A Review on Handoff Latency Reducing Techniques in IEEE 802.11 WLAN

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ABSTRACT
Wireless communication plays a significant role in our life as it provides mobility and flexibility as well as scalability. Handoff delays make a serious problem. A lot of research has been done in last few years to reduce the handoff delays occur in the different levels of wireless communication. Due to the mobility of devices handoff is an important aspect in WLAN and cellular communications and in WLAN this aspect is much more important due to limited range of APs, WLAN also provides sufficient bandwidth for real time streaming services. In the literature a number of handoff schemes have been proposed to reduce the handoff latency and support fast handoff in IEEE 802.11 wireless networks. In this article, we review these fast handoff schemes and analyze their advantages and disadvantages qualitatively. Our aim is to make available groundwork for future research on reducing the handoff latency for intelligent transport systems (ITS) in vehicular scenarios and give emphasis on requirement of fast handover for seamless connectivity. We comprise here various techniques to reduce handoff delays. Some future research ideas are also suggested here.

Keywords
IEEE 802.11 WLAN, Handoff; Access Point, Handoff Latency, Selective scanning, Neighbor Graph

1. INTRODUCTION
The deployment of the Wireless Local Area Networks (WLANs) is much easier and easy to maintain compared to the wired networks hence it is becoming essential component of the networks. WLAN is a local area network that uses high frequency radio signals to transmit and receive information over a distance. In physical and link layers many protocols can be adopted to build a wireless network to make available wireless connection for example IEEE 802.11 [1], Bluetooth [2], WiMax [3], etc.

To support various important applications such as VoIP, video conferencing live telecast, video streaming etc 802.11 wireless networks have enough bandwidth and supports 2Mbps practical data rates [4]. For VoIP 90 Kbps is sufficient bandwidth. VoIP stands for voice over Internet Protocol (IP) and it is the methodology for delivery of voice communications and multimedia sessions over IP network such as Internet. Mobility needs to be supported to provide seamless connections and uninterrupted services to the users if they are moving around. Supporting user mobility in WLAN remains a challenging task. Mobile wireless stations (STA) require frequently handoff between different cells due to limited range of the access points (APs).

When the ongoing connection between mobile node and corresponding node from one point of attachment is transferred to another neighbouring point of attachment due to poor signal quality, is called handoff. These points of attachment are called access points (APs) in 802.11 WLAN and APs range is limited. In WLAN, handoff is the mechanism of transferring the ongoing connection from one AP to another AP. In the process of handoff mainly three entities are participating namely station, prior-AP, and posterior-AP. Prior-AP is the AP to which the STA had the connectivity prior to the handoff whereas the AP to which the STA gets connectivity after the handoff process is posterior-AP. The state information consists of the client credentials and some accounting information is transferred. Inter Access Point Protocol (IAPP) [5] or a proprietary protocol is used to transfer the state information.

There are two basic types [6] of handoff are defined namely Hard and Soft handoff. When the STA must break from the ongoing connection with prior-AP before joining the posterior-AP (break before-make), it is called hard handoff. In IEEE 802.11 and cellular systems hard handoff is employed using time division multiple access (TDMA) and frequency division multiple access (FDMA). If the old connection is maintained until the new connection is established (make-before-break), it is known as soft handoff. Soft handoff is adopted by CDMA [7]. According to the transition in different wireless networks handoff can be classified into two parts: Horizontal handoff and Vertical handoff. Horizontal handoff is the intra-system handoff like transferring the ongoing connection from one AP to another in different BSS in WLAN whereas in vertical handoff ongoing connection is transferred between different wireless networks or systems (inter-system) such as WLAN to cellular or WLAN to GPRS systems etc. The roaming STA can access the wireless network through various APs and it is recognized at medium access control (MAC) layer (L2) and network layer (L3) [8]. Network layer mobility can be defined into two categories, first one is macro mobility which deals with the STAs roaming in wireless networks using different access technologies and the example of macro mobility are Mobile IP [9] and its derived techniques [10-12]. Other one category is micro mobility. When the STAs moving in wireless networks with same access technology, is known as micro-mobility. The Radio systems like WLAN and GPRS are mainly focused on MAC layer (L2) handoff. Data rate of WLAN is much greater than 3G or GPRS. MAC layer handoff is break-before-make, hard-handoff. Layer-2 handoff deals with STAs moving between APs range belonging to the same IP sub-network and the handoff process is handled by the MAC level. Handoff is handled at the IP level and is called layer-3 handoff, if STA moves from the range of one AP to another belonging to different IP sub-network. To resolve it Mobile IP (MIP) protocol is used [9]. In IEEE 802.11 WLAN, the STA must break the connection with prior-AP before joining the posterior-AP, so during the handoff time interval STA unable to send or receive any data. In the literature a number of handoff techniques have been proposed on diminishing the handoff latency or buffering data during this interval. We have to reduce handover latency more and more to use some real-time applications such as VoIP, live broadcasting, many kinds of alarm systems and video surveillance systems. Due to the limited service range of APs mobile STAs require frequently handoff [13]. This survey paper is organised as follows: Handoff is defined in Section II. Section III reviews the IEEE 802.11WLAN handoff procedure and describes related works. The various handoff latency reduction techniques are explained in section IV and Section V concludes the paper.

2. HANDOFF PROCESS

The Handoff is the process of transferring the ongoing session between mobile STA and corresponding node from one point of attachment to another point of attachment or the same. Due to the mobility of devices, the handoff is an essential aspect in WLAN and cellular networks. Handoff is shown in fig.1 [14].

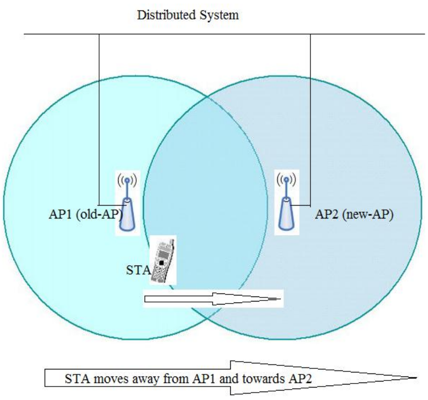

Fig.1: Possible Handoff scenario in WLAN.

Handoff process allows a user to move around without interrupting the ongoing connection between STA and corresponding node. It changes the current channel in the current cell to a new channel in the different cell or in the same [14]. The time interval in the complete handoff process is known as handoff latency. Handoff affects the quality of service directly. Handoff occurs if the signal quality falls below a predefined threshold level. The Quality-of service (QoS) and capacity of the network may be affected due to handoff [15]. There are some requirements to reduce the adverse effect of handoff such as handoff latency must be as low as possible, the total number of handoff should be minimal.

3. HANDOFF PROCEDURE IN WLAN

In WLAN handoff is the mechanism of transferring the ongoing connection from one AP to another due to poor signal quality. Handoff is the process of disassociating from the prior-AP and establishing a connection with the posterior-AP. The necessity of handoff is detected if the received signal strength (RSS) from current AP falls below the certain threshold level. The L2 handoff of WLAN is hard-handoff and divided into three phases: scanning, authentication, and re-association [16]. The complete handoff process [17] can be classified into two different logical steps, (1) Discovery (scanning), (2) Re-authentication. An authentication and re-association to the posterior AP are collectively called Re-authentication. The handoff latency or delay is the sum of delay incurred by search and re-authentication phase. The overall handoff delay is the sum of the delays incurred by m individual phases given by following equation:

$$Handover\ Delay = \sum_{i=1}^{m} Delay_i \quad (1)$$

Scanning also called probing is the first phase of handoff process and it is the process of selecting a suitable AP from neighbouring APs to handoff. Detection phase is considered the first phase of handoff in some works (Velayos and Karlsson 2004 [18]). Need for the handoff is determined by the detection phase as shown in the fig-2. RTS/CTS mechanism is used after failed frames to overcome probable radio fading or collisions in a burdened cell.

The station conform the out of range status after various unanswered requests and starts the search phase. Velayos and Karlsson 2004 [18] suggested another approach in which STA starts search phase directly by excluding the reason for failure of collisions because above detection procedure is long as shown in fig-2 and if the selected AP by search phase is current one then handoff will not be executed.

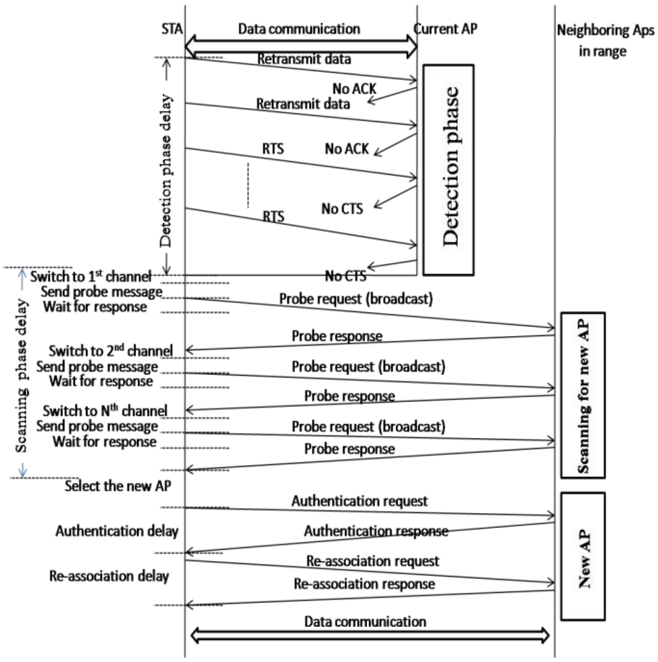

Fig.2: Possible Handoff scenario in The IEEE 802.11 WLAN

Scanning phase is the most time consuming phase in the entire handoff process which is more than 90% of the overall handoff delay [18] and the primary cause of MAC layer handoff latency is probing of available channels [19]. Scanning can be defined into two types: active and passive. In passive scanning each channel is listened by STA for the beacon frames for a fixed amount of time (usually 100msec). In most WLAN deployments generally passive scanning is used and it is power efficient. In active scanning, the STA broadcast the "Probe Request" to all IEEE 802.11 channels and wait for response called "Probe Response" from probed APs as shown in fig-2. In active scanning, the STA sets a timer to *MinChannelTime* and waits for response if the channel is during *MinChannelTime* then there is neither the response nor the any traffic in the channel. Channel is declared empty and completed the scanning of that channel. STA waits for *MaxChannelTime* for more responses from other APs on the same channel if an AP sends a response message. Active scan reduce the time taken to scan but increases the traffic load and also increases power consumption. Using channel scanning best AP is selected after this authentication and re-association phases start means actual handoff begins. For authentication STA sends authentication request to the selected new AP and it sends the authentication response to the STA, if response is not received by STA then, STA could not re-associate to the new AP. The re-association service is implored to "move" a current association from one AP to another. An authentication and re-association to the posterior AP are collectively called Re-authentication. Transfer of credentials and other state information is involved in the re-authentication phase. Through the IAPP [5] protocol this can be achieved [17].

In the complete handoff process the sequence of messages typically observed is shown in fig-2. Complete handoff latency can be divided into three delays:

1. *Scanning or Probe Delay:* It is time taken by the STA to scan all the IEEE 802.11 channels; it is the composition of mainly three times namely switch to channels, send probe request and wait for response for all channels. During the probe process the actual number of messages may vary from 3 to 11.
2. *Authentication Delay:* Authentication service may be used by all STAs to establish their identity to STAs with which they communicate, in both ESS and IBSS networks. Only after the successful authentication establishment re-association can be established. Time interval during the exchange of authentication frames is authentication delay.
3. *Re-association Delay:* Re-association is the service that enables an established association (between STA and AP) to be transferred from one AP to another or the same AP. Time interval during the exchange of re-authentication frames is re-authentication delay. Handoff process is completed after the re-association response in the answer of re-association request from the new AP.

Using multi-radio handoff technology handoff latency can be minimized but it increases cost [20]. To achieve smooth handoff probing channels are divided into various groups in [21]. STA scans the channels one by one and in between scanning of two groups it resumes data communication. Beacon messages of APs can be received at lower handoff latency by synchronizing the STAs in SyncScan technique [22], it reduces the passive scan time. Handoff latency is more than 50msec in [23], so handoff is a challenge in handoff algorithms. If STA has one radio for data communication, another for scanning and handoff then handoff delay can be completely eliminated in multiple radio technique but cost will increase [24].

4. TECHNIQUES TO REDUCE HANDOFF LATENCY

4.1 Distributed Handoff Mechanism

To reduce the handoff latency in IEEE 802.11 based WN, an efficient MAC layer handoff protocol is presented in [25]. In Fig.3, example of Distributed Handoff scheme, to scan all the available channels, a mobile node selects several neighbouring nodes before it starts initiating the MAC layer Handoff process. All channels are grouped and these groups are scanned by selected neighbouring nodes separately. In each node the number of scanning channels is reduced and minimized the scanning latency. A mobile node requires nodes in a certain range to help it scan the available channels as soon as the handoff process is initiated. These nodes help the mobile device by forming (or organizing into) a temporary group. Each node requires scan only some of channels which are distributed to nodes in a group. A big problem of probing (or scanning) is divided into small problems and all these problems can be executed simultaneously.

Received signal strength (RSS) can be measured by STA. In this scheme predefine the three RSS levels: RSS_L, RSSH, RSS_G Threshold to trigger handoff is RSS_L By using the assistant nodes to form a temporary handoff group RSS_H is used. Before starting the handoff process by STA, it ensure the existence of assistant nodes RSS_H little higher than RSS_L.

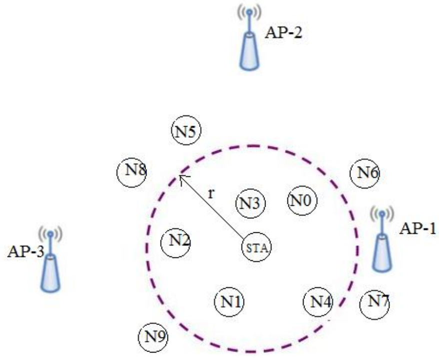

Fig.3: An example of Distributed Handoff scheme

Received signal strength (RSS) can be measured by STA. In this scheme predefine the three RSS levels: RSS_L, RSS_H, RSS_G Threshold to trigger handoff is RSS_L By using the assistant nodes to form a temporary handoff group RSS_H is used. Before starting the handoff process by STA, it ensure the existence of assistant nodes RSS_H little higher than RSS_L. To define the largest distance from the STA to its neighbour nodes RSS_G is used. This scheme consist three main components, group construction, distributed scan mechanism and cache scheme. When the RSS is lower than RSS_H, grouping process is triggered in group construction. STA inspects neighbour nodes in range r as the assistant nodes; so, nodes N0, N1, N2, N3, and N4 are selected in the given example as shown in given fig-3 [27]. AP information based on the result of distributed scan mechanism can be stored in the cache structure, since it is also possible for assistant nodes to re-associate with the same AP after a short time interval due to closeness of the assistant nodes to the STA. The assistant nodes will save the new AP in its caching structure with a lease time *Tlease* in the response of the broadcasted message with the new AP from STA to all assistant nodes. . Only the latest AP is saved in the cache, and the old AP is usually overwritten. When the assistant node wants to initiate handoff, in the first it will try to re-authenticate with the AP stored in the cache during the *Tlease* time. Scanning time is saved if the AP accepts the assistant node and directly can re-associate with the AP. If the Tlease time is expired then the assistant node should start a complete distributed handoff mechanism. Channels are grouped and assigned to the closest neighbour nodes to scan instead of scanning of all channels by STA only and each node scan only a few channels. By this scheme handoff latency is reduced and by using caching scheme further decreases the handoff latency.

4.2 Pre-active Scanning Scheme

Scanning phase is the most time consuming phase, it has more than 90% of the overall handoff total delay. By using the Pre-active Scanning scheme [26] which works during normal connectivity, we can reduce the handoff delay time in detection and search phase. In Pre-active scan STA start execution phase directly without delay in the detection and search phase, it has advantage of traffic load sharing and STA take decision to start handover to new AP which is providing higher quality than the previous AP. Traffic load is increased in this scheme due to reserve time to broadcast "Probe Request" frame and wait for "Probe Response" frame from (to) neighbour APs in range. Throughput is decreased and traffic load is increased in the Pre-active scan scheme.

4.3 Distance Measurement Technique

In this technique [6], the Hexagonal cell concept is used to accelerate the handoff process. The position of mobile node is obtained by using GPS or some other localization technique in terms of coordinates (r, θ). It is well known fact that power of radio frequency signal is inversely proportional to the square of distance. The mobile node can update the values of (r, θ) in regular intervals and maintain a cache. Now, the instantaneous distance R_i between mobile node and APs is calculated by using

$$R_i = \sqrt{r^2 + D^2 - 2rD\cos\left((2i-1)\frac{\pi}{6} - \theta\right)} \quad (2)$$

Where, $$D = \sqrt{3}R \quad (3)$$

When the distance between mobile node and current AP is greater than a fixed threshold level then the handoff process is initiated and the AP which is nearest is selected for association by mobile node. There is no need of handoff when the mobile node is in the in-circle of the cell while the circum-circle defines the range of individual AP (see fig-4 [6]).

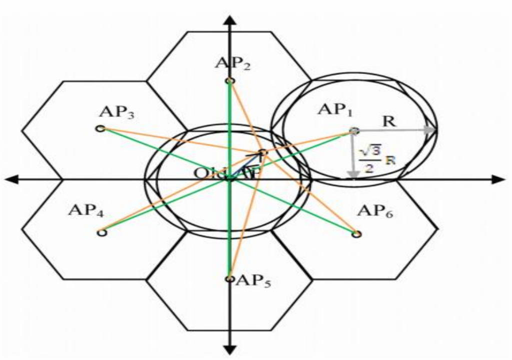

Fig.4: Distance to neighbouring APs.

The distance between these two circles is sufficient to complete the handoff procedure. This method bypasses the scanning process and hence reduces the handoff latency.

4.4 Selective Channel Scan

By reducing the number of channels to be scanned, handoff delay in scanning phase can be reduced. Using certain criteria the limited number of channels can be selected to scan, is known as selective channel scanning. Orthogonal principle can be used as the selection criteria [19]. The channels Ch1, Ch6 and Ch11 are non-overlapping channels in the IEEE 802.11 spectrum which are called orthogonal channels as shown in the fig-5 [19].

According the equation-4 if f (n) = 1; the particular channel will be scanned then only, means f (n) decides whether channel number n is to be scanned.

$$f(n) = \begin{cases} 1, & if\ n = 1,6,11 \\ 0, & otherwise \end{cases} \quad (4)$$

Selective channel scan scheme following advantages:

1. Saves scanning time, therefore reduces overall handoff delay.
2. It offers interference-free communications due to non- overlapping channels used.
3. Reduces packet loss due to collisions due to this reduce need of re-transmissions.
4. Almost all APs can be reached because most of the APs are operating on these orthogonal channels.
5. Dedicated processing power and memory space should not require.

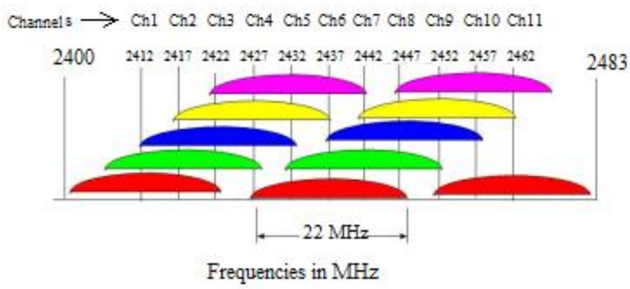

Figure 5: IEEE 802.11 channels

Disadvantage of this scheme is that only scanning of the orthogonal channels shall miss the AP which has the greater quality. Pre-scanning is introduced to in [27] to extend selective scanning. Available channels marked by the mask are scanned by STA before the handoff is triggered. Then it is saved in the dynamic cache structure. STA tries to associate with APs in the cache structure if signal strength falls below threshold. Handoff latency is minimized much more by using this technique.

4.5 Zone Based Interleaved Scanning Handoff scheme

Using zone based interleaved scanning we can achieve the handoff latency within the 50msec limit which is required for real time applications [28]. We can define the coverage area under an AP into three zones by using RSS1, RSS2 and RSSc as shown in the fig-6 [28]. RSS 1 and RSS2 are two received signal strength threshold levels and RSSc is the current received signal strength (RSS). RSS1 is greater than RSS2. In zone1 RSSc is greater than RSS1, in zone2 RSSc greater than RSS2 but less than RSS1 and in zone3 RSSc is less than RSS2. RSS2 is decided so that if RSS falls down below the RSS2, STA needs to find another AP to handoff and may not maintain communication with current AP. When the STA is in zone1, there is no probability of handoff. STA is potential candidate to handoff in zone3 and in zone2, handoff is imminent. At the circumference of inner circle signal strength is RSS1 and RSS2 at outer circle.

The data communication and scanning is interleaved in time in the interleaved scanning scheme. The information of the scanned APs is stored in *ScanAPList* by STA. STA makes a circular list of channel numbers (all the 802.11 channels except current channel), if it enters into zone2 and initializes a variable *NextChannel* to the channel number of the first channel in the list.

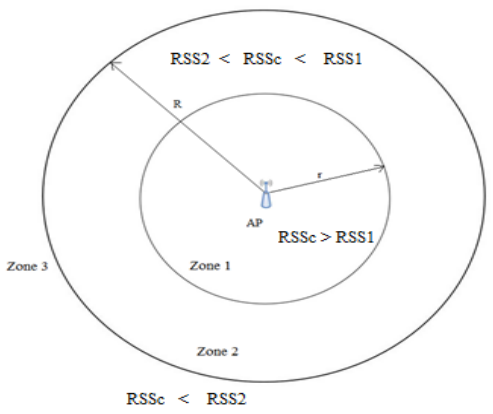

Fig.6: The division of the AP's range into Zones.

It empties *ScanAPList*, start a timer *ScanRepeatTimer* and set time out value T_O of this timer. After the completion of time period T_O, it stops communicate with current AP and scans *NextChannel* of circular list of channels. APs information obtained within probe response waiting time is stored in *ScanAPList*. After this STA changes its previous channel in which it was with its associated-AP and updates *NextChannel* with next channel number from circular list.STA starts normal communication by re-starting the *ScanRepeatTimer*. After the completion of the time interval of this timer whole process repeat again.During the scanning data communication is not possible, so T_O should be large. Interleaved scanning is advantageous because it eliminates the scanning phase in the handoff process and reduces the overall handoff delay. Disadvantage of this technique is that it reduces the data rates due to scanning and data communication is interleaved in time.

4.6 Fast Handoff by Avoiding Probe Wait (FHAP)

In this scheme [29], the STA will not wait for the probe responses from the neighboring APs. STA sends the probe request to all the neighboring APs and the response of these probe requests is sent to the old AP by all neighboring APs. After the probing process STA sends the probe response request to the old AP. The threshold level for handoff is slightly decreased to provide enough time for old AP to collect and send probe responses of all APs. The probe responses from all APs are then sent to the STA by old AP. If old AP has not received the probe response from any neighboring AP then that issue is also addressed to the STA. The STA maintains a priority list of channels to be scanned when the search phase fails. The APs for which receives the probe responses are pushed to bottom of priority list. Now, STA will scan all the channels according to their priority when STA fails to find a best AP in search phase. The exchange of all the signals between STA, neighboring APs and old AP is shown in fig-7 [29].

4.7 Handoff using Neighbour Graph

Neighbor graph technique is used to reduce the handoff latency in IEEE 802.11 wireless networks. The scheme proposed in [30] uses the neighbor graph and scan the channels based on position, speed and direction of the STA using neighbor graph technique. We can use the neighbor graph to get the information about neighbor APs. STA scans only those channels which are selected by neighbor graph. STA gets best scanned AP's information from neighbor graph server if there is requirement of handoff and handoff latency can be reduced. Physical topology of the wireless network and corresponding neighbor graph are shown in fig-8 and fig-9 [30]. Neighbor graph is a undirected graph G = {V, E} where V = {AP1, AP2, AP3, AP4, . . . ,APn} is the set of all APs (nodes), and E is the set of all edges defined by e = (APi, APj).

Advantages:

1. Organize and manage wireless networks
2. Eliminate the expensive scanning operation for fast handoff by making an intelligent guess about the list of APs on a particular channel.
3. Perform load balancing (traffic load sharing).

This scheme requires the additional changes at the AP level. By constructing the relationship among APs, based on these relationships reduces the number of scanning channels in [14] authors use the neighbor graphs and non-overlapping graphs. To predict the available the available the available channels Shin et al. proposed selective active scanning in [16]. To record possible channels in the next association a simple channel mask is used to further reduce handoff latency caching scheme is adopted. Neighbor graph is used to know the neighbor APs and free channels of these APs [31]. Neighbor APs information can be stored in neighbor graph cache and using this handoff latency can be reduced [32].

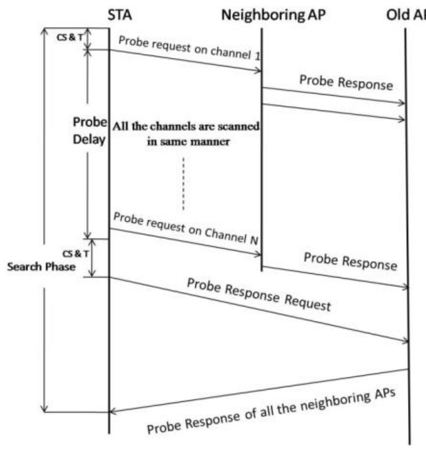

Fig.7: The Search Phase for FHAP

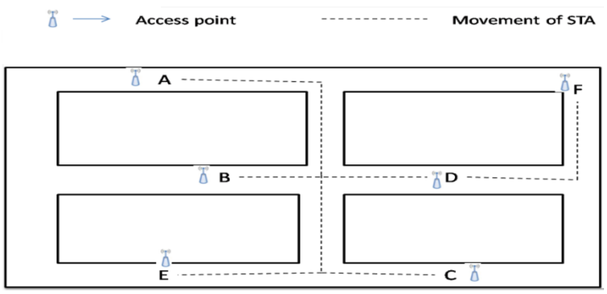

Fig.8: The Physical topology of the wireless network

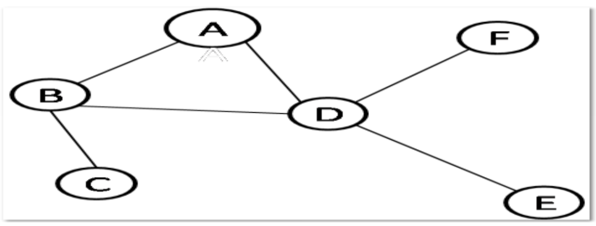

Fig-9: Corresponding Neighbour Graph of fig-8

4.8 CONCLUSION AND FUTURE DIRECTIONS

We have provided a comprehensive survey on handoff latency in IEEE 802.11 wireless LAN. In this paper, we have introduced various types of handoff latency reducing techniques, also included there advantages and disadvantages. Our aim is to prepare a platform for future research on reducing the handoff latency. This report provides the understanding of handoff in IEEE 802.11 WLAN and brief description of different handoff schemes that gives the reader good foundations on handoff in IEEE 802.11 WLAN. We can provide the serial number to APs in a particular area and make a data base. Using the trajectory information and this prepared database, we can reduce the handoff latency much more. Handoff latency can be reduced using the location detection in IEEE 802.11 WLAN in near future. We can detect the location of the STA using the location detection techniques in 802.11 WLAN and using this location information, we will reduce the handoff latency in near future. We can also combine the movement pattern with location information and will reduce the handoff latency in IEEE 802.11 WLAN in future. We will also reserve some fixed or adaptively changing number of channels for handoff only. By using this technique we will reduce the handoff latency and packet loss also in future.

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