Trace-based Analysis of Wi-Fi Scanning Strategies

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1. INTRODUCTION

Constant access to the Internet on smartphones enables a plethora of mobile applications. Wireless networking technologies on todays smartphones include: 802.11, and cellular technologies, such as EDGE or EVDO, and recently 3G technologies.

Although cellular networks are more ubiquitous, 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.

Accessing the Internet using Wi-Fi on smartphones requires careful management of the WLAN interface. The design of 802.11 MAC protocol makes scanning and idle operation of WLAN interfaces more expensive than cellular technologies in terms of power consumption, and energy is a primary resource on mobile phones.

In this work we evaluate the performance of several WLAN scanning strategies using real-world mobility traces. We consider two performance metrics: number of scans, and missed opportunity. Missed opportunity is the ratio of the Wi-Fi opportunity time detected by the scanning strategy to the total available opportunity time.

We identify the trade-off between the energy consumed by scanning and the missed opportunity for each strategy. We discover that static scanning presents a good trade-off between the number of scans and the daily missed opportunity.

2. EXPERIMENTS

Six iPhones with firmware version 1.1.4 were instrumented to periodically scan on both the WLAN and GSM interfaces. we developed two scanning tools for this purpose: *TCLAPLogger* and *TCLGSMLogger*.

Each execution of TCLAPLogger commands the WLAN interface to perform an active scan on all channels, and

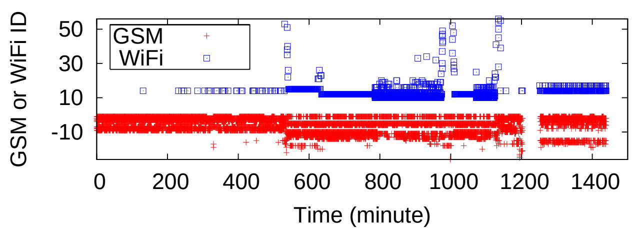

Figure 1: Visualization of a typical day

log ESSID, BSSID, WEP/WPA status, and the signal strength for each access point.

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

A daemon on the iPhones periodically runs these two commands and records their output along with a time stamp. 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 we chose a scanning interval of one minute.

The six iPhones were given to a diverse group of individuals that included undergraduate and graduate students as well as faculty and staff persons. 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 smartphones 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 five week period. Figure 2 shows the number of scanned access points, and GSM cell towers for each user. User 4 visited considerably more Wi-Fi and GSM IDs than all the other users, because she has

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.

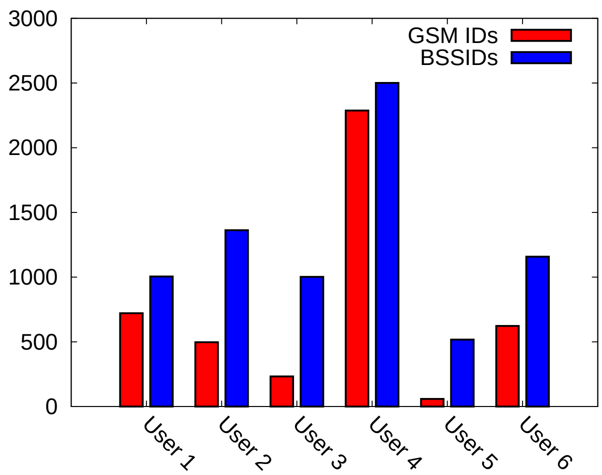

Figure 2: Comparison of the number of scanned GSM and Wi-Fi IDs by different users

had two long trips (one out of the country). Unfortunately, user 5 did not regularly carry the iPhone.

Figure 1 visualizes the Wi-Fi and GSM IDs discovered during a typical day of the experiment for user 3. Each GSM ID has been assigned a unique negative integer ID, and each BSSID has been assigned a positive integer greater than 10. 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 for each user, after encryption enabled access points were filtered from the dataset. The mean length of the availability blocks is about 16 minutes. The *availability rate* in each day is the ratio of time that the user is covered by Wi-Fi during the day. User number 1 is a staff person who does not use wireless at home, and has the lowest availability rate among all users. Excluding this user from the dataset increases the average availability rate to 0.78. This finding confirms that by effectively taking advantage of Wi-Fi opportunities, smartphone users can save considerable energy.

3. EVALUATION OF SCANNING STRATEGIES

In this section we introduce three WLAN scanning strategies: Naïve, Static, and Exponential Back-off. We use trace-based simulation to evaluate and compare their performance.

The Naïve strategy continuously scans the medium until it detects a usable [2] 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 at a fixed interval. The scanning interval can be used to adjust the energy consumption and missed opportunity trade-off 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 the Opportunistic Connectivity Management Simulator [1], to compare the performance of these scanning strategies against the off-line optimal strategy, that makes decisions using future knowledge. In our results, 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 Static, with a five minute interval, Exponential Back-off, and Optimal strategies. Aside from 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 strategy performs fewer scans compared to Static for this user, which results in high (80%) missed opportunity.

Figures 3 and 4 suggest that the Static scanning strategy detects more wireless opportunities with fewer scans for a majority of users. Figure 5 demonstrates the effect of varying the scanning interval of Static scanning on the number of scans and the missed opportunity of user 2. The low slope of the missed opportunity suggests

[1] http://blizzard.cs.uwaterloo.ca/mhfalaki/ocms/

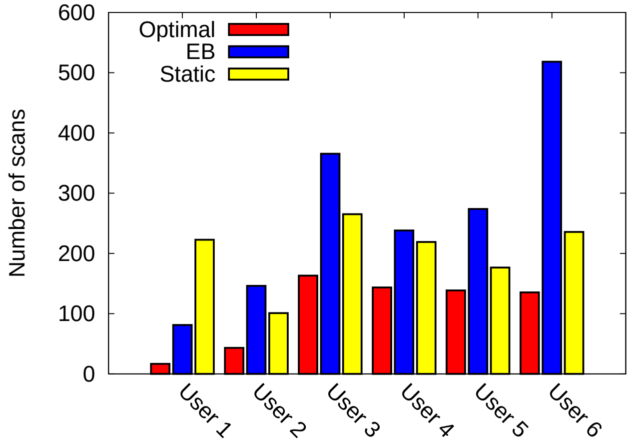

Figure 3: Comparing the number of scans performed by Optimal, Static, and Exponential Back-off strategies on the Waterloo dataset

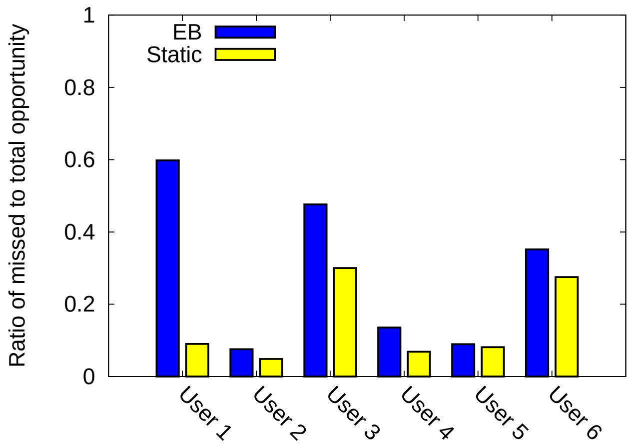

Figure 4: Comparing the missed opportunity by static, and Exponential Back-off strategies on the Rice dataset.

that increasing the scanning interval has a marginal negative effect on the detected Wi-Fi opportunity, but it dramatically decreases the number of scans performed by the Static strategy.

4. CONCLUSIONS

Our early results suggest that static scanning with relatively large scanning intervals is a good scanning strategy for delay-tolerant applications that wish to opportunistically communicate with the Internet over Wi-Fi. We also highlight the effect of the scanning interval on the trade-off between the number of scans and the missed opportunity.

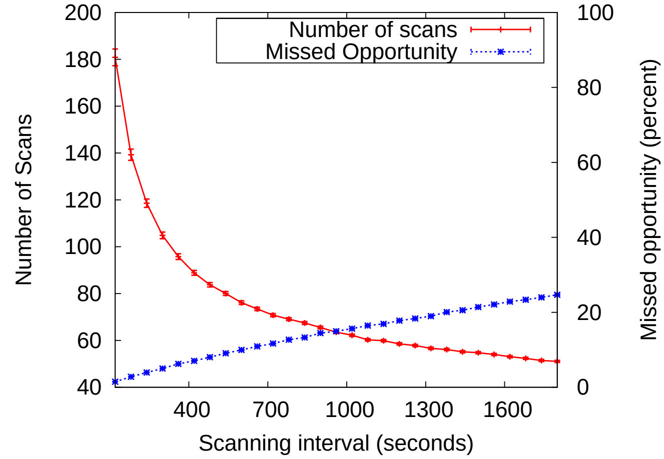

Figure 5: The number of scans and percentage of missed opportunity vs. scanning interval of the Static strategy

5. FUTURE WORK

In future work we plan to explore the reason behind the good performance of the Static scanning strategy, especially the low slope of the missed opportunity vs. scanning interval line in Figure 5. We are also working on discovering the effect of user initiated Wi-Fi scans on the performance of the background scanning process. We have also done experiments with using context hints to reduce the number of scans, through an innovative caching technique.

6. ACKNOWLEDGMENTS

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7. REFERENCES

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[2] Nicholson, A. J., Chawathe, Y., Chen, M. Y., Noble, B. D., and Wetherall, D. Improved access point selection. In *MobiSys* (2006), pp. 233–245.