Characterizing User Behavior and Network Performance in a Public Wireless LAN

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Introduction

This study was performed at the conference held at U.C. San Diego in August 2001 using a trace recorded over three days.
Goals of this study

• Understanding of wireless user behavior and wireless network performance.

• Characterize wireless users in terms of a parameterized model for use with analytic and simulation studies involving wireless LAN traffic.

• Apply this analysis results to issues in wireless network deployment, such as capacity planning, and potential network optimizations, such as algorithms for load balancing across multiple access points (APs) in a wireless network.
Network Environment

- IEEE 802.11b.
- Installed in a large auditorium with 4 AP providing overlapped coverage.
- The APs connected to the gigabit backbone.
- The APs were operating at a data rate of 11 Mbps, on channels 1, 4, 7, and 11, and at a power of 100mW.
- The AP handoff algorithm was configured to use “small” cells.
- The wireless user community consisted of 195 distinct users.
Trace Collection and Analysis

The trace consist of two parts:

- Continuous trace of SNMP data from each of the four APs over a period of 52 hours using a wrote program called `snmputil` that uses the SNMP Management API in Windows.

- The second trace collected was a `tcpdump` trace of the network level headers of the packets passing through the network switches.
<table>
<thead>
<tr>
<th>Attribute</th>
<th>Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of wireless users</td>
<td>195</td>
</tr>
<tr>
<td>Maximum users at an AP</td>
<td>32</td>
</tr>
<tr>
<td>Total hours of trace</td>
<td>52</td>
</tr>
<tr>
<td>Total bytes transmitted</td>
<td>4.6 GB</td>
</tr>
<tr>
<td>Total flows</td>
<td>298995</td>
</tr>
<tr>
<td>Peak throughput at an AP</td>
<td>3.2 Mbps</td>
</tr>
</tbody>
</table>

Table 1: Overall statistics for the trace.
USER BEHAVIOR

- User Distribution across Access Points
- User Session Duration
- User Data Rates
- User Application Popularity
- User Mobility
User Distribution across Access Points

- Users are evenly distributed across the AP
- User arrival modeled as a Markov-Modulated Poisson Process (MMPP).
User Session Duration

- The results show that 90% of the sessions last less than one hour and 10% ranging between one and three hours.
- The PDF of the session time closely follows a General Pareto Distribution.
- One implication is IP address leasing.
Figure 6: Histogram of users with session time less than an hour.
User Data Rates

- Data rates are relatively low, average bandwidths range from as low as 15 kbps to as high as 590 kbps.
- There is some correlation between data rate and session time, the longer the session the lower average data rate.
User Application Popularity

- Most traffic is generated by TCP (91%).
- Web browsing (HTTP) is by far the most popular application, contributing 46% of the total bytes transferred.
User Mobility

- Analysis of user mobility shows that users are mobile at the beginning and end of the conference sessions. About 75% of the users are seen at more than one AP during the day.
Network Performance

- the offered load on the network directly correlates with the conference schedule. It is highest during the talks, and lowest during the breaks.
- With four APs for 195 users, the network is over-provisioned. None of the APs in the network reach their maximum capacity even with peak loads.
- The overall median packet error rate is 2.15%, and the median packet retransmission percentage is 1.63%.
Network Performance

• There is uneven load distribution among the APs.

• Existing AP load balancing algorithms that try to balance AP load according to the number of associated users can perform poorly.
Conclusion

- We can correlate user arrivals into the network according to a two-state Markov-Modulated Poisson Process (MMPP).
- Most sessions are relatively short, so The session time distribution can be approximated to a General Pareto Distribution.
- Longer sessions tend to be idle for the majority of time.
- Web browsing and secure shell are the dominant applications.
Conclusion

• The low bandwidth requirement imply that even with 802.11b a few number of APs are needed for a large number of user.

• The APs load balancing can be optimized effectively by distributing the user bandwidth requirements.
Comment

This study can be applied in a network characterized by a concentrated space and scheduled periods of use like classrooms, meeting and conference rooms, airport gates, etc., but does not represent all settings in which public-area wireless networks will be deployed.
Questions...