❏   54

Service-Oriented Management for Internet of Things

Hui Xu, Wei Liu, Chunzhi Wang, Hongwei Chen
School of Computer Science, Hubei University of Technology

Article Info	ABSTRACT
	Considering the popularity of Internet of Things, this paper discusses its management problem from the viewpoint of "Management as a Service", and proposes a service-oriented management solution for Internet of Things. This paper then focuses on issues related to the lightweight implementation of service-oriented management for Internet of Things and demonstrates the definition of service-oriented management information based on YANG with the use of JavaScript Object Notation. The case study for cooperative management of campus security in the Internet of Things environment shows that, the proposed approach has a management-tolerant resource cost and a suitable performance of service-oriented management for Internet of Things.

Corresponding Author:

Hui Xu,
Department of Network Engineering, School of Computer Science,
Hubei University of Technology,
Wuhan 430068, Hubei, China.
Email: xuhui_1004@hotmail.com

1. INTRODUCTION

The idea of Internet of Things traces back to 1995, when Bill Gates mentioned in his book, and it authentically presented itself in 1999 by Massachusetts Institute of Technology. In short, the Internet of Things [1] can be seen as an extension of Radio Frequency Identification (RFID) [2], and smart objects can then become the building blocks for Internet of Things [3]. Since 2009, the conception of "Smart Planet" proposed by IBM has played a significant role in USA, and China government has also put forward the strategic envision of "Perceptive China". It is worth mentioning that, Reference [4] applies Service-Oriented Architecture (SOA) to interconnection of real-world embedded equipments, the infrastructure of which can be utilized by users to dynamically select, choose and use real-world services. The aim of this paper is then to discuss the management problem of Internet of Things from the viewpoint of "Management as a Service", and propose service-oriented management for Internet of Things.

The remainder of this paper is organized as follows. Section 2 proposes a service-oriented management solution for Internet of Things from the viewpoint of "Management as a Service". Section 3 then focuses on issues related to the lightweight implementation and demonstrates the definition of service-oriented management information based on YANG with the use of JavaScript Object Notation (JSON). Section 4 studies the case for cooperative management of campus security in the Internet of Things environment using the proposed serive-oriented management approach. Section 5 concludes this paper.

2. MANAGEMENT AS A SERVICE

Considering the thinking of "Sensor as a Service" [5], the function part of smart devices (main components of Internet of Things) can be seen as services, and SOA can then be utilized for management of Internet of Things, named as "Management as a Service".

2.1. Proposed Solution

In a SOA [6], functionality is "published" on a network where two important capabilities are also provided that are "discovery", the ability to find the functionality, and "binding", the ability to connect the functionality. Figure 1 presents the proposed solution of service-oriented managment for Internet of Things.
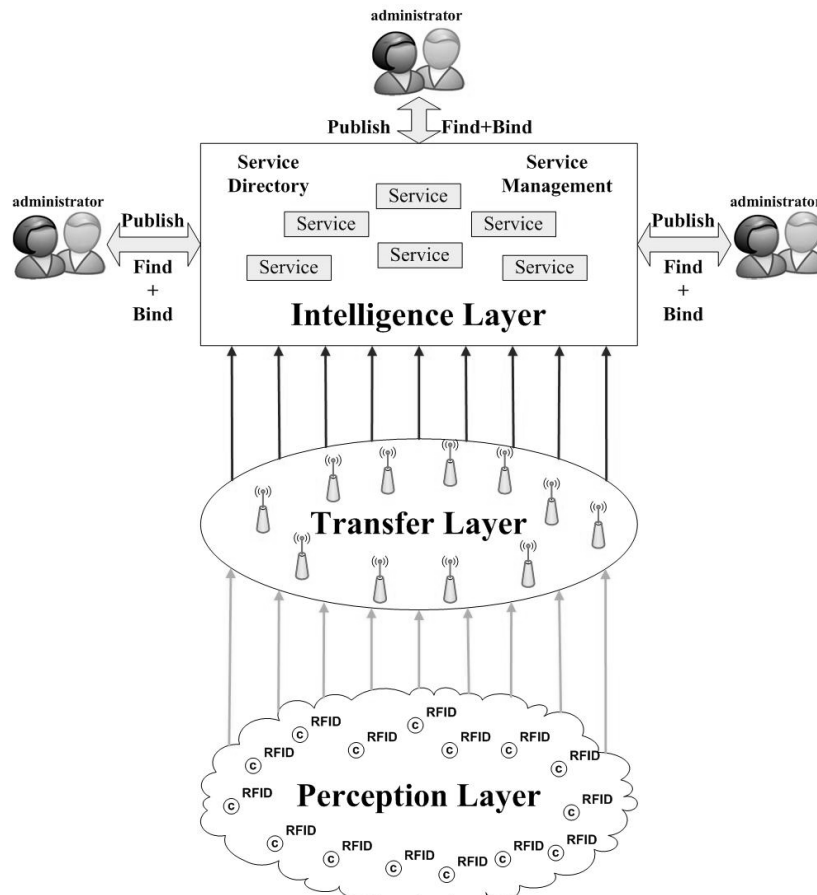

Figure 1. Proposed solution of service-oriented managment for Internet of Things

As is shown in Figure 1, the Internet of Things is divided into three layers, which are depicted as follows. (1) Perception Layer: This layer utilizes RFID to realize context-aware management information collection. (2) Transfer Layer: This layer mainly relies on current network infrastructure, such as Internet, aiming to guarantee the transmission of service management information and operations. (3) Intelligence Layer : This layer makes full use of SOA, where its three parts, briefly presented as "publish", "find", and "bind", have been taken into account. And this layer is responsible for maintaining service directory and performing service management, which focuses on consumer-oriented services and human-machine interaction.

2.2. Management Functions

In order to promote the interaction between administrators and the Intelligence Layer for the Internet of Things, Table 1 demonstrates possible management functions from the viewpoint of "Management as a Service".

Table 1. Possible management functions from the viewpoint of "Management as a Service"

Management Functions	Demonstration
management service publishing	administrators publish management services based on collaboration for the Intelligence Layer
management service querying	administrators query management services based on service directory for the Intelligence Layer
management service subscribing	administrators subscribe for required management services for the Intelligence Layer
management service provisioning	management services will be provisioned to subscribed administrators when it is triggered by the Internet of Things

If Web Services based on Simple Object Access Protocol (SOAP) and Web Services Description Language (WSDL) are directly reused for the management of Internet of Things, the cost for encoding and decoding is incompatible with the limited resource provided by smart devices. From this point of view, issues related to lightweight implementation of service-oriented management for Internet of Things should be taken into further consideration.

3.   LIGHTWEIGHT IMPLEMENTATION ISSUES

In view of service-oriented management for Internet of Things, existing management information specifications can be utilized, and related lightweight implementation issues will be seriously considered at the same time.

3.1. Adoption of YANG for Service-Oriented Management Information Modeling

As the new-generation management information specification proposed by Internet Engineering Task Force (IETF), YANG [7] can be used to define service-oriented management information for Internet of Things. Figure 2 shows an example of Managed Objects (MOs) based on YANG, and Figure 3 provides its corresponding description by XML Schema.

```
/* XXX table comments here XXX */

list diffServDscpMarkActEntry {

    key "diffServDscpMarkActDscp";
    description
      "An entry in the DSCP mark action table that describes a single
       DSCP used for marking.";
    smi:oid "1.3.6.1.2.1.97.1.5.3.1";


    leaf diffServDscpMarkActDscp {
        type diffserv-dscp:Dscp;
        // config false;
        description
          "The DSCP that this Action will store into the DSCP field of the
           subject. It is quite possible that the only packets subject to
           this Action are already marked with this DSCP. Note also that
           Differentiated Services processing may result in packet being
           marked on both ingress to a network and on egress from it, and
           that ingress and egress can occur in the same router.";
        smi:oid "1.3.6.1.2.1.97.1.5.3.1.1";
    }
}
```

Figure 2. An example of YANG MO

```
- <xs:element name="diffServDscpMarkActEntry" minOccurs="0" maxOccurs="unbounded">
  - <xs:annotation>
      <xs:documentation>An entry in the DSCP mark action table that describes a single
        DSCP used for marking.</xs:documentation>
    - <xs:appinfo>
        <ncx:orderedby>system</ncx:orderedby>
        <smi:oid smi:oid="1.3.6.1.2.1.97.1.5.3.1"/>
      </xs:appinfo>
    </xs:annotation>
  - <xs:complexType>
    - <xs:sequence>
      - <xs:element name="diffServDscpMarkActDscp" type="diffserv-dscp:Dscp">
        - <xs:annotation>
            <xs:documentation>The DSCP that this Action will store into the DSCP field
              of the subject. It is quite possible that the only packets subject to this
              Action are already marked with this DSCP. Note also that Differentiated
              Services processing may result in packet being marked on both ingress
              to a network and on egress from it, and that ingress and egress can
              occur in the same router.</xs:documentation>
          - <xs:appinfo>
              <smi:oid smi:oid="1.3.6.1.2.1.97.1.5.3.1.1"/>
            </xs:appinfo>
          </xs:annotation>
        </xs:element>
        <xs:element name="__.diffServAction.diffServDscpMarkActEntry.A__"
          minOccurs="0" maxOccurs="unbounded" abstract="true"/>
      </xs:sequence>
    </xs:complexType>
  - <xs:key name="diffServDscpMarkActEntry_Key">
      <xs:selector xpath="."/>
      <xs:field xpath="diffServDscpMarkActDscp"/>
    </xs:key>
  </xs:element>
```

Figure 3. An XML Schema description of the YANG MO example

However, in the Internet of Things environment, a more lightweight description for service-oriented management information than XML-related formats is of great significance, due to the limitation of resources for smart devices.

3.2. Definition of Service-Oriented Management Information using JSON

In order to provide a more lightweight description for management information than XML-related formats, JSON [8] is introduced into service-oriented management for Internet of Things. Figure 4 then shows a JSON example of service-oriented management information instance for Internet of Things.

```
{ "mos" :
  {{ "oid" : "…" , "value" :…}
   …
  }
}
```

Figure 4. A JSON example of service-oriented management information instance for Internet of Things

As is indicated in Figure 4, compared to XML-related formats, JSON has lower cost, and then is more suitable for describing service-oriented management information instance in the resource-limited environment for Internet of Things, in which "mos" means a list of MOs, "oid" means the object identifier of a particular MO, and "value" means the instance value acquired from monitoring the MO of a particular smart device.

In IETF NETCONF Data Modeling Language (NETMOD) Working Group, the definition of rules for mapping data models expressed by YANG to configuration and operational state data encoded as JSON text has been discussed by specifying a procedure for translating the subset of YANG-compatible XML documents to JSON text, including names and namespaces, mapping XML elements to JSON objects and mapping YANG datatypes to JSON values, and also vice versa [9].

4.   CASE STUDY

In order to validate the feasibility of the proposed service-oriented management approach for Internet of Things, this section will study the case of cooperative management of campus security and propose a corresponding architecture.

Using service-oriented management for Internet of Things, Figure 5 proposes an architecture for cooperative management of campus security. As is presented in Figure 5, the proposed architecture has two remarkable advantages as follows.

(1) Context-aware perception technology based on the Internet of Things.

Based on the Internet of Things technology, campus security management can be cooperative, relying on context-aware perception by deployment of RFID.

(2) Cooperative management application for campus security by utilizing "Management as a Service".

From the viewpoint of cooperative management application for campus security, SOA is utilized by the introduction of "Management as a Service".

Evaluation of the proposed service-oriented managment approach in the Internet of Things environment for cooperative management of campus security has been conducted. With the adoption of uIP for TCP/IP stack, the proposed approach has a management-tolerant resource cost and a suitable performance of service-oriented managment for Internet of Things.

5.   CONCLUSION

The main contribution of this paper is to propose service-oriented management for Internet of Things from the viewpoint of "Management as a Service". This paper utilizes JSON to define management information based on YANG in view of the lightweight implementation of service-oriented management for Internet of Things.

The case study for cooperative management of campus security in the Internet of Things environment shows that, the proposed approach has a management-tolerant resource cost and a suitable performance of service-oriented management for Internet of Things.
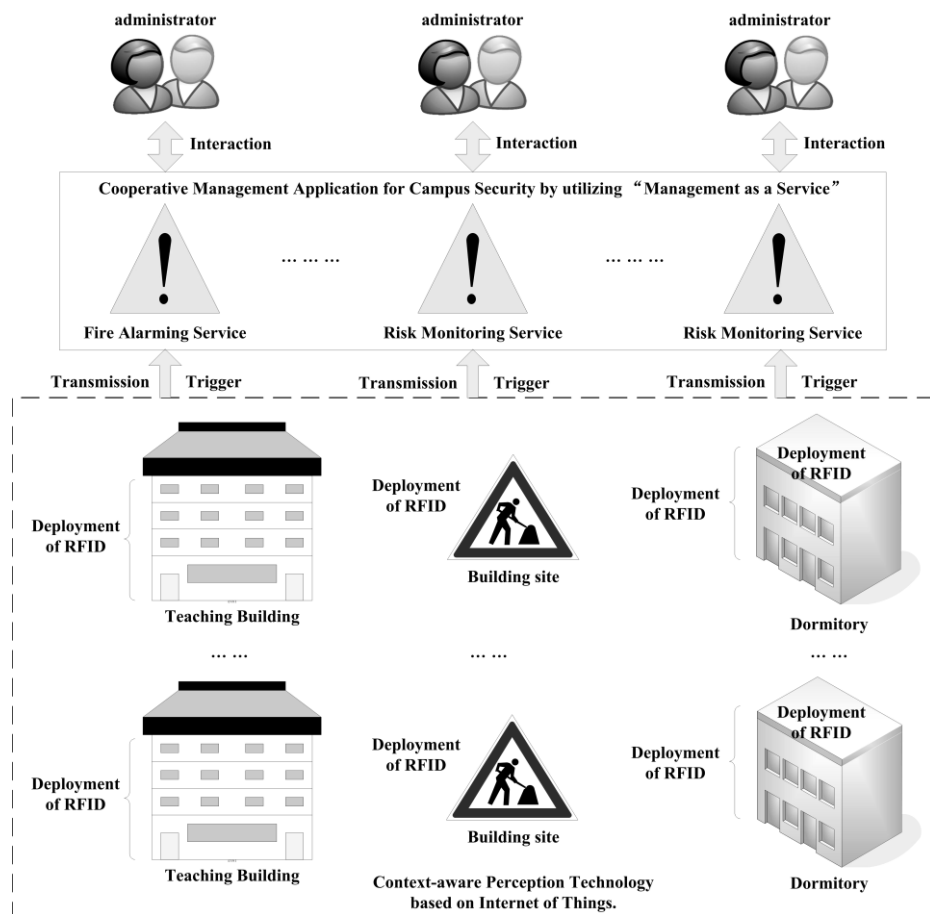
Figure 5. Proposed architecture for cooperative management of campus security using service-oriented management for Internet of Things

REFERENCES

[1]   Luigi Atzoria, Antonio Ierab and Giacomo Morabitoc, "The Internet of Things: A Survey", Computer Networks, Vol. 54, No. 15, pp. 2787–2805, 2010.
[2]   E Welbourne, et al., "Building the Internet of Things using RFID: the RFID Ecosystem Experience", IEEE Internet Computing, Vol. 13, No.3, pp. 48-55, 2009.
[3]   G. Kortuem, F. Kawsar, D. Fitton and V. Sundramioorthy, "Smart Objects as Building Blocks for the Internet of Things", IEEE Internet Computing, Vol. 14, No.1, pp. 30-37, 2010.
[4]   D. Guinard, V. Trifa, S. Karnouskos, P. Spiess and D. Savio, "Interacting with the SOA-based Internet of Things: Discovery, Query, Selection, and On-Demand Provisioning of Web Services", IEEE Transactions on Services Computing, Vol. 3, No. 3, pp. 223-235, 2010.
[5]   S. Alam and J. Noll, "A Semantic Enhanced Service Proxy Framework for Internet of Things", Proceeding of 2010 IEEE/ACM International Conference on Green Computing and Communications & 2010 IEEE/ACM International Conference on Cyber, Physical and Social Computing, IEEE Press, pp. 488-495, 2010.

[6] T. Erl, "Service-Oriented Architecture: Concepts, Technology, and Design", e-Book, 2007.
[7] M. Bjorklund ed., "YANG - A Data Modeling Language for the Network Configuration Protocol (NETCONF)", RFC6020, 2010.
[8] D. Crockford, "The Application/json Media Type for JavaScript Object Notation (JSON)", RFC4627, 2006.
[9] L. Lhotka, "Modeling JSON Text with YANG", draft-lhotka-yang-json-01, http://stuff.mit.edu/afs/athena/reference/internet-drafts/draft-lhotka-yang-json-01.txt, 2012.

BIOGRAPHY OF AUTHORS

Hui Xu received a bachelor's degree in Computer Science and Technology from Huazhong Normal University, Wuhan, China in 2005, a master's degree in Computer Application Technology from Huazhong Normal University, Wuhan, China in 2008, and a doctor's degree in Radio Physics from Huazhong Normal University, Wuhan, China in 2010. Since 2006, she has been a certified computer system analysis in China. Now, she is a Lecturer in the School of Computer Science at Hubei University of Technology, Wuhan, China. Currently, her major field of study is network and service management.

Dr. Xu became a Member of Institute of Electrical and Electronics Engineers (IEEE) in 2007, a Member of Association for Computing Machinery (ACM) in 2007 and a Member of China Computer Federation (CCF) in 2008. She has authored or coauthored 1 book and 2 book chapters in the field of network management, 7 papers published by international journals, 4 papers published by Chinese journals, and more than 20 papers published by international conferences. In April 2008, she was awarded by International Association of Engineers (IAENG) for her first-authored paper presented to 3rd IAENG International Conference on Communication Systems and Applications. In July 2008, her biography was selected for inclusion in the 26th edition (2009) of the Marquis Who's Who in the World, California, USA. Additionally, she was a Session Co-Chair or a Paper Reviewer for 2nd&3rd&7th International Conference on Computer Science & Education (ICCSE 2007&2008&2012), a Session Chair for 1st International Symposium on Electronic Commerce and Security (ISECS 2008), a Paper Reviewer for 4th IEEE Conference on Industrial Electronics and Applications (ICIEA 2009), a Paper Reviewer for 3rd International Conference on Computer and Network Technology (ICCNT 2011). And she is also a Paper Reviewer for Security and Communication Networks, an international journal published by Wiley Press.

Wei Liu is an Associate Professor in the School of Computer Science at Hubei University of Technology, Wuhan, China. Currently, his major field of study is Internet of Things.

Chunzhi Wang is a Professor in the School of Computer Science at Hubei University of Technology, Wuhan, China. She is also the Dean of the School of Computer Science at Hubei University of Technology, Wuhan, China. Currently, her major field of study is cooperative management.

Hongwei Chen is an Associate Professor in the School of Computer Science at Hubei University of Technology, Wuhan, China. Currently, his major field of study is distributed management.