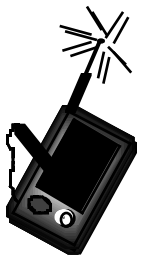
CS 294-7: Media Access—Aloha and CSMA

Prof. Randy H. Katz

CS Division

University of California, Berkeley

Berkeley, CA 946720-1776

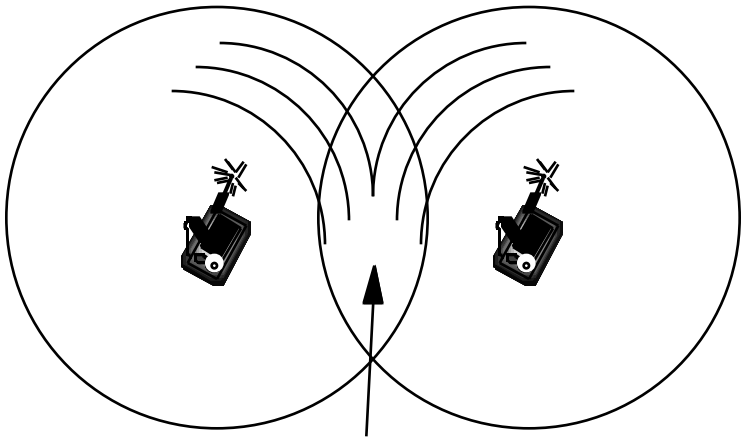


Media Access

- **Aloha**
  - Transmit when desired
  - Positive ACK from receiver on independent link
  - Back off and retransmit if timeout
  - Slotted scheme reduces chance of collision
  - Aka “random access channel”
- **Carrier Sense/Multiple Access (CSMA)**
  - Listen before transmit
  - Back off and retransmit if collision detected
- **Inhibit Sense/Multiple Access**
  - Base station transmits busy tone
  - Transmit when not busy
  - Back off and retransmit if collision
  - Aka Digital Sense Multiple Access (DSMA)

Media Access

- **Hidden Terminals**
  - Cannot hear each other
  - Adds complexity to carrier sense methods
  - Renders carrier detection techniques ineffective
- **Near-Far Problem**
  - Near-by terminal over powers signal from the far-away terminal
  - Unfair access to channel: "Capture" effect



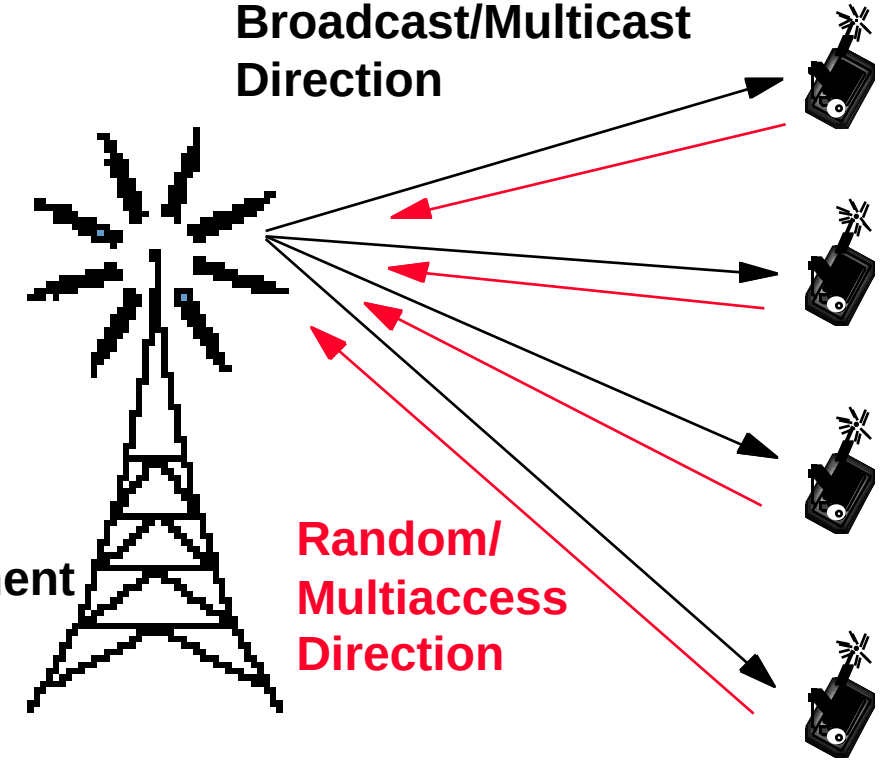
Hidden terminal disrupts the communications

Media Access

Satellite Systems—TDMA. CDMA
Cellular Systems—TDMA, CDMA
WLANs w/ Base Stations—SS
Packet radio/ad hoc networks—
no base station infrastructure

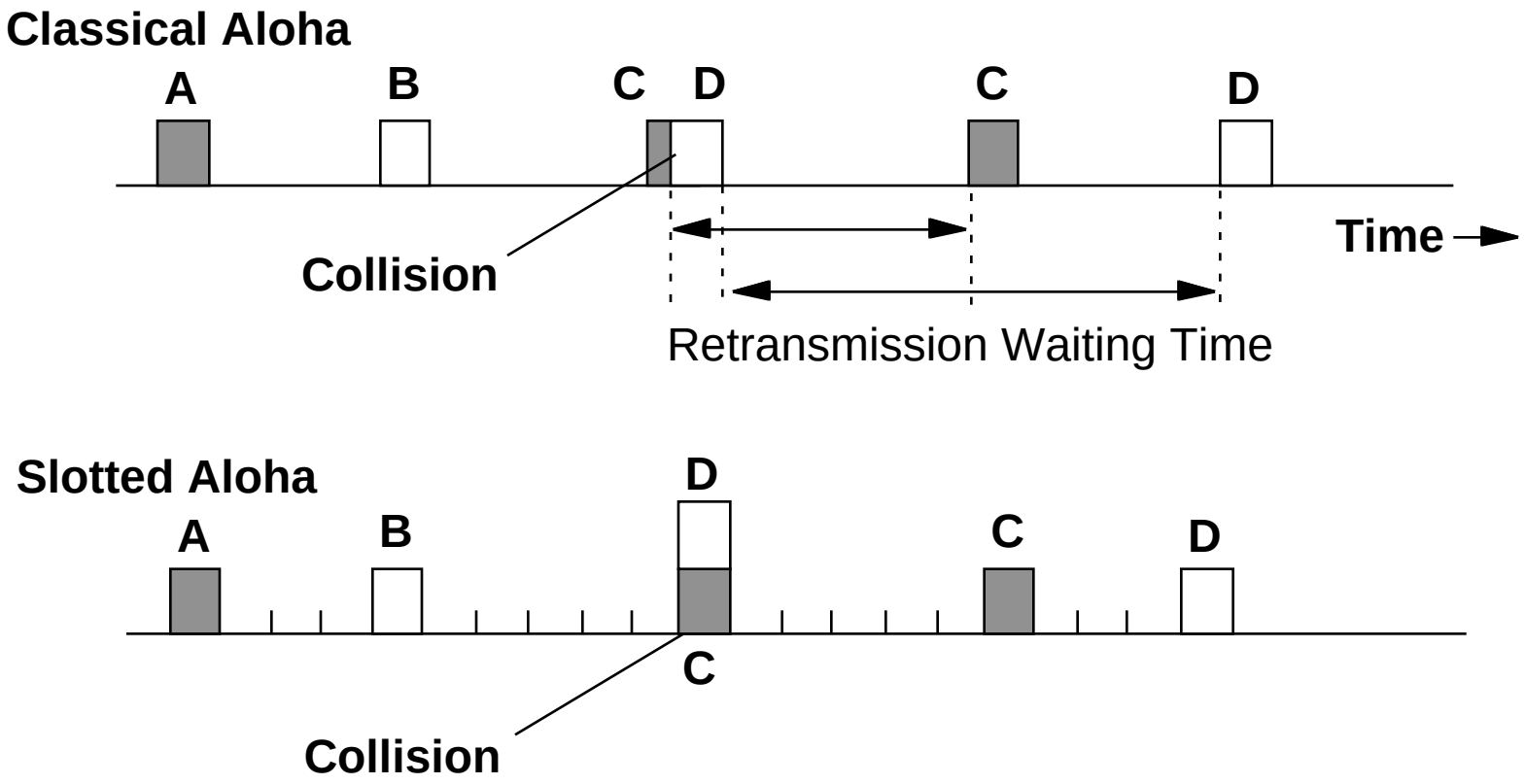
Demand Assigned Multiple Access (DAMA) request channel

Steady traffic: static assignment
Slowly varying traffic: demand assignment



"Multi-Access Problem"

Aloha Channels



Aloha Channel Utilization

Channel utilization: $\rho = \lambda T$
= Total time sending original packets/total time

User initiated packets per second: λ

Packet transmission time: T

Packets per second, including retransmissions: λ' ($\lambda' > \lambda$)

Probability of n packets originating in a second (Poisson):
$P(n) = \lambda'^{n} e^{-\lambda' } / n!$

Probability of no packets in time duration t:
$[P(n=0)]^{t} = e^{-\lambda' t}$

If packet is to be sent at time t_0, there can be no transmission at times (upto) $t_0 \pm T$: $[P(n=0)]^{2T} = e^{-\lambda' 2T}$

Fraction of retransmitted packets: $R = 1 - e^{-\lambda' 2T}$

$\lambda = \lambda' [1 - R] = \lambda e^{-\lambda' 2T}$

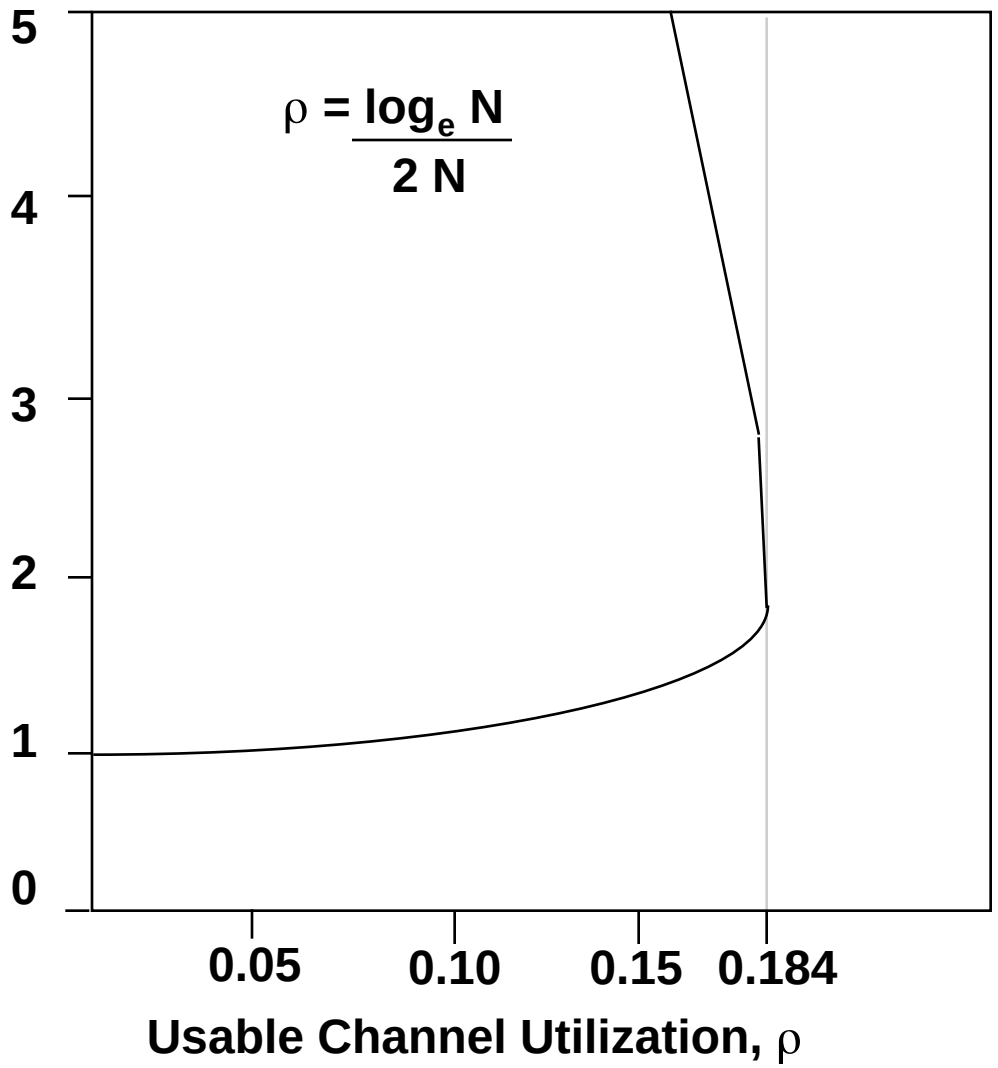
$\rho = \lambda T = \lambda' T e^{-\lambda' 2T}$

Mean # of retransmissions $N = 1+R+R^2+R^3+\ldots = 1/(1-R) = e^{-\lambda' 2T}$

$\rho = (\text{Log}_e N)/2N$, reaches its maximum value at $1/2e =$ **0.184**

Aloha Channel Utilization

Mean # of Times a packet is trans-mitted, N



Slotted Aloha Channel Utilization

Channel utilization: $\rho = \lambda T$

Packets per second: λ

Packet transmission time: T

Packets per second, including retransmissions: λ'

Probability of n packets originating in a second (Poisson):

$P(n) = \lambda'^{n} e^{-\lambda' } / n!$

Probability of no packets in time duration t:

$[P(n=0)]^{t} = e^{-\lambda' t}$

Fraction of retransmitted packets: $R = 1 - e^{-\lambda' T}$

$\lambda = \lambda' [1 - R] = \lambda e^{-\lambda' T}$

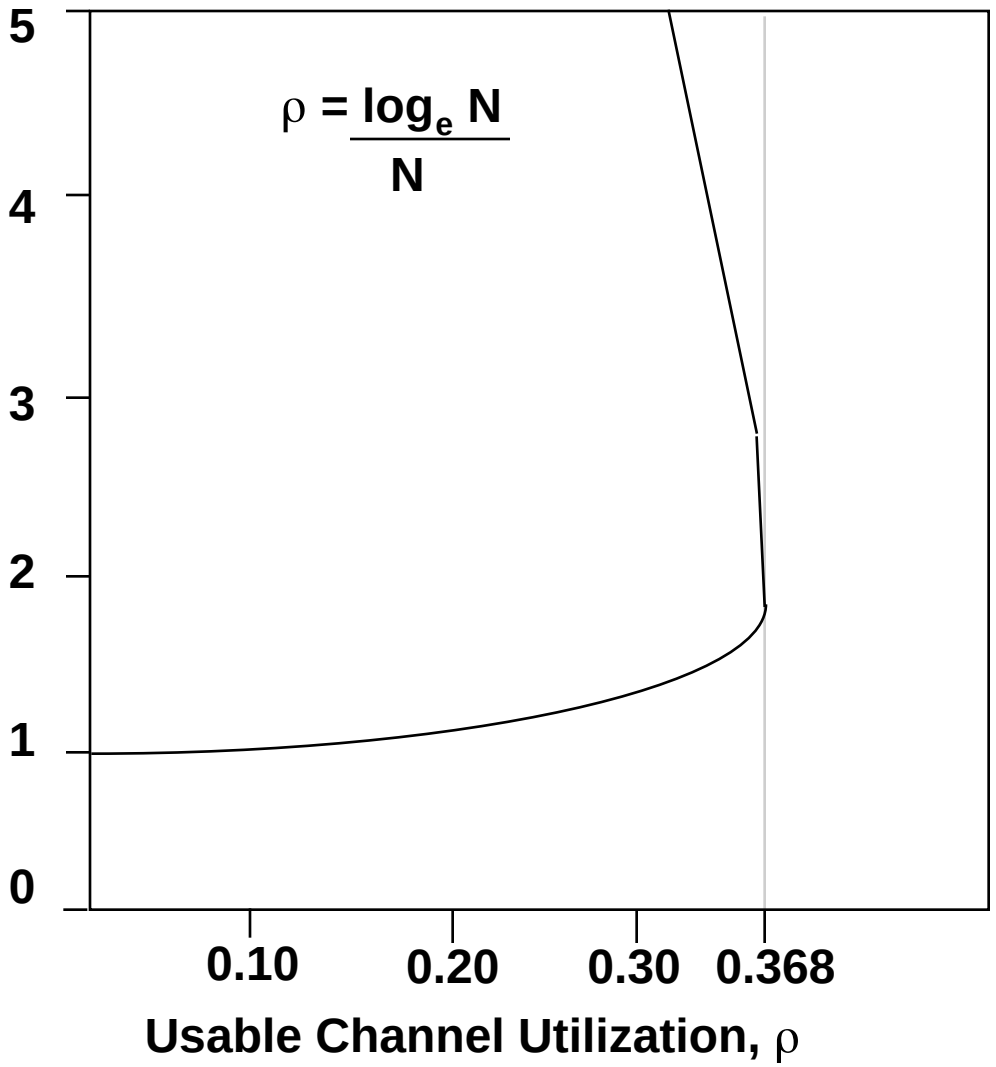
$\rho = \lambda T = \lambda' T e^{-\lambda' T}$

Mean # of retransmissions $N = 1+R+R^2+R^3+\ldots = 1/(1-R) = e^{-\lambda' T}$

$\rho = (\text{Log}_e N)/N$, reaches its maximum value at 1/e = **0.362**

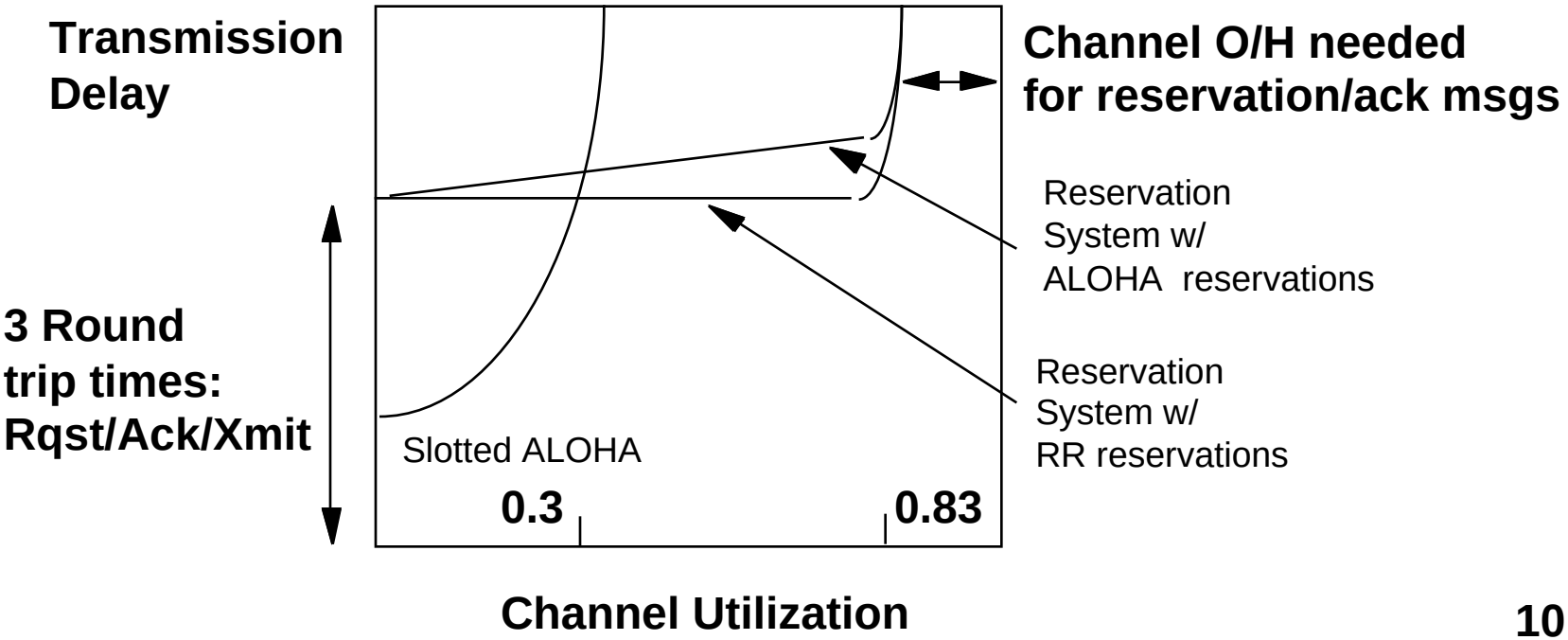
Utilization can be improved (but mean delay is increased) by using *packet reservation* schemes (up to 0.80!)

Slotted Aloha Channel Utilization



Demand Assigned Multiple Access (DAMA)

- **"Burst Reservation" System**
  - **Senders request reservation for future time slot**
  - **When slot time comes, transmit without contention**
  - **Trades higher utilization for higher latency**
  - **Commonly used in satellite systems**



Carrier Sense Multiple Access

- **Wired LANs: CSMA/CD—Collision Detection**
  - **Listen to carrier before transmit**
  - **When carrier is quiet, transmit while reading back transmitted signal**
  - **If read back ≠ transmit, then collision; back off and retransmit later**
  - **Problem for wireless: transmitter may not be able to detect the collision (hidden terminal problem)**

Expected Features Wireless LAN MAC (IEEE 802.11)

- Throughput—high effective throughput
- Delay—predictable delays
- Transparency—diverse underlying PHY layers
- Multimedia Support—time bound services
- Fair Access—near-far problem
- Battery Power Consumption—sleep mode
- Maximum Number of Nodes
- Robustness in Collocated Networks
- Support for Mobility—low latency handoff
- Support for Ad Hoc Networking

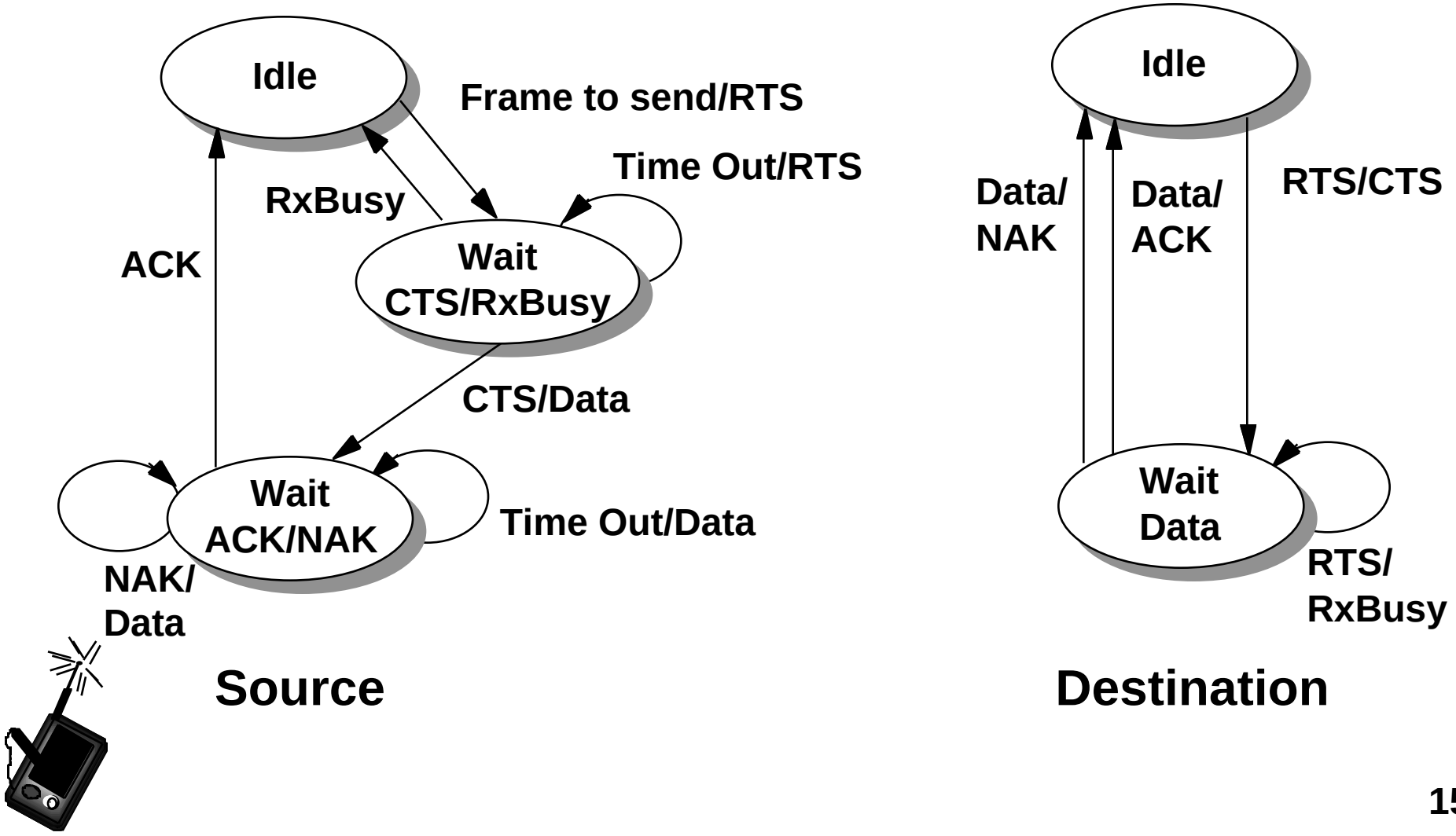
Expected Features Wireless LAN MAC (IEEE 802.11)

- Unauthorized Access/Impact on Performance
- Support for Broadcast/Multicast
- Critical Delays Limit Coverage Area—sync problems
- Insensitivity to Capture
- Support Priority Traffic
- Asymmetric Access—Downlink vs. uplink
- Preserve Packet Order
- Works over wide range of distances, # of nodes
- Limit Physical Layer Complexity

Carrier Sense Multiple Access

- **CSMA/CA—Collision Avoidance**
  - **When carrier is quiet, WAIT a random time and try again**
  - **If still quiet, then transmit**
  - **No guarantee that just because the transmitter obtains the medium that the receiver can hear the transmission**
- **Distributed Foundation Wireless MAC (DFW MAC—IEEE 802.11)**
  - **RTS: Request to send, transmitter to receiver: sender wishes to communicate with destination**
  - **CTS: Clear to send, receiver to transmitter: destination ready and available to receive from sender**
  - **DATA/ACK frame by frame; NAK indicates frame corrupted**
  - **RxBUSY: Receiver Busy, try again later**

DFW MAC

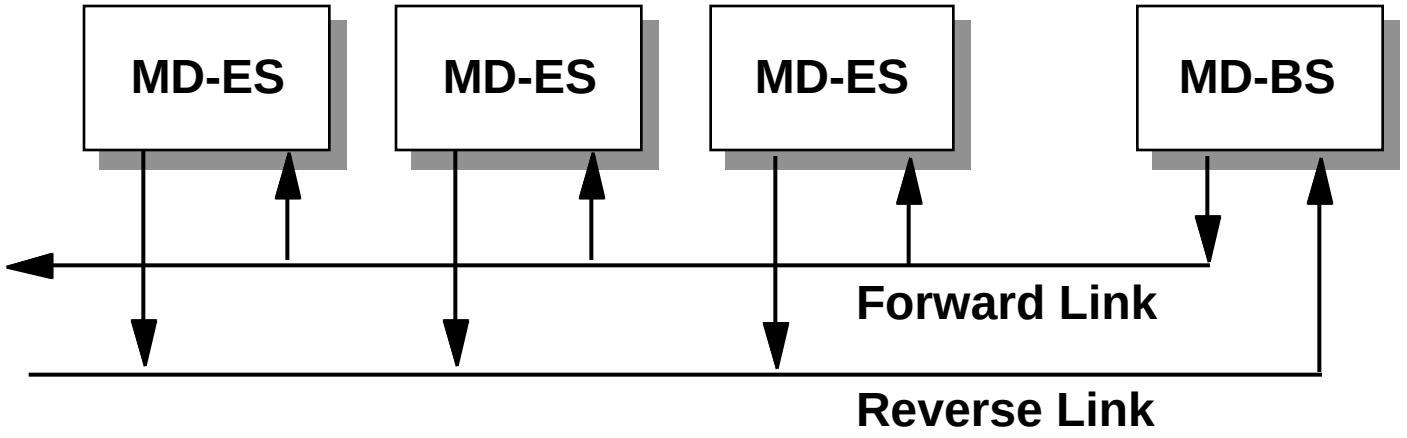

Idle
Frame to send/RTS
Time Out/RTS
RxBusy
ACK
Wait
CTS/RxBusy
CTS/Data
Wait
ACK/NAK
Time Out/Data
NAK/
Data
Source
Idle
Data/
NAK
Data/
ACK
RTS/CTS
Wait
Data
RTS/
RxBusy
Destination

Randomly Addressed Polling

- **Use distributed polling algorithm, BS to MH, to avoid/ minimize collisions on the uplink**
  - ***Invitation to contend*: BS broadcasts READY to receive signal.**
  - ***Contention scheme*: MHs wishing to transmit generate random number (dynamic address) and transmit these simultaneously. These are sent orthogonally, using CDMA or FDMA techniques.**
  - ***Coordination scheme*: Exchange of random numbers repeats in multiple stages in an effort to detect the distinct number of ready-to-send MHs.**
  - ***Uplink packet transmission*: BS chooses an address with which to poll the MHs (collision is possible since two MHs may have generated same random number).**
  - ***Acknowledgement*: BS sends positive ACK if packet received successful or negative ack if not received, polls another MH immediately.**
  - **Once all random numbers have been used in polling, the process repeats from the beginning**
  - **Claim 70-90% of channel throughput can be achieved, compared with 45-60% in CSMA schemes**

Inhibit Sense Multiple Access

- **CDPD MAC Layer: Digital Sense Multiple Access**



  - **Forward link: scheduled by BS, signals channel idle/busy**
  - **Reverse link: contention access with back-off**
    BS signals frame by frame ACK—contending stations can determine collision from this forward link signal