Estimation of Bus Traveling Section Using Wireless Sensor Network

Hajime Adachi, Hidekazu Suzuki, Kensaku Asahi, Yukimasa Matsumoto and Akira Watanabe
Graduate School of Science and Technology, Meijo University, Aichi 468-8502, Japan
Email: hajime.adachi@ucl.meijo-u.ac.jp, {hsuzuki, asahi, matumoto, wtnbakr}@meijo-u.ac.jp

***Abstract*—One of the means to improve convenience of bus users is to introduce a bus location system that provides the users with such useful information as the present bus location and estimated time of arrival at the bus stop. However, since most of the existing bus location systems utilize the cellular network, the communication cost could become quite high. In order to alleviate this problem, we have been proposing a novel bus location system using a wireless sensor network that does not require any communication cost. This paper improves this system further, and offers a method to estimate the bus traveling section without the support of GPS so as to reduce the manufacturing cost of transceivers on board community buses. We have developed a prototype device of the system and conducted on-road demonstration experiments to verify the effectiveness of our proposed system, and it was confirmed that by our proposed system, the present bus traveling section can be estimated with sufficient accuracy.**

I. Introduction

With the progress of motorization, users of public transportation means such as buses tend to decrease in Japan. Due to the effect of such tendency, many fixed route bus services by private companies have been abolished or reduced in local cities. Yet, fixed route buses are important means of transportation, especially for elderly people and students who do not have driver's licenses. Thus, the number of local governments which operates community buses is increasing. However, as most of the community bus services are being conducted on a small scale and there aren't many buses running on the same route, users could encounter a problem when a bus is delayed due to certain problems such as a traffic jam, because they can't easily figure out whether the bus has already passed the stop or is still coming. One of the means to improve the convenience of bus users is to introduce a bus location system that provides the users with such useful information as the present bus location and estimated time of arrival at the bus stop. Most of the existing bus location systems utilize a cellular network to detect bus locations so as to provide users with operational information of the bus [1]–[4]. Bus location systems using a cellular network require a transceiver equipped with a GPS chip on each bus, and provide the bus position information obtained by GPS to bus stops as well as to user's mobile terminals. Thus, the existing bus location systems can deploy services over a wide range with a small amount of installation cost, but because they use a cellular network, they could incur a fairly high amount of communication cost. Then, as the financial condition of local governments is quite severe, there are cases where the operation of their bus location systems is abandoned.

In such a situation, we have been proposing a novel bus location system that uses Wireless Sensor Network (WSN) which does not require any communication cost [5]. The wireless sensor network is constructed with multiple IEEE 802.15.4-compliant sensor nodes installed at various places, such as the bus operation center, transceivers on board individual buses, bus stops, as well as street lights and utility poles along the bus route. Since information is exchanged through the wireless sensor network, no communication cost is incurred, and as a result, it is possible to manage the bus location system with quite a small amount of operation cost. We have conducted demonstration experiments for more than one year at part of a community bus system called "Kururin Bus" [6] which is operated in Nissin City, Aichi Prefecture, Japan, and it was confirmed that the operation of the bus location system using WSN is quite effective.

It is noted that in one of our other projects, the authors have created a system by which you can check the bus location information collected in the server on Google Maps, or instantly find it out by mobile phones or smart phones [7]. By interviewing bus users who use the system, we discovered that the provision of bus location information on a simplified map is much more useful compared with that by way of the latter.

In the meantime, community bus systems are often operated in unprofitable areas where private bus operators abandoned their services, and tax money is sometimes used to compensate for the deficit. For that reason, there is also a strong requirement on the part of communities to reduce operation cost as much as possible.

In this paper, we propose a method to estimate the present traveling section (not the exact spot but a certain predetermined section of a route) of a bus from the degree of strength of radio waves, namely, by using Received Signal Strength Indicator - RSSI detected at the time when the traveling bus equipped with a transceiver periodically receives beacon frames transmitted from sensor nodes installed in various places in the city in the wireless sensor network, without depending on GPS system. By this method, we can reduce the manufacturing cost of a bus transceiver by about 10 %, and furthermore, installation of GPS antenna is no longer required. Since the location of sensor nodes and bus traveling routes are already known, we define the road section between a sensor node and the next one as a traveling section, and create a list of traveling sections for the entire route of the service. The on-board transceiver identifies the nearest sensor node by using RSSI when it receives a beacon frame, and estimates the present traveling section by comparing it with the traveling section list. We conducted verification experiments by using

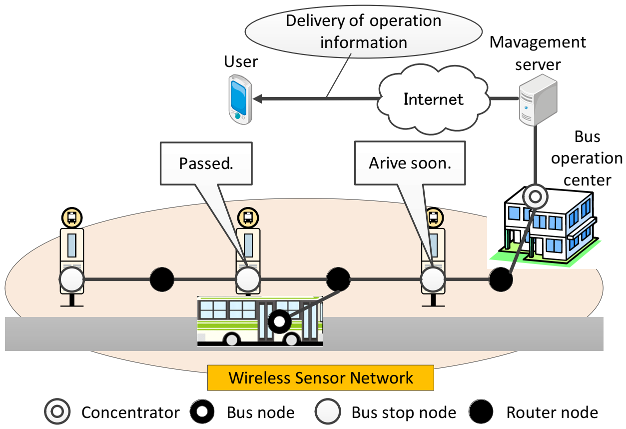


Fig. 1: Overview of our bus location system using wireless sensor network.

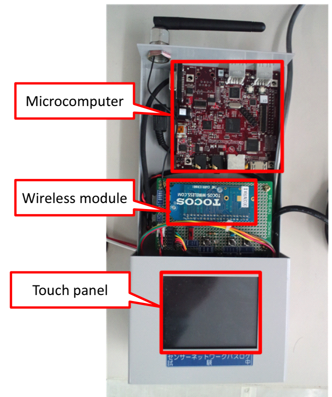


Fig. 2: Bus-mounted device.

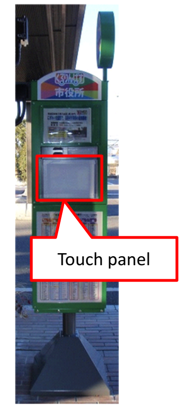


Fig. 3: Bus stop.

a private vehicle and confirmed that the result of estimation (accuracy of the location of the traveling bus) was within a tolerable range, even if GPS is not used.

Herein below, we show an overview of our already built bus location system using the wireless sensor network in Chapter II, our newly proposed method in Chapter III, the results and evaluation of demonstration experiments using our proposed method in Chapter IV, and the conclusion in Chapter V.

II. Bus Location System Using Wireless Sensor Network

A. Overview of Already Built System

We have been proposing a novel bus location system using a wireless sensor network that does not require any communication cost [5]. An overview of the system is shown in Fig. 1. In this system, multiple IEEE 802.15.4 [8]-compliant sensor nodes are installed at various places, such as the bus operation center, transceivers on board individual buses, bus stops, as well as street lights and utility poles along bus routes. These sensor nodes are called “Concentrator”, “Bus stop node”, “Bus node” and “Router node”, respectively. Bus node measures the bus position by using GPS periodically, and sends its location information to the concentrator. Router nodes relay the location information frames sent from bus nodes to the concentrator and the operation information frame sent from the concentrator to bus stop nodes. The concentrator is connected to the management server in the bus operation center, and the collected location information is stored in the server. The management server stores every bus location information, and generates bus operation information, and sends the operation information to bus stops via WSN, as well as to mobile terminals via the Internet. Bus stop nodes relay the frames just like router nodes, and display the operation information sent from the server on the screen. The installed node displays not only the received bus operation information bus also such other information as community event guides and notices from the relevant local government.

We plan to apply the sensor network built in the city also for purposes of providing emergency information at the time of disaster occurrence and assisting children and elderly people using small sensor nodes, by displaying the relevant information on the screen at bus stops.

B. Bus Node (Bus-Mounted Device)

Fig. 2 shows the bus-mounted device. The bus-mounted device consists of a Linux microcomputer, a GPS module, a wireless module and a small touch panel display, those are attached by the serial port of the Linux microcomputer. The bus-mounted device boots at the time of supplying power from the bus, and displays a route selection screen on the touch panel. After a bus driver selects the route, the microcomputer starts the measurement of own position by GPS, and generates the bus location information message. The message is transmitted to the concentrator through the sensor nodes periodically.

C. Router Node

The router node is made of a wireless module, two D size batteries and the water/dust proof box. The wireless module is just driven by these batteries. When the router node receives the bus location information message transmitted from the bus node, the router node searches the route to the concentrator, and forwards the message to the neighbor router node or the concentrator. In addition, all router nodes periodically notifies the concentrator of the battery condition.

D. Concentrator and Management Server

The management server is connected to the concentrator with a serial cable, and saves the data or control message received from the concentrator, such as the bus location information and the battery voltage of router nodes. In addition, the management server generates the bus operation information based on the relationship between the current bus location and bus time tables, and sends it to bus stops.

E. Bus Stop Node (Bus Stop)

Fig. 3 shows our developed bus stop. The bus stop consists of an embedded PC, a wireless module and a touch panel display. Information received from the management server such as the bus operation information and local government information is displayed on the touch panel screen at bus stops.

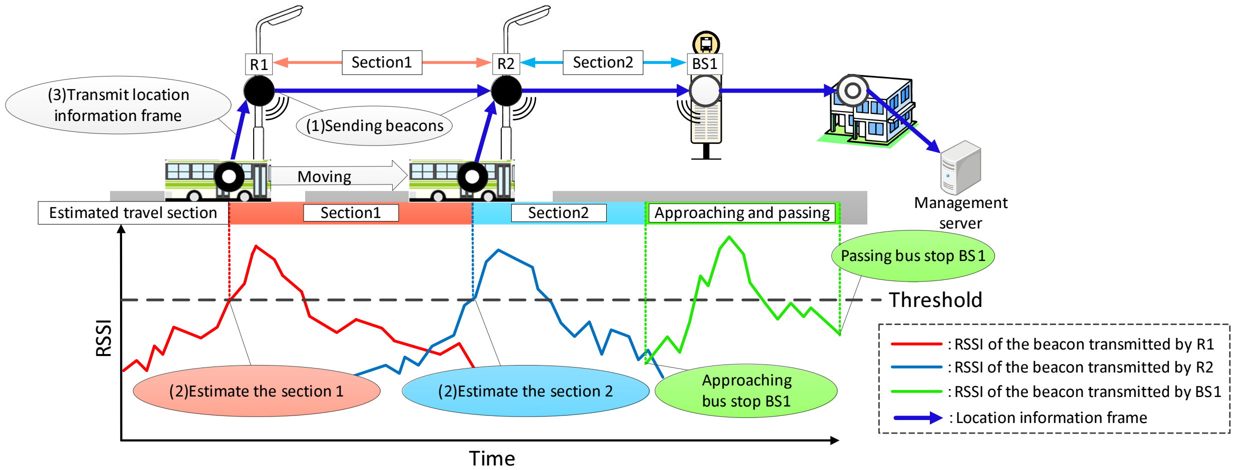


Fig. 5: Overview of our newly proposed method.

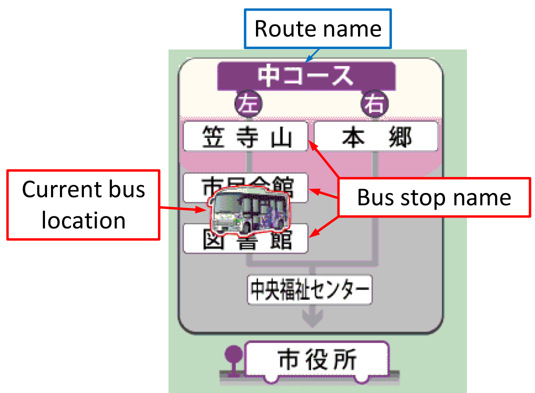


Fig. 4: Example of display of the bus traveling position on the screen at bus stops.

III. Our Newly Proposed Method

From the demonstration experiments we had conducted, we found that RSSI varies greatly depending on the surrounding environment, but the variation is rather small and it is possible to obtain relatively stable RSSI values even in the outdoor when the distance between the transmitter and the receiver is close. Thus, we propose here a new method to estimate the present travel section of a bus based on RSSI instead of GPS.

A. *Required Accuracy of Location Information*

The distance between two bus stops in the case of community bus systems is generally short, and the route is rather complicated. Thus, we decided to make the display at each bus stop quite simple as shown in Fig. 4. In the case of bus location information indicated in Fig. 4, we think that no accurate GPS information is required, and it will be sufficient if only the present bus traveling section (instead of the exact location) is indicated on the screen.

B. *Change in Specifications as the Consequence of Using RSSI*

In our new system, bus stop nodes and router nodes send beacon frames at regular intervals, and bus nodes receive them. This means that the relationship between the sender and the receiver is reversed, compared with our already built system using GPS. A bus node identifies the nearest sensor node by using RSSI of a beacon frame, and estimates the present bus traveling section. The bus node sends the location information to the concentrator via the neighboring bus stop. And, as the bus node is constantly moving, the radio wave environment also changes constantly. Therefore, the bus node judges the nearest router node correctly when the value of RSSI is larger than a certain threshold value.

C. *Definition of the Traveling Section*

Sensor nodes are supposed to be located along the bus service route at certain intervals. Thus, we define that the "traveling section" is a section between two adjacent router nodes. In other words, the traveling section "Sn" is defined as the section from the point of router node Rn to the point of router node R$n+1$. When the interval between nodes is very narrow, the traveling sections can be integrated into one section.

D. *Procedures for Estimating the Present Traveling Section*

Fig. 5 shows the overview of our newly proposed method. The procedures for estimating the traveling section are as follows:

1) Bus stop nodes and router nodes periodically transmit beacon frames with their ID information attached to them.
2) Bus node checks the RSSI when it received a beacon frame, and if the RSSI value is larger than a certain threshold value, it determines that the router node is the nearest one, based on the attached ID information.
3) Bus node estimates the traveling section from the nearest router node and sends the location information frame to the server via the neighboring bus stop to the concentrator as well as to nearby bus stops.

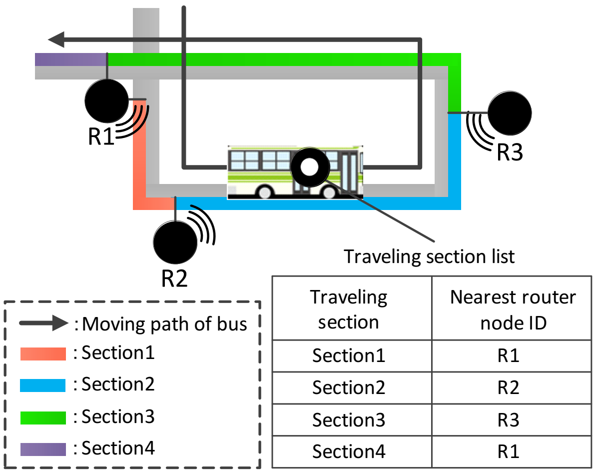


Fig. 6: Example of the relationship between the moving path of the bus and the traveling section list.

E. Method of Identifying the Present Traveling Section

Community bus sometimes takes a complicated route and may run near the same router node more than once. However, since the locations of router nodes and the bus service router are known in advance, it is possible to figure out the order of the router nodes that the bus passes through. For that purpose, the bus node carries with it a traveling section list and estimates the present traveling section by using the ID information of the nearest router node and the traveling section list, as shown in Fig. 6. In this way, it is possible to estimate the present traveling section correctly.

IV. Verification Experiment

In order to verify the effectiveness of our newly proposed method, we conducted traveling section determination experiments by using a private car on public roads. We describe the method and the result of our experiments as below: In order to verify the feasibility of our proposed method, we conducted travel section determination experiments using the private car on public roads. We will report the experimental method and the results as below.

A. Method of Experiment

Fig. 7 shows the running route chosen for our experiment. We placed 9 router nodes along the route of 2 km at intervals of 100 to 300 meters. We adopted "TWE-001 STRONG" manufactured by Tokyo Cosmos Electric Co., Ltd. [9] as the sensor. Router nodes are water/dust proof boxes containing the above-said sensor, and each of them is mounted on a tripod of 3 m high. Beacon frames were dispatched at intervals of 1 second. Fig. 8 shows the bus node in the private car, which consists of a laptop PC for data analysis and a GPS logger to obtain the exact location information for reference. The running speed of the car was set at 20 to 40 km/h, which is equivalent to the running speed of the bus. The bus node checked RSSI when it received the beacon frames transmitted from the router nodes on the route. When RSSI of more than -50 dBm was detected, the bus node estimates the present

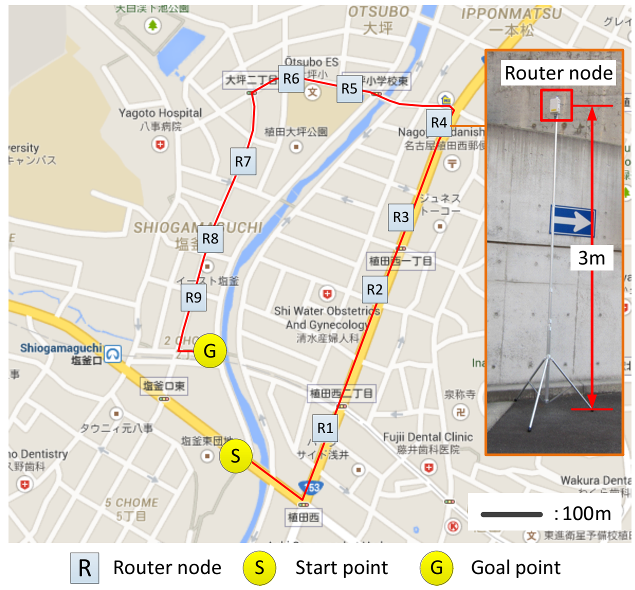


Fig. 7: Traveling route.

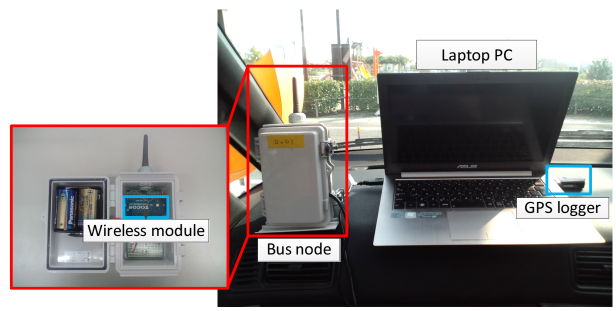


Fig. 8: Bus node and laptop computer for data analysis mounted on the car.

traveling section from the ID information and the traveling section list. We conducted the experiment 10 times in total and made a comparison between the results obtained by our proposed method and those obtained by the GPS logger.

B. Result of Our Experiment

Fig. 9 shows the RSSI data from one run out of the 10 experimental runs we conducted. From this Figure, it is seen that the value of RSSI is on the high side when the car is traveling near router nodes. Then, we checked the nearest router nodes to the car based on the threshold of -50 dBm, by using the ID numbers of the relevant nearest router nodes. Fig. 10 shows the estimation of the traveling sections. The upper part of Fig. 10 indicates the contents of Fig. 9 and the estimated traveling sections of the car based on the established threshold, and the lower part indicates the changes in the location information obtained by GPS while the car is running in the traveling sections. From Fig. 10, it is seen that it is possible for our proposed system to correctly estimate the order of traveling sections. In addition, it is also seen that many of the estimated traveling sections Sn make the router node Rn as the starting point. Fig. 11 shows the changes in the values

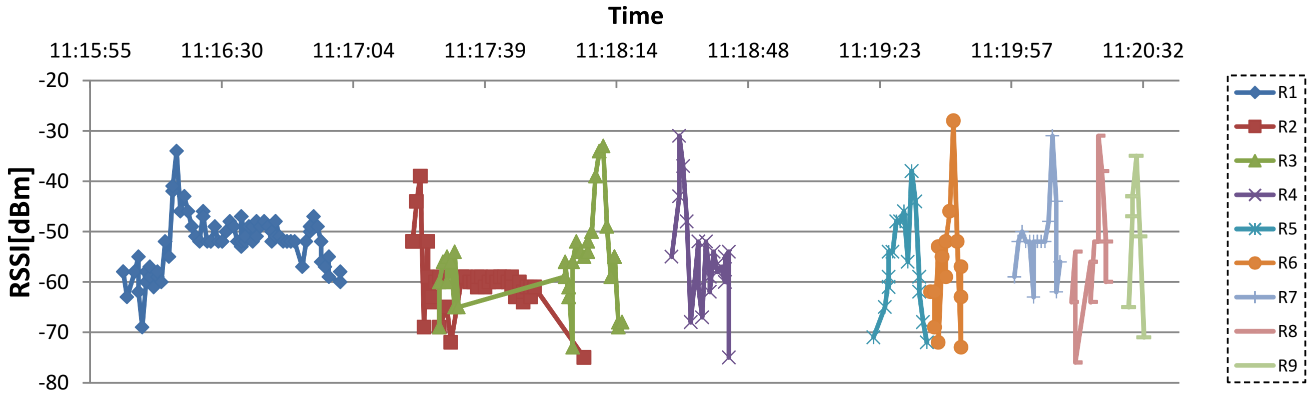


Fig. 9: RSSI data obtained when the car is traveling.

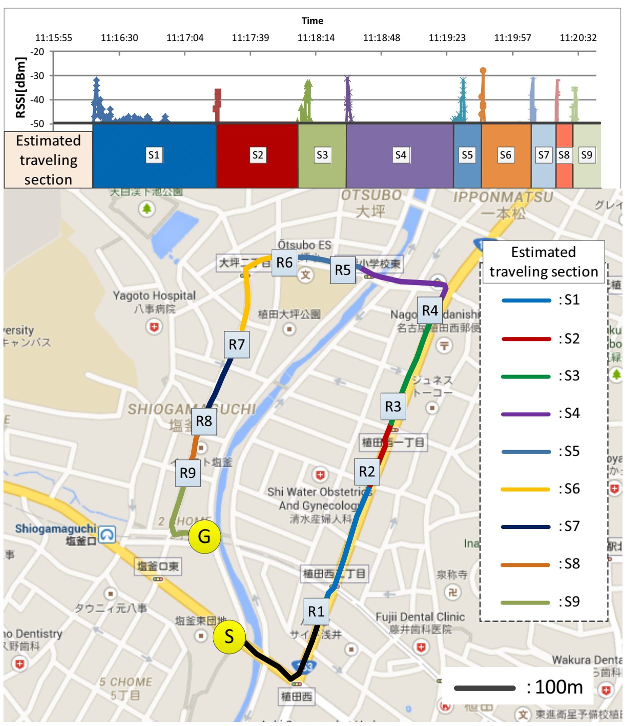


Fig. 10: Result of estimated traveling sections with threshold at 50dBm.

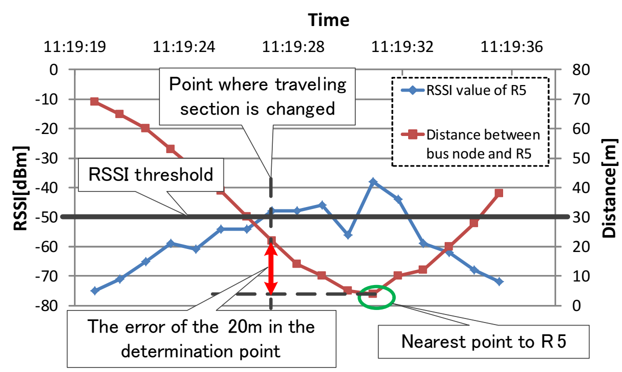


Fig. 11: Change in RSSI values and in the distance between bus node and router node.

of RSSI, as well as in the distances between the bus node and the router node R5. The distance between the bus node and the router node R5 was measured by GPS. Looking at Fig. 11, it is seen that the error in the distance between the point where the car was the nearest to the router node and the point where the identification of the traveling section was made was about 20 meters. In the case of other router nodes, too, the error in the distance was about 20 to 30 meters. Assuming that all router nodes are installed at bus stops, and that a bus exists at a distance of 20 meters from the bus stop, it is possible for bus users to visually observe the bus. Therefore, an error in the distance of about 20 meters is considered to be within a tolerable range.

Table. I shows the estimated accuracy of each traveling section on the assumptions that one section from Rn to R$n+1$ is Sn and that the section between two routers is one traveling section. The estimated accuracy is calculated on the basis of 3 patterns; namely, the average value, the minimum value and the maximum value for all 10 runs. From Table. I, it is seen that the obtained accuracy is more than 90 % in all traveling sections.

C. Considerations

From the above mentioned results, it is seen that the traveling section is switched to the adjacent traveling section when the car approached the router node, if the established threshold value of RSSI is high. The most important role of the bus location system is to provide bus users with the information on the traveling section of the bus correctly, and from such a viewpoint, it is desirable that the present traveling section of a bus is estimated based on a certain rule, and it is considered to be more preferable if the threshold is established based on a certain rule, and it is considered to be more preferable if the threshold is established at a certain high value.

In the real environment, the distance between two bus stops is 300 to 500 meters in normal cases. Thus, we assume that

TABLE I: Accuracy estimation for each traveling section.

Section	Average[%]	Lowest[%]	Maximum[%]	Standard Deviation
S1	99.1	96.4	100	1.35
S2	98.4	94.1	100	2.37
S3	98.5	95.5	100	2.09
S4	97.9	95.3	100	1.64
S5	98.6	91.7	100	3.11
S6	98.8	96.1	100	1.70
S7	98.7	92.3	100	2.87
S8	98.5	90.9	100	3.39
Average of All Sections	98.6	97.7	100	0.84

R2, R5 and R8 in Fig. 7 are bus stops, and evaluated if it is possible to estimate the present traveling section of a bus in the way shown in Fig. 4. As it was considered to be more preferable if the threshold value of RSSI is set at a relatively high point, as mentioned above, evaluation was performed for the case of Fig. 10 above. From Fig. 10, there exist router nodes R3 and R4 between the router nodes of R2 and R5. Likewise, there also exist multiple sections between R5 and R8. Thus, we can estimate the present bus traveling section more in detail when there are multiple router nodes between two bus stops, and it is quite possible to make such a display on the screen as shows in Fig. 4.

However, if the RSSI threshold value is set at a very high point, it will become difficult to identify the nearest router node and correctly estimate the present traveling section of the bus. Furthermore, depending on the bus traveling condition, we can think of a possibility that despite the situation where RSSI values beyond the threshold value can normally be observed, RSSI data exceeding the threshold value cannot be detected depending on the timing of the reception of beacon frames. In order to solve such problems, the following two measures are considered.

1) Dynamic adjustment of beacon transmission intervals: One way is that the router node shortens the transmission intervals of beacon frames when the bus is approaching. By doing so, the number of beacon frames that the bus node can detect will increase. The bus node, after determining the nearest router node, gives instructions to the router node to return to the original intervals of beacon frames. Through this operation, we will be able to get the RSSI data which the bus node can detect correctly, while minimizing the power consumption by the router node.

2) Introduction of adaptive threshold: Even if the above-said measures are taken, any positive effect will not be obtained if the observed RSSI value is below the threshold. Thus, there is a way of adopting different values of threshold in accordance with the radio-wave propagation environment in the places where router nodes are installed, instead of setting up the threshold at a certain fixed value as Fig. 12. A list of traveling sections are created in which the ID numbers of certain specific router nodes are related with lower levels of threshold, for the places where only low RSSI values can be detected, and it becomes possible for the bus node to change the threshold dynamically according to the situation of each traveling section. As a result, it is possible to prevent the cases of non-detection of the nearest router node.

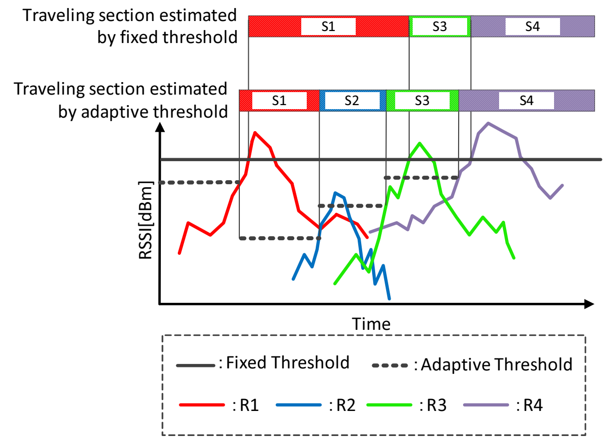


Fig. 12: Example of an application of the adaptive threshold.

V. Conclusion

In this paper, we have proposed a new method of estimating the present traveling section of a bus based on RSSI, in the bus location system using a wireless sensor network. We conducted experiments to determine the present traveling section by using a private car. The result of our experiments confirmed that the present traveling section can be determined with sufficient accuracy by using RSSI. Hereafter, we will perform implementation of the idea of adjusting the beacon transmission intervals and also introduce the adaptive threshold to the bus node. We will also install router nodes in actual bus service lines and verify the feasibility of identifying the present traveling section based on RSSI.

References

[1] N. Kanatani, T. Sasama, T. Kawamura, and K. Sugahara, “Development of bus location system using smart phones,” in *Proc. of the SICE Annual Conference 2010*, 2010, pp. 2432–2433.

[2] L. Zhian and H. Han, “A bus management system based on zigbee and gsm/gprs,” in *Proc. of 2010 International Conference on Computer Application and System Modeling (ICCASM 2010)*, vol. 7, 2010, pp. V7–210–V7–213.

[3] U. Farooq, T. ul Haq, M. Amar, M. Asad, and A. Iqbal, “Gps-gsm integration for enhancing public transportation management services,” in *Proc. of 2010 Second International Conference on Computer Engineering and Applications (ICCEA)*, vol. 2, March 2010, pp. 142–147.

[4] R. Anderson, A. Poon, C. Lustig, W. Brunette, G. Borriello, and B. Kolko, “Building a transportation information system using only gps and basic sms infrastructure,” in *Proc. of 2009 International Conference on Information and Communication Technologies and Development (ICTD)*, April 2009, pp. 233–242.

[5] M. Hata, H. Adachi, H. Suzuki, Y. Matsumoto, and A. Watanabe, “Proposal for novel bus location system usingwireless sensor network,” in *Proc. of the 20th ITS WORLD CONGRESS TOKYO 2013*, no. 3209, 2013, pp. 1–10.

[6] Kururin bus (nissin city round route bus) — nissin city. [Online]. Available: http://www.city.nisshin.lg.jp/shisetsu/bus/index.html

[7] A. Sakata, Y. Matsumoto, and H. Suzuki, “Development of bus location system with smartphone and effect of providing regional information added on bus information,” *Journal of the Eastern Asia Society for Transportation Studies*, vol. 10, pp. 1311–1322, 2013.

[8] IEEE 802.15 WPAN task group 4 (TG4). [Online]. Available: http://www.ieee802.org/15/pub/TG4.html

[9] TWE-Strong-TOCOS-WIRELESS.COM. [Online]. Available: http://tocos-wireless.com/jp/products/TWE-001STRONG.html

スマートフォンとモバイルネットワークを用いた弱者見守りシステムTLIFESの実現
(Total LIFE Support system)

渡邊晃
中野倫明
山本修身
川澄未来子
山田宗男
小中英嗣
旭健作
鈴木秀和

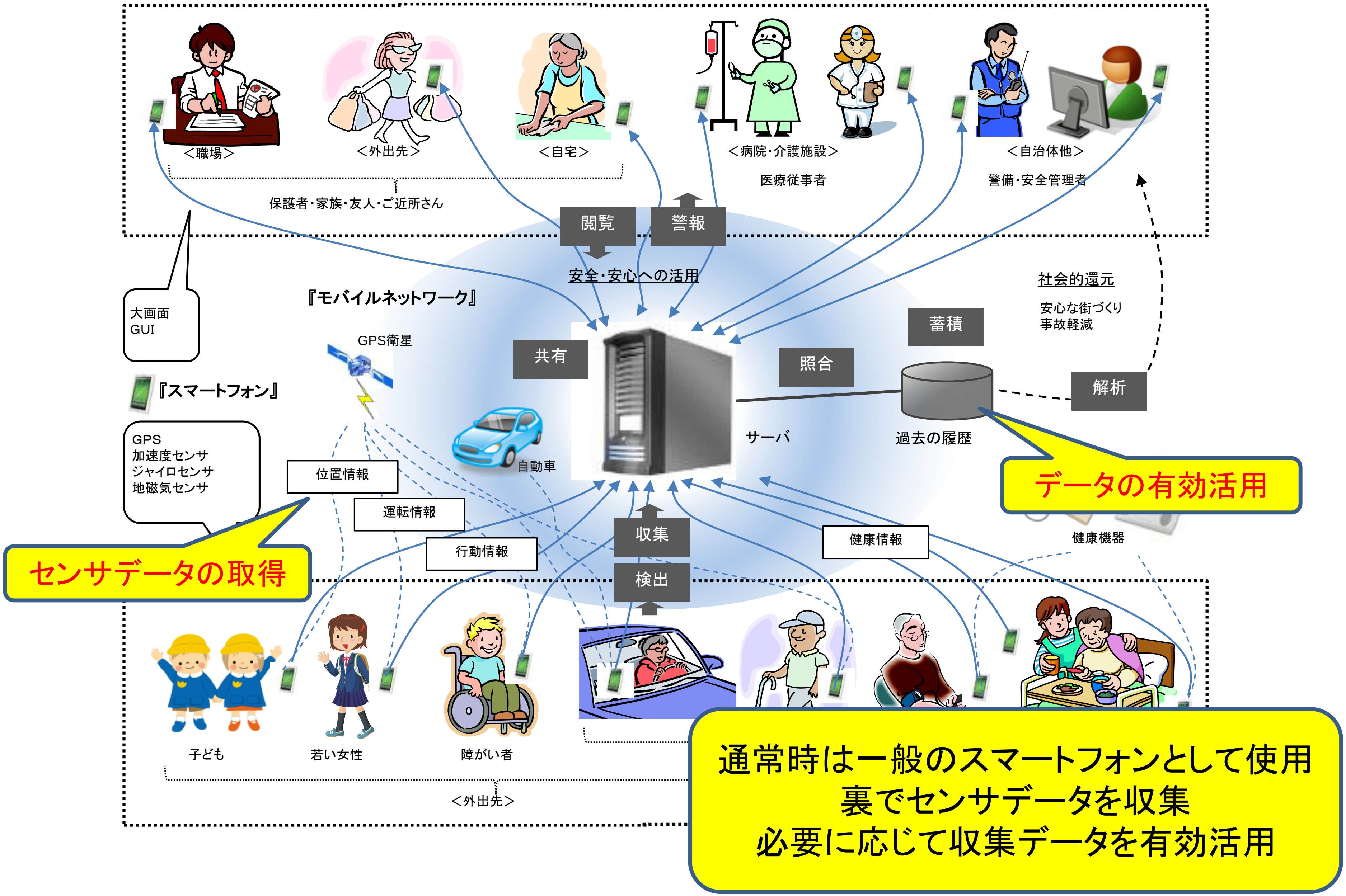
名城大学理工学部情報工学科

TLIFESのコンセプト

スマートフォンを利用した生活支援システム

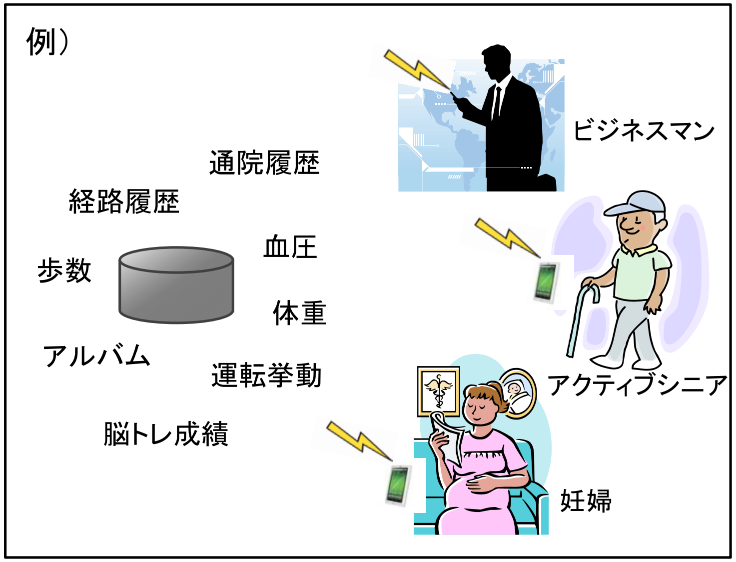
スマートフォンを必須アイテムと位置付ける。
スマートフォンを介してあらゆる情報を共有する。
通常時にはコミュニティ（家族を含む）の生成に寄与するためのツールとして利用する。
有事においてはコミュニティを介した相互扶助を行う。

TLIFESのシステム構成

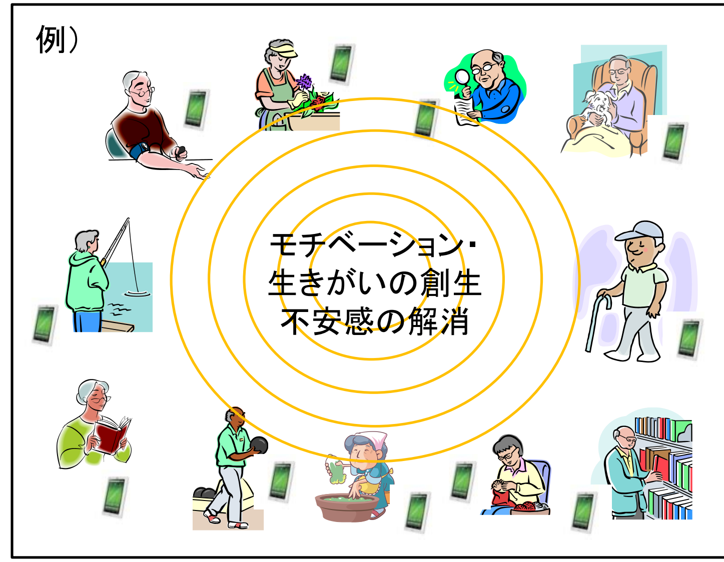


TLIFESの活用

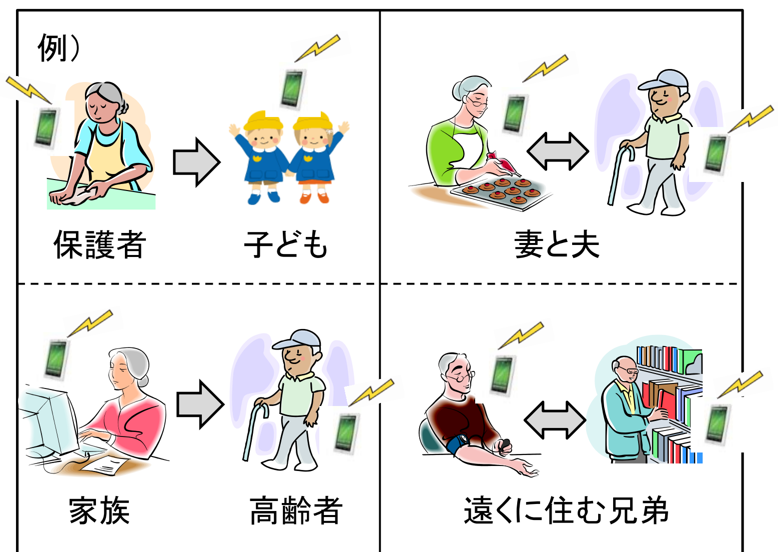
①個人のライフログ（自分の管理）



③SNS（仲間とのつながり）

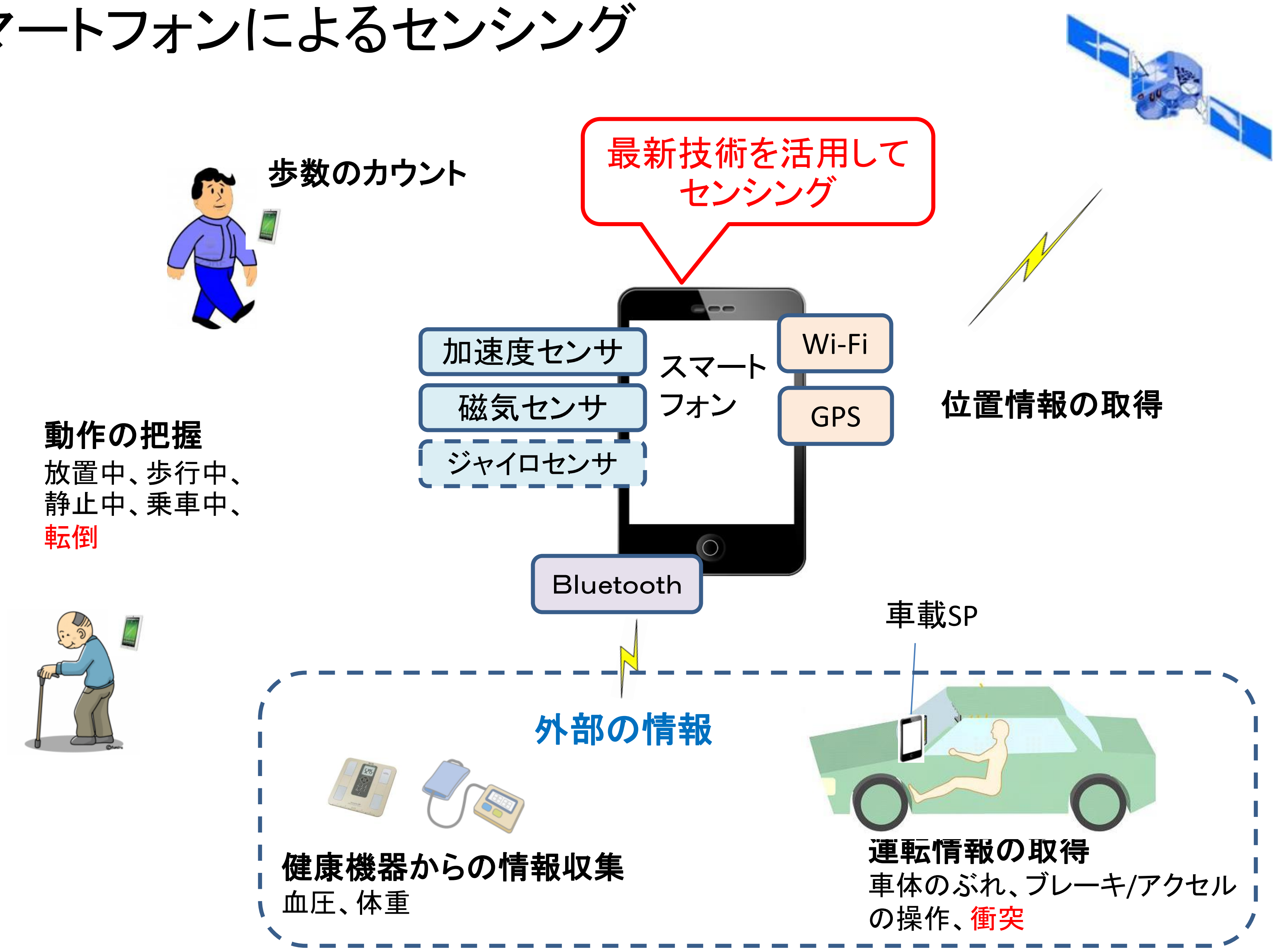


②見守り（弱者の見守り、相互見守り）



④有事の相互扶助

技術のポイント①
スマートフォンによるセンシング



技術のポイント②
サーバにおけるデータベース構築と異常検出

リアルタイム閲覧

各種センサ情報

サーバ

利用者ごとの
データベース

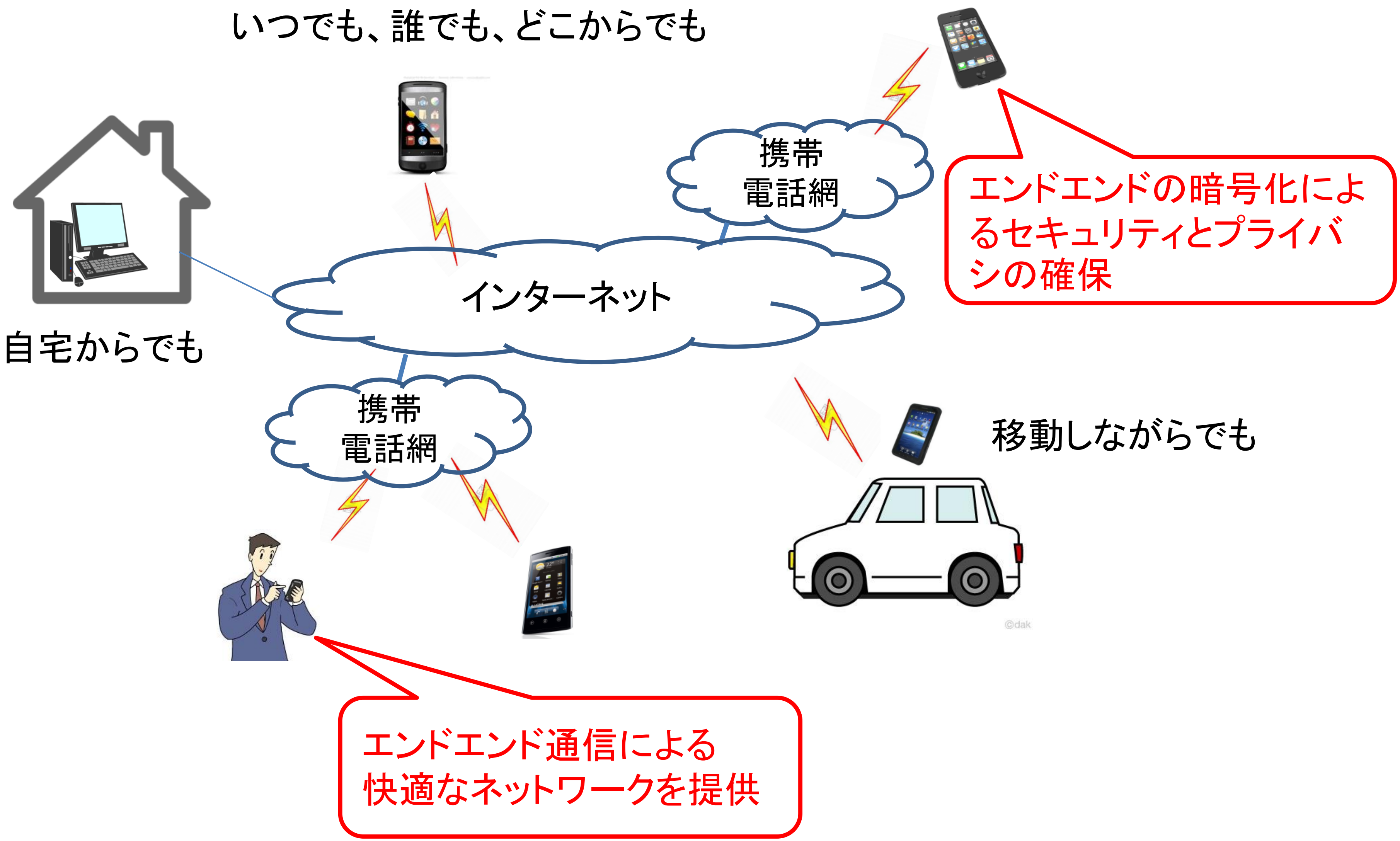
常時アラームチェック
（過去の履歴から）

アラームメール

異常の検出内容
・日常の行動範囲を逸脱
・過去のデータから個人差に応じた
異常を検出

件名：アラームのお知らせ
いつもと違う行動範囲です。 http://www. ◆◆◆◆. △△. ○○

技術のポイント③
スマートフォンによる情報交換（無料会話、チャット）

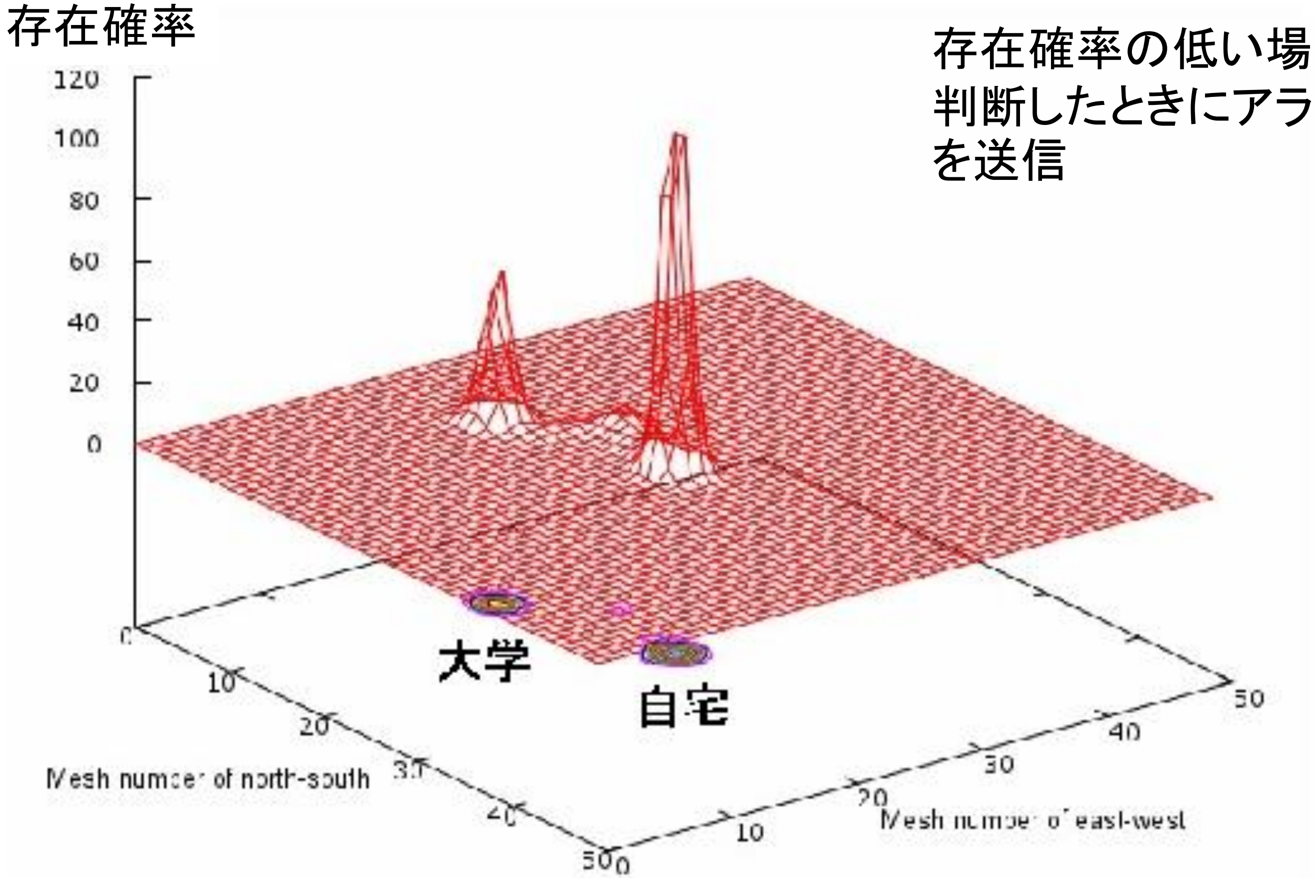


TLIFESの現状①
位置履歴と行動履歴の表示

TLIFESの基本機能が完成

- Androidのアプリを駆動し続けるしくみ
- 位置測位、センサ類のノーハウ蓄積
- バッテリ消費をできるだけ減らすしくみ
- 行動判定のアルゴリズム

TLIFESの現状②
行動範囲の学習と異常行動の判定



存在確率の低い場所にいると判断したときにアラームメールを送信

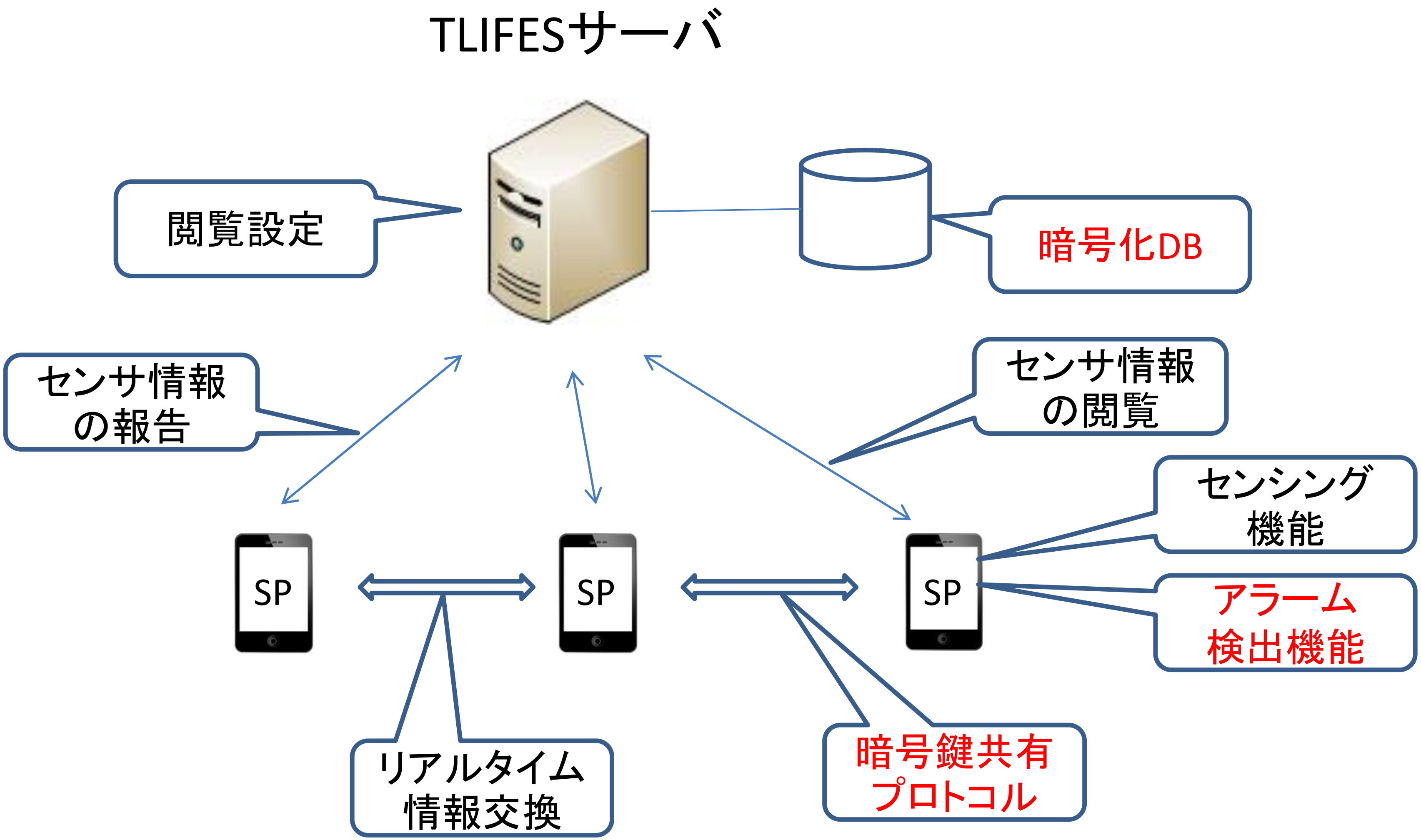
徘徊行動の検出機能を実現→自治体最大の課題を解消
（サーバでないとわからないアラーム検出の例）

TLIFESの現状③
汎用的な独自の情報交換ツール：Mobile line（仮称）

	LINE（商品名）	Mobile line（技術名）
基本機能	無料会話、チャット	
通信中のネットワーク切り替え	会話が切れる	会話が継続される
セキュリティ/プライバシ	**チャットの内容がサーバに平文で蓄積されている アドレス帳がサーバに読み込まれる**	**情報は全てエンドエンドで暗号化 登録した情報以外が他人に漏れることはない配慮**
会話の快適性	サーバ経由のため遅延が大きい	エンドエンド通信のため快適な会話が可能
ユーザインタフェース	変更不可	高齢者向けなどにアレンジが可能

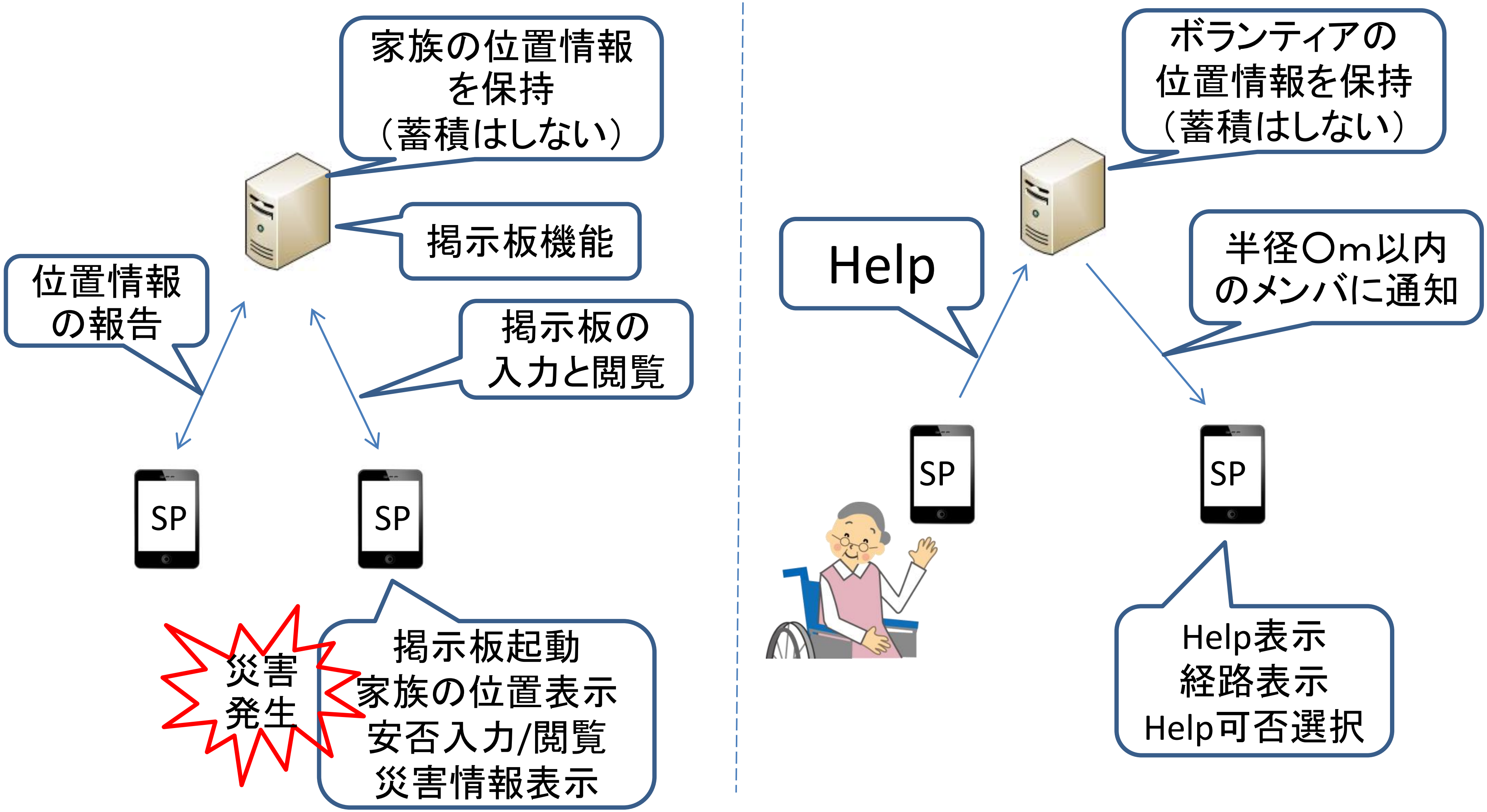
快適で安全なネットワークを実現

TLIFESの今後①
プライバシの保護を考慮したライフログサービスの実現

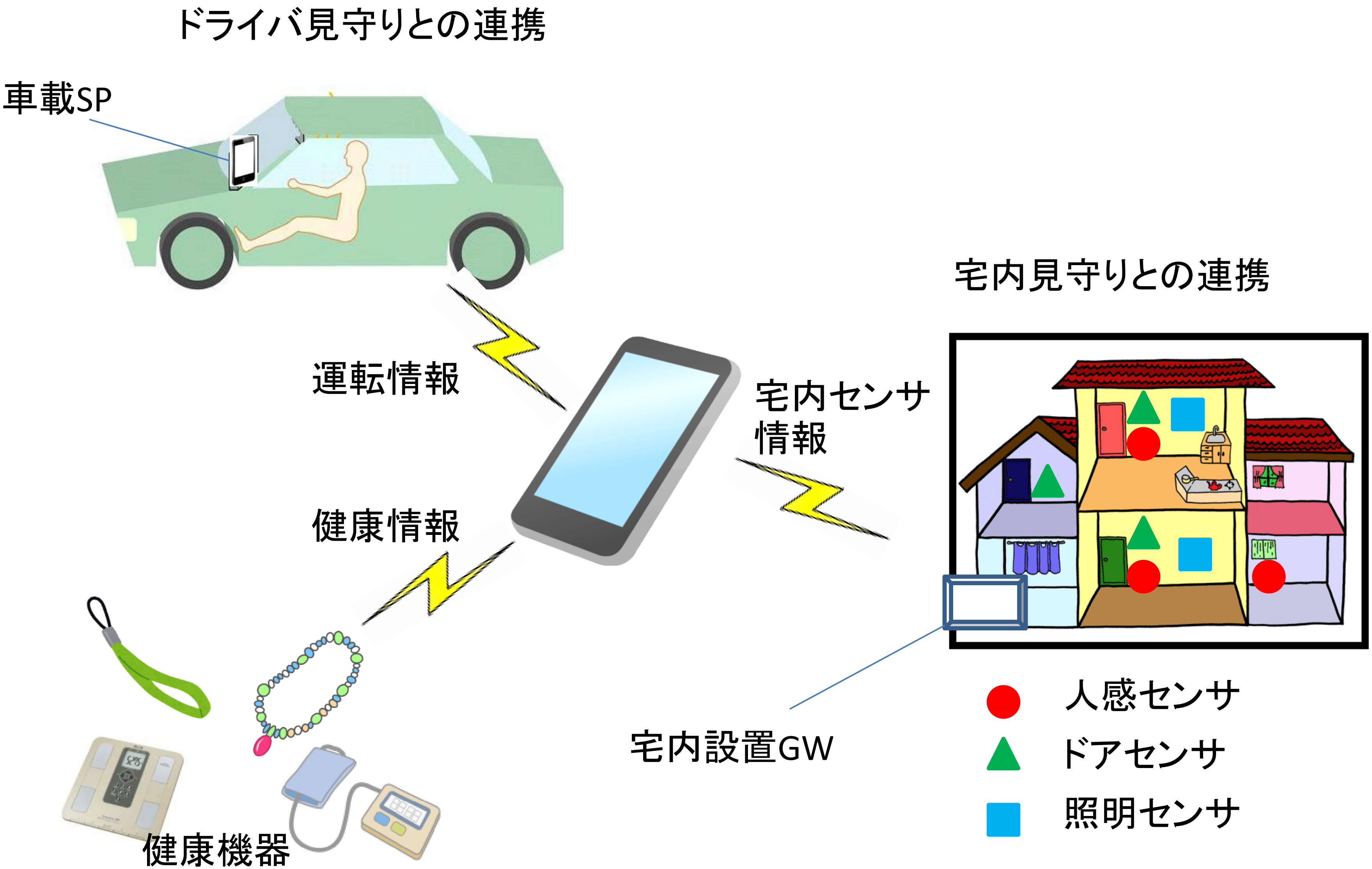


TLIFESの今後②
位置情報を利用したサービスプラットホーム

災害発生時の安否確認サポート　　障がい者のボランティアサポート



TLIFESの今後③
他システムとの連携強化



まとめ

・TLIFESのコンセプト
・TLIFESの現状
・TLIFESの今後

現場のニーズは何なのか
実用化に必要な活動とは何か