Self Management in Chaotic Wireless Networks

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Wireless Proliferation

- Sharp increase in deployment
  - Airports, malls, coffee shops, homes…
  - 4.5 million APs sold in 3rd quarter of 2004!
- Past dense deployments were planned campus-style deployments
Chaotic Wireless Networks

- **Unplanned:**
  - Independent users set up APs
  - Spontaneous
  - Variable densities
  - Other wireless devices

- **Unmanaged:**
  - Configuring is a pain
  - ESSID, channel, placement, power
  - Use default configuration

→ “Chaotic” Deployments
Implications of Dense Chaotic Networks

■ Benefits
  ■ Great for ubiquitous connectivity, new applications

■ Challenges
  ■ Serious contention
  ■ Poor performance
  ■ Access control, security
Outline

- Quantify deployment densities and other characteristics
- Impact on end-user performance
- Initial work on mitigating negative effects
- Conclusion
Characterizing Current Deployments

Datasets

■ **Place Lab: 28,000 APs**
  o MAC, ESSID, GPS
  o Selected US cities
  o wwww.placelab.org

■ **Wifimaps: 300,000 APs**
  o MAC, ESSID, Channel, GPS (derived)
  o wifimaps.com

■ **Pittsburgh Wardrive: 667 APs**
  o MAC, ESSID, Channel, Supported Rates, GPS
AP Stats, Degrees: Placelab

(Placelab: 28000 APs, MAC, ESSID, GPS)

<table>
<thead>
<tr>
<th>City</th>
<th>#APs</th>
<th>Max. degree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland</td>
<td>8683</td>
<td>54</td>
</tr>
<tr>
<td>San Diego</td>
<td>7934</td>
<td>76</td>
</tr>
<tr>
<td>San Francisco</td>
<td>3037</td>
<td>85</td>
</tr>
<tr>
<td>Boston</td>
<td>2551</td>
<td>39</td>
</tr>
</tbody>
</table>

50 m
Degree Distribution: Place Lab
Unmanaged Devices

- Most users don’t change default channel
- Channel selection must be automated

<table>
<thead>
<tr>
<th>Channel</th>
<th>%age</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>41.2</td>
</tr>
<tr>
<td>2</td>
<td>12.3</td>
</tr>
<tr>
<td>11</td>
<td>11.5</td>
</tr>
<tr>
<td>3</td>
<td>3.6</td>
</tr>
</tbody>
</table>

WifiMaps.com
(300,000 APs, MAC, ESSID, Channel)
Opportunities for Change

Wardrive
(667 APs, MAC, ESSID, Channel, Rates, GPS)

- Major vendors dominate
- Incentive to reduce “vendor self interference”

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linksys (Cisco)</td>
<td>33.5</td>
</tr>
<tr>
<td>Aironet (Cisco)</td>
<td>12.2</td>
</tr>
<tr>
<td>Agere</td>
<td>9.6</td>
</tr>
<tr>
<td>D-Link</td>
<td>4.9</td>
</tr>
<tr>
<td>Apple</td>
<td>4.6</td>
</tr>
<tr>
<td>Netgear</td>
<td>4.4</td>
</tr>
<tr>
<td>ANI Communications</td>
<td>4.3</td>
</tr>
<tr>
<td>Delta Networks</td>
<td>3.0</td>
</tr>
<tr>
<td>Lucent</td>
<td>2.5</td>
</tr>
<tr>
<td>Acer</td>
<td>2.3</td>
</tr>
<tr>
<td>Others</td>
<td>16.7</td>
</tr>
</tbody>
</table>
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Impact on Performance

Glomosim trace-driven simulations

- “D” clients per AP
- Clients are located than 1m from their APs
- Transmit power=15dBm
- Trans. range = 31m
- Interference range = 65m
- Each client runs HTTP/FTP workloads
- HTTP transfers are separated by a sleep time drawn from Poisson(s)
Impact on HTTP Performance

3 clients per AP. 2 clients run FTP sessions.
All others run HTTP.
300 seconds
Optimal Channel Allocation vs. Optimal Channel Allocation + Tx Power Control

Each AP is statically assigned 1 of the 3 non-overlapping channels

Some of the APs use a power level of 3dBm.

![Graphs showing normalized HTTP performance vs stretch for Channel Only and Channel + Tx Power Control scenarios.](image-url)
Incentives for Self-management

- Clear incentives for automatically selecting different channels
  - Disputes can arise when configured manually
- Selfish users have no incentive to reduce transmit power
- Power control implemented by vendors
  - Vendors want dense deployments to work
- Regulatory mandate could provide further incentive
  - e.g. higher power limits for devices that implement intelligent power control
Impact of Joint Transmit Power and Rate Control

Objective: given \(<\text{load, txPower, } d_{\text{client}}\rangle\) determine \(d_{\text{min}}\)

\[
\text{mediumUtilization} = \sum(\text{utilization of all in-range APs})
\]

require: mediumUtilization \(\leq 1\)

\(d_{\text{client}}\), \(d_{\text{min}}\)

txPower determines range

APs
Impact of Transmit Power Control

- Minimum distance decreases dramatically with transmit power
- High AP densities and loads requires transmit power < 0 dBm
- Highest densities require very low power → can’t use 11Mbps!
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Power Selection Algorithms

- **Rate Selection**
  - **Auto Rate Fallback (ARF)**
    - 6 consecutive packet transmissions → selects the next higher transmission rate
    - 4 consecutive packet trans. failures → selects the next lower transmission rate
    - No packet is sent in 10 seconds → uses the highest possible rate for the next transmission.
  - **Estimated Rate Fallback: ERF**
    - Each packet contains its transmit power level and the path loss and noise estimate of the last packet received.
    - This allows the sender to estimate the SNR at the receiver.
    - ERF then determines the highest transmission rate supported for this SNR.
Power and Rate Selection Algorithms

- Joint Power and Rate Selection
  - Power Auto Rate Fallback (PARF)
    - At the highest rate, after a given number of successful transmissions → reduce the transmit power
    - At the lowest rate, after a given number of failures → increase the transmit power
  - Power Estimated Rate Fallback: PERF
    - The sender estimates the SNR at the receiver.
      - If SNR > the decision threshold for the highest transmit rate → lower the transmit power
Lab Interference Test

Topology

Results

Victim Pair

TCP benchmark

79 dB pathloss

Aggressor Pair

95 dB pathloss

110 dB pathloss

Throughput (Mbps)

No Interference

ARF

ERF

PERF

Throughput

No Interference ARF ERF PERF

0 0.5 1 1.5 2 2.5 3 3.5 4

0 0.5 1 1.5 2 2.5 3 3.5 4

0 0.5 1 1.5 2 2.5 3 3.5 4
Conclusion

- Significant densities of APs in many metro areas
- Many APs not managed
- High densities could seriously affect performance
- Static channel allocation alone does not solve the problem
- Transmit power control effective at reducing impact
Ongoing Work

- Joint power and multi-rate adaptation algorithms
  - Extend to the case where TxRate could be traded off for higher system throughput
- Automatic channel selection
- Field tests of these algorithms