

# CS 525M – Mobile and Ubiquitous Computing Seminar

## Characterizing User Behavior and Network Performance in a Public Wireless LAN

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Lamp Time Expired

# Outline

- Introduction
- Network Environment and Data Collection
- Analysis of Results
  - User Behavior
  - Network Performance
- Conclusion



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## Introduction

- Analysis of user behavior and network performance in a public-area wireless network
  - Captured data from a 3-day ACM conference at UC San Diego, 2001
- 2 phases
  - Monitored SNMP data from 4 APs
  - Packet headers of all wireless traffic



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## Goals

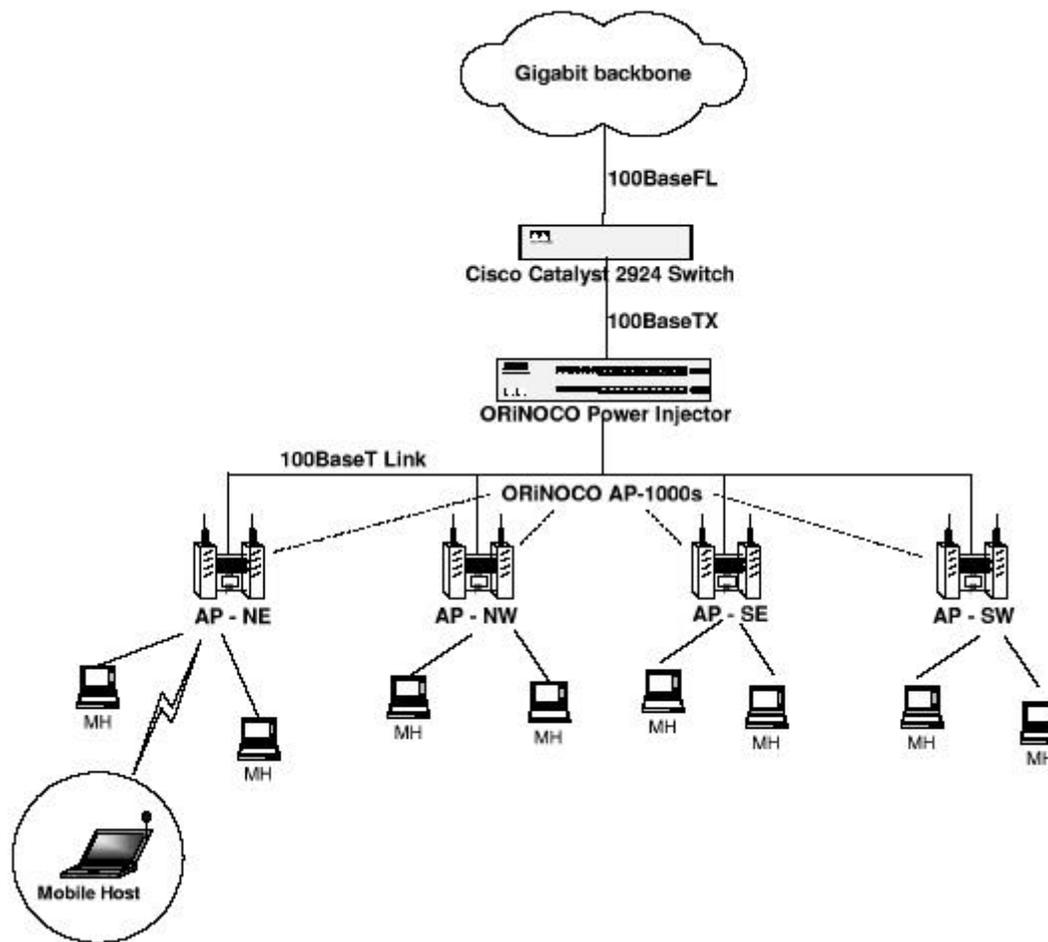
- Gain knowledge of wireless user behavior, wireless network performance. Identify wireless workload characteristics.
- Characterize user behavior for use with analytic and simulation studies
- Better understanding of wireless network deployment issues



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# Network Environment

- 802.11b network in conference auditorium. 110x60x27 ft
- 4 ORiNOCO AP-1000 wireless access points in ceiling.
- 195 users (40% of attendees).
- Wireless cards from 8 different vendors



Lamp: 5 min remaining

## Trace Collection

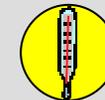
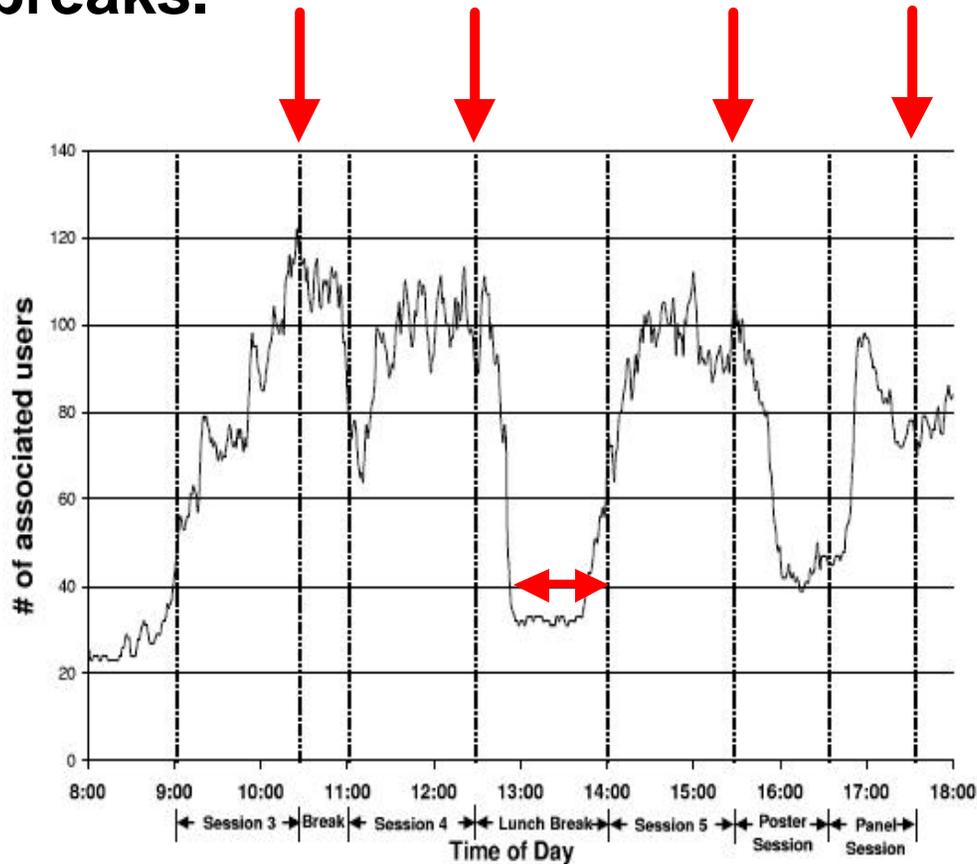
- SNMP data from each AP for 52 hours
  - Wrote *snmputil* to walk the MIB tree every minute. Post-processed with perl scripts.
- *Tcpdump* trace of packet headers from cisco 2924 switch.
  - Analyzed using *CoralReef* software



Lamp: 3 min remaining

# User Behavior

- Number of associated users climbs to a peak when conferences are in session, falls sharply during breaks.



Lamp Temp Exceeded

# User Behavior

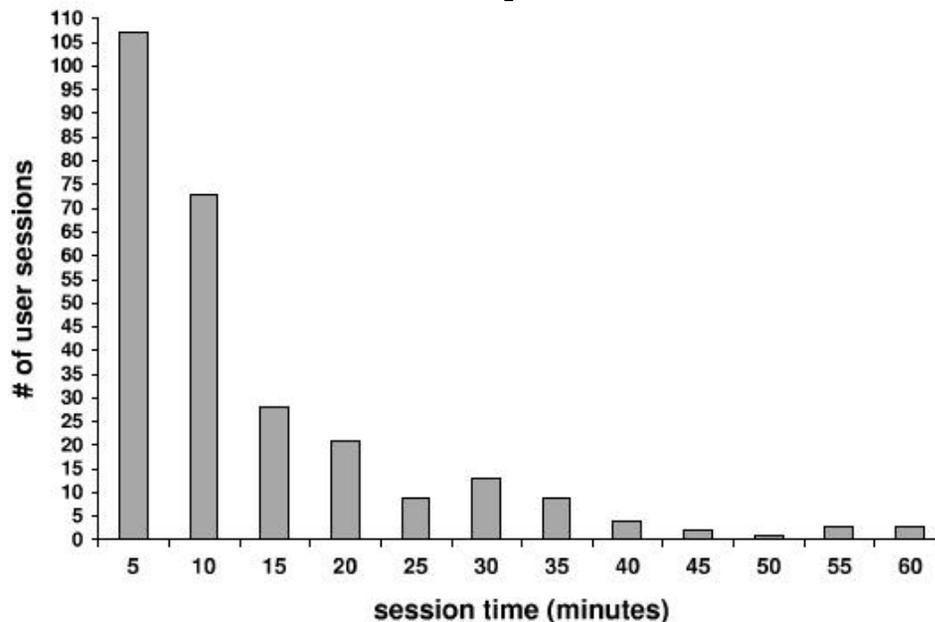
- User arrivals
  - Steady increase as sessions start, decrease as sessions conclude.
  - Correlations in time and space
- Modeled as a Markov-Modulated Poisson Process (MMPP)
  - Two states: ON, OFF
    - ON – Random arrivals at constant rate
    - OFF – No arrivals into the system
  - Mean inter-arrival time is 38 seconds
  - Mean OFF state duration: 6 minutes



Warning: Lamp on fire

# Session Duration

- 90% of sessions last less than one hour. 10% are between one and 3 hours.
- Fits the General Pareto Distribution with shape parameter .78 and scale parameter 30.76 . (Coefficient of determination is 0.9)
- Long sessions are mainly idle



Warning: Lamp on fire

# Session Duration

- Implications

- Short session times means DHCP servers can have shorter lease times.
- A good way to deal with limited IP addresses by recycling them quickly.



Warning: Lamp on fire

## User Data Rates

- Data rates are relatively low and correlate with session times.
- Bandwidth range from 15kbps to 590kbps
- 3 intervals of bandwidth distribution
  - Light: Lower 25<sup>th</sup> percentile
  - Medium: 25<sup>th</sup> to 90<sup>th</sup> percentile
  - Heavy: top 10%
- Long sessions have a low average data rate
  - All sessions longer than 40 minutes are light

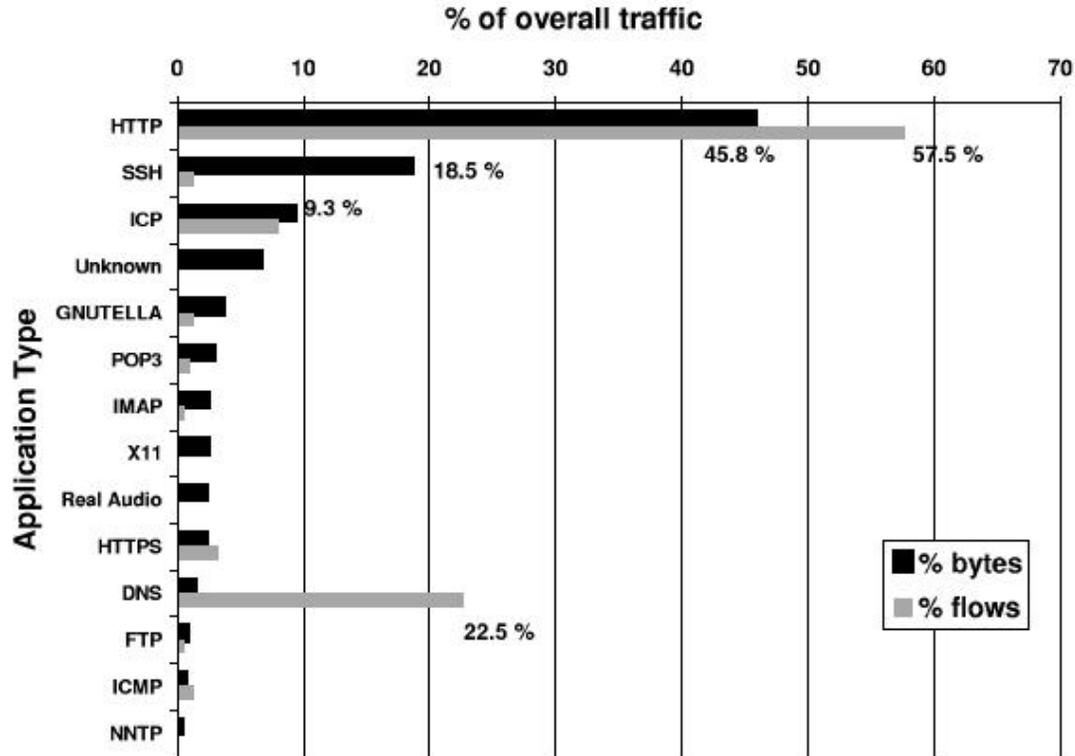
Session Type	Mean data rate (Kbps)	Peak Data Rate (Kbps)
Light	below 15	below 60
Medium	15-80	60-175
Heavy	above 80	above 175



Exhaust Fan Failure

# Application Popularity

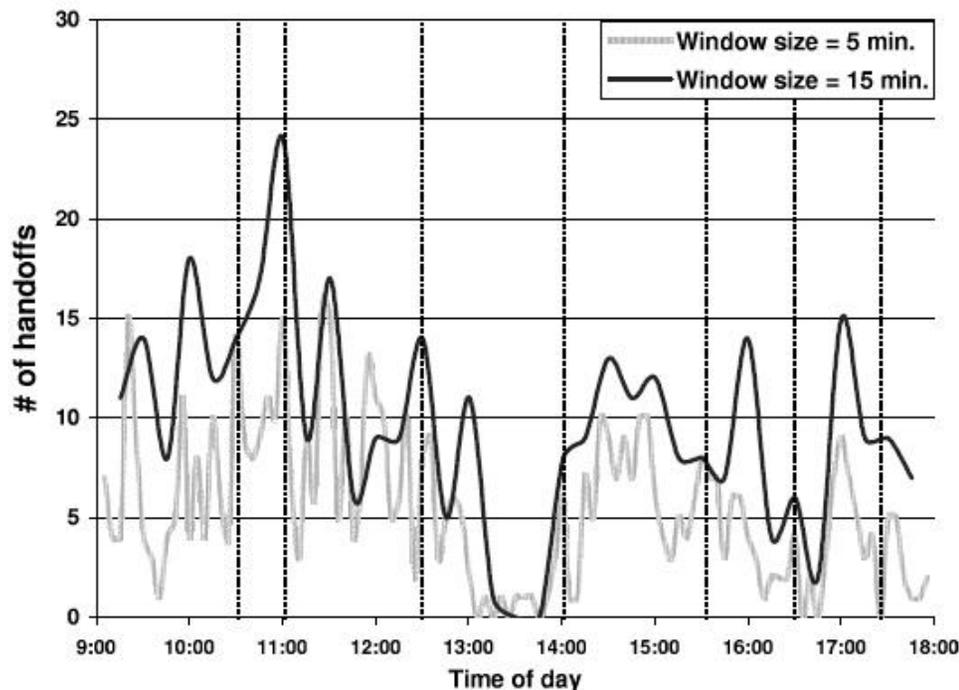
- TCP is 91% of traffic, by byte count. (76% of all flows)
- HTTP is 46% of total bytes
- SSH: 18%
- Users



LCD Meltdown Imminent

# User Mobility

- Users were mobile at the beginning and end of conference sessions.
- 80% of users seen at more than one AP
- 16% stationary
  - Majority of stationary users had longer sessions



Radiation Leak

## User Behavior Summary

- Users evenly distributed across APs
  - Arrivals correlated in time and space
- Most sessions are short. 60% < 10 minutes
  - Longer sessions are typically idle
- Sessions are either light, medium, or heavy and range from 15-590kbps
- HTTP and SSH total 64% of bytes and 58% of flows.
- Users are mobile when expected.



Evacuating Personnel

## Network Performance

- Load peaks from 11am-12:30 and drops during lunch.
  - Peak throughput of 3.2mbps
- Uneven load distribution across APs
  - 37% difference between NE and SW
  - Due to application workload of users
- Load is sensitive to individual bandwidth requirements, not number of users
- Peak load does not occur when number of users is at maximum.



Self Destruct in 5 min

# Channel Characteristics

- Packet error rate obtained from SNMP
- Error rates are bursty, and correlate to a large number of handoffs
- Error greater than normally used in simulations
  - Difference due to measurement at packet-level rather than bit-level
- Number of link-level retransmissions does not match number of errors because MAC beacons are not retransmitted.

Statistic	% Packets in Error				
	NE	NW	SE	SW	Overall
<b>Mean</b>	2.81	2.81	2.83	2.75	2.41
<b>Median</b>	2.16	1.99	2.13	2.18	2.15
<b>90<sup>th</sup> %ile</b>	5.32	6.07	5.33	5.59	4.01



Self Destruct in 3 min

## Summary of Performance

- “Not surprisingly”, load correlates with conference schedule
- Bandwidth is determined by individual behavior
- Network is overprovisioned with 4 APs for 195 users.
- Wireless channel characteristics are similar for all APs, more time-dependent than location-dependent.



Self Destruct in 1 min

## Conclusions

- Most sessions are relatively short
- DHCP can be configured with short lease times
- Few APs are needed for a large number of users
- Study is characterized by concentrated space and scheduled use and would share characteristics with classrooms, airports, etc.



Self Destruct activated

