Sensor-based Hardware Technology Supporting Daily Activities

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Abstract

Services that provide remote sensing and remote control of home appliances connected to a home network are expected to make our daily lives safer, healthier, more convenient, and more comfortable. After reviewing the current state of sensor-based services, this article introduces technology for expanding the possibilities of home networks focusing on small adaptive sensors with communication functions (sensor nodes) that can respond flexibly to diversified and changing user needs.

1. Distributing people-centered information via a home network

As broadband "always-on" access environments such as ADSL (asymmetric digital subscriber line) and FTTH (fiber to the home) become commonplace, there are growing expectations for services that connect home sensors and electronic appliances into a network and send information obtained from that home network to an Internet site to enable home appliances to be controlled from remote locations [1]. People are mainly involved with real-world events, and services for obtaining and distributing information about such events as well as providing services related to that information are expected to increase network traffic in a completely new way compared with conventional uses of the Internet such as Web browsing and e-mail. **Figure 1** illustrates the infor-

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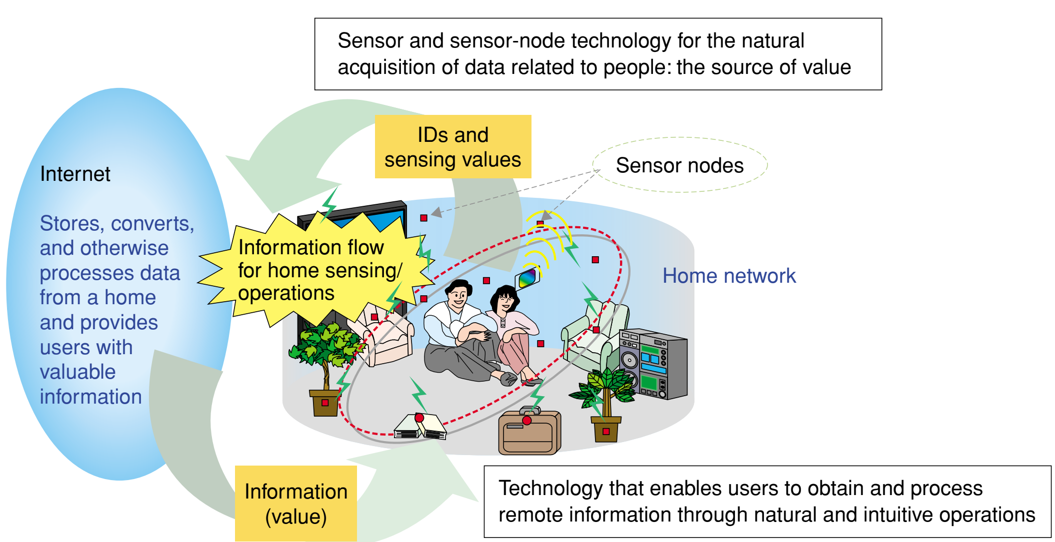


Fig. 1. Data generation and information flow in a home network.

mation-distribution cycle in the home network. It requires sensor and sensor-node technology for obtaining data related to people (the source of value) and those sensors need to be given communication functions. It is now becoming possible to supply low-cost sensors for detecting a wide variety of environmental data such as temperature, humidity, heat, light, pressure, sound, smell, and acceleration. Placing such sensors inside a house should lead to value-added services for the home such as monitoring the health of occupants to prevent lifestyle-related diseases, managing the expiry dates of purchased products and foodstuffs, tracking the location of valuables and important documents, and controlling the indoor environment to reduce stress. One example of such a value-added service that is already being provided is a weekly health check whereby familiar measurement devices such as weight scales, pedometers, and blood pressure gauges are given communication functions and the data they obtain is sent to an Internet site via a personal computer. Another requirement for maintaining this cycle of information is to enable an ordinary home user to obtain remote information through natural and intuitive operations. Specifically, it must be easy for the user to access sensing information collected at his/her house from a remote location and to control household appliances connected to the home network. Here, we introduce sensor-based hardware technology as the key to expanding home-network services.

2. Home sensing services and associated problems

Home-network sensing services can be classified as shown in **Fig. 2**. In Type I, the simplest format, a sensor installed in a home sends sensing data to the network either periodically or at certain times in a unidirectional manner. Two examples in this category are home security services that detect and report intruders using sensors that detect motion or human characteristics (infrared sensors) and health management services that send data from medical and measuring devices such as electrocardiographs, blood pressure gauges, and weight scales. Type II features bidirectional transmission. In contrast to Type I, this allows devices connected to the home network to be controlled in some way from the network side. Two examples are webcam services that allow the user to control the camera's field of view and appliance-control services based on sensing data that describes conditions within a home. Type-I and Type-II services are both based on a one-to-one relationship between sensors and services. In other words, the assumption is that a sensor installed in the home will be used only for a specific, predetermined service. But looking to the future, sensors that can be used for multiple applications would enable diversified network services based on home sensing data. At present, however, sensor nodes have fixed hardware specifications (such as measurement period, measurement precision, and signal amplification factor) established for

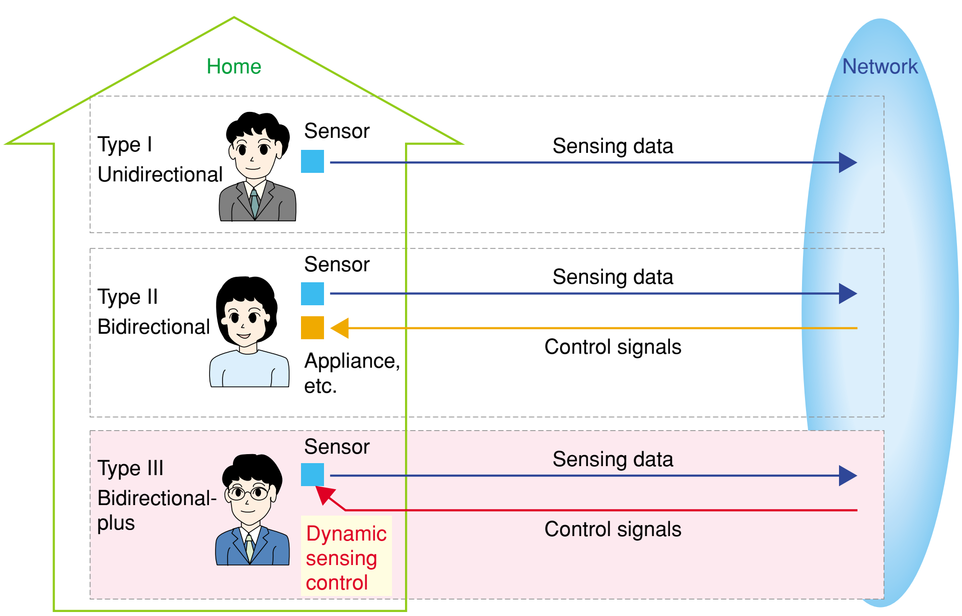


Fig. 2. Types of sensing and remote control in a home network.

specific applications, so it is not possible to obtain optimal sensing results for different applications.

3. New sensor nodes to promote the use of home sensing

Type-III sensing services (Fig. 2) aim to solve this problem through a configuration based on adaptive sensing nodes [2]. The key feature of this type of service is the ability to control sensing operations by sending setting commands from the network side. Sensing is accomplished by amplifying the extremely small analog signal output by the sensor, converting that analog signal to a digital signal at a certain sampling frequency and number of bits, and sending that digital value to the network. A new circuit configuration is introduced so that sensing control commands can be sent from applications on the network to the sensor-nodes and interpreted there to set the amplification factor, sampling period, conversion precision, etc.

An adaptive cyclic analog/digital converter is shown in **Fig. 3** as an example of such a circuit configuration. The sampling frequency can be adjusted by changing the operating frequency of transistor (switch) S1 and conversion precision adjusted by controlling feedback to satisfy the sensing needs of different users. A screenshot of an adaptive sensing service using body monitoring as an example is shown in **Fig. 4(a)**. This service obtains and displays a remote user's pulse, body temperature, and other vital signs as an application on the network side. **Figure 4(b)** shows a window for setting sensing conditions remotely. It allows the user and sensors to be selected and the analog/digital converter's frequency and precision and the amplifier's amplification factor to be set from a remote location.

4. Integrating video for natural access to the home

Services that connect the network with the home are beginning to be proposed and offered to enable users to control electronic devices connected to the network and to check sensor output (such as the video output of a security camera). These are advanced examples of Type-II services. We believe, however, that two main issues must be addressed before these services can achieve widespread penetration. First, a service menu centered on user needs must be pro-

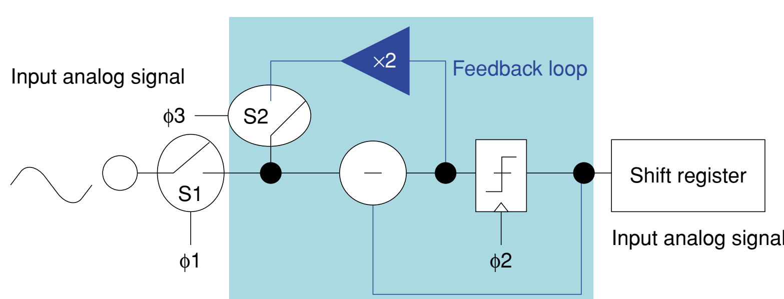
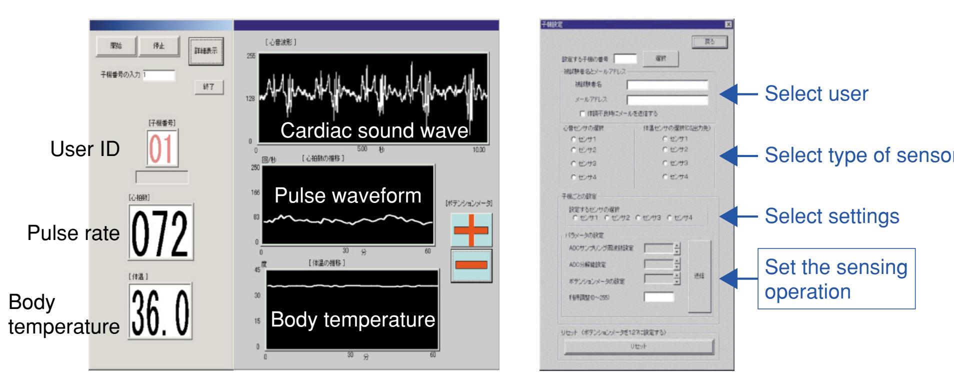


Fig. 3. Adaptive cyclic analog/digital converter.



(a) Screenshot of display of sensing results (b) Window for setting sensing operations

Fig. 4. Application to remote health monitoring (home-sensing operations are set from the network side).

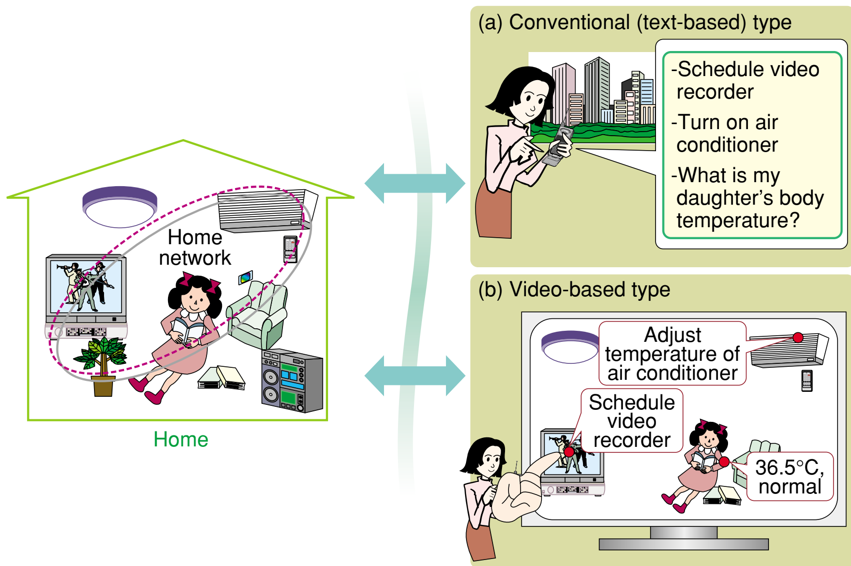


Fig. 5. Remote access to home network services (controlling home appliances and obtaining sensing data).

posed and initial deployment cost and monthly service cost must be decreased. Second, services must be user friendly. Using them must be just as easy as switching on a television set and changing channels. As shown in **Fig. 5(a)**, to switch on a home appliance from a remote location, for example, the current procedure is to use a personal computer or cell phone, enter the appliance ID from the keyboard, press the appropriate keys to enter information in the channel-setting box or on/off-control section, press the Enter key, and wait for the transmission to complete.

To provide a better solution, NTT Microsystem Integration Laboratories is studying technology for integrating video images with remote control and sensing operations [3], [4]. The service concept based on this technology is shown in **Fig. 5(b)**. The display adds a red mark near an object like a television set or air conditioner. The user need only click on a red mark to control the device to schedule a video recorder or adjust the temperature setting of the air conditioner, for example. A user can also get a child's pulse rate and body temperature from a remote location by simply clicking on the mark near that child. The idea here is to achieve remote sensing and device control through natural and intuitive actions, that is, by simply touching (clicking) an "object about which I want information" or an "object that I want to control" displayed in a realtime video of the real world. The concept is based on miniature tags (**Fig. 6**) that transmit and receive infrared radiation so that the two-dimensional coordinates of each object in a camera's field of view can be obtained with high precision. First of all, an infrared camera is used to capture the infrared radiation emitted by the miniature tag having the current ID number of interest. Using light instead of radio waves enables greater precision in position detection. The output signal from the camera is then used to determine the coordinates of the emission point from the intensity of that radiation. In this way, the position of people and objects in the camera's field of view can be extracted in real time. This system can perform high-speed recognition of 50 real objects per second including moving bodies and can identify the positions of about 100 objects in the field of view. As a result, detailed information about almost all objects in a room can be obtained, ranging from their presence or absence to their movement history.

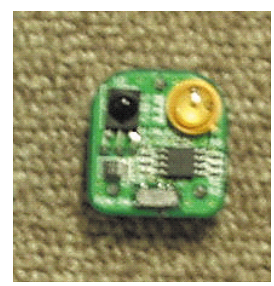


Fig. 6. Infrared tag.

In this system, the processing to be executed when a displayed mark is clicked must be set up beforehand. The current prototype system supports four clickable positions per mark, so up to four actions can be performed for the device corresponding to a mark.

However, the number of actions that will actually be needed and whether or not hierarchical processing (e.g., by displaying a process menu with sub-menus for item selection) will be required will depend on the service in question. The chosen configuration may also have to be modified in future and dynamic downloading of processes from the network may also be needed. For these reasons, this system should be managed by software. Finally, to make it even easier to use, the system should be linked with user interface technology oriented to the real world so that users can specify intended marks using hand or body gestures instead of using a mouse, for example, to select a mark displayed on the screen [5].

5. Future developments

We introduced an adaptive-sensor-node configuration and infrared position-detection tag as key devices for expanding the use of home networks. These devices support diverse user needs above and beyond network connections and make home-network operations intuitive and easy to use. To launch such home-network services, we will need to address various issues associated with marketing such small-scale hardware including cost, shape, performance, and battery life. NTT Microsystem Integration Laboratories is working to overcome such issues through the research and development of low-voltage and low-power analog and RF circuit techniques, high-performance and ultrasmall components fabricated with MEMS (microelectromechanical systems) technology, and small batteries.

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