WaveLAN - Measurement and Analysis

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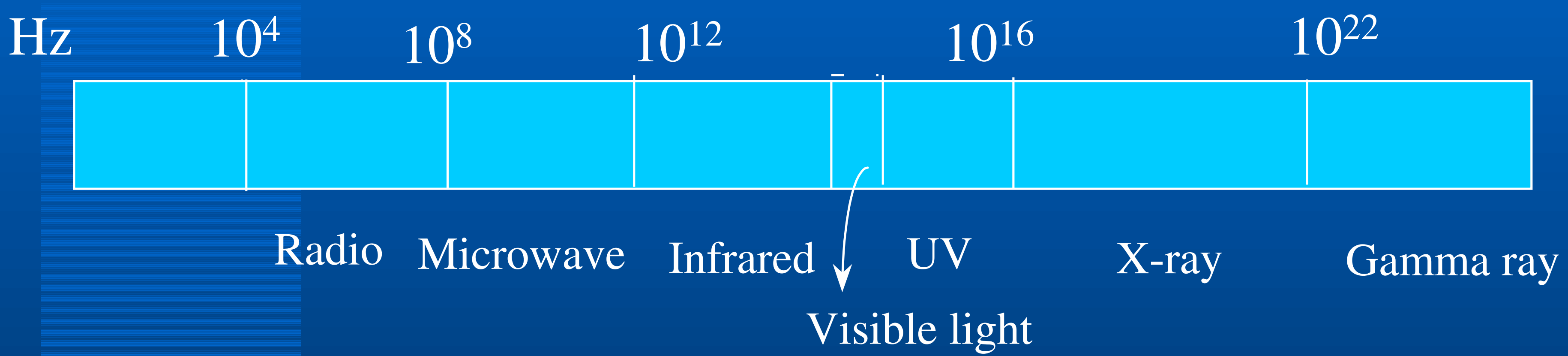
References

- D. Duchamp and N. F. Reynolds, Measured Performance of a Wireless LAN, In *Proceedings of the 17th IEEE Conference on Local Computer Network*, pages 494-499, July 1992
- D. Eckhardt and P. Steenkiste, Measurement and Analysis of the Error Characteristics of an In-Building Wireless Network, *Computer Communication Review* 26(4): 243-254, Oct. 1996

Introduction

- **Electromagnetic spectrum**



Wireless Transmission

- Radio transmission
  - omnidirectional
  - easy to generate
  - penetrate buildings easily
- Microwave transmission
  - travels in straight lines (> 100 MHz)
  - multipath fading
  - long-distance telephone, celluar telephones, television
  - includes ISM (Industrial/Scientific/Medical) bands
    - 2.4 - 2.484GHz, 902-928MHz, 5.725-5.85GHz
    - cordless telephones, garage door openers, ...
- Infrared waves
  - short-range communication
  - do not penetrate solid objects
- Lightwave transmission

Introduction

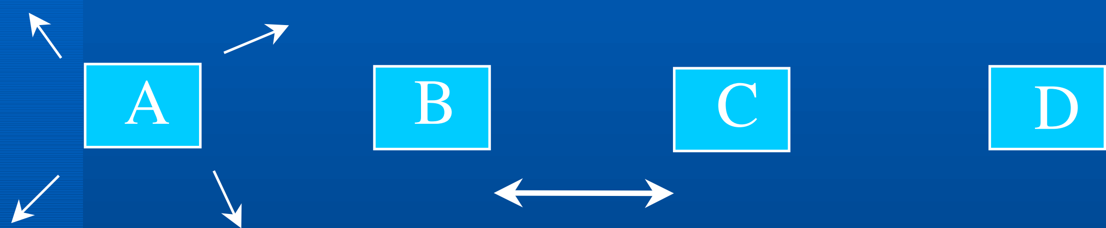
- Wireless services
  - FM (1946~)
  - Analog cellular services
  - Digital cellular services
  - Wireless WAN
    - CDPD: 19.2kbps, Metricom: 100kbps
  - Wireless LAN
    - WaveLAN: 2Mbps, RangeLAN: 1.6Mbps
    - Freeport: 16Mbps, HIPERLAN: 23.5Mbps
  - Satellite networks

Wireless LAN Protocols

- Hidden station problem
  - cannot detect a potential competitor for the medium because the competitor is too far away

Wireless LAN Protocols

- **Hidden station problem**

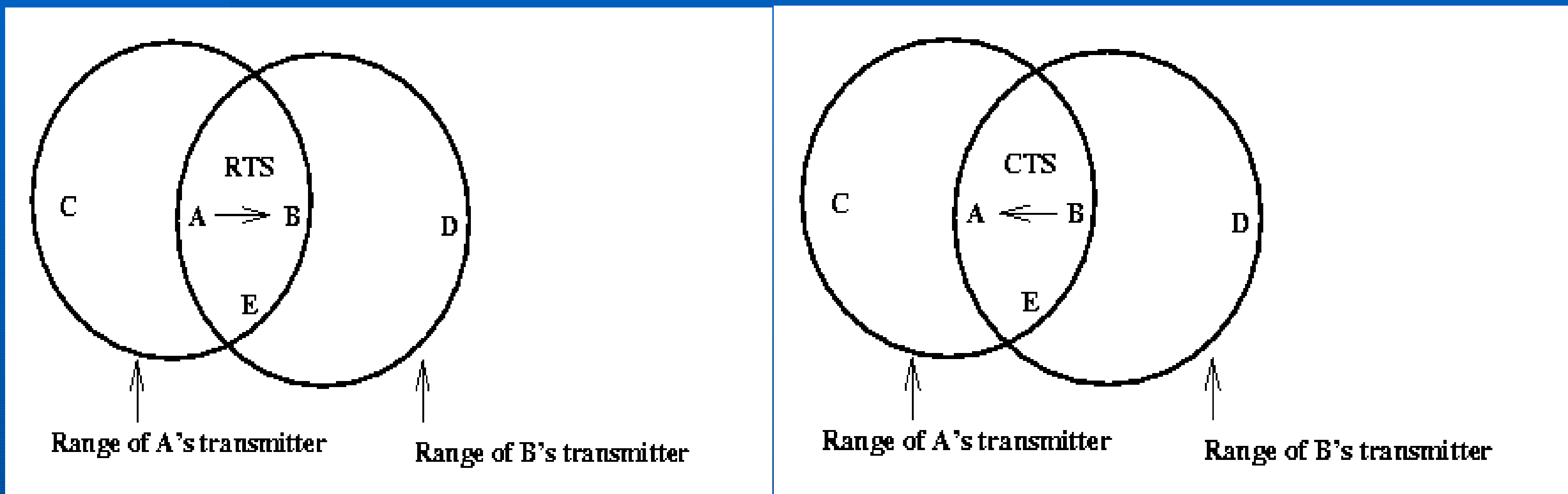


  - **if C senses the medium, it will not hear A since A is out of range**

Wireless LAN Protocols

- CSMA/CA
  - avoids collision losses by considering a busy medium as a collision
  - transmitters will delay for a random interval when the medium becomes free

CSMA/CA (basis of IEEE 802.11)



- Any station hearing the RTS remain silent long enough for the CTS to be transmitted back to A
- Any station hearing the CTS remain silent during the data transmission

AT&T WaveLAN

- 902-928 MHz or 2.4-2.8GHz ISM band
- 2 Mbit/s (1.4Mbit/s), 500 milliwatts
- Signal level (5 bits), Silence level (5 bits)
- Signal quality (4 bits)
- CSMA/CA
  - basically similar to the Ethernet protocol

Sources of Wireless Errors

- Attenuation
  - loss of electromagnetic energy
- Front end overload
  - transmitter's overwhelming filters in the receiver
- Narrowband interference
  - overlapping of a small frequency band
- Spread spectrum interference
  - frequency hopping or Direct Sequence Spread Spectrum (DSSS)
- Natural background noise
- Multipath interference
  - interference due to multiple paths b/w the transmitter and the receiver

Methodology

- DECpc 425SL laptops (25MHz 80486), NetBSD 1.0A
- UDP
  - packet size: 256 32-bit words
- Modified device driver to log status information
- Identical data words for each packet

Methodology

- Packets received: test packets received
- Packet loss: percentage of transmitted test packets that were lost
- Packets truncated: # of received test packets truncated
- Bits received: # of body bits received, rounded down
- Wrapper damaged: # of packets with damaged headers or trailers
- Damaged body bits: total # of body bits damaged

Reasons of packet damage

- Missing marker for beginning-of-frame $\longrightarrow$ loss
- Errors in the packet headers and trailers
- Truncated body or incorrect bit

Experimental Results

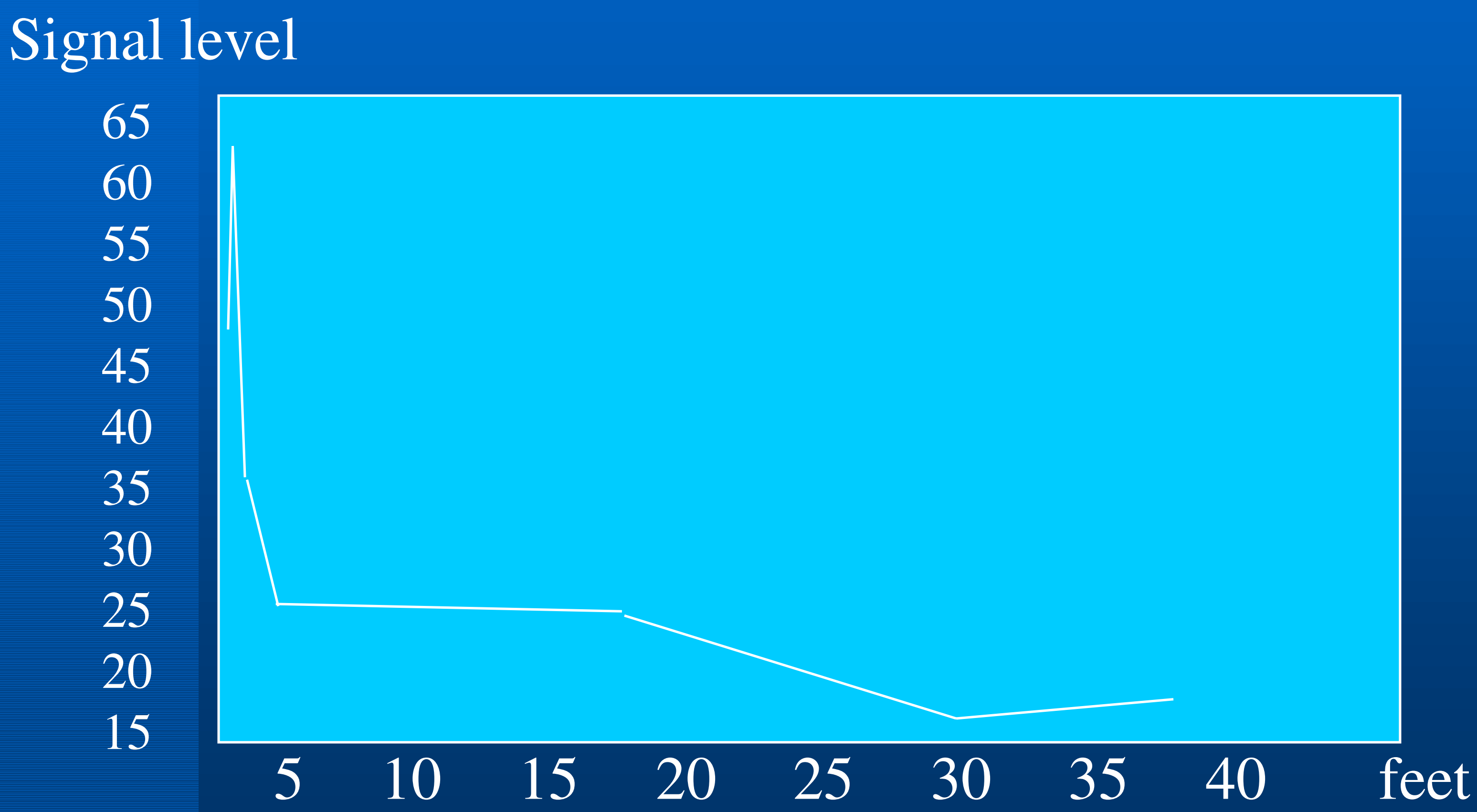
- In-room communication
  - Base case (experiments at 9 offices without any physical objects, Table 2)
  - Effects of distance (Figure 1)
- Errors due to passive obstacles
  - Single wall (Table 4)
  - Multiple obstacles (Table 5, Table 6, and Table 7)
  - Human body (Table 8 and Table 9)
- Errors due to active radiation sources
  - Front end overload
  - Narrowband interference
  - Spread spectrum cordless phones
  - Competing WaveLAN units

In-room communication

- Base case (experiments at 9 offices)
  - packet loss (0% ~ 0.07%, avg. 0.03%)
  - packets truncated: 1/102,720 at 1 office
  - wrapper damaged: 1/122,160 at 2 offices
  - damaged body bits: 1/122,160 at 1 office
- Effects of distance

  \- the receiver is fixed

In-room Communication



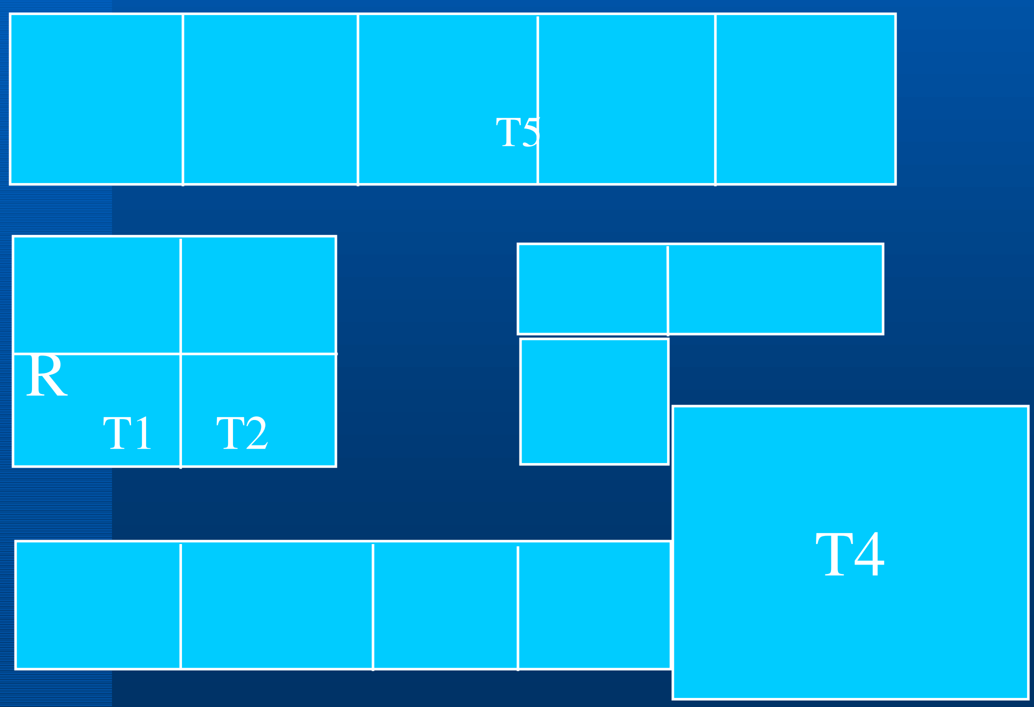
Errors due to passive obstacles

- Single wall (Table 4)
  - \- Air 1: 7 feet free space b/t a transmitter and a receiver
  - \- Wall 1: 6 inch plaster wall b/t a transmitter and a receiver
  - \- Air 2: 11 feet free space
  - \- Wall 2: 6 inch concrete wall
  - ❍ the wall affects the signal level though the quality is not significantly reduced

	Signal level	Signal silence	Signal quality
Air 1	30.58	1.80	15.00
Wall 1	25.78	1.25	15.00
Air 2	28.58	3.35	15.00
Wall 2	26.66	3.25	15.00

Errors due to passive obstacles

- **Multiple obstacles (Table 5, Table 6, Table 7)**
  - **concrete walls**
  - **layout of multiple obstacle experiment (Figure 4)**



Errors due to passive obstacles

Table 5

	Packet loss	Wrapper damaged	Damaged body bits
T1	0%	0	0
T2	0.007%	0	0
T4	0.07%	0	0
T5	0.07%	0	7

- it requires multiple walls to safely isolate two transmitters in different offices

Errors due to passive obstacles

- Human body
  - 56 feet b/t a transmitter and a receiver
  - concrete walls b/t two WaveLAN units
  - a person bending over as if to examine the laptop
  - Table 8

	Packet loss	Wrapper damaged	Damaged body bits
No body	0%	0	0
Body	0.14%	1	224

Errors due to active radiation sources

- Front end overload
  - 144 MHz Radio FM transmitter (2 watts): no error
  - 2 GHz microwave oven with the door closed : no error
- Narrowband interference
  - 900 MHz cordless phones (AT&T 9100 and Panasonic KX-T9500)
  - 20 feet b/t 2 WaveLAN units
  - Phones off, cluster, handsets nearby, handsets nearby talking, and bases nearby
  - Table 10
  - except for the “cluster” trial handsets handsets received solid static
  - WaveLAN : no damaged packet
  - DSSS transmission scheme (known to resistant to narrowband sources)

Errors due to active radiation sources

- Spread spectrum cordless phones
  - 900 MHz cordless phones (AT&T 9300 and Radio Shack ET-909)
  - 25 feet b/t 2 WaveLAN units
  - near trial: several inches from phone to WaveLAN
  - far trial: 14 feet from phone to WaveLAN
  - ❍ Table 11

  - severe damage to WaveLAN

Errors due to active radiation sources

- **Spread spectrum cordless phones (continued)**
  - **- ISM bands spread spectrum cordless phones can damage the WaveLAN environment**
- **Competing WaveLAN units**
  - additional WaveLAN transmitters at T4 and T5 locations
  - it can cause significant interference
  (ex. hundreds of invalid Ethernet address)

Summary

- Wireless LAN systems can provide good connectivity
- Spread spectrum cordless phones operating in the same frequency band cause worst errors
- Self-interference is substantial
  - we need to develop a robust cellular architecture