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INTEGRATION BETWEEN WSNS AND INTERNET BASED ON ADDRESS INTERNETWORKING FOR WEB SERVICES

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Abstract. There has been an increasing interest in wireless sensor networks as a new technology to realize ubiquitous computing, and demands for internetworking technology between the wireless sensor networks and the Internet which is based on IP address. For this purpose, this paper proposes and implements the internetworking scheme which assigns IP addresses to the sensor nodes and internetworks based on the gateway-based integration for internetworking between the wireless sensor networks and the Internet. That is, the proposed scheme makes the access to the wireless sensor networks be serviced as like the Web service with internetworking Internet IP address and ZigBee address which is allocated to the sensor node in wireless sensor networks. For validating the proposed scheme, we made experiments using Berkeley TinyOS, Mica Motes, dual protocol stack based on ZigBee and IP, and showed the service result using browser (IE) and IPv6 address based on DNS.

Keywords: USN, integration, address internetworking

1 INTRODUCTION

Sensor networks which have been studied recently as new leading technologies along with ubiquitous computing are the internetworking technology with application services in real life with environmental data obtained from various sensor devices based on wireless and wired network [1]. Wireless sensor networks are constructed with various hardware sensors based on MEMs (Micro-Electro Mechanical System) and NANO technologies, and have been recognized as one of core technologies for the future ubiquitous sensor networks. Because it is possible to recognize, collect, and process the various events that occur in the real life using wireless sensor networks [2], there will be an increasing demand for the sensor network applications in the future ubiquitous environments such as watching the movement of enemies in battlefields, monitoring rainfall and geological conditions, and long-term observation of ecological adaptation.

But since wireless sensor networks are constructed with very small size sensor nodes unlike the general wireless networks, they have limited power and processing capability. In addition, nodes in wireless sensor networks communicate in Ad-Hoc mode because there is no specific network infrastructure. Various recent research works in the field of wireless sensor networks include SensorWeb [3], Wireless Sensor and Actor Networks [4], ocean sensor network [5, 6], ZigBee technologies [7] for low power communication, memory management mechanisms in sensor devices, various routing technologies, and the solving the problem of the data distortion due to the Ad-Hoc networking. However, the data obtained from legacy wireless sensor networks are forwarded to the server systems (sink node or base station), processed, and provided to the clients via the Web application only in an indirect way such as SQL and any other similar one. Therefore, considering the future ubiquitous and user environments, sensor nodes in wireless sensor networks should be recognized by an identifier (address), and the direct access to attribute information of the specific sensor node in wireless sensor networks should be provided by using unique URI in Web services. For this purpose, this paper proposes and implements the internetworking scheme [8, 9, 10] which assigns IP addresses to sensor nodes and internetworking based on the gateway-based integration accomplishes between the wireless sensor networks and the Internet. That is, the proposed scheme makes the access to the wireless sensor networks possible through the Web service with IP and ZigBee addresses.

The related work is reviewed in Section 2. In Section 3, an address internetworking scheme is proposed. The experimental results are examined in Section 4 for validating in the proposed scheme. Conclusions and future works are described in Section 5.

2 RELATED WORKS

The research in the wireless sensor networks has mainly focused on MAC protocol, routing protocol, location management of the sensor nodes, and Internet applications which handle and use the collected data as considering the future ubiquitous computing. Recent studies [11, 12, 13], which are related to internetworking between the wireless sensor networks and the Internet, have done a lot of research groups. These works are divided into two fields. One is a gateway-based integration which is performed by gateway located between the wireless sensor networks and the Internet, the other is overlaying-based integration which is performed by overlay networks constructed on either the wireless sensor networks or the Internet.

2.1 Gateway-Based Integration

The gateway-based integration operates the gateway systems between the wireless sensor networks and the Internet; it is of two kinds. One is application-level gateway, and the other is a DTN (Delay-Tolerant Networking)-based gateway [12]. Application-level gateway is implemented on the function which enables protocol transformation. This method is easy to implement, has low deployment cost, and supports the internetworking efficiently on heterogeneous networks because the isolated operation between the wireless sensor networks and Internet, is possible [14]. The DTN is defined as a network constructed with regional networks. Here, region implies a network that employs same technology. So, the DTN-based gateway internetworks between the regional networks which employ the same technology using application-level gateway. This method controls the delay time, transforms the protocol efficiently and provides the interoperability between the regional networks. The application-level gateway and DTN-based gateway are shown in Figure 1 a) and b), respectively. DTN-based gateway supports the message exchanges between different networks via bundle layer b) in Figure 1 [15].

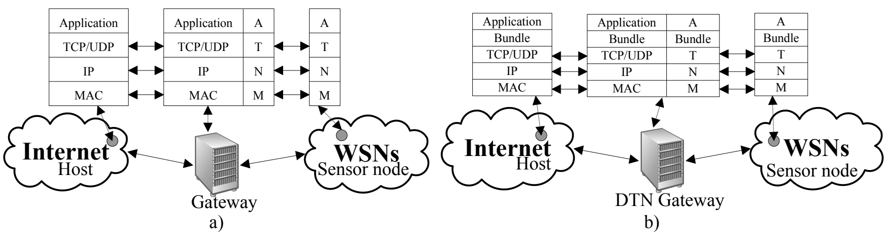

Fig. 1. Gateway-based integration

2.2 Overlaying-Based Integration

IP overlay network [11, 12] based on overlaying-based integration is a structure which can send and receive the data via IP packets after implementing the IP protocol and assigning the IP address to the sensor nodes on wireless sensor networks. Therefore, this method has two hot issues. First, "How IP address is assigned to the sensor node?" and second, "How to mix the address-based and data-based routing efficiently according to network traffic?". Recently using the location of the sensor node was introduced in IP address assignment and the Directed Diffusion and ACQUIRE were proposed in routing protocol as above issues. On the other hand, overlay sensor networks [13] based on overlaying-based integration combine the sensor networks with the Internet extending the data centric routing on the sensor networks to application-level overlay sensor networks on the Internet. Therefore, collected data from the sensor networks is forwarded to the host on the Internet after encapsulating the payload of the IP packet on the gateway. Therefore, this method can be easily implemented and interconnected via program on the host because data of the sensor networks can be processed with an application message of the Internet protocol. The IP overlay networks and overlay sensor networks are shown in Figure 2 a) and b).

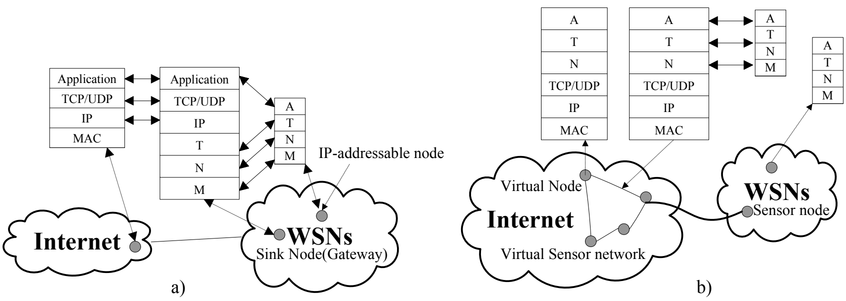

Fig. 2. Overlaying-based integration

2.3 6LoWPAN

The goal of the 6LoWPAN is defining the transmission method of the IPv6 packet on LoWPAN which is constructed with IEEE 802.15.4 devices. These device have features such as low power, low prices, low bandwidth, high density, and star or mesh topology. Therefore, 6LoWPAN implements the routing that considers available cyclic sleep, low overhead, small size routing table, and extensions in constructing the IP and TCP/UDP environments over MAC/PHY layer. Due to the above reasons, 6LoWPAN expects re-use of the verified legacy technologies, interchange of the information and collaboration to non-IEFT Corporation like ZigBee Alliance. Currently, 6LoWPAN, uses verified and well-known IP technologies, has an outlook that can use the legacy network infrastructure and save the additional cost, but this scheme which adopts IPv6 on ZigBee, is not good because it spends more memory(64K), incurs high costs, and is difficult to implement [16].

2.4 IPv6 DDNS (Dynamic DNS)

Dynamic DNS updates (DDNS) which is a standardized mechanism for dynamically updating the DNS. Unlike DNS that only works with static IP addresses, DDNS works with dynamic IP addresses, such as those assigned by an ISP or other DHCP server. DDNS is popular with home networkers, who typically receive dynamic, frequently-changing IP addresses from their service provider. To use DDNS, one simply signs up with a provider and installs network software on their host to monitor its IP address. Therefore, it works equally well with Stateless Address Autoconfiguration (SLAAC), DHCPv6, or manual address configuration. It is important to consider how each of these behave if IP address-based authentication, instead of stronger mechanisms (RFC3007), was used in the updates. As relying on IP addresses for DDNS is rather insecure at best, stronger authentication should always be used; however, this requires that the authorization keying will be explicitly configured using unspecified operational methods [17].

3 THE MEHOD OF AN ADDRESS ASSIGNMENT

Currently, implementation of the IP protocol stack on the sensor node is far from realistic owing to the limitation of processing capability of the sensor node in wireless sensor networks. Therefore, this section describes the method of IP address assignment which is core of IP address internetworking scheme based on gateway-based integration that is internetworking between the client and the wireless sensor networks based on IP address and solving the above problems. Figure 3 shows a concept of this paper that clients can have direct access to the wireless sensor networks based on IP address.

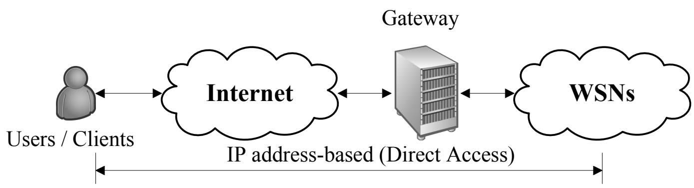

Fig. 3. WSNs service using IP mechanism

3.1 The Method of IP Address Assignment and Application of WSNs

IT industry has already commercialized the RFID and IPv6 for assigning the recognizable identifier to all the thing: It is expected that one identifier or IP address will be assigned to the sensor node in wireless sensor networks for managing the sensor node in the future ubiquitous computing. Applications of the wireless sensor networks also require the classification of address as static or dynamic, assigned by services. Therefore, we assign the IP address to sensor node statically (Static Method: All sensor nodes have one IP address) when requiring the direct access to the sensor node from client's Web application; otherwise, we assign the IP address to sensor node dynamically (Dynamic Method: All sensor nodes have the same IP address). Accordingly, this paper proposes the static and dynamic address assignment by wireless sensor network applications [7] as shown in Table 1. *tsn* identifier which is total number of the sensor node in wireless sensor networks and *tip* identifier which is total number of the prepared IP address for assignment also influence the method decision of address assignment.

Assignment	Sensor App.	Category
Static	Building Automation	Security, HVAC, Lighting, Access Control, AMR
	Residential Light,Commercial Control	Lawn, Garden Irrigation
	Personal Healthcare	Patient, Fitness Monitoring
Dynamic	Industrial Control	Asset, Process Control, Energy Management
	Consumer Electronics	TV, VCR, DVD, CD Remote
	PC, Peripherals	Mouse, Keyboard, Joystick

Table 1. ZigBee Application

3.2 The Scheme of IP Address Assignment

This is the scheme for saving the assignment information when assigning the IP addresses to ZigBee ID which is assigned to the sensor node in wireless sensor networks. At this time, the assigned IP address is IPv6 global unicast and gateway has to prepare it in advance. Therefore, address assignment is managed and processed in application layer of the gateway. ZigBee ID, corresponding to IP address which was used in client requests, can be founded on the scheme, and it is used by gateway when sending the information of the client request to the sensor node. The scheme of the IP address assignment consists of identifier (*sNID: Integer*) of wireless sensor networks, the method of address assignment (*mAA: String*), the group id (*gID: String*) of the sensor node, the sensor node ID (*sID: String*) which is expressed *Cskip* and *Addr* which are address as based on routing by hierarchical structure of ZigBee, and IPv6 address (*ipADR: String*) which was allocated to sensor ID.

3.3 The Structure of IP Address Internetworking System

The structure of the proposed internetworking scheme is shown in Figure 5. Communication addressing method is a ZigBee-base between the wireless sensor networks and the IP address internetworking system, and is TCP/IP-base between the address internetworking system and Internet. In *Internetworking Module*, *TinyDB Internetworking* get the collected data from the sensor node by using serial(*USB*) mode, or receive the results from the sensor node after sending the client query which is passed by *Server Module* to corresponding sensor node. The *Address Internetworking* processes the requests about the address internetworking from the *Service Application*, or passes the results of the *TinyDB Internetworking* to the *Service Application*. The *Query Application* passes the client request to the *Service Application* when address internetworking about sensor node is required in the *Server Module*, or provides client with the related data within database when address internetworking is not required. The *Service Application* provides client with the results of the *Address Internetworking* by using TCP-base. The network layer in protocol stack of the address internetworking system has the dual stack for internetworking between the ZigBee ID and the IP address, and physical and link layer has an IEEE 802.15.4 specification.

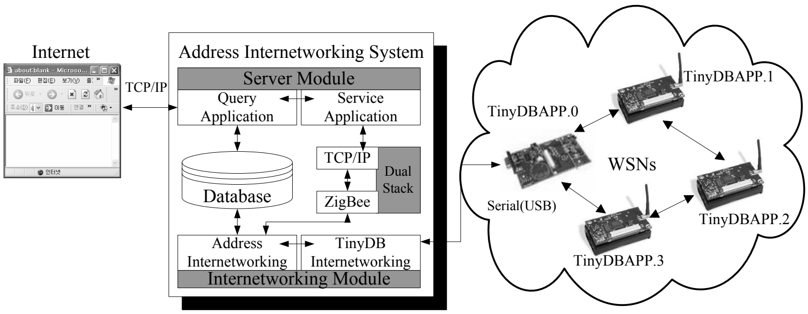

Fig. 4. The structure of the address internetworking system

4 SIMULATIONS AND RESULTS

4.1 Environments

Experimental environment for proposed address internetworking scheme is as follows. First, the operating system of the gateway that performs address internetworking, is TinyOS (version 1.11)-base. Second, the address pool is organized as IPv6 which will be used to address internetworking. Third, wireless sensor network was constructed with MIB 510 sensor programming board, Micaz Mote Kit and deployed the *TinyDB Application* to the sensor node and sink node (base station). Finally, MS-SQL DBMS, Pentium computer with 2.80GHz as a gateway system, JAVA, JSP, and DDNS were used for processing the Web-base application access of client.

4.2 Results

Figure 6 shows and analyzes the collected data by sensor node using *Internetworking Module* of Figure 5. As a result, we got the destination address (*DestAddr*), source address (*SourceAddr*), group ID (*GroupID*), and additionally data as TOSmsg format of Mote Kit. The *Address Internetworking system* uses the *groupID* and *SourceAddr* for getting the sensor node ID in Figure 6. Therefore, the *Address Internetworking System* was able to internetwork one IPv6 address to one sensor node which is recognized by *"FF"* and *"0001"* value which were assigned based on proposed address assignment; for this, entry that was composed with sensor node identifier (*GroupID* and *SourceAddr*) and IPv6 address must be managed in the database. The results (three of the IPv6 addresses were assigned to the sensor nodes in *Surge Application* and ten of IPv6 address were assigned to the sensor nodes in *TinyViz Application*) were shown in Figure 7 like a) and b), respectively. In here, all addresses were assigned statically. Therefore, the proposed address assignment can assign the IPv6 addresses to *sID* 0, 1 and 2 like Table 2 and is able to internetwork M ($M \geq 1$, the number of the sensor node in wireless sensor networks) to N ($N \geq 1$, the number of the Internet IPv6 address) relationships. Particularly, *ipADR* of *sNID* 0 was native IPv6 address; on the other side, *ipADR* of *sNID* 1 were 6 to 4 tunneling address.

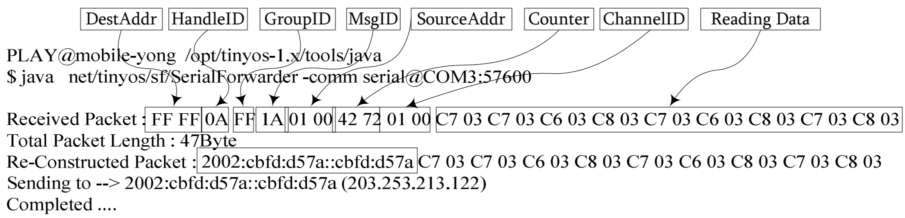

Fig. 5. Data analysis by TOSmsg

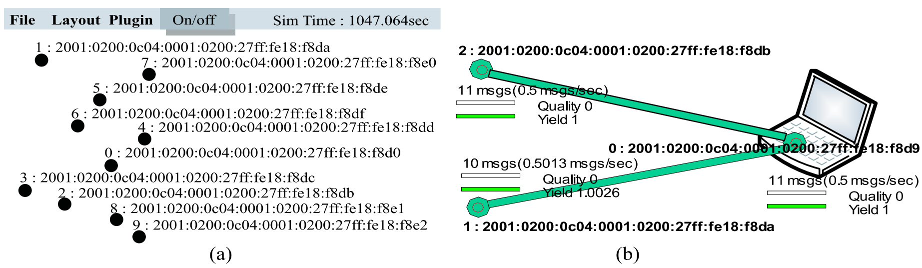

Fig. 6. Modeling of IPv6 address assignment

DDNS was also settled like b) in Figure 8 by reference to DDNS service site (`http://6dns.org`) using the 6 to 4 tunneling addresses on Windows XP after installation of IPv6 address like a) in Figure 8.

Accordingly, we got the following benefits as from experimental analysis of this paper. One is that we can assign the IP address to the sensor nodes statically or dynamically. The other is that clients are able to access the sensor nodes using Web

sNid	mAA	gID	sID	ipADR
0	S	0xff	0	
0	S	0xff	1	2001:220:C04:1:64bits
0	S	0xff	2	
1	S	0xff	0	2002:cbfd:d57a::cbfd:d57a
1	S	0xff	1	2002:cbfd:d57a::cbfd:d57b
1	S	0xff	2	2002:cbfd:d57a::cbfd:d57c

Table 2. Modeling of the address assignment

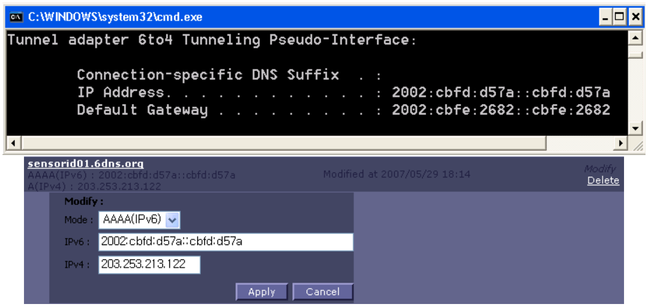

Fig. 7. Setting the DDNS

browser which is common access application to Web site and host name corresponding to IPv6 address like in Figure 9. But, we do not overlook the following issue. For getting the simple and plain information, "How many clients access the sensor node?". This weakness must be solved with a high quality contents provided from the wireless sensor networks, and with development of good contents.

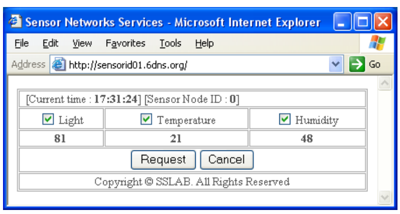

Fig. 8. WSNs service via Web browser and host name

5 CONCLUSIONS

This paper proposed and implemented the internetworking scheme which allocates IP addresses to the sensor nodes and internetworking based on the gateway-based integration between the wireless sensor networks and the Internet. That is, the proposed scheme made direct access to the wireless sensor networks like the Web service with internetworking Internet IP address and ZigBee address which is assigned to the sensor node in wireless sensor networks. Future research issues include the design about WSNs service based on semantic Web.

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