Lectures 14: LAN technologies: Token Rings, Wireless LANs

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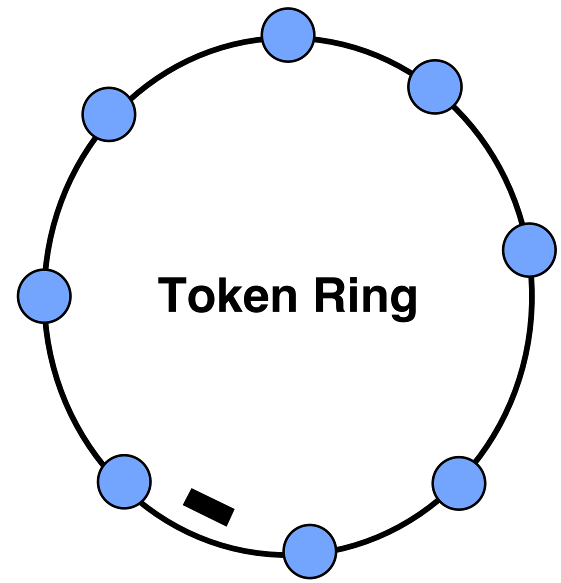
Token rings

- **Token rings were developed by IBM in early 1980's**
  - IEEE Standard 802.5
- **Token: a bit sequence**
  - Token circulates around the ring
    - Busy token: 01111111
    - Free token: 01111110
- **When a node wants to transmit**
  - Wait for free token
  - Remove token from ring (replace with busy token)
  - Transmit message
  - When done transmitting, replace free token on ring
  - Nodes must buffer 1 bit of data so that a free token can be changed to a busy token
- **Token ring is basically a polling system**
  - Token does the polling



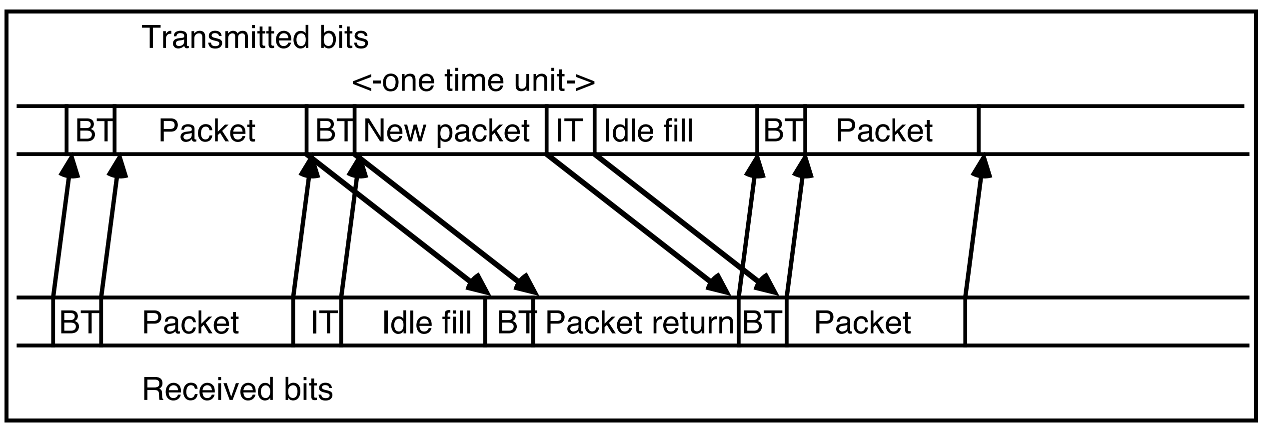
Release of token

- **Release after transmission**
  - Node replaces token on ring as soon as it is done transmitting the packet
  - Next node can use token after short propagation delay

- **Release after reception**
  - Node releases token only after its own packet has returned to it
    - Serves as a simple acknowledgement mechanism

PACKET TRANSMISSION
(release after transmission)

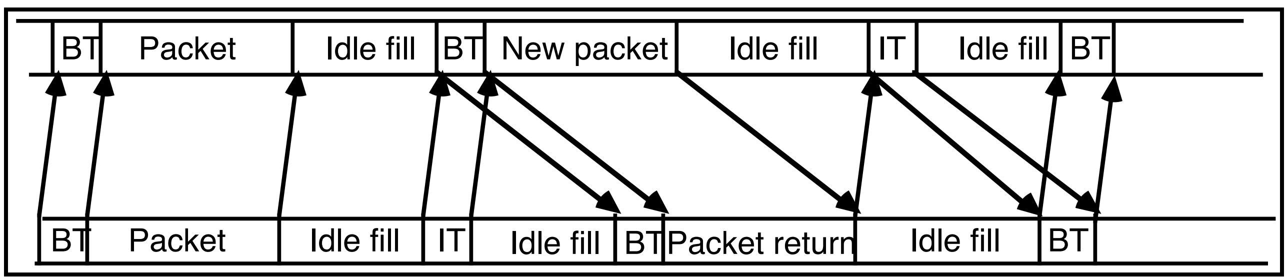
- **When not transmitting their own packets nodes relay whatever they receive**
- **After receiving an idle token a node can start sending a new packet (discard incoming bits)**
- **After a node sends a packet and the idle token, it sends idle fill until:**
  - **The packet followed by idle, or**
  - **busy token, returns around the ring**



PACKET TRANSMISSION
(release after reception)

- **In many implementations (including IEEE802.5, but not including FDDI), a node waits to check its packet return before sending the idle token.**

  This increases packet transmission time by one round trip delay.



Delay analysis

- System can be analyzed using multi-user reservation results
- <u>Exhaustive system</u> - nodes empty their queue before passing token on to the next node
- Assume m nodes and each with Poisson arrivals of rate λ/m
- Let v = average propagation and token transmission delay
- System can be viewed as a reservation system with m users and average reservation interval (see reservation system results)

$$W = \frac{\lambda E[X^2] + v(m-\rho)}{2(1-\rho)}, \quad \rho = m(\lambda / m)E[X] = \lambda E[X]$$

- Notice that 100% throughput can be achieved for exhaustive system

Throughput analysis (non-exhaustive)

- Gated system with limited service - each node is limited to sending one packet at a time
  - When system is heavily loaded nodes are always busy and have a packet to send
- Suppose each node transmits one packet and then releases the token to the next node
  - V_i = propagation and transmission time for token between two nodes (transmission time is usually negligible)
- The amount of time to transmit N packets

$$T_N = N*E[X] + V_1 + V_2 + \ldots + V_N = N*E[X] + N*E[V]$$

$$\lambda < N*E[X]/(N*E[X] + N*E[V]) = 1/(1+E[V]/E[X])$$

- Compare to CSMA/CD, but notice that V is the delay between two nodes and not the maximum delay on the fiber

Throughput analysis (token release after reception)

- **Nodes release token only after it has returned to it**
- **Again assume each node sends one packet at a time**

- **Total time to send ONE packet**

- $\mathbf{T = E[X] + V_1 + V_2 + \ldots + V_m + V_i}$

Time to send token to next node

M nodes on the ring

- $\mathbf{T = E[X] + (m+1)E[V]}$ **=>**

$$\lambda < E[X]/T = 1/(1+(m+1)E[V]/E[X])$$

Delay Analysis

- **Release after transmission**
  - **Partially gated limited service system (sec. 3.5.2)**

$$W = \frac{\lambda E[X^2] + v(m + \lambda E[X])}{2(1 - \lambda E[X] - \lambda v)}$$

- **Release after reception**
  - **Homework problem 4.27**
  - **Additional round-trip time can be added to the packet transmission time**

$$W = \frac{\lambda(E[X^2] + 2mv + m^2v^2) + v(m + \lambda(E[X] + mv))}{2(1 - \lambda(E[X] + (m+1)v))}$$

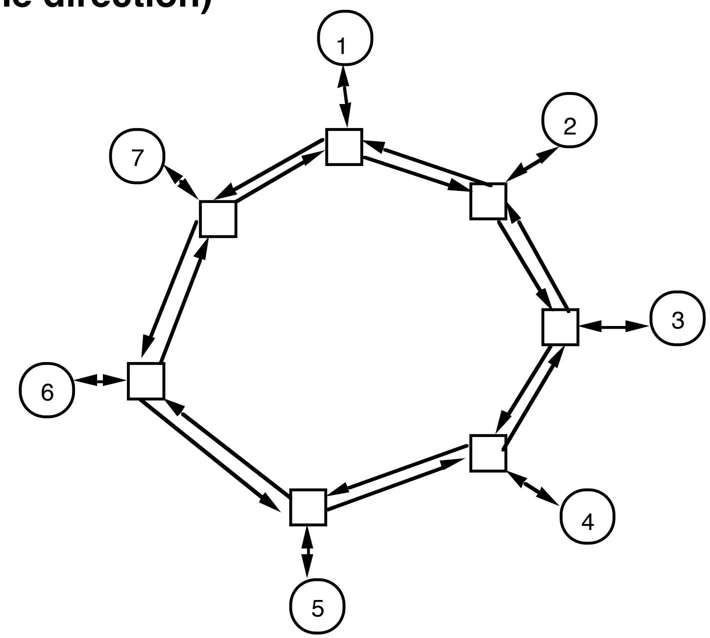
Token ring issues

- Fairness: Can a node hold the token for a long time
  - Solution: maximum token hold time
- Token failures: Tokens can be created or destroyed by noise
  - Distributed solution:
    - Nodes are allowed to recognize the loss of a token and create a new token
    - Collision occurs when two or more nodes create a new token at the same time => need collision resolution algorithms
- Node failures: Since each node must relay all incoming data, the failure of a single node will disrupt the operation of the ring
- Token ring standard: IEEE 802.5

Token Ring Example: FDDI

- Fiber distributed data interface (FDDI) is a 100 Mbps Fiber Optic Token Ring network standard

- FDDI uses two counter-rotating rings
  - Single faults can be isolated by switching from one ring to the other on each side of fault (loop back)
  - Only one ring used under normal operation (one direction)



- Token release after transmission

- Limit on token hold time

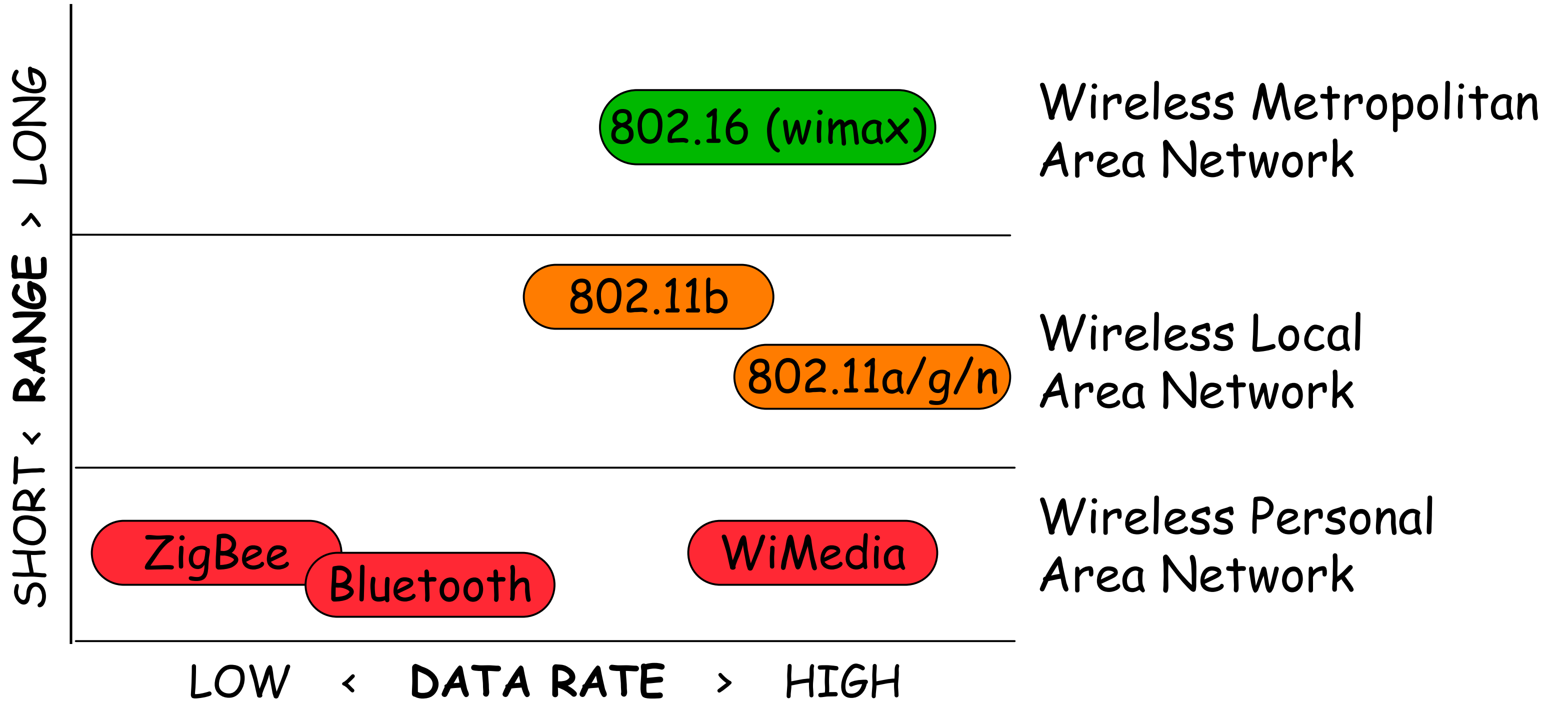
- Upper-bound on time between token visits at a node
  - Support for guaranteed delays
  - Imposes a limit on the size of a ring (distance between nodes, number of nodes)

- FDDI designed to be a metro or campus area network technology

Resilient Packet Rings (RPR) (IEEE 802.17 standard)

- Uses two counter rotating rings
  - Both rings used for working traffic, using shortest path routing
- Buffer insertion mechanism (instead of token)
  - If no frame to forward, insert your own frame
- Failure recovery
  - Allows for both loop-back link protection and end-to-end path protection
- Sophisticated (i.e., complex) QoS mechanisms
  - Class A: low latency and low jitter
  - Class B: predictable latency and jitter
  - Class C: best effort
- Successful in MANs where reliability and QoS are critical

Wireless Networking Technologies



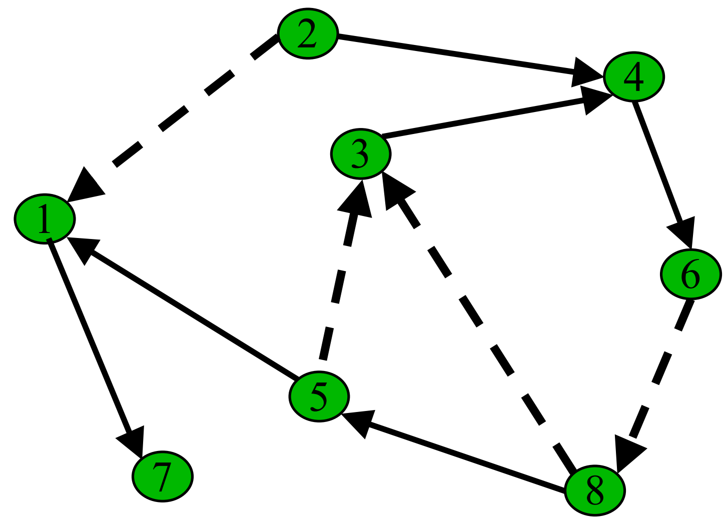
- **Standards typically define the Medium Access Control (MAC) and the Physical layers**

	Bluetooth	WiFi (802.11)	WiMax (802.16)
Data rate	2.1 Mbps	54 Mbps	70 Mbps
Link length	10 meters	100 meters	10 km
application	Peripheral devices	LAN	Access

Most slides on wireless MAC borrowed with permission from Prof. Gil Zussman of Columbia University

Medium Access Control (MAC)

- Nodes are scattered in a geographic area
- Need to somehow coordinate the access to channel
  - Transmission time, power, rate, etc.



- Centralized
  - Managed by an Access Point/Base Station
- Distributed
  - Random access (Aloha, CSMA, Ethernet)
  - Scheduled access
- Requirements
  - Throughput, delay, fairness, energy efficiency

IEEE 802.11 / WiFi

- **Set of standards for Wireless Local Area Networks (WLANs)**
  - Define Medium Access Control (MAC)
  - Physical layer
- **Most common 802.11g**
  - Maximum data rate: 54Mb/s
  - Frequency band: 2.4 Ghz
- **Other variations 802.11a,b,e,n**
  - Different bands, physical layers, data rates, QoS, etc.

Ad Hoc and Infrastructure Modes

- Ad Hoc mode
  - The stations communicate with one another
  - Not connected to a larger network

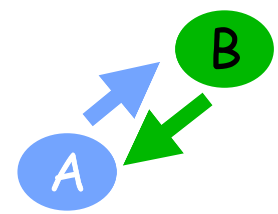
- Infrastructure mode
  - An Access Point connects Stations to a wired network
  - Overlapping Access Points connected to each other
  - Allows Stations to roam between Access Points

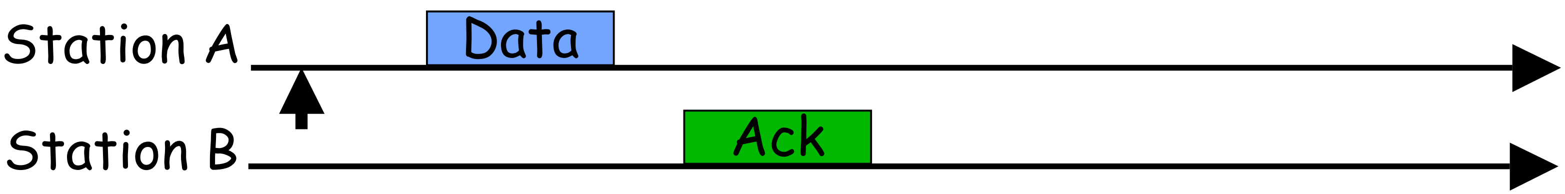
Medium Access Control - CSMA\CA

Carrier Sense Multiple Access \ Collision Avoidance

- **Station wishing to transmit a Data packet senses the medium**
- **If it is idle for a given period - Transmits**

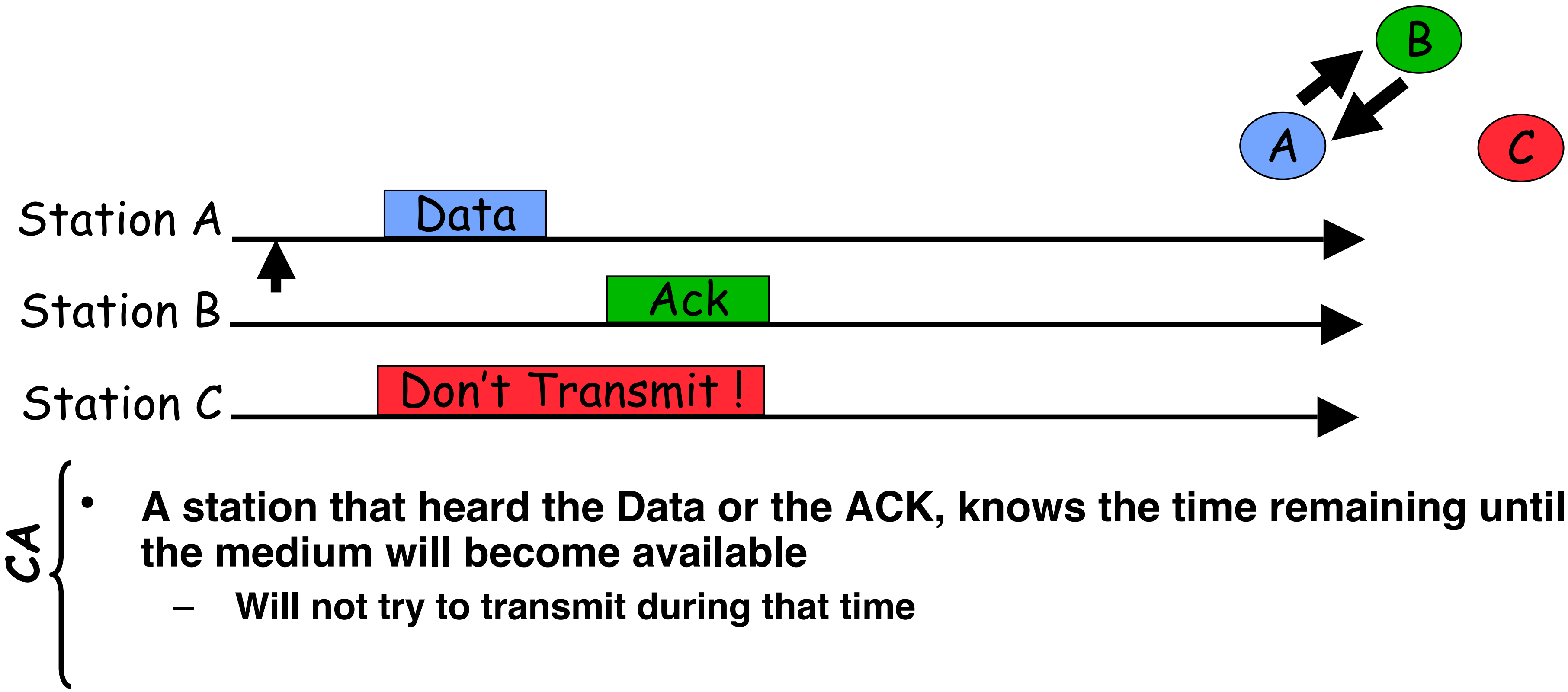
  (CSMA)
- **ACK packet is sent by the receiving station**
- **Collision assumed if sending station doesn't get ACK**
  - **Data is retransmitted after a random time**





Medium Access Control - CSMA\CA

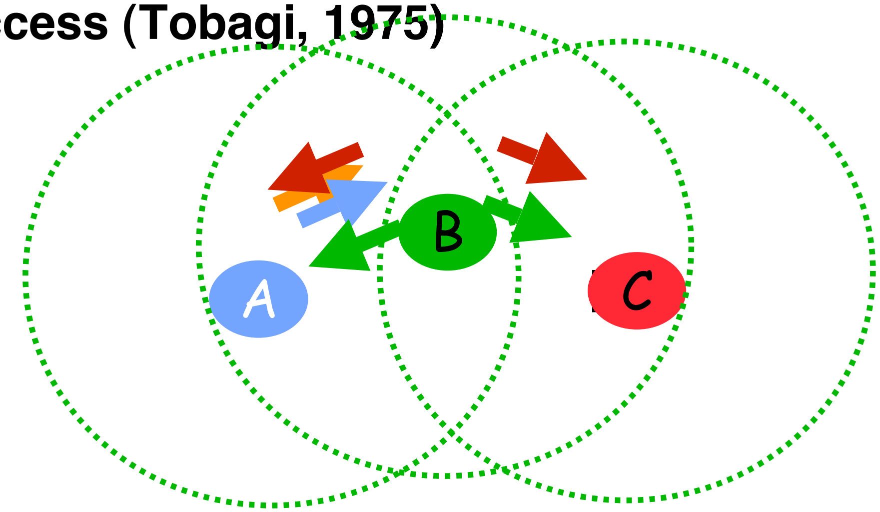
Carrier Sense Multiple Access \ Collision Avoidance



- **A station that heard the Data or the ACK, knows the time remaining until the medium will become available**
  - **Will not try to transmit during that time**
- **Carrier Sensing**
  - **Physical**
  - **Virtual: using RTS/CTS procedure and NAV values within**

Hidden Node Problem

- ***Hidden Node*** **- A node that a station does not hear but can interfere with its transmissions**
  - **Solution: Busy tone multiple access (Tobagi, 1975)**



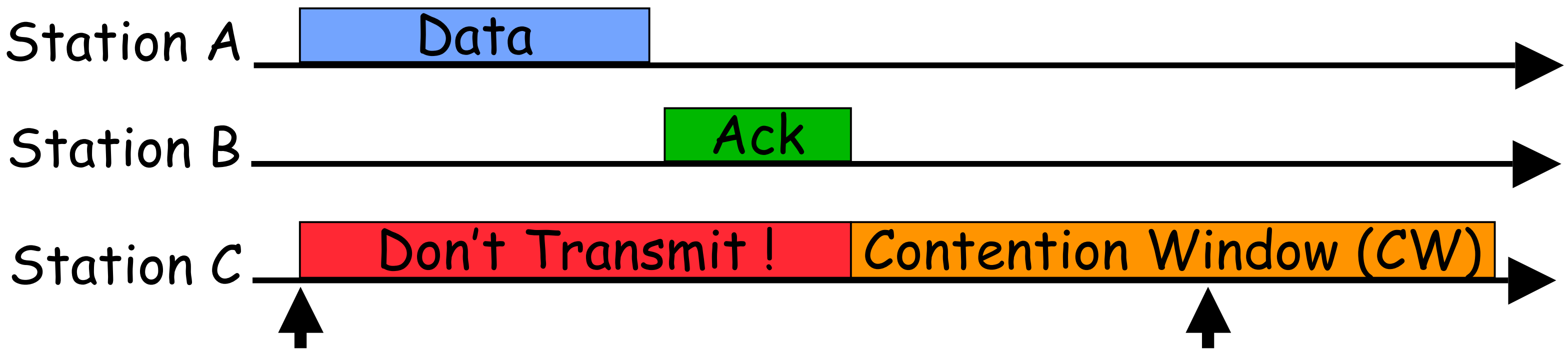
- **Enhancement:**
  - **A ➔ B Request to Send (RTS)**
  - **B ➔ A Clear to Send (CTS)**
  - **A ➔ B Data**
  - **B ➔ A ACK**

CA

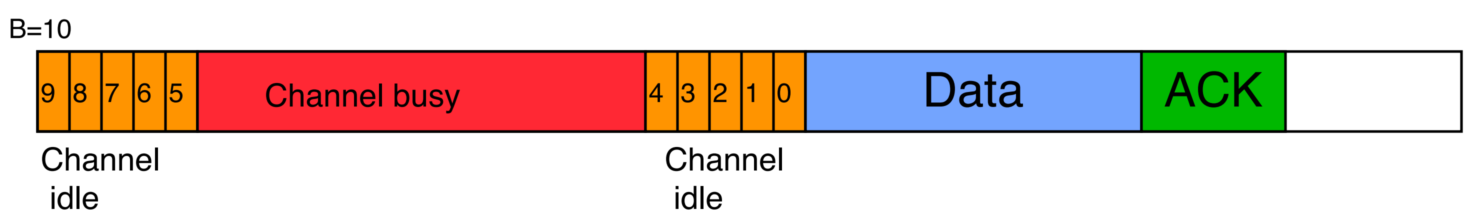
- **Neighboring nodes will keep quiet for the duration of the transfer**
  - **Network allocation vector (NAV) - specifies duration of transfer**

Contention Window

- **A station that sensed the medium busy or did not receive an ACK will try to retransmit**



- **The back-off interval is uniformly distributed within the CW**
- **The window is doubled every time there is a need to retransmit**
  - **Upper limit on CW**
  - **Count down back-off interval when channel idle**
  - **Stop counting when busy (resume when idle again)**
  - **Transmit when back-off interval reaches 0**

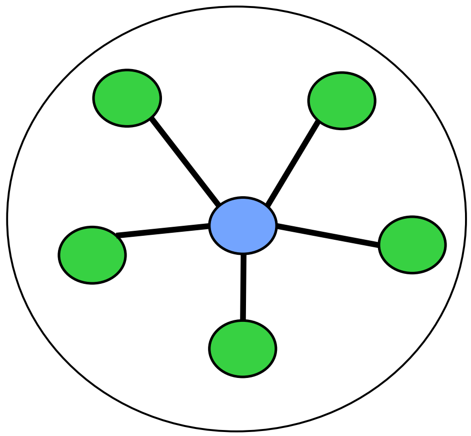


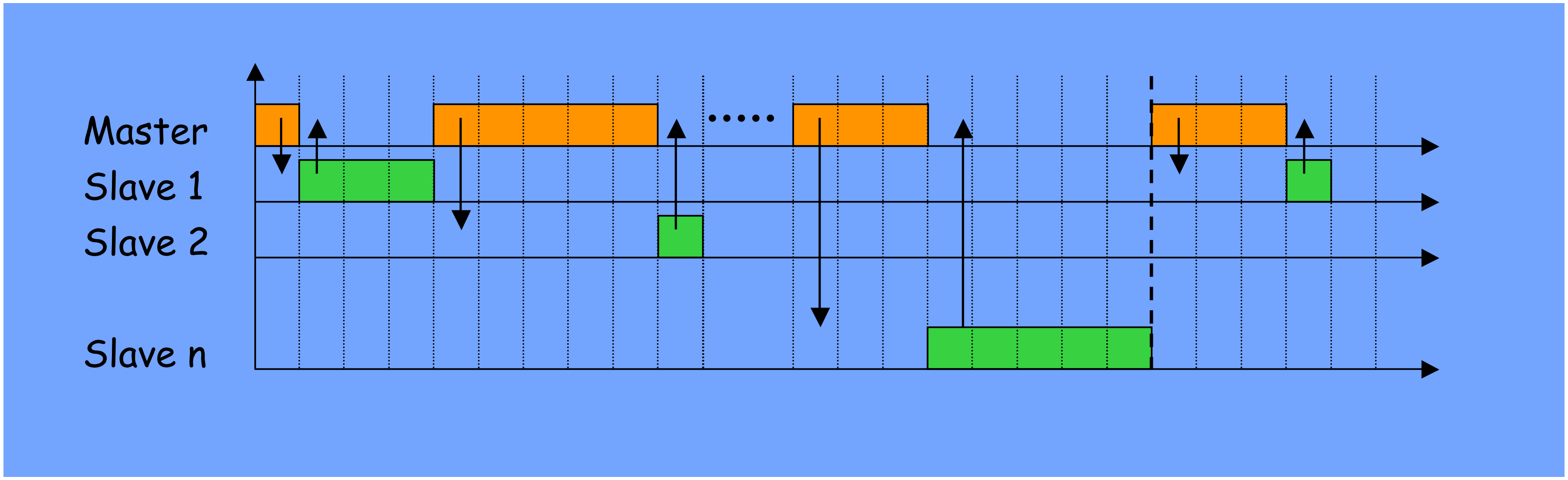
Bluetooth

- Very short-range communications between computers and peripheral devices
  - E.g., replace connector cables such as usb
- Operates in 2.4 GHz unlicensed band
  - Uses spread-spectrum communications
    - Frequency hopping between 79 frequency channels
    - New frequency every slot (625 μs)
- Piconet: master and 7 slave devices
  - All communication goes through the master
- ZigBee - a competing technology (will not discuss much)
  - Newer technology for low bandwidth, low power applications
  - Very simple and inexpensive
  - Designed for sensor networks; and communications between very inexpensive devices (e.g., appliances)

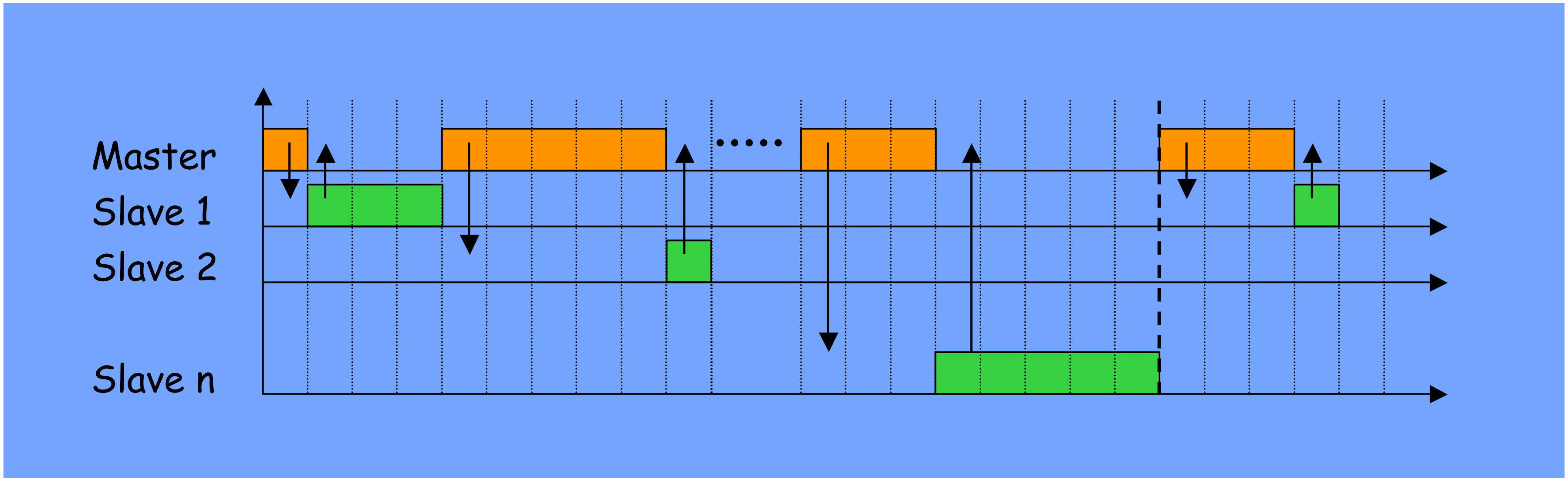
Bluetooth MAC

- **Frequency Hop / Time Division Duplex Scheme**
  - **Frequency band: 2.4 GHz ISM Band**
  - **1,600 slots per second (625 μs/slot)**
- **Piconet - A Master and up to 7 Slaves sharing a common hopping pattern**
- **Intra-Piconet Communication (TDD):**

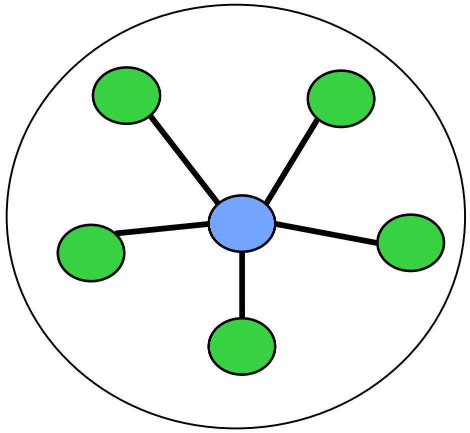




Bluetooth MAC

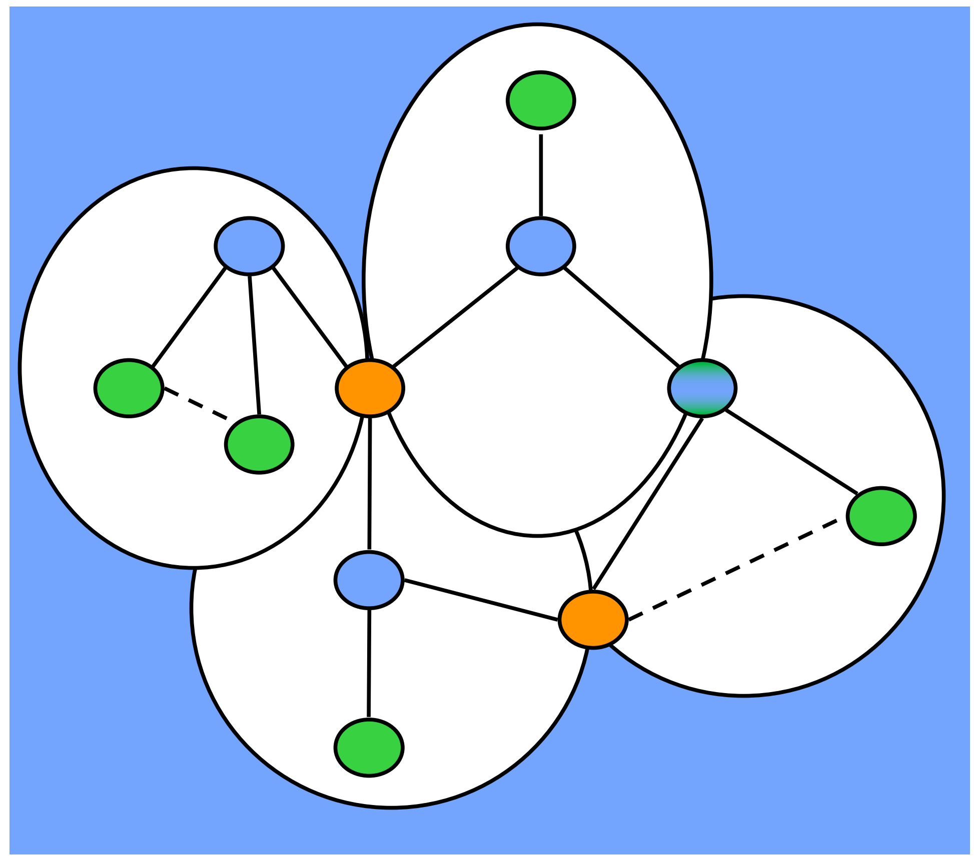


- 1, 3, and 5-slot data frames
- If the master has no data to transmit, it can address a slave by sending a 1-slot POLL packet
- If a slave has nothing to send, it must respond by sending a 1-slot NULL packet



Multi-hop Topology

- **Several piconets may coexist in the same coverage area with minimal interference**
- **A unit can be:**
  - **Piconet Coordinator / Device / Bridge**
- **There are links and neighbors**

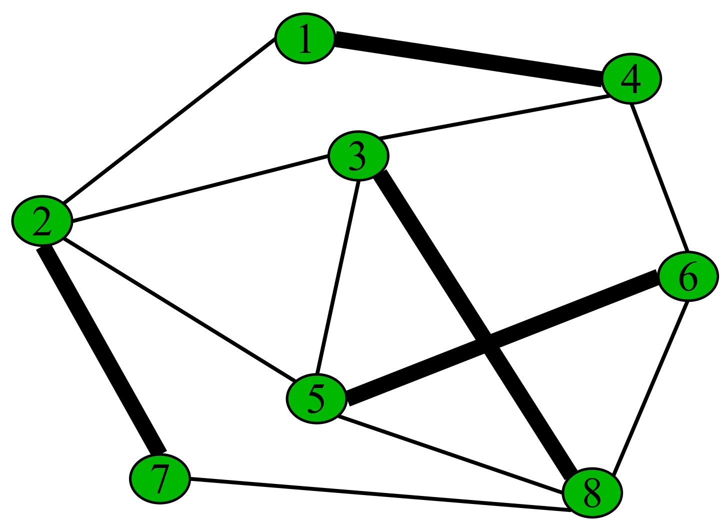


WiMAX (802.16)

- Access technology - metro area
  - Last (few) miles to home or business
- Data rates of up to 70 Mbps
- Physical layer
  - Microwave band: 10 to 66 GHz (line of sight)
  - Other bands also possible
- Connection oriented to offer QoS guarantees
- Medium access
  - Fixed assignment (guaranteed rate)
  - Reservations (polling)
  - Contention mechanism for best effort services

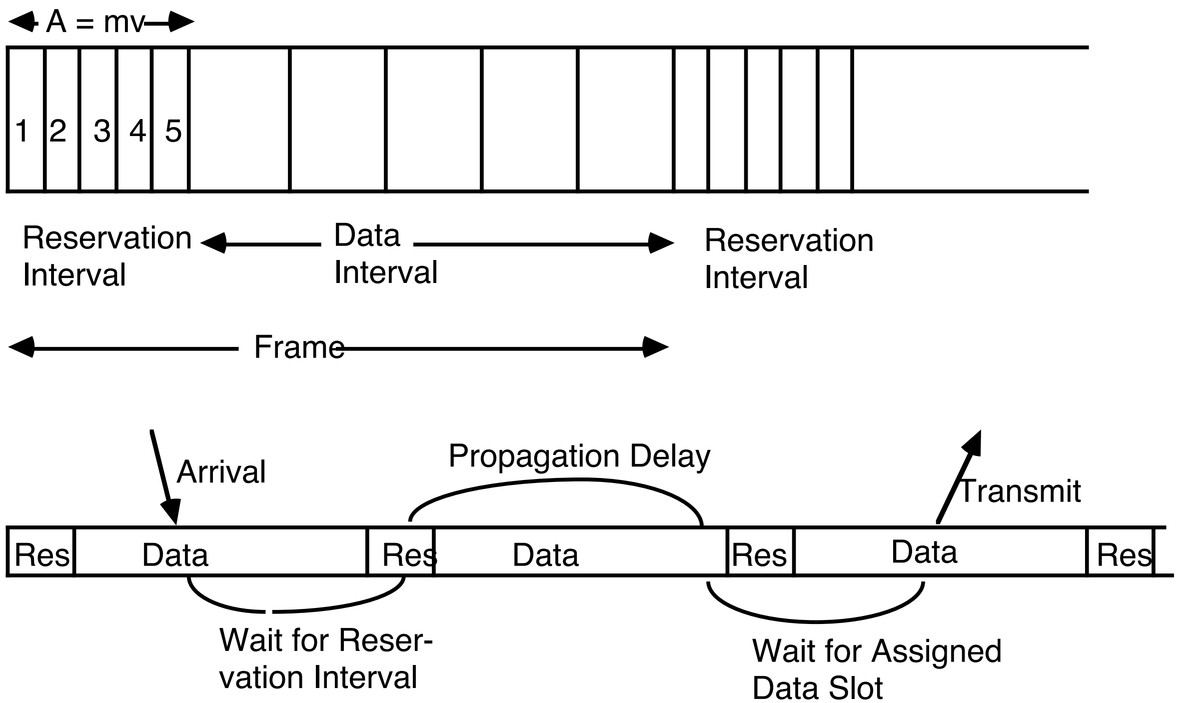
Simple Interference Model

- **Primary interference constraints (e.g. Bluetooth)**
  - **A node transmits to a single neighbor at a time**
  - **Multiple transmissions can take place as long as they do not share a common node**



  - **The set of active links is a matching**

Large propagation delay (satellite networks)



- **Satellite reservation system**
  - **Use mini-slots to make reservation for longer data slots**
  - **Mini-slot access can be inefficient (Aloha, TDMA, etc.)**
- **To a crude approximation, delay is 3/2 times the propagation delay plus ideal queueing delay.**

Satellite Reservations

- Frame length must exceed round-trip delay
  - Reservation slots during frame j are used to reserve data slots in frame j+1
  - Variable length: serve all requests from frame j in frame j+1
    - Difficult to maintain synchronization
    - Difficult to provide QoS (e.g., support voice traffic)
  - Fixed length: Maintain a virtual queue of requests
- Reservation mechanism
  - Scheduler on board satellite
  - Scheduler on ground
  - Distributed queue algorithm
    - All nodes keep track of reservation requests and use the same algorithm to make reservation
- Control channel access
  - TDMA: Simple but difficult to add more users
  - Aloha: Can support large number of users but collision resolution can be difficult and add enormous delay

Packet multiple access summary

- Latency: Ratio of propagation delay to packet transmission time
  - GEO example: Dp = 0.5 sec, packet length = 1000 bits, R = 1Mbps
    - Latency = 500 => very high
  - LEO example: Dp = 0.1 sec
    - Latency = 100 => still very high
  - Over satellite channels data rate must be very low to be in a low latency environment
- Low latency protocols
  - CSMA, Polling, Token Rings, etc.
  - Throughput ~ $1/(1+a\alpha)$, α = latency, a = constant
- High latency protocols
  - Aloha is insensitive to latency, but generally low throughput
    - Very little delays
  - Reservation system can achieve high throughput
    - Delays for making reservations
  - Protocols can be designed to be a hybrid of Aloha and reservations
    - Aloha at low loads, reservations at high loads