Impact of Openflow on Wireless Mesh Network (wmSDN)

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Abstract—**Software-defined architecture is growing in many computer networks as it reduces costs, increases management power, and improves security and The wireless mesh software defined network (wmSDN) architecture was developed to improve security and management. The most important challenge to this new architecture is to separate the data network from the control network, and various solutions have been proposed to this problem. In the first part of this paper, the wireless mesh network, different methods of implementing the software architecture in a wireless mesh network, the effect of the new architecture on traffic, and its challenges are discussed. This paper mainly explores the effects of the management traffic approach in the new architecture, management traffic classification and the effect of flow quantity, the rule installation packets in nodes, nodes movement, and graph changes on the management traffic. Simulation results revealed that the management traffic in the new architecture changes unlike the traditional architecture and it grows with an increase in flow and the network management traffic. Our comparisons revealed that the management traffic amount and growth in wireless mesh software defined networks are higher than the software-defined and wireless mesh networks. The classification of the management traffic packets into the operating, monitoring, and event categories also revealed that the operating, monitoring, and event categories had the largest shares of the traffic, respectively.**

Keywords—software-defined network, wireless mesh network, wireless mesh software-defined network, openflow

I. INTRODUCTION

One of the issues discussed in smart power grids is exploring the possibility of applying new information and communication technologies such as Internet of Things and Software Defined Network to meet the requirements of the power grid. In general, increasing the level of power system information and improving the efficiency of the use of communication infrastructure in power systems in all generation, transmission, distribution and consumption sectors in the power industry are required. Networks are integral parts of today's world. Since the dawn of networks, many technologies have been introduced and different types of computer networks have been created. As regards the advantages and applications, some of the most important computer networks include the wireless mesh networks. The wireless mesh networks have numerous advantages. The software-defined architecture is used in wireless mesh networks due to the lack of centralized management in these networks. Separating the control network from the data network and reducing management traffic constitute one of the most important research topics in this field. The new architecture uses the south-bound port to manage the network data layer equipment. As a result, the management traffic is not announced and increases by network changes and flows. In this paper, the traditional and software-defined, methods of separating the data network and control network and analyzing management traffic are studied.

This paper is arranged as follows. The software-defined architecture is introduced in section 2, while the wireless mesh network is introduced in section 3. Section 4 analyzes the hybrid architecture and methods of data-control network separation. The effect of the new architecture on the management traffic and the important separation challenges are discussed in sections 5 and 6, respectively.

II. SOFTWARE-DEFINED NETWORK AND OPENFLOW PROTOCOL

The software-defined network [1] was introduced in 2008 and it has been growing ever since. The idea behind this network is to separate the control unit from the forwarding unit of equipment and centralize it on the central controller . SDN reduces the implementation and maintenance costs, allows centralized management, increases security, and offers network programmability.

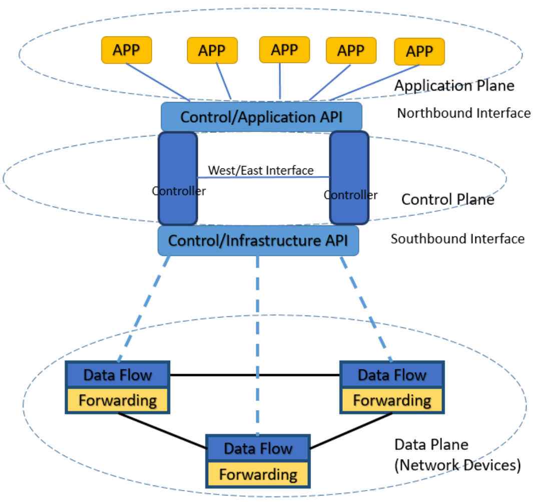

Figure 1. The software-defined network architecture

As seen in Figure 1, the SDN architecture is composed of three layers known as the application layer (which includes the management software) and the network equipment layer (such as the central controller layer switch, which establishes links between the network software and hardware). An open-source portal containing a north-bound port (connecting the control layer and the third-layer software), and an east or west-bound port (which connects the controllers in the second layer) connects the layers. In the SDN architecture, the forwarding network is physically or logically separated from the control network. When the SDN architecture is used in other networks, separating the data network from the control network is one of the challenges.

III. Wireless Mesh Network

The wireless mesh network is a new and improved technology for the provision of high-quality services and establishment of links between a gateway (the Internet) and the users. Its architecture consists of several stationary or mobile nodes that are connected via one or several wireless communication links. This wireless connection increases power and flexibility [3].

The wireless mesh network has many applications and advantages. One of the most important advantages of wireless mesh networks is their reliability, use of common technologies, vast geographical coverage and facilitation of increased coverage, autonomy, high development rate, ease of development, self-configuration and self-repair, low implementation costs, scalability, and flexibility [4,5,6]. Given the numerous advantages of these networks such as the expansion of the radio range and automatic connection of routers to each other [5], this network has various application in, for example, home broadband networks, networks consisting of neighbors, metropolitan area networks, home automation, wide area coverage, transportation, military communications, farming, natural disasters, and incidents[7, 8].

IV. Wireless Mesh Software Defined Network

The wireless mesh software-defined network is a double-edged sword. Furthermore, the implementation of a network without a stationary and specific infrastructure sets the scene for infrastructure-free development and expansion. For instance, with the establishment of several mesh routers, it is easily possible to enable mobile users to access the Internet without the support of workstations or base stations. Besides, considering the management of wireless mesh networks, the network is at risk of attacks and intrusion as well as numerous security challenges due to its dynamic topology, difficult-to-install equipment, the lack of infrastructure, the lack of control and the lack of central monitoring [9]. To use the advantages of SDN, two researchers, namely Kessler and Bayer, introduced the wireless mesh software-defined network (wmSDN) to solve the load balancing problem.

The data-control separation, the instability of link quality, the number of network interfaces in the node, unavailability of the right equipment and tools for network management, and the difficulty of proper management of nodes movement with an increase in the management traffic are among the other complexities of the implementation of SDN in WMN as compared to the traditional state [10-14].

In [10], the virtual network interface classification was carried out separately by creating two IDs assigned to the data and control networks to separate the data network from the control network. The same data and control networks are used in [11]. Routing in the data network is carried out by the central controller while routing in the control network is carried out using the traditional mesh network algorithms. In [12], an effective step is taken in developing the idea of separating the third-layer addresses in the main network by placing the support routing mechanism in a combination of the equipment with the OSLR algorithm [15]. In [13], tunneling is used for the control network. In this paper, two-layer routing is employed to improve the control network. One of the flaws in [13] was that the central controller had to be aware of the physical addresses of the existing equipment network interfaces to carry out routing. In [14], the control network is separated from the data network using sub-channels and the proposed methods are compared in Table 1.

The existing challenges are classified into the following categories by analyzing the separation articles in wmSDN. The limitation of hardware and resources in mesh routers, the limitation of the operating and particular frequencies for the data and control channels, the network collection and

TABLE 1. COMPARING THE PROPOSED METHODS IN THE REFERENCES [14]

#	Separation method	Network interface demand	Control traffic assurance	Frequency reuse	Management model
1	SSID (Service Set Identifier)	Yes	No	No	Out-of-band channel
2	Wired	Yes	No	No	Out-of-band channel
3	Old mesh	Yes	No	No	In-band channel
4	Optimized Link State Routing	Yes	No	No	In-band channel
5	Tunneling	Yes	No	No	Out-of-band channel
6	Fixed-Band Non-Sharing Algorithm	No	Yes	Average	Out-of-band channel
7	Non-Fixed-Band Non-Sharing Algorithm	No	Yes	Average	Out-of-band channel
8	Non-Fixed-Band Sharing Algorithm	No	Yes	Good	In-band

Monitoring status, and congestion control in links are among the most important concerns.

V. Management Traffic

In this section, management traffic in the WMN, SDN, and wmSDN architectures is studied. The analyses include the value and effect of the increased flow on the management traffic in the aforesaid three architecture types and the classification of the OF management traffic into the operating, monitoring, and event categories. Afterward, the share of each category of the traffic and the effects of the number of flows, node movements, and network graph changes on the traffic were studied. The floodlight, Mikrotik, mininet, and D-ITG controllers were used using a core i7 computer with 8GB of RAM.

A. *wmSDN Management Traffic*

After comparing the separation methods, the most effective solution for separating the control network from the data network was dynamic channel assignment. Hence, separation in dynamic channel assignment was carried out using a constant base value. After randomly generating the graph in a state similar to the mesh state and generating traffic with D-ITG from the source to random destinations, it was run and measured several times. For the generated random graph, the traffic illustrated in Figure 2 was obtained. Since the management traffic increases over time with an increase in the number of flows in wmSDN and the number of OF packets also increases in the graph, it grows as depicted in figure 2.

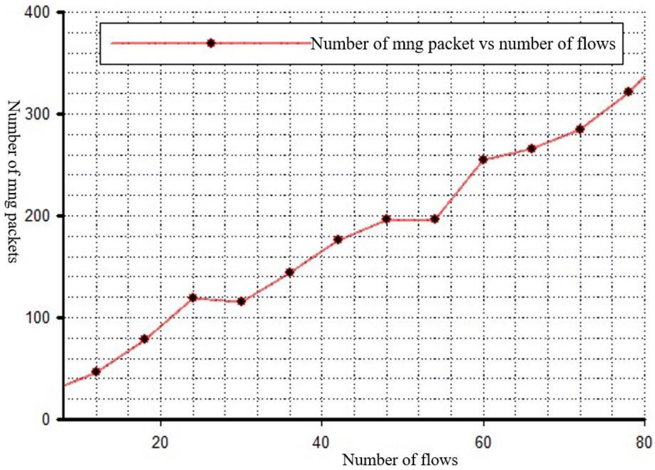

Figure2. The effect of increased flow on the management packets

B. *Comparing Management Traffic in WMN, SDN, and wmSDN*

Following the assessments, the wmSDN management traffic was compared to the traditional and SDN states. As seen in figure3, in the traditional state, the routing management traffic remains unchanged and flow-independent with the OLSR management protocol. Unlike the traditional routing protocol, in wmSDN, the rule installation packets increase drastically with an increase in the number of flows. Hence, in the new architecture, the traffic caused by the rule installation packets is added to the network. With an increase in the number of flows, the network links transform into bottlenecks over time and the potential for communication between different network components and the controller decreases. re-establish the connection, the nodes ignore the traffic and the new and management packets are avoided until the network restores to normal and connections are re-established.

In figure 4, the comparison between the wired SDN and wmSDN is illustrated. With a gradual increase in flow, the increase in the management packets due to the considerable changes in the links topology and quality is higher in wmSDN as compared to SDN.

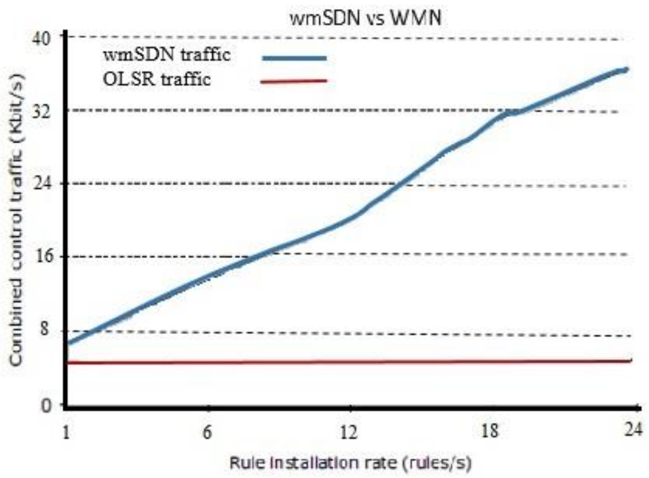

Figure 3. Comparing the management traffic of WMN and wmSDN

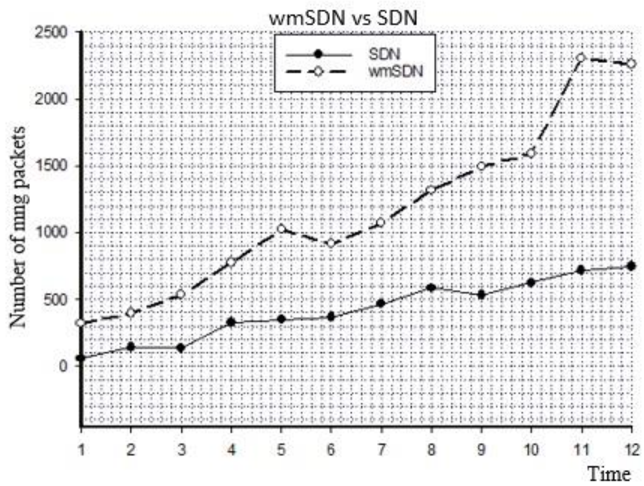

Figure4. Comparing the management traffic of SDN and wmSDN

C. *OF Traffic Classification in wmSDN*

Next, the OF management packets were grouped into the monitoring, event, and operating categories. Thereafter, the share (%) of each category of the total management traffic with the constant number of flows in each period was measured. The share (%) of each category of the total management packets is depicted in figure 5. As seen, the operating category has the largest traffic share (the packets that exert changes on the network) followed by monitoring packets (packets collecting statistical information from the network) and eventually the event packets (packets announcing a change or incident in the network).

D. The Effect of Rule Installation in Nodes

Afterward, time periods were selected to compare the effects of installing forwarding rules and increased flow in the SDN and wmSDN architectures. Each time, a certain number of flows was generated incrementally and the results were compared thereafter. In the assessment, the network flow increased uniformly over time. As a result, the number of operating packets, especially packets required for rule installation, was obtained (figure 6) as seen, the rule installation growth chart in larger for wmSDN than SDN. As it increases at a given network-dependent point, the increase in the operating traffic grows substantially.

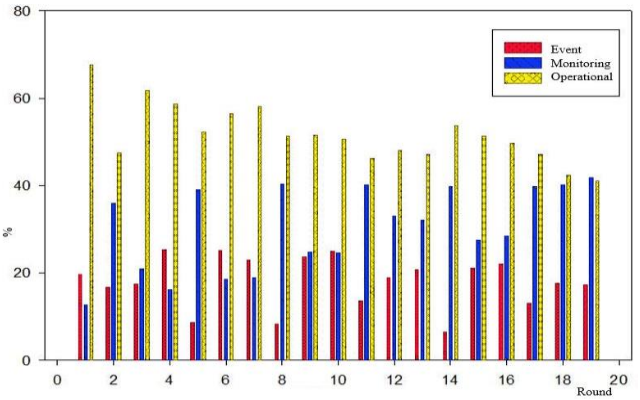

Figure5. The share of each category of the OpenFlow protocol classification

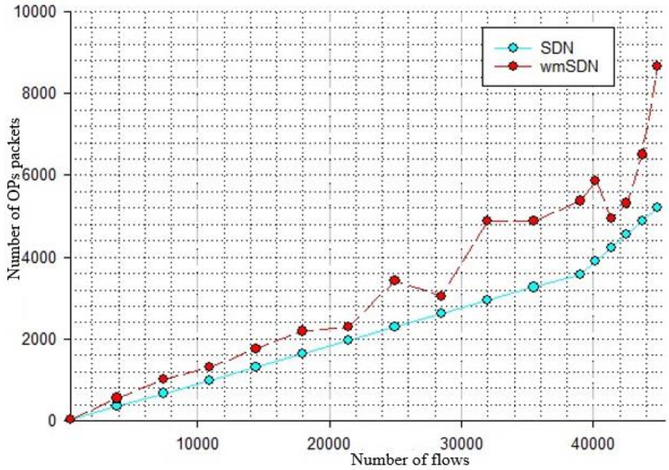

Figure6. The effect of the increase in flow on the operating packets

E. The Effect of Graph Movement and Changes on Traffic

In the next simulation, the effect of node movements was considered a continuous change in the link or link quality, which changed the topology. The resulting values for each category are depicted in figure 7 and 8. Node movements result in an increase in the number of packets in each category, particularly in the operating traffic. The most important effect on the management traffic was associated with the changes in the network graph, which re-initiates the installation of many rules.

In Figure 8, a change in the link resulted in heterogeneity in traffic growth. The traffic increased and peaked over time. After the stabilization of the graph, the management traffic was reduced and reached a state of balance. As seen in figure 8, the highest effect was exerted on the operating category followed by the monitoring category and then the event category.

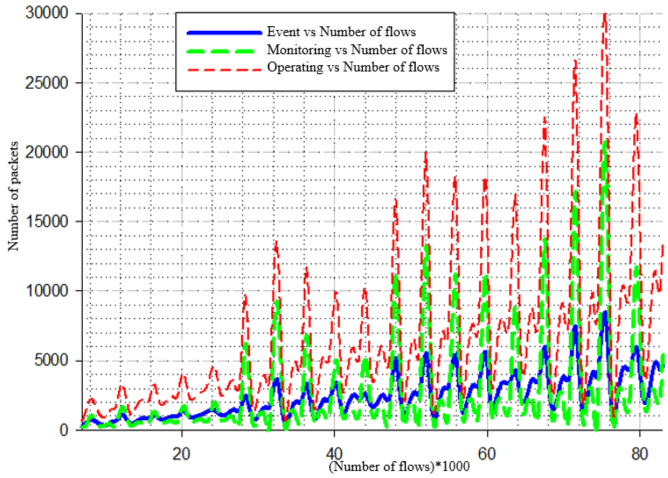

Figure 7. The number of management traffic messages by category

In figure 7 and 8, it was found out that first the traffic of the events reporting the changes to the controller was affected by increasing precision and shortening the measurement periods. Thereafter, the monitoring traffic needed to collect information and update the information due to the substantial graph changes. Finally, rule installation, which was associated with the operating category, was carried out.

According to the simulation results, changing the network graph first affected the event traffic followed by the monitoring traffic and eventually the operating traffic. However, the largest effect on traffic value was exerted in a reversed manner. In other words, the largest effect was observed on the operating traffic, followed by the monitoring traffic and then the event traffic.

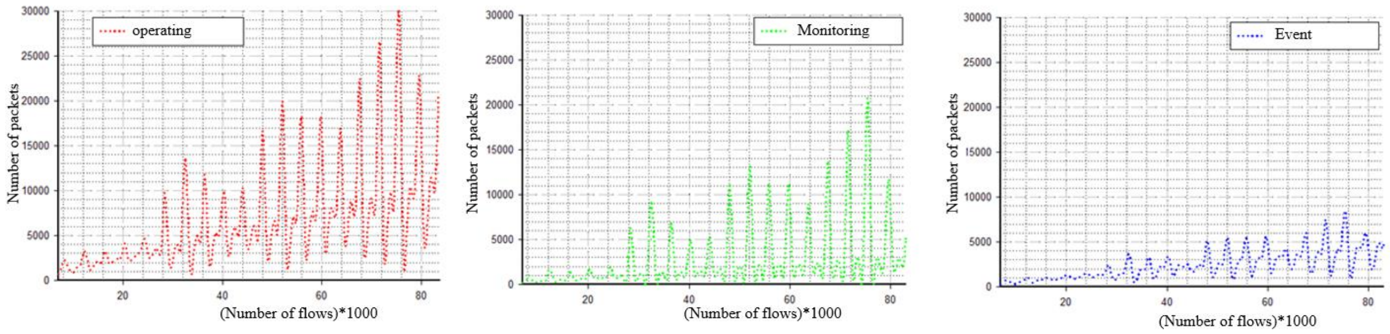

Figure 8. The number of OF messages by category

VI. Conclusion

In WMN, the wireless mesh network management traffic is uniform in packet forwarding. However, as a result of the software-defined architecture, the management traffic loses its uniform state and increases with an increase in flow and network changes. Besides, the amount and slope of the management traffic growth are larger than the software-defined network. Based on the management packets classification, the operating packets have the largest share of management traffic for applying changes to the network. The traffic created by the collection of statistical information from the nodes or the monitoring traffic has the second rank. Finally, the packets that inform the controller of the network changes using the information in nodes have the smallest share.

In wireless mesh software-defined networks although management traffic is not in the traditional uniform state and shows growth, it is negligible because it is not possible to use the software-defined network advantages, especially centralized management and higher security. Considering the current research findings about management traffic, management traffic is decreasing daily in the new architecture.

Furthermore, it is tried to reduce the operating, monitoring, and management traffic by compiling the flow switching rules into the rule installation packets (in the operating category) and using the spanning tree to select the flows in the nodes for fetching at a lower cost. The decrease in the management

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