

February 13, 2007

Analysis of a Campus-wide Wireless Network

William Lee

Duke University

Department of Electrical and Computer Engineering

Durham, NC 27708



Nature of the problem

OBJECTIVE:

- To understand user behavior as well as physical mobility within a campus environment

BACKGROUND:

- WLANs are increasingly common particularly on university and corporate campuses.
- IEEE 802.11b is broadly deployed, but little known about how networks used.
- Extension upon WaveLAN (building) and Metricom (geographical area) study by Tang and Baker
- Dartmouth size, population diversity, and detail of data collection offer extensive insight into wireless network usage

Outline

- Test Environment
- Trace Data Collection
- Analysis
- Summary

Test Environment

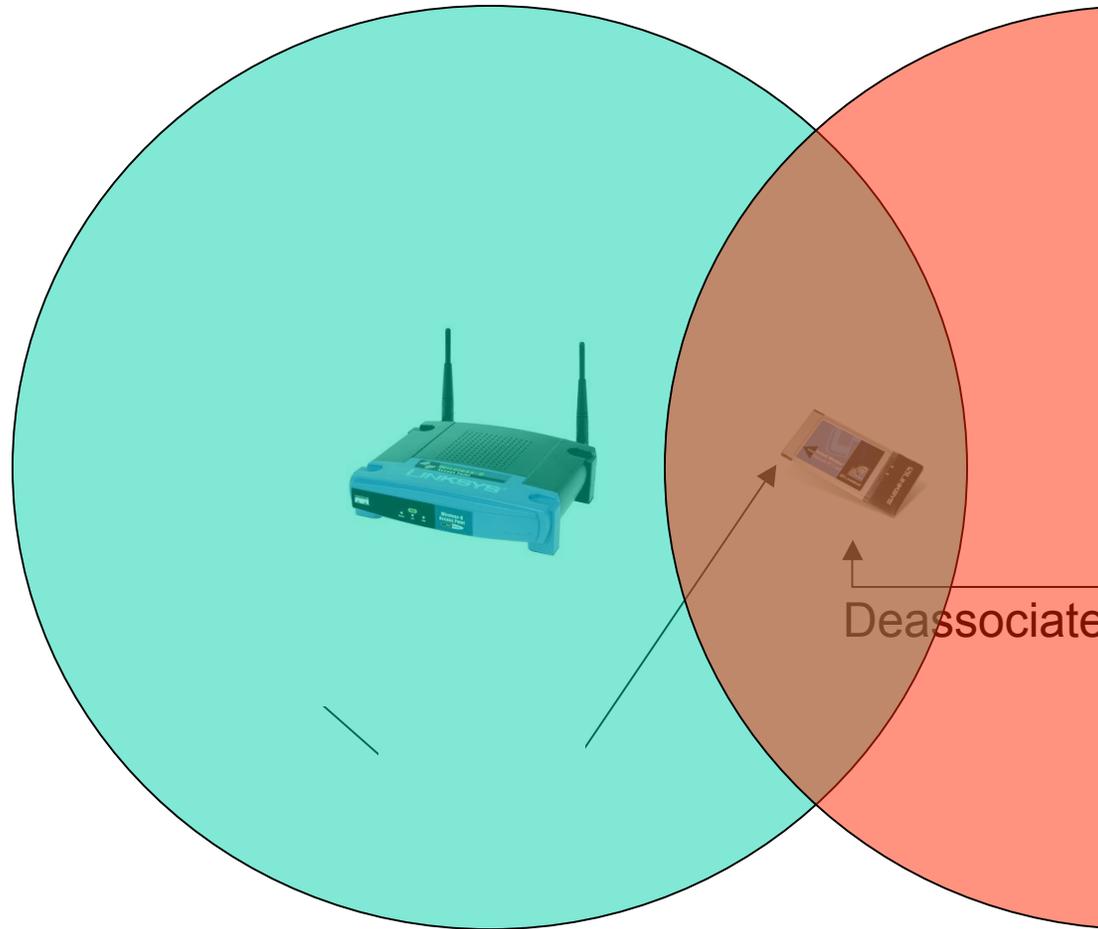
- Performed at Dartmouth College campus using 476 APs spread over 161 buildings (200 acres with administrative, academic, residential, and athletic buildings).
- Each AP has a range of about 130-350 feet indoors.
- All APs share the same network name allowing wireless clients to roam seamlessly from one AP to another.
- 161 covered buildings span 81 subnets → roaming from buildings require new IP addresses

Trace Data Collection

- 11 week Fall 2001 term data collection (Sept 25 – Dec 10)
- Data limited to active periods (Fall Term)
- Incomplete due to power loss
- Syslog
 - APs transmit a system log message
- SNMP
 - Simple Network Management Protocol used to poll APs
- Sniffers
 - Tcpdump used to capture all packet headers
- Syslog and SNMP traces used to compute basic statistic about traffic, users, and mobility

General Definitions

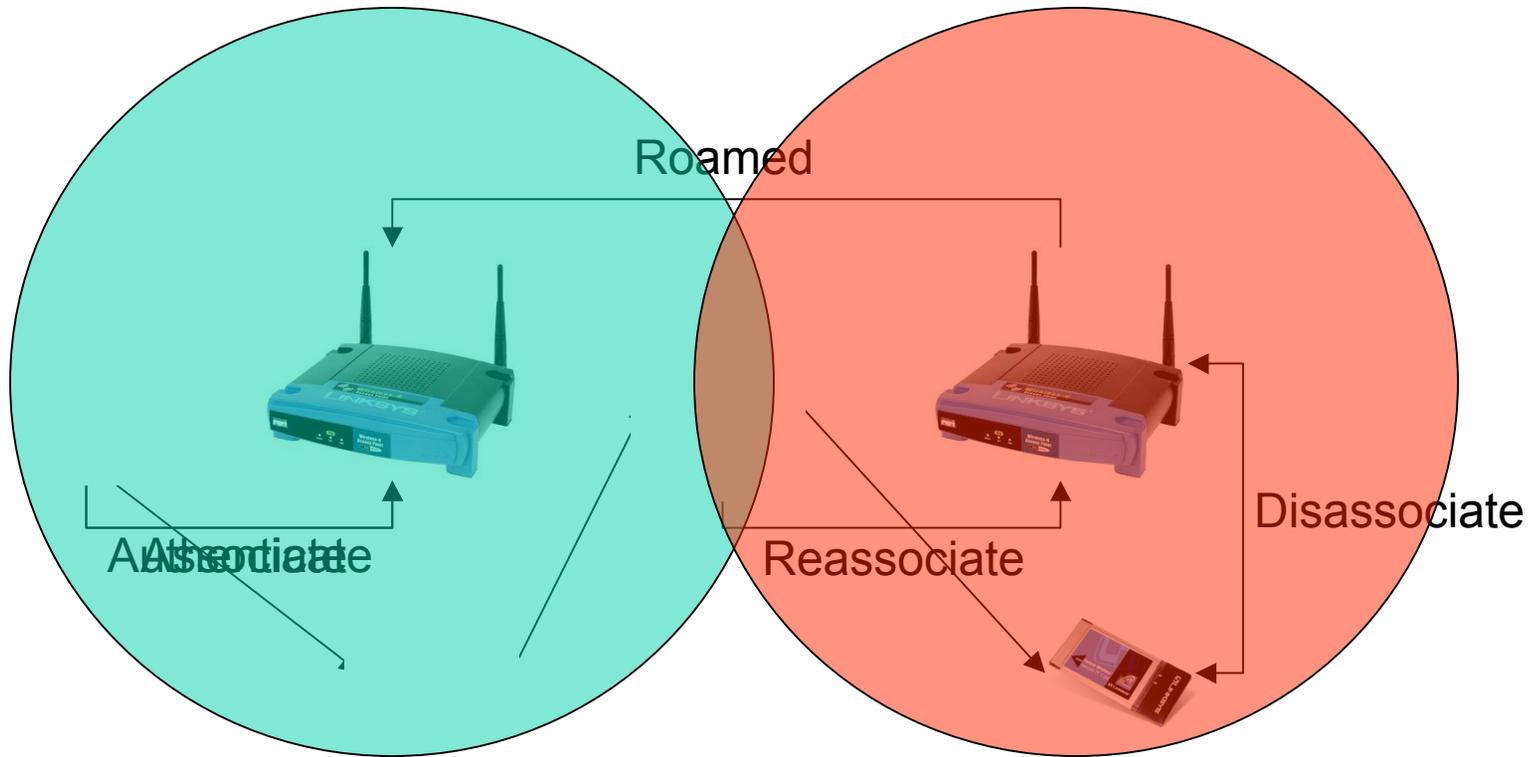
End Session



Syslog

- Of 476 APs only 430 represented (some never used → misconfigured)
- APs configured to transmit every time a client card authenticated, associated, reassociated, dissociated, or deauthenticated with the AP.
- Syslog uses UDP (user datagram protocol) therefore messages potentially lost or misordered (recall difference between TCP)
- Network does not use MAC authentication or IP authentication → IP addresses given to users vary from time to time and building to building
- Assumed one card per user (users with multiple cards/shared cards)

Syslog Messages

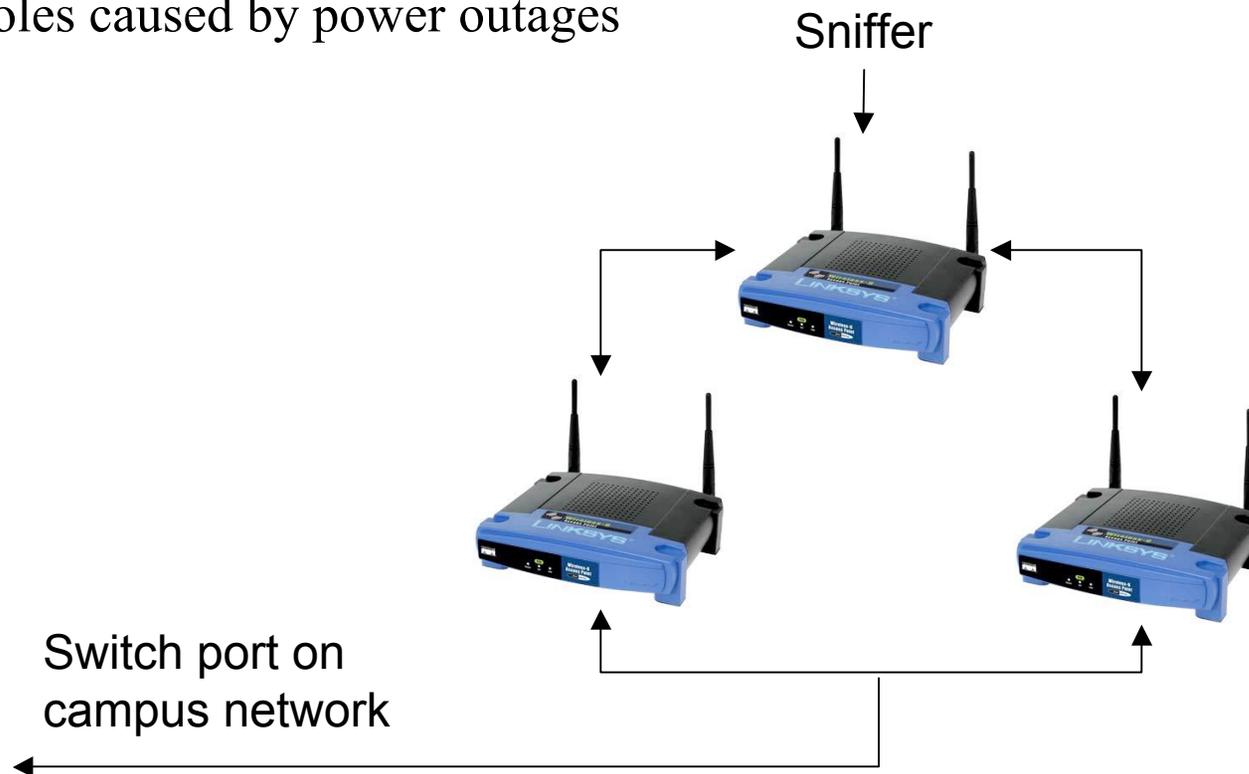


SNMP

- Of 476 APs only 451 monitored
- Used to periodically poll the APs (poll every 5 min)
- Each poll returned MAC addresses of recently associated client stations and two counters (inbound, and outbound bytes)
- SNMP contains list of cards but syslog data used for tracking cards as syslog provides the exact series of events for each card while SNMP polling is less precise

Sniffers

- Of 451 APs only 22 monitored
- Tcpdump used to capture all of the packet headers
- Packet headers recorded for privacy
- Holes caused by power outages

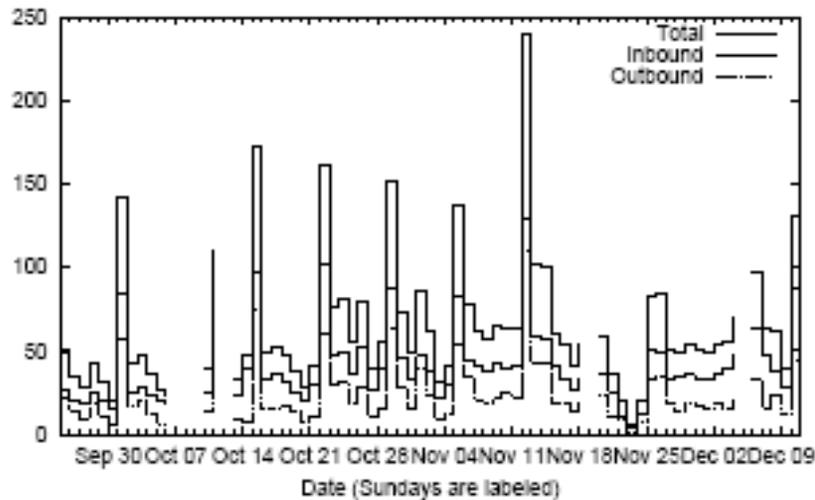


Analysis

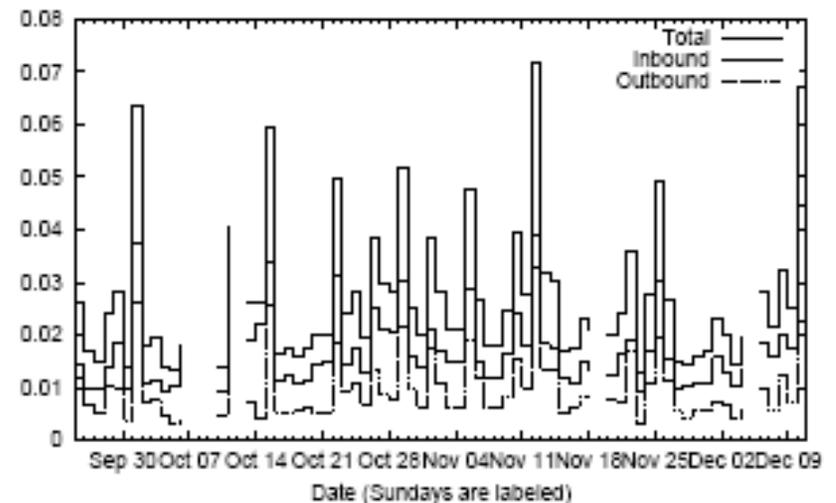
- During trace period 1706 unique cards identified.
- Distributed among 161 buildings with (82 residential, 32, academic, 6 library, 19 social, and 22 administrative)
 - Traffic
 - Card Activity
 - AP Activity
 - Building Activity

Traffic

- 3.3 terabytes of total traffic (half caused by 5% of cards)
- Less outbound traffic than inbound traffic, daily variation (18 - 89%)
- Data skewed by activity in particular buildings
- Most users limit their activity to a few key sites in their daily routine.



SNMP Daily Traffic (GB)



SNMP Daily Traffic per Card (GB)

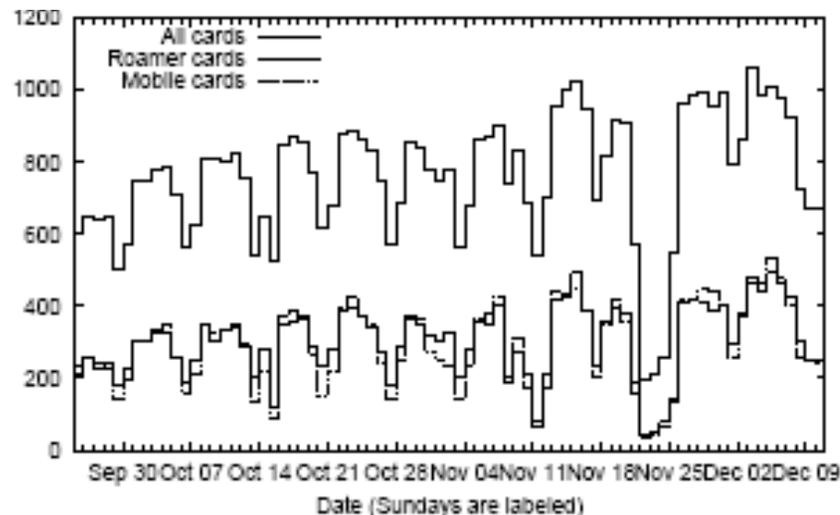
Card Activity

- Half the card population active on a typical day, and a third of those are mobile
- Users varied in the number of days that they used their cards from once to every day during the trace period
- Median card movement of five buildings (9 APs) and no card visiting greater than half of the entire network.
- Median session length was 16.6 min
- Extremely long sessions are likely artifacts of holes in the syslog data where session-ending message was lost
- Most (82%) sessions are non-roaming
- Nearly 60% of roaming sessions roamed only within one subnet

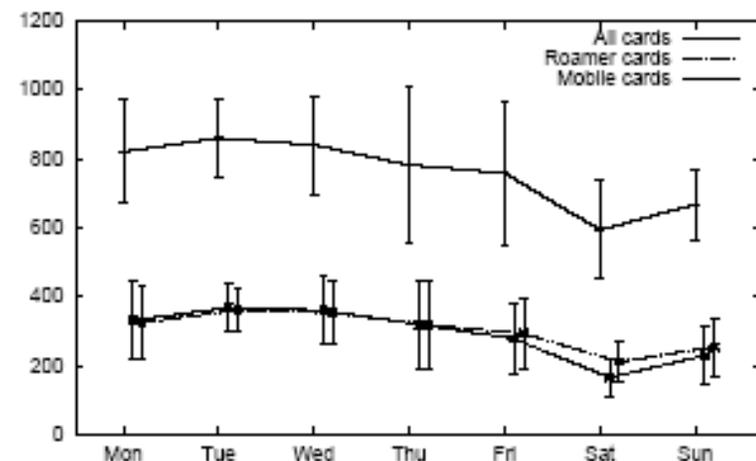
Card Activity (Cont.)

- The cards aggressively search for a strong signal, and in an environment with many APs and overlapping cells, cards will roam frequently.
- Either card firmware needs to be less aggressive, or environment needs to reduce the resulting load on the network, and give better service to the user

Syslog Active, Mobile, and Roamer cards per day

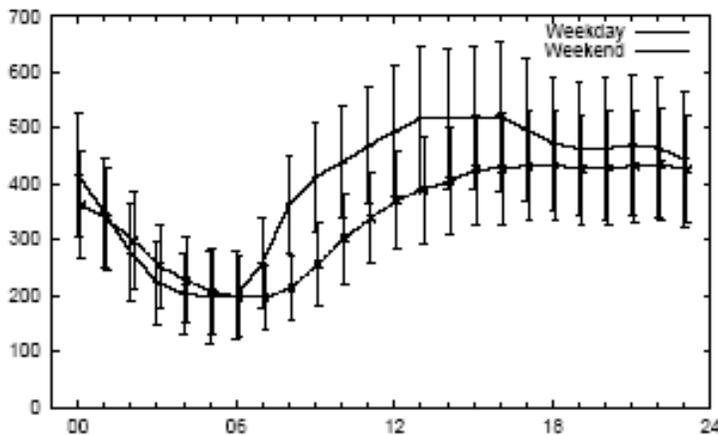


Syslog Active, Mobile, and Roamer cards per day

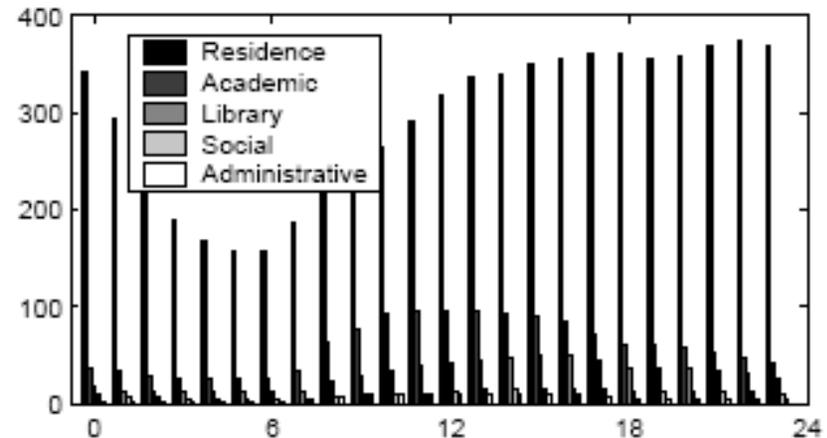


AP Activity

- There are many locations where a card may associate with APs in multiple buildings, despite being physically stationary
- APs with the most active cards in their busiest hour were those located near large lecture halls
- The busiest AP had 71 active cards
- APs varied widely in the amount of traffic they handled



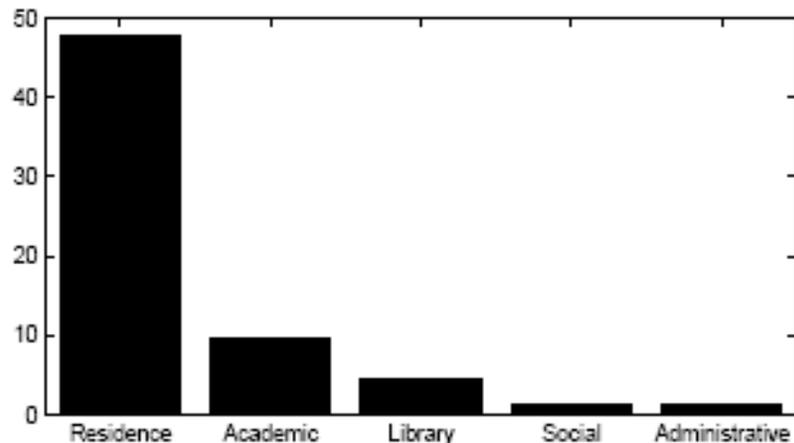
Syslog Number of active cards per hour



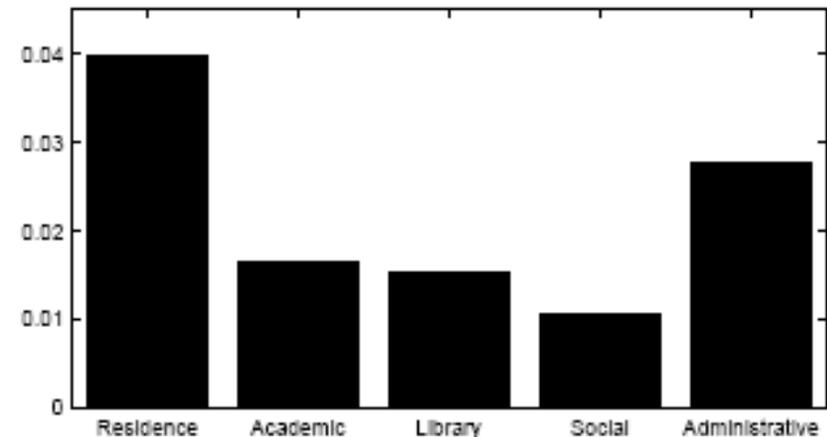
Syslog Mean active cards per hour

Building Activity

- Residential users spend more hours in residences than most people spend in other buildings.
- Buildings with the busiest hour in terms of active cards are mostly buildings with large lecture halls



SNMP Average Daily Traffic (GB)



SNMP Average Daily Traffic per Card (GB)

Summary

- Largest trace-based study conducted
- Activity and traffic varied widely from hour to hour, day to day, and week to week
- Wireless cards are extremely aggressive when associating with APs leading to large number of short sessions and high degree of roaming within a session
- A new solution is necessary to prevent cards from roaming too frequently without sacrificing coverage
- Most users visited few APs and building over life of the trace

Questions





Protocols

Figure 28: [tcpdump] Total connections, by TCP protocol, normalized.

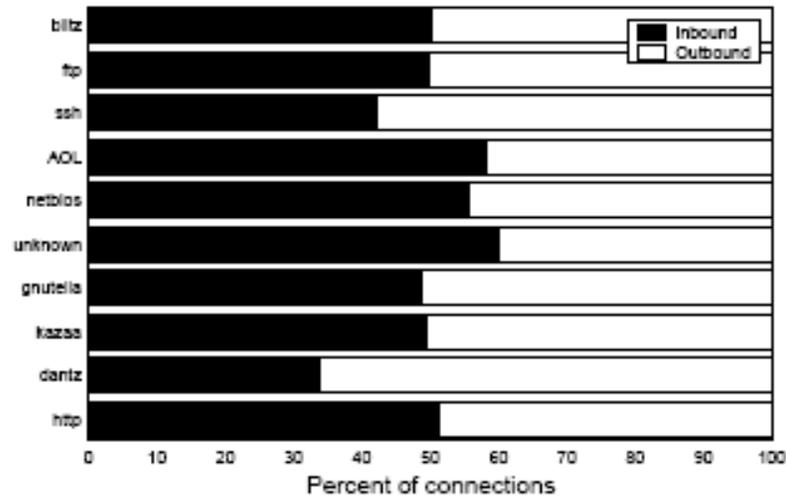


Figure 26: [tcpdump] Total traffic (GB), by TCP or UDP protocol, normalized.

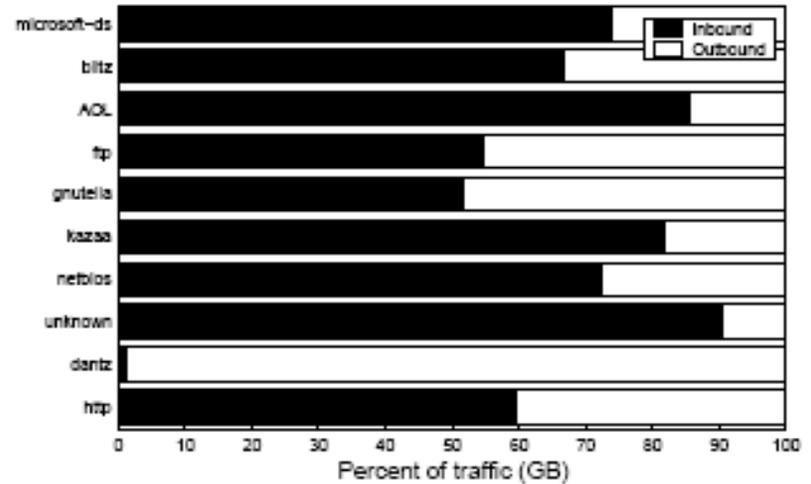
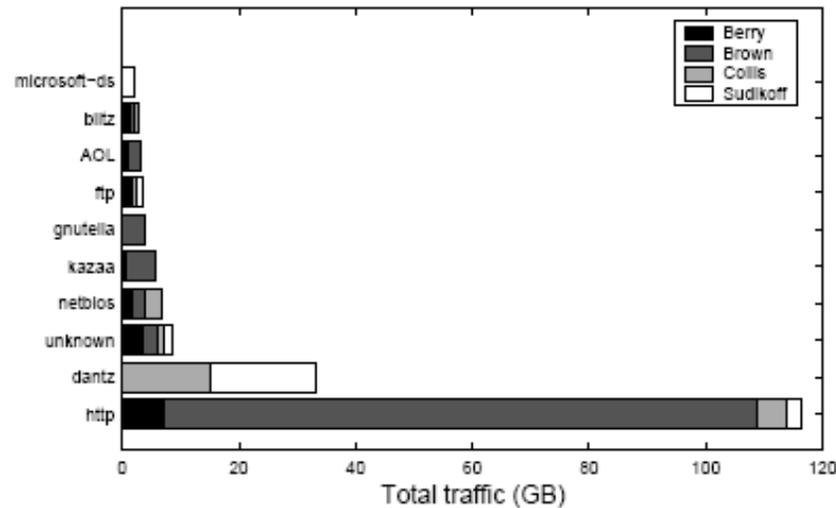


Figure 25: [tcpdump] Total traffic (GB), by TCP or UDP protocol.



Traffic

Figure 4: [SNMP] Average daily traffic (GB), by weekday.

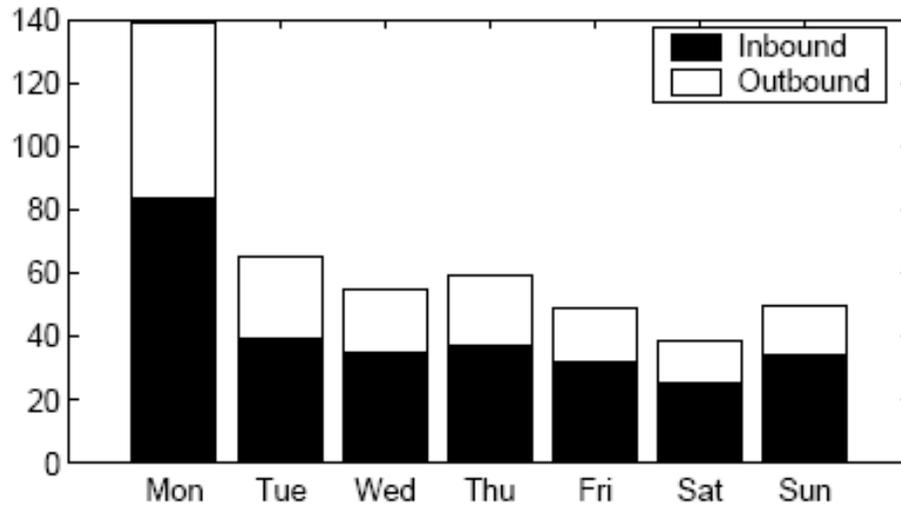


Figure 5: [SNMP] Average hourly traffic (GB), by hour (truncated). The 10am peak reaches 11.4 GB (60% inbound).

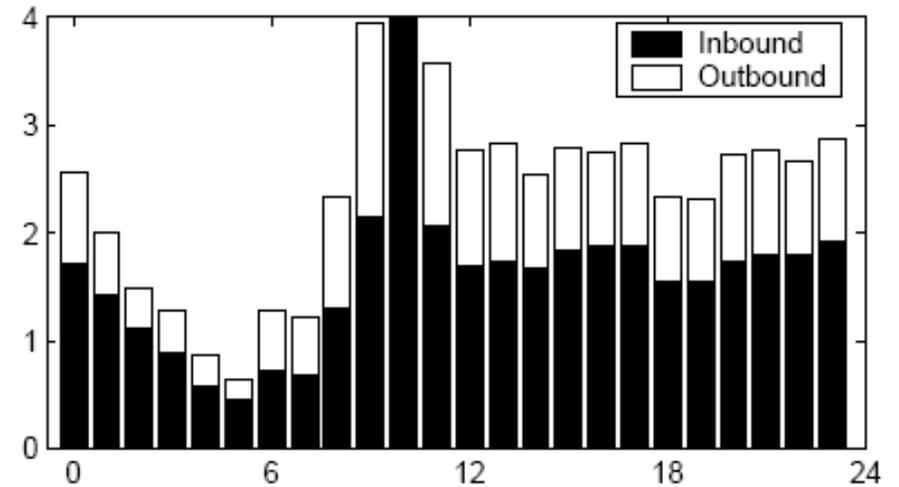


Table 1: [syslog] Common card vendors.

Number	Vendor
624	Lucent/Agere
536	Apple Computer
489	Cisco/Aironet
57	Other (15 brands)
1706	Total