Energy Efficient Routing Protocols for IoT Devices

Surbhi Singh[1], Archna Goyal[2], and Er. Saurabh Sharma[3]
[1,2]*Asst.Professor, Aryabhatta College of Engineering & Research Center, Ajmer*
[3] *HOD, Aryabhatta College of Engineering & Research Center, Ajmer*

Abstract- **The Internet of Things (IoT) is a technology of connected computing and physical devices, vehicles, sensors, actuators, home appliances etc., and connectivity mechanism make sense in the devices to exchange data. The IoT environment consists of numerous devices with resource constraint characteristics such as small radio range, narrow processing capability and small battery life. Wireless Sensor Networks (WSN) now uses IEEE 802.15.4 standard which identify the characteristic of a wireless link for low-power personal area networks, which are predominantly a battery-operated device, it possesses certain constraints such as low bandwidth, low transmit power and low data rate. With the emergence of smart environment and smart computing using IoT, here is need of some protocols which act as an interface between the WSN technology and Internet.**

Index terms- **IoT, Wireless Sensor Networks, Software Defined Networking (SDN) and Network Function Virtualization (NFV), Aggregation-based Topology Learning (ATL), Cluster Heads.**

I.INTRODUCTION

The IoT uses machine-to-machine (M2M) communication technology with large number of sensor nodes executed independently and generates large amount of data. These lead to difficulty in managing the network because it also produce huge traffic and cause energy dearth, which have an effect on the lifetime of sensor nodes [19]. 6LowPAN is the protocol under IPv6, defined especially for low power and low transmission range IoT devices and provides IPv6 connectivity to the wireless devices. This network technology permits large IPv6 packets to be passed out inside tiny link layer frames, which is defined under IEEE 802.15.4 standard [28]. M2M sensor network is mainly uses battery power for devices and contains huge number of tiny devices, so need to poise the energy utilization and the value of data exchanged between them.

II. RATIONALE AND SIGNIFICANCE OF THE STUDY

There are various approaches and protocols are available to minimize energy consumption in the M2M sensor networks which is backbone of IoT technology based on WSN. IPv6 provides better address space of 2128 and 3.4*1038 exclusive addresses [28] for implementation of different protocols with large number of devices. 6LoWPAN is the protocol for devices which works on low energy and low data rate. Software Defined Networking (SDN) and Network Function Virtualization (NFV) are being used in the IoT sensor network to put in some flexibility to accept the increasing traffic with programmability to allow network formation even after use [19]. Some distance based cluster head selection algorithms provide good solution for energy saving in WSN, such a communication method enables the network existence of WSN to reach maximum[2][3][4]. Another approach based on smart sleep mode [20], [21] also provides good techniques to increase the lifetime of network. Still, there is scope for improvement in energy utilization in sensor networks for making them sustainable for long time with some hybrid approaches.
IoT, as network of sensors with the capability to sense, process and communicate, have been gradually more used in different fields together with engineering, some mission critical application in military, healthcare and environment, to smartly monitor distant locations at little cost. Sensors in such network are responsible for functions like data aggregation, in-network data processing, sending and receiving data, etc. This shows that they have to efficiently utilize their resources, together with memory usage, CPU power and, more essentially, energy, to raise their life span and efficiency.

III. LITERATURE REVIEW

Recently, Internet of Things (IoT) has become accepted due to their exceptional capabilities, availability and use. Agriculture to military, application for IoT cover a considerable range of domains. Now days IoT is very useful technology in disaster management. Zhengguo Sheng et al. [1], represented an general idea of industrial ecology, different architectures, standards in industrial device organization, and most recent study in developing a WSN system for industry. Also, presented key IoT areas with its application requirements and challenges. Hongyan Xin et al. [2], identified an energy fissure close to the sink in WSN and its life span diminution. They have proposed accurate distances based communication scheme, which aims to get best transmission distances in diverse regions in network. Such a communication method provides the improvement in network lifetime of the strip-based WSN. Suraj Sharma et al. [3], have proposed a method in which they used a Grid-Based Routing Protocol where Mode-Switching mechanism is used for WSN. Here they select one node as a grid head from all nodes available in single grid. Grid heads working is based on switching between active and sleep modes of the head. Therefore, only active grid heads get part in the routing process at the equal time. This helps to minimize energy use in grid heads. Haojun Huang et al. [4], have proposed routing protocol based on multicasting and good energy efficient solution for WSN. In this technique an energy conscious multicast tree is used, which contains the information about the set of destinations and the source nodes. This helps to deliver multicast message based on adaptively selection of the nodes closest to the energy finest relay position as the subsequently forwarders for energy preservation. [5]-[10], have provided fuzzy logic based energy efficient and energy harvesting approaches for WSN. Ayesha Naureen et al. [11], have proposed a protocol, called an aggregation-based topology learning (ATL) protocol, to discover energy gap in a arbitrarily deployed hierarchical WSN which works on tree-structured hierarchical wireless sensor network. Gal Oren et al. [12], proposed an algorithmic approach for reduction of energy in WSN Cluster-Heads, by employing a homogenous sensor network in a distributed fashion and changes the sampling rates of the CHs based on the variance of the sampled data without damaging significantly the accuracy of the sensed area. Faycal Ait Aoudia et al. [13], proposed a distributed algorithm for energy harvesting in WSN based on faire packet rates calculation for multi-hop networks. S. M. Bozorgi et al. [14], proposed hybrid methodology involving static and dynamic clustering operations. It uses a distributed-centralized approach and multi-hop routing and considers criteria, such as the energy level, the amount of harvested energy and the number of neighbours in the clustering process. Wenbo Zhang et al. [15], have proposed a relatively balanced and improved protocol (IRPL) and it uses topology control model for finding the routes for communication based on an proficient clustering algorithm. Chuanxin Zhao et al. [16], are considering sink assignment based on joint optimizing and routing between sensor and sink for Maximizing Lifetime of a WSN. Mahdi Arghavani et al. [17], have proposed finest energy responsive clustering for circular WSN which aims to take the edge off energy spending and augment the life span of WSN. Barun Gorain et al. [18], have proposed solution for minimizing energy utilisation by sensors in sweep coverage problem in network with considering of two variations in it. First, an energy efficient sweep coverage problem where the aim is to reduce energy utilization by a set of sensors with definite sweep coverage and in second an energy constrained sweep coverage problem is projected, where the purpose is to discover the least number of mobile sensors to assurance sweep coverage issue to the situation that the energy utilization by a mobile sensor in a given time period is bounded. Bilal R. Al-Kaseem et al. [19], proposed an energy proficient method for M2M networking by cloud-based 6LoWPAN testbed based on SDN and NFV. Wasan Twayej et al. [20], proposed an energy competent machine-to-machine routing in IoT based on 6LoWPAN. Here elegant approaches for sleeping nodes are considered for enhancing the life span of a network from end to end a special structure. The sensor area is separated into quarters with diverse levels of cluster heads (CHs) and two useful position sinks. N Hari Kumar et al. [21], proposed to solve nodes sleeping issue using "Hierarchical directional routing". Josua Arndt et al. [22], presented implementation of a 6LoWPAN Sensor Node for IoT based Home Automation Network with sensor nodes, router, border router, home automation server and user interfaces a sensor node. Maha Bouaziz et al. [23], proposed energy competent and mobility conscious routing named as EC-MRPL based on the well known RPL standard. Carles Gomez et al. [24], This paper systematically analyzes the 6Lo technologies and adaptation layers and provides the inspiration for crucial design decisions, highlighting fundamental characteristics for performance, and presenting major challenge. Mohammad Fouladlou et al. [25], proposed an energy competent clustering approach for wireless sensor devices in Internet of Things. Genetic algorithm is employed for clustering sensor devices for the sake of efficient routing and prolonging network lifetime. Mohammad Mozaffari et al. [26], presented exploitation and mobility of several unmanned aerial vehicles (UAVs), which are used for collecting data from Internet of Things (IoT) devices. Liumeng Song et al. [27], have proposed quality of service attentive energy efficient scheme based on cooperation between cluster-based IoT systems.

IV. NEED OF INVESTIGATION

The Internet of Things (IoT) has the capability to transform our life if we are using this. Now or soon, almost every device we are using is connected with internet. Whether it’s through our mobile device, wearable technology or everyday household equipments, the Internet of Things (IoT) will connect us in ways we can’t even dream yet. So, in an attempt to make sense of this promising technology we need to develop the technimques that makes these devices alive for long time.

V. IMPLEMENTATION METHODOLOGY

The study investigates the direction of the energy efficient model for Internet of Things implementation using cloud based 6LoWPAN testbed, analyzing the limitations of methodologies for the systems which can be classified based upon three major phases in implementation:

1. Software defined network (SDN) and network functioning virtualization (NFV).
2. Smart method of sleeping node identification and its use for minimizing energy consumption.
3. New hybrid energy efficient model based on smart sleep mode using software defined networking (SDN) and network functioning virtualization (NFV) with cloud-based 6LoWPAN.

A. 6LoWPAN

Integration of WSN over Internet required a light weight protocol for gaining the benefits of Internet and to tackle the limitation of wireless sensor network is possible with the help of IPv6 over the standard IEEE 802.15.4. The Internet Engineering Task Force (IETF) 6LoWPAN working group plays an important role here. 6LoWPAN under IPv6 is the communication protocol between nodes with limited power and low bandwidth. It allows large IPv6 packets to be passed out capably within tiny link layer frames, which is defined by IEEE 802.15.4[28].The 6LoWPAN uses IPv6 protocol as the network layer protocol where the IPv6 network layer's MTU is large and not attuned with the MAC layer of IEEE 802.15.4 standard, therefore in between the network and MAC layer an adaptation layer is introduced. An adaptation layer is useful for performing fragmentation and reassembling of IPv6 packets with IPv6 header compression and addressing mechanism of various nodes in IoT. The 6LoWPAN network contains small local LoWPANs and router is used for connecting these with each other. The edge router or border router is used for connecting 6LoWPAN network to the Internet. The LoWPAN devices are categorized by small radio scope, low bandwidth and low power. Therefore this network uses small size packets on low bandwidth and needs resource optimization for increasing the life of network nodes.

A.a. 6LoWPAN network architecture

The roll of IPv6 router is important in the IPv6 network, which act as an Access Point (AP) and it handles the uplink to the Internet. Different types of nodes in the network are associated with AP in usual setup, such as servers, PC’s etc. Another device in the 6LoWPAN mesh network is the edge router, used for connecting 6LoWPAN network with IPv6 network. Normally edge router performs following operations [28],

- It is used to transfer data between 6LoWPAN nodes and the Internet;
- Also used for exchanging local data between nodes within the 6LoWPAN;

- The radio subnet for 6LoWPAN is generated and maintained by edge router.

Figure 1 shows an example of IPv6 based 6LoWPAN mesh network.

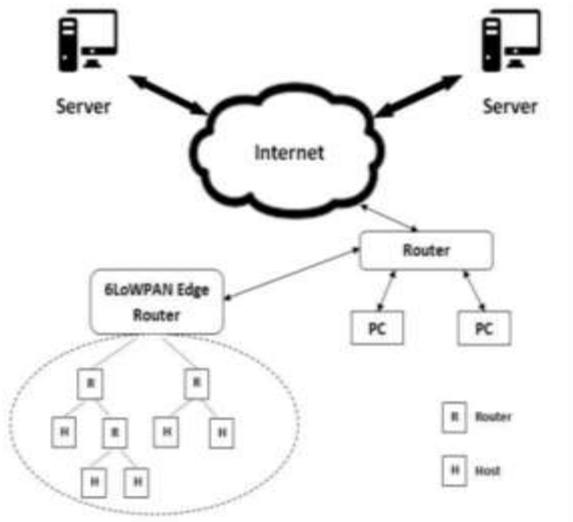

Figure 1 An IPv6 based 6LoWPAN mesh network

A.b. 6LoWPAN stack

The 6LoWPAN adaptation layer resolve the issue of devices such as Bluetooth, Zigbee etc, which required a special application layer gateway for connecting to the internet. An adaptation layer is introduced between the IP stack's link and network layers to allow communication of IPv6 datagram's over IEEE 802.15.4. Figure 2 shows the 6LoWPAN stack. The Physical layer provides the basic communication capabilities, converts data bits into signals. IEEE 802.15.4 is used in the example of 6LoWPAN. IEEE 802.15.4e is a MAC amendment gives enhancement such as time slotted channel hopping (TSCH) and coordinated sampled listening (CSL). These two improvements intend to further lesser the power utilization and create the interface extra vigorous. IEEE 802.15.4g is a MAC amendment provides an additional radio frequency range. Error detection and correction is done by using datalink layer. The 6LoWPAN layer also called as adaptation layer introduced between the MAC and Network layer to provide the proficient transmission of payload, by header compression is mandatory. Packet fragmentation and reassembling with layer-two forwarding is necessary in 6LoWPAN

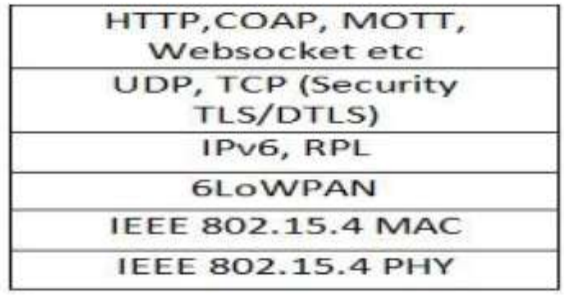

Figure 2. 6LoWPAN Stack

Figure 2. 6LoWPAN Stack Addressing, mapping and routing protocols are available in the 6LoWPAN network layer and provides the internetworking ability to sensor nodes. The 6LoWPAN transport layer is responsible for delivering data segment to the appropriate application process on the sensor node. Both transport protocols UDP and TCP are used for data delivery. Application layer is responsible for data formatting. The 6LoWPAN application layer uses a socket interface for a particular application, each application opens a socket to receive or send packets. Figure 3 shows the roll of edge router as a bridge between 6LoWPAN and IP world.

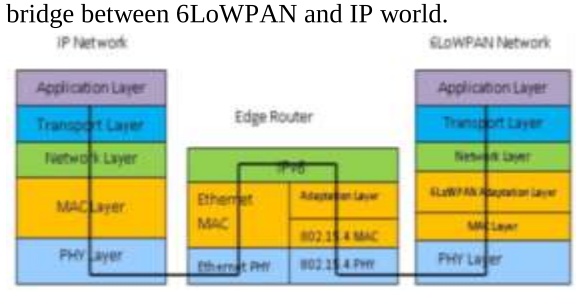

Figure 3. Edge router as a bridge between 6LoWPAN and IP world.

B. INTRODUCTION OF SD-NFV

Software Defined Network is about transforming or restructuring the existing network infrastructure and that can be done in efficient manner. Existing network infrastructure contains different switches and each of these switches run different layers; these are hardware, operating system and applications running on that network. This is the network stack on existing network switch. These switches forward packets in distributed manner and they do not have the comprehensive view of the network and route the traffic in distributed manner. Current network is mostly depends on vendor-specific architecture of switches, this limits dynamic configuration according to application-specific requirements. Another issue is the switches in the network are required to configure according to the installed operating system (OS) and also centralized control is not feasible in traditional network.

Now it is required to make these networks efficient by trying to overcome these challenges. SDN is to take care of the limitations by separating the application and the operating system from the hardware, so in the SDN packet forwarding hardware is separated from application and OS layer of each switch. OpenFlow, the first standard interface, is basically used in the SDN architecture. Figure 4 shows the SDN architecture.

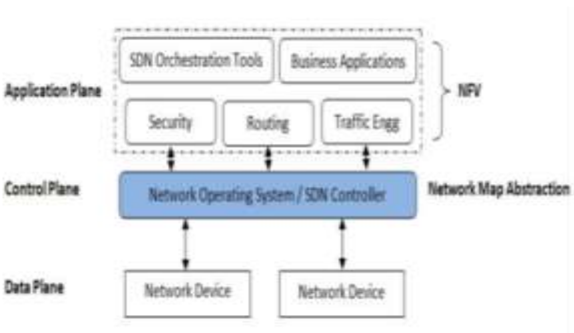

Figure 4. SDN Architecture

SDN supports features like adding centralized programmability in the network control plane and the decoupling of the data and control planes. This adds great flexibility of network management by adding the programs in the control plane for management of network resources. The API's in the SDN are divided into two parts, Northbound APIs and Southbound APIs. Northbound APIs defines the interaction between SDN controller and application plane whereas Southbound APIs defines the interaction between SDN controller and SDN data plane. SDN controller is liable for controlling the flow control, with the help of flow table, in SDN networking devices using Northbound APIs and Southbound APIs [19]. Network Function Virtualization technology is used to virtualized the network applications and services. It condenses functioning and capital expenses of the network and also provides the use of deferent services on the existing network by decoupling the network functionality. Bilal R. Al-Kaseem et al. [19], introduces a novel customized SDN controller to convene the 6LoWPAN network needs in stipulations of packet size and node finding purpose. The customization uses limited available memory in the IoT devices with small processing unit to realize a small software image. The SDN controller perform following tasks: 1) finding network topology; 2) management of different services; 3) virtualization; and 4) data routing with load balancing. Also, in this approach a new flow table entry is maintained for managing the more memory use of the programmable interface. Figure 5 shows the customized SDN controller architecture designed by [19]. This architecture contains four managers in control plane. The Network Discovery Manager performs a detection function which identifies the alive devices and newly joined nodes periodically. Based on nodes priority Service Manager allocates different levels of services. The Virtualization Manager permits diverse 6LoWPAN devices to share the similar NFs in the gateway. The routing and load balancing manager is competent for execution of diverse routing function and makes load balancing optimization methods based on 6LoWPAN stack to reduce end-to-end delay and to achieve high throughput.

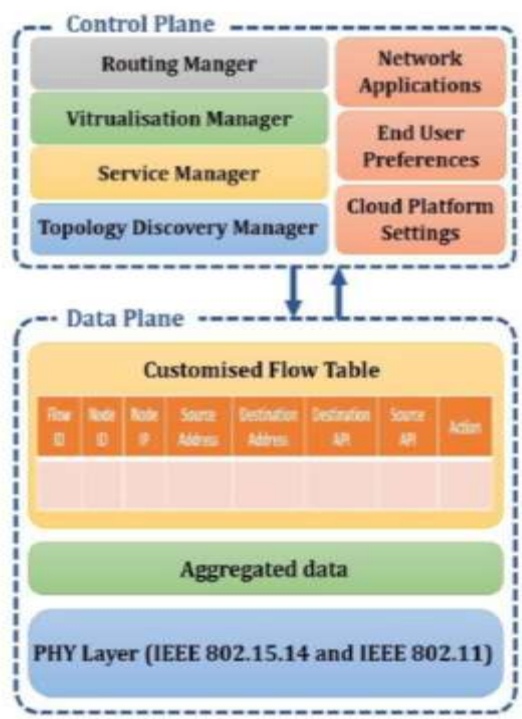

Figure 5. Customised SDN controller Architecture

C. Sleep mode of Nodes

Energy use optimization is a significant deliberation in the 6LoWPAN protocol. It is important to make sure that the nodes being lively in the network are not using power unnecessarily. This is possible to

achieve by maintaining a few devices active and the others devices inactive, depends on their responsibility in the network. A node which goes in to sleep mode voluntarily for saving power is called sleeping node [20].
Several routing protocols are available to minimize the network energy waste. LEACH is the cluster-based energy competent protocol, and here both the sensor devices and the sink are static [29]. Other protocols are PEGASIS [30], TEEN [31] and APTEEN [32]. In LEACH protocol a threshold value of cluster head (CH) will be considered. If CH uses small amount of energy for the period of its function and has more than the essential threshold is available, then it will be stay as a CH. In another case, if CH has a smaller amount of energy than the essential threshold then it will be changed in agreement with the LEACH algorithm. Another approach for minimizing energy waste is a multilevel clustering multiple sink (MLCMS) [20]. MLCMS divides sensing field into four quarter. At each level, there is a maximum transmission range for nodes, which is the diagonal length of the level. Nodes which are within this range use this to send out their parameters so that they may become the new CH, if selected. Otherwise, if outside TR then nodes are unable to connect with the CH.
So here if we are considering the customized Software Defined Network on 6LoWPAN [19], in that the role of the network discovery manager, and smart sleep mode of the node defined in [20], gives us a scope for improvement in minimizing the wastage of energy in IoT nodes. The scope of the proposed system is to focus on designing an improved energy minimization technique by considering smart sleep mode of nodes into customized SDN based on 6LoWPAN.

VI. CONCLUSION

There are a number of existing routing protocols of IoT implementation. We are developing the software defined networking (SDN) and network functioning virtualization (NFV) using cloud-based 6LoWPAN and its implementation on IoT devices (open source hardware) to work on the sleep mode of IoT devices. We have derive the energy efficiency in the area of IoT using the design of efficient protocol and analyze the performance of a new energy efficient model based on smart sleep mode using software defined networking (SDN) and network functioning virtualization (NFV) with cloud-based 6LoWPAN testbed.

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