An IoT based Monitoring Framework for Software Defined 5G Mobile Networks

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ABSTRACT

This paper presents a new approach for comprehensive monitoring of software defined 5G mobile network by using IoT (Internet of Things) based framework. The proposed framework gives much easier implementation of monitoring system for mobile network operators. Moreover, the framework uses a unified IoT protocol for telemetry transport, which is light, data-agnostic, and interoperable.

CCS Concepts

• **Information systems →Database management system engines; 300**

Keywords

IoT, SDN, NFV, MQTT, knowledge management, network monitoring.

1. INTRODUCTION

1.1 Rapid Growth of IoT and Smart Systems

Modern society and economy are driven by information. Delivery of relevant data and ability to analyze these data in an appropriate way create the intelligence of any system. With the advent of IoT a lot of new unusual devices have been connected to the global network [1]. Some of them generate a lot of data, which are used to create a variety of smart systems such as smart city, smart health care, smart transportation, smart manufacture, etc. The key features that distinguishes smart system are the ability to analyze the data, create a knowledge about specific processes and apply this knowledge to the target object.

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IMCOM '17, January 05-07, 2017, Beppu, Japan
© 2017 ACM. ISBN 978-1-4503-4888-1/17/01…$15.00
DOI: http://dx.doi.org/10.1145/3022227.3022331

1.2 The Concept of Software Defined Network

Whereas IoT systems use the mobile networks to become smarter, the mobile network itself is not smart at all. In order to assess this issue a concept of software defined network (SDN) was introduced for mobile networks [2]. SDN technologies aim at decoupling networks by shifting the intelligent part from physical nodes to the cloud. Recent studies have shown that SDN is highly perspective technology to improve the performance of 5G mobile network by coordinated use of available small cells and interference aware spectrum allocation [1, 2]. SDN is able to make cognitive decisions on network configurations by using data from lower layers.

1.3 Improving the Network Intelligence by SDN and IoT

Existing SDN technologies are still away far from being smart due to lack of knowledge on the overall network performance. To improve the intelligence of SDN, much more parameters should be taken into account such as traffic statistic for each cell, service requirements for each user, efficiency of spectrum utilization, signal quality indicators of each user and many others. All these data should be acquired in real-time, stored for a long period and analyzed in a proper way [3]. Combination of current and previous data allows to create a comprehensive knowledge on network functionality and performance. Therefore, new approaches are required for monitoring the 5G mobile network with high scalability, good interoperability, and low overhead. There are many approaches developed for network monitoring and control [4-6]. However, most of them produce a heavy overhead on network. In addition, some of them are proper for and can work only with specific equipment or one network operator. In this paper, we propose a new IoT framework for network monitoring based on data collection from end devices. The key feature of proposed framework is that it is based on independent IoT system and can be shared by multiple mobile network operators.

2. COMPREHENSIVE NETWORK MONITORING BY IOT FRAMEWORK

The proposed framework is based on data acquisition from target devices. These devices can be either user equipment (smartphone, tablet, etc.) or network equipment (base station, router, SDN controller, etc.). The list of parameters for monitoring is not limited to specific values and can be enhanced on behalf of mobile network operator. For our example we have selected the most important parameters of radio access network: carrier frequency, used spectrum band, cell ID, user velocity, etc. In addition, a few parameters are selected for metadata to arrange the database in correct order. These parameters are timestamp, latitude, longitude, etc.

2.1 Software Defined Mobile Network Architecture

The general architecture of the proposed system consists of four planes: radio access network (RAN), core, control and knowledge. RAN plane is responsible for "last mile" wireless access for end users. Core plane provides the functions of quality assurance, billing and secured access. All functional elements of network core are virtualized in a cloud by using NFV (Network Function Virtualization) technology [7]. Control plane consists of SDN controller (or multiple SDN controllers), which is responsible for spectrum management, load balancing, traffic routing, mobility management and coverage planning by applying available knowledge on 5G network state [8]. In this paper, we introduce the additional knowledge plane that is responsible for knowledge creation and management by using context aware data analytics.

We also introduce an IoT monitoring framework for data acquisition from each network plane. The IoT framework collects data from network units (i.e. things) and provides these data to the knowledge plane. The architecture of software defined 5G network with IoT monitoring framework is shown in Fig. 1.

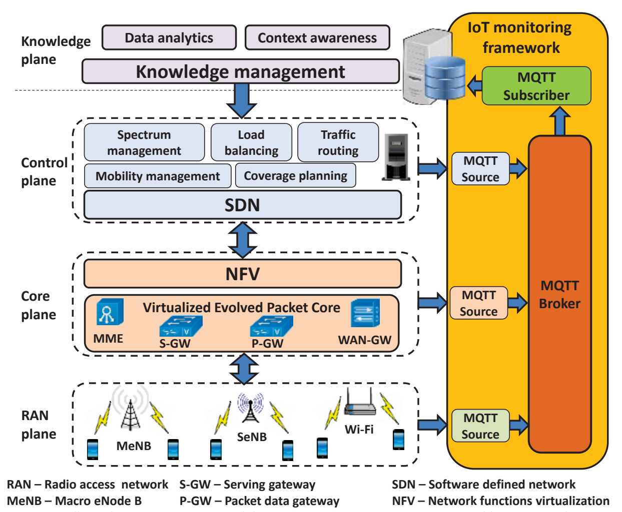

Figure 1. Architecture of Software Defined 5G Network with IoT Monitoring Framework

RAN plane. RAN plane consists of small cells and macro cells, Wi-Fi access points and D2D (Device-to-Device) connections. This plane encompasses all the functionality of signal processing, data encoding and modulation, users scheduling and wireless transmission. However, in difference to conventional mobile network, in software defined mobile network all complicated computing tasks are not performed by each node independently. Instead, control plane decides the configuration of all transmitters such as user spectrum, type of modulation and transmission scheduling.

Core plane. In terms of functionality, core plane is very similar to the LTE-EPC (Long Term Evolution-Evolved Packet Core). It encompasses the packet and service gateway, edge routers and mobility management entities. Core plane is intermediate between control plane and RAN plane, and it is responsible for traffic aggregation from all the base stations, mobility management of users and some functionality of AAA (authentication, authorization and accounting). Moreover, this plane is also interacting with other public networks to provide access to the world area network (WAN).

Control plane. The main responsibility of control plane is to provide network intelligence by using advanced algorithms of load balancing, spectrum sharing, channels allocation, etc. The complexity of network management is in the large amount of data, which are needed for SDN controller to make effective decisions on network configurations. In order to acquire the data on network condition, it is necessary to monitor all network nodes simultaneously including both network side equipment and user side equipment. This is quite a complex problem, because conditions in mobile network are rapidly variable due to high mobility of users. Control plane is intermediate between knowledge plane and core plane. The main responsibilities of control plane are to apply the knowledge on network behavior and effective configuration obtained from knowledge plane by SDN controller. According to the gained knowledge, SDN controller performs load balancing, RAN reconfiguration and spectrum reallocation in order to improve the network performance and satisfy users experience [9,10].

Knowledge plane. Knowledge plane consists of high-performance servers and databases, which are used to collect the data. The important function of knowledge plane is not only to collect the data, but also to process these data according to the fundamentals of wireless communication theory. For example, knowledge plane is able to detect when network performance are becoming worse when something changes in the channels allocation, severe interference appears or some cells are facing traffic overloads. Our proposed IoT monitoring framework are aimed to improve the network intelligence by feeding the knowledge plane with variety of data from network monitoring and reducing the overhead of monitoring data compared to conventional monitoring approaches. The detail principle of the proposed monitoring framework is depicted in Fig. 2.

2.2 Description of the Proposed IoT Monitoring Framework

The monitoring framework is designed in a way of collecting any type of data in a cloud database, either in text or numerical form. All data, which are sent to the remote database are coming through MQTT (Message Queuing Telemetry Transport) that allows to select exactly only. This feature opens up a lot of opportunities for operators to customize the monitoring system according to their demands in target deployment area. Obtained information is transformed into knowledge by using advanced data processing. By using this knowledge, SDN controllers makes the decisions on network reconfiguration according to current conditions. Moreover, in our system the collected data are stored for the unlimited period and statistic is available for later use by SDN controller in order to train the knowledge plane for better decision making. Due to the low amount of monitoring data it is possible to collect the statistics through few years period that is helpful to predict traffic behavior and prevent cells overload. In order, to simplify load balancing and spectrum allocation on the control plane, spectrum and RAN are virtualized by using NFV.

For data acquisition we use MQTT [11]. MQTT is the light weight TCP (Transmission Control Protocol) based open protocol designed for IoT systems. The advantages of MQTT are that it is easy to implement, guarantees data delivery, agnostic to transmitted data, produces low overhead and works during long session periods. MQTT consists of three main parts namely MQTT source, MQTT broker, and MQTT subscriber.

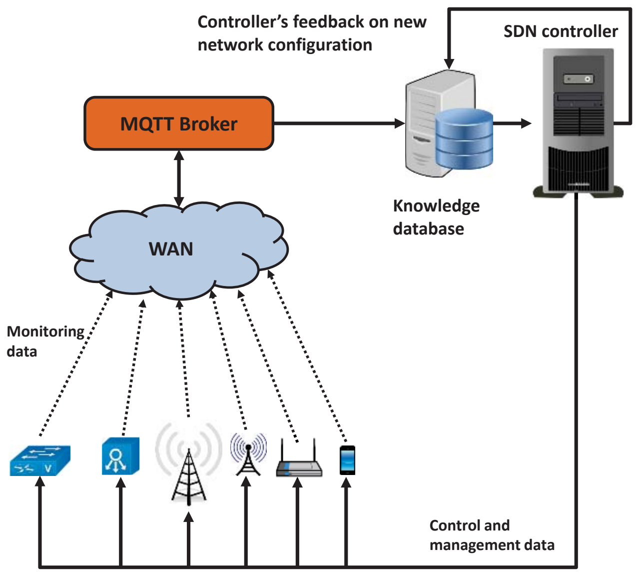

Figure 2. Principle of Network Monitoring Process by Proposed IoT Framework

In our system, all network units are MQTT sources, which send all acquired data to the MQTT broker. Data are separated by different topics, i.e. signal strength, frequency band, used service, etc. The metadata (timestamp, latitude, longitude) are tied with each item of network data to ensure correctness of the produced knowledge. MQTT broker forwards all the data to the MQTT subscribers according to their subscriptions. In order to reduce overhead we suggest subscription only for necessary data, which will be useful in knowledge generation process. The proposed framework supports many MQTT subscribers and thus can be used for multi-operator 5G networks. Each network operator is able to subscribe only necessary data in IoT framework and do not have to create his own bulky monitoring system.

Another advantage of the proposed monitoring framework lies in small size of transmitted data blocks (less than 1 KB) and low traffic overhead. Fig. 3. shows the experimental result of signal strength monitoring from macro cell and small cell by using our proposed framework. Experiment was conducted with 140 users in the university campus. The studied area is covered by macro cell and small cell. Total of transmitted data volume is 4200 Kb. Size of transmitted data unit per user is 30 bytes.

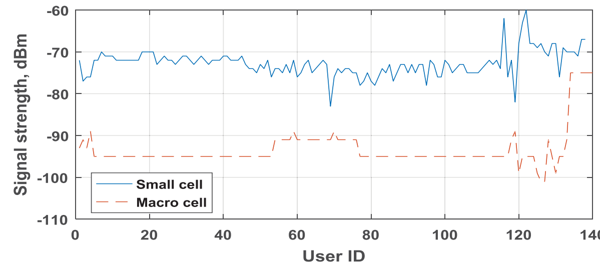

Figure 3. Simple experimental example of proposed IoT monitoring framework

Existing networks support data rates from tens to hundreds Mbit/s, while 5G is expected to provide tens of GBit/s. Thus, the overhead of our proposed IoT framework will be neglected by both RAN and core network. Nevertheless, the total amount of data volume will be massive and diverse. Therefore, knowledge plane will be able to generate the knowledge on current network conditions and predict further important corrections, which should be made by SDN controller to maintain the required network performance. SDN uses the knowledge to allocate the spectrum with interference awareness, balance the load of small cells, handle the mobility of users, etc.

3. CONCLUSION

Monitoring of 5G network by using the proposed IoT framework opens a lot of new opportunities to the mobile operators. Available statistics collected through long period, is useful to predict network behavior, prevent overloads, and maintain the quality of user experience. In our further work, we aim to develop more advanced practical applications of IoT framework for knowledge-based 5G mobile networks.

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