A Gateway based Fog Computing Architecture for Wireless Sensors and Actuator Networks

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Abstract—**The technologies of Internet of Things have been wide used in many areas such as intelligent building, logistics, security, and health. One of the key elements of the Internet of Things is Wireless Sensors and Actuators Networks(WSANs). Fog computing, the new concept of the cloud at the edge of the network, is considered the appropriate platform for many Internet of Things services and applications. In this paper we present a gateway based fog computing architecture for WSANs and argue that the key requirements of this architecture. This architecture mainly consists of master nodes and slave nodes, and manages virtual gateway functions, flows, and resources.**

***Keywords*— Internet of Things, Fog Computing, Wireless Sensors and Actuators Networks, Gateways, Virtual Functions**

I. INTRODUCTION

Internet of Things(IoT) is a huge global information system composed of many objects that can be identified, sensed and processed based on standardized and interoperable communication protocols. IoT services and applications are Connected Vehicle, Smart Grid, Smart Cities, and Wireless Sensors and Actuators Networks(WSANs). The stakeholders of the IoT envision all aspect of our life to be covered by smart things. The smart sensors are the typical exemplar of such smart things. One of the good examples as smart things, Radio-Frequency identification (RFID) or Auto-ID, is a wireless non-contact system using radio-frequency electromagnetic fields to transfer data from a tag attached to an object for the purposes of automatic identification and tracking. Traditionally, tags are attached to items in supply chain for the purpose of identification, monitoring, and security. IoT represents the future of the connectivity and the reachability in this regard.

Many standards, protocols and platforms have been developed in order to integrate and visualize the networked things. Such examples are Web of Things, oneM2M, Cloud of Things and so on. The Web of Things is used to describe approaches, software architectural styles and programming patterns that allow real-world objects to be part of the World Wide Web. The concept of this reuses the Web standards to connect the embedded devices built into the networked things. Well-accepted and understood standards such as URI, HTTP, REST, RSS, etc. are used to access the functionality of the networked things. oneM2M is the global standards initiative for Machine to Machine Communications and the Internet of Things. Machine to Machine(M2M) refers to technologies that allow both wireless and wired systems to communicate with other devices of the same type. M2M is considered an integral part of the IoT and brings several benefits to industry and business.

In general, most the IoT requires mobility support, location awareness and low latency. Some researches argue that a new platform, fog computing, is needed to meet these requirements [1][2]. Fog computing is proposed to enable computing directly at the edge of the network, which can deliver new applications and services especially for the future of Internet [1].

Applications of fog computing are Connected Vehicle, Smart Grid, and Wireless Sensor and Actuator Networks. In this paper, we are focusing WSANs as an application of fog computing in regarding the information flow. The information flow in WSANs is not unidirectional from the sensors to the sink, but bidirectional between sensors and sink, and controller node and actuators. Furthermore, one of the the key elements of the Internet of Things is Wireless Sensor Networks. We present a gateway based fog computing architecture for Wireless Sensors and Actuators Networks(WSANs).

This paper is organized as follows. In the second section we introduce the fog computing and its features. The following section takes a close look at gateways and services of WSANs in favour of the fog computing. In the fourth section we present a gateway based fog computing architecture for WSANs and its application scenario. In addition, we argue that the key requirement of this architecture and their functionality. We conclude with comments about the new platform in regarding fog computing and discussion of future work.

II. FOG COMPUTING AND ITS FEATURES

Fog computing is a highly virtualized platform that provides compute, storage, and networking services between end devices and traditional cloud data centers. Bonomi[1] defines characteristics of the fog computing. Location awareness and low latency, mobility, very large number of nodes, wide-spread geographical distribution, strong presence of streaming and real time applications, predominant role time applications and heterogeneity are such characteristics. For these reasons, fog computing is considered the appropriate platform for many Internet of Things services and applications.

Fog computing is an extension of the cloud computing paradigm from the core of network to the edge of the network. There are some differences between fog and cloud computing. The latency of application is low requirements in fog computing while cloud is high. Application are gaming, video streaming, augmented reality. Important fog applications involve real-time interactions rather than batch processing. Access methods of cloud are fixed and wireless while fog is mostly wireless. The control topology of fog computing is distributed and cloud is centralized. Large-scale sensors networks to monitor the environment is an example of inherently distributed systems, requiring distributed computing and storage resources. Fog computing has very large number of nodes as evidenced in sensor networks in general.

Applications of fog computing are Connected Vehicle, Smart Grid, and Wireless Sensor and Actuator Networks. The Connected Vehicle deployment displays a rich scenario of connectivity and interactions: cars to cars, cars to access points, and access points to access points. Smart Grid is one of good examples in fog computing. It is an electrical grid which includes a variety of operational and energy measures with various nodes including smart meters, smart appliances. WSNs is another rich fog computing use case. In this paper, we are focusing on this in next section.

III. WIRELESS SENSOR AND ACTUATORS NETWORK

Wireless Sensor Networks(WSNs) consist of individual nodes that are able to interact with their environment by sensing or controlling physical parameters. WSN nodes have to collaborate to fulfil their tasks and they use wireless communication to enable this collaboration. Energy constrained WSNs advanced in several directions: multiple sinks, mobile sinks, multiple mobile sinks, and mobile sensors were proposed to meet the requirements of new applications. Some applications require actuators to exert physical actions such as open, close, move and focus. Actuators which can control a system, bring new dimensions to sensor networks. The information flow is not unidirectional from the sensors to the sink, but bidirectional between sensors and sink, and controller node and actuators.

Wireless Sensor and Actuators Network is a group of sensors and actuators linked by wireless medium to perform distributed sensing and actuation tasks. For practical deployment, a sensor network only concerned with itself is insufficient. The network rather has to be able to interact with other information devices, for example, a user equipped with mobile devices moving in the coverage area of the network or with remote user, trying to interact with the sensor network via the Internet.

However, It's difficult to connect the WSANs and the Internet with each other because it lacks of uniform standardization in communication protocols. In addition, sensing technologies and the data from WSANs cannot be transmitted in long distance with the limitation of WSAN's transmission protocols. To this end, the WSAN has to be able to exchange date with such a mobile device or with some sort of gateway, which provides the physical connection to the Internet.

A. Gateway

In the early stage of WSN era, Karl[4] emphasized that sensor networks based on TCP/IP have the advantage of being able to directly communicate with an infrastructure consisting either of a wired IP network or of IP-based wireless technology.

Typically, a wireless sensor network consists of thousands or hundreds of nodes that communicate each other with ad hoc networking. All queries from the sink node are disseminated to the sensor network, and all responses from the wireless sensor network are aggregated to the sink node. A wireless sensor gateway is placed on the route to connect a wireless sensor network to the fixed Internet, and it must provide a flexible delivery of query and response between two networks.

In order to understand gateway, we provide the the functionality of the basic and the smart gateway. A basic wireless sensor gateway satisfies the following basic requirements; sensing data aggregation, flexible query management between the web and a sensor network, and efficient access by the Internet. There are largely two parts in the basic gateway; the one is an internet access part having TCP/IP stack and a small web server, and the other is a sensor network access and management part including Sensor Data Aggregation, Sensor Query Management and Data Analysis Process. After processing in each part, the processed data is delivered to the sink node connected to the gateway through interfaces. Then the sink node disseminates the query to the sensor network. Hong[5] provides the architecture of the smart gateway. It is equipped with a full TCP/IP stack for both the IPv6 and the IPv4 protocols. It supports IPv4-to-IPv6 translation for the interoperability with IPv4 networks. In addition, it provides NTP and HTTP for the time synchronizing and applications. Recent advanced gateways provide a Web access approach to integrate network-things into the Internet. According to the rapid growth of CPU and memory technology, the performance of gateways is increasing with the evolution of software engineering. Thus, the functions of gateway are more increasing and more powerful like micro servers.

B. Virtualization

One of the the key elements of the Internet of Things is Wireless Sensor and Actuator Networks, where multiple heterogeneous wireless communications coexist: such as WiFi, ZigBee, cellular and Bluethooth. WSANs are still domain specific and usually deployed to support a specific application. Furthermore, WSANs' nodes are becoming more powerful and the applications sharing their information in heterogeneous and homogeneous WSANs are increasing. Khan[6] describes benefits of the virtualization of WSN. Related benefits are utilization, innovation, and new business model. WSN virtualization can help realize the SaaS model through cost-efficient utilization of deployed sensors. Several other motivational examples can be found in [7] and [8].

WSN virtualization can be broadly classified into two categories: Node-level virtualization, Network-level

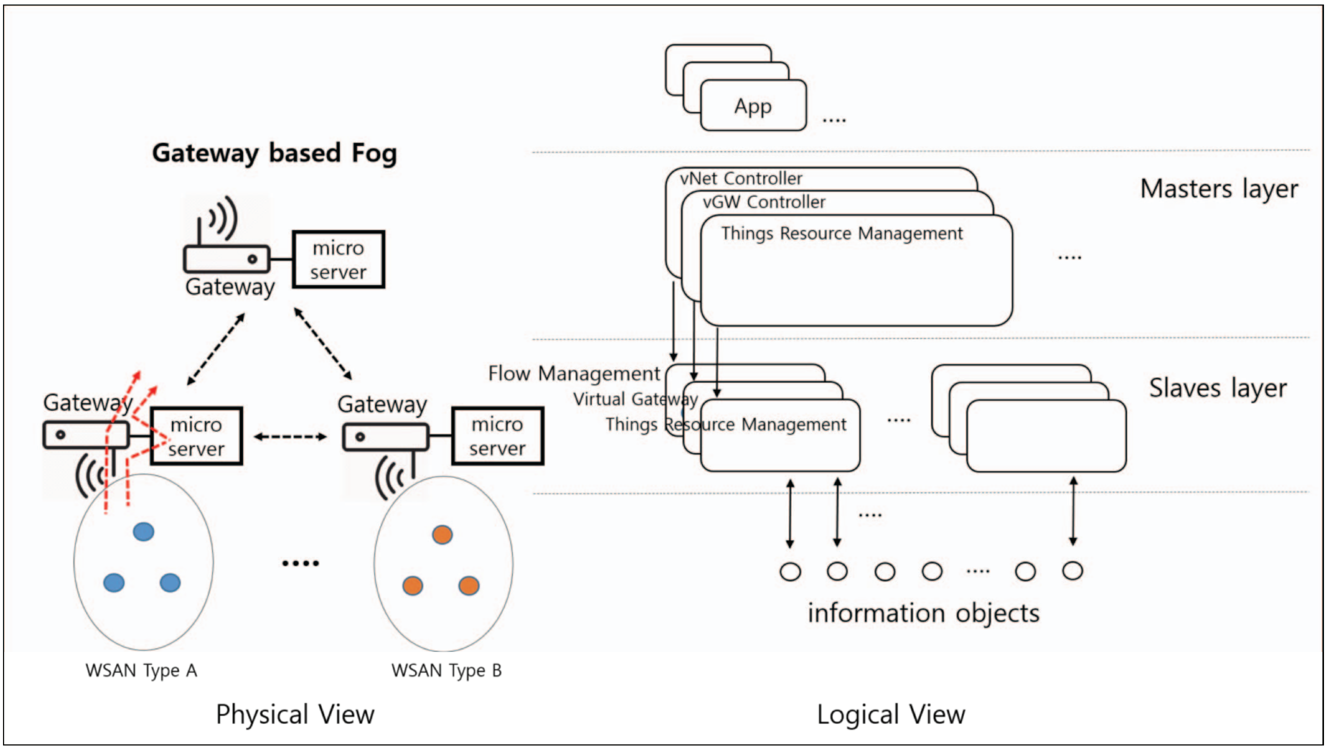

Figure 1. A gateway based fog computing architecture for WSANs

virtualization and hybrid virtualization. However, the lacks of resources in nodes is an obstacle in node-level virtualization. Network-level virtualization and hybrid virtualization are quire feasible, however, the complexity is high because of their architecture. [9] propose the Multi-layer WSN virtualization architecture consists of the data plane, the control plane, and several interfaces. Their implements are the proxy based virtualization. A virtual sensor access layer has the functional entities providing unified interfaces to support heterogeneous sensor nodes and a virtual sensor layer has the logical representation of each sensor executing multiple tasks. From their prototyping and their performance measurement, proposed architecture has the lack of scalability.

IV. PROPOSED ARCHITECTURE

We propose a gateway based fog computing architecture for WSANs. This architecture is shown in figure1 including physical view and logical view. Types of WSANs are different, such as BLE and Zigbee. This fog computing consists of the sets of gateway and micro server. Gateway can be conventional one or smart gateway with high performance and diverse interfaces. Gateway and micro server are connected by Ethernet interface. Interfaces between gateway nodes are wired interfaces and wireless interfaces such as 3G, LTE, and Ethernet.

Slave nodes have the functions including flow management, virtual gateway and resource management. Master nodes have their control functionalities. Gateways have their own role such as a master mode and a slave mode. Master node controls the virtual path of virtual gateway function located in Slave nodes. Flow management is based on software defined network such OpenFlow, and virtual function management needs to light version of NFV architecture such as ClickOS[10], a high-performance, virtualized software middlebox. ClickOS virtual machines are small, boot quickly, add little delay and over one hundred of ClickOS VM can be concurrently run on a commodity server. Proposed architecture provides the WSAN virtualization. Our virtualization model is event driven. It provides virtual event from networked objects and shares them to various applications.

V. CONCLUSIONS AND FUTURE WORKS

Fog computing, the new concept of the cloud at the edge of the network, is considered the appropriate platform for many Internet of Things services and applications along with virtualization of WSN/WSAN. We present a gateway based fog computing architecture. This is conceptual model. We need to elaborate our architecture and, implement prototype and simulate its performance. Conventional WiFi devices and OpenWrt platform are good start point for prototyping. Micro server platform will be based on Raspberry Pi. The 2-tiered distributed architecture consists of gateways in the lower tier and control masters, relatively more powerful gateway platform, in the upper layer. We will prove that this architecture provides the scalability and manageability for many networked objects.

Virtualization of WSAN is a very rich research area. How to define and find the resources, what resources are to be virtualized, and how to integrated with virtual resources are those issues. We need more research works to come up with these issues.

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