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Development Recovery Protocol for Dynamic Network Reconstruction on Disaster Information System

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So far, we have developed effective Wide area Disaster information Network (WDN) using Internet over the combination of both wired and wireless network. In this information network, two important functions including resident safety information system and bidirectional video communication system between evacuation places and disaster information center are provided. However, in this WDM, system failure of network and computing facilities by disaster was not considered. In order to recover the information system as soon as possible from the system failure, network protocol has to deal with those requirements. In this paper, we introduce Wireless Recovery Protocol (WRP) to temporally recover WDM with minimum configuration as soon as possible even though some of network and computing facilities were damaged by disaster, using network management and GPS functions. The design and implementation of the WRP is precisely described. The prototype system and its hardware and software environment to evaluate its functionality are also precisely described.

災害時におけるネットワーク再構成のための復旧プロトコルの開発と機能評価

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本研究ではこれまで、インターネット環境において有線と無線の相互接続より構築される広域防災・災害情報ネットワーク（ WDN ）を開発した。 この情報ネットワークでは、安否情報システムと避難所と災害情報センターの間の双方向性のビデオコミュニケーションシステムの２つの重要な機能が提供される。 しかしながら、WDN では災害によって、ネットワークと計算資源のシステム故障が考慮されなかった。 システム故障からできるだけ迅速に情報システムを復帰させるため、ネットワークプロトコルが必要がある。そこで本稿では、ネットワークと計算資源のいくつかが災害によって損害を与えられた場合に、できるだけ迅速に最小の再構成で WDN を復旧するためにネットワーク管理と位置情報を復旧プロトコル（ WRP ）に導入し、その設計と実装について述べる。そしてプロトタイプシステムでは、その機能性を評価するためのハードウェアとソフトウェア環境について述べ、そして実験、評価を示す。

1. Introduction

Since Japan island is mainly formed by mountain volcano along the entire country, a number of large scale sizes of earth quick, mountain explosion, seismic sea wave, frequently happened in addition to ordinal disasters, such as typhoon, rain flooding and snow-slide since our history has started. In order to save our life from those disasters, more reliable and robust information network for disaster prevention purpose than the conventional information network system for business or research and education purpose is required in various locations along the island. On the other hand, as advent of advanced mobile computing and Internet technologies, communication by multimedia data including voice, video, image, graphics and text can be realized at anytime and from anywhere.

So far, we have developed a unified wide area disaster information network (WDN) using Internet based on the combination of both the wired and wireless and mobile networks. Wireless network is more suitable for disaster prevention information network than wired network because the possibility of network disconnection by breaking down of the communication line is quite low and the recovery from failure with communication equipments is easy when disaster happened. In WDM, two important functions including resident safety information system and bidirectional video communication system between evacuation places and disaster information center are provided[1].

We also suggested a resource management system (RMS) whether the system components are damaged or not and where and how the damage are serous or not when disaster happened. Network management protocol combined with GPS functions is introduced in WDN to identify the exact failure points and to quickly recover from the failure. The system configuration, architecture and its functionality are precisely explained [2][3].

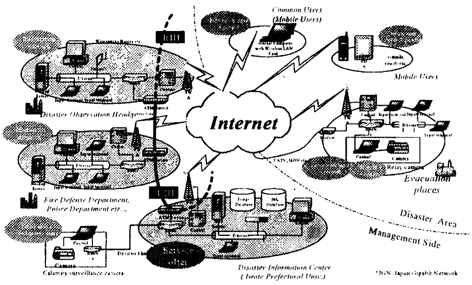

Fig.1:Wide area Disaster information Network

The prototype system based on our suggested WDN was build around Mt. Iwate, which is currently active and is likely possible to explore in the near future, and was evaluated to verify its functionality and usefulness through the annual training for the case of the mountain explosion[4][5].

However, in this WDM, system failure of network and computing facilities by disaster was not considered. In order to recover the information system as soon as possible from the system failure, network protocol has to deal with those requirements. In this paper, we introduce Wireless Recovery Protocol (WRP) to temporally recover WDM with minimum configuration as soon as possible even though some of network and computing facilities were damaged by disaster, using network management and GPS functions[6]. The design and implementation of the WRP is precisely described. The prototype system and its hardware and software environment to evaluate its functionality are also precisely developed.

In the followings, system configuration of WDM is described in section 2. The Resource Management system (RMS) on WDM is explained in section 3. The Wireless Recovery Protocol (WRP) to recover form system failure by disaster is precisely defined in section 4. The prototypes system based on the WRP is described to evaluate its functionality and performance in section 5. Finally concluding remarks and current status of our research is summarized in section 6.the prototype which mounted this is reported.

2. Wide area Disaster Information Network

By taking into consideration of the requirements for disaster information network, our suggested information network system is indicated in Fig.1. Internet is used as a platform of the information system. As network infrastructure, wireless WAN/LAN and mobile networks are employed to raise robustness and redundancy in case the disaster happened. The information network system consists of mainly four information centers and two resident areas.

Disaster Observation Headquarter is located at the local governmental office and observe and directly control of the information system by commands of emergency disaster cooperating with fire defense and police departments of local areas. Those information and commands decided by governmental headquarter are conventionally broadcasted by radio and TV media.

Disaster Information Center performs main functions for residents by gathering and multicasting the safety information whether each resident safely evacuated or not, their health conditions are normal or not, and they require something as soon as possible or not.

The residents when the disaster happened can register his safety information using PCs at evacuation places or their mobile terminals on the ways of evacuation. Each evacuation place can be at least connected by wireless network and the evacuated residents on different places can communicate each other using bi-directional TV conference system. The resident life information are also collected and multicasted through the Internet.

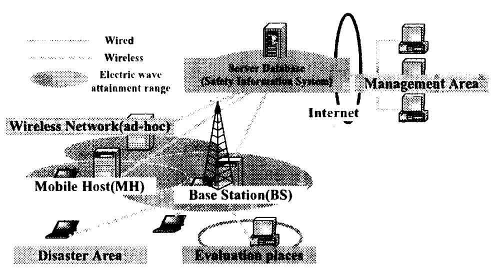

Fig. 2: Resident Safety Information System

2.1 Resident Safety Information System

A system configuration is shown in Fig. 2.

Resident Safety Information System(RSI) is consisted of Base Station(BS) Mobile Host (MH), and Database and Server (Safety Information Network System Server/Database, Resource Management System). BS achieves the Gateway function between a wireless network and a cable network. MH is a mobile terminal for disaster evacuated residents performing registration and renewal of the safety information, and reception of disaster information, in addition to the present resident location by GPS. The safety information server offers safety information whether the residents in the disaster area evacuated safely to the evacuation places or not to their families, relatives or friends through Internet.. Furthermore, by introducing the ad hoc network with the combination of wireless LAN, cellularphone, mobile PC, or PDA can be backup function can be attained using the resources management system which is explained in the following section.

3. Resource Management System

Just after a disaster occurrence, the possibility of failure or destruction is exited at terminals, servers, network equipments and transmission lines. Therefore, a source management system which manages the state of the computing and network resources is required. Using the resources management system, the status information with computing and network resources is directly collected from the objective area. In order for the whole system to temporaly and quickly recover from the failure. The wireless recovery protocol, which will be explained later, carries out such recovery process using the resource information.

3.1 Basic Function

The resources management system (RMS: Resource Management System) performs early restoration from a disaster. As a basic function, connection status, bandwidth, zone and delay time of the network is managed. This information in addition to the resource status information with hardware resources and electric wave intensity can be collected using network management tools, such as SNMP. The location information management function to manage the physical locations of the related resources, such as gateways, routers, wireless LAN and a terminal are identified by GPS function.

The Fig. 3 shows the flow of Temporal Recovery Process. The operator shifts state of RMS from normal operation mode to the temporary recovery mode to attain the minimum required function from disaster. The minimum required function performs at least network connection to each terminal, and transmits text data with resident safety information. There are 4steps for the RMS to complete temporal recovery process as follows:

Step1:Checks the connection status of computing and network resources. If not, the connection is regarded as disconnected.

Step2:Check the operation condition whether those resources are normally operated or not. If not, then those resources are restarted. Or if required, mirroring the resources carried out.

Step3:Collect the routing status information and reconstruct the temporal new network to provide the minimum required function to use in the disaster area using WRP protocol based on the collected information.

Step4:Correct the location information with computing and network resources.

The WRP protocol initiates network reconfiguration dynamically using wireless mobile network.

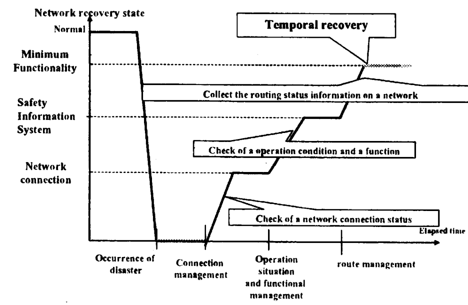

Fig. 3: The Flow of Temporal Recovery Process

4. Wireless Recovery Protocol (WRP)

Since WDM is based on the wireless and mobile networks in addition to wired network, the whole network can be easily reconfigured when disaster happened. Dynamic network re-configuration is realized by changing the mode from the normal operation mode to disaster operation mode after resource management system confirms the network connection status. In the case of disaster, the failure on the destination BS and transmission lines may happen. In this case, by rearranging the normal mobile terminals as intermediate node, more flexible and reconfigurable network to support the minimum required function can be attained.

In the normal operation mode, the network can be organized as a direct star structured network at the BS as a root as shown in Fig. 4(left).

On the other hand, in the disaster operation mode, the network is reconfigurated form the star structure to tree structured network where the BS is used as a root, a mobile terminals as middle nodes or leaves as shown in Fig. 4(right). At this time, the WRP protocol performs several important functions to find the best route from the MH to BS based on,

- the minimum hop steps among the possible routes.
- higher redundancy even sudden damage
- higher connectivity even network environmental change such as electric wave intensity

Those conditions are used in the WRP as a reliability level. As one of reliability level, the physical distance and the number of hop between the recognized BS and MH is used. The number of hop is added when the MH acts as a relay intermediately, and regarded higher reliable if its reliability level is lower. A physical distance between MHs and BS is calculated from position information using GPS. Then, the resources information with the network equipments offered by the resources management system and the position information on a terminal is used for recovery process.

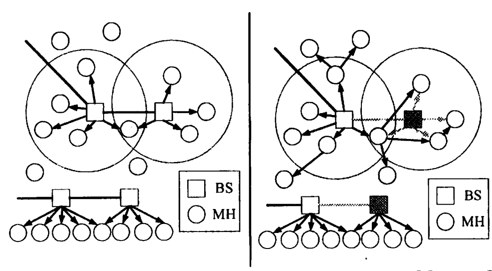

Fig. 4: Network Configuration in Normal Operation Mode(left) and in the disaster operation mode, the network (right)

4.2 WRP Protocol Stack

The WRP protocol is located at the upper half in Network layer, and is realized using the extended portion of IPv6 header. Moreover, WRP is used only in the disaster mode. In a WRP, the following functions to quickly recover from disaster are included:.

- The routing control function which carries out data between MH and BS transmission
- The routing information management function to treat a terminal and course information,
- Mode management function to manage whether current mode show let be changed to other or not. In a resources management system
- GPS function which acquires position information with MH and BS.
- The network management function to treat the connection status of the network, available bandwidth, and delay time between MHs and BS
- The hardware resources management function observes electric wave intensity measures

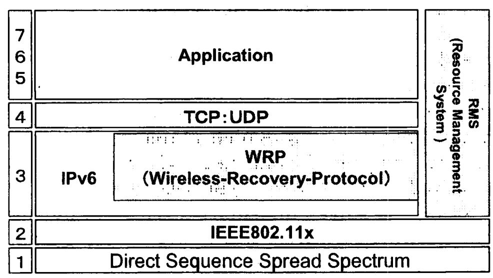

Fig. 5: Protocol Stack

4.3 WRP Header

The protocol header structure of WRP is shown in Fig.6. Data size expresses the data in the following the data size. CRC checks the packet data in the following Next ID, Packet ID. The packet descriptor expresses the kind of packet, such that HELLO, CHECK, and CHECK_REPLY and DATA_SEND. Source ID, Destination ID, and the relay terminal ID have 8 bytes as descriptors for BS or MH. The source, destination, and relay host position information shows the position information with MHs and BS. Reliability level shows the priority among terminals. TTL is time of life of a packet and a sequence number is used to adjust the time of communication. The number of relay hosts expresses the number of the terminals which acted as intermediate.

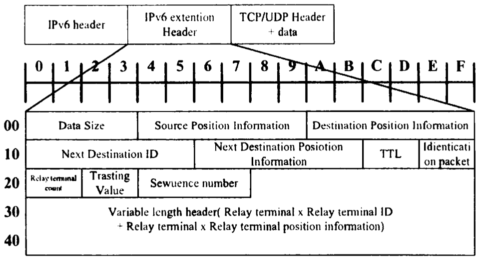

Fig:6: Header Information

4.4 Operation of a recovery protocol

When the disaster occurred, the operator shifts the capable BS from normal mode to disaster mode. Then, HELLO packet with the descriptor "BS-ID" is broadcasted. The MH which received this HELLO packet, appends "MH-ID" and then broadcasts this to its neighborhood. The MH which received this packet again repeats with in a limited time. Thus, MH can eventually recognize the BS which can be reachable.

On the data transmission in the disaster mode, the MH transmits CHECK to the BS to confirm a route from the MH to BS, then waits to receive CHECK_REPLY. When the BS received CHECK, the BS replies to the MH. After the source MH received CHECK_REPLY from the BS using relay MH-ID information that it acted as intermediate. Host, also using this procedure, the MH can transmit data to BS by confirming connection state even the MH is moving.

When the MH issued CHECK to the BS, but does not receive CHECK_REPLY, the transmission route is regarded as lost. In this case, the MH uses a back up route to recover the lost route to the BS. If there is no backup route to BS, MH wait until it receives HELLO from a new BS.

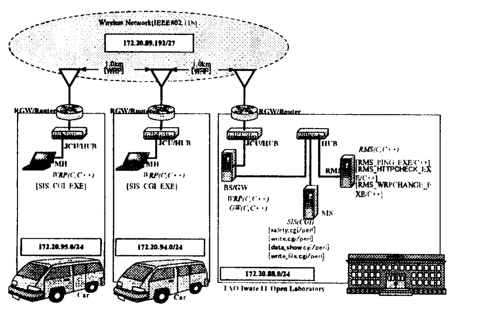

Fig.9:Hardware and Software System on Prototype

5. Prototype System

In this section, we describe resources management system and the prototype system of a recovery protocol. Hardware system configuration on this prototype is shown in Fig.9. In this prototype, IEEE801.11b wireless WANs are used as a network which is interconnected each other.

Since 2.4GHz bandwidth signal can communicate in relatively large area around max 5 km, all of the MHs can communicate and access to the Resident safety Information server. Desktop PC is used to perform as the Resident safety Information server using Apache Web server function and relational DB and GBS function.

A safety information system is implemented by CGI and PostgreSQL. The WRP which performs connection establishment among the MHs and BS and transmits the data with resident safety information is implemented by C and C++ language.

The prototype system is performed to the communication experiment centering on the Iwate IT Development Support Center in Iwate, Japan. In the experiment, the safety information is sent from the MH through wireless WAN and is recorded by the database in the IT center, and this information be referred by anybody through the Internet.

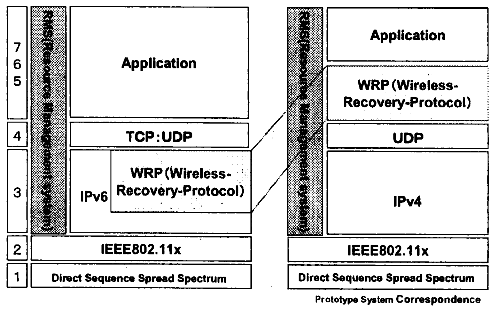

Fig.11:Prototype Protocol stack

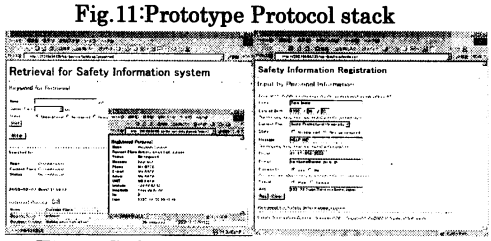

Fig.12:Safety Information Registration

6. Evaluation

In order to verify the usefulness of our suggested WRP, functional evaluation of the dynamic reconstruction of the system and performance evaluation of the response time for temporal recovery from disaster were carried out using the prototyped system. The case of the disaster was assumed as network and server failures on the prototyped system. The WRP was used to recover from those failures and establish the temporal minimal restoration. The response time of the recovery process on each step, including 4steps after the disaster until the temporal minimum function was completed.

The result of the measured response time on each step is shown in Table.1 As can be seen form this table, the 1st step dominated among the total time. This is because that the check of all of the hardware resource were carried out by "Ping" message five times. Each "Ping" command took relative long time period when the resource had damaged and the reply from became them timeout, eventually leaded to long operation time at this step although the other time was not critical. This time have to be improved by using multicasting protocol.

Temporal Recovery Process	Time(s)
STEP1	27.0
STEP2	1.0
STEP3	4.8
STEP4	0.4
TOTAL	33.2

Table1:Experimental Result

7.Conclusion

In this paper, we introduced Wireless Recovery Protocol (WRP) to temporally recover WDM with minimum configuration as soon as possible even though some of network and computing facilities were damaged by disaster, using network management and GPS functions. The design and implementation of the WRP is precisely described. The prototype system and its hardware and software environment to evaluate its functionality are also precisely described.

Currently, we are evaluating this system for more large area by increasing the number of wireless LANs and movable vehicle with wireless LANs.

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