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A Study on Access Point Selection Algorithms in Wireless Mesh Networks

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ABSTRACT

In IEEE 802.11 based wireless mesh network (WMN), a mesh client often finds multiple access points (AP) to associate with. How to select the best AP is the open research problem. The traditional AP selection method defined by IEEE 802.11 standard is based on received signal strength. This method is proven inefficient as it does not consider many important factors such as channel conditions, AP load, etc. Many alternate solutions have been proposed so far in the literature, but they are all focused on wireless local area network (WLAN) environment. As there are significant differences between WLAN and WMN, all these proposed association mechanisms must be redesigned to fit into WMN environment. This paper studies the AP selection problem in the context of WMN. We critically analyze the existing work and identify technical challenges involved in AP selection problem. This paper also provides directions to design the metrics of AP selection method in WMN.

Keywords - **Access Link Metric, AP Load Balancing, AP Selection, Cross-Layer Association, Dynamic Association, IEEE 802.11 WMN.**

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1. INTRODUCTION

The IEEE 802.11 Wireless Local Area Networks (WLANs) [1] have become very popular because they are inexpensive and provide flexible access to the Internet. Since no cabling is required to connect a wireless client host with an AP, the WLAN has advantages over wired LAN such as low installation and management costs, easy host relocations and flexible service areas. However, the WLAN has a drawback that one AP can cover only the limited area within approximately 100 meters due to the weak transmission signal. To extend the WLAN service area, numerous APs should be installed. Since these APs are connected through wired cables, the cabling cost may impair the cost and flexible advantages of WLAN. Moreover, the cabling may not be possible in some outdoor places such as historical buildings. As a solution to this problem, the APs can be interconnected with each other using wireless links in addition to conventional wireless communications between APs and hosts. The APs that are not adjacent can be communicated through multi-hop wireless links, where intermediate APs act as repeaters to replay packets. This multi-hop WLAN is called the wireless mesh network (WMN) [2], [3], [4]. The figures 1 and 2 show the architectures of WLAN and WMN respectively.

In contrast to single-hop infrastructure-based WLAN, a WMN is a multi-hop infrastructure-based wireless network. There are two types of nodes in WMN: mesh routers and mesh clients. The mesh clients can be different kinds of user devices with wireless network interface cards (NIC), such as PCs, laptops, PDAs, and mobile phones. They have limited resources and capabilities in terms of energy supply, processing ability, radio coverage range, etc. The mesh routers are typically stationary or with low mobility. They form the infrastructure of the WMNs. The mesh routers are different from traditional wireless routers in that they are often equipped with multiple wireless interfaces. This increases their transmission compatibilities and capabilities. The mesh routers are connected with each other in a way to form an infrastructure through which their clients can access to other larger networks such as the Internet. One of the advantages the mesh routers have is that they require less transmission power, since they can use multi-hop connections. A few mesh routers are provided with gateway functionality also, so that WMN can be easily integrated with other types of networks such as the Internet. In addition, the mesh router providing network access to clients is known as the mesh access point (MAP). In order to access the Internet via WMN, the user has to associate with one of the MAPs. The difference between the mesh routers and the mesh clients is that mesh clients do not have the gateway or bridge functions. As specified in [2], a WMN has three types of architecture: infrastructure WMN, client WMN, and hybrid WMN. In the client and hybrid architectures, the routing functionality is implemented in both the mesh clients and the mesh routers whereas in infrastructure WMN architecture, just mesh routers are capable of routing. This paper studies the AP selection problem in infrastructure WMN architecture only.

Researchers have started to revisit the protocol design

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of existing wireless networks, especially of IEEE 802.11 networks, ad-hoc networks, and wireless sensor networks, from the perspective of WMNs. Particularly, the AP selection problem in WLAN is attracting more researchers as it has the high impact on the network capacity and user throughput.

As of today, the majority of WLANs are based on IEEE 802.11 standard. In an infrastructure-based WLAN, a wireless client station (STA) can find multiple APs in its vicinity. As per IEEE 802.11 standard, each STA has to associate with one and only one AP. The proper selection of AP increases the user throughput and system performance. As per IEEE 802.11 standard, the STA selects the nearest or strongest AP, i.e. the AP with the highest Received Signal Strength Indicator (RSSI). This greedy approach causes the concentration of STAs to specific APs; many STAs may associate with just a few APs; while only a few STAs may associate with the remaining APs. This leads to an imbalanced traffic load on APs in the WLAN; the STA throughput associating with a concentrated AP will be degraded. As a consequence, the fairness in STA throughput is degraded and the network resources are not utilized effectively. Moreover, this method of AP selection does not consider many important parameters such as channel conditions, AP load and contending stations, etc. As there are significant differences between WLAN and WMN, this method is unsuitable in WMN. Therefore, it requires to redesign the method to be applicable in WMN.

This paper studies the AP selection problem in the context of WMNs along with design issues and technical challenges. The relevant research work is critically analyzed, and also a few research directions are provided at the end.

The remainder of the paper is organized as follows: the section 2 presents the classical association and its limitations. AP selection parameters are discussed in section 3. The estimation of access links metric and AP load metrics are presented in sections 4 and 5 respectively. Cross-layer association in section 6 and dynamic associations in section 7 are presented. The guidelines for AP selection are provided in section 8 and section 9 concludes the paper.

2. ASSOCIATION PROCEDURE

This section presents the classical procedure of association in WLAN and its limitations.

2.1 Association in WLAN

As users want to access wireless networks in different places such as homes, offices and hot-spot areas, it is required to install many 802.11 WLAN APs to cover whole areas where users reside. When APs are deployed in centralized control, the administrators usually ensure that the service area of each AP is overlapped because of seamless coverage and capacity enhancement considerations. Under decentralized control, overlapped service areas may also occur due to unplanned APs. In the overlapped service areas, an STA usually finds many APs to associate with. It is the critical issue for users to select one AP that provides users with better performance than other APs because the achievable throughput of the users heavily depends on it. As shown in figure 3, three STAs (STA1, STA2 and STA3) are associated with AP1 and one STA (STA4) is associated with AP2. The STA5 is in the overlapped service area of AP1 and AP2 so it has a choice of selecting AP1 or AP2. Which one to select is the critical choice for its performance?

As per IEEE 802.11 standard, an STA selects AP using one of the two ways: active scanning and passive scanning. In active scanning, an STA sends a probe request frame, and the AP replies with a probe response frame. This frame exchange allows the STA to obtain basic information about the AP cell such as signal strength, available transmission modes, encryption, etc. The STA repeats this frame exchange for all APs in its vicinity. Alternatively, in passive scanning, an STA listens to beacon frames, which are periodically transmitted by APs. The STA measures the RSSI of beacon frames or probe response frames transmitted by APs. The STA then selects the AP from which it received highest RSSI frame. Afterwards, the STA stays associated with that AP until the RSSI falls under a predefined threshold.

The RSSI is the only metric used in the association process defined by IEEE 802.11 standard. It is proven that RSSI-based association process is not efficient for several reasons [5], [6], [7]:

-As the AP load is not considered in the association's decision, the network load would be unevenly distributed among APs in WLAN.

-High RSSI values cannot univocally indicate the high throughput because RSSI not only depends on the distance from the APs, but also on the transmission powers of the APs.

-The traffic between the STAs and the APs is usually bidirectional, but RSSI is an indicator for the downlink but not for the uplink channel conditions.

-The user throughput not only depends upon highest RSSI values, but also on MAC layer contention, which is not considered in the association process.

-Multi-rate capability of STAs also helps to select best AP, but it is not considered.

-RSSI is measured during packet reception only so it can't reflect the real conditions of the channel all the time.

2.2 Association in WMN

The unique characteristics of WMNs pose new requirements on the association scheme. Unlike WLAN, the APs in WMN are connected by wireless links, which form the backbone. The clients are associated with the MAPs and access the Internet through multi-hop wireless backbone connected to the gateway. Due to the relatively low bandwidth and high latency of the wireless links, the multi-hop paths become the bottlenecks of the WMN. Considering the requirements of many real-time applications, existing methods proposed in the context of

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WLAN are unsuitable for the WMN environment. Therefore, the association scheme must be redesigned for WMNs. Since the user traffic passes through wireless multi-hop backbone, reducing the transmission latency becomes the critical problem in the MAP selection procedure in WMN [8].

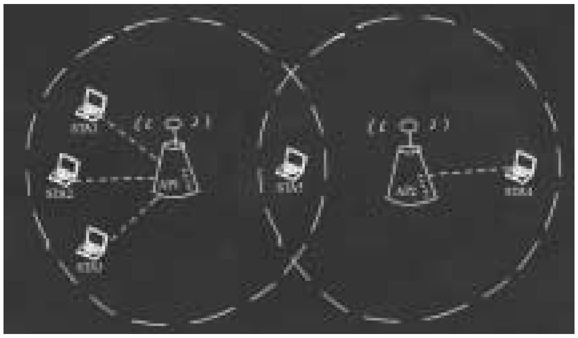

Figure 3. AP association in WLAN

Among the available MAPs in an STA's vicinity, some of them provide good access links but lead to poor performance in the wireless backbone. Others may have a high-quality path to the gateway but provide the lossy or slow access links on the first hop. To achieve good end-to-end performance, the association mechanism needs to be redesigned to take both the access link quality and the backbone condition into account [9].

In WLANs, especially in WMNs, the wireless links fluctuate randomly and the network conditions such as traffic requirements and node mobility may vary with time. To address the time-varying network status, the dynamic re-association should be addressed.

Usually the MAP is provided with multiple radio interfaces, and each radio can be configured independently. During the MAP selection design, one must ensure that co-channel interference is not present in MAP radios.

3. AP SELECTION PARAMETERS

What are the important parameters to consider while designing AP selection procedure in WMNs? This section presents all such parameters to make efficient association scheme.

3.1 Link Quality

The first thing in association scheme design in WMN is to estimate accurately the access link quality between MAP and STA. As in WLANs, the wireless link quality is one important parameter of MAP selection method. However, how to estimate accurately the link quality is the critical issue. Given the link quality between STA and all available MAPs, then STA will select MAP with highest link quality for reliable connection to the network.

3.2 Load Balancing

Improper load distribution is the main drawback of classical association mechanism, which must be avoided in WMN. Prior to association, an STA must know which MAP is heavily loaded and which MAP is light loaded. Estimating accurately the MAP load and providing this information to STA is a challenge.

3.3 Cross-Layer Association

The WLAN has wired backbone infrastructure whereas WMN has the multi-hop wireless backbone. There exists only one wireless link between STA and AP in WLAN but multiple wireless links are present between STA and gateway via MAP in WMN. Assuming high speed wired backbone in WLAN, the IEEE 802.11 standard designed the association scheme for WLAN by taking into account only the access link quality between AP and STA and discarding wired backbone conditions. However, the association scheme for WMN must consider the wireless backbone link quality in addition to access link quality. Mesh routers are responsible for data transfer in the backbone, but STAs are unaware of backbone routing. So this routing information must be provided to STA during MAP selection so that it can choose the MAP for achieving better end-to-end performance. If only access links between STAs and MAPs are considered without backbone conditions, then high performance is not guaranteed. What is the better routing metric and how to share the routing information with STA without many overheads involved are the critical factors for optimal association in WMN? Mesh routing is network layer function and association is MAC layer management function, which is aided by PHY layer parameters such as RSSI, SINR. For an effective association scheme, the cross-layer interactions of these three layers must be provided properly.

3.4 Dynamic Association

Designing the association scheme only for the new users is not an adequate solution. Association scheme would be efficient when it is applicable not only to the new users but also for the existing users. As the characteristics of wireless access links and multi-hop, wireless backbone fluctuates randomly, the association mechanism must consider these dynamic network conditions. The AP selected now may not be optimum in very near future. Therefore, dynamic re-association should be designed efficiently to reflect randomly varying network conditions. How to capture and use the dynamic network conditions in the association process is an important thing.

3.5 Association Overhead

The efficiency of association mechanism is measured with its overhead involved. The time for association plays a critical role in the system performance. If the association takes more time, then more data packets will be dropped during re-association. This time overhead can be controlled by shortening the duration of association and reducing the number of re-associations. How to reduce association time and number of re-associations is a big challenge for researchers.

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3.6 Compatibility

Today most of the wireless networks deployed are IEEE 802.11 based networks. We must ensure that the association mechanism that we are designing should be compatible with all 802.11 products. Otherwise, if it is limited to certain type of networks or not compatible with existing networks, then it is not considered as of much significance.

All these parameters are essential but not limited in an MAP selection scheme. Other parameters like the wireless station's mobility and hidden terminals can also be taken into account. Based on STA's movement direction, one best MAP can be selected. Similarly, the STA can select the best MAP cell where the hidden terminal problem is minimized.

4. ACCESS LINK METRIC ESTIMATION

The first important thing in association process development in WMN is estimating access link quality between STA and MAP. This section presents how to estimate it accurately.

There are four primary metrics for estimating the quality of a wireless link: RSSI (Received Signal Strength Indication), SINR (Signal-to-Interference-plus-Noise Ratio), PDR (Packet-Delivery Ratio), and BER (Bit-Error Rate). Determining which one is the appropriate metric to use, and under what conditions? It is important in this regard.

The RSSI is a dimensionless quantity and measured only during the reception of a packet. The RSSI cannot capture the amount of interference on links so it is inappropriate for estimating accurate link quality. The RSSI based AP selection is defined by IEEE 802.11 standard, and it is proven inefficient.

The SINR is the comparison between the received signal from the intended transmitter, and the total interference experienced at the receiver. Commercial wireless cards do not provide SINR values; only the RSSI values are provided. The computation of SINR from RSSI inherits all deficiencies of RSSI. Though SINR is an accurate estimator of link quality, it is extremely difficult to compute it accurately in practice. The SINR based AP selection is proposed in [10]. Authors in [11] show that SINR alone is unsuitable for selecting AP in WLAN.

The PDR is a good metric for characterizing link quality, but it is highly dependent on the packet size and the transmission rate. The link quality estimation based on the PDR is done in [15], [16]. The PDR based AP selection is presented in [12]. In [13], the author showed that RSSI cannot be used to derive PDR as there is no correlation between them. The RSSI is computed only during the reception of PLCP preamble and header, which are transmitted at the lowest rate. If the rest of the packet is transmitted at a much higher rate, one would not expect to see any correlation between the PDR and the signal power with which the preamble and header are received.

The metric BER represents the ratio of the number of erroneous bits to the total number of received bits. The BER is not reported (by default) by commodity wireless cards. Repeated computations of this metric are required over extended periods of time. Moreover, one needs to ensure that outliers do not result in biased BER estimation. The BER based link quality estimation is presented in [17]. The BER based AP selection is presented in [14], but certain implementation conventions assumed are not compatible with all IEEE802.11 products.

Each of these metrics has its own limitations. So the researchers have to combine these different primary metrics in an intelligent way to derive secondary metrics for evaluating the link quality. The RSSI and SINR are PHY measurements whereas PDR and BER are measured at higher layers in the protocol stack. Association is the MAC layer operation which cannot be done purely based on PHY measurements. Therefore, we strongly recommend estimating the access link quality accurately using the MAC/PHY cross-layer approach. In [29], the author designed a metric "expected throughput" that combines information from the physical and MAC layer to assist clients in their association decisions. However, this metric heavily depends on user rate adoption scheme and saturated traffic; furthermore, the author modified firmware and micro code of wireless adaptor so it is not compatible with all products. Whatever the metric may be; we recommend estimating access link quality in both directions between MAP and STA.

5. AP LOAD ESTIMATION

Designing AP selection algorithm based on only link quality but without AP load is not an optimum solution. This may result in improper load distribution among APs. Therefore, the AP selection algorithms should consider AP load in addition to access link quality. As there is no specific definition, the AP load is measured in different ways by researchers as follows:

5.1 AP Load as Number of Stations

The number of STAs that are currently associated with AP is defined as AP load in [18], [19]. This definition is meaningful if each STA has same traffic pattern, and hence same bandwidth requirement. However, in reality, STAs bandwidth is different. There is no correlation between the works done by two APs in terms of the number of STAs associated with each of them, because some STAs might be actively transmitting, while others remain silent. Even among the active STAs, they might differ in bandwidth requirements. Some researchers suggested to modify the beacon and probe response frames to include a new field to specify the number of STAs that are currently associated with AP. As a result, in IEEE 802.11e, QBSS (Quality of Service Basic Service Set) load element is introduced, which contains information on the current STAs population and traffic levels in the AP. However, the QBSS load element is not always present in Beacon or Probe Response frames. The

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information element is present if both MIB (Management Information Base) attributes dot11QosOptionImplemented and dot11QBSSLoadImplemented for APs are set to true.

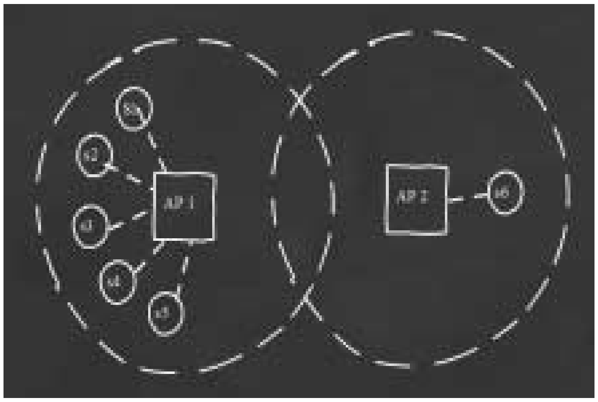

Figure 4. AP Load Distribution

5.2 AP Load as Number of Frames

The AP load is defined as the number of frames processed (transmitted and received) successfully by AP in a unit time period [20], [21]. As shown in figure 4, AP1 and AP2 are two neighbour APs operating at orthogonal channels, and AP1 has many STAs than AP2. If all STAs of AP1 are contending for the channel, then many collisions occur at AP1, and the throughput decreases. However, as there is only one STA, s6, associated with AP2, without any contention s6 can transmit successfully many frames. So as per the definition, AP2 has high load than AP1 as it processes more frames than AP1. Therefore, a new STA will associate with AP1, which is already overloaded. Another weakness of this definition is the multi-rate support of STAs. If a load of say, x frames per second might indicate congestion if data rate is 1Mbps, but the same load might imply low channel utilization if the data rate is 11Mbps in case of IEEE 802.11b WLAN.

5.3 AP Load as Channel Busy Time

The AP load is defined as the percentage of time that the channel is busy during some measured interval [22], [23]. From figure 4, the busy time for AP2 is greater because a lot of time is wasted in the Basic Service Set (BSS) of AP1 by back off delays and large contention window sizes. As a result, the load estimation algorithm will incorrectly indicate that AP2 has the higher load than AP1, and new user will select AP1, which is already congested. Channel utilization is not an appropriate AP selection metric as it does not capture transmission capabilities of respective APs: for example, an 80% utilized IEEE 802. 11g AP can offer even more bandwidth than a 40% utilized IEEE 802.11b AP.

5.4 AP Load as Available Bandwidth

The AP load is defined as maximum achievable throughput when associated with the AP [25], [26]. However, throughput or bandwidth usage is affected by time-varying channel conditions, which is intrinsic to IEEE 802.11 networks, as well as traffic patterns.

5.5 AP Load as Delay Time

The queuing and channel-contention delay, which reflects AP's load level, can be estimated by the delay between scheduled and actual transmission time of periodic Beacon frames [21], [24]. These low-level estimations assume certain implementation conventions and may not apply universally to all products. Clearly, using beacon delay for bandwidth estimation assumes that the beacon frames experience the same contention as other frames. In a WLAN, where the beacon frames are typically sent prior to data frames, such an assumption is typically not valid.

For the wireless STAs with dynamic bandwidth demands, the AP load is better expressed in terms of effective or observed throughput. Moreover, an STA can communicate with AP at different data rates. An STA using lowest data rate for a long time can significantly degrade the performance of other STAs associated with AP [27]. Any load metric without considering this factor will definitely fail.

5.6 Load Balancing Approaches

As there is no specific method for estimating AP load and use it for network load balancing, the researchers have followed different approaches:

5.6.1 Online vs Offline

Based on the type of application that uses load estimation, there are two approaches to measure AP load: offline and online approaches. The offline approach is used by applications that do not need a real time load estimate. For example, a network administrator might want to analyse the network usage patterns over one month, to determine hot-spots; the admin can then deploy additional APs in the area to overcome persistent congestion. The online approach is used for real-time applications such as association control.

5.6.2 Centralized vs Decentralized

In centralized approach, a specialized server will decide which STA associates with which AP [7], [28]. In decentralized approach, each STA will select its own AP. As the IEEE 802.11 standard does not define any specific servers for association, the researchers have to develop the decentralized AP selection algorithm. We strongly recommend that due to compatibility reasons, in WMN, the MAP load estimation should be decentralized.

5.6.3 Active vs Passive

In active approach, an STA will learn of AP's load status somehow and, accordingly, select an AP that maximizes its potential benefits [21]. The acquisition of AP's load condition may be realized in several ways. An STA may measure channel utilization or the delay between the scheduled and actual transmission time of periodic beacon frames. Such a measurement requires no assistance from any network-side entity. Alternatively, in

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passive approach, an AP may assist the measurement by broadcasting its current STA population and/or traffic level in probe response or beacon frames [19], [18], preferably with a QBSS Load element if the AP supports IEEE 802. 11e. In WMN, the MAP or mesh router has complex functionality compared to the STA. In order to reduce the overhead on STA, the network has to provide all information relevant to load calculation. Therefore, we recommend that in WMN, the MAP load estimation should be passive.

5.6.4 Static vs Dynamic

In static cases, an STA performs AP selection prior to its association with the target AP and does not reassociate to other APs as long as the association holds [18], [28]. A drawback of static AP selection is the inflexibility to adapt to networking dynamics. In contrast, with dynamic AP selection, an STA may determine to reassociate with another AP even if the current association still holds [23]. Dynamic AP selection is better suited to highly dynamic networking environment. However, it may also lead to unstable STA-AP associations or so-called ping-pong effects, the phenomenon of repeated association changes from one AP to another. To avoid ping-pong effects, there should be a way to distribute re-associations in the temporal domain [30]. As the WMN has dynamic network conditions, the MAP load estimation should be dynamic.

5.6.5 Cell Breathing Approach

By adjusting the transmission power, the AP can control its transmission range. Based on this idea, the congested AP can reduce the transmission power of beacon frames so that some STAs can associate with another AP [40]. In WMN, if the transmission power of MAP is not controlled properly, then the MAP may lose its connection with its neighbour MAP, which is a dangerous connectivity problem. Also in some cases, some STAs may not associate with any MAP in WMN if each MAP reduced its transmission range as the part of load balancing. In [31], the power-efficient AP selection is presented. In WMN, the MAPs or mesh routers are usually stable and provided with power supply. Hence, the power-conservation is needed for STAs but not necessary for the MAPs or the mesh routers. So the STAs overhead must be reduced to the possible extent while designing the AP selection schemes.

5.6.6 Association Management

A congested AP may issue explicit disassociation frame to the selected STAs so that they can associate with another AP [20]. However, here the critical issue is to determine which STA has to disassociate from the current AP. The STA selection should balance the network load and improve the system performance which is a challenge for the researchers.

5.6.7 Channel Switching

In WMN, usually an MAP has multiple radio interfaces, which are usually coordinated to operate on orthogonal channels to minimize co-channel interference. If the load on a particular channel exceeds the threshold value, then the MAP can alert some of its stations to switch from the overloaded channel to the underload channel to balance the load. This method improves the reassociation time compared to one AP with one radio interface. i.e. switching from one AP to another AP takes more time than switching from one interface to another interface of same AP. However, one must ensure that the method should not be extra communication overhead to the backbone network and also backwards compatible with legacy 802.11 devices. Moreover, modifications required for implementing this method should be done on MAP but not on STA to reduce the complexity of STA. Such a method is presented in [28], [42]. Frequent channel switching is expensive and not suggested due to channel switching delay.

The approaches specified here are a few but not limited to estimating the AP load. The researchers have to select one of the approaches or design their own approach to accurately estimate the AP load. However, the approach should not involve much overhead and must be compatible with all IEEE 802.11 products.

We argue that for WMN, the MAP load estimation approach should be online, decentralized, passive and dynamic. Since the WMN is like ad-hoc network with infrastructure, the AP selection must be done by the STAs only. In order to reduce the overhead on mesh client devices, the mesh network should provide all required information to the client for estimating the MAP load. As the wireless link quality and the user traffic randomly changes in the network, the association must be dynamic to reflect the network conditions up to date. Furthermore, there is a trade-off between system throughput and user fairness, which are actually alternate goals. To improve the system performance, both are essential goals. However, most of the load balancing algorithms focused on only one goal; either to improve system performance or user fairness. It is a big challenge for researchers to design load balancing algorithm to achieve both the goals. The trade-off relationship of system throughput and fairness with quality of service support is addressed in [41].

6. CROSS-LAYER ASSOCIATION

In WMN, most of the traffic flows between STA and the gateway. So considering access link quality and MAP load is not sufficient for association in WMN. In addition, wireless multi-hop backbone conditions must be considered to achieve end-to-end performance. Among the available MAPs in an STA's vicinity, some of them provide the good access links but lead to poor performance in the wireless backbone. Others may have a high-quality path to the gateway but provide the lossy or slow access links on the first hop. To achieve good end-to-end performance in WMN, the association mechanism needs to be redesigned to take both the access link quality and the wireless backbone conditions into account. In

infrastructure-based WMN, an STA has no routing functionality; it simply sends/receive packets to/from MAP. The mesh routers have to provide routing information to the STAs for selecting best MAP. What is the best routing metric in WMN and how to share routing information with STA is an important issue regarding MAP selection in WMN? The discussion of WMN routing metrics is beyond the scope of the paper. A survey on WMN routing metrics can be found in [36], [38], [39]. In WMN, the MAP/mesh router typically has multiple radios. A survey on routing metrics for multi-radio mesh networks is presented in [37]. The Cross-Layer Association schemes are presented in [32], [33].
Currently, the 802.11x suite of standards does not provide much information to higher layers. As per the standards, the RSSI is the only metric used to measure the channel quality. If the channel conditions information from PHY and MAC layers are provided to routing layer, then it will result into an optimal routing metric.

7. Dynamic Associations

Most of the AP selection schemes are designed for the new user association and do not account for re-associations of existing users [32], [33]. As the network conditions vary dynamically, particularly in WMN, the association procedure must be dynamic in nature. The MAP selected now may not be the best one in near future. Therefore, dynamic association must be designed efficiently to reflect network conditions from time to time. However, the frequent re-associations may result in ping-pong effects, which must be avoided. This can be solved in two ways: by reducing association time, and reducing the number of re-associations. As pointed out in [34], the association mechanism converges to a Nash equilibrium after a finite number of steps. This means the network will converge to a stable state within the finite time. The rate at which the network converges is very important. In [35], the author determined the re-association threshold of 5% and STA scan period of 4 seconds through the simulations for making the network to converge to a stable state. Therefore, deciding re-association threshold value is the critical challenge for researchers.
There are two main reasons for highly uneven load distribution across a network: uneven client distribution and uneven user demands. These two factors are dynamic and so the association scheme would be efficient if it considers these factors.

8. Guidelines to Design MAP Selection

We recommend the following guidelines to follow while designing the MAP selection scheme in WMNs:
-The access link quality between STA and MAP should be determined accurately. Using PHY/MAC cross-layer approach, the four primary metrics: RSSI, SINR, PDR and BER must be combined intelligently to derive secondary metrics of link quality estimation. The link quality must be estimated in both directions (uplink and downlink) to reflect real network conditions.
-The MAP load must be determined accurately and in a realistic manner. The load metric must consider the effect of the performance anomalies of IEEE 802.11 networks [27] without which the load estimate fails. The MAP load estimation should not involve much overhead on STA, and it must be universally compatible with all products.
-In WMN, the MAP usually has multiple radios; each radio can be configured independently. While estimating the MAP load, one must ensure that co-channel interference is not present in MAP radios.
-In WMN, the STA needs to be aware of the status of the network path between the MAPs of interest and the mesh gateway node. Then only it can select the best MAP to achieve better end-to-end performance.
-The mesh network itself should aid in the association process by providing the client with an accurate image of the network performance. The cross-layer interactions implemented should not be complex and must be compatible with existing networks.
-The association mechanism must be adaptable to dynamic environment of WMN. The researcher must ensure that the network can converge to the stable state at a faster rate.
-As the demand of multimedia services (e.g., voice, video and web browsing) is increasing in WMN, the MAP selection method should consider the service type and access priority. To be efficient, the MAP selection scheme can also consider the STA's mobility and the hidden terminals.
-In WMN, most of the traffic flows between STA and gateway. So we suggest to consider gateway conditions into account while selecting the MAP.
-Finally, we recommend that the different metrics of interest should be gathered as efficiently as possible, while introducing the least possible amount of overheads. The measurement process should not significantly impact the network resources, nor result in performance degradation for the end user.

9. Conclusion

The association control is an active research area to improve WMN performance significantly. This paper presents MAP selection parameters and technical challenges in WMN. Furthermore, it discusses different metrics used in MAP selection by analyzing existing relevant literature of AP selection in WLAN. The summary of papers under discussion is presented in figure 5. Moreover, we propose the guidelines to be followed to design a better AP selection metric in WMNs.

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Figure 1. WLAN Architecture

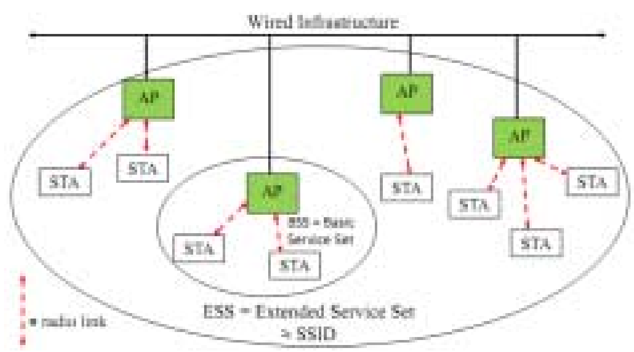
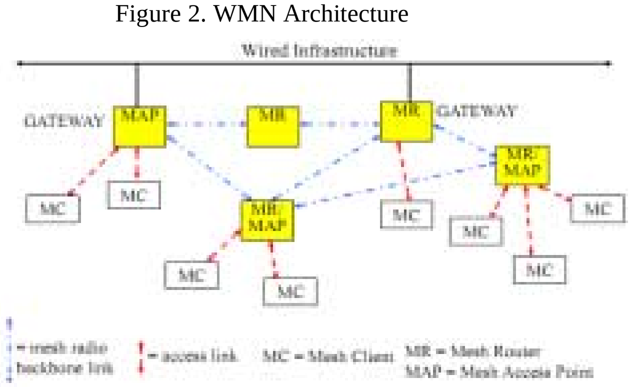


Figure 2. WMN Architecture



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Author	Access Link Metric	AP Load Metric	AP Load Estimation Approach	AP Selection Metric	Compatibility
Liyange [10]	SINR	No.of STAs	Passive	APSP (RSSI + No. of STAs)	yes
Zhao [12]	PDR	No.of STAs	Passive	Throughput (PDR + No.of STAs)	yes
Sundaresan [29]	RSSI	Delay	Passive	Expected Throughput (RSSI+Transmission Delay + AP Capacity)	yes
Papanikos [18]	RSSI	No.of STAs	Decentralized, Passive and Static	Mean RSSI + No. of STAs	No
Fukuda [19]	PER derived from RSSI	No.of STAs	Decentralized, dynamic and Passive	Achievable Throughput (PER + No. of STAs)	No
Velayos [20]	RSSI	No. of Frames	Passive, Dynamic and Decentralized	AP Throughput	yes
Vasudevan [21]	RSSI	Delay	Decentralized, Dynamic, Active	Potential Bandwidth	yes
Wu [22]	RSSI	Channel Busy Time	Dynamic, Centralized, Passive	Available Bandwidth	yes
Lee [23]	RSSI	Channel Busy Time	Dynamic, Decentralized, passive	RSSI + Channel Busy Time	yes
Pradeepa [24]	RSSI	No. of STAs	Decentralized, Passive	Estimated Delay	yes
Lee [25]	RSSI	Channel Busy Time	Decentralized, Passive, Dynamic	Estimated Available Bandwidth	yes
Lu [26]	RSSI	Number of Users	Passive, Decentralized, dynamic	Effective Bandwidth	yes
Bejerano[7]	RSSI	Effective Bandwidth	Centralized, Passive,Dynamic	Effective Bandwidth	no
Balachandran [28]	RSSI	Effective Bandwidth	Centralized, Passive, Static	Effective Bandwidth	no
Tsai [30]	RSSI	Effective Bandwidth	Centralized, Dynamic	Effective Bandwidth	yes
Luo [32]	CAETT, LAETT based on SINR	Delay, Channel Busy Time	Decentralized, Passive, Static	Effective Bandwidth	no
Athanasiou [33]	SINR	Channel Busy Time	Decentralized, Active Static	Air Time Metric	yes
Wang [35]	PER	Channel Busy Time	Decentralized, Passive, Dynamic	Attainable Bandwidth	yes
Chen [42]	RSSI	Channel Busy Time	Decentralized, Passive, Dynamic	RSSI + Channel Load	yes

Figure 5. AP Selection Metrics