Characterization of 802.11 Wireless Networks in the Home

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Introduction

• Home networks have become increasingly popular
• Anecdotal evidence indicates unpredictable performance
• Little is really known about the properties of home networks
• This paper attempts to measure the characteristics of typical home wireless networks
Experimental Environment

• Three homes (two in the US and one in the UK) with different properties were evaluated
• The experiments were designed to investigate the impact of
  – Type of house, e.g. size, construction material.
  – Wireless technology used: 802.11a or 802.11b.
  – Transmission power, denoted by $txpower$.
  – Transmission rate, denoted by $txrate$.
  – Node location.
  – Interference from appliances.
Experimental Environment

High-level details of the three homes:

<table>
<thead>
<tr>
<th>Label</th>
<th>Size (ft²)</th>
<th>Construction</th>
<th># Floors</th>
<th># Nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>ushome1</td>
<td>2,500</td>
<td>Wood</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>ushome2</td>
<td>2,000</td>
<td>Wood</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>ukhome1</td>
<td>1,500</td>
<td>Brick / steel</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>
 Experimental Setup

- 6 nodes in each home
  - Each node is
    - For the 802.11b experiments: a small form-factor PC with a Netgear MA701 compact flash 802.11b card, running Linux kernel version 2.4.19 and the hostap driver
    - For the 802.11a experiments: a laptop with a NetGear WAG511 CardBus 802.11a card running Linux kernel version 2.4.26 and the MIT madwifi-striped driver
  - Nodes placed “wherever computing or consumer electronic devices might be located”
  - All nodes joined to an ad-hoc network, at a frequency at least 5 channels away from the next occupied frequency
Experimental Methodology

- Each node, in turn, sends a series of UDP packets to each other node
- All Packets list source node and sequence number
- Each node tests link to every other node by sending 300 1024 byte UDP packets over 150 seconds.
  - This test is repeated for different transmission rates and powers
- Link layer retransmissions are disabled
• Each link tested individually (i.e. between node 1 and node 2)
• No simultaneous transmissions occur during testing
• Receiving node records source node and sequence number of all successful receives
• Most tests performed at night
Experimental Methodology

Results in ushome1, 30 mW, 2 Mbps
Experimental Methodology

Note asymmetry between nodes 3 and 4
• Same experiment run with same node setup twice
  – Both tests run at same time of day (on different days)
  – Tests whether loss rates for each link is property of link or transient
• Results indicate that loss rates are generally not transient
• This was done in each of the three homes
• The following results are from ushome1
Methodology Validation

• Validity of using only 300 packets was tested
• Same tests in ushome1 ran for 20 minutes each (2400 packets) at 30 mW, 11 Mbps
• Success rate from first 300 packets compared with success rate from all 2400 packets:
Methodology Validation

- Validity of running tests at night tested
- Two 150 second, 300 packet, tests run once per hour for 24 hours
  - One from node 4 to 6
  - One from node 6 to 4
- Link from 4 to 6 is “bad” at night
- Link from 6 to 4 is “good” at night
- Found that time of day does not play a large role, but good link does suffer around noon
- Since time of day does play a small role, all comparable data is taken at same time of day
Methodology Validation

- Tested at 30mW, 11Mbps
- First bar is node-4 to node-6
- Second bar is node-6 to node-4
Results: Overall Characteristics

- **1 mW, 2 Mbps**
- **1 mW, 11 Mbps**
- **30 mW, 2 Mbps**
- **30 mW, 11 Mbps**

Loss rates for ushome2
Results: Overall Characteristics

• In general
  – Lossy links likely to be found inside every home
  – Loss rates higher when encoding rate higher
  – Loss rates lower when the power level increased
  – Wireless connectivity not always omnipresent
  – Many asymmetric links present among all power levels and rates
  – Changes to power or transmission rate
    • Will not generally eliminate loss in bad links, but can decrease it
    • Will not generally affect loss in good links
Multipath fading

- The same signal can take multiple paths and cause interference with itself, leading to locations with high loss rates.
Signal Attenuation

- Same as wired networks, the further away the two destinations are the weaker the signal, and more error prone.

- Not as large a factor on loss rate as node orientation and positioning.
US Home 1

US Home 2

Loss Rate Vs Distance 802.11a
802.11a/b Physical layers

• Differences between the 802.11a and 802.11b
  • 11a operates at 5ghz, 11b operates at 2.4ghz.
  • 801.11b loss rates have more variation.

• Similarities
  • Both sensitive to small changes in orientation or position.
  • Distance is not a large indicator of loss rate.
External Interference

• Homes contain many sources of radio interference.
• Devices such as Microwaves can create localized interference.
Conclusions

• Homes often have obstacles that can make communication between nodes impossible.
• Distance is often not the issue for node connectivity.
• Node positioning extremely important.
• 802.11a/b are unlikely operate effectively at the highest rates due to loss.
• Wide variety in link performance based off node location.
• Due to AP usually being determined by the point of entry for internet service new topologies may be needed for wireless networks in the home.