Wireless Sensor Networks

4. Medium Access

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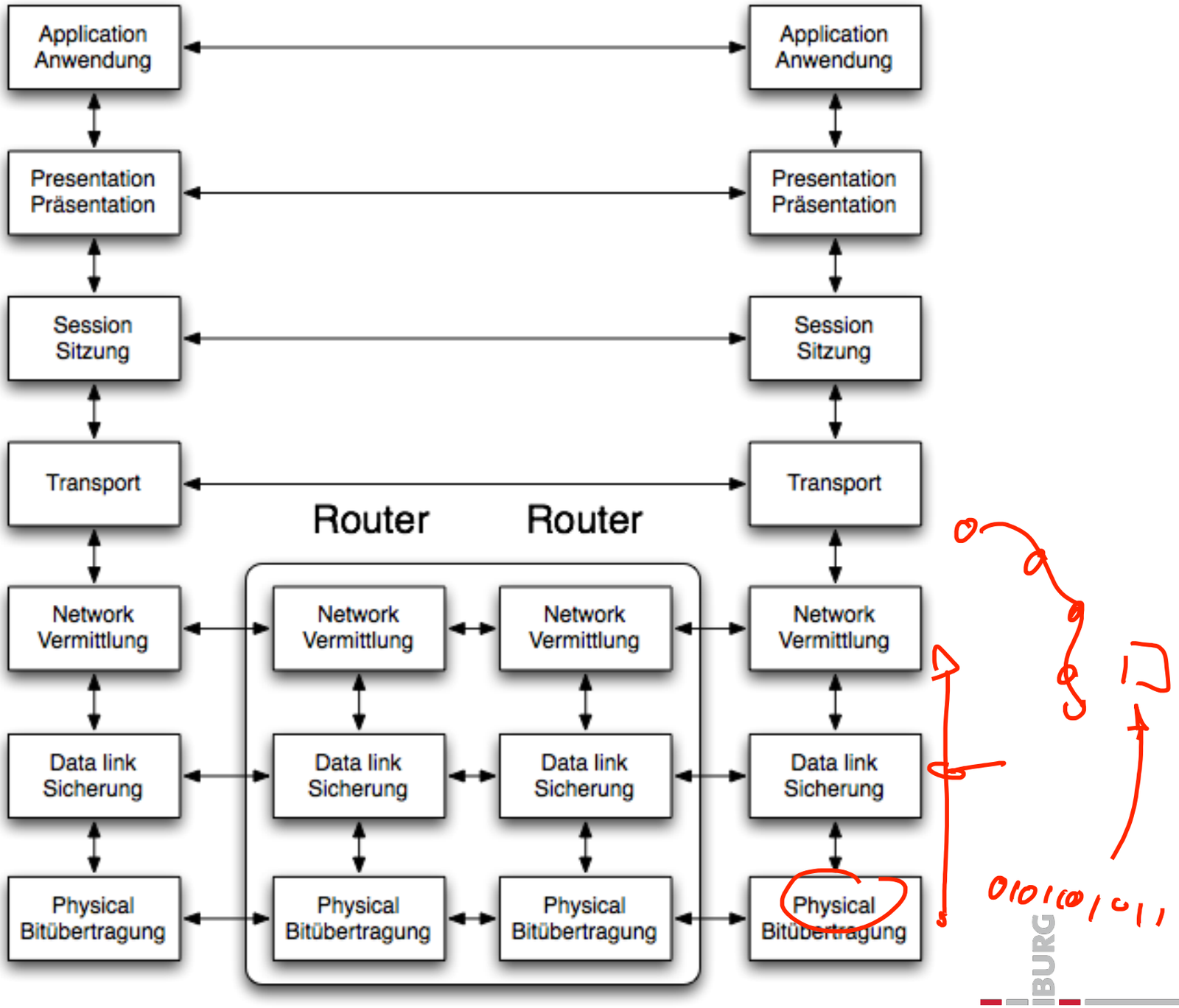
ISO/OSI Reference model

- 7. Application
  - Data transmission, e-mail, terminal, remote login
- 6. Presentation
  - System-dependent presentation of the data (EBCDIC / ASCII)
- 5. Session
  - start, end, restart
- 4. Transport
  - Segmentation, congestion
- 3. Network
  - Routing
- 2. Data Link
  - Checksums, flow control
- 1. Physical
  - Mechanics, electrics



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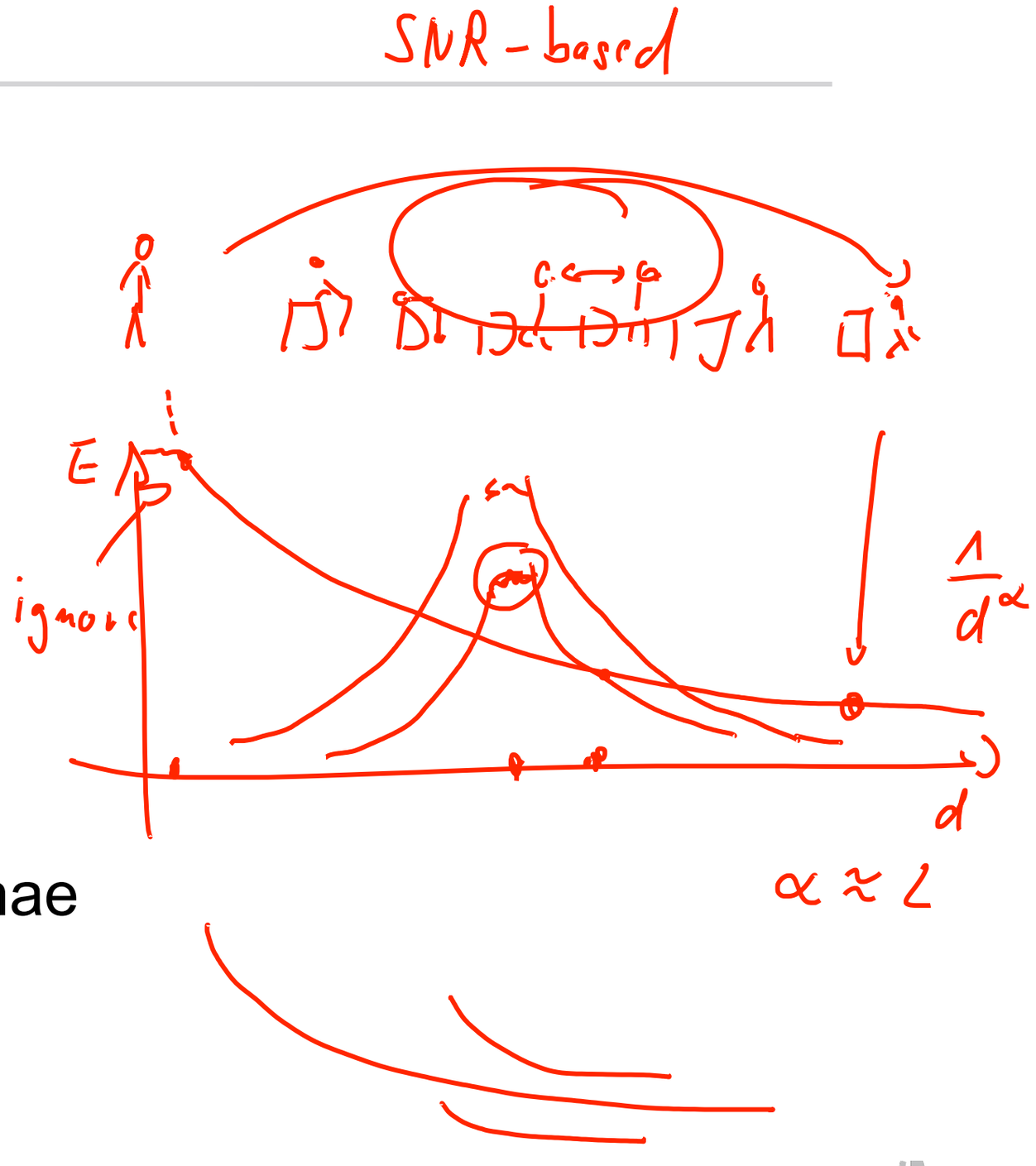
Types of Conflict Resolution

- Conflict-free
  - TDMA, Bitmap
  - FDMA, CDMA, Token Bus
- Contention-based
  - Pure contention
  - Restricted contention
- Other solutions
  - z.B. MAC for directed antennae



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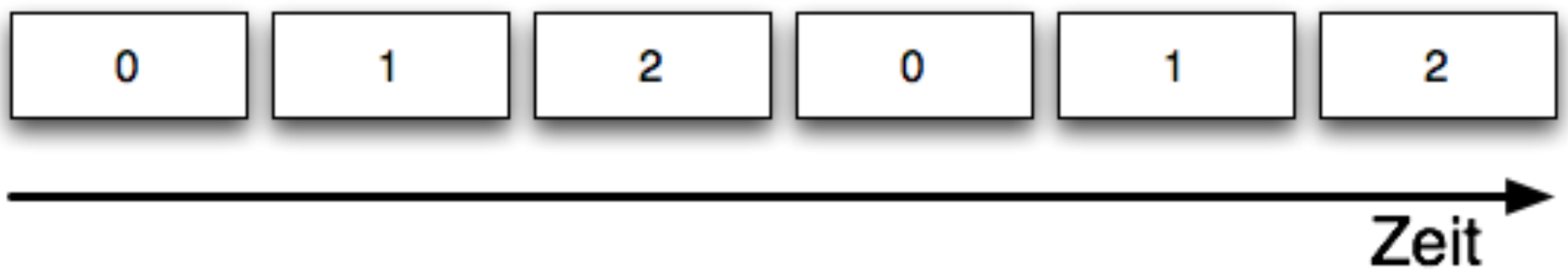
Contention Free Protocols

- Simple Example: Static Time Division Multiple Access (TDMA)
  - Each station is assigned a fixed time slot in a repeating time schedule
  - *Traffic-Bursts* cause waste of bandwidth



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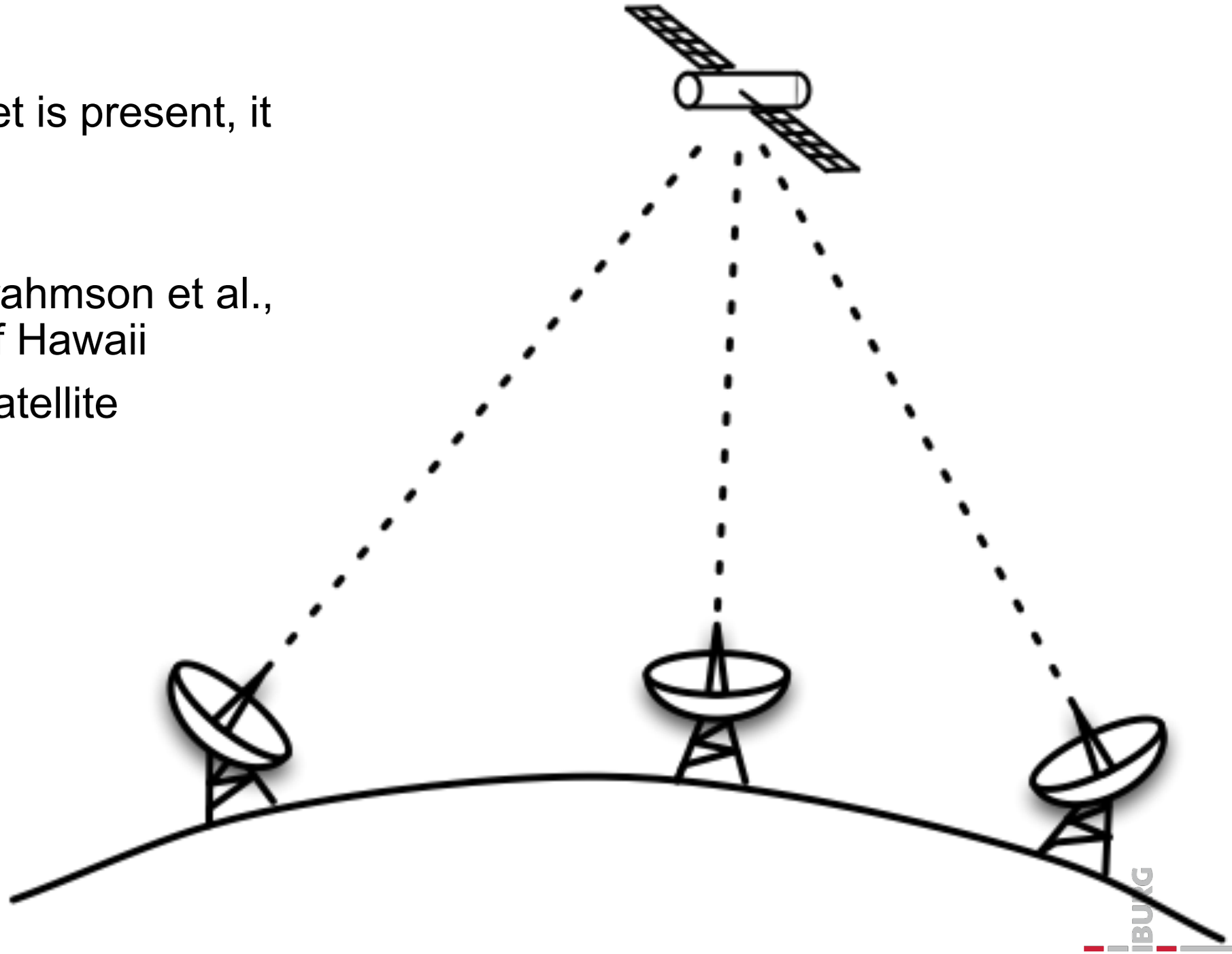
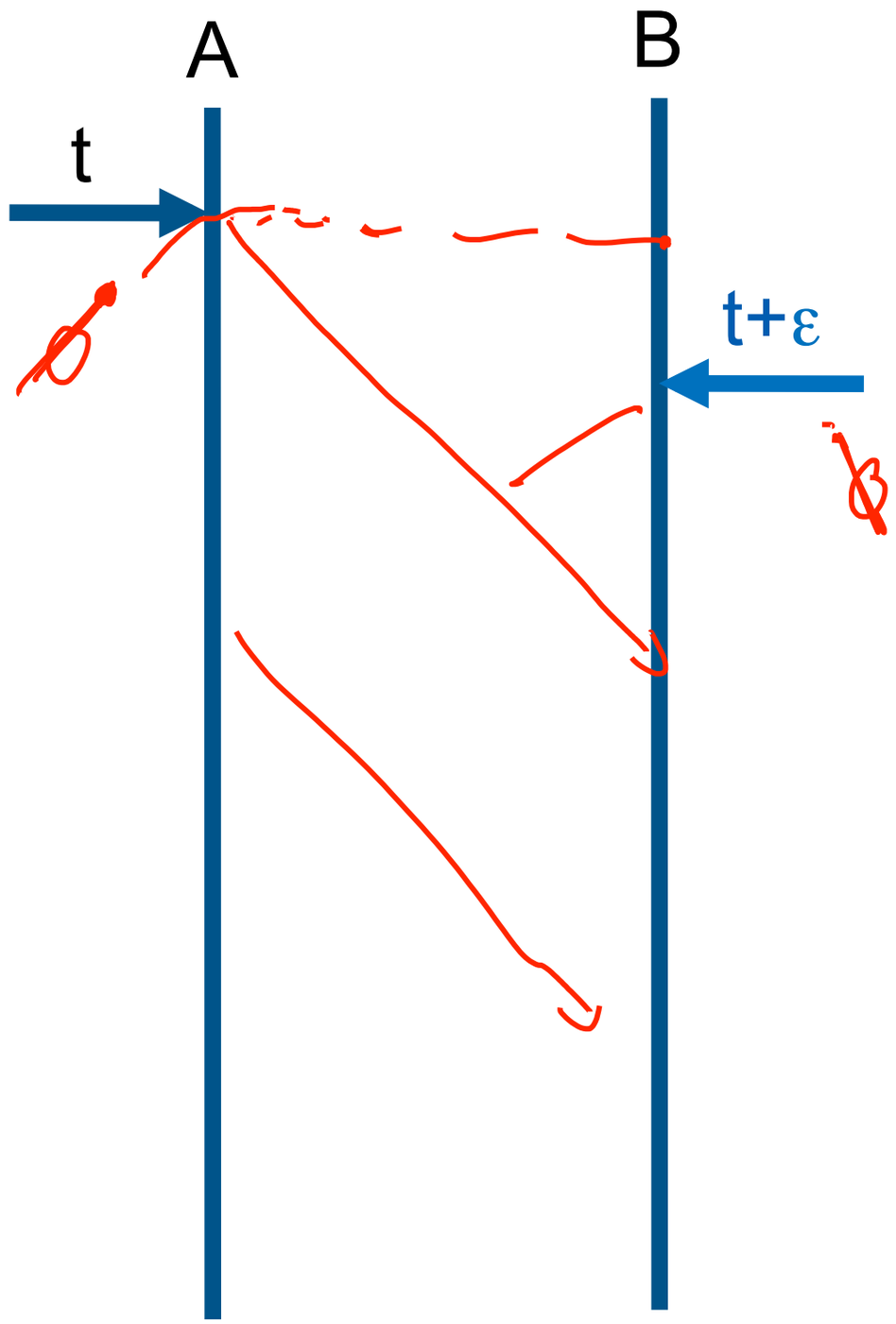
ALOHA

- Algorithm
  - Once a paket is present, it will be sent
- Origin
  - 1985 by Abrahmson et al., University of Hawaii
  - For use in satellite connections



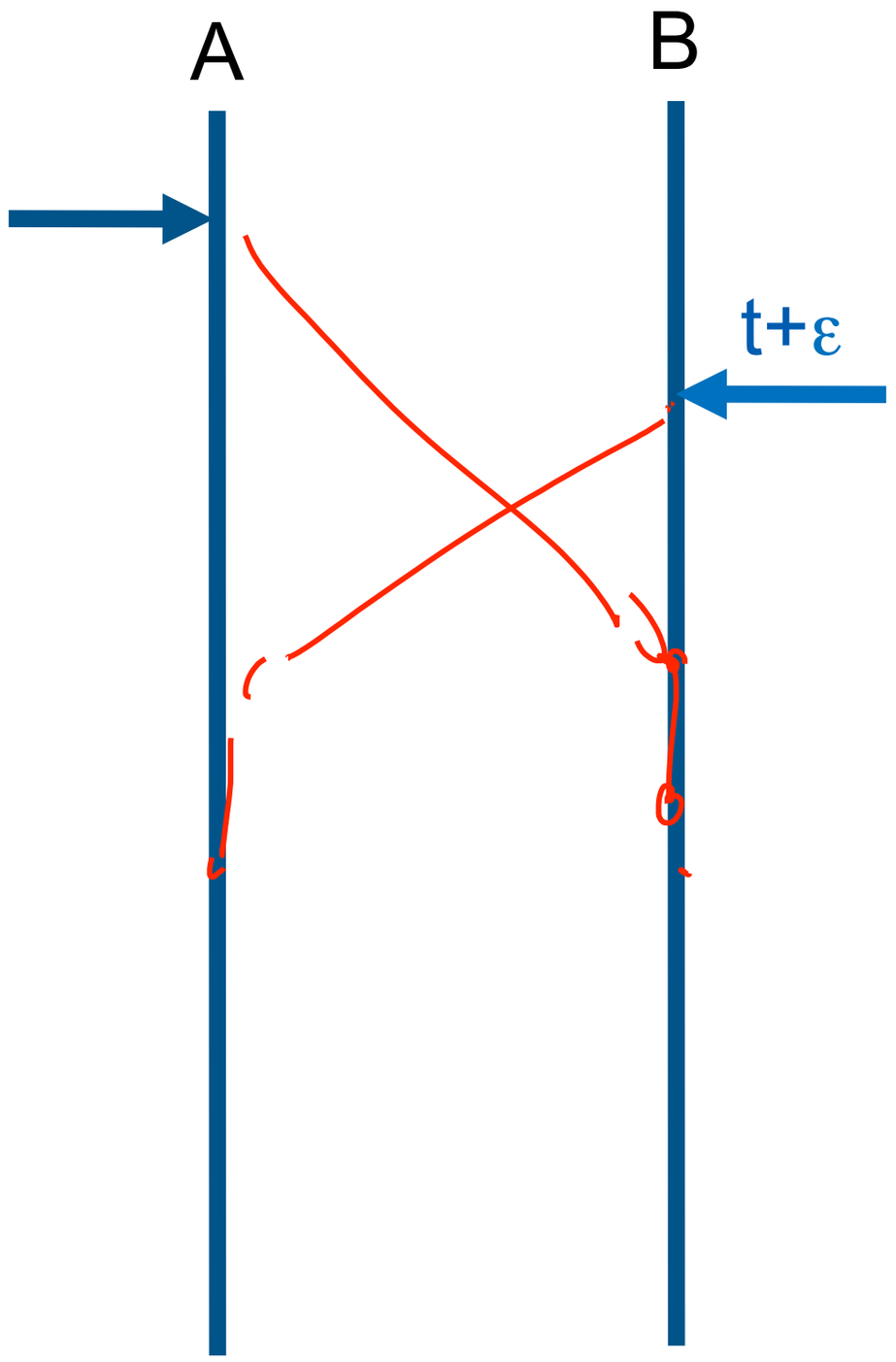
CSMA und Transmission Time

- CSMA-Problem:
  - Transmission delay d
- Two stations
  - start sending at times t and t + ε with ε <d
  - see a free channel
- 2nd Station
  - causes a collision

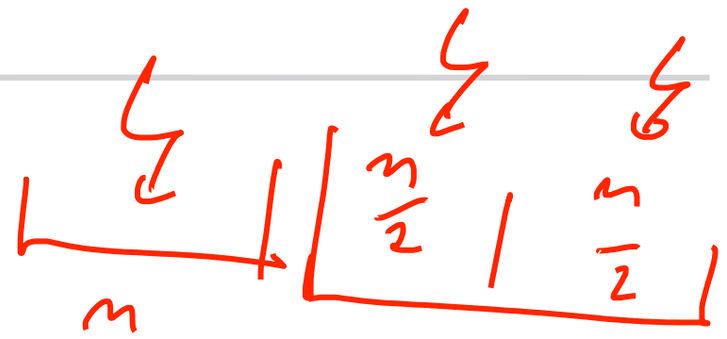


Collision Detection in Ethernet – CSMA/CD

- CSMA/CD – Carrier Sense Multiple Access/Collision Detection
  - Ethernet
- If collision detection during reception is possible
  - Both senders interrupt sending
  - Waste of time is reduced
- Collision Detection
  - simultaneously listening and sending must be possible
  - Is that what happens on the channel that's identical to the message?



Computation of the Backoff



- Algorithm: Binary Exponential Backoff
  - k:=2
  - While a collision has occurred
    - choose t randomly uniformly from {0,...,k-1}
    - wait t time units
    - send message (terminate in case of collision)
    - k:= 2 k
- Algorithm
  - waiting time adapts to the number of stations
  - uniform utilization of the channel
  - fair in the long term

Problem of Wireless Media Access

- Unknown number of participants
  - broadcast
  - many nodes simultaneously
  - only one channel available
  - asymmetric situations
- Collisions produce interference
- Media Access
  - Rules to participate in a network

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Aims

- Delay
- Throughput
- Fairness
- Robustness and stability
  - against disturbances on the channel
  - against mobility
- Scalability
- Energy efficiency

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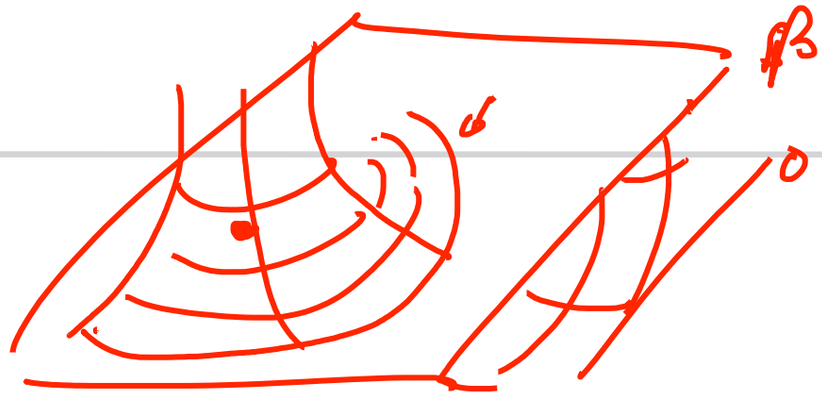
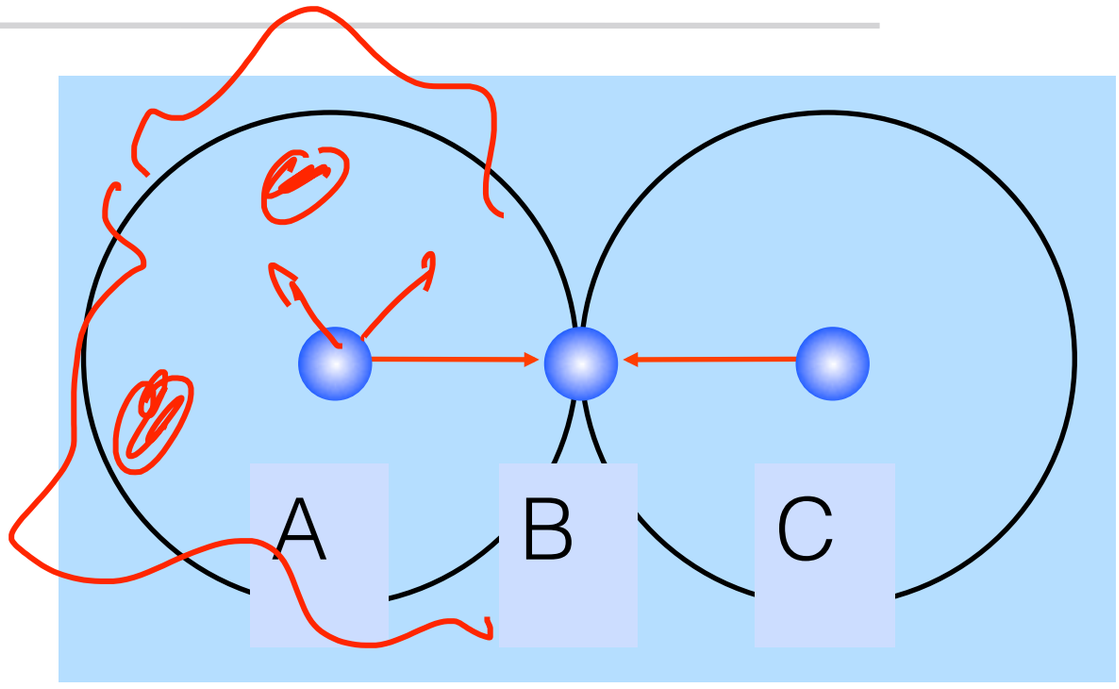
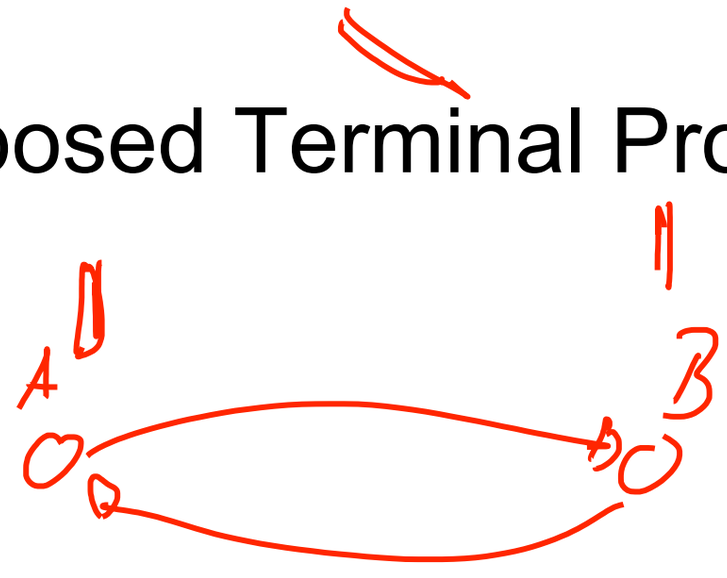
Hidden Terminal and Exposed Terminal

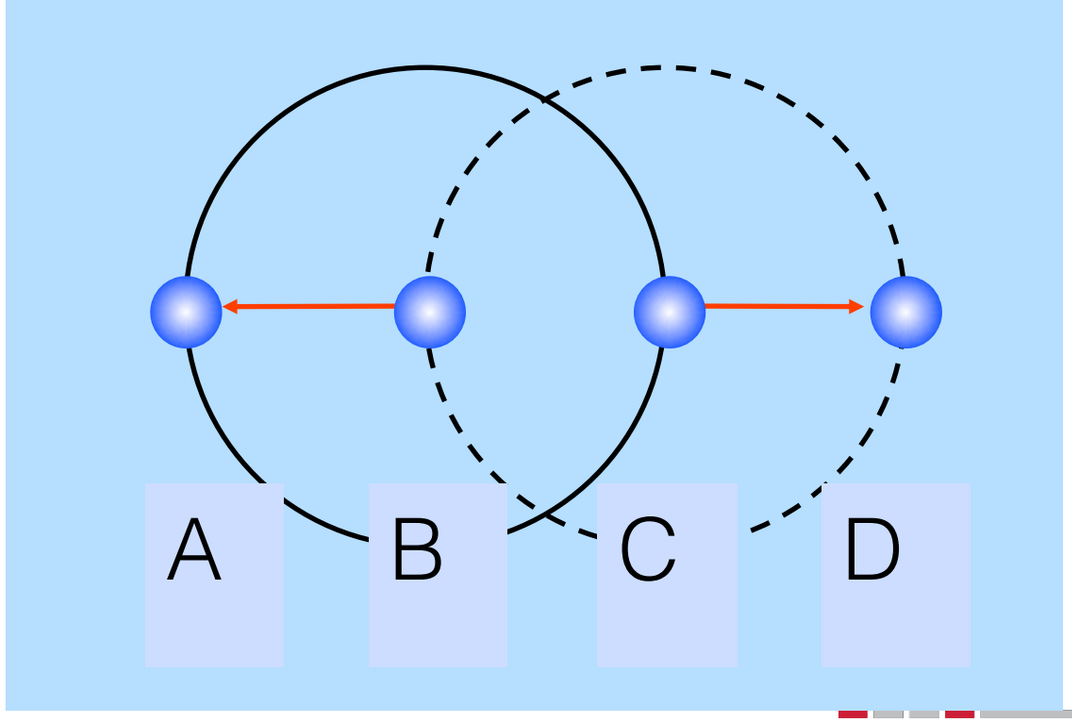


- Hidden Terminal Problem



- Exposed Terminal Problem





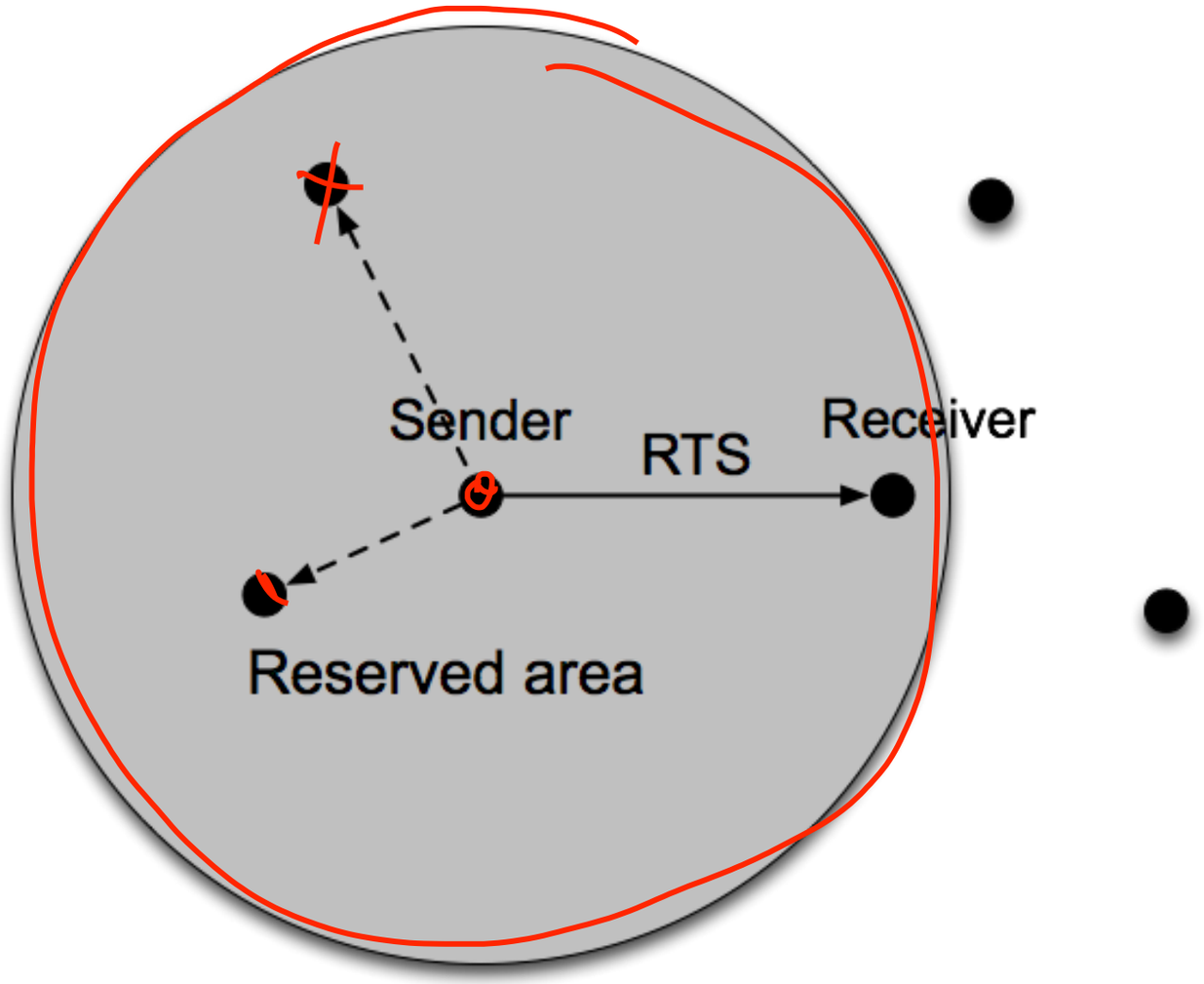
MACA

- **Phil Karn**
  - MACA: A New Channel Access Method for Packet Radio 1990
- **Alternative names:**
  - Carrier Sensing Multiple Access / Collision Avoidance (CSMA/CA)
  - Medium Access with Collision Avoidance (MACA)
- **Aim**
  - Solution of the Hidden and Exposed Terminal Problem
- **Idea**
  - Channel reservation before the communication
  - Minimization of collision cost

Request to Send

(a) A sends Request to Send (RTS)

(b) B answers with Clear to Send (CTS)



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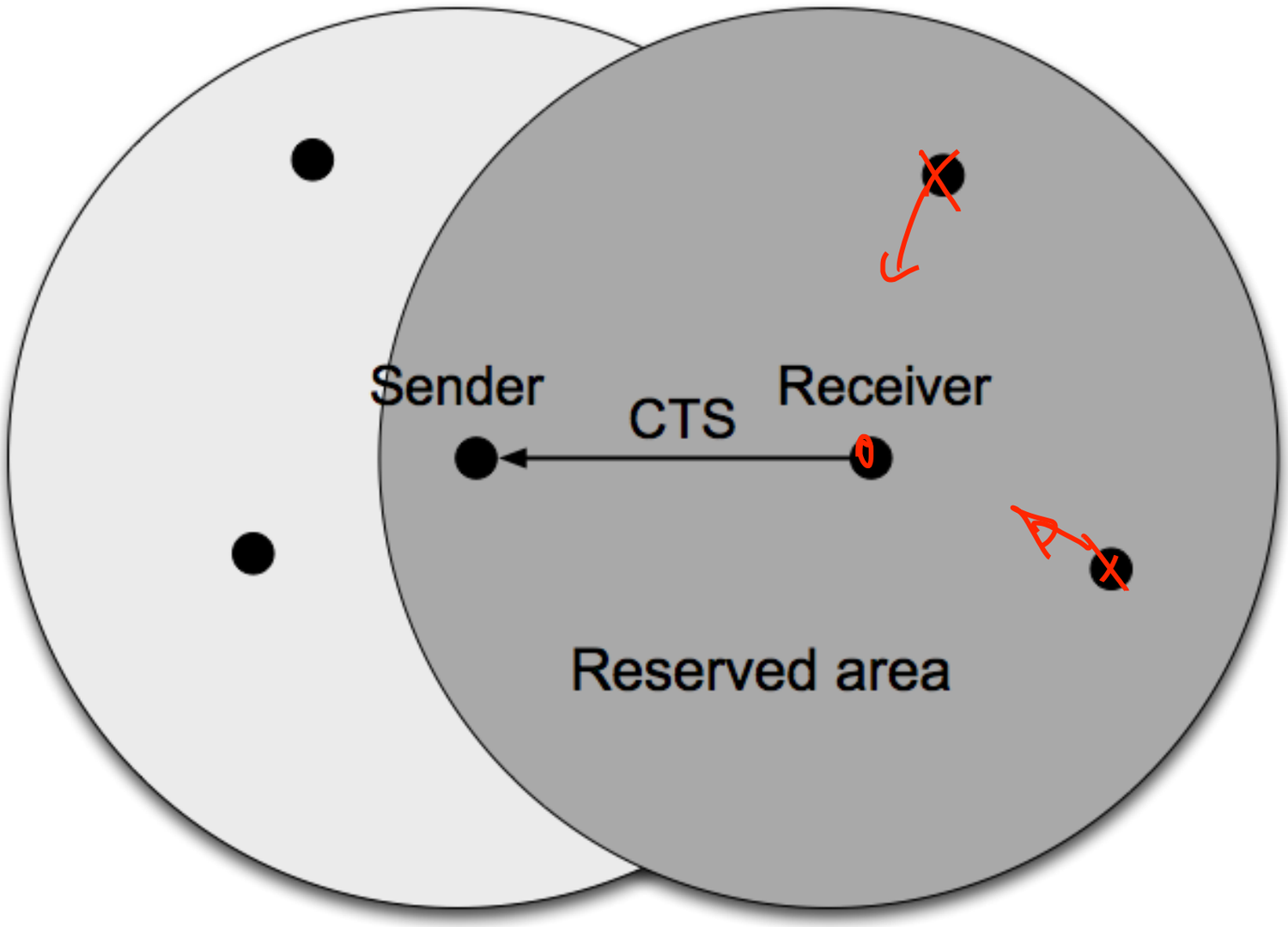
Clear to Send

(a) A sends Request to Send (RTS)

(b) B answers with Clear to Send (CTS)



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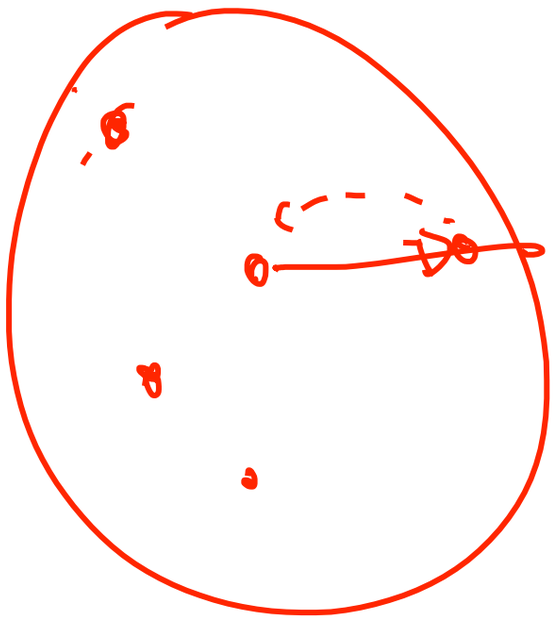
Details for Third Parties

- D receives CTS of B
  - waits long enough such that B can receive the data packet
- E receives RTS of A and CTS of B
  - waits long enough such that B can receive the data packet



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MACAW

- Bharghavan, Demers, Shenker, Zhang
  - MACAW: A Media Access Protocol for Wireless LAN‘s, SIGCOMM 1994
  - Palo Alto Research Center, Xerox
- Aim
  - Redesign of MACA
  - Improved backoff
  - Fairer bandwidth sharing using *Streams*
  - Higher efficiency
    - by 4- and 5-Handshake

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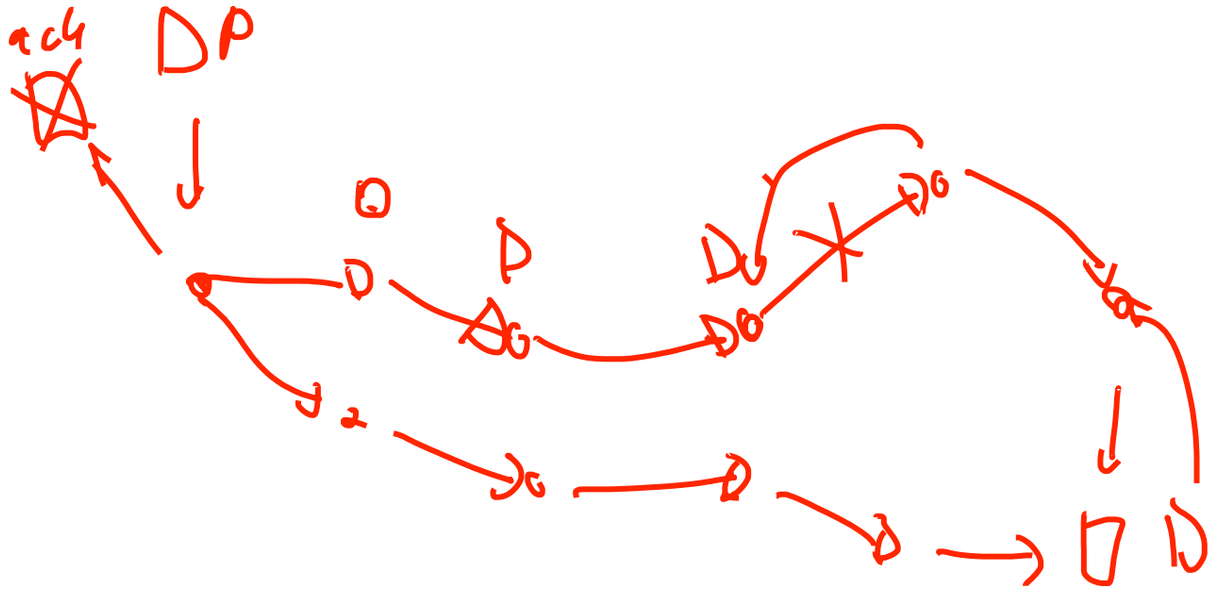
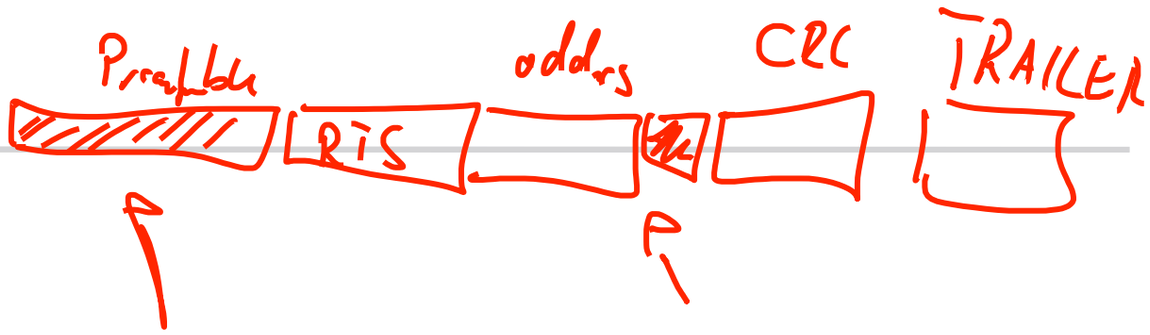
Acknowledgment in the Data Link Layer

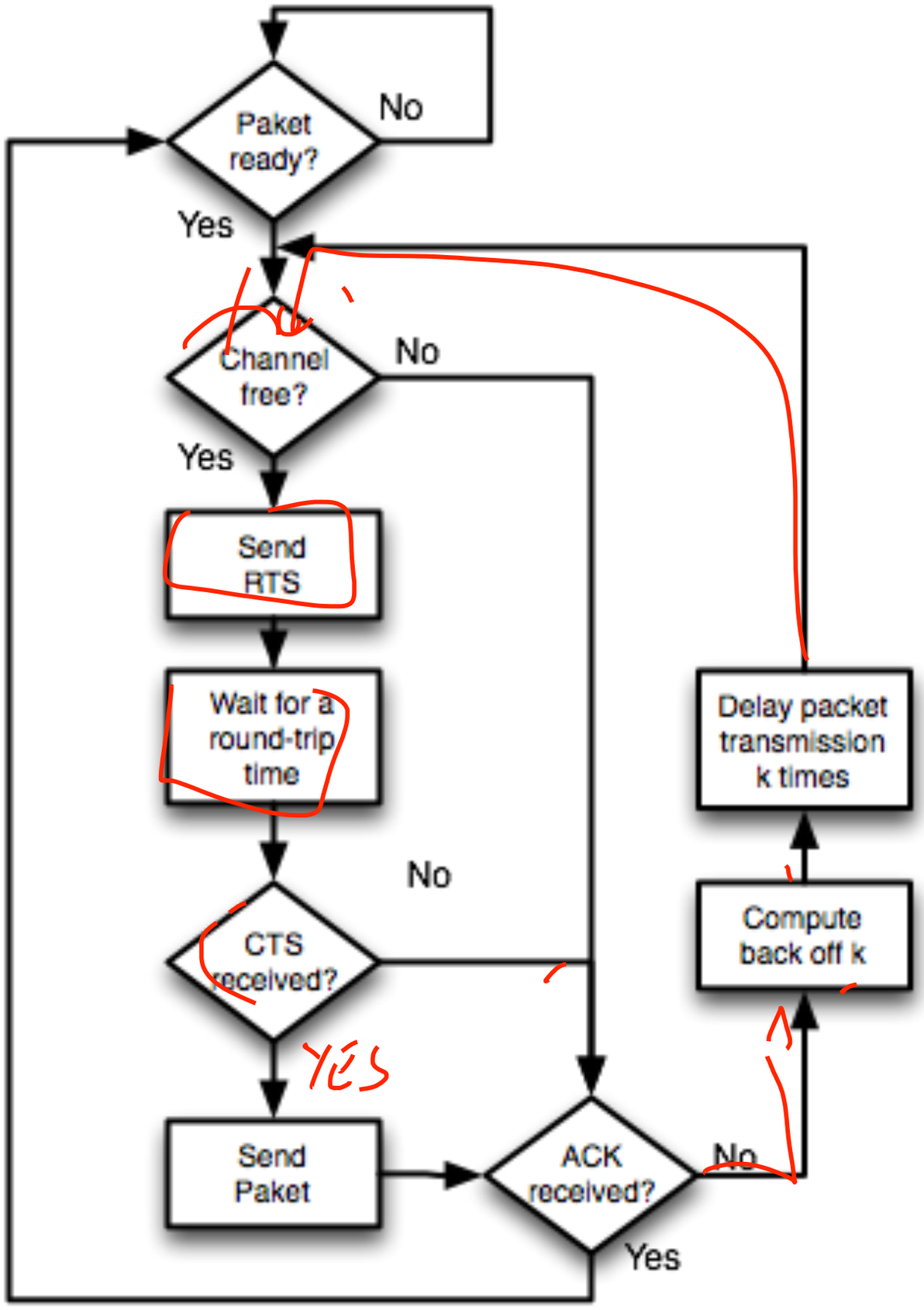
- MACA
  - does not use Acks
  - initiated by Transport Layer
  - very inefficient
- How can MACA use Acks?

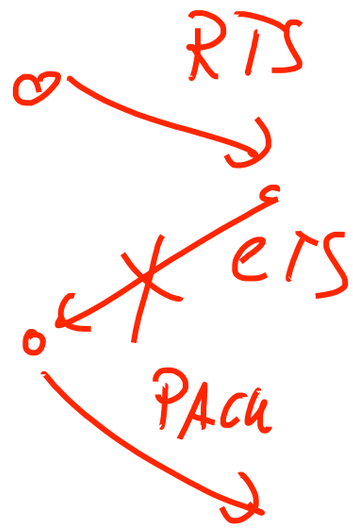


MACAW
4 Handshake

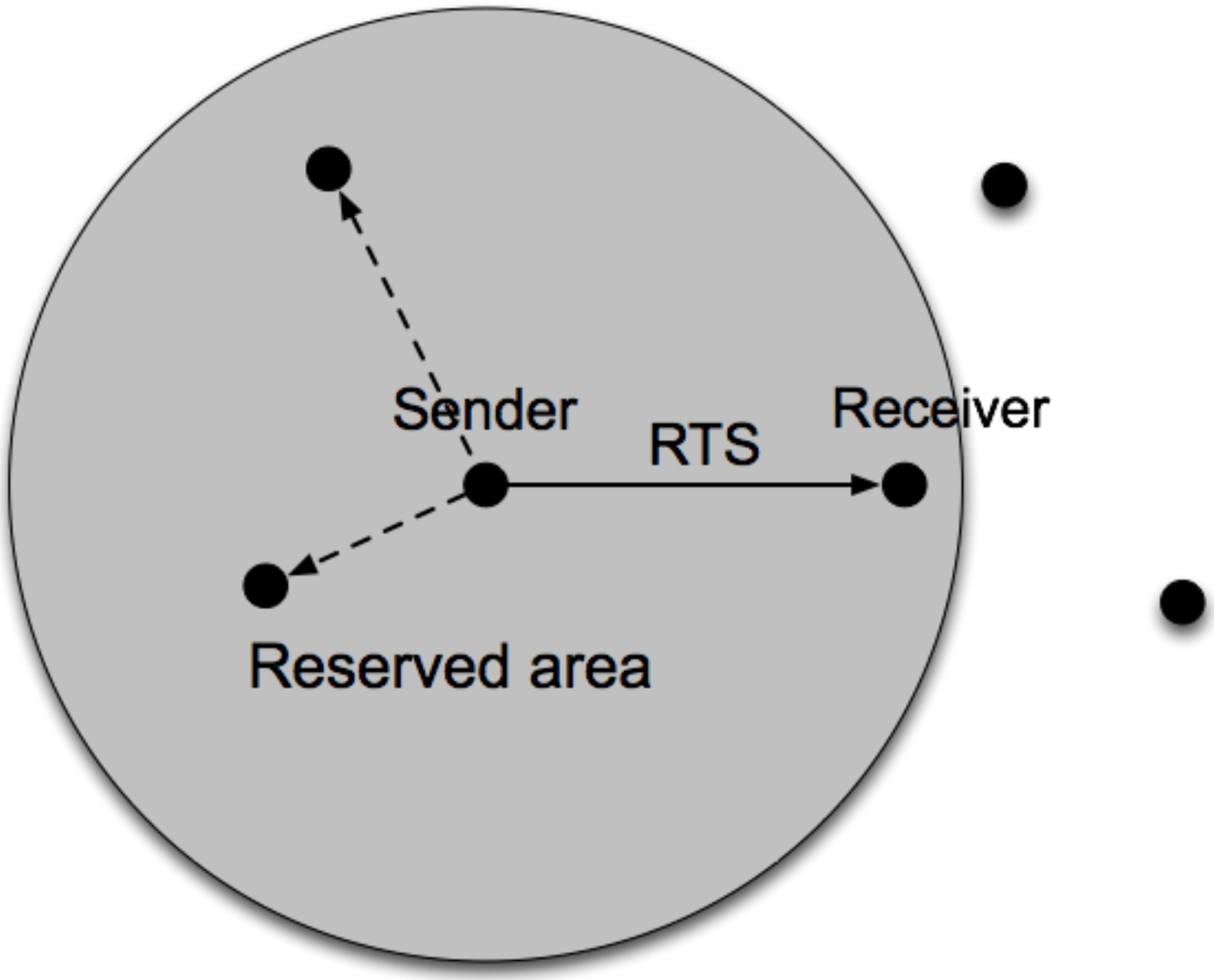


- Participants
  - Sender sends RTS
  - Receiver answers with CTS
  - Sender sends data packet
  - Receiver acknowledges (ACK)
- Third parties
  - Nodes receiving RTS or CTS are blocked for some time
  - RTS and CTS describe the transmission duration
- Sender repeats RTS, if no ACK has been received
  - If receiver has sent ACK
  - then the receiver sends (instead of CTS) another ACK


Paket ready?
No
Yes
Channel free?
No
Yes
Send RTS
Wait for a round-trip time
No
CTS received?
YES
Send Paket
ACK received?
No
Yes
Delay packet transmission k times
Compute back off k


RTS
CTS
PACH

MACA 4-Handshake
RTS



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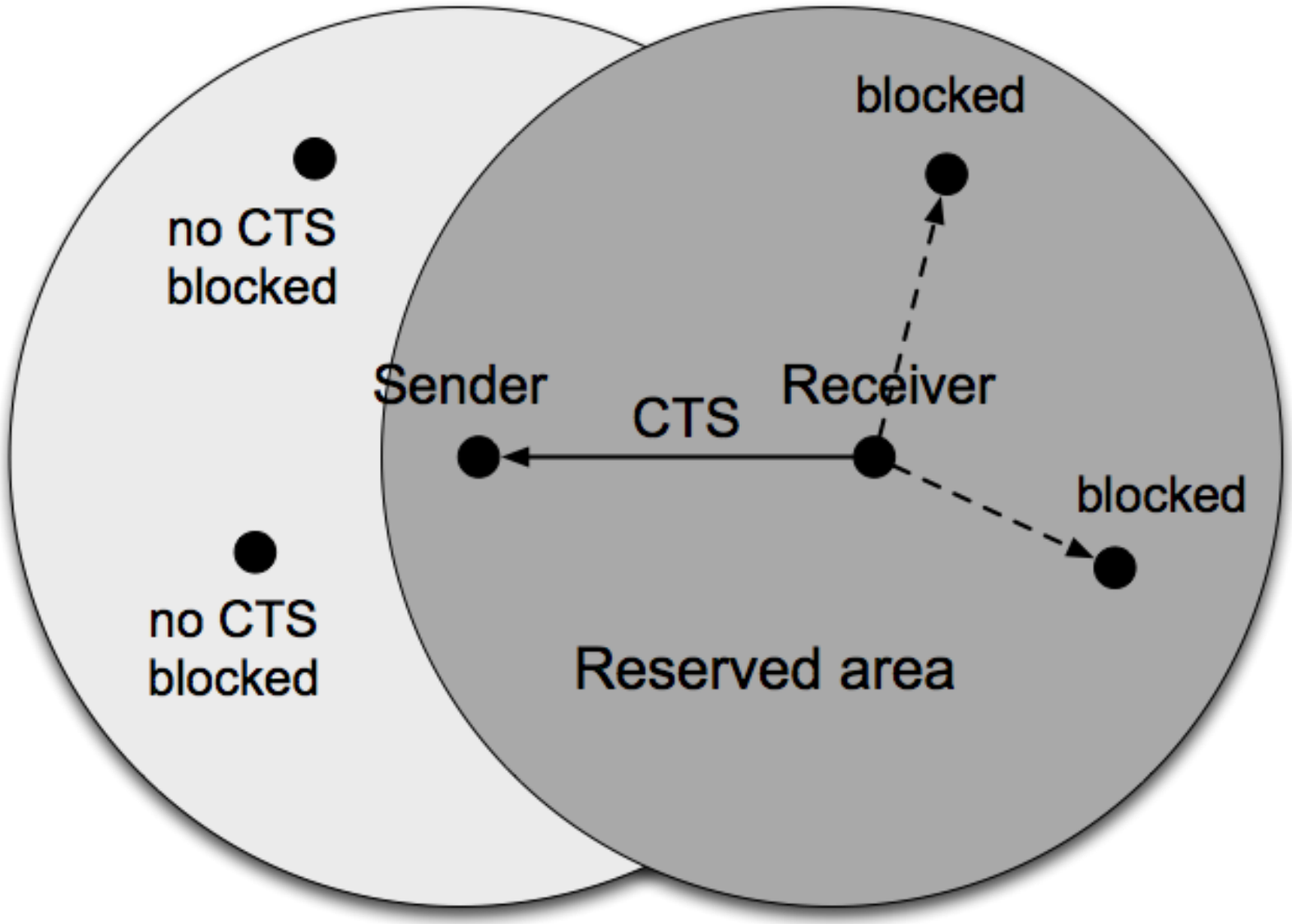
MACAW 4-Handshake CTS



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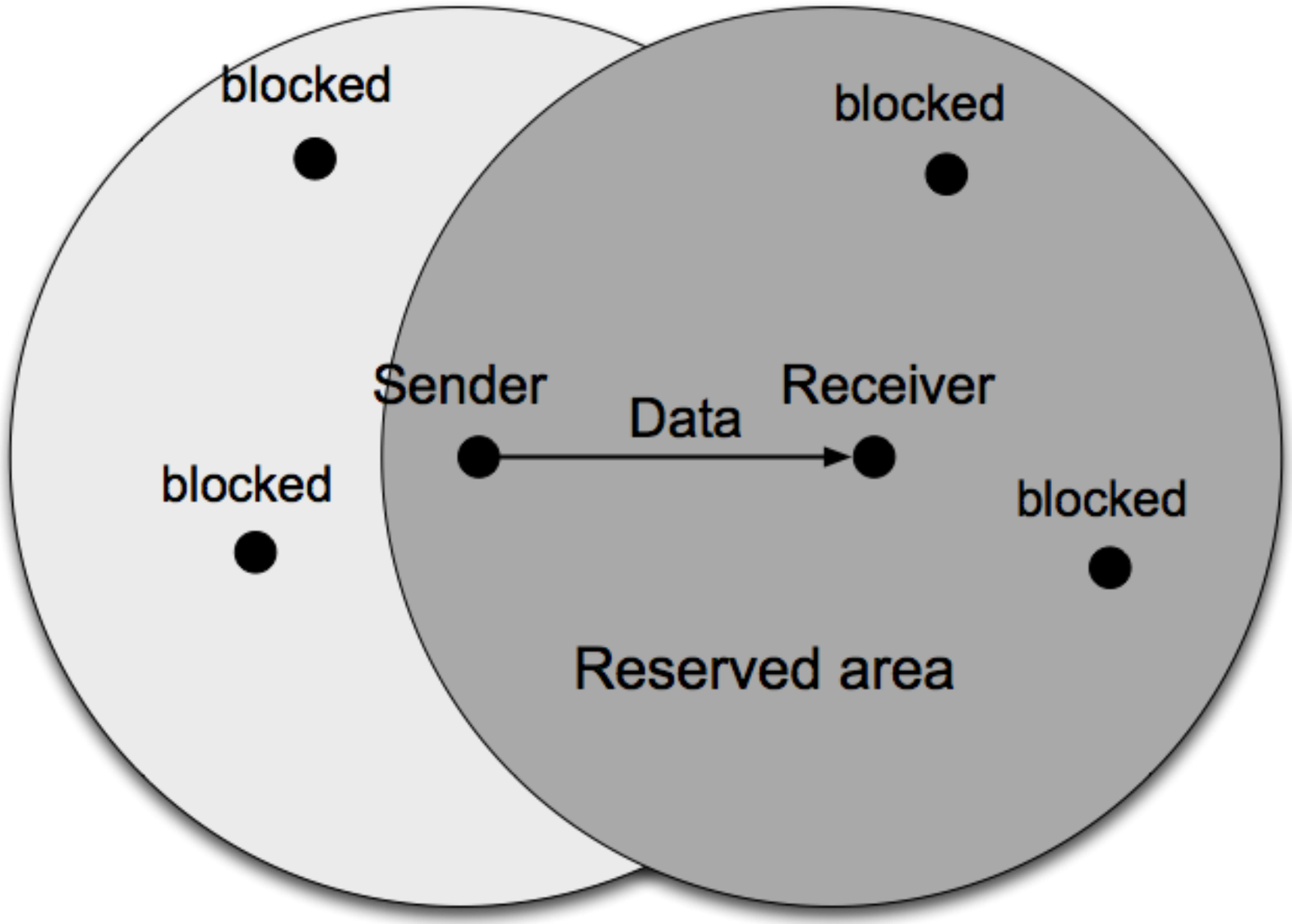
MACAW 4-Handshake Data



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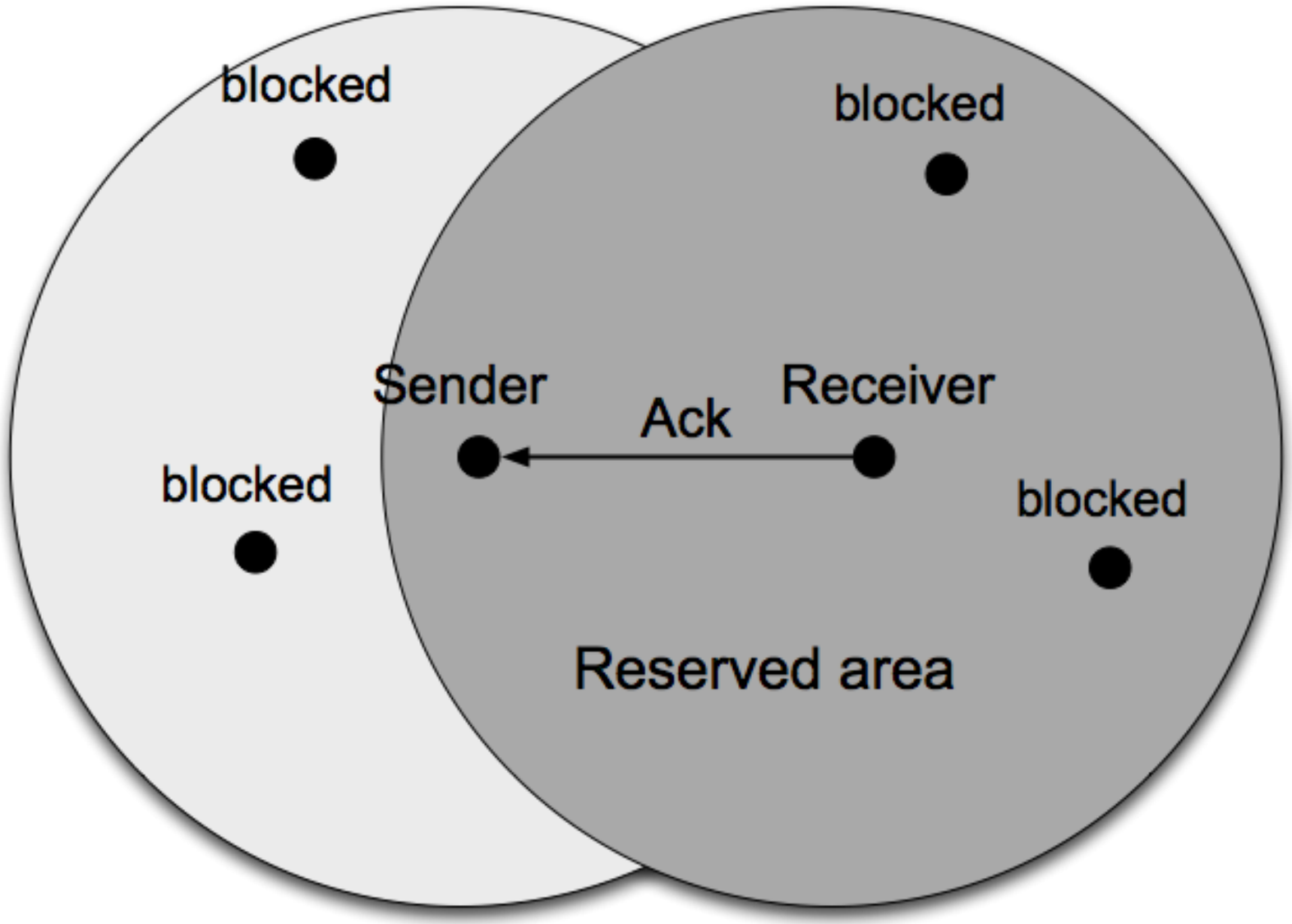
MACAW 4-Handshake
Ack



Acknowledgments

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- Adding ACKs to MACA
  - In MACA done by transport layer
- leads to drastical improvements of throughput even for moderate error rates

error rate	throughput	
	RTS-CTS-DATA	RTS-CTS-DATA-ACK
0	40	37
0,001	37	37
0,01	17	36
0,1	2	10

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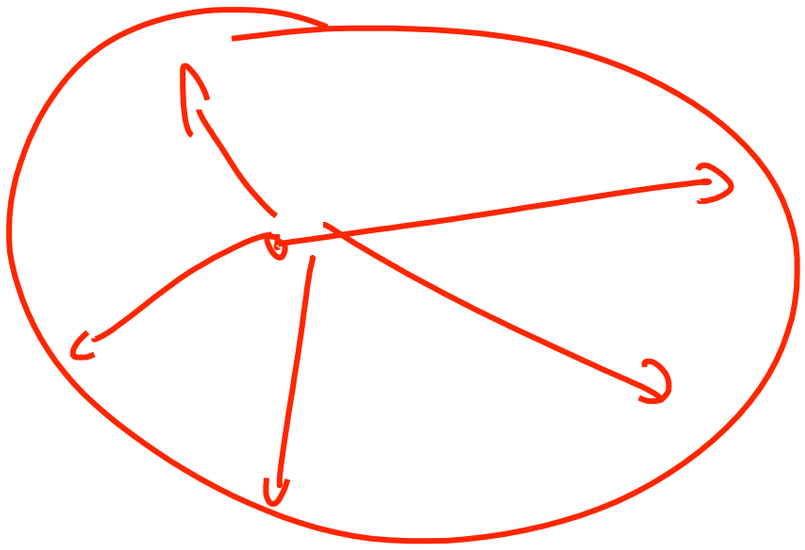
MACAW
4 Handshake

- Worst-Case blockade
  - Sender sends RTS
  - Receiver is blocked
  - Sender is free
  - But the environment of the sender is blocked



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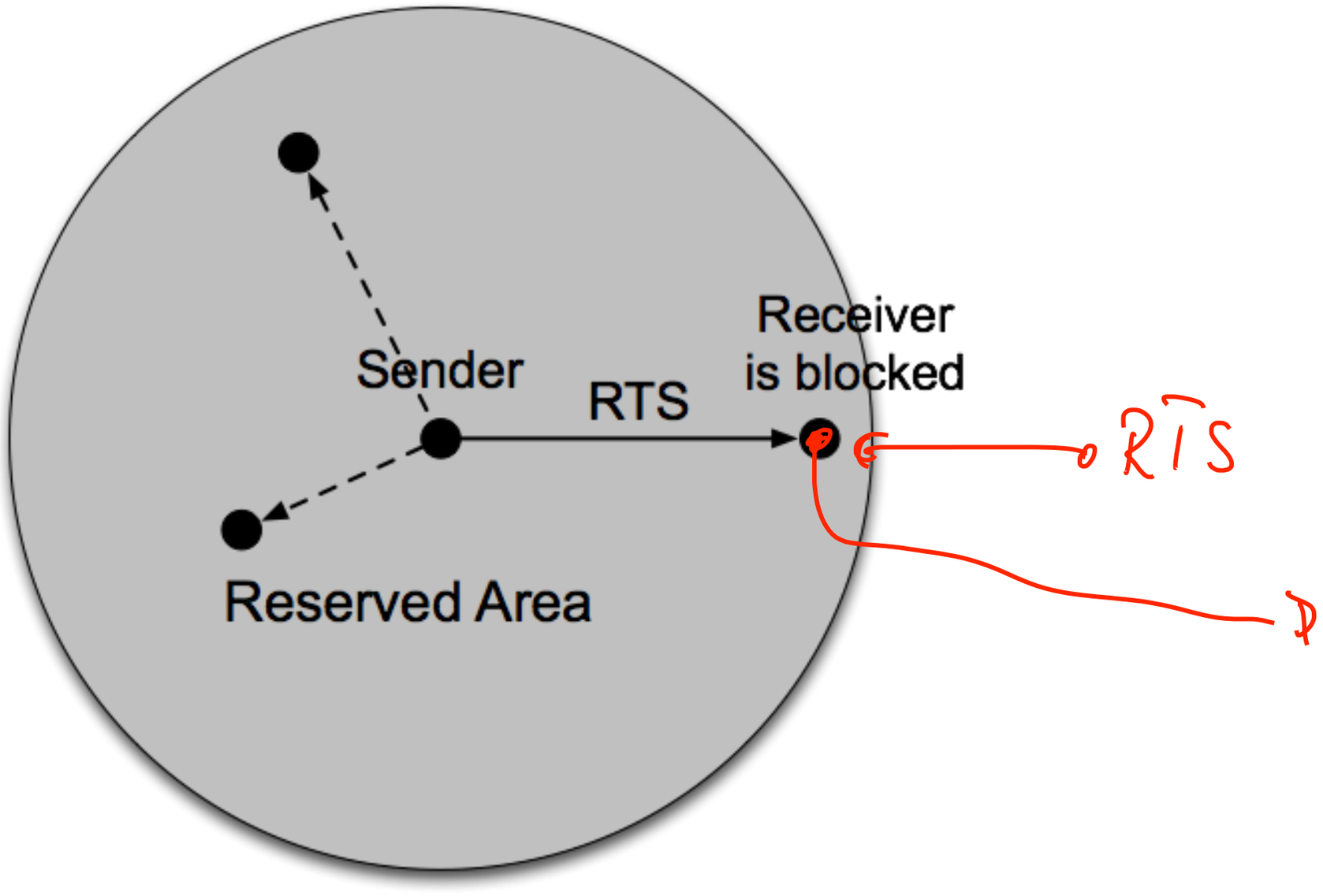
MACAW 4-Handshake RTS



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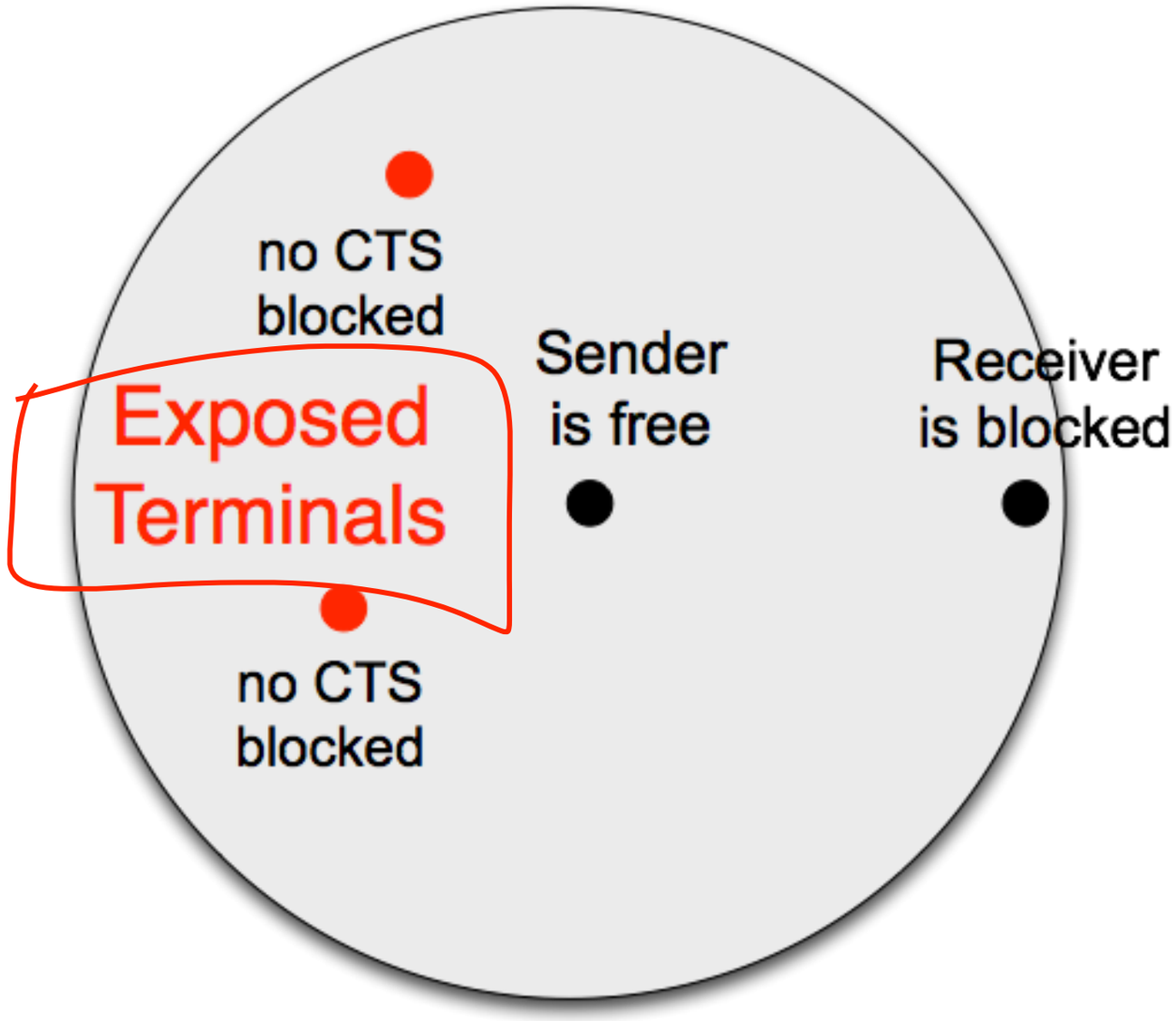
MACAW 4-Handshake
CTS is missing



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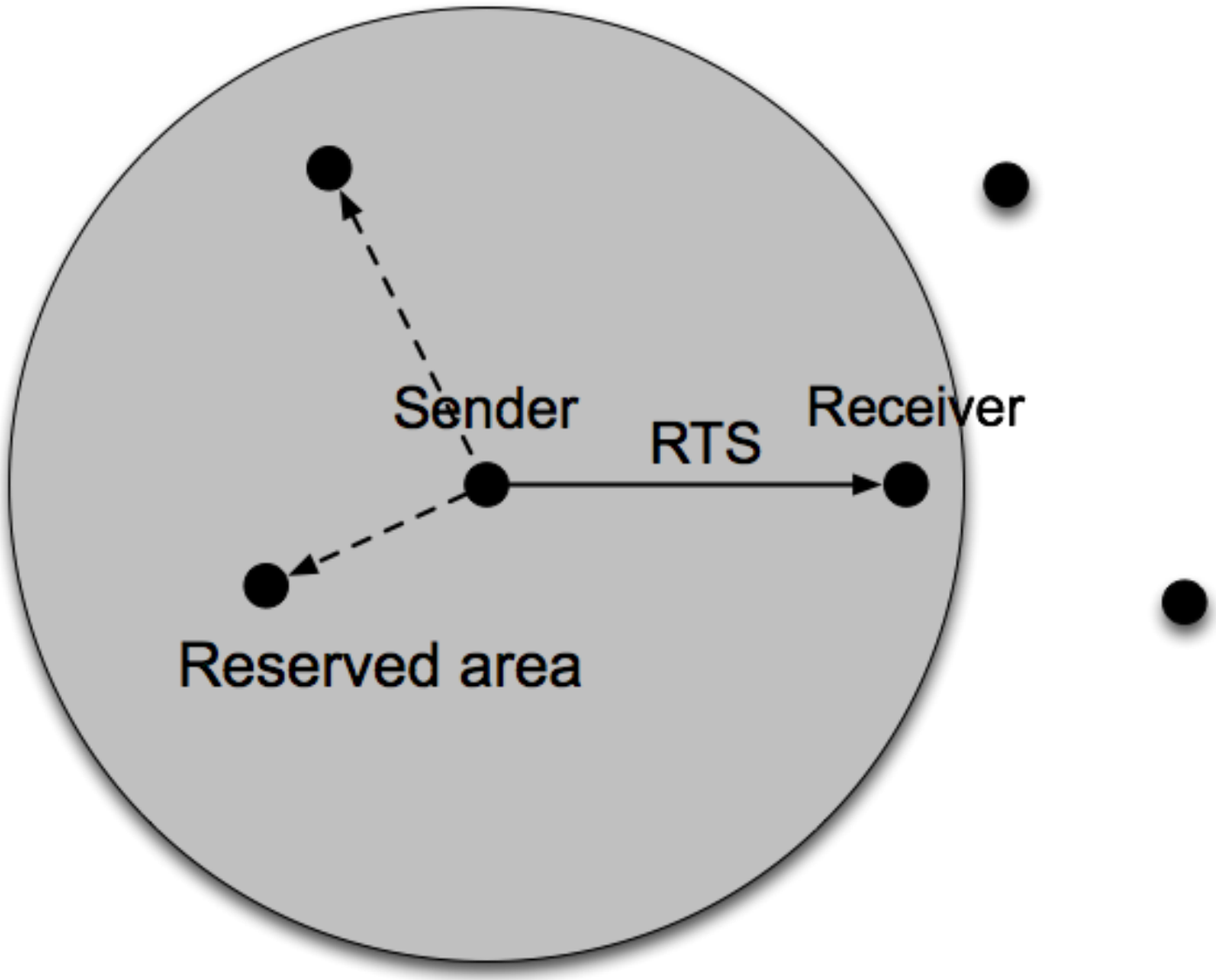
MACAW
5 Handshake

- 4-Handshake increases Exposed Terminal Problem
  - Overheard RTS blocks nodes
  - even if there is no data transfer
- Solution
  - Exposed Terminals are informed whether data transmission occurs
  - Short message DS (data send)
- 5 Handshake reduces waiting time for exposed terminals

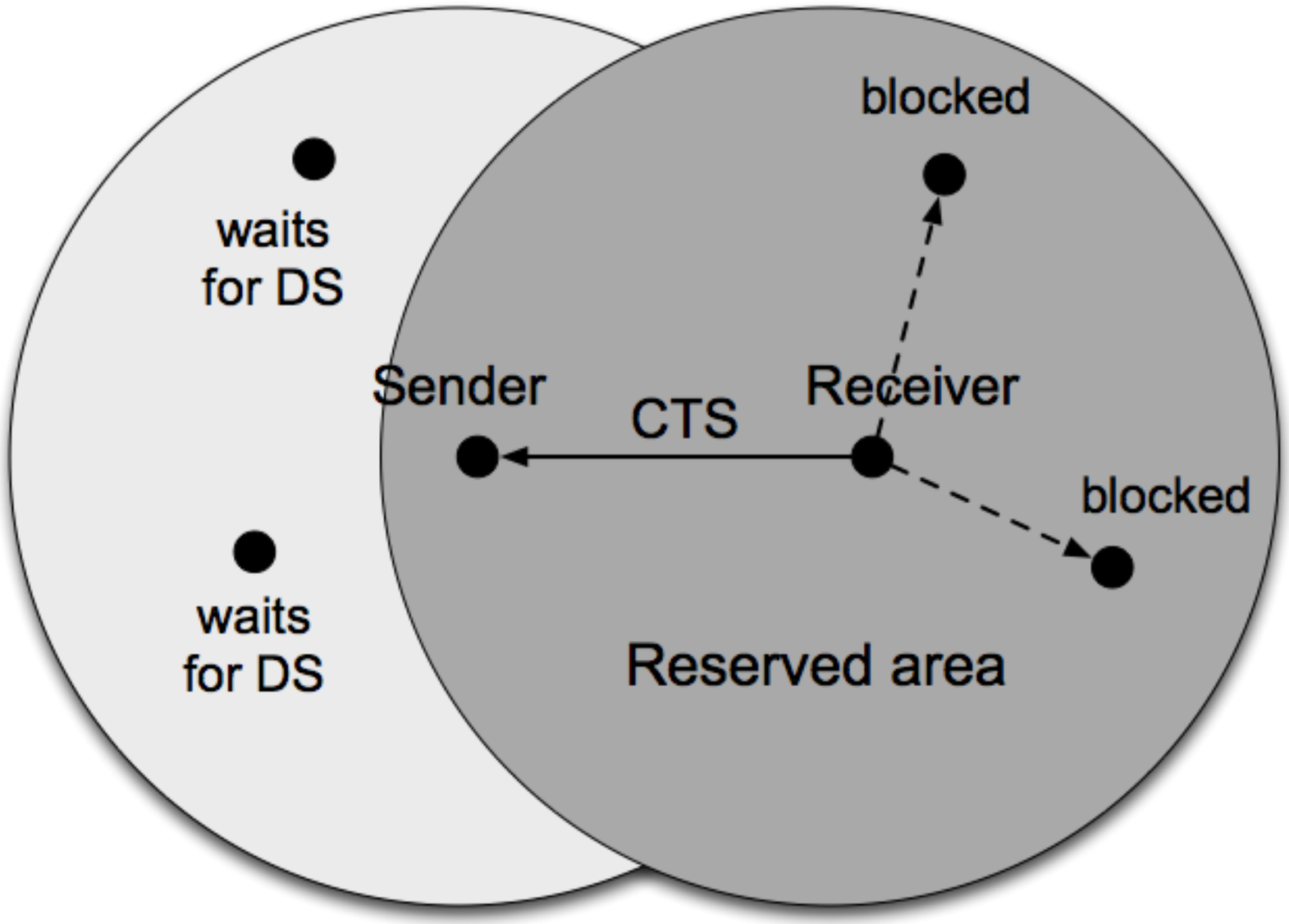
MACAW
5 Handshake

- Participants
  - Sender sends RTS
  - Receivers answers with CTS
  - Sender sends DS (Data Send)
  - Sender sends DATA PACKET
  - Receiver acknowledges (ACK)
- RTS and CTS announce the transmission duration
- Blocked nodes
  - have received RTS and DS
  - have received CTS
- Small effort decreases the number of exposed terminals

MACAW 5-Handshake
RTS

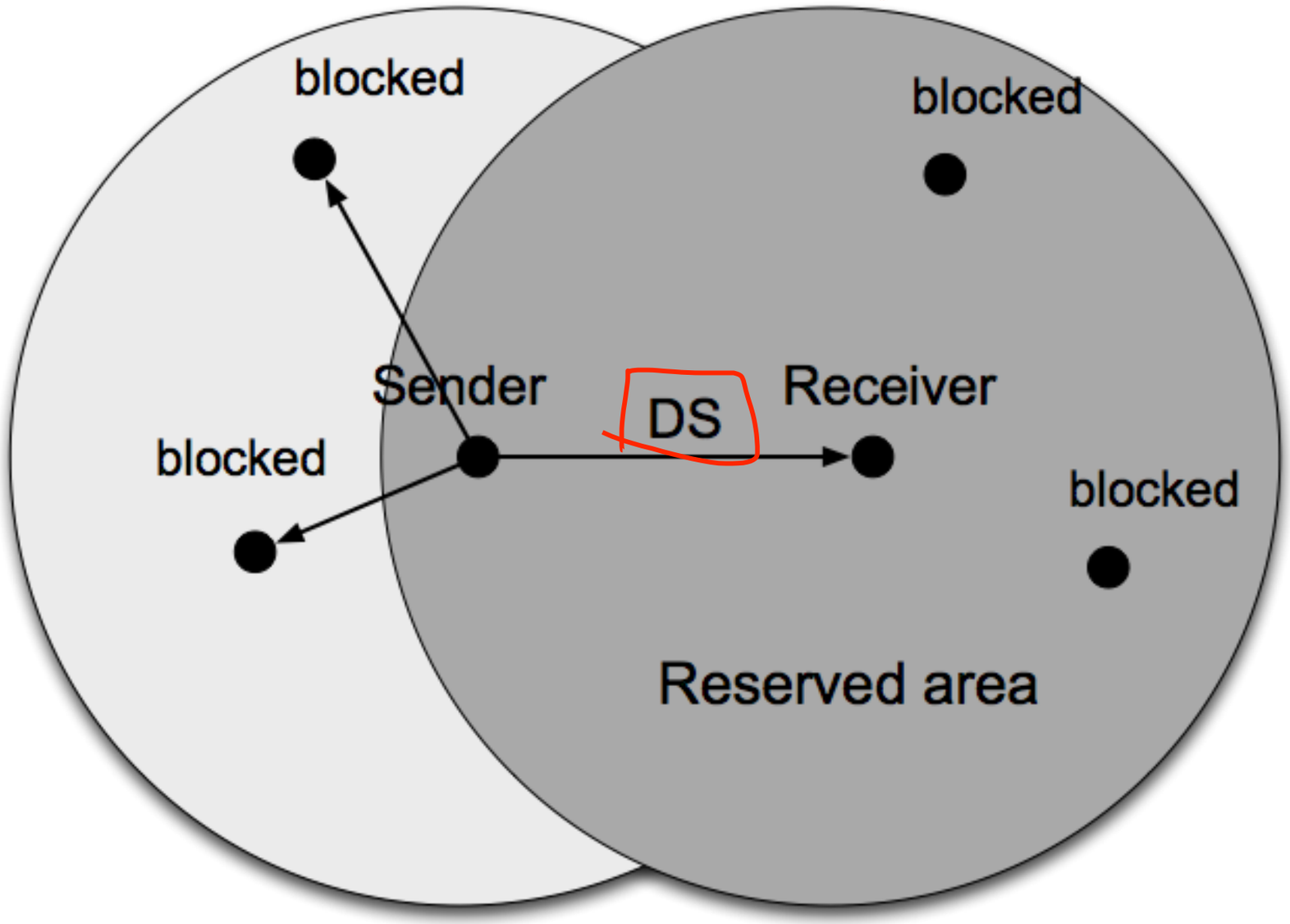


MACAW 5-Handshake
CTS

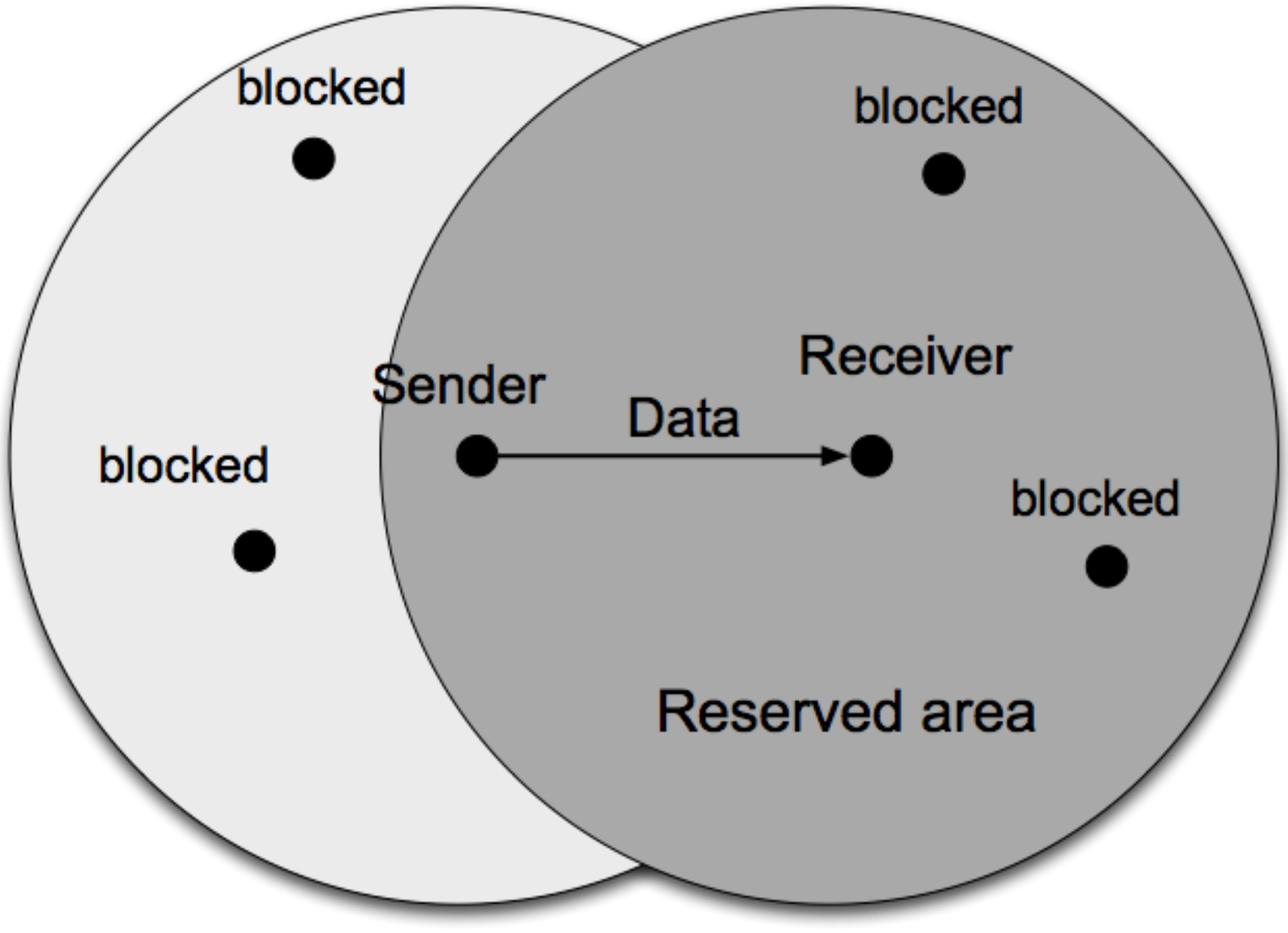


MACAW 5-Handshake

DS



MACAW 5-Handshake Data



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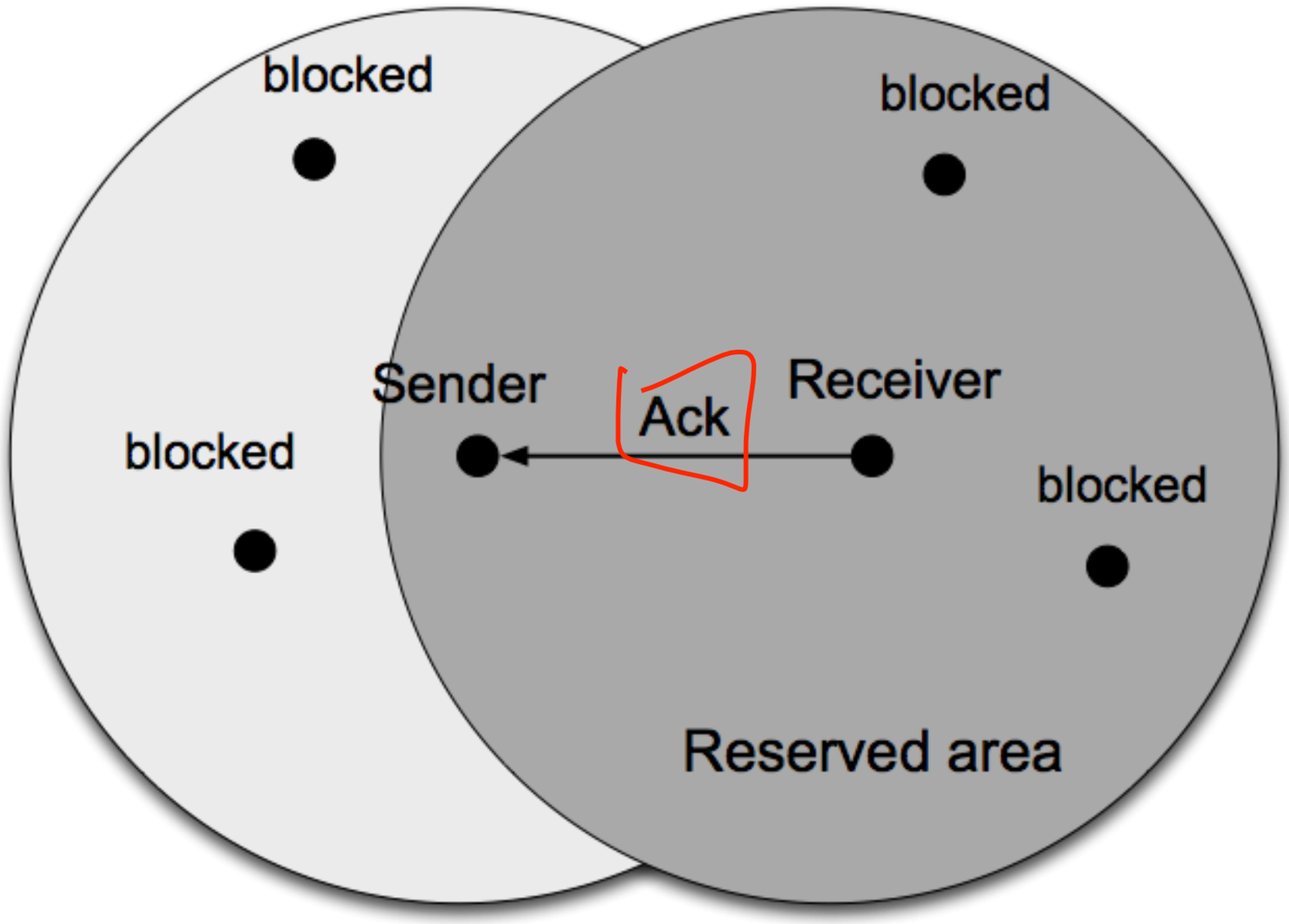
MACAW 5-Handshake ACK



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Unfair Distribution

- 4 and 5-Handshake create unfair distribution
  - A has a lot of data for B
  - D has a lot of data for C
  - C receives B and D, but does not receive A
  - B can receive A and C, but does not hears D
- A is the first to get the channel
- D sends RTS and is blocked
  - Backoff of D is doubling
- At the next transmission
  - A has smaller backoff
  - A has higher chance for next channel access