Coordination of Urban and Service Infrastructures for Smart Cities

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OVERVIEW: While various urban and service infrastructures are available for use in smart cities, their mutual interdependence means that attempting to optimize each one independently may result in their being used inefficiently. Therefore, a new type of urban service provider called Social System Coordinator provides urban and service infrastructures that suit consumers' lifestyles and consumption needs, as well as coordinating infrastructures to improve the overall efficiency of their use in the community. Hitachi promotes the coordination of infrastructures for smart cities by providing the associated equipment and IT platforms.

INTRODUCTION

MEASURES aimed at creating smart cities through the introduction of the latest information and control technologies[1] have been adopted in various countries in recent years. Smart cities are expected to improve the convenience of urban and service infrastructures and make people's lives more comfortable, with the aim of achieving sustainable development while also taking account of the environment. What has become essential is the creation of new usage value by operating urban infrastructure (such as electric power and water use) and service infrastructure (such as healthcare) in a coordinated way, rather than just improving their efficiency independently.

This article describes the need for the coordination of urban and service infrastructures in smart cities, the merits of coordination from a consumer's perspective, and examples of how this coordination might work along with the methods for achieving it.

NEED FOR COORDINATION OF URBAN AND SERVICE INFRASTRUCTURES

Coordination of infrastructures is needed as a way of solving the issues that arise from changes in the operation and use of urban and service infrastructures.

Changes in Operation and Use of Urban and Service Infrastructures

The operation and use of urban and service infrastructures such as electric power, water, mobility, and healthcare are undergoing the following changes:

(1) Increasing diversity of infrastructure

In the past, the urban and service infrastructures available for use were determined in advance. However, the improving efficiencies of photovoltaic power generation, use of recycled water, and EVs (electric vehicles) are increasing the number of urban and service infrastructures that can be used.

(2) Greater use of information

The spread of the Internet and the rapid proliferation of sites providing information have made a wide variety of information available. While this provides valuable information to consumers, it also makes it required to be able to filter unnecessary information from the necessary one.

(3) Advanced infrastructure operation

Advances in IoT (Internet of things) technology for connecting large numbers of objects together has made it possible to monitor the status of urban and service infrastructures. The impact of faults can be minimized by being quick to replace or repair equipment when this information indicates a potential problem.

Challenges for the Operation and Use of Urban and Service Infrastructures and Need for Coordination

Challenges for operation and use

It is anticipated that the following challenges will arise for the operation and use of urban and service infrastructures as they become more diverse.

(1) Challenges for operations

The advent of technologies such as photovoltaic power generation and EVs mean that those who, until now, have only ever been power consumers now have the potential to become power producers. However, because the power from such sources cannot be indiscriminately connected to the grid, it is necessary to monitor electric power consumption and only connect to the grid when appropriate.

(2) Challenges for use

Although EVs and other similar technologies can be described as an environmentally conscious form of mobility because they do not emit CO_2 (carbon dioxide), their range is shorter than conventional vehicles. This makes it necessary to pay close attention to charging as the vehicle may run out of power before reaching its destination if the charge is insufficient.

Need for coordination

It is difficult to solve the challenges faced in the operation and use of urban and service infrastructures within their own respective operational scopes because it is impossible to know what impact changes will have on other infrastructure. Accordingly, it is necessary to improve convenience by coordinating the various urban and service infrastructures and optimizing operation by assessing their interrelationships.

In the case of recycled water production or seawater desalination, for example, some of the power requirements can be met by photovoltaic power generation, wind power generation, and power supplied from EVs. Also, trouble-free use of EVs can be achieved without the vehicles running out of power by providing appropriate guidance based on location information. The following sections give examples of this sort of coordination of urban and service infrastructures.

MERITS OF COORDINATION OF URBAN AND SERVICE INFRASTRUCTURES FROM CONSUMER'S VIEWPOINT

The coordination of urban and service infrastructures can be thought of both in terms of coordination within particular fields and in terms of coordination across different fields such as electric power and water use.

Although the coordination of urban and service infrastructures in itself is not something visible to consumers, it can lead to the creation of new value, provide a way to reduce usage costs, and improve things like convenience and comfort. In this case, the key word for use is "lifestyle." Hitachi recognizes that the benefits of coordination of infrastructures result from their use in ways that suit consumers' lifestyles made possible by the coordination of urban and service infrastructures.

(1) Reduction of usage costs

Consumers are billed for their use of urban and service infrastructures and can reduce this cost by producing electric power or other utilities for themselves. For example, generating electric power and selling it can provide an income. The resulting electric power can then be taken and used to produce recycled water, thereby reducing the charges for water use.

(2) Improvement of comfort

The increase in the number of urban and service infrastructures that are available must lead to improved comfort. For example, a shortage of water can be avoided if electric power generated in the home is diverted to purify water. Also, a comfortable lifestyle can be facilitated by using the recycled water for district cooling.

(3) Improvement of convenience

While the spread of the Internet has improved convenience by making it easier to obtain information, it is common for consumers to want information to be aggregated. For example, if the choice of hospital appointment and means of transportation is combined, convenience is improved by also informing the consumer about how they can get to the hospital when they specify the date on which they want to make the appointment. Coordination of urban and service infrastructures can identify interrelationships and complementarity between infrastructure information, which can then be provided to consumers.

COORDINATION OF URBAN AND SERVICE INFRASTRUCTURES BY SSC

Coordination of different urban and service infrastructures is performed by operational organizations that use an IT (information technology) platform (a system that supports coordination). An operational organization that uses an IT platform for coordination of urban and service infrastructures

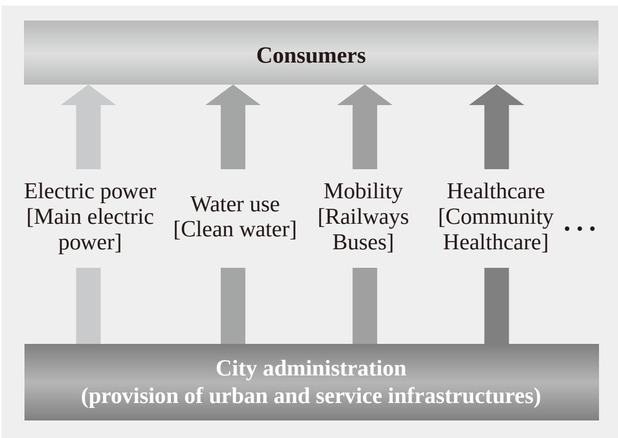

Fig. 1—Conventional Approach to Use of Urban and Service Infrastructures.
In the past, the urban and service infrastructures used by consumers were determined in advance.

is called a Social System Coordinator (SSC), a new business category.

SSCs are community managers and manage communities that use urban and service infrastructures. The position and role of SSCs are described below.

Position of SSCs

Past urban and service infrastructures have been predetermined, which meant changes in the way they were used were not possible. That is, the number of available urban and service infrastructures was small and consumers had no choice but to use them (see Fig. 1).

On the other hand, when the number of available urban and service infrastructures increases, consumers become able to choose which they will use (see Fig. 2). As a result, SSCs act as intermediaries for the operation and use of the many different urban and service infrastructures. The following are specific examples of urban and service infrastructures available for use:

(1) Electric power: Possibilities include use of electric power from renewable energy such as photovoltaic or wind power generation and from thermal storage using city gas. In homes and buildings, consumers are able to generate their own power using photovoltaic power generation or by supplying power from EVs.

(2) Water use: In addition to clean water, use of recycled water is also possible. At locations such as islands or deserts, new water produced by seawater desalination can be used.

(3) Mobility: Vehicles such as EVs and PHVs (plug-in hybrid vehicles) can be used. Also, environmentally conscious forms of mobility such as electric trams can provide the public with a way of getting around.

(4) Healthcare: Performing diagnosis in the home or elsewhere (remote diagnosis) becomes possible as an alternative to having patients visit a hospital for diagnosis and treatment. Meanwhile, the growing use of PBT (proton beam therapy) machines and other medical technology makes it easier for patients to receive highly advanced forms of treatment.

Role of SSCs

In acting as intermediaries for the operation and use of urban and service infrastructures, SSCs have the following three roles (see Fig. 2):

(1) Monitoring of urban and service infrastructures

SSCs monitor the operational status and other aspects of urban and service infrastructures using tools such as sensors and the Internet. Advances in IoT technology accelerate the use of sensing in urban and service infrastructures.

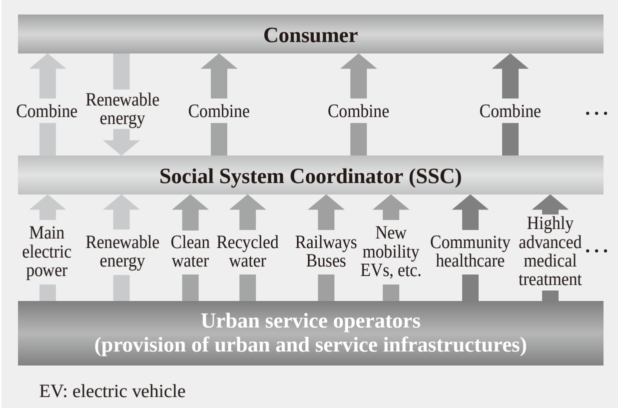

Fig. 2—Future Ways of Using Urban and Service Infrastructures.
SSCs can advise consumers on how to combine use of urban and service infrastructures.

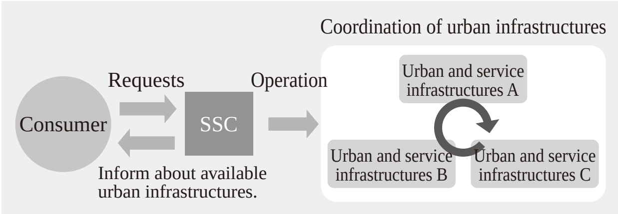

Fig. 3—Role of SSCs (1).
In addition to providing information about what urban and service infrastructures are available to suit consumers' wants, SSCs also handle their operation.

(2) Provision of information on available urban and service infrastructures

Numerous different urban and service infrastructures can be used in each field. However, it is anticipated that consumers will find it difficult to decide the best combination to use. Accordingly, SSCs suggest which options suit a consumer's lifestyle. In the case of a household in which both partners work, for example, they may want to operate photovoltaic power generation in the daytime and consume the power at night. They may also want to earn some income by selling the electric power if they are away from home for an extended period due to travel or some other reason. SSCs seek to suggest ways of combining urban and service infrastructures so as to satisfy consumer requests such as these.

(3) Operation of urban and service infrastructures

In addition to providing consumers with information about urban and service infrastructures, SSCs also respond to public needs by operating this infrastructure, including providing control (see Fig. 3).

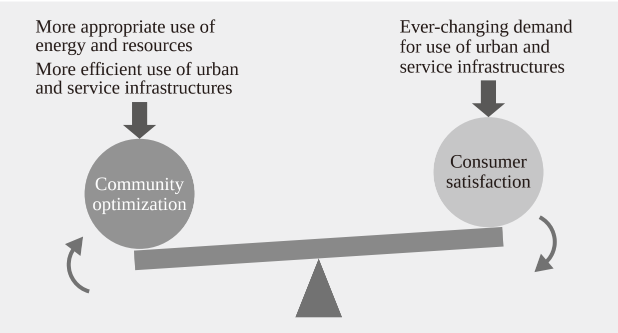

Fig. 4—Role of SSCs (2).
SSCs operate urban and service infrastructures in a way that balances the wants of consumers with what is best for the community.

For example, they execute energy saving and resource saving, the appropriate combination of energy and resources, and the provision of ways of accessing mobility instead of consumers. On the other hand, when viewed from the perspective of the overall community, operating urban and service infrastructures in accordance with consumer lifestyles has the potential to result in under- or over-supply of energy and other resources. For this reason, SSCs coordinate operation across the entire community (see Fig. 4).

Also, when it is not possible to satisfy demands from within the community, an SSC can negotiate with SSCs that manage other communities to acquire energy or other resources, or to reserve use of the other community's means of mobility, healthcare, or other services.

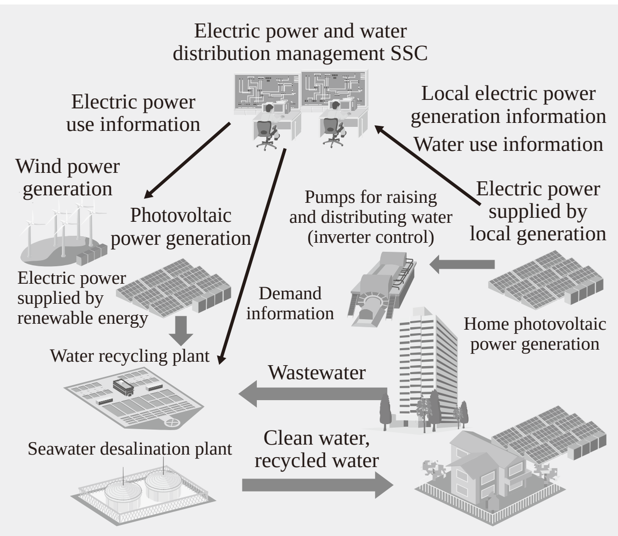

Fig. 5—Coordination of Electric Power and Water Use.
Renewable and other forms of energy are used for purposes such as treatment of recycled water and seawater desalination.

In this way, SSCs operate urban and service infrastructures in a way that balances the requests of consumers with what is best for the community.

EXAMPLES OF COORDINATION OF URBAN AND SERVICE INFRASTRUCTURES

The following two key points relate to the coordination of urban and service infrastructures:
(1) Greater choice of urban and service infrastructures
(2) Support for use of urban and service infrastructures from SSCs

Bearing these in mind, the following sections use coordination of electric power and water use, coordination of mobility and electric power, and coordination of mobility and healthcare as examples to present a specific and representative image of how coordination of urban and service infrastructures might work in practice.

Coordination of Electric Power and Water Use

This section describes the coordination of power supplies with seawater desalination, use of recycled water, improvements to pumping efficiency for raising and distributing water, and district cooling (see Fig. 5).

Although electric power is required for water treatment and cooling, power use can be made more efficient by incorporating renewable energy. SSCs assess the demand for recycled and clean water and ensure that adequate electric power is available for its supply.

(1) Recycled water

It is accepted that recycled water that can be purified with less power consumption is appropriate for uses such as flushing toilets or cooling buildings. Meanwhile, the spread of facilities for treating recycled as well as clean water means that electric power is required for their operation. Use of recycled water can be encouraged if electric power stored in batteries during the night or other times when electricity is cheap is used to provide the power for water treatment. It is also possible to reduce the cost of energy and resource use for both electric power and water use by incorporating other sources, such as electric power from consumers who want to sell the power they have generated in their home or elsewhere, or from large-scale photovoltaic or wind power generation. SSCs promote the use of cheap recycled water by distributing it for use by consumers.

(2) Seawater desalination

Seawater desalination systems are recognized for their potential to provide a reliable supply of water in locations concerned about water shortages, such as islands or deserts. However, seawater desalination requires large amounts of electric power. If the power is supplied by conventional forms of power generation, generation can become very expensive in the event of sudden oil price rises, for example, and this would likely lead to a jump in the price of water. Consequently, the installation of practical photovoltaic, wind, or other such forms of power generation at the island or desert location should help eliminate worries about electric power shortages.

(3) Inverter control of pumps for raising and distributing water

Water usage varies with the time of day. This means that the flow rate must be regulated to match user demand. While this has typically been executed by opening or closing valves, this does not change the power consumption. In contrast, power can be saved by using inverter control to vary the pump speed based on the amount of electric power. Also, if electric power supplied from photovoltaic or wind power generation is introduced, water use can also be reduced along with providing the required amount of electric power.

Coordination of Electric Power and Mobility

Initiatives aimed at encouraging greater use of EVs are evident around the world and progress is being made on establishing the infrastructure for supplying the electric power.

EVs have attracted attention as an environmentally conscious form of transportation that does not emit any exhaust gas. Although progress is being made on installing charge stations along with the standardization of things like fast charging and connectors, the distance current EVs are able to travel on a single charge is still only a few hundred kilometers. This means that EVs require frequent charging and careful use to avoid having them run out of power before reaching their destination.

Solving these problems requires management of the EV's electric power and driving the vehicle to a charge station or other charging site when the remaining battery power is low. However, having consumers monitor the remaining charge on their EVs and make their own decisions about when to stop at a charge station will be an obstacle to wider use of EVs as it is dependent on traffic conditions such as congestion and is likely to pose problems in situations such as when the charge stands are busy. Accordingly, the SSC responsible for the management station handles things like charge stand usage and ensuring convenience (see Fig. 6).

At the management station, information is collected on the location of all EVs, their power consumption, and the number of charge stands available at charge stations. The management station then directs EVs that are running low on charge to a charge station with an available slot. It can also reserve the charge stand to cut down on waiting time by avoiding having it taken by another EV. The supply of electric power can be made more efficient by increasing the number of available charge stands and the amount of electric power supplied to heavily used charge stations while decreasing the number of available charge stands and the power supply to infrequently used charge stations.

Coordination of Mobility and Healthcare

It is now possible to use the Internet for tasks such as making healthcare appointments or getting updates on the status of public mobility, and combining these

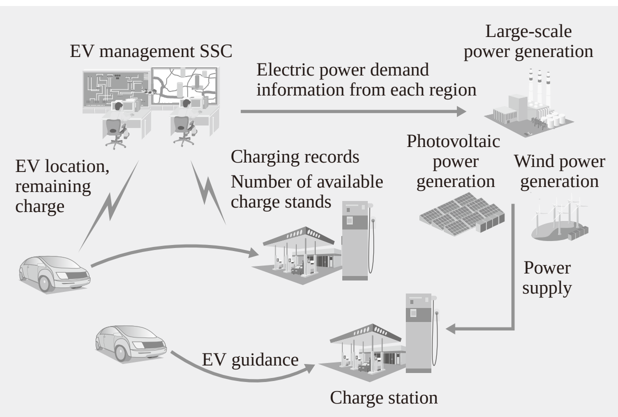

Fig. 6—Examples of Coordination of Electric Power and Mobility.
Coordinating the management of EV use with the supply of electric power to charge stations facilitates safe EV motoring.

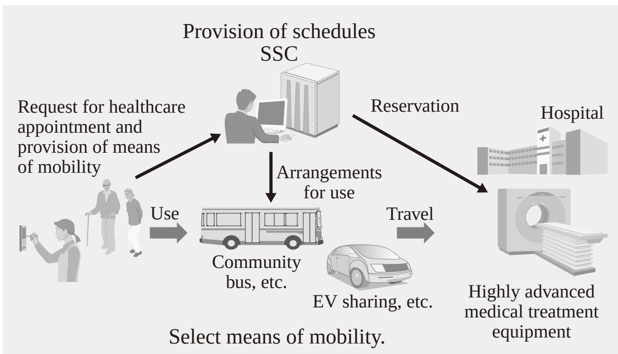

Fig. 7—Examples of Coordination of Mobility and Healthcare.
Convenience can be improved by coordinating reservations for highly advanced medical treatment equipment with arrangements for travel to the hospital.

enables a one-stop service to be offered for healthcare appointments and mobility scheduling (see Fig. 7).

The realization of smart cities will also encourage progress in healthcare. Increasing populations of elderly are forecast in developed countries in particular. This creates a need for greater use of IT and more advanced healthcare for the elderly in some communities.

While progress is being made in remote diagnosis technology, a visit to the hospital is still needed for things like face-to-face consultations with a doctor, treatment, and use of highly advanced medical treatment equipment such as PBT and MRI (magnetic resonance imaging). In this case, the consumer makes an appointment for a consultation and finds a way of getting to the hospital. While the spread of the Internet means it can be used to obtain information, such as about healthcare institutions and forms of mobility, or to make an appointment if necessary, this can be a time consuming process of trial and error involving repeated adjustments to appointments and transportation schedules. Therefore, convenience can be improved by making the necessary appointments and healthcare equipment bookings, and providing a means of mobility for getting to the hospital, in response to the consumer entering their reason for visiting the hospital.

The SSC acts as an agent, providing information like this about healthcare and mobility as well as arranging a means of mobility if needed. The SSC makes appointments for consultation or treatment instead of the consumer based on what they want, and coordinates or arranges a travel schedule.

Inter-community Coordination of Urban and Service Infrastructures

SSCs handle the coordination of electric power, water use, mobility, and healthcare on consumers' behalf. The consumers are able to reap the convenience, comfort, and other benefits of the coordination of infrastructures that is taking place behind the scenes. However, the quantity of resources such as electric power and water may in some cases be insufficient to satisfy the demands of all consumers. Similarly, it is not always possible to satisfy all consumers when making reservations for healthcare equipment or forms of mobility. To deal with this, SSCs responsible for other communities are contacted to see if some accommodation can be reached regarding the required resources. Similarly, an SSC will consider such arrangements with other SSCs. It is anticipated that mutual arrangements among communities will allow the maximization of community satisfaction (see Fig. 8).

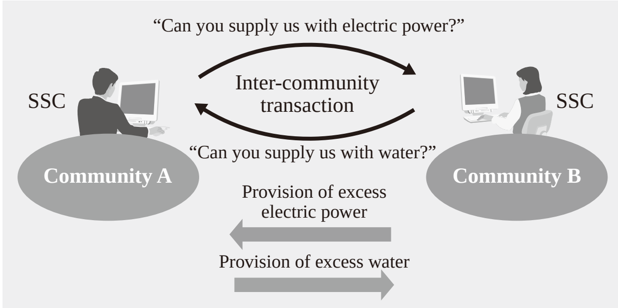

Fig. 8—Use of Inter-community Transactions to Secure Energy and Resources.
By reaching accommodations between communities on the use of electric power, water, and other resources, the wants of the consumers in each community can be realized.

METHODS FOR COORDINATION OF URBAN AND SERVICE INFRASTRUCTURES

SSCs collect information on urban and service infrastructures and devise ways of making them work together based on the results of analysis. This information collection is performed by an IT platform and the urban and service infrastructures are operated based on the results of analysis. As the IT platform adopts autonomous decentralized technology, it can easily accommodate the addition and upgrading of equipment needed for services and has a structure that allows a different server computer to take over if the service system goes offline.

The overall system has a three-layer structure consisting of a sensing layer for collecting information about the urban and service infrastructures, a network layer for carrying the information to the SSC, and a service layer that produces services by consolidating the collected information and conducting analysis. Of these, the SSC corresponds to the service layer (see Fig. 9).

(1) Sensing layer

Sensing is used to determine the status of the urban and service infrastructures. As the size of sensors and other hardware becomes smaller and the infrastructure for wireless communications more widespread, it becomes possible to more closely monitor the status of the urban and service infrastructures. This use of networks for sensing objects is made possible by the progress of IoT technology.

(2) Network layer

This corresponds to existing carrier networks and IP (Internet protocol) networks.

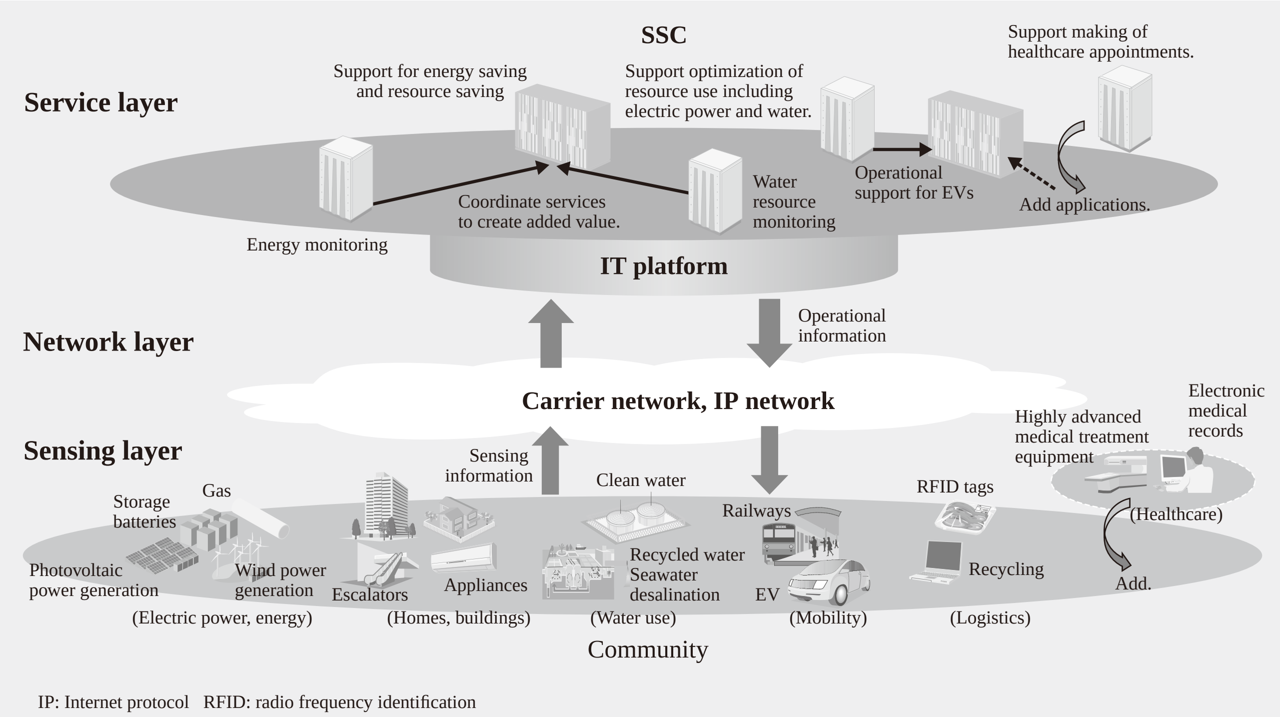

Fig. 9—Overall System Configuration.
The overall system has a three-tier structure consisting of a sensing layer for monitoring the urban and service infrastructures, a network layer for transmitting information, and a service layer that operates services for coordination of urban and service infrastructures.

(3) Service layer

Acquired information is collected on an IT platform and analyzed by a system called an application to determine the status of the urban and service infrastructures. This also facilitates coordination because it provides a view of the statuses of the different parts of the urban and service infrastructures, as well as the relationships between city functions such as logistics and payments. Simulation and other techniques are used to analyze the status information. The results of this analysis are used to provide consumers with services such as a one-stop payment service that consolidates payments of charges for different infrastructural services with income from electric power generation, and including infrastructure information presentation services that inform consumers about infrastructure that suits their lifestyle. Services for city managers include operating infrastructure under contract and infrastructure diagnosis services, which monitor and diagnose infrastructure to ensure that it operates continuously. In particular, use of urban and service infrastructures varies with the time of day and fluctuates with the seasons. Accordingly, operational records are stored and utilized as knowledge to help with operation.

CONCLUSIONS

This article has described the need for the coordination of urban and service infrastructures in smart cities, the merits of coordination from a consumer's viewpoint, and examples of how this coordination might work along with the methods for achieving it.

It is recognized that the number of urban and service infrastructures (such as electric power, water use, mobility, and healthcare) will increase in the future and that consumers will be able to select those that best suit their own lifestyles. Also, SSCs will become more active in their role of operating infrastructure and providing information based on consumer needs. It is also anticipated that coordination of urban and service infrastructures will reduce the burden on consumers and allow for electricity saving and other frugality without compromising things like the comfort and convenience of the overall community.

Hitachi intends to continue contributing to the ongoing progress of society by promoting coordination of infrastructures through the supply of IT platforms and other equipment for urban and service infrastructures.

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