Characterization of 802.11 Wireless Networks in the Home

Michael Bruno
James Lawrence

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:

Label	Size (ft^2)	Construction	# Floors	# Nodes
ushome1	*2,500*	*Wood*	*2*	*6*
ushome2	*2,000*	*Wood*	*2*	*6*
ukhome1	*1,500*	*Brick / steel*	*3*	*6*

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-stripped 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

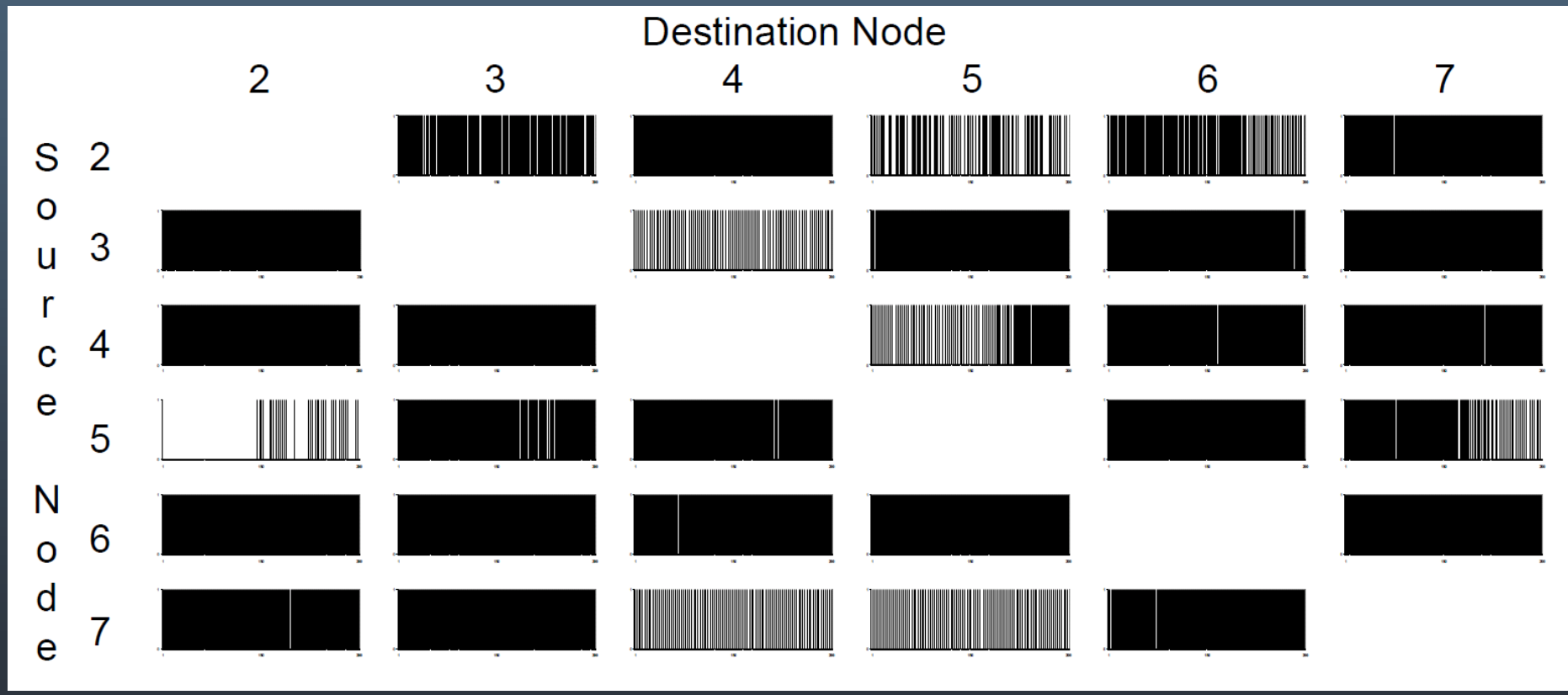
- Each node, in turn, sends a series of UDP packets to each other node
- All Packets list source node and sequence number
- Each node tests link to every other node by sending 300 1024 byte UDP packets over 150 seconds.
  - This test is repeated for different transmission rates and powers
- Link layer retransmissions are disabled

Experimental Methodology

- 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

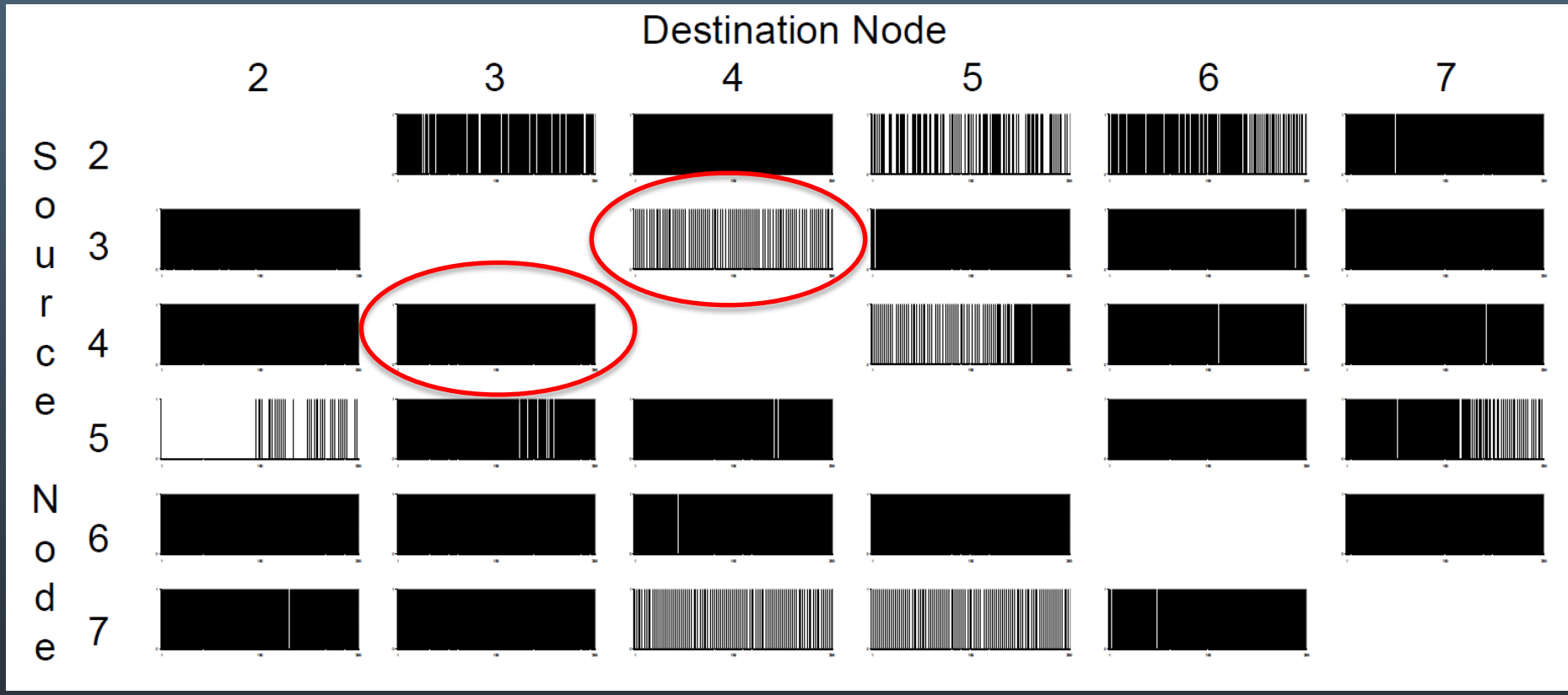
Experimental Methodology

Results in ushome1, 30 mW, 2 Mbps



Experimental Methodology

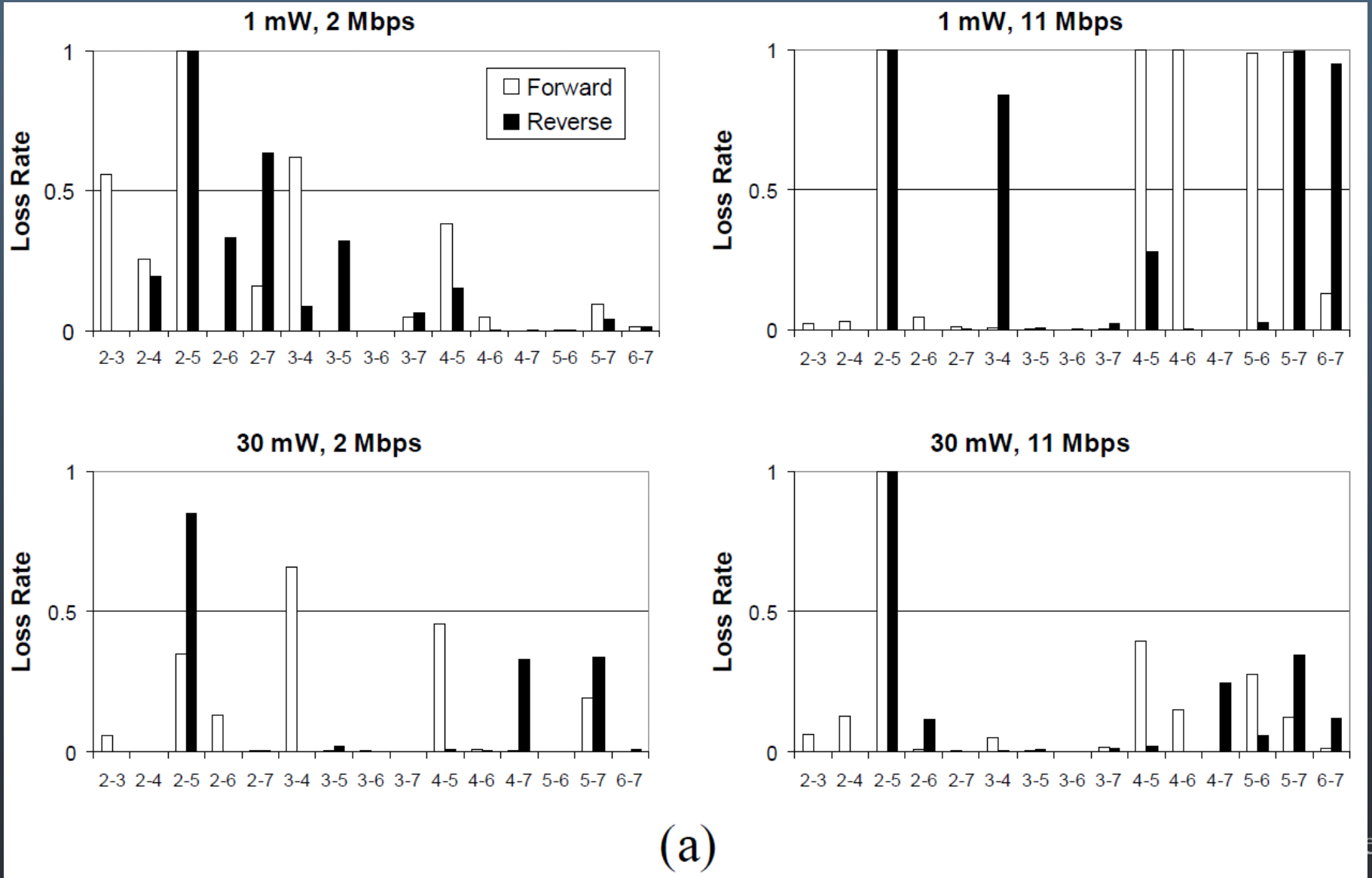
Note asymmetry between nodes 3 and 4



Methodology Validation

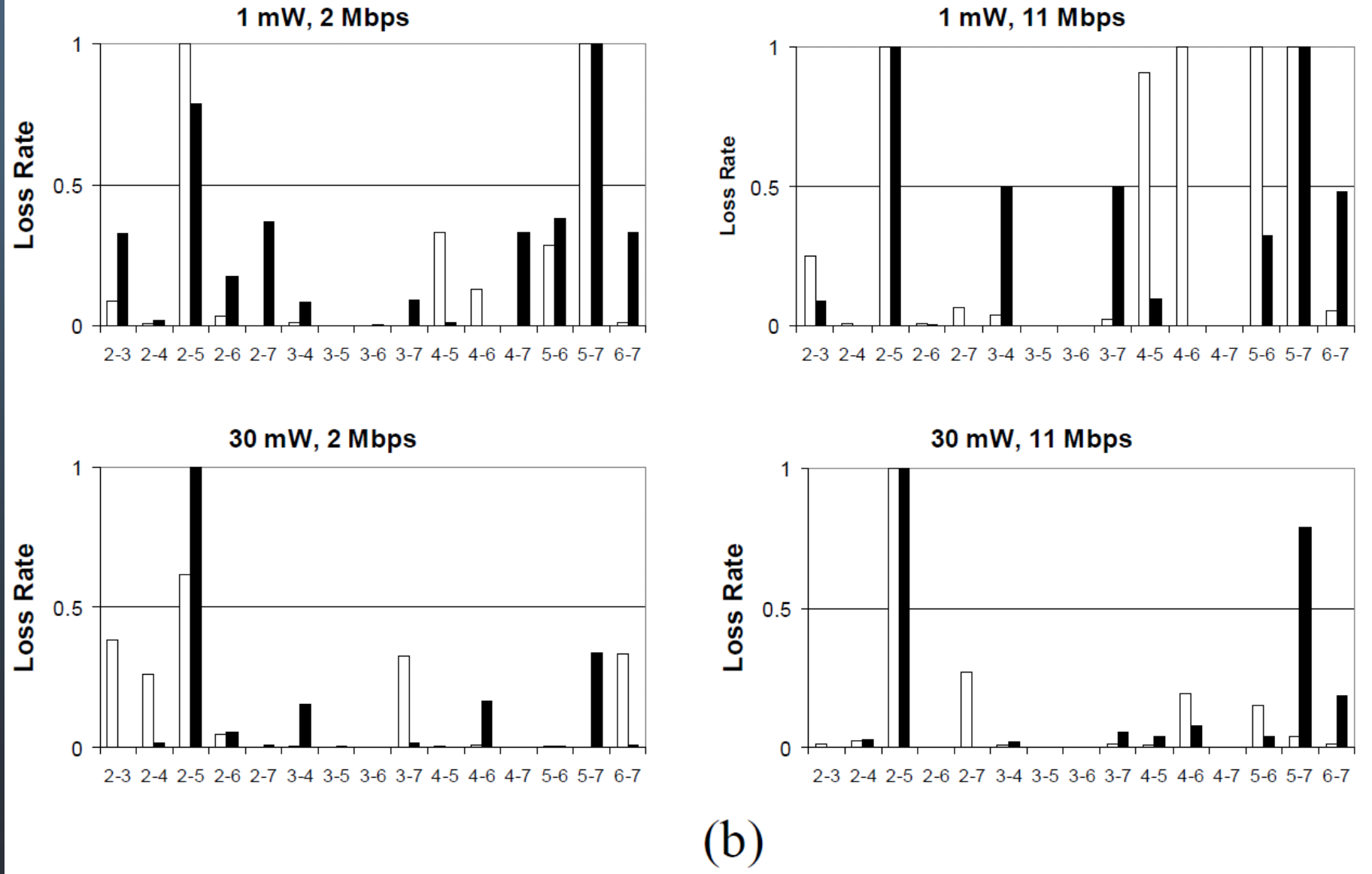
- Same experiment run with same node setup twice
  - Both tests run at same time of day (on different days)
  - Tests whether loss rates for each link is property of link or transient
- Results indicate that loss rates are generally not transient
- This was done in each of the three homes
- The following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

Methodology Validation



(a)

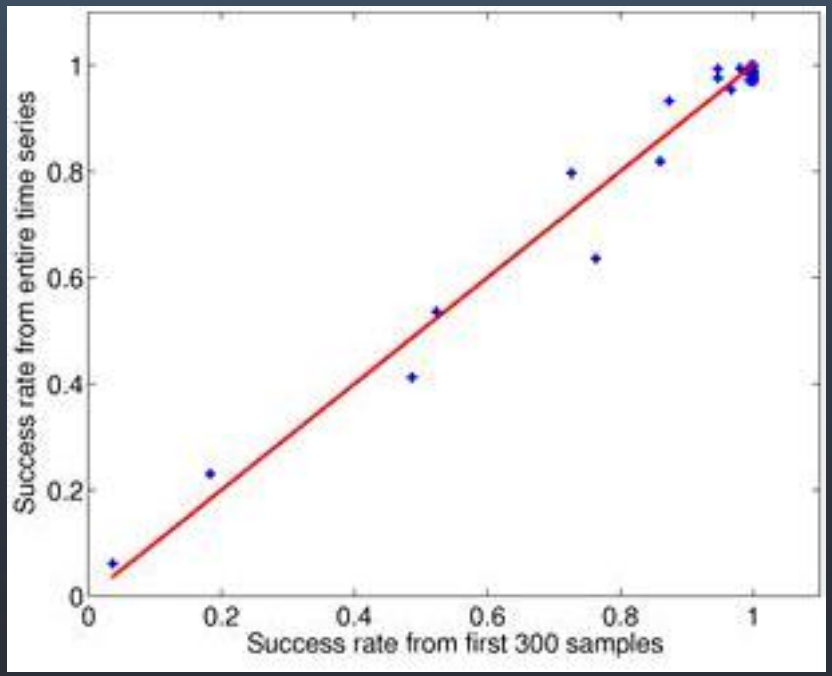
Methodology Validation



(b)

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:

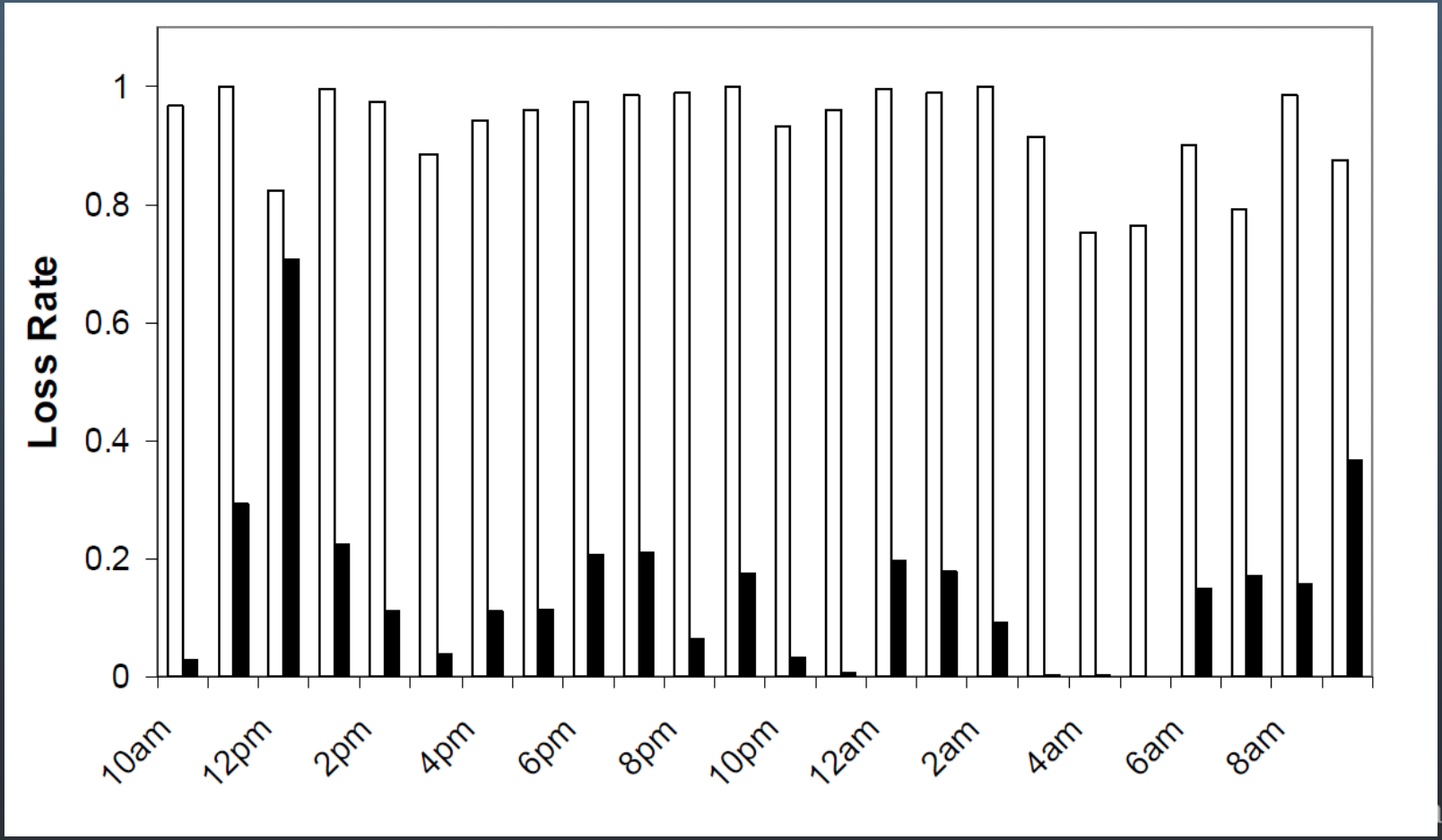


Methodology Validation

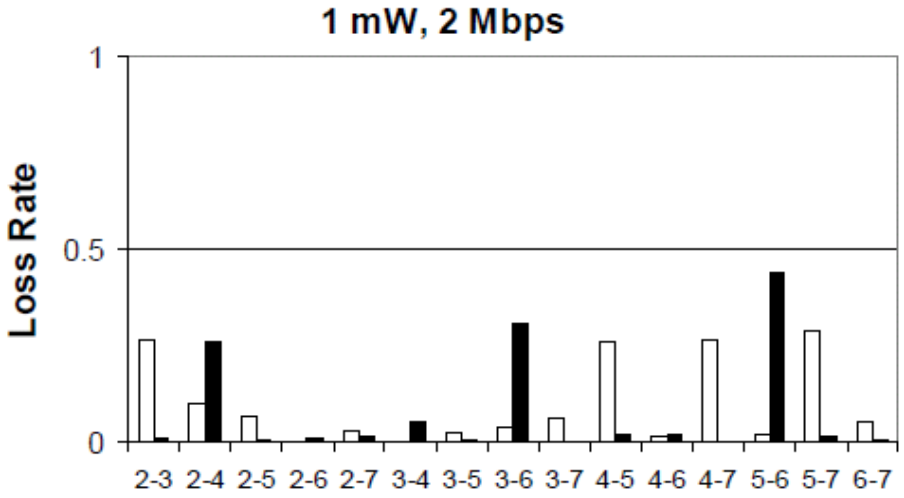
- Validity of running tests at night tested
- Two 150 second, 300 packet, tests run once per hour for 24 hours
  - One from node 4 to 6
  - One from node 6 to 4
- Link from 4 to 6 is “bad” at night
- Link from 6 to 4 is “good” at night
- Found that time of day does not play a large role, but good link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

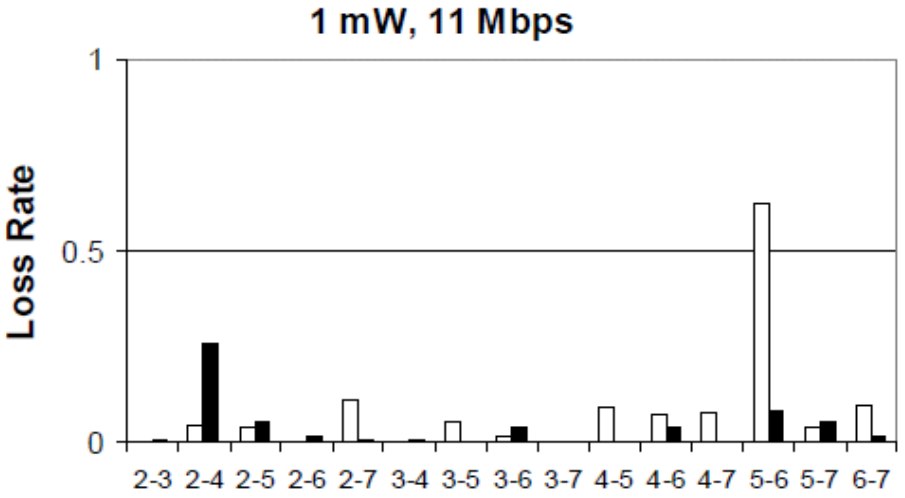
Methodology Validation

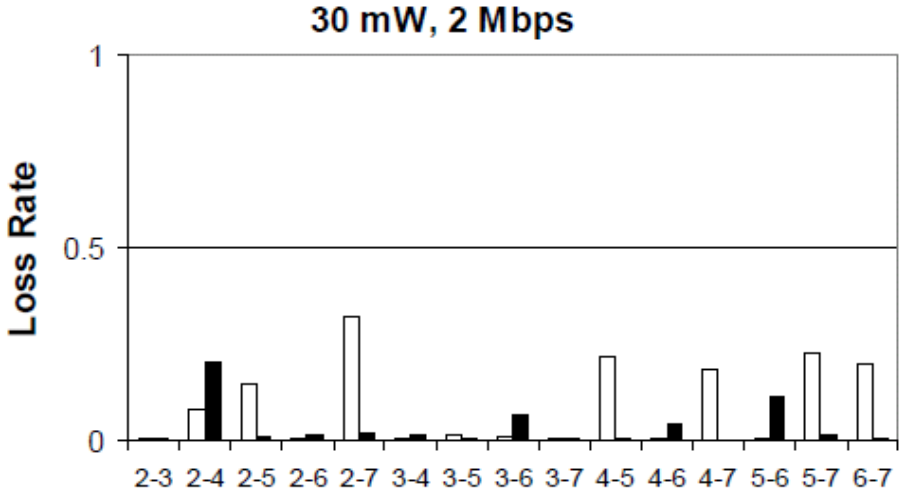
- Tested at *30mW, 11Mbps*
- *First bar is node-4 to node-6*
- *Second bar is node-6 to node-4*

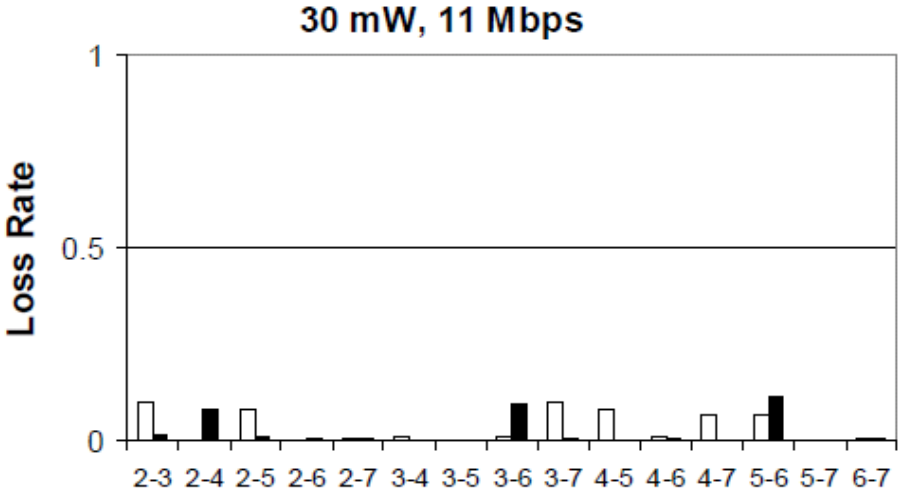


Results: Overall Characteristics









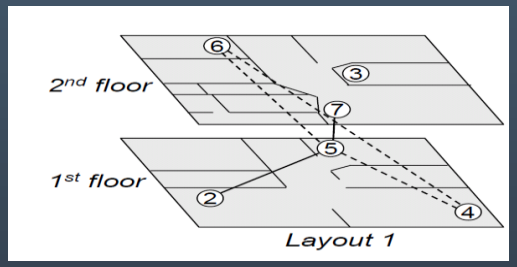
Loss rates for ushome2

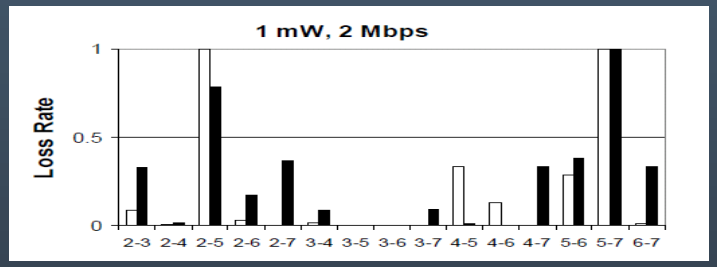
Results: Overall Characteristics

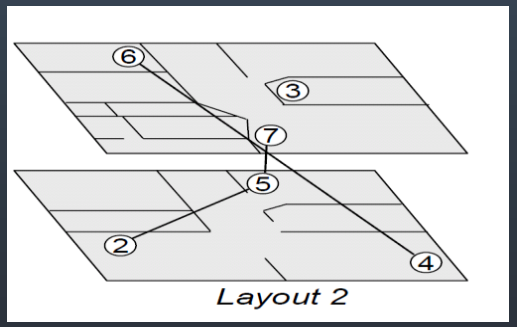
- In general
  - Lossy links likely to be found inside every home
  - Loss rates higher when encoding rate higher
  - Loss rates lower when the power level increased
  - Wireless connectivity not always omnipresent
  - Many asymmetric links present among all power levels and rates
  - Changes to power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

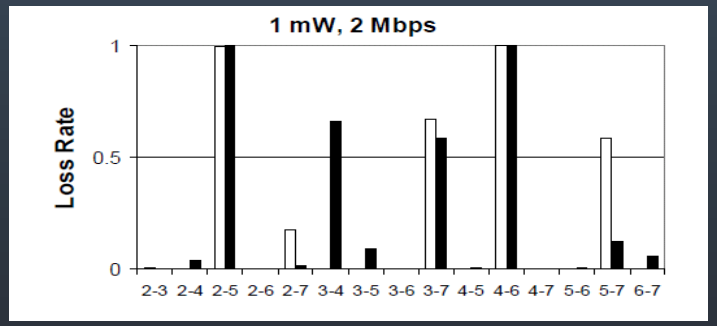
Multipath fading

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



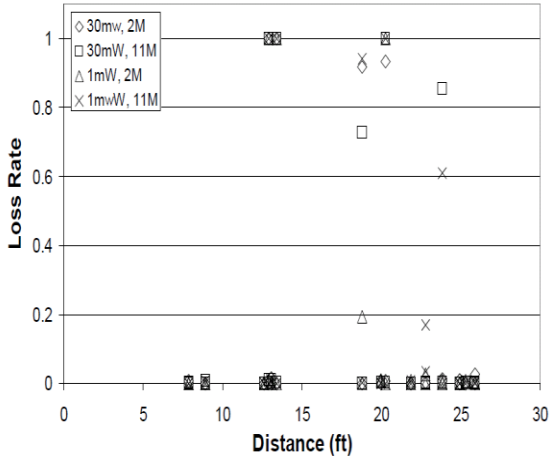




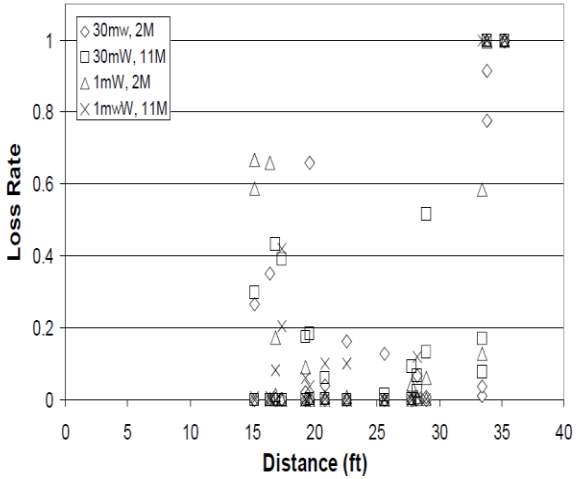


Signal Attenuation

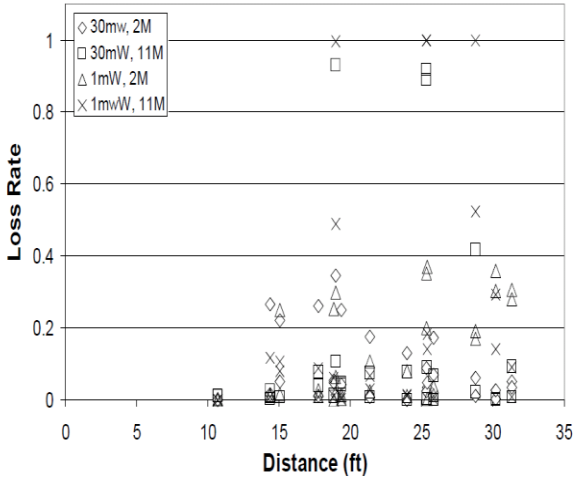
- Same as wired networks, the further away the two destinations are the weaker the signal, and more error prone.
- Not as large a factor on loss rate as node orientation and positioning.



(a)



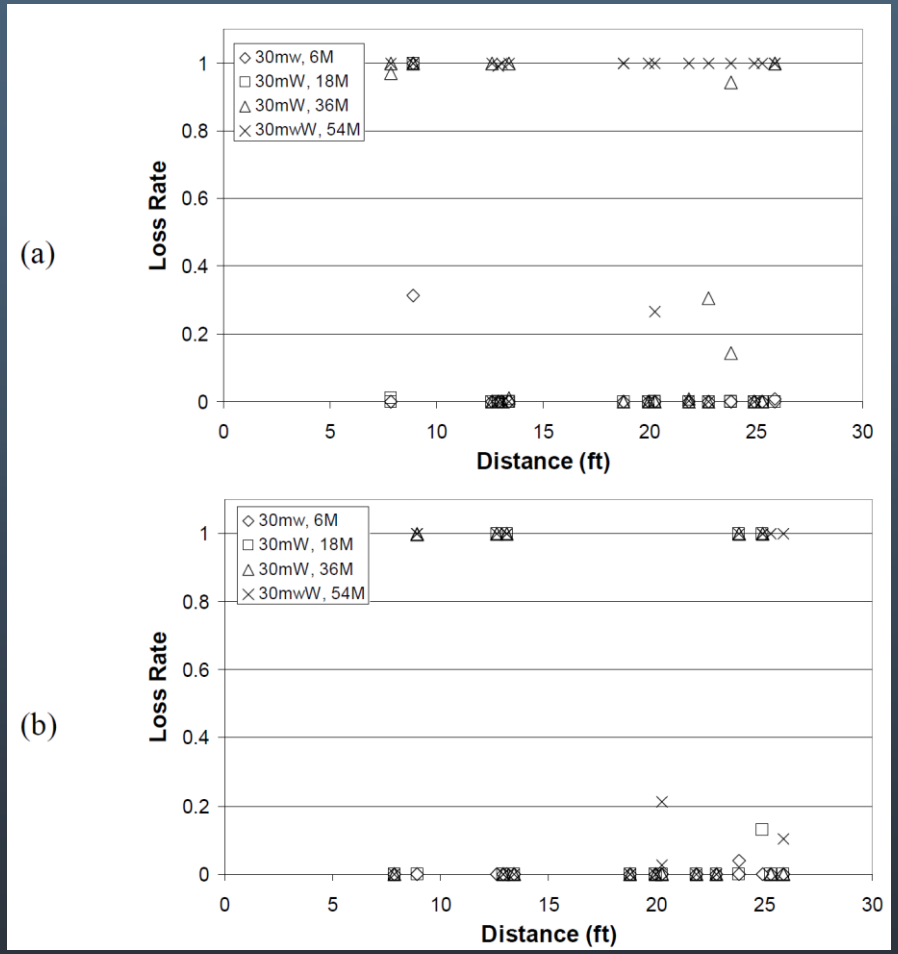
(b)



(c)

US Home 1

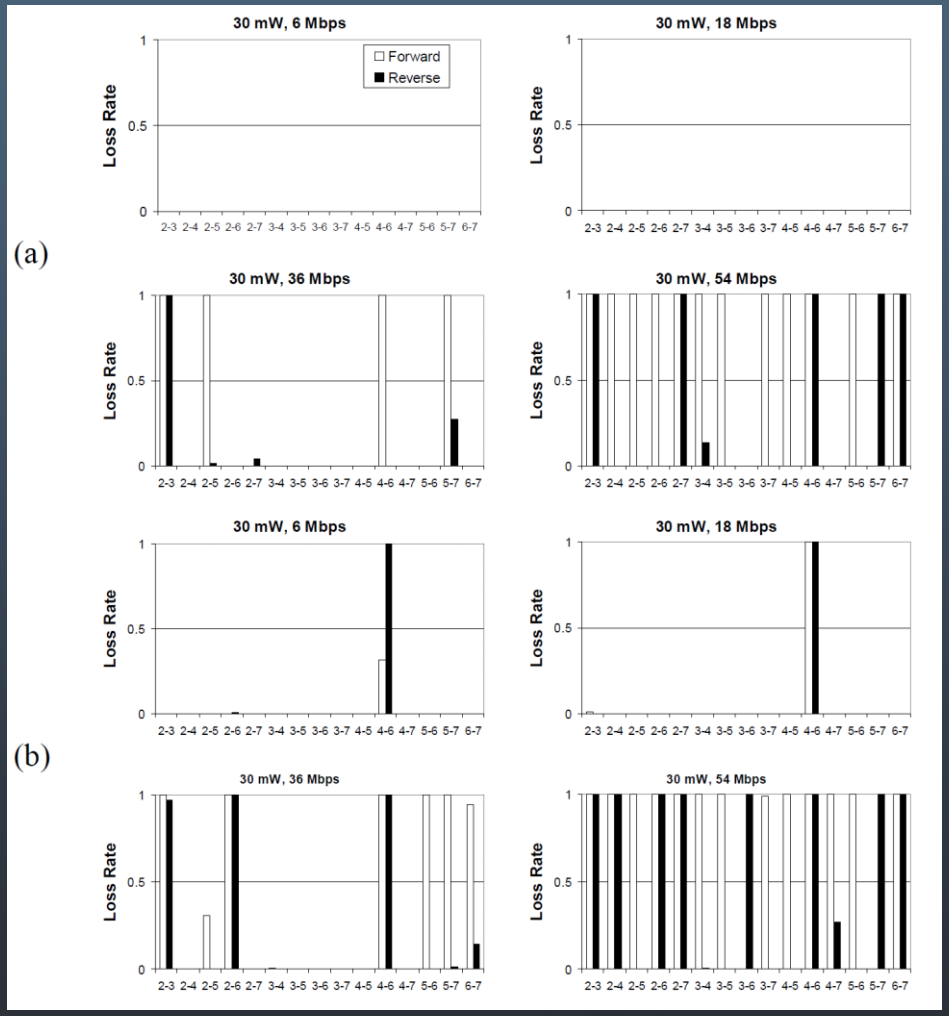
US Home 2



Loss Rate Vs Distance 802.11a

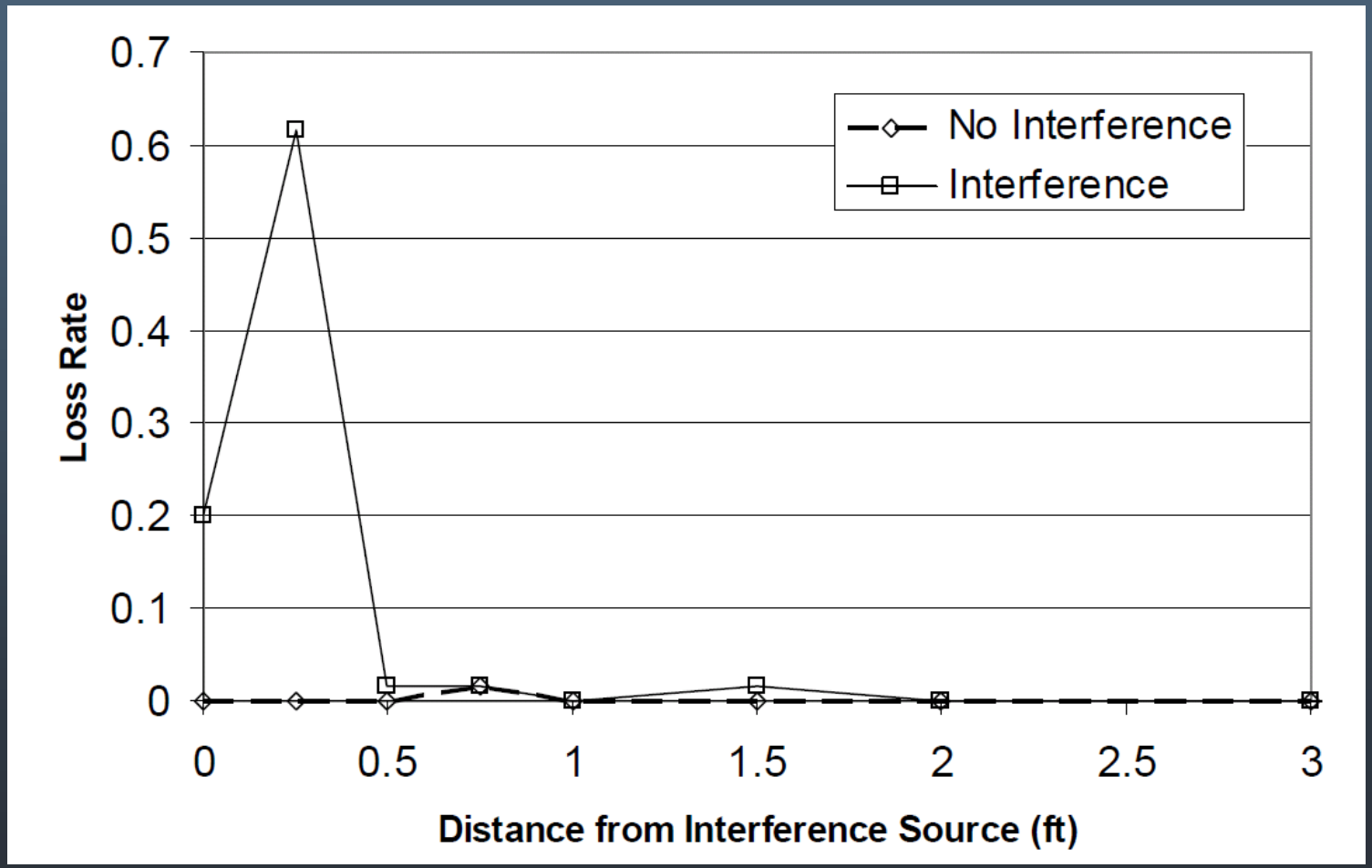
802.11a/b Physical layers

- 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.


(a)
30 mW, 6 Mbps
Forward
Reverse
30 mW, 18 Mbps
30 mW, 36 Mbps
30 mW, 54 Mbps
(b)
30 mW, 6 Mbps
30 mW, 18 Mbps
30 mW, 36 Mbps
30 mW, 54 Mbps
Loss Rate
1
0.5
0
2-3 2-4 2-5 2-6 2-7 3-4 3-5 3-6 3-7 4-5 4-6 4-7 5-6 5-7 6-7

External Interference

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


0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Loss Rate
No Interference
Interference
0
0.5
1
1.5
2
2.5
3
Distance from Interference Source (ft)

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.