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IOT Enabled Energy Efficient Wireless Sensor Network & Services – A Pathway towards Green Engineering - Part 3 (Routing Algorithms for WSN)

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Introduction

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. 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 [6]. 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.

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[6].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.

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 [6] -

- It is used to transfer data between 6LoWPAN nodes and the Internet;

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- Also used for exchanging local data between nodes within the 6LoWPAN;
- The radio subnet for 6LoWPAN is generated and maintained by edge router.

And also support transition between IPv6 and IPv4. Figure below shows an example of IPv6 based 6LoWPAN mesh network.

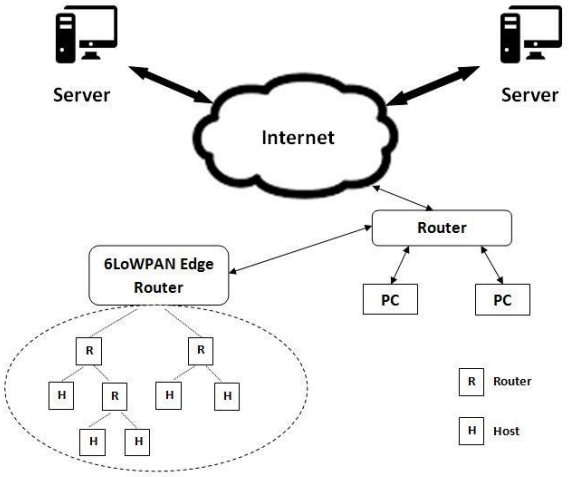

Figure:1 An IPv6 based 6LoWPAN mesh network[5]

LoWPAN 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. Figure2: shows the 6LoWPAN stack below. 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.

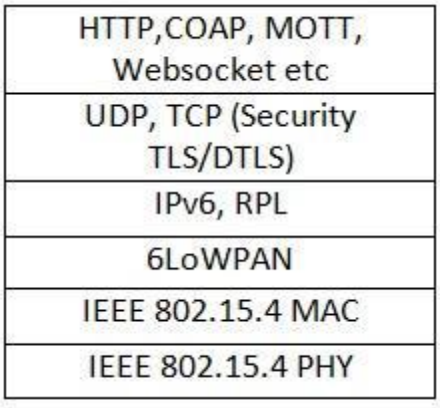

Figure 2. 6LoWPAN Stack

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.

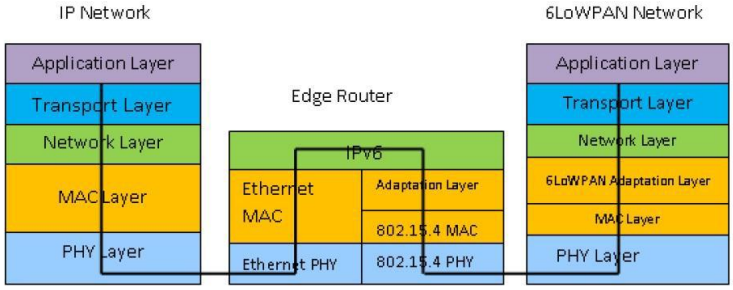

Figure 3. Edge router as a bridge between 6LoWPAN and IP world.

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

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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.

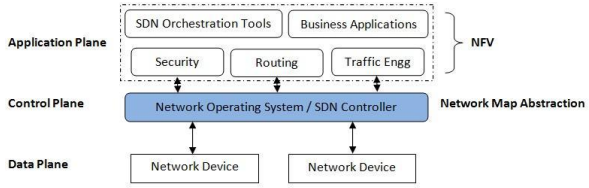

Figure:4 shows the SDN architecture.

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 [6]. 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. [6], 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 [6]. 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.

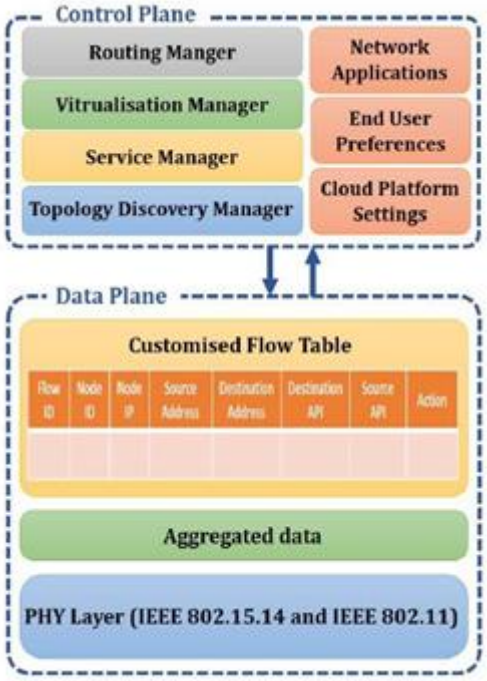

Figure:5 Customised SDN controller Architecture [6]

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 [8].

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 [8]. Other protocols are PEGASIS [8], TEEN [8] and APTEEN [8]. 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) [8]. 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

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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 [9], in that the role of the network discovery manager, and smart sleep mode of the node defined in [9], 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.

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