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POWER SAVING SCHEME FOR WI-FI ACCESS POINTS

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Abstract

To satisfy the increasing demands for high bandwidths, mobility and reliability, high density of access points (APs) are being deployed rapidly in public area, universities, hospitals etc. However, due to the always-on usage model of these APs, huge amount of power is being wasted during low traffic. In this paper, we consider possible energy savings through dynamically turning off the APs. We exploit the knowledge of the distance between the User Equipment's (UEs) and APs for powering off certain APs. Our proposed algorithms are thoroughly evaluated by means of ns-2 simulations. The result shows a significant reduction in power consumption, without compromising Quality of Service (QoS).

I. Introduction

These days with increasing data demand, Wireless Local Area Networks (WLANs) have shifted their deployment objective from providing just basic coverage to designing dense WLANs with redundant layers of APs. These redundant APs are dimensioned to provide very high bandwidth in situations where hundreds of enterprise clients simultaneously run bandwidth-intensive and delay-sensitive applications. One example of such an enterprise WLAN is installed at Intel Corporation's buildings in Portland, Oregon, where 125 APs have been deployed at distances of about five meters from each other within a single four floor building. Although redundant capacity benefits

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enterprise users during times of peak demands, our studies show that peak demand rarely occurs [1]. In fact, only a small fraction of APs are utilized during the day, and even fewer during nights and weekends. The majority of the APs frequently remain idle. Additionally, the existing design approaches lack several key elements. First of all, traffic demand and user density are not considered. The coverage-based optimization approaches may appear insufficient for networks where user density and traffic load are high. However, we argue that these may be insufficient in the future WLAN environments with higher user concentration and data intensive applications.

Hence, the objective of this paper is to develop solution technique to manage WLAN resources to save energy while ensuring end-user performance guarantees. We propose a novel approach for the energy-aware management of access networks, consisting in a dynamic network planning that based on the instantaneous traffic intensity reduces the number of active access devices when they are underutilized. Here the turning on/off decision parameter is dynamically set according to the distance value of client with respect to the access point. As a result, WLAN coverage is still maintained; only redundant coverage is reduced. When user demand increases, WLAN resources are powered on to scale resource and coverage redundancy proportionately. In high-density WLANs, our proposed model strategies thus reduce energy wastage without adversely impacting coverage and end-user performance. Therefore, in this paper, a novel demand based WLAN design model has been developed and formulated which ensure coverage and maintain client performance.

The rest of the paper is organized as follows. Section II discusses related work. System architecture and proposed energy efficient algorithm with implementation measures are discussed in Section III. In Section IV, simulation results are provided to demonstrate that the proposed schemes increase overall system throughput and reduce network power. Section V draws conclusions.

II. Related Work

Reducing power consumption can be achieved on a larger scale by introducing intelligence into the network infrastructure at various levels. Previous work in the field of WLANs relative to reducing power consumption efficiently has been done at various levels, to core [2], edge [3], mobile [4] and data-center networks [5] including construction of the algorithm, design of the infrastructure etc. Several works like [6] proposed approaches to reduce the energy consumption in WLANs, but they mainly focused on the user side, in order to preserve battery lifetime. Jardosh et al.

[1] suggest the adoption of resource on-demand strategies for centrally managed WLANs without adversely impacting the performance of clients in the network. The most important message of this paper is that the energy wasted in large-scale and high-density WLANs can be reduced through on-demand powering off APs, named SEAR algorithm. Another research, a mixed mode [7], which is the combined result of the infrastructure mode and the ad-hoc mode, was introduced to maximize energy efficiency through switching between the ad-hoc mode and the infrastructure mode. Last but not the least, energy harvesting is one of the best resources for energy efficient network. The renewable sources can be easily adopted to supply energy for APs.

III. Proposed Algorithmn

We consider a dense deployed network, where the coverage areas of neighboring cells overlap each other. The network consists of a set of cells that have the same coverage radius and traffic load having the periodic day/night pattern. Figure 1 shows the architecture of the wireless access network on which the proposed scheme is employed. The centralized controller collect information from each AP such as mean received signal strength indicator (RSSI) from User Equipment's (UE), list of neighbor APs, and the number of connected UEs. By using these information, the central controller determines whether each AP should be power-on or power-off. The power-on APs and the power-off APs are defined as active APs and sleeping APs, respectively. Based on distance value, the controller transmits power-on or power-off requests to each AP. The proposed switch off algorithm works as follows:

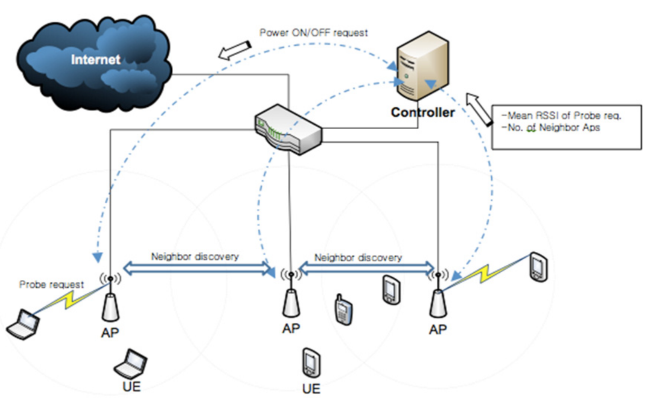


Figure 1. Network architecture.

Step 1. The first step is neighborhood discovery where we determine whether two APs that belong to the same WLAN can be neighbor to each other. In this technique, every AP will transmit beacon message in regular interval of time and neighboring APs use to hear and update its neighbor table after receiving *n* beacons and remove from the table after *m* missed beacons.

Step 2. At the second step, UEs send a probe request to all channels in order to localize the AP. Each AP estimates the RSSI value of the probe request from UEs from its own clients as well from neighboring APs and this information is stored in the AP for statistical purpose.

Step 3. The APs calculate the average distance of the traffic load based on the results of the second step. The APs are ranked based on the estimated average and they are examined from the top one with the maximum average distance value, which is less than the average RSSI probe power.

Step 4. The first AP is switched off if it exceeds threshold number (depends on network size) of the neighboring APs in its neighboring table and the number of connected users.

Step 5. The algorithm continues with the next APs in the list, until less than equals to the half of APs are switched off.

Once the APs have been identified to be switched off, it is not possible to just switch off the APs because number of users might be presently accessing the candidate AP. There can be three different possibilities we can think off [8]. First one is, the network waits until no user is accessing the candidate AP, i.e., switched off only when idle. This is the least disturbing approach for users, but a drawback is that the time between the switch-off decision and the AP idling may be long, thus limiting the effectiveness of the energy saving approach. Secondly, no new service requests are accepted by the AP. In this case, the delay between the switch-off decision and the actual switch-off is less than in the previous case, but still it coincides with the longest residual time of the services in progress. Last one is, immediately after the switch-off decision is taken, users are forced to implement a handover from the AP that is going to be switched off to one of the APs that remain active. This is the invasive approach for users, but forced handovers are foreseen by WLAN standards, and thus the algorithm is well within the possibilities of present WLANs equipment. Actually, forced handovers are previously used by many operators, called as Blacklisting, where access control black lists to enforce a client handoff between APs. The advantage of using black-lists on APs is that the clients are forced to associate with only those APs on which they are not black-listed. Hence, the time between the switch-off decision and the actual switch-off can be controlled by the operator, and kept very low to maximize the energy.

Table 1. Simulation parameters

Traffic Model	
Model	Poisson
Packet Size	100 bytes
Rate	5-1000kbps
Radio Network Model	
Propagation Model	Two Ray Ground
Coverage	250m
Area	1000×500m 1000×1000m
Energy Model	
Rx Power(watts)	0.5
Tx Power(watts)	0.75
Sleep power(watts)	0.002
Node Model	
Time (sec)	30

IV. Simulation

We use NS-2.35 as a network simulator. We test our algorithm for different scenarios with varying numbers of access points. In each iteration of the simulation, APs generate traffic according to the Poisson distribution. The packet size use for the simulation is 100kb and the rate varies from 5kbps to 1000kbps. The simulation was observed for 30 sec. For the calculation of the power consumption, we consider the power that is consumed in the APs for the downlink transmission. Models and simulation assumptions are selected according to the 802.11 evaluation criteria (summarized in Table 1). For neighborhood discovery, we deployed APs to transmit a beacon signal every 0.02 sec so that neighborhood APs can detect the signal and add it to the neighborhood APs table for further processing. We apply the active scanning process where the entire client starts scanning the channel, which is done through sending multiple probe requests and recording the probe responses. Dump agent has been used as a routing protocol to direct all the packets through the AP. Three different network conditions have been tested for exactly same traffic pattern and node positions. The first experiment was tested with all APs On with full power. In the second case, we randomly turn off the APs. In the third case, APs radio is turned off on the basis of the purposed algorithm and power consumption and throughput was measured for different traffic generation rates. The two metrics power consumption and throughput have been chosen for performance analysis of the networks.

(a) Scenario 1. The first scenario checks the infrastructure mode operation in a simple topology composed of 3 APs and 4 UEs in 1000×500m area. While nodes 0, 1 and 2 are APs, nodes 3, 4, 5 and 6 represent 4 UEs as shown in Figure 2. From an analysis Figure 4(a) of the data, we can say that by using a distance aware switch off mechanism, we reduce the energy consumption of the whole network for the same amount of traffic generation. We assume that all APs can be switched off for about 12 hours, saving 31% of power consumption during the night compared to the random switch on/off algorithm. Our proposed scheme achieves up to 1.44 % more efficiency. Figure 5(a) shows the average UDP throughput achieved by the network for various data rates with three different experiment scenarios. We observed that when our proposed method is used, the average throughput received by clients was 3.1% less than the throughput received in the always-on case. This small drop in average throughput occurs because some of the APs are powered off and the clients associated with an AP that does not provide them with the highest throughput. Fortunately, the drop in throughput is not too high. We believe that WLANs with a higher density of APs and/or stricter neighborhood AP conditions are likely to have an even smaller impact on client performance. It clearly illustrates that although 40% of APs have been switched off the whole network throughput sees unremarkable change.

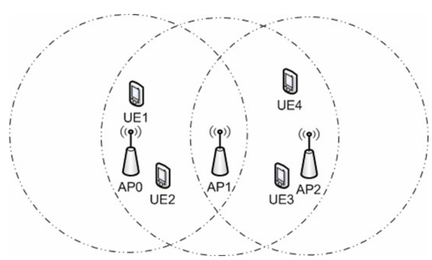


Figure 2. Scenario 1.

(b) Scenario 2. The second scenario was checked with a grid topology composed of 9 APs with 10 UEs in 1000×1000m area. While nodes 0 to 8 represent APs, nodes 9 to 18 represent 10 UEs in the random position (see Figure 3).

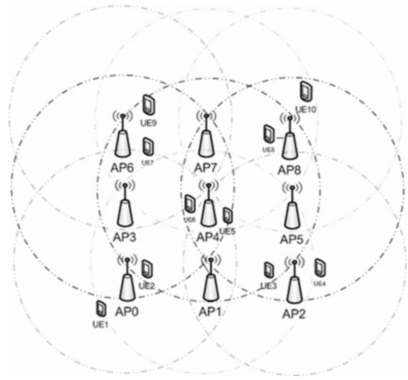
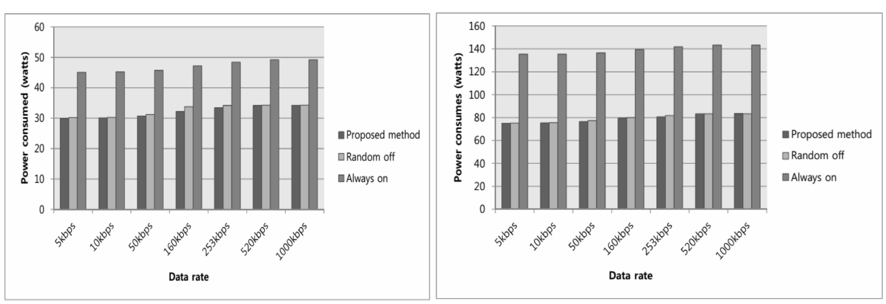


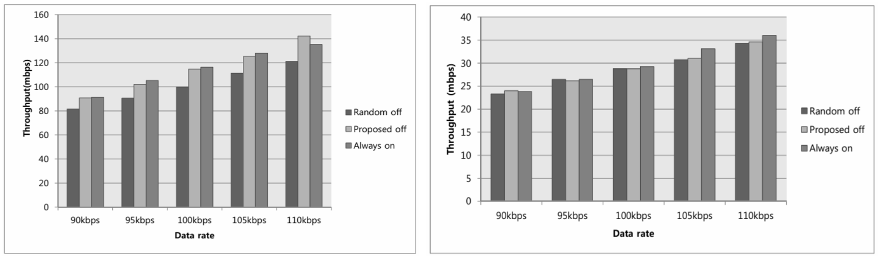
Figure 3. Scenario 2.

Similarly, when we apply the random switch on/off scheme, we assume that AP0, AP3, AP4, and AP8 are switched off based on a random decision. However, according to our proposed algorithm, AP1, AP3, AP5, and AP7 are switched OFF according to the result of the RSSI power calculation [9]. From analysis of the data, we can say that by using a distance aware switch off mechanism, we can reduce the energy consumption of the whole network by 40 % (see Figure 4(b)) of energy saving by turning off less than half of the network and over a random switch-off, our proposed scheme has a higher percentage of energy savings. In addition, we achieved a very small drop in average throughput. The drop in throughput was just 2%, (see Figure 5(b)) which is very good for client performance. For comparison, with the random-off case scheme, we can see that the network throughput degrades by 12.47%.



(a) Scenario 1 (b) Scenario 2

Figure 4. Analysis of power consumption vs. data rates.



(a) Scenario 1 (b) Scenario 2

Figure 5. Analysis of throughput vs. data rate.

V. Conclusion

This paper proposed the power saving scheme by turning off unnecessary APs for wireless access networks where many APs, each providing full coverage and service during peak traffic time, but offering redundant resources when traffic load is low. We introduced a distance-aware algorithm that achieves a significant reduction in power consumption, without compromising the offered QoS. In particular, we proved how important is to efficiently choose the APs to be switched off during low traffic periods, by considering the distance of the UEs from the APs. Our results indicated that we could save up to average of 30% to 40% of the power consumed to operate the network, by decreasing the number of the active APs during low traffic periods. The most important message of this paper is that the energy wasted in large-scale and high-density WLANs is a new and serious concern. We stress that energy-efficient mechanism for large-scale and high-density WLANs be designed and developed today to save energy in future WLANs and thus avoid the escalation of energy wastage.

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References

[1] A. P. Jardosh, K. Papagiannaki, E. M. Belding, K. C. Almeroth, G. Iannaccone and B. Vinnakota, Green WLANs: on-demand WLAN infrastructures, Mobile Networks and Applications 14 (2009), 798-814.

[2] J. Chabarek, J. Sommers, P. Barford, C. Estan, D. Tsiang and S. Wright, Power awareness in network design and routing, The 27th Conference on Computer Communications, INFOCOM 2008, IEEE, Phoenix, AZ, 2008.

[3] P. Tsiaflakis, Y. Yi, M. Chiang and M. Moonen, Green DSL: energy-efficient DSM, 2009 IEEE International Conference on Communications, Dresden, 2009, pp. 1-5.

[4] L. Chiaraviglio, D. Ciullo, M. Meo and M. A. Marsan, Energy-efficient management of UMTS access networks, 21st International Teletraffic Congress, ITC 21 2009, Paris, 2009, pp. 1-8.

[5] J. Shuja, K. Bilal, S. A. Madani, M. Othman, R. Ranjan, P. Balaji and S. U. Khan, Survey of techniques and architectures for designing energy-efficient data centers, IEEE Systems Journal 10(2) (2016), 507-519.

[6] X. Zhang and K. G. Shin, E-MiLi: energy-minimizing idle listening in wireless networks, IEEE Transactions on Mobile Computing 11(9) (2012), 1441-1454.

[7] J. Chen, S.-H. G. Chan and S.-C. Liew, Mixed-mode WLAN: the integration of ad hoc mode with wireless LAN infrastructure, Global Telecommunications Conference, GLOBECOM'03, IEEE, 2003, pp. 231-235.

[8] L. Chiaraviglio, D. Ciullo, M. Meo and M. A. Marsan, Energy-aware UMTS access networks, Proc. First International Workshop on Green Wireless in Conjunction with WPMC, Lapland, Finland, 2008.

[9] H. Zhu and T. Alsharari, An improved RSSI-based positioning method using sector transmission model and distance optimization technique, International Journal of Distributed Sensor Networks, 2015, Article ID 587195, 11 pp.