Characterization of 802.11 Wireless Networks in the Home

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Outline

- **Introduction**
- **Experimental Environment**
- **Results**
- **Conclusions**

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Introduction

- Little was known about the properties of home wireless networks in 2005.

- Conjecture is that wireless home behavior will be similar to enterprise wireless network behavior.

- The goal was to specifically examine the impact of transmission rate and transmission power on the quality of home wireless links.

Experimental Environment

- **Experimental Setup**
- **Methodology**
- **Validation**

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Experimental Setup

Measurements in Three Homes

Table I
Description of homes used in experimental testbeds.

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

- *Six wireless nodes inside each home*
- *Ad Hoc communication (No AP)*

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Experimental Methodology

- Data link layer retransmissions disabled.
- 300 1024-byte UDP probe packets sent every 500 ms (150 seconds).
- No simultaneous transmissions.
- Experiments run during the night to avoid interference from moving people.
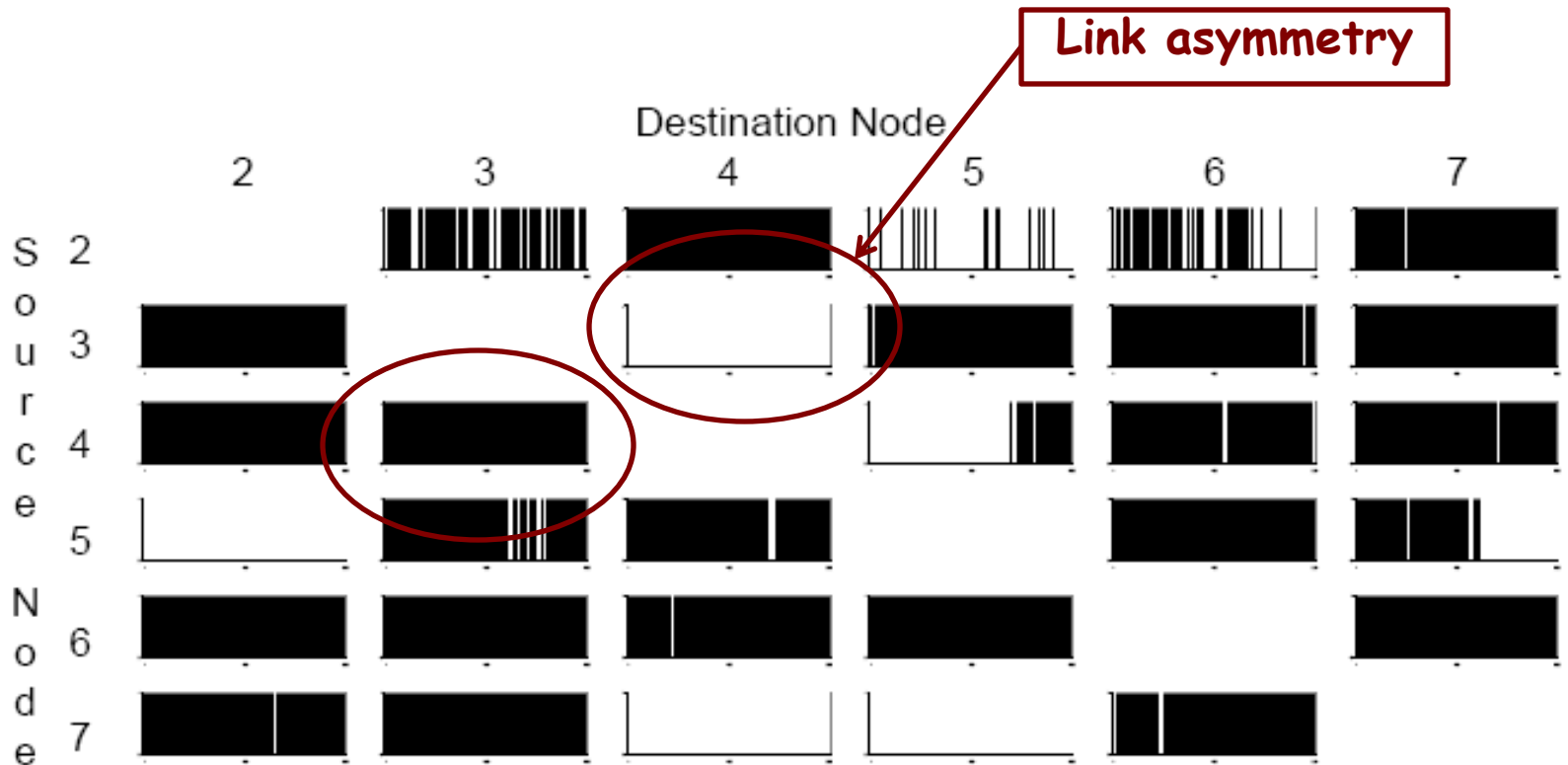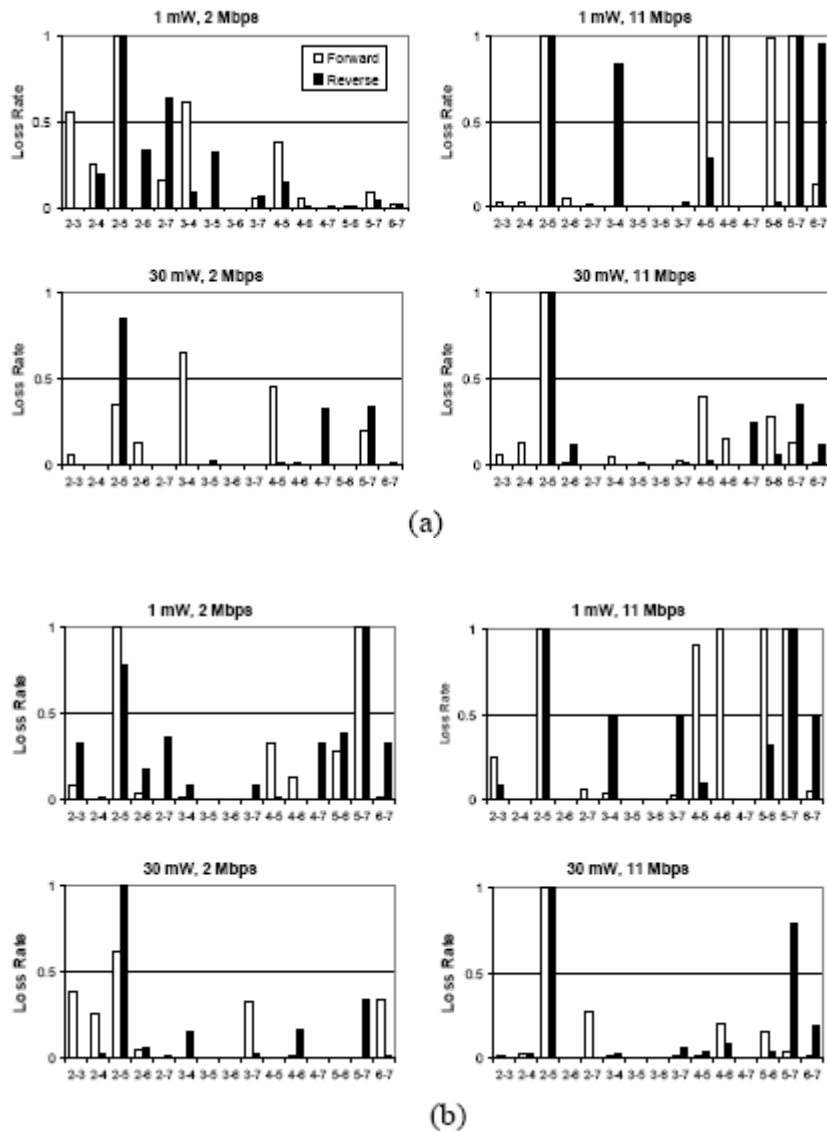- Allows quantifying loss rate observed by each wireless link.

ushome1 Experiments

Fig. 1. Matrix of probe packets successfully delivered between each pair of nodes in *ushome1* at 30mW and 2Mbps.

Methodology Validation

- **Duplicated results**
- **Experimental length**
- **Time of day variability**

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Fig. 2. Loss rates for each pair of nodes in two runs at *ushome1*

Link performance does not change significantly.

Experiment Length ?
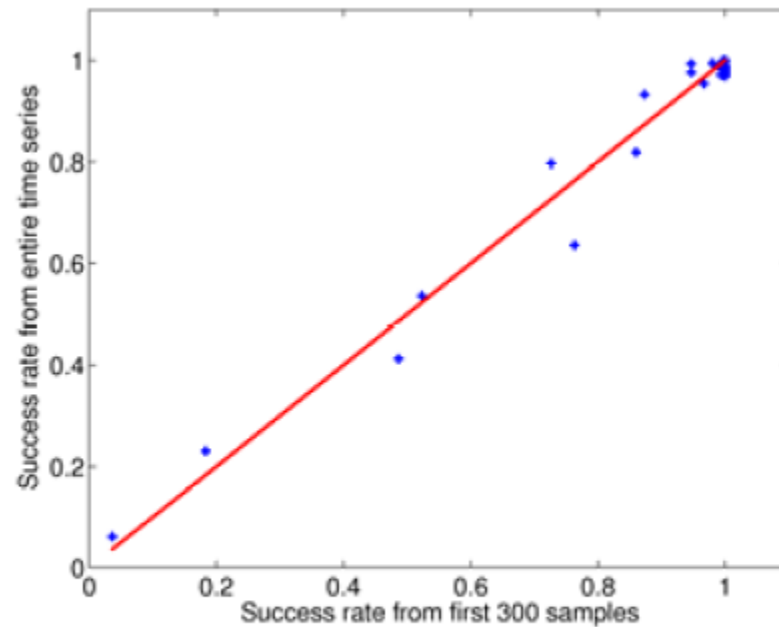
Fig. 3. Comparison of success rate results for 300 and 2400 sample lengths. The straight line provides a reference for equality (y=x).

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Time of Day Effect ?

Good link remains good, bad link remains bad.
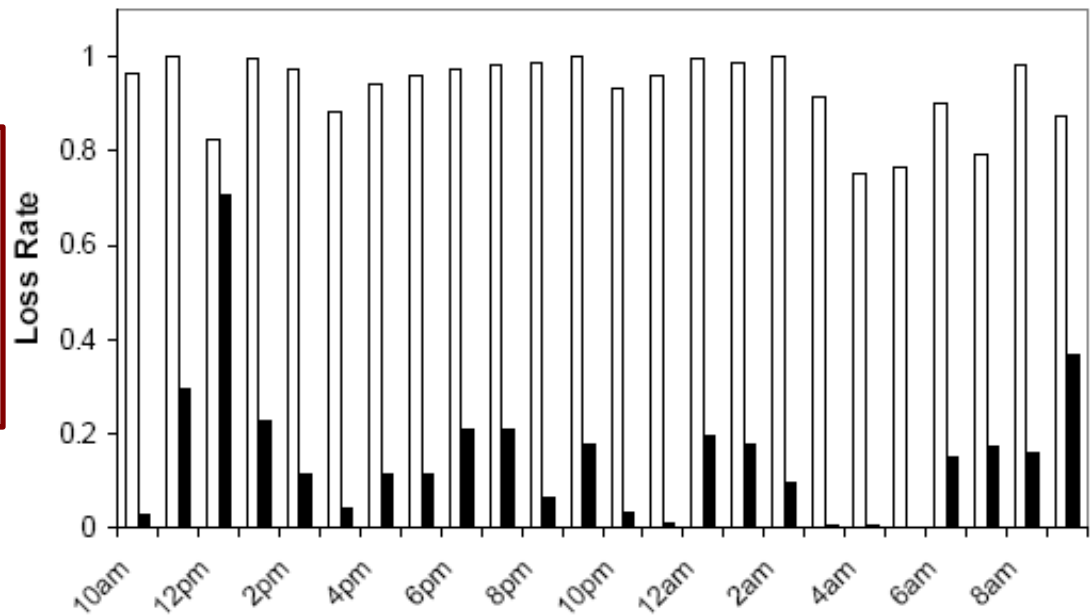
Fig. 4. Loss rate as a function of time of day for *ushome1* (*txpower*=30mW, *txrate*=11M). First bar is node-4 to node-6, second bar is node-6 to node-4.

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Results

Evaluates the home wireless environment along six dimensions:

1. Transmission rate (txrate)
2. Transmission power (txpower)
3. Node location
4. House type
5. External interference
6. Physical layer

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Overall Characteristics

- **Link loss rates** were higher when the **encoding rate** was higher.

- **Link loss rates** were lower when the **power level** increased.

- Wireless connectivity is NOT omnipresent.

- Several asymmetric links were observed.

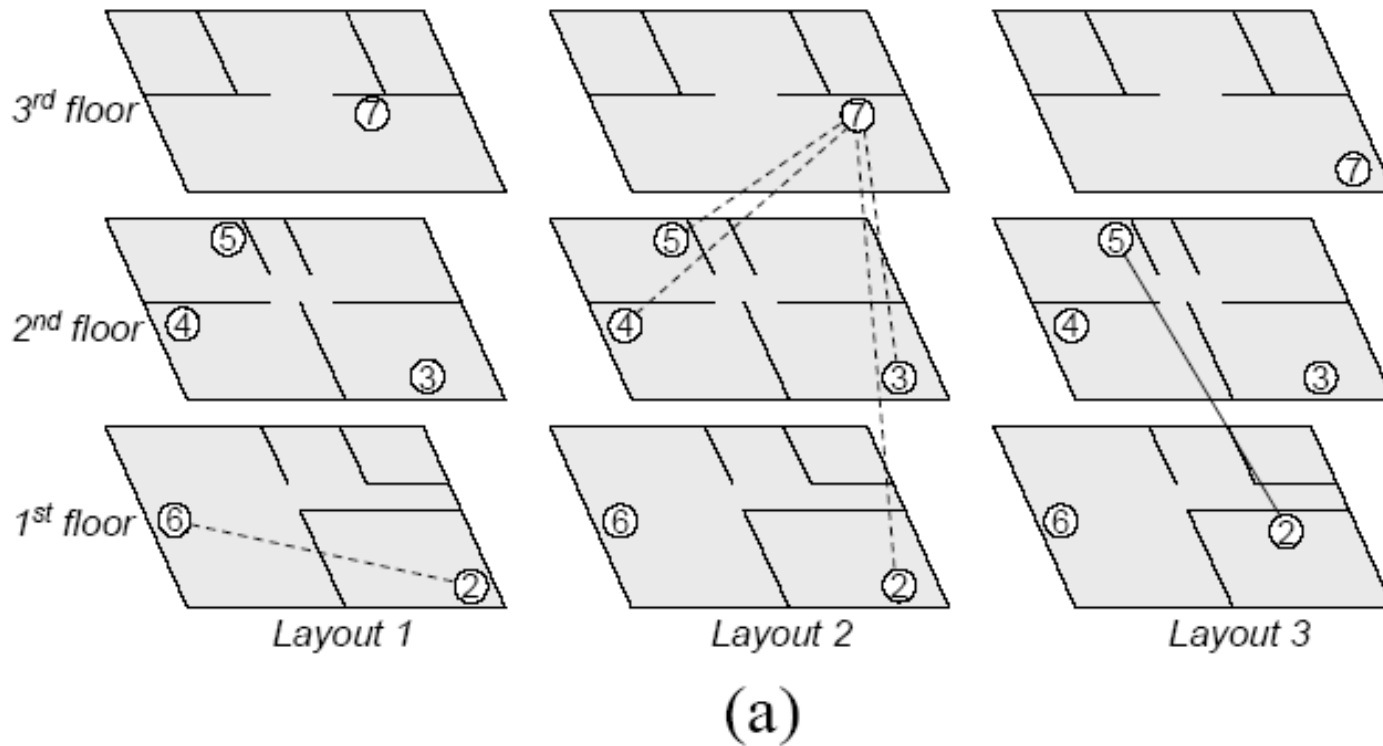- In most experiments, at least one node pair had 30% loss.
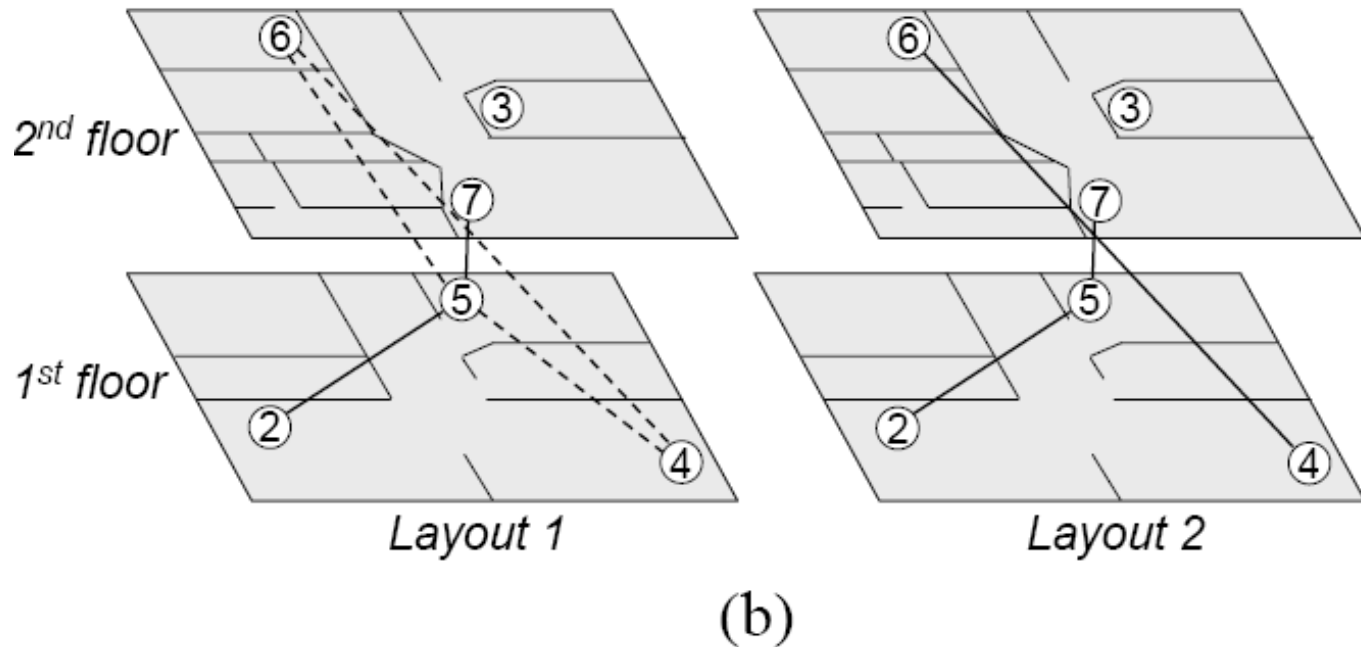
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ukhome1

Fig. 7. Abstract home floorplans and location of links with greater than 95% loss rate at 1 mW and 11 Mbps under different configurations: (a) *ukhome1* for *layout1*, *layout2*, and *layout3*, (b) *ushome1*, and (c) *ushome2* for *layout1* and *layout2*. Dashed lines indicate asymmetric links.
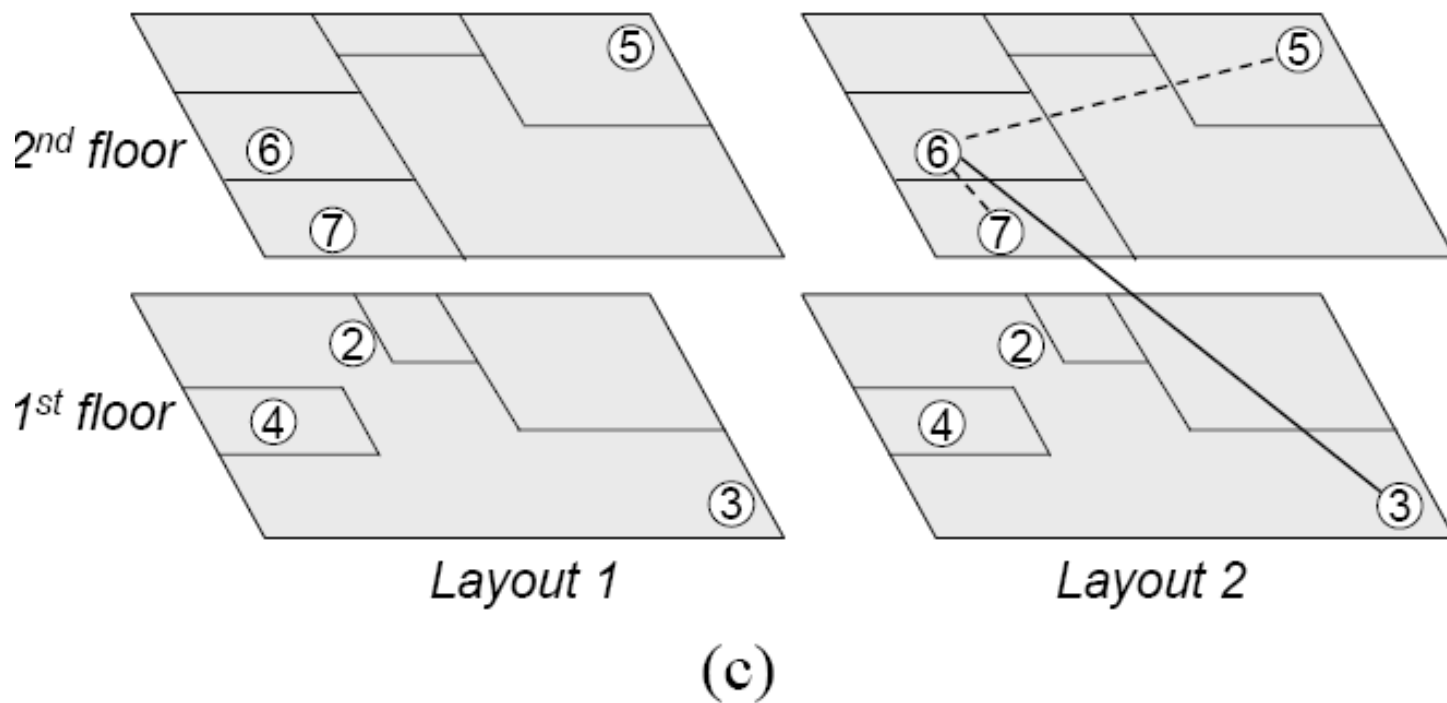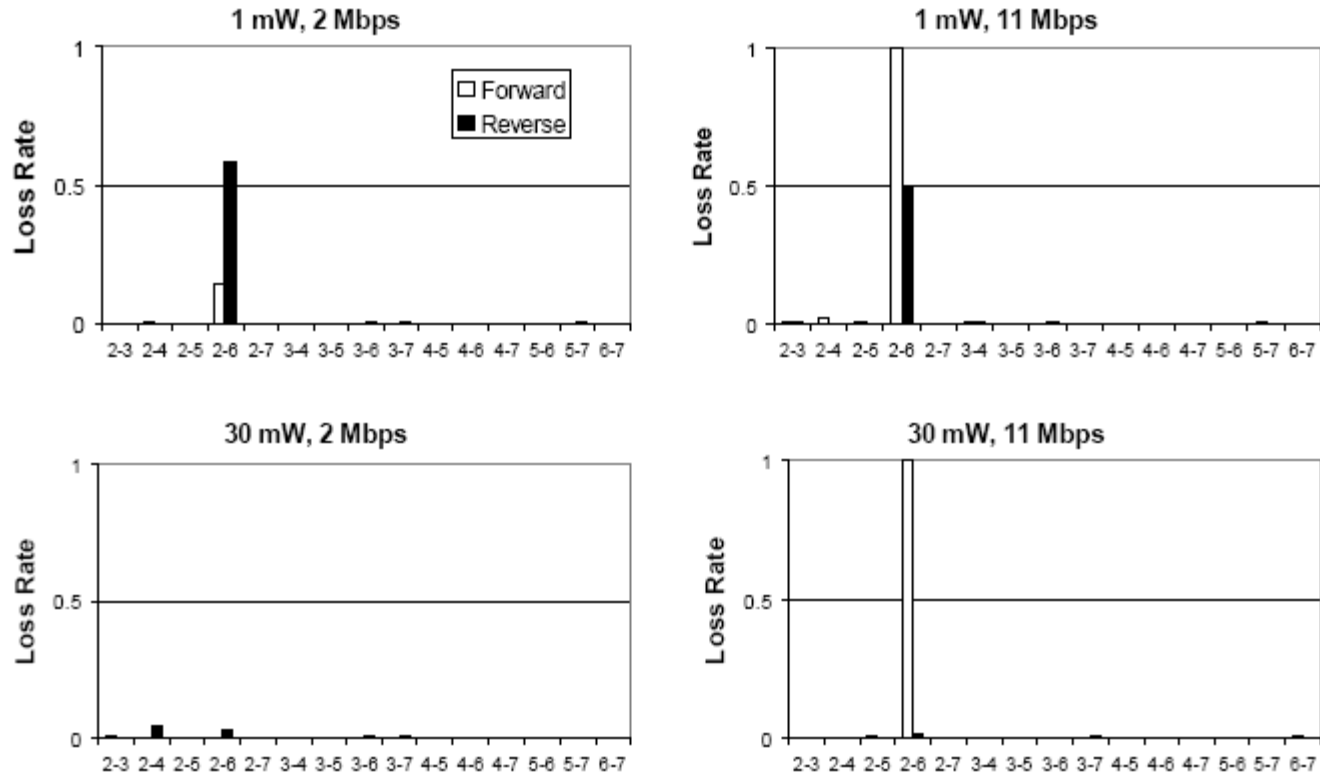
ushome1

Fig. 7. Abstract home floorplans and location of links with greater than 95% loss rate at 1 mW and 11 Mbps under different configurations: (a) *ukhome1* for *layout1*, *layout2*, and *layout3*, (b) *ushome1*, and (c) *ushome2* for *layout1* and *layout2*. Dashed lines indicate asymmetric links.

ushome2

2nd floor

1st floor

Layout 1

Layout 2

(c)

Fig. 7. Abstract home floorplans and location of links with greater than 95% loss rate at 1 mW and 11 Mbps under different configurations: (a) *ukhome1* for *layout1*, *layout2*, and *layout3*, (b) *ushome1*, and (c) *ushome2* for *layout1* and *layout2*. Dashed lines indicate asymmetric links.
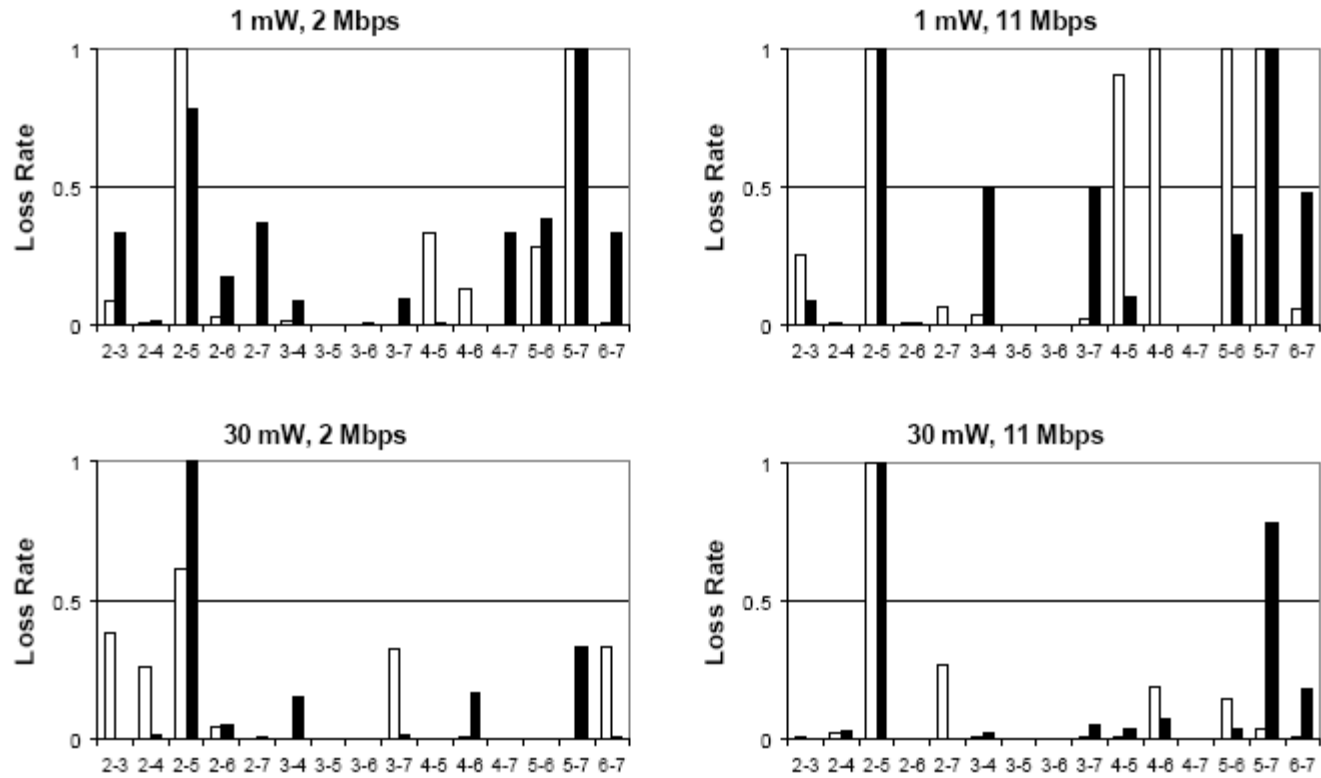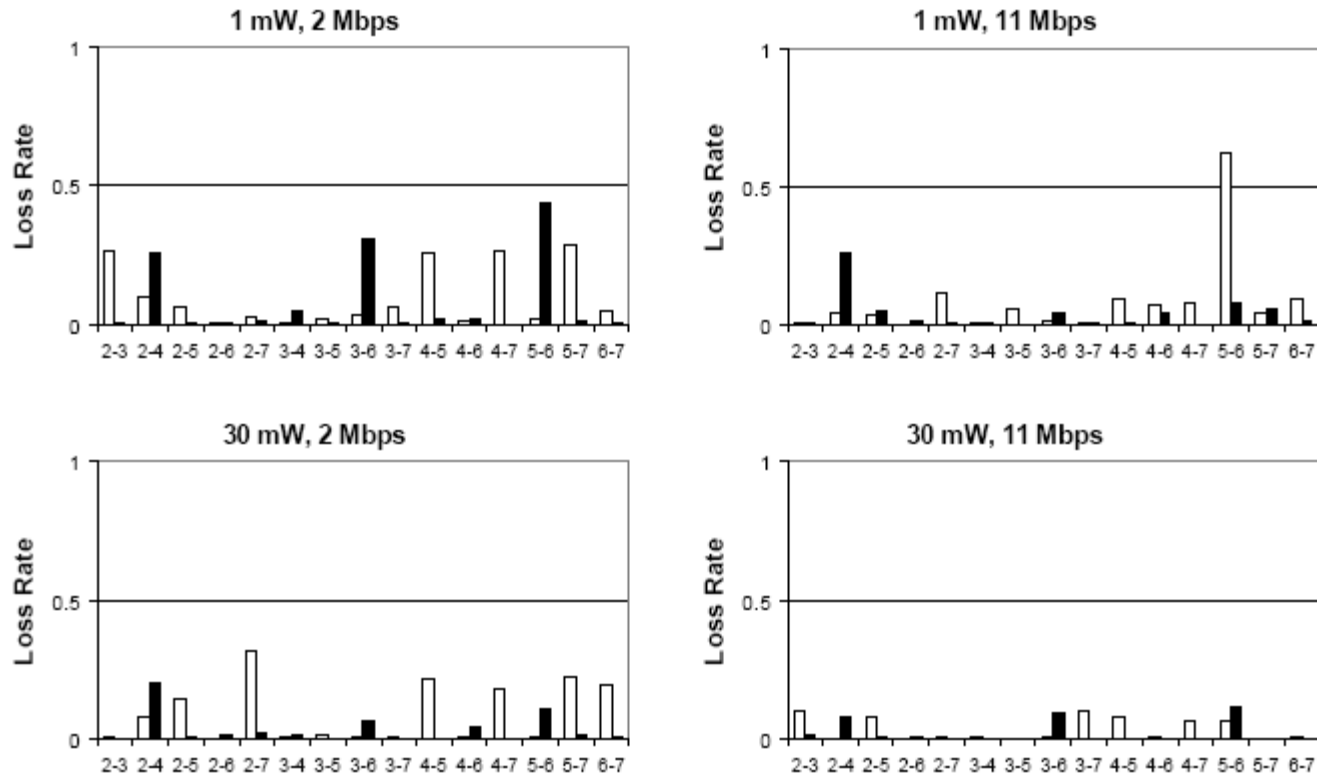
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Figure 5
Loss Rates Layout1 ukhome1

(a)

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Figure 5
Loss Rates Layout1 ushome1

(b)

Characterization of 802.11 Wireless Networks in the Home

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Figure 5
Loss Rates Layout1 ushome2

(c)

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Small changes in antenna orientation and location

- For layout2, layout1 nodes are translated a few inches and antennas are rotated to face another direction.

- Conclusion:: exact node placement is a key contributor to performance.
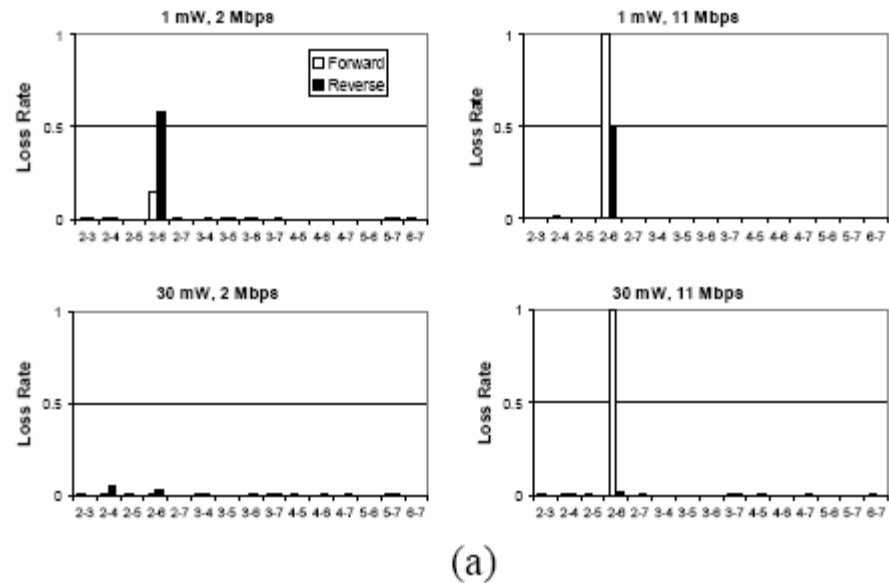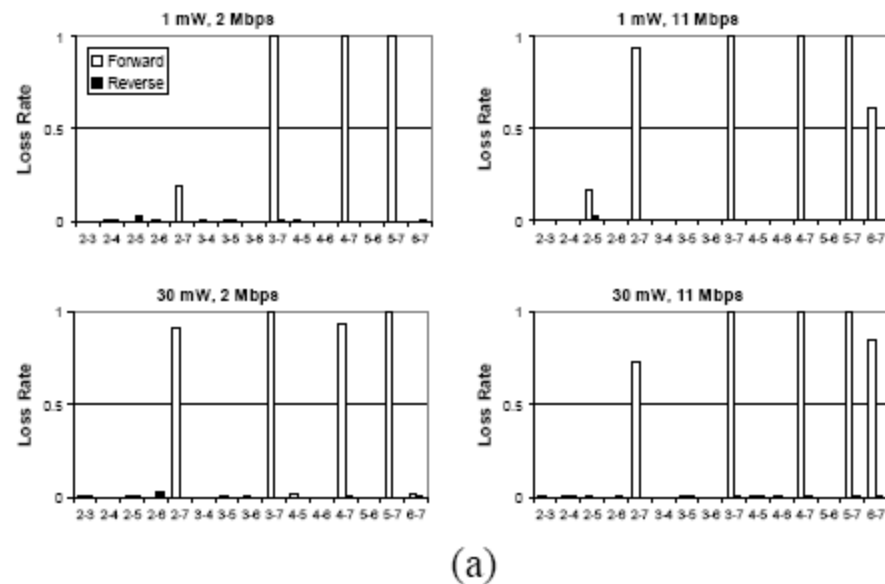
Figure 5a ukhome1 Layout1

Figure 6a ukhome1 layout2

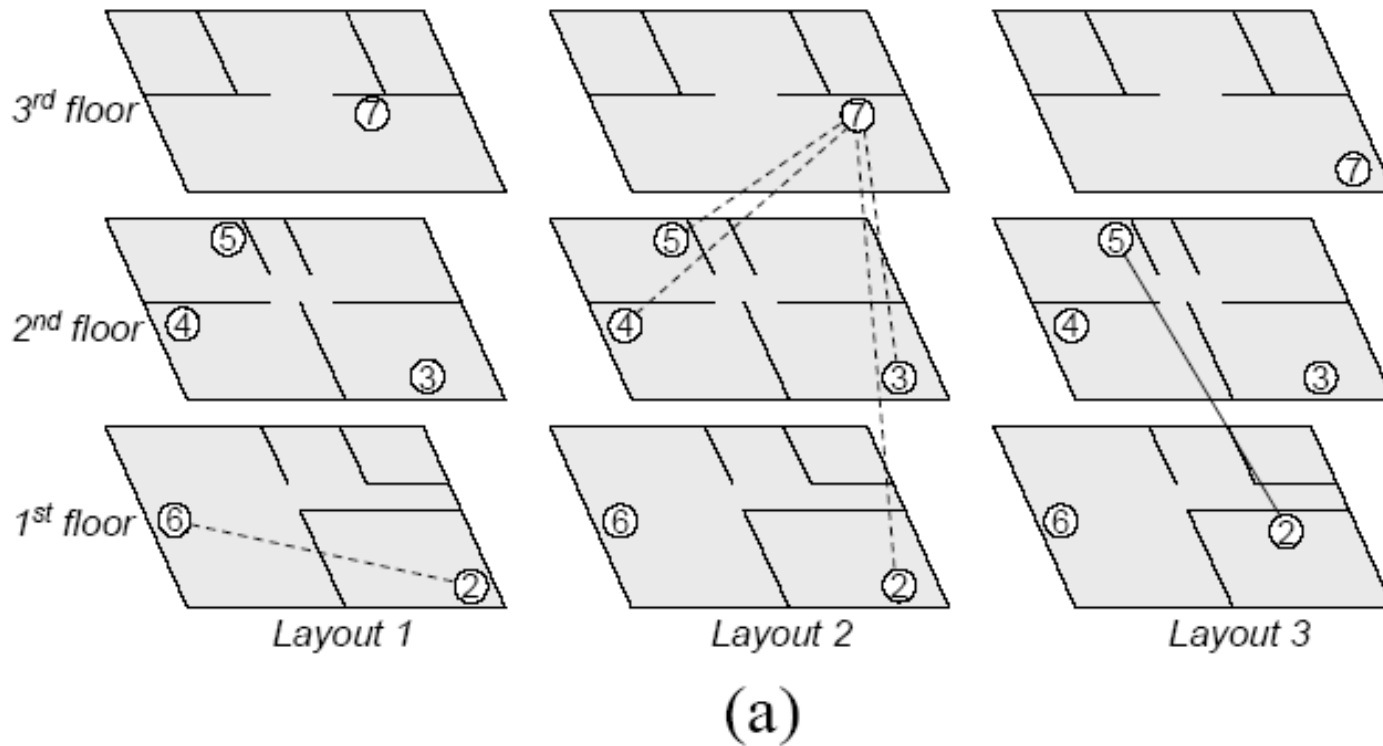**Characterization of 802.11 Wireless Networks in the Home**

ukhome1

Fig. 7. Abstract home floorplans and location of links with greater than 95% loss rate at 1 mW and 11 Mbps under different configurations: (a) *ukhome1* for *layout1*, *layout2*, and *layout3*, (b) *ushome1*, and (c) *ushome2* for *layout1* and *layout2*. Dashed lines indicate asymmetric links.

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Large changes in node placement

- **For ukhome1 nodes 2 and nodes 7 were moved to a different location within the same room from layout1 to produce layout3.**
- **The other nodes were moved slightly from their layout1 positions.**
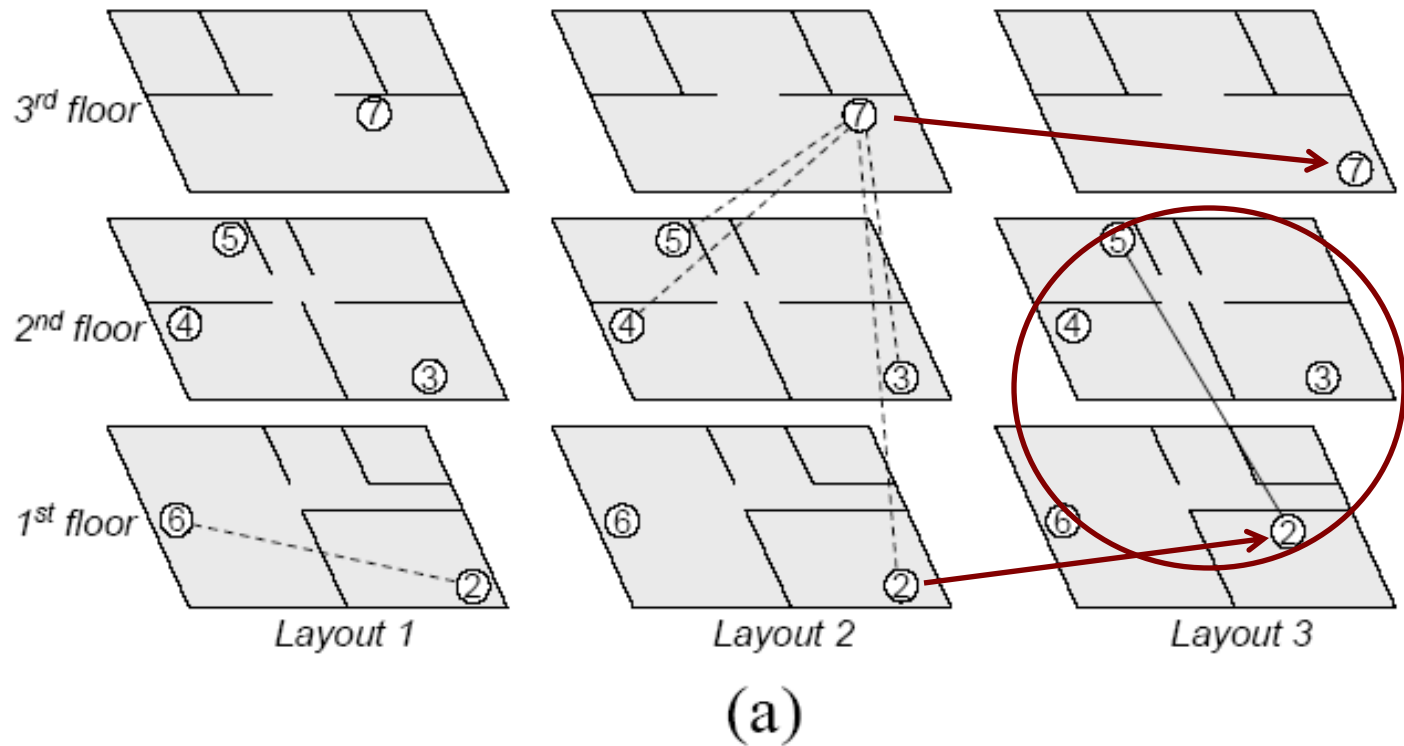
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ukhome1

Fig. 7. Abstract home floorplans and location of links with greater than 95% loss rate at 1 mW and 11 Mbps under different configurations: (a) *ukhome1* for *layout1*, *layout2*, and *layout3*, (b) *ushome1*, and (c) *ushome2* for *layout1* and *layout2*. Dashed lines indicate asymmetric links.

Figure 5a ukhome1 Layout1

(a)

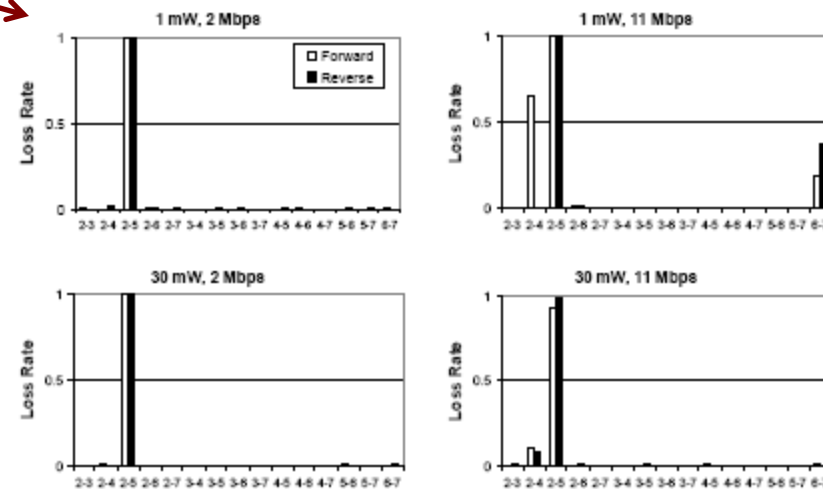**More significant loss in links and quality**

Figure 8 ukhome1 layout3
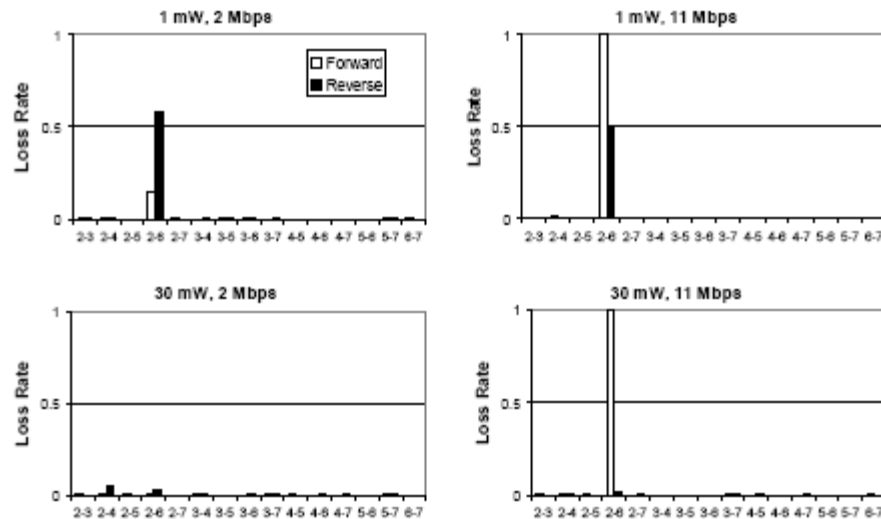
Fig. 8. Loss rate for each pair of nodes in *ukhome1, layout3*.

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Link quality and distance relationship

- **Results in Figure 9 for layout2 for all three homes show there is no correlation between physical distance and wireless link quality.**

- **This result holds across homes and across txrate and txpower settings.**
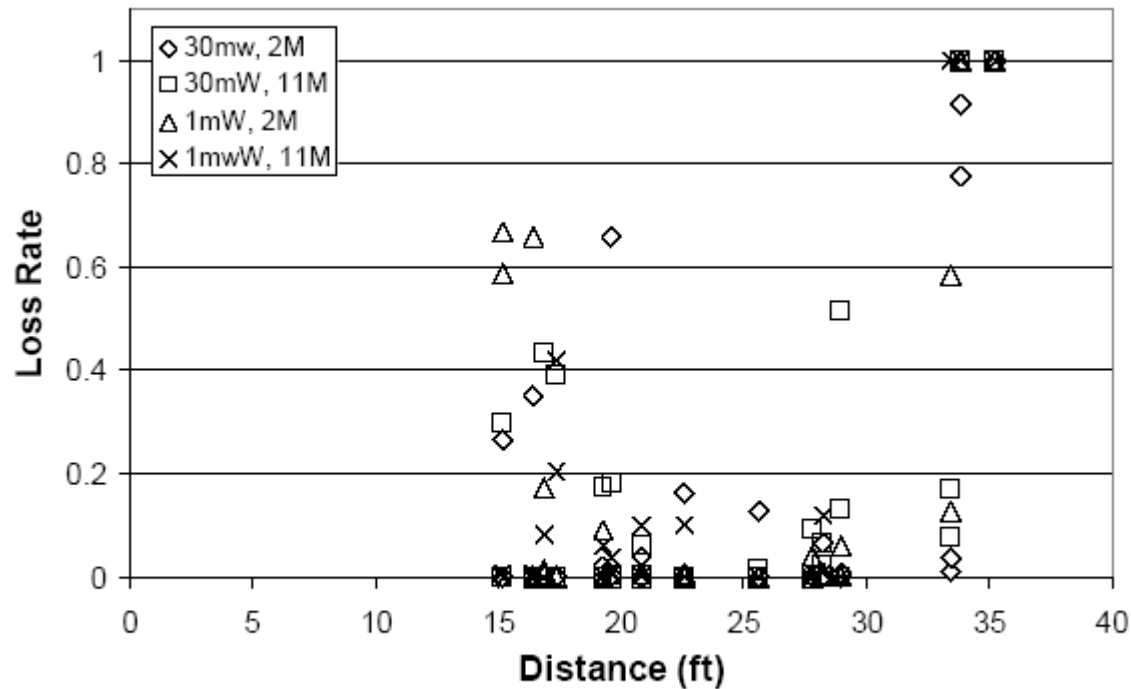
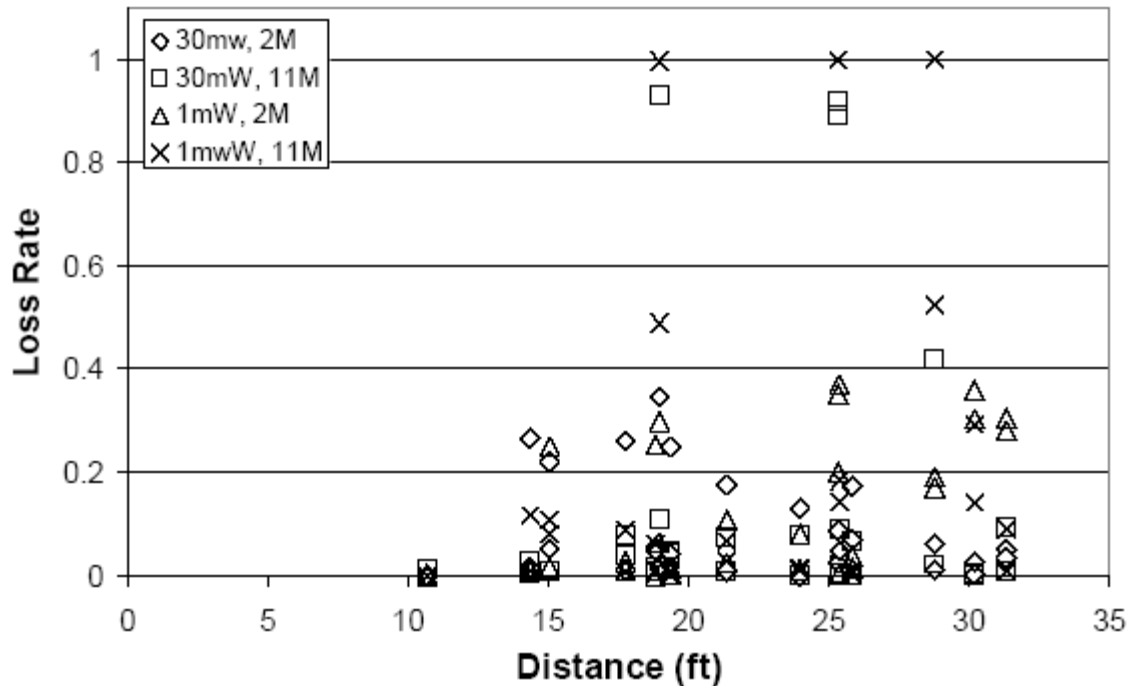# Link quality and distance relationship layout2

(a)

Figure 9: ukhome1

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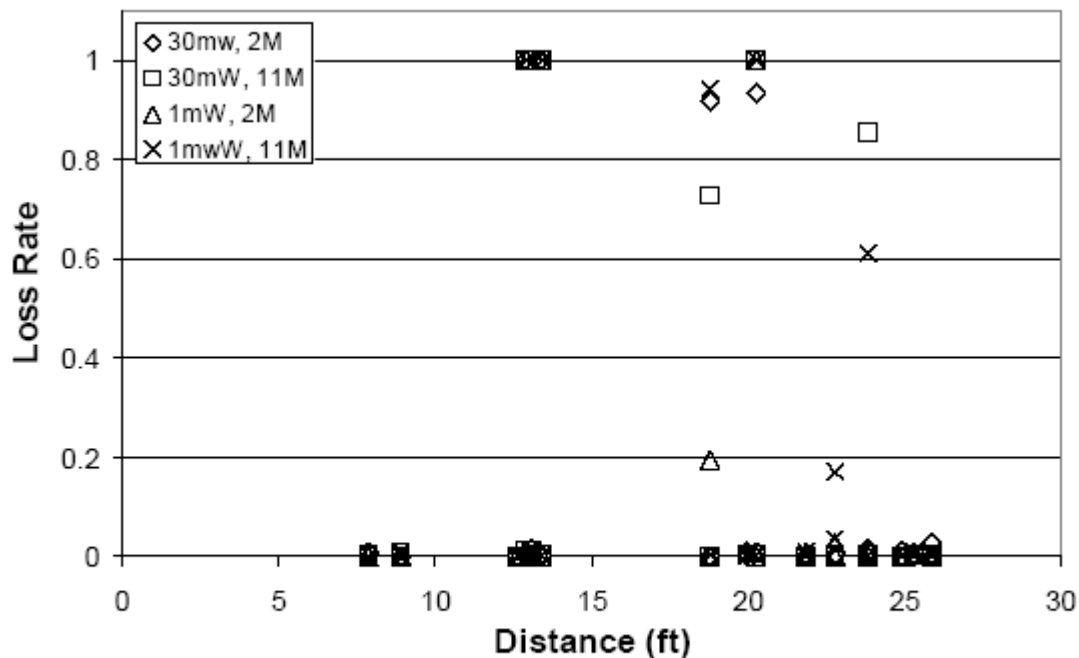
Link quality and distance relationship layout2

(b)

Figure 9: ushome1

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Link quality and distance relationship layout2

(c)

Figure 9: ushome2

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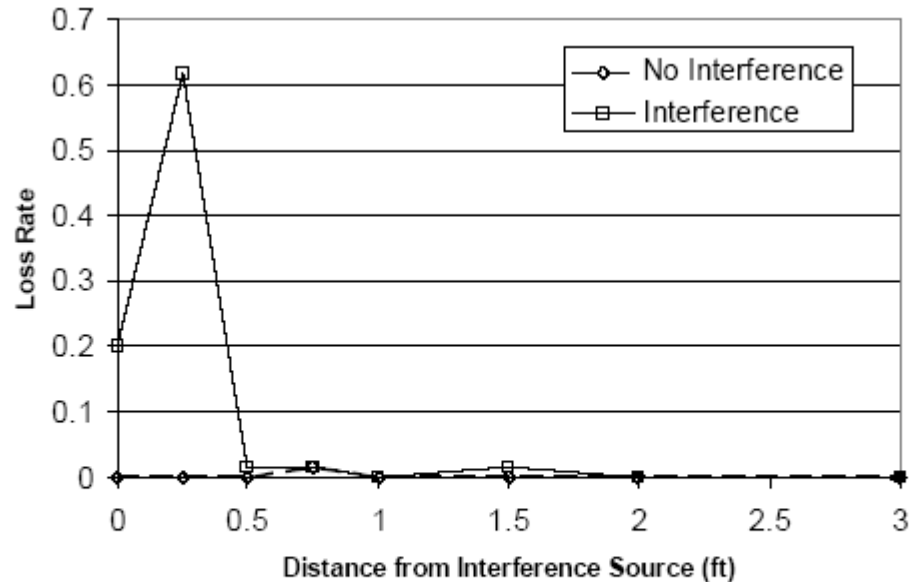
Microwave Oven Interference

Fig. 10. The impact of a 600W microwave on a receiver at varying distance from the interference source and a distance of 15 feet from the sending node.

Between home comparisons

- Small home (ukhome1) had better results sometimes (layout1), but worse performance under layout2.
- Precise node location is more important than home size or distance.

IEEE 802.11a Experiments

- **Results were quite similar to 802.11b results!**

- **802.11a yielded slightly better performance.**

- **Although 802.11a results were more 'binary', namely either good or very bad.**

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Layout1 ushome1

Figure 5b
802.11b

Figure 11a
802.11a

Characterization of 802.11 Wireless Networks in the Home
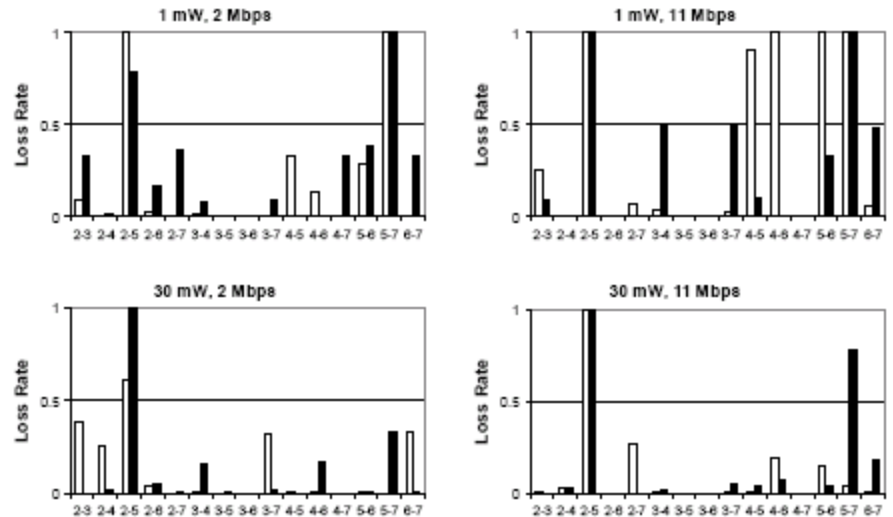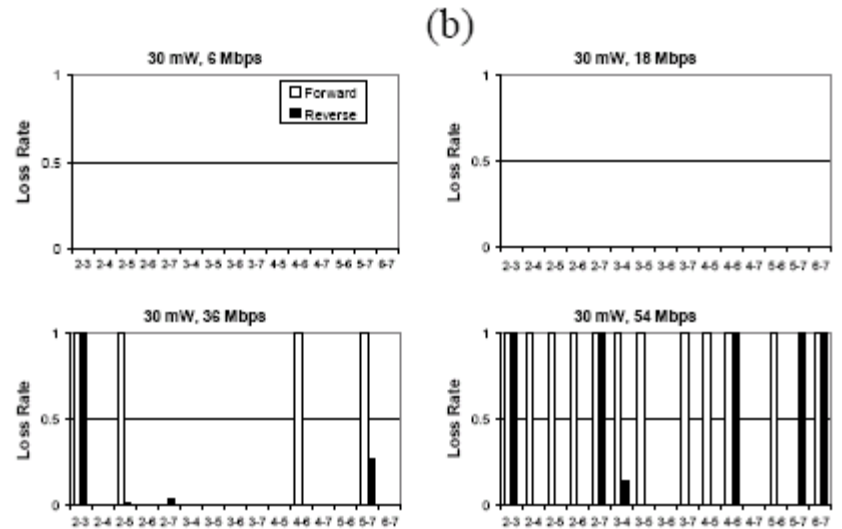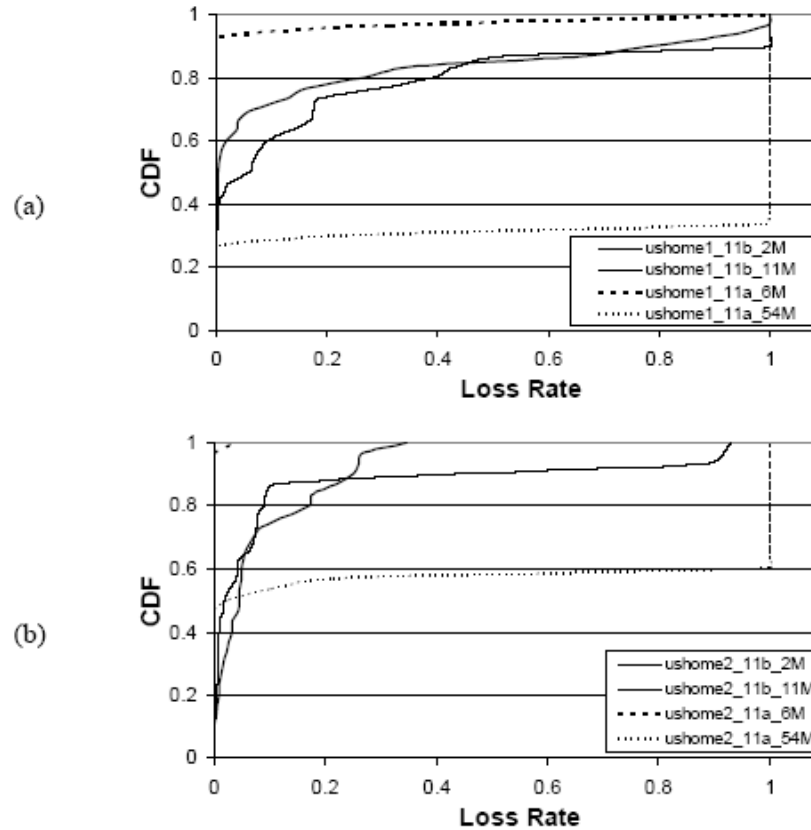
IEEE 802.11a Experiments

Fig. 14. Cumulative density function of loss rates under IEEE 802.11b and IEEE 802.11a in (a) *ushome1* and (b) *ushome2*.

Conclusions

- Wireless links inside homes tend to be stable over time, highly asymmetric and highly variable from one link to the next.

- Precise node location is probably the single most important factor.

- Distance has no impact on quality of the wireless links.

- Small changes in antenna orientation and node location can dramatically change individual link performance.

Conclusions (cont.)

- 802.11a performed slightly better in homes.
- But for both 802.11a and 802.11b the highest allowable rate may not be possible due to high loss.
- Home networks face similar problems to larger networks.
- Results imply the location of the AP will have a significant impact on overall performance.

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Thank You!

Questions ??