Traffic Reduction: A Wifi Energy Efficiency Management

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Abstract: ***Wi-Fi (Wireless Fidelity) is a popular technology that allows an electronic device to exchange data wirelessly (using radio waves) over a computer network, including high-speed Internet connections. The Wi-Fi consists of Access Points (AP) and several clients. Large number of clients makes use of single AP's. This will lead to traffic, which in turn lead to loss of energy and battery lifetime in Mobile Devices. One of the early protocols used is Power Save Mode (PSM) in which the client wakes up periodically. The solution is that, there contains a technology called SleepWell, a system that achieves energy efficiency by evading network contention. That is, the client will give the request to the AP and battery of the mobile devices will be in sleep mode. The Access Points regulates clients sleeping window in which the AP's may be active or inactive during the process. It also dynamically schedules the requests that are given to the AP by clients. And finally provides the response to the client. As soon as the response from the AP is provided, the mobile devices will come to active mode again. The solution is analogous to the common wisdom of going late to office and coming back late, thereby avoiding the rush hours. The technique used in this is SleepWell Queuing Technique in which the traffic can be avoided and the battery lifetime of the mobile devices can be maintained. The gain will be more even when the WiFi links are weak.***

Keywords: Wireless Fidelity (WiFi), Access Points (AP), SleepWell, Power Save Mode (PSM), Network Traffic.

1. Introduction

The emergence of mobile computing has introduced various challenges and research opportunities, one of which was energy management in mobile devices that arose from the mobility of used hardware. Such hardware includes devices such as cellular phones and laptop computers. The mobility of these devices implies that they are powered by mobile power sources represented by the battery of each device; and that, in turn, implies that the power source is limited.

As these devices become more popular, and their use becomes more apparent and frequent, the need to manage their energy consumption becomes more vital to their operation. This is because the more often a battery needs to be charged, the more often the mobile device is rendered immobile. The problem of energy management within mobile devices has gained a lot of attention. This is due to the increased number of mobile devices by a large number of users.

Smartphones, for instance, are rapidly becoming the convergent platform for a large variety of network applications, including e-mails, music, videos, games, web browsing, and picture sharing. In addition, background applications are continuously running push-based alert services, location-based notifications, and periodic sensor updates. This growth in network traffic is beginning to impose a heavy demand on the phone battery, to the extent that some users are already expressing dissatisfaction.

The inability to cope with the energy demands can be serious, and may even hinder the steady growth in the mobile computing industry. Among the typical network interfaces found in today's mobile devices, Wi-Fi provides arguably the best combination of throughout, range, and power efficiency for data transfers. On the downside, Wi-Fi is the least power efficient in idle state and incurs a high overhead when scanning for new networks WiFi network communication is a predominate source of energy consumption. This has been well known for many years, and a rich body of research has addressed the problems in various ways.

For example, WiFi Power Save Mode (PSM) is one of the early protocols that attempts to turn off the device whenever beneficial. While WiFi energy efficiency has progressively improved since PSM (with the most recent NAPman protocol offering substantial gains), we find that there is still an opportunity for improvement. We describe this opportunity by first describing the core ideas in PSM and NAPman, and then identifying their respective deficiencies.

The basic power saving method is to put the wireless network interface (WNI) into the sleep mode when it is idle, e.g., IEEE 802.11 power saving mechanism. However, 802.11 power saving mode (PSM) may increase the connection round trip time due to the lagged data reception, and thus may significantly degrade the throughput of TCP-based applications. In order to achieve a high TCP throughput, the WNI has to be active to generate timely acknowledgments for received data. As a result, a significant amount of energy is wasted on channel listening.

For applications like TCP-based streaming media, which has strict requirements on packet delay and can quickly drain out the battery of mobile devices, it is difficult to explore the trade-offs between the power saving and the caused delay to applications. To overcome this, a technique used is SleepWell. Briefly the AP tracks the periodicity of nearby AP. It dynamically reschedules it own period to avoid overlap among themselves. This will reduce the competition among various clients to download their own packets uninterrupted and sleep when the channel is occupied by other transmissions.

The main design challenges in SleepWell appear from:

1. Distributedly scheduling traffic to achieve quick convergence.
2. Ensuring disassociation of clients during dynamic rescheduling.
3. Preserving channel utilization, latency, and fairness, even under traffic variation and node churn.

SleepWell addresses these systematically, while requiring no software changes at the client. By carefully modifying the time stamps (as a part of the WiFi clock synchronization process), the SleepWell AP regulates the client's sleep and wake-up schedules. The client remains unaware of the changes in its own duty cycle; neither does it get disassociated. 802.11a/g/n standard-compatibility remains intact.

The power saving mode can be most effectively managed if the streaming traffic flowing to a client is in a predictable pattern, such as periodic bursts. Accordingly, the client can accurately adapt to streaming traffic pattern to sleep and to work periodically. Therefore, the power consumption on the client device is maintained.

2. Existing Measures

Mobile devices are increasingly equipped with multiple network interfaces with complementary characteristics. In particular, the Wi-Fi interface has high throughput and transfer power efficiency, but its idle power consumption is prohibitive. To overcome this large number of protocols and procedures are used previously. Some of the protocols used are PSM (Power Save Mode), NAPman, ZMAC (Zebra MAC), SMAC (Simple MAC) and Blue-Fi Bluetooth Signaling. These protocols make use of several methods.

The 802.11 standard allows these devices to save power through an energy-conserving Power Save Mode (PSM). However, depending on the PSM implementation strategies used by the clients/Access Points (APs), we find competing background traffic results in one or more of the following negative consequences: a significant increase, up to 300%, in a client's energy consumption, a decrease in wireless network capacity due to unnecessary retransmissions, and unfairness.

NAPman: Network-Assisted Power Management for WiFi devices that addresses the above issues. NAPman leverages AP virtualization and a new energy-aware fair scheduling algorithm to minimize client energy consumption and unnecessary retransmissions, while ensuring fairness among competing traffic. In case of ZMAC protocol they make use of combined features of CSMA and TDMA. Here, finding the clients associated with the access point makes difficult.

In case of SMAC protocol the task presented within the AP are dynamically scheduled. Thus, new clients entering within the AP's cannot be scheduled and the responses provided to them are delayed. During PSM and NAPman protocols the client after sending the request to AP's will go to sleep mode.

And the wakeup of these clients are done periodically. Hence, the response to the clients are provided only when the clients wakes up.

2.1. Impact of Network Contention on Energy

Energy consumption is a function of a large number of parameters (hardware, traffic, bit rates, mobility, topology, density, etc.). Measuring over all permutations of this parameter space is difficult. We have narrowed down the space to a smaller set of common-case scenarios, and report measurements from them.

2.2. Impact of Background Traffic

In Scheduled PSM, it is observed that background PSM unicast and multicast traffic can result in energy drain on static PSM clients. The authors refer to competing PSM flows as background traffic relative to a selected PSM client, whereas we generalize the notion of background traffic to include other CAM clients associated to an AP. Scheduled PSM overlays a TDMA-like structure over 802.11 whereby the beacon period is divided into *time slices* and each PSM client's packets are delivered only in its advertised time slice.

This is achieved by changing the TIM field in the 802.11 standard to include new slicing control and slicing map fields that indicate the number and offset of the time slices in the beacon interval. At the beginning of each time slice, the AP takes control of the channel by using either RTS/CTS or Self-CTS, and schedules traffic for the appropriate PSM client during that interval. However, this solution requires modifications to the 802.11 standard and, thus, changes to both mobile clients and APs are necessary.

3. Related Work and Design

Maintaining the traffic within WiFi and also maintaining the battery lifetime of mobile devices is a broad research area today. Many researchers have done research and found numerous results.

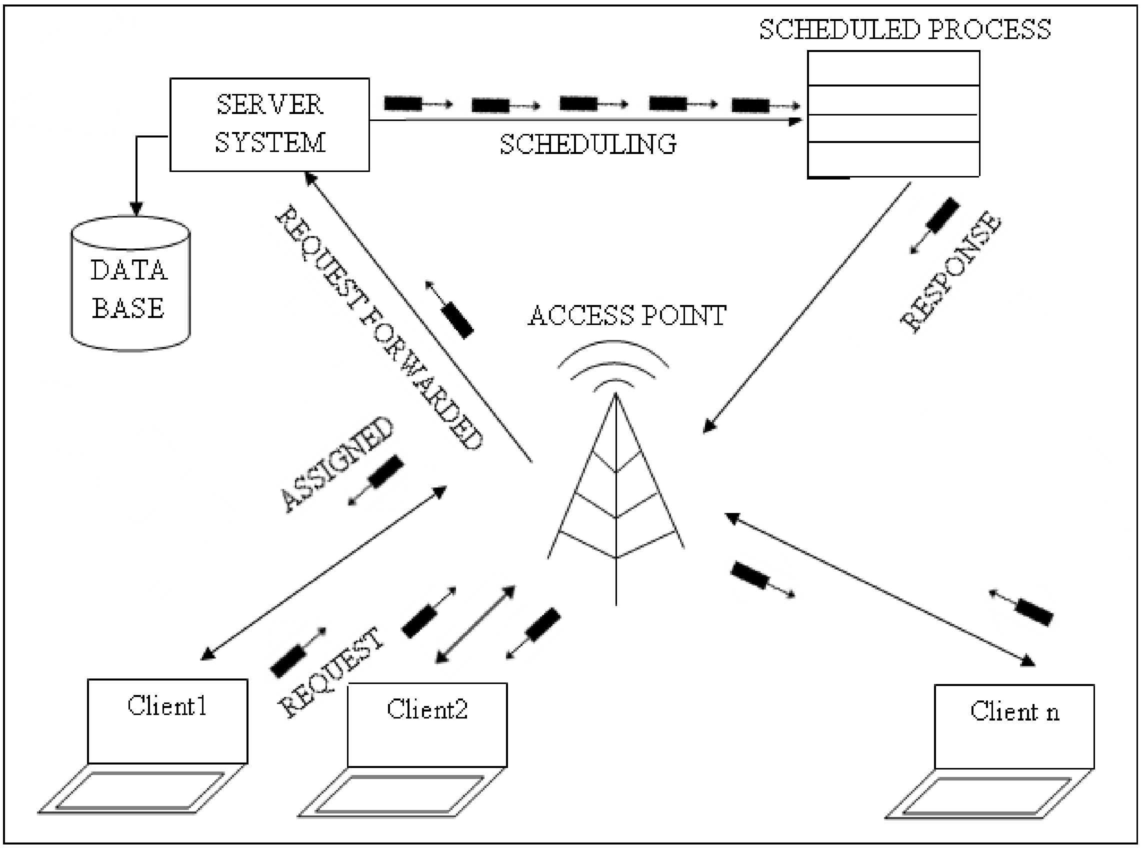

Figure 1: Architecture diagram of Access Point Processing

3.1. Sleepwell Basic Design

The major modules presented in maintaining the traffic within WiFi devices are

1. Network setup and traffic identification
2. Traffic monitoring within the network
3. Traffic migration to another AP
4. Traffic preemption mechanism
5. Dealing with Traffic Dynamics
6. Seamless Beacon Readjustment
7. Multiple Clients per AP
8. Load balancing among the AP

3.1.1. Traffic Monitoring Within the Network

Here to implement a SleepWell AP, also listens for ongoing beacons, and identifies which other APs are within its collision domain Observe that beacons are transmitted at base rate, and hence, are audible over the carrier sensing zone of an AP. Each AP assimilates this information into a traffic map that captures when each of its contending APs start their beacon intervals. The maps can clearly be different at different APs, depending on the AP's neighborhood.

3.1.2. Traffic Migration to another Ap

To implement the traffic migration process, given n other contending APs in the traffic map, each AP computes its fair share of the channel. The fair share is expected to be at least one client. Each AP also computes its actual share of the channel as the time from its beacon to the immediate next (in the clockwise direction). If an AP's actual share is less than its fair share, and assuming that the AP has saturated traffic, the AP is said to be unsatisfied. Now, each unsatisfied AP looks into its traffic map and finds the largest inter beacon interval, not including its own beacon denotes the start and end points of this interval as T start and Tend. If this interval is twice that of the AP's fair channel share, then the AP moves its own beacon to the midpoint of this interval.

3.1.3. Traffic Preemption Mechanism

The traffic preemption mechanism process is implemented here. SleepWell employs a simple preemptive mechanism. When AP i observes that its traffic is likely to "spill" into AP j's, it turns off the MORE_DATA flag in the subsequent data packet, forcing its client to go to sleep until the next listen interval. This permits AP j's transmissions to progress without competition, reducing time to completion. When AP i's client wakes up at the next PSM beacon, AP i transmits the pending packets. Now the other APs preempt their respective transmissions, allowing AP i to use the channel without contention. This is indeed a loose form of TDMA, where clients "avoid the rush hours" and sleep instead.

1) Any PS-Poll from any of AP j's PSM clients;
2) AP j's download packets with the ORE_DATA flag enabled; or
3) An ACK from one of AP j's clients. Steps 1 and 2 may not be always feasible as high bit rate transmissions may prevent overhearing at AP i. Step

3 is more robust, as ACKs are transmitted at a lower bit rate, often at half the transmission rate of the preceding uncast packet. In case all of these techniques fail, SleepWell defaults to a simple inference scheme. AP i look into AP j's prior beacons to see if AP j has pending traffic for any of its clients (recall that the beacon TIM embeds pending traffic information).

3.1.4. Dealing with Traffic Dynamics

In order to perform the traffic dynamic modified SleepWell, although the pseudo code seems involved, the key idea is simple. In face of varying traffic demands, we require SleepWell APs to advertise the minimum of the needed channel share and the available channel share. AP3 will advertise 1/5 if it has adequate traffic to fill up its own slot. Otherwise, if it has queued traffic only for, say 1/7 channel time, it advertises 1/7. Knowing this information, the traffic map can be updated to additionally reflect the burst following each PSM beacon. This facilitates efficient traffic migration.

3.1.5. Seamless Beacon Readjustment

To implement, whether SleepWell APs can reposition clients without client-side changes and re-associations. The key idea here is to manipulate the TSF timestamps in advertised beacons. As mandated by the 802.11 standard, clients treat these timestamps as authoritative, and correspondingly update their clocks to a new beacon schedule. By advertising different beacon schedules to different clients, SleepWell APs move clients between beacons until a desirable distribution is reached.

3.1.6. Multiple Clients per AP

In order to implement, more than one client is moved from one beacon schedule to another when it receives a manipulated (but authoritative) beacon TSF clock value. Upon the next wake up on the new schedule, the client must receive a clock value in line with the new schedule or else it will again be migrated.

Thus, the clock value advertised by beacons on the new schedule must reflect the time separation between the old and new schedules. If other clients are already listening to the "new" wake-up schedule (and are not to be migrated elsewhere), their clock value should not be changed. To prevent disruptions to any client, and yet allow migrations from one wake-up schedule to another, the initial clock values for each beacon schedule are selected to represent the time Difference between a pair of successive beacons.

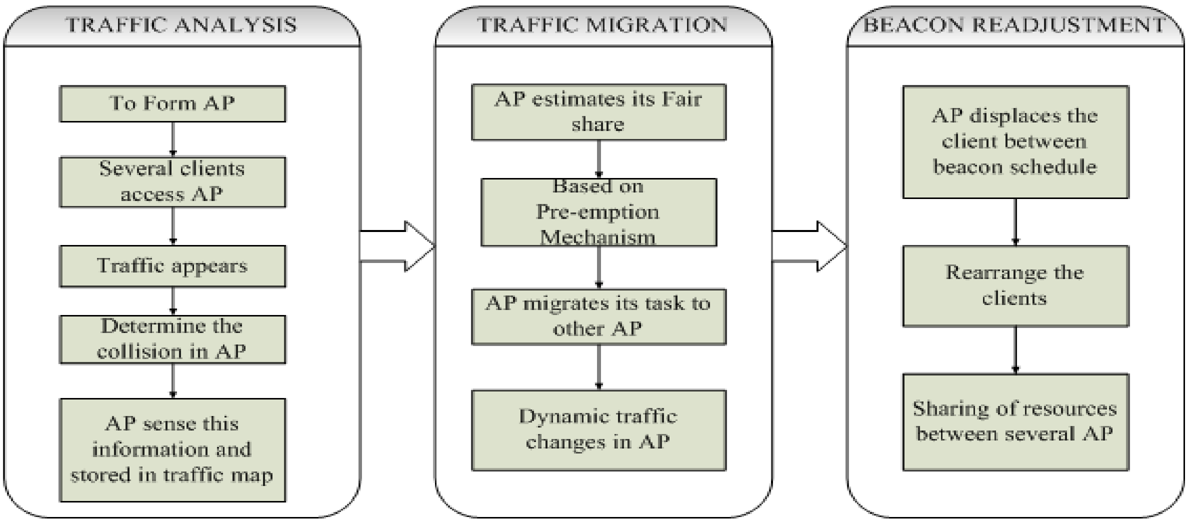

Figure 2: The process done within the access point

3.1.7. Resource Sharing Among the AP

Here all the access points are sharing the resource within the network. Because any access point has occurring the preemption and overload process are reducing the energy consumption. The particular access points are sharing his information to all access point it will help to reduce the particular AP energy consumption. These processes are applicable to all AP.

3.1.8. Load Balancing Among the AP

During this, if any one of the AP is overcrowded then the loads are balanced. The AP with less number of clients are found and the clients of the crowded AP are distributed to other APs. Thus the WiFi may response to the clients easily and the traffic occurred within them is less.

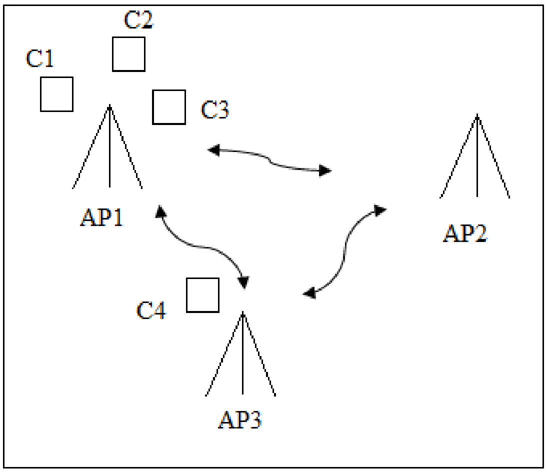

Figure 3: AP with crowded clients

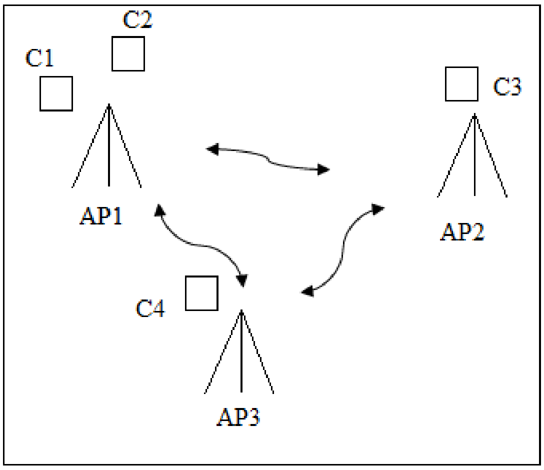

Figure 4: Balanced AP

The Fig. 3 and Fig. 4 clearly explain about load balancing among APs. In Fig 3, AP1 is overcrowded where AP2 is in idle mode. Thus, to avoid traffic occurred within the AP1, the client C3 presented in AP1 is forwarded to AP2. Thus, each of the AP presented will contain minimum amount of client. And the process within the WiFi is done faster. The traffic within AP1 is avoided.

4. Basic Terminology

4.1. Power Save Mode (PSM)

A polling based power optimizations provided by IEEE 802.11 standards in order to maintain the battery lifetime of mobile devices.

4.2. Beacon Interval

A specific or fixed time duration between two successive access points beacons, typically 100ms.

4.3. Listen Interval

The interval at which a client chooses to wake up to listen for one AP beacon. Listen intervals are an exact multiple of the beacon interval.

4.4. More Data Flag

Flag embedded in download a unicast data packet that specifies weather more data packets are queued at the AP for the PSM client. Once this flag is set to false, the client may immediately return to sleep.

5. Limitations and Discussion

In this section, we discuss practical challenges for a SleepWell deployment.

5.1 Impact of Hidden Terminals

Hidden terminals complicate SleepWell, as much as it does 802.11. They may cause collisions, forcing a client to stay awake longer, and thereby, increasing the energy overhead. While hidden terminals are mostly mitigated by carefully tuning the carrier sense threshold and bitrates, SleepWell can adopt countermeasures to alleviate the problem. Specifically, since the hidden APs will also impose bursty traffic, a SleepWell AP may observe that its download packets are failing despite a high SNR to its client. The download SNR can be inferred from SNR of upload packets, coming back over a roughly symmetric link. At this point, the SleepWell AP can assume a "virtual beacon" on its traffic map and readjust its own beacon as per the protocol heuristic.

5.2 Incremental Deployability

Thus far, our discussion has assumed all APs in the wireless vicinity to be running SleepWell. For practicality, SleepWell must be and is incrementally deployable; it is also able to coexist with legacy access points with fixed beacon schedules and no traffic preemption. SleepWell APs treat legacy APs identically for the purpose of beacon placement. Although the latter will not readjust to obtain their fair share of the beacon interval, they can still be expected to have bursty PSM traffic starting with a PSM beacon. Thus, the time period immediately following their beacon is best avoided.

5.3 Interactive Traffic

SleepWell is not intended for interactive, highly latency sensitive traffic (e.g., VoIP). PSM explicitly forgoes support for low-latency operation for energy savings; SleepWell is subject to the same pitfalls.

5.4 TSF Adjustment

The mechanism for adjusting the TSF clock (to migrate clients to a new beacon schedule) has no side effect. However, we cannot guarantee this to be universal among all devices.

6. Conclusion

The design of SleepWell is based on client frees up time to sleep, ultimately resulting in promising energy gains with practically negligible loss in performance. The SleepWell enabled WiFi access points can stagger their activity cycles to minimally overlap with others, ultimately resulting in promising energy gains with negligible loss of performance. Load balancing within WiFi plays a major role and maintains the clients presented within WiFi. Hence the overcrowding of clients among APs is avoided. With cloud computing on the horizon, mobile devices will need to access the Internet more frequently. Thus the process is going on based on the technology to maintain traffic within WiFi and also to maintain the lifetime of mobile devices.

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