IoT Mashups : from IoT Big Data to IoT Big Service

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ABSTRACT

Internet of Things (IoT) addresses the challenge to provide a transparent access to a huge number of IoT resources that can be either physical devices or just data resources. Moreover, because of the large number of resource-constrained devices and the dynamic nature of IoT environments, integrating the resulted data becomes a non trivial task. We believe that the use of mashups, a way to compose new services from existing ones, can be a solution to the above challenge if each resource exposes its functionalities as a Web service. In the IoT environment, this will constitute a Web of Things where mashups development will take advantage of the connected physical world. The huge amounts of IoT-generated data from physical devices and data sources, called IoT Big Data, requires new design solutions to speed up data processing, scale up with the data volume and improve data adaptability. Besides existing techniques for IoT data collection, filtering, and analytics, we present in this article a mashup oriented model, called IoT Big Services, for provisioning data-centric IoT services in the context of IOT mashups. These IoT services are organized in tree structure where each node, called an IoT Big Service, acts as an integrator that collects data from lower level, processes them and delivers the results to higher level in the architecture.

CCS CONCEPTS

• **Networks** → *Location based services*; *Location based services*; *Location based services*; • **Software and its engineering** → *Data flow architectures*; *Software as a service orchestration system*; *Data flow architectures*;

KEYWORDS

Internet of Things; Mashup application; Big Services; Big Data

ACM Reference format:
Marwa Boulakbech, Nizar Messai, Yacine Sam, Thomas devogele, and Mohammad Hammoudeh. 2017. IoT Mashups : from IoT Big Data to IoT Big Service. In *Proceedings of ICFNDS '17, Cambridge, United Kingdom, July 19-20, 2017,* 5 pages.
DOI: 10.1145/3102304.3102324

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1 INTRODUCTION

The main goal of Internet of things (IoT) systems is to bridge together the small islands of smart-devices networks, i.e., bridging devices and sensor networks with the cyber world in order to assist users in their activities [4]. This may concern multiple application domains like health-care, home automation and smart cities.

The core challenge is to give to billions of interested users a transparent and seamless access to millions of different available interconnected IoT resources that can collect and store several kinds of data, such as environmental, geographical and logistics data, from a multitude of sensor-equipped physical objects[4]. The problem is, in other words, how to help users, and especially end-users, to easily explore the large amounts of such generated data in what can be called the big data ecosystem.

Mashupping, a way to help end-users to aggregate and combine existing contents in order to compose new ones, can be expected to play an important role to solve this challenge. Using mashups techniques in IoT environments can in fact be possible if each "thing" exposes its functionalities as a Web service [6] that can be directed used or composed with others in order to meet users' requirements . So, easily and freely composing new services from existing ones will provide humans with many new useful services because people have different use-cases and preferences; a useful service to someone may be unnecessary or even inconvenient to others.

In this context, the European Commission's Internet of Services (IoS) can be an example of a future vision of a networked form of IoT services [14]. The IoS initiative presents a paradigm in which everything is available as a service on the Internet. It can also be viewed as networked services or systems across the real and virtual worlds over the Internet. In the IoS, services, as encapsulated functional entities containing interaction processes, are distributed, virtualized, and converged over the Internet to meet the users' requirements and create added-value for them [14]. This IoT services concept can be useful in multiple domains like health-care, smart cities or smart tourism. It can give rise to a bottom-up way of constructing composite services from existing ones in IoT environments. When the composite service is the result of multiple services giving access to large amounts of data, they can be called Big Services. For example, in the tourism domain, a big service can be a customer-oriented service composed of various data-centric travel services, i.e., a travel data system responding quickly to travel events gathered from a wide range of resources such as transportation, accommodations, entertainment and tourist's smart devices.

Due to the increasing number of these smart devices, the amounts of generated data are generally large, and accordingly necessary computation power becomes large [7]. Thus, collecting and processing the data generated by such a huge number of devices lead to unprecedented challenges in mining and processing the generated data, such as heterogeneity and variety of data, real-time data processing, and discovering the value of data produced by multi-purpose and shared smart devices. Considering the aforementioned characteristics, large-scale IoT systems, as the dominant generator of big data sets, have attracted particular attention implying the need for a data-centric service modeling approach that can effectively achieve the premises of big services for IoT big data. Even if the data may be processed by external Web services, mashup services are still responsible for the performance requirement [7]. Therefore, applying current Web mashups technologies may not be sufficient in IoT environment. Instead, a new mashup service model needs to be designed in order to speed up data processing, scale up with the data volumes and improve data adaptability.

We propose in this paper a new mashup service model, called IoT mashup, defined as composition of IoT resources. In fact, recent initiatives in integrating service-oriented technologies and big data have focused on Big-Data-as-a-Service and service generated big data. The former encapsulates various big data storage, management, and analytics techniques into services and provides APIs for seamless system integration [11]. Approaches on service-generated big data propose infrastructures to provide common functionalities for data management and analysis. However, there exists a gap in the design and architecture of data-centric IoT services in big data scenarios. The focus of this paper is on the services design aspect of IoT generated big data processing platforms. Using context-driven nature of data sensing and processing, the essence of the proposed approach is to structure data-centric IoT services hierarchically in a multi-root tree data structure where the nodes represent Big Services. A Big Service therefore acts as an integrator, collecting data from lower level Big Services, processing them, and delivering the result to its upper level Big Services.

The remaining of the paper is organized as follows. Related work is presented in Section 2. Section 3 introduces the vision of data mashups as a mean of composing new IoT services form existing ones and presents an overview of IoT mashup applications. In Section 4, we present our mashup oriented model, called IoT Big Services, for provisioning data-centric IoT services in the context of IoT mashups. We conclude and give some perspectives in Section 5.

2 RELATED WORK

IoT Big data addresses inherent data processing challenges, such as data acquisition, storage, management and analysis, whereas the focus was not on the services supporting such features. Big Data-as-a-Service and service-generated big data [15] are the most recent initiatives in integrating service-oriented technologies and big data. The goal is to encapsulate big data processing aspects into services and provide then the associated APIs for seamless integration. Thus, the service composition in IoT environments will be possible by existing Web based mashup technology if things expose their functionalities in lightweight RESTful Web services [7] compelling subsequently the concept of IoT Mashups as a Service.

In [1], the authors present a sensor-as-a-service concept, which is a semantic enhanced service proxy approach that exposes sensors as Web services. SOCRADES [5] also exposes smart devices with embedded software as a form of service using the Device Profile for Web Services (DPWS) which is a subset of standard Web service interface enabling Web service integration and eventing on resource-constrained devices. The exposed services are composed according to the description in extended BPEL then integrated with enterprise systems such as ERP.

Another IoT platform, Atlas [8] , abstracts all the Things in the unit of sensor node, hardware or software platform, and service gateway framework. Using the OSGi framework, these nodes can be dynamically composed. However, scalability aspects are not taken into account if the number of things and data to process expands. Some other solutions are based on the cloud resources. In [7] a cloud computing approach is proposed offering a new category of cloud services, IoT MaaS. This approach provides end-users with an interface to customize a mashup service at runtime. The mashup service communicates with things to collect and process data on an allocated computing resource. Another cloud-based approach was proposed in [9] for IoT mashups to compose a new service from existing cloud-based IoT services. However, generally, contributions in this category mainly focus on efficient usage of cloud features in IoT services. Moreover, they propose infrastructures to provide common functionalities for managing and analyzing different types of service-generated big data but don't explain the way to compose IoT services. The design and architecture of data-centric IoT services in big data scenarios is still barely addressed.

In [12], the authors propose an approach where IoT services are composed based on a data flow graph. They address the scalability issue in composing large-scale IoT networks through approximately-optimal composition, using the concepts of expansion and mapping. These types of contributions are devoted to core technological challenges for services composition that is different from the focus of this paper. Finally, in [11] a design model for large scale IoT system is proposed. It is based on a tree structure where data is collected and processed in lower level then aggregated in the higher level. This approach is close to our work but we devote attention to user's requirements in service mashups, which is not addressed in the latter proposition.

3 IOT MASHUPS

IoT mashups are connected, integrated, contextual and personalized applications. They enable users to connect sensors, manage data and build personalized services in multiple application domains like health-care, home automation and smart cities [4]. As an example, they can make cities smarter, more accessible and enjoyable for both citizens and visitors by allowing to enjoy their daily lives and stays and help them to plan their activities [3]. In the same context, given the cross-cutting nature of travel and tourism, a smart city can help build and sustain smart tourism, but so far this connection is not quite visible yet. Through embedded technologies on all organizations and entities, destinations can exploit synergies between ubiquitous sensing technologies and their social components to support the enrichment of tourist experiences [3]. In fact, in smart city context, information and communication technologies can be used to collect and measure some parameters and conditions in streets, buildings, transportation and the air quality. That means embedding sensors and other technologies throughout a destination to monitor and collect data from everything [13]. The data is then communicated through wired and wireless connections, through what is known as the Internet of Everything (IoE) in which everything is inter-connected . For example, Stockholm smart city [1] collects real-time information from distributed sensors in the city and processes them in order to provide accurate city information through end-user devices. Using ICT as a predictive tool to implement a smarter way of managing Tourism Destinations .

Another example is for improving the quality and sustainability of what a destination offers can benefit visitors and tourism development. For the visitor, resident, business owner and investor, the result is a destination that is greener and cleaner and thus a healthier and higher quality place to visit, live and do business in. Hotels, restaurants, tourism-related transportation and attractions all benefit from the increased quality of life throughout the destination. Visitors flock to a place that exudes high quality.

Thus globally, by applying smartness concept to address travellers' needs before, during and after their trip, destinations could increase their competitiveness level. A generic reference architecture for IoT mashups, presenting the general big data processing model is depicted in Figure 1.

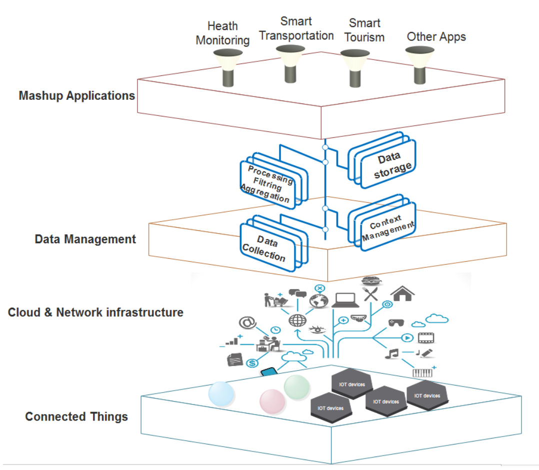

Figure 1: An overview of IoT mashup applications

In the lowest layer, one can find a wide range of connected IoT resources provided through a cloud infrastructure. There are two main information sources: (i) data coming from the city resulting from sensors, city elements and Open Data; and (ii) data coming from the citizens and visitors as digital footprint from their social media activities. Such great amount of (big) generated data are then collected, processed, filtered and stored in the Data Management level based on end-users contexts. The highest level, Mashup Application layer, displays smart city applications such as smart transportation, health monitoring, etc., to end-users.

The architectural model shows implicitly the data flow from IoT devices towards the data analytics components and further up to mashup applications. In this architecture, the role of the components in the lowest level considering Real-Time Analytics are more crucial because of tight dependency between the network and deployment model of IoT resources and data acquisition and in-network processing techniques for IoT systems. Moreover, the Context Management component at Data Management layer directly influences the IoT data acquisition, processing, and delivery model. It plays a critical role in eliminating the gap between diverse individual customer requirements and the massive number of services in big service.

Hence, the framework architecture provides efficient service design and integration models that realize complicated data centric processes. To implement such an architecture, a zoom on the Mashup Application Layer is needed. This layer considers three types of services:

- **IoT Resources Access Services:** are atomic services that do not rely on other services. They provide the basic infrastructure to access, collect, process, and store data generated from IoT resources.
- **Domain-centric Data Processing Services:** are the result of the aggregation of services form the lower level (IoT Resources Access Services) into more powerful composite services according to the domain-oriented business. It can concern for example the domains of traffic monitoring, weather services, health services, etc. Moreover, this kind of services may include an event processing engine that analyses requested queries and takes real time actions based on the application's criteria. Through service convergence across multiple domains, networks, and cyber-physical worlds, more complex service communities will be developed in the cloud and big data environments [14]
- **Dynamic On-Demand Services:** focus on mashing-up and aggregating the domain-centric services offered by the lower level in order to fulfill customer requirements which are mass individualized or extremely diverse. Matching reliable demand-oriented services with the customer requirements is an important factor in this layer, as it is highly tuned to value creation of the big service customer.

4 IOT BIG SERVICES

IoT Big services are basic components for IoT mashup applications which are integrated and context-aware applications. These services can be qualified as IoT big services. IoT Big services are described in their turn as managed integration of a various data-centric services. They allow to enhance the adaptability and extensibility over data diversity and heterogeneity, and facilitate the interpretation of low level data into more useful knowledge to better understand

[1]http://www.hotelmanagement.net/tech/how-smart-cities-are-leading-way-to-smart-tourism

and manipulate big data [11] To deal with IoT mashups, Iot big services should be of scalable and extensible design due to the high diversity of data-centric IoT resources. Moreover, to meet various requirements, there can exist different ways to compose data-oriented IoT big services. Accordingly, in IoT environments, such integration model based on diverse domain-specific service composition scenarios is considered as a big challenge. In addition, IoT big services need to support context-awareness particularly spatio-temporal aspects since the dependency between sensing data and the physical environment is tight.

Regarding current service integration solutions for large-scale environments [5], they are more focused on the communication protocols and technologies and are not adapted to on-demand service integration for data-centric services. Therefore, we adopt the notion of Big Services for the IoT view to propose a novel service composition design model for IoT mashup applications.

This is analogous to typical graph-based service access structures. However, the hierarchical top-down access to IoT services is hardly achievable by a general graph-based modeling of IoT services. The graph-based model applies to cases in which a single IoT service needs to be associated to several contexts which are not hierarchically linked. The tree-based service access model enables more efficient distribution of data processing services. Moreover, the tree structure is a multi-rooted to meet different service composition scenarios needed by an end-user IoT mashup application or encapsulated in other applications based on the same set of IoT devices.

The abstraction composition model for IoT mashup applications based on big services is presented in figure 2. Edges between nodes illustrate information flow from low-level smart city devices to high-level integration of sensor data at the smart application level. This model reflects a free-flowing from low-level IoT devices to high-level integration of big service for IoT mashup applications creation.

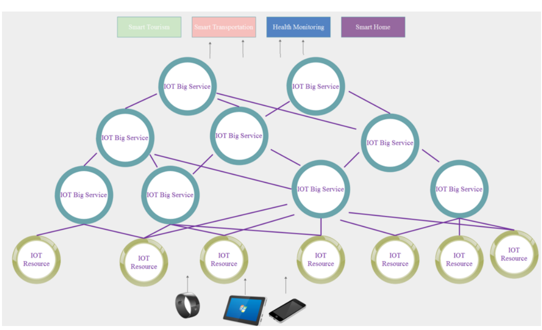

Figure 2: Design model for IoT mashup applications

As shown in figure 2, the middle level represents IoT big services that are mainly in charge of integrating services exposed by the services at the next level down in the tree, processing the service's data, and sending the output to the service node at the level above. For data processing, the Big service applies either inherited composition logic functions from the level above, or defined ones for the current level. The top level represents mashup applications integrating domain-specific Big Services and employing the necessary data processing functions. Hence, we consider multiple Big services for the integration based on the diversity of on-demand Big Services. For instance, in a smart tourism application, an on-demand Big Service is the composition of several domain-specific services in the tourism domain. i.e., the travel related data can be coupled with the transportation system to help tourists planning their trips.

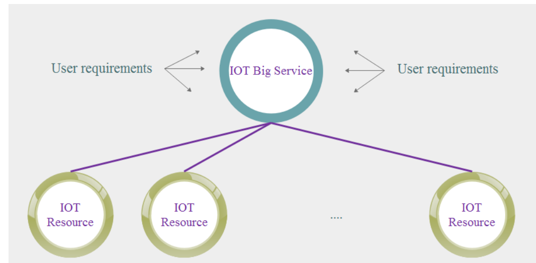

Figure 3: IoT Big service concept

First, the Big Service framework invokes service discovery process to find lower level Big Services, then it applies aggregation functions to create the concrete service composition plan. When a Big Service receives a request from other services in the system, it executes the service composition and returns the results to the requesting service.

Execution of a composition consists of sending invocations to each individual lower level Big Service and applying the appropriate data processing functions during the composition taking into consideration the user's requirements as depicted in Figure 3. This is performed using configuration theory which is one of the most successful applications of AI theories [10]. It consists of selecting from a set of components those that satisfy a set of requirements and obey to a set of constraints, as depicted in our previous work [2]. As individualized requirements are more and more increasing nowadays, we believe that this technique can be an adequate solution for composition problem in the context of mass customization in IoT environments. Thus, IoT Big services nodes apply configuration techniques as a composition model for aggregating services to create customized mashup applications. This will allow a flexible selection process of best candidate data and services to satisfy user's requirements.

5 CONCLUSION

As increasing amount of data generated by IoT systems, there is a need for provisioning scalable data centric services that can be freely composed to create IoT mashup applications . Thus, the problem tackled is how to provide a transparent access to a huge number of IoT resources and how to integrate the great amounts of the resulted data.

We propose in this paper a design model for IoT mashup application based on IoT Big services to speed up data processing in large-scale environments. In this model, all service are linked together in a hierarchical manner. The Big Service is responsible of integrating services exposed by its subordinate services, processing the service's data and sending the output to the aggregating service. Since multiple and diversified user requirements in IoT environment, we apply configuration technique that allow mass-customization to create dynamic on-demand service. Our work in progress concerns the implementation of our model in tourism domain for smart Loire project aiming to help tourists for planning for their trip in Loire Valley region in France.

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