11 every hour were 0.02% and 2.51%, respectively.

Next, we examine a result that shows the resilience of NerveNet. We switched off the Wi-Fi transceiver of the link between BS2 “Hotel A” and BS4 “Hotel B” on the night of September 13, 2016. A management protocol running on each base station probes the connectivity of the links. The protocols running on BS2 and BS4 detected the failure at approximately 21:53:53. Then, the information about the disconnection was broadcast from BS2 and BS4, thus triggering BS2, BS4, and BS8 to change the route between BS4 and BS1 through BS2 (top of Fig. 18) to through BS8 (bottom of Fig. 18).

Since the new route had already been calculated when the network started, the route switching was completed in a short time $[5]$. Traffic from BS2 to BS1 on link BS2-BS1 (top of Fig. 18) and traffic from BS8 to BS1 on link BS8-BS1 (bottom of Fig. 18) during the failure is shown in Fig. 19. The traffic was measured every minute. From Fig. 19, you can see the traffic on one link started decreasing and traffic on another started increasing at the same time. This fast switching occurred because the network is based on fast layer-2 switching, and multiple paths are configured in advance.

Some users’ profiles are presented in Figs. 20 and 21. They were collected when users registered in the system. Users were requested to answer questions about their age, sex, occupation, living place, purpose of stay, length of stay, number of accompanying persons, and means of transportation. These data are mainly for an analysis of tourism. The ages and purposes of stay are shown in Figs. 20 and 21. This proves that more than half of the users came to the town to sightsee. The language modes of users’ devices were automatically obtained upon registration. Their trends, shown in Fig. 22, could represent the trends of foreign tourists. These data are beneficial for creating evacuation plans for tourists and residents, as well as for developing and improving tourism in the town.

4. Summary, Related Works, and Future Plans

4.1 Summary of Features

The functions and benefits of NerveNet are summarized as follows:

1. It works as a regional LAN to directly interconnect local governments, authorities, companies, and residents as well as IoT devices such as digital signage and monitoring sensors. This enables two-way data communi-
2. Because of its resilience in both networking and information processing in a distributed but cooperative manner at each base station, even in cases where public networks and the Internet are not available, it is expected that NerveNet will distribute important information on disasters, evacuation and rescue, the food supply, etc. NerveNet provides voice and message communications for government staff and residents.

3. It is possible to deploy an outdoor regional network at low initial cost and maintain it at low running cost because it can be configured with a variety of transmission systems including unlicensed radio systems. It is not necessary to deploy a network from scratch. Existing fiber-based local-government networks, for example, can be updated to NerveNet by installing NerveNet base stations as LAN switches and adding several new connections between the base stations to increase resilience.

4.2 Related Works

There have been many research studies on mesh networks, which can be categorized into layer-2 mesh and layer-2 mesh. Layer-3 mesh (or an ad hoc network) is a network where IP packets are routed on layer 3 at routers, hop by hop, from the source router to the destination router. It assumes the use of Wi-Fi for interconnecting routers. Software-based routing makes it difficult to obtain high-speed packet routing. Route switching takes time because each router works autonomously. Layer-3 mesh does not have a mechanism to provide a connection between end nodes. Other networking functions such as DNS, SIP, and ID/locator resolution are indispensable for providing end-to-end communications.

A typical example of layer-2 mesh is the IEEE802.11s standard [9]. Some other mesh protocols also exist, such as Babel [10] and B.A.T.M.A.N [11]. They apply a layer-3 mesh routing mechanism to a layer-2 Ethernet switching network. Several products are already available from vendors [12], [13]. Each of these products equips one or two wireless interfaces to form a mesh-topology network. Since they adopt autonomous and distributed routing mechanisms, they have a problem with hidden and exposed terminals, which makes it difficult to ensure end-to-end QoS and throughput.

Ethernet Fabric is a related technology that enhances the availability, efficiency, and throughput of wide-area Ethernet. Transparent Interconnection of Lots of Links (TRILL) is a solution, which is being specified at the TRILL WG of IETF, for transparent unicast shortest-path and multidestination frame routing in multihop networks with arbitrary
topology (RFC 6325 [14], RFC 6326 [15], RFC 6327 [16], RFC 6361 [17], and RFC 6439 [18]). Another solution was standardized as IEEE802.1aq Shortest Path Bridging (SPB) [19]. In current LAN architecture, a spanning tree protocol (STP) running on LAN switches works to avoid a loop in the network because a loop causes a storm of frames, breaking down the network. This is the reason why a LAN has a tree topology to avoid loops. TRILL and SPB try to realize frame routing even on non-tree-topology Ethernet networks. To accomplish this, TRILL switches exchange routing tables with each other by periodically using an intermediate system to intermediate system (IS-IS) protocol. SPB calculates the shortest symmetric path tree from the source to the destination, and forwards a frame based on this path tree using MAC-in-MAC encapsulation.

NerveNet, on the other hand, is not a system controlled in a fully autonomous and distributed style. The path settings of a NerveNet switch are first calculated and configured by an NM. The NM is required only when a new path tree needs to be calculated in case a new base station is attached to the network. Otherwise, base stations automatically switch paths when they detect a link failure on the path.

NerveNet has a unique communication function, which is provided by NNAF with the use of several server functions and distributed database functions on the base stations. It provides not only real-time P2P communications but also Delay/Disruption Tolerant Network (DTN) [20] style communications. DTN basic protocols were standardized in IRTF as Experimental RFC and are currently being standardized by the DTN Working Group in IETF to be a Standard-Track RFC.

The DTN protocol basically provides point-to-point communication in which the source node needs to specify the destination node in advance before it starts sending a message. NerveNet-database-synchronization-based communication, on the other hand, does not need to specify a destination but needs to specify a group ID to be shared. The messages are automatically synchronized for a certain time period among the base stations, and then synchronized with the user terminal’s NNAF database based on the group ID to which the terminal belongs.

An Information Centric Network (ICN) [21] aims at achieving a new information-oriented networking paradigm. The key is name-based mechanisms including routing, information caching, searching, and forwarding on the network nodes. Several designs and protocols have been proposed, and standardization is in progress at the ICN Working Group in IETF. NerveNet is said to be a real system that manifests the ICN concept in its architecture and implementation.

4.3 Future Plans

According to interviews conducted by NICT and companies with several dozen Japanese local governments with regard to their needs and problems, they want to provide public local services at low cost in a safe manner. These services include the distribution of sightseeing information, surveillance of roads and rivers, warnings and alerts, road traffic control, sharing of bicycles, surveillance of garbage dumps, local security such as outdoor monitoring of children and elderly people and indoor monitoring of elderly people living alone, prevention and control of wildlife damage, and position reporting of local buses. Another interview with local governments that suffered from The Great East Japan Earthquake showed that they needed a tool for talking or information exchange between staffs in situations where neither cellular nor fixed networks were available. They did not mind if the tool was not available anywhere. They would be satisfied even if the tool were available in very limited locations in case of emergencies.

NerveNet could be a solution to these needs and problems. Figure 23 shows an image of NerveNet and its use scenes in an area from the viewpoint of a local government. People need a network like NerveNet for disaster prevention and emergency communications. We think it should be a multipurpose, daily-use network rather than a dedicated, emergency-only one. Otherwise, it may not work, or people might be unable to use it in emergencies.

The latest NerveNet base station accepts power sources of AC (alternating current) 100 to 240 volts and DC (direct current) 12 volts. Also, owing to its low consumption of power, NerveNet can work with a car battery for a while or can continue working with a set of a certain size of solar panel and battery. This feature is effective in operating after or in preparation of blackouts due to disasters. Although NerveNet was designed and developed as a network for urban and suburban areas, its resilience and low power have been gaining attention from developing countries. Because power supplies and network services are not stable in those countries, they need a resilient network that runs without requiring a stable power supply from the outside. In rural areas in developing countries, it is expected that NerveNet will provide universal access for users to the Internet at low cost, security against disasters, and sensing and alert services, and it will allow local communications without outer networks such as the Internet and telephone networks. This is depicted in Fig. 24. These demands come not only from developing countries but also from Japanese rural areas.
5. Conclusion

NerveNet, which was originally designed as an access network of Future Network, has been developed as a resilient regional network platform based on past experience and related works. This technology has garnered attention from companies, local governments, hospitals, fire departments, and authorities in ASEAN countries as well as in Japan. This is because there is no technology that can provide data access, data exchange, data sharing, voice calls, and messaging without the Internet at low cost and low power. We expect that field experiments in Shirahama and other sites will prove NerveNet’s effectiveness and sustainability, and that people will decide to introduce NerveNet or other resilient social infrastructures in local areas to prepare for disasters and to enrich their lives.

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References


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