

Performance Study on SNMP and SIP over SCTP in Wireless Sensor Networks

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Abstract—Wireless sensor networks (WSNs) have received lots of attention in recent years. WSNs have been applied to multiple fields such as video surveillance, home automation, and health care. How to efficiently manage WSN devices thus becomes an important issue. Simple Network Management Protocol (SNMP) is an IP-based network management protocol which can collect and modify management information from network devices. Another protocol, Session Initiation Protocol (SIP), is also applied to network management, in addition to its traditional application in IP telephony. SNMP and SIP are both application layer protocols transported over UDP or TCP protocols. Recently, a newly proposed transport layer protocol, Stream Control Transmission Protocol (SCTP), shows its advantages over TCP by providing many new features and better performance. Especially, in a wireless communication environment where data are easy to get lost, SCTP demonstrates excellent performance over TCP. This paper proposes to adopt SNMP and SIP over SCTP as network management protocols and evaluates their behaviors in WSNs.

Keywords—Network Management, SCTP, SIP, SNMP, Wireless Sensor Networks

I. INTRODUCTION

IEEE802.15.4 is a wireless communication standard protocol which was developed for wireless personal area networks (WPAN) [1]. It specifies the physical layer and data link layer in OSI the seven-layer model and focuses on low data rate, low power consumption and short distance transmission functions. Wireless Sensor network (WSN) [2] adopting IEEE802.15.4 standard can be applied in a myriad of applications such as smart grids, smart logistics, environmental monitoring, home automation, and so on.

ZigBee [3] specifies upper layer protocols above IEEE 802.15.4. Its well-known characteristics include low cost, low data rate, and low power consumption. Proposed by the ZigBee Alliance, ZigBee can be considered as one popular technology in WSN. ZigBee devices can communicate with each other and transfer data between devices in ZigBee local area network. Because ZigBee protocol is incompatible with existing Internet Protocol (IP), it does not directly send data to servers on the Internet. In case that is necessary, an additional auxiliary translation mechanism is required.

There are many on-going efforts to introduce Internet Protocol (IP) into WSNs. If sensor devices have native support for the IP protocol, they do not need additional auxiliary translation mechanisms, and sensor devices can directly send data to servers on the Internet. Since there are a lot of application developed based on the IP protocol, this would allow us to save the cost in developing new upper layer applications in devices. With this vision, Internet Engineering Task Force (IETF) formed a working group IPv6 over Low-power Wireless Personal Area Network (6LoWPAN) [4] to study how to apply Internet Protocol version 6 (IPv6) in WSNs.

However, ZigBee and 6LoWPAN are simply network layer protocols which connect nodes together. With rapidly growing number of sensors, how to efficiently manage devices in WSNs has become an important topic which receives a lot of attention in recent years. Right now there is still no universal network management protocol standard to jointly manage heterogeneous ZigBee and 6LoWPAN devices. Some promising candidates in WSN management include Simple Network Management Protocol (SNMP) [5] and Session Initiation Protocol (SIP) [6], which are both application layer protocols.

Because the bandwidth of a wireless link in WSNs is limited, WSNs are unstable and packets get lost easily during transmission processes. Therefore, the traditional network management system which adopts SNMP over UDP to monitor Internet routers does not work well in WSNs. This paper studies SIP and SNMP transported over the Stream Control Transmission Protocol (SCTP) [7]. SCTP offers high performance and high reliable transmission which can overcome disadvantages of WSNs [8][9]. We shall illustrate how SIP over SCTP or SNMP over SCTP can provide better efficiency to manage devices in WSN.

II. RELATED WORK

SIP is an IETF protocol which can establish point-to-point or multiple-point real time communication. SIP has been widely used as a signalling control protocol in Voice over Internet Protocol (VoIP). Third Generation (3G) mobile network operators also propose using SIP as the major technology. In addition to the basic call setup and tear-down, SIP supports a lot of extensions such as register, subscribe,

notify, instant messaging (IM), presence, and so on. Therefore, SIP framework is suitable for developing network management systems, where there is a lot of communication between servers and network devices. Network devices can actively send data to servers, and vice versa.

Another candidate for developing network management systems is SNMP. SNMP is an IP-based network management protocol. Due to the maturity of SNMP, many network devices support SNMP. Like SIP, SNMP can be used to monitor and configure network devices, network devices can immediately notify servers when abnormal events occur.

In recent years, WSN is one important emerging network technology. There are two popular WSN protocols: ZigBee and 6LoWPAN. Different hardware vendors develop their own network management tools, such as ZigBee Sensor Monitor [10] which supports ZigBee CC2530ZDK module developed by Texas Instruments. Each vendor may propose its own management tool, somethings in proprietary management protocols. The lack of a uniform open network management tool has been an obstacle to manage ZigBee and 6LoWPAN devices in WSN.

To manage WSN devices with open standard protocols, some previous studies proposed to adopt SNMP [11][12], while others suggests adopting SIP[13]. SIP and SNMP are application layer protocols which can be used over various underlying networks. Both SIP and SNMP can run over TCP and UDP, depending on whether reliability or efficiency is preferred.

TCP provides reliable transmission, while UDP provides unreliable transmission. Meanwhile, a new transport protocol SCTP offers higher reliability and performance than TCP. SCTP proposes an *association* concept of communication relationship between endpoints. Typical TCP protocols only support a single stream of data delivery and allow a single endpoint to possess one IP address. On the contrary, SCTP provides multihoming and multistreaming which allow two endpoints to set up an association using multiple IP addresses and multiple streams of data delivery. These two powerful functions make SCTP a highly efficient and reliable transmission mechanism.

A. Multihoming

SCTP can create multiple network connection paths between two endpoints. The multihomed endpoints support redundancy mechanism, when the master network connection path fails, the two endpoints can switch to a backup path to continue transmitting data. Figure 1 shows how SCTP multihoming mechanism works.

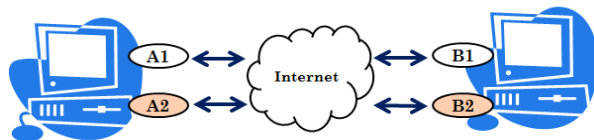


Figure 1. SCTP Multihoming

B. Multistreaming

In contrast with TCP which only supports a single stream, SCTP allows upper layer applications to classify data into different categories to be transferred by independent streams. The advantage of multistreaming is that, if in one data stream there are some packets lost, the congestion control mechanism only slow down the transmission in this stream, so that other data streams will not be affected. Thus the performance of SCTP would be higher, especially in wireless networks with lossy links.

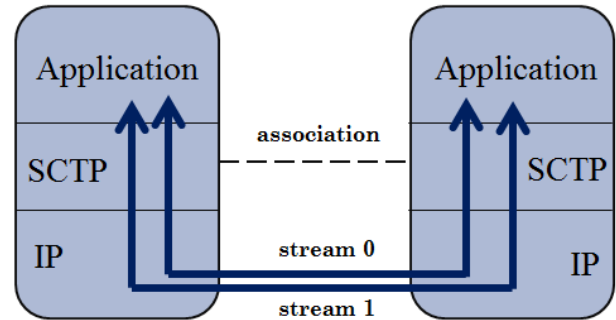


Figure 2. SCTP Multistreaming

By nature, ZigBee and 6LoWPAN WSNs have lossy communication channels, low data rate and small packet sizes. For example, ZigBee networks operating in the 2.4 GHz radio band can support data rate of 250 kbps [14]. Related studies on SCTP shows that its throughput and transmission delay is better than TCP and UDP transport protocols, especially when it is applied in communications with limited bandwidth where packets get lost easily. SIP over SCTP or SNMP over SCTP may be a good idea to increase the management performance in WSNs.

III. SYSTEM ARCHITECTURE

The new Internet Protocol version 6 (IPv6) not only solves problems of IPv4 address depletion but adds more new features. We propose using IPv6 as the network layer protocol to integrate ZigBee and 6LoWPAN networks. IPv6 support 2^{128} IP addresses. Therefore, even if there are a large number of devices deployed in a WSN, each device can be assigned with a unique IP address. This feature makes it easy to support end-to-end communications.

A. ZigBee network

There are three types of devices in a ZigBee network: a coordinator, routers, and end devices. A coordinator is responsible for establishing, maintaining, and controlling a ZigBee network. It allocates network addresses to other nodes which join the network successively. Routers, which are sometimes called relay nodes, take care of data transmission and have capability to extend the scope of a ZigBee network. End devices collect data and transmit them to routers or coordinators.

Because the ZigBee protocol is not compatible with IP, a ZigBee network always needs a gateway for protocol conversion between the ZigBee network and the Internet. This paper studies gateways and servers in the Internet both use

SCTP as the transport protocol and use SIP as upper application layer to manage devices in a WSN. Gateways and servers are multihomed endpoints which can utilize redundancy mechanism.

Figure 3 shows both a gateway and a server are equipped with two Ethernet cards. One Ethernet card is the master network interface and the other Ethernet card is the backup network interface. Even if a master network interface fails, the two hosts can switch over to the redundant network interface to continue the communication.

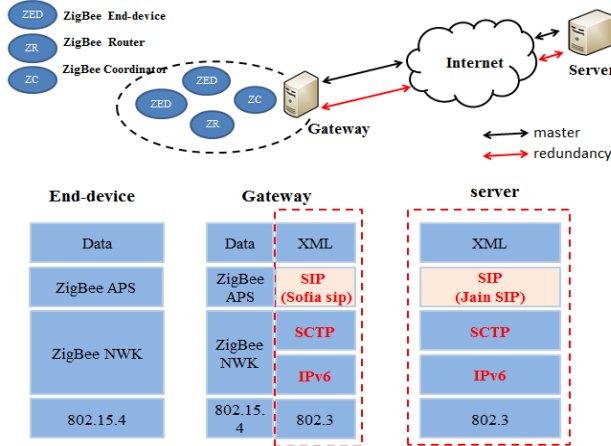


Figure 3. ZigBee network

B. 6LoWPAN network

Devices support native IPv6 in 6LoWPAN networks. Therefore, in real-time data collection, devices can directly send data back to the server on the Internet without protocol conversion. Figure 4 shows a 6LoWPAN network.

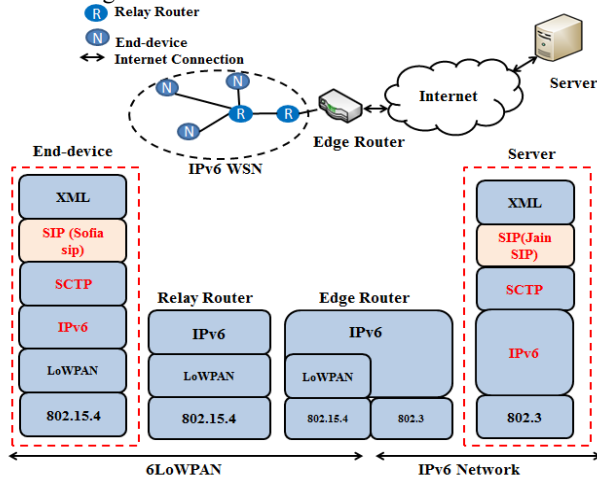


Figure 4. 6LoWPAN network

C. SIP network management

SIP is a signalling protocol which uses plaintext formats such as the eXtensible Markup Language (XML) to describe data. XML use tags to define data. Depending on different requirements and data types, new tags can be defined. SIP provides subscribe, notify, IM functions. This paper uses IM

function to deliver messages so that the server can send commands to devices and devices can send data back to the server.

1) Signal flow of instant messages:

Server can send messages to devices and devices also can send messages to server. Figure 5 shows signal flow of instant messages.

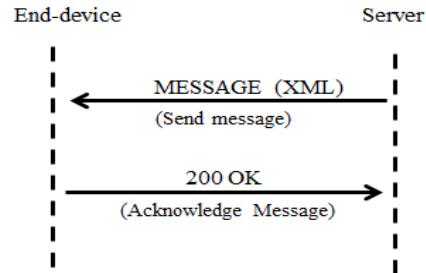


Figure 5. Signal flow of instant messages.

2) Instant messages module:

- Sofia sip library: Compliant with RFC3261 specification, Sofia-sip library is developed at Nokia Research Center. This SIP protocol stack is written by C language which is an open source library.
- Jain-SIP library: We use Java Server Pages (JSP) to develop a web-based management system. To integrate web programs and communication programs, Jain-SIP library is chosen to develop Java programs which communicate between servers and devices.

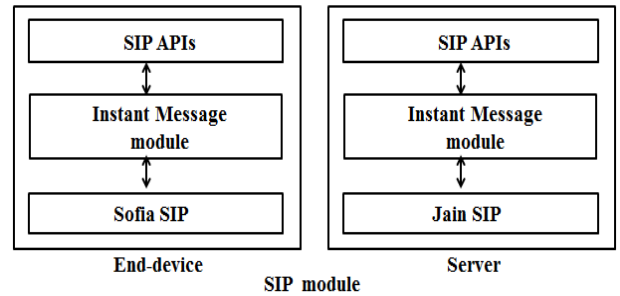


Figure 6. SIP-IM module

3) XML format:

Using the smart outlets as an example, SIP IM data formats are explained below.

Suppose the server sends a command to turn off a smart outlet when a smart outlet receives the command from the server, it replies a 200 OK response and turns off its power. The instant messages may look like the ones in Figure 7 and Figure 8.

The `type` tag represents command types, while value 2 indicates that this is a switch control command. The `oid` tag value represents the smart outlet identification number. The `status` tag represents device status, while value 0 specifies to turn it off.

IPv6 Header	
SCTP Header	
Request-Line: MESSAGE sip:Device@[2001:db8::2]:5000 SIP/2.0 CSeq: 1 MESSAGE From: "Server" <sip:Server@[2001:db8::1]:5070>;tag=12345 To: "Device" sip:Device@[2001:db8::2]:5000 Content-Type: application/pidf+xml Date: Mon, 10 Oct 2011 13:15:37 GMT	SIP Header
<?xml version="1.0" encoding="UTF-8"?> <Device> <webcommand> <type>2</type> <cmd> <devtype>outlet</devtype> <oid>0x0001</oid> <status>0</status> </cmd> </webcommand> </Device>	SIP Body

Figure 7. SIP command in an instant message

IPv6 Header	
SCTP Header	
Status-Line: SIP/2.0 200 OK CSeq: 1 MESSAGE From: "Server" <sip:Server@[2001:db8::1]:5070>;tag=12345 To: "Device" <sip:Device@[2001:db8::2]:5000>;tag=1313376406 Content-Length: 0	SIP Header

Figure 8. Response to a SIP command

IV. CONCLUSIONS

ZigBee and 6LoWPAN are popular WSN technologies because of their ease of use and low cost, low power consumption characteristics. However, there is no open standard for network management system in ZigBee or 6LoWPAN networks. In recent years, many WSN researchers adopted SIP or SNMP as the network management system to manage devices in WSNs. For these SIP and SNMP network management systems, they usually use UDP or TCP as the transport layer protocol.

SCTP is a new transport protocol that offers multihoming and multistreaming features, thus it can provide better transmission performance than TCP and UDP under harsh network environments. ZigBee and 6LoWPAN networks are both bandwidth-constrained and wireless transmission is usually unstable. In our study of SIP and SNMP, SCTP demonstrated better performance as a transport protocol in WSN, compared with TCP and UDP.

Some interesting future work would be analysing the behavior of SIP and SNMP over SCTP in WSNs by simulation tools, and verified its performance in real

testbeds. This would allow network administrators to wisely choose the best management protocol to manage their WSNs.

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