Towards Reducing Handoff Times in Next Generation Wireless Networks

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Abstract. In today's world, there is a great amount of increase in network devices, applications and services. This has also increased the user expectations on the network service providers. Quality research is being carried out by eminent researchers in the area of network design and optimization. Nowadays IEEE 802.11 based wireless local area networks (WLAN) have been preferred by smart devices consumers to access low cost, tremendous throughput and provision for multimedia applications. The arise in the demand for WiFi networks encourages researchers and industry to develop the best results compared to previous versions. The new standards should facilitate improved quality-of-service, and enhance the mobility management features.

Traditional WLANs have suffered a lot from the issue of frequent handovers as it has not been well defined in 802.11 according to demand of the future Internet usage. Software defined networking (SDN) can be a prominent approach in order to achieve a future Internet technology revolution to achieve a rational impact on a wireless network. SDN enables mobility management, load balancing, and position management applications on top if centralized controller. SDN separates the network control function from its network forwarding functions thus provides centralized management. It abstracts its underlying architectures from applications and services. SDN provides programmability into the network which provides us efficient control to manage networks. Thus, SDN may play a crucial role in handover management.

In this thesis, we study the application of software defined WiFi networks (SD-WiFi) in the mobile environment to effectively improve the handover times when a wireless station moves from one access point (AP) to another. A detection and discovery (DeRy) method is proposed, based on automatic detection and discovery of access points in SDWN. A centralized controller implements effective handover decisions and selects the target APs for user's devices. The SNMP protocol along with management information base (MIB) is used for extracting the required data from the wireless stations and APs, which helps the controller to manage handovers. DeRy is implemented in the Mininet-ns3-WiFi network emulator. The handover times are improved by reducing the time consumed in detection and discovery phases. The simulation results show that the DeRy significantly reduces the handover time, increases the normalized throughput and reduces the average number of retransmissions when compared to the standard RSSI-based handoff scheme and the mean probe delay scheme.

Keywords: WiFi, SDN, Optimization, APs, IEEE 802.11 DCF, Handovers

Introduction

1 Background

The rise of new technologies and smart devices as mobiles and tablets are making people more towards the usage of internet services. With the developing of fresh services our life is changing. Most of the tasks revolve around using the web, multimedia voice calls etc. As the number of users are getting high and high so there is more need of proficient, flexible, fast and good facilities in network to accommodate the need of every single user.

At the current time most the devices for the sake of internet are using WiFi networks. The forthcoming traffic of IP will be carried out by wireless medium. 47 percent of the worldly IP traffic will be consisting of mobile node till 2021 [1]. Internet should be of very good quality for real time tasks as audio/video. But this task is very perplexing of maximizing the capacity and enhancing the proficiency for the users. The growing amount of users as well as traffic asks for the enhancement in conventional WiFi networks. The present WiFi structure has some issues which makes it unsuitable regarding moving/mobility organization. Because of the coupled nature of data and control plane in present structure, its sums the feature of applications, services and policies. This restricts the feature of management of mobility. As there is no centralized management network in the traditional WLAN so users have to go through the authentication process during handover. Thats why because of cost of set-up and conventional infrastructure the procedure of revolution has become slow [2].

The leading of two kinds of networks are cellular networks and WiFi networks. Various technologies as 4G, 5G and LTE are included in cellular networks. This wireless network is considered more promising, proficient and reliable but unfortunately is not cheap when it comes to setting up and working. Whereas, setting and working of WiFi is easy and is inexpensive than previous system but there are some restrictions in this system that should be deciphered. Moreover, its coverage is narrow as compared to previous system resulting postponement and huge loss of information when the devices are moving. Main wireless network that is commonly in use these days is WiFi on tablets, mobile phones etc. These services includes HD video streaming, Internet of Things, online games, cellular data offloading etc [3] [4]. This depicts in the coming time wireless mode would be used to gain IP traffic. For the customers the important things to be discussed are capability of the network and the upgrading in proficient way [1] to give various users an approach to network at a same time hindrance and jitter is familiarized.

The number of the users and flow of a traffic directs a message that in traditional WiFi networks there should be a balance in alteration to achieve all wanted tasks in a network. Because of the working cost and old frame structure the procedure is not made fast in WiFi network [2]. In the present days the smart devices can change and take decisions by their own. These kind of devices need proper check and balance and needs to be well organized because sometimes these can create alarming situation to the network. For achieving this goal network should be fast and active in sending information and organizational tasks with progressive programmability task. Moreover, network should give some edges to applications that are governable, easy to manage and accessible [5].

In the traditional networks the route in the network is learned by the protocols such as Open Shortest Path First (OSPF) or Extended Interior Gateway Routing Protocol (EIGRP). When the route is learned, the node makes flow tables and then takes forwarding decisions. Apart from these distributed protocols the nodes such as switches and routers also run protocols such as Cisco Discovery Protocol (CDP) and Link Layer Discovery Protocol (LADP) that are useful to in showing the information of the neighbor nodes. The control decisions among the nodes is distributed. The control plane distribution makes the network petrified and this results in lack of modularization and abstraction layer in the network, which discourages the programmability and leads to no innovation of the network. Moreover, the vendor-oriented devices are not supporting the deployment of new services and only limited services can be used.

In order to increase efficiency, strength and scalability by decreasing the tool cost software defined networking can be best approach. It is a developing technique that gives opportunity to manage the network. SDN is mainly divided into three types: Control plane, Data plane and applications. If we take a look into organization of SDN, there is a controller in the center and switches too. Control plane benefits us for particular jobs as targeted applications and it interacts with the data plane with the aid of southbound interface. If we talk about data plane so it is responsible for paneling mutual protocol. OpenFlow serves as a protocol, in terms of communicating with controller and switch it serves as an Access Point Interface. Software Defined Wireless Networking(SDWN) can be viewed as the further extension of the SDN for wired one. SDWN is all about the control of wireless devices by a central controller. The common differences between the traditional networks and SDN are depicted in Figure 1.

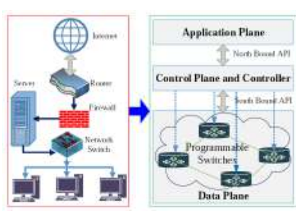


Fig. 1: Traditional networks versus SDN.

When a Mobile Node (MN) moves from one base station to another or we can say from one system to some other system so this whole scenario is termed as handover [6] and it straight away effects the worth of a service. Handover basically consists of Collecting the important information as if a system really needs a handover or not. Second is to give a user satisfied access of the system so its connection didnt break. In addition to this step there are usually two techniques are used and those are named as static and dynamic. And these techniques can be implemented through three of different types as: Hard Handover, Soft Handover and Smart Handover. The last one is Handover Decision.

WiFi networks are now used publicly instead of customized and local infrastructure [7] [8]. And this change is not as simple as it is seen , there is a big amount of challenge in terms to cover large area and less postponement of information in network. Capability of a one access point (AP) is to cover 50 meters inside and 200-300 meters outside. Because of more placements of APs for the ease of users, regular handovers happen. It is problematic to figure out difference nodes if the change is minimum in in network rules and regulation in conventional structures.

In order to resolve handover problems Software Defined based WiFi network helps in this scenario. Along with handover problems also management tasks can be checked and measured by a central controller. With the help of SDN approach there is no need of adding WiFi protocols in the access points. There are forwarding choices done by central controller in short WiFi with SDN is very easy going in terms of realizing fresh services and providing proficient method of organizing and making network better.

Software Defined Networking is capable of controlling the network as it gives a feature of programmability by which network traffic as well as devices are controlled. SDN gives us ability to program control and data plane. In SDN a very operative southbound protocol is OpenFlow in real environment [9]. Mainly SDN was used in wired environment but now it has started to be used in wireless frameworks [10]. A separate controller is provided by software defined wireless networks for the proficient control of wireless nodes. Lately there are plenty of efforts in research have been carried out in implementation of cellular networks and SDWN [11]. The usual extension to SDN is SDWN. For the enhancement of performance of WLAN and modifying network, SDWN is the best solution [12].

2 Motivation

The present information depicts that the devices using WiFi are setting up nonstop and so their flow of traffic is through WLANs. This demands that there should be enhancement in network capacity as well as maximum spatial reuse in terms of setting up more APs. but putting more APs is not a piece of cake it strengthens the channel contention, maximizes intervene between access points as well as make it more challenging for handovers. Though there is much of the achievement has been achieved to enhance performance and quality of WiFi networks but the main thing is that efforts are not still fully satisfied as there are a lot more issues that needs attention [13].

If we set up more access points, then for sure there must be more regular handovers needed between clients. According to conventional networks continuous mobility of clients made handovers. After altering of position, client gets attached with the access point and it depends on the greatest signal strength that client gets from various APs. there is a consumption of time in all these swapping process among clients and access points because of handover. There is a new network architecture to ease such described problems is Software Defined Network (SDN). It gives a good solution to the issues present in conventional architecture. Now it can be used for both cellular and WiFi networks. SDN decouples the control and forwarding tasks. It has a centralized controller which manages the network by providing programmability and controls the network in very effective way. SDN subtracts the fundamental structure from application and services [14]. It is very important in terms of handover as it provides ease for users in the network in terms of management.

3 Problem Statement

In the standard WiFi networks users have a lot of problem regarding handovers. For handover process there are usually time delays for the client. Clients have the authority to make decisions to which access point they want to attach to. The power of association and re-association is only at the client side. In the past, study was made on architecture under SDN. There focus was on altering the client side [15, 16] but this planned scheme focuses on making changing on other side which incurs extra cost [17, 18].

The purpose the proposed work is to improve the handover delays in software defined WiFi networks. The evaluation is done on the basis of handover times against the number of connections, normalized throughput against the wireless stations, and average number of retransmissions against the wireless stations. The research questions to be answered while making this research more convenient are listed below:

- What benefits does SDN bring over the WiFi networks for studying handover problems?
- How SDN is helpful in enhancing the performance of handovers in WiFi?
- How to improve the network throughput performance and delay performance in software defined WiFi networks?

To answer these questions an emulation setup is needed to find out if the SDN is the best solution for the handover as compared to traditional networks or not? This research helps us in reducing the handover time between the APs in SDWN by considering two important factors such as RSSI and traffic load on each AP. The proposed DeRy works opposite to traditional systems where control is in hand of wireless stations as opposed to DeRy where the network control is managed by the centralized SDN controller.

4 Objectives

This research work mainly focuses on some parts. Firstly, the documentation about WiFi network, handover and the implementation of SDN in WLAN. The second part is the simulation of the proposed topology in NS3. Finally, the obtained result is compared with traditional network.

5 Research Contribution

Two of the main reasons for handover delay occurs in detection and discovery phases that is why my research contribution includes design of DeRy architecture that works on detection and discovery phases to reduce the handover delays in software defined WiFi networks. SNMP agents resides inside the AP and wireless stations to get the desired information of RSSI and traffic amount. The information helps the controller to take the final decision in choosing the best AP for the wireless station without loss of information. The implementation of this approach has been done in Mininet-ns-3-WiFi emulator and results show the efficiency in terms of reduced handover times, improved normalized throughput and reduced number of retransmissions.

6 Challenges

In research process there might be some challenges to be faced. First is need to read the documentation of a software defined networks and understand its architecture. Separation of control and data plane to improve the network performance and the benefits of introduction of programmability should be understood. The best suited controller for wireless networks in terms of the performance and reliability is needed. A WLAN handover simulation using ns-3 should be developed. The difference of wireless networks from wired network and the possible issues to face during the simulation of SDN based topology.

7 Thesis Organization

The thesis organization is as follows: Chapter 7 presents the traditional and SDN based handover schemes in wireless local area network. Chapter 13 explains the DeRy architectural design to reduce the handover delays and setup scenarios for prerequisite in implementing the proposed scheme. In chapter 20 performance evaluation comparison is made between the proposed scheme and the traditional scheme. Finally the thesis is concluded in chapter 24.

Related Work

8 Wireless Local Area Networks

The standard of IEEE 802.11 is Wireless Local Area Network (WLAN) and usually it is known as WiFi. There are also previous versions have realized for IEEE 802.11 and the last one was implemented in 1997 [19]. With the help of WiFi, we are able to give wireless access of internet to our devices. It is used in health, education, finance etc, almost in every possible fields. It is less expensive and gives maximum output that is why it used commonly [20]. Moreover, it is expanding to more fields to gain a maximum advantage. Because of its use in large areas user demands more and more proficient and reliable network. The structure of WLAN is shown in Figure 2

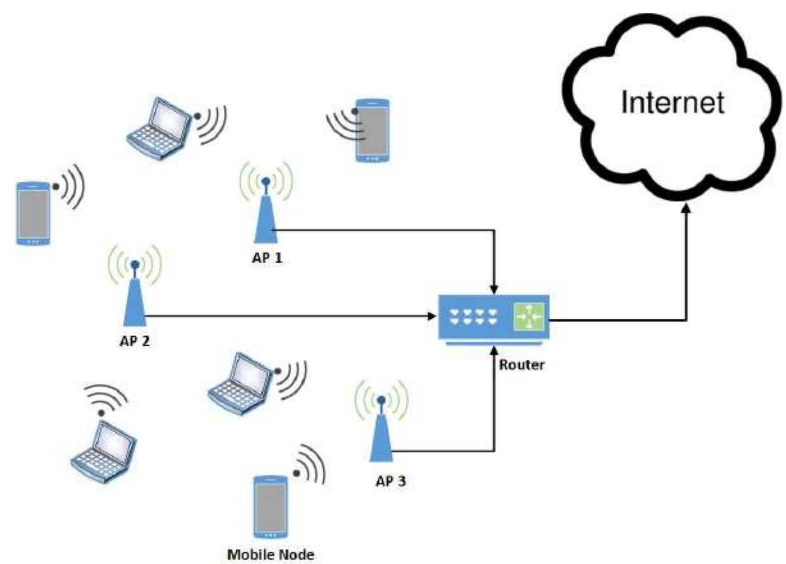


Fig. 2: WLAN architecture.

9 Software Defined Networks

Software Defined Networking (SDN) begin into life at the campus of Stanford University when main focus and studies were going about OpenFlow. SDN is mainly divided into three types: Control plane, Data plane and applications. If we take a look into organization of SDN, there is a controller in the center and switches too [21–23]. For the application layer it benefits for different jobs as safety, organization and also cooperates with a central controller through a northbound interface. Control plane benefits us for particular jobs as targeted applications and it interacts with the data plane with the aid of southbound interface. It basically focuses on organization of network by means of a single controller that gives overall view of a system. It is programmable and gives decisions on the basis and demands of application and tasks [24]. With the help of SDN many problems have been solved as well as along with proficiency, maximum results and reduced money along with a union of technologies [25]. It is not much load since the development of SDN but still it has taken over networks by resolving the problems in systems. The basic components of SDN are a s follows:

– The decoupling of planes as data and control so that there is separate control functionality.
– The verdicts are based upon the information flow being sent/received, instead of just the final location. There is equal approach for every frame of information in a flow [26, 27]. Flow abstraction [28] is helpful in making a union of different devices of network as routers, middlebox and switch. It also offers the coding environment for the matchless flexibility but to some extend there is still some restriction regarding used flow tables [29].
– All the verdicts are taken by SDN Controller. It provides the overall scenario about whats going on in a Network by giving the coding opportunities to data plane devices.
– In NOS there are many applications that are running and also links with basic forwarding devices in data plane. Because of this ,the system appears to be programmable thus making major property of SDN. A basic SDN structure [23] is shown in Figure 3.

SDN has many terminologies that are related to it and these are described as:

– **forwarding Devices:** These devices could be hardware as well as software in data plane. They perform basic tasks. The tasks that are performed are followed by some already defined rules and are defined by south-bound interface. The protocol used here is OpenFlow [29], ForCES [30], POF [31]. These protocol needs to installed by SDN controller in forwarding devices.
– **Data Plane:** The connection of forwarding devices makes data plane. These are usually connected by wired cables or wireless sources. It is consist of devices like middles-boxes, switches and routers etc.
– **Southbound Interface:** The instruction set of devices present in data plane are defined by Southbound API , a segment of southbound interface. This protocol tells us about how the communication will take place between data and control plane entities.
– **Control Plane:** It is basically a brain of the system. It has all control logics needed and already present in applications and controllers.
– **Northbound Interface:** It is made by a API presented by controls to the designers of application. It programs a understandable (not too complicated) instruction sets for devices.
– **Management Plane:** It constitutes tasks as checking, routing , load balancing etc. It delivers policies to show performance of data plane devices.

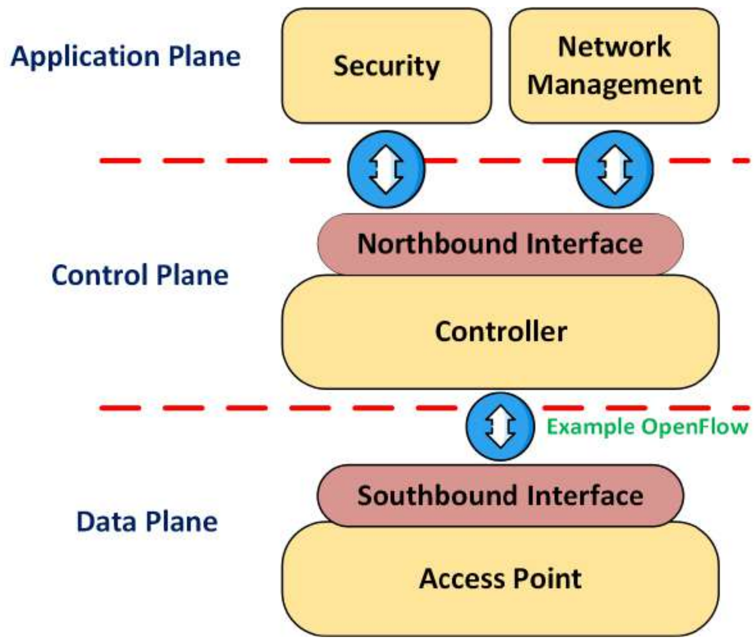


Fig. 3: Software defined network architecture.

9.1 OpenFlow

The standard interface protocol is OpenFlow [29] in SDN as like in SDN controllers, switches etc. It basically takes all abilities of hardware and software and make bare to open interface. It basically helps different networking devices as routers, wireless APs etc. thus this thing has provided ease for researchers to continue with experiments without asking developers or vendors. The entries in flow table of routers and switches can be alter by flow OpenFlow protocol [32]. It really has made researchers work easy because they can control the flow using this. This totally upheaval for new period in designing protocols changing IP and other tasks relevant to security models. The basic architecture of OpenFlow [23] is shown in Figure 4.

9.2 Software Defined WiFi Networks (SDWN)

In the architecture of Enterprise WLAN, developers have particular tool to centralize the network management. This is not an easy task to make changes in these hardware or software functionalities, so it cannot mange the continuous evolving features as well as traffic is increasing drastically [33]. So, the best substitute is Software Defined Networking for enterprise WLAN.

Thus it comes a balance change in comparison of traditional architecture. By the centralize controller, the management tasks have become way easy moreover it has an overall view of network. The devices have a connection with SDN and

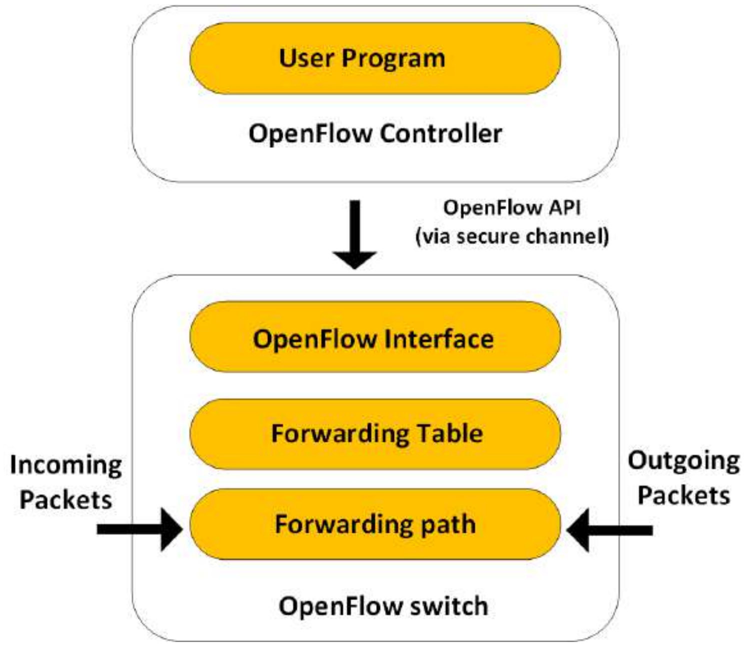


Fig. 4: OpenFlow architecture.

AP. By the help of central controller there is no, more need of putting different kinds of protocols in APs. For the packets sending and dealing [34] in SDWN there is centralized technique that makes the flexibility and programming easy for these tasks. Because of wireless intermediate have a broadcast environment therefore it comes intervention as in outcome and quality. This could be caused by APs and clients [35]. But there could be a lot more reasons for interference are there as total devices, volume and rate of traffic, environment of system [36–39]. The architecture of software defined WiFi networks is depicted in Figure 5

10 Handovers in Wireless Local Area Networks

The techniques that are used in WLAN are already descried by standards of IEEE 802.11 made by standards Committee IEEE LAN/MAN (IEEE 802). The process of handover is executed in layer 2 which has three phases and it is described in IEEE 802.11 specifications [40, 41].

- **Discovery:** This process could be active or inactive. In active scanning MS sends requests to access point signal receiver, each AP will respond which receives it whereas it is sent periodically in passive scanning.
- **Re-authentication:** The finest access point is authenticated in this phase.
- **Association:** After the authentication a request of re-association is sent to new AP, it also send the same request in addition to information as rate

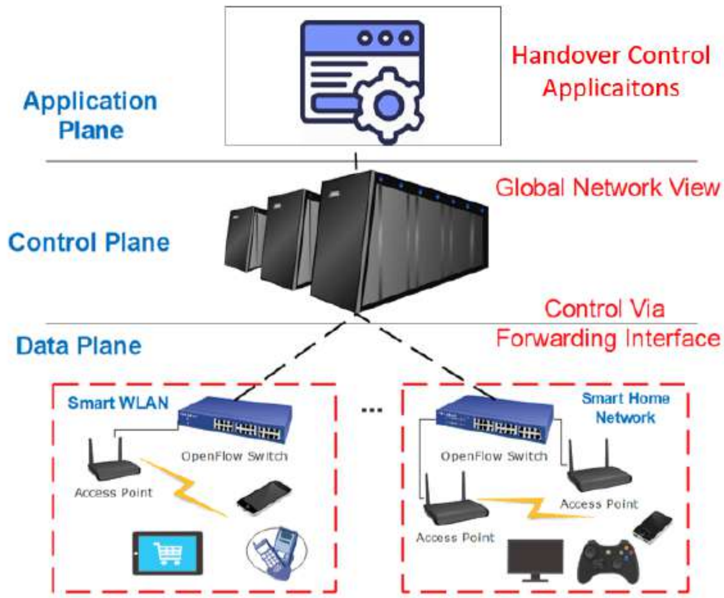


Fig. 5: Software defined WiFi networks architecture.

of bit, station ID, etc. This process is not informed to old AP. The final step of handover is completed by inter-Access point Protocol(IAPP) [42]. For the indication that handover has taken place two of the protocol data units (PDUs) are used. These are moved by wired medium from new to old Access Point with the aid of UDP/IP.

The basic structure of WiFi doesnt have present problems and issues related to moving management. As the control and data plane are together, WiFi architecture restricts the description of networks tasks, services and polices [43]. Hence it is very difficult to make such mobility tasks and services implementation for real time applications. It is always crucial task in the wireless system to perform mobility. APs are therefore used as they make an area so mobility is continuous without a break of a connection for mobile stations. Every AP has a limited signal to cover an area thats why handovers are used for break free mobility.

This process contains two main steps, first is the exchanging of packets among clients and APs and second is the total expected time it would be taken by the clients to end this process [44]. This whole process starts with association process by the clients by sending authentication packets to the AP having a strong value of RSSI and ends with re-association process to connect with the most match able AP. Three bodies take part actively for handover process and these bodies are as: Mobile station, previous AP and new AP. there is also a decrease in overall outcome of the system during handover.

In conventional structure, devices have their own control plane to take details about to form a forwarding table and this tables aids in telling us about the operation to be performed on packets. In this sense they have both the control plane and forwarding plane. But in SDN all the controller tasks have been shifted to SDN controller. SDN controller basically just performs the task as described by SDN software. OpenFlow switch is used in establishing a connection with switch so we can say in SDN, control plane and SDN plane are parted. There are different techniques that have been used to make handover performance better. By using SDN in the wireless system modification we can have programmable control and data plane into AP. The associated work is categorized as Non-SDN handover and SDN-based handover.

11 Traditional Handover Schemes

This section describes the handover without involvement of SDN or we can say this research on handover is before SDN. These are all relevant to traditional architecture but if we look into system structure they are different comparatively. The described work is based on area where handover is taken and this could be either network based and client based [45].

11.1 User-Driven Approaches

The algorithms of the handover [46–50] based on the choice by user describe the user handover algorithm.In such systems all the authority is given to the users. creators of these systems are just accountable for making a particular tool to resolve issues, but its up to the end users that they use this tool or not. The basic HOW, WHAT and WHEN control is given to the users. The above described techniques on the basis of signal power from available AP gives an opportunity to the user to make a smart choice. In [49], tell us about the same scenario described as association of user and AP. This performance in context of IEEE 802.11 depends on the ability of user as it has to look for the most suitable AP. The existing way is based on measuring the power of a signal that has been done in a number of users and identified by users from all APs in its neighboring. Thus user at the end chooses the AP with the best signal power. Virgil [46] was discussed as user level task that is performed on end devices. With the help of vergil every devices gets connected with the AP in system. It also finds the bandwidth and different time values by performing different experiments with the help of a servers like TCP/UDP.

Now a days access points get attached to the high strength of the signal but Virgil attaches to every available access point for a test session and calculates the required parameter as quality of the system of every access point. Virgil also keeps a check on congested ways for the betterment of choosing access point. By making some examination it clearly shows that with the aid of Virgil the performance rate is very high. By selecting an access point by our own it is quicker. Virgil works in three main steps. First it checks all the access points then it examines all the checked access point as extracts the parameters of AP, then DHCP from access point, if it goes positive then inquire the particular AP, saves the examination output and finally chooses the most suitable one access point. There is some related work as SyncScan where the changing are done at both on client as well as access point side. Clients usually gathers the beacons frames fast because they already knew about mediums, distributing frames at what time. Another technique to enhance the checking of access points is Shin. To lead the WiFi, detecting of access points have been made prominent. But these schemes arent attached with the checking of access points. They are just for improving the choice for choosing access points but there is nothing to do with the selection of strong signal strength.

There is another user-driven application ALDP [50] which uses server as SNMP to aid users for extracting the wireless constraints. This agent is run by both end devices and APs. Moreover, this server also gives the information about congestion in all APs. And by this data user can re-associate to another Access Point if its necessary.

11.2 Network-Driven Approaches

There is no already made features in APs of IEEE 802.11, so they there is no backing of centralized system management. In 802.11 the delay in handover is usually more than 50ms Huang:2007. Because of introduction of jitter, this delay is harmful for multimedia as audio, video etc, it can also be identified even with human ears during communication over a because it is large enough to be detectable. Thats is why it a most important task to reduce handover time and it is necessary to make handover fast video and voice for IEEE 802.11. The performance of handover in reference with OSI depends upon assessing input layer 3 and above or layer two and below of the seven-layered OSI model. Above layer parameters witch are famous are as round trip and packet loss.

To minimum the handover delays in WLAN algorithms grounded by fuzzy logic and neural network are presented by [51–53]. These mentioned algorithms functions in MAC layer that is known as Layer 2. The inputs that are used in fuzzy logic are signal and change in signal power [53]. By the given algorithm in comparison with the conventional one, nearly 70 percent improvement in handover delays has achieved. Another scheme is link-layer delivering that is used in [54]. This delivering technique includes two components, one is store and forwarding and other is suspecting of handover. Both these components are already applied in APs drive drivers. By keeping the information frames for forwarding in first component there is a que made by drivers for handovers. Packets would be transferred to the new AP because of poor connection after handover in second component. This technique simply shows that there is a less loss of packets in processing of a handover in WLAN.

There is one more technique used in Layer 2 [55] is combined signal to noise ratio, association and burden time as an input constraint for algorithms of handover. The time for which mobile node keeps on communicating with an access point with no involvement of handover is known as association time. The results

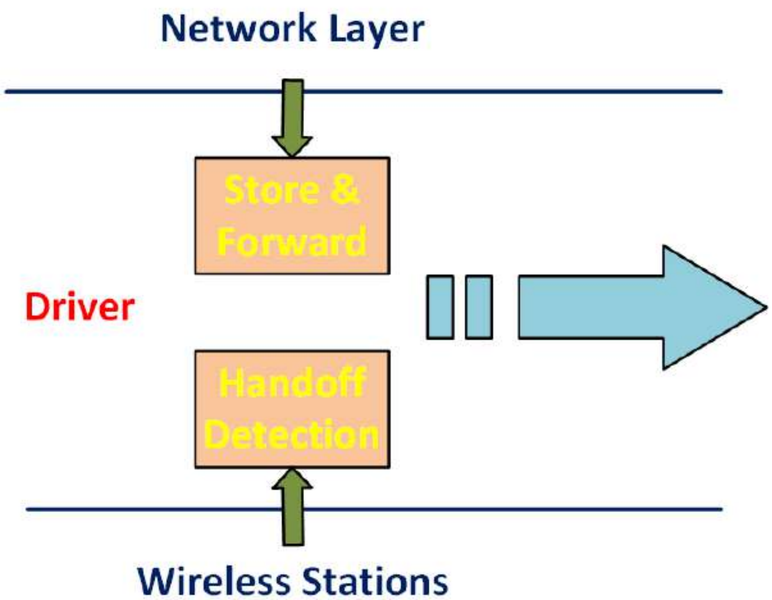


Fig. 6: Link layer scheme.

of these algorithms shows that there is a clear reduction of extra handovers and at the same time load level is also upheld by this technique. But the drawback is it is weak in delivering handovers because algorithm is complex. This technique also reduces the usage of finding phase selective scanning and a process of caching.

There are also some more schemes of handovers described in [56–58], these are both of Layer 2 and Layer 3. IP protocol of mobile could be also used as Layer 3 aids in accessible and efficient mobility within the internet. This basically allows the mobile nodes to move from one station to another but by keeping a fixed and permanent IP. The two IPs are as IPv4 [59] and IPv6 [60]. For a single level and two level unified 802.11 based hierarchical, this paper tells us about the multimedia applications WLAN/WAN. In 802.11 the access points and Domain Access Points (DAPs) are also interconnected by a hierarchical method. Through corresponding Gateway Access Point (GAP) , DAP is associated to gateway Access Point (GAP) in single-level architecture. Moreover, two or more than two DAP are associated with one another through aid of corresponding Access Point (CAP) in two level architecture. For the internet connection CAP associates with DAP. Moving of devices could be done in two ways. For using same DAP means that movement is local while it could be termed as global if the mobility is between different DAPs.

Basically for these two setups hierarchical handover technique was introduced. In comparison with the standard one, this described approach is better while considering handover delay by 20 to 25 percent. IPv6 hierarchical also considered for handovers. By using this technique there is a 300-400 ms [58] reduction in handover delay, thus make it fast-handover approach. One of the unique architecture is Seamless Mobile IP (S-MIP) [57]. There happen lossless handovers at IP layer as compared to hierarchical Mobile IPv6. This phase describes the ending of discovery phase and mobile device, at the new AP restarts authentication procedure.

12 SDN-based Handovers

In wireless access network, OpenFlow is used lately. It gives good control of information packets. Just like that SDN departs the physical architecture of system with the provided control tasks [22]. For establishing a link between forwarding and control functions, we use a protocol called OpenFlow. Hanover needs may include in prevailing OpenFlow for the sake of good throughput results [61]. To enhance conventional handover methods to make changing in SDN in IEEE 802.11 access point. Figure 7 display the SDN-based handover architecture. OpenWRT [62] Aids in reorganizing the wireless protocols. To guide more in area of research and provide wide stage, Open Roads [63] was the first scheme in respect with SDN founded WLAN ideas. It helps in different ways as instructions of routing, system handling.

Using OpenFlow [29, 64] it aids to manage the track of data. To add function of moving it includes the OpenFlow grounded testbed [63]. OpenRoads [63] could also aid in making operational example of structure and tasks to provide moving feature in WiFi network and a handover among WiFi and WIMAX. The structure discussed in [65] needs many receivers at every node due to which users can get connect with man access points. Authors were capable of checking many moving features as bicat//tricast(N-cast) [65] in the architecture one transmitter is transmitting data while second one checks the strength of signal. On reaching certain set value a request of accessing to a new AP will be generate from client to controller. At the end client will got the access and it will de-associate itself from first AP and gain traffic from second access point. Thats why for creating a moving feature, two radios are there which aid in sending and receiving and therefore using a lot more power and getting cloning of messages on interfaces before cutting off from first access point.

There is another mobility technique [66] presents OF-PMIPv6. It performs OpenFlow protocol with aid of PMIPv6 [29] thus has converted to OFPMIPv6. The track of data communication and control signals are torn apart. By elimination of re-authentication phase it estimates the time and goal of handover. To hosts, its obvious. Because of the use of RS and RA communication it suffers additional delays. Moreover, it has more overheads because of the usage of IP tunneling instead of OpenFlow forwarding to decrease the pressure of AP CloudMAC [67] describes scattered structure.

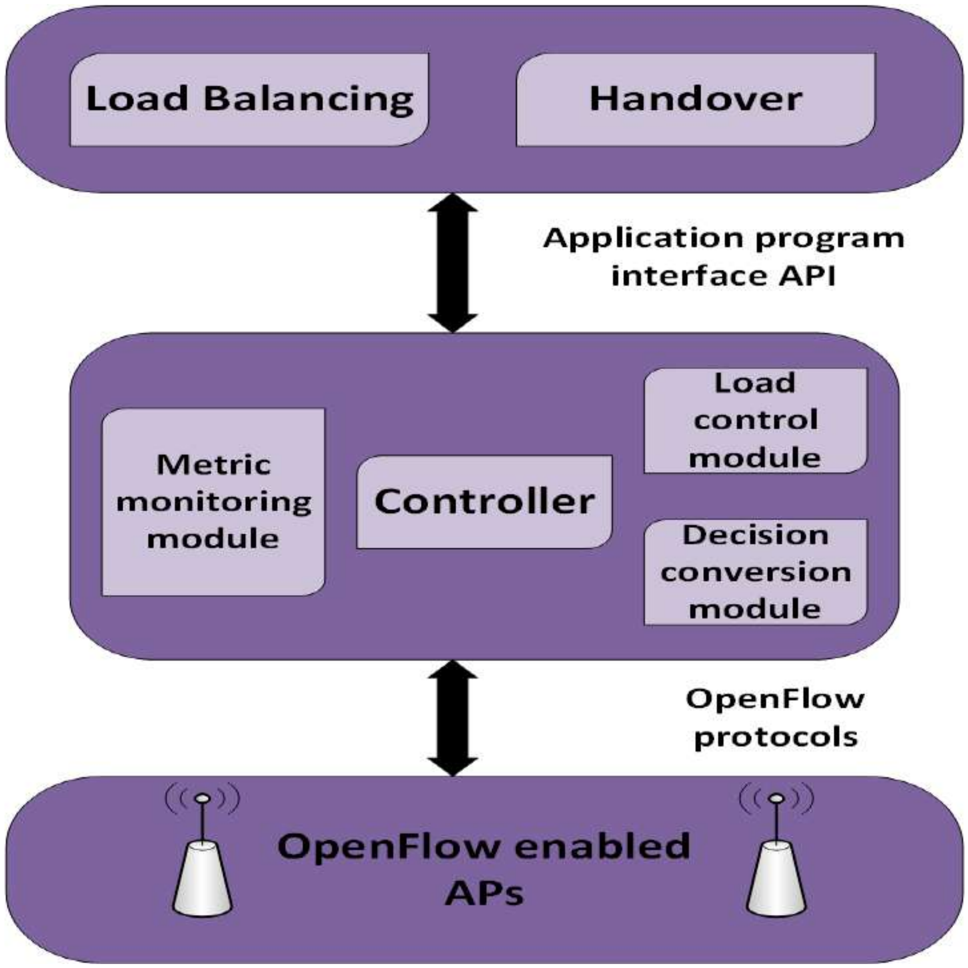


Fig. 7: SDN based handovers.

This is done when centralized servers have performed MAC functions. In APs switching setup has not been done by CloudMAC [67] but this is essential for handover. As all traffic is forwarded towards the cloud by CloudMAC [67] so the load over there increases. To involve seamless moving feature in WLAN, the authors in [68] describes Odin in SDN. There is a logical virtual access point (LVAP) in Odin. By the aid of BSSID LAVP guarantees a good connection to the moving users. With the aid of virtual AP there is no need to re-associate with target AP while making a handover procedure. With the help of Odin architecture, the delays are reduced rather than traditional architecture. Parameters of handovers are mostly dependent on value of RSSI. There is an another technique in SDN [61] that depends on the response of surrounding Aps. It improves quality of video by fast switching among access points. SDWLAN [69] formulated an infrastructure that helps to take user unaware handover on 802.11 AP MAC layer. It gives combined control stage for both wired and wireless structure. OpenFlow protocol is used in wireless switch for delivering functions from access point to controller. To execute wireless switch to WLAN structure is a big hardship.

One extra structure that is executed in IEEE 802.11 in SDN is Ethanol [70]. It gives more Facilities in terms of quality, organization, checking and restricting users. But not all the trials are described in this mentioned paper. A stage to work for Open APs (COAP) is explained in [71]. To work in large construction COAP is made. From APs data about wireless medium is extracted from APs. Because of the reduction of airtime utilization of channel, throughput is improved of given AP.

13 Summary

For wireless networks the traditional IEEE 802.11 techniques that have been discussed before focuses more on an architecture based on coupled network. There were some problems in those techniques as that was a constraint related to flexibility and association of networks as wired and wireless. For the removal of above issues there were some steps needed to take as correction in standard of IEEE 802.11 or some new component to include or altering the existing protocol to solve difficulties. The structure is made difficult by these described steps. SDN on the other side initiates in providing the solutions of IEEE 802.11 issues in consistent and good environment. But these faults are not fully enclosed in architecture based on SDN. Some efforts are described in [67, 68] relevant to seamless Handover in SDN architecture.

Methodology

14 Overview

The main objective of this thesis is to create a solution based on SDWN to improve the handover delays between the APs in a WiFi Network. A DeRy method is proposed. A word DeRy is drawn out from detection and discovery because these phases play important role in handover delays. Solution is to give the control over the network so that the centralized controller can help to overcome the handover delay and increase the efficiency. The general idea of few related works where SDN and handovers are involved, are discussed in this chapter.

Handover study is presented ussing SDN [72]. A controller, two APs and four stations are used for the experiments. The main findings of the research is functionality of controller to gain crucial data from OpenFlow. Inside the controller there are three components as the load module for sharing the load decisions, update MAC filter and metric monitoring module for collecting load information. The focus is to avoid the load on the APs, when some node comes in region where there is overlapping of signals.

In another study an SDN-based architecture is used for smart handovers to improve the quality of experience (QoE) in IEEE 802.11 WLANs [73]. The basis of fuzzy logic control is applied. The central controller provide a full view of the network. There are several components in the algorithm as handover management controller, which manages the overall network and gathers some important information as delay, SINR etc. Information central base(ICB) stores the important data which is useful for the network. The third component is the crucial part of the handover algorithm and it computes membership functions, membership design and finally the decision of fuzzy handover.

Seamless handovers between the APs based on traffic load in SDWN are carried [74]. There is a modification in Odin architecture. Data frame new AP status is deployed. The data frame load of every access point is taken. In this paper the handover decision is made by extracting the traffic load and clients need to be connected to the APs where during less load values.

15 DeRy Architecture

In the traditional handovers the handoff procedure takes place in layer two of the open system interconnection (OSI) model. The three main steps are: discovery, authentication an authorization. The hybrid networking approach, SDWN helps us to reduce the handover delay by reducing detection and discovery times. OpenFlow is used for communication between the centralized controller and the OpenFlow enabled APs. The proposed DeRy architecture is depicted in Fig.8.

The role of both the detection and discovery phases are important in reducing the handover delays. The first reason of delay is client's responsibility for initiating the handover and this happens in detection phase. Wireless stations reach to handover decisions because of signal strengths or packet loss during the transmission. There is no such standard for this phase because developers of the equipment have the authority to use different threshold values. The handover delay also comes with the discovery phase because discovery could be of two types that is active or passive discovery. For passive discovery a wireless station has to wait for the frames being sent by the APs but in active discovery the station sends the requested frames to all the channels. There are two important parameters in IEEE 802.11 standards for setting the standard of station waiting to get response from the channels. These two parameters are $MinChannelTime$ and $MaxChannelTime$ as minimum and maximum waiting times by the wireless stations. These values are editable but for majority of the APs these are 20 ms and 40 ms respectively. So, the time is between 280 ms and 560 ms to scan the 14 channels by the standard strategy, usually used for multimedia applications.

The time consumed in authentication and re-association steps are evaluated by IEEE 802.11f, 802.11r, 802.11k and 802.11v. The time taken is 50ms or less. DeRy provide the solution based on the detection and discovery phases in SDWN. The controller decide/control two of the important tasks as, when to

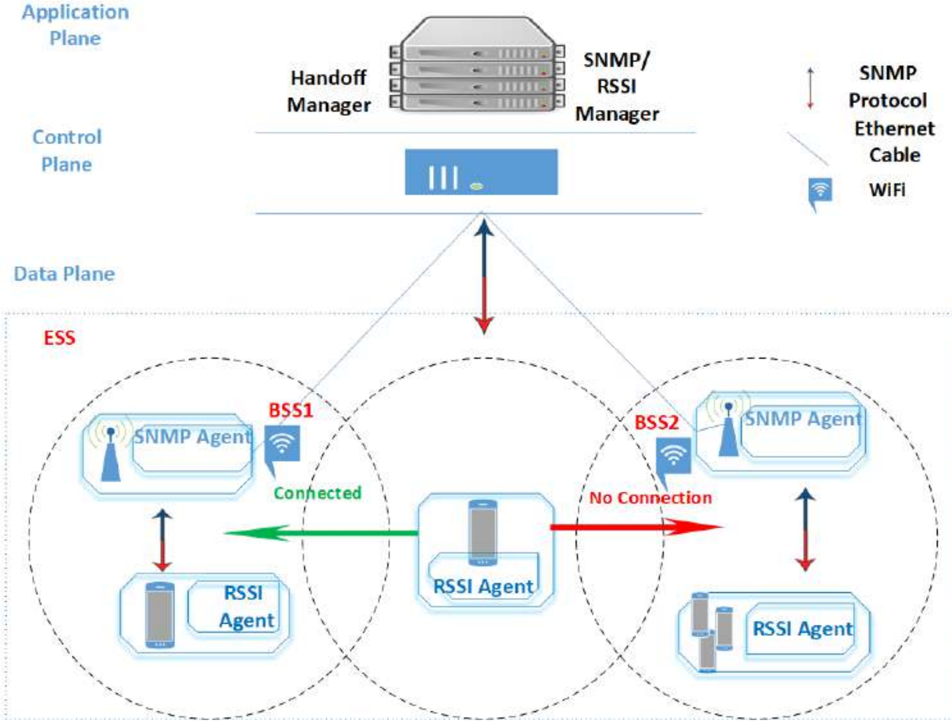


Fig. 8: The proposed DeRy architecture in SDWN.

initiate a handover and which AP is most suitable for the wireless station. The four important components in the DeRy based solution are the controller, RSSI Agent, SNMP Agent and RSSI/SNMP Manager.

For the general idea let's assume, there are three APs. One AP is to which the wireless station are connected, other is to which the wireless stations will attach and third is for the comparison of traffic amount. Wireless stations receive a frame sent by the APs. Agents in the wireless stations send the received RSSI of the AP to the manager and manger wills send the value to the controller to find the threshold. Controller instructs the manger to send the load of each AP. Manager informs the agent inside APs for load conditions and deliver these values to the controller. The whole function goes on until threshold is achieved. The controller has to choose the best AP for the wireless station. If option is just one AP, then controller will go for it but if not, then on basis of RSSI and traffic conditions the controller will choose the best destination AP.

15.1 Role of SNMP in DeRy

Simple network management protocol is an application layer protocol that helps to monitor the networking devices for instance routers, switches, printers, workstations and other devices by a simple management software/system. It uses UDP as its transport protocol because whenever it's not receiving the response or request, it regenerates the request so no sequencing is needed. Moreover, each response or request moves as a single datagram. But TCP could also be used. In DeRy, SNMP uses several components to report the traffic condition back to the SDN controller through OpenFlow protocol. Manager is a simple piece of software which after integration called as network management system (NMS) that collects the values stored inside the agents. Agents, ports and traps are again a piece of software to be installed within OpenFlow enabled APs. The messages that are sent by manager to agents are using port UDP 161 and sent by agents to manger are using port UDP 162 also known as traps. Traps are sent when agents want to alert the NMS about certain condition, often having predefined rules. MIB and OID is the database also called management information base that is shared by agents to the manager. These are set of files that are consisting of questions that manager is allowed to ask and agents stored them locally and just shares them on demand by NMS. The working of the SNMP in DeRy is depicted in Figure 9.

Object identifier is a number that resides inside the devices database and is unique therefore when there is any query regarding any device so this OID helps in getting the response. OID's are of two main kinds, scalar, which consists of one number as name of a vendor. Tabular can have many outcomes as there would be a 4 CPU values in result of quad core processor.

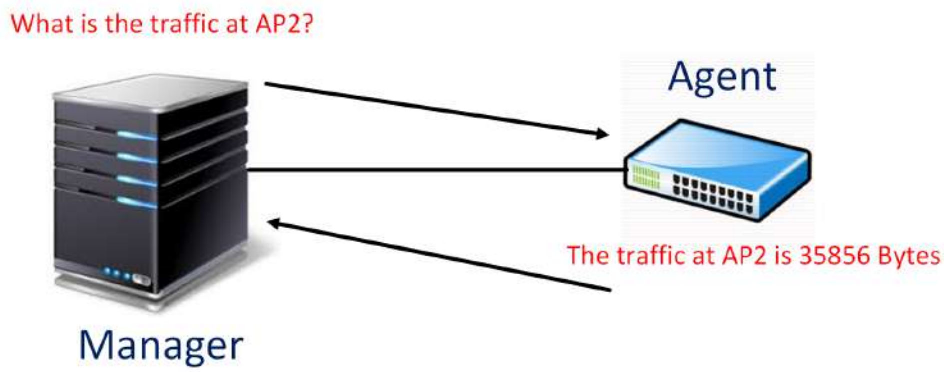


Fig. 9: SNMP in DeRy.

15.2 Reducing Handover Times

For the clarification of execution of DeRy, there is a sequence diagram to show step by step procedure of the scheme. For this work we assume there are two APs one is source and second is destination.

Wireless stations will continuously receive the beacon frames sent by the APs. There is a RSSI agent inside the station that collects the values of RSSI and send these values to the RSSI/SNMP manager. Moreover, manager will forward these values to the controller. The reason for sending these RSSI values to the controller is the comparison that controller will make between source and the destination APs to check the strong signal strength. Meanwhile controller also needs the information regarding the traffic of each AP and this is done through SNMP agents that reside in all APs and shares this information with manager afterwards. Managers sends this information to the controller. The information is necessary for the final decision to choose the destination AP. The information process will be done repeatedly till the threshold of RSSI is reached.

Controller will inform about the decisions after the selection of destination AP to the SNMP RSSI manager for installing the flow to the destination AP. It is because the flow is by now installed when a station attaches to the selected AP. Manager through RSSI agent inside the station sends a destination AP's SSID.

For getting attached to a destination AP, agent inside station run a command $iwconfig\ wlan0\ essid\ SSIDname$. The commands create two activities as wireless station would send a frame of de-authentication to the source AP and then wireless station would send a probe request which has SSID of the destination AP to get attach to the new station. As a result, only targeted AP will response and station associates with it.

With DeRy, responsibility is on the controller to take decisions regarding the handover procedure. There is a crucial thing, that the values as threshold of RSSI and maximum allowed traffic are easy to configure. This approach has two

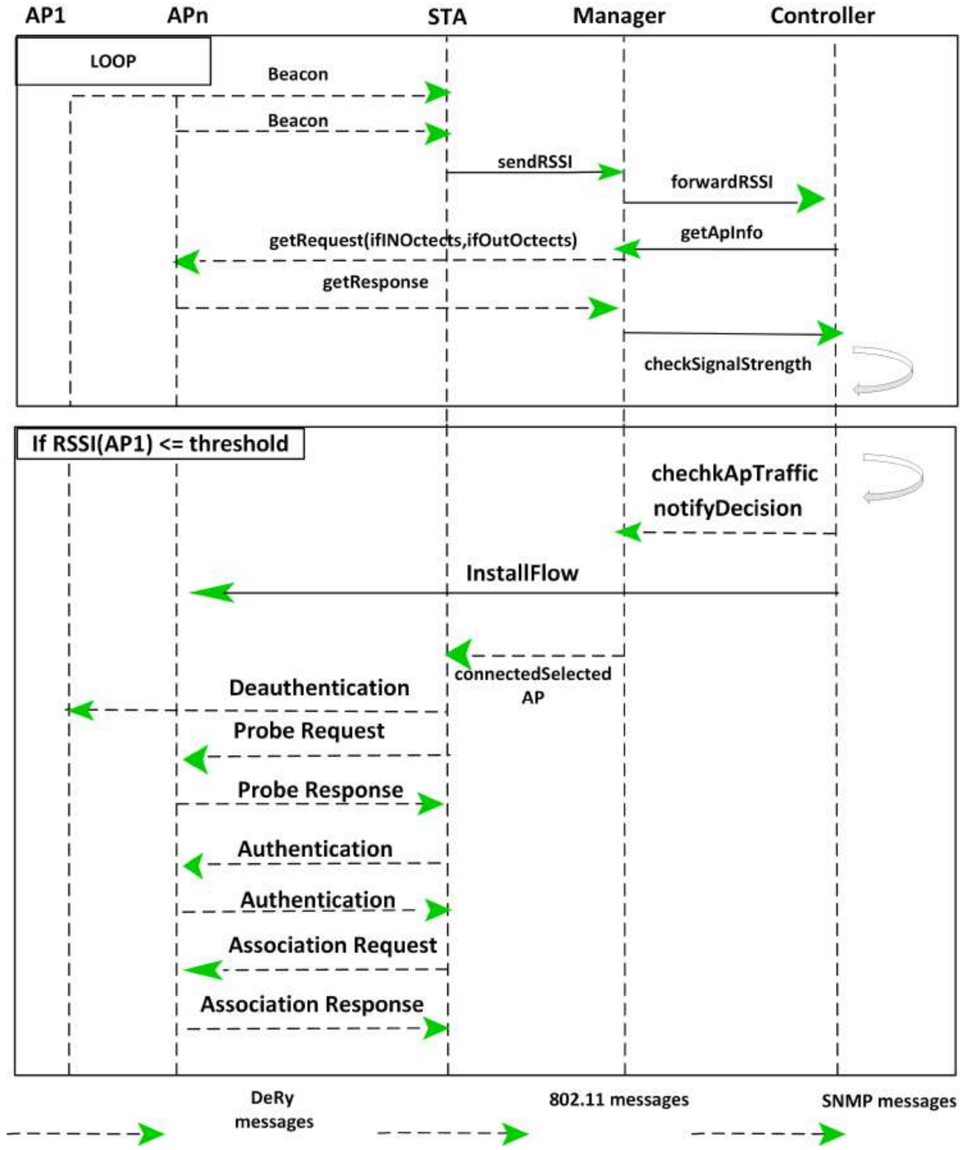


Fig. 10: Sequence diagram used in DeRy.

basic benefits, first is enhancement of the network and the second is, network becomes vendor independent.

16 Traffic Evaluation at APs

The major parameter that DeRy takes into account is measuring the traffic load at each AP to choose the most appropriate AP as destination AP. To evaluate this information, two of the components from management information base (MIB) are used. Those components are $ifInOctects$ which is defined as the total bytes reached at interface and $ifOutOctects$ which is defined as the total bytes sent from the APs interface. The value of these two component summed right from the time when SNMP agent starts working and the process is updated after every 15 seconds. The octets information is needed after every 15 seconds and the traffic load value is calculated. The assumption is as recent value of traffic at the AP is the recent octet subtracts the previous octet value informed. For the equation to establish, desired variables are total traffic (TF) as overall amount of traffic at the interface, recent octets requisition Rr, previous octets requisition Pr, Value of the ifInOctects object (TFin), value of the ifOutOctects object (TFout) and time of the requisition (T).

$$TF = \frac{TFin(Rr) + TFout(Rr) - TRin(Pr) + TRout(Pr)}{T(Rr) - T(Pr)} \tag{1}$$

17 DeRy Algorithm Design

For the controller to take decision about the best AP, it needs information regarding source AP and expected destination APs. This crucial step is done by an algorithm, according to which controller will keep the record of necessary details related to AP that will help it selecting the final AP. Controller receives RSSI and traffic load values from SNMP/RSSI agents with the help of SNMP/RSSI manager. Controller compares RSSI value of each AP with threshold value T. If there are no competing APs then the choice is very clear but if there are more APs then controller will compare in terms of different parameters. The most simplest way to compare the APs are by the RSSI value. But here there is another parameter involved which is allowed traffic (TF) where (TFmax) is maximum allowed traffic.

18 OpenFlow Extension Message formats

In order to reduce the handover times in the SD-WiFi, the OpenFlow plays an important role in communication between the SDN controller and the OpenFlow enabled switches. The OpenFlow message formats used in DeRy are depicted in Figure 11. The message formats are the payloads used to carry the RSSI and traffic information from the APs to the controller, the results computed from the controller back to the APs, and the actions taken by the SDN controller. The payload APStat_prefix@ is used to carry the APs RSSI and traffic information to the controller. The field contains the daemon process ID (Dpid), service set

Algorithm 1 Algorithm design of proposed DeRy architecture

```
Suppose R is set of APs and T is Maximum threshold for RSSI
APs (a,b,c and d) ∈ R and TFmax is maximum allowed traffic
if RSSI(a) ≥ to T then
  Controller takes no action
else
  if RSSI(a) ¡ T AND RSSI(a) is ≥ RSSI(b) then
    Controller takes no action again
  else
    if RSSI(a) ¡ T and RSSI(a) ¡ RSSI(b) then
      than Controller selects AP b and takes Handover action
      For traffic measuring, there would be two scenarios
      if RSSI(b) ≥ RSSI(c) AND TF(b) ≤ TFmax then
        b is selected as destination AP
      else
        if RSSI(b) ¿ RSSI(d) ¿ RSSI(c) AND TF(b) ¿TFmax ≥ TF(d) then
          Controller chooses the AP wth less traffic
        end if
      end if
    end if
  end if
end if
```

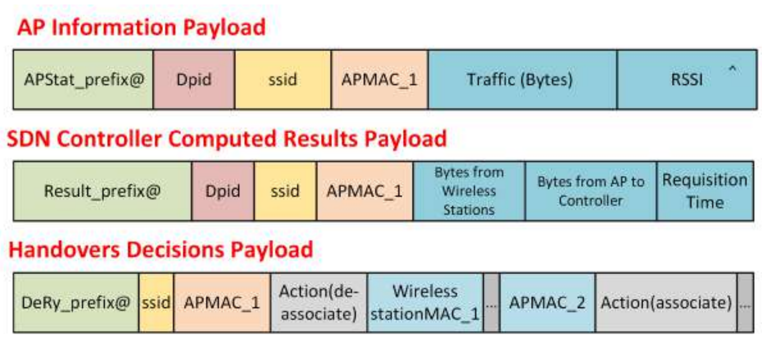


Fig. 11: OpenFlow messages formats.

ID (ssid), the MAC address of the source APs (APMAC_1), the RSSI and the traffic information.

The payload results_prefix@ is similar to the APStat_prefix@ with the exception that it carries the bytes information (from wireless stations and from APs) and time of requisition of the bytes. The last payload is the DeRy_prefix@ which is used to support the reduction in delay in handover times. The information carried in the fields is the AP MAC address, the actions taken by the specific AP and the MAC addresses of the wireless stations that are chosen to be de-associated.

19 Extending OpenFlow for Wireless Networks

Simulation undertaken to setup the performance evaluation for the proposed DeRy scheme are explained as,

- Building OpenFlow 1.3 Module in ns-3.
- Making connections of the switch to external controller in ns-3.

19.1 Building OpenFlow 1.3 Module

There is a component in ns-3 to support OpenFlow 1.3 known as $OFSwitch13$. It is created for SDN to work efficiently in ns-3. This module also gives aid to the OpenFlow protocol 1.3 by providing interface to ns-3 for controller application and switch devices.

OpenFlow 1.3 Module in ns-3 needs configuration as shown in Figure 12. A sequence of codes are needed to build the module which allows the successful transmission of packets from source to the destination. The packets are traced in wireshark by enabling the trace option to "True" in the example.cc file. To keep the track of packets transmitted Wireshark provides the packet inspection. The successful build of the OpenFlow module is depicted in Figure 13a and Figure 13b.

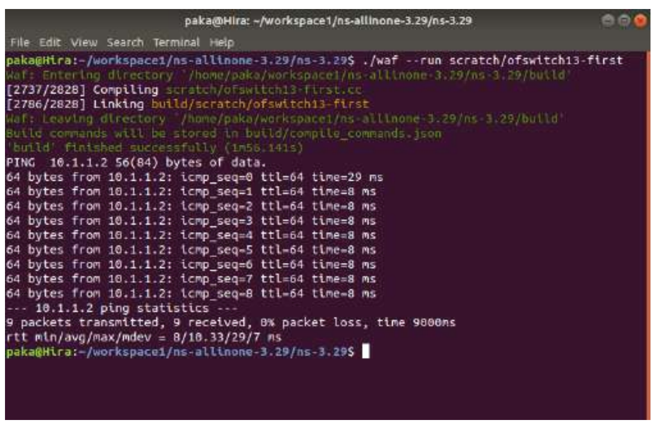
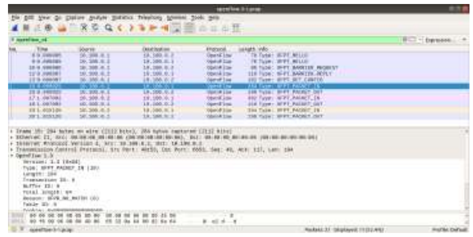


Fig. 12: OpenFlow 1.3 module.

19.2 Extension of External Floodlight Controller

The Floodlight SDN Controller is a controller that is an enterprise-class. Its is Java-based OpenFlow and Apache-licensed. A big group of makers such as engineers from switch network have given support to them.

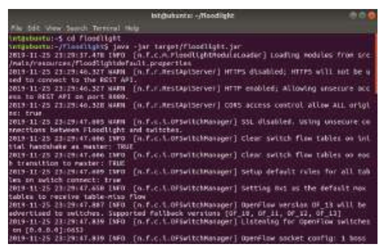
(a) Enabling trace option.



(b) Packets tracing in wireshark.

OpenFlow is achieved by open networking foundation and is an open standard. Through using a protocol, the networking devices strategies could be changed by far off controller using well described forwarding instruction set. The Floodlight controller mainly aims to give a support to networking devices such as routers, switches, access points, virtual switches etc. Which further give support to the OpenFlow standards. After coding the connection between the OpenFlow Switch and an External Controller Floodlight is build, as shown in Figure 14a and Figure 14b.

(a) Building floodlight controller.



(b) Running floodlight controller.

Finally Figure 15 shows the topology for the external controller.

20 Summary

In this chapter, overview of the handovers is presented in SDWN. There are two important phases, detection and discovery. The reduction of handover times in the aforementioned phases explicitly explained. In the solution to the handover delay issue, we have proposed a DeRy method which gives the decision control to the controller to decide when to initiate a handover and which AP to connect to. DeRy aims to reduce the handover times and increase the efficiency. Along with RSSI another parameter taken into the account is the traffic. Emulation setup and how this approach will work has been thoroughly discussed. Steps of traffic evaluation has also been explained. At the end, an algorithm shows how to

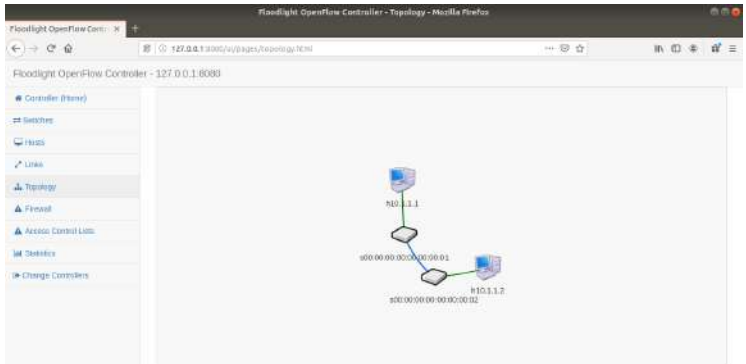


Fig. 15: Topology of the Floodlight controller.

select the best destination AP for the station regarding RSSI and traffic amount values.

Performance Evaluation

21 Overview

In this chapter, there are necessary tools and parameters that are enough for setting up the proposed DeRy as discussed in chapter 13. The performance evaluation of the proposed DeRy is compared to the standard RSSI-based handoff scheme. Two scenarios have been explained. One is for detection and other for discovery phases. Floor plan for both the phases have shown with the total of ten connection. There are four performance metrics taken into account as handover times, RSSI performance, normalized throughput and average number of re-transmissions. Emulation results show the comparison of the DeRy to the traditional RSSI based scheme where association decisions are made by the wireless stations themselves.

22 Emulation Setup

For the implementation of the experiments, Mininet and NS-3 simulators are used. The basic emulation topology use one extended service set, two basic service sets, one floodlight controller, 8 OpenFlow enabled access points, 50-100 user devices, 802.11 WiFi of standard g, allowed traffic for handover is 40 Mbps, threshold for the RSSI is -70 dBm, which means that if the AP's RSSI decreases from this value the hand-off would be initiated. Operating system taken into account is Linux Ubuntu 18.04.

In order to get the desired output of the research work, Table **??** shows the simulation parameters.

Table 1: Emulation parameter

SN	Parameters	Values
1	ESS	1
2	BSS	2
3	Controller	1, Floodlight
4	OpenFlow enabled Access Point	8
5	User's Device	50-100
6	WIFI PHY Standard	802.11g
7	Operating System	Linux Ubuntu 18.04
8	Simulator	ns3-3.30
9	Maximum Allowed Traffic	40 Mbps
10	Threshold Value	-70 dBbm

22.1 Mininet-ns3-WiFi

The experiments for SDWN are frequently done using Linux based platform. In Mininet there is a built-in support for OpenFlow switches but when it comes to wireless links the support is restricted. To overcome this restriction together ns-3 and Mininet integrates IEEE 802.11 real time medium feature of emulation of both the Mininet and ns-3.

For the emulation of SDWN there is combination of tools that aid as Mininet-ns3-WiFi as shown in 16. In ns-3 the emulation of real time mode aid to integrate virtual or real emulation code of real time nodes.There is a synchronization of emulation mode among clock of real time with clock of emulation. The following figure depicts such connection of virtual Mininet nodes, regarding emulated ns-3 medium. To Bridge the connection there is NetDevice and TapBridge. There is a unique protocol stack and Linux name in each node in Mininet. For getting connection with the ns-3 channel there is use of Linux Tap NetDevice by Mininet node. Moreover, Tap Device gets linked to ns-3 medium by TapBridge.

By ns-3 simulator the link of Tap Device and TapBridge is perceived as ns-3 NetDevice. There is a layer two in network whose simulation is done by ns-3 and gets attached to interface of outer real time network with the aid of NetDevice. We can easily and are able to calculate the performance of high density real time SDWN just by combing ns-3 and Mininet.

22.2 Topology Design

There are several devices used to perform the test such as WiFi Routers that supports OpenFlow, these routers act as APs, Floodlight Controller running on a core i5 desktop, for the gain of traffic that is created by the Station , a quad Core desktop is needed on which iPerf software is running in server mode; WiFi adapter running the iPerf software in client mode in a Core i5 notebook which creates the UDP traffic at 1 Mbps, thus multimedia transmission is reproduce thus represents a station; To gain the traffic there is a software called airodump-

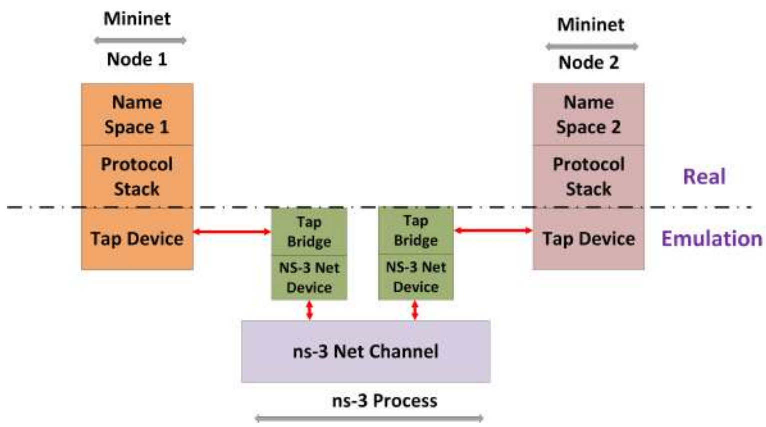


Fig. 16: Mininet and ns-3 integration.

ng which is running on Linux virtual machine and station is responsible to run this machine. Figure 17 display that the topology design used in our experiment.

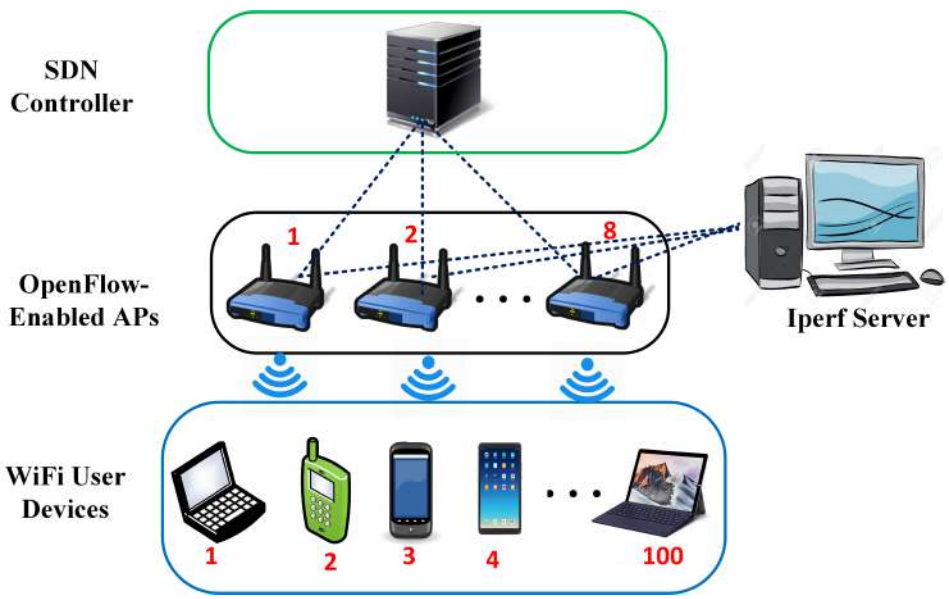


Fig. 17: Topology design.

The results are acquired using Mininet-ns3-WiFi emulator. Considering the overall handover time, initial time would be consider as a time when a station is still attached to the source AP and the last UDP packet is transmitted by the station to server. Whereas final time is the time when first UDP packet is sent through the station to server after it is connected to the final AP. Moreover the signal strength is set to 10 dBm. This was necessary so if the handover procedure takes place the APs would not be far way from each other to initiate a handover.

The value of the threshold (T) is set as -70 dBm that means it is the limit for controller to initiate a handover that is if the RSSI approaches to this value. Moreover another value has also set to 40 Mbps that is the maximum allowed traffic (TF). This means if the traffic amount of access point increases from this rate so that would be not selected as a destination AP.

It should be noted that there is an influence of hardware component too for the handover delay as WiFi adapter and chip set of AP. In the proposed DeRy, low cost APs have been used with limited capabilities and to support OpenFlow their firmware was replaced by OpenWrt. These above mentioned components are used for both experiments that is with and without DeRy, thats shows both uniformity of both tests.

23 Performance Evaluation

Evaluation of a performance in DeRy approach is compared by standard approach in which station takes the decision of handover along with detection and discovery phases themselves. So, the efficiency would be tested by both detection and discovery phases. In detection phase the station moves from one access point to other and RSSI used is the major parameter to take decision about movement of station from source access point to destination access point. In the second experiment there would be an addition of one more AP to test the efficiency of DeRy in terms of choosing destination AP that is discovery phase. There is also another parameter as traffic load for taking efficient decision in choosing final AP.

23.1 Reducing Detection Times

This test is to perform to clarify the efficiency of DeRy under detection phase. The Figure 18, shows the floor plan of testbed with the disposition of APs. Two tests are performed. First one is standard RSSI-based handoff scheme where initiation of handover is from the wireless stations and the other test under DeRy approach with decision parameter only as RSSI. Test is initiated when the stations are already connected to AP1 that is the source AP and then it starts moving near to the AP2. The station would connect to AP2 that is destination AP. Afterwards the same experiment is reversed in which the wireless station is connected to AP1 and disconnected from AP2. Each of the step is carried out for 5 times with the total connections of 10.

In the Figure 19, the handover time in DeRy is compared to standard RSSI-based handoff scheme. When compared to the standard approach, it could been seen that handover times are more similar and fast in DeRy. Handover time

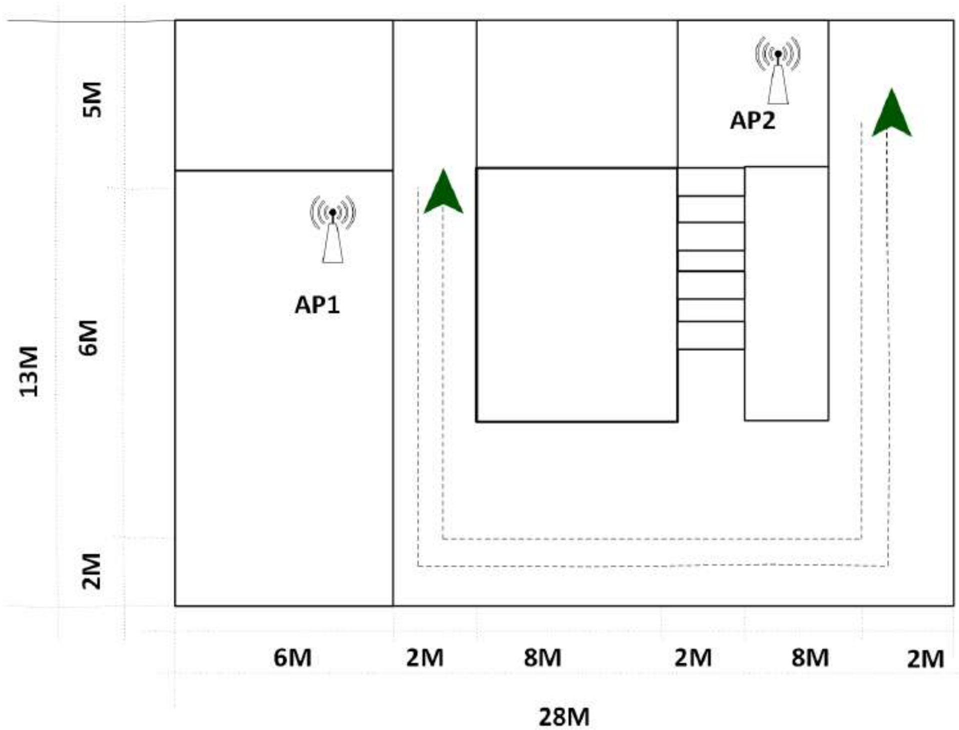


Fig. 18: Floor plan for the detection phase.

in standard approach is 4 times greater in particular scenarios. In dealing with delay sensitive device, this gain could be more significant.

In the Figure 20, the results of RSSI have been shown at the initial time of handover process. For the standard RSSI-based handoff scheme, the RSSI values degrade considerably. Most of the times in the standard approach the RSSI values collected from destination access point were way stronger as compared to the source but the handover did not initiate through the wireless station. Due to this delay of handover initiation, the quality of communication degrades as a result, there is re-transmission of packets. Moreover, when there is a controlled way to initiate a handover process so maintaining of signal strength become possible for all tests.

23.2 Reducing Discovery Times

The main purpose of these tests are to verify efficiency of DeRy approach in the discovery phase. In the previous tests DeRy approach is compared to standard RSSI-based handoff scheme for AP selection whereas here, the tests would be the same but with a new parameter that is traffic amount at AP to make controller capable of choosing the best AP. Figure 21 of testbed floor shows that there is

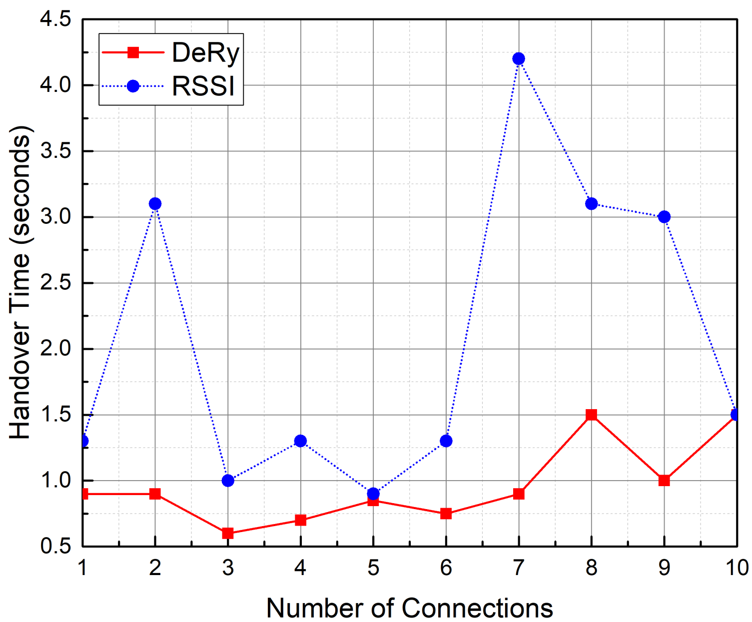


Fig. 19: Performance of handover times.

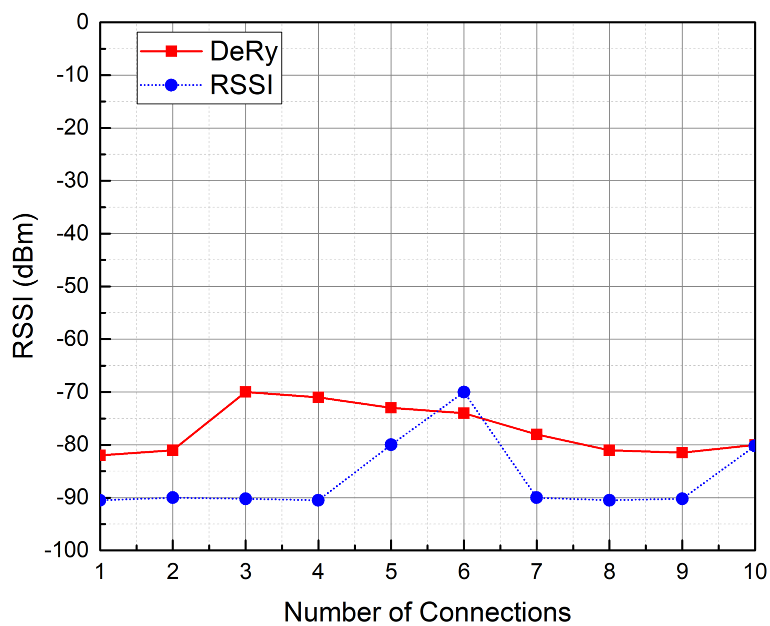


Fig. 20: RSSI performance.

addition of one new AP that is AP3 with the signal strength of maximum as 27 dBm (501mW), whereas other AP's remain with same signal strength as 10 dBm (10mW). These modifications are necessary between AP2 and AP3 to witness variation in RSSI values.

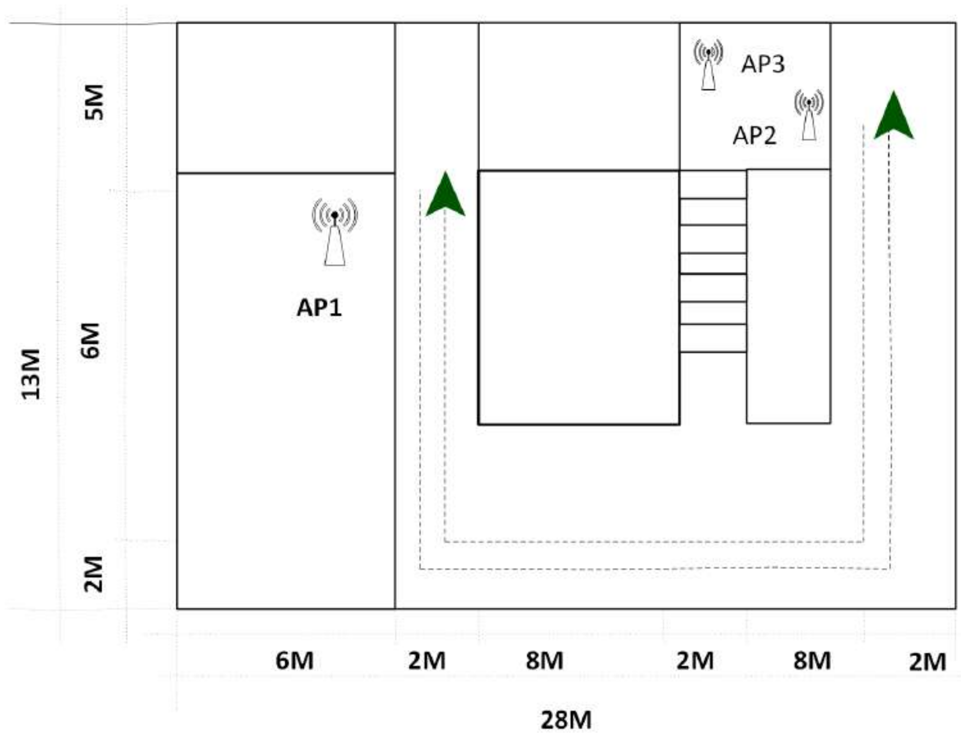


Fig. 21: Floor plan for the discovery phase.

Again ten tests are performed with the same rules as station would be connected to AP1, the source AP and then it will move towards AP2 and AP3 that are destination APs. So, this is the point for the controller to decide which AP to be selected as destination AP.

The following Figure 22 and Figure 23 show when the traffic is less than or equal to and greater than the 40 Mbps at AP3 respectively. DeRy uses the traffic amount as a decision parameter but the standard RSSI-based handoff scheme considers only RSSI value. So, for the case 1 DeRy selects AP3 as destination AP because the RSSI is high whereas in case 2 DeRy chooses AP2 because the traffic is less as compared to AP3 where as AP3s traffic is more than 40 Mbps. But for standard RSSI-based handoff scheme the choice would also be AP3 regardless of the traffic amount.

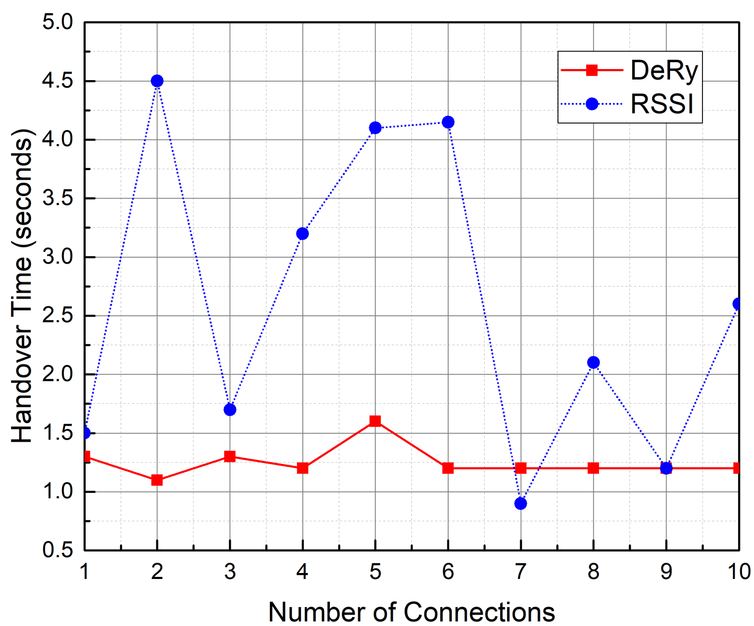


Fig. 22: Handover times with TF(AP3) $\leq$ 40Mbps.

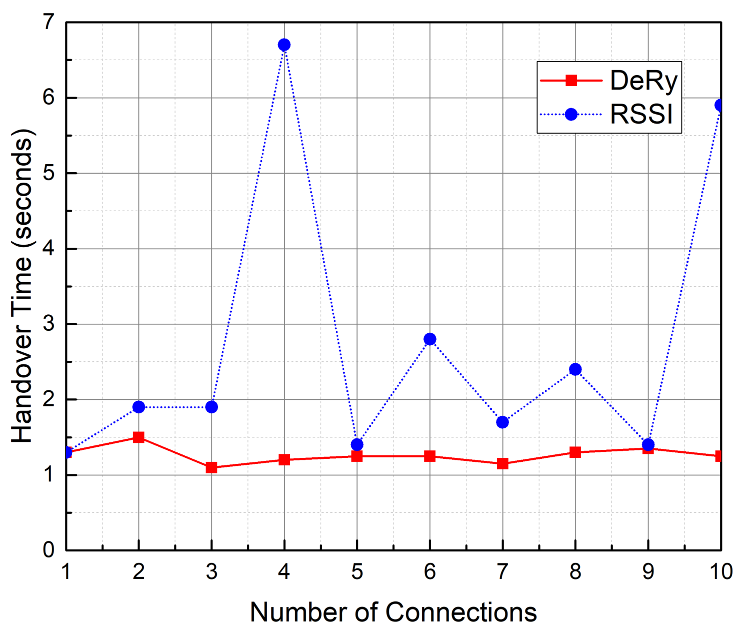


Fig. 23: Handover times with TF(AP3) ¿ 40Mbps.

It is noted when decision of choosing destination AP is taken under considering both parameters as RSSI and traffic amount so there appears narrow range of handover time (between 1s and 1.5s). If compared to standard RSSI-based handoff scheme, it is very low. It is important to note that while in standard approach there are some cases where the handover time reaches to 6 seconds, if considering multimedia scenarios. This causes loss of big amount of data.

23.3 Normalized Throughput

The performance of the normalized throughput is depicted in Figure 24. The number of wireless stations increase the normalized throughput also increase. On further increasing the wireless stations the increase in throughput saturates and becomes constant. This is satisfies the WiFi network which utilizes the distributed coordination function (DCF), that when the traffic load increases the throughput eventually becomes constant. The standard RSSI-based handoff scheme shows a poor throughout performance because the destination AP is chosen based on only one parameter. Too many wireless stations get associated to a single AP causing packet collisions and degraded throughput performance. The association in the RSSI scheme is kept until the wireless station moves away from the AP or the connection terminates due to some AP failure. The contribution of the RSSI scheme towards total throughput is just 40% of total throughput. The mean probe delay (MPD) scheme shows less throughput due to unnecessary probing frames. These frames estimate the load values. The load on the AP is calculated by calculating the delays between the transmitted and received frames. The AP with the least load is chosen by the wireless stations. The congestion in the network is reduced.

In the proposed DeRy, apart form the RSSI, traffic at the APs is evaluated by the SDN controller which helps in maintaining fairness in terms of traffic load among the OpenFlow enabled APs. When a certain AP gets overloaded in terms of traffic, it receives the de-association list so that the throughput is not compromised. The de-associated wireless stations get re-associated to the APs chosen by the SDN controller through SNMP protocol. In this way the contention is reduced. The APs with the highest traffic is instructed to optimize the load on even basis. When the throughput is enhanced, the packet delivery rate is also enhanced.

23.4 Average Number of Re-Transmissions

The average number of retransmissions performance is depicted in Figure 25. It can be seen that as the number of wireless stations increase the average number of retransmissions increase quickly for RSSI scheme but increase slightly for the DeRy. The average number of retransmissions in DeRy is less than that in RSSI and MPD scheme by approximately 19% and 13% respectively. The results show that efficiency for the proposed DeRy scheme.

In the proposed DeRy, the handover times are reduced by using the SDN controller which has the overall view of the network. The SDN shifts the loads

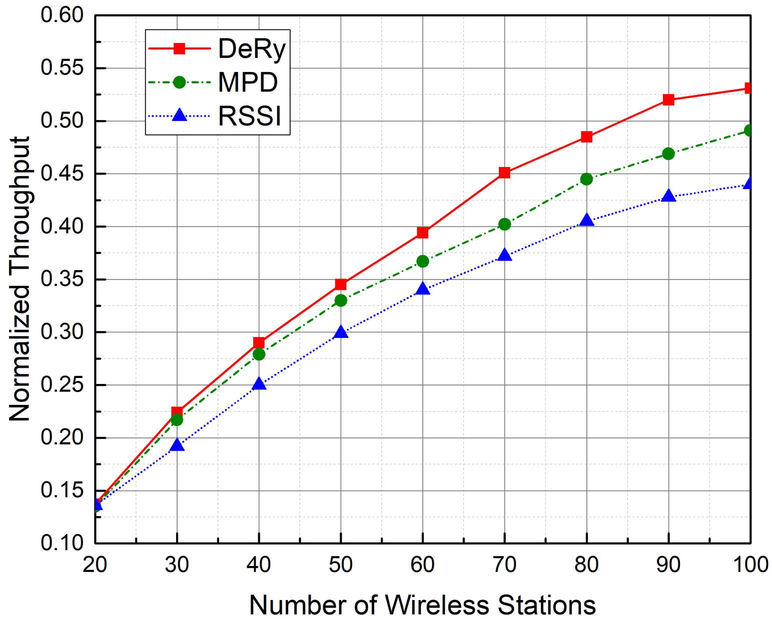


Fig. 24: Normalized throughput performance.

from the overloaded APs to the underloaded APs. The re-associations are made through the traffic values obtained from the SNMP protocol and RSSI agents. The enhanced throughput allows the wireless stations to associate to the most suitable candidate AP. The fairness of traffic among of the APs lead towards the minimal average number of re-transmissions.

24 Summary

The performance evaluation is depicted in this chapter. The proposed DeRy is compared to the standard RSSI-based handoff scheme. Emulation setup for the Mininet-ns3-WiFi are presented. The results are presented by comparing proposed scheme with the standard RSSI-based handoff scheme. Two scenarios have been explained, one is for detection and other for discovery phases. Floor plan for both of phases have shown with the total of ten connection. Emulation results show the efficiency of th proposed scheme in terms of improved handover times, normalized throughput and average number of re-transmissions.

Conclusion

A SDWN based approach DeRy is used for simplifying the process of handovers in IEEE 802.11 networks. In the standard handover scheme, RSSI is the

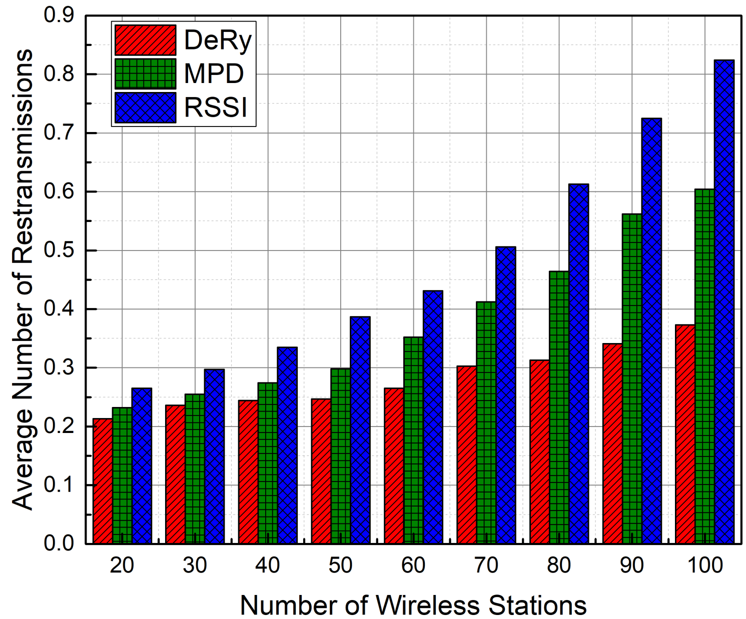


Fig. 25: Average number of re-transmissions performance.

only key parameter to select the destination AP and the association decision is carried at the clients end. DeRy takes the control of detection and discovery phases because role of both these phases are very influential for the handover delay. Reducing the detection and discovery times is a must to make handovers efficient for the real time multimedia applications and for security of data, which is transmitted without loss. The proposed scheme has taken all the authority from the wireless station side and shifted this to the single and centralized SDN controller. The controller has overview of the network and periodically acquires all the information related to the APs and wireless stations to manage the handovers efficiently. DeRy takes into account agents and manager residing inside the network devices and server respectively. These components help the controller to take the best decisions for the handover process. With the help of RSSI received and value of traffic at the APs the controller makes the best decision of when to initiate the handover and which destination AP to re-associate too.

The tests which are performed show that DeRy is reducing the handover times for about 50 percent as compared to the standard RSSI-based handoff scheme. Moreover it keeps the delay range narrow between (1s to -1.5s) maintaining stability. When the handover is initiated by the wireless station, the RSSI is degraded and thus causes loss in information and packets. The DeRy on the other hand maintains the signal strength. Extensive emulations are performed to show the efficiency of the proposed DeRy. Emulation results show that the DeRy outperforms the standard RSSI-based handoff scheme and the mean probe delay scheme in terms of handover times, normalized throughout and average number of re-transmissions. We plan to extend the proposed emulation setup to create a real time testbed using Zynq-based programmable WiFi systems. The comparison will include the software/hardware co-approach for real time SDWN with diversity of heterogeneous wireless stations.

Acknowledgment

The research project titled "Towards Reducing Handoff Times in Next Generation Wireless Networks" was successfully completed in the Wireless Networking Research and Development Lab under the Pakistan Engineering Council (PEC) Annual Award of the Final Year Design Projects (FYDPs) for the year 2022-23. The project was supervised by Engr. Dr. Sohaib Manzoor.

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