Fog Computing Architecture to Enable Consumer Centric Internet of Things Services

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***Abstract*— Fog Computing is a recent computing paradigm that is extending cloud computing towards the edge of network. Due to its proximity to end-users, dense geographical distribution, open platform and support for high mobility, Fog Computing platforms can provide services with reduced latency and improved QoS. Thus it is becoming an important enabler for consumer centric Internet of Things based applications and services that require real time operations e.g. connected vehicles, smart road intersection management and smart grid. The paper discusses one such architecture for connected vehicles with Road Side Units (RSUs) and M2M gateways including the Fog Computing Platform. M2M data processing with semantics, discovery and management of connected vehicles are briefly discussed as consumer centric IoT services enabled by the distinct characteristics of Fog Computing.**

Keywords*— *Fog Computing; Internet of Things; Consumer Centric; Smart Mobility; Connected Vehicles; oneM2M.

I. INTRODUCTION

Internet of Things (IoT) is extending the connection of Internet to embedded devices sensors, actuators and RFID tags. An estimate from Cisco[1] portrays 50 Billion of such things will be connected to the Internet by 2020. Majority of these things will be part of a much larger platform, thereby requiring high computational capabilities for M2M data processing and storage systems. Such demands will be generated by both fixed and mobile things covering a wide geographic area and pertaining to heterogeneous domains and use cases. To meet these demands, IoT platforms must have low latency, support for high degree of mobility and real time data analysis with decision making abilities. Looking at these, cloud computing infrastructure may seem as the obvious choice to deploy an IoT platform. Although cloud computing provides many benefits but also creates challenges for latency sensitive IoT applications. Several such applications (specifically those which cater to connected vehicles and intelligent transportation systems) require low latency as well as support for high mobility, real time data analytics and wide range of geographic coverage. Fog Computing is a new platform introduced by Cisco[2] and extends the cloud computing paradigm to the edge of the networks. Both paradigms provide similar set services in terms of data storage, computation etc. But the "Fog" has additional advantage due to its proximity to consumers, dense geographic coverage and mobility support. Utilizing the Fog computing platforms, IoT applications and services could be operated from edges of networks as well as from end devices like access points, set top boxes, Road Side Units (RSUs) and M2M gateways. Such efforts in turn reduce latency, improve QoS, and allow real time data analysis with actuation resulting in superior user experience and creation of consumer centric IoT products [1] [2] [3]. Additionally Fog computing saves bandwidth as data are process at the edge of network, promotes distributed architecture. Due to dense geographic coverage and distributed operations, "Fog" promotes fault tolerance, reliability and maintains scalability of the system.

The main contribution of the paper is in establishing Fog computing as consumer centric IoT service deployment platform. To further motivate that, we illustrate an IoT architecture for connected vehicles and describe how Fog computing can enable consumer oriented applications and services. The entire "Fog" architecture is integrated into an oneM2M standard architecture[3].

II. ENABLING CONNECTED VEHICLE SERVICES

This section presents an architecture (Figure 1) for IoT based connected vehicle scenarios. Such scenarios are example of rich connectivity and interactions among vehicles (V2V) and infrastructures (V2I). This domain of IoT requires services like infotainments, traffic and public safety, real time traffic analysis, support for high mobility, location awareness and wide spread geographic distribution. Such requirements point to Fog computing platforms as the ideal solutions for consumer centric applications.

The architecture comprises of – (i) virtual sensing zones with vehicular sensors acting as source of M2M data, (ii) Access points (RSU) and M2M gateways (DataTweet Box) and (iii) cloud system (DataTweet Cloud). The vehicular sensors report M2M data in a uniform format as described in Sensor Markup Language [6]. These data are communicated primarily to the RSU or M2M gateway which include the Fog Computing platform. The M2M data are sent over one-hop or multi-hop communication. The Fog Computing Platform provides the following consumer centric services.

A. M2M Data Analytics with Semantics

The M2M data generated by the vehicles and smartphones are considered as raw data. They must be treated with semantic web technologies to generate high level abstractions which could provide actionable intelligence and allow the connected vehicles to take smart decisions. For this purpose, Machine-to-Machine Measurement (M3) Framework [4] is deployed at the RSUs and M2M gateways. The framework receives the sensor metadata in SenML format and generates "inferred" data. The framework also provides IoT application templates which can propose user centric cross-domain applications based on the sensor metadata and domain information. Use of semantics also promotes interoperability at M2M data processing. The connected vehicles could request a particular service from the

[1] http://share.cisco.com/internet-of-things.html
[2] https://techradar.cisco.com/trends/Fog-Computing
[3] ftp://ftp.onem2m.org/Deliverables/20140801_Candidate%20Release/TS-0001-oneM2M-Functional-Architecture-V-2014-08.pdf

M3 framework. Since it is receiving M2M data from numerous vehicles, it can provide smart mobility services enabling highly autonomous vehicles in optimizing the path taken to destination.

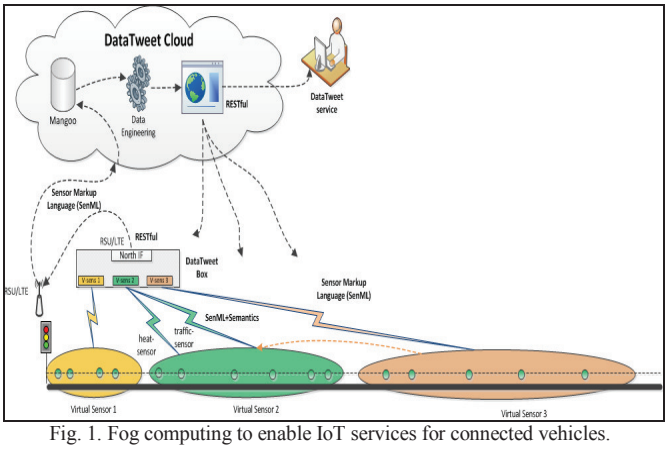

Fig. 1. Fog computing to enable IoT services for connected vehicles.

B. *Discovery*

Discovery is another consumer centric IoT service facilitated by the proposed Fog Computing platform. The discovery module looks for information about the applications and services provided by the RSUs and M2M gateways. The connected vehicles requesting for specific services are initially routed to the discovery module for the information in its database. If the nearest RSU or the gateway does not provide the requested service, then the service request is routed to the platform which provides the same. For highly autonomous vehicles, this is possible due to low latency and wide geographic distribution criteria of Fog Computing platforms.

C. *Management of connected vehicles*

Another highly desirable criteria for consumer centric connected vehicle services is the management functionality. We have developed a framework based [6] on OMA Lightweight M2M Technical Specifications which supports high mobility of M2M devices (vehicles in this case). The framework allows the consumers to interact with the vehicles to read, write and update sensor configurations. Also there is a provision for automatic management of connected vehicles to keep track of mobility through Fog Computing platforms.

III. Integration in oneM2M Architecture

The Fog computing platform is integrated into recently released oneM2M architecture. The prototype architecture is shown in Fig. 2. The field domain comprises of (i) physical things which belong to the vehicles, (ii) middle node which is the M2M gateway i.e. the DataTweet Box and (iii) the application service node which houses the end user mobile application. The infrastructure node comprises of the remote cloud system which provides additional services at the core of the network. The main "Fog" platform is deployed at the middle nodes which are tactically placed at the edge of the networks. The mentioned connected vehicle services are integrated in the architecture components as common services functions (CSF).

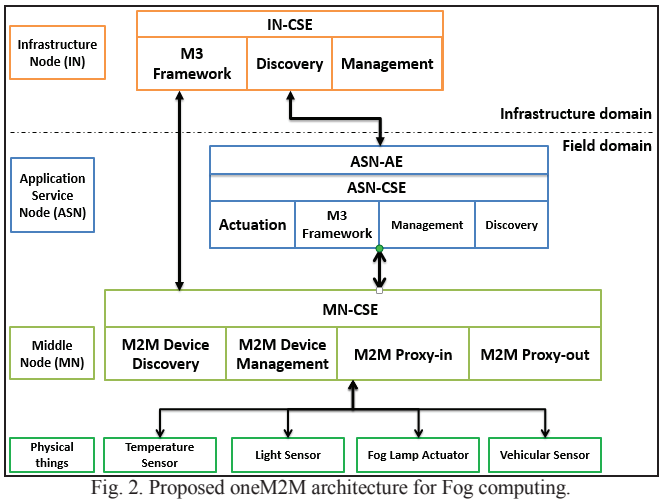

Fig. 2. Proposed oneM2M architecture for Fog computing.

IV. Conclusion

In a nutshell, the paper discusses advantage of Fog Computing paradigm and how they can offer consumer centric IoT services. To motivate that, an architecture is presented for connected vehicles where the "Fog" platform is deployed at the RSUs and M2M gateways. Due to its characteristics, such architecture enables consumer centric services like M2M data analytics with semantic web technologies, discovery of IoT services and management of connected vehicles. The "Fog" platform is also integrated into the oneM2M architecture. As of future work, we are extending the platform for data management and repository, application and service management and crowdsourcing of vehicular data.

Acknowledgment

The authors acknowledge the fruitful discussions with colleague Amelie Gyrard. The paper is supported by French research project DataTweet[4] (ANR-13-INFR-0008).

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