A Process-Aware Goal Description Language for the Internet of Things Community Computing Environments

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***Abstract*—This paper[1] proposes an abstract language for describing process-aware goals to be accomplished by collaborative smart-objects communities over the Internet of Things (IoT) platforms. The proposed abstract language is based upon the process-driven IoT-community computing model [5] that is derived from a conceptual integration of the process-aware collaborations and the standardized IoT framework announced *via* the ITU-T SG13[2] Y.2060. We assume that a group of collaborative smart-objects communities can be built-up statically, dynamically, or autonomously and their process-aware goals can be specified and achieved adaptively over an IoT-based community computing environment. We also strongly expect that the proposed abstract language will deliver us a meaningful means in specifying and achieving adaptive process-aware goals of the IoT-based communities formed in a ubiquitous computing society.**

***Keywords*—community computing model; the Internet of Things; Web of Things; smart-objects collaboration; process-aware goal description language; ubiquitous community computing architectures and systems**

I. INTRODUCTION

In recent, we are in the midmost era of the Internet of Things[1], which provides a variety of smart-objects collaboration services on ubiquitous computing environments. The widespread use of mobile smart-phones, smart-watches and O2O[3] products is the evident, and these little gadgets have become an integral and intimate part of everyday life for many millions of people, even more than the internet users. According to the report of [1], this situation opened a new form of communication between people and things, and between things themselves, which means that a new dimension, *anything* connectivity, has been emerging in the world of information and communications technologies characterized with *anytime* connectivity and *anyplace* connectivity for anyone. These three dimensions (*anything*, *anytime*, and *anyplace*) of connectivity give a clue to creating an entirely new dynamic network of networks—the Internet of Things (IoT)—as a future network.

The Internet of Things (which is abbreviated as IoT) is a conceptual platform for the ubiquitous community computing environments[2], and it is conceptually widened into the Web of Things (WoT)[3] and the Web of Objects (WoO), which have been recently issued in the RFID and sensor network (USN) literature. The IoT-based community computing environment supports the concept of ubiquitous community and society computing models and systems[2], and physically implies a computerized situation or space formed by a group of smart objects (or Things)[4], such as devices, sensors, actuators, and people as well, each of which may have various computing capabilities and/or ubiquitous networking capabilities. In the previous research of the authors' research group, we proposed an advanced and new community computing concept, which is called process-driven community computing model[5], with aiming to be deployed on the IoT-based community computing environment.

Imagine that a group of community-members (smart objects or Things) on an IoT-based community conducts their own roles to accomplish the community's goal in a fashion of process-aware collaborations[6][7]. For the sake of realizing the imagination, we tried to extend the ITU's standardized IoT framework by embedding the concept of process-aware collaborations into the standardized IoT conceptual architecture. As the next step of the research work, this paper devises an XML-based abstract language to describe a process-aware goal that should be accomplished by an IoT-based community over the Internet of Things community computing environment. The XML-based abstract language is called a process-aware goal description language that is based upon a set of XML-based schema structures consisting of procedural combinations of atomic role types[8] and compound role types[8], such as DAG (Directed Acyclic Graph) role, IF role, FOR role, WHILE role, and ALT (alternative) role.

II. PROCESS-AWARE IOT COMMUNITIES

In this subsection, we introduce a conceptual definition of process-aware communities on the Internet of Things community computing environment. The IoT community computing environment is a computerized situation and society where a group of Things, including smart objects like devices, sensors, actuators, and even people, is connected each other through the Internet, and a partial group of the members is organized into a collaborative community (statically, dynamically, or autonomously) to accomplish it's goal[9]. The community

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[2]International Telecommunication Union, Telecommunication Standardization Sector, Study Group 13 - Future Networks

[3]O2O stands for Online-To-Offline combining the online shopping and the front line transactions, and it represents a recent IT convergence business model and its related products.

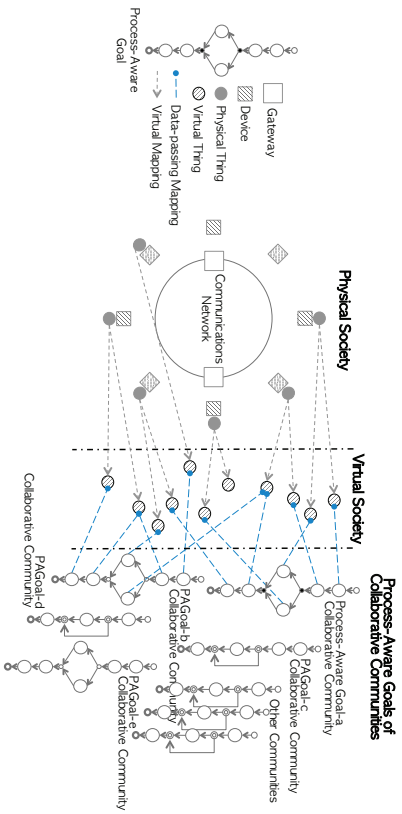

Fig. 1. A Conceptual Architecture of the Process-Aware IoT Community Computing Environment

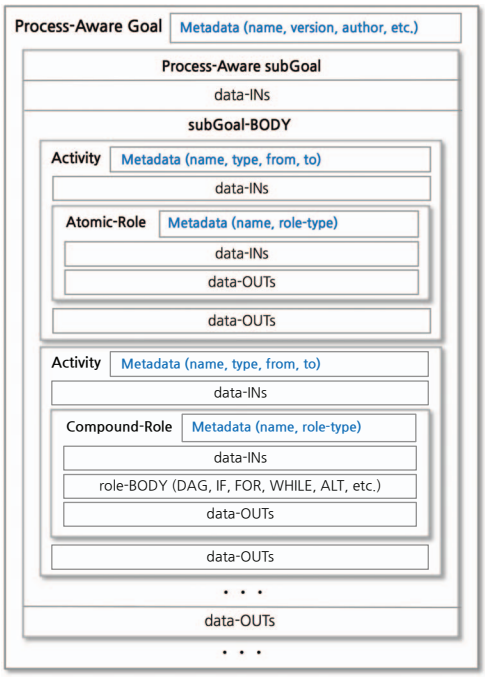

Fig. 2. The XML Schema Skeleton of the Process-Aware Goal Description Language

is broken up and rejoin its members into the corresponding society after completing the goal. In this section, we simply introduce how to abstract the goal of the process-aware collaboration community to be modeled, deployed, and enacted over a process-aware IoT community computing environment.

Fig. 1 illustrates a conceptual architecture for the process-aware IoT community computing environment that is arranged by physical IoT society, virtual IoT society, and a group of process-aware communities that can be statically, dynamically or autonomously formed out of smart-objects in the virtual IoT society. As shown in the conceptual architecture, the virtual IoT society spawns a series of collaborative communities, and the role of each community is to perform its own stepwise-activities described by a process-aware goal. The previous research of the authors proposed the process-driven IoT community computing model [5] as a formal description methodology for abstracting the concept[4] of process-aware goals in the IoT community computing environment. As the next step of the research, we concretize the concept and the model [5] *via* a process-aware goal description language with its XML-based schema.

[4]Note that the **process-aware goal** is defined by a predefined or intended set of tasks or roles, called activities, and their temporal ordering of executions. A process-aware IoT-community computing system helps to organize, control, and execute process-aware IoT-communities by defining their process-aware goals that are represented by the process-aware IoT-community computing model proposed in [5].

III. XML Schema of the Process-Aware Goal Description Language

Based upon the process-aware IoT community computing model, we devise an XML-based description language designated for abstracting process-aware goals of the corresponding Internet of Things communities. The major constructs of the abstract language consist of activities, sourcing and sinking data repositories, and community-members. The activity construct is concretized by two types of roles: atomic role type and compound role type.

Fig. 2 shows the XML-based schema skeleton that is made up of four partitions with the primitive tag types—Metadata, data-INs, data-OUTs, and BODY—to build the textual representation of a process-aware goal. Assume that the accomplishment of a process-aware goal implies to perform all of the associated roles of the corresponding IoT-based collaborative community. In particular, the subGoal-BODY portion of a process-aware goal description language is composed of a bundle of procedural activities, each of which abstracts either atomic role or compound role. The detailed schema of the atomic roles type and the compound roles type are described in the following subsections. In terms of the notational XML syntax[8], the following are used to simplify the descriptive representations of the process-aware goals:

- Elements and attributes of XML tags may have one of the wildcard characters as follows: `?` (`0` or `1`), `*` (`0` or *more*), `+` (`1` or *more*), `#` (*exclusive-existence*)
- Elements ending with "..." (e.g. <*element* ... /> or <*element* ... >) indicate that elements or attributes irrelevant to the context are being omitted.

A. The Activity Construct

The process-aware goal description language is used for the user to compose a process-aware goal by defining an abstract model as well as a concrete model. The abstract model is defined by a procedural combination of the activity constructs, while the concrete model is defined by associating either an atomic role or a compound role with each of the corresponding activity constructs. Eventually, those defined process-aware goals are deployed and enacted on the Internet of Things community computing environment.

```
<activity name="Name" type="Type" from="α1" to="α2">
  <data-INs>
      <data-IN name="Name" type="Type">
          <value> Constants </value>?
      </data-IN>*
  </data-INs>
  <atomic-ROLE name="Name" type="Type"/>#
  <compound-ROLE name="Name" type="Type"/>#
  <data-OUTs>
      <data-OUT name="Name" type="Type"/>*
  </data-OUTs>
</activity>
```

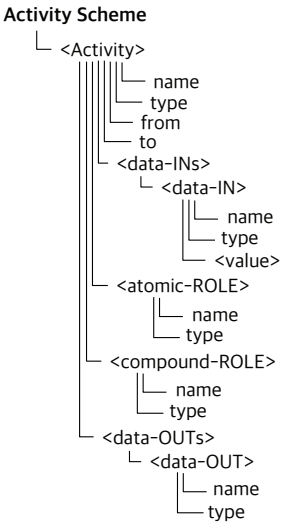

Fig. 3. The XML Scheme of the Activity Construct

Fig. 3 shows a graphical structure of the XML-based activity construct and its XML scheme with tag elements, such as data-INs, data-OUTs, atomic-ROLE, compound-ROLE, and attributes, such as name, type, from, to. A corresponding activity is exclusively concretized by associating with either an atomic role or a compound role. This association rule is represented by the tag elements of ROLE with the *exclusive-existence* wildcard character, #.

B. The Atomic Role Type

In the process-aware goal description language, the atomic role type is built by three tag elements: Metadata, data-INs, and data-OUTs. The metadata has a name property and a type property. The name property is an unique identifier of a corresponding atomic role; the type property characterizes its corresponding atomic role as a concrete service provided a specific task chosen from a group of tasks. Each task in the group is a concrete smart-object having a same functionality with probably different performances (behaviors, QoS characteristics, costs, etc.), and being implemented and deployed in the virtual society of the Internet of Things community computing environment. Assume that the affiliative information between atomic roles and concrete smart-objects is managed by the worklist registry component of a process-aware goal IoT community enactment system. Fig. 4 illustrates the XML scheme of the atomic role type with its XML language Skeleton.

```
<atomic-ROLE name="Name" type="Type">
 <data-INs>
   <data-IN name"Name" type="Type" source="Source"? >
     <value> Constants </value>?
   </data-IN>*
 </data-INs>
 <data-OUTs>
   <data-OUT name="Name" type="Type" saveto="Loc"? />*
 </data-OUTs>
</atomic-ROLE>
```

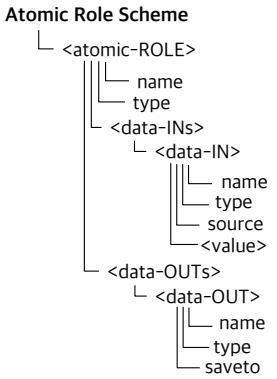

Fig. 4. The XML Scheme of the Atomic Role Type

C. The Compound Role Type

The process-aware goal description language is able to provide a rich set of compound role types. That is, the compound role type supports making a variety of collaborative formations in a group of roles, which is sub-classified into mesh-type, loop-type, and alternative-type formations. The mesh-type collaborative formation is represented by DAG (Directed Acyclic Graph) compound role; the loop-type collaborative formation is defined by FOR and WHILE compound roles; and the alternative collaborative formation is formatted by IF and ALT (Alternative) compound roles. In this section, we design the detailed XML schema and formats of those atomic role and compound role types after defining the XML scheme of the activity construct. In particular, we introduce only the DAG compound role type due to the page limitation. Fig. 5 illustrates the XML scheme of the DAG compound role type with its XML language Skeleton. A DAG compound role type is a commonly used type to express control flow dependencies among the affiliated atomic roles

in a corresponding compound role. The possible formation of the control flow dependencies is classified into sequential and parallel dependencies inside of a DAG compound role.

```
<dag-ROLE name="Name" type="Type">
 <data-INs>
   <data-IN name"Name" type="Type" source="Source"? >
     <value> Constants </value>?
   </data-IN>*
 </data-INs>
 <atomic-ROLEs>
   <atomic-ROLE name"Name" type="Type" from="Role" >+
 </atomic-ROLEs>
 <data-OUTs>
   <data-OUT name="Name" type="Type" saveto="Loc"? />*
 </data-OUTs>
</dag-ROLE>
```

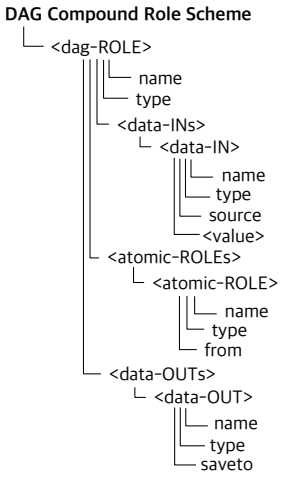

Fig. 5. The XML Scheme of the DAG Compound Role Type

IV. Conclusion

In this paper, we have proposed an XML-based description language, which is so-called "process-aware goal description language," to specify process-aware goals of the Internet of Things communities. A process-aware goal is abstracted by a group of activities and their procedural and temporal combinations. Each activity is reified by either an atomic role or a compound role. Therefore, we devised a set of XML-based schema structures for the activity construct and its concrete components: atomic role type and compound role type. In particular, we described the detailed specification of the DAG (Directed Acyclic Graph) compound role type only in this paper. As future works, we have plans to extend the XML schema so as to express all the remaining compound role types, and implement a process-aware goal modeling system supporting the process-aware goal description language proposed in this paper.

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