Proposal and Implementation of a System to Remotely Watch the Health Conditions of Elderly Persons

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***Abstract*—In Japan, senior citizen population is rapidly increasing as a result of the progress in super-aging society, while many younger generation people live separately from their elderly relatives under the current societal environment. Nevertheless, young people often have a desire for constantly watching health conditions of their elderly relatives even remotely. In this paper, we propose a system to constantly trace the moves of elderly people and accumulate the information obtained through SmartPhone in the management server so that watchers (families and/or relatives) are able to cope with the situation urgently, should any abnormal conditions be detected. We have implemented part of our proposed system and confirmed the effectiveness of the system.**

I. Introduction

In Japan, aging society is rapidly progressing and one person out of four is reported to be above 65 years old in 2010. In the meantime, the trend toward nuclear families is also apparent and it is said that over 20 percent of the entire households in Japan is currently those of elderly persons. Under such circumstances, various societal problems such as solitary death and home health care of elderly people are taking place here and there.

In super-aging society, it is important to protect safe and secure life of elderly people and assist their various activities so as to promote their participation in society and improve their quality of life. In this sense, it is useful if we can build a system whereby families, administrative and medical institutions as well as neighbors can constantly watch health conditions of elderly people and share obtained information. In addition to elderly people, we can think of children, medical patients, and handicapped people as the targets of this system. In this paper, we call these people collectively " the vulnerable " or " vulnerable persons ", and aim at realizing a system to constantly watch them in a comprehensive manner.

The vulnerable have usually a desire for going out, and therefore, it is important to set up and improve the environment that can satisfy such desire as much as possible. Recently, the vulnerable have also such desires as traveling to enjoy leisure and driving a car to participate in social activities. However, it is quite possible that physical function of the vulnerable is weakened and that there is a rather high possibility of their encountering accidents while spending time outside their homes.

As an example of existing systems to watch the vulnerable, there exists " high-efficiency health measurement system for home health care " [1] developed by NEDO. However, this system assumes that sensor equipment is installed in the residence and does not take into consideration the situation in which the vulnerable go out of home. There are also several similar systems supported by the national government, aiming at watching the vulnerable. In the case of " Watching the Vulnerable, Safety Net Kuden-cho Project " [2] promoted by the Ministry of Land, Infrastructure, Transport and Tourism, the monitoring of the vulnerable is being performed by installing sensors in the residence, but here again, this Project does not take into account the situation of the vulnerable being outside their homes. In the cases of " Ubiquitous Watching-Information Network " (Kyushu District) [3] and " Project to Create Safe and Lively Towns utilizing ICT " (Mie Prefecture), they make it possible to locate places of the vulnerable by having them carry SmartPhone when they go out, but these projects are being run by municipal governments or NPO groups and state of the art technologies are not used. As a result, the amount of information they can obtain are limited.

There is a service system for drivers called " Telematics ". This is a system which combines a telecommunication system with moving objects such as automobiles, and is capable of providing information on a real-time basis to obtain advice from HelpNet Center. Targeted people of this system are young to middle-aged / elderly drivers. This system is useful when fellow passengers have encountered health problems. However, if a health problem has occurred at the time when a vulnerable person alone was driving a car, it will not be easy for the person to cope with the situation promptly.

In the meantime, because of the recently rapidly advancing SmartPhone and mobile network technologies, it has now become possible to realize a highly efficient, practical system

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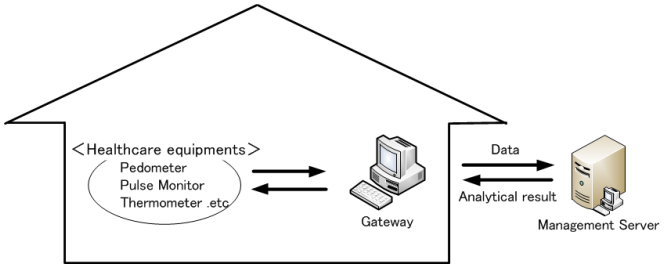

Fig. 1. Configuration of NEDO's Home Health Care Project

to watch the vulnerable remotely by making the best use of these technologies. Recent SmartPhones are equipped with various types of sensors such as GPS, acceleration sensor, gyro and magnetic field sensor, in addition to the function of telecommunication. They are also equipped with high-speed CPU and large-capacity memories, and thus, they are useable as handy platforms capable of performing signal/information processing with high efficiency. Furthermore, since SmartPhones have a relatively wide screen and excellent GUI, they have a superior function as an information-reading terminal. Accordingly, SmartPhone is the most appropriate device to be constantly carried by the vulnerable.

The purpose of this paper is to introduce a system to realize the following.

- To share information about a vulnerable person through a network using SmartPhone and mobile network environment.
- To realize a system to constantly watch a vulnerable person who is located remotely from his or her family and protectors and to take appropriate measures promptly when any urgent or dangerous situation was detected.
- To conduct remote sensing of the behavior and status of a vulnerable person through SmartPhone carried by the person and to send his or her health information regularly to a server on the Internet.
- To make it possible for his/her family and doctors to read data about the person accumulated on the server at any time, and to deal with the situation promptly by sending an alarm when any abnormal condition was detected.

We will describe hereafter, various existing services/systems in Chapter II, our proposed system in Chapter III, implementation of our system in Chapter IV, and the summary of this paper in Chapter V.

II. EXISTING SERVICES AND SYSTEMS

A. Home Health Care Project implemented by NEDO

As an example of health support system for individuals, we show below the outline of the " Project to develop a high-efficiency health measurement device for home health care " conducted by NEDO (New Energy and Industrial Technology Development Organization) in Fig. 1. This is a system to collect health-related information measured by devices such as blood pressure monitor and thermometer at home in a gateway device. In this system, data are transmitted between health measurement devices and the gateway device by an independent HAP (healthcare application protocol). Then, the obtained data are sent to the management server, which analyzes and stores the collected health information. Information accumulated on the management server can be read at home or from medical institutions at any time. However, this system assumes that the targeted persons always stay at home, and does not take into account the situation where the targeted persons go out of home.

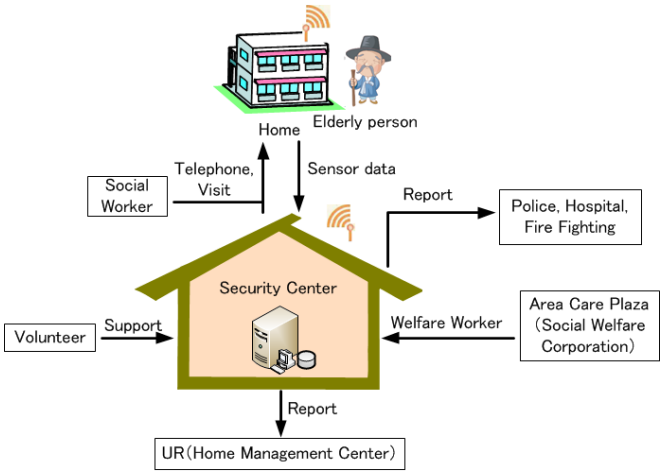

Fig. 2. Configuration of Kuden-cho Project

B. Watching the Vulnerable, Safety Net, Kuden-cho Project

Shown in Fig. 2 is a project implemented by Urban Renaissance Agency at the apartment complex at Kuden-cho, Yokohama City. Under this Project, they conduct activities to watch the vulnerable in order to provide them with safe-living conditions, to promote their participation in local activities and to prevent them from solitary death, and the effectiveness of such activities was verified. In this Project, staff members at Safety Center check health information sent from the residence of the vulnerable twice a day, and the staff members and/or local welfare workers confirm their health conditions by calling up or visiting the vulnerable in question if need be and get in touch with the police, fire department or hospitals, as appropriate. Staff members of Safety Center report the information obtained as above (i.e. status of individual elderly people, existence of abnormal situation, etc.) to Urban Renaissance Agency. However, in this Project, too, it is assumed that the targeted persons stay at home without going out. Nothing is considered about the case where those people are out of home.

C. Ubiquitous Watching-Information Net (or Higo-Yu Net)

" Higo-Yu Net " is an ICT system implemented by NPO Kumamoto-Machizukuri (town-making). Higo-Yu Net is a welfare service which supports activities that watch the vulnerable such as elderly people, handicapped people and children. In this system, welfare workers and neighbors watch the vulnerable and report their conditions to the management server. By activating the application of SmartPhone carried

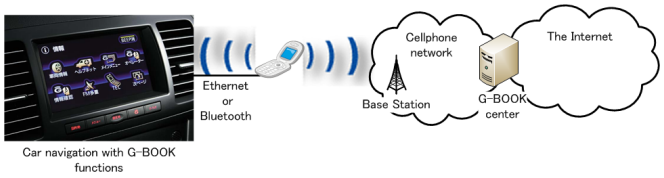

Fig. 3. Configuration of G-BOOK

by a vulnerable person, you can locate the position of the person on the Internet. However, this system imposes a lot of burden on the people in the district and it is necessary for many people to watch a single vulnerable person. Another weak point of this system is that you can obtain locational information of the vulnerable only and you cannot know their physical conditions.

D. Telematic services

With respect to Telematics Services, G-BOOK [4] and CARWINGS [5] are already deploying their own services. Fig. 3 shows the configuration of G-Book. In the case of G-Book, they offer Map-On-Dmand services, by sending to the automobile navigation system information about newly opened roads on major roads and toll roads between the present location and the destination, as well as probe communication services to predict future traffic conditions from the up-to-date traffic information from VICS and past statistical data. They also offer HelpNet services to assist communications from vehicles encountering emergency situations to HELPNET Center.

In the case of CARWINGS, in addition to similar services as those offered by G-BOOK, they provide services to check locational information using Google map as well as to confirm the schedule registered by Google calendar in the vehicle.

However, their services are all for the benefit of drivers themselves. Also, such services are offered in a closed manner and not open to general users, as they use their own administration centers. Therefore, these services are not appropriate as the means for families and relatives of vulnerable persons to confirm the conditions of those people.

III. Outline of our Proposed System

Fig. 4 shows the configuration of our proposed system. Our system realizes a system whereby we can constantly watch vulnerable persons wherever they are. We have vulnerable persons carry SmartPhone (hereinafter called " SP "), and collect sensor data through SP. The collected sensor data are sent to the sensor data management server (hereinafter called " SMS "). Watching-side people can read the contents in SMS from home terminals at any time.

A. Collection of Information from the Vulnerable

We describe three different ways of collecting information from the vulnerable; namely, the first is the way to collect information when a vulnerable person is driving a car, the second is the way when the person is out of home, and the third is the way when the person stays at home. The information

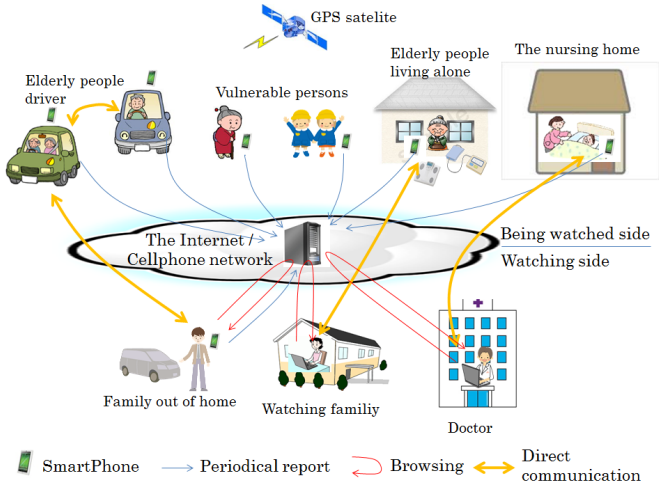

Fig. 4. Configuration of our Proposed System

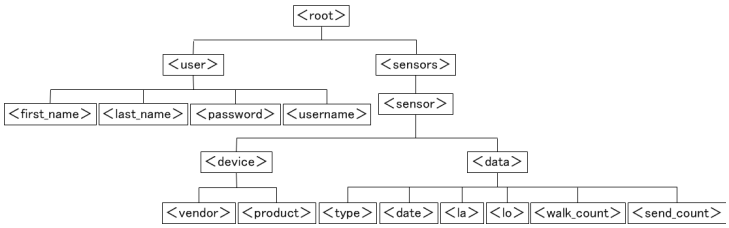

Fig. 5. Format for sending sensor data

collected by these three ways is all accumulated in SMS. When a vulnerable person is driving a car, driving information (such as breaking, acceleration, turning to right or left, degree of shaking, etc.) is obtained from SP's acceleration sensor, and locational and speed information is obtained from GPS. Then, such information is regularly sent to SMS via UDP. When a vulnerable person is out of home, behavior information (such as walking, running, falling down, etc.) and the count of steps are obtained from SP's accelerator sensor, and locational information is obtained from GPS. Then, such information is sent to SMS. When a vulnerable person is at home, biological information (such as blood pressure, bodily information, etc.) in addition to the information obtained when the person is out of home is obtained, and sent to SMS through SP. Health measurement device equipped with wireless function, available at home, is used as the measurement device, and the obtained information is accumulated in SP.

B. Transmission of Sensor Data

We defined as Fig. 5 the packet format to regularly send information from SP to SMS. The description in Fig. 5 follows the below-stated rules, based on the description method of XML format.

- <user>tag
  User's account information is described. With this information, the server correctly recognizes the user.

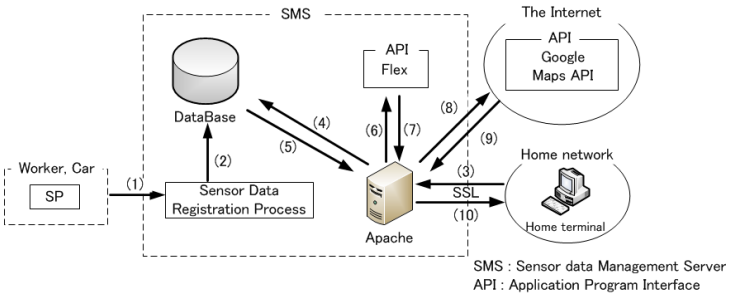

Fig. 6. Processing sequence by the server

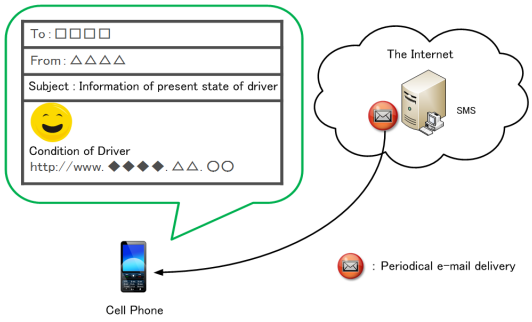

Fig. 7. An example of the description of an e-mail

- <sensors>tag
  As child elements, more than one <sensor> tags are inserted. All sensor data are described in this tag all together. When sending multiple sensor data, <sensor> is to be described within <sensors> multiple times.
- <device>tag
  Sensor's device information is described. With this information, it is identifiable from which sensor device the data in question are obtained, even if the type of sensor data is the same.
- <data>tag
  Data obtained from the sensor are described. The number and the names of child elements change depending on the types of sensor data. For the types of sensor data, IDs that can distinguish different types of data are inserted.

C. Browsing of Sensor Data

When browsing of the data from a home terminal or a mobile terminal (such as mobile phone or SP), a watching person performs user authentication, by inputting his or her user ID and password. When the watching person designates specific sensor information, SMS obtains the information from the database and sends it to the home terminal after making it in a graph form using the graph-making API (Application Program Interface). For this communication, SSL is used.

D. Processing by the Server

Fig. 6 shows the processing sequence by the server.

- The sensor data which SP has obtained are regularly received by UDP. (1)
- In the sensor data registration process, the sensor data are analyzed using XML analysis library. Thereafter, user authentication is performed and if the packet is in a normal condition, the sensor data are registered in the database by SQL. (2)
- Apache in SMS receives a request for browsing of the sensor data from a home terminal. (3)
- The sensor data are read out from the database. (4), (5)
- The read-out data are made into a graph form through processing by the graph making API. (6), (7)
- The data made into a graph form are sent to the home terminal. (10)

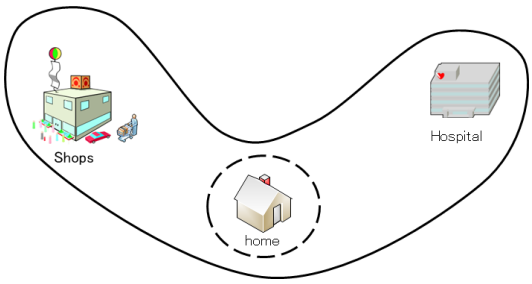

Fig. 8. An example of abnormality detection by activity region

E. Periodical e-mail delivery

There are two types of e-mail delivery. One type is " periodical delivery " and the other is " delivery at the time when abnormality " is detected. In order for a watching person to grasp the situation of a vulnerable person, it is necessary to get access to SMS every time. Thus, e-mails expressing the conditions of the relevant vulnerable person in the form of pictographs are periodically sent from SMS to the watching person (e.g. one time a day). Fig. 7 shows an example of the description of an e-mail. If no problem is found in pictographs, the watching person can omit the labor of getting access to SMS. URL is described in the e-mail, and the contents of SMS can be browsed by making just one click as needed.

F. Alarm Detection by the Server

By accumulating the information mentioned in Item III-A in the server, any abnormal condition can be detected by making comparison with the behavior in the past. For instance, when behavior of a vulnerable person deviates from his or her normal activity range, an alarm by way of an e-mail can be sent to the watching-side person. An example of abnormality detection is shown in Fig. 8. A certain behavior range can be determined from the data accumulated in the database. For example, if a behavior pattern of going out from home to a hospital and returning home after shopping at certain stores is accumulated and regularized in the database, SMS can designate a certain distance (the dotted line in Fig. 8) from home, and when the vulnerable person goes beyond the dotted area, an e-mail is sent to the watching person indicating that the vulnerable person is going out of home. And if the

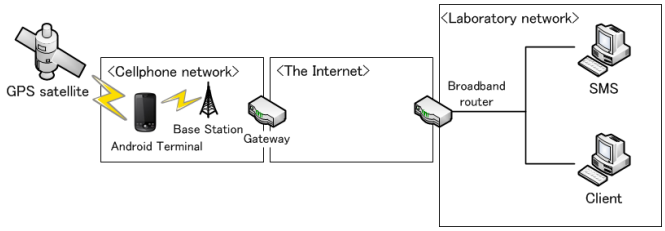

Fig. 9. The configuration of our trial system

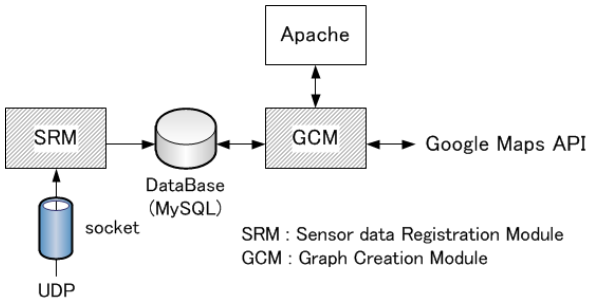

Fig. 10. The module configuration in SMS

behavior of the vulnerable person is different from his or her normal pattern (namely, if the person goes beyond the area indicated by a solid line), an e-mail is sent to the watching person indicating that an abnormal behavior is detected.

G. Security

Because certain personal data are included in the sensor data sent from SP to SMS, it is important to secure security. In order to secure security, two types of methods are considered. One method is to embed DPRP (Dynamic Process Resolution Protocol) [6] for authentication and PCCOM (Practical Cipher COMmunication) [7] for encryption in the kernel. The other method is to make encryption independently in the application. In the former case, although there is no need to take security into account on the application side, it is necessary to make a certain modification to the kernel. In the latter case, while this method can be used by any SP, it is necessary to consider encryption for each application.

IV. Implementation of our Proposed System

A. Configuration of our Trial System

The configuration of our trial system is shown in Fig. 9. We implemented functions to obtain locational information and the count of steps taken in an Android terminal and sent the information to SMS periodically via mobile phone network. We set up a port-forwarding function to the broadband router and had SMS within the laboratory network receive packets. We also made it possible to browse the sensor data stored in SMS from client terminals.

B. Module Configuration

The module configuration implemented in SMS is shown in Fig. 10. We created SRM (Sensor data Registration Module) and GCM (Graph Creation Module) in our trial system. In the case of SRM, data are received from the Android terminal by way of socket communication. After XML analysis, user authentication is performed and if packets are in a normal condition, sensor data are stored in the database by SQL. In the case of GCM, we extracted the information designated by Apache from the database and created a program which operates in conjunction with graph creation API and map creation API. As map creation API, we used Google Maps API [8] and Flex [9]. Meanwhile, we described SRM by C language and GCM by php and javascript.

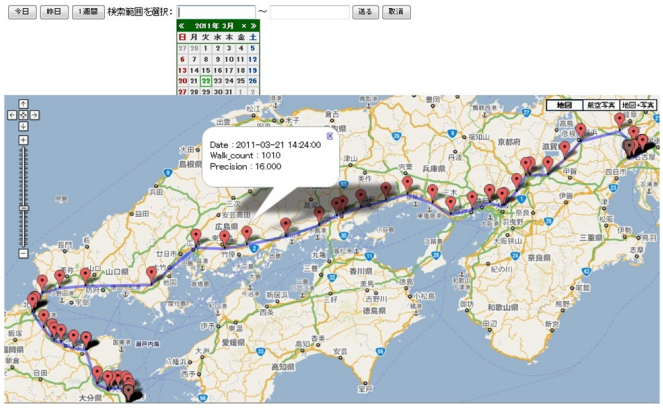

Fig. 11. A picture of GPS data displayed on Google Maps API

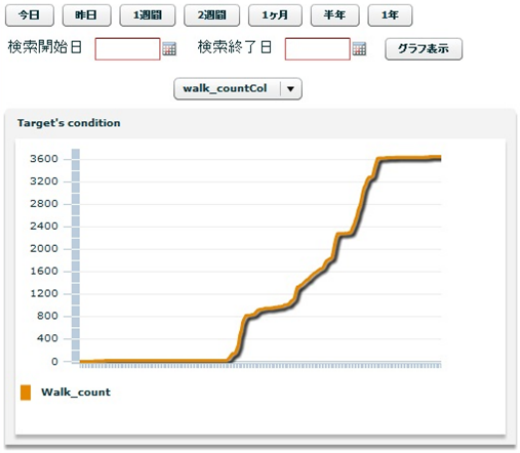

Fig. 12. A picture of walk count data

C. Result of our Trial System Operation

We got the locational information and the count of steps taken on the side of SP. We created a database related to such information. We requested the contents stored in SMS from the client terminal and displayed the results. We made the interval of periodical transmission 15 minutes. A picture of GPS data displayed on Google Maps API is shown in Fig. 11. We can see that the movement is indicated in this map. We created buttons to designate the month and the date freely.

A picture of walk count data is shown in Fig. 12. The

vertical axis indicates the accumulated count of steps taken in the case of one day display, and we made it possible to show changes in the total steps taken in the cases of every one-week, two-weeks, one-month, six-months and one-year displays. The horizontal axis shows the time and date when the data are taken. By selecting out of the buttons indicated in the upper portion of Fig. 12, we can show the information on the count of steps taken during the designated period.

D. Implementation planned in the Future

The implementation we performed this time is only the first step of our proposed method. We plan to implement the functions of periodical e-mailing to watching persons and e-mailing at the time of abnormality being detected, as well as of displaying behavior history and driving history of vulnerable persons, one after another. We also proceed with studies on the methods of securing security between SP and SMS and on the contents of end-end communication in the wake of the detection of abnormality.

V. SUMMARY

In this paper, we described the outline of various systems remotely watching the vulnerable as well as the operation of our proposed system. We proposed a system by which watching persons can watch the present conditions of elderly people remotely by storing in the management server the information received by way of SmartPhone carried by them. We confirmed by using a trial system that by storing the information received from SP, the locational information and the count of steps taken can be displayed in an appropriate manner.

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Watanabe Lab.

Background

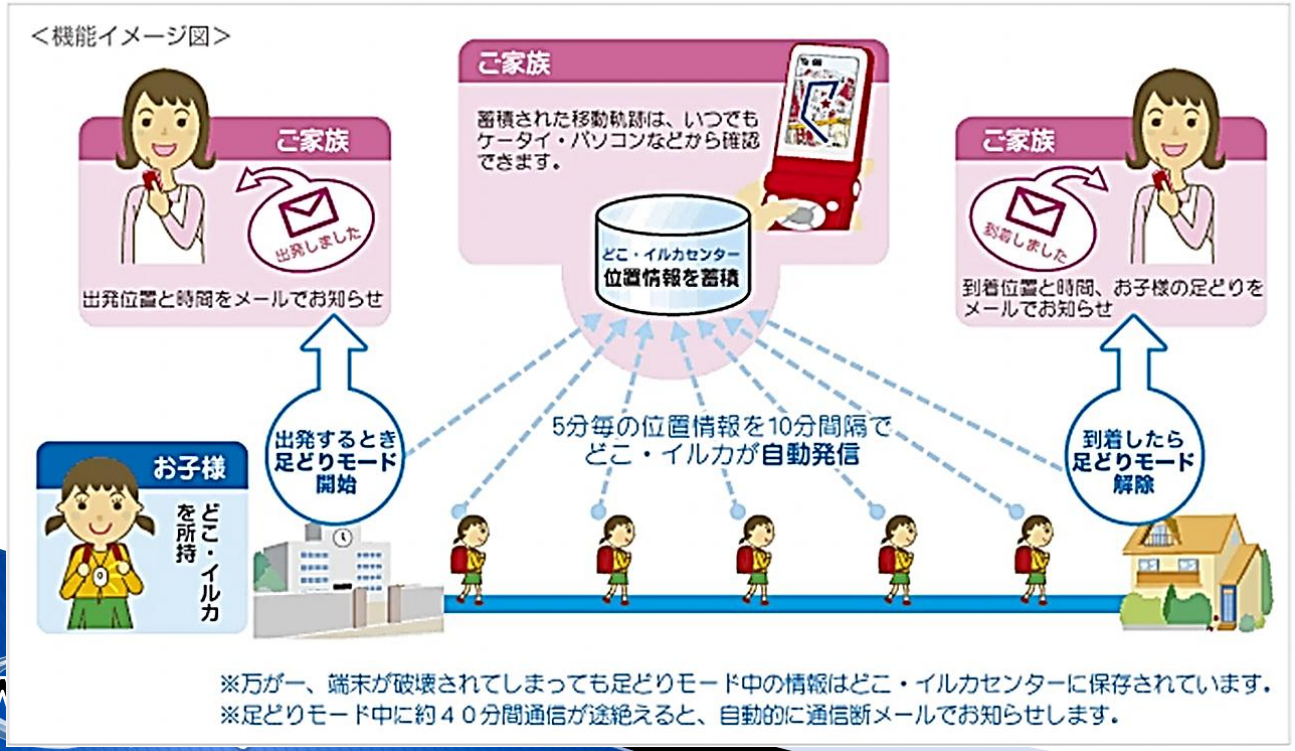
- Fewer Children and Aging Society
  - Elderly people are going to increase in population
- Trend towards nuclear families
  - An increase in elderly households
  - Young family members cannot necessarily watch the elderly at any time

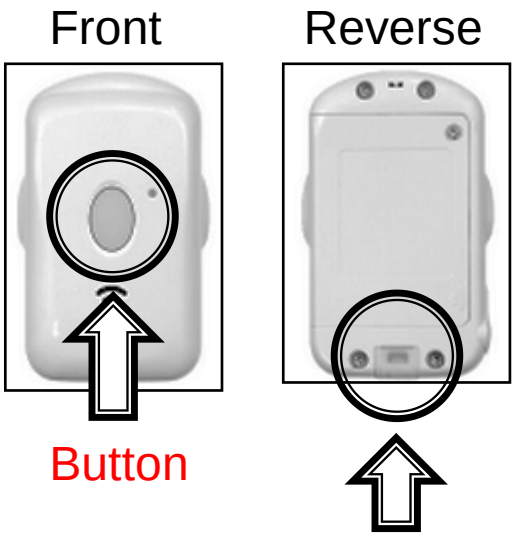
Purpose of the study

- Development of system to watch the vulnerable
  - A service for those around the vulnerable
    - The vulnerable : Children, Disable people, Elderly
    - Sensor data : Location information, Activity information, Biological information
  - Wandering behavior in the elderly

1. Doko Iruka[1]

- This product is provided by a venture company
- The vulnerable holds a special device
  - Location information is periodically transmitted to the management server on the Internet
- Watcher can see his location on the WEB page



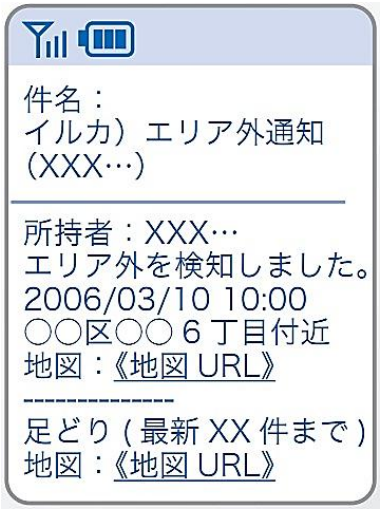


1 : http://www.dokoiruka.jp/

1. Doko Iruka

- If the vulnerable goes out of the specified area, the watcher receives an email from the server
- The specified area can be defined at the server

The area can be defined only by a circle
-> It is not possible to define a detailed area
The device does not have communication functions
-> A watcher has to go there to talk to the vulnerable



2. Higo-Yu Net[1]

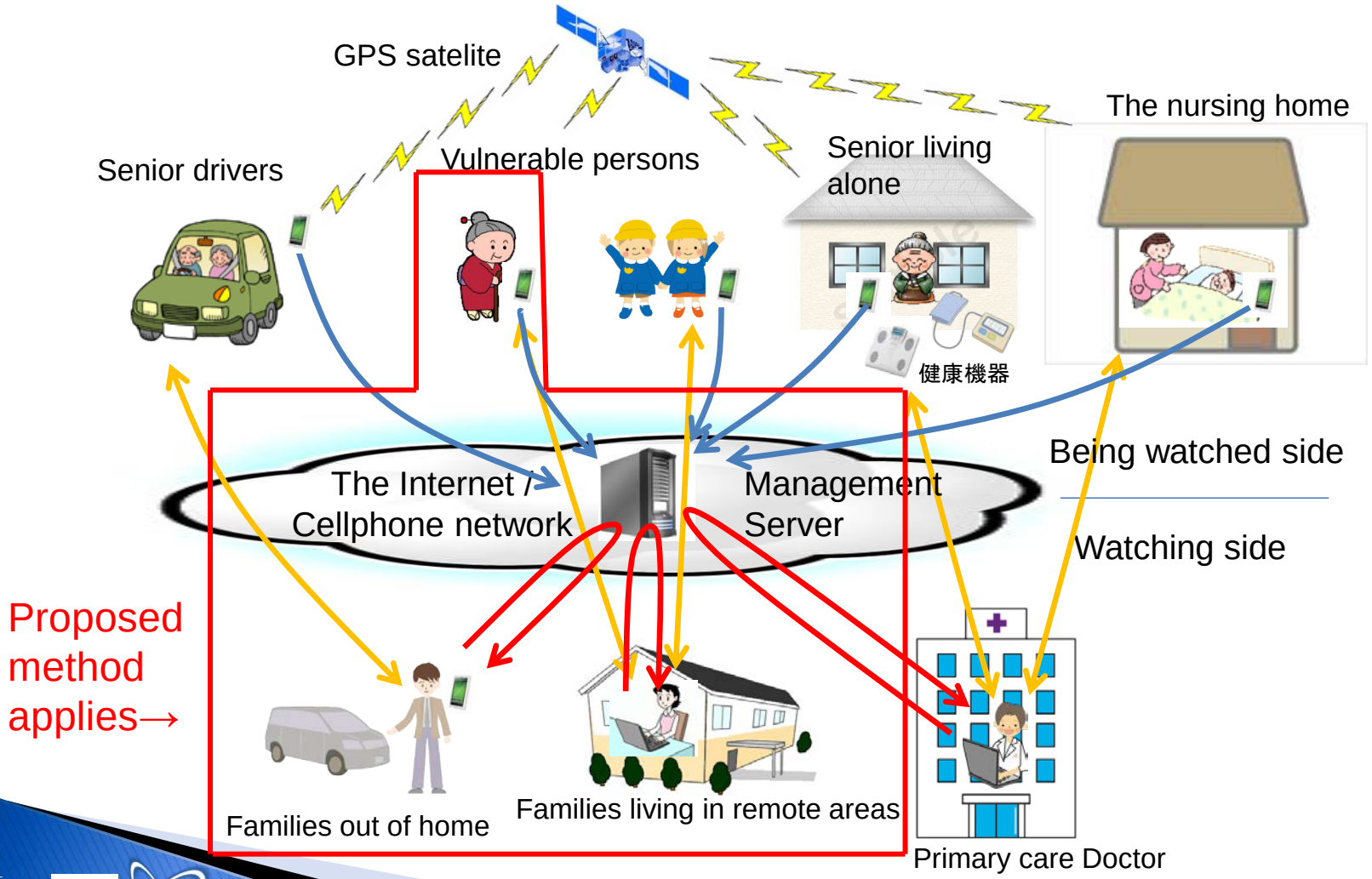
- This system is offered by an NPO that specializes watching the vulnerable
- Welfare specialists and neighbors watch the vulnerable, and reports the state of the vulnerable to the management server on the Internet
  - State : Good, having a cold
- The vulnerable holds a smartphone, and location information is obtained from it
- Watchers can watch location information on the WEB page

Require many people to watch the vulnerable
Not possible to take an appropriate action in the case of an emergency

1 : http://portal.higoyou.net/

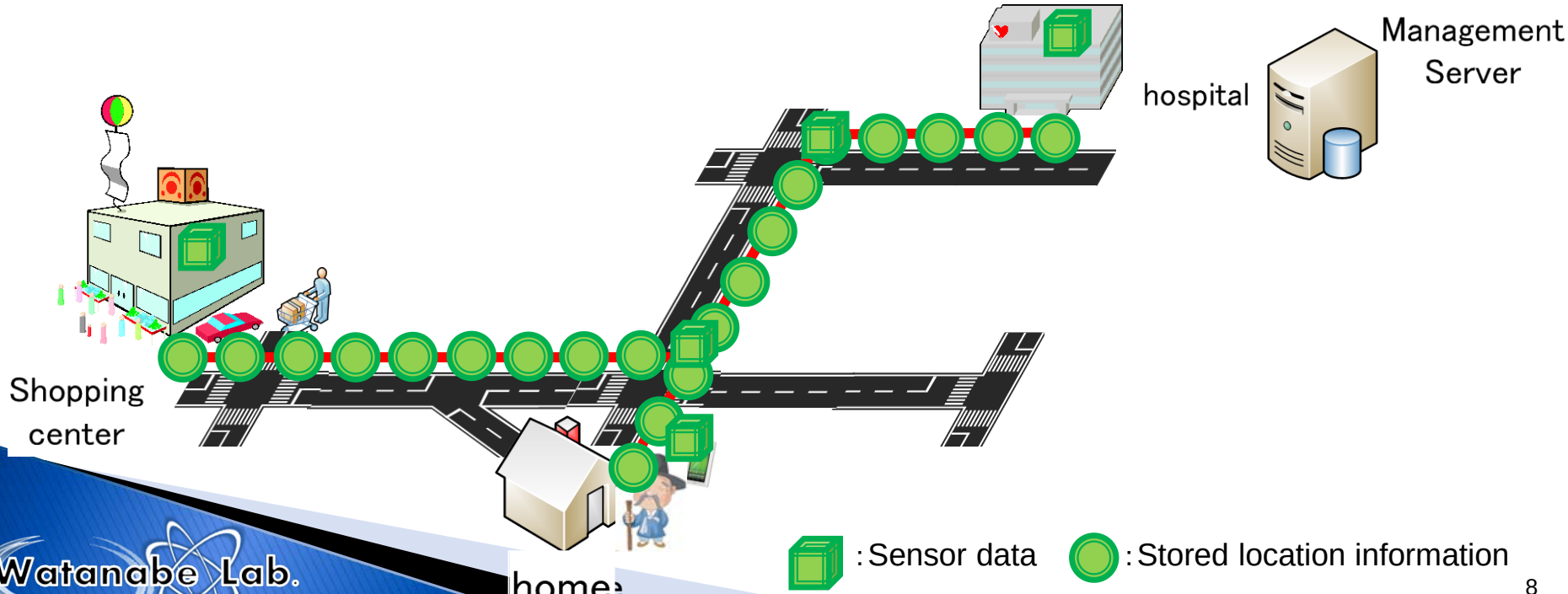
Objective of our proposal system

- TLIFES : Total LIFE Support system

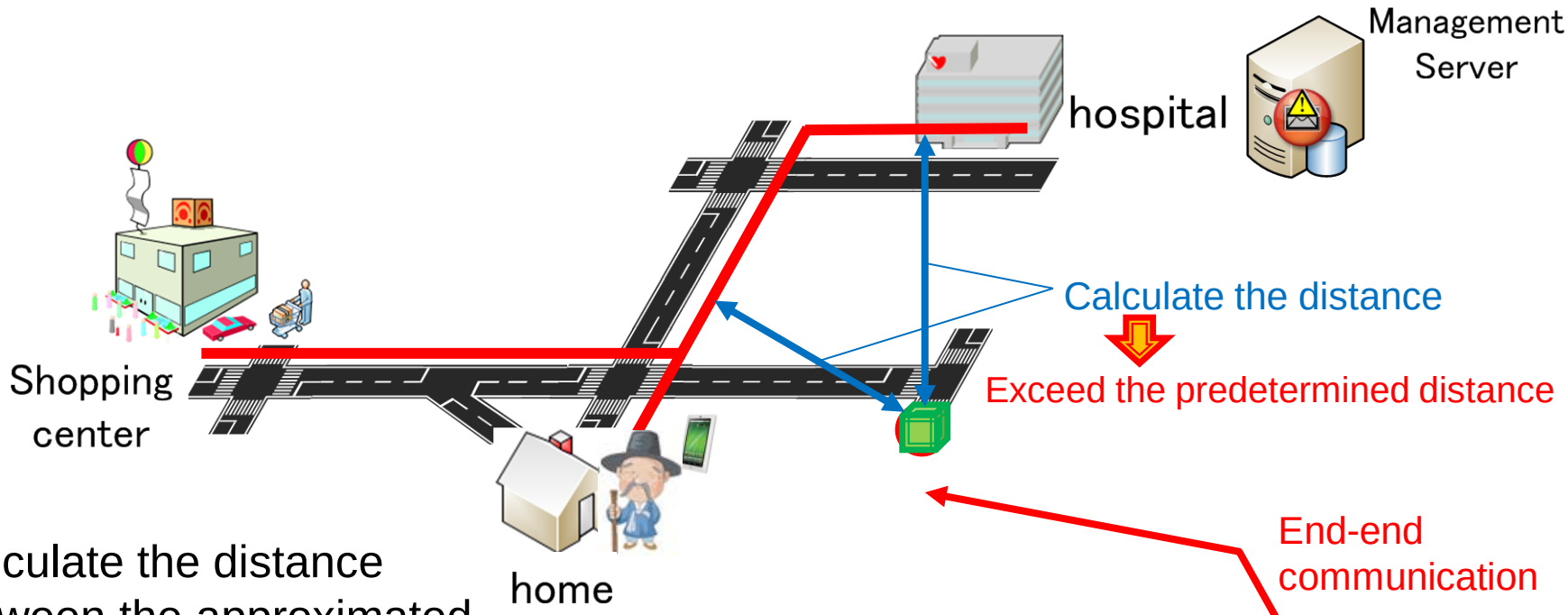


How to obtain the normal range of activities of the vulnerable

- The location of the vulnerable is periodically transmitted to the management server on the Internet via his smartphone
- The management server stores the location history in the database per person
  - The shape of location history will form along the road
  - The location history is approximated to the combination of short lines



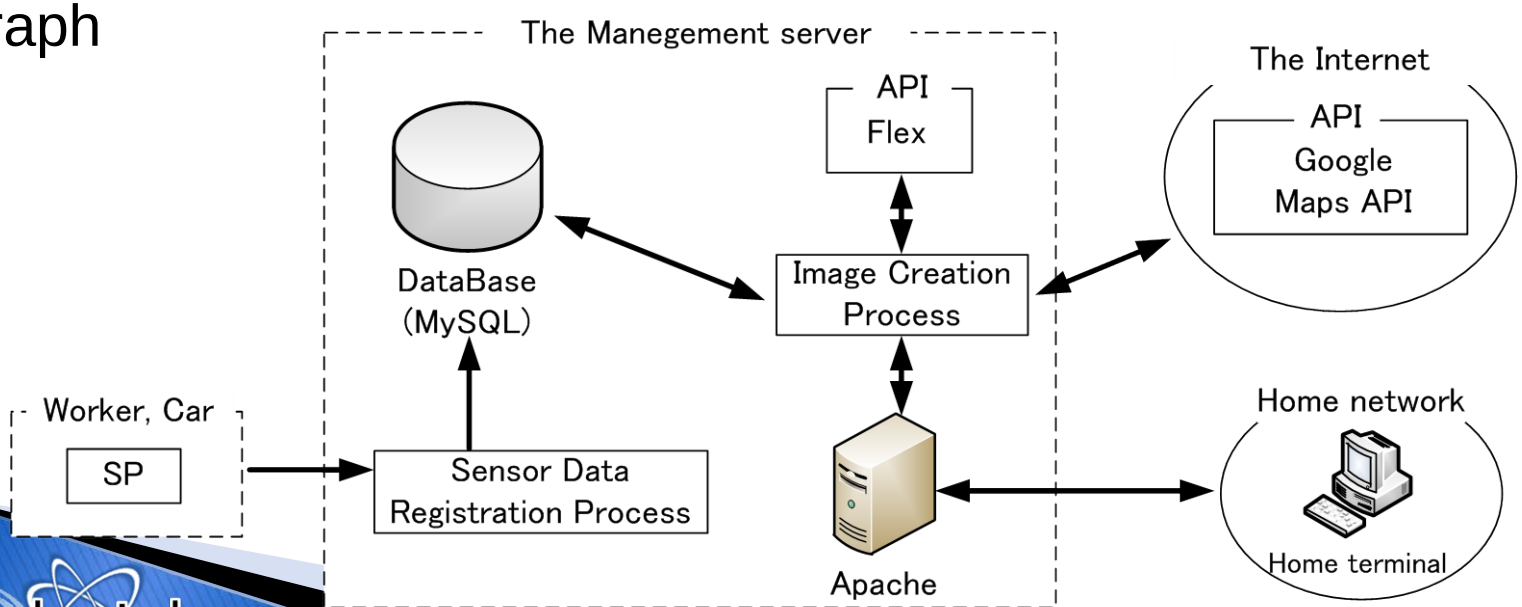
How to detect an alarm



- Calculate the distance between the approximated location history and the newly received location information
- If the distance exceeds the predetermined distance, the management sever sends an alarm mail to the watcher

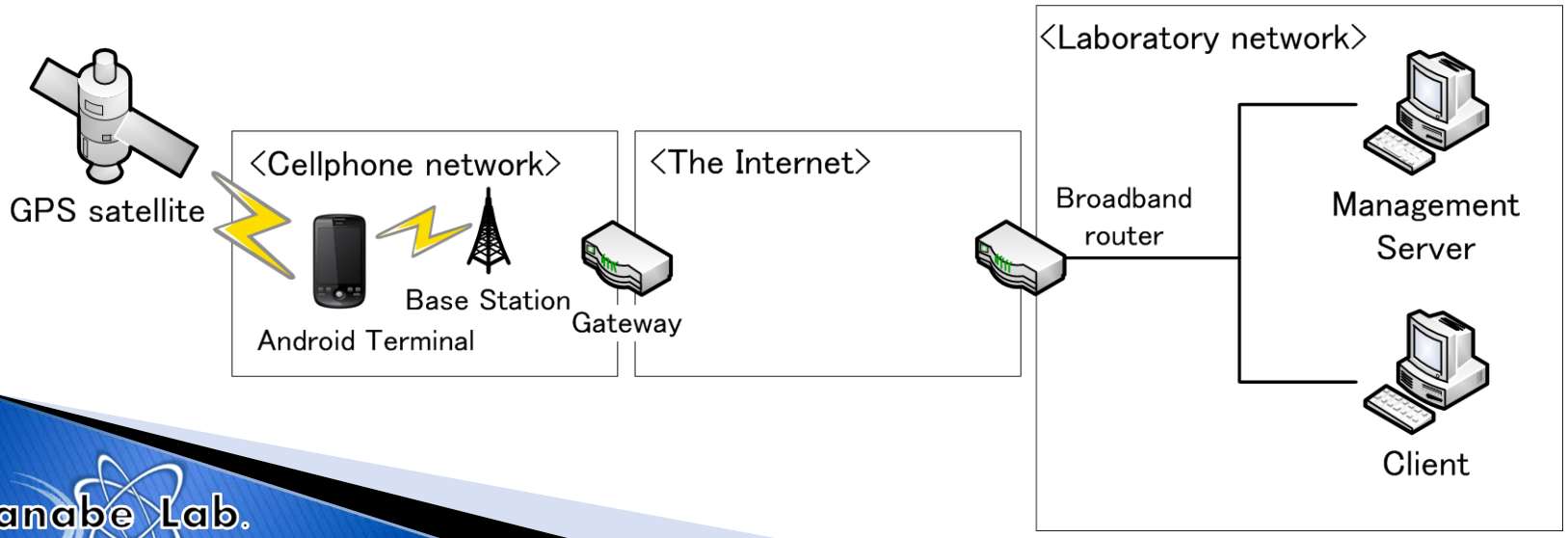
Implementation

- The management server receives sensor data periodically from a smartphone
- Sensor Data Registration Process module analyzes the packet and authenticates the user, and stores it in a MySQL database
- Apache receives the request packet from his home terminal, apache calls Image Creation Process module and it creates a map or a graph



Implementation-System Configuration-

- Smartphone transmits the sensor data to the management server in our laboratory via the cellular and the Internet
- Port forwarding is set in the broadband router
- A client accesses the management server



Result

- A student walked around the university having the smartphone in his pocket
- GPS information is reported to the server every 5 minutes
- An alarm mail function is already confirmed under a simple condition
- The formal alarm detection functions in the server, I said earlier is now underdevelopment

Conclusions & Future Works

- Conclusions
  - We have proposed the remote watching system that watchers can check the state of the vulnerable at anytime from anywhere
  - We have confirmed the basic operations with the trial system
- Future Works
  - Completion of the system
  - Evaluation in the real environment