Empirical Study of 802.11b Wireless Networks in the Presence of Bluetooth Interference

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Outline

- Current Wireless Technologies
- The Interference Problem
- Throughput Testing
  - Setup/Methodology
  - Results

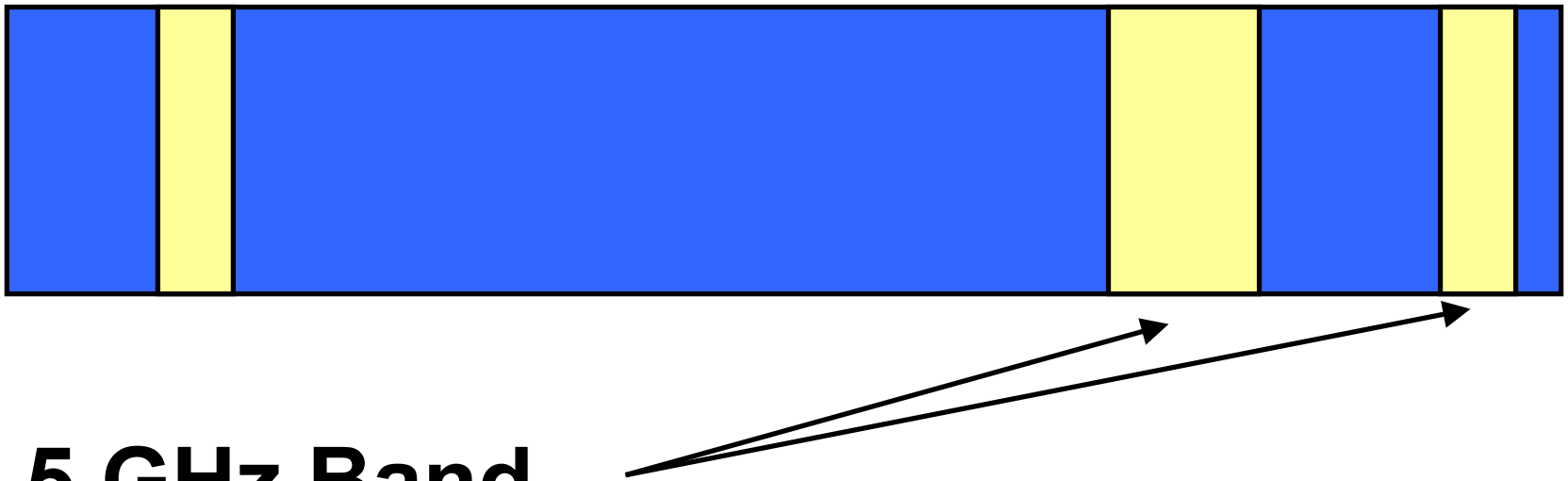
Current Wireless Technologies

2.4 GHz Band

5 GHz Band

Two bands commonly used for wireless networking

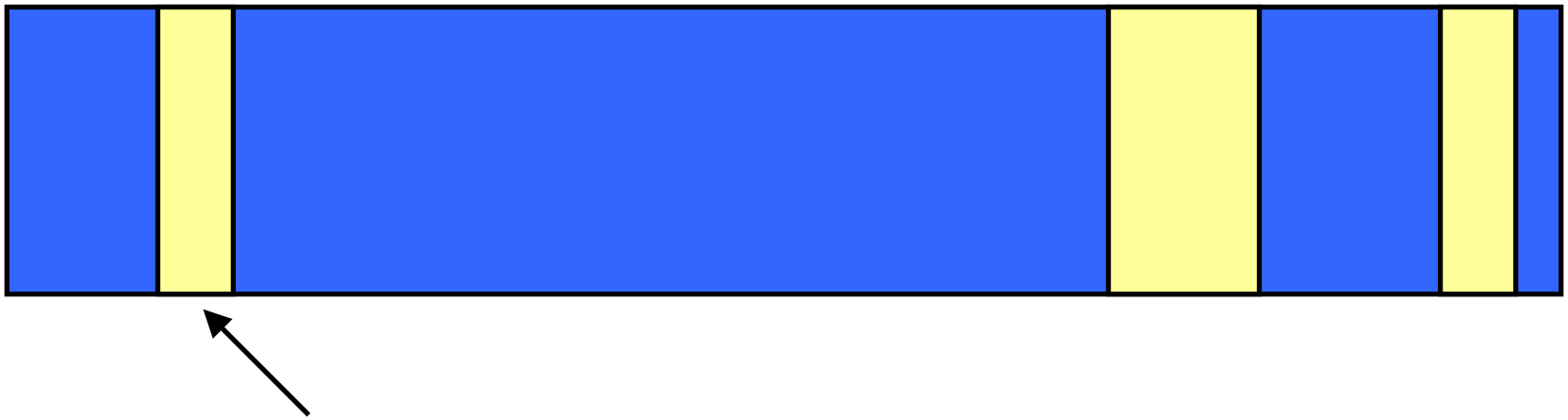
Current Wireless Technologies



5 GHz Band

- 5.15 – 5.35 GHz and 5.725 – 5.825 GHz
- 300 MHz total
- Home to…
  - 802.11a (54 Mbps)

Current Wireless Technologies



2.4 GHz Band

- 2.4 – 2.483 GHz
- 83 MHz total
- Home to…
  - Bluetooth (1 Mbps)
  - 802.11b (11 Mbps)
  - 802.11g (54 Mbps)

Current Wireless Technologies

- Two big players
  - 802.11b (aka Wi-Fi)
    - 11 Mbps
    - Used for medium-range wireless networks
      - 100 m nominally
    - 15 – 20 dBm power output

Current Wireless Technologies

- Two big players
  - Bluetooth
    - 1 Mbps
    - Frequency-hopping
    - Included with many cell phones and PDAs
    - Used for short-range cable replacement
      - Syncing PDAs with computers, wireless headsets, connecting cell phones with PDAs/laptops
    - Three power classes
      - 0 dBm: 10 cm range
      - 4 dBm: 10 m range (most common)
      - 20 dBm: 100 m range

The Interference Problem

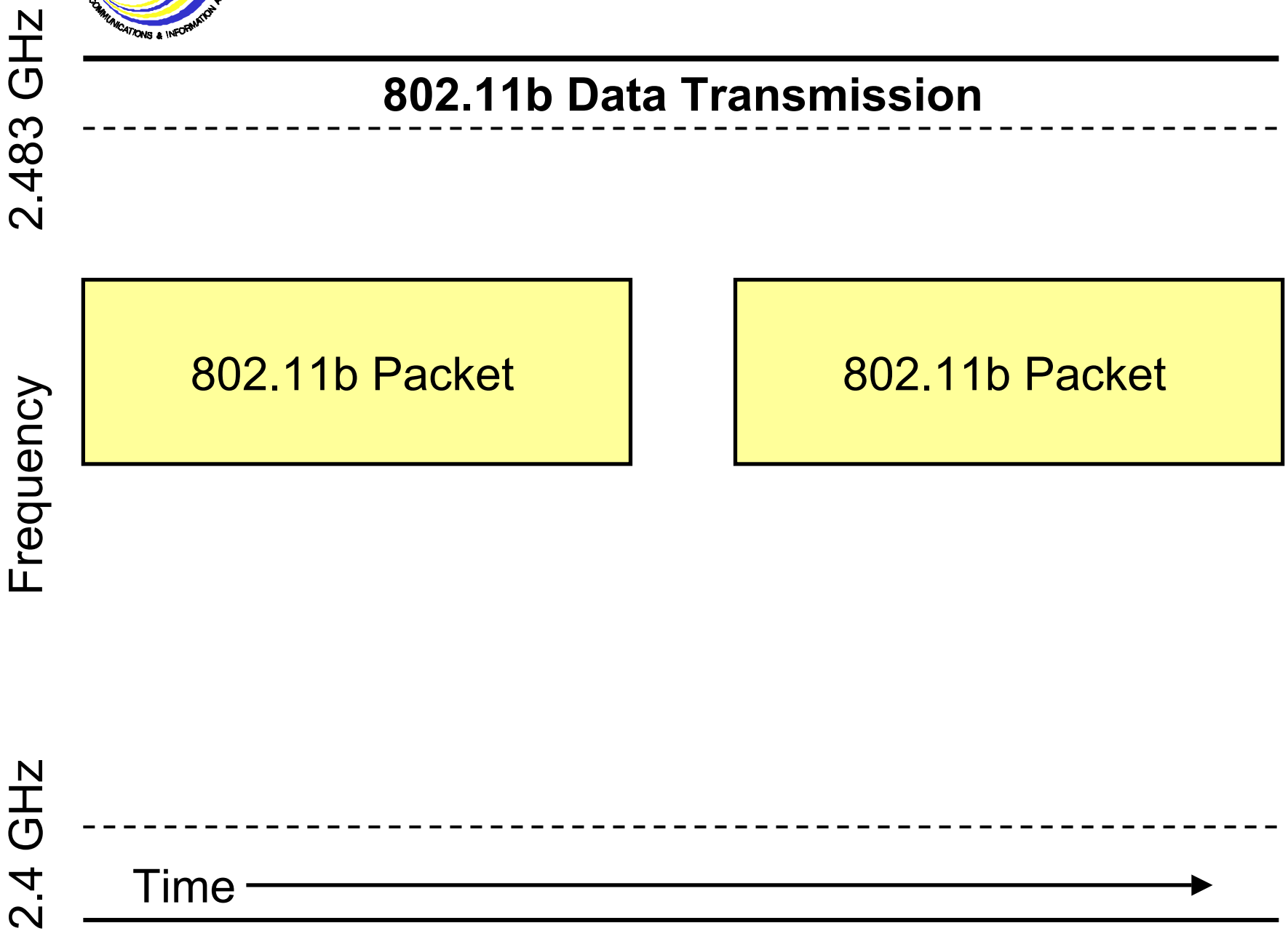
Bluetooth and 802.11b are **complementary** (not competing) technologies that need to coexist…

BUT

Since they use the same 2.4 GHz frequency band, there will be some level of interference

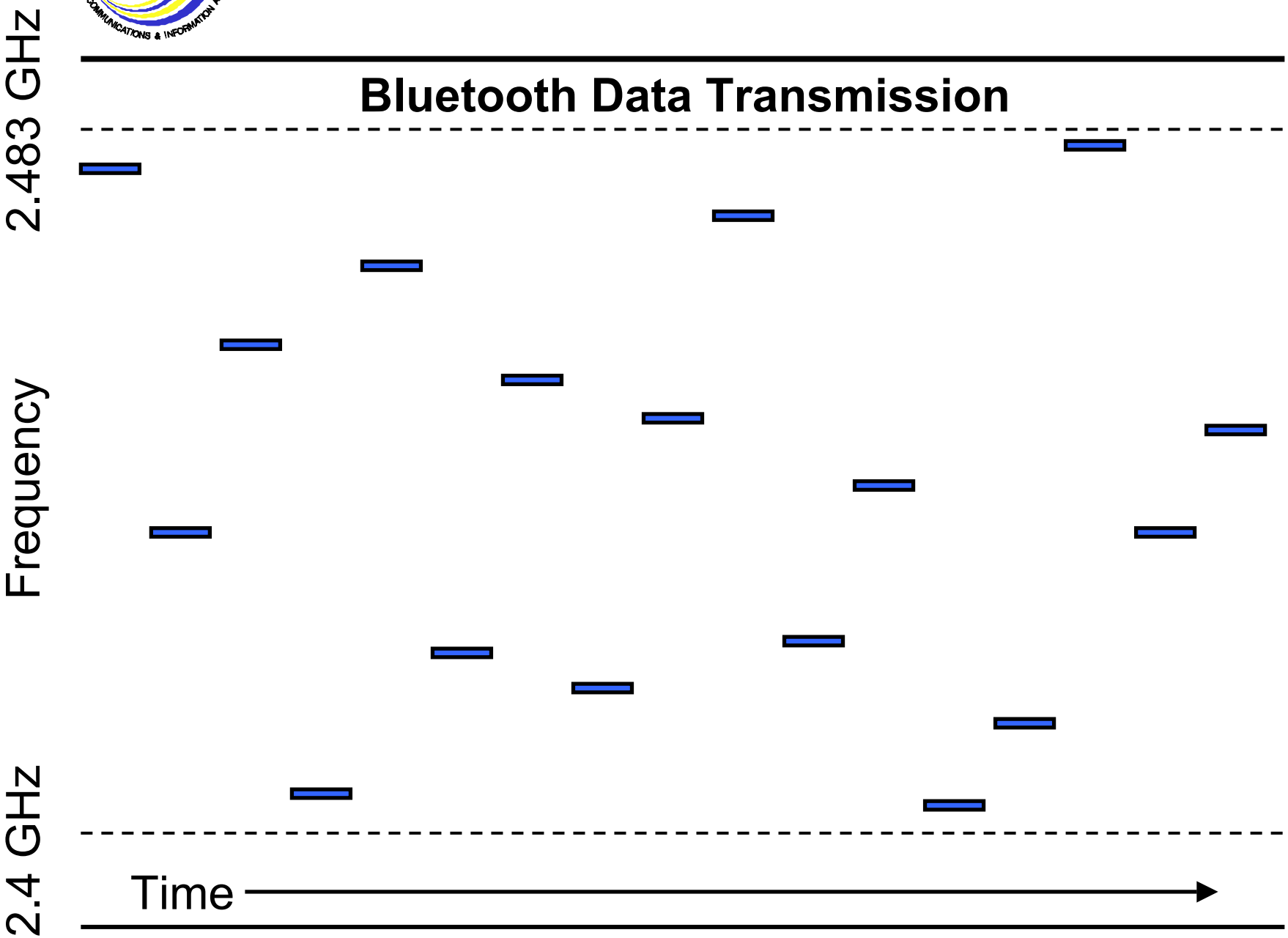
The Interference Problem

802.11b Data Transmission

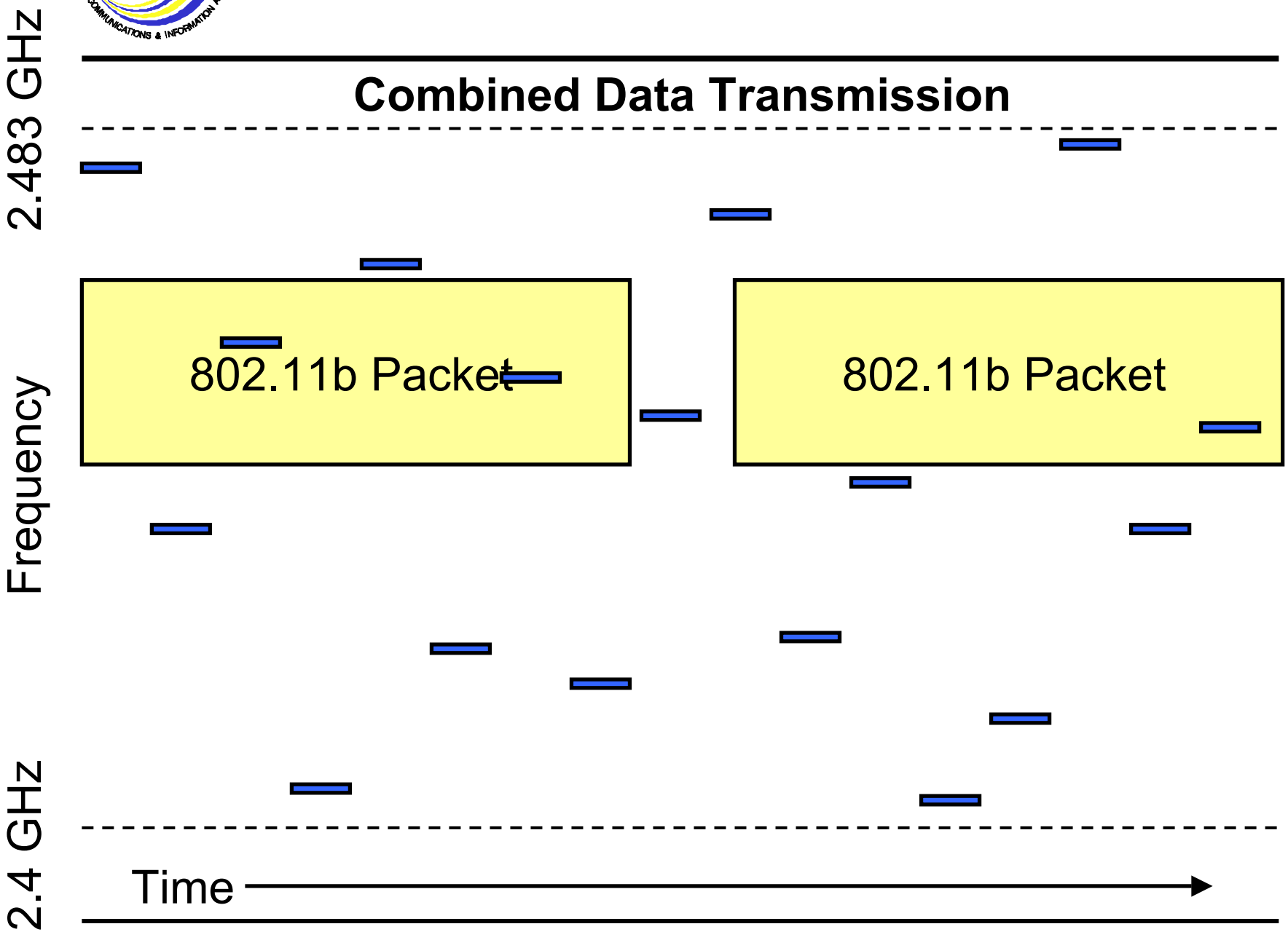


The Interference Problem

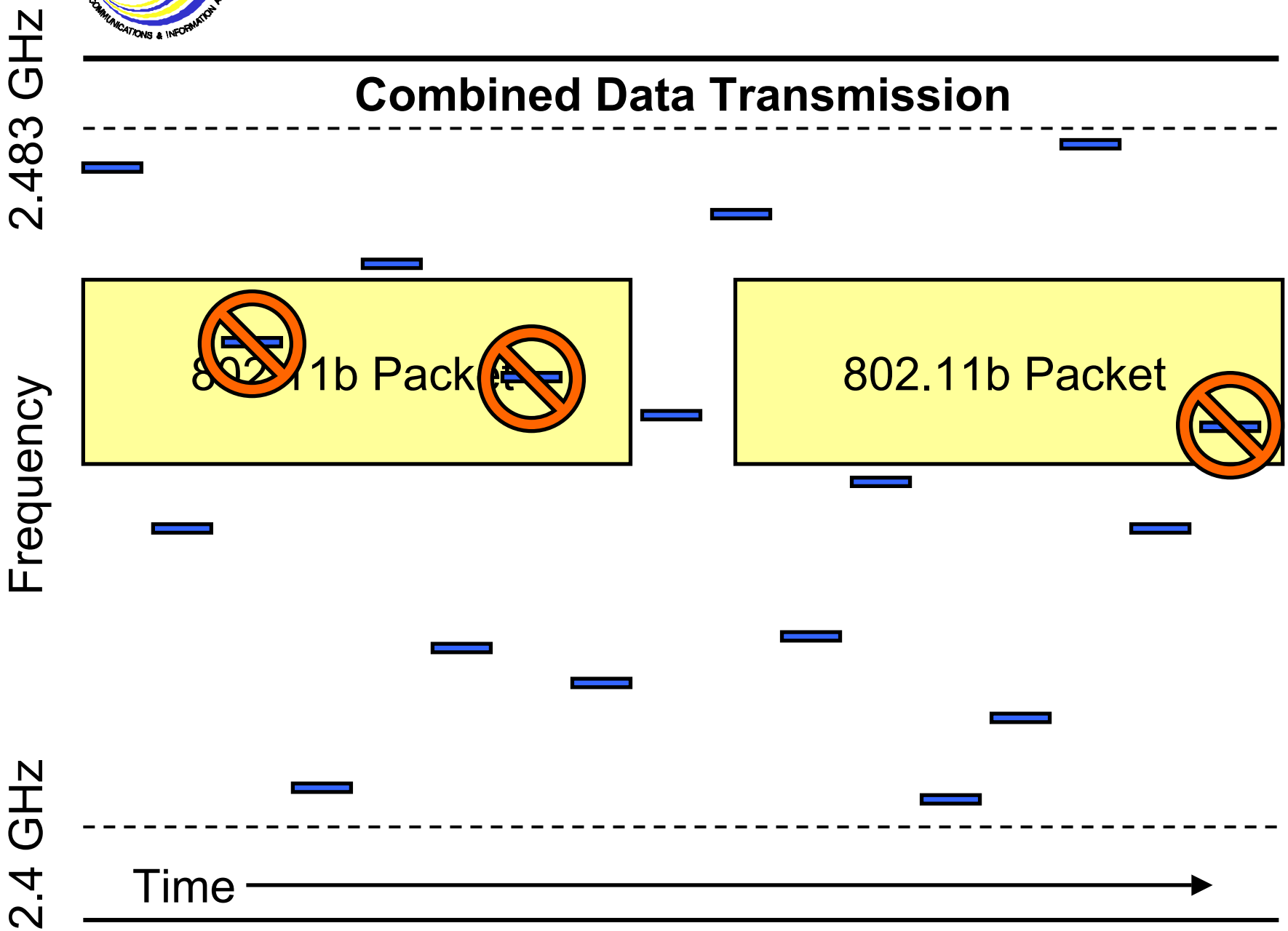
Bluetooth Data Transmission



The Interference Problem



The Interference Problem



The Interference Problem

How do Bluetooth devices affect the speed of nearby 802.11b links?

Throughput Testing

- Previous work
  - Simulations
  - Laboratory Experiments
    - idealized conditions
  - Few real-world empirical studies

Throughput Testing

- Our work
  - Speed measurements under real-world conditions
  - Multiple Bluetooth interferers

Throughput Testing

- Our Testing – Basic Idea
  - Set up an 802.11b link
  - Vary its SNR
  - Measure the link speed without interference
  - Activate some Bluetooth devices and measure the speed again

Throughput Testing

In other words, we want to fill in this matrix with speed numbers

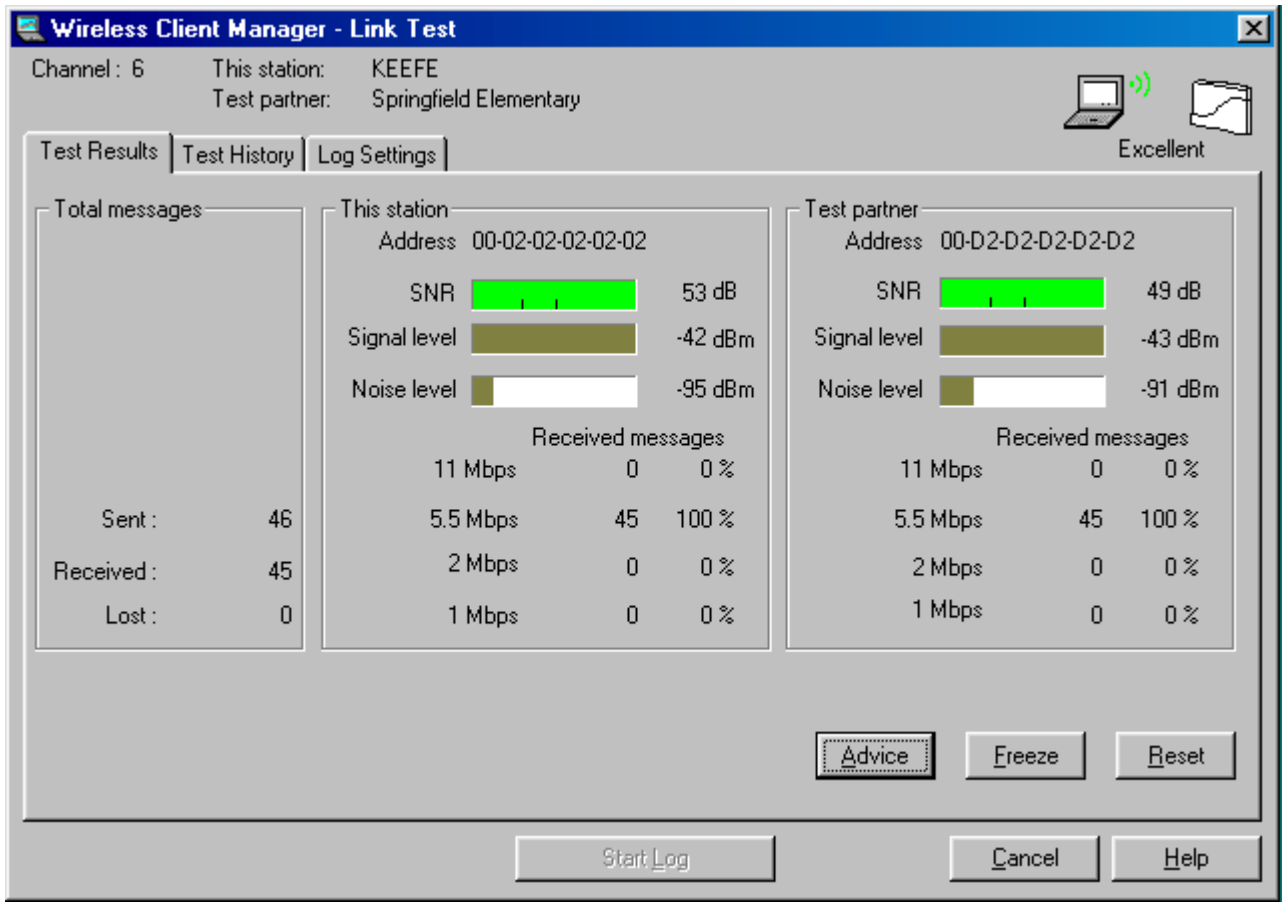
802.11b SNR (dB) **measured before interference**

Number of Interferers

	50	45	40	35	30	25	20	15	10
0									
1									
2									
3									

Throughput Testing

- How to measure the SNR?



Throughput Testing

- How to measure the link speed?
  - Network testing application (Chariot) would have been easiest
  - FTP works just fine (and is free)
    - Send a file over the wireless network
    - Speed = (File Size)/(Time)

Throughput Testing

Test Setup – Hardware

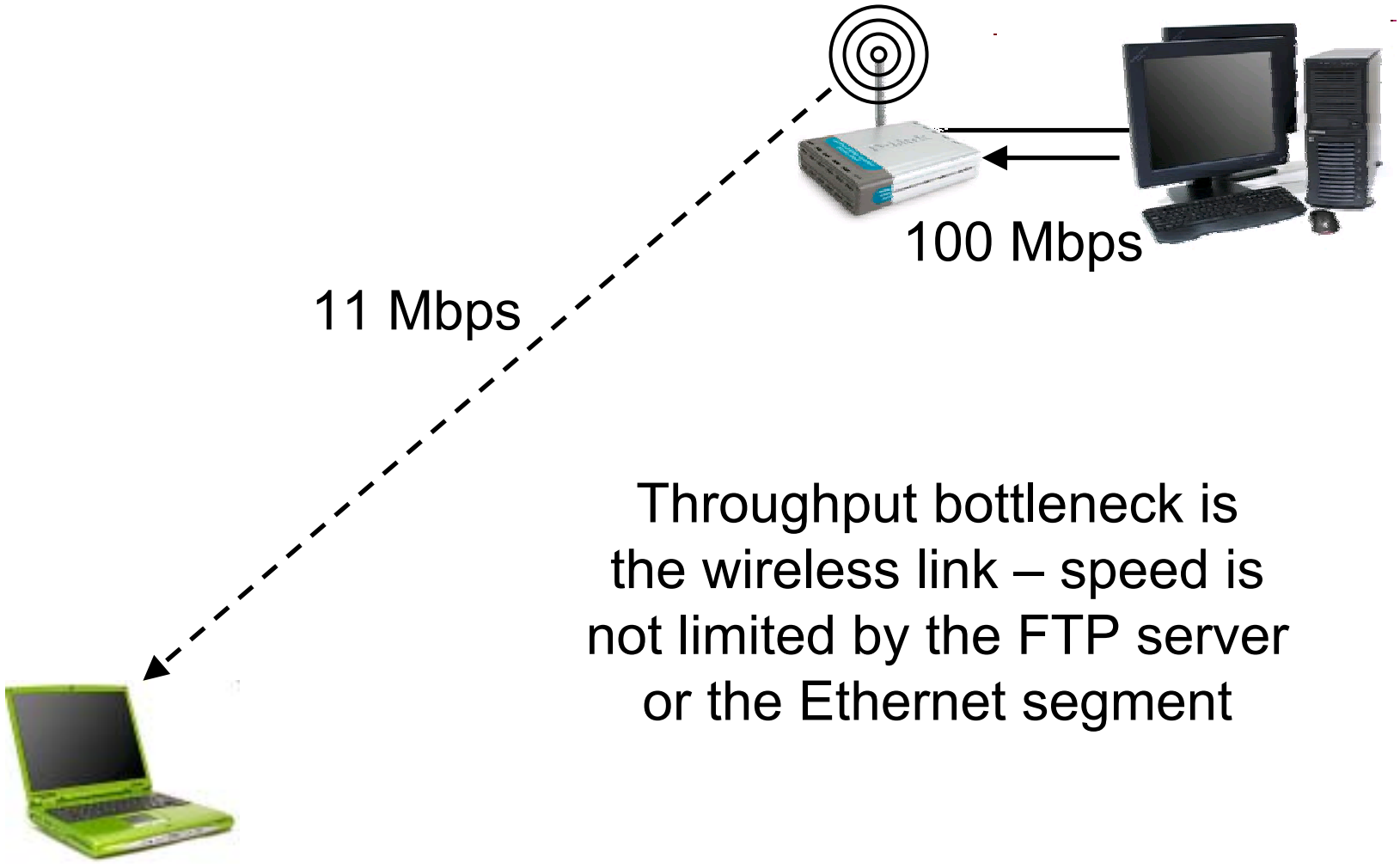
802.11b Access Point

FTP Server
(connected via
100 Mbps Ethernet
to the Access Point)

802.11b-equipped Laptop

Throughput Testing

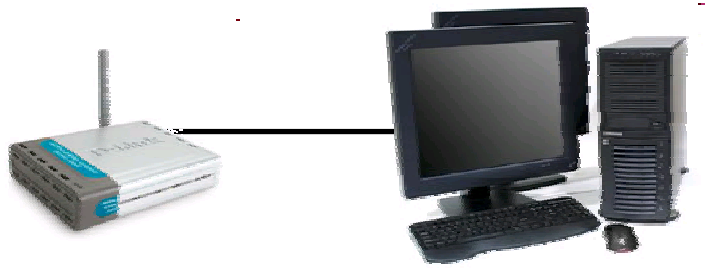
Test Setup – Hardware



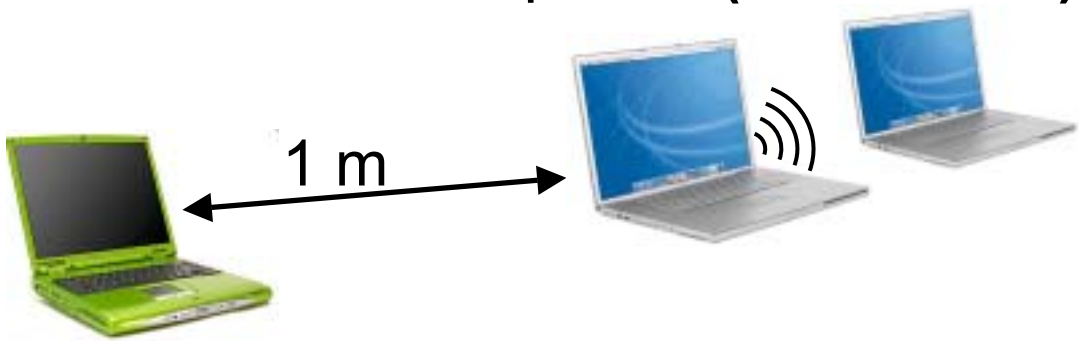
Throughput bottleneck is the wireless link – speed is not limited by the FTP server or the Ethernet segment

Throughput Testing

Test Setup – Hardware

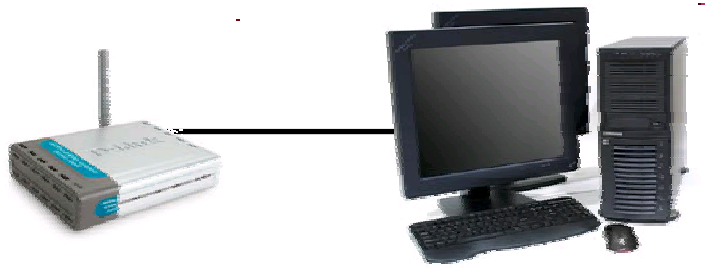


Pair of Bluetooth-equipped computers **(Interferers)**

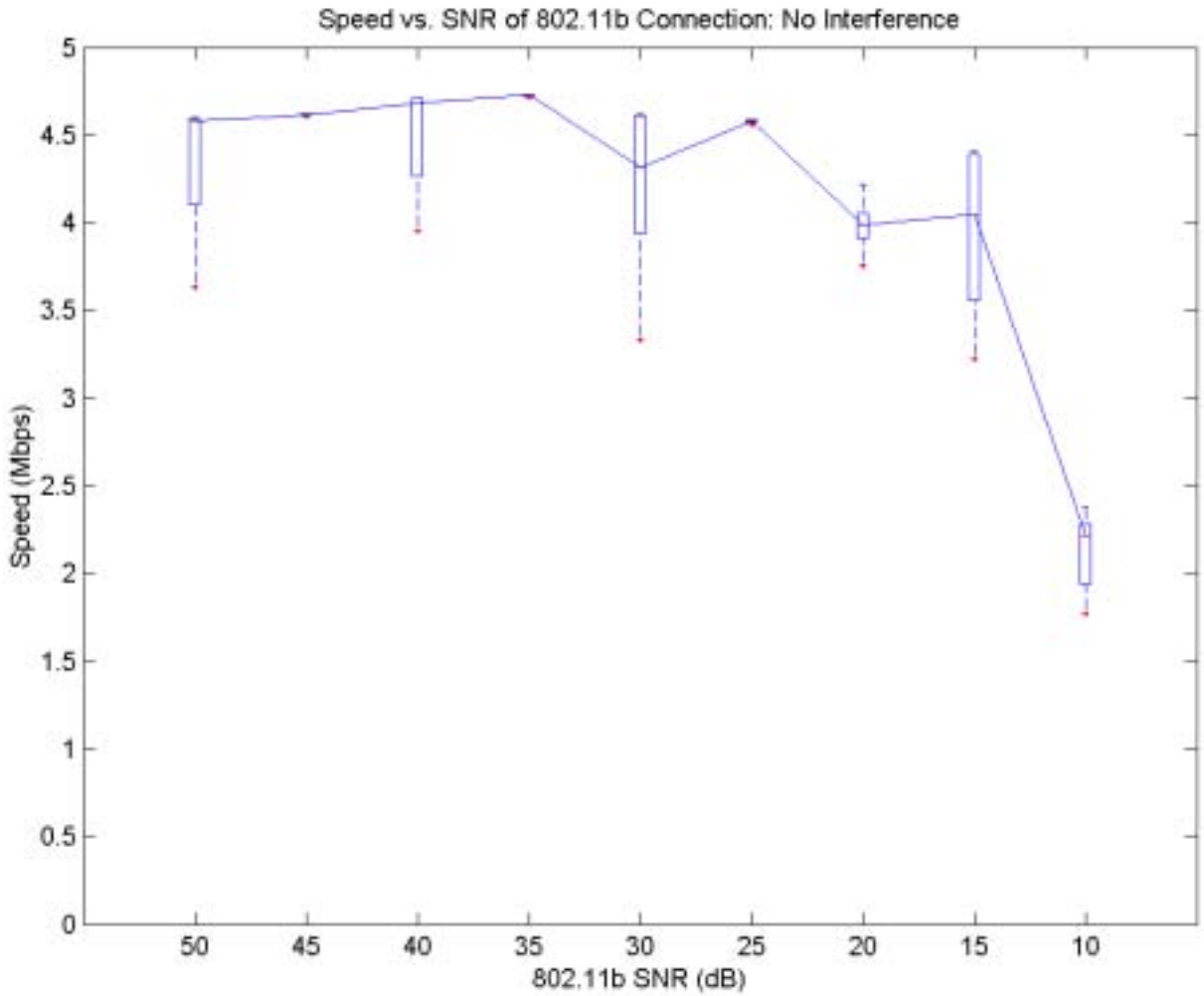


Throughput Testing

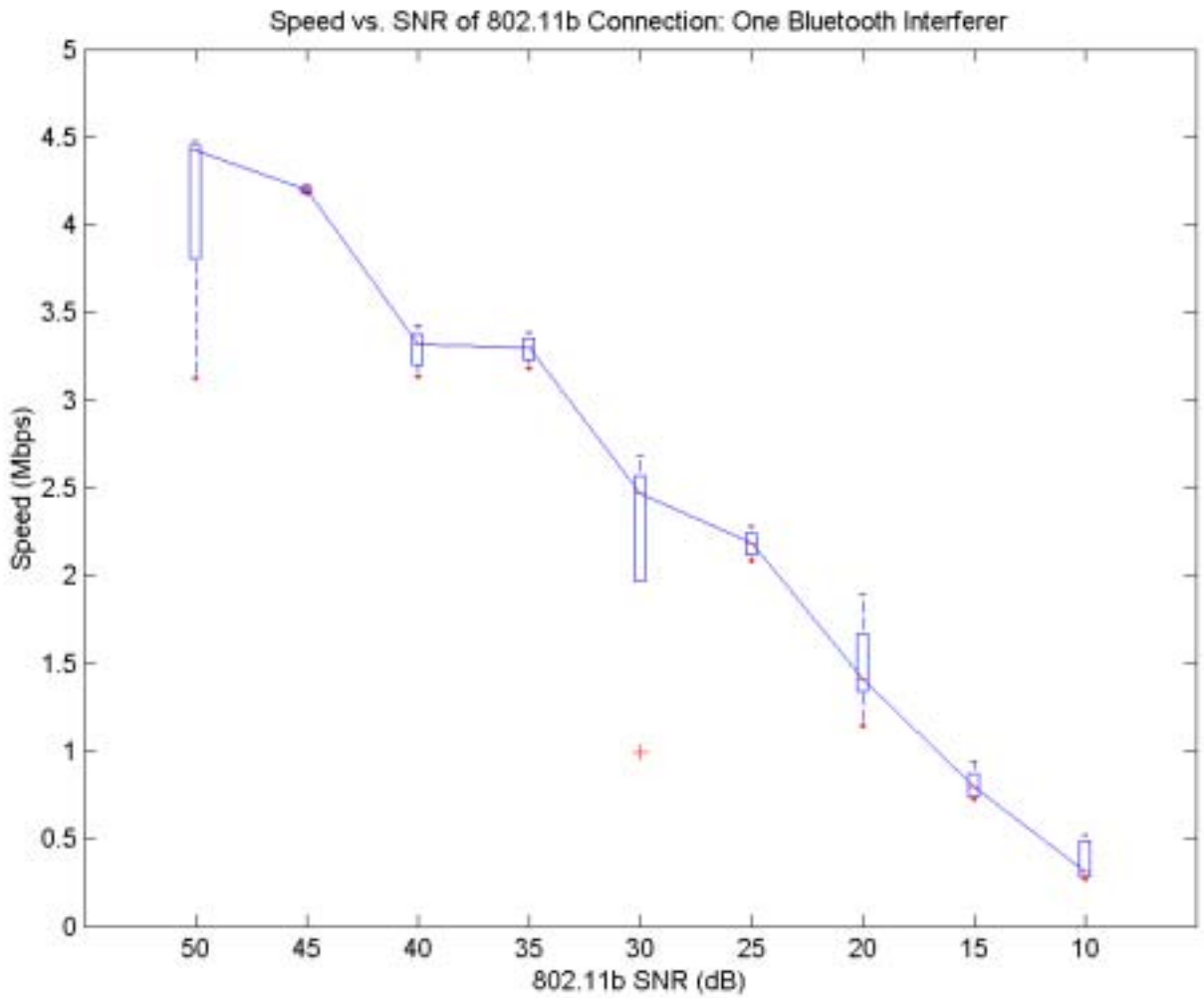
Test Setup – Hardware



Data Rate – No Interference

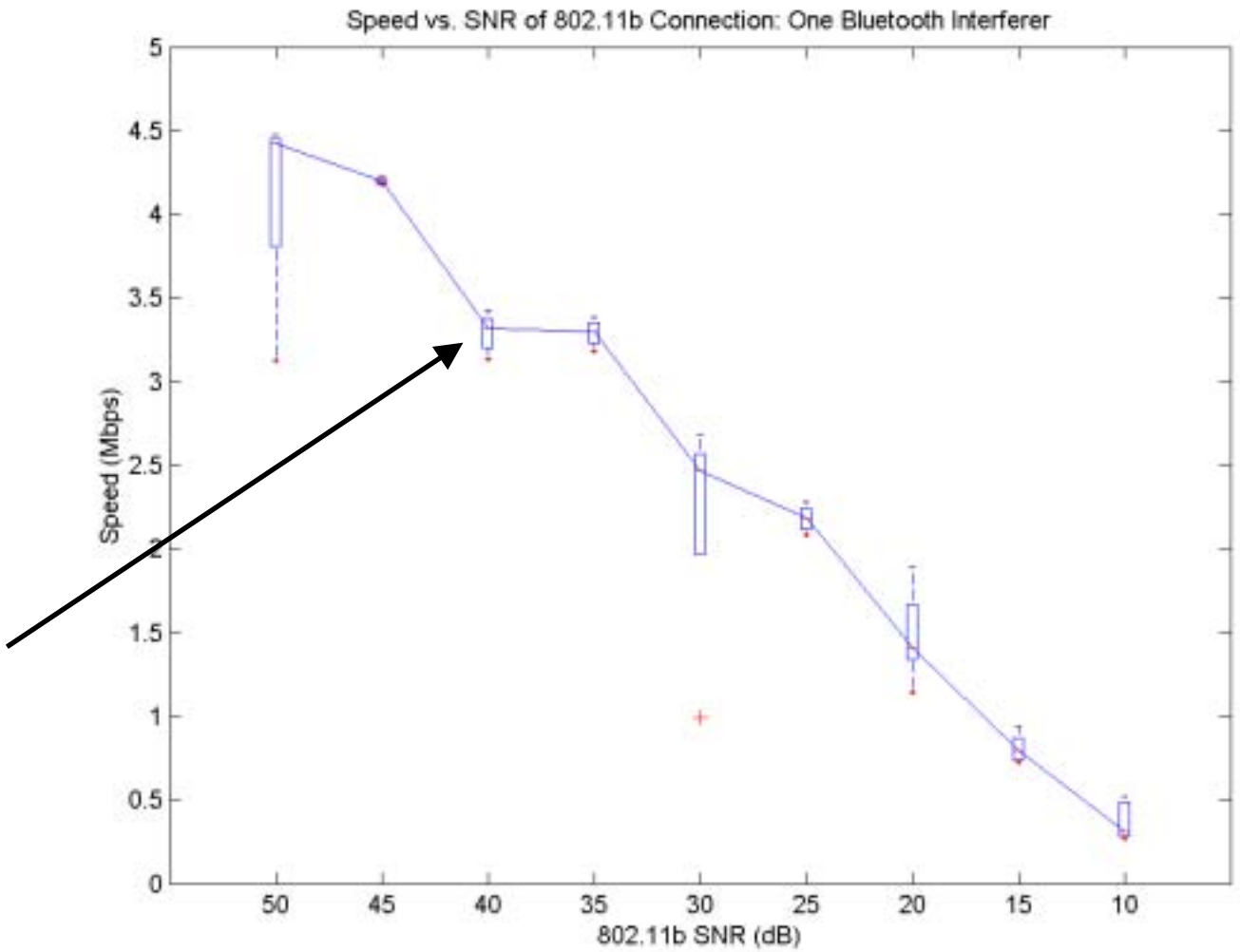


Data Rate – One Interferer

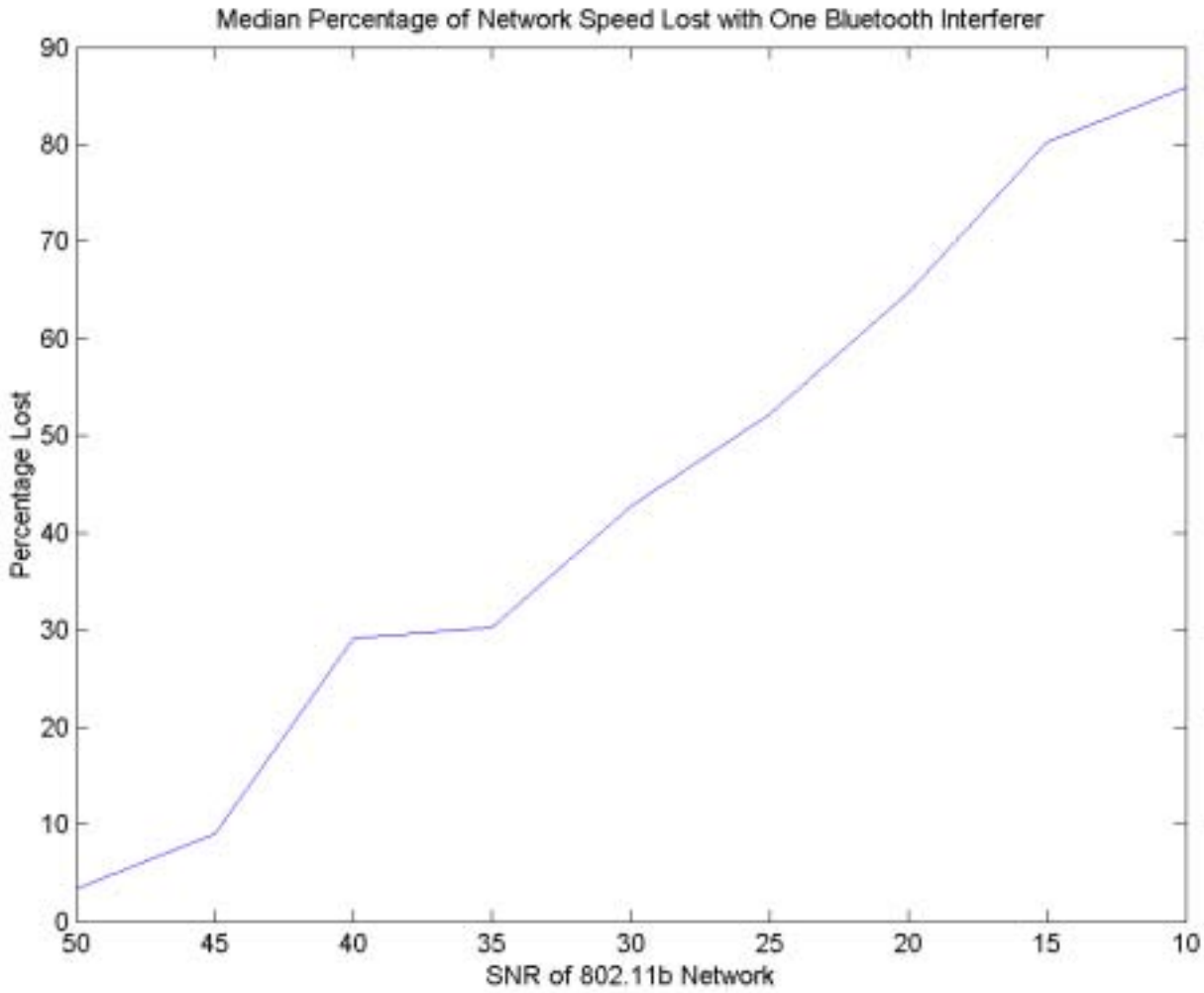


Results

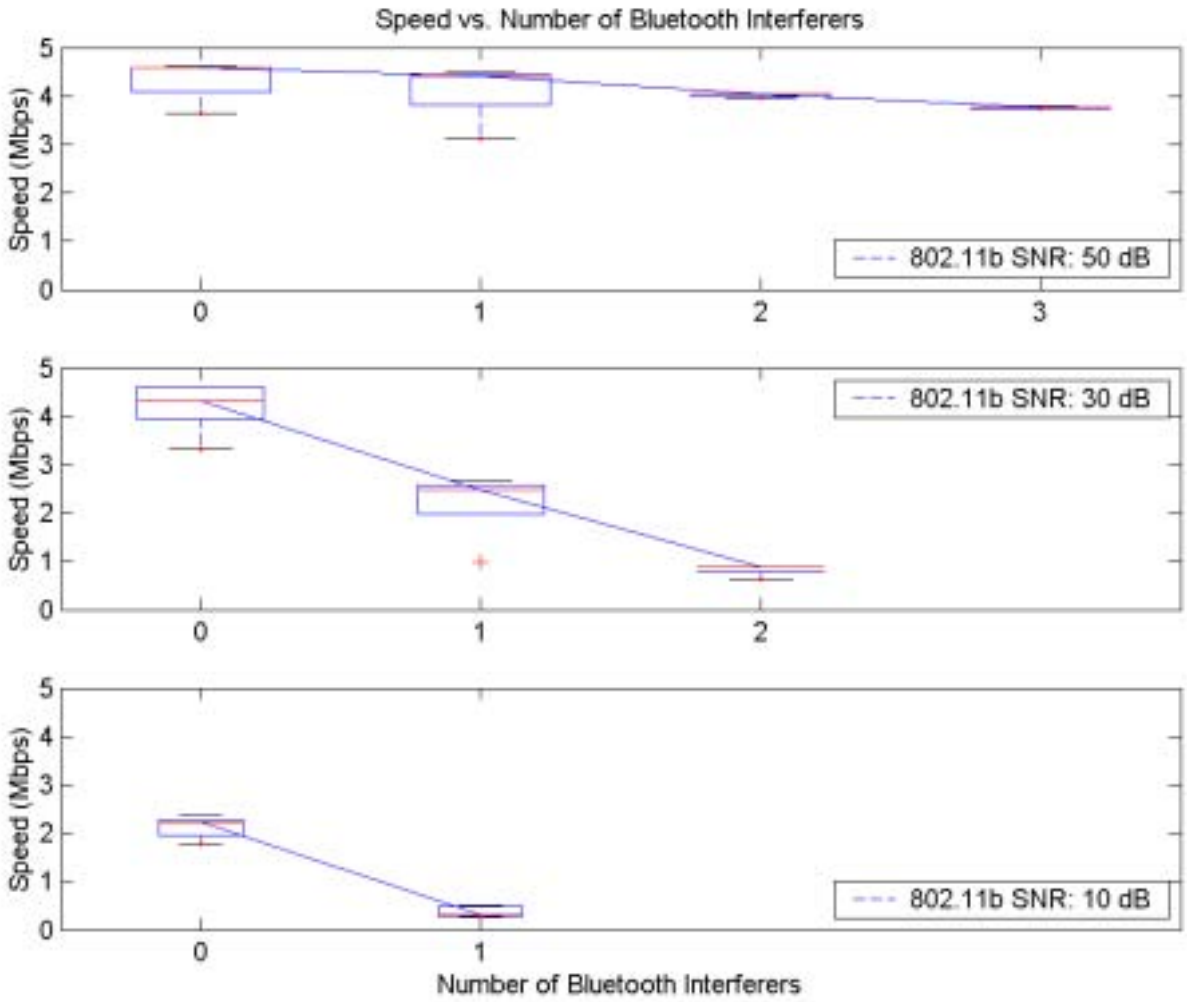
Data Rate – One Interferer



Percentage Network Speed Lost



Data Rate – Multiple Interferers



Results

- Single Interferers
  - 50% network speed lost at SNR of 25 dB
- Multiple Interferers
  - Effects are highly dependent on SNR