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Applying the Extension Model to Management of Smart Objects

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Abstract

Considering the management problem for Internet of Things, existing IP-based network management protocols such as Simple Network Management Protocol (SNMP) and the Network Configuration (NETCONF) protocol may possibly be utilized to manage smart objects (the main components in Internet of Things). Based on the thinking of extension indicated by some network management standardizations, this paper tries to introduce Extenics into the study on management of smart objects. This paper proposes a simplified formalization for management of smart objects based on the extension model, and formalizes information, knowledge and policy related to Manager, Agent and Management Information Base (MIB) for management of smart objects by making use of basic-elements, composite-elements, extension transformations, dependent functions and extension sets. The case study of this paper shows that, the proposed formalized framework of Manager, Agent and MIB in the form of information-knowledge-policy for management of smart objects based on the extension model is feasible.

Keywords: *Internet of Things, Management of Smart Objects, Extension Model, Composite-elements, Dependent Functions*

1. Introduction

Network management should be a natural part when designing Internet of Things, instead of being an additional function in the traditional sense. Typically, network management adopts the Manager-Agent model, which defines the principles of operations for protocol-based management solutions [1], and managed resources are then modeled as Managed Objects (MOs) and a particular set of MOs is named as Management Information Base (MIB). As an important example for this model, Simple Network Management Protocol (SNMP) has been used mostly in monitoring for fault and performance, providing inadequate coverage of the five functional areas of network management specified as the FCAPS model, which defines network management as consisting of five functional areas encompassing Fault, Configuration, Accounting, Performance and Security management [2]. And as the new-generation network management standardization, the Network Configuration (NETCONF) protocol has overcome the weaknesses of SNMP, and provides a better configuration of IP network devices due to the effective use of XML and related technologies.

Our prior work [3] tries to make full use of NETCONF to promote the standardization of integrated management for Internet of Things by utilizing RESTful Web Services. Reference [4] investigates the question of whether the management of constrained networks and devices in the Internet of Things can be accompanied by adopting existing network management protocols, and it seems that SNMP and the NETCONF protocol for the IP network infrastructure are prospective for Internet of Things with further consideration of resource requirements. As for smart objects that are regarded as the main components in Internet of

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Things, IP-based network management protocols provide a feasible way with further considerations on management mediation. In this case, Extenics prospects a promising means for management of smart objects from the viewpoint of extension. The aim of this paper is then to introduce Extenics into the study on management of smart objects and discuss the application of the extension model.

The remainder of this paper is organized as follows. Section 2 proposes a Manager-Agent model for management of smart objects, and introduces composite-elements for a simplified formalization for management of smart objects based on the extension model. Section 3 applies the extension model to formalize Manager, Agent and MIB for management of smart objects by utilizing basic-elements, composite-elements and extension transformations. Section 4 analyzes a typical scenario to automate management of smart objects by applying the extension model for formalization especially with the use of extension transformations, dependent functions, and extension sets. Section 5 concludes this paper.

2. Proposed Simplified Formalization based on the Extension Model

Interconnecting smart objects with IP is a prospective direction, and IP-oriented network management standardizations might be utilized. As for management of smart objects, the thinking of extension indicated by the Extenics-based approach prospects a promising way, and the logic cell of Extenics is basic-elements [5], which are of great significance for application of the extension model.

2.1. The Manager-Agent model for management of smart objects

Figure 1 proposes a specific Manager-Agent model for management of smart objects.

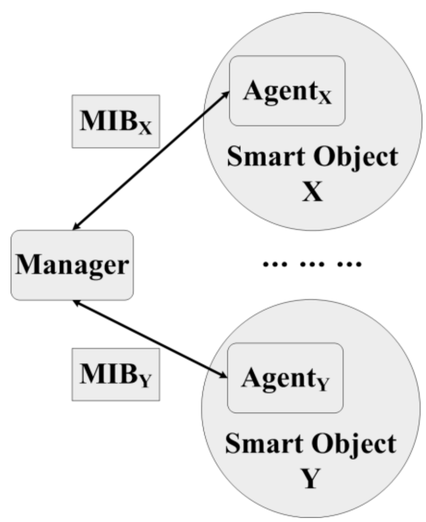

Figure 1. A specific Manager-Agent model for management of smart objects

As is indicated in Figure 1, the Manager-Agent model for traditional network management is also feasible for management of smart objects, and both SNMP and the NETCONF protocol for the IP network infrastructure are prospective as management communication protocols for smart objects.

2.2. Introduction of composite-elements for management of smart objects

Basic-elements include matter-elements, affair-elements and relation-elements. Reference [6] discusses the necessity of establishing a formalized information-knowledge-policy framework and demonstrates the feasibility of Extenics.

Formula 1 demonstrates a common definition of basic-elements, in which $Object$ means the object for the research, with its characteristics $c_1, c_2, ..., c_n$ and corresponding values $v_1, v_2, ..., v_n$.

$$B = \begin{bmatrix} Object, c_1, v_1 \\ c_2, v_2 \\ ...... \\ c_n, v_n \end{bmatrix} \quad \text{… (1)}$$

Base on Formula 1, the class for a type of basic-elements can be defined as Formula 2, in which $V_1, V_2, ..., V_n$ describe the value domains of characteristics $c_1, c_2, ..., c_n$ for the set of objects that is $\{Object\}$.

$$\{B\} = \begin{bmatrix} \{Object\}, c_1, V_1 \\ c_2, V_2 \\ ...... \\ c_n, V_n \end{bmatrix} \quad \text{… (2)}$$

Considering the complexity of the management problem of smart objects, the composition formats of basic-elements named as composite-elements are then introduced to formally represent information, knowledge and policy for management of smart objects.

Formula 3 provides a common definition for the class of composite-elements, in which $\{Object_c\}$ means a set of objects or a set of basic-elements, with characteristics $c_1, c_2, ..., c_n$ and corresponding value domains $V_{c1}, V_{c2}, ..., V_{cn}$, and it seems that any value domain may be a set of basic-elements.

$$\{C\} = \begin{bmatrix} \{Object_c\}, c_1, V_{c1} \\ c_2, V_{c2} \\ ...... \\ c_n, V_{cn} \end{bmatrix} \quad \text{… (3)}$$

2.3. Proposed simplified formalization of Manager, Agent and MIB for management of smart objects based on the extension model

As discussed above, information, knowledge and policy for management of smart objects may possibly be represented in a formal manner using composite-elements. Thus in this way, two roles for network management that are Manager and Agent, along with their MIB can then be formalized by means of composite-elements in a unified manner. And the relationship of Manager, Agent and MIB can further be simplified by relation-elements based on the extension model, as presented in Figure 2.

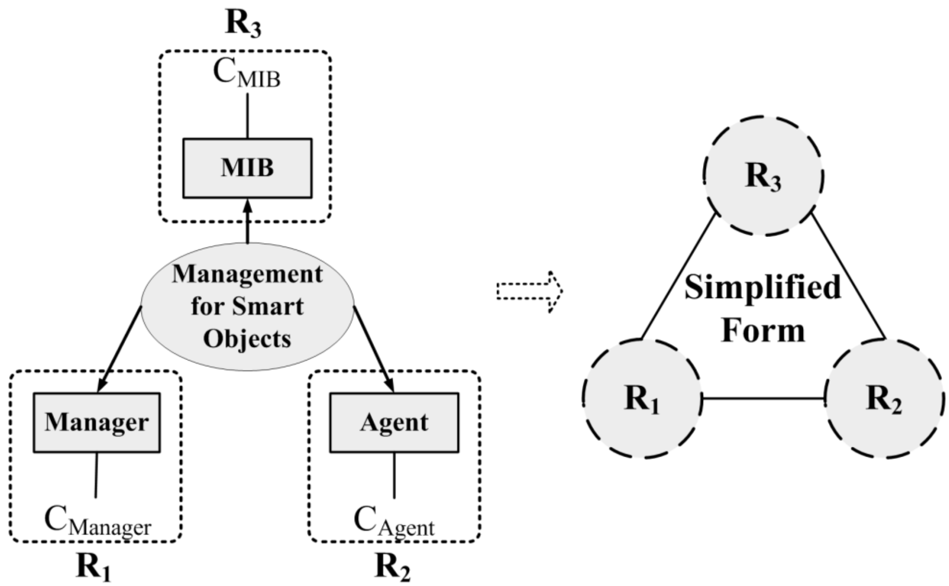

Figure 2. A simplified form of the relationship of Manager, Agent and MIB for management of smart objects by relation-elements based on the extension model

As is indicated in Figure 2, the extension model utilizes composite-elements to optimize the study on the relationship of Manager, Agent and MIB, and proposes a simplified formalization of information-knowledge-policy by relation-elements for management of smart objects.

3. Application of the Extension Model for Management of Smart Objects

Based on proposed simplified formalization of Manager, Agent and MIB for management of smart objects, this section tries to apply the extension model to formalize information, knowledge and policy related to Manager, Agent and MIB for management of smart objects by utilizing basic-elements, composite-elements and extension transformations.

3.1. Formal representations of Manager for management of smart objects

Manager for management of smart objects supports basic operations and their extensions. From Extenics point of view, the function of Manager can be formalized by extension transformations. Formula 4 demonstrates the formalization of extension transformations with the use of basic-elements, in which $\{T_q\}$ means a particular set of objects, with its characteristics $c_{q1}, c_{q2}, ..., c_{qn}$ and corresponding value domains $V_{q1}, V_{q2}, ..., V_{qn}$.

$$T : S \rightarrow S^{'}$$

$$\Leftrightarrow \{B_T\} = \begin{bmatrix} \{T_q\}, c_{q1}, V_{q1} \\ c_{q2}, V_{q2} \\ \ldots\ldots \\ c_{qn}, V_{qn} \end{bmatrix} \quad \ldots (4)$$

As is implied in Formula 4, the extension model can deal with all kinds of transformations in a unified manner by means of basic-elements. Thus in this case, extension transformations are then applied to formalize various management operations for smart objects supported by Manager.

There are five basic transformations for management operations of smart objects, which are 1) replacement transformations, 2) addition and deletion transformations, 3) expansion and shrinkage transformations, 4) decomposition transformations and 5) copy transformations, as respectively shown in Formula 5-9.

$$TS = S^{'} \quad \ldots (5)$$

$$TS = S \cup S_0, TS = S_0 (S_0 \subset S) \quad \ldots (6)$$

$$TS = \alpha S \quad \ldots (7)$$

$$TS = \{S_1, S_2, ..., S_n\}, S_i \subset S(i = 1,2,..., n) \quad \ldots (8)$$

$$TS = \{S, S^*\} \quad \ldots (9)$$

As is indicated in Formula 6, considering management operations of smart objects supported by Manager, the first expression means the case of addition transformations, and the second expression demonstrates the case of deletion transformations. Additionally, note that, as for management operations of smart objects supported by Manager, Formula 7 presents the case of expansion transformations when $\alpha \rangle 1$, and explains the case of shrinkage transformations when $0 \langle \alpha \langle 1$.

3.2. Formal representations of Agent and MIB for management of smart objects

When considering the Manager-Agent model for management of smart objects, the extension model realizes formal representations of Agent by means of basic-elements and composite-elements.

First of all, as for the formal representation of Agent for management of smart objects, the AGENT-CAPABILITIES macro defined by SMIv2 in RFC2580 [7] can be utilized as the basis for the formalization by means of composite-elements. Formula 10 then proposes a basic class for a kind of composite-elements used as the formal representation of Agent for management of smart objects based on Formula 3.

$$\{C_{Agent}\} = \begin{bmatrix} \{Object_{agent}\}, product\_release, V_{a1} \\ status, V_{a2} \\ description, V_{a3} \\ reference, V_{a4} \\ supports, \{C_{Supports}\} \end{bmatrix} \quad \ldots (10)$$

As is shown in Formula 10, the basic formalization of Agent contains characteristics $product\_release$ for a textual description of the product release that includes this set of capabilities, $status$ for demonstration of whether this definition is current or historic, $description$ for a textual description of this set of capabilities, $reference$ for a textual cross-reference to some other document, and $supports$ for a repeated use of naming each MIB module for which the agent claims a complete or partial implementation. Formula 11 proposes a basic class for a kind of composite-elements used as the formal representation of $\{C_{Supports}\}$.

$$\{C_{Supports}\} = \begin{bmatrix} \{Object_{supports}\}, includes, \{M_{MO}\} \\ variation, \{M_{Variation}\} \end{bmatrix} \quad \ldots (11)$$

As is indicated in Formula 11, the characteristic $includes$ for $\{C_{Supports}\}$ is used to name each MIB group, which the Agent claims to implement, and $\{M_{MO}\}$ consists of the formalization of MOs for MIB models. Our prior work [8] discusses issues related to formal presentation of objects for MIB models based on matter-elements by generating from meta-schema based on concept lattices, the basis of which are Module, Scalar, List, Table and Notification.

4. Case Study

Based on formal representations of information, knowledge and policy for management of smart objects, the extension model is then promising to automate management of smart objects using extension transformations, dependent functions and extension sets [9, 10]. In order to promote the formalization of management policies based on extension transformations for smart objects, dependent functions and extension sets will be introduced from both the qualitative point of view and the quantitative point of view.

As a typical scenario, the controllability of performance management for smart objects will be seriously considered for validation of the proposed formalized approach for management of smart objects based on the extension model. Definition 1 then provides the definition of the extension set for related management policies of smart objects.

Definition 1 Suppose that the field X represents a set of the managed entities for smart objects, $x \in X$ is a managed entity, and the dependent function $y = c(x)$ indicates the degree of controllability for x, then the extension set for X can be defined as $\overleftrightarrow{X} = \{(x, y, y') \mid x \in T_X X, y = c(x) \in I, y' = T_c c(T_x x) \in I\}$, in which $T = (T_X, T_c, T_x)$ means extension transformations representing the formalization of performance management policies for smart objects and I is the field of real numbers.

When T is not realized, the dependent function of the positive field of $\overleftrightarrow{X}$ for state under control is $c(x)\rangle 0$, while the dependent function of the negative field of $\overleftrightarrow{X}$ for state out of control is $c(x)\langle 0$. And the zero point of $\overleftrightarrow{X}$ for the case of $c(x)=0$ reflects the critical condition between under control and out of control for performance management of smart objects. With the use of the extension set, Figure 3 demonstrates state transition of controllability for performance management of smart objects.

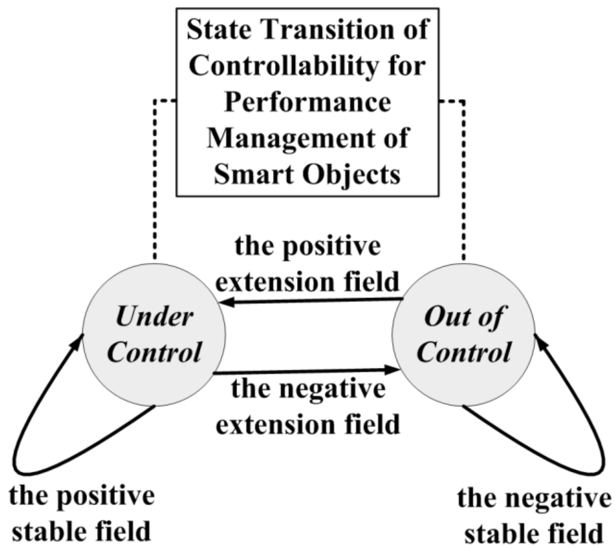

Figure 3. State transition of controllability for performance management of smart objects with the use of the extension set

Table 1. Measuring range of the dependent function that formalizes management policy for performance management of smart objects according to extension classification

Extension Classification		Measuring Range of the Dependent Function that Formalizes Management Policy for Performance Management of Smart Objects
fields of qualitative change	positive extension field	$\{(x, y, y') \mid x \in X, y = c(x) \le 0, y' = c(T_x x)\rangle 0\}$
	negative extension field	$\{(x, y, y') \mid x \in X, y = c(x) \ge 0, y' = c(T_x x)\langle 0\}$
fields of quantitative change	positive stable field	$\{(x, y, y') \mid x \in X, y = c(x)\rangle 0, y' = c(T_x x)\rangle 0\}$
	negative stable field	$\{(x, y, y') \mid x \in X, y = c(x)\langle 0, y' = c(T_x x)\langle 0\}$

As is indicated in Figure 3, when T is realized, a management policy for performance management of smart objects will lead to state transition of controllability for either a qualitative change or a quantitative change. Table 1 then explains the measuring range of the dependent function that formalizes management policy for performance management of smart objects according to extension classification.

5. Conclusions

The main contribution of this paper is to introduce Extenics into the study on management of smart objects. This paper proposes a simplified formalization for management of smart objects by application of the extension model, formalizes information, knowledge and policy related to Manager, Agent and MIB for management of smart objects by making use of basic-elements, composite-elements, extension transformations, dependent functions and extension sets, and validates the feasibility of proposed approach based on the extension model.

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