

An AP Selection Scheme for Enhancement of Multimedia Streaming in Wireless Network Environments

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무선 네트워크 환경에서 멀티미디어 서비스를 위한 AP 선정 기법

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Abstract Recently, there has been a growing interest in the use of WLAN technology due to its easy deployment, flexibility and so on. Examples of WLAN applications range from standard internet services such as Web access to real-time services with strict latency/throughput requirements such as multimedia video and voice over IP on wireless network environments. Fair and efficient distribution of the traffic loads among APs(Access Points) has become an important issue for improved utilization of WLAN. This paper focuses on an AP selection scheme for achieving better load balance, and hence increasing network resource utilization for each user on wireless network environments. This scheme makes use of active scan patterns and the network delay as main parameters of load measurement and AP selection. This scheme attempts to estimate the AP traffic loads by observing the up/down delay and utilize the results to maximize the link resource efficiency through load balancing. We compared the proposed scheme with the original SNR(Signal to Noise Ratio)-based scheme using the NS-2(Network Simulation-2). We found that the proposed scheme improves the throughput by 12.5% and lower the network up/down link delay by 36.84% and 60.42%, respectively. All in all, the new scheme can significantly increase overall network throughput and reduce up/down delay while providing excellent quality for voice and video services.

요약 최근 무선 랜(WLAN : Wireless Local Area Network) 기술이 사용자에게 편리성과 유연성을 제공함에 따라 무선 분야에 대한 관심이 증가하고 있다. 무선 랜 어플리케이션의 웹 접근과 같은 표준화된 인터넷 서비스에서부터 멀티미디어 비디오 및 음성 서비스와 같은 분야에서 매우 엄격한 지연시간/처리율이 요구된다. 따라서, 무선 랜의 효율을 높이기 위해 AP(Access Point)들 간 트래픽의 공정하고 효율적인 부하의 분산이 중요한 문제가 된다. 본 논문에서는 보다 나은 로드 밸런스를 달성하고, 네트워크 리소스 사용률을 증가시키기 위한 AP 선정 기법을 제안한다. 제안된 기법은 부하 측정과 AP 선정의 주요 파라미터로서 활성화 검사 패턴과 네트워크 지연을 사용한다. 또한, 상향링크/하향링크 지연을 관찰함으로써 AP 트래픽 부하를 예측하고, 로드 밸런스를 통해 링크 자원의 효율성을 극대화하기 위해 예측 결과를 사용한다. 제안하는 기법은 NS-2(Network Simulation-2)를 이용하여 SNR(Signal to Noise Ratio) 기법과 비교하였다. 제안한 기법은 전체 네트워크의 처리율이 12.5% 향상된 것으로 나타났고, 상향링크/하향링크 지연 시간은 36.84%, 60.42%씩 감소되었다. 또한 제안한 기법은 전체 네트워크 처리율을 증가시켰으며, 비디오와 음성 서비스를 우수한 품질로 제공하면서 상향링크/하향링크의 지연 시간을 감소시킴을 확인하였다.

Key Words : Wireless Access Point, Wireless Network, QoS, Multimedia Streaming

1. Introduction

Wireless LANs [1] have become popular in our life due to ease of installation, and the increasing popularity

of laptop computers and mobile hosts. According to this trends, many researches such as network traffic algorithms [2], routing scheme[3], or light weighted protocol[4] are being investigated. Today, WLANs are commonly utilized

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in homes, offices, public areas such as airports, factory and intelligent buildings.

The combination of the decrease in price of wireless LAN access points (APs) and the increase in wireless link capacities has prompted a significant increase in the number of wireless networks environment. The promise of up to 54 Mbps capacity from a wireless AP means that users now expect to have applications such as video that require high bit rates run seamlessly from well connected wired media servers to wireless media clients. However, since many multimedia techniques are primarily designed for wired networks, media applications may perform load poorly when running over a complex network environment with wireless network. Therefore, Fair and efficient distribution of the traffic loads among Access Points (APs) has become an important issue for improved utilization of WLAN.

In this paper, we purposed a wireless access points (APs) selection scheme for enhancement of the link resource efficiency based on load balancing. When there are several BSSs (Basic Station Sets) in WLAN network, this scheme is particularly important, for there are several access points available for on node.

Wireless access point selection mechanism is not specified in the current IEEE 802.11 standards. The wireless stations (STAs) can join a Basic Service Sets (BSSs) and access some data transmission services. AP selection scheme is proposed in this work for IEEE 802.11e WLANs, which comprises with the SNR-based scheme on their requirements. Some important factors and parameters, such as uses active scan pattern and use the network delay as main parameter of load and throughout measure and AP selection. The main contributions of this paper are as follow.

- The formulation of AP selection scheme for IEEE 802.11e that considers the channel conditions and QoS requirements of different traffic types (voice and video services).
- The performance evaluation of the proposed AP selection scheme and its performance comparison with the SNR-based algorithms.

With the same load, the proposed scheme can achieve larger throughput and lower network delay. Based on

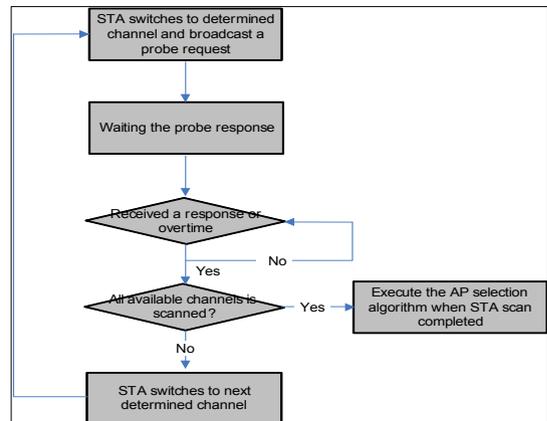
simulation results, show that the new scheme can achieve larger throughput while has excellent features of voice and video services.

The rest of this paper is divided into 4 chapters. Chapter 2 reviews the technology of WLAN and legacy IEEE 802.11e standards. In addition, the chapter discusses several IEEE 802.11e AP selection schemes provided in the literature. The proposed AP selection scheme is presented in Chapter 3. Simulation results are provided and discussed in Chapter 4 where the performance of the AP selection scheme is compared with the SNR-based scheme. Finally, we draw our conclusion in Chapter 5.

2. Related Works

There is no definition of this mechanism in IEEE802.11e[5] and it is under study. Before STA switching in network, it is necessary to scan AP and connect to it to analyze the current research and use. The process of scan and connection is usually in two methods:

Active scanning: follow as Fig. 1, STA switches to every determined channel and broadcast a probe request to search for new APs. If an AP receives a probe request, it will acknowledge the request by sending back a probe response, which indicates that the AP is in vicinity.



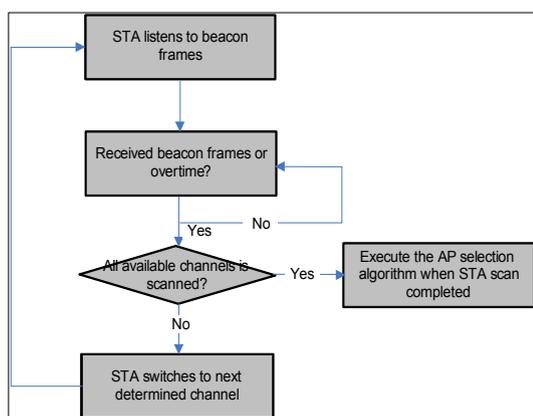
[Fig. 1] Active scanning

Passive scanning: following as the Fig. 2, STA listens to beacon frames which are periodically transmitted by neighboring APs. The STA learns the existence of other

APs by the received beacon frames.

After the scanning, it will use AP selected arithmetic. The traditional arithmetic is usually based on Signal-to-noise ratio (SNR) [6] and Received Signal Strength Indication (RSSI).

Moreover, the newly-added nodes may seriously influence the communication quality of the original nodes in BSS. For example, when the user terminal distributes non-uniformly, the result of this kind of algorithm are that lots of nodes link with the same AP and the load of the network is unbalanced, so the traditional algorithm can not meet the QoS[7] needs of the network to its most limit.



[Fig. 2] Passive scanning

In [8], the author considers that STA will select a BSS that enables it to provide the best service for its service to insert, so STA will probably select an AP whose link attenuation is the smallest, i. e. SNR is the largest, However, if this BSS is already very congestive, it is impossible to improve the service quality of the service despite of the high SNR. Meanwhile, adding this node lowers the service quality of the nodes that already exist in BSS. This paper brings up a kind of predictive mechanism that model the influence of the node added to the BSS's throughput. The paper uses the passive scanning, considers both the STA number of the present AP service comprehensively and that the adding of the new nodes causes the data rate of the original nodes in BSS declines, however this method has some shortcomings. First of all, the predictive mechanism refers to the empirical data which is static and inaccurately

reflects the characteristics of this kind of time-varying network-WLAN. Secondly, when the data rates of the other nodes are influenced in the computer network, considering the time-varying characteristics of the network and the unsurely equal-characteristics of the STA data rates, it uses the method of formula calculation and has a high complexity, however a low accuracy.

In [9], the author provides the STA numbers that can be compared with that of AP to have the AP select, i. e. to select the AP that has the smallest number presently when it is related to STA. This method is simple and can balance the load of the network, however it also has some limits: firstly, 802.11b[10] supports some kind of the transfer rate, and at the different rate, the node numbers that the network supports are different. Secondly, when the data and the required service quality of the users are different, it is not enough to select the best AP, gain the load balancing and QoS just by the node numbers.

In [11], when AP makes the select, it considers the PER and the STA numbers that build relation with AP comprehensively, but this calculation method also has limitations.

In [12] considers the two factors of SNR and network load, so it can realize the load balancing better. What's more, the network load uses time delay to measure, and compared with the node numbers in network, time delay is the quantity that can dynamically reflect the network load better, but this time delay is got by calculating the time delay of the detection request frame and detection response frame, so it does not have the stability. The experiment proved that time delay has much randomness at every time unit, and only the long-time average can reflect the load condition of the network. Besides, this calculation does not distinguish the servicing category and lacks the consideration of category QoS.

In [13] forward that it can use a load balancing to STA distribute AP, but this method needs a central controller, the resources of the administrative network, meanwhile, it consumes the network resource too.

3. The AP Selection Scheme

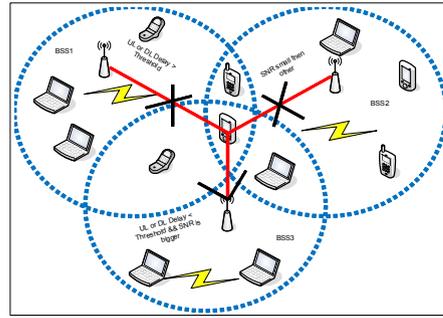
This paper puts forward a newly insertion point select calculation to direct the multimedia service such as voice

and video service. The method can be implemented on mobile stations alone. It considers two factors of the users' communication quality and the network's load balancing. The one uses SNR [6] (Signal-to-noise ratio) to identify while the other judges by experimental parameters. When the users select insertion points, they use the active detection method to poll every useful channel and exchange information with AP. AP informs STA of its loading condition of BSS, network quality, and whether AP allows new STA to join. When STA collects the detection response frame on every channel, it treats the allowable insertion AP as candidate AP, and selects one that is most helpful for itself based on SNR data. This calculation is simple and practical, and it realizes the bidirectional select between AP and STA by active detection. Because the present wireless insertion point calculation is in the research period and, without mature references, while practical applications mostly use the traditional SNR benchmark, the paper compares this calculation with the traditional calculation based upon SNR. The result proves that calculation realizes the load balancing better and gains more network throughput capacity than the traditional one while has excellent features for mobile multimedia service.

In ESS, there are three BSS that all work on different frequency bands without intersection and, disturbance.

In 80.211b, it assumes that the three working channels are respectively 1, 6, and 11. Node A attempts to build link with one certain AP, and masters the list of all the useful channels in the network. A uses the active detection method by which it, sends the detection request frame respectively in three channels, and waits for the detection response frame of AP. Fig. 3 shows, in the coverage area of have three APs, so under the condition of the normal network, A can receive the responses from three APs.

After the receiving of the channel scanning, the messages of three response frames are analyzed, and an imbalance case is recognized, which the up-link or down-link delay in BSS 1 has already been beyond the threshold, while BSS 2 and BSS 3 meet the delay requirement, so the APs of BSS 2 and BSS 3 are treated as the candidate AP. Next, STA compares the SNR of AP signal in BSS 2 and BSS 3 and select the better AP to insert in SNR, so the AP in BSS 3 is chose.



[Fig. 3] Arrangement of APs

The delay information in every BSS is time-lapse collected by AP and is divided into up-link delay and down-link delay. The up-link delay is the delay when STA sends to AP, and the down-link delay is the delay when AP sends to STA.

Without the need of the central controller to administrate the network, the up-link delay counts at AP, and the down-link delay counts at every node. At intervals of a period, AP counts the up-link and down-link delay of the network. At this time, STA reports the condition of the delay to AP. Because the statistical interval can be from 1S to 10S, with the demanding changes of the network, it does not increase much load to the network. We calculate delay using the follows parameter:

$$\nabla ay = T_{recv} - T_{\geq n} = T_q + T_m + T_{maxs} + T_{tm}$$

, where T_{recv} is the STA receive the packet required time, T_{gen} is received the MAC layer packet arrival time, T_q is packet delay in the queue, T_m is competition channel consume time, T_{trans} is transmission delay, include the re-transmission part, and T_{tm} is in the media transmission delay, respectively.

When STA receives the detection response frame from AP, it judges the SNR data by this frame. With the difference of the physical layer model, the counting method of SNR data [14] is also different.

In next simulation section, we used the NS-2 provided the space transmission mode. In this paper, the signal to noise ratio, SNR and effective SNR, $SNR_{effective}$ are calculated as follow.

$$SNR = 10 \cdot \log_{10} \left[\frac{P_s}{(P_b + P_i)} \right]$$

$$SNR_{effective} = SNR_{actual} + G_p$$

, where P_s is Signal, P_b is Background Noise, P_i is Interference Noise, and G_p is Processing Gain.

This mechanism needs to initiate STA of service to have AP select, but the feedback delay by AP also directs the service, because the demands of mobile multimedia service to the throughput and the delay are comparatively high, meanwhile, its adding has a comparatively large influence on the network too.

STA moves away from AP and approaches the other AP, the SNR of AP decreases. Then the SNR of AP start the predefined search threshold, the STA starts to discover other APs to associate with. In order to improve the service quality, it is necessary to improve the time delay of the source-destination less than the threshold data, while the enable data are 150ms, 400ms, the delay thresholds of the unilateral uplink and downlink are 75ms, persevered threshold is 20ms.

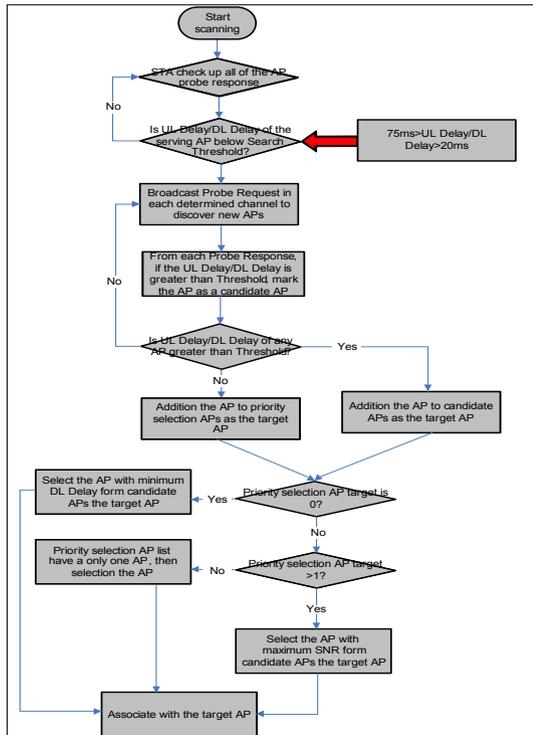
Following as Fig. 4, depicts the work flows of our proposed scheme. STA firstly collects and detects all the detection responses from all AP. If the up-link and down-link time delay are both less than the threshold data among them, then they begin the next-round judge. If the time delays of the up-link and down-link are both less than the dense threshold data—20ms, then this AP is added to the AP list that is chose early, if not, then the AP is added to the list of spare AP. After gaining the list, it begins the next-round select.

An ideal AP selection scheme should allow service to continue and should balance the loads of the overall network. As discussed earlier, conventional approaches select an AP with strongest SNR to use without considering traffic loads among AP, which results in significantly uneven traffic loads.

The SNR is still used to discover candidate APs and to ensure the availability of the wireless links. We simply replace the SNR-based selection AP selection scheme with our proposed schemes. Instead of selection an AP with maximum SNR, our proposed schemes measure the traffic load as well. In addition, our proposed techniques could be accomplished by STA alone or with little assistance form APs. There is no need to exchange information among APs.

We first propose a simple scheme that allows STA to estimate the traffic load of different APs by using probe frames. Indicates that the major variance in frame transmission time depends on the backoff time, which is greatly affected by the traffic load of the wireless channels. If there are more users accessing the media simultaneously, the probability of frame collisions will be higher, which in turn increases the probability for each STA to wait for another backoff period. Because 802.11 adopts exponential backoff, the backoff Time will become longer when traffic load is heavy. It results in more time required to transmit a frame. Based on this observation, we reasonably presume that the longer the transmission delay, the heavier the traffic load.

We take advantage of this feature by calculating the down-link delay which is defined as the time from a STA sends out the probe request until the time it receives the probe response from a specific AP. The down-link delay is then used to estimate the traffic load of the AP. The longer the down-link delay, the heavier the load of the



[Fig. 4] Flow chart of the proposed scheme

AP.

Whenever receiving a probe response, the STA first checks the SNR. If it is greater than the handoff threshold, the STA marks the AP which sends the probe response as a candidate AP. The STA also records the down-link delay. After the scanning of every determined channel is completed, the STA selects the AP with least down-link delay from candidate APs as the target AP. The STA produced hands off to the AP and associates with it.

Next step, we will check the AP target, if priority selection AP target equal to 0. Then select the AP list with down-link delay minimum. If not, our scheme rechecks whether AP targets in the priority selection list are equal to 1 or not. If the priority selection list has only one AP target, then the scheme selects that AP. If the priority selection list has one or more AP, the scheme selects the AP with SNR maximum. At the last we will associate with the AP.

4. Experiment

In this section, for evaluating the benefits of our AP selection scheme, we have compared the throughput, data drops, and delay with traditional SNR-based scheme by NS-2(Network Simulation 2). Our simulation MAC layer based on IEEE 802.11e EDCA(Enhanced Distributed Channel Access) MAC layer. We first implement the proposed IEEE 802.11e MAC in NS2-2.28 version, also we have made the patch to let the IEEE 802.11e module can be simulated in NS2-2.28. The PHY layer based on the 802.11b and VoIP's data rate are 64K/s. We first considered the imbalance service network situation; from this condition we have designed a WLAN network scene includes 100m*100m areas. We have built 3 APs in this WLAN network. Each AP maybe has different network offered load. And then, we have carried on a series of comparative simulation about throughput, data drops, and delay. Through the simulation results analysis confirms our AP selection algorithm have the high throughput and less delay with the SNR-based scheme[6]. Therefore, our design has the high usability and reliability.

4.1 Simulation Environment

The simulation experiment environment is divided into hardware environment and software environment. Hardware environment is follows as the Table 1.

The IEEE 802.11e EDCA model was used in our simulation. Above environment has some effects on the multimedia mobile service provision. We assume that APs and STAs use the same transmission level. The services select their transmission rates dependent on the perceived SNR. The possible data rates actually are 11Mbps and 5.5Mbps with 8 CCK(Complementary Code Keying) code length in IEEE 802.11b[10]. STAs are uniformly distributed in an area of 100m*100m square meters in wireless network environment overall our intelligent building. All of the STAs were distributed across the coverage area of the 3 APs by random methods. We can consider an area like a conference intelligent building equipped with 3 APs. The other 3 APs are deployed in the neighborhood with less terminal density. We will use the active scanning methods and select the delay number in the network as the critical parameter to estimate the network load and select the wireless AP. Each AP was assigned to same maximum throughput in the simulation.

[Table 1] Hardware Environment

CPU	Intel Core 2 Quad Q6600 2.4 Ghz
RAM	4 GB
O/S	Redhat Linux 9.0
NS-2 Version	2.28
MAC Layer	IEEE 802.11e EDCA
PHY Layer	IEEE 802.11b

Table 2 lists the values of the parameters as used in simulation. We experienced the comparative simulation while 400 to 500 seconds for obtaining the differences between SNR based scheme and proposed scheme. Since the results are saturated after those seconds, we venture to suggest that there's no need to simulate.

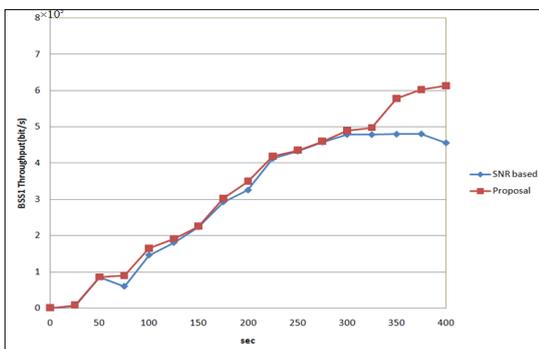
[Table 2] Constant Parameters

Parameter	Value
Start Time	Uniform(1s, 10s)
Service Type	Voice Service
On/Off Modes	On/Off constant 100/0
Packet Slot Time	Constant 0.014s

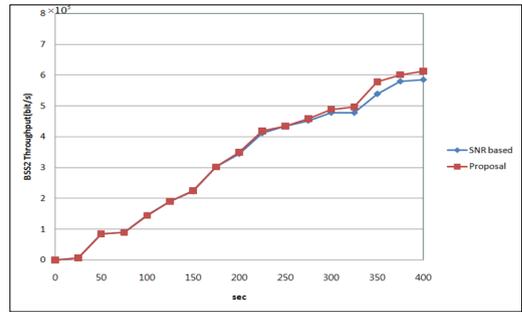
Packet Size	640bytes
Beacon Frame slot time	0.02s
AP num	3
STA num	12, 13, 15
BSS3	3
WLAN	10,000M ²
Service Interval	30s
Data Rate	64k/s
Transfer Rate	11Mbps

4.2 Simulation Result

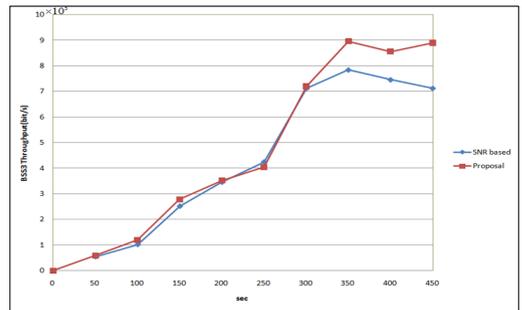
The first simulation experiment Fig. 5 depicts that, under heavy load condition with 40 STAs, our scheme achieves enhanced overall network throughput. We measured the overall throughput of WLAN, BSS1, BSS2 and BSS3, according to the number of STAs. In addition, since our scheme selects lighter loaded APs to use, the overall throughput is not quickly saturated, comparing to SNR based scheme. If the overall WLAN, BSS1, BSS2 and BSS3 has same throughput, then many STAs can join some specific AP and traffic load imbalance will be encountered to us later than the SNR based scheme. Through the comparison, the BSS1 is follows as the Fig. 6. AP neighborhood STAs is the less density then other BSSs. By the BSS2 and BSS3, follow as the Fig. 7, 8, respectively, for the same reason discussed for throughput, our scheme performs the increased when the network will get approach saturation. Our scheme achieved the highest throughput because BSS1 derived the mean traffic load using even more samples. The overall network throughput achieved by our scheme improved 4Mbps. the SNR-based algorithm is 3.5Mbps. So, we found that the proposed scheme improves the throughput by 12.5%.



[Fig. 6] BSS1 Throughputs

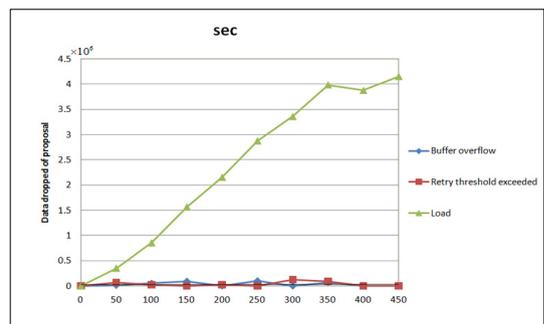


[Fig. 7] BSS2 Throughputs

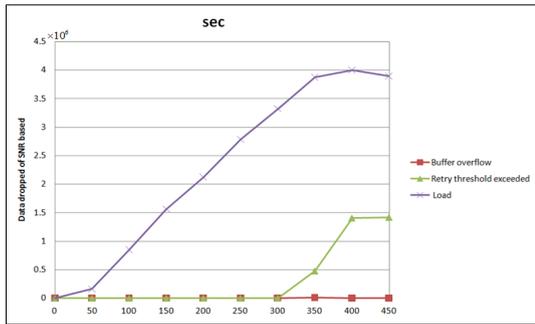


[Fig. 8] BSS3 Throughputs

Follows as the. Fig 9, 10 we have compared the data dropping ratio between our AP selection scheme and SNR-based schemes. This indicates that our proposed AP selection scheme are reduce average packet loss ratio is 0.25% then conventional SNR based algorithm when the load will be balanced. The conventional SNR based algorithm produce a higher packet loss ratio is 12.5%.

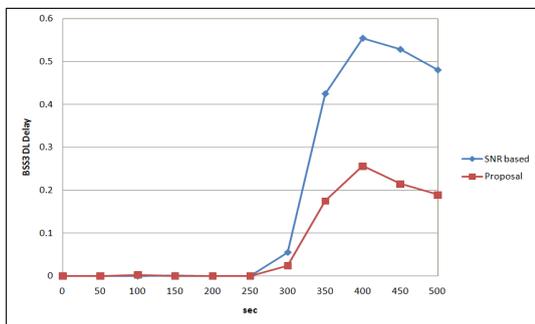


[Fig. 9] Data dropped of proposal

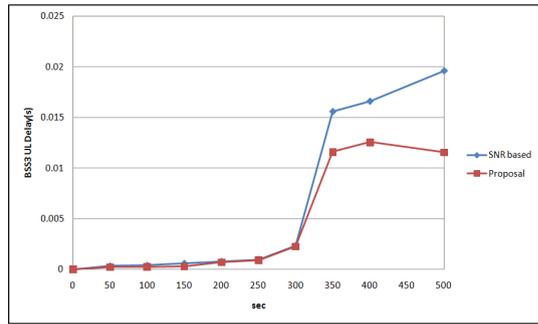


[Fig. 10] Data dropped of SNR-based

By the network topology, AP3 neighborhood STAs is the highest density, our scheme presented to achieve load balancing, derived the BSS3 traffic load. Fig. 11, 12 as shows the delay conditions. That AP need to derive the BSS traffic load, when the network will be approach saturation, the AP Buffer is longest. According to the formula, we measure that downlink delay will be larger than the uplink delay, used our scheme, many STAs can join some specific AP, the BSS3 downlink delay of more than threshold, the new added STAs is select the load smaller BSS1 access. Therefore Fig. 14 shows used our scheme that BSS3 downlink delay and uplink delay are significantly smaller than the value of SNR-base algorithm. The downlink delay is achieved by our scheme improved by 0.19s. The SNR-base schemes is by 0.48s. Our scheme improved by 60.42%. Meanwhile, the uplink delay is achieved by our scheme improved by 0.012s. The SNR-base schemes is 0.019s. Our scheme improved by 36.84%.



[Fig. 11] BSS3 Downlink Delay(s)



[Fig. 12] BSS3 Uplink Delay(s)

5. Conclusion and Future Works

Wireless area local networks have experienced a tremendous surge in popularity in recent years. Currently, the wireless access point selection mechanism is not specified in the IEEE 802.11 standards. The traffic load among different APs are usually not balanced in 802.11e WLANs. This paper presents the scheme to select an AP effectively and balance the load. Extensive simulation has been performed to compare the performance of the proposed AP selection scheme with the conventional SNR-based approach. We found that the proposed scheme improves the throughput by 12.5% and lower the network up/down link delay by 36.84%, 60.42%. The results show that the our scheme can significantly increase overall network throughput and reduce up/down delay. Therefore we can safely say that enhanced voice and video services can be provisioned to users by means of our scheme.

References

- [1] B.P. Crow and J.G.Kim. IEEE 802.11 Wireless Local Area Networks, IEEE Communications Magazine, pp. 116-126, Sep. 1997.
- [2] M. J. Lee and D. S. Park, "Performance Evaluation of Smoothing Algorithms Reflecting Network Traffic," *Journal of the Korean Academic Industrial Society*, Vol.10, No.9, pp.2326-2333, 2009.
- [3] S. R. Huh, et. Al., "Hopping Routing Scheme to Resolve the Hot Spot Problem of Periodic Monitoring Services in Wireless Sensor Networks", *Journal of the Korean Academic Industrial Society*, Vol.10, No.9,

- pp.2340-2349, 2009.
- [4] S. J. Kim, et. Al., "Design and Implementation of Tiny TCP/IPv6 Protocol for Wireless Sensor Networks" *Journal of the Korean Academic Industrial Society*, Vol.10, No.8, pp.1955-1961, 2009.
- [5] Y. Xiao, "IEEE 802.11e : QoS Provisioning at the MAC Layer", *IEEE Wireless Communications*, Vol.11, No.3 , pp.72-79, 2004.
- [6] G. Jubb and P. Steenkiste, "Fixing 802.11 access point selection", *SIGCOMM Comput. Commun. Rev.* Vol.32, pp.31, 2002.
- [7] S. Mangold. et. Al., "IEEE 802.11e Wireless LAN for Quality of Service," *European Wireless*,2002.
- [8] M. Abusubaih, J. Gross, S. Wiethoelter, and A. Wolisz, "On Access point selection in IEEE 802.11 wireless local area networks", *Proceedings of - 6th International Workshop on WLN*, pp.1-8, 2006.
- [9] A. Sang, X. Wang, M. Madhian, and R. Gitlin. "Coordinated Load Balancing Handoff/Cell-Cite Selection and Scheduling in Multi-Cell Packet Data Systems", *Proceedings of ACM/IEEE MOBICOM, Philadelphia, PA, USA*, pp. 302-314, 2004.
- [10] IEEE p802.11b. Supplement to Standard IEEE 802.11, High speed Physical Layer (PHY) extension in the 2.4GHz band. 1999.
- [11] Y. Fukuda, M. Honjo, and Y.i Oie, "Development of Access Point Selection Architecture with Avoiding Interference for WLANs", *IEEE 17th International Symposium on Personal*, 2006.
- [12] J. C. Chen, T. C. Chen, T. Zhang, and Eric van den Berg, "Effective AP Selection and Load Balancing in IEEE 802.11", *Proceedings of Global Telecommunications*, 2006.
- [13] G. Fanglu and C. Tzi-cker. "Scalable and Robut WLAN Connectivity Using Access Point Array", *Proc. Of the 2005 International Conference on Dependable Systems and Networks(DNS'05) Vehicular Technology Conference*, 2005.
- [14] D. R. Pauluzzi, N. C. Beaulieu. "A comparison of SNR estimation techniques for the AWGN channel", *IEEE Transactions on Communications*, Vol.48, No.10, pp.1681-1691, 2000.

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