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Working of Software Defined Networking (SDN) based devices using Cloud Computing

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Abstract:-Proposes a wireless Software Defined Networking (SDN) solution for M2M gateway based on the cloud environment. The proposed approach takes the advantage of SDN in separating the control plane from the data plane in network devices and running the software component on centralized M2M gateway connected to the cloud. The proposed approach validated through experimental analysis testbed, the obtained result shows that SD-M2M gateway reduces the end-to-end delay by approximately 24% and 15% compared to M2M gateway without SDN in terms of data gathering and control command sending respectively..

I. INTRODUCTION

The number of embedded devices has exponentially in-creased in recent years. In the year 2020, the number of connected devices expected to be more than 50 billion device connected to the Internet [1]. Wireless networks will be the backbone for the connected devices, accordingly, more machines than people will be deployed across the world and Machine-to-Machine (M2M) technology will be the promising technology for energy and cost-efficient applications. M2M communication represents the communication between de-vices without (or with limited) human intervention to mon-itor/retrieve an event, which is forwarded through a network to an application, that interpreted the monitored event into useful information [2].

Traditionally, such connected devices have worked locally and provided services for human users in an independent way. Advances in radio communication technologies have enabled more connectivity such as Radio Frequency Identification (RFID) and low power wireless personal area network (LoW-PAN) to connect these devices to the Internet and provide global connectivity, which can also be called as Internet-of-Things (IoT) [3].

The merging of M2M networks in the IoT produces new applications for remote measurement and remote control of the connected devices. Remote measurements represent the sensing process of the physical phenomenon then storing and sending the data to extract the useful information. Where the remote control of devices includes processing the received data and sending or receiving control commands among the connected devices.

The development in the connected household devices (e.g., PCs, tablets, smart phones, multimedia gateways and smart TVs) makes the home networks more complicated, with the diversity of the user applications (browsing, video streaming, VoIP and interactive games) a new approach for home gateway is needed to handle the different user applications and utilize the sharing connection to the Internet.

The proposed approach is this paper integrates the SDN benefits and M2M communication connectivity advantages with the cloud computing facilities to provide global remote monitoring and control for the home appliances through the home automation gateway from web based portal.

The rest of this paper is organized as follows: Section II gives an overview for Software Defined Networking (SDN) technology, while Section III gives a clear introduction to cloud computing architecture. Section IV summarizes the liter-ature review of exciting related works. Section V provides the detailed steps of the proposed software defined-M2M gateway. Section VI describes the obtained results and discussions. Finally, the conclusions are presented in Section VII.

II. SOFTWARE DEFINED NETWORKING

The idea of programmable networks has been developed as new way to facilitate the network management and con-trol. Software Defined Networking (SDN) was developed to enable simple management and control of the network data-path. SDN is a new networking paradigm in which control plane is decoupled from data plane. The separation of the forwarding

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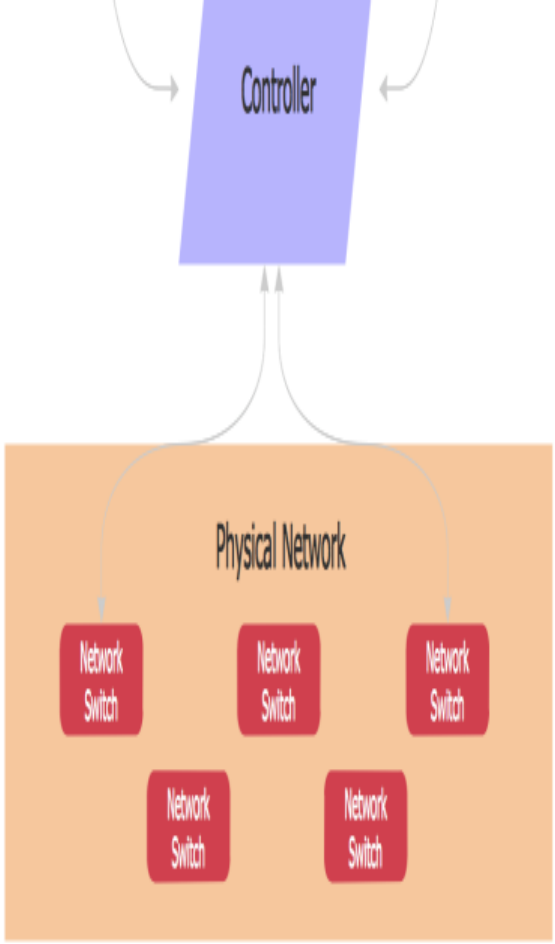

CLOUD COMPUTING

The term cloud computing refers to the delivery of computing resources over the Internet. The data are stored in a remote location instead of storing them locally and can be accessed via the Internet. The cloud has no borders and has global communication paths. Accordingly, the data can be accessed from everywhere to deliver a service to other people from anywhere else [6].

Fig. 2. Cloud computing architecture

Fig. 2 shows the cloud computing architecture where the shared pool of resources can provide different services for the connected users. The cloud computing architecture consists of three main parts :

1. Front end platform represents the visible part of the network for the client including the infrastructure of the network that is used for accessing the cloud system
   1) Connected network represents the Internet connection that provide global access between front end platform and back end platform
   2) Back end platform represents the service provider side where various servers and data storage systems are installed with different dedicated applications to manage each server

IV. RELATED WORKS

The topics M2M, SDN and cloud computing are the hot research areas in recent years and many researchers focus on how integrating them to achieve seamless connectivity and balance the traffic load across the network. for example, the approach proposed in [8] represents the first effort that synergies SDN and wireless sensor networks (WSN), which aims to tackle the inherent problems of WSN such as rigidity to policy changes and difficulty to manage by developing Software-Defined WSN architecture and Sensor OpenFlow to address key technical challenges for its core component.

The authors in [9] show the possibility of improving the M2M network load balancing by using SDN, they propose a traffic-aware load balancing mechanism that is able to adopt different Quality-of-Service (QoS) requirements by instant traffic identification and dynamic traffic rerouting, the proposed approach is able to dynamically monitor and control the entire M2M network.

The authors in [10] propose cloud networking gateway (CNG) manager to distribute cloud resources by authorized customers and achieve network control and configuration capabilities using any kind of underlying networking technology. The CNG manager is integrated with a Cloud Broker architecture for evaluation in the multiple providers context.

The approach in [11] leverage the emerging paradigm of SDN to provide certain level of control to the users in order to manage the service quality for specific devices and applications in their household. Video, web-browsing, and large downloads are the three main applications used to evaluate the proposed approach via experiments in a laboratory testbed.

The authors in [12] propose smart management system using SDN in WSN. The proposed architecture illustrates the implementation of the SDN controller in the base station (sink node), also, the authors argue that the developed approach

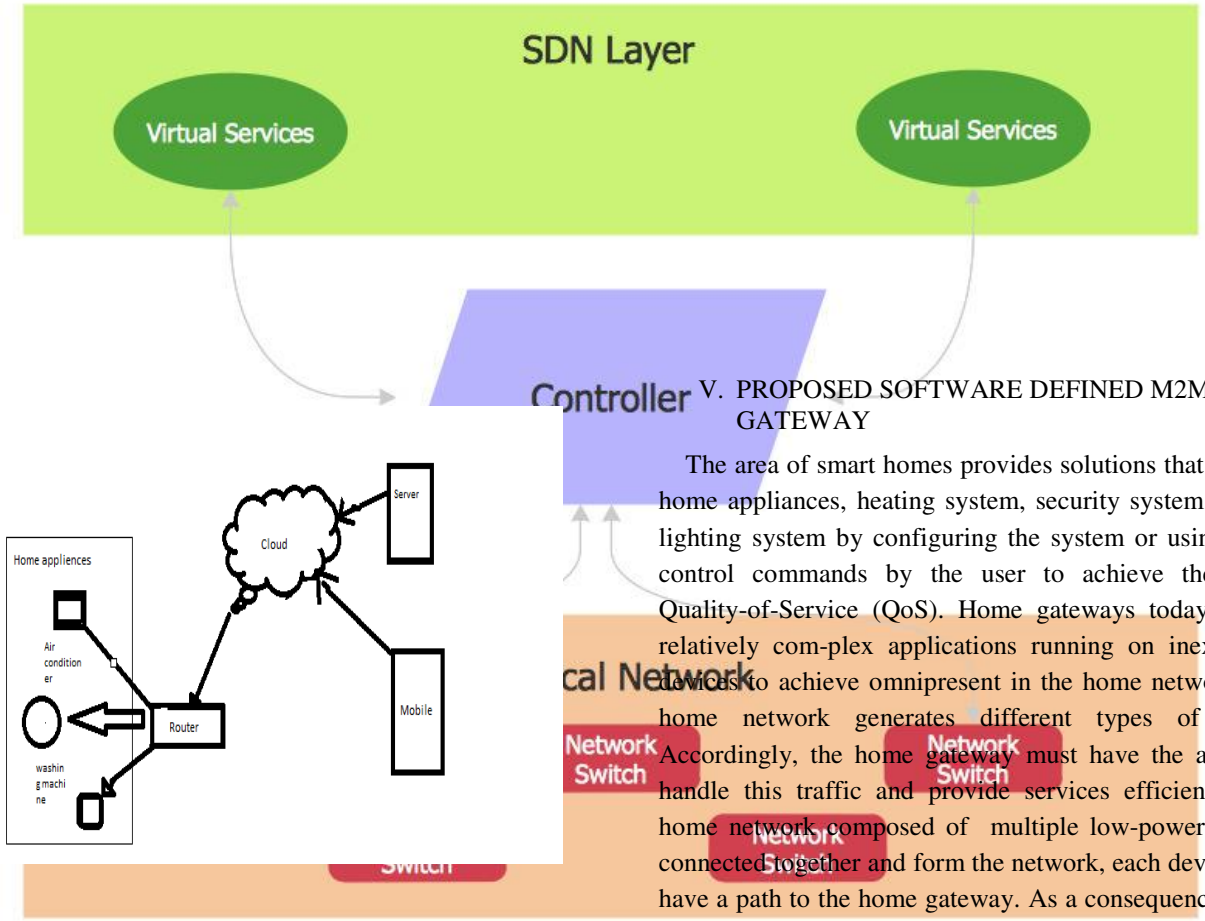

Fig. 3. Proposed SD-M2M home automation gateway Architecture

The [14] is a case study of energy management system (EMS) applied to building of Electrical Engineering Depart-ment at Assiut University, the proposed system consists of two parts. The first part is an energy management unit (EMU) which is implemented using NI LABVIEW software and XBee PRO ZigBee module to communicate with sensor nodes. The second part is sensor nodes which are implemented using Arduino Uno microcontroller, XBee-PRO ZigBee module and the ACS712 current sensor.

As mentioned above, despite of the SDN brings new op-portunities to improve load balancing and utilize the network resources, it also costs extra overhead due to continuous update of flow tables. This scenario become a problem for massive number of M2M nodes connected through the same gateway. To overcome this problem, a new cloud based connectivity with M2M communication and customized SDN controller approach has been proposed for home automation applications.

V. PROPOSED SOFTWARE DEFINED M2M GATEWAY

The area of smart homes provides solutions that monitor home appliances, heating system, security system or even lighting system by configuring the system or using direct control commands by the user to achieve the user's Quality-of-Service (QoS). Home gateways today deliver relatively com-plex applications running on inexpensive devices to achieve omnipresent in the home network. The home network generates different types of traffic. Accordingly, the home gateway must have the ability to handle this traffic and provide services efficiently. The home network composed of multiple low-power devices connected together and form the network, each device must have a path to the home gateway. As a consequence, M2M technology provides such a connectivity between the low-power devices and the home gateway. M2M and IoT gateways narrow the gap between devices in the home network and the cloud, where data is collected, stored and can be accessed from anywhere by anyone.

The home user may want to have certain services without changing the hardware devices, as a result, the home gateway need to be programmed to adopt proprietary communications protocols or customized existing protocols. The main concept of SDN is the separation of the control plane from the data plane, this feature allows home network to be more dynamic and centralized control. Using SDN capabilities, the flow table contains the M2M traffic pattern that leaves the home to be directed to the correct service provider. As an example, the smart meter measures electricity and the usage data being directed to cloud solution provides by the electricity providers, this approach will increase the network performance and reduce end-to-end delay.

Fig. 3 shows the detailed architecture of the proposed Soft-ware Defined-M2M (SD-M2M) home gateway, the home net-work consists of M2M nodes equipped with radio transceiver (XBee Series 2 Module) to form a star topology with the personal area network (PAN) coordinator, the PAN coordinator and SDN controller are

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located in the SD-M2M gateway. The SD-M2M gateway has two communication paths, one with the local network through the southbound interface of the SDN controller and the other with the Internet (wire or wireless) and used by the northbound interface of the SDN controller. The home gateway is responsible for local data collection and running

user propitiatory protocols. The data aggregator located in the cloud responsible for online data analysis, visualization and reporting. The exploratory analysis can be done either by retrieve the data from the cloud and analyses it locally or through the deployment of cloud data analytics. The user can access the SDN controller through the control API in the cloud and deploy different algorithms or adjust the required QoS parameters of the home network.

The proposed approach has been tested and verified by experimental analysis of the home network testbed, the M2M nodes have been implemented in two types:

1. Simple M2M node has the ability to sense and send the data to the PAN coordinator without any processing or network intelligent capabilities
2. Developed M2M node has the ability to sense, process and send the data to the PAN coordinator with network intelligent capabilities such as bi-directional communica-tion and run complex routing algorithms

where the SD-M2M gateway has been implemented using MATLAB installed on PC running Windows 7 with XBee module, while the remote exploratory end has been imple-mented using MATLAB installed on another PC running Windows 7. Both sensor nodes types are equipped with XBee series 2 module for low rate data transmission and sensing unit. [5] proposed a novel scheme for mobile Television services over WiMAX network, called the Wireless Switched Digital Video (WSDV) scheme, is proposed. Compared with the conventional broadcast or unicast schemes, the hybrid approach introduced in the proposed WSDV approach exploits the merits of two conventional schemes and mitigates their demerits, which enables it to increase wireless capacity for mobile Television services.

The SDN controller information must fit the link layer frame of the IEEE 802.15.4 standard and not exceed 127 bytes, also, the increase in control messages will increase the energy consumption in battery powered simple M2M nodes. Our proposed system data flow can be divided into four stages:

First Stage (Sensing) where the M2M nodes sense the environmental data like temperature and light intensity to turn on or off the air conditioning system or lighting system respectively

Second Stage (Sending) after the data has been sensed the SD-M2M gateway collect the data and make data fusion to reduce the number of transmitted packets to the data aggregator in the cloud

Third Stage (Visualization and Reporting) when the data has been sent to the cloud, there is a built in add-on provided by the cloud provider to visualize the received data and store the data for future retrieve

Fourth Stage (Retrieving and Modification) the end user can retrieve the data from the cloud, after analyzing the data, the user can send control messages to the controller via the cloud to modify home network parameters. The main challenges in this approach are: (i) SDN imple-mentation in wireless networks; (ii) smaller link layer frames of the IEEE 802.15.4 standard; and (iii) limited energy supply in simple M2M nodes. The main contributions in this work include the design and implementation of customized wire-less SDN controller framework that enables cloud computing within M2M network in SDN environment. The customized controller aims to reduce end-to-end delay and enhance net-work performance. The testbed experiments were conducted on MATLAB simulator and ThingSpeak cloud platform [15].

VI. PERFORMANCE EVALUATION RESULTS

Different vendors of M2M sensor nodes is not only the main cause of incompatibility problem, but also the

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different nodes architectures. These problems have been solved by building the proposed M2M gateway with the SDN technology. Two M2M home gateways have been implemented, Gateway #1 contains the customized SDN controller and PAN coordinator, while the Gateway #2 contains only the PAN coordinator of the legacy M2M sensor network.

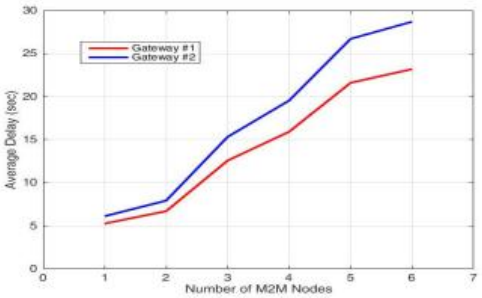

Fig. 4. Average delay for reading sensor nodes from M2M gateway

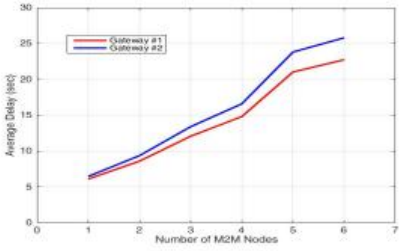

Fig. 5. Average delay for sending control command from M2M gateway

Fig. 4 shows the experimental results for the average delay time to read sensor's data, its clear that the proposed SDN approach reduce the end-to-end delay for reading sensor nodes data by 23% in Gateway #1 compared to delay experienced in legacy network connected to Gateway #2, because SD-M2M gateway handles more simultaneous packets and reduce the processing time through the centralized controller.

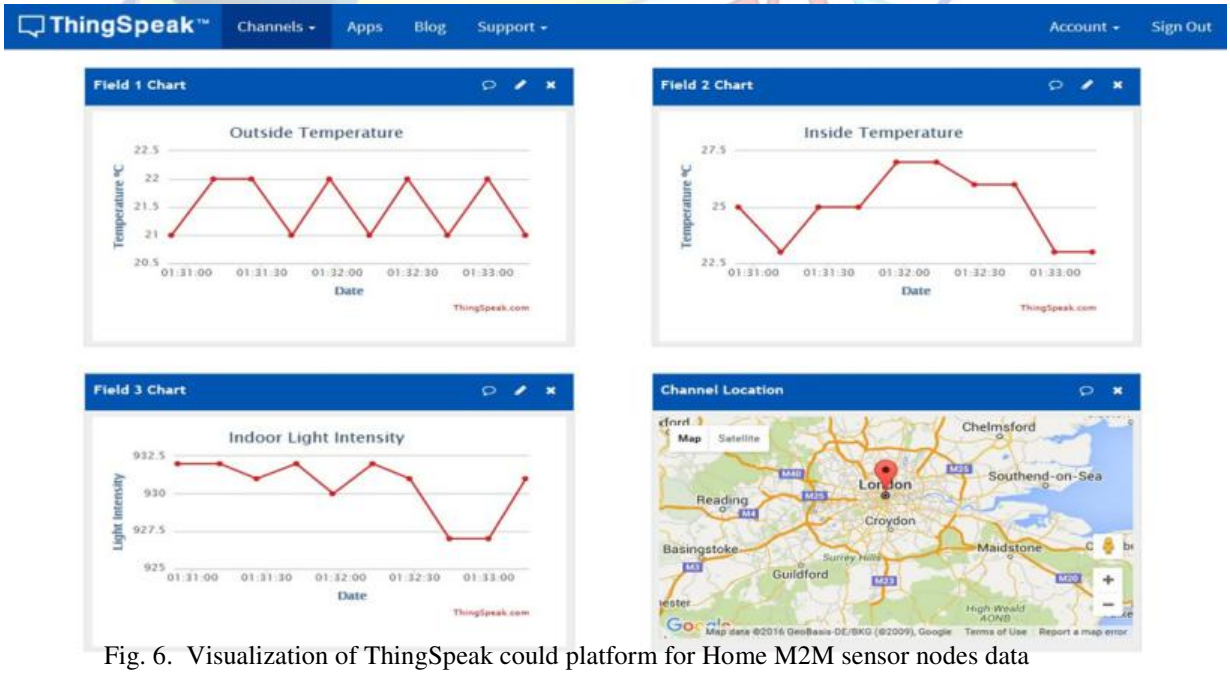

Fig. 6. Visualization of ThingSpeak could platform for Home M2M sensor nodes data

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Fig. 5 shows the command sending delay as a function of the M2M node, as the number of M2M nodes increased, there is a slight increment in the average delay in both the Gateways. However, the delay in Gateway #1 is reduced by 15% compared to the delay experienced in Gateway #2. In legacy M2M sensor network, the M2M gateway needs to address each M2M sensor node in both control and data plane separately and increases the delay of sending control commands to the nodes or receiving sensor data. Therefore,
the proposed SD-M2M gateway enhances the successful control data delivery as compared to legacy approach implemented in Gateway #2 by moving the control plane to centralized position. Fig. 6 shows the ThingSpeak data visualizer which is the cloud platform used in the proposed SD-M2M testbed

The obtained delay values for both reading sensor data and sending control commands are slightly high. The high delay value arises from the software library for interfacing the XBee module and the MATLAB testing environment through the universal serial bus (USB) of the M2M gateway PC. The delay can be minimized by implementing the SD-M2M gateway using Arduino microcontroller as an example or any other microcontroller where no interfacing or intermediate software libraries were needed.

Several experiments were conducted to compare SD-M2M gateway and the legacy M2M gateway in terms of end-to-end delay impacted by the number of M2M sensor nodes (N). As shown in Fig. 4 and Fig. 5, with the increase number of M2M nodes, end-to-end delay increases for both Gateway #1 and Gateway #2. The improvement of delay effect in Gateway #1 is not obvious when 1 N 3. The average network delay of SD-M2M gateway is smaller than that of legacy gateway when N 4, and especially the improvement is about 24% and 15% when 4 N 6 for reading sensor data and sending control command respectively. The longer delay for N 4 is caused by the increase of the simultaneous number of data packets to be processed in the MATLAB test environment.

VII. CONCLUSION

The proposed approach is a new framework for home net-work configuration based on the SDN in cloud environments using M2M technology. This paper presented an experimental analysis of SD-M2M home gateway. Experimental based val-idations shows that the proposed customized SDN controller builds the network flows using scheduling algorithm and has better performance when compared with existing ones, it reduces the end-to-end delay between the gateway and sensor nodes by 23% and less delay achieved approximately by 15% when sending the control commands from the gateway to sensor nodes. The SDN controller design is critical to manage the heterogeneous traffic and different cloud platforms. The controller may be physically or logically centralized and the flow table entries may be configured in the SD-M2M home gateway in reactive or proactive manner (in this paper the reactive flow table was used). The high delay experienced in both gateways came from the interfacing program between the XBee module and MATLAB, and expecting much less delay while running the same algorithms in microcontrollers or microprocessor based gateway and sensor nodes.

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