

# Neighbor Discovery in wireless (sensor) networks

Presented by:  
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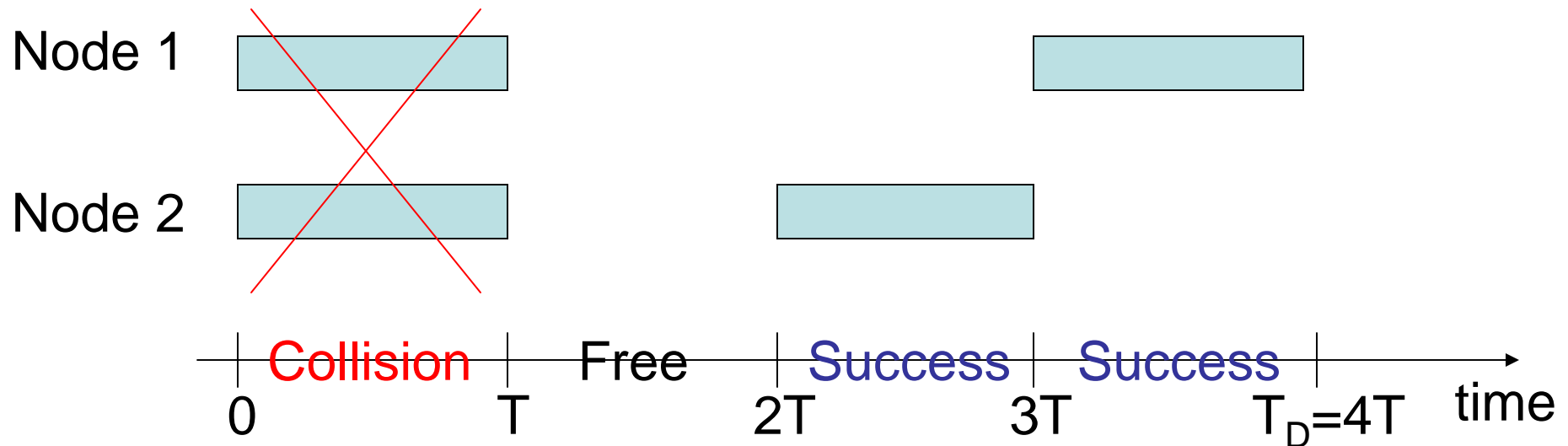
# Neighbor Discovery

- Determination of all nodes a given node may communicate directly
- First step in self-organization process of a ad-hoc network
- Essential for routing & medium-access protocols
- Important enabler of Network connectivity and energy conservation

# Rapid discovery

- Nodes discover their neighbors as quickly as possible
  - Energy efficiency
  - Other protocols quickly start their execution
- Goal: maximize discovery probability of neighbors ( $P_D$ ) within a given amount of time ( $T_D$ )

# Classic algorithms



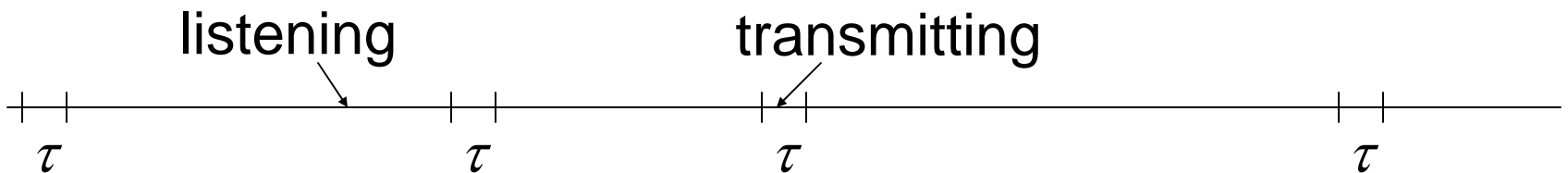
- Transmits with probability  $p_T$  & listens with probability  $(1-p_T)$
- Finding optimum  $p_T$  to maximize  $P_D$ :
  - $P_D=1/N$ ;  $N$ =number of nodes in network

# Assumption I

- N is known a priori
- Using an estimation of N:
  - Under-estimate: more collision
  - Over-estimate: more free slots
- Estimating N using collision information?
  - Can be also useful when N is not fixed
  - Addition of new nodes

# Assumption II

- Nodes are synchronized
- Suddu et *al.*: asynchronous algorithm
  - Listen intervals: exponentially distributed with rate  $\lambda$
  - Transmission duration:  $\tau \approx 0$
- Twice time for same  $P_D$



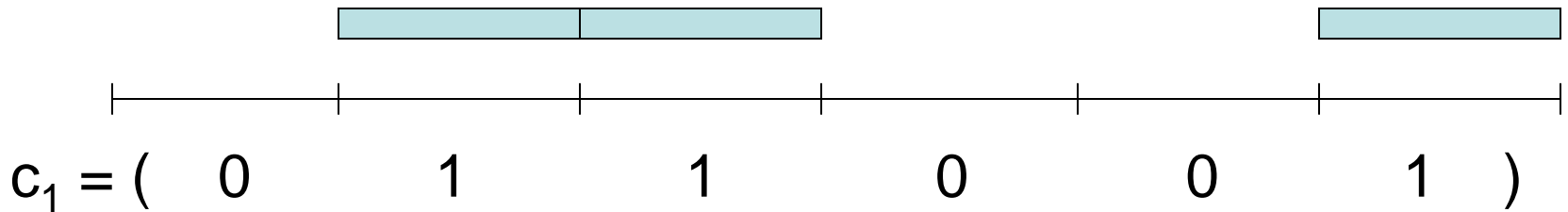
# Assumption III

- Nodes know when the algorithm begin
- Ephremides et *al.* algorithm:
  - Most of nodes in LOM “Listen Only Mode”:  
Reception ( $p_R=\varepsilon$ ) or Sleep ( $p_S=1-\varepsilon$ )
  - Rest on DM “Discovery Mode”
- Node transmits from LOM to DM if
  - In state R
  - Receive message

# Discussion

- No collision information at transmitters
- No info. about reception of msg's; continue transmitting
- Increasing redundancy; resource (energy & time) consumption
- “*a priori*” estimation of collision may improve performance

# Code-based protocol (Keshavarzian et al., Infocom'04)



- $c_1$ : codeword of length  $F=6$
- Transmits if  $c_1(i)=1$ , listens if  $c_1(i)=0$   
 $1 \leq i \leq F=6$
- Each node has a unique codeword

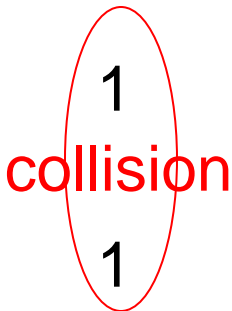
# Constant-weight codes

- $C=(F,W,d)$  constant-weight code
  - Binary code
  - $F$ : length of code
  - $W$ : weight of code; number of 1's
    - Number of transmissions
  - $d$ : minimum distance between any  $a,b \in C$ 
    - $d= a \oplus_2 b$

# Collision analysis

$$c_1 = ( 0 \quad 1 \quad 1 \quad 0 \quad 0 \quad 1 )$$
$$c_2 = ( 1 \quad 0 \quad 1 \quad 1 \quad 0 \quad 0 )$$

collision



- For any  $a, b \in (F, W, d)$
- $\lambda$ : max # of collision positions between  $a$  &  $b$
- $\lambda = W - d + 1$
- $W \geq 1 + \lambda N$ ; guarantees at least one successful reception

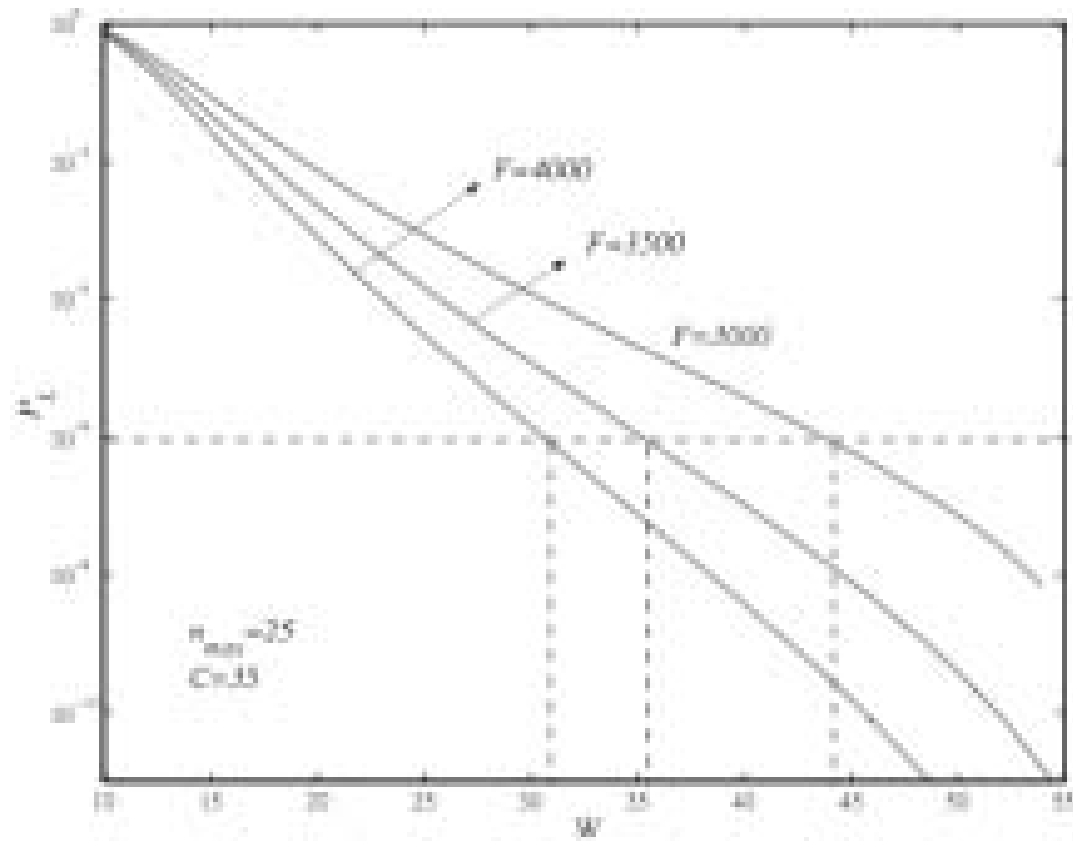
# Energy consumption

- Suppose  $C=(F,W,d)$  when  $W \geq 1 + \lambda N$
- $E_{TX}$  &  $E_{RX}$ : energy consumed in transmit & receive state
- $E_{node} = WE_{TX} + (F-W) E_{RX}$
- Optimum design to minimize  $E_{node}$ 
  - $\lambda=1$
  - $W=1+N$
  - $F \approx W^2$

# What if $W \leq 1 + \lambda N$

- As  $\lambda=1$ ; two nodes collide max in one position
- Probability of this collision; less than  $W^2/F$
- N nodes, total # collision:  
Binomial(N,  $W^2/F$ )
- $P_D$  can be calculated

$$P_L = 1 - P_D$$



# Comparing with random protocols

- Suppose  $F$ , # time slots, same for both random and coded-based protocols
- Random protocols:
  - $W \approx p_T F$  (# transmissions per node)
  - $\lambda \approx (p_T)^2 F$  (# collision between any two nodes)
- Coded-based protocols:
  - $W \approx F^{1/2}$
  - $\lambda \approx 1$

# Discussion

- Require synchronization
- Estimation # node in network
- What is probability that two nodes pick same codeword
- What if links are lossy
  - Collision estimation might not be enough
  - Receiver state at transmitters??