A Future Access Network Architecture for Providing Personalized Context-Aware Services with Sensors

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Abstract. We propose a future access network architecture that can provide advanced context-aware services by securely delivering diverse kinds of dynamically changing sensor information about specific localities or private individuals. The architecture features individual and group management of peer-to-peer-based secure connections established between terminals and servers. It implements multi-access functions that enable terminals to deliver sensor information to multiple different application servers and multi-service functions that enable the terminals to receive information-provision services from those servers.

Keywords: Internet of things, wireless mesh network, sensor networks, context-awareness, platform.

1 Introduction

AS part of our research related to a New Generation Network [1], we have been conducting research on access networks. In this research, we are focusing on the future access networks based on the clean slate design approach that is not limited by the constraints of conventional networks.

It is generally believed that new sensor devices will be connected to the network in addition to PCs or mobile phones. However, considerable discussion is still required regarding the kinds of access networks to which the sensor devices will be connected, the manner in which those devices will be connected, the locations to which the sensor information will be transferred, the manners in which those transfers will be carried out, and so on. If we turn our attention to the "local region" that an access network will directly cover, the "individuals" who live in that local region, the various "communities" that are formed by that local region and those individuals, and the communications that they desire, it is apparent that new features will be needed which are not provided by existing networks.

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From this perspective, we presented requirements for a community communications service platform and proposed a managed wireless mesh technology as the means of implementing it [2, 3]. Then, based on the concept that a platform is required to implement diverse sensor application services which make practical use of information from sensors, a sensor application platform and sensor application operation model based on the same technology were shown [4].

In this paper, we will discuss future access networks viewed from the perspective of sensors that are connected to the network to serve a local region, individuals, and communities.

2 From Access Network to Regional Network

2.1 Existing Access Networks

As its name implies, an access network in an existing network mainly provides a means of "access" to the networking facility. In other words, it functions as a relay medium for connecting a terminal located at an edge of the network to a central facility on the network such as the Internet. This is not just because the terminal communicates with other terminals located at remote locations through the central network. It is also because the central network is a place where various kinds of information provided to the terminal by the client-server model is collected, summarized, accumulated, processed, and provided. This kind of central network-based information processing and information exchange model had been developed because it had been extremely efficient both technologically and from a business standpoint to gather, process, and provide information that was commonly required by many users in a central and collective manner.

2.1 Future Regional Networks

The first kinds of information that will be detected by sensors includes information related to the environment such as traffic or weather conditions of a certain locality and information related to a specific individual or group of individuals. It must be handled appropriately with regard to ensuring public and private safety and security. Another important point to note is that the primary users of these kinds of information are the local region and its citizens and communities.

From this perspective, central network-based sensor information processing model, on which sensor information for a certain local region is transported, accumulated, processed, and provided to other places through the global Internet, would need to be investigated carefully in terms of safety, security and efficiency although this can certainly provide benefits.

In light of this, we believe that the information that will be detected by various types of sensors will be so-called “local-oriented fresh information” (time-sensitive information about a specific locality that may quickly become inaccurate or irrelevant) of that local region. The information should be used efficiently and safely for

services targeting the relevant local region and its citizens. To achieve this, a network is required for appropriately circulating those kinds of information within the local region. That will be the access network of the future, whose concept is illustrated in Fig. 1. It will not only provide a terminal with a means of accessing a central network (core network) such as the Internet, but it will also include information processing and exchange functions, which have conventionally been provided by the central network. To avoid implying that it just has network access functions, we will refer to the future access network here as a regional network.

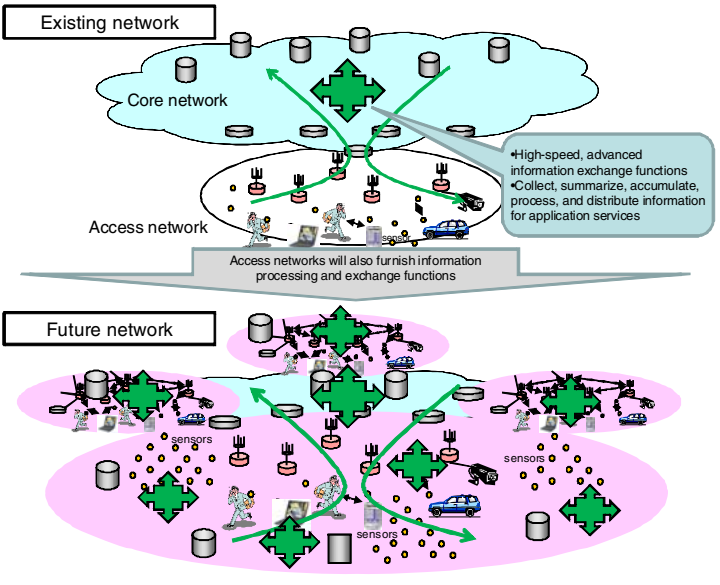

Fig. 1. Future access network will be a regional network that includes information processing and exchange functions

When viewed from the perspective of the characteristics of the information, the central network is good at accumulating a massive amount of information that is used "in common" or information that is relatively "static". On the other hand, a regional network is good at collecting, accumulating, and processing information that is related to real space or people and will be used mainly in that local region because the information is "dynamically changing" and carries a sense of “locality” or “privacy”.

However, local-oriented sensor information is not information that should only be used within that local region. It also includes information that is required by users in other regions. Therefore, it is important for a regional network to be able to circulate sensor information, when necessary, between itself and another regional network or external wide-area network such as the Internet. This circulation of information will facilitate business development and service cooperation that is beneficial to both network parties.

By safely gathering and accumulating local-oriented fresh information and providing various application services, the regional network can contribute not only to the enrichment of that local region and the lives of its citizens but also to the renewal or growth of the local region by creating new industries and employment.

2.3 Requirements of a Regional Network

Generally, the existing local information services that are distributed from a service provider include newspaper insert advertisements, fliers distribution in front of stations, and electronic billboards. The existing distribution of local information had relied on physical media such as paper or objects in this way. There have been cases in which an application service provider (ASP) that uses a wide-area network such as the Internet to provide application services also provides local information services. However, when a wide-area network is used in this way, it is basically limited to information distribution to individuals through email. Problems that tend to occur with this method are that personal information must be registered first, email is distributed to individuals regardless of their own situation, and sometimes it is delivered with high frequency, making the recipients annoyed. Some ASPs have attempted to deal with these problems by emailing information according to position information gathered by using the GPS function installed in mobile phones. However, since the number of users is limited, business development is difficult for the conventional ASPs because the cost benefit ratio is low when they use systems or operating technologies designed on the assumption that a wide-area network infrastructure would be used. Also, it will be difficult to apply their service model in which an ASP charges a fee for each information service to the citizens who will be regularly receiving various types of information services.

Based on the considerations mentioned above, we believe that a new business model that has not previously been used is required to enable a service for providing local-oriented fresh information to be successful in the future as a business. Also, if a new service model is assumed in which, for example, the position information of an individual or the environmental information in the vicinity of an individual is collected in real-time to provide beneficial services to the individual, the terminal system itself must be newly designed in addition to the means of constructing and operating the network and providing services.

Specifically, let's consider some scenarios for using future sensor networks. A situation is being considered in which the mobile terminals that individuals will carry in the future will themselves fulfill the roles of sensors [5]. Also, a model has been considered in which various sensors that have been installed surrounding an individual's body form a body area network (BAN), and sensor information that is detected by those sensors is delivered to the network through a mobile terminal [6, 7]. In both of these cases, various types of sensor information continue to be accumulated in servers on the network. The application server classifies and analyzes that information and processes it so that it becomes appropriate service for each individual. To link the collection of information and the provision of service as replies, the terminal must be provided with "multi-access" functions, which enable the terminal to simultaneously

access multiple application servers, and "multi-service" functions, which enable services to be offered to the terminal by each application server. Figure 2 illustrates this concept.

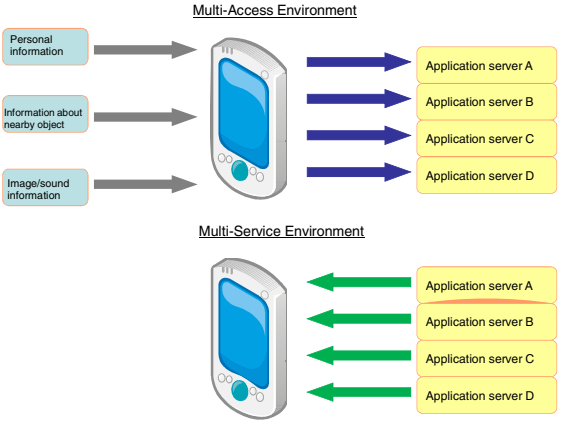

Fig. 2. Multi-access and multi-service environments

Also, a regional network must not operate independently, but must also be interconnected with other regional networks to form a regional information infrastructure so that the service provision area can be selected according to the service content or objective. The regional information infrastructure should be a platform that is operated as a network system that can collect various information in real-time from sensors that are deployed throughout each regional network and after classifying and analyzing it by application use, processes and generates it as value-added information that can be distributed to terminals. Because of the regional information infrastructure, an independent system will no longer have to be constructed for each domain (communications provider or service provider) as in the past. Instead, system resources such as sensors or terminals that were installed by separate service providers can operate while being shared by various separate service domains. Sharing system resources in this way not only provides cost and operational benefits to service providers on the regional information infrastructure but also enables higher value-added information to be provided to users since one piece of sensor information can be used and applied by various applications.

Figure 3 shows the layer configuration of the platform. The platform provides networking functions and sensor management functions. It also provides the sensor connection gateway interface (SCGI) as the interface to the sensors and end devices, and the sensor network application gateway interface (SNAGI) as the interface to the applications. As for functions for sensors, the SCGI provides gateway functions for collecting data from the sensors and transferring that information to the upper layer, and the SNAGI provides functions for collecting, classifying, and accumulating information and transferring it to various applications.

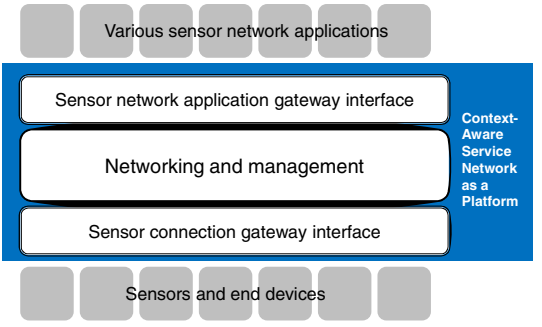

Fig. 3. Layer Configuration of the Proposed Platform

3 Regional Network Configuration

The following two kinds of connections are defined in a regional network.

1. Seamless connection to a wide-area network
2. Community domain connection within the regional network

These two types of connections are provided by a service gateway that is called a community service gateway (CSG). A CSG, which is installed at a location that provides a service, is connected to both the regional network and wide-area network. Fig. 4 shows a physical network configuration when a managed wireless mesh is used as the means of implementing the regional network [2, 3].

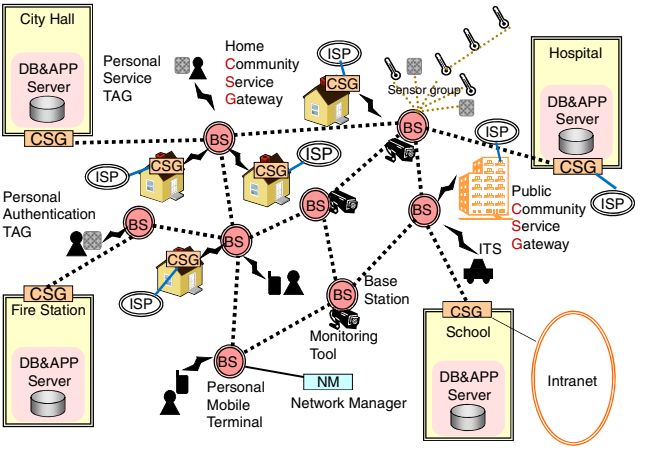

Fig. 4. Regional network configuration based on managed wireless mesh technology

The CSG governs a logical domain called a community domain, which is constructed on the regional network. A community domain is easy to understand if it is considered as a virtual network. Each CSG can accommodate various types of terminals such as

mobile terminals or sensors in the community domain that it governs and can independently provide applications according to usage objectives. In addition, a CSG provides gateway functions for seamlessly connecting the group of terminals accommodated in the community domain to the wide-area network. Since the CSG itself also has terminal functions, it can also connect as a terminal to a community domain that is managed by another CSG.

Figure 5 describes an example of the relationships between a regional network and community domains. Community groups exist in various forms such as welfare centers, schools and companies. Individuals live their lives while participating in multiple community groups. Therefore, a regional network must be able to multiplex community groups. Moreover, the terminal that an individual possesses must be able to belong to multiple different community groups.

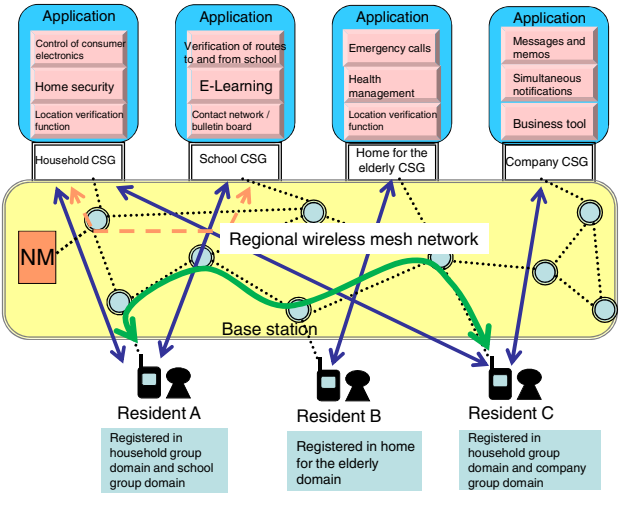

Fig. 5. Relationships among regional network, communities, and users

To accomplish this, a CSG forms and governs a community domain. Also, the terminal has functions for simultaneously belonging and connecting to different CSGs. These functions enable relationships between real world communities and individuals as well as communications based on those relationships to be implemented on the regional network.

In a normal access network that contains an existing mesh network, communications between terminals and application servers are generally first temporarily concentrated at a gateway, which is a relay point between the access network and external network, and then routed to the individual application servers that are on the external network. On the other hand, a regional network proposed here is configured in the mesh network, and the individual routes from terminals to multiple CSGs generally differ. Therefore, those routes must be managed or controlled. The device that administers this is the network manager (NM). The NM distributes IP network addresses to

each base station in advance. Those addresses will be used for service domains managed by CSGs that are connected to base stations. When a CSG connects to a nearby base station, the base station assigns a service domain IP network address to the CSG. At the same time, the NM also configures data paths to reach the CSG that the group of terminals managed by the CSG take while passing through various base stations in the mesh network. The NM that manages resources of an entire mesh network in this way is established for an individual mesh network.

The applications that will be provided by CSGs will continue to become more diverse depending on uses and objectives. For example, in a household CSG, there will probably be a demand for remote monitoring and control applications that can control home electronics and provide home security or applications that can obtain the locations of family members in real-time. In schools, there will probably be a demand for applications that will distribute information verifying routes to and from school or applications that will distribute educational videos that were recorded as part of a student's home study for supplementing lessons in school.

4 Multi-service and Multi-access Implementation Methods

A characteristic of a multi-service and multi-access environment on this regional wireless mesh network is that peer-to-peer-type virtual private network (VPN) paths between CSGs and terminals can be dynamically constructed and those VPNs can be grouped together at the CSG side for each application service. A group, which is a single domain on the network, is managed by the CSG. The multi-service and multi-access functions that were described earlier are implemented when individual terminals are connected by peer-to-peer-type VPN paths to multiple different domains.

Figure 6 explains the multi-service function. The CSG provides applications 1 and 2 to terminals. For providing application-1, the CSG establishes VPN tunnels with

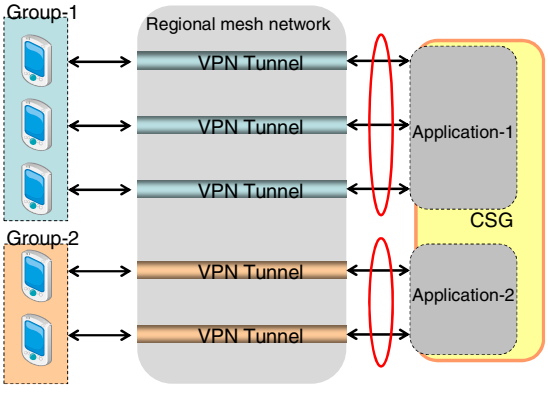

Fig. 6. Domain management and multi-service function achieved by configuring and grouping peer-to-peer-type VPNs for which the CSG, which is a server, is considered as a terminal

terminals belonging to Group-1 (a service domain) on the regional mesh network in advance. Also, for providing application-2, the CSG configures another service domain named Group-2 and sets up VPN tunnels with terminals in Group-2. The multi-service function by CSGs is provided by configuring multiple VPN tunnels between terminals and CSGs in this way. Figure 7 explains the multi-access function. The terminal starts three applications, which connects with application services provided by different CSGs. Separate VPN tunnel is used for each connection. The terminal manages the tunnels.

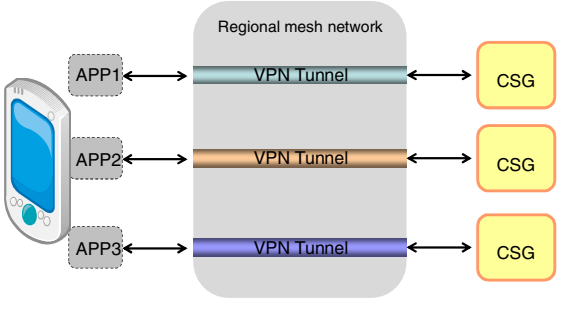

Fig. 7. Multi-access from a terminal to CSGs, which is implemented by configuring peer-to-peer-type VPNs with the CSGs that provide each application

5 Secure Communication Function

An authentication session is essential in control communications to perform peer-to-peer group communication between CSGs and terminals, and if a regional wireless mesh network provides those functions, safe regional services can be offered.

Since the existing IP network platform in the Internet uses a connectionless protocol, it is difficult to know who got access to the network, where they got access to it from, and through which path they connected. Therefore, access is generally restricted by a user authentication in which ID and password are entered. As shown at the top of Fig. 8, in a conventional network system, a firewall function or encryption-based security function such as IP-VPN or SSL-VPN must be introduced as a means of dealing with DoS attacks to a server system that has a global fixed IP address. As a result, not only do system management and operation costs and equipment costs increase, but the installation locations may also be limited from a secure maintenance and operation standpoint.

In contrast, the proposed regional wireless mesh network provides an environment in which CSGs can be deployed at various locations and facilities within the local region, and community domains are managed and operated by the CSGs. For the CSGs to provide services to terminals that are participating in community domains, the regional wireless mesh network platform must provide high-security functions. This is specifically accomplished as follows.

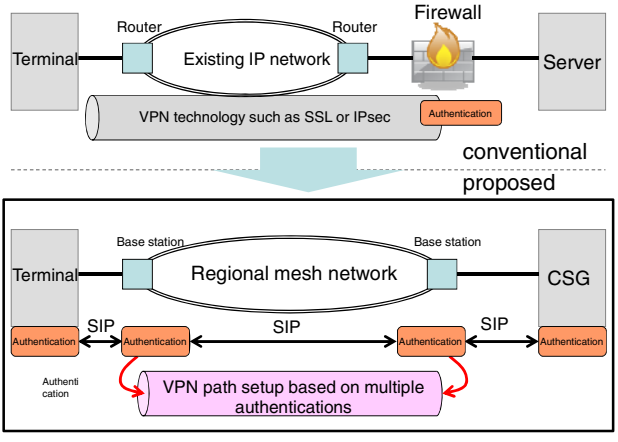

Fig. 8. Provision of security function

When a CSG and terminal perform peer-to-peer communication, each of them first performs access authentication between itself and a base station. Then, device authentication and group participation authentication are performed in both directions between the CSG and terminal, and application connections are established. If a terminal or CSG that has not been registered in advance in the regional wireless mesh network attempts to accesses the network, it will be completely denied by the base station. In addition, an access to a terminal from a CSG at which that terminal has not been registered or is not participating or an access to a CSG from a terminal that has not been registered at that CSG will be completed filtered (denied) at the communication level, and application communication within the mesh network will not be executed.

Note that since a base station completely disables resources for VPN paths that had been assigned for application communications between terminals and CSGs when they terminate the communications normally, all base stations that form the mesh network effectively work as a firewall function. As a result, robust network admission control (NAC) can be provided within the entire regional network.

6 Support for Context-Aware Services

A feature of the proposed platform is that open APIs provided by the mesh communication control module can be used to independently develop special-purpose applications for CSGs and terminals according to usage objectives. Also, intranet or LAN type community domains can be developed on the regional network to manage services independently. In addition, users can easily make practical use of regional network resources without configuring network information or managing network operation. By constructing this kind of regional network infrastructure environment, a sensor network environment that is closely tied to everyday life can be created.

Finally, we will present an example of support for context-aware services. Assume that a person is regularly using a sensor network to check his health. Figure 9 illustrates the operation of linked personal terminal and CSG applications involved in the health check. First, consider a scenario in which the person will be eating in a restaurant. The personal terminal senses store-provided menu information and sends it to the household CSG. Then, it senses the person's order information and sends that to the household CSG. The person's health application that is running at the household CSG automatically creates advice information for menu selections based on the information that was sensed and sends it to the terminal. In addition, the terminal senses information such as the menu that the person brought with him and meal status video information (including information from sensors in the environment that was received by the terminal) and sends it to the store CSG. The store CSG determines the meal time or amount of leftovers for each menu selection and calculates the total number of calories and provides this information as a customer information service. Also, the store CSG runs a menu consulting application, which helps improve store management and make it more efficient by using customer sensing information to collect and analyze the order rates of the store's menu items, the amounts of leftovers, and the status of customers' meals (such as meal times or facial expressions) in real-time. Service information that the store CSG sent to the terminal is also transferred from the terminal to the household CSG, and a household CSG application associates it with detailed meal guidance or insufficient nutrients and then analyzes the person's health status and reports it to the terminal.

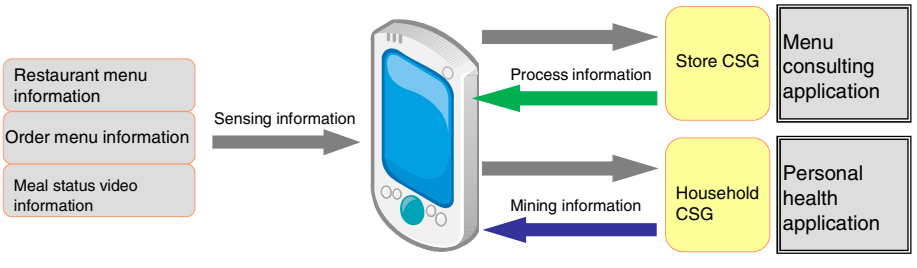

Fig. 9. Example healthcare service by linking restaurant's CSG and household CSG

7 Conclusions

As a new generation access network, we proposed a regional network for safely and efficiently providing context-aware services to a local region that is making practical use of sensors as well as to its citizens and communities. We also described requirements for this regional network, configuration methods, and implementation methods for multi-service and multi-access functions. In future work, we plan to continue to make the regional network platform more specific and extend the managed wireless mesh functions that support its implementation.

References

[1] AKARI Project, http://akari-project.nict.go.jp/
[2] Inoue, M., Nakauchi, K., Kafle, V., Morino, H., Sanefuji, T.: Community Service Platform using Wireless Logical Mesh Paths. In: WPMC (September 2008)
[3] Morino, H., Kawamura, H., Inoue, M., Sanefuji, T.: Load-balanced multipath routing for wireless mesh networks: A step by step rate control approach. In: Proc. of the 9th international Symposium on Autonomous Decentralized Systems (ISADS 2009), March 2009, pp. 281–286 (2009)
[4] Inoue, M., Kafle, V., Morino, H., Sanefuji, T.: Sensor Application Platform on a Novel Managed Wireless Mesh. In: IEEE Globecom Workshop, on Wireless Mesh and Sensor Networks (November 2008)
[5] Mastroianni, S., Lewis, J., Manes, G., Giorgetti, G., Gupta, S.: The personal sensor network: a user-centric monitoring solution. In: Bodynets 2007: Proceedings of the International Conference on body Area Networks (2007)
[6] FP6 IST e-SENSE Project, http://www.ist-e-sense.org/
[7] Zhong, L., Sinclair, M., Bittner, R.: A phone-centered body sensor network platform: cost, energy efficiency & user interface. In: BSN 2006: Proceedings of the International Workshop on Wearable and Implantable Body Sensor Networks, pp. 179–182 (2006)