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QoS Comparison of Proactive & Prevent Scanning Handover Schemes in WLAN

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Abstract— This paper, critically, compares the Quality of Service (QoS) of two handover schemes namely proactive scanning handover scheme (PAHS) and prevent scanning handover scheme (PRHS) in wireless local area networks (WLAN). These schemes are employed within the scanning phase of the handover process which contributes to more than 90% of the handover delays. Two QoS indicators are examined: Access point resource utilization and Traffic losses. The two algorithms are modeled and simulated using blocks from the MATLAB/Simulink Simevent library and data obtained and analyzed in Microsoft Excel. Three access points AP1, AP2, and AP3 are used. The results obtained show that at traffic intensity of 942000, resource utilization of AP1 for PRHS and PAHS are 0.056 and 0.0683 respectively, at traffic intensity of 484500, resource utilization of AP2 for PRHS and PAHS are 0.0287 and 0.035 respectively, at traffic intensity of 969470, resource utilization of AP3 for PRHS and PAHS are 0.0574 and 0.0701 respectively. The PRHS and PAHS offered traffic losses of 0.684 and 0.746 respectively at traffic intensity of 2250416. The results clearly show that the PRHS is superior to PAHS in terms of reduction in traffic losses during handover while the PAHS offers better utilization of access resources.

Index Terms—WLAN, QoS, IEEE 802.11, Handover, Traffic Loss, Utilization, Traffic Intensity

1 Introduction

Rapid growth in wireless local area network (WLAN) has made it very popular and widely used in data communication [1]. New technologies in WLAN provide high data rates for real time services and also support multimedia applications such as voice over IP and e-conference. Critical to the 802.11 MAC operations, is the handover function which occurs when a mobile node moves its association from one access point (AP) to another. Ineffective handover procedure reduces the quality and reliability of the network. Over the past 15 years, researchers have been proposing various handover techniques for wireless local area network (WLAN) with the aim to optimize key quality of service (QoS) requirements [2,3].

A fast handover scheme based on mobility prediction was proposed in [4,5] . In the proposed scheme, a mobile host entering the area covered by an access point (AP) performs authentication procedures for multiple Access points (APs), rather than just the current AP. These multiple APs are selected by a prediction method called the frequent handoff region (FHR) selection algorithm, which takes into account users' mobility patterns, service classes etc. The benefit of this scheme is that since a mobile host is registered and authenticated for an FHR in advance, handoff latency resulting from re-authentication can be significantly reduced.
Simulation was used to show that the proposed scheme is more efficient than other schemes in terms of handoff delay and buffer requirements. A detailed analysis of horizontal handoff in WLAN in which they performed the handoff process and measured all the latencies at different stages of handoff was conducted in [6]. It was found that the specific wireless interfaces (hardware) used in the station(STA) and the AP affects the handoff latency, and the maximum average difference in handoff latency they found was around 335.53ms when the STA was fixed and different AP were used, and 186.47ms when the AP was fixed and different STAs were used.

Handoff performance and its effects on voice traffic was discussed in [7]. The main difference from [6] is that there is a voice like traffic between STA and a host connected to the distribution system (DS). Just as in [6], the search phase is the longest of all phases in handoff and its length depends on the STA in use. The STA may receive data from the old-AP during search phase. The exact handover behavior not only depends on type of hardware (WLAN interface) used in STA and AP, but also on the data flow (i.e., direction) between STA and AP. Techniques to reduce handoff time were presented in [8]. The study analyzed the detection phase in detail which no earlier research had done. It was concluded that the detection and search phase are the main contributors to total handoff delay.

Selective scanning was used to reduce the search phase in [9], and also used a neighbor caching algorithm at the STA to avoid the search phase, hence greatly reducing the overall handoff latency in open WLAN networks. They also used VoIP traffic in their tests and present packet loss during handoff. Their suggested solution only requires changes at STA side. However, WLAN networks which are secured using 802.11i will not benefit from their proposed solution and this solution may not work well when the APs are concentrated, heavily overlapped and use more than 3 to 5 channels in the WLAN system. A novel data structure, the neighbor graph that dynamically captures the mobility topology of a wireless network was introduced in [10]. The paper showed how neighbor graphs can be utilized to obtain a 99 percent reduction in the authentication time of an IEEE 802.11 handoff (full EAP-

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TLS) by proactively distributing necessary key material one hop ahead of the mobile user.

Furthermore, a location-based approach that reduces handoff overhead in IEEE 802.11 networks was presented in [11]. With this approach, an STA can derive the prospective access points (APs) most likely to be visited next, using the current location and the AP topology information acquired from some designated server. The server also provides parameters for AP (re)association so that the MS can re-associate with an AP directly without a probe beforehand. Channel scanning was identified as an important aspect of seamless handovers since it is required in order to find a target point of attachment (PoA) and that in IEEE 802.11 WLAN, scanning of other channels causes service disruptions with the current AP so that the provided quality of service (QoS) will be degraded seriously during the handoff [12]. A QoS supported dynamic channel scanning algorithm was proposed. A CDMA-assisted handover scheme (CAHO) for WLAN, which uses the CDMA connection during the handover was proposed in [13]. An experimental test-bed was set-up to compare with other schemes. The experimental results showed that the CAHO can reduce disruptions and lost packets during handover in WLAN.

Several other handover strategies within the scanning phase have also been proposed [14,15,16]. It is clear that handover schemes in WLAN are expected to be seamless and effective to support real-time services in many multimedia applications.. It is also observed that handover delays are predominantly high during the scanning phase. It is, therefore, the objective of this paper to critically compare the access point resource utilization and traffic losses for the PAHS and PRHS which are scanning phase-based handover schemes.

This work aims to evaluate two handover schemes that reduce scanning phase delay which contribute more than 90% of the overall handover delay: proactive scanning handover scheme (PAHS) and prevent scanning handover scheme (PRHS). Specifically, the comparison is based on the following quality of service (QoS) indicators: access point resource utilization and traffic losses. MATLAB 2014 will be used for the simulation of the models based on the developed flow charts.

2. Proactive scanning handover scheme (PAHS)

The proactive scanning handover scheme takes place during normal connectivity. It is active every 2 seconds when the signal strength of the current AP falls below -80dBm where the STA and AP can communicate in 1Mbps data rate to scan and find information from the neighboring APs. The station will compare the information with the current AP to know if there is need for handover [17]. In this scheme, the STA continues to monitor the signal strength and at the same time, scan neighboring APs in the range every 2 seconds. If a packet is sent between the STA and its associated AP within this time, the packet will wait until the transaction is completed. The STA first sends a buffer request message to its associated AP to buffer data that might be sent to the STA during this phase. By so doing, this prevents packet loss. The STA later scans neighbor APs in range by using the active scan mode to broadcast a probe request in each channel. The information from APs in range including signal strength, AP properties and traffic load conditions is replied to the STA. The STA analyses and compares this information to the association APs. Example operation data in the STA is shown in Table 1.

TABLE 1:
EXAMPLE OPERATION DATA IN THE STA

From`	Signal Strength	Traffic load
AP1	-87dBM	42%
AP2	-73dNm	38 %
AP3	n/a	n/a
:	:	:
APn	-x dBm	y %

The following terminologies are associated with the algorithm

S_C :Signal strength from the current AP

S_N :Signal strength from the neighboring AP

T_C :Traffic load of current AP

T_N : Traffic load of neighbor AP

S_{TH} : Signal strength threshold

Δ :Signal strength hysteresis window

HOF_C : Handover factor for current AP

HOF_N : Handover factor for new AP

HOF_{TH} : Handover factor hysteresis window

The average signal strength of the packets sent by the current AP (S_C) and the neighboring AP (S_N) using the weighted average are first calculated as shown in equations 1 and 2 respectively. At the same time, the average traffic load (the throughput in the MAC layer) of the current AP (T_C) and neighboring APs (T_N) using equations 3 and 4 respectively.

$$S_C = \frac{\sum_{i=1}^{n} w_i S_{Ci}}{\sum_{i=1}^{n} w_i} \quad (1)$$

$$S_N = \frac{\sum_{i=1}^{n} w_i S_{Ni}}{\sum_{i=1}^{n} w_i} \quad (2)$$

$$T_C = \frac{\sum_{i=1}^{n} w_i T_{Ci}}{\sum_{i=1}^{n} w_i} \quad (3)$$

$$T_N = \frac{\sum_{i=1}^{n} w_i T_{N\,i}}{\sum_{i=1}^{n} w_i} \quad (4)$$

Where the weighted average, w_i, is:

$$w_i = \frac{1+(n-i)}{n+i} \quad \text{and} \quad n = 4$$

Also, handover factor for the current APs (HOF_C) and the neighboring APs (HOF_N) are:

$$HOF_C = \frac{S_C - S_{TH}}{S_{TH}} \quad (5)$$

$$HOF_N = \frac{S_N - S_{TH}}{S_{TH}} \quad (6)$$

The algorithm is given below and summarized in the flow chart of figure 1:

I: $if\ S_C < S_{TH}\ and\ S_N > (S_{TH} + \Delta)$ then

II: start handover

III:

$elseif\ S_N > (S_{TH} + \Delta)\ and\ HOF_N > (HOF_C + HOF_{TH})$ then

IV: start handover

V: end

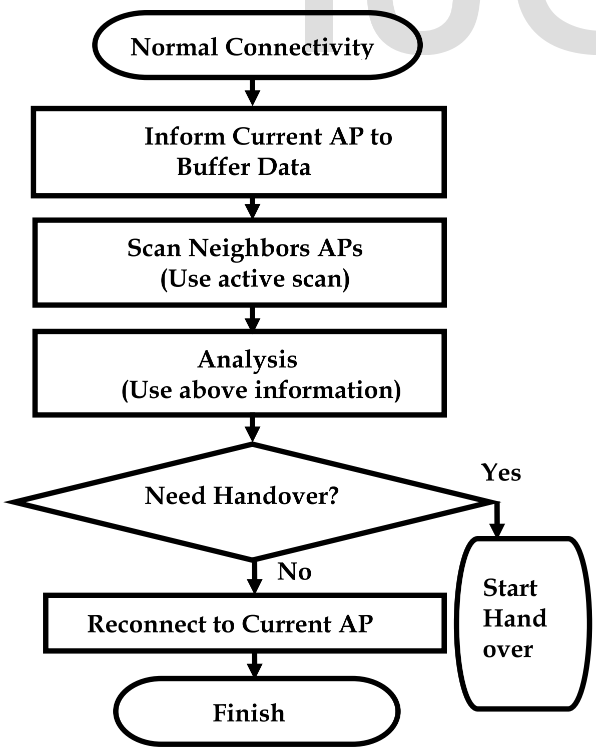

Fig. 1. Proactive Scanning Phase Algorithm

To determine the quality and the strength of the current AP with the neighbouring AP, the above parameter defines the handover factor (HOF). The handover factor enables us to determine both the signal strength and traffic load conditions.

The handover factor is based on the following conditions.

- If the signal strength of the packet sent from the current AP is lower than the threshold and the signal strength from the new intended AP is higher than the simple sum of the threshold and the hysteresis, then the STA will start a handover to the new AP.
- If the signal strength of the current AP is higher than the threshold, then the STA will start a handover process only if the new AP can provide a better performance than the current AP. This means that the signal strength of the new AP is higher than the simple sum of the threshold and the hysteresis and also the handover factor for the new AP is higher than the handover factor for the current AP and the handover factor of the hysteresis else the STA will send a reconnect signal to the current AP to continue to associate with the current AP and the current AP will send all buffered data to the STA.

2.1 ***Proactive scanning process***

The use of proactive scan phase helps the STA to determine the reason for frame loss and know when to start handover or retransmit the packet. The proactive scan phase uses the active scan mode for its scanning. The number of APs in range is the main factor that increases traffic load in the STA. The proactive scan phase uses the active scan mode to scan neighbor APs in range. This technique can reduce the number of APs that the STA will scan. The active scan mode shown in figure 2 illustrates how the proactive scan phase can find information from neighbor APs in range.

When the STA is idle, the STA will scan all available neighbor APs, meaning that the STA will broadcast a probe request frame in each channel and then wait for probe responses. After the STA receives all responses from the neighbor APs, the STA will arrange them in the AP list by quality of signal strength and traffic load conditions. When the STA is busy, the STA will scan only two or three APs in the list and then rearrange them. With active scan mode, we can reduce delay time in the proactive scan phase; this reduces delay time from 70-87ms to 16-36ms. A lot of wireless networks use only three channels (IEEE 802.11b/g) and by scanning three channels only, it is easy to find the most neighboring APs.

3 Prevent scanning handover scheme (PRHS)

This scheme is aimed at preventing scanning phase which contributes a greater percentage of handoff delay in the system. Moreover, handover latency in IEEE 802.11 b with inter access point protocol (IAPP) network may take a probe delay of 40-300ms with a constant IAPP delay of 40 ms [18]. For IAPP protocol to reduce this delay, the STA must authenticate itself with the first AP of the external service set (ESS), but IEEE 802.11 standard requires that authentication must proceed immediately with association or authentication can follow a channel scan cycle. Note that IAPP based pre authentication is achieved before the STA enters into discovery state and so does not contribute to the handover latency [19]. These result in a new threshold called prevent received signal strength indicator ($RSSI_{prev}$). This is the value of the link quality above which the STA is not under the threat of imminent handover. This ($RSSI_{prev}$) is given by the equations (7) below.

$$RSSI_{PREV} = RSSI_{MIN} + \frac{RSSSI_{MAX} - RSSI_{MIN}}{2} \quad (7)$$

Where $RSSI_{max}$ represent the best link quality that can exist between the STA and its AP. The process of this scheme start with detecting the mobility of the STA. When the RSSI value of the current AP falls below $RSSI_{prev}$ threshold value, the STA starts to look for new AP that has a better signal strength or link quality than the current AP. The STA must predetermine a new AP before it will start-off handover. Therefore, when the handover threshold is reached, the STA will start directly the re-authentication phase thereby jumping the discovery phase. Note that the operation associated with handover such as the selection of the next AP and transfer of STA contents are being executed before the handover is triggered including the selection of the next AP and the transfer of STA's context. For each SyncScan procedure, the STA must switch to a specific channel until it receives the corresponding beacon, then it switches back to the original channel. So, for each channel the SyncScan latency is given by:

$$SyncScan_{delay} = 2 * T_{switch} + T_{wait} \quad (8)$$

Where, T_{switch} is the switching delay from one channel to another and T_{wait} is the time required to recover the beacons issued by the APs running on a given channel. The total delay of the handover scan depends on the number of channels to be scanned.

3.1 *Prevent scanning process*

The Prevent scanning procedure is illustrated in figure 3. Prevent scanning process uses passive scan mode where the STA must listen to the wireless medium for beacons frames. This beacon frames provide the STA with timing and advertising information [20]. During passive scanning, the STA listens to each channel of the physical medium one by one, in an attempt to locate the potential APs using the probe channel. Current APs have a default beacon interval of 100ms [21]. Therefore, passive scan incurs significant delay. The polled AP is elected only based on RSSI parameter. During prevent scan process, the STA switch channels and wait for the beacons from the potential APs, which produces additional temporal cost composed by switching time between channels and waiting time on each one. Consequently, for each channel, we calculate the total time of the prevent scan process using the expression stated in equation (9).

$$T_{pre-scan} = N \times (T_{switch} + T_{wait}) \quad (9)$$

Where N is the number of available channels.

Although, T_{switch} and T_{wait} has a relatively small values but are still greater than the maximum retransmission time of 802.11 frames (4ms). Therefore, the time bounded packet is being dropped since STA is unable to acknowledge them. Because of this problem, the STA is modified and an algorithm is built-in to announce the entering of a power saving mode just before switching channels. This causes the AP to buffer packets until the STA returns to its channel and reset the PSM mode. The buffer will not be overfilled during this PSM mode, they are quickly emptied when the STA finishes the prevent scan process and returns to normal mode.

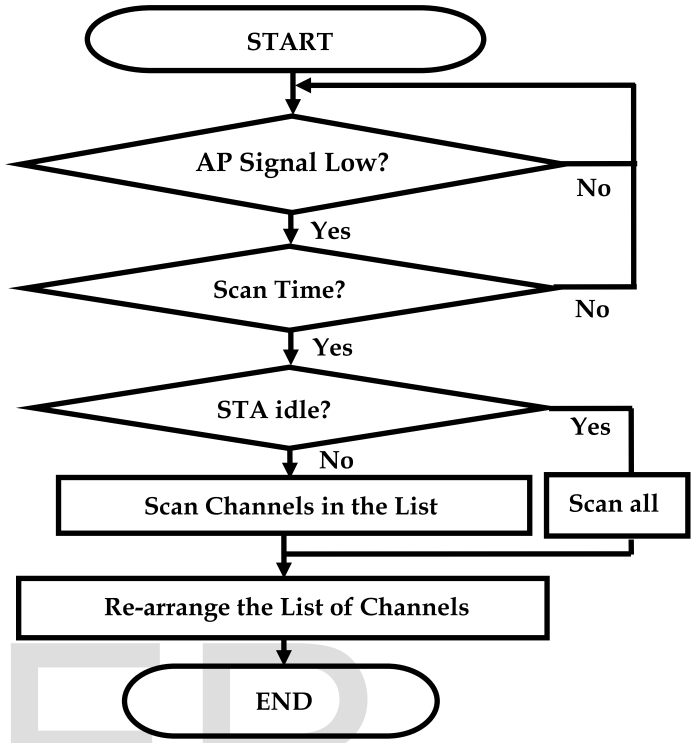

Fig. 2. Active Scan Mode

The STA maintains its classified AP list. Using this list, the STAs no longer need to carry out a full scan when handover is initiated. Rather, it directly selects the AP on the first position of the AP list and perform association request.

An association request is accepted only if the RSSI value of the first AP in the dynamic list has a value greater than both the handoff threshold and the actual RSSI measured with the current AP (i.e. this request is accepted only if the first AP of the dynamic list offers to the STA a better link quality than the current AP and also sufficient to continue operation without losing connectivity with other entities of the network). After the execution of the prevent scan, once the STA associates with a new AP, then it initiates a prevent scan again. If the association fails, with the first AP then the dynamic list is purged and the STA carries out a new prevent scan cycle.

4. Simulation Results

In this section, the performance of the two handover schemes: proactive scanning handover scheme, (PAHS) and prevent scanning handover scheme (PRHS) are evaluated and compared based on handover delay and resource utilization. Blocks from MATLAB Simulink simevent library is used to build the models. Simulation parameters are outlined in table 2.

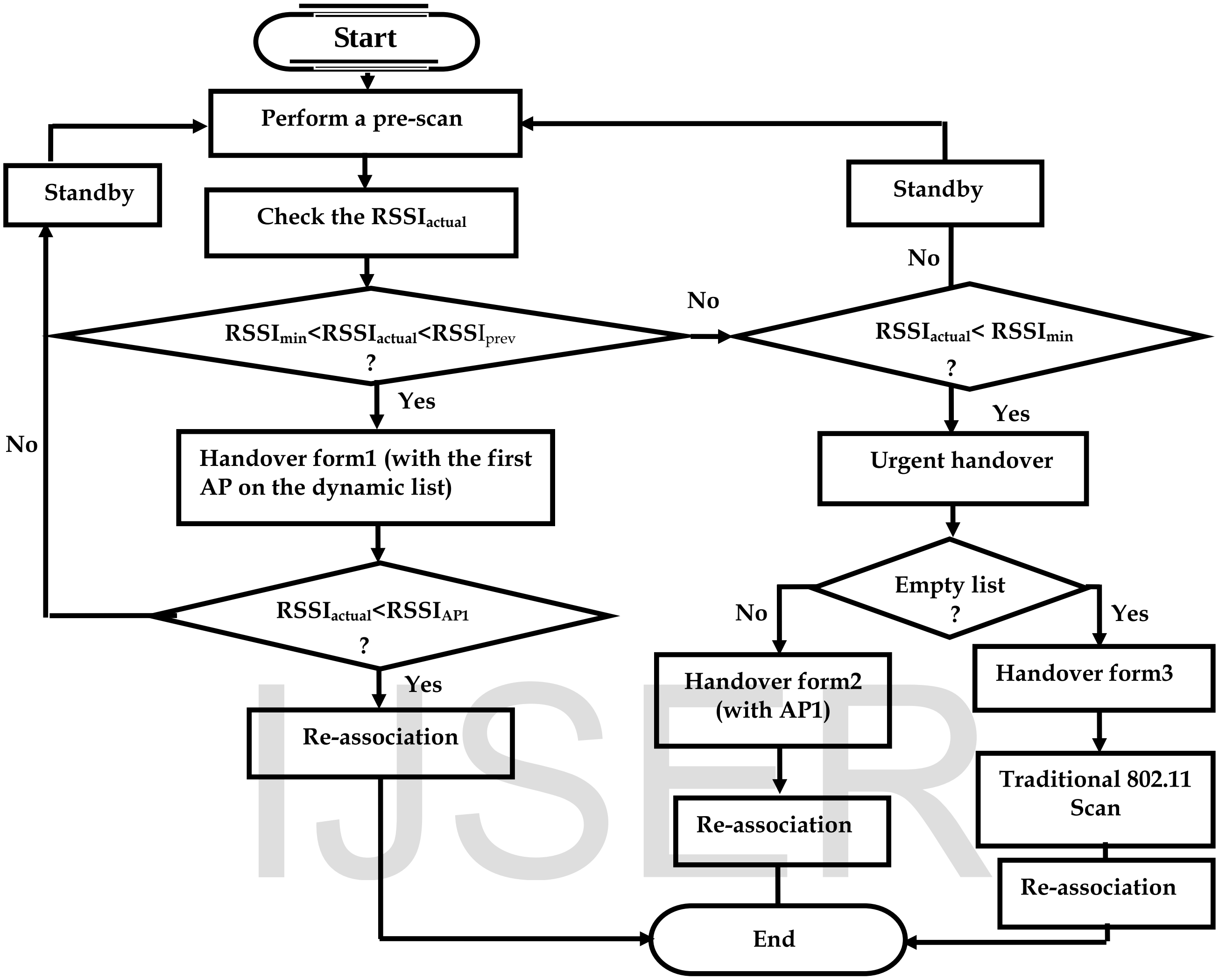

Fig. 3. Prevent Scanning Process Flowchart

Table 2
Simulation Parameters

Parameter	**Value**
No of mobile stations (STA)	2
No of access points (AP)	3
Number of Channels	11
Simulation Time	100 seconds
Generation type	Exponential
Type of queue	FIFO
Threshold for AP1	-36.5dB
Threshold for AP2	-40dB
Threshold for AP3	-44dB

In performing the simulations, the received signal strength indicator value is based on the distance between an STA and its AP (RSSI-based positioning) as shown in [22]. The relationship between the distance, d separating an STA and its AP and the received signal strength P_r, is shown in equation (10).

$$P_r = P_0 - 20\log_{10} \frac{4\pi d}{\lambda} [dB]$$

Where P_0 =transmitting power, d= distance and λ is the wavelength

$$\lambda = {}^{c}/_{f}$$

Where c = velocity of light (3×10^8) and f = transmission frequency (8×10^6). Transmitting power P_0 (200mW)

5. Analysis of simulation results

The two schemes are compared as follows:

- Access point resource utilization against traffic intensity.

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- Traffic loss against traffic intensity.

5.1 Access point resource utilization against traffic intensity

In this case, the utilization of the different access points by traffic that gets into the network is compared. This is basically done with intention of determining which scheme best utilizes the AP at different traffic intensity. Figures 4, 5 and 6 show the set of curves obtained for the three APs under investigation for the two schemes of interest (i.e. PAHS and PRHS). From the set of curves obtained, it can be seen that there is a linear relationship between AP utilization and traffic intensity. The linear relationship is attributable to the fact that as the traffic intensity increases, more traffic contends for the access point and as such increasing the utilization of the access point.

With respect to the two schemes under investigation, it is observed from the curves in Fig 4, 5 and 6 for the different AP that the proactive scanning handover scheme (PAHS) experiences more utilization of the AP when compared with the preventive scanning handover scheme (PRHS). This is as a result of the complexity of the system at mobile station since decisions are taken at the STA.

5.2. Traffic Loss against Traffic Intensity

In the case of investigating the PAHS and PRHS with respect to the traffic loss encountered by traffic as they gain access into the network, certain observations are made. From the figure 7, the obtained curves show an increase in mean/average traffic loss with respect to traffic intensity and it shows that as the traffic intensity is increasing, the probability of traffic drop increases in the network. The result from the observation shows that for every instant of traffic intensity, the proactive scanning handover scheme (PAHS) experiences more traffic drops relative to the preventive scanning handover scheme (PRHS). This is attributed due to the fact that PRHS minimize the time during which STA remains out of contact with AP and allowing handover to be made earlier and with more confidence unlike PAHS in which the STA moves away from API. STA also spends time in waiting for probe response and as result encounters more traffic loss.

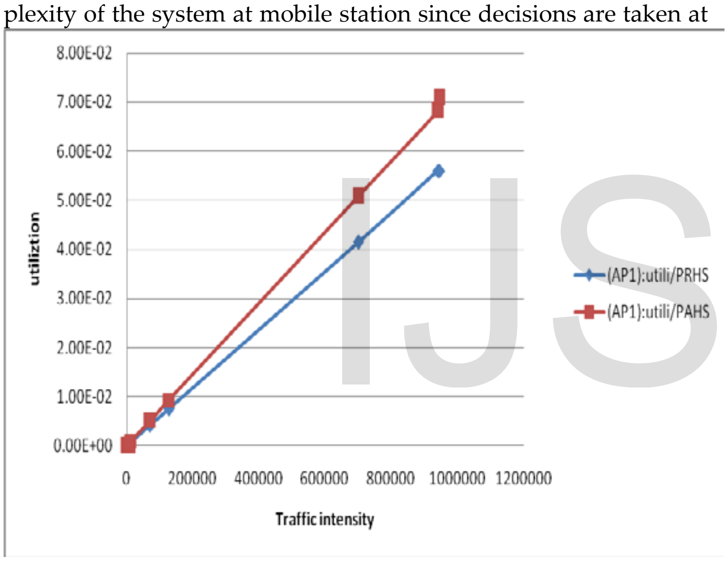

Fig. 4. Access point utilization against traffic intensity for AP1

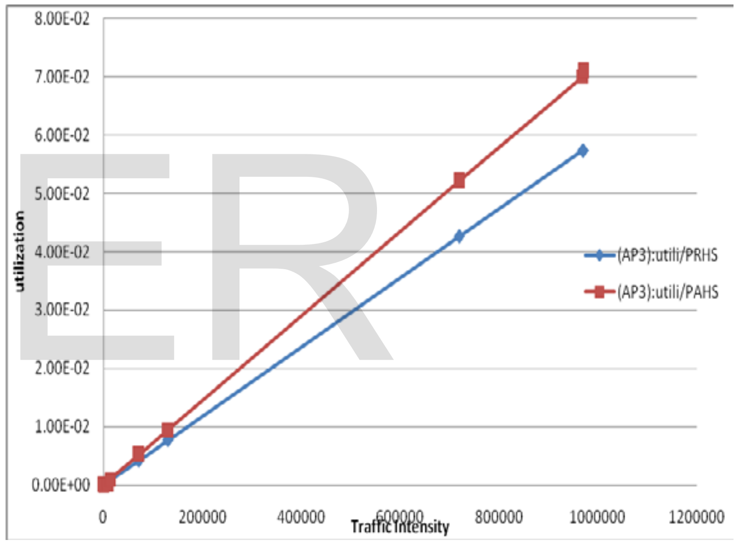

Fig. 6. Access point utilization against traffic intensity for AP3

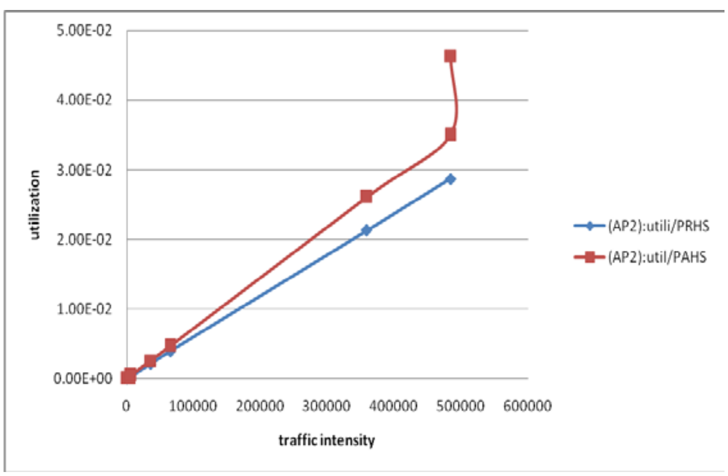

Fig. 5. Access point utilization against traffic intensity for AP2

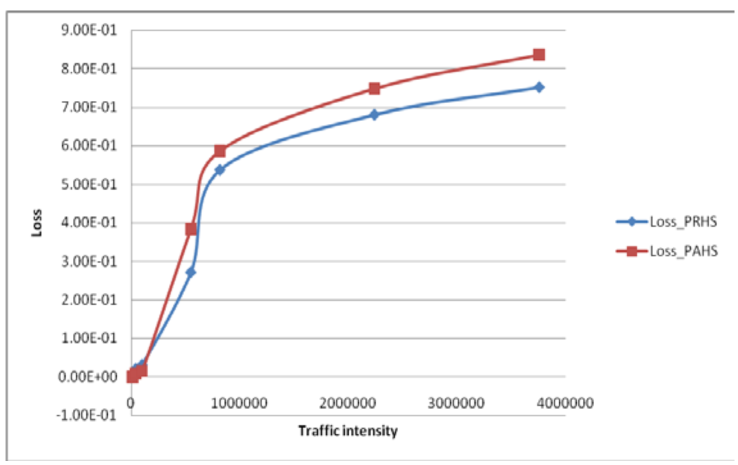

Fig. 7. Traffic loss against traffic intensity for the PAHS and PRHS Schemes

6. Conclusion

This paper has presented a quality of service comparison of proactive scanning handover scheme (PAHS) and prevent scanning handover scheme (PRHS) in wireless local area network (WLAN) considering the following quality of service requirements: resource utilization and traffic loss. The two handover scheme algorithms under study have been described using flow charts and modeled using blocks from MATLAB Simulink Simevent library. The resulting data was analysed using Microsoft Excel for graphical presentation. Compared to the PAHS, less traffic drop (loss) is experienced in the PRHS for each instant of traffic intensity. The PRHS and PAHS offered traffic losses of 0.684 and 0.746 respectively at traffic intensity of 2250416.This reduced traffic loss in the PRHS is attributed to the reduced delay in handover in the PRHS as mentioned above. It is seen that the PAHS offered better utilisation of network resources compared to the PRHS for the three access points considered: AP1, AP2, and AP3. The results obtained show that at traffic intensity of 942000, resource utilization of AP1 for PRHS and PAHS are 0.056 and 0.0683 respectively, at traffic intensity of 484500, resource utilization of AP2 for PRHS and PAHS are 0.0287 and 0.035 respectively, at traffic intensity of 969470, resource utilization of AP3 for PRHS and PAHS are 0.0574 and 0.0701 respectively.

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