

EEC 687 Mobile Computing (Spring 2008)

Medium Access Control

Chansu Yu

Cleveland State University

Simplified Reference Model...

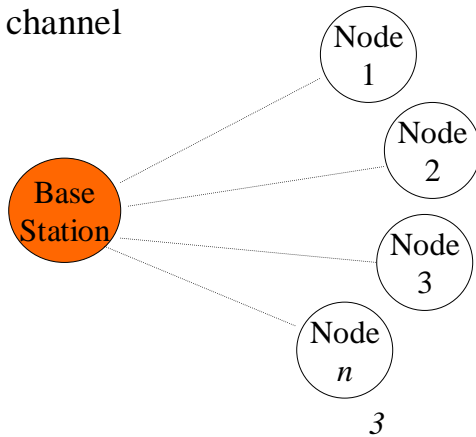
<input type="checkbox"/> Application layer	<ul style="list-style-type: none">➤ <u>Location/context-sensitive services</u>➤ <u>Multimedia applications</u>
<input type="checkbox"/> Transport layer	<ul style="list-style-type: none">➤ <u>congestion and flow control</u>➤ <u>quality of service</u>
<input type="checkbox"/> Network layer	<ul style="list-style-type: none">➤ <u>addressing, routing, device location</u>➤ <u>hand-over</u>
<input type="checkbox"/> Data link layer	<ul style="list-style-type: none">➤ <u>Authentication</u>➤ <u>Multiplexing of multiple data streams</u>➤ <u>Correction of transmission errors</u>➤ <u>Media access control</u>
<input type="checkbox"/> Physical layer	<ul style="list-style-type: none">➤ <u>Modulation</u>➤ <u>Generation of carrier frequency</u>➤ <u>Frequency selection</u>➤ <u>Signal detection</u>

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Centralized Protocols

- ❑ Base station coordinates access to the wireless channel



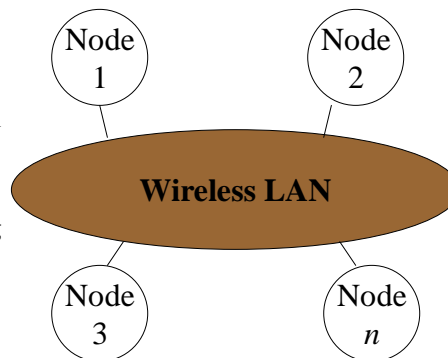
Disadvantages:

- If a node cannot talk to the base station, it cannot transmit to any other nodes
- Base station needs to keep track of state of other nodes
- Hard to use failure-prone nodes as coordinators in centralized protocols

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Distributed Protocols

- ❑ All nodes have identical responsibilities
- ❑ Arbitration difficulty
 - Random access mechanism
 - May incur many conflicts
 - Performs “carrier sensing” before actually transmitting



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Two medium access methods

- ❑ TDMA-based fixed allocation methods
 - TDMA assigns frequencies to channels for a certain amount of time
 - Requires sender-receiver synchronization

- ❑ Contention-based random access methods
 - Aloha - classical and slotted
 - Carrier Sense Multiple Access (CSMA)
 - Demand Assigned Multiple Access (DAMA)
 - Multiple Access with Collision Avoidance (MACA)

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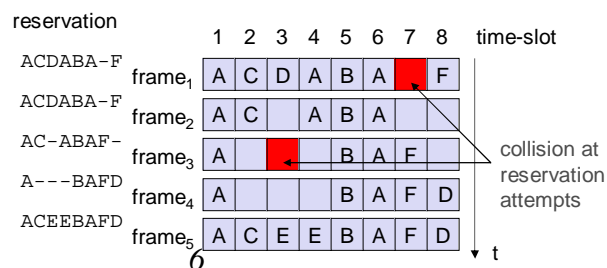
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TDMA Method – PRMA (Packet Reservation Multiple Access)

- ❑ AP broadcasts the reservation status (e.g., 7th slot is empty)
- ❑ Nodes compete for empty slots according to the Slotted Aloha principle

- ❑ Once a station reserves a slot successfully, this slot is automatically assigned to this station in all following frames as long as the station has data to send

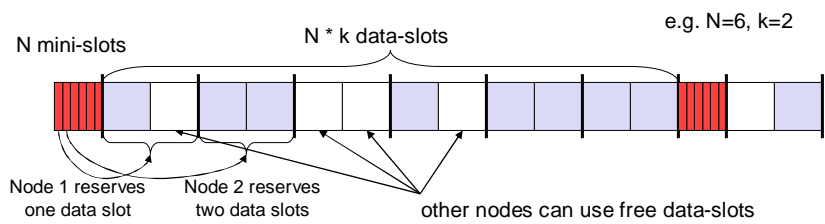
- ❑ Competition for this slots starts again as soon as the slot was empty in the last frame



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Reservation TDMA

- ❑ Every frame consists of N mini-slots and x data-slots
- ❑ Every node has its own mini-slot and can reserve up to k data-slots using this mini-slot (i.e. $x = N * k$)
- ❑ Other nodes can send data in unused data-slots based on round-robin or Aloha scheme



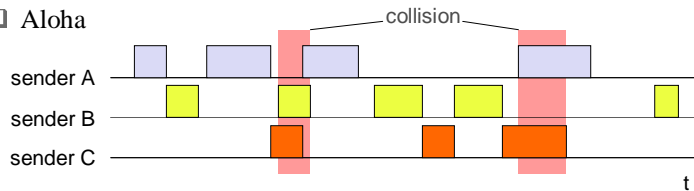
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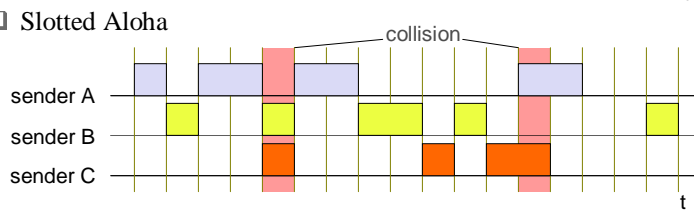
Random access methods: Aloha

- ❑ Mechanism
 - Simply transmits and waits for ack for some time. Repeats if timeout
 - Slotted Aloha additionally uses time-slots, sending must always start at slot boundaries

❑ Aloha



❑ Slotted Aloha



How do you compare?

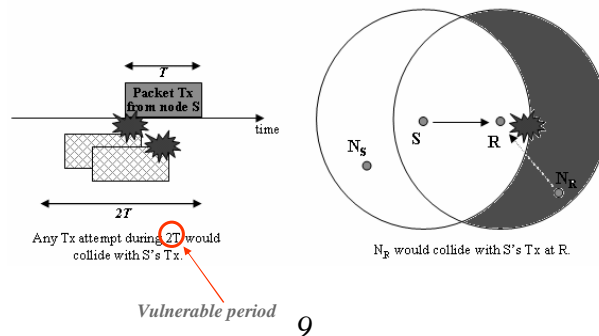
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MAC Analysis: ALOHA (No CS)

□ Parameters

- T = packet transmission time (average)
- G = number of packets attempted during T (including retransmissions)



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MAC Analysis: ALOHA

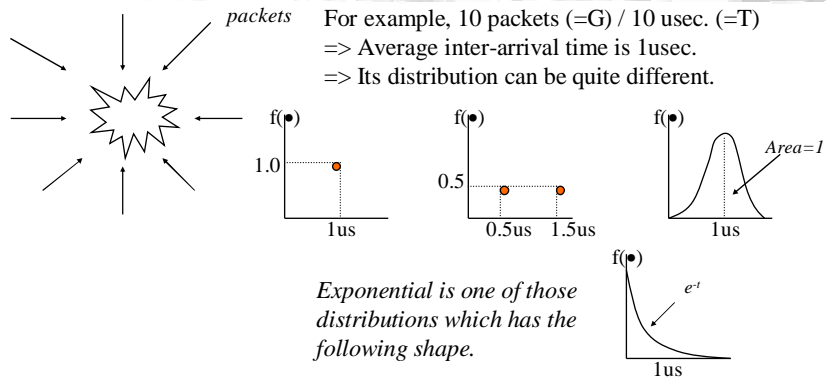
□ How often and in which intervals are packets transmitted?

- Packet inter-arrival time is assumed to be exponentially distributed
- I.e., $F(t) = \text{Prob}[\text{inter-arrival time} \leq t] = e^{-\lambda t}$: exponential function, where λ is average packet rate (G/T)
- Thus, $f(x,t) = \text{Prob}[\text{there are } x \text{ packets during } t] = (\lambda t)^x e^{-\lambda t}/x!$: Poisson distribution

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*Exponential Distribution



When inter-arrival time follows exponential distribution,
 the number of packets (x) during t follows Poisson: $(\lambda t)^x e^{-\lambda t} / x!$
 Thus, zero packet during t follows: $e^{-\lambda t}$

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MAC Analysis: ALOHA

❑ Channel throughput S

- No. successful packets during T among G attempts =
 No. attempted packets during T * Prob[no collision]
- Prob[no collision] =
 Prob[no additional packets during "vulnerable period"]
- Vulnerable period = 2T
- Thus, $S = G * f(0, 2T) = Ge^{-2G}$ (Because, $\lambda = G/T$)

❑ Channel throughput S for slotted ALOHA

- Vulnerable period = ???
- Thus, $S = G * f(0, ???) = Ge^{-???}$

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MAC Analysis: ALOHA Efficiency Plot

TDMA max performance with large number of users along a 1Mbps channel = 1Mbps

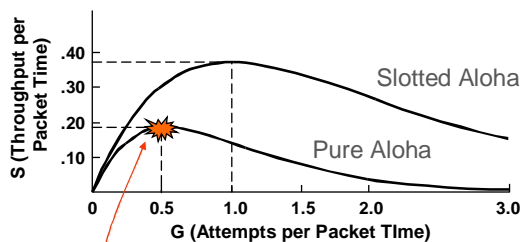
Pure ALOHA max performance with large number of users = 180Kbps

Pure ALOHA max performance with one user = 1Mbps

S cannot be larger than 1 &

S cannot be larger than G .

How can G be larger than 1: retransmission



0.18 packets were successful out of 0.5 attempted packets.
What happen to 0.32 packets?
=> Retransmission
Thus, input rate becomes 0.82

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Random access method: CSMA

- ❑ Channel efficiency is only 18% for Aloha, 36% for Slotted Aloha
 - It is acceptable when offered traffic is light but generally not acceptable
 - The main problem is collisions

- ❑ CSMA (Carrier sense multiple access) algorithm reduces collision probability by first sensing the medium
 - Vulnerable period = ???

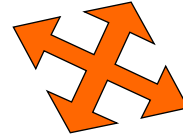
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Basic Carrier Sense Approach

❑ Carrier Sense Multiple Access with Collision Detect (CSMA/CD)

- Used in Ethernet
- Distributed, no central authority granting access
- When to transmit
 - 1-persistent : start transmission with prob 1 when idle
 - p-persistent : start transmission with prob p when idle
 - non-persistent : wait a random time and check
- Characteristics
 - Max packet size & Min interpacket gap to reduce starvation probability
 - Collision detection is free
 - Exponential backoff strategy when collision detect

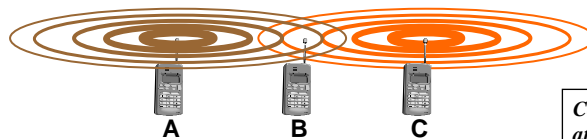


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CSMA in Wireless Networks

Signal strength decreases with square of distance



❑ Hidden terminals

- A sends to B, C cannot receive A
- C wants to send to B, C senses a “free” medium (CS fails)
- Collision at B not detected by A (CD fails): C is *hidden* from A

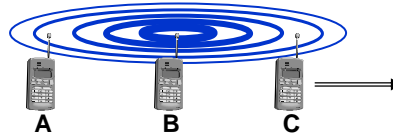
*Collision is detected at the receiver but **not** at the source (unlike Ethernet) !!*

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CSMA in Wireless Networks

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❑ Exposed terminals

- B sends to A, C wants to send to another terminal (not A or B)
- C has to wait, CS signals a medium in use
- But waiting is not necessary: C is *exposed* to B

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Collision Avoidance instead of Collision Detection

- ❑ Reduce collision probability by first sensing the medium
 - Not sufficient, given hidden terminals
- ❑ Uses short signaling packets for collision avoidance
 - Request To Send (RTS): a sender first requests the right to send from a receiver
 - Clear To Send (CTS): the receiver grants the right to send as soon as it is ready to receive
- ❑ CSMA with Collision Avoidance (CSMA/CA) or Multiple Access with Collision Avoidance (MACA)
- ❑ Available in IEEE802.11

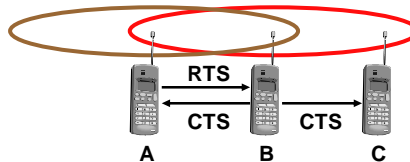
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RTS/CTS Solves Hidden & Exposed Terminal Problems

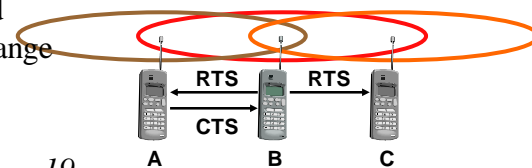
Hidden Terminal

- CTS from B to A is also heard by C, which then waits



Exposed Terminal

- C doesn't hear A's CTS and concludes A is outside its range
- C can start its transmission



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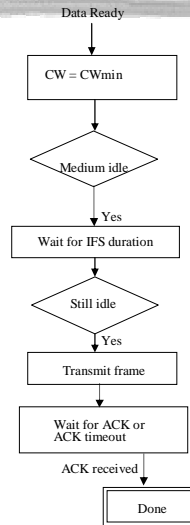
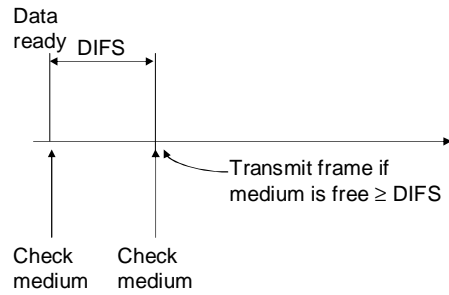
Contention & Backoff Algorithm to Further Reduce Collisions

- ❑ Carrier sense
 - When a node wishes to transmit a packet, it first waits until the channel is idle
- ❑ Collision avoidance
 - RTS/CTS avoids collisions from hidden terminals (Virtual carrier sensing or VCS)
- ❑ Further collision avoidance
 - If medium is idle when the packet is ready,
 - just send it
 - However, when the medium was busy and becomes idle,
 - the node waits for a randomly chosen duration before attempting to transmit
 - Contention & backoff algorithm

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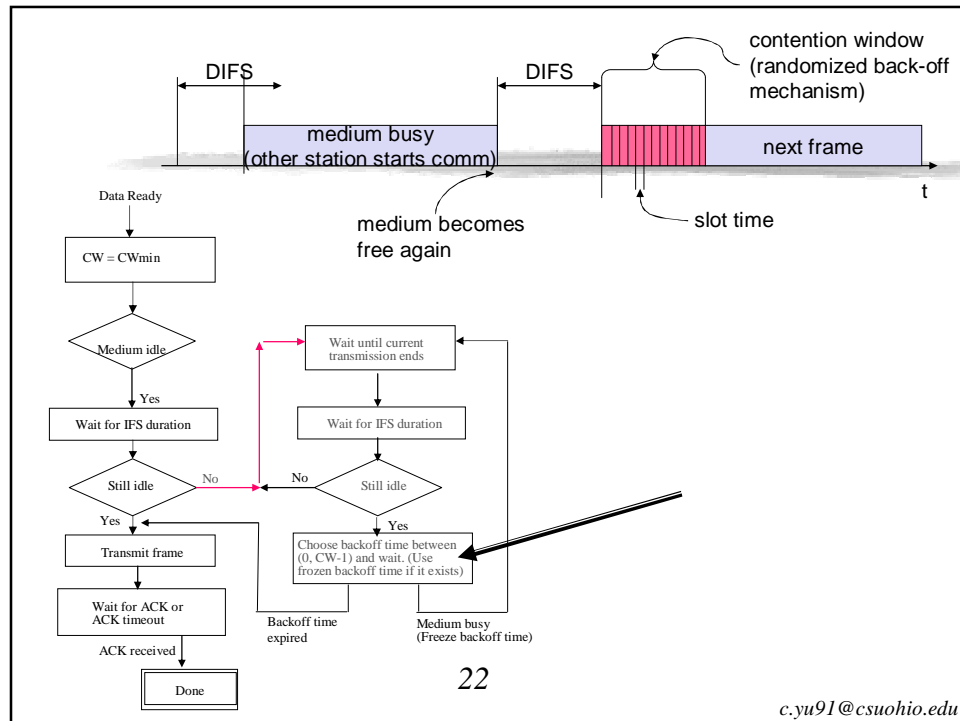
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Example: 802.11 MAC



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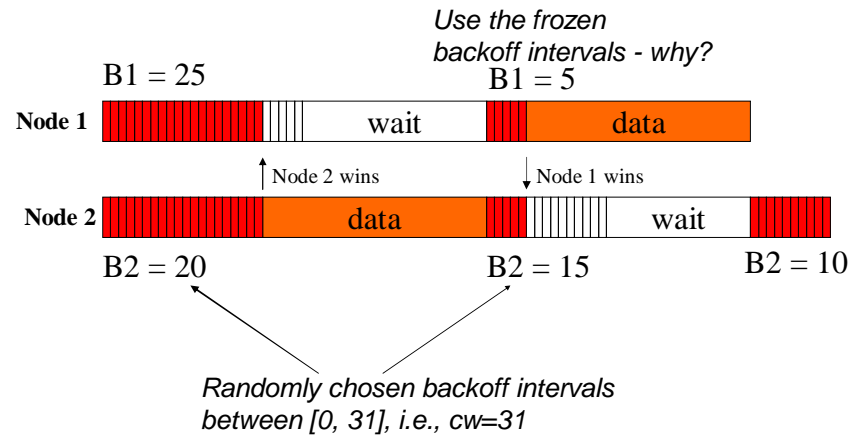
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Example: IEEE 802.11 MAC



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Other MAC Protocols Issues

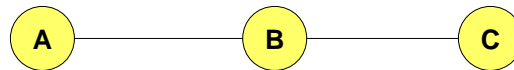
- Hidden Terminal Problem and Collision avoidance
- Reliability
- Congestion control
- Energy efficiency
- Fairness

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(2) Reliability

- ❑ Wireless links are prone to errors
 - High packet loss rate detrimental to transport-layer performance.
 - Mechanisms needed to reduce packet loss rate experienced by upper layers
- ❑ A simple solution
 - Acknowledgement (Ack)
 - Retransmission

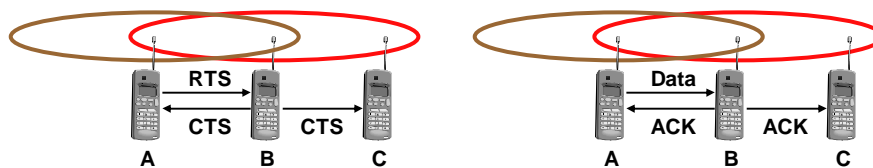


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Example: IEEE 802.11 MAC

- ❑ Uses ACK to achieve reliability
 - 2-way handshake: Data-Ack
 - 4-way handshake: RTS-CTS-Data-Ack

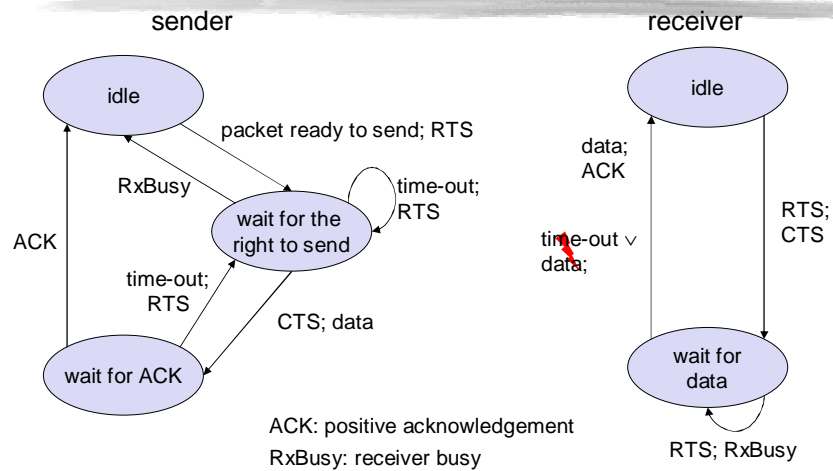


What makes C from causing interference?
⇒ NAV (Network Allocation Vector) in RTS and CTS

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4-Way Handshake (RTS-CTS-Data-Ack)



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Link-level ACK

- Usually not used in wired networks
- In wired networks,
 - TCP-level ack is used to achieve reliability as well as to alleviate the congestion problem via sliding window protocol
 - Link-level ack is overkilling
- In mobile networks,
 - Link-level ack is used to provide comparable link-level reliability
 - But it competes with Data as well as with TCP-level ack

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c.yu91@csuohio.edu

(3) Congestion Control

- ❑ The time spent counting down backoff intervals is a part of MAC overhead
- ❑ Choosing a *large* cw leads to large backoff intervals and can result in larger overhead
- ❑ Choosing a *small* cw leads to a larger number of collisions (when two nodes count down to 0 simultaneously)

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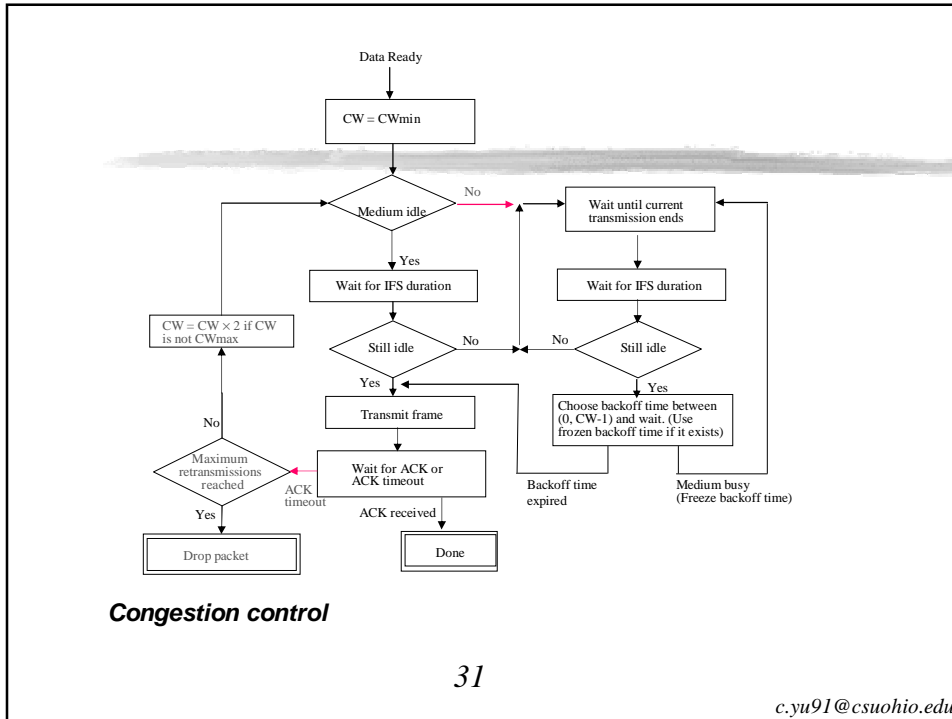
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Example: Binary Exponential Backoff in 802.11 MAC

- ❑ Since the number of nodes attempting to transmit simultaneously may change with time, some mechanism to manage congestion is needed
- ❑ IEEE 802.11 DCF: Congestion control achieved by dynamically choosing the contention window cw
 - When a node fails to receive CTS (ACK) in response to its RTS (Data), it increases the contention window: cw is doubled (up to an upper bound)
 - When a node successfully completes a data transfer, it restores cw to CW_{min}

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c.yu91@csuohio.edu



MILD Algorithm in MACAW

- ❑ When a node fails to receive CTS in response to its RTS, it multiplies cw by 1.5
 - Similar to 802.11, except that 802.11 multiplies by 2
- ❑ When a node successfully completes a transfer, it reduces cw by 1
 - Different from 802.11 where cw is restored to $Cwmin$
 - In 802.11, cw reduces much faster than it increases
 - MACAW: cw reduces slower than it increases
 - Exponential Increase Linear Decrease
- ❑ MACAW can avoid wild oscillations of cw when congestion is high

Reading Assignment

*** See ns-2 manual**

Chap. 16

Chap. 18

*** See 802.11 standard**

Section 5.1~4

Section 7

Section 9.1~2

Section 11.1~3