

Managing Heterogeneous Wireless Sensor Networks with the Session Initiation Protocol (SIP)

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Abstract— Despite of the development of wireless sensor networks in recent years, there lacks a general mechanism to manage these network devices. Because most managing mechanisms for wireless sensor networks are proprietary, when multiple platforms of wireless sensors networks are deployed together, interoperability and scalability would become a big issue. In this paper, we propose to utilize Session Initiation Protocol (SIP) as a common platform to manage heterogeneous wireless sensors networks. SIP is a mature protocol for signalling, and it is used in network management in addition to its popular adoption in voice over Internet Protocol (VoIP). SIP supports registration and re-direction, providing a great scalability and flexibility for network management. To develop the sensor management system with SIP support, we utilize the Sofia-SIP library to develop the SIP user agent, and adopt OpenSER as the SIP server. After SIP user agents register to the SIP server, we can send SIP messages to these end devices to control them. Furthermore, we develop a web platform to support sending SIP messages via a PHP script, which enables us to send SIP instant messages as control messages easily even with web browsers on mobile phones. Being verified on experimental platforms, the results showed that our system can be applied to different kinds of networks, such as IEEE802.11 and IEEE802.15.4.

Keywords—IEEE 802.15.4, IPv6, SIP, Wireless Sensor Network, ZigBee

I. INTRODUCTION

Wireless Sensor Networks (WSN) [1] become a ubiquitous technology that can be used for various industries and living environments, such as surveillance and home automation [2]. In a typical application of WSN, such as a home automation system, we shall use various commands to control our network appliances. We may remotely turn on a light, shutdown an air conditioner. Furthermore, we can monitor the electricity consumption of sensor nodes. This allows us to smartly manage the electric appliances in our houses. Another example is the environment monitoring. In Taiwan, many places suffer from mudflows and landslides. Therefore, there are many disaster prevention projects using sensors to collect information of gliding distance. As WSNs becoming popular in recent years, massive information of sensor nodes must be transmitted over a WSN, so a uniform and efficient mechanism for management is the key technology to manage WSNs. In addition, an ideal mechanism of management must be reliable and scalable. Standardized systematic services should be supported, including data integration, control management, and effective use of system resource. A mechanism of management should be general, so that any type of sensor data can be communicated through this mechanism,

regardless of time and place. The mechanism should be applicable in different kinds of networks, so that it can be integrated with existing systems.

Several network managing mechanism have been developed, among which Simple Network Management Protocol (SNMP) is the most popular one. SNMP is a simple protocol, which is easy to implement and easy to use. However, SNMP is too simple, so it has some drawbacks, such as unreliable transport layer protocol (UDP), non-encrypted data transmission. Moreover, it does not support Network Address Translation (NAT) traversal [3].

To solve the problems mentioned in the previous paragraph, we proposed SIP as a clear choice for WSN management [4]. Because SIP is an application layer protocol, heterogeneous networks can communicate with each other. The contents of SIP messages can adopt eXtensible Markup Language (XML) format, which provides a high flexibility and an efficient method to manage WSNs. Since IEEE802.15.4/ZigBee [5] is a popular standard in WSN, our study focuses on porting SIP onto ZigBee end-devices. Figure 1 illustrates a WSN which is managed by SIP. We can use common softphones as SIP user agents. Furthermore, we provide a web platform to send SIP messages to control ZigBee end-devices in the WSN.

The remaining of this paper is structured as follows: Chapter II describes some related background knowledge about ZigBee, IPv6, and SIP. Chapter III describes existing methods of WSN management using SIP. Chapter IV describes the Sofia-SIP library and our software platform. Chapter V describes the conclusion and future directions for our further study.

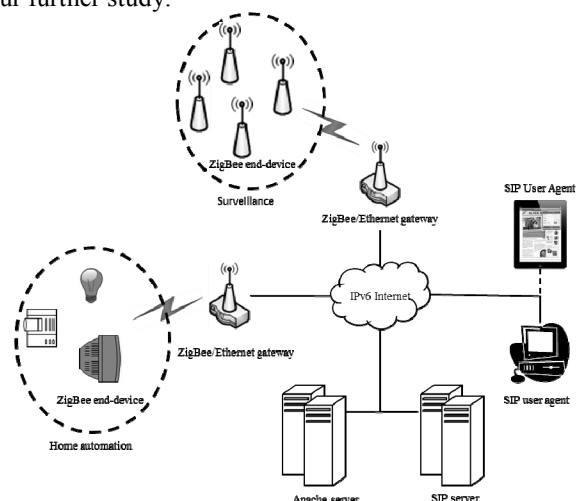


Figure 1. WSN management architecture

II. RELATED TECHNOLOGIES

A. ZigBee

Based on IEEE 802.15.4, ZigBee defines two layers of communicated protocols: the network work layer and the application layer. ZigBee network includes three different types of nodes: ZigBee coordinator, ZigBee router and ZigBee end-device. Network layer handles the following works: joining or leaving ZigBee network, providing secure processing for ZigBee packets, transmitting ZigBee packets to target nodes, searching and maintaining best paths to nodes, searching neighbour nodes, building ZigBee network (by coordinator), configuring network arguments (by coordinator) and allocating address (by coordinator). The application layer consists of Application Support Layer, Application Frame and ZigBee Device Object. Unlike existing wired network terminals, ZigBee end-devices work on a limited computing capacity. Our prototype platform uses Texas Instruments (TI) ZigBee Development Kit (ZDK). The main hardware components of an end-device are shown in Figure 2.

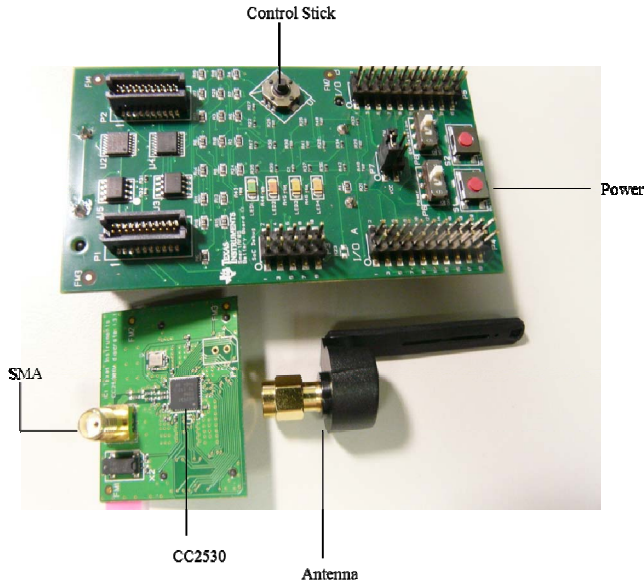


Figure 2. Hardware components of a ZigBee end-device

B. IPv6

As the size of the Internet grows up unexpectedly, and new network applications and wireless network get popular, IPv4 address is obviously insufficient. According to the report of Internet Assigned Numbers Authority (IANA), unallocated IPv4 address was exhausted on February 3 in 2011 [7]. Therefore, next generation Internet Protocol — IPv6 emerges.

IPv6 solves the lack of IP address; furthermore, IPv6 simplifies IPv4 header. Some interesting features of IPv6 include:

- The size of address extends from 32 bits to 128 bits
- The size of IP header is fixed at 40 bytes
- Stateless auto-configuration
- Add IPsec to increase security of transmission
- Provide anycast mechanism

In order to manage heterogeneous networks between ZigBee and the Internet, we need network addresses that are appropriate for ZigBee and the Internet. To allow direct communication, every ZigBee end-device needs a corresponding IP address, and the SIP proxy server needs a ZigBee network address [6]. WSNs need large number of ZigBee sensors, and each ZigBee sensor has a unique 64-bit extended address. Therefore, IPv4 is not suitable for ZigBee because IPv4 address is not enough for a large number of sensors. If IPv6 is used, we can easily combine a 64-bit IPv6 prefix and a 64-bit ZigBee extended address to obtain a complete IPv6 address.

C. SIP

SIP is a signalling protocol in the application layer of TCP/IP model. SIP defines two types of messages: request and response.

Some SIP request messages as shown in TABLE 1.

TABLE 1. SIP REQUEST MESSAGES

Request Methods	Description	Defined in
INVITE	Establishes a session	RFC 3261
ACK	Confirms an INVITE request	RFC 3261
BYE	Ends a session	RFC 3261
CANCEL	Cancels establishing of a session	RFC 3261
OPTIONS	Queries the capabilities of SIP phones	RFC 3261
REGISTER	Communicates user location (host name or IP address)	RFC 3261
PRACK	Provisional acknowledgement	RFC 3262
NOTIFY	Notify the subscriber of a new event	RFC 3265
SUBSCRIBE	Subscribes for an event of notification	RFC 3265
UPDATE	Modifies the state of a session without changing the state of the dialog	RFC 3311
MESSAGE	Transports instant messages using SIP	RFC 3428
PUBLISH	Publishes an event to the server	RFC 3903
INFO	Sends mid-session information that does not modify the session state	RFC 6086

After a SIP user agent receives request messages, SIP user agent reply response messages as shown in TABLE 2.

TABLE 2. SIP RESPONSE MESSAGES

Status code	Description
1xx	Informational responses
2xx	Success responses
3xx	Redirection responses
4xx	Request failures
5xx	Server errors
6xx	Global failures

III. EXISTING METHODS

There was some previous work that implements SIP into ZigBee [8]. In [9], it provides a ZigBee/Ethernet gateway which processes SIP packets, defining its own format of packets and then transmitting to ZigBee end-devices. It also developed a SIP user agent to control ZigBee end-devices. The SIP packets transmission flow is as shown in Figure 3.

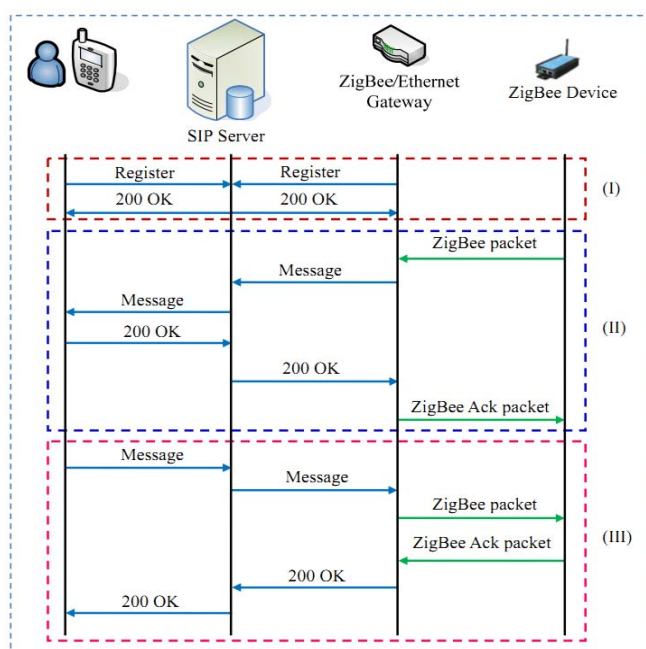


Figure 3. Transmission of SIP messages through the gateway [8]

IV. IMPLEMENTATION

In order to transmit SIP packets from Ethernet to ZigBee, we chose the addressing scheme of [6] on our ZigBee/Ethernet gateway. We also chose Nokia Sofia-SIP library to implement our SIP user agents. Sofia-SIP is designed for embedded devices, so the size of Sofia-SIP protocol stack is much smaller than other SIP libraries such as eXosip. Furthermore,

Sofia-SIP supports Transmission Control Protocol (TCP) and Stream Control Transmission Protocol (SCTP) as transport layer protocols, which provides a reliable transmission.

Sofia-SIP consists of several modules as the following:

- su: Contains a simple, portable socket/synchronizing library
- sresolv: Consists of an asynchronous DNS resolver with EDNS extensions
- ipt: Utility library for IP Telephony applications
- nua: Contains the user-agent library taking care of basic SIP User Agent functions
- nea: Provides an interface to different events used in SIP presence and conferencing
- iptsec: Provides interface to HTTP Basic and Digest authentication
- nta: Provides a simple interface to the SIP transaction, transport and message handling
- tport: Contains a generic transport interface used by SIP, Real Time Streaming Protocol (RTSP), and HTTP protocols
- sip: Contains interface to the SIP parser and the header and message objects
- msg: contains parser and functions for manipulating messages and headers for text-based protocols like SIP, HTTP or RTSP. It also provides parsing of Multipurpose Internet Mail Extensions (MIME) headers and MIME multipart messages common to these protocols
- url: contains macros and functions for using URL datatype url_t, parsing and printing URLs
- bnf: contains macros and functions for parsing text-based formats, for example, for SIP
- sdp: Provides a simple "C" parser interface for Session Description Protocol (SDP)
- soa: Consists of an asynchronous SDP Offer/Answer engine library

Each module has their dependency graph, for example the dependency graph of nta is shown in Figure 4.

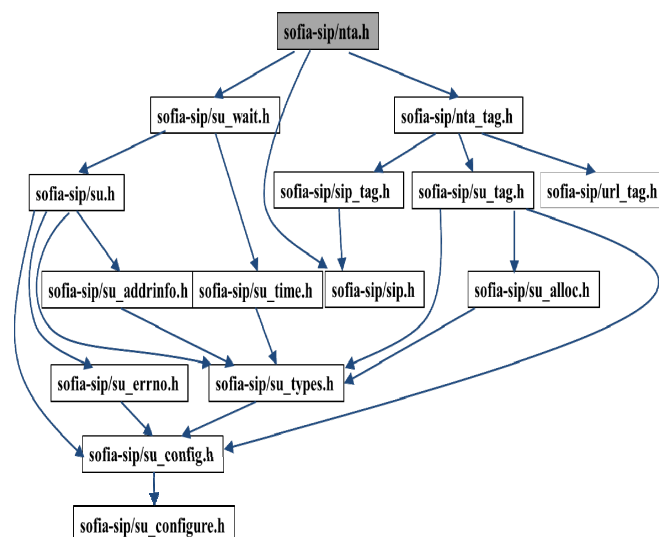


Figure 4. Dependency graph for nta [10]

Because of the limited computing power and memory storage of ZigBee end-devices, we re-built the Sofia-SIP protocol stack and the underlining Linux kernel [11]; we find out the only necessary libraries of Sofia-SIP and remove unnecessary functions in WSN such as voice communication functions, reducing the size of the Sofia-SIP protocol stack from 18 MB to less than 2 MB. Figure 5 shows SIP packets transmission flow of our approach.

Although the system architecture of Figure 5 and Figure 3 looks similar, please note that in Figure 3 only the ZigBee/Ethernet gateway registers to the SIP proxy server. The ZigBee/Ethernet gateway decapsulates SIP packets and transfers ZigBee packets to ZigBee end-devices. The ZigBee/Ethernet gateway needs to process a great deal of packets, so it assumes a heavy loading which will thus decrease the network performance. On the contrary, in our approach shown in Figure 5, we implement SIP on every ZigBee end-device. As the result, the ZigBee/Ethernet gateway only needs to forward SIP packets to ZigBee end-devices without parsing the payload. This will significantly reduce the heavy loading of the ZigBee/Ethernet gateway.

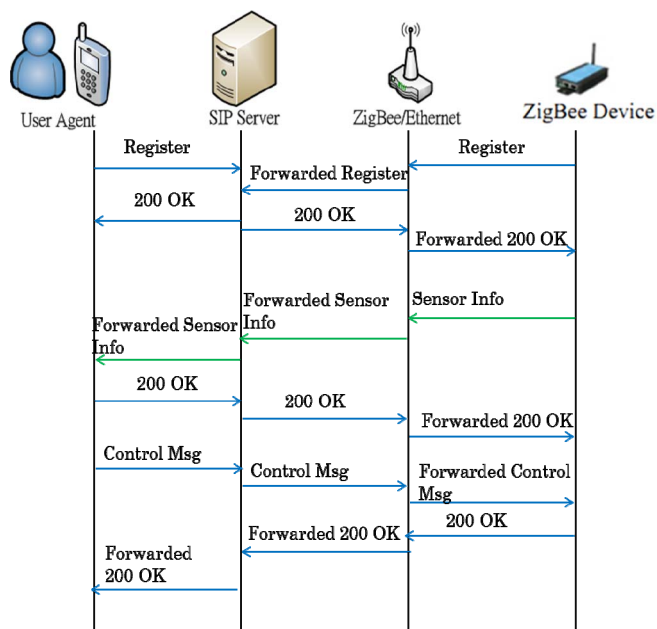


Figure 5. Transmission flow of SIP messages to ZigBee end-devices

V. CONCLUSION

SIP is widely used for VoIP communications. In addition to this mature application, more and more researchers propose using SIP as a mechanism of network management. As the WSN is becoming important, porting SIP into WSN is regarded as a general managing mechanism. Because of the limited computing power of ZigBee end-devices, in the past the usage of SIP in ZigBee were only developed on ZigBee/Ethernet gateways, which possesses better computing ability to handle the application-layer translation. However, processing massive SIP packets degrades the performance of WSNs because ZigBee/Ethernet gateways are prone to

become bottlenecks. In our proposed scheme, a SIP protocol stack is simplified from 18 MB to 2 MB, and ported to end-devices. As a result, a ZigBee/Ethernet gateway only needs to handle the network-layer translation between ZigBee and Ethernet. In our scheme, because the gateway need not inspect the payload to do application-layer translation, this can reduce significant amount of resources and improve the transmission performance of ZigBee/Ethernet gateways accordingly.

However, since the format of SIP messages contains XML texts, this will surely constitute a heavy payload. In the future, reducing the overhead of SIP will be critical to make SIP more appropriate for WSN management.

ACKNOWLEDGMENT

This work is partly supported by National Science Council in Taiwan under grants NSC 100-2218-E-029 -001.

We are grateful to the National Center for High-performance Computing for providing Taiwan Advanced Research and Education Network (TWAREN) as a perfect networking environment to support this experiment.

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