Software-Defined Networking based Ad-hoc Networks Routing Protocols

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Abstract. A modern networking structure that employ on software-based controllers to control and interact with primary hardware devices for directing the traffic on a network is called Software-Defined Networking (SDN). It differs from conventional network by creating a centralized control over routing of data packets. Networks are widely used network in which the spontaneous network connectivity among the nodes is needed for communicating the useful information quickly to the target audience. Nodes in Ad-hoc Networks (AHN) down to function in infrastructure less environment can form a group among themselves freely and launch wireless multi-hop communication without any centralized access point. Every node can have direct communication among each other and involved in relying data packet. Routing in AHN is difficult and has specific constraints over wireless transmission such as frequently changing topology, self-organizing nature, wireless link fluctuation and resource constraint nature of nodes. Imposing SDN technology in designing routing protocols for various application needs of upcoming scenarios of AHN are crucial for improved network management and reducing the overall communication cost. SDN based routing protocols shift the routing choices from basic network elements to the controller. This technique helps to identify the shortest route with minimum latency and to reduce the control packet exchange rapidly. This article first proposes the various network structures that rely on SDN technology for competent message transmission in Mobile AHN and then present a survey on SDN based networks routing protocols from different branches of AHN with methodology used and advantages and disadvantages of each. This helps the researches to enhance them further to meet the requirement of various application scenarios.

Keywords: Mobile Ad-hoc Networks, Routing, Software Controller, Vehicular networks, Wireless sensor routing, Quality of Service, challenges of AHN.

[1] Please note that the LNCS Editorial assumes that all authors have used the western naming convention, with given names preceding surnames. This determines the structure of the names in the running heads and the author index.

1 Introduction

A network provides wireless devices that communicate with each other directly without the assistance of a wireless gateway. Wireless networks often have to be managed and route data stream between wireless devices using a Base Station (BS) or a Wireless Access Point (WAP) device. The design of the wireless network is divided in two respects; one is infrastructure in which the nodes are connected with the permanent physical network. Therefore the exchanging packets between nodes happen by means of Access Point (AP). The next is infrastructure less architecture where the nodes are connected without any fixed physical network structure [1]. Linking the endpoints to the decentralized multi-hop architecture forms the networks. The nodes can operate as routers for the sending and receipt of data due to their lack of a centralized structure.Fig.1. Shows 1. (a) Infrastructure based and1. (b) Infrastructure less Network architectures of wireless environment. The AHN is built instantaneously by connecting the devices quickly since these devices should preferably be in close contact with each other, in this setup, the connection quality and network speed will be affected when adding more devices to the network.

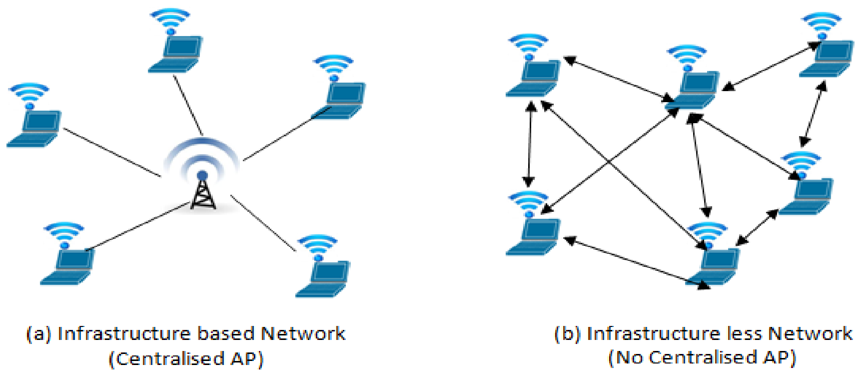

Fig.1. Classification of wireless network

1.1 Design Objectives of Mobile Network (MANET) Routing Protocols

- Should be scalable
- Should be entirely distributed, no central management
- Should be adaptive to change in topology due to node movement
- Calculation and maintenance of routes must include a sufficient number of nodes

- The global exchange must be localised with a high overhead must be loop-free
- Stagnated paths must be effectively avoided
- Must converge fairly on best routes quickly
- The best use of precious resources is needed: bandwidth, power of battery, memory, computation.
- The QoS should give time sensitive traffic support assurances [1].

1.2 Properties of Mobile networks

Mobile networks possess numerous features and the most essential are as follows:

- **Self-organizing:** Without centralized control, nodes can promote coordination amongst themselves by their own. With the Self-organizing nature of devices, possibility of On-the-fly network configuration in hostile environment
- **Dynamic Topologies**: Continually changing network set-up over time, multi-hop communication takes place either in unidirectional or bi-directional way.
- **Bandwidth constrained, variable capacity links:** The dependability, efficiency, strength and capability of wireless connections are generally lower than the wireless network.
- **Autonomous Behaviour:** Each node can operate as a host and router that demonstrate its independent activity. The network requires little human involvement; thus it is completely autonomous.
- **Decentralized administration**: Mobile networks differ from other network by without having pre-fixed infrastructure and centralised management. Mobile hosts are subject to regular network connection development and maintenance. AHN is less cost effective [2].
- **Resource Constraint devices:** In general, few or most of the mobile nodes are relying on their energy, Network devices have less memory, less power, and less lightweight attributes.

- **Shared bandwidth:** The utilisation of a shared communication channel is one of the main features of wireless networks. The bandwidth for a host is low because of this sharing.
- **Vulnerable to attacks:** Because of the distributed nature of AHN and the absence of central firewall gateway, the Security risks tend to be worsened in wireless networks in routing and host configuration functionality [3].
- **Peer-to-Peer communication (P2P):** network devices are immediately accessible through a P2P wireless link to each other's resources.
- **Distributed management:** No direct communication provision for a BS. Rather, nodes interact directly with one another and each node is a router and a host. Failure of one node does not interfere with the overall network communication [4].

Self-sustaining nature of AHN makes them very helpful in emergencies like natural calamities, actions involving military aid, or simply to transport information rapidly between two computers. Although AHN has simplicity in its usage and scalability, in the actual world has physical and performance limits. There are numerous challenges in this area without constant infrastructure. Routing, bandwidth limitations, hidden terminal issues and small energy are the challenges of the AHN that needs to be answered. Some of the critical issues in AHN are described in the following section [5], [6].

1.3 Issues of Mobile Network

- **Dynamic network topology**: The regular node movement causes frequent route breakdowns makes a network more challenging.
- **Insufficient admission control:** Managing the network topology and controlling the channel utilisation is difficult due to lack of centralized network authority.
- **Limited bandwidth:** The low radio frequency reduces the data rate through wireless networks. Thus, it is vital to optimise the bandwidth by maintaining a minimal overhead [7].

- **Energy constraints:** Shorter battery life of nodes is a significant problem in the design of a network. This limited energy has to be utilised carefully for monitoring, data collection and processing and for routing packets to their destination.
- **Routing overhead:** The routing table produces stalled routes resulting to overhead routing caused by the dynamically changing devices in AHN.
- **Packet loss due to transmission error:** Wireless networks are susceptible in nature and typically result in frequent packet loss owing to traffic crashes induced by hidden terminals, interferences and frequent node movement interruptions.
- **Frequent network partitions**: Random node mobility leads to a partitioning of the network. This mostly impacts the middle nodes.
- **Inadequate physical security:** Mobile nodes are highly inclined to attacks both inside and outside the network.
- **Quality of Service (QoS):** Maintaining the expected QoS by the application is difficult owing to infrastructure less network and poor link choice made by the relay nodes for routing the traffic. Reliability, resolution, throughput, packet delay, control packets and transmission efficiency are the fundamental QoS factors required by many applications.
- **Interference:** This is the biggest concern of interference with mobile AHN. Links rely on the quality of the transmission. One node can readily interfere with another node during the transmission by which it has interfered.

Though there are some practical limitations to the overall capacity of AHN, the distributed nature gives them an advantage for a range of applications, where no middle node to limit the data forwarding and can increase network scalability over wirelessly operated networks [8], [9]. With the increased number of miniaturized hardware as well as advancement in wireless communication technology, AHN become more popular through its widespread application. Based on the application framework the network fit into, AHN can be classified into four categories such as

Mobile Networks (MANETs), Wireless Sensor Networks (WSNs), Wireless Mesh Networks (WMNs), and Vehicular Ad-hoc Networks (VANETs).

Designing an appropriate routing protocol is most significant task in Ad-hoc networks and is critical for the basic network operations. Nodes in AHN can communicate with in the range of coverage and must depend on its neighbor for relay the packets towards the destination [10], [11]. A routing protocol should lead the packet transmission among the nodes from source to destination and it must be wise enough to satisfy the QoS requirements and performance metrics of the associated application. Some of the exclusive properties of AHN make routing an interesting and challenging. Routing is the way to find the optimal path for enable the communication between nodes [12]. AHN must supply messages in the right place and in an adequate method. Within AHN, each device works as a router without any common connecting access point. The user nodes must perform the routing that can be mobile, unstable, and with few energy and resources [13-15].

1.4 Classification of AHN routing

Wireless network routing techniques may be classed based on the routing information notifications method, time information use, topology information use and resource use [16], [17]. Related to routing information notifications method, the first category consists of Proactive (table-driven) routing protocols includes Destination Sequenced Distance Vector Routing (DSDV) protocol, Wireless Routing Protocol (WRP), Cluster head Gateway Switch Routing Protocol (CGSR). The routing tables are constructed in these protocols before packets are transmitted and each node knows the paths to all other network nodes [18], [19].

As reactive, routes are formed and the results of the route are saved in a cache when necessary. A route repair operation is launched when intermediate nodes relocate. The protocols come under this category are the Dynamic Source Routing Protocol (DSR), On-demand Distance Vector (AODV), Associativity-based Routing (ABR), Flow-Routing Protocol (FORP), and Preferred Link-Based Routing (PLBR). The advantages of reactive and proactive routing systems are combined with hybrid routing. These protocols adapt by nature and adjust mobile nodes according to their zone and position. Core-Extraction Distributed Routing (CEDAR), Zone Routing

Protocol (ZRP) and Zone-Based Hierarchical Link State Routing Protocol (ZHLS) are come under hybrid routing [20], [21].

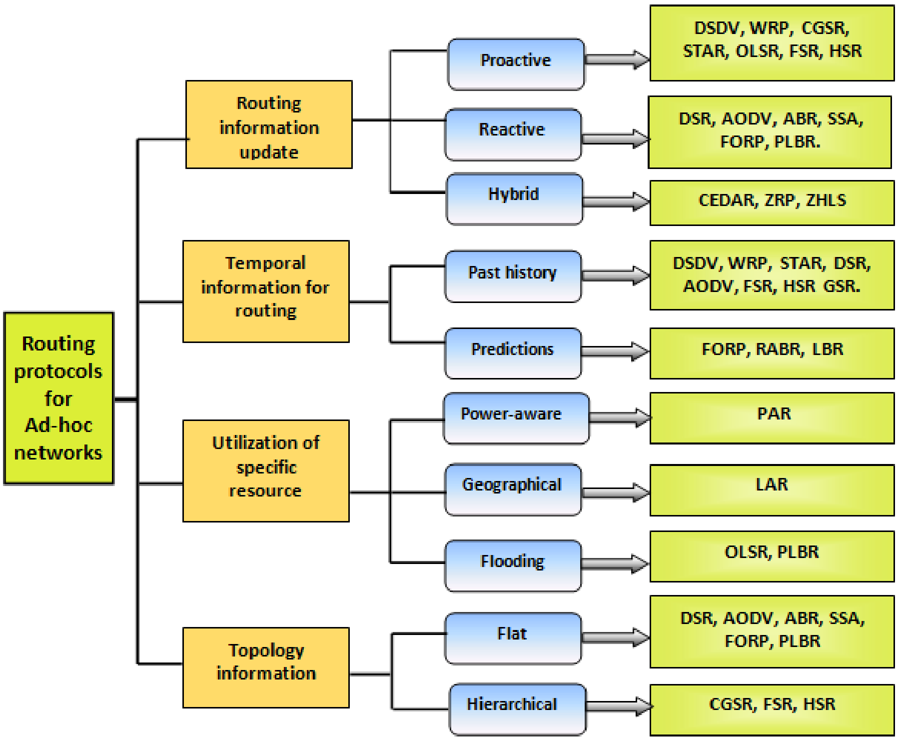

Fig.2. Classification of Routing protocols for Networks

The protocols using the Temporary Information (TI) for routing are classified as past temporal and future temporal routes of information. In these routes, depending on the duration of stability of the wireless networks, each node retains the count of the beacons of its neighbors in order to assess temporal stability [22 - 25]. FORP, Route-lifetime Assessment Based Routing (RABR) and Location-Based Routing (LBR) are the future TI routing. DSDV, Source-Tree Adaptive Routing (STAR), DSR, AODV, Fisheye State Routing (FSR), Hierarchical state routing (HSR) are the past TI routing protocols. According to the use of specific resources, PAR and LAR are power-aware routing systems and location-aware routing systems respectively [26].

1.5 Introduction to SDN over wireless environment

The evolution of SDN has played vital role in the creation of Next Generation Networks (NGN). A paradigm change has been introduced for advances in SDN, which seeks for centralized designs for wired and wireless networks in a similar way [27].

SDN technique unbundles the control plane from the transmission system into switches and aggregates all control plane into a single controller. SDN allows for the management of the network behaviour by software outside of the physical connection network devices. The operators are able to quickly create unique, distinctive new services by not connecting the hardware from the software, free from closed and proprietary platforms. The central controller collects network data from switches and calculates optimum routing pathways for switches based on global network information in an SDN-based routing architecture. The overhead routing is substantially reduced, as switches do not need to communicate routing information [28], [29].

Intention of SDN is to create an unbounded, user-connected network administration framework for transmission devices. Depending on the scale of the network, a control plane may be one or several [30]. A rapid, dependable scattered control with distributed configuration may be established in many controller setups. Differentiated data planes from control planes play a major part in SDN in extensive speedy computing network, whereas switches employ the flow table for data plane packet forwarding. Five important characteristics of the SDN focus are:

- Divide data plane from the control plane
- Get a broad overview and provide to the centralised controller of the whole network.
- Open interfaces between data plane devices and control plane devices
- Network can be programmed by external applications.
- Ensure the overall management of traffic.

In a variety of infrastructure-heavy wireless network environments, SDN offers flexibility. There is a lot more of an industry turn in the infrastructure-heavy environment. This offers SDN flexibility to provide a selection of vendor appliances, enhance network latency and provide inexpensive transfers between various wireless network technologies to these dense Wireless Network operators. In contrast to the Packet Gateways (P- GW's) in the network, SDN may mainly be used for mobile networks, distributing the data plane over several inexpensive network switches.

1.6 Contributions of the paper

The proposed paper includes the aspects of SDN based Ah-hoc routing protocols as follows:

- Opportunities and challenges of SDN in AHN and impact over the design of routing protocol with SDN in AHN
- Architectural components of SDN are explained with its functionalities related to AHN
- Applications of SDN in different networking domains and the benefits of SDN used in various application scenarios are explained with an example.
- Classifications of SDN based routing protocols for AHN are described with their pros and cons.

Organization of the paper is given as follows:

In section 2, Comparison of SDN with Traditional network, Reference architecture, Components of SDN, Various applications of SDV over different scenario is described. Section 3 explains the Classification of SDN-based Networks and section 4 details the challenges of routing protocols in AHN. Section 5 presents the various SDN based routing protocols for AHN and section 6 concludes the chapter and the details of future enhancement is given.

2 SDN for Wireless Networks

2.1 Conventional Vs Software Defined Network

In general, data plane and the control plane are the two components used to form the network designs. The main duty of the data plane is to send packets according to the IP address of the r recipient host. The fundamental role of control plane is to determine the end-to-end path for forwarding the packets. In a typical network design, the operations of these planes are grouped together in every router. The forwarding table is a critical component of the data plane and includes Internet Protocol (IP) address entries. The transmission function matches the arriving packet with the destination IP address in the packet header to the entries in the transmission table and determines the activities to be performed. These items in the forwarding table are configured with the routing function [31].

The networking architecture, which defines the software, removes the control plane operations from the routers and transfers towards a piece called SDN Controller (SDNC). The transmission function remains on the router, but the SDNC is used for the routing function. This distinction means that the routers are called forwarding devices. SDN is software-based whereas conventional networking is often hardware based. Since it is software based, SDN is more flexible and enables users to manage resources digitally throughout the whole control plane more easily and more quickly. Conversely, conventional networks are linked and administer their set-up via switch, router and other hardware [32].

SDNC provide Application Programming Interface (API) connected north-bound interface functionality. Due to this connection, the creators of applications may programme the network directly, in contrast to utilizing the standard networking protocols [33], [34]. Instead of physical infrastructure, SDN permits customers to utilize software to prove new devices so that Information Technology (IT) managers may control network channels and arrange network services proactively [35]. SDN has also the capability, unlike traditional switches, to communicate better with network devices. The main distinction between SDN and conventional networking is represented by virtualization. SDN produces an abstract duplicate of physical network when whole network is virtualized and enable to provide resources from a centralized place. Conversely, the physical placement of the control plane in a conventional network restricts a traffic flow control capacity of an IT administrator.

The SDN enables the control plane to be accessible via a connected device on a software basis. This access enables IT administrators to regulate circulation from a centralized User Interface (UI) in more detail. It provides better control over the way network functions and network configurations. This site is centralized. Especially in network segmentation, the ability to process various network settings from a centralized UI rapidly. SDN has become a popular alternative to conventional networking, allowing IT managers to provide the necessary resources and bandwidth without the need for extra physical infrastructure investment. New hardware is required to boost the capacity of traditional networking.

2.2 SDN Reference Model

The SDN Wireless Network (SDWN), a software-based and highly efficient network control, is predicted in order to facilitate the administration of Wireless Operators. The SDWN also opens up several constraints in typical wireless networks and have new options for advancement in network structure. SDN isolates the control functions and transfers them to a central entity known as the SDN Controller [36]. All nodes are used as both forwarders and end hosts in the proposed SDN-based AHN. They have restricted broadcasting ranges, such that both data transfer and control take place through multi-hop pathways. In this background the SDNC need to perform following tasks for efficient routing:

- For each modification in network topology, SDNC broadcasts route changes to the entire network.
- Connection details are continually sent to SDNC from which it can learn the topology of the network.
- The path to SDNC is kept in each node.

Fig. 1 illustrates the three levels and a number of standard interfaces in SDN design. Application layer and control plane are connected through the APIs, also known as the northbound interfaces [37]. In particular, the rules and directives of the application layer for controllers are translated via the northbound interface. The boundary that connecting a control unit in the control plane and hardware devices within the data plane is indicated by the southbound interface. OpenFlow, specified by the Open-Network Foundation, is a common SDN southbound interface. A number of controllers, including NOX, POX and Floodlight, have been designed based on OpenFlow. Southbound interface is used by the controller for employing the network management on the functional devices at the network layer using the southbound interface. The east-west bound interface is responsible for communication in the control layer between different controllers.

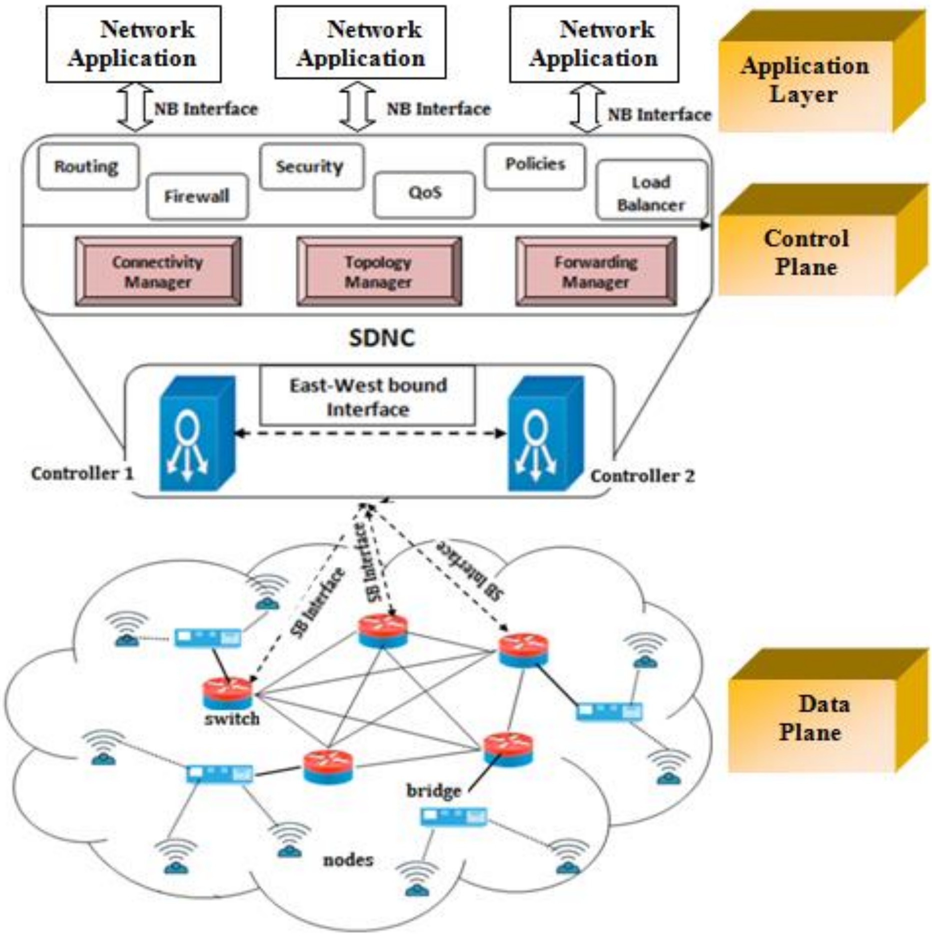

Fig.3. SDN architecture for Networks

In addition to other features like load balancer, QoS, policy and firewall, the routing feature is implemented within the SDNC as an application [38], [39]. The SDNC manages the network state, for example network topology, linking rates and flow information. The flow-based transmission model enables for QoS priority for entries (ie. flow rules) and differential network traffic services.

2.3 Components of SDN Architecture

The SDN Architecture consists of different components and each has its own duty in running the network effectively [40]. The basic SDN Terms, SDN Components are as follows:

- **Network Devices (Data Plane):** Data Plane consists of several physical and virtual connecting devices. But with SDN, just the data plane is available for network devices. So, the main task of these network devices is only forwarding the data. This provides a very efficient Forwarding mechanism.
- **SDN Controller (Control Plane):** The most important and central component of SDN architecture is SDN Controller, it is called as the intellect of the system. The SDNC is used to govern all data plane devices. The application on the application layer is continuously monitored. This top and bottom layer is connected by the SDN Controller using interfaces.
- **Sound bound Interface:** To enable the communication with bottom layer of network elements through southbound protocols – Openflow, Netconf, Ovsdb, etc.
- **Northbound Interface:** North Bound Interfaces (NBI) is an interface of SDN and SDN controller applications, generally offering a short overview of the network's behaviour and requirements straight away. This may happen at any level of abstraction and in a range of functions.
- **Network Operating System (NOS):** It is software that is supplied on conventional server hardware separately and delivers APIs as a platform in SDN applications for switching or routing. Current examples include OpenFlow, which is being upgraded by start-ups such as ADARA, LineRate, Midokura and Brocade includes updates to the NOS (for example, Big Switch, IBM, NEC etc.). It abstracts transport layer and virtualized network services, providing northern bound APIs which enable the network to be programmed and services requested by applications. In most SDN architectures, the SDN NOS stands for controlling layer.

- **Application and Services (Application Plane):** SDN applications are programmes which send their requirements of network needs and network behaviour to the controller explicitly, directly and programmatically using NBIs. In addition, for internal decisions, they may use a conceptual representation of the network. A SDN system comprises of one or even more NBI drivers and one SDN application logic. SDN Applications can expose an abstract network control layer by themselves to offer one or higher level NBI via the relevant NBI agents.

  Application layer is open space to design the most inventive application by utilising all topology details, current status and facts about the network. Applications are implemented like the network automation, network setup and administration, network monitoring, network fault resolution and safety policies. Such SDN applications can provide final solutions for real-world enterprise networks and data centres. SDN applications are developed by network vendors.
- **Management and Administration:** In every application, there is a functional interface to a manager for SDN controller and network element. The manager has to assign the resources to the applications residing at higher plane from a resource pool in the lower and to provide accessibility information which allows lower and higher levels to communicate with one other. Further management features are not excluded, subject to restrictions on the exclusive control of an application, the SDN controller on any particular resource. Each unit from north to south planes may reside to a distinct administrative framework. The manager shall live in the same administrative domain as the managing entity [41].

2.4 SDN Applications

2.4.1 Datacenter

Due to versatile and vendor-neutral property of SDN network, the operators of data center and network domain, clients are similar in using the application. . Updating a policy or enhancing a specific application is not about buying a new device or confronting a proprietary physical interfacial instead programming software [42], [43]. A Software-Defined Data-Center (SDDC) utilises virtualization practices in order to separate the hardware infrastructure into a separate virtual machine. For SDDC customers, the benefit are that the infrastructure cannot be built rather they simply can "rent" them via the cloud if they need computing, networking and storage resources. Fig.4 shows the exploitation of OpenFlow for Cloud and Data and is referred from [44], [45]. In particular, the five primary advantages provided by SDN to data center as follows:

- **Processing Big Data:** An enterprise would like to examine big parallel information sets, but they need adequate bandwidth to do so. SDN can assist by managing performance and connectivity more efficiently.
- **Cloud-based mobility support:** The emergence of cloud is the major trends in information technology and telecommunications. Cloud is based on an idea of supplying based on demand and conscience that SDN can deliver actively depending on the availability of resources inside the data centre [46].
- **Traffic management for a wide range of IP and virtual equipment:** It agree to active routing tables, which make the priority routing easier for virtual machine based on real-time network feedback [47].
- **Flexible and adaptable network:** SDN can be used to add devices to the network more easily, reducing the risk of service disruption. SDN is more suitable to work with virtualized networks.
- **Managing policy and security:** SDN can be used to spread security policies more resourcefully and effectively across the network, including firewall devices and other key elements.

2.4.2 Telecommunications

The cellular telecommunications market is probably one of the most cost effective. The rapidly growing numbers of mobile devices have pushed existing cellular networks to limits over the past decade. Integrating the recent developments in the current mobile architecture includes 3G Universal Mobile Telecommunications

System (UMTS) and Long-Term Evolution (LTE) with SDN plays a significant attention [48].

The greatest disadvantage of existing mobile networking topologies is the centralization of the network, handling all transit traffic by specialized equipment that includes numerous networking operations from routing to management and pricing access, resulting in increased infrastructure costs owing to device complexity and major problems with scalability. Instead, the SDN controller decides on behalf of the complete network and directs the data plane to work. The third advantage is that using SDN facilitates the launch into the telecommunications market of virtual operators and increases their competitiveness. All the suppliers are accountable for controlling their own subscriber flows through own controls by virtualizing the underlying changeover equipment, without the need to pay the high for getting their own infrastructure [49], [50].

2.4.3 SDN in the Industry

In comparison with the conventional networking, the advantages offered by SDN led the corporate to gain attention on SDN to use it to shorten administration load and to advance services in its individual confidential networking systems or to create and provide marketable SDN solutions. Generally common instances of SDN deployment in production networks is Google with its B4 network joined the realm of SDN, designed internationally to link its data centres. Google engineers indicated that the primary reason for moving to an SDN paradigm was Google's fast development of the back-end infrastructure [51].

2.4.4 Internet of Things (IoT)

IoT and SDN are the latest technologies introduced in wireless networking that creates more attention in research communities due to its vibrant real world applications. The purpose of the SDN is to connect objects via the Internet by decoupling the controller and data planes. The orchestration and control of the networks is a challenging issue for a huge, decentralized system and there are billions of linked items. The SDN offers agility and computing to IoT network with no compromising in conventional implementations of underlying architecture [52-54].

2.4.5 Vehicular networks

Vehicle-to-everything (V2X) communications system in vehicular networks is a recent technology that dramatically reduces road accidents and enables high-level automation with the development of SDN [55]. Network flexibility and programmability not only changes the plan of new vehicle network structures, as well the execution in the future of smart transportation systems of V2X services [56-59].

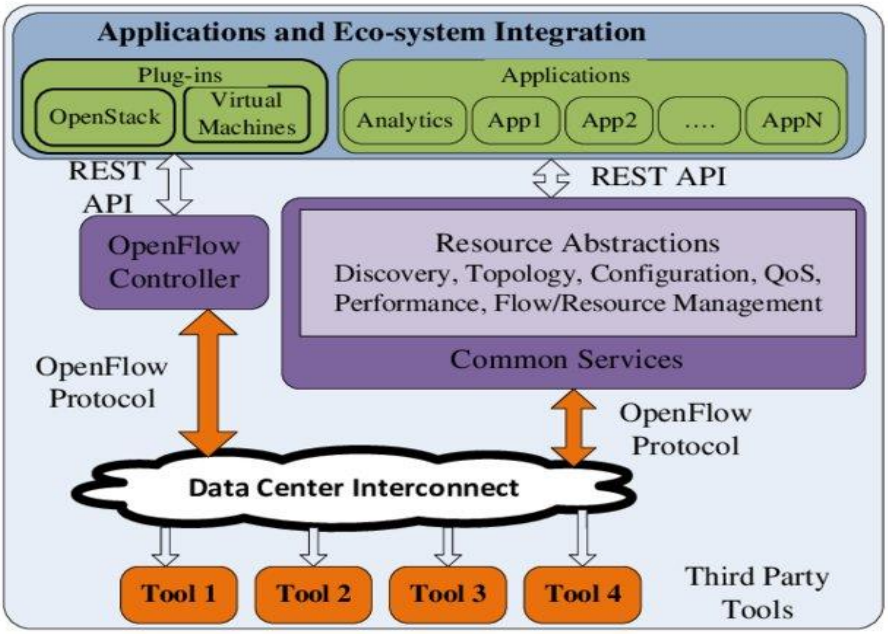

Fig.4. The use of OpenFlow for Cloud and Datacenter

2.5 Advantages of SDN in different Application services

2.5.3 Security services

The present ecosystem for virtualization supports a particular virtual service that runs at the network layer. This means that the SDN systems incorporate functions like Network Functions Virtualization. This sort of network security enables a really proactive environment to decrease risks and respond to issues extremely rapidly.

Every second is critical to stop the attack whenever a violation occurs. The attack also needs to be identified and other network components must be protected from attack. A more proactive environment can be created to respond to changes by integrating powerful services into the SDN layer.

2.5.4 Network Monitoring and Intelligence

Modern SDN technologies help to resume an important layer in the network's data centre. System architecture is very complex and much more data than ever before must be handled. Remission, heterogeneity, huge network traffic are the challenges that need to be reduced with a firm network supervision and intelligence layer. By integrating these technologies into the SDN architecture it is possible to gain advantage and proper insight. Optimization, alerting, hypervisor connection, port setup, and flow may also be included into network monitoring and intelligence solutions. Such agile solutions are also employed for traffic monitoring between the cloud environment and the data centre.

2.5.6 Bandwidth Management

Operators are able to use bandwidth management through SDN applications to ensure end users are provided with the optimal experience of online video viewing and browsing. This SDN application may also monitor the requirements for bandwidth and provide user flows to meet Layer 7 latency and bandwidth requirements. This kind of bandwidth management approach will also improve user experience with zero buffering by improving video playback. There is little doubt at this stage that SDN in the operating networks is becoming a reality.

3 Classification of SDN-based Networks

3.1 Mobile Networks

MANETs is a network without any assistance for infrastructure to transmit network traffic between two nodes. It is a continual self-ordered mobile device network with a flat grid infrastructure and a wireless connection. It has a shared medium which is extremely demandable for radio communication. In MANET architecture, nodes or devices are often independent and act like both host as well as router.

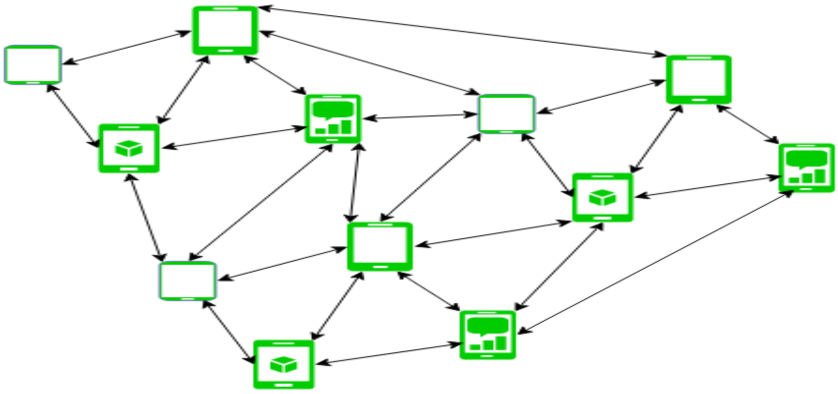

Fig. 5. MANET Architecture

MANET offers dynamically changing topology that supports mobility [60]. The conventional MANET organization is depicted in Fig.5.

3.2 Wireless Sensor Networks (WSNs)

A WSN uses resource restricted sensor nodes to monitor the environment's physical circumstances, at the same time the SDN paradigm offers a straightforward and efficient communication network control method. The convergence of these systems is known as Software Defined Wireless Sensor Networks (SDWSN). Fig. 6 shows a basic architecture of a SDWSN [61]. The sensor nodes in such design just transmit packets, while a conceptually centralised controller performs all control-plans actions such as forwarding, service quality control and channel assignment [62], [63]. A SDN controller can govern and optimise Performance of WSN, for example energy consumption and communications flow, against the distributed organization of a WSN based on an integrated overview of the complete network [64].

In order to decrease energy consumption, SDWSN employs energy management technologies like duty cycling, data aggregation in the network and improving layer functionalities. It allows sensor nodes to be programmable to execute applications without stateless solutions like finite state machines. It features an API that makes network programming simple and versatile, and allows developers to design the SDN controller in their self knowledge and is very constructive in supervising a huge and wide range WSN.

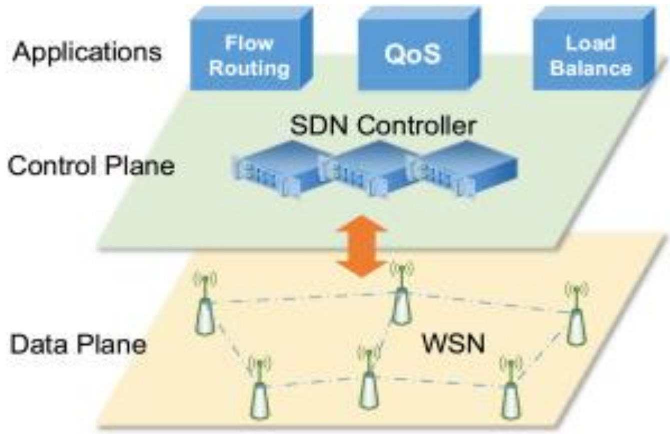

Fig. 6. SDN based WSN architecture

3.3. Wireless Mesh Networks (WMNs)

WMNs are a sort of mobile network which can organise itself, into any network topologies dynamically. With this functionality, client devices may be connected to the network seamlessly. The design of WMNs has progressively more being implemented in recent communications and internet access applications. Naturally, it is adaptable with the variety of devices, such as switches, processor, personal computers and routers. However, the attachment and disconnection of these nodes from the network can produce topological dynamics and fluctuation in communication needs [65].

Furthermore, limited gateway routers in WMN add to the growing congestion trouble. To mitigate these challenges, WMNs should include efficient load control, traffic engineering and allocation of resources. In addition, multi-hop configuration causes worsening of network speed and loss of packets. Similarly, additional factors such as fluctuating connection quality, network asymmetry, and traffic loads all pose significant issues. In addition, the changing of the hardware equipment in WMN network nodes might require full or partial replacement once established and deployed, leading to substantial increases in the operational expenses. This enables WMN to be programmed to implement modifications with software applications [66].

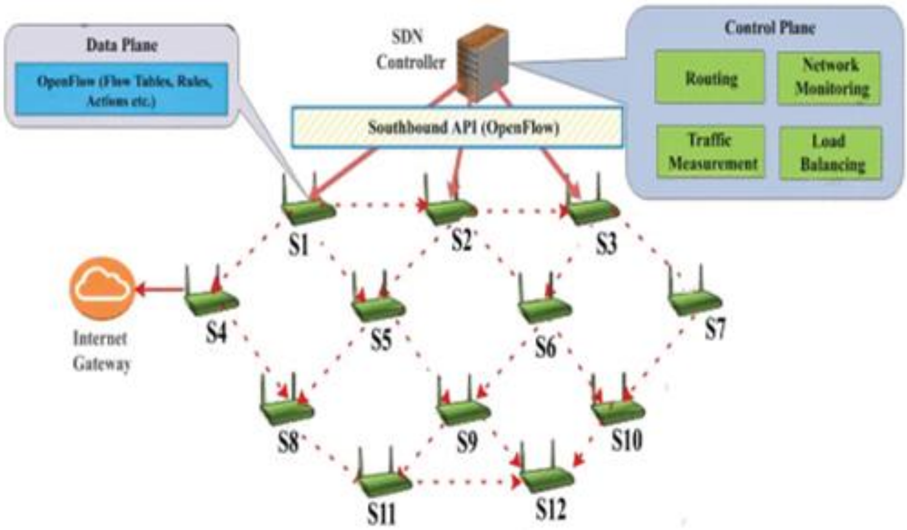

Fig. 7. SDN based WMN Architecture

DSR, AODV, DSDV, Optimized Link State Routing Protocol (OLSR) and Better Approach to Mobile Networking (BATMAN) are the routing protocols employed on WMNs. All these routing methods indicate a significant drop in average capacity and do not enable mobility management. The OLSR and BATMAN protocols, nonetheless, demonstrate good multi-hop performance. The performance of the OLSR protocol is often superior to the BATMAN [67], [68]. Through the application of the SDN methodology, the previous challenges of design and execution may effectively be resolved. The purpose of programmable WMNs may be achieved with a logically central controller that can remotely work and construct mesh nodes and to make trouble-free data transfers. Policies for control of congestion and load balance have also been created to improve traffic and load balance management. However, the dependability of the network may be compromised by a single control, because this fault tolerance must also be taken into account during the paradigm adjustment [69].

Network operators can adopt multiple QoS policies while maintaining the requirements of the user and application [70], [71]. Proposed design in Fig. 7 demonstrates the two-stage SDN routing architecture, where initial route from a controller to switches is identified in the first stage and in the second the inefficient routes from the first stage are optimised. The suggested design solves additionally linkage or node failure, one of the most important wireless environment difficulties.

3.4. Vehicular Networks (VANETs)

The SDN-based routing framework architecture in VANETs is illustrated in Fig. 8. Three types of components are included in the entire vehicular network, i.e. the SDN controller, local controller and forwarding nodes. Each route is also divided into several pieces of the same duration. It helps the network by optimizing the travel time between all routes between the source and destination. The SDN controller keeps up-to-date global information about the network structure. Vehicles have Wi-Fi and WiMax networking equipment and a routing customer application for event transmitting packets is developed [72].

The routing client uses a WiFi network device to communicate data to other cars and will ask a route from the routing server through WiMax network device if no route entry is made for the destination. The Road Side Units (RSU), which are connected to regular clouds, function as gates on the VANET component. The burden of SDN controllers reduced by RSUs that serves as local controllers by keeping local updated topology data in the communication area. Note that the local controller is responsible for providing mobile vehicle controls alone, but does not need the provision of automobile data. The OpenFlow protocol is designed for enabling the interactive environment between data plane and controller, with the main advantage of efficient SDN operation of the current hardware.

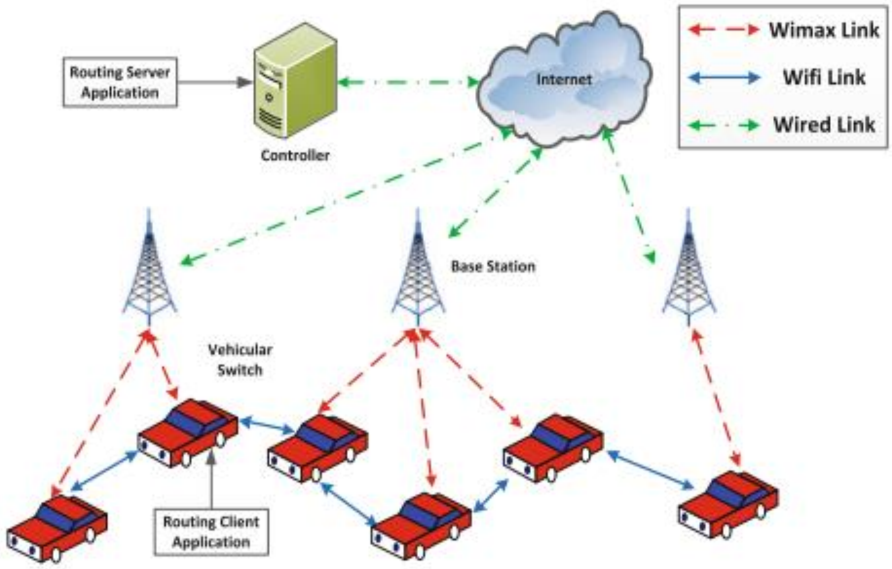

Fig. 8. SDN based VANET Architecture

4 Challenges of Network Routing Protocols

Mobility, limiting bandwidth, limiting resources, flawed medium of transfer, location related conflict are the major Challenges for routing protocol in networks.

Current Challenges in the wireless networks are given below:

- **Unavailability of the Infrastructure:** Ad-hoc network that runs its nodes irrespective of any infrastructure. The mobile Ad-hoc network will not have permanent boundaries.
- **Lack of Centralized Monitoring Channel:** The dangers to the network are caused by the absence of a central control channel. This big Ad-hoc network is difficult to manage. Ad-hoc network problems including transmission errors and packet loss problems are widespread.
- **Reliability and Security**: Ad-hoc network has the security issues and wireless connection vulnerabilities. Data transmission mistakes are also a concern with dependability owing to the constrained wireless transmission range.

- **Less Transmission Quality**: The number of fewer communication systems can lose high-rate data. The network performance might be degraded.
- **Changing the Network Topology**: In their infrastructure, nodes may roam freely. The topology of the network can be randomly limited to one end of the other node. This might unpredictably affect the topology that degrades communications.
- **Power Consumption**: Mobile nodes in the battery dependent network may only utilise a power supply for managing the device mobility. MANET must optimise this resource to enable nodes to connect with a broad time channel.
- **Transmission Control Protocol (TCP) Performance**: TCP is based on Round Trip Time (RTT) measurement and network packet loss. Mobility and network congestion are impossible for TCP. Node mobility can lead to a packet loss that has a lengthy RTT.
- **Security and Privacy:** The data packet is not very secure in the wireless networks. By authentication from the neighbour, a user is able to understand that the nearest users are hostile or friendly. Data encryption technology for packet security needs to be applied.
- **QoS Support:** In addition to the available resources, the QOS for wireless networks depends on the mobility rates of these resources. Bandwidth limits, network dynamic topology, restricted capacity processing and storage of mobile nodes are the three basic limitations in relation to service quality.
- **Energy Efficiency:** Battery-operated devices are mostly used. The microprocessor technology is trailing behind. Limiting a device's working hours indicates the necessity to save power.

5 SDN based routing protocols for AHN

5.1 Hierarchical Centralized Proactive Routing (HCPR)

A hierarchical protocol is the HCPR protocol, which builds network clusters. There is a Cluster Head for each cluster (CH). Nodes get information from CH about the intra-cluster routing. The HCPR protocol picks gateway nodes for inter-cluster routing besides the formation of clusters. HCPR is proactive and regularly carries out all its activities to account for network dynamics.

The HCPR functionalities, for example the learning path to the SDNC, network architecture and network transmission, are outlined as follows: The SDNC regularly transmits the Topology Discovery message (TD). A field for the radius cluster is likewise included in HCPR. For transmitting network routes, HCPR employs messages for the configuration of intra-cluster and inter-cluster routes through the Routes Update (RU) and Cluster Information (CI). HCPR is a proactive protocol that updates all nodes periodically. Depending on the cluster level of a node, however, routes for inter-cluster routing can or may not exist. Nodes also invalidate their routes when link breakdowns are detected. When a node does not receive a packet from that neighbor in the last NbrMaintenance period, a link break is identified. Line breaks with the Carrier Sense Multiple Access / Collision Avoidance 802.11 system can also be detected by nodes if available [73].

HCPR minimizes the overhead communication by making it possible for cluster heads to setup intra-cluster routing and locate inter-cluster gateway nodes. With the use of its hierarchical routing strategy and reduced communication complexity, the results of the simulations demonstrate that the HCPR is better at achieving a minimal interference than the CPR, reducing package losses.

5.2 SDN-based Routing Protocol for Networks (SRPA)

SRPA includes the idea of SDN for path selection and it segregate the core routing decision from the nodes and tied to one controller. Thus, in the absence of SRPA flow table, the node will transmit a routing request to the controller rather than relay it to neighboring nodes. This protocol uses the two data structures as SRPA flow table and SRPA neighbor table [74]. SRPA Flow Table for the selection of data packet paths is the main data structure. Each flow table input includes six fields: Type, Destination, Next Hop Node, Hop Count, life span and Counter.

The neighboring table reflects the neighboring relationship between nodes. A node encapsulates and sends to the controller the neighboring table list. The controller may therefore collect topology information from the whole network. The neighboring list does not only store neighbor addresses, but may also retain the weight of neighbors.

In order to assess different parameters of a node, such as battery power and trust value, the next level of power can be employed for differing network purposes.

The experimental findings indicate that the performance of SRPA in route discovery time and RTT is superior to AODV. Many difficulties may be solved on the basis of SRPA, such as trust and security. The weight of neighbor list is the standard value when the node transmits the neighbor details to the controller. To increase network security, nodes can utilize the weight of the attribute to indicate their neighbor nodes' trust values. The controller may therefore evaluate confidence problems in routing decisions and acquire packet forwarding pathways that comply with security standards.

5.3 SDN- and Fog-Based VANET Routing Protocol (SFIR)

SDN-based vehicle networking system routing protocol is presented in [75]. The routing protocol is designed to find the desired route for routing data packets in real time density. With the use of greeting messages sent by the cars, SFIR determines the traffic conditions at the fog node. The computation for a particular route is carried out using the following equation (1).

$$Score_i = \alpha(L_i + ED_i) + ({}^{\beta}/_{D_i}) \quad (1)$$

where $Score_i$ is the fitness value, α and β are the distance factor and the density factor, respectively, L_i is the length of the road, $ED_i$is the Euclidian distance and, and $D_i$is the vehicle density of each road. The parameter value is modified according to the traffic situation value. For further investigation, the computed road conditions are subsequently forwarded to the SDN controller. The SDN controller acquires the overall position of the whole network after receiving input from all nodes. A graph based on the data obtained from the nebula takes the SDN controller to assume the road junctions as the nodes and the roads as the edges. The controller performs the Dijsktra algorithm for routing a packet, so that the shortest path may be found from source to destination.

SFIR provides the uniformly dispersed traffic parts more priority. In order to compute road real-time distribution, the controller employs the standard deviation. The buffer size is taken into account in this protocol. A vehicle's buffer may overflow due to excessive networking. In these circumstances, they send the light messages to the other cars to distribute this information. If the buffer limit drops below the threshold limit, the cars can revisit the messages. In the scenario of a genuine dispersed network, SFIR stores carry forwarding techniques. If the buffer boundary falls below the threshold, vehicles can review the messages. SFIR stores carry forwarding mechanisms in the context of a really scattered network.

5.4 An SDN-based congestion-aware routing algorithm over wireless mesh networks

A novel SDN control structure-based methodology to route packets is suggested [76]. Saturation to SDN and advocate for SDNR is part of the architecture of the link quality model. The network structure defined in software (SDN) promises to effectively get the network configuration and can deploy fine-grained routing algorithms with a centralized controller to fully exploit the network resources while guaranteeing the overall control over the network is acceptable. In order to assure network performance, the saturation link to the SDN controller is implemented, which can track the crowded path and redirect the following traffic to a non-congested road, which is the optimum in time. The benefits of SDNR are compared with normal routing techniques and shown the output.

With the OpenFlow Protocol, the controller may achieve full network topology as one of SDN's important features in the design. A link quality model is necessary for the controller to identify the optimal path to the arriving fluxes from the overall network architecture. The saturation link to the SDN architecture has been set, where the controller may detect the connected state and route to the next better paths. The congested route also keeps the flows active prior to the packed state. This is because the identical flows will be transmitted according to the rules of transmission in the forwarders, and the controller will never be sent. Therefore the traffic on the packed track is gradually decreased and the crowded state improves. Sometime later, the controller will again allocate more flows on that path if the path metric is detected again. The transmitters send saturation to the controller on a regular basis. The controller takes information from all forwarders in the context of the quality template for the connection and chooses the optimum path from source to location:

$$\left\{\begin{matrix} Cog_{path} = 1 - \prod_{l\in path}(1 - Pol_l) \\ T_{path} = \sum_{l\in path} T_l \\ M_{path} = (1-\alpha)T_{path} + \alpha Cog_{path}, \ 0 \leq \alpha \leq 1 \end{matrix}\right\} \quad (2)$$

where Pol_l stands for the saturation factor of l^{th} link of the route, Cog_{path} indicates congested condition and Cog_{path} > 0 means that the path has been larger the congested condition. The route is seen as better if it has lesser Cog_{path} since that suggests the route has more resources available for bandwidth still. T_{path} symbolizes the wait time of the path, T_l Specifies the connection latency of the path and is a factor of a scale factor, it decides significance of the delay and the path α. State of congestion depending on the dynamics and the network conditions. The choice of route will be more sensitive to crowded conditions for a big number of people. The selection of paths will instead be more sensitive to delay for tiny ones.

It is deployed with the Opendaylight controller and Mininet out-of-band control framework over WMN to undertake our SDNR studies. Simulation findings indicate that SDNR performs well in average performance, packet delivery and standardized overhead routing.

5.5 SDN-Based Geographic Routing Protocol for VANET (SDGR)

In [77] is suggested a VANET geographically supplemented SDN routing protocol named SDGR. In SDGR the geographical position and direction of every routing node are communicated regularly. The central SDN controller uses RSU to collect messages and estimate road density through update of status messages for the vehicle. The server takes into account the width of the road in calculating the road density [78]. The server assigns weight for each route by assessing the length and density of the automobiles on the route [79]. Weight is computed on the basis of the following equation:

$$w_{ri} = \beta * f(L_{ri}) + \frac{\gamma}{g(T_{ri})} \quad (3)$$

In the equation, the density and length of the road are denoted by T_{ri} and L_{ri} , respectively, γ and β are the controlling parameters, and wri is the weight of the roadway. The shortest weight based route computation is a lengthy operation. The SDN controller therefore creates a sub graph based on the source node and the destination node from the derived graph. The process of creating sub graphs begins both from source and destination and only takes into account the related intersection. If the source node contains the destination in its routing table, the data can be sent to the destination using a greedy hop selection procedure. The vehicle takes into account speed and direction in a V2V connection the next hop selection procedure. Two primary approaches of direct mode and cross mode are applied by SDGR. The immediate mode is used to supply the data packet according to the position, speed and direction of the next hop.

Data transmission prevents vehicles from the opposite way. As a rule, so many cars from different directions come together at the intersection that might produce various networking difficulties, such network congestion and buffer overflow. In order to avoid this situation, a warning message is sent to other cars by the cars if their buffer limits reach a threshold. The advantage is that packet transmission technology in junction mode can have a favorable influence on the road junction traffic signals when cars remain halted for certain duration. The downside is that the protocol does not employ an overall strategy that minimizes the intersection of the transmission.

5.6 Hierarchical Software-Defined Vehicular Routing (HSDVR)

HSDVR applies in particular to SDN networks, which for any cause have broken connections with the central controller. This routing protocol provides vehicles for communication with the main controller in various clusters and forms local SDN domains [80]. With the assistance of beacon messages the clusters are built. The beacon transmissions contain vehicle geo-location, speed and direction. In HSDVR there are two major controllers: local and main controllers. The cluster head is regarded a local control unit and a major control unit is considered the principal control unit of the central architecture. The controller uses two control packets, namely request path packet and route info packet, in order to transfer data from source into destination. A path packet is requested for the source vehicle to go to the destination route [81-89].

The route info packet is the same one in which the route request packet has been received by the destination. The host verifies if the destination route is known or not before the request path is broadcast. The host redirects packets to the target node if the host holds the details of the intended node in the route table. If the host car has no target information, it will examine whether or not it is a controller. If the host is a controller, it will try to figure out the gates through which it may reach the target. This protocol benefits from filtering algorithms to discover the gates to the destination, which decrease the overhead transport and the drawback, which is not so good for sparse road conditions.

6. Conclusion

Emergence of SDN technology made tremendous changes in wireless community like network design support, end user support, programmability, routing overhead minimization and less cost. Advancement, ease of deployment and adverse benefits of using this in conventional network design and protocol operation leads to grab the attention by researchers. SDN now playing a crucial role in all aspects and gain more advantages in interoperability of the network, network management, security, energy efficiency, topology control and etc., The proposed article gives a clear overview on challenges and opportunities of MANET and the types of AHN. The need of routing protocols and different categories of routing in MANET are tabulated. Classification of AHN with respect to the application scenario was presented with architectural components. SDN based network routing protocols for various application scenarios are explained with its pros and corns.

This work gives an insight of researchers to address the open issues in AHN. In future, this work can be expanded with more routing parameters and application need for categorizing the routing protocols proposed for SDN based routing in AHN. Application specific requirements for SDN for routing protocols design in WSN will be described to give a clear overview of researchers to identify the problems in design aspects.

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