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An architecture for aggregating information from distributed data nodes for industrial internet of things

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ABSTRACT

The current Internet of Things (IoT) has made it very convenient to obtain information about a product from a single data node. However, in many industrial applications, information about a single product can be distributed in multiple different data nodes, and aggregating the information from these nodes has become a common task. In this paper, we provide a distributed service-oriented architecture for this task. In this architecture, each manufacturer provides service for their own products, and data nodes keep the information collected by themselves. Semantic technologies are adopted to handle problems of heterogeneity and serve as the foundation to support different applications. Finally, as an example, we illustrate the use of this architecture to solve the problem of product tracing.

1. Introduction

Internet of Things (IoT) covers a bundle of information and communication technologies, such as identification, sensing, communication and so forth. The ambitious vision of IoT is to interconnect any substantial entity in both the real and digital worlds by extending the Internet and using intelligent interfaces such that everything in IoT can communicate, be identified and interact [1,2]. Although this vision is still a long way from being completed, the development thus far has benefited many areas, including various industries such as healthcare services [3,4], supply chains [5,6], transportation [7] and so forth.

IoT enables an entirely new class of services, such as identification and tracking, with which the operation and role of many industrial systems are being transformed [8]. In [8], the authors surveyed some important IoT industrial applications. For example, using IoT, intelligent transportation systems can be created. From the office, transportation authorities can identify and track each vehicle with loads, monitor its movements, predict load conditions and even recommend driving directions to drivers[7]. In the food supply chain, products can be tracked all the way from farms to retailers, which is helpful in terms of food quality and safety management [9,10].

In these applications, a key fundamental functionality of IoT is to provide a product's information when the product's ID is read. The ID is generally written in radio-frequency identification (RFID) tags. To implement this functionality, there are two representative systems: the electronic product code (EPC) system[1] and the ubiquitous ID (uID) system [11]. These two

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[1] EPCglobal: EPCglobal specifications. http://www.epcglobalinc.org/standards/specs/.

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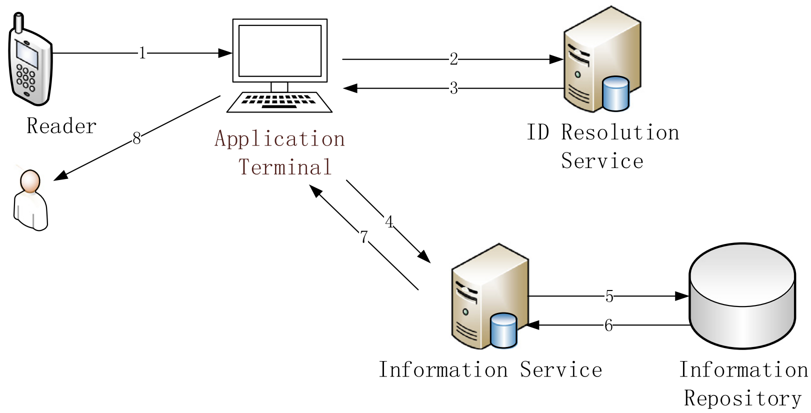

Fig. 1. The classic one-to-one architecture.

systems vary in many aspects, but they have a similar one-to-one (one ID, one record) architecture, as shown in Fig. 1. Once a terminal reads a product's ID, it first forwards it to the ID resolution service, which is called Object Name Service in EPC system and uCode Resolution Server in uID system.[2] The resolution service then returns to the terminal the address of a certain data node that issued the product's ID. This data node generally belongs to the product manufacturer, and we call it the source node of this product. Using this address, the terminal can find the information service provided by the node and obtain the target record from it. Since one ID can be associated to only one record from one data node, we call this a one-to-one architecture.

However, in many applications, a single product could have multiple records spreading over multiple distributed data nodes, and we need all the information to complete some operations [10,12]. For example, in a product supply chain, a product could leave a record at every data node where it arrives and is scanned [13].

The information from all these data nodes is needed to trace the product. The current one-to-one architecture does not directly support such functionality; therefore, supplementary components are indispensable for product tracing. In practice, aggregating information of an object from multiple distributed data nodes is a common task in many industrial applications [10]. Therefore, an architecture that can conveniently aggregate information from multiple distributed data nodes would facilitate many industrial IoT (IIoT) applications, and this is the motivation of our work.

Several requirements should be satisfied for the new architecture to be practical and feasible in multiple applications. First, scalability should be achieved since the development of IoT is very fast. Second, the heterogeneity of information across different applications and data nodes should be considered because we expect the architecture to have a relatively wide applicability. Third, the aggregating operation should clearly be efficient.

In this paper, we propose a new architecture that attempts to satisfy these requirements. The proposed architecture is compatible with the existing IoT infrastructure, including both EPC and uID systems. In this architecture, each manufacturer provides service for their own products, and data nodes retain the information collected by themselves. Semantic technologies are adopted to handle problems of heterogeneity and serve as the foundation to support different applications. To validate the proposed architecture, we apply it to the problem of product tracing.

The remainder of this paper is organized as follows. In Section 2, we briefly introduce the preliminaries needed in this paper. Then, in Section 3, we discuss some issues that should be addressed in the information aggregation architecture, which are also the criteria for evaluating an architecture. Section 4 details and discusses the proposed architecture. In Section 5, taking product tracing as an example, we explain how to use the proposed architecture in IIoT applications, in which the use of semantic web technologies is emphasized. Finally, Section 6 concludes the paper and presents directions for future work.

2. Preliminaries

2.1. Semantics for internet of things

Semantic technologies are focused on describing the meaning of information in a formal and machine-processable way, and the resulting descriptions are often called ontologies [14]. Some semantic technologies are used in our work. The Web Ontology Language (OWL) is designed to represent rich and complex knowledge about things, groups of things, and relations between things.[3] SWRL is the Semantic Web Rule Language that combines OWL and RuleML, which is a sublanguage of the

[2] http://www.uidcenter.org.
[3] https://www.w3.org/2001/sw/wiki/OWL.