Current Studies on AP Selection and Load Balancing in IEEE 802.11WLAN

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***Abstract*— IEEE802.11 WLAN (Wireless LAN) has been widely used in enterprise and public space. The important aspect of such network is the efficient use of radio resources and optimal load balancing among APs (Access Point). In IEEE802.11, a Station (STA) or a node has the right to select an AP with which it will associate. In an IEEE 802.11 WLAN, a station (STA) can be within the range of several access points (APs), and can associate with each one of these at a certain maximum physical bit rate, de-pending on various radios channel conditions. If STAs have no strategy for association, they may associate with one of the APs. As a result, throughput in an AP will decline due to congestion even though radio resource in another AP might be available. Therefore some intelligent strategy is needed for optimal association of STAs and APs. In this paper we present a few research papers regarding to the solution of the problem of access point selection strategy.**

Keywords- STA, VoIP, AP, DCF,FCF

I. INTRODUCTION

In this era of digitization, computer network has influenced almost every aspects of the human society. The increasing popularity of wireless network is because of only the mobility factors and providing networks to those areas where other form of network is not possible. IEEE802.11 WLAN is primarily used for Inter-net access, but real-time applications like VoIP and video conference have become one of the most important and sophisticated application in WLAN which needs special attention to few attributes like delay sensitive or bandwidth requirement. It is found that majority of the Internet usage is subjected to web browsing and most of the current research is related to the issues like efficient utilization of radio resources, AP deployment strategy and optimal association of STAs and APs. In these large WLAN networks, RRM (Radio Resource Management) is important for the efficient use of wireless bandwidth. When workload in an AP exceeds then a certain threshold the overall performance of the WLAN gets affected. This situation is called overloading or congestion. The usual approach increase overall system throughput is to deploy additional APs covering the same region, in a way to distribute the load these APs. As in 802.11WLAN a STA may select an AP independently of its interest particular AP may get overloaded at any point of time leaving other AP idle. In this paper we discuss the approaches in the field of AP selection and load balancing in IEEE 802.11 infrastructure WLAN.

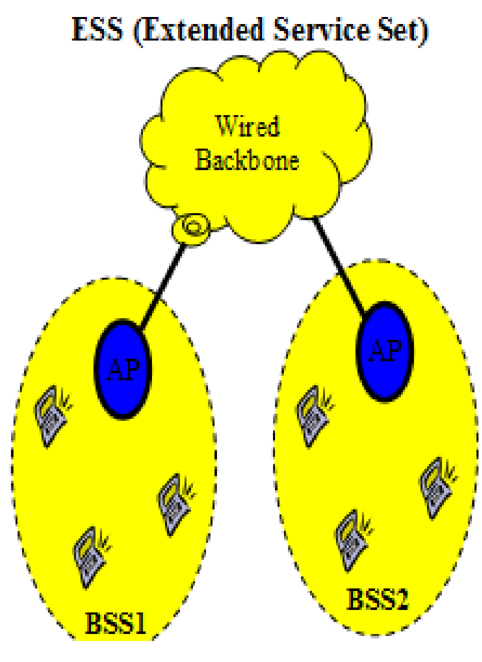

Figure 1. Architecture of IEEE 802.11 WLAN

The IEEE802.11 [2] WLAN is based on a cellular architecture as shown in figure 1 where the whole system is spitted in to some cells called BSS(Basic Service Set) which in turn is controlled by a base station also called Access point, shortly AP. Even though the IEEE 802.11 WLAN may be formed with a single AP but most of the installations comprises of multiple APs and connect them with some sort of backbones and act as a distributed system. The whole of the interconnected wireless network including the BSS, their respective APs and the distributed system is called to be ESS (Extended Service Set)

II. IEEE 802.11 MAC LAYER

The 802.11 MAC [2] sub layer protocol is quite different from that of Ethernet due to the inherent complexity of the wireless environment compared to that of a wired network. The basic MACA and MACAW protocol suffers from two major problems, the ***Hidden terminal*** and ***exposed terminal*** problem. To deal with this problem, 802.11 support two modes of operation, the basic Distributed Coordination Function (DCF) and the optional Point Coordination Function (PCF). Asynchronous transmission is provided by DCF which operate in contention-based period, and synchronous transmission is provided by PCF that basically implements a polling-based access which operates in contention free period. A group of STAs coordinated by DCF or PCF is formally called a Basic Service Set (BSS). The area covered by BSS is the Basic Service Area (BSA), like a cell in a cellular mobile network. Two modes exist: ad-hoc mode and infrastructure mode The first mode forms an Independent BSS (IBSS) where the STAs can directly communicate with each other by using only the DCF, without any connectivity to any wired backbone. In the second mode, the STAs communicate with the wired backbone through the bridge of Access Point (AP), which can use both DCF and PCF.

A. DCF (Distributed Coordination Function)

When DCF is employed, 802.11 uses a protocol called CSMA/CA [2] (CSMA with Collision Avoidance). Here both physical carrier sensing and virtual carrier sensing are used. Two methods of operation are supported by CSMA/CA. In physical carrier sensing, when a station wants to transmit, it senses the channel. If the carrier is idle, it just starts transmitting. It does not sense the channel while transmitting but transmits its entire frame, which may well be destroyed at the receiver due to interference there. If the carrier is busy, the sender defers until it goes idle and then starts transmitting. If a collision occurs, the colliding stations wait a random time, using the binary exponential backoff algorithm, and then try again later.

The other mode of CSMA/CA operation is based on MACAW and uses virtual channel sensing, as illustrated in Figure 2. In this example, A wants to send to B. C is a station within range of A (and possibly within range of B, but that does not matter). D is a station within range of B but not within range of A. The protocol starts when A decides it wants to send data to B. It begins by sending an RTS frame to B to request permission to send it a frame. When B receives this request, it may decide to grant permission, in which case it sends a CTS frame back. Upon receipt of the CTS,

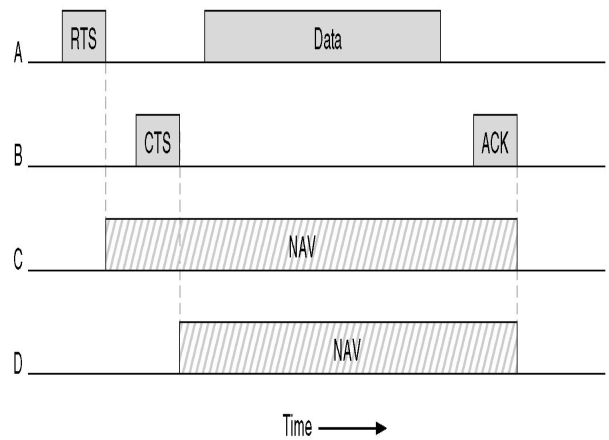

Figure 2. Virtual Carrier Sensing with CSMA/CA

A now sends its frame and starts an ACK timer. Upon correct receipt of the data frame, B responds with an ACK frame, terminating the exchange. If A's ACK timer expires before the ACK gets back to it, the whole protocol is run again. The protocol starts when A decides it wants to send data to B. It begins by sending an RTS frame to B to request permission to send it a frame. When B receives this request, it may decide to grant permission, in which case it sends a CTS frame back. Upon receipt of the CTS, A now sends its frame and starts an ACK timer. Upon correct receipt of the data frame, B responds with an ACK frame, terminating the exchange. If A's ACK timer expires before the ACK gets back to it, the whole protocol is run again. Now let us consider this exchange from the viewpoints of C and D. C is within range of A, so it may receive the RTS frame. If it does, it realizes that someone is going to send data soon, so for the good of all it desists from transmitting anything until the exchange is completed. From the information provided in the RTS request, it can estimate how long the sequence will take, including the final ACK, so it asserts a kind of virtual channel busy for itself, indicated by NAV (Network Allocation Vector) in Figure 2. D does not hear the RTS, but it does hear the CTS, so it also asserts the NAV signal for itself. Note that the NAV signals are not transmitted; they are just internal reminders to keep quiet for a certain period of time.

B. PCF (Point Coordination Function)

In DCF mode, there is no central control, and stations compete for the carrier, just as they do in wired network. Another allowed mode is PCF [2], where the base station polls the other stations, asking them if they have any data to send. Since transmission order is completely controlled by the base station in PCF mode, no collisions ever occur.

The basic mechanism is for the base station to broadcast a beacon frame periodically (10 to 100 times per second). The beacon frame contains system parameters, like hopping sequences and dwell times (for FHSS), clock synchronization, etc. It also asks new nodes to get in polling service.

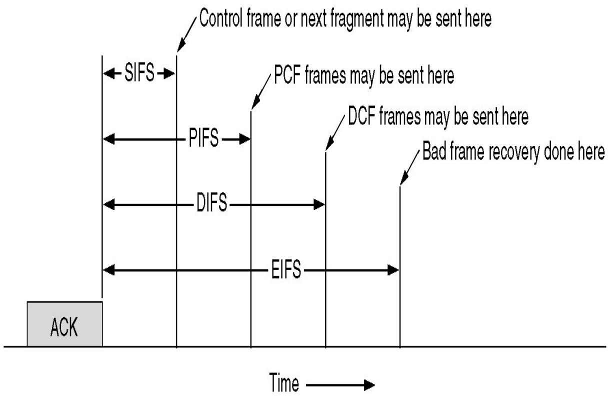

Figure 3. IEEE 802.11 inter frame spacing

Once a station has signed up for polling service at a certain rate, it is effectively guaranteed a certain fraction of the bandwidth, thus making it possible to give quality-of-service guarantees. PCF and DCF can coexist within one cell. At first it might seem impossible to have central control and distributed control operating at the same time, but 802.11 provides a way to achieve this goal. It works by carefully defining the inter frame time interval. After a frame has been sent, a certain amount of dead time is required before any station may send a frame. Four different intervals are defined, each for a specific purpose. The four intervals are depicted in Figure 3

The DCF mode has many advantages because of its simple in terms of implementation and suitability for data applications. But DCF has some serious drawbacks as it only supports best effort traffics. Real-time traffics are not supported in DCF. Real Time applications are sensitive to some attributes like bandwidth, delay, and jitter guarantees. The point is explained in the previous sections that with DCF, all the STAs compete for the channel with the same priority. There is no differentiation policy among the traffics for providing guaranteed QoS for real-time multimedia applications. It seen in the literature that DCF shows high variation of throughput, delay and relatively poor performance for audio transmission.

As PCF was designed to support Real Time applications, but it has been experienced inflexible for doing the same due to some major drawbacks and as a result it leads to poor QoS. PCF defines a single-class round-robin scheduling algorithm, and hence it cannot tackle the claimed QoS requirements from various types of traffics. Moreover it is very much difficult for PCF to control the transmission time of a polled STA. When a STA is polled then it is allowed to send a frame segment of any size in between 0 and 2304 bytes, and as a result variable transmission time is needed. In addition to this, the PHY data rate of an already polled STA may change according to variable channel situations. And hence the AP is not able to determine the transmission time exactly. This forbids the AP from providing guaranteed delay and jitter performance for other STAs engaged in the polling list during the rest of the CFP interval.

Both DCF and PCF do have a common QoS [18] problem as no admission control mechanism is specified in the 802.11 legacy MAC. When traffic load is very high, the performance of both functions can be degraded and QoS requirements are not satisfied.

C. EDCA

In IEEE 802.11e standard the compulsory MAC protocol is EDCA. It is the enhanced version of the legacy MAC protocol function DCF of the 802.11 standard to support the QoS requirements by QSTAs. The EDCA mechanism is designed to offer priotrized or differentiated channel access. EDCA adopts the CSMA/CA mechanism of 802.11 channel access. The operation is based on contending for the wireless medium using a backoff procedure. EDCA uses different inter framing spaces as waiting intervals of different length, also called Arbitrary Interframe Spaces (AIFSs), and differentiated backoff time called Contention Windows (CWs), according to the priority of the traffic category or Access Category (AC). AIFS is the amount of time a station would sense the channel to be idle and the length of CW is used for the value of backoff counter. These different lengths of the AIFS values represents access probabilities for different category of traffics based on their priorities. By assigning different waiting intervals for different traffic classes it is possible to have differentiated service and thus QoS can be supported. More over to avoid collisions EDCA additionally deploys a collision avoidance mechanism using a two-way message passing, called RTS/CTS (Request to Send/Clear to send), and explained in earlier sections. This technique handles to some degree the serious hidden station problem.

EDCA primarily access to the wireless medium in a differentiated and distributed manner based on the 8 different UPs (User Priorities). Any packet destined from higher layers to the MAC layer is given a UP value. The entire higher layer UPs are mapped into some ACs (Access Categories) as shown in figure 4.2. The UP to AC mapping procedure can be found in [18]. As shown in figure 4.2, there are four transmission queues being implemented in a QSTA and each of these queues supports one AC and each of this

AC functions like a single DCF entity, contending for the wireless medium access, and also each access category initiates its backoff procedure by its own. In EDCA AC-0 is having the lowest priority also known as best effort traffic and AC-3 is the highest priority of all in the real time traffic category. Therefore to have service differentiation EDCA defines the following parameters in each AC[k] where k ($0 \leq k \leq 3$)

- MinimumCW size is $CWmin[k]$,
- Maximum CW size is $CWmax[k]$,
- Arbitration inter frame space is $AIFS[k]$
- Arbitration inter frame space number is $AIFSN[k]$.

The relation between $AIFS[k]$ and $AIFSN[k]$ is defined as follows

$$AIFS[k] = AIFSN[k] \times slotTime + SIFS$$

Here slotTime is the amount of time defined in the setting of each PHY layer setting. The backoff procedure in each AC k is selected in the range of $[0, CW[k]]$, where $CW[k]$ represents the the current CW in the particular AC k. At the very first attempt, the value of $CW[k]$ is assigned to the value of $CWmin[k]$. When successive transmissions fail because of collisions, the value of $CW[k]$ increases up to the maximum value of $CWmax[k]$ in binary exponential manner. In EDCA standard, the smaller the $AIFSN[AC]$ and $CWmin[AC]$, the higher the probability of winning the contention with the other ACs. the smaller the $AIFSN[AC]$ and $CWmin[AC]$, the higher the probability of winning the contention with the other ACs. If a particular AC has smaller AIFS value and shorter CW values than traffics from that category gets more access to the wireless medium. In EDCA standard, an AC of real-time category has always smaller and shorter values of AIFS and CW size than that of other ACs of non real-time category.

Table 1 shows the default values of the channel access parameters defined in EDCA for the four ACs (BK = background, BE = best effort, VI = video, VO = voice). These parameters are not fixed: in each beacon frame, the access point (AP) broadcasts the values chosen for each AC. Indeed, these values may also be dynamically adjusted according to network conditions when more than one AC of the same station expire its backoff counter, a virtual collision occurs, and the packet having highest-priority among the colliding ones is selected for actual transmission on the radio channel. . Figure 4 shows the IEEE 802.11e channel access method.

III. CHALLENGES IN AP SELECTION

WLAN is widely used in office and public areas. In these large WLAN networks, Radio Resource Management is very important for the efficient use of wireless medium. As an example, since three channels (1, 6 and 11) can be used simultaneously in IEEE802.11b WLANS, APs have to be installed to reduce the overlaps between the same channels and to reduce interferences between STAs using the same channel. When a STA enters a 802.11 WLAN it scans all the 802.11 channels and sends association request to the APs. If the AP authenticates the STA then the STA gets associated with the selected AP.

In IEEE 802.11 WLAN a station has the right to select an AP to which it will associate. But the selection of the AP is a complex issue due to the following challenges. The challenges are outlined and explained below

1) **Distance:** Station near from the AP communicates in higher data rate. The common approaches for assignment of AP are based on RSSI value. As shown in Fig.4, the stations get associated with the AP nearby it from which it getting strongest signal and

2) **Number of STA:** Considering number of STA associated with an AP does not always lead to the better channel utilization because the required data rate for various traffics are different. As shown in Fig. 5 more stations are

3) **Mixed WLAN environments:** With the wide popularity of real time traffic applications like video conferencing and VOIP has got many attentions. The real time applications are very much delay and bandwidth sensitive. For ensuring QoS, the MAC layer has to provide adequate support for providing services to real time traffics. The challenge is that the legacy AP treats each traffic as best effort traffic

TABLE 1 EDCA DEFAULT PARAMETER

Access Category (AC)	CW_{min}	CW_{max}	AIFSN
AC_VO(Voice)	7	15	2
AC_VI(Video)	15	31	2
AC_BE(Best Effort)	31	1023	3
AC_BK(Background)	31	1023	7

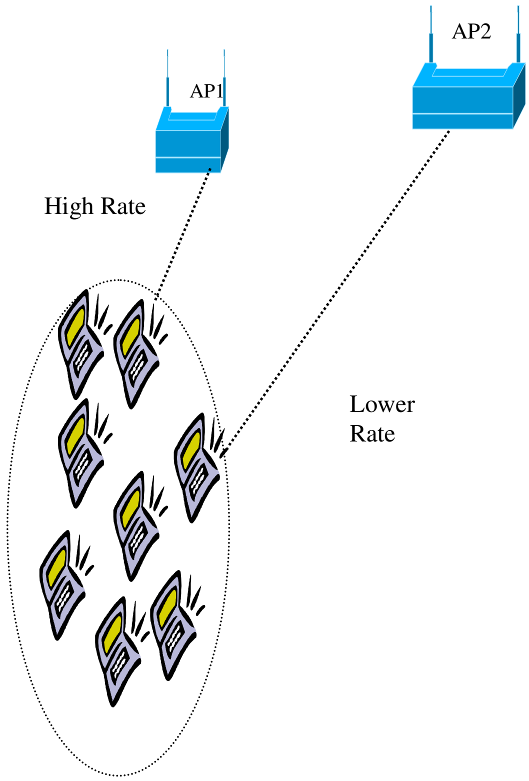

Figure 4. Congestion due to maximum association

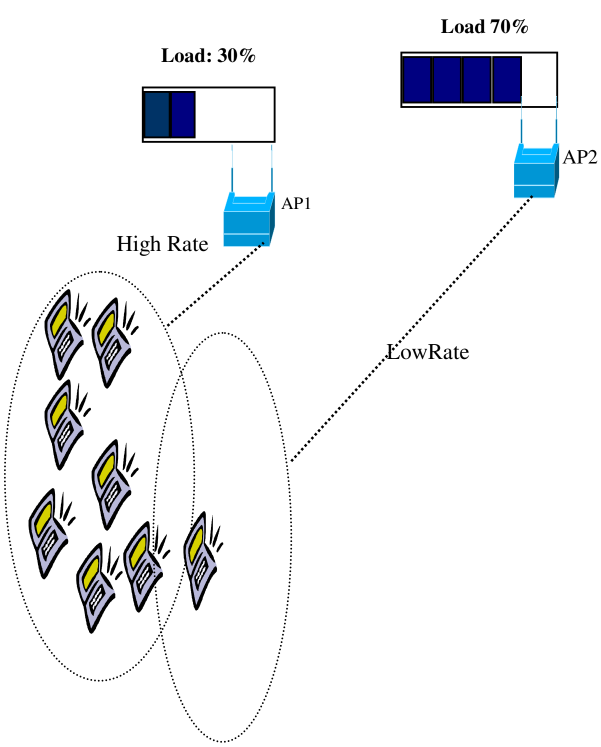

Figure 5. Load imbalance with different category of traffics

IV. AP SELECTION STRATEGIES

The existing load-balancing protocols distribute traffic load by managing AP-STA associations. Depending on which part of the network is responsible for such managements, these protocols could be classified into two categories Centralized and Decentralized approach.

A. *Decentralized Strategy*

In a decentralized approach, STAs learns the load status in an AP somehow and, accordingly, select an AP that maximizes potential bandwidth [5]. An AP acts passively in the whole selection process. Most of the centralized AP selection mechanisms are not designed to balance load system wide rather STA selects AP for their own interests. The load in an AP can be realized in several ways. A may know the channel utilization or the delay between the scheduled and actual transmission time of periodic Beacon frames [5]. In such approach, the AP may let the STA to know about channel load by simply broadcasting its current STA population and traffic level in Probe Response or Beacon frames [1, 12], preferably with a QBSS Load element if the AP supports IEEE 802.11e. In [13], a STA briefly connects to each available AP for performance test and select the best eventually. The STA-AP association management can be carried out either in a static or dynamic fashion. In static cases, a STA performs AP selection prior to its association with the target AP and does not re-associate to other APs as long as the association holds. A drawback of static AP selection is the inflexibility to adapt to network dynamics. With dynamic AP selection, a STA may re-associate with another AP even if the current association still holds. Dynamic AP selection shows better performance in a network which is highly dynamic. But this technique may cause the WLAN unstable (ping-pong effect) state. To avoid ping-pong effects, either static AP selection should be used or there should be a way to distribute re-associations in the temporal domain. For instance, in [8] a STA periodically searches for the best AP that has the least load. When the best AP found is different from the previous one, the WS does not switch to that AP immediately but generates a random value *d*. The STA can switch to the best AP only after the AP has been identified the best for *d* successive times. As in centralized approach STA select APs for their own interests, these approaches generally do not lead to a network-wide load balance. An alternative is to distribute load by a network-side entity.

A. *Centralized strategy*

In a centralized approach [6,10], STAs behave passively in modifying AP-STAs associations. It is a network-side entity (could be an AP, a switch, or a dedicated server) that controls the distribution of AP's load. There are three basic techniques for APs to control their own load level

a) Coverage Adjustment:

Heavily loaded APs can reduce the transmission power of their beacon signal so that new STAs are less likely to discover them [1]. APs may contribute each other in adjusting their radio range patterns in a way that less-loaded APs cover maximum area than heavily-loaded APs. And there is no coverage hole to ensure continuous coverage [4, 14].

b) Admission Control:

In this mechanism each AP contains an admission [15, 18] controller which is responsible for accepting new connections or not. An AP may simply reject or accept new connections to the STA depending on the network load conditions. The request can be granted only when the predicted load level after the association does not exceed some threshold.

c) Association Management:

A crowded AP may issue explicit disassociation frame to selected STAs which are associated with it so that notified STAs would re-associate with other lightly-loaded APs. Theoretically, the best disassociation candidate is the one for which there exist an optimal association in anther AP and balances the load among APs in the WLAN.

V. Centralized Vs Decentralized Strategy

In centralized approach, the association and re-associations are controlled by a centralized entity which can be a switch, AP or some dedicated server. If the centralized entity ever becomes malfunctioning then the entire process of association and de-association is affected. Moreover the link between STA and central node may become bottleneck potentially and resulting affect in the whole process of AP selection. In centralized approach the STA behaves passively.

But in decentralized strategy the selection procedure is located within the STA itself hence no central control is there. The STA makes the optimal association or de-association based on various information conveyed in beacon frames. Therefore there is no distributed affect in the decision making process of AP selection. In decentralized approach STA behaves actively.

When centralized servers are used for association then the latency taken during the HO (Hand-Over) procedure will increase and significant delay may affect on the performance of the WLAN. But in decentralized strategy, the STA itself makes HO decision, and thus the latency is greatly reduced.

The decentralized approaches do not have a global view of the WLAN and therefore it does not have a customized association, de-association and balancing load among APs in the WLAN, but they have the potential advantage of exploiting off the-shelf APs without much modification. On the other hand the centralized strategies do not require modification in STAs. Centralized strategies AP selection can provide system wide load balance at the time of high traffic congestions. But deploying AP selection mechanism centrally produces an overhead in the system installation and also it may create problems when the central controlling server ever becomes malfunctioning.

VI. Prior Arts

The basic and preliminary AP selection mechanisms for load balancing among APs consider only RSSI (Received Signal Strength Indicator) and the number of STAs connecting to an AP. But considering only RSSI [5] for load balancing leads to traffic congestion and produces lower performance. In this section we describe the important and relevant research works that we have come across during the literature survey related to this PhD work.

In [7], the authors have presented a decentralized AP selection mechanism by considering the control metric Signal Strength, throughput, and AP's load. In the proposed mechanism they have derived a function namely **Eligibility of Access Point**, (EoAP), which is a function of signal strength, throughput, and channel speed, considered in appropriate AP selection by the stations. For each discovered AP, in particular WLAN the signal strength and channel speed is computed and when the association between STA and AP is established then the throughput is estimated actually by transmitting TCP/IP packets. When a mobile node starts up, the algorithm for AP selection is operated, and function **EoAP** is automatically evaluated.

$$\mathbf{EoAP = SS\% \times TP \times LF.\ SS\%}$$

Where SS% is the signal strength of the received AP which is usually converted into a percentage, while TP means the network throughput when transmitting data. Loading Factor (LF), defined as LF = TP / channel speed, reflects the current load of the access point. Channel speed is the transmit rate of the current channel between the mobile node and associated AP. Finally, the access point with the largest **EoAP** is selected for association.

As very advantage of this AP selection mechanism is that it considers the load factor and channel speed as control metric and thus achieves efficient utilization of radio resources.

The weak point we have observed in this mechanism is that it considers only best effort traffic only. Therefore traffics with real time traffic experience lower throughput and bad QoS.

In [5] the authors have designed a new AP selection mechanism to overcome the problems as shown in figure 3.2. and figure 3.3. The proposed new mechanism for AP selection is called HRFA (High Rate First Association) [5]. In this mechanism the authors have considered three metrics Transmission Rate, Channel Load in AP and real-time traffic load in an AP**.** Transmission rate is used to communicate with an AP is determined by LA (Link Adaptation) algorithm implemented in STAs. Channel load and real-time traffic load in an AP are conveyed to STAs through the QBSS [5] load element in beacon frame.

Their proposed strategy considers both real-time traffic and non real time traffics. Traffics from STAs with real time are accepted by admission controller implemented in the AP. In this mechanism STA with real-time traffic selects an AP whose real-time traffic load is less. But if there is a difference in load among various APs, the STA selects an AP, with which it can communicate using higher transmission rate, in order to efficiently utilize radio resource.

The first advantage of this proposed mechanism is that, by considering transmission rate and channel load level, this strategy justifies to the utilization of radio resources. Moreover this AP selection mechanism also provides a way for justifying real time application from non real time application.

The weak point we have observed in this mechanism is that it is a decentralized AP selection mechanism. The STAs do not have a global view of the WLAN. In certain situations the frequent association and de-association mechanism may result in ping-pong behavior in to the WLAN.

In [17] the authors have represented two mechanisms for improving QoS in a WLAN for both real and non real time traffic. They have first derived an analytical model for specifying upper bounds for both delay means and variations for services of different priorities in the non-saturated 802.11e WLAN. Their proposed mechanisms include one admission control mechanism and a rate control mechanism to ensure that QoS requirements of real-time traffics are statistically guaranteed and at the same time the best effort traffics can effectively utilize the residual bandwidth.

Their admission control mechanism namely CAC (Call Admission Control) uses the concept of imposing quota on the channel utilization due to the real-time traffic [5 17]. They have given maximum channel utilization for real time traffic but leaving some portion of the bandwidth for best effort traffic so that the best effort traffic is operational all the time.

The transmission rate of the best effort traffic is determined by Rate control algorithm which is conducted basically at the wireless nodes.

Their proposed mechanism [17] clearly shows an improvement in the QoS of real time traffic but the weak point of this algorithm is that it does not consider the greedy station problem; where upon the stations with higher priority always gets more opportunity for packet transmission due to reservation in channel utilization. Reservation in channel access does not ensures efficient channel utilization directly because traffics of higher category may not exist in particular situations and also by accommodating more traffics of higher category can affect other traffics QoS

In [18] the authors have proposed an adjustment method for QoS parameter by dynamically adjusting the CW values. Their proposed scheme adjusts the QoS parameters in the AP. The AP distributes the changed QoS parameters in wireless LAN within transmission range. Two-way handshaking mode of EDCA is good for real time traffic, and by using the RTS/CTS helps resolving the hidden/exposed terminal problem. Proper adjustment of maximum CW value of real time traffic produces efficient channel access for higher priority ACs and at the same time the non real time traffics get better chances to access the residual channel bandwidth.

The advantage of their proposed mechanism is that the default EDCA parameters alone don't sufficiently improve the QoS performance of real-time traffic; rather it produces increased data drops. So with their proposed scheme [17] for adjusting the CW values dynamically depending on the network conditions they have achieved better throughput from simulation.

But the dynamic tuning of CW values may increase the overhead in a QAP when there are a significantly large number of real time transactions and frequent association and de-association and it may lead to some unstable state of the WLAN.

The QoS mechanisms should have a certain amount *of* fairness, specifically when it comes for improving throughputs. Without fairness various traffic classes may experience unjustified bandwidth distribution.The QoS mechanisms should be designed with minimal or no changes to the existing MAC standards of IEEE 802.11/11e [5 16 17 18] so that the proposed mechanisms are easily compatible with the current standard and thus easy to implement and adopt.The QoS mechanisms must be designed to support high scalability. That means the QoS performance should not be affected when more active connections having different data rates exist at the same time.

The QoS mechanisms must provide throughput services with minimal v*ariation.* Because the performance of real-time applications strictly relies on the stability of the available channel bandwidth. The QoS mechanisms must be carried out with minimal computational complexity. We know that without simplicity it is not possible to get wide acceptance of any mechanisms

VII. CONCLUSION

In this paper we have reviewed existing AP selection strategies and load balancing challenges IEEE 802.11 networks. The decentralized approaches are generally not customized to balance load among APs in the WLAN, but they have the potential advantage of exploiting off the-shelf APs without much modification. On the other hand the centralized strategies do not require modification in STAs. Centralized strategies can provide system wide load balance at the time of high traffic congestions. But employing load balancer centrally produces an overhead in the system installation and also it may create problems when the central balancing server ever becomes malfunctioning. In the literature various mechanisms have been proposed for improving the QoS performance in a WLAN We have rightly observed that there exist some differences among the various properties of QoS. While some QoS performance is achieved others are scarified. A dynamic and fare AP selection in load balancing strategy should be deployed to achieve optimal QoS support in such WLANs.

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