WLAN Interface Management on Mobile Devices

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Master's Thesis

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Motivation

Smartphones are proliferating

- Multiple Network Interfaces:
  - Bluetooth
  - EDGE or 3G
  - WiFi

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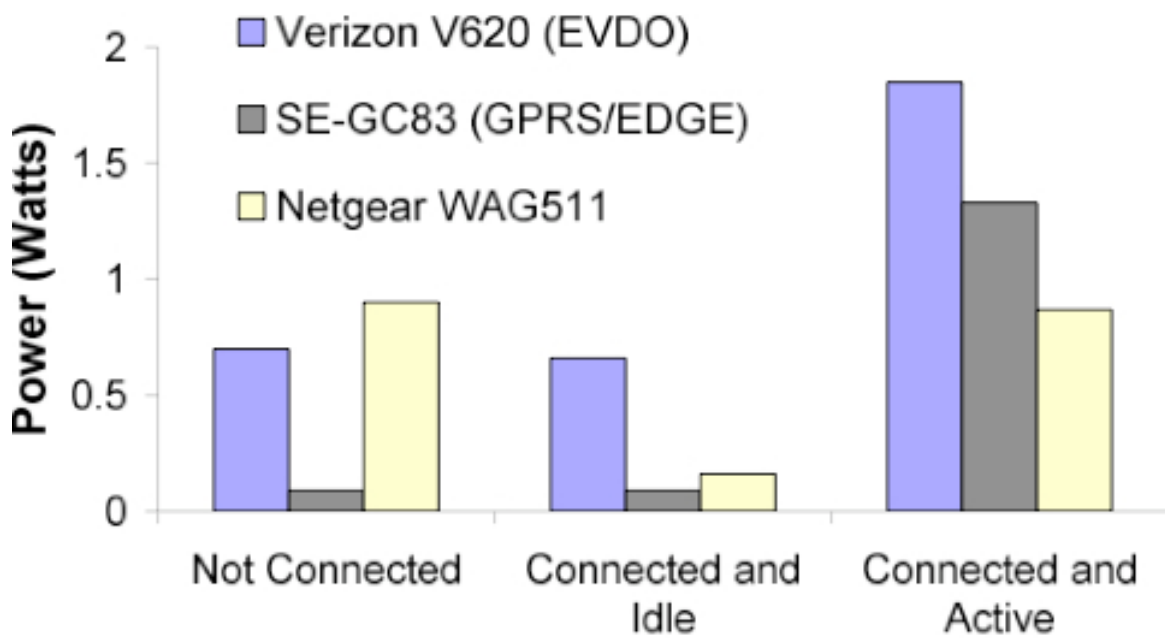
Motivation

Advantages of WiFi

- Higher bandwidth
- Good energy trade-off
- Free



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Problem

- WLAN interfaces consume considerable energy in idle mode
- WLAN scanning is highly energy consuming
- To discover a WiFi opportunity the WLAN interface should be "up" and "scanning"

What is a good strategy for turning the WLAN NIC on and scanning?

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WLAN Scanning

- Passive Scanning:
  - The interface listens for periodic AP beacons on each channel
- Active Scanning:
  - On each channel the interface sends a broadcast probe request, and waits for probe responses

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Thesis

- For background/delay-tolerant applications, static scanning works better than expected due to the power-law distribution.
- Context hints can be used through a cache to help interface management.
- User-initiated WLAN scans do not appear to incur significant costs.

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Outline

- **Modeling**
- Heuristic Strategies
- Measurements
- Evaluation
- Conclusions

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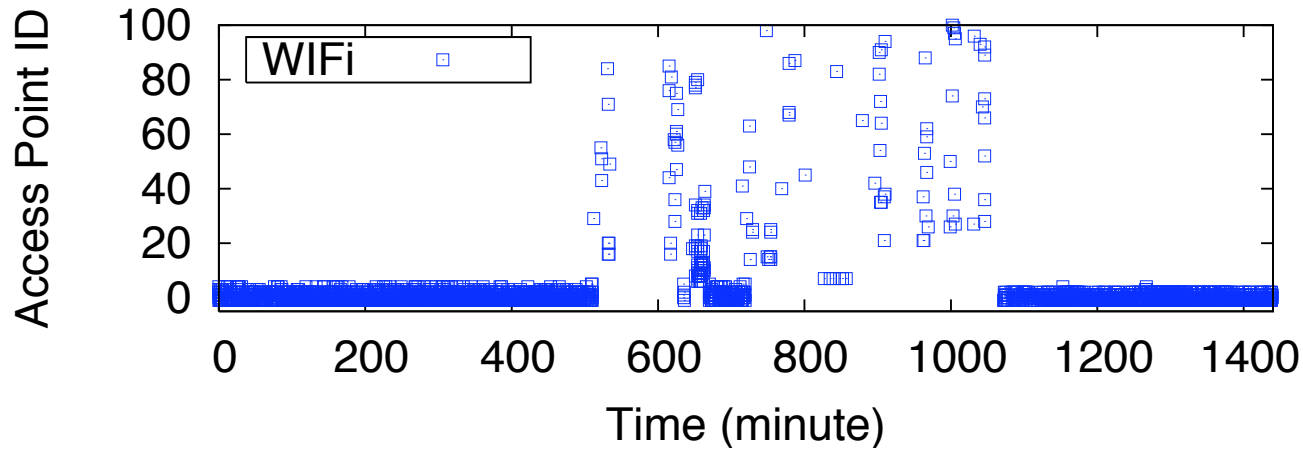
Definitions



1. Medium
2. Availability block
3. Interface states
4. Schedule, T-connected schedule
5. Strategy

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Optimal Strategy

- Optimal T-Connected schedule
- Optimal strategy
- Future knowledge assumption

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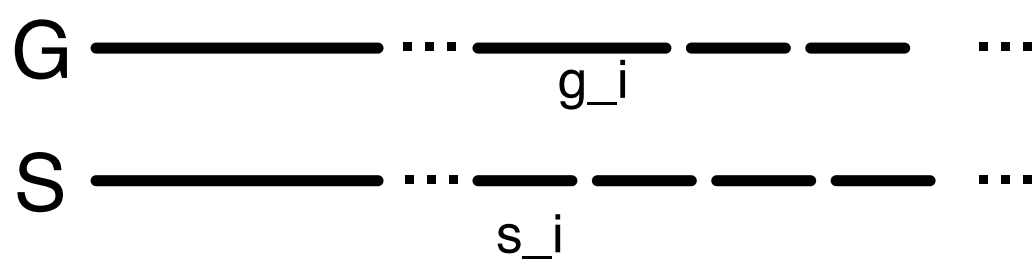
Greedy

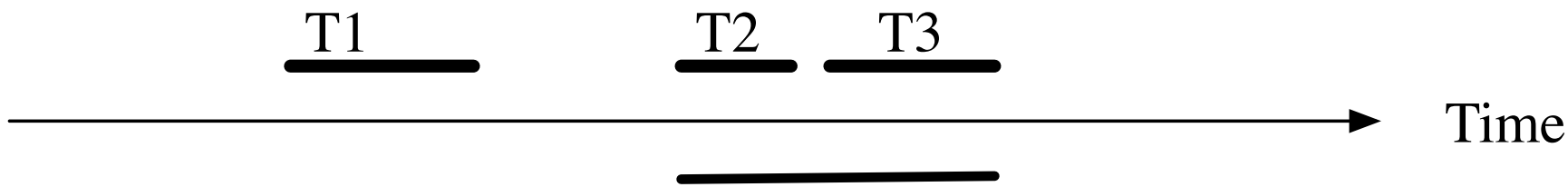
If blocks are "far apart," the greedy algorithm finds the optimal schedule:

- Sort the blocks according to length
- Start filling the schedule with the longest blocks
- The NIC is off between blocks



Dynamic Programming

If some blocks are "too close," it is better not to turn off the NIC.



$$
\begin{aligned}
f_i^j \quad = \quad & min\{ \\
& f_{i-1}^j, \\
& f_{i-1}^{j-l_i} + c_i, \\
& min_{1 \le k \le i}\{f_k^{j-l_{k \ldots i}} + c_{k \ldots i}\} \\
& \}
\end{aligned}
$$

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Heuristic Strategies

- Naive
- Static
- Exponential Back-off
- Bounded Exponential Back-off

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Naive Scanning

$$Scan_{Naive} \sim \frac{1}{t} \times \lambda \times 3600 \times 24$$

- Considerable number of scans
- Almost zero missed opportunity

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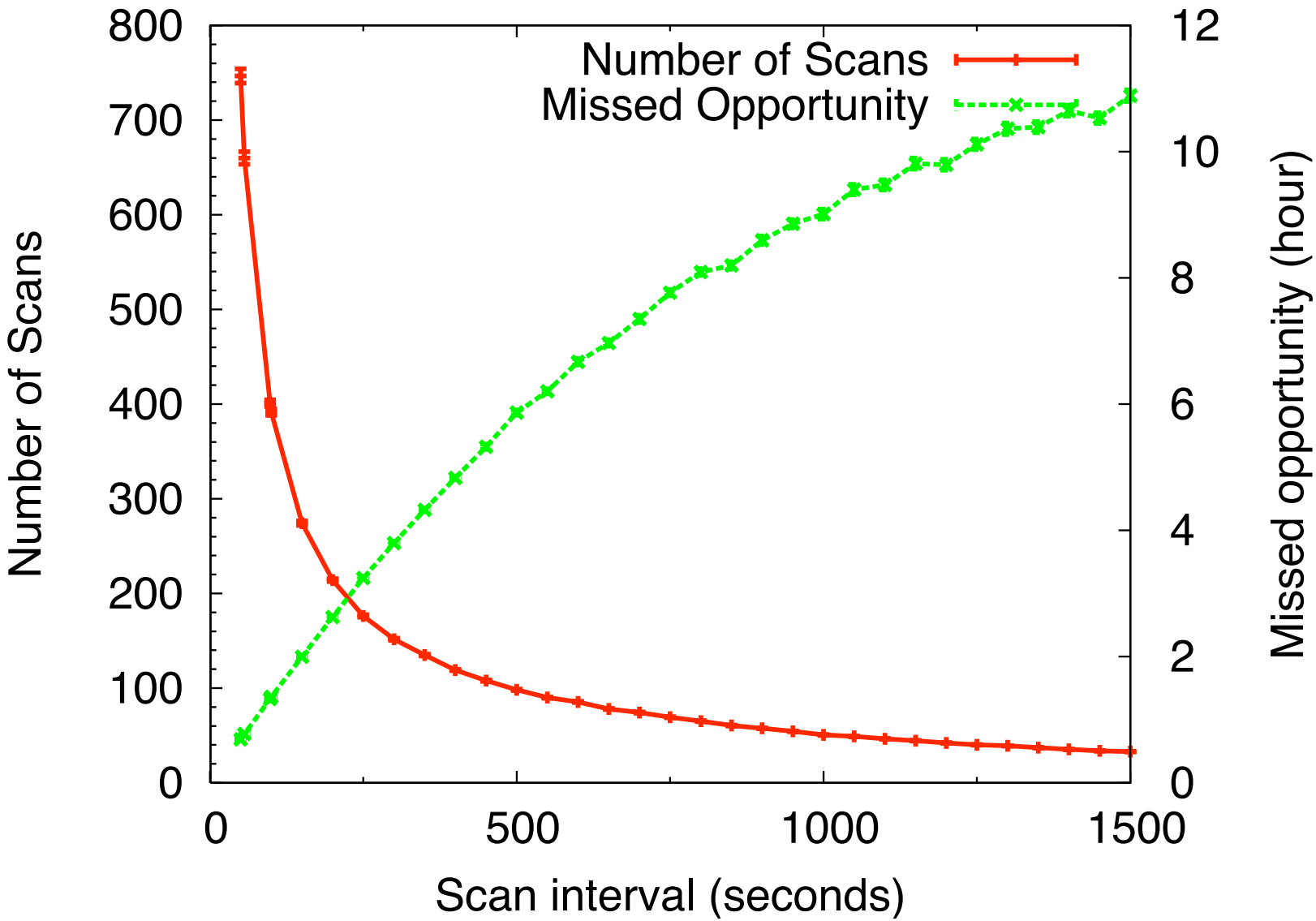
Static Scanning



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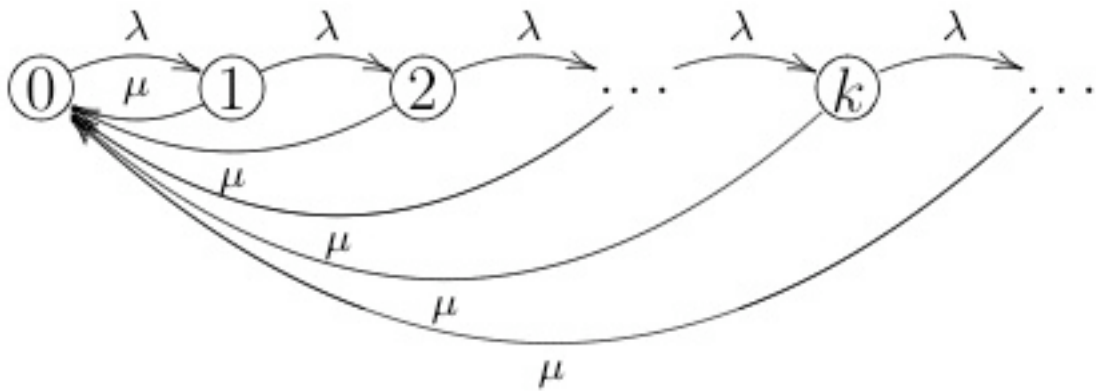
Exponential Back-off



$$P_0 = \mu$$
$$P_k = \lambda^k \mu$$

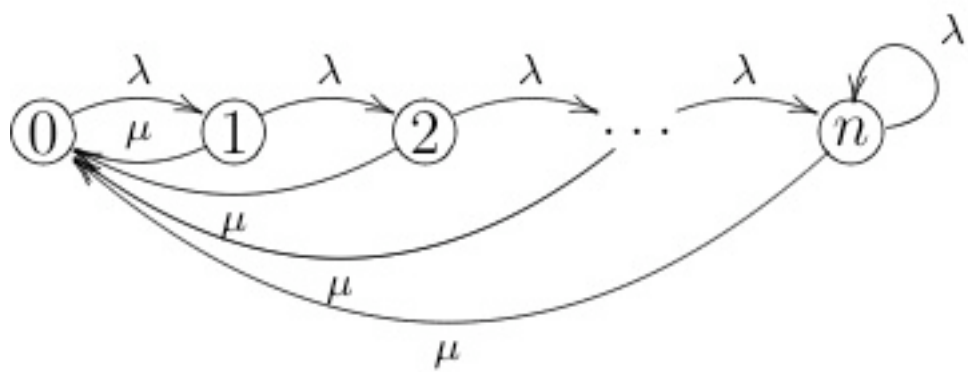
$$E[Missed_{EB}] = \sum_{i=1}^{m} P_i \times Missed_{static}(2^i)$$

$$E[Scan] = \sum_{i=1}^{m} i \times P_i$$
$$= \sum_{i=1}^{m} \mu i \lambda^i$$

Bounded EB

$$E[d] = \sum_{i=1}^{\infty} P_i \times d_0 2^i$$

$$= d_0 \mu \sum_{i=1}^{\infty} (2\lambda)^i$$



If availability rate is "too low," the number of back-offs should be bounded.

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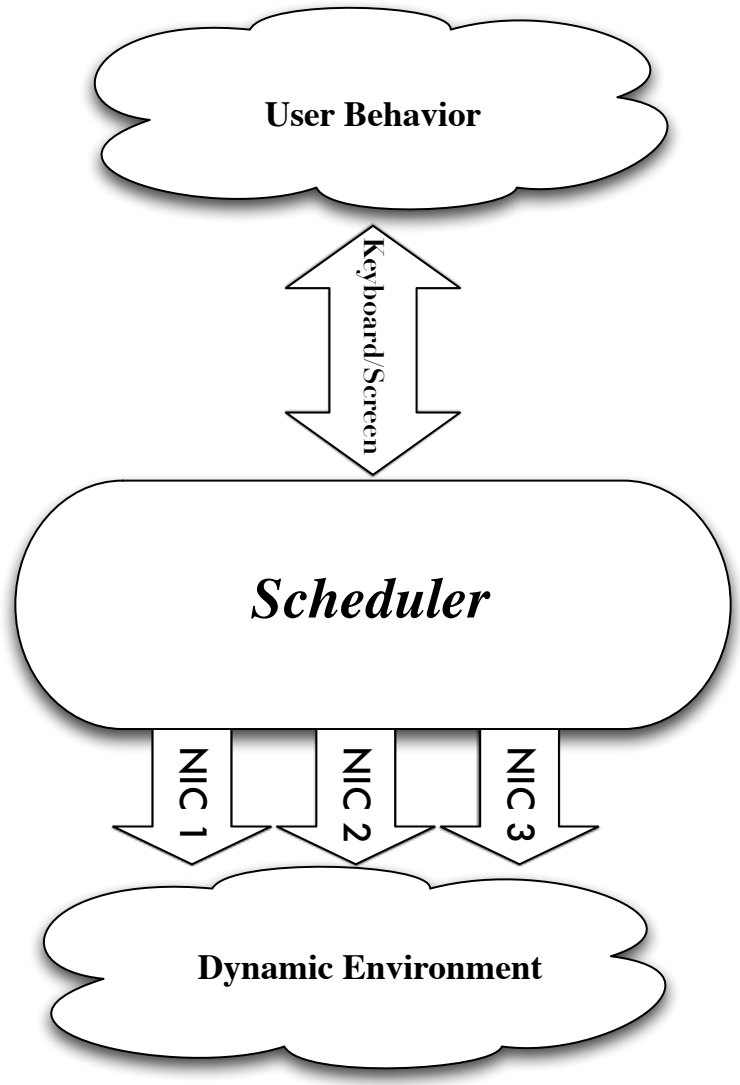
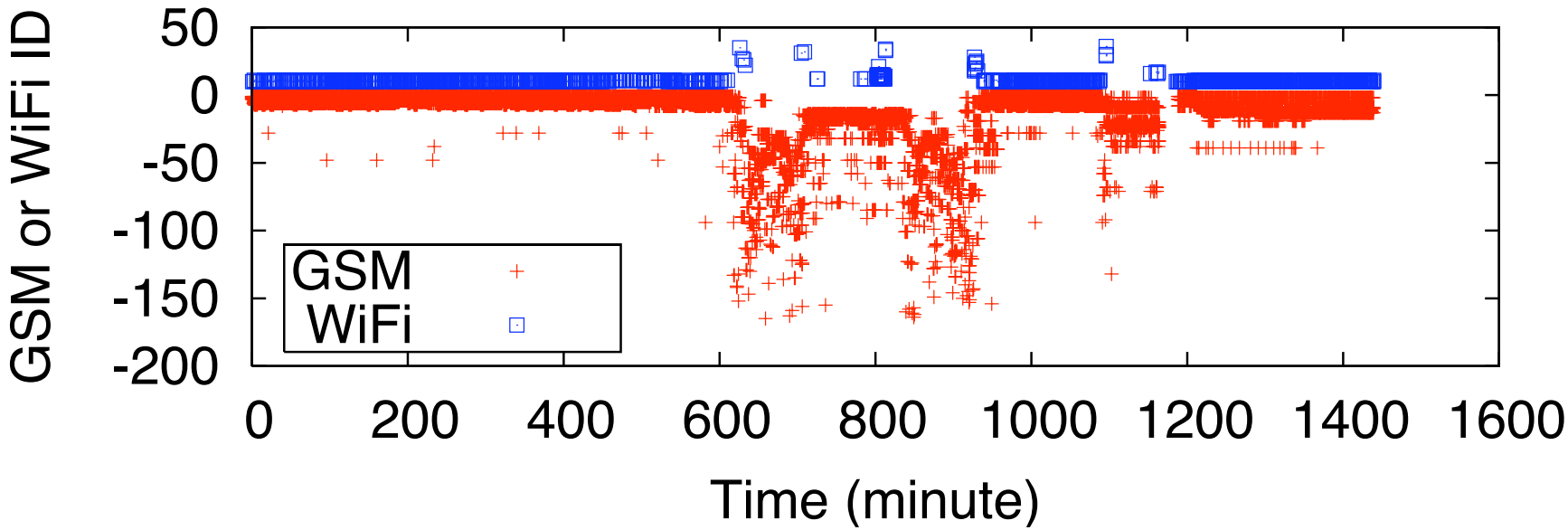
Measurements



Wireless Measurements

- Six iPhones scanned WiFi and GSM every minute for five weeks
- Similar to the Rice measurement (10 WM), with fewer missed samples



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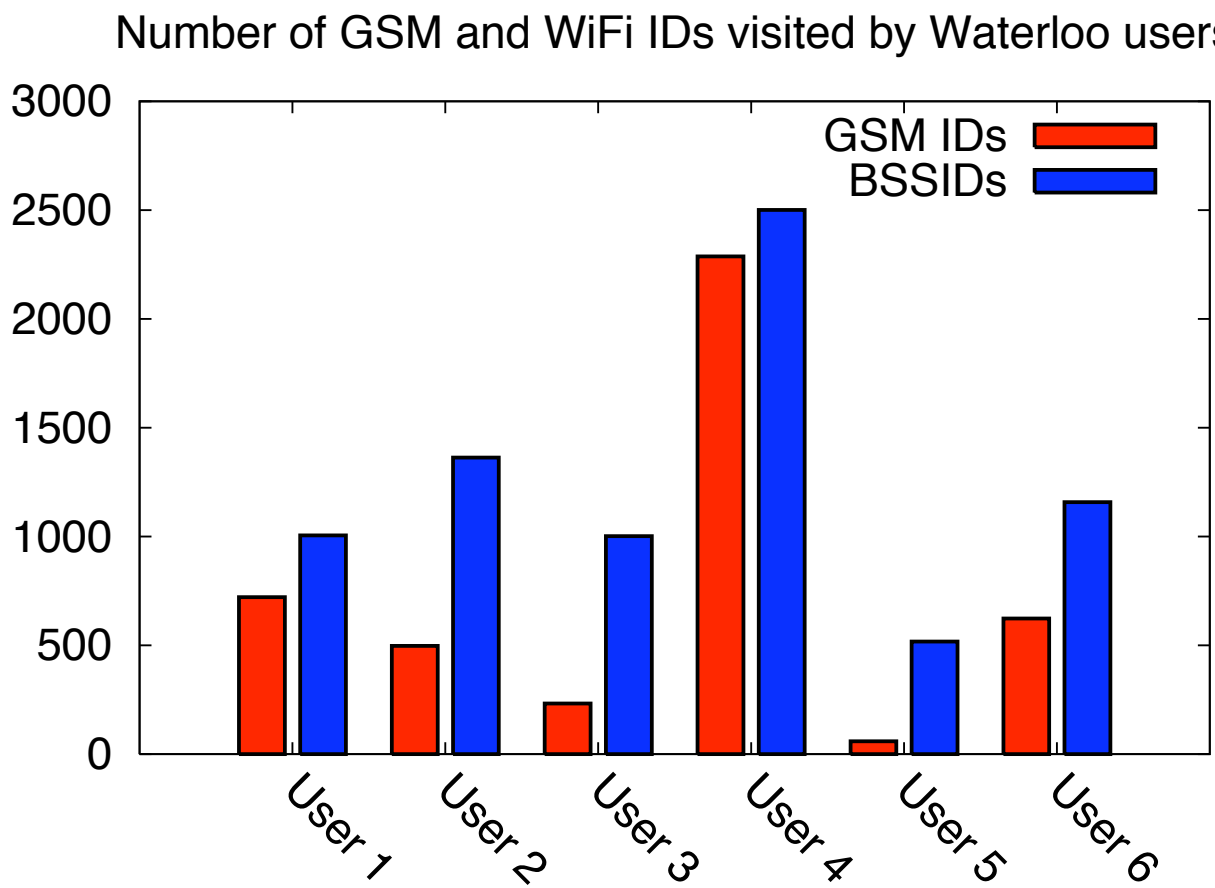
Waterloo Dataset



3070 GSM and 5709 WiFi unique IDs

Avg. availability rate: 0.62

Avg. missing samples/day: 66

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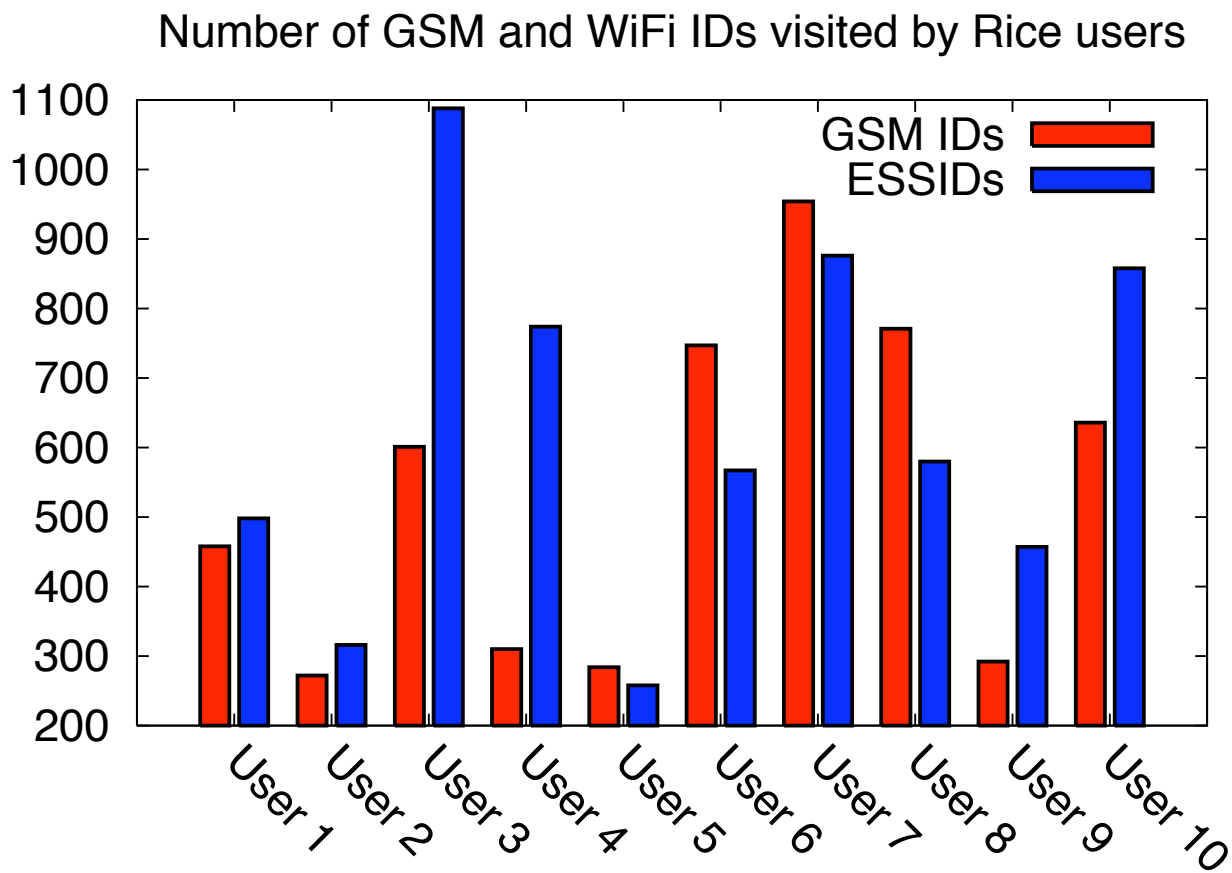
Rice Dataset

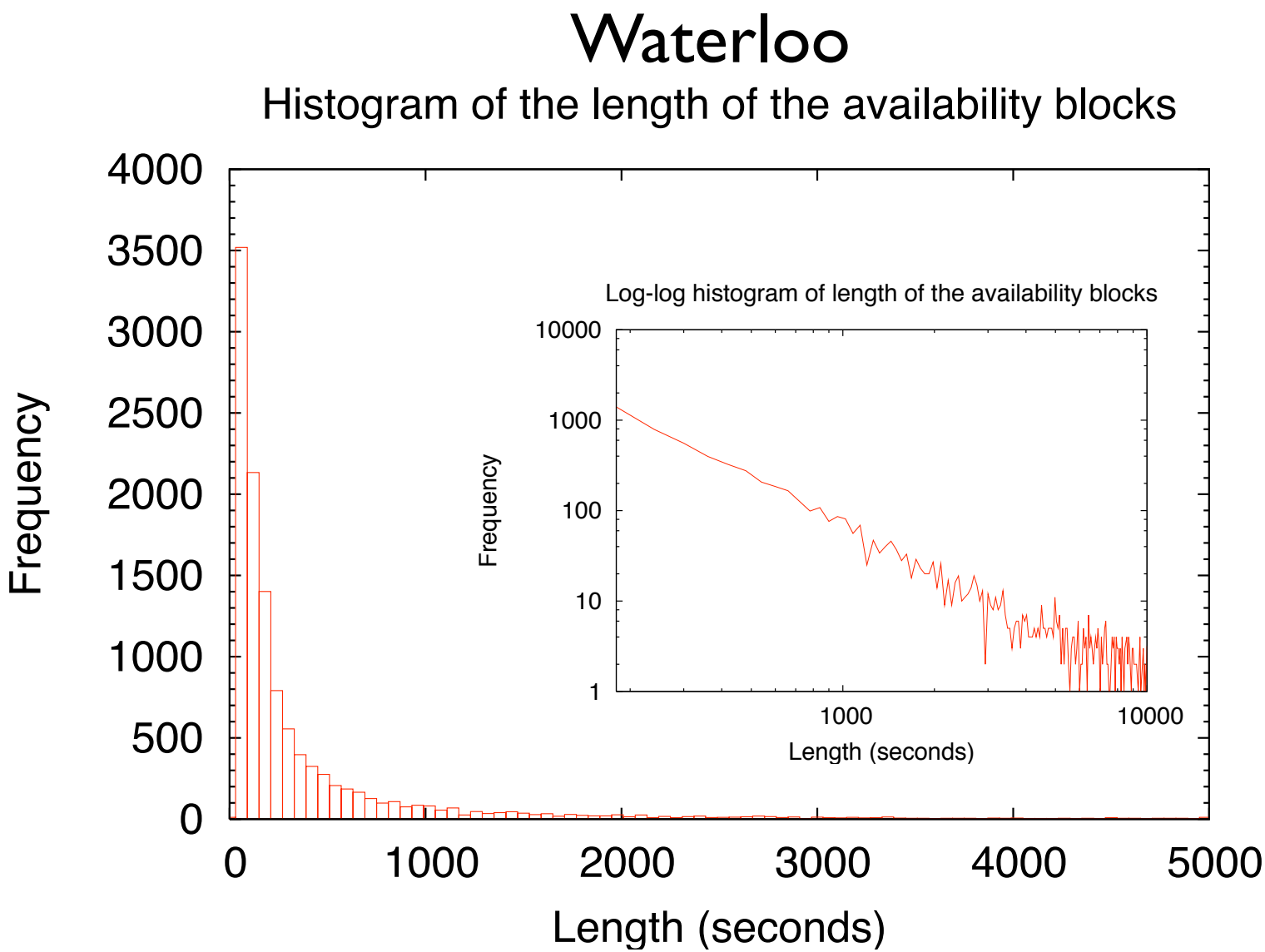


2806 GSM and 3907 WiFi unique IDs

Avg. availability rate: 0.48

Avg. missing samples/day: 147

Block Length



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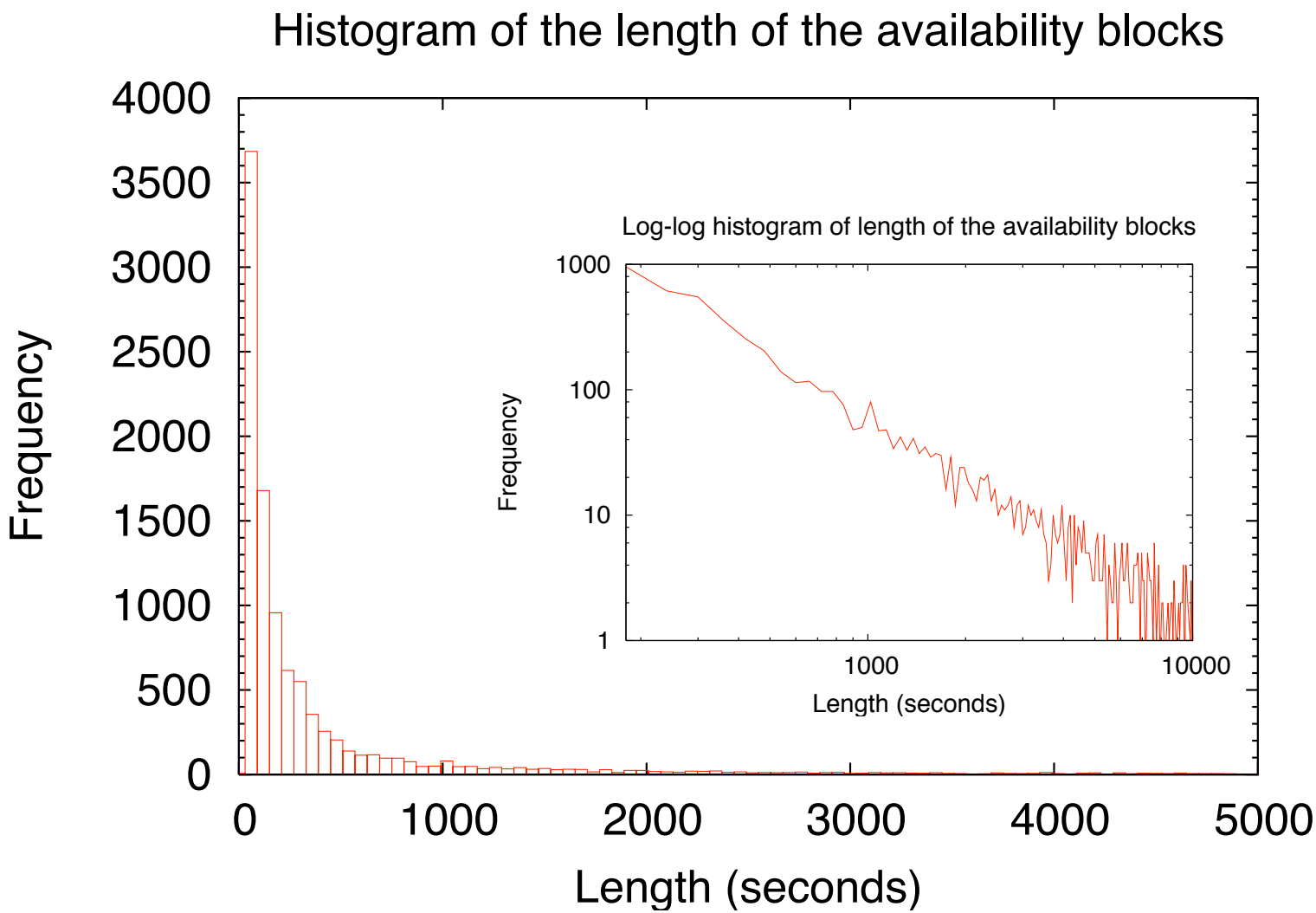
Block Length

Rice



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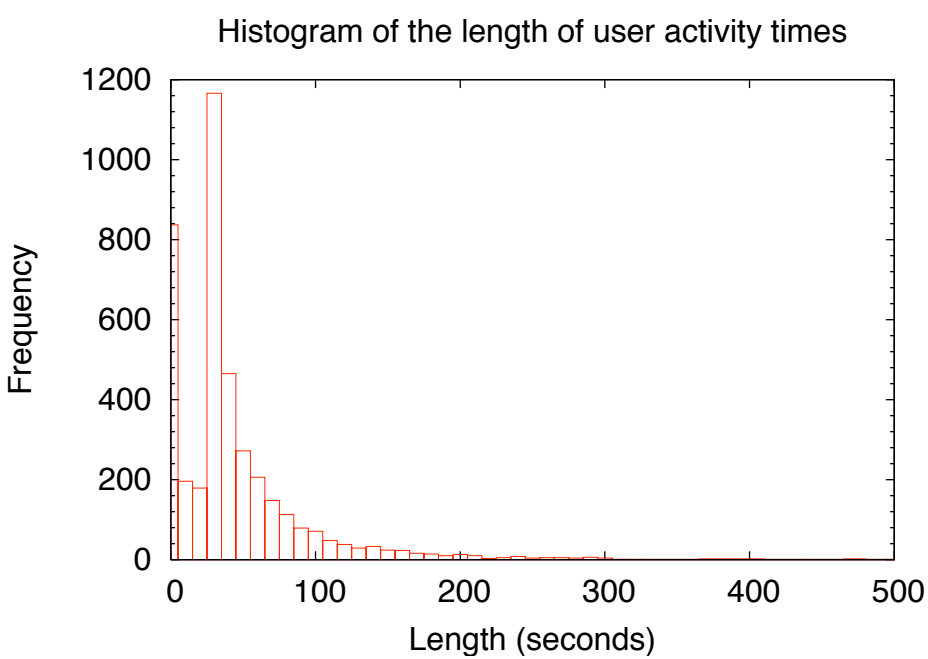
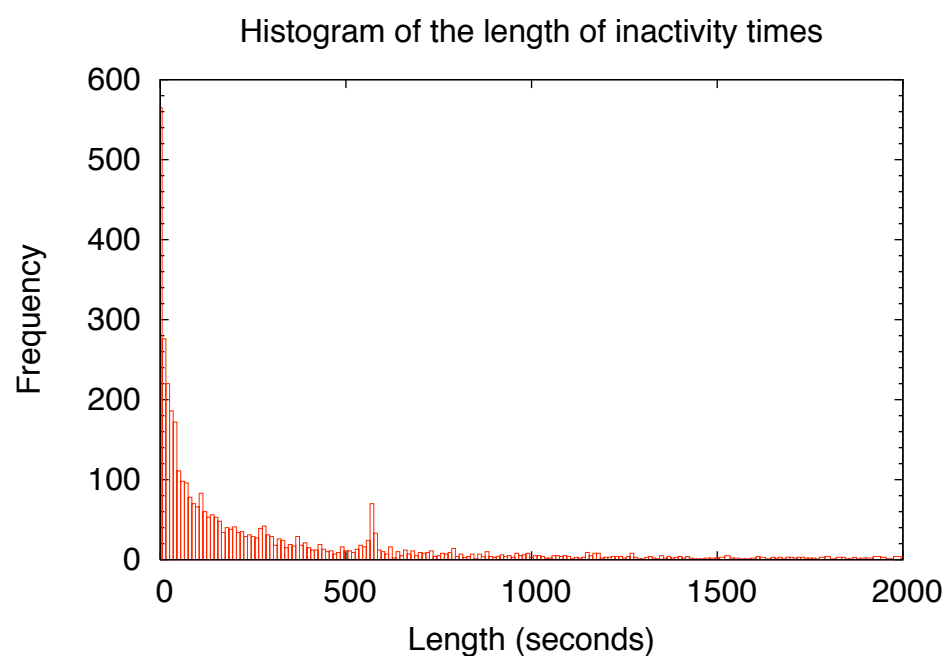
User Measurements

- Two BlackBerrys logged user interaction times for about three weeks

Activity



Inactivity



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Evaluations

- Performance metrics:
  - Number of scans
  - Missed opportunity
- Configurable parameters:
  - Scanning interval
  - Maximum back-off

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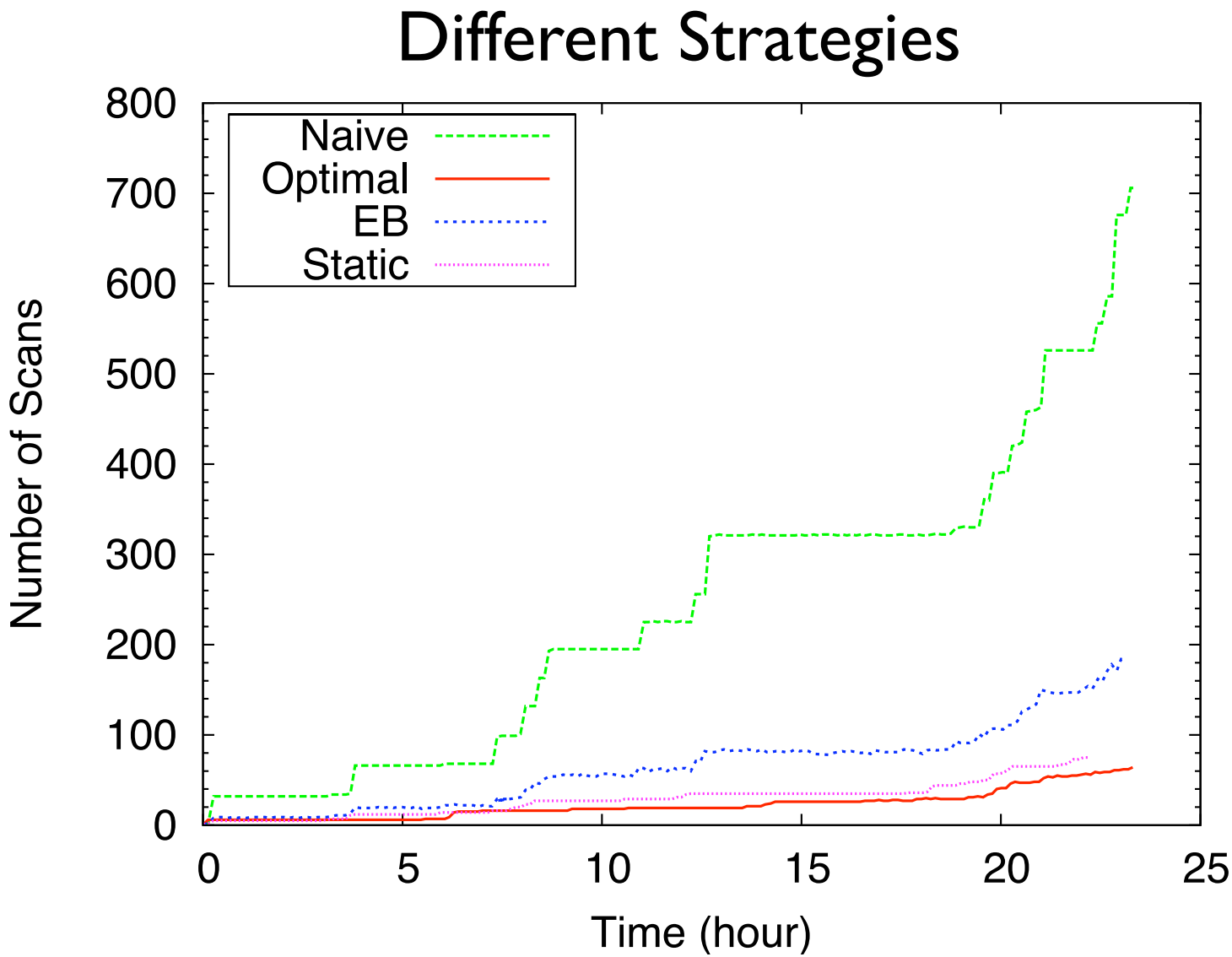
Comparing Strategies



Number of Scans

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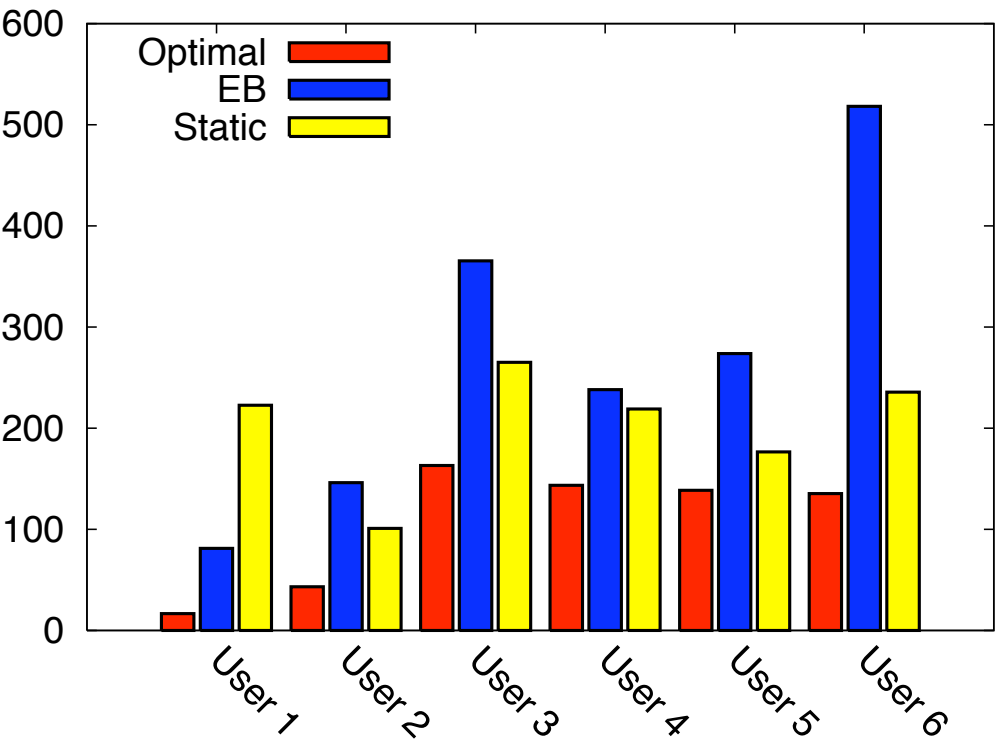
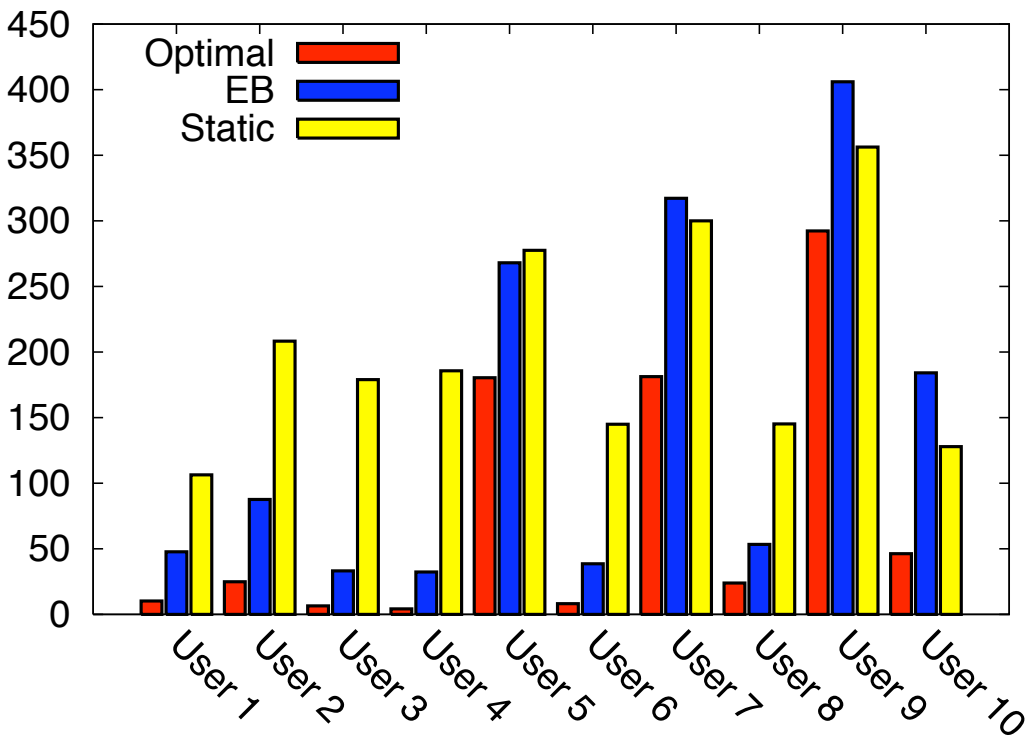


Rice



Missed Opportunity

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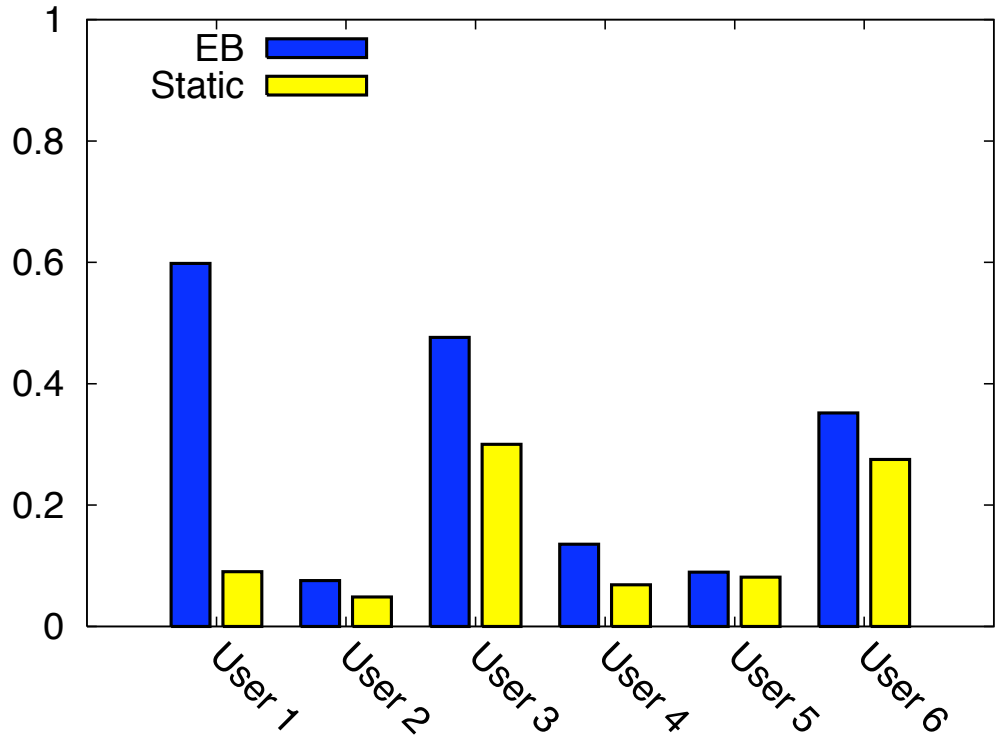
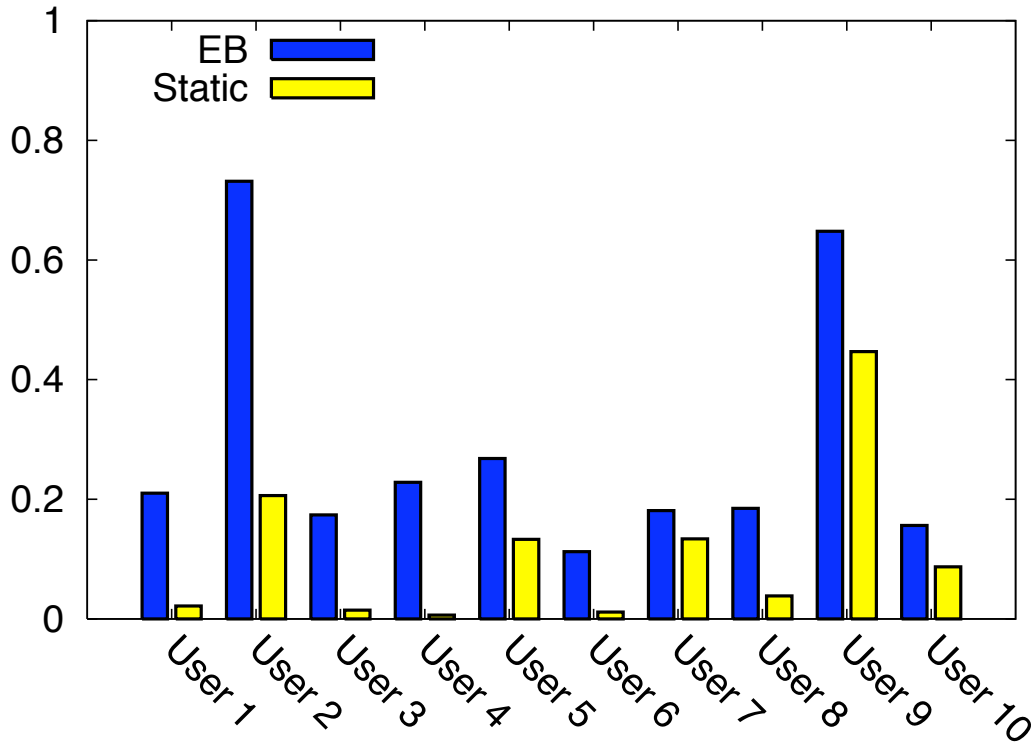


Rice



Simulation Results

- Static scanning performs well
  - Low missed opportunity
  - Consistently low number of scans
- Exponential Back-off performs fewer scans for some users, but with very high missed opportunity

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Discussion

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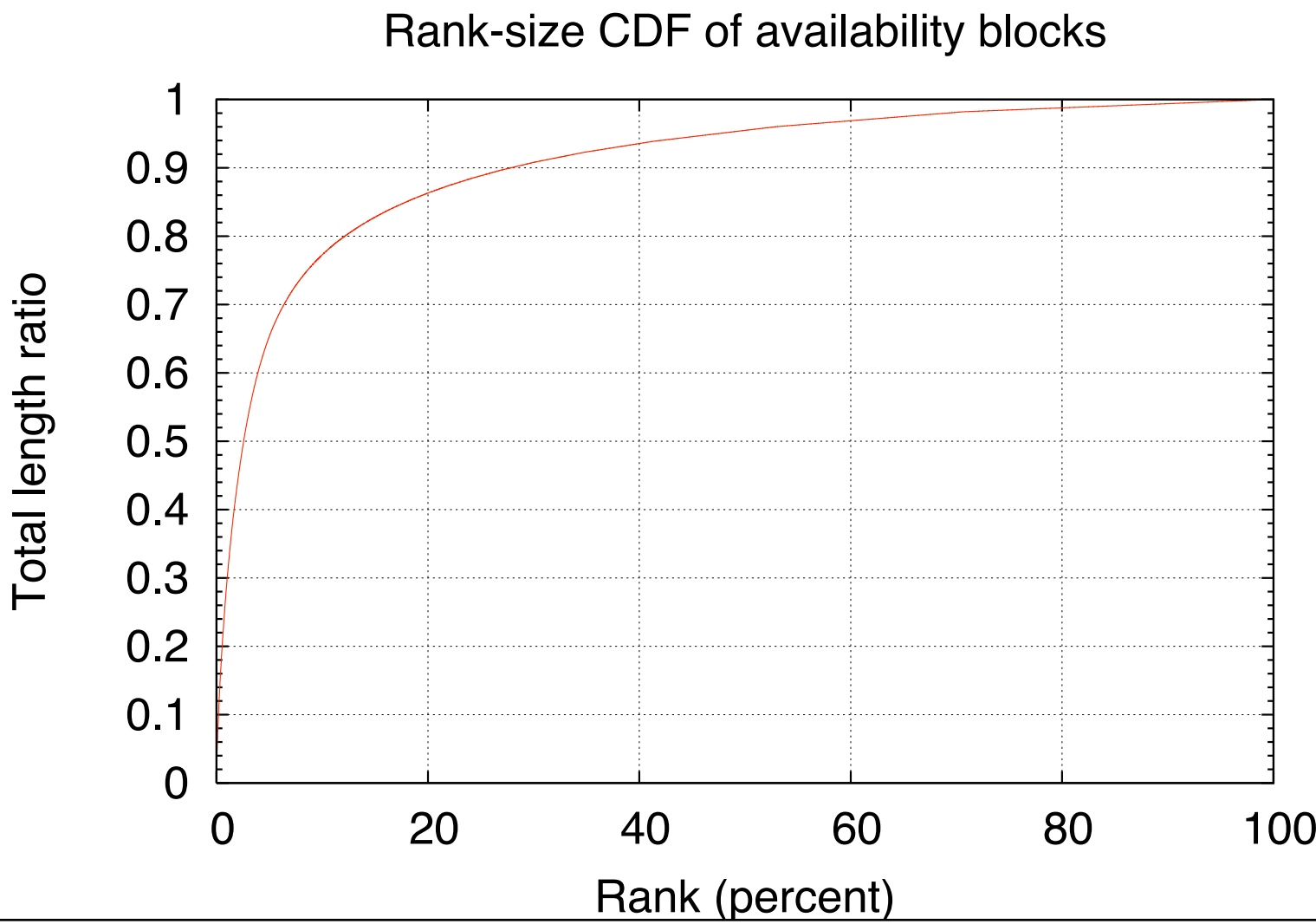

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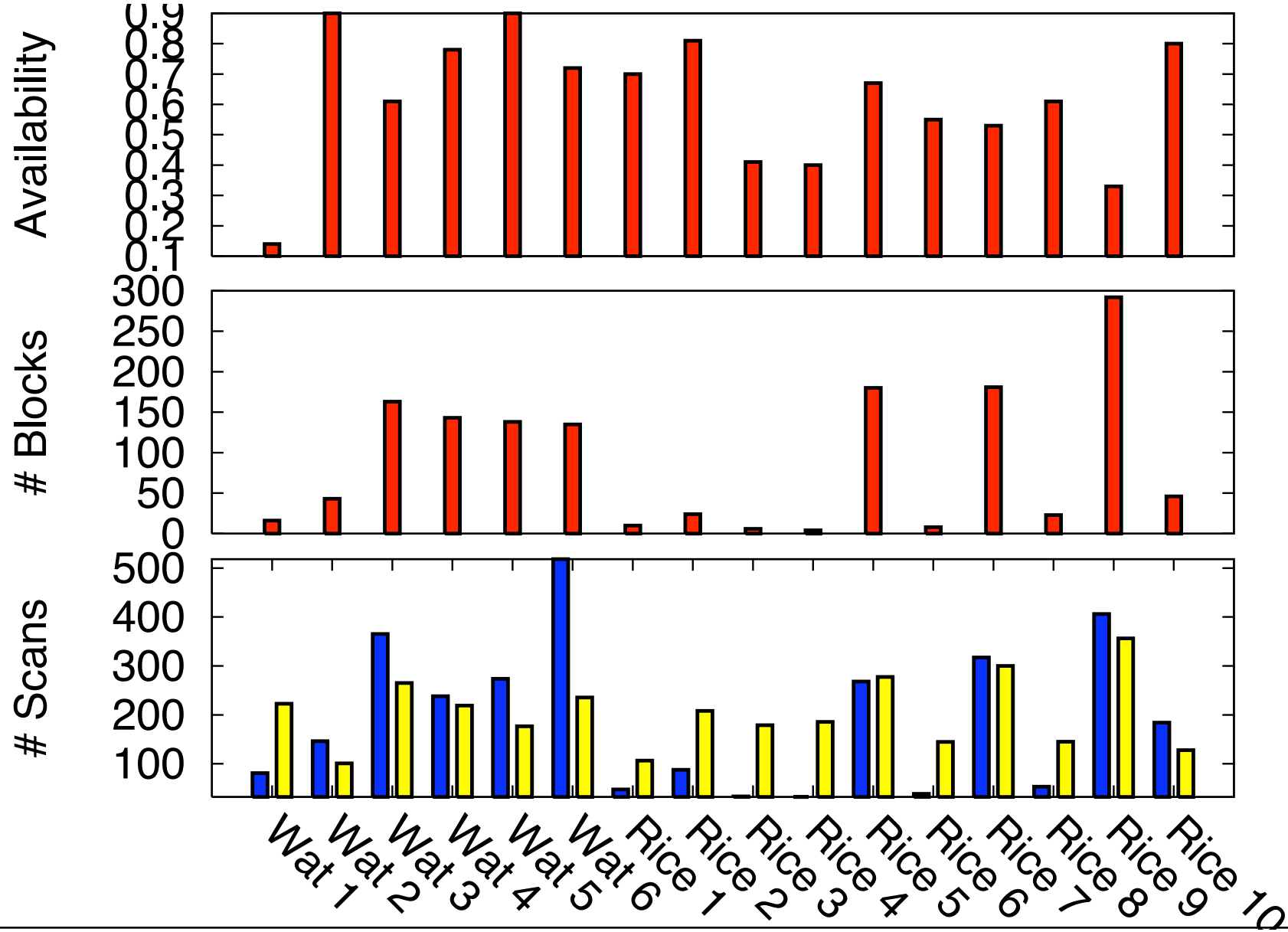
Discussion



Tuning Static Scanning

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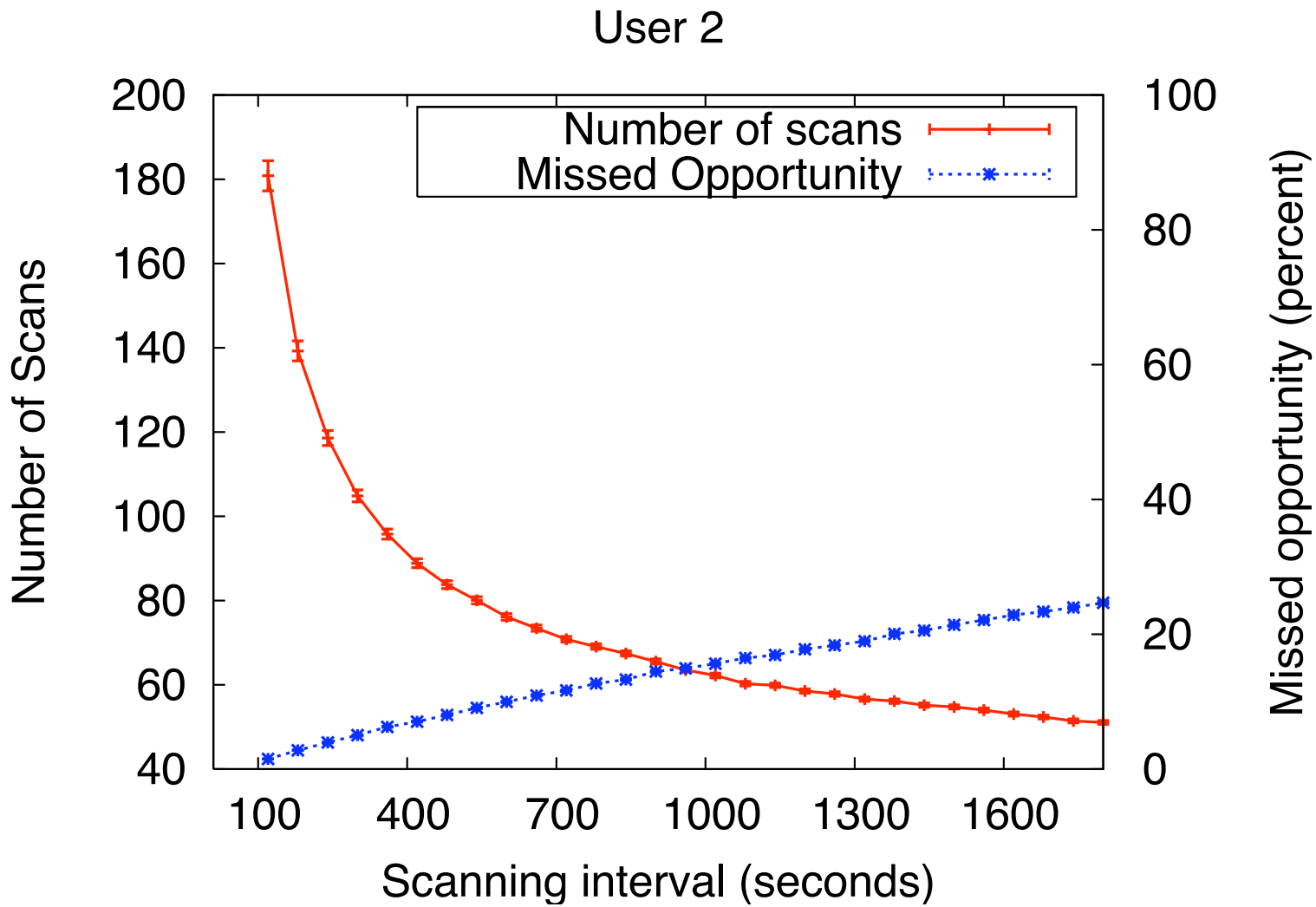
Sample Waterloo user:



Tuning Static Scanning 2

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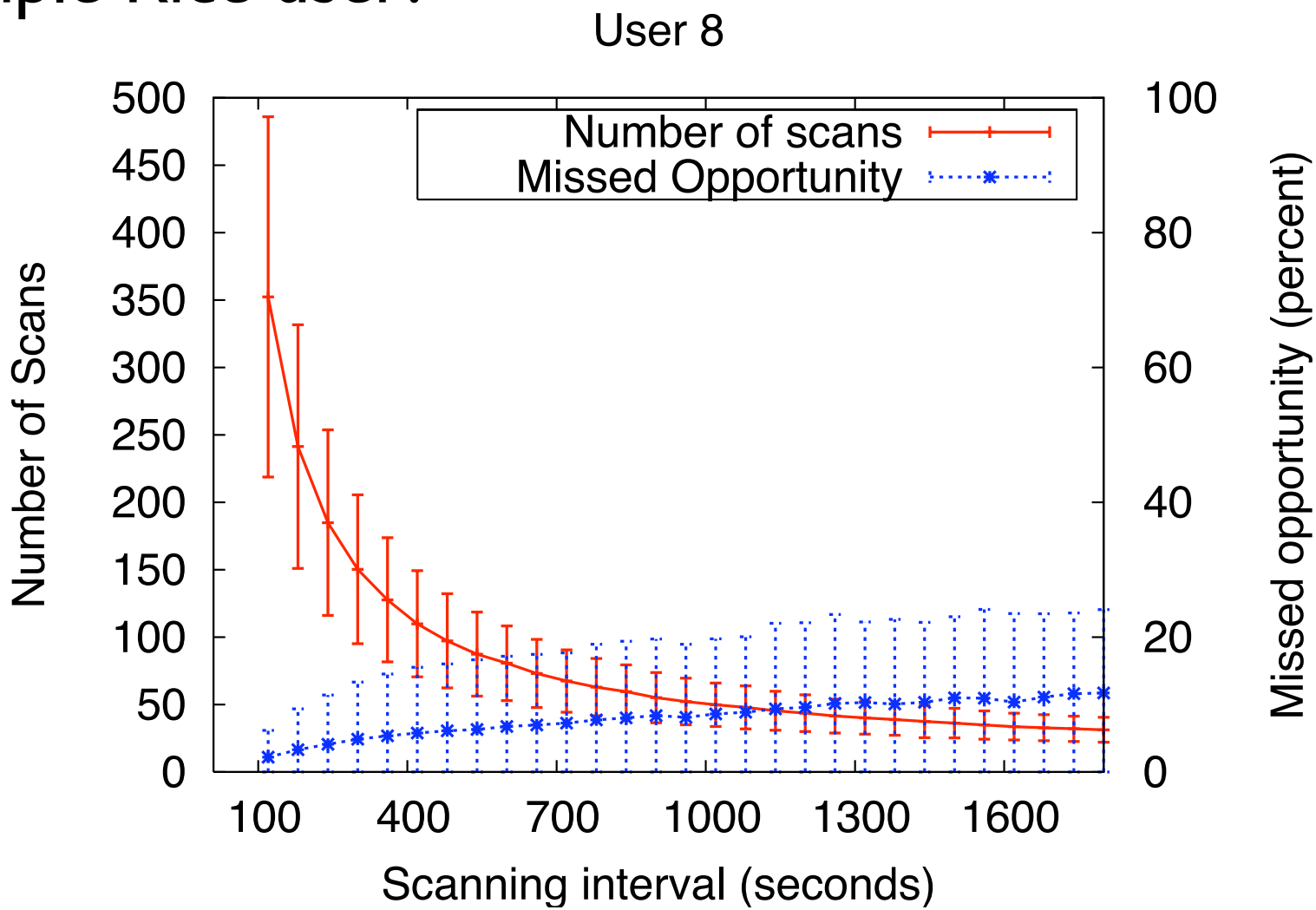
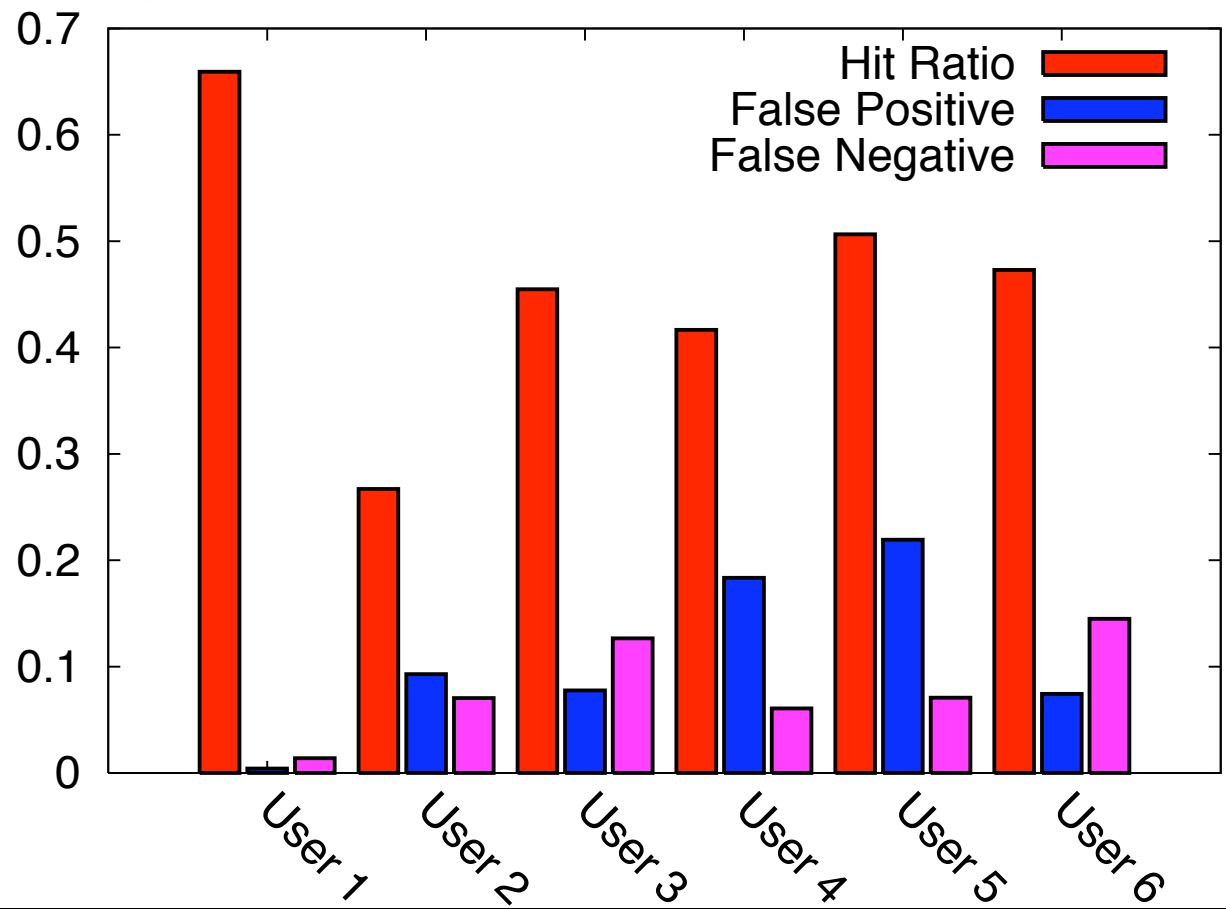
Sample Rice user:

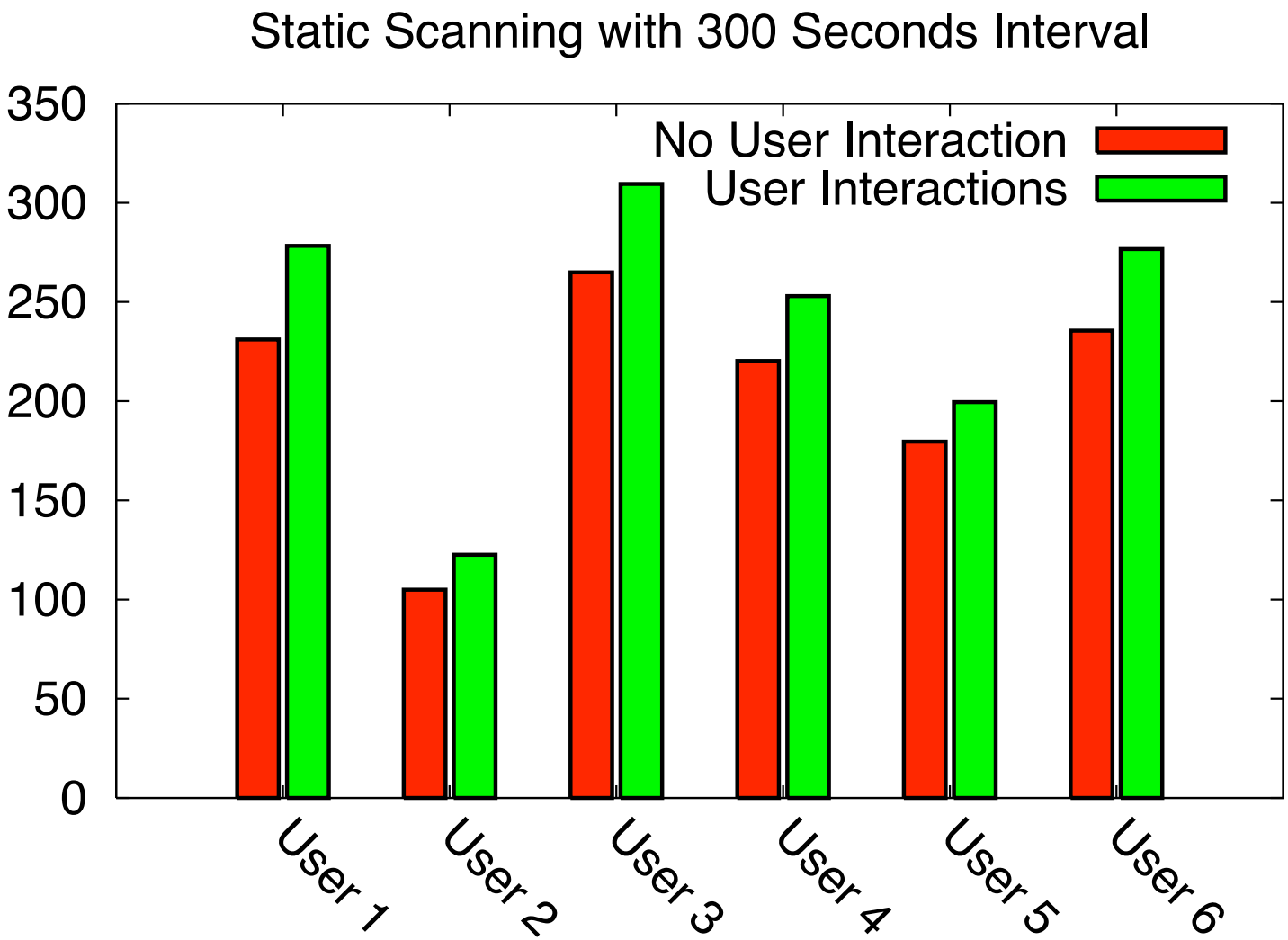


Caching Scan Results

Dataset	Hit ratio	False Positive	False Negative
Waterloo	0.46	0.25	0.19
Rice	0.46	0.16	0.25



Interactive Processes



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Conclusions

- Separate delay-tolerant and interactive processes
- For delay-tolerant applications use static scanning with the largest possible scanning interval
- For interactive processes use an aggressive scanning strategy
- Use context hints to avoid unnecessary scans

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Future Work

- Considering usability of access points
- Improving caching
- Making interactive scans smarter
- Management of multiple NICs
- Collaborative scheduling

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