

# **WLAN Interface Management on Mobile Devices**

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Master's Thesis

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# Motivation

## Smartphones are proliferating

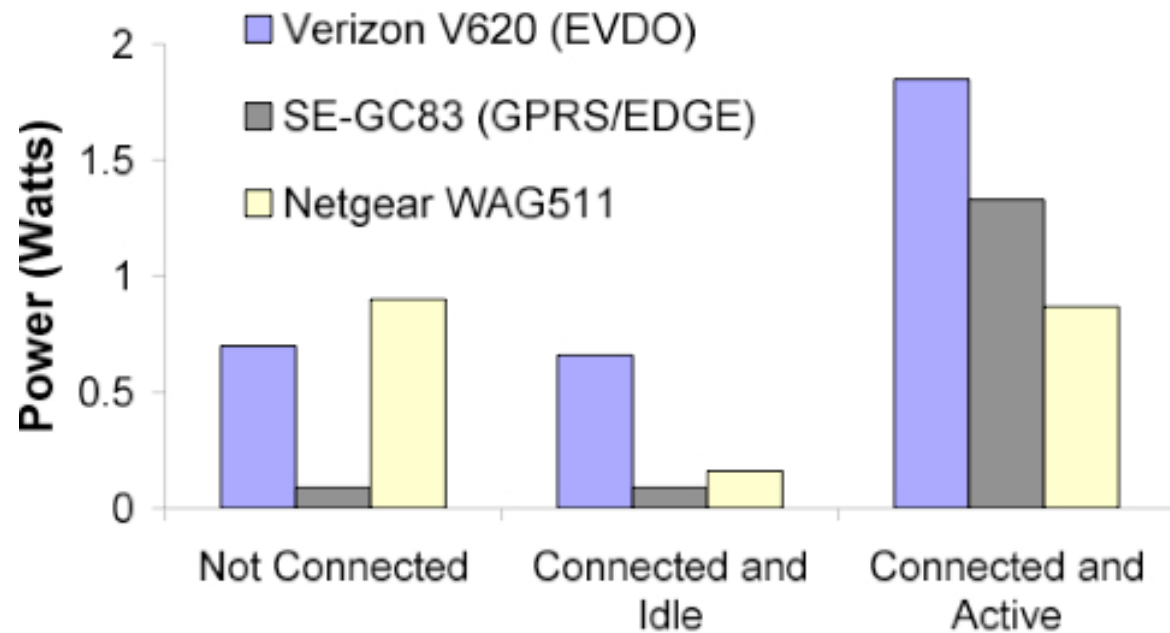


- Multiple Network Interfaces:
  - Bluetooth
  - EDGE or 3G
  - WiFi

# Motivation

## Advantages of WiFi

- Higher bandwidth
- Good energy trade-off
- Free



# 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?**

# 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

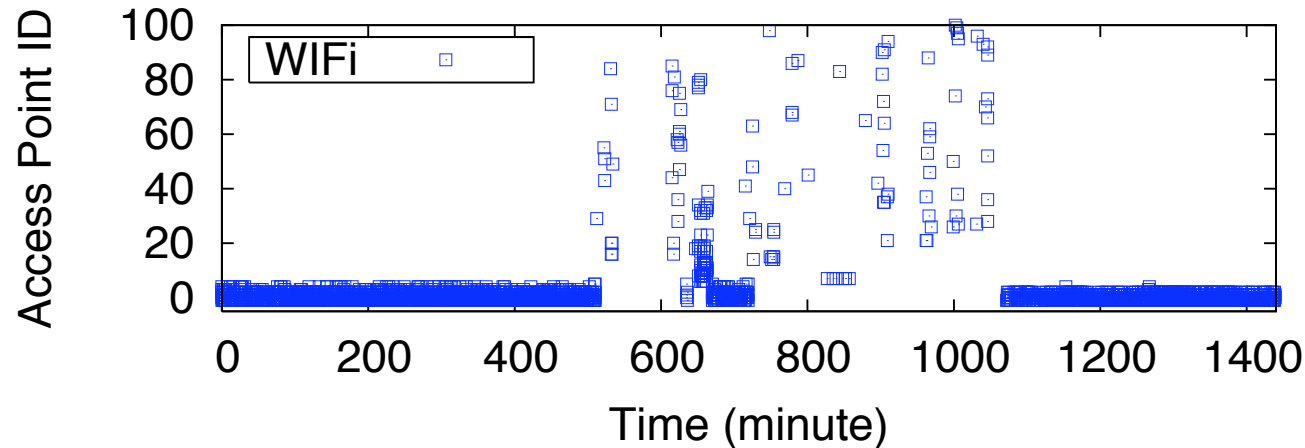
# Thesis

- 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.

# Outline

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

# Definitions



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

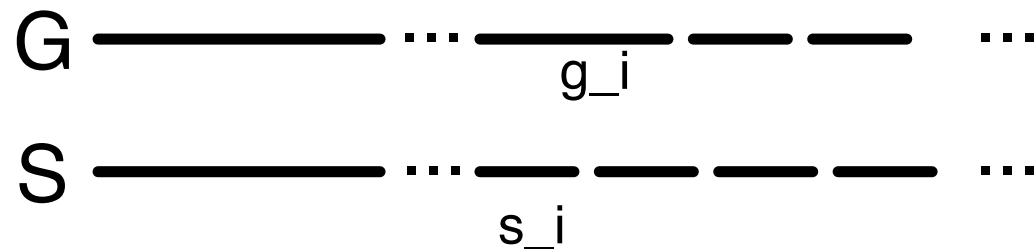
# Optimal Strategy

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

# Greedy

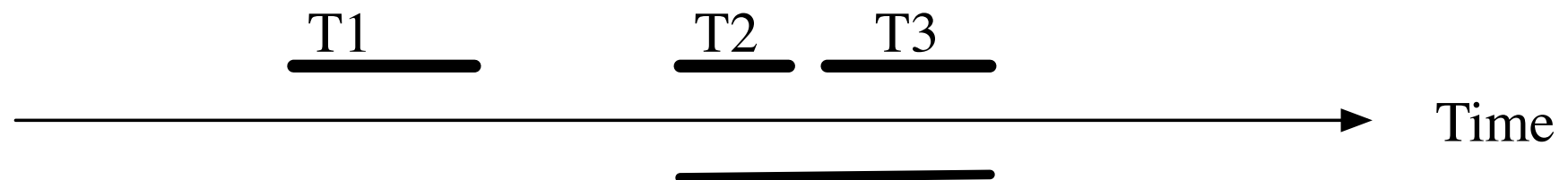
If blocks are “far apart,” the greedy algorithm finds the optimal schedule:

- 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.



$$f_i^j = \min \left\{ \begin{array}{l} f_{i-1}^j, \\ f_{i-1}^{j-l_i} + c_i, \\ \min_{1 \leq k \leq i} \{ f_k^{j-l_{k\dots i}} + c_{k\dots i} \} \end{array} \right\}$$

# Outline

- Modeling
- **Heuristic Strategies**
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# Heuristic Strategies

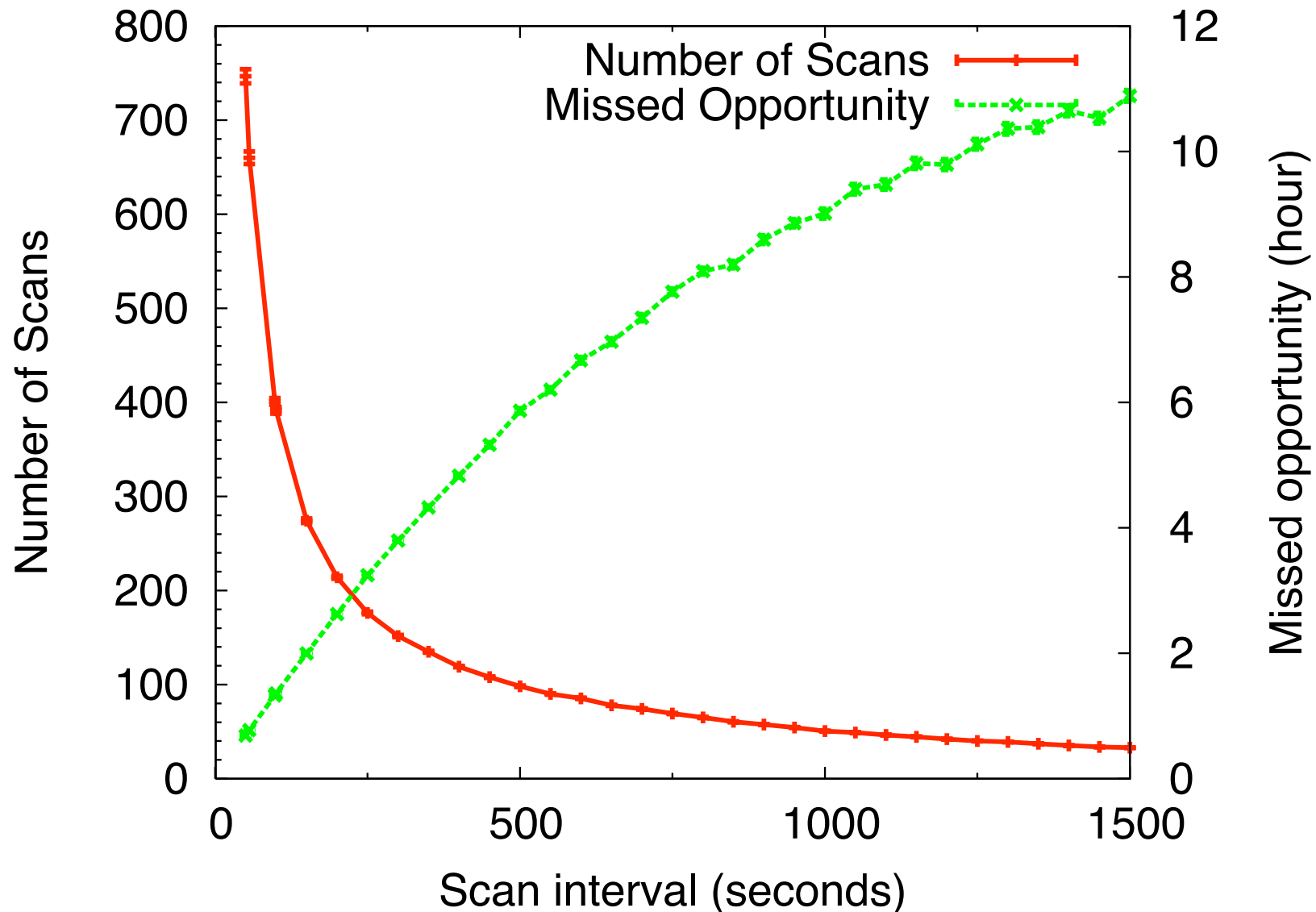
- Naive
- Static
- Exponential Back-off
- Bounded Exponential Back-off

# Naive Scanning

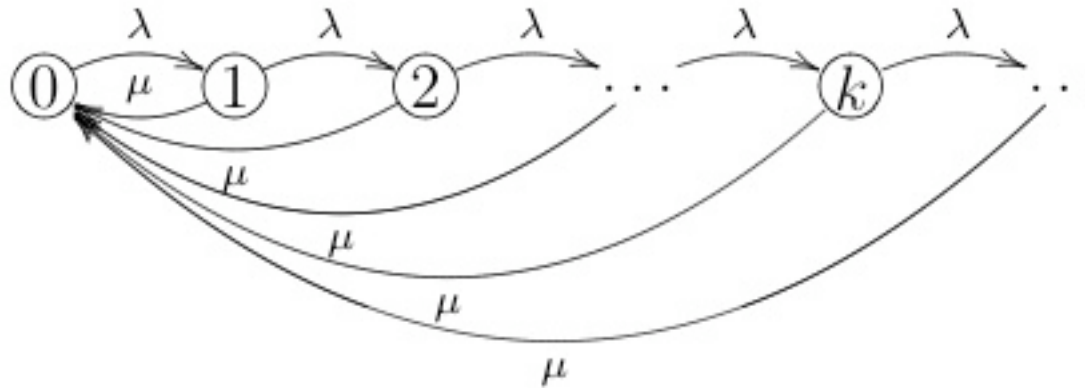
$$Scan_{Naive} \sim \frac{1}{t} \times \lambda \times 3600 \times 24$$

- Considerable number of scans
- Almost zero missed opportunity

# Static Scanning



# Exponential Back-off



$$P_0 = \mu$$

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

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

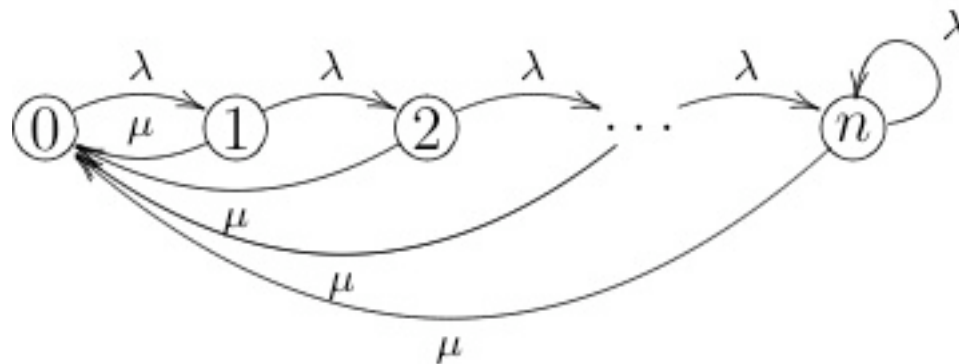
$$E[Scan] = \sum_{i=1}^m i \times P_i$$

$$= \sum_{i=1}^m \mu i \lambda^i$$

# Bounded EB

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

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

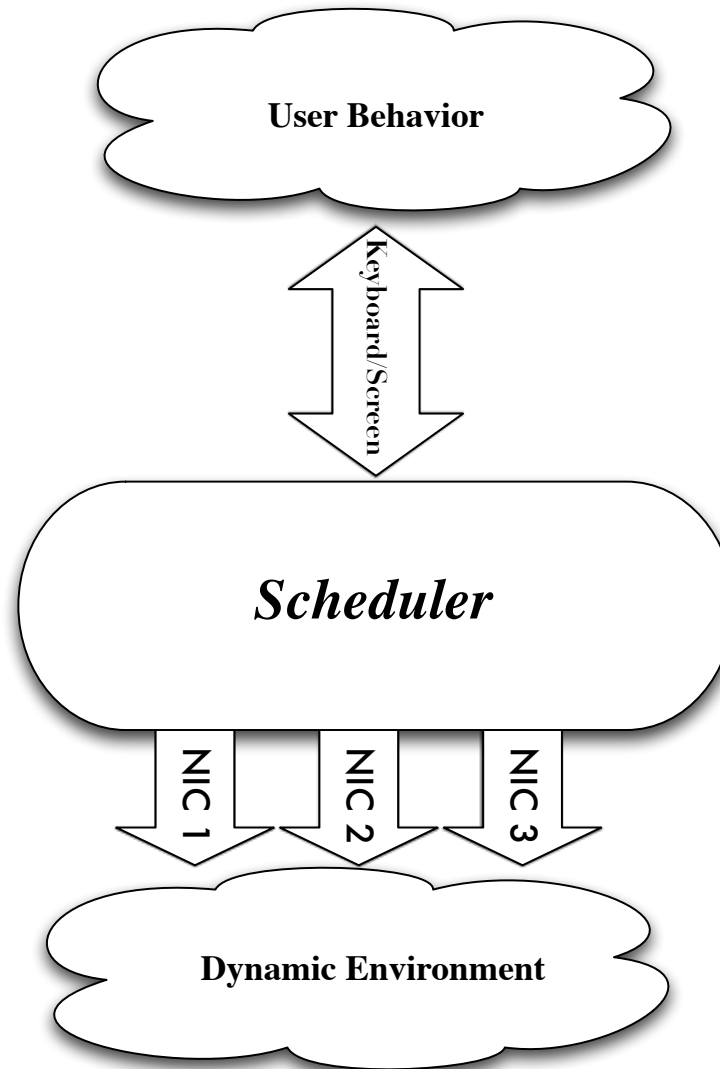


If availability rate is “too low,” the number of back-offs should be bounded.

# Outline

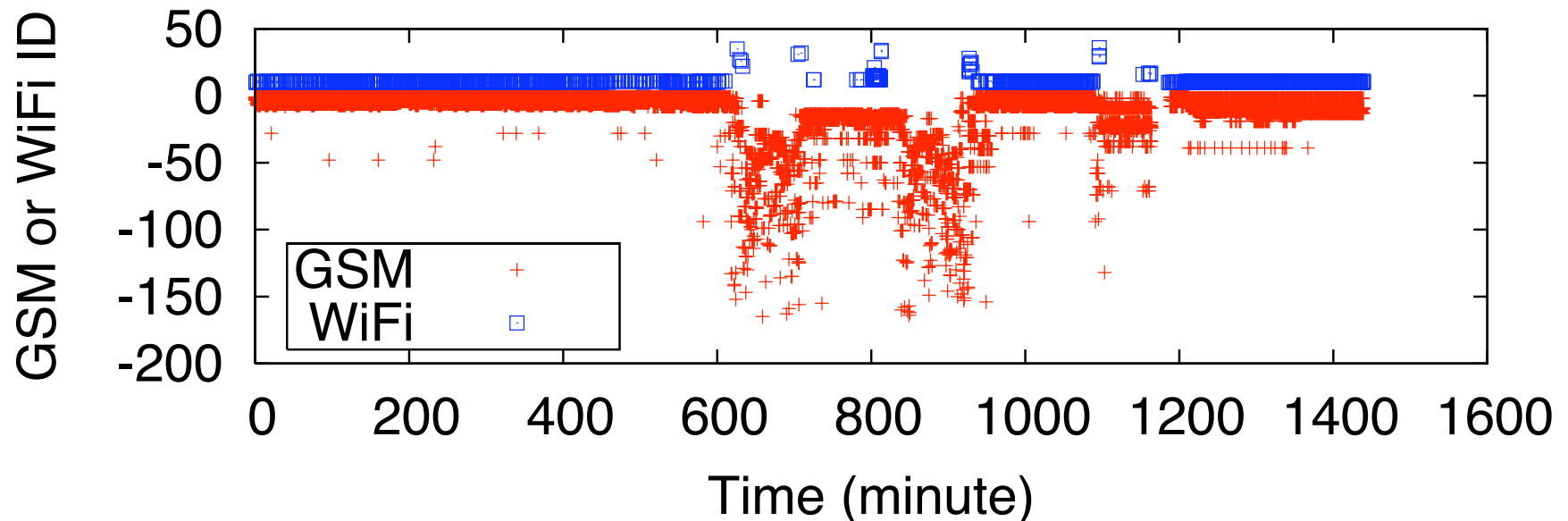
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# Measurements



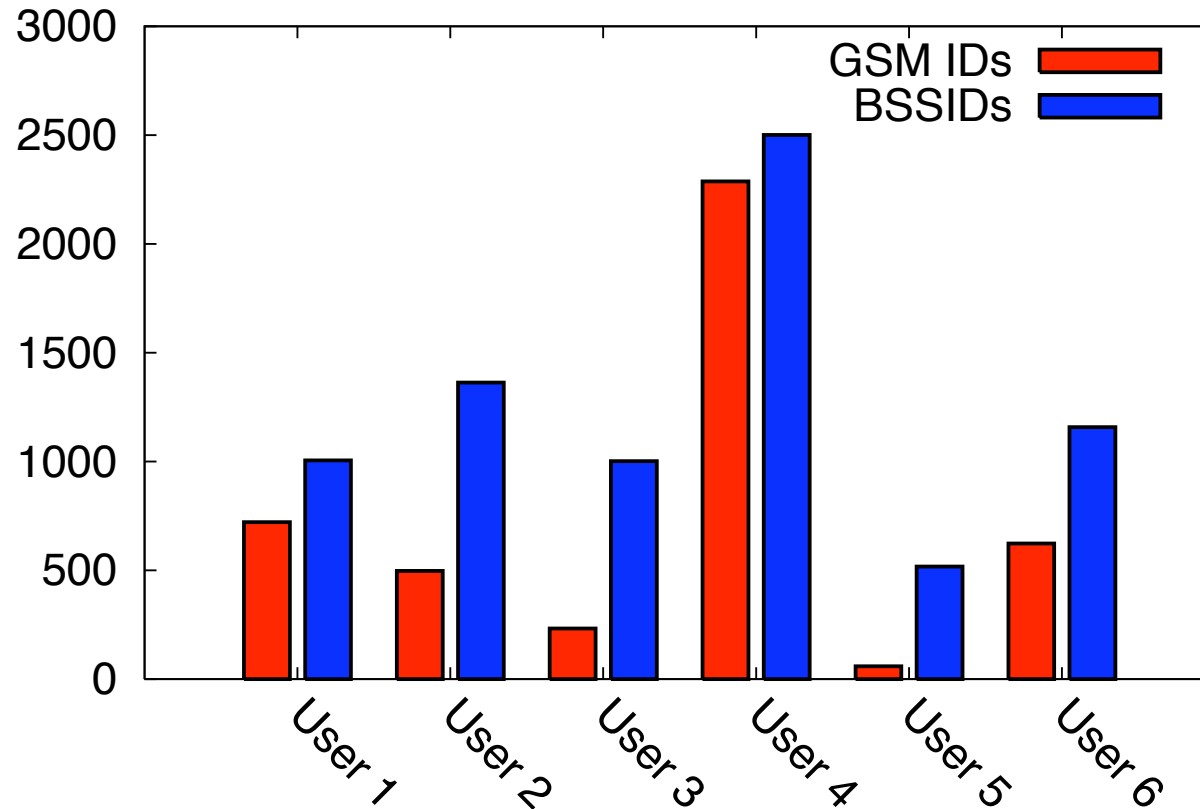
# Wireless Measurements

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



# Waterloo Dataset

Number of GSM and WiFi IDs visited by Waterloo users



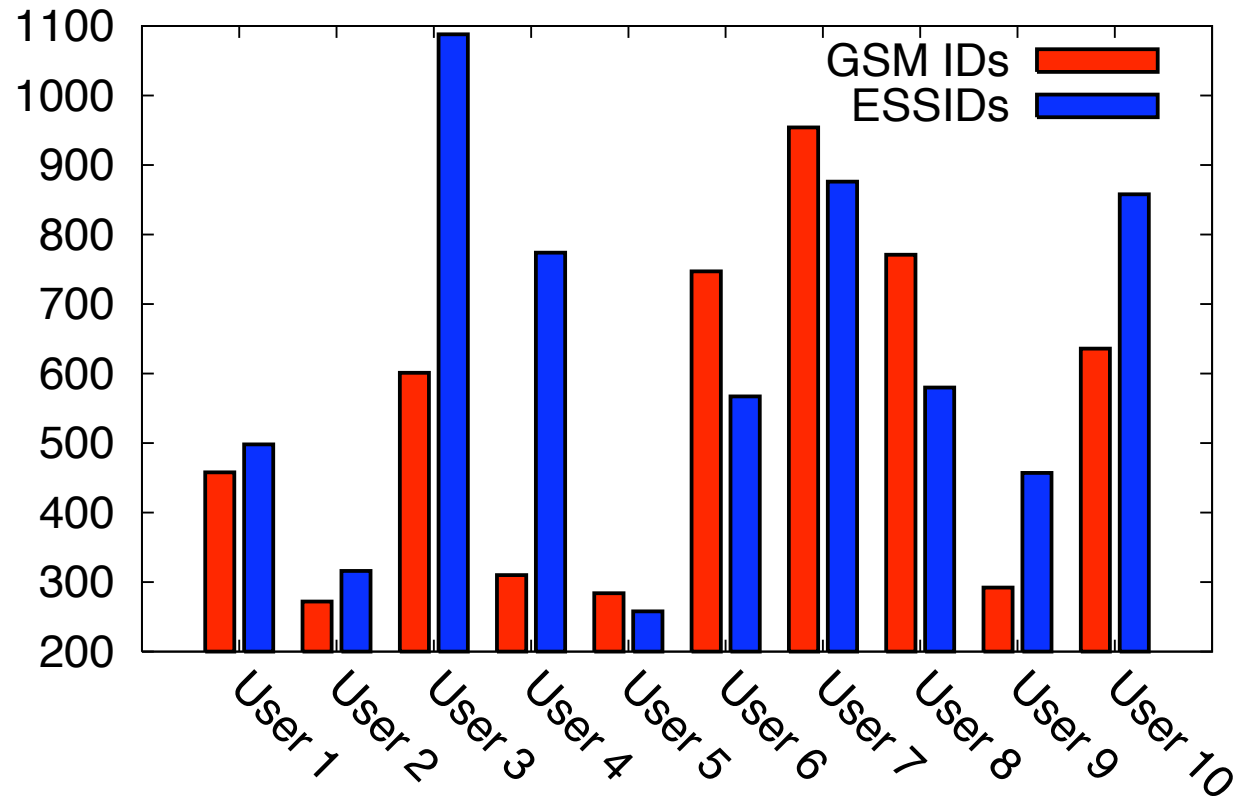
**3070 GSM and 5709 WiFi unique IDs**

**Avg. availability rate: 0.62**

**Avg. missing samples/day: 66**

# Rice Dataset

Number of GSM and WiFi IDs visited by Rice users



**2806 GSM and 3907 WiFi unique IDs**

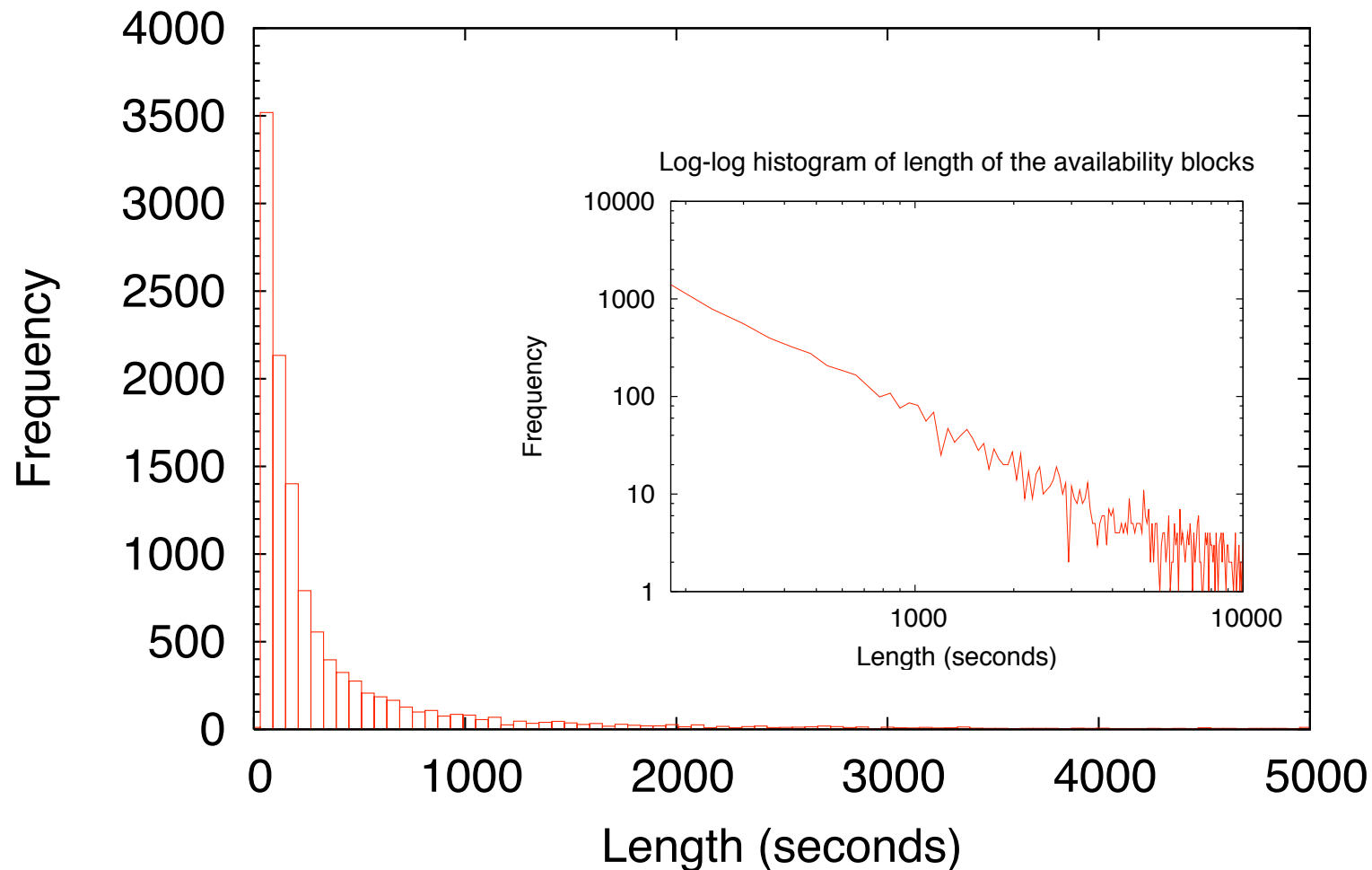
**Avg. availability rate: 0.48**

**Avg. missing samples/day: 147**

# Block Length

## Waterloo

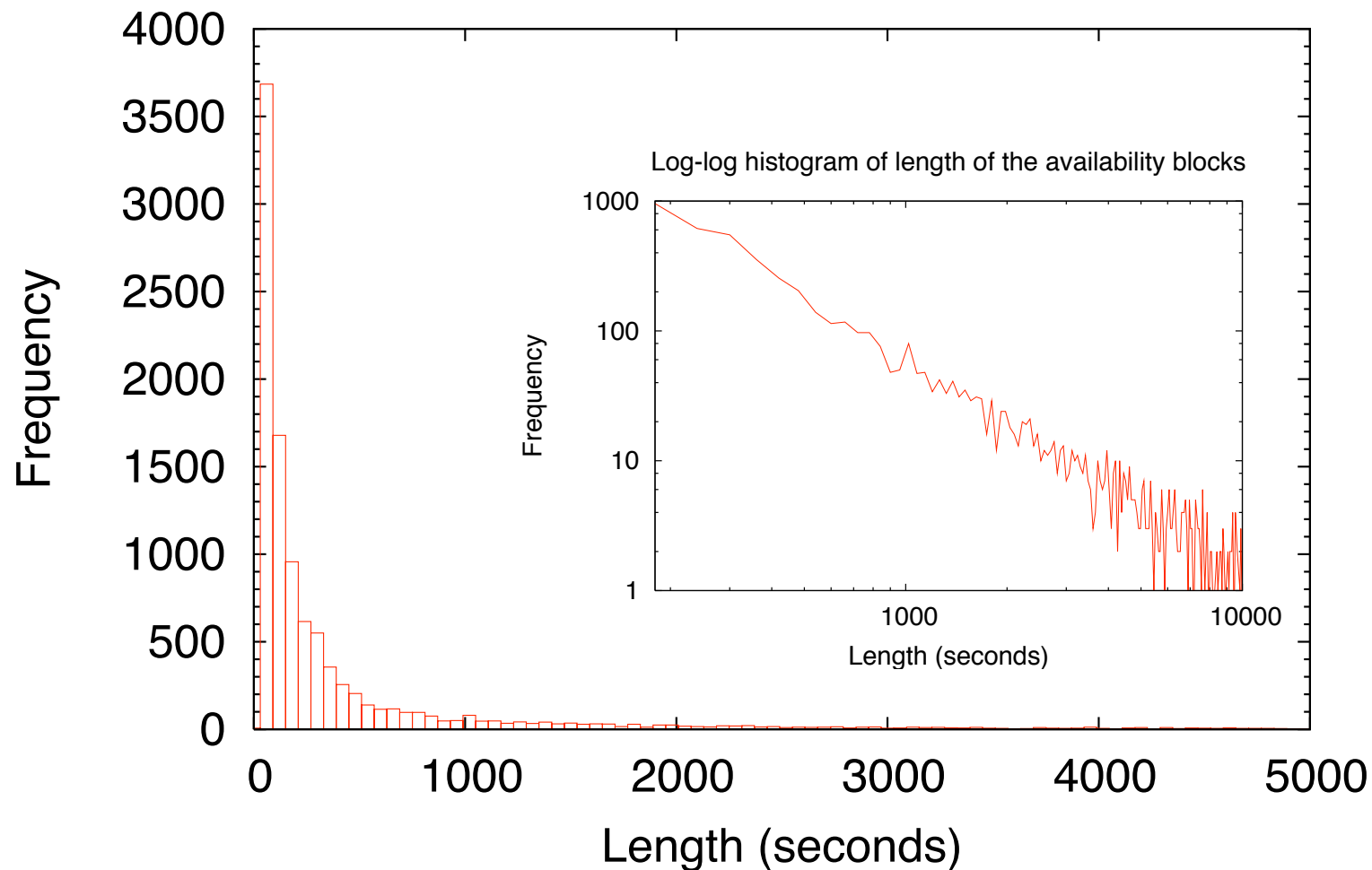
Histogram of the length of the availability blocks



# Block Length

## Rice

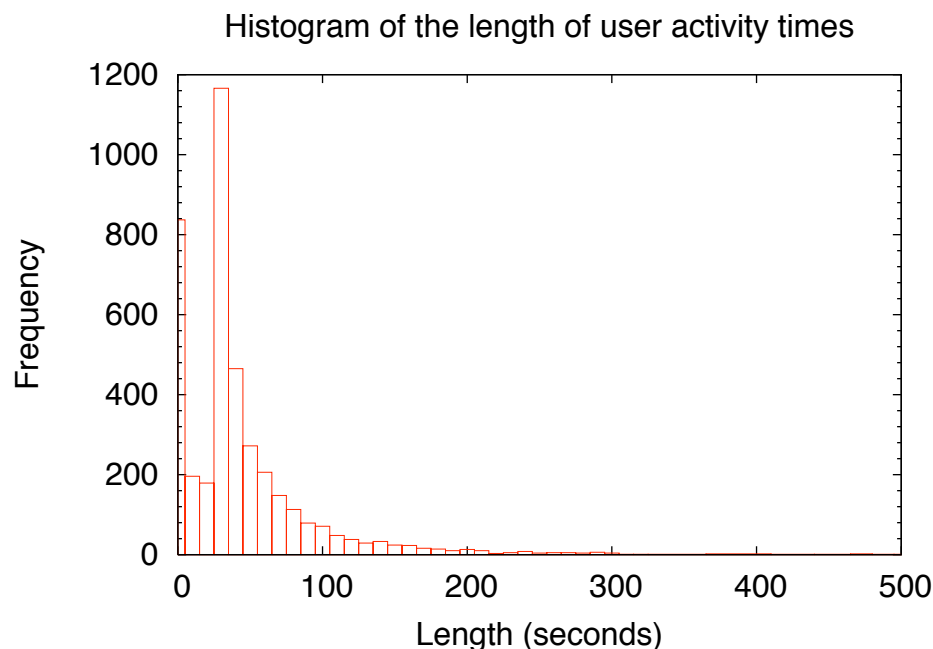
Histogram of the length of the availability blocks



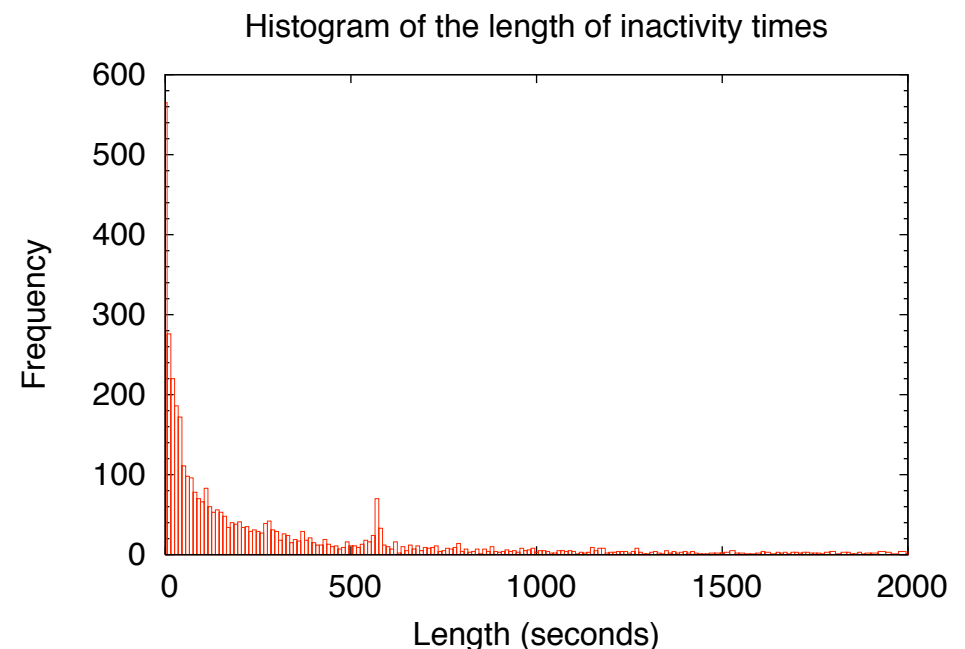
# User Measurements

- Two BlackBerrys logged user interaction times for about three weeks

## Activity



## Inactivity



# Outline

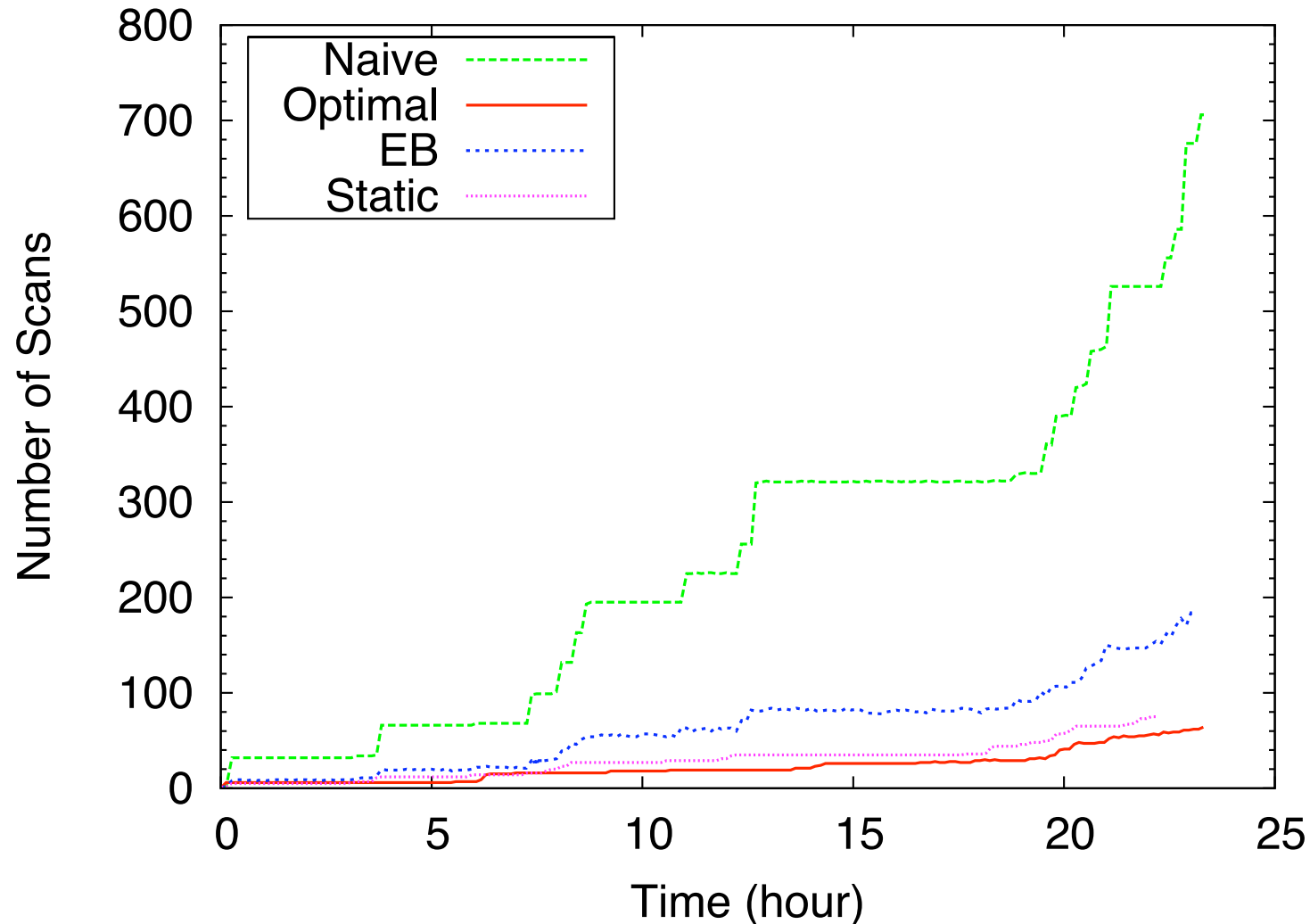
- Modeling
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- Measurements
- **Evaluation**
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# Evaluations

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

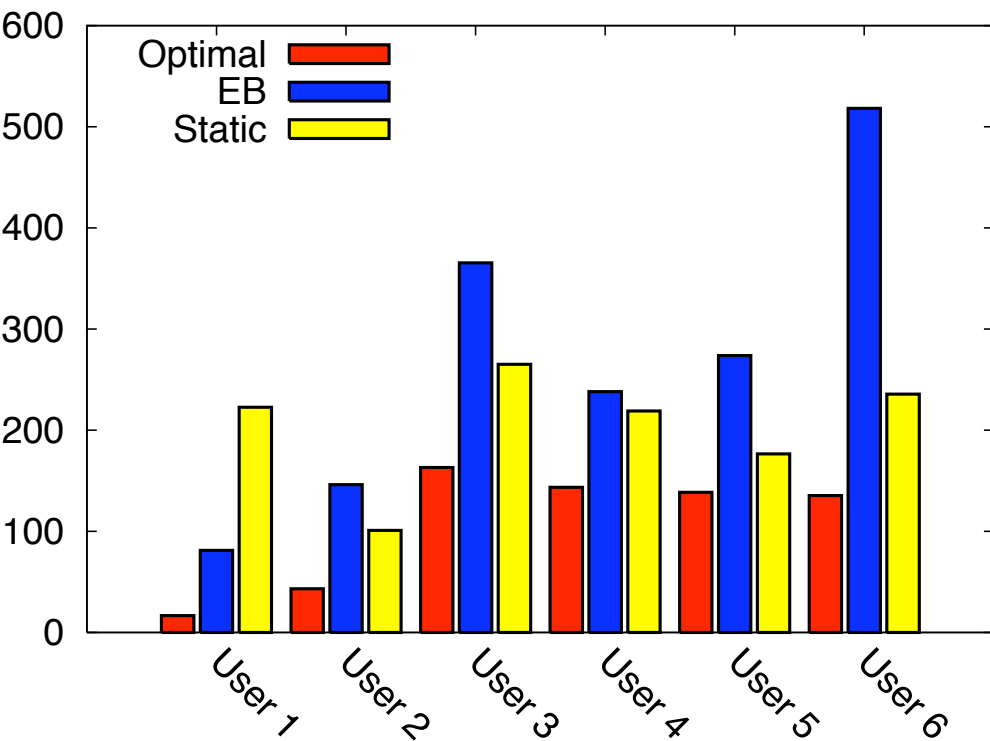
# Comparing Strategies

## Different Strategies

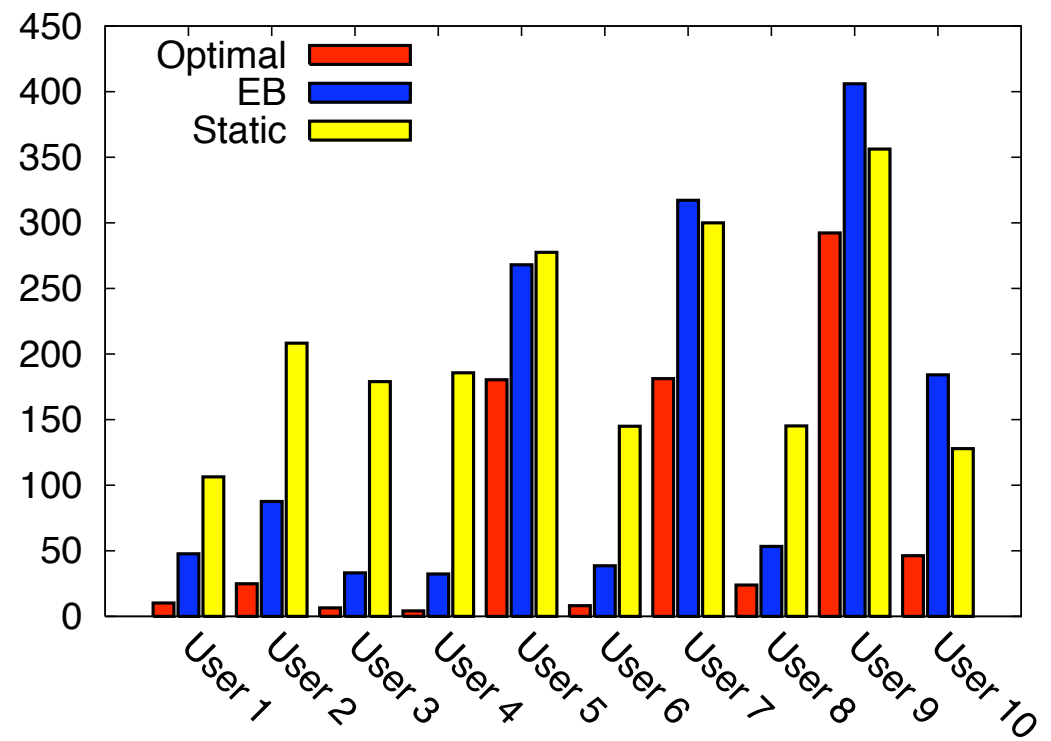


# Number of Scans

## Waterloo

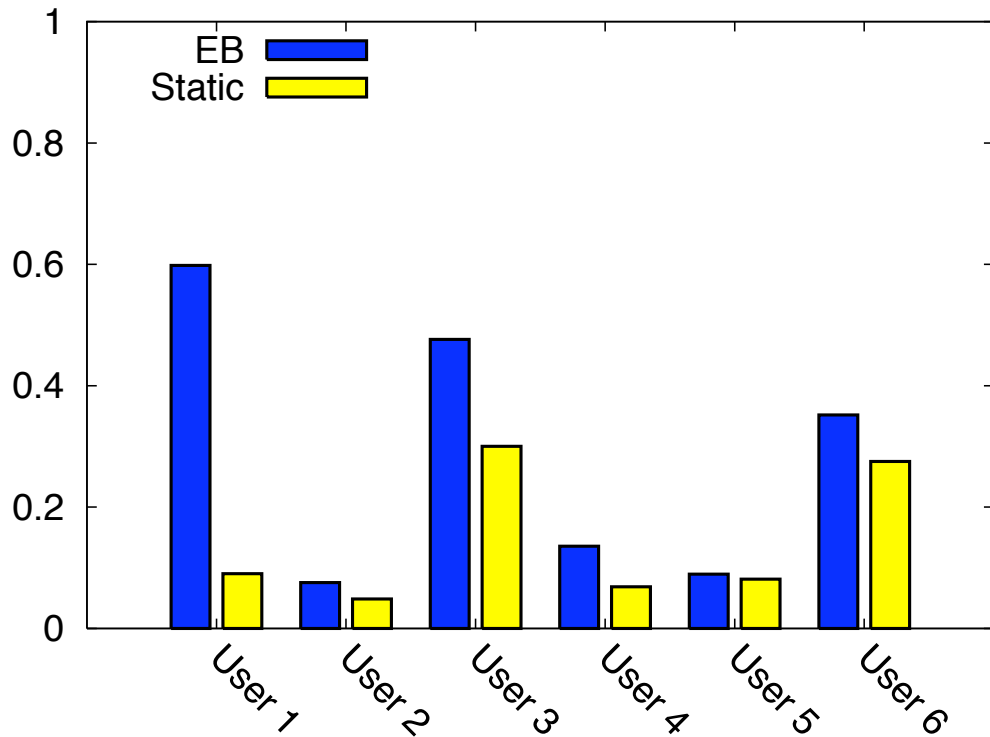


## Rice

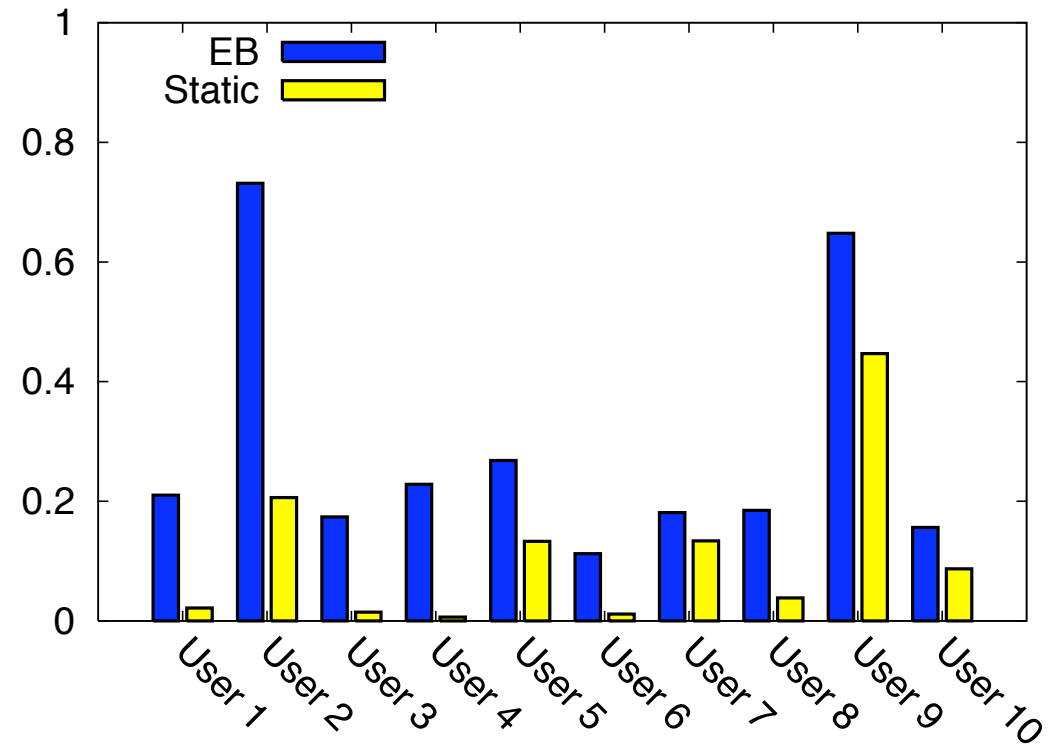


# Missed Opportunity

## Waterloo



## Rice



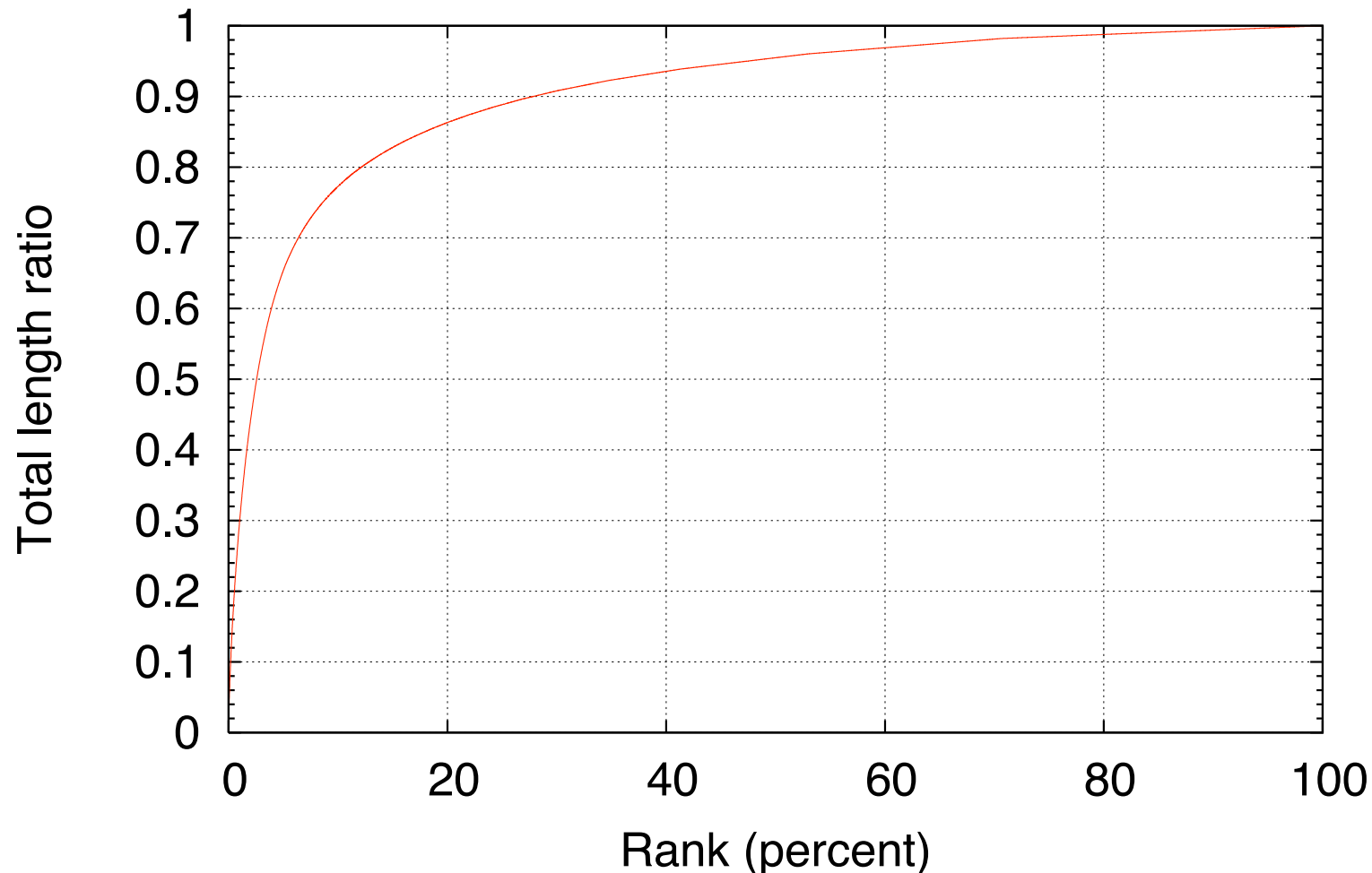
# Simulation Results

- 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

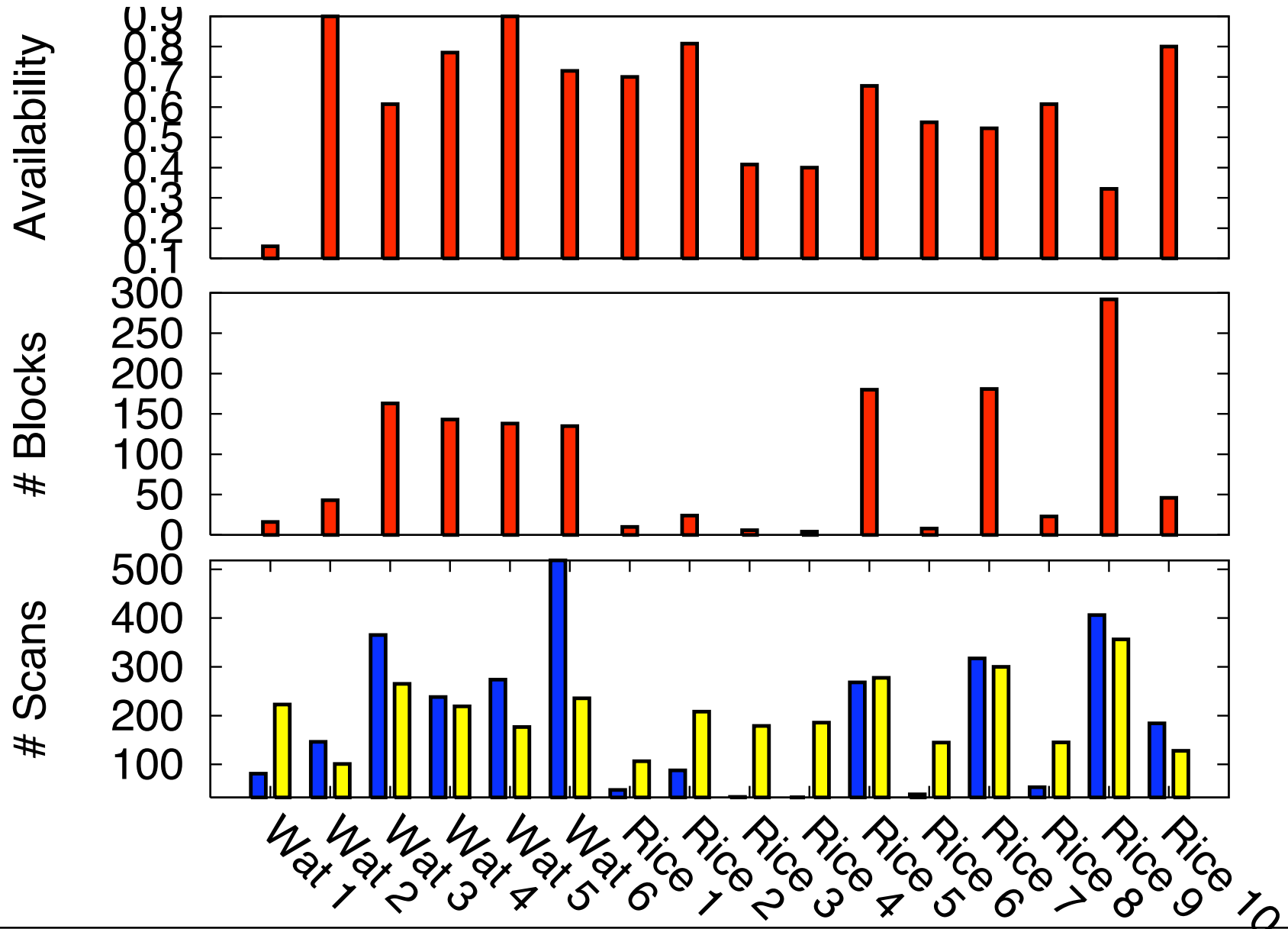
# Discussion

## Waterloo

Rank-size CDF of availability blocks



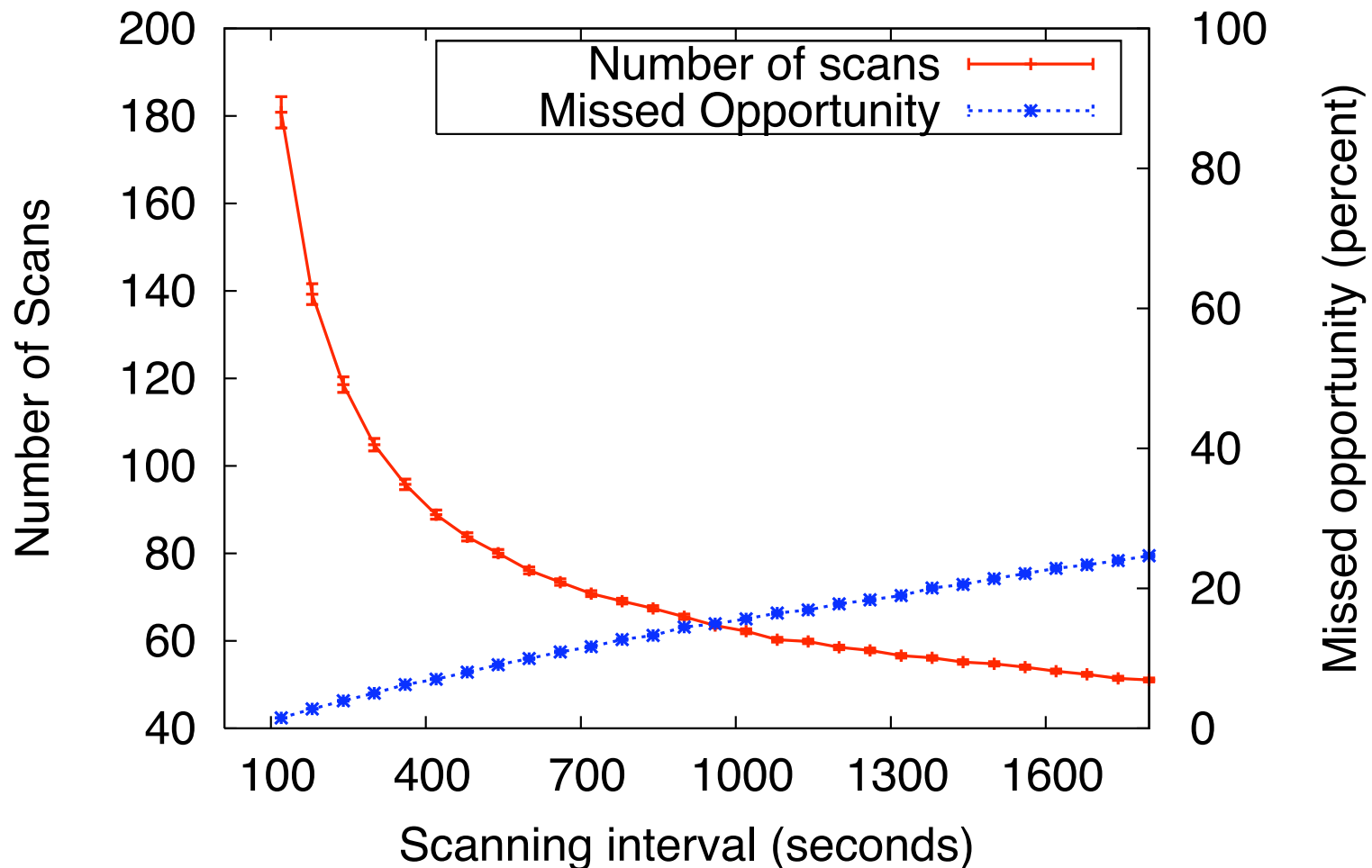
# Discussion



# Tuning Static Scanning

Sample Waterloo user:

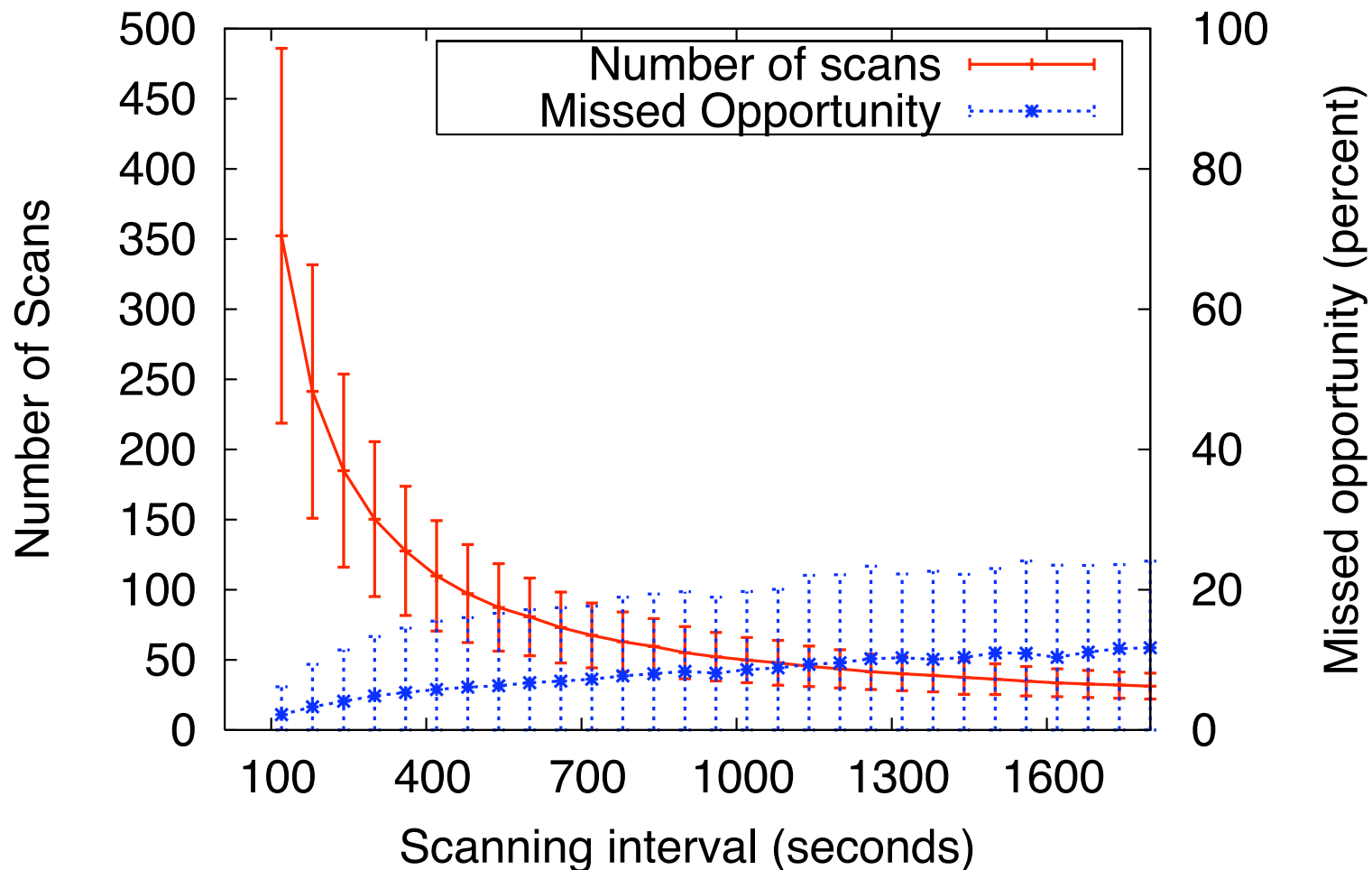
User 2



# Tuning Static Scanning 2

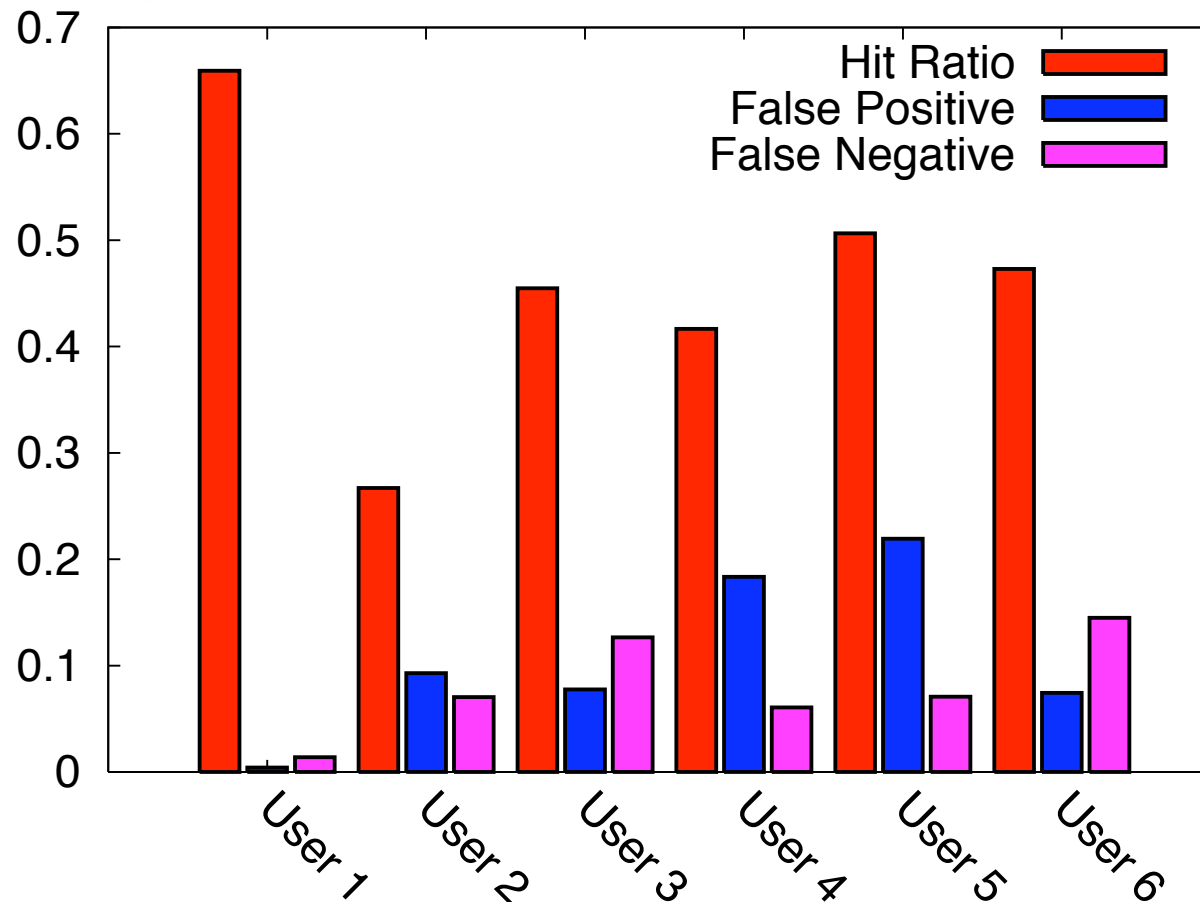
Sample Rice user:

User 8



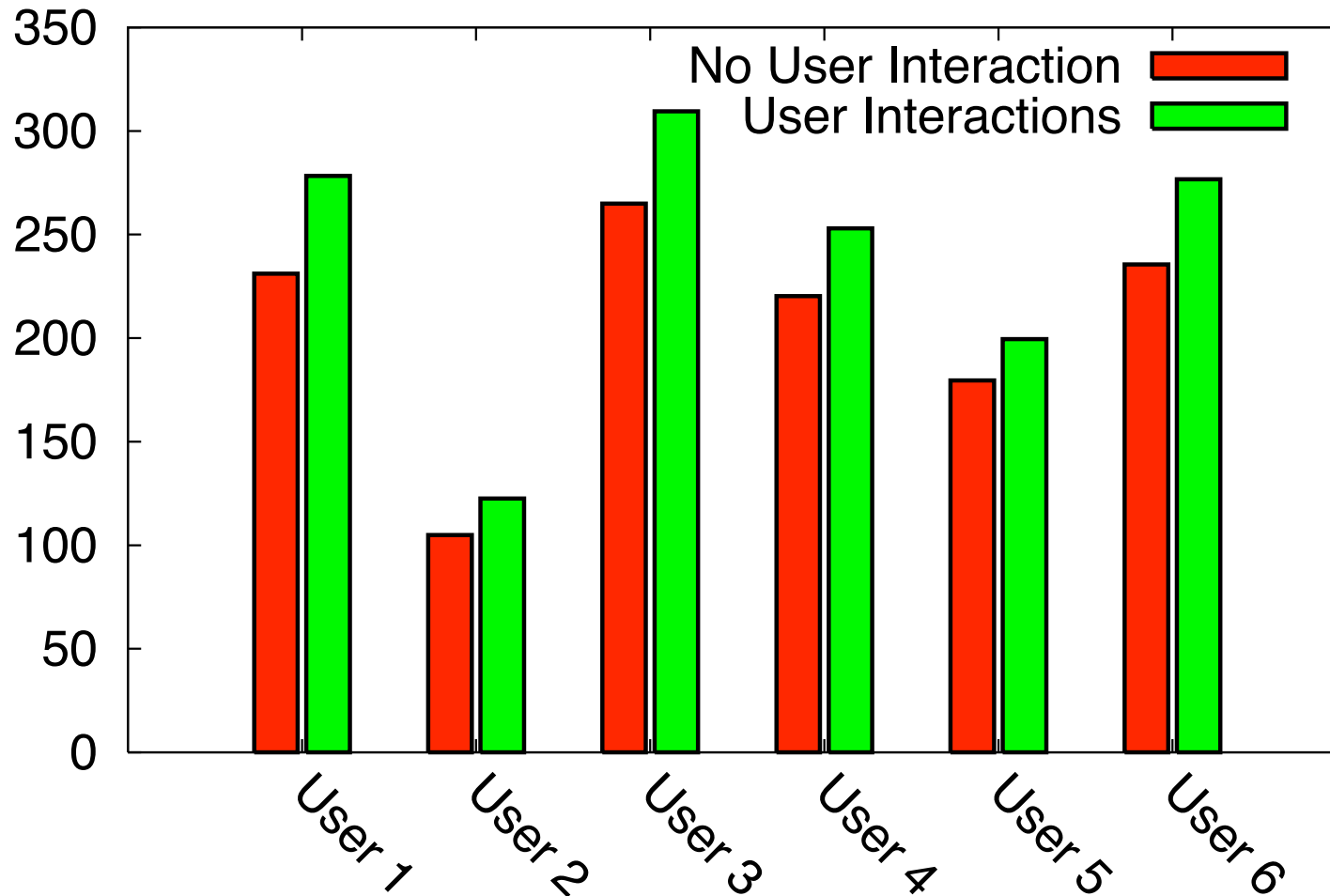
# Caching Scan Results

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



# Interactive Processes

Static Scanning with 300 Seconds Interval



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- **Conclusions**

# 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

# Future Work

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

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