## Token Ring Overview
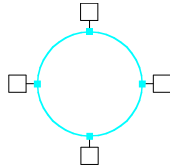
- Examples
  - 16Mbps IEEE 802.5 (based on earlier IBM ring)
  - 100Mbps Fiber Distributed Data Interface (FDDI)

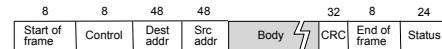## Token Ring (cont)

- Idea
  - Frames flow in one direction: upstream to downstream
  - special bit pattern (token) rotates around ring
  - must capture token before transmitting
  - release token after done transmitting
    - immediate release
    - delayed release
  - remove your frame when it comes back around
  - stations get round-robin service
- Frame Format

| 8 | 8 | 48 | 48 | | 32 | 8 | 24 |
|---|---|---|---|---|---|---|---|
| Start of frame | Control | Dest addr | Src addr | Body | CRC | End of frame | Status |

## Timed Token Algorithm

- Token Holding Time (THT)
  - upper limit on how long a station can hold the token

- Token Rotation Time (TRT)
  - how long it takes the token to traverse the ring.
  - TRT <= ActiveNodes x THT + RingLatency

- Target Token Rotation Time (TTRT)
  - agreed-upon upper bound on TRT

## Algorithm (cont)

- Each node measures TRT between successive tokens
  - if measured-TRT > TTRT: token is late so don't send
  - if measured-TRT < TTRT: token is early so OK to send
- Two classes of traffic
  - synchronous: can always send
  - asynchronous: can send only if token is early
- Worse case: 2xTTRT between seeing token
- Back-to-back 2xTTRT rotations not possible

## Token Maintenance

- Lost Token
  - no token when initializing ring
  - bit error corrupts token pattern
  - node holding token crashes
- Generating a Token (and agreeing on TTRT)
  - execute when join ring or suspect a failure
  - send a claim frame that includes the node's TTRT bid
  - when receive claim frame, update the bid and forward
  - if your claim frame makes it all the way around the ring:
    - your bid was the lowest
    - everyone knows TTRT
    - you insert new token

## Maintenance (cont)

- Monitoring for a Valid Token
  - should periodically see valid transmission (frame or token)
  - maximum gap = ring latency + max frame < = 2.5ms
  - set timer at 2.5ms and send claim frame if it fires

1

## Outline

- Wireless networks
  - 802.11
  - Infra-red Irda
  - Bluetooth

## Wireless LANs

- IEEE 802.11
  - Bandwidth: 1 or 2 Mbps
  - 802.11b - 11 Mbps (2.4 GHz)
  - 802.11g - 54 Mbps (2.4 GHz)
  - 802.11a - 54 Mbps (5 GHz)
- Physical Media
  - spread spectrum radio (2.4 GHz)
  - diffused infrared (10 m)

## Spread Spectrum

- Idea
  - spread signal over wider frequency band than required
  - originally designed to thwart jamming
- Frequency Hopping
  - transmit over random sequence of frequencies
  - sender and receiver share…
    - pseudorandom number generator
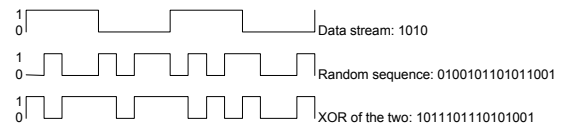    - seed
  - 802.11 uses 79 x 1MHz-wide frequency bands

## Spread Spectrum (cont)

- Direct Sequence
  - for each bit, send XOR of that bit and n random bits
  - random sequence known to both sender and receiver
  - called n-bit chipping code
  - 802.11 defines an 11-bit chipping code

Data stream: 1010

Random sequence: 0100101101011001

XOR of the two: 1011101110101001

## Challenges

- Limited wireless transmission range
- Broadcast nature of the wireless medium
  - Hidden terminal problem
- Packet losses due to transmission errors
- Mobility-induced route changes
- Mobility-induced packet losses
- Battery constraints
- Potentially frequent network partitions
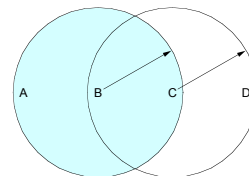- Ease of snooping on wireless transmissions (security hazard)

Nitin Vaidya @ UIUC

## Collisions Avoidance

- Similar to Ethernet
- Problem: hidden and exposed nodes
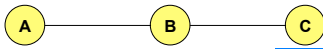
A    B    C    D

## Hidden Terminal Problem

- Node B can communicate with A and C both
- A and C cannot hear each other

- When A transmits to B, C cannot detect the transmission using the *carrier sense* mechanism
- If C transmits, collision will occur at node B
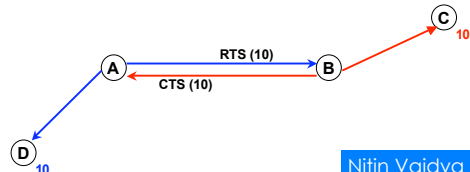
A — B — C

Nitin Vaidya @ UIUC

## RTS/CTS Handshake

- Sender sends Ready-to-Send (RTS)
- Receiver responds with Clear-to-Send (CTS)
- RTS and CTS announce the duration of the transfer
- Nodes overhearing RTS/CTS keep quiet for that duration
- RTS/CTS used in IEEE 802.11

A  RTS (10)  B  C 10
   CTS (10)
D 10

Nitin Vaidya @ UIUC

## Multiple Access Collision Avoidance – Wireless (MACAW)

- Sender transmits RequestToSend (RTS) frame
- Receiver replies with ClearToSend (CTS) frame
- Neighbors…
  - see CTS: keep quiet
  - see RTS but not CTS: ok to transmit
- Receive sends ACK when has frame
  - neighbors silent until see ACK
- Collisions
  - no collisions detection
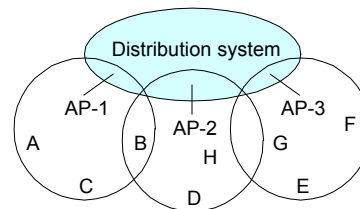  - known when don't receive CTS
  - exponential backoff

## Supporting Mobility

- Case 1: ad hoc net working
- Case 2: access points (AP)
  - tethered
  - each mobile node associates with an AP

Distribution system

AP-1    AP-2    AP-3
A       B   H    G    F
   C       D       E

## Mobility (cont)

- Scanning (selecting an AP)
  - node sends Probe frame
  - all AP's w/in reach reply with ProbeResponse frame
  - node selects one AP; sends it AssociateRequest frame
  - AP replies with AssociationResponse frame
  - new AP informs old AP via tethered network
- When
  - active: when join or move
  - passive: AP periodically sends Beacon frame

## irda

- Infrared Data Association – Point and Shoot Profile

3

## irda

- Founded in 1993
- Short range, point-to-point, low cost infra-red based
- Speeds from 9600b to 16Mb
- Great non-cable device
  - Ubiquitous deployment
  - 4 Mbps irda can talk to 9600 irda
- Protocols for point and shoot, exchange mp3, images, vcards, wrist watch ….

## Point and shoot model

- Point to the device. If both device understand object begin shared then transparent access
- Push server – the device that provides an object exchange server. Waits passively for the client to initiate an operation
- Push client – the client that pushes the object to the push server. Push client initiates operation
- Security not an issue because of range

## Discussion

- Available in PDA's, laptops, printers, projectors, digital cameras, wrist watches, pagers, ……

## Bluetooth

- *Bluetooth: Vision, Goals, and Architecture*, Jaap Haartsen, Mahmoud Naghshineh, Jon Inouye, Olaf J. Joeresson, and Warren Allen, ACM Mobile Computing and Communications Review, Volume 2, Number 4, October 1998.

## Bluetooth

- A cable replacement technology
- 1 Mb/s symbol rate
- Range 10+ meters
- Single chip radio + baseband
  - at low power & low price point

Pravin Bhagwat @ AT&T Labs



Why not use Wireless LANs?
- power
- cost

## Bluetooth

- Low cost, low-power radio-based cable replacement
- Related technologies
  - IrDA – Uses Infrared
    - Pros: Less governmental restrictions, lower cost, lower standby power, higher bandwidth
    - Cons: Line of sight
  - IEEE 802.11 – Same wireless band
    - Wireless LAN capability for a larger range
  - HomeRF – Wireless for data and voice
    - Data similar to 802.11, voice ADPCM

## Value proposition of Bluetooth



Cordless headset
mouse
Cell phone
Cable replacement

Data access point
Internet access

Ad hoc networking

Pravin Bhagwat @ AT&T Labs

## Bluetooth working group history

- February 1998: The Bluetooth SIG is formed
  - promoter company group: Ericsson, IBM, Intel, Nokia, Toshiba
- May 1998: Public announcement of the Bluetooth SIG
- July 1999: 1.0A spec (>1,500 pages) is published
- December 1999: ver. 1.0B is released
- December 1999: The promoter group increases to 9
  - 3Com, Lucent, Microsoft, Motorola
- February 2000: There are 1,800+ adopters

## New applications enabled by Bluetooth

## Synchronization

- User benefits
- Automatic synchronization of calendars, address books, business cards
- Push button synchronization
- Proximity operation



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## Cordless Headset

- User benefits
- Multiple device access
- Cordless phone benefits
- Hands free operation

Cordless headset



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## Three-in-one phone

- At home, your phone functions as a portable phone (fixed line charge). When you're on the move, it functions as a mobile phone (cellular charge). And when your phone comes within range of another mobile phone with built-in Bluetooth wireless technology it functions as a walkie talkie (no telephony charge).
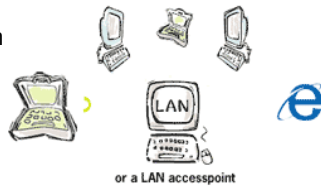- Source: bluetooth.com



mobile phone

## The Internet Bridge

- Use your mobile computer to surf the Internet wherever your are, and regardless if you're cordlessly connected through a mobile phone (cellular) or through a wire-bound connection (e.g. PSTN, ISDN, LAN, xDSL).

- Source: bluetooth.com

or a LAN accesspoint

## The Interactive Conference

- In meetings and conferences you can transfer selected documents instantly with selected participants, and exchange electronic business cards automatically, without any wired connections
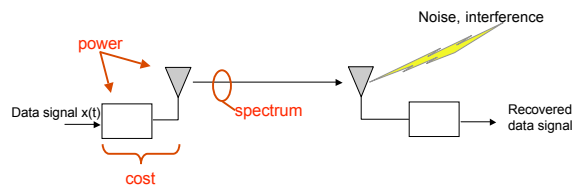- Source: bluetooth.com

file transfer

## Design considorations

power

Data signal x(t)

spectrum

cost

Noise, interference

Recovered data signal

Goal
- high bandwidth
- conserve battery power
- cost < $10

Pravin Bhagwat @ AT&T Labs

## EM Spectrum

ISM band
902 – 928 Mhz
2.4 – 2.4835 Ghz
5.725 – 5.785 Ghz

AM radio    S/W radio    FM radio    TV    TV    cellular

| LF | MF | HF | VHF | UHF | SHF | EHF |

$\nu$

30kHz    300kHz    3MHz    30MHz    300MHz    3GHz    30GHz    300GHz

10km    1km    100m    10m    1m    10cm    1cm    100mm    $\lambda$

$\nu$

infrared  visible  UV        X rays        Gamma rays

1 kHz    1 MHz    1 GHz    1 THz    1 PHz    1 EHz
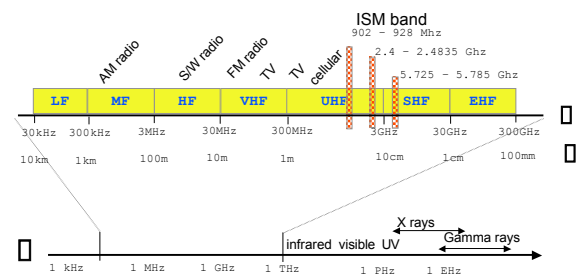
Propagation characteristics are different in each frequency band

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## Unlicensed Radio Spectrum

$\lambda$

33cm        12cm        5cm

26 Mhz    83.5 Mhz    125 Mhz

902 Mhz        2.4 Ghz        5.725 Ghz
928 Mhz        2.4835 Ghz        5.785 Ghz

cordless phones    802.11        802.11a
baby monitors    Bluetooth
Wireless LANs    Microwave oven
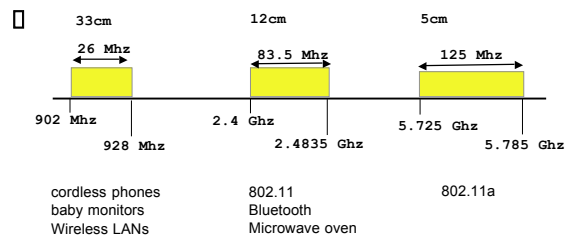
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## Bluetooth radio link

- frequency hopping spread spectrum
  - 2.402 GHz + k MHz, k=0, …, 78
  - 1,600 hops per second
- GFSK modulation
  - 1 Mb/s symbol rate
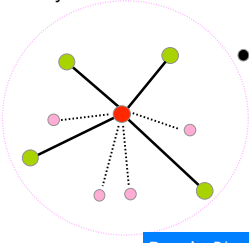- transmit power
  - 0 dbm (up to 20dbm with power control)

1Mhz

1 2 3    . . .    79

83.5 Mhz

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6
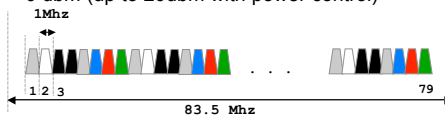
## Piconet formation
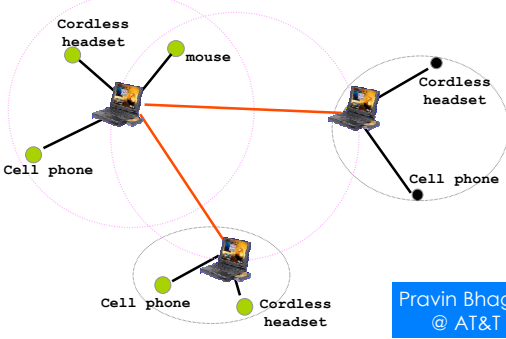
- Page - scan protocol
  - to establish links with nodes in proximity

● Master

● Active Slave

● Parked Slave

● Standby

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## Inter piconet communication

Cordless headset

mouse

Cell phone

Cordless headset

Cell phone

Cell phone

Cordless headset
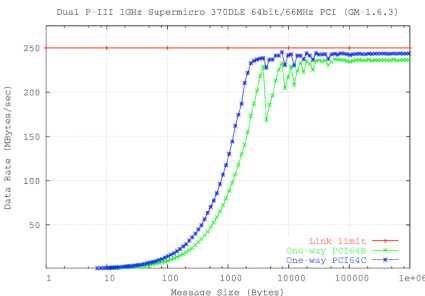
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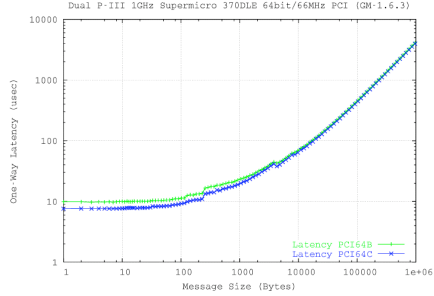
## Myrinet

- 2 GB full duplex high speed network interface

Dual P-III 1GHz Supermicro 370DLE 64bit/66MHz PCI (GM-1.6.3)

Data Rate (MBytes/sec)

Message Size (Bytes)

Link limit
One-way PCI64B
One-way PCI64C

## Myrinet

- Few μsec latency

Dual P-III 1GHz Supermicro 370DLE 64bit/66MHz PCI (GM-1.6.3)

One-Way Latency (usec)

Message Size (Bytes)

Latency PCI64B
Latency PCI64C