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Towards Reducing Handoff Times in Next Generation Wireless Networks

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Highlights

- SDN is extended to wireless networks
- Efficient algorithm design
- Reduced handoff times in traditional Wi-Fi networks (from 2.4 ms to 1.11 ms)

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Abstract: —In high density Wi-Fi networks, due to a large number of access points (APs), the handoff mechanism is critical for maintaining service continuity. Wireless devices initiate the handoff process, which takes a few seconds. When working with delay-sensitive applications, this could lead to data loss. We propose an efficient, detection and discovery technique (DDT) based on software defined networking (SDN) to reduce the handoff times. The AP traffic and signal strength values are reported to the SDN controller through received signal strength indicator (RSSI) manager and simple network management protocol (SNMP) manager. Decisions, such as, when to initiate the handoff (detection time) and which AP to connect to (discovery time) are taken by the SDN controller. Extensive simulation runs are carried on the Mininet-NS3-Wi-Fi network simulator for the performance evaluation of DDT. The proposed scheme reduces the handoff times by 60—70% when compared to the traditional Wi-Fi network scheme.

Keywords: Handoff Times, Next Generation Wireless Networks, SDN, Wi-Fi.

1. Introduction

Wi-Fi has become an important tool for the internet among wireless devices [1]. It is a secure, reliable, efficient, and a quick way of accessing the internet. By 2030, most wireless devices, (approximately more than 70%) would use Wi-Fi as an internet source [2]. In traditional Wi-Fi networks, the mobility support, scalability, and load balancing is difficult to get using programmability. Handoff means the de-association of the wireless device from one AP and its association with another AP [3]. The time-lapse between these two is usually a few seconds, but this small delay is very important while using delay-sensitive applications, such as voice calling or video conferencing. The first handoff delay occurs when the wireless device itself makes the decision to connect to another AP . The detection phase is vendor specific as different APs have different threshold for RSSI. Delay also extends during the phase when a wireless device searches for all possible APs to connect to and then has to wait for the response message from the AP. A new model, software defined networking (SDN) [4], that fits well for cellular and Wi-Fi networks, is used to address the above-mentioned problems.

This paper proposes a DDT approach based on SDN to improve the overall network management in terms of handoff times. The centralized controller collects the information of APs with the help of SNMP manager and RSSI manager.

The association/de-association decisions are taken by the SDN controller. The controller then determines when to begin the handoff (detection phase) and re-associate the wireless device to the best available AP (discovery phase). Our solution brings innovation in three ways. Traditional networks use only one metric for handoff decisions i.e. RSSI, creating hotspots in the Wi-Fi network. We propose a multi-factor technique utilizing traffic load on the APs and RSSI. The second component of this study is that it considers both client and AP side information when reducing the handoff time, as opposed to earlier studies that only consider client-side or AP-side information separately. Finally, the proposed approach demands no hardware modifications, it can work on any wireless device supporting the OpenFlow standards.

The rest of this paper is designed as follows: Section II presents the related work. In section III the proposed DDT approach is discussed. Section IV explores the simulation setup and the V explain the performance evaluation. Finally the paper is concluded in section VI.

2. Related Work

User-driven approaches allow wireless devices to start the handoff process on their own, but they are not well-aware of the network structure, resulting in considerable handoff delays [5]. Before achieving a QoS-satisfying condition, repetitive association and re-associations are required. At the same time, to make sure there is a smooth data transmission and handoffs, a two-Wi-Fi interface approach is used [6]. Most APs on the market only have one Wi-Fi interface and the concept of two interfaces is limited. By knowing the position of the wireless stations and neighboring APs, the handoff times are reduced [7], [8]. The APs are responsible for deciding which AP to use in their service region (selective scan). The AP to which the wireless stations are presently linked chooses the destination AP [9]. After a sequence of messages are exchanged between the neighborhood APs, the destination AP is chosen. Higher handoff times are caused by excessive irrelevant message exchange between the APs. For a flawless handoff, a dynamic frequency selection (DFS) is employed between AP channels [10]. Two Wi-Fi interfaces are used in the procedure, one for traffic monitoring and second for passive monitoring.

To overcome SD-Wi-Fi handoff issues, mobility support is necessary. Machine learning and probing techniques are used to improve the control plane's scalability [11]. DDT approach is used to reduce handoff times in Wi-Fi networks at the cost of extensive messages exchange between switches and the controller [12]. The RSSI is the sole access selection parameter that is insufficient for highest possible throughput. New user identification and network connectivity require an adaptive load balancing approach based on RSSI values. The time it takes to join the new wireless device with the destination AP is not taken into account. To observe the motion of wireless stations, an RSSI and fuzzy-based method is studied [13]. Whether or not a handoff occurs is determined on the wireless station's mobility. The dedicated server makes reassociation decisions depending on RSSI values and bandwidth consumption. Within the wireless station, an RSSI value threshold is maintained. The solution is vendor-dependent because the threshold in the wireless station must be updated every time a handoff occurs, limiting agility and flexibility. The statistics from the network are utilized to balance the load allocation among the APs [14]. The SDN controller computes the statistical data to make load balancing decisions. The SDN controller selects the destination AP. The scheme is unable to determine when the handoff should occur. Software access points (SAPs) abstract the relationship between the AP and the wireless devices [15]. The lowering of handoff times during seamless handovers is not evaluated.

3. Results

In traditional Wi-Fi networks, the handoff time is influenced by the detection and discovery

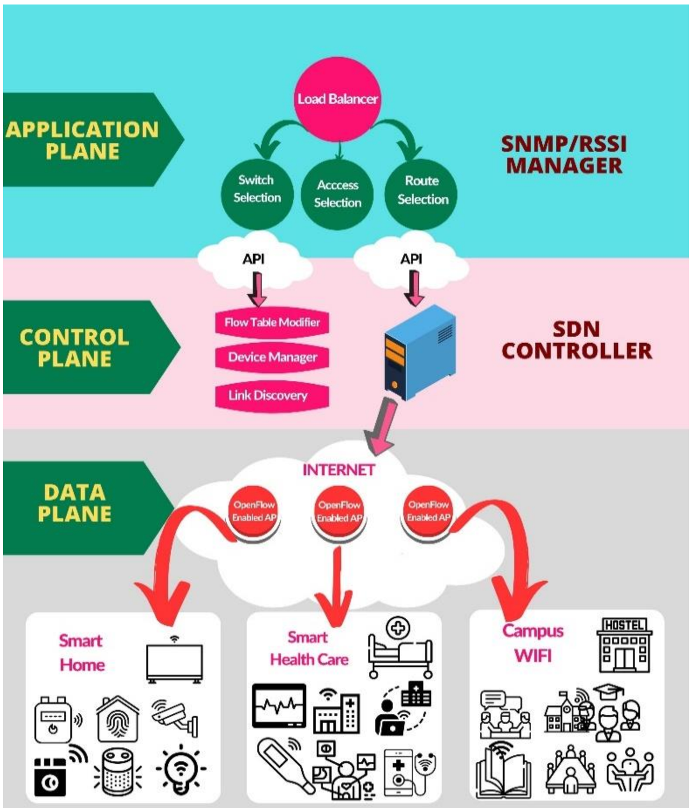

Figure 1: DDT architecture

phase. When to delink (detection) and when to re-link (discovery) to a certain AP. The proposed DDT approach consists of three planes as shown in Figure 1. The data plane has the wireless devices which initiate the handoffs. The wireless devices report the RSSI values through the RSSI manager to the SDN controller. The SDN controller also gathers the traffic load of each AP through the SNMP Manager. The controller plane has the SDN controller which computes the gathered reports and makes suitable handoff decision including when to initiate the handoff and which destination AP to connect to. The application plane has the SNMP and RSSI manager applications installed in SDN controller.

3.1. Reducing Handoff time

The sequence diagram in Figure 2 reveals all the decisions taken by the SDN controller. The beacon frames transmitted by the APs are captured by the wireless devices. The RSSI values are gathered then sent to the RSSI manager (forward RSSI). After that, the RSSI manager sends the RSSI data to the controller for processing (compute RSSI). The RSSI values are compared to the AP's source values (compare RSSI). In the same way, the SNMP manager collects and sends AP traffic information to the controller (collect/ transmit. AP reports). The data is forwarded to the OpenFlow enabled APs and the controller decides the destination AP. The process continues until an RSSI threshold has been reached. The paper investigates three scenarios:

The controller would only initiate handoff process if RSSI of source AP is less than the threshold and less than the RSSI of destination AP. No action would be performed by the controller if the source AP has RSSI less than threshold and higher than the RSSI of destination AP. Same will be the output, if source AP has RSSI less than threshold and greater than the RSSI of destination AP.

If there are a number of APs, the destination AP is picked based on a number of factors such as traffic and RSSI values. The SDN controller selects the destination AP after collecting RSSI and traffic reports (evaluate AP). The handoff decision is taken by the SDN controller

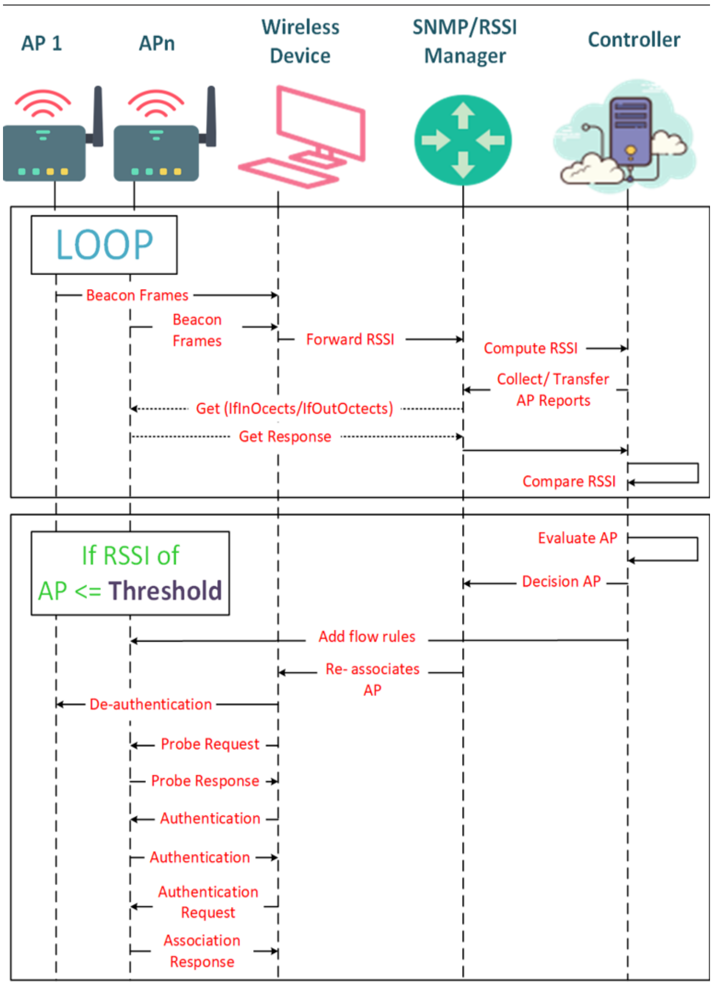

Figure 2. Decisions taken by the SDN Controller

considering two conditions:

(1) Handoff is not initiated if the RSSI value of the source AP is higher than the threshold and higher than the RSSI of other APs and the amount of traffic is lower than the maximum permissible traffic

(2) The controller will switch to the AP with the next higher RSSI value and the least amount of traffic and choose it as the ideal destination AP if the source AP RSSI is higher than the threshold and higher than the RSSI values from other APs plus the amount of traffic exceeds the maximum permissible limit. The controller informs the SNMP and RSSI managers

(decision AP) of the decision, and the flow rules are added at the destination AP (addflowrules).

The OpenFlow protocol is used to initiate the handoff, which sends the SSID of the destination AP from the controller to the source AP. The wireless device issues the command "iwconfig wlan0 essid SSIDname" after getting this information. The commands do two functions: (1) The wireless device disconnects from the AP, (2) A probe request containing the SSID of the target AP is broadcast, and only the AP with SSID information responds with a probe response frame.

3.2. Traffic Evaluation at APs

The optimal AP selection is RSSI based values and traffic load at the APs. SNMP manager uses "ifInOctects" (total number of bytes moving to the interface) to calculate the traffic load at AP and "ifOutOctects" (total number of bytes moving out of the interface). The collective sum of ifInOctects and ifOutOctects is used everytime by the SNMP manager to collect the data after every 15s. This 15s margin makes the process in sequence and helps to calculate the traffic flow of the AP. It is adopted that the current traffic of AP is equal to the current octet values minus the last octet values as given in Eq. 1.

$$Tf = \frac{OiCr + OoCr - OiLt + Oo(Lt)}{T(Cr) - T(Lt)} \quad (1)$$

where Tf represents total traffic at the interface which is measured in B/s, Cr denotes the requested current octects, Lt is for the last octects requested, Oi denotes ifInOctetcs, Oo denotes ifOutOctects and T is the time of request respectively.

4. Platform for DDT

To analyze the handoff performance of the proposed DDT, we use Mininet-NS3-Wi-Fi simulator:

4.1.Mininet-NS3-Wi-Fi

A Mininet emulator based on a Linux platform is used for the SDN experiments. Mininet provides much support for the OpenFlow switches, however not so much for the wireless

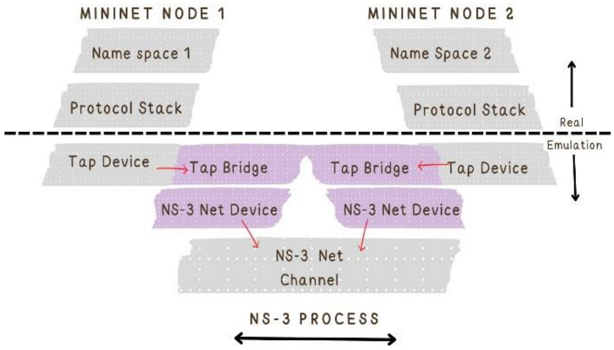

Figure 3. Platform for DDT

networks. NS-3 is implemented into Mininet to model a real-time IEEE 802.11 channel. To simulate software defined Wi-Fi networking (SD-WiFi), Mininet-NS3-Wi-Fi is utilized. In NS-3, we use the real-time emulation mode to add real-time devices to the simulation code. The simulation clock and the emulation clock are synced. Figure 3 shows how the virtual Mininet nodes are connected using a Mininet-NS3-Wi-Fi channel. The NetDevice and TapBridge interfaces facilitate the connections. In the Mininet, each node has its own Linux name and network protocol stack. The Linux Tap NetDevice is used by the Mininet node to connect to the NS-3 channel. By simulating the layer 2 network interface, NS-3 is allowed to connect to an external real-time interface by the NetDevice. The Mininet-NS3-Wi-Fi architecture makes the evaluation of SD-WiFi simpler.The results are analyzed with Wireshark. The Iperf server is used to keep the track of the overall traffic generated by the wireless devices. -70 dBm has been set as the RSSI threshold. The controller initiates the handoff process when the threshold value is reached. The maximum AP traffic is set to 40 Mbps.

5. Performance Evaluation

The performance of DDT is compared to the conventional handoff strategy in traditional Wi-Fi networks. DDT's efficiency is tested using separate simulation topologies for detection and discovery stages. While in detection phase, handoff time of wireless device depends on only one factor,RSSI. Another AP is added during the discovery phase to ensure that the DDT method is effective. In addition to RSSI, the volume of traffic is employed as a criterion in the discovery phase to choose the best destination AP.

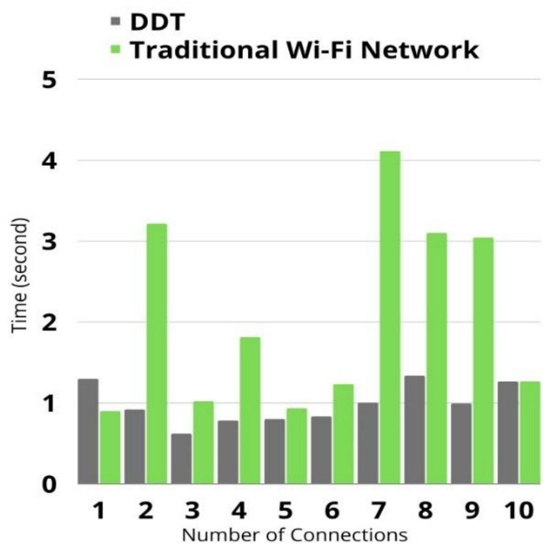

Figure 4. Handoff time performance

Table 1. Parameter Settings.

Parameters	Values
Test time	30 min
Wi-Fi standard	IEEE 802.11 “g”
Operating system	Linux Ubuntu 18.04
Simulator	Mininet-NS3-Wi-Fi
Maximum transmission unit	1500 bytes
RSSI threshold	-70 dBm
Maximum permissible traffic	40 Mbps
Mobility	5—10 mps
Number of wireless devices	1

Transmission range of each AP	33 m
Number of APs	3
SDN controller	1, Floodlight

5.1.Detection Phase

The simulation topology is intended to test the detection phase efficiency in DDT. Figure 4 shows the topology design for the detection phase. Two simulation runs were performed. One for a standard Wi-Fi network, in which the wireless devices make the association decisions themselves and the other for the DDT, in which RSSI is the only decision factor used to identify the destination AP.

The wireless device was initially attached with the source AP1. The wireless device gradually moved closer to AP2, de-authenticated from AP1, and connected to AP2. Similarly, from AP2 to AP1, the same method was repeated. This process was done five times, yielding a total of ten connections. In Figure 5, the performance of handoff time of the DDT is compared with a standard Wi-Fi network. When compared to the traditional approach, the handoff times are noted to be efficient and almost similar. In some circumstances, the handoff time of a standard Wi-Fi network is about 60 percent longer than the DDT method, which could cause additional delays while operating with delay-sensitive applications like VoIP.

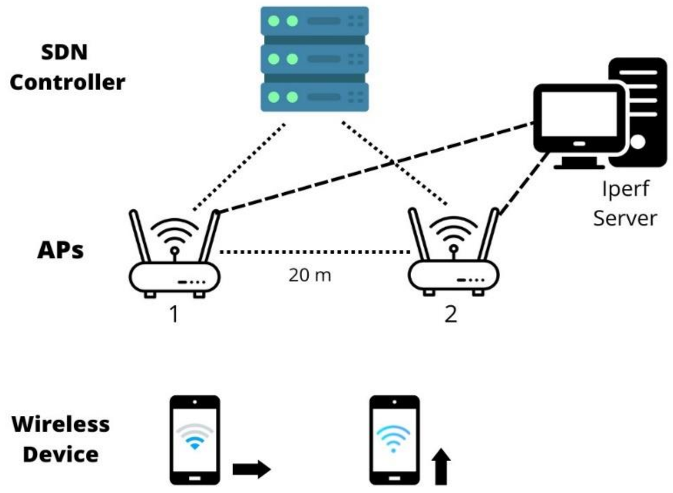

Figure 5. Topology design for detection phase

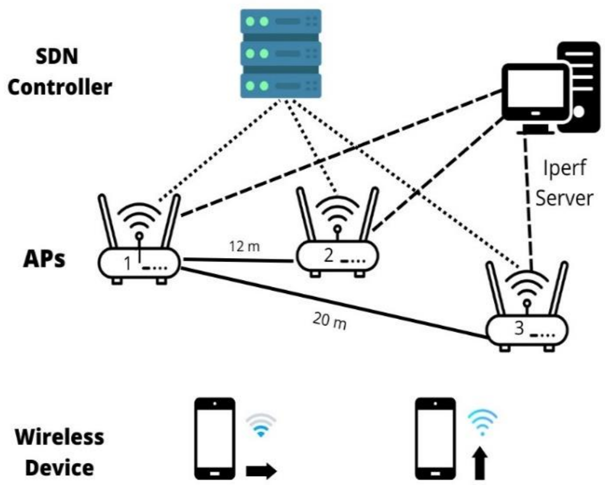

Figure 6. Topology design for discovery phase

Figure 5 shows the RSSI values received at the time, when handoff is initialized. During the simulation run, RSSI of AP2 was greater than the source AP more than once, but the wireless device did not triggered a handoff. Packets were lost during communication due to an incorrect decision on whether or not to initiate a handoff, resulting in re-transmissions. The DDT technique, on the other hand, activated the detection phase through a centralized controller with a comprehensive view of the network, ensuring QoS.

5.2. Discovery Phase

The simulation setting is created to test DDT efficiency throughout the discovery phase. In addition to RSSI, which was the only scale for decision in the previous part, the quantity of traffic was now taken into account while choosing the best destination AP. In the discovery phase, an additional AP was introduced, as shown in Figure 7. The signal power of AP3 was increased to 25 dBm, while the signal strength of the other two APs remained at 9 dBm. Within a simulation context, the calibration allowed for varying RSSI values. A total of ten simulation runs were carried out. The wireless device was initially connected to the source AP1. The wireless equipment gradually advanced to AP2 and AP3. The controller had to choose between AP2 and AP3 as the best destination AP. Figure 8 indicates that when the traffic at AP3 is less than or equal to 40 Mbps, handoff times in DDT are reduced by about 70% when compared to a standard Wi-Fi network. Figure indicates that when traffic at AP3

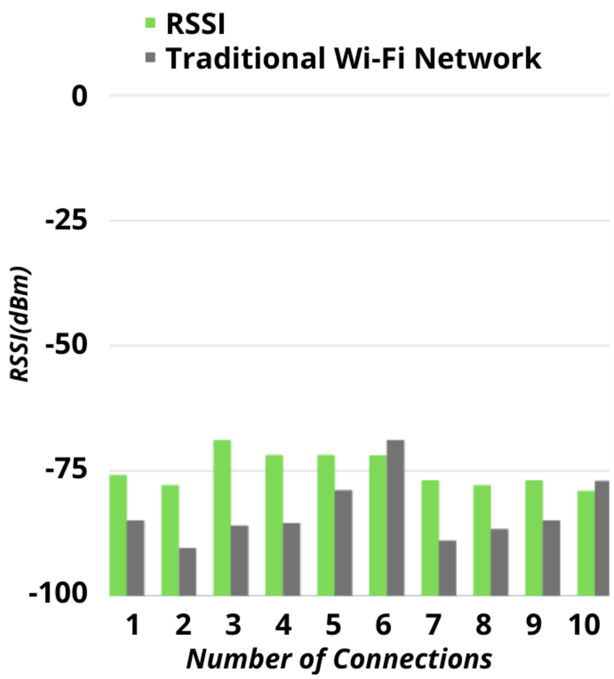

Figure 7. RSSI values at initial handoff time

exceeds 40 Mbps, the handoff time efficiency is nearly same, with the exception of a Wi-Fi network by 70%.

SDN controller chooses AP3 as the destination AP in the first case because AP2 has lower RSSI value than AP3. In the second situation, the SDN controller selects AP2 as the target

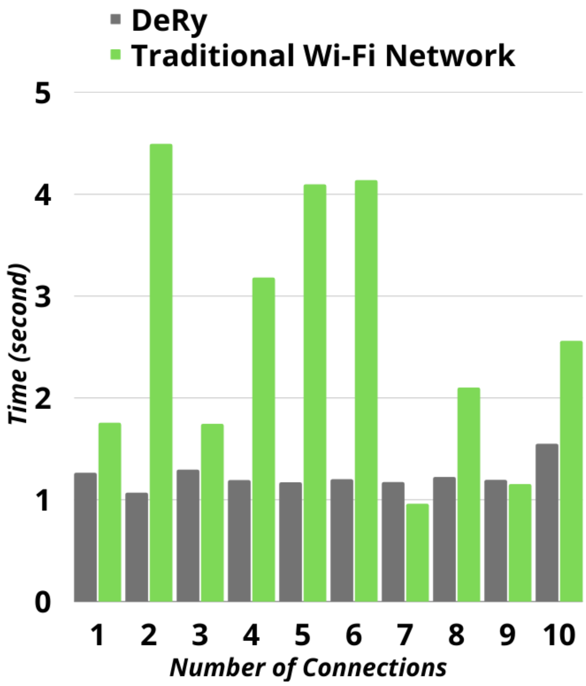

Figure 8. Handoff times when traffic of AP3 ≤ 40 Mbps

AP because AP3 traffic exceeds the allowed threshold as shown in Figure 9. As the sole decision factor used to identify the destination AP is RSSI, therefore in a typical Wi-Fi network AP3 is always selected as destination AP. Even when utilizing a multi-factor methods to select the best destination AP, the DDT method produced a fairly acceptable handoff time of 1 to 1.5 seconds. It is also worth noting that in a standard Wi-Fi network, the handoff time increased to 6 seconds when the destination AP to be chosen was overcrowded. When using delay sensitive applications, a 6s interval results in packet and information loss. Two simulation runs were carried out to asses how big of an impact a multi-factors could have on handoff timings. First test was carried out using RSSI as only selection parameter, while both the RSSI and traffic information parameters were used in the second test. The controller selects an AP having traffic value less than 40 Mbps with lower RSSI, when the AP is loaded. Handoff time is decreased by 20% compared to when only RSSI is used as the only selection parameter. As a result, it is demonstrated that QoS is not ensured during the handoffs when alone RSSI is used as selection parameter.

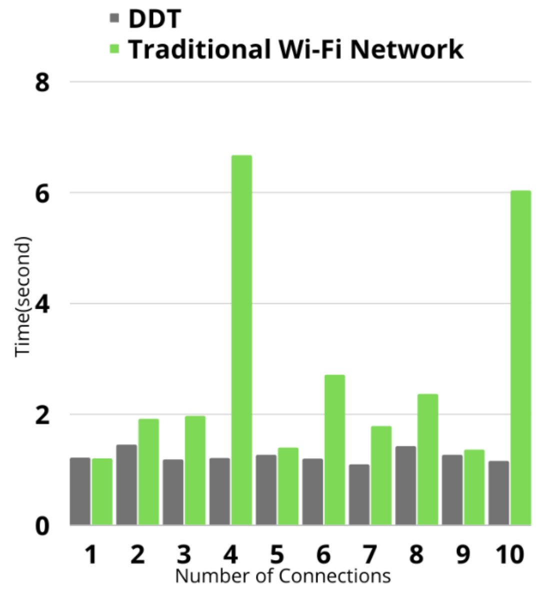

Figure 9. Handoff times with RSSI and (RSSI + traffic)

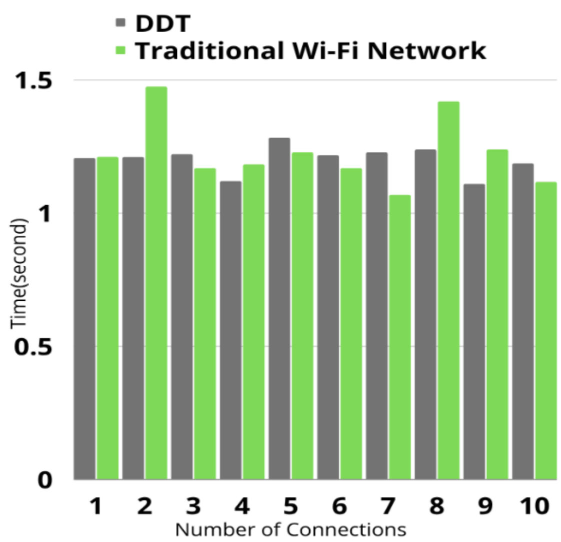

Figure 10. Handoff times when traffic of AP3 ≥ 40 Mbps

6. Conclusion

In this paper, DDT is proposed to reduce the handoff delays. The handoff procedure in a traditional Wi-Fi network is started by the wireless devices itself, which makes it vendor specific. DDT seeks to use a centralized SDN controller to regulate the detection phase (when the handoff is initiated) and discovery phase (which AP to re-link with), resulting in reduced handoff times. When compared to the traditional Wi-Fi networks, DDT reduces handoff times by 60% to 70%, resulting in improved communication and less packet loss. Instead of using a single selection parameter, such as RSSI, as in standard WiFi networks, the DDT considers both RSSI and AP traffic factors for choosing the best destination AP. Considering multiple connections, the proposed DDT is far better than the conventional Wi-Fi networks in terms of handoff times. We hope to study the performance evaluation of DDT by considering metrics like throughput rate and packet loss rate while choosing the destination AP in near future.

Author Contributions:

Algorithm design, Sohaib Manzoor, Muhammad Akbar Kayani; Code design, Ali Raza, Mahak Manzoor; emulation setup, Hira Manzoor, Muhammad Akbar Kayani; Writing and formatting, Mahak Manzoor, Sohaib Manzoor; over all proof read, Sohaib Manzoor, Ali Raza.

Conflicts of Interest:

The authors declare no conflicts of interest related to this research. [Author Name 1] is affiliated with [Medical Center Name], but this affiliation did not influence the design, execution, or interpretation of the study.

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