Poster Abstract: Trace-based Analysis of Wi-Fi Scanning Strategies *

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The number of smartphones in use is overwhelmingly increasing every year. These devices rely on connectivity to the Internet for the majority of their applications. The ever-increasing number of deployed 802.11 wireless access points and the relatively high cost of other data services make the case for opportunistic communication using free WiFi hotspots. However, this requires effective management of the WLAN interface, because by design the energy cost of WLAN scanning and interface idle operation is high and energy is a primary resource on mobile devices. We study several heuristic strategies for interface management, and use real-world user traces to evaluate and compare their performance against the optimal algorithm. Trace-based simulations show that simple static scanning with a suitable interval value is very effective for delay-tolerant, background applications.

I. Introduction

Constant access to the Internet on smartphones enables a plethora of mobile applications. The wireless networking technologies on todays smartphones that can be used toward this purpose are: 802.11 and cellular technologies such as EDGE or EVDO, and recently 3G technologies.

Although cellular networks are virtually available everywhere, accessing the Internet over Wi-Fi is preferred for the following reasons:

1. As a short-range wireless technology, Wi-Fi provides higher bit rate and consumes less energy per byte [1].
2. In many countries cellular data plans are too expensive while home and work Wi-Fi access is almost free.

However, accessing the Internet using Wi-Fi on smartphones requires careful management of the WLAN interface, because the career sense design of 802.11 makes scanning and idle operation of WLAN interfaces more expensive than cellular technologies.

In this work we evaluate the performance of several WLAN scanning strategies on smartphones using real-world mobility traces. We identify the trade-off between the energy consumption resulted from scanning and the missed opportunity for each strategy. We discover that static scanning presents a good performance both in terms of the number of scans and the daily missed opportunity.

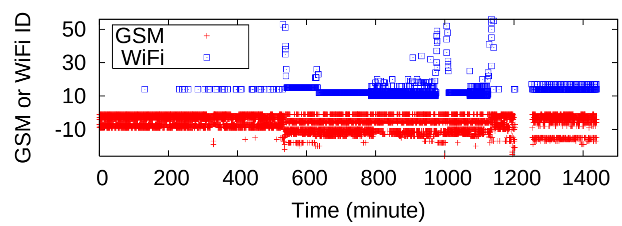

Figure 1: Visualization of a typical day

II. Experiments

Six iPhones with firmware version 1.1.4 were instrumented to scan on both the WLAN and GSM interfaces periodically. Using the unofficial iPhone SDK, we developed two scanning tools: *TCLAPLogger* and *TCLGSMLogger*.

Each execution of TCLAPLogger commands the WLAN interface to perform an active scan on all the channels, and print ESSID[1], BSSID[2], a bit that is set to 1 if the access point is WEP/WPA enabled, and the signal strength for each discovered access point.

Each execution of TCLGSMLogger commands the GSM interface to scan for the visible GSM cell towers. For each discovered tower it prints the service Mobile Network Code ID, Cell Location ID, Cell ID,

*This work was done while the first author was a student at the University of Waterloo.

[1]Extended Service Set Identifier is a human readable string that identifies the wireless LAN.

[2]Broadcast Service Set Identifier is the MAC address of the station in the access point.

and signal strength. We use the combination of MNC, LAC and CI as the unique cell ID.

A daemon on the iPhones runs these two commands frequently and records their output along with a time stamp in a file on the local file system. The iPhone service start-up system was configured to launch this daemon on system start-up, and relaunch it if it dies for any reason.

A pilot test was used to find a suitable value for the scanning interval. We found that any interval less than 60 seconds reduces the battery life to less than a day. Therefore one minute seemed the best scanning interval.

The six iPhones were given to six volunteers: two graduate students, two undergraduate students, a faculty member and a staff person. The volunteers were asked to use the iPhones as their cell phones (i.e., place their SIM cards in the iPhone). This provided enough incentives for the participants to keep the smartphone charged all the time and carry it with themselves. The experiment lasted for five weeks through June and July 2008.

The six subjects scanned 5709 unique Wi-Fi access points over the period of five weeks. The number of scanned access points, and GSM cell towers for each user is plotted in bar charts in Figure 2. User 4 has visited considerably more Wi-Fi and GSM IDs than all the other users, because she has had two long trips (one out of the country). Also, unfortunately, user 5 did not carry the iPhone with him regularly.

Figure 1 visualizes a sample day of the dataset. Each GSM ID has been assigned a unique negative integer ID, and each BSSID has been assigned a positive integer greater than 10. For each sample point, each GSM ID is marked with a red plus and each BSSID is marked with a blue square. In this figure, the [1253, 1438] interval is a continuous Wi-Fi *availability block* and [1204, 1253] is an *unavailability block*.

Table 1 summarizes statistics about each user, after encryption enabled access points have been filtered from the dataset. The *availability rate* in each day is the ratio of the day that the user is covered by Wi-Fi. User number 1 is a staff person who does not use wireless at home, and has the lowest availability rate among the users. Excluding this user from the dataset increases the average availability rate to 0.78, which is higher than our initial expectation. This finding confirms that by taking advantage of Wi-Fi opportunities, smartphone users can save considerable energy. The mean length of the availability blocks is 976 seconds (about 16 minutes).

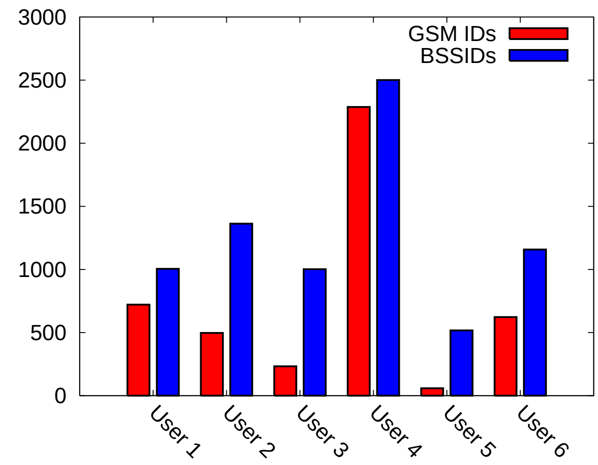

Figure 2: Comparison of the number of scanned GSM and Wi-Fi IDs by different users.

III. Evaluation of Scanning Strategies

In this section we introduce three WLAN scanning strategies: Naïve, Static, and Exponential Back-off. We consider two performance metrics: number of scans, and missed opportunity. Missed opportunity is the ratio of the Wi-Fi opportunity detected by the scanning strategy to the total available opportunity.

The Naïve strategy scans the medium in a tight loop until it detects a usable [3] Wi-Fi opportunity. It has the lowest missed opportunity among all scanning strategies, but at a potentially high scanning cost. The Static strategy scans the environment with a fixed interval. The scanning interval can be used to adjust the energy consumption and missed opportunity of this strategy. The Exponential Back-off strategy exponentially increases the scanning interval every time a scan fails to find a usable access point.

We used trace-based simulation, using the Opportunistic Connectivity Management Simulator [2] to compare the performance of these scanning strategies against the off-line optimal. In the results that will be presented, each day is simulated separately, therefore the simulation results refer to the average of all days for each user.

Figure 3 plots the average number of scans performed by the Static, with five minutes intervals, Exponential Back-off, and the off-line optimal strategies. Except for user 1, the Static strategy performs fewer scans than Exponential Back-off.

Figure 4 plots the average missed opportunity of the two strategies for each user. The missed opportunity of the Static strategy is consistently less than that of Exponential Back-off for all users. The difference is the highest for user 1. The Exponential Back-off strat-

User	Availability	APs per scan	Blocks per day	Missing samples/day
1	0.14 ± 0.13	0.24 ± 0.23	16 ± 18	41 ± 162
2	0.90 ± 0.20	1.78 ± 0.59	43 ± 21	41 ± 163
3	0.61 ± 0.18	0.90 ± 0.31	163 ± 76	87 ± 204
4	0.78 ± 0.24	4.02 ± 2.03	143 ± 108	70 ± 196
5	0.90 ± 0.15	2.74 ± 1.01	138 ± 93	115 ± 331
6	0.72 ± 0.21	1.32 ± 0.59	135 ± 446	42 ± 164
Avg.	0.62 ± 0.26	1.83 ± 1.24	135 ± 55	66 ± 27

Table 1: Summary of availability information for the Waterloo dataset. Missing samples are treated as unavailable times

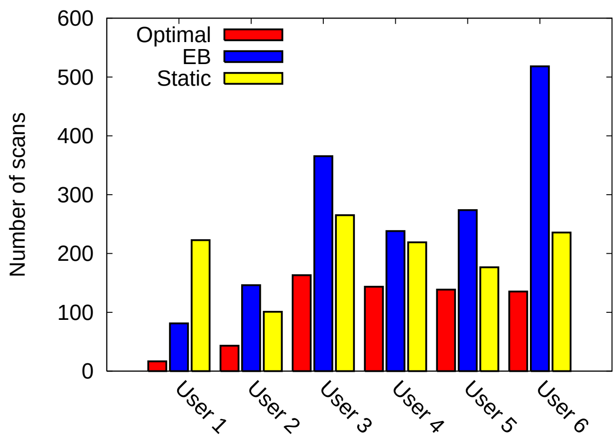

Figure 3: Comparing the number of scans performed by Optimal, Static, and Exponential Back-off strategies on the Waterloo dataset

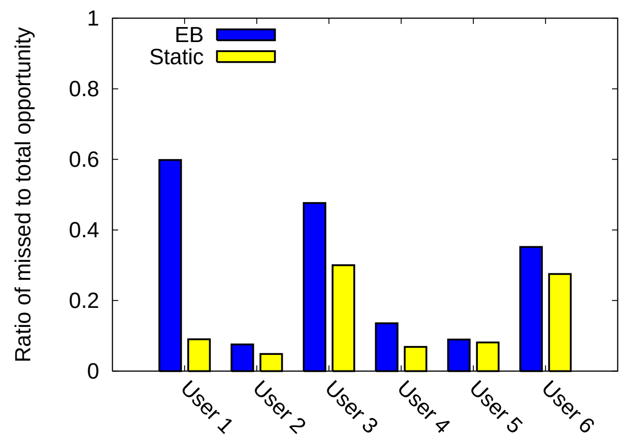

Figure 4: Comparing the missed opportunity by Static, and Exponential Back-off strategies on the Rice dataset.

egy performs fewer scans compared to Static for this user, which is resulting in the very high (80%) missed opportunity.

Figures 3 and 4 suggest that the Static scanning strategy, with five minutes intervals, detects more wireless opportunities with fewer scans for the majority of users. Figure 5 demonstrates the effect of varying the scanning interval of the Static scanning strategy on the number of scans and the missed opportunity on user 2. The low slope of the missed opportunity suggests that increasing the scanning interval has a marginal negative effect on the detected Wi-Fi opportunity, but it dramatically decreases the number of scans.

IV. Conclusions

Our early results suggest that for background/delay-tolerant applications that wish to opportunistically communicate with the Internet using the Wi-Fi interface, Static scanning with relatively large scanning intervals seems to produce better results.

V. Future Work

In a future work we plan to explore the reason behind the good performance of the Static scanning strategy,

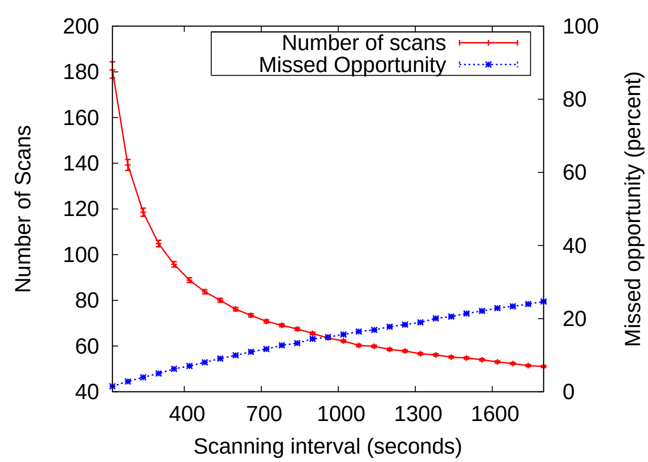

Figure 5: The number of scans and percentage of missed opportunity vs. scanning interval of the Static strategy

especially the low slope of the missed opportunity vs. scanning interval. We are also working on discovering the effect of user initiated Wi-Fi scans on the background scanning process.

VI. Acknowledgments

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