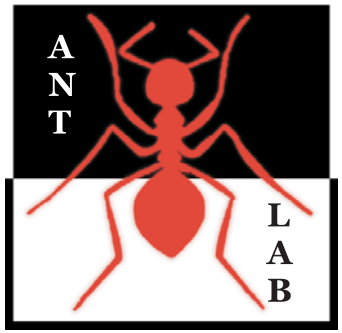

Advanced
Network
Technologies
Laboratory

ADHOC – MAC : a new, flexible and reliable MAC architecture for ad-hoc networks

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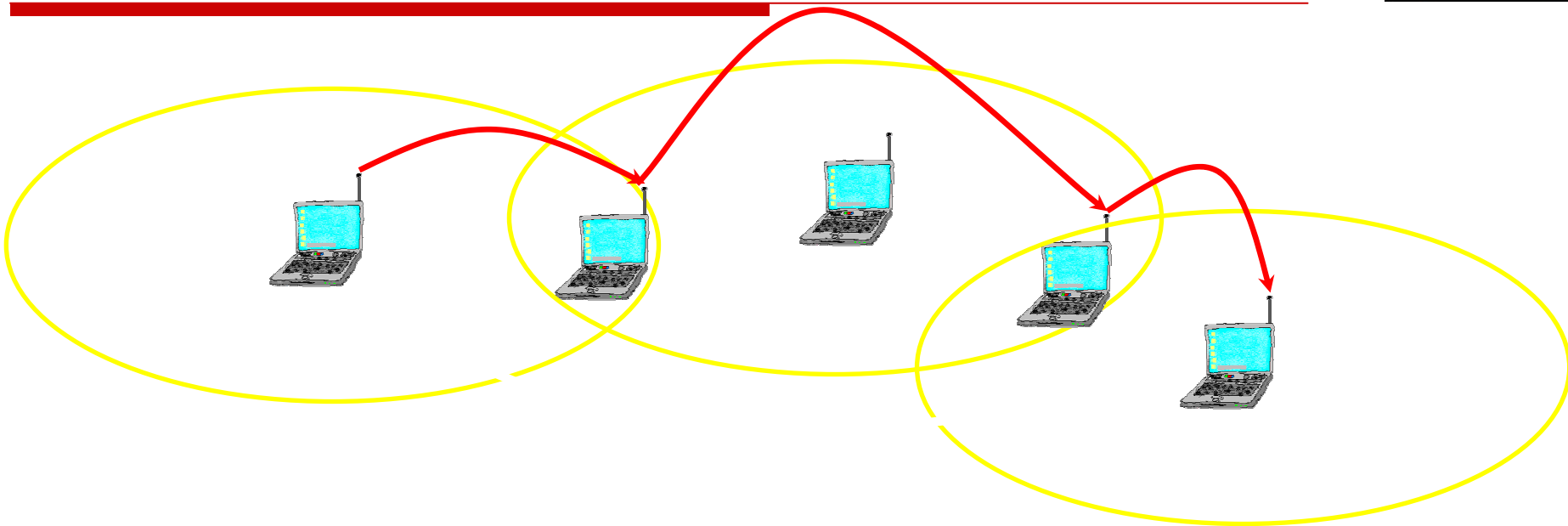
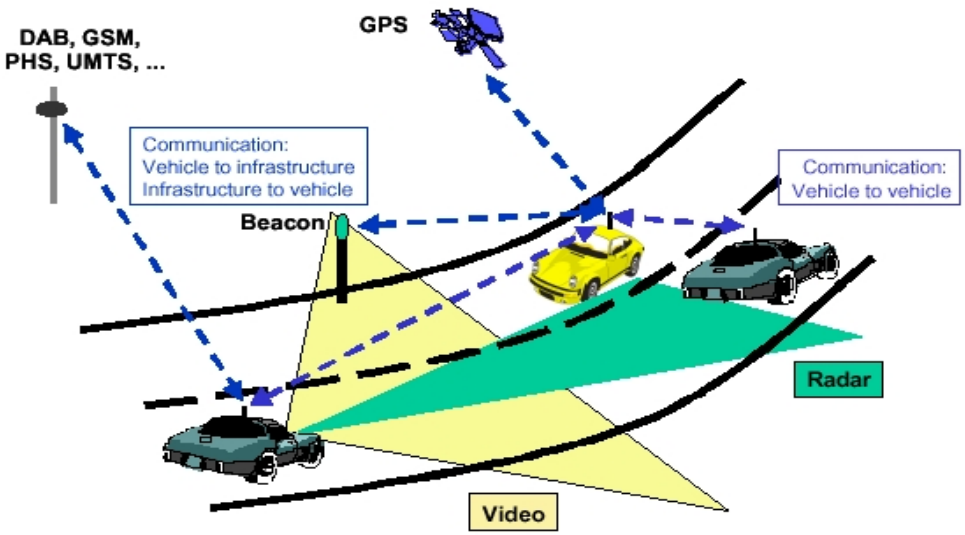
Politecnico di Milano

Ad-Hoc Networks



- No fixed infrastructure
- Limited propagation range
- Need for terminal relaying/routing

Inter-vehicles ad-hoc Networks

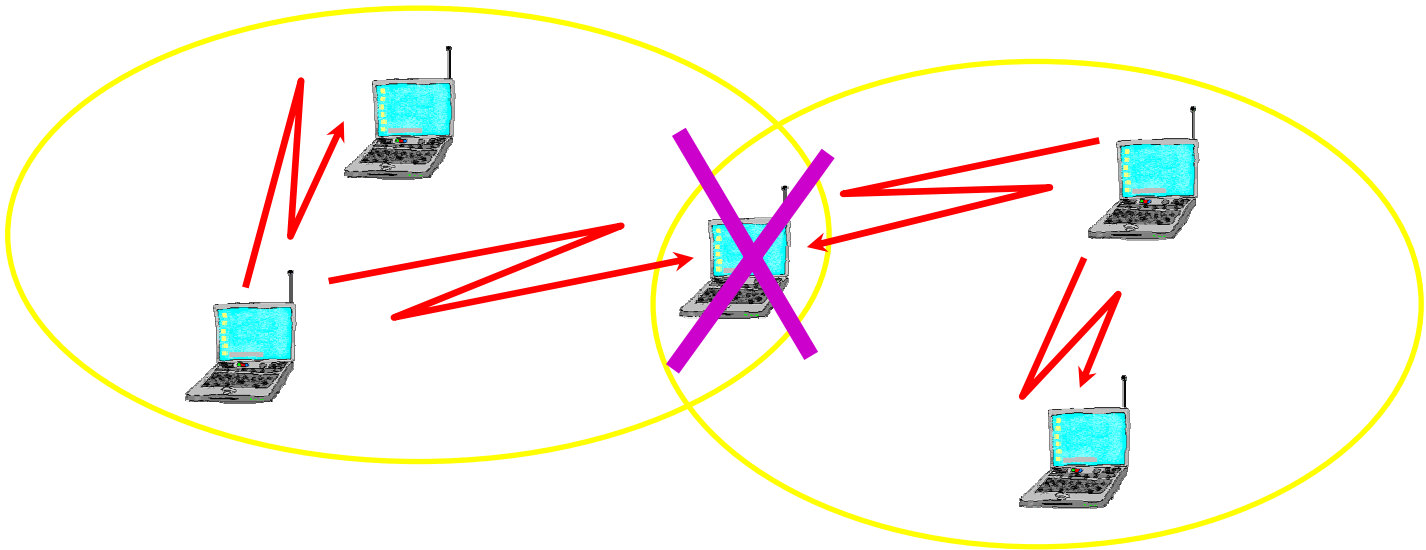


- Self sustaining networks
- No need of central control
- High Flexibility
- Effective MAC
- Robust Physical Level

- Application scenarios:
  - Traffic control
  - Entertainment
  - Internet access
  - Extension to backbone services

MAC problem: Hidden terminal

not completely solved by IEEE 802.11(CSMA/CA)

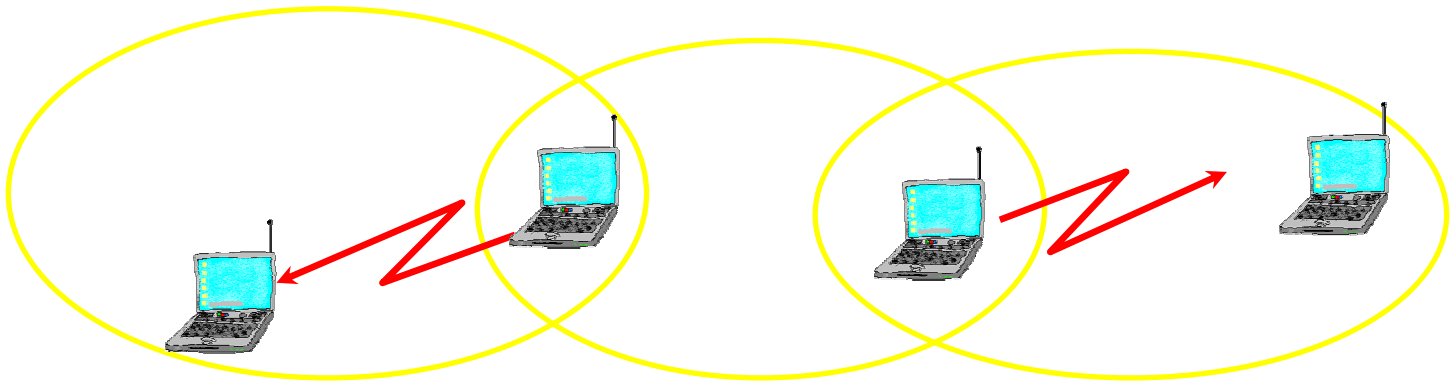


Impact on :

- radio access
- local broadcast

MAC problems: exposed terminal

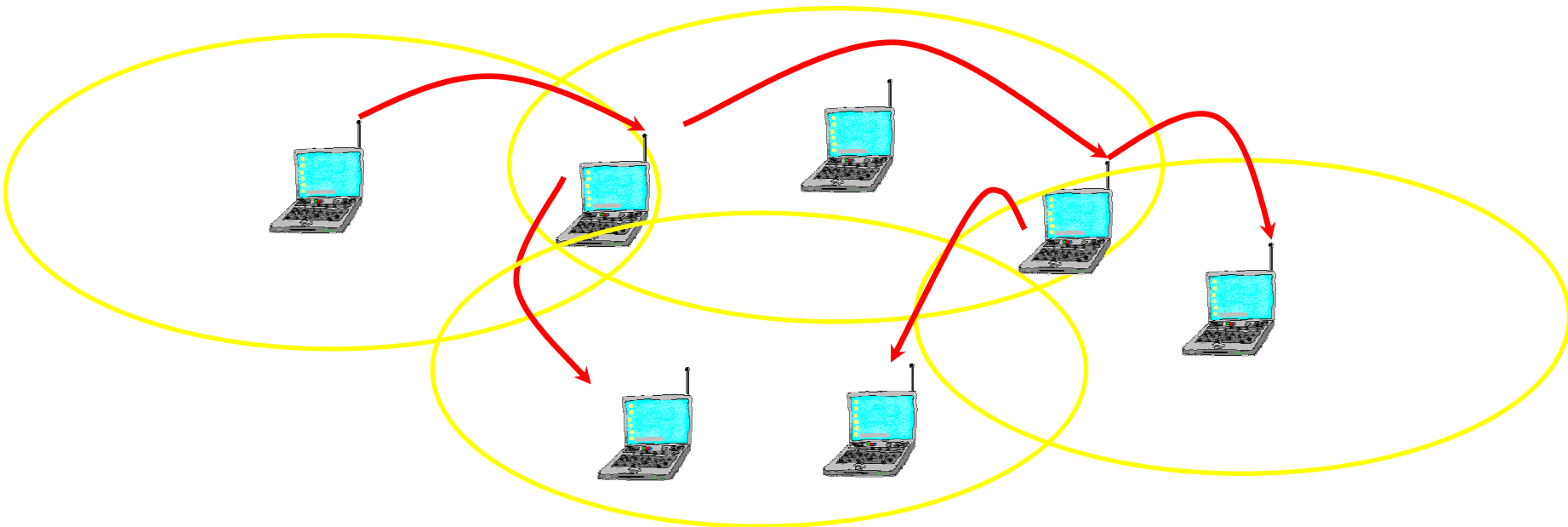
unsolved by IEEE 802.11 (RQS/CLS)



Impact on efficiency since parallel transmissions can be prevented

MAC problems: broadcast service

how to chose bridges



Tree-based protocols not applicable due to dynamic topology

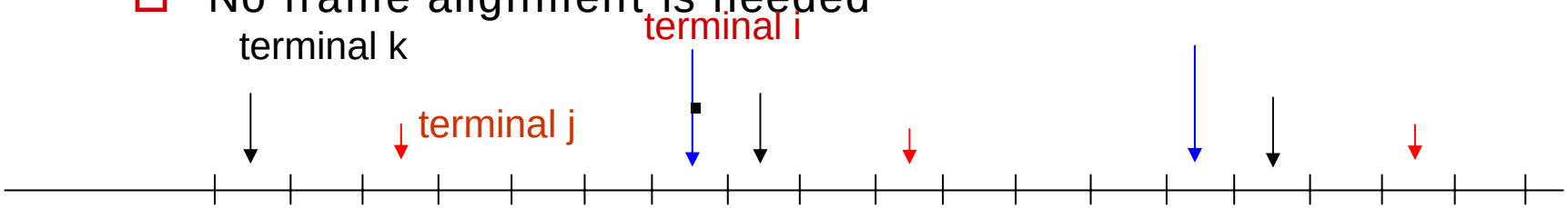
Flooding highly inefficient with high degree of connectivity (n transmissions instead of 1)

ADHOC MAC

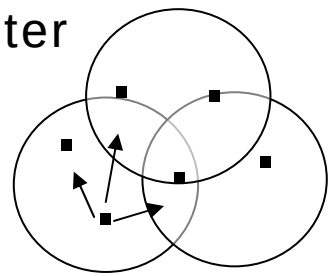
- **Features:**
  - Layer two connectivity information
  - Access to a reliable single-hop broadcast
  - QoS support for different applications
  - Efficient point-to-point communication (parallel transmissions)
  - Efficient multi-hop broadcast

ADHOC MAC

- Time slotted channel
- By external sources (GPS)
  - By first active terminal
- Basic Channel (BCH)
  - All active terminals periodically transmit channel status information
  - Slots are grouped into virtual frames (VF) of length N
  - No frame alignment is needed



- Transmissions are received by all terminals in one hop cluster

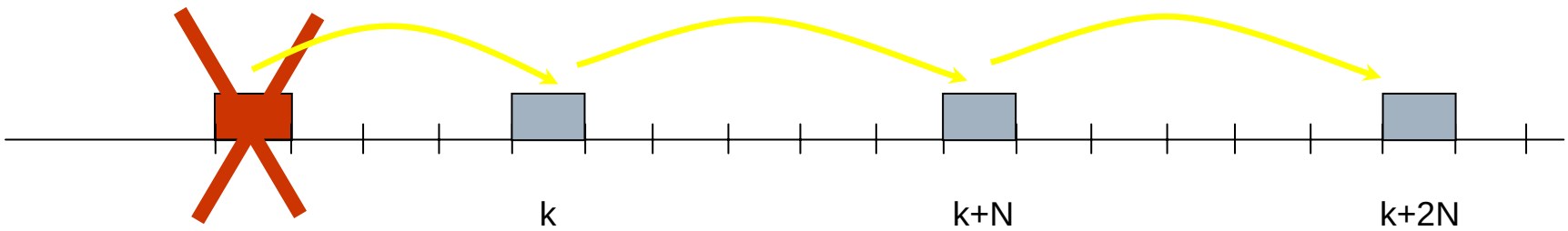


BCH is established by the **Reliable Reservation ALOHA** protocol

Reservation ALOHA

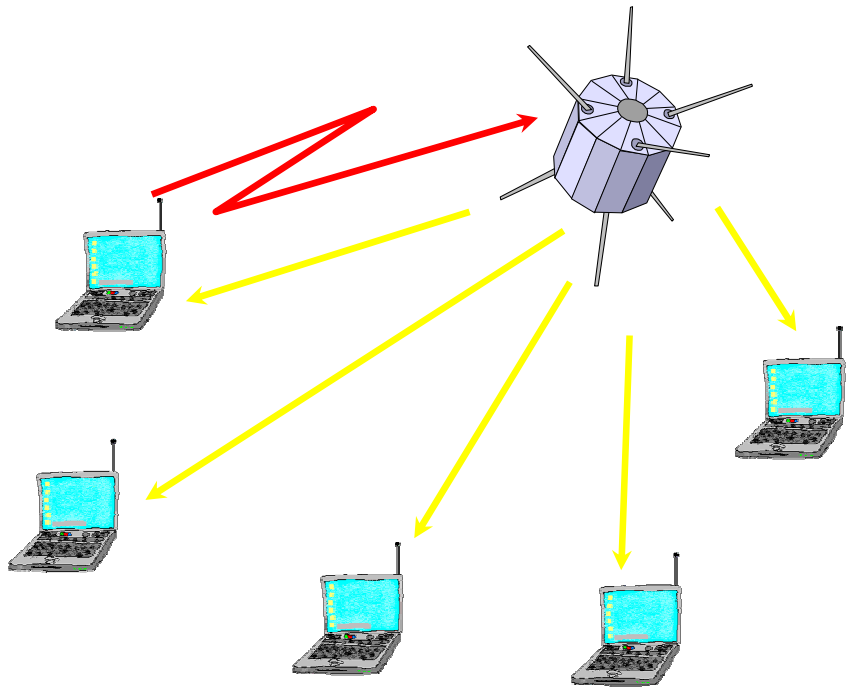
a distributed way to establish TDMA channels

a slot successfully captured is periodically reserved (every N slots) till released



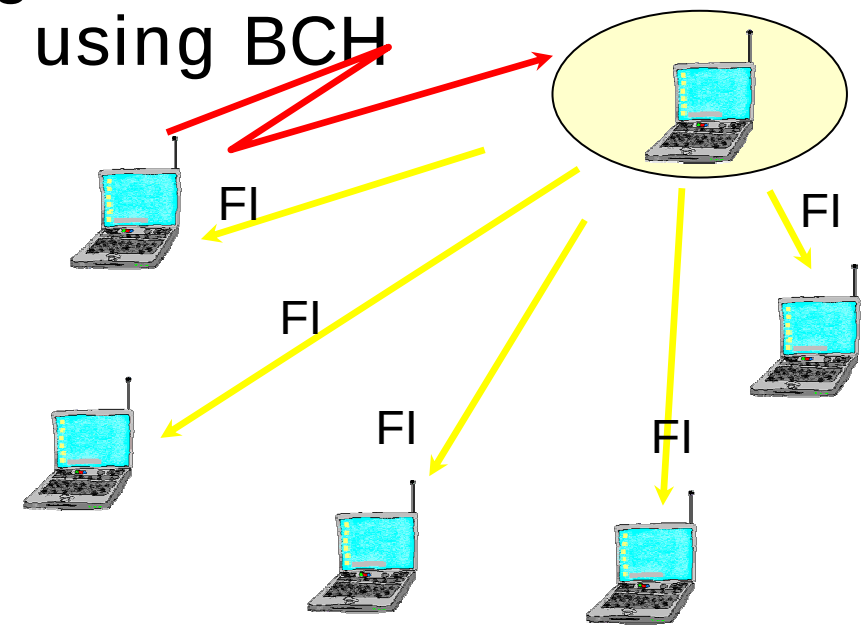
Reservation ALOHA

needs a centralized radio environment (full broadcast) so that all terminals "see" the same slot status: busy, free, collided



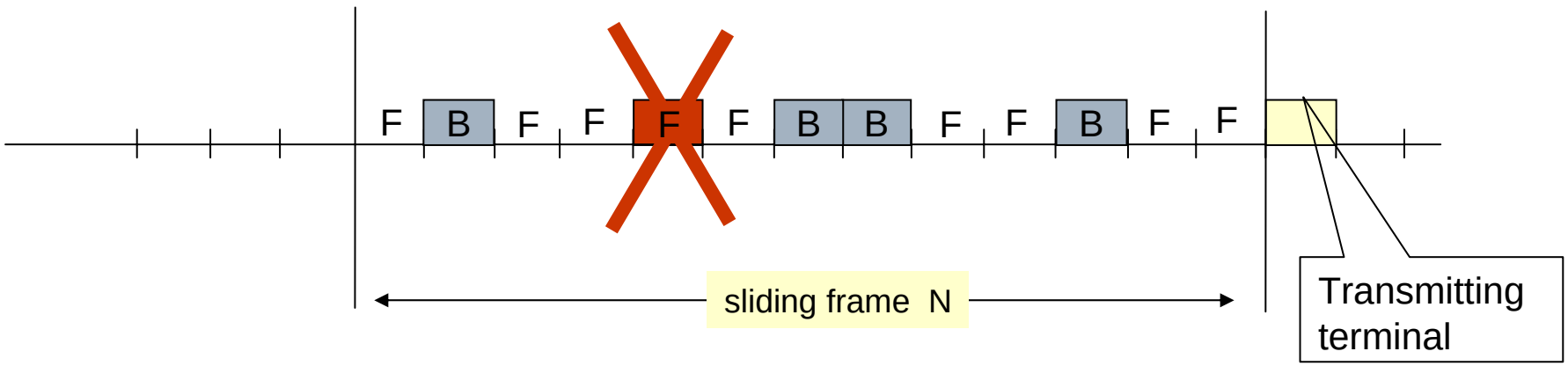
Reliable Reservation ALOHA

- operates in a distributed radio environment with limited broadcast capability (hidden terminals, interference, no ACK)
- each terminal propagates slot status information (Frame Information) using BCH

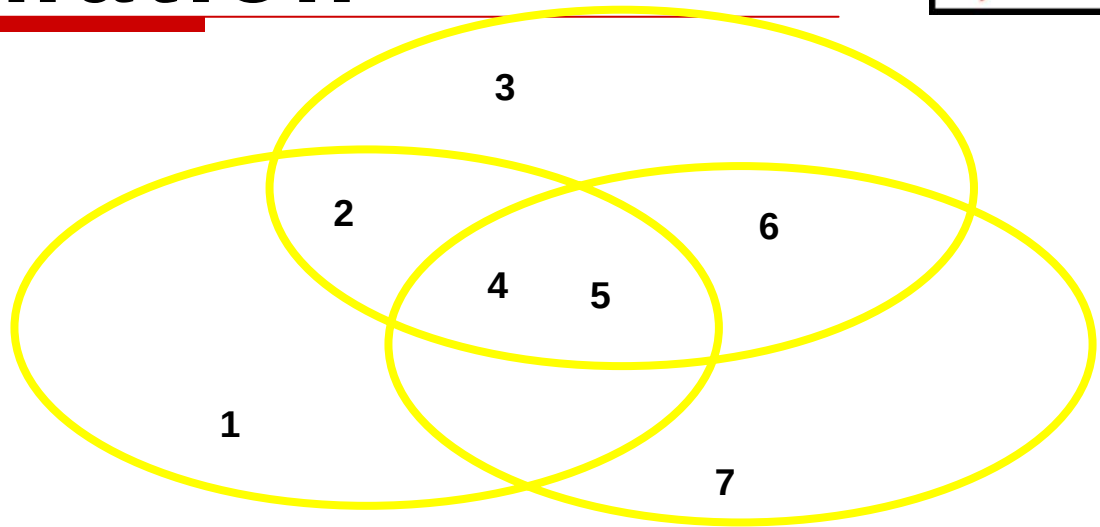


Reliable Reservation ALOHA

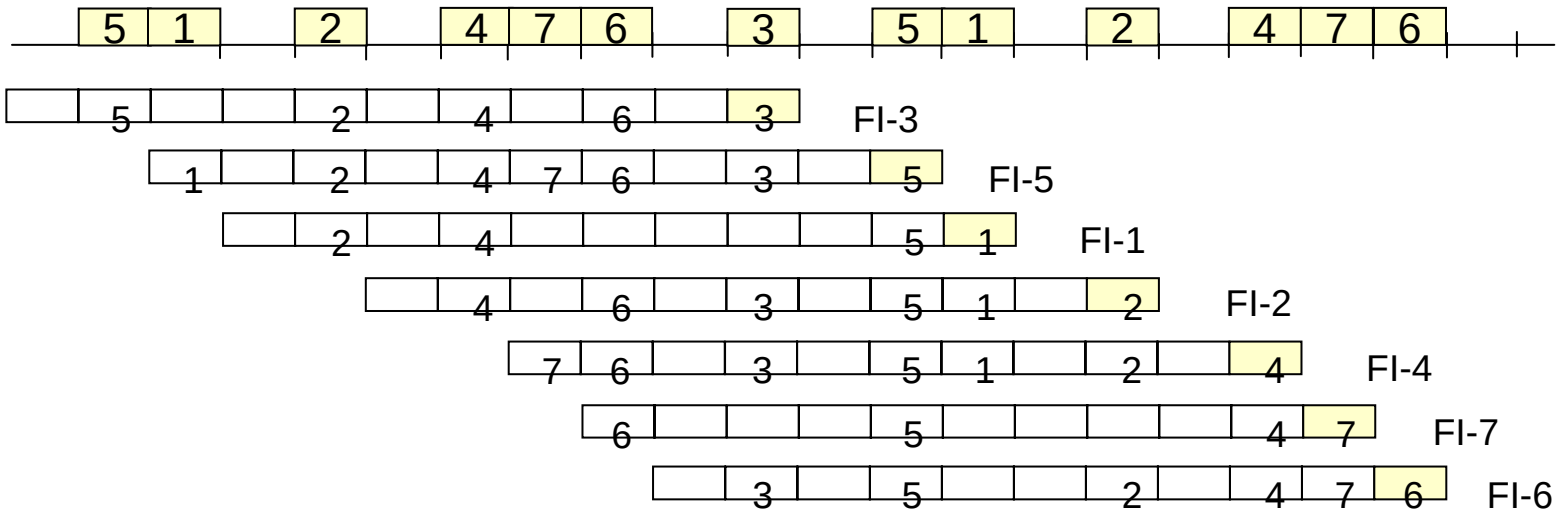
- all active terminals transmit the **Frame Information** every N slots (frame)
- FI specifies the status of the previous N slots (Sliding Virtual Frame) as observed by the terminal
  - BUSY correct transmission
  - FREE no transmission or collision



RR-ALOHA : Frame Information

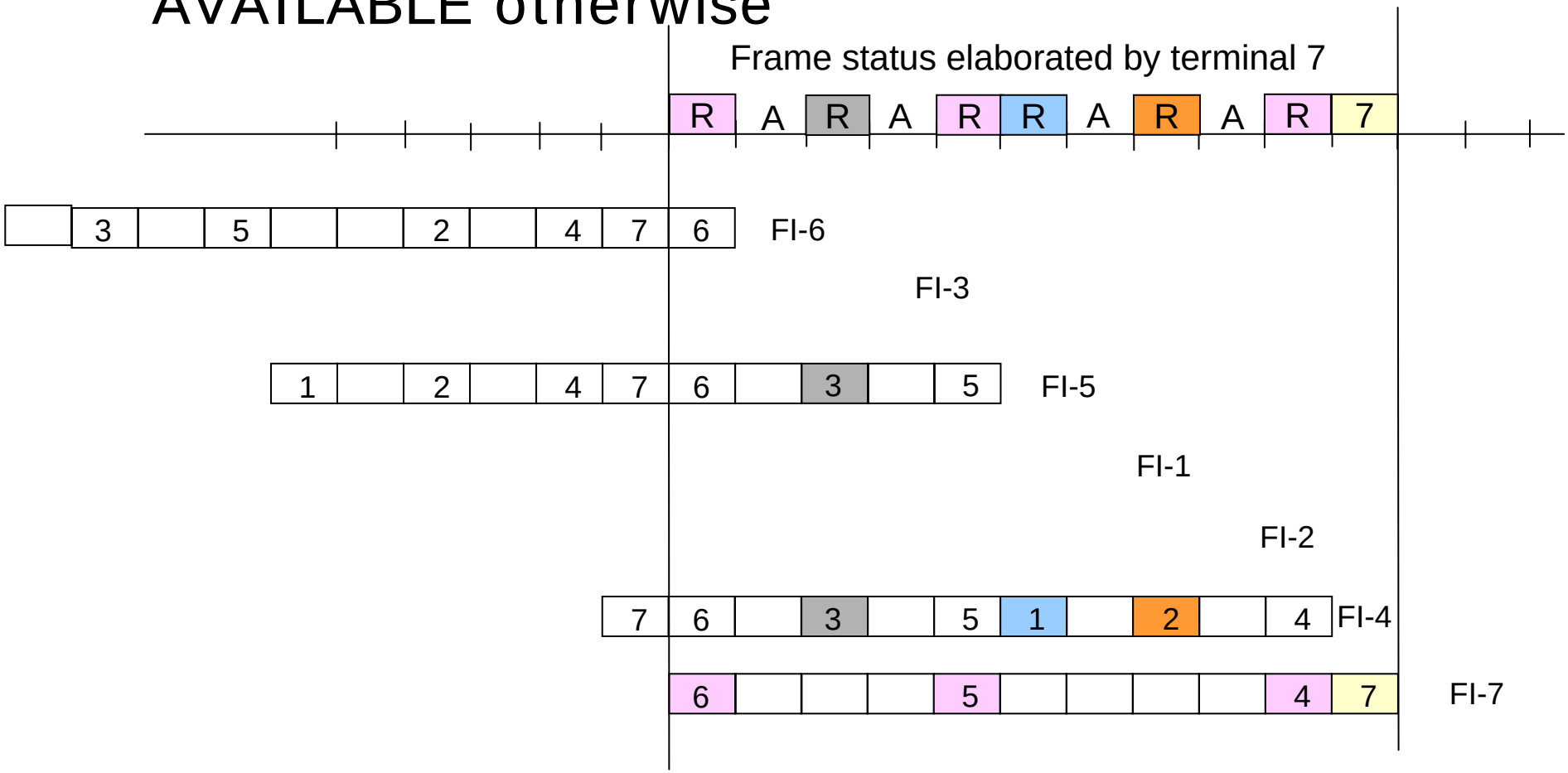


Transmissions



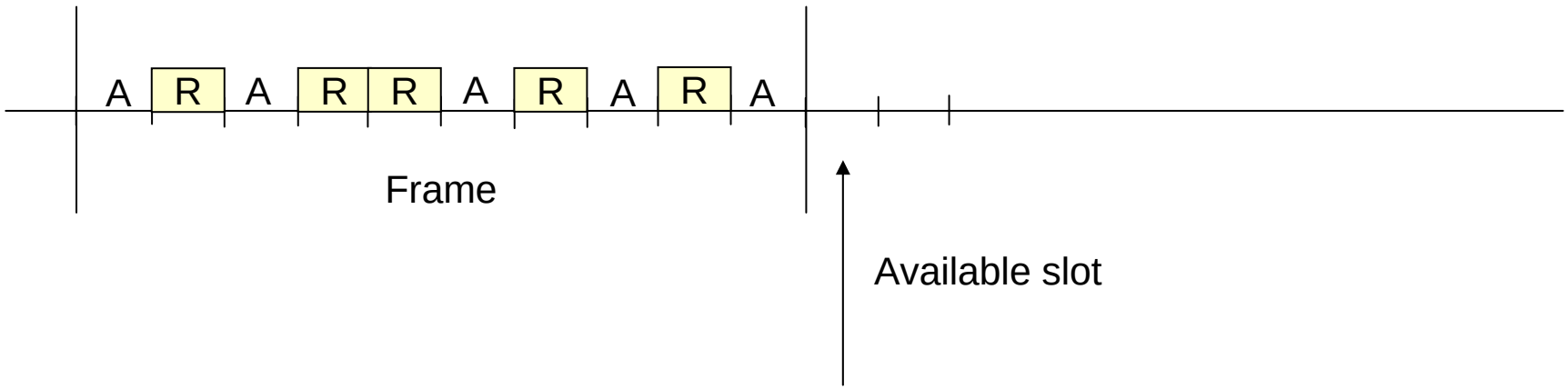
RR-ALOHA : slot status

RESERVED if at least one FI says “BUSY”
AVAILABLE otherwise



RR-ALOHA : access

- AVAILABLE slots can be used:
  - by a new active terminal (as in R-ALOHA)
  - by an already active terminal to increase its transmission bandwidth
- No Hidden-Terminal problem

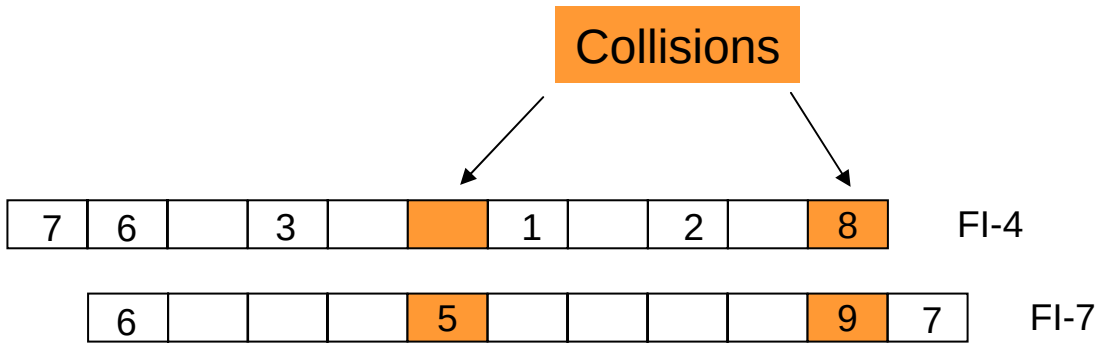


RR-ALOHA : access

The ID of the slot “owner” must be included in the FI

The transmission is successful if

- the slot is coded as BUSY with the same station ID in all the received FI



RR-ALOHA : access

One terminal attempting access:

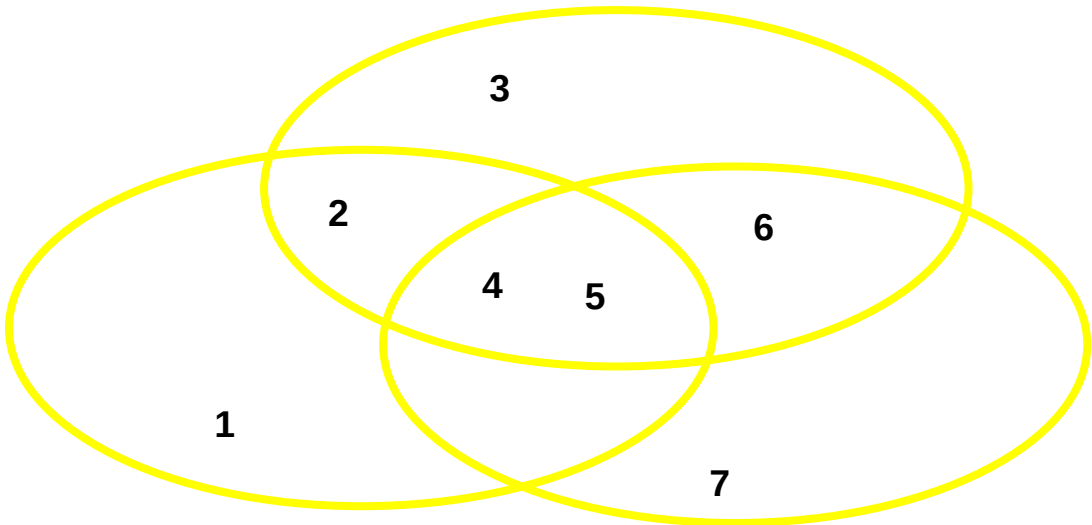
- All terminals in the same cluster recognize the transmission.
- All FI will code the slot as BUSY.
- All other terminals will receive FI with the slot as BUSY.
- The slot is declared RESERVED.

More terminals attempting access:

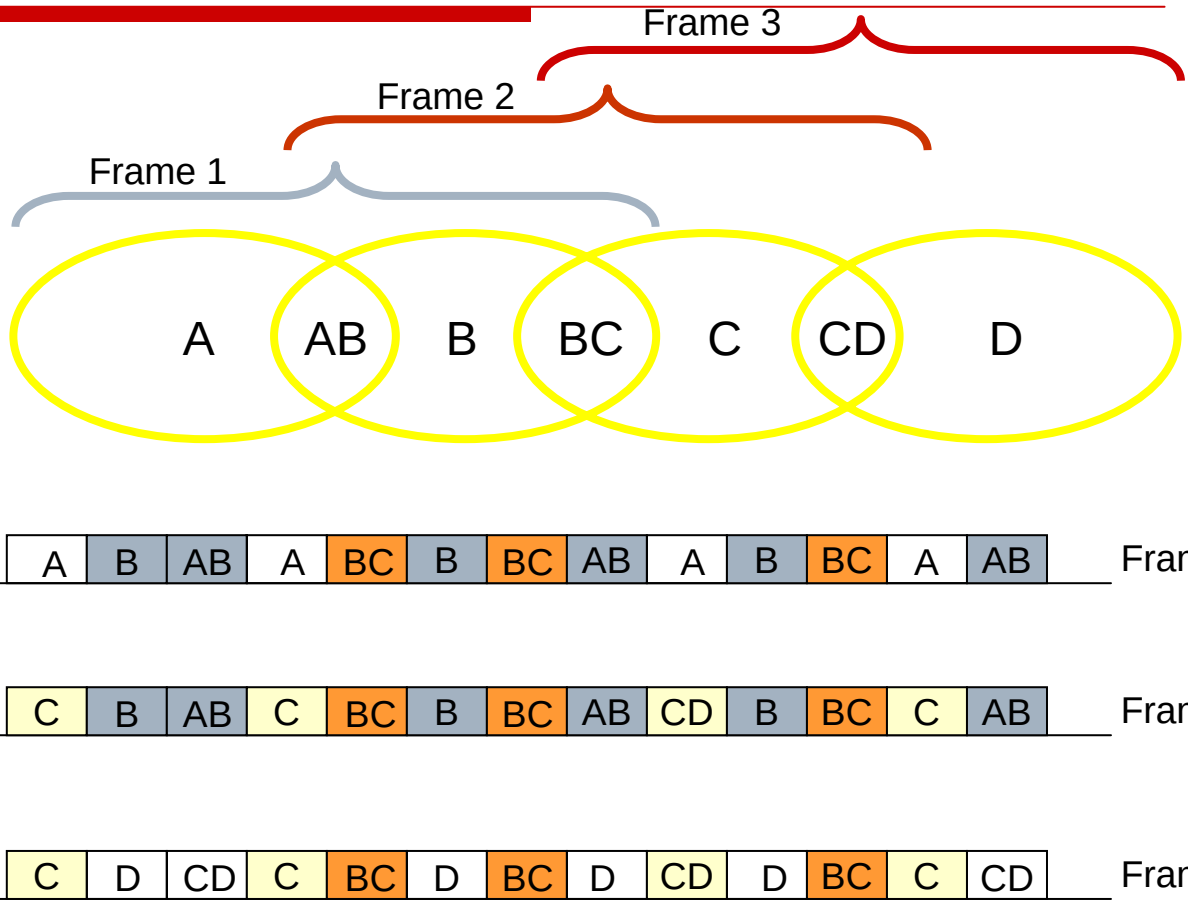
- The terminal recognizing collision codes the slot as FREE.
- The slot remains AVAILABLE.

RR ALOHA : common frame

- a unique frame is established among non disjoint radio broadcast domains based on FIs transmitted by nodes in common



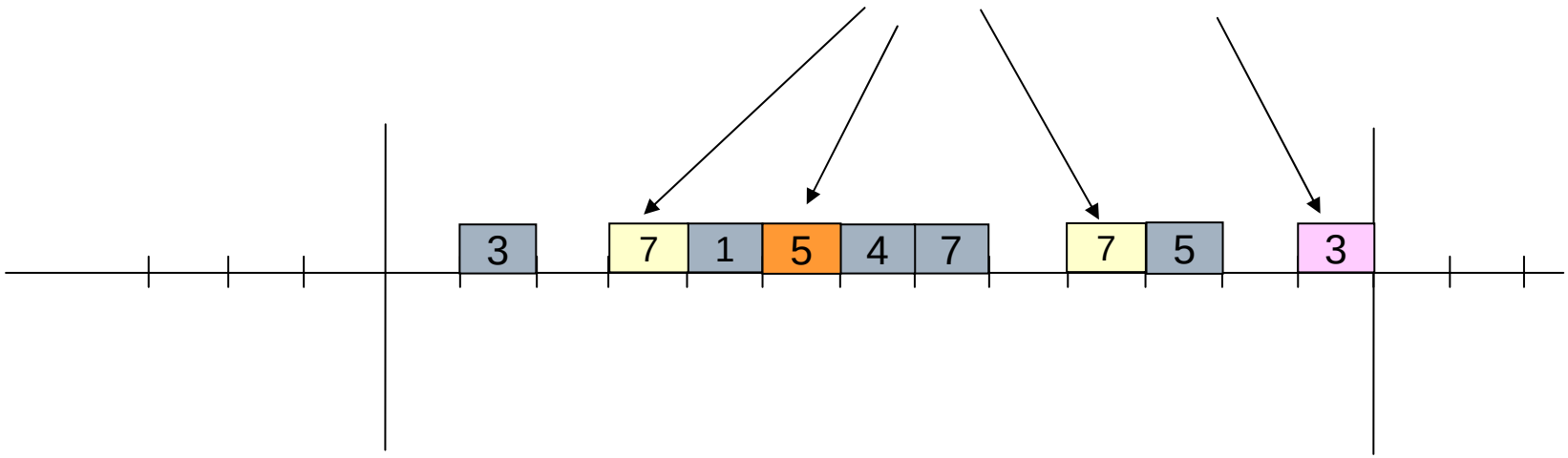
RR ALOHA : slot reuse



23 transmissions in 13 slots

Reserving additional bandwidth

- Each active station sets up and manages a BCH
- Payload can be transmitted in the BCH slots
- Additional available slots can be reserved for increasing transmission bandwidth (**additional channels**)



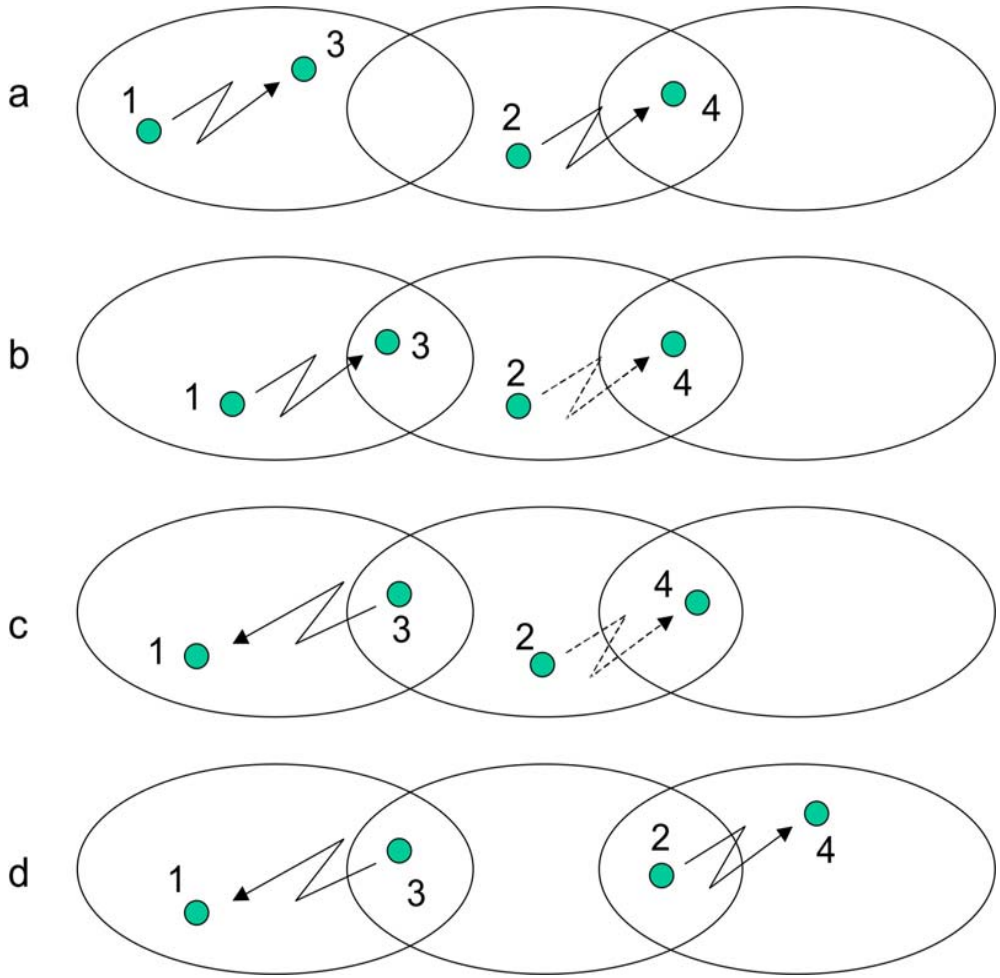
Reserving additional bandwidth

- Using RR- ALOHA procedure on the AVAILABLE Slots
- Using estabilished BCH.
  - New channel requests are signaled
  - Possibility of priority management
  - FI guarantees reservation collision detection

ADHOC MAC : Point-to-point channels

- To exploit slot reuse in the same or adjacent clusters (parallel transmissions)
- PTP flag is needed in the FI for each slot
- PTP flag is set by a terminal if:
  - The packet received is broadcast or
  - The packet is destined to the terminal itself
- A reserved slot can be accessed if:
  - The PTP flag is off in all received FI and
  - The FI received from the intended destination marks the slot FREE
- Due to concurrent access attempts: the transmission is successful if the slot is coded as BUSY in the FI of the destination terminal.

ADHOC MAC : Point-to-point channels



ADHOC MAC : Multi-hop Broadcast service

C_i the set of neighbors of i

$S_i \subseteq C_i$ the subset of neighbors that have not received the broadcast packet in slot k

from FIs

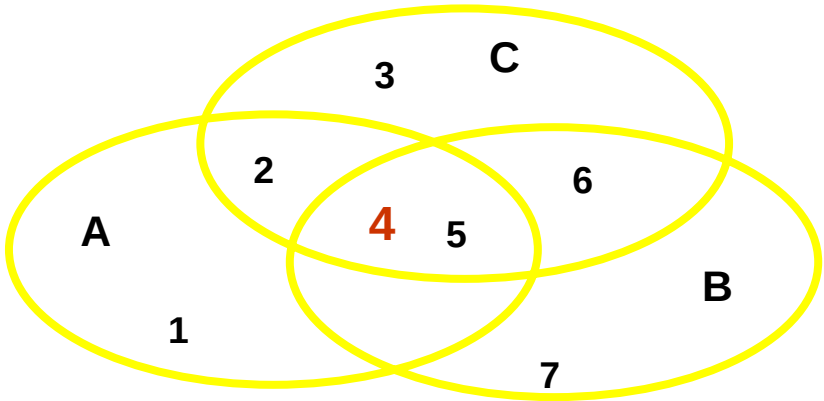
Terminal *i* relays the broadcast packet received in slot k if

$$|S_i| > 0$$

and the following condition is **not** satisfied for all *j*

$$S_i \subseteq C_j \text{ AND } \left\{ |C_j| > |C_i| \text{ OR } \left\{ |C_j| = |C_i| \text{ AND } ID_j > ID_i \right\} \right\}$$

Multi-hop Broadcast mechanism



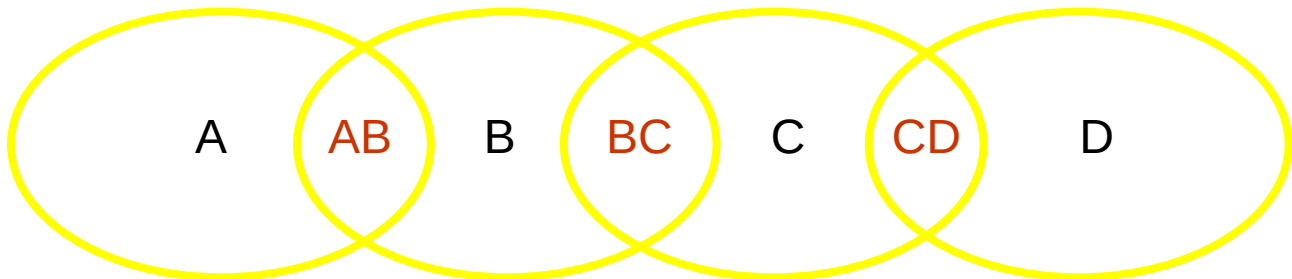
for j in ABC

$S_i \subseteq C_j$ satisfied

$|C_j| > |C_i|$ satisfied if i not in ABC

$|C_j| = |C_i|$ if i in $ABC \Rightarrow$ LowestID

One terminal for each set AB, BC and CD is elected as relay terminal

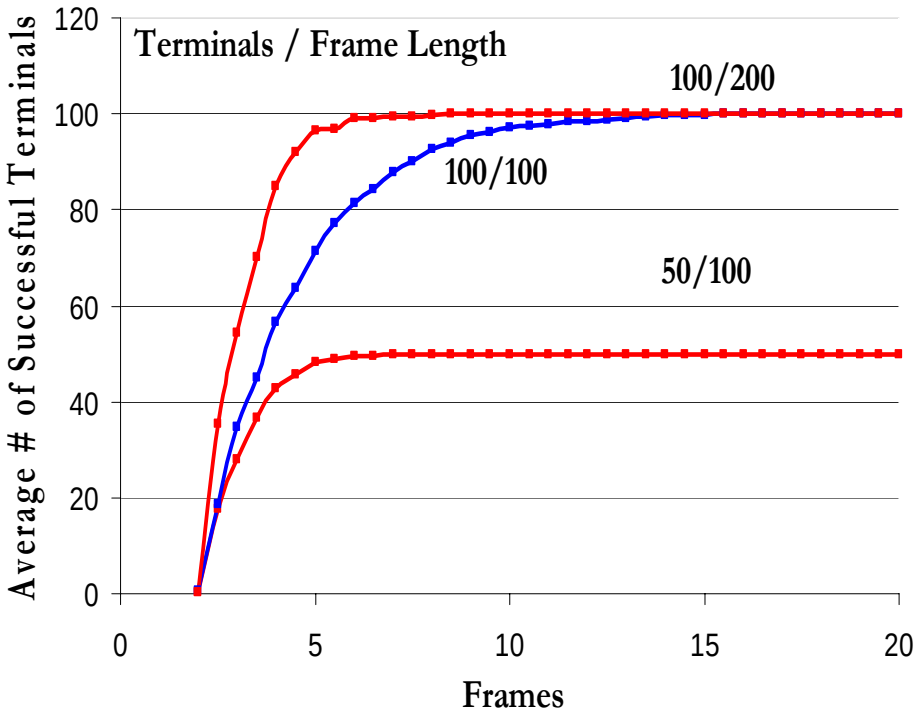


Simulation Analysis

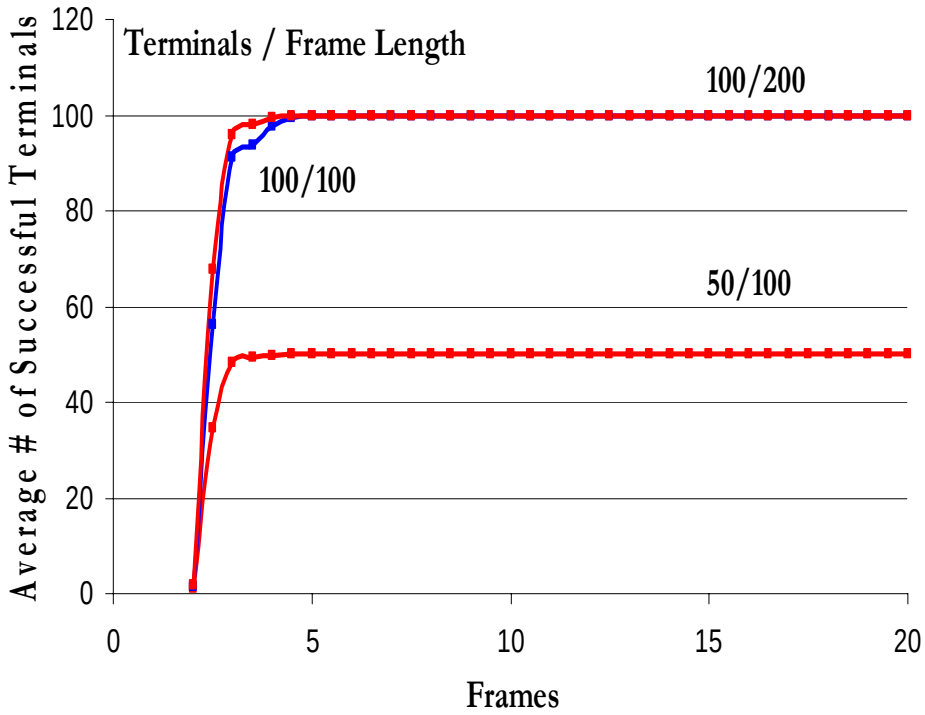
- Fixed Radius (r parametric)
- Uniform Power
- 1Km^2 Square Area
- Poisson distributed users (G parametric)

Access Delay

r = 1000 m

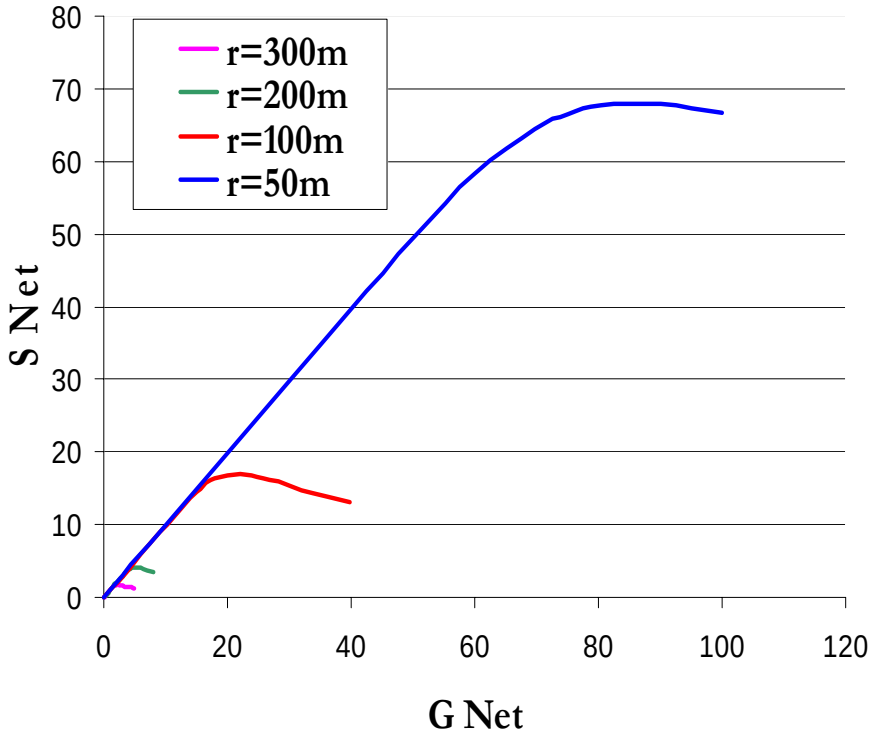


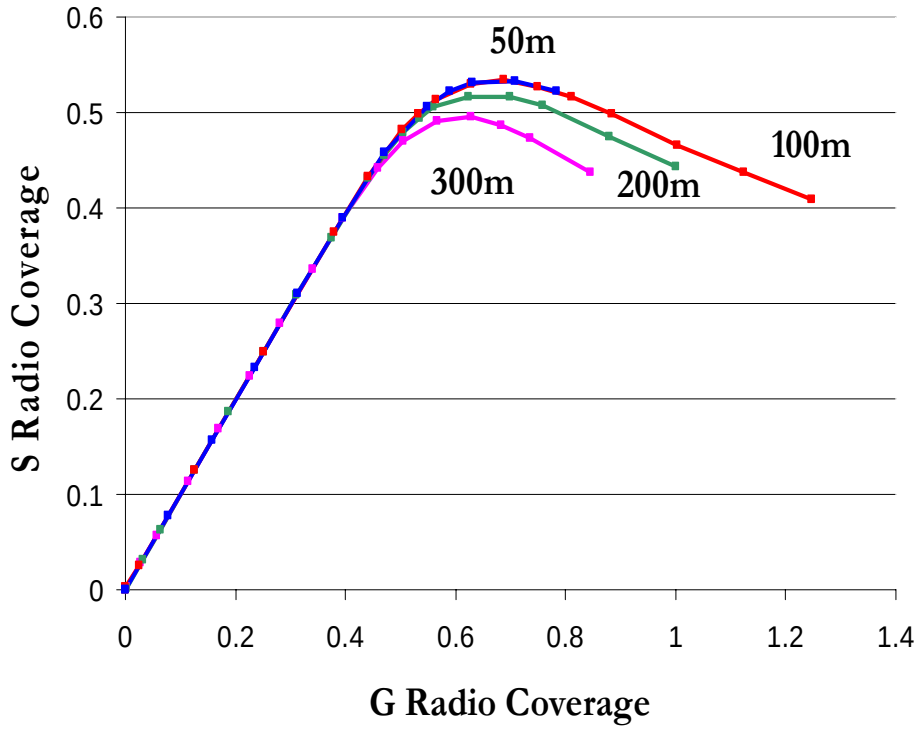
r = 100 m



- **Very prompt access**
- **With slot reuse the access delay is even lowered**

Single Hop Broadcast Performance



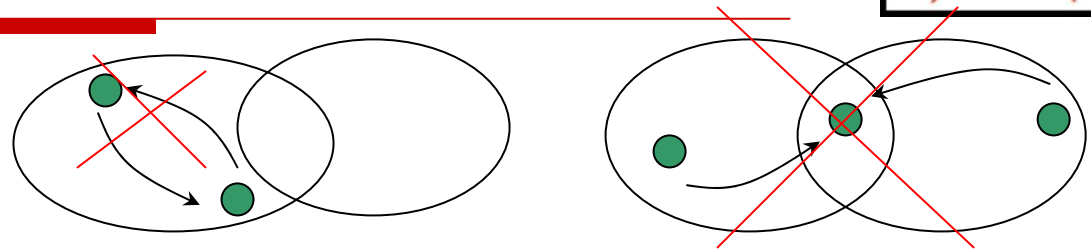


THROUGHPUT LIMITING FACTORS

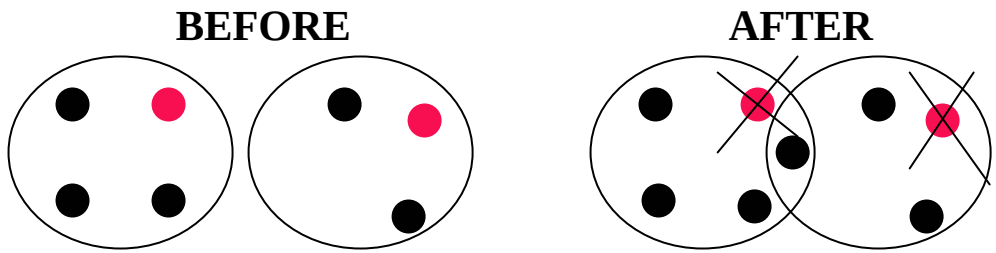
- Collisions due to access and clusters' fusion
- Spatial reuse

Throughput Limiting Factors

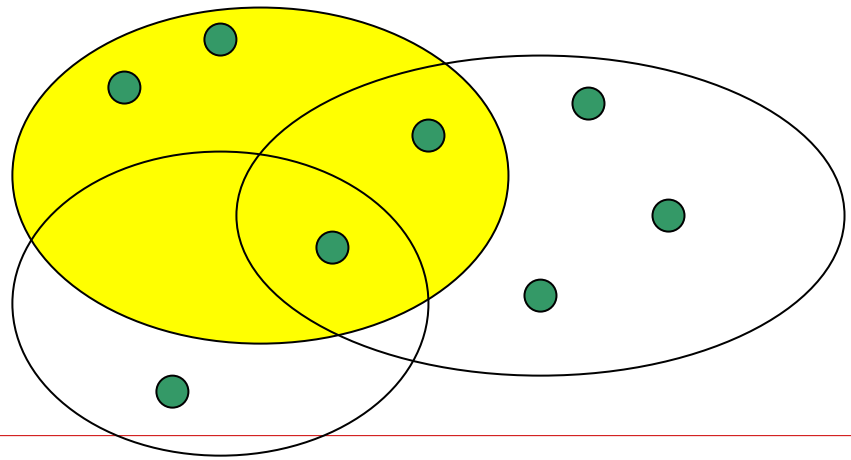
- **COLLISIONS**
  - **ACCESS**



  - **CLUSTERS' FUSION**

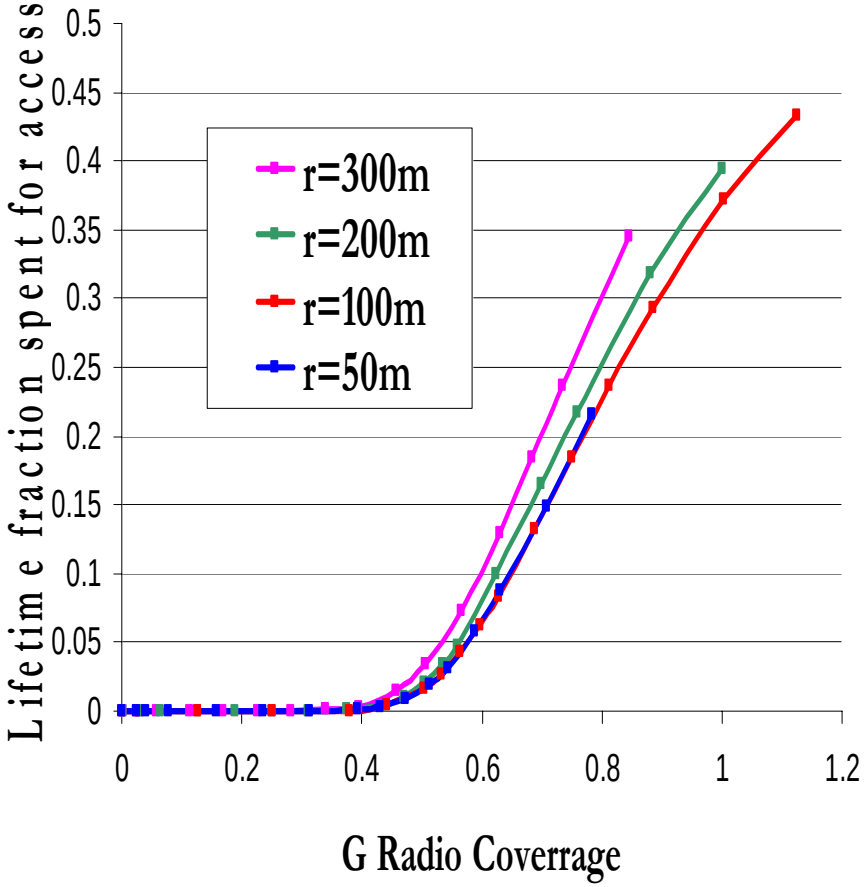


- **SPATIAL REUSE**

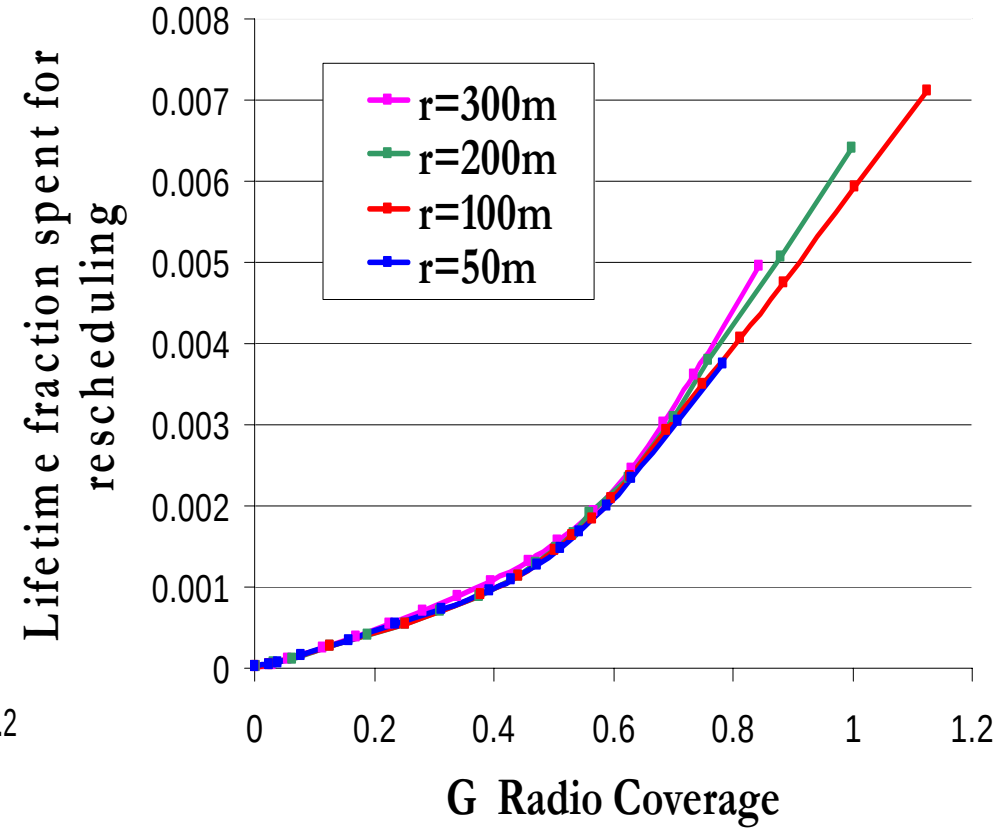


Collisions

ACCESS COLLISIONS

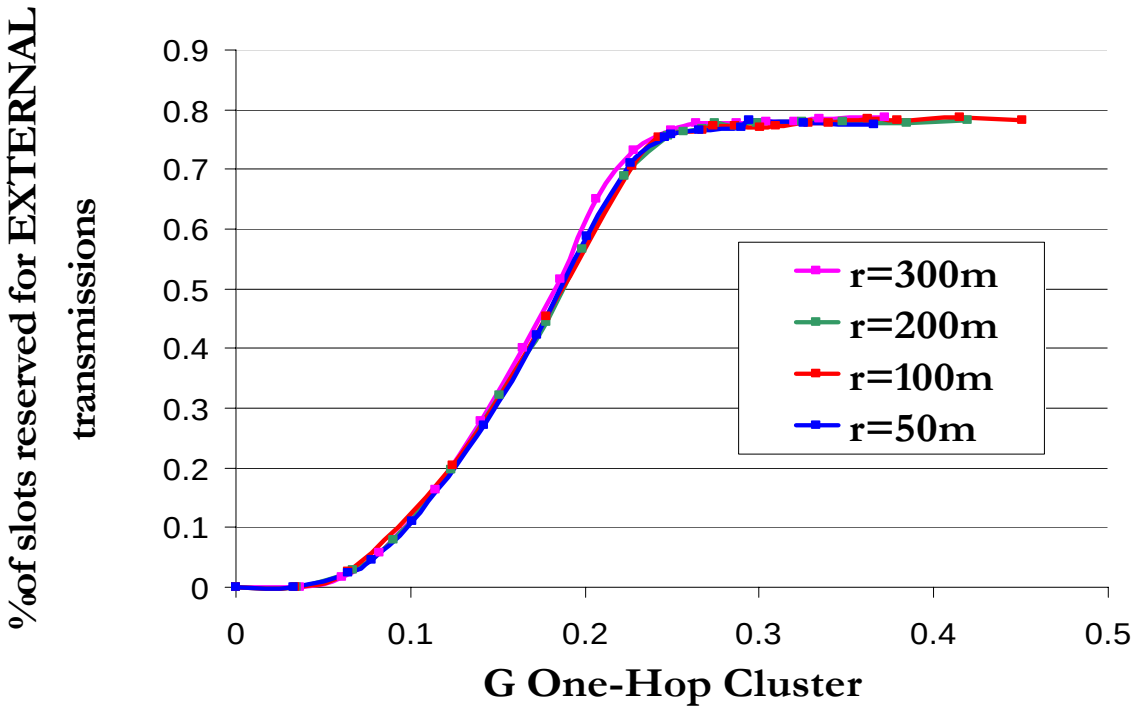


FUSION COLLISIONS



Spatial Reuse

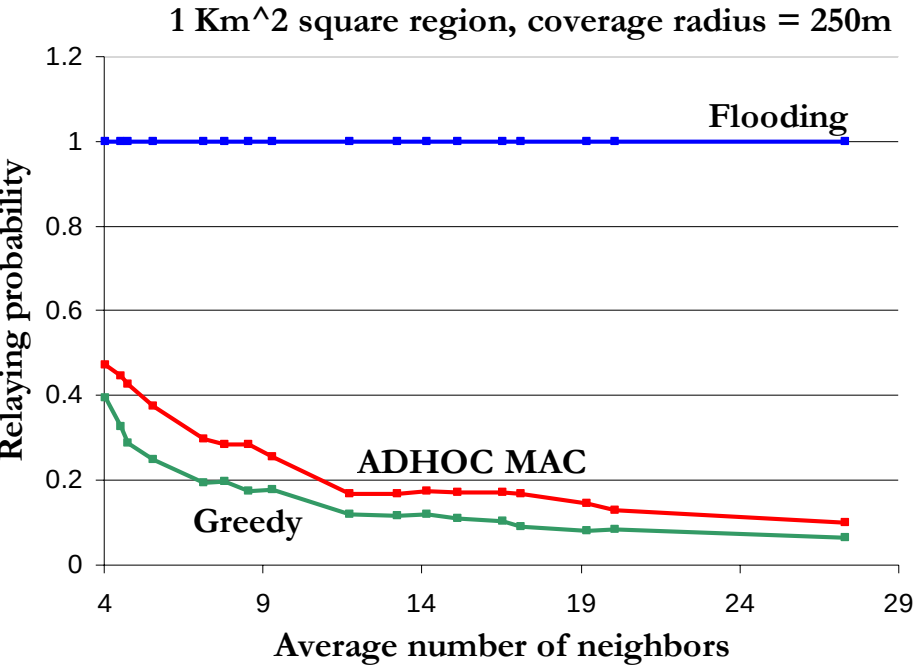
- Not all the slots within a OH cluster can be used for internal transmissions
- The hidden terminal problem is solved but spatial reuse is lowered

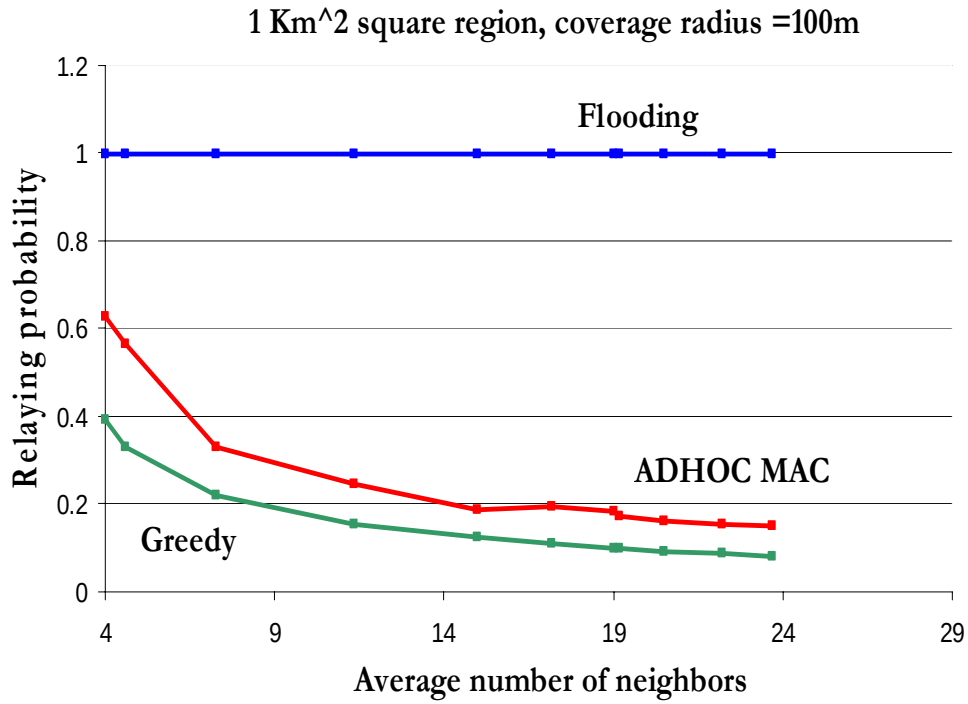


Broadcast Multi Hop

- Flooding
- ADHOC MAC
- Centralized Greedy

For high connected topologies ADHOC spares 80% of relaying transmissions with respect to flooding





Conclusions

PROs

- Suitable for highly variable ad-hoc net environment
- Fast access to a reliable single-hop broadcast
- Provision of different QoS according to applications needs
- Parallel transmissions for point-to-point communications
- Efficient multi-hop broadcast

CONs

- High overhead (25%)
- Power saving is jeopardized by the need for the BCH