CZECH TECHNICAL UNIVERSITY IN PRAGUE

FACULTY OF ELECTRICAL ENGINEERING

DEPARTMENT OF TELECOMMUNICATION ENGINEERING

B(E)2M32BTSA - Wireless Technologies

Medium Access Control

Techniques and analysis

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Outline

Overview of wireless channel access problem

Deterministic medium access

- Polling, Token, Reservation-based
- Overview and principle

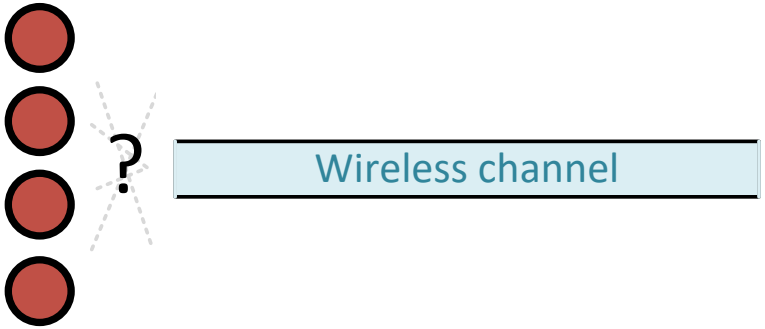
Non-deterministic medium access

- **ALOHA**
  - Principle and throughput analysis
- **Carrier Sensing-based approach(es)**
  - Methods and their principle

Access to wireless channel

Multiple devices willing to **access shared resources**

- Channel allocated to devices when they request it
- If amount of requests exceeds amount of channels → **blocking**
- If more devices access the same channel → **collision**
- A need for a mechanism controlling who transmits at what time
  - Efficiency vs overhead
  - Medium Access Control layer (just above physical layer)



Medium access protocols

Deterministic

- **Outcome** of access procedure **always the same**
  - Any realization provides the same output for same inputs
  - Does not matter how many times we repeat the procedure, output is always the same
- Multiple users access channel → same user always gets channel
  - Under assumption of the same status of the network, channels, requests,…
  - Outcome depends on definition of rules/protocol
- "**Predictable**" outcome
- **Management required** → more complex

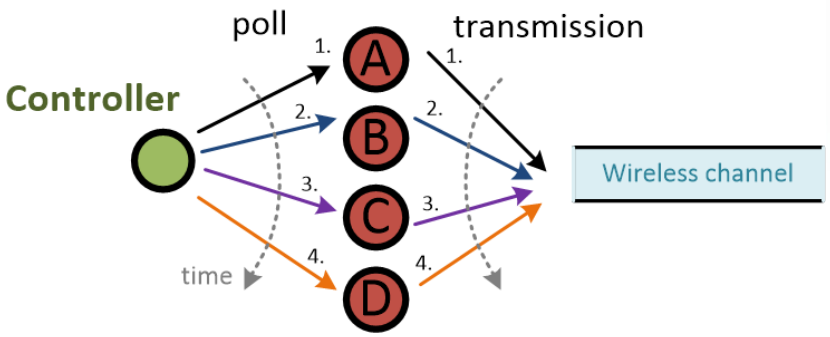
Non-deterministic (Random)

- **Outcome** of access procedure is driven by **randomness**
  - Every realization of the protocol can give different results
- Multiple users access channel → different user can gets channel in each realization
  - Depends on actual value of random variables
- "**Unpredictable**" outcome

Polling

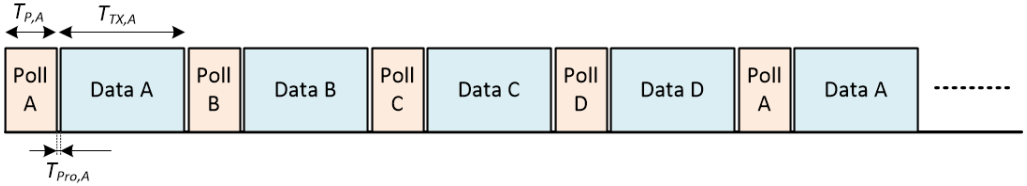
Managed by a controller → no collisions

- **Centralized controller polls devices and offers them transmission**
  - If data ready, then transmit
  - If no data ready, poll next station



Usage of communication resources

- Resources shared between **polling** (T_p) and data **transmission** (T_{TX})
  - Plus propagation and processing (T_{pro})
- $Efficiency = {T_{TX}}/{(T_p+T_{pro}+T_{TX})}$

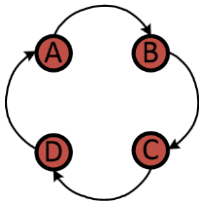


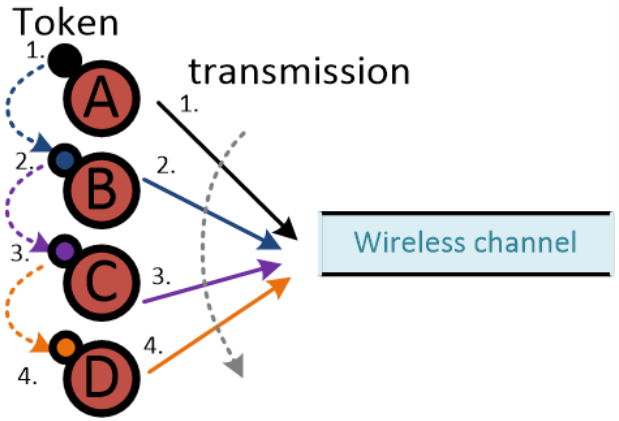
Deterministic or not?

Token passing

Distributed control (no central controller)

- **Devices pass "token"** (polling request) among themselves
- Device **transmits when it has token**
- Order in which token is passed – **token ring**
  - To be defined in advance





Principle **similar to polling**

- **Similar efficiency** (depends on propagation and processing)
- **No central controller** required, but still **no collisions**
- Problem in case of **"device failure"**

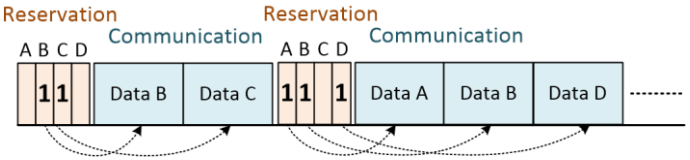
Reservation-based bit map protocol

Slotted time split into

- **Reservation** part
  - Devices indicate willingness to communicate (reserve communication resources)
    - Short (e.g. 1 bit) message in reservation slots belonging to device → known order of devices in advance
    - Number of reservation slots = number of devices
- **Communication** part
  - Data transmitted by devices that indicated willingness to transmit their data

Devices "hear" reservations of others

- Each device can determine its own transmission time → **no collisions**



Usage of communication resources

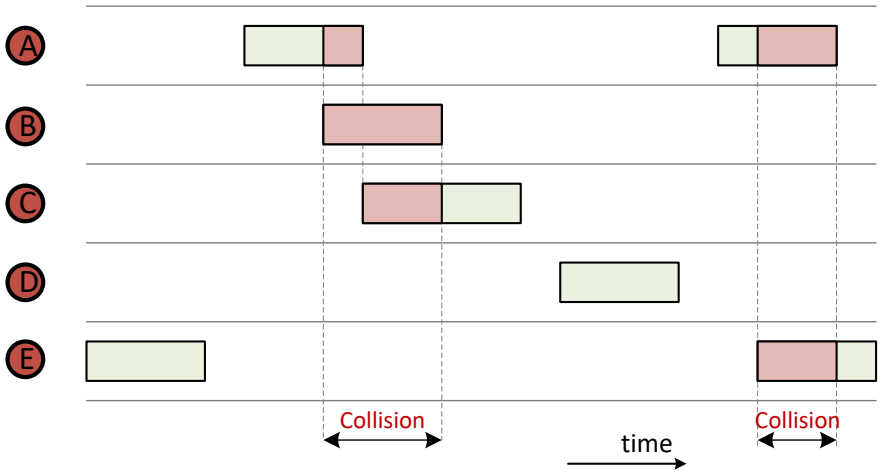
- Resources shared between reservation (T_r) and data transmission (T_{TX})
  - Plus propagation and processing time (T_{pro})
- $Efficiency(time) = {}^{T_{TX}}/_{(T_r+T_{pro}+T_{TX})}$

Deterministic or not?

ALOHA protocol

Pure ALOHA

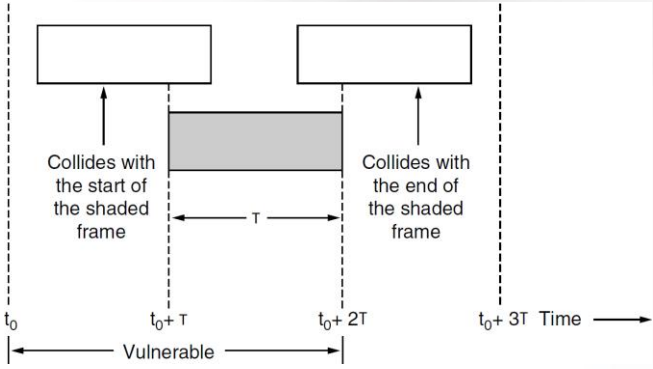
- **Device sends data** (frames) **whenever it has some**
- If another device(s) starts transmitting when the device transmits → **collision** → resend later (after random back-off interval)
- Very simple, but low efficiency



Pure ALOHA analysis

Throughput (S) of Pure ALOHA

- Assumptions
  - Frame duration T for all frames (data) of all devices
  - Poisson frame arrival: $Pr[k] = \frac{G^k e^{-G}}{k!}$
    - k frames generated during a frame time (with duration T) in which G frames are expected in average (offered load)



- $S = GP_0$
- Successful transmission in T: $P_0 = e^{-G}$ (for Poisson distribution of frame arrivals)
- **Vulnerable period**
  - Period within which any other transmitted frame inevitably causes collision
  - **Collision** if another transmission starts **within current T and preceding T**
  - **Vulnerable period for pure ALOHA is $\underline{2T}$** → number of frames is $\underline{2G}$
  - $P_0 = e^{-2G}$
- **Throughout** $S = Ge^{-2G}$
- **Maximum throughput (S_{max})**
  - $S' = 0$
  - $e^{-2G} - 2Ge^{-2G} = 0$ → maximum at → $\boldsymbol{G = 1/2}$
  - $\boldsymbol{S_{max} = \frac{1}{2}e^{-2\frac{1}{2}} = \frac{1}{2}e^{-1} = 0.184}$

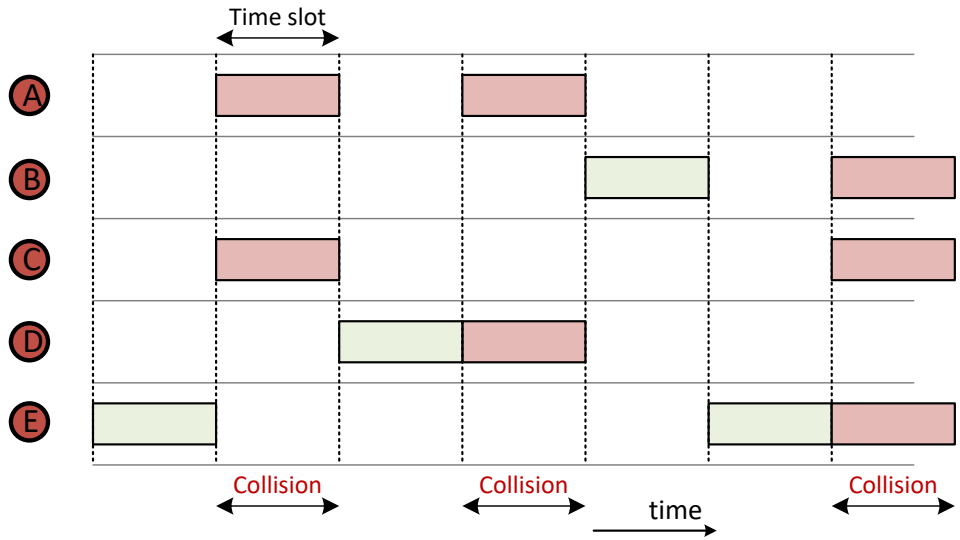
Slotted ALOHA

Discrete time slots for transmission

- Duration equal to frame duration *T*

Each **device transmits at the beginning of time slot**

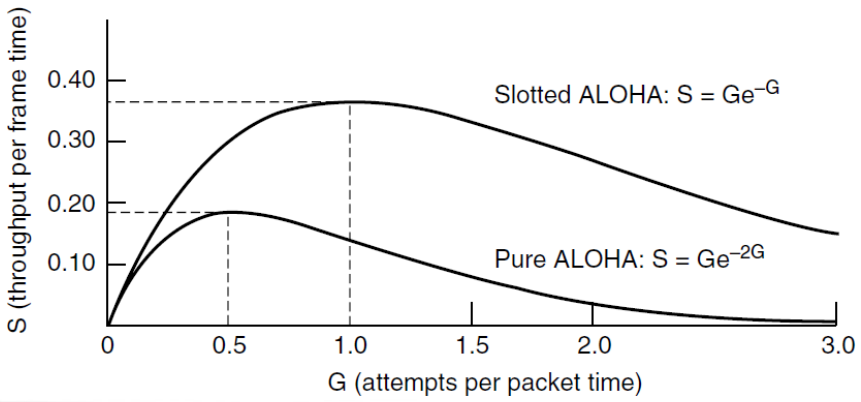
- Requires **synchronization** among devices



Slotted ALOHA analysis

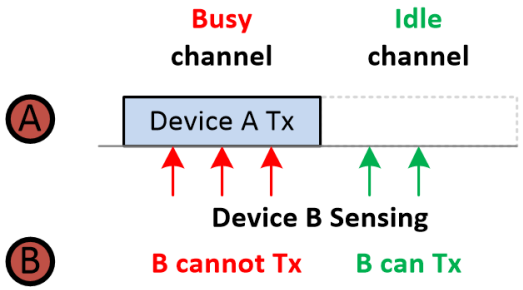
Throughput (S) of Slotted ALOHA

- Same assumptions as for pure ALOHA
  - Poisson frame arrival, all frames with duration T
- $S = GP_0$
- **Vulnerable period for slotted ALOHA**
  - **Collision** if another transmission starts in the same slot, i.e., within $\mathbf{1}T$
  - **Vulnerable period for slotted ALOHA is $\underline{T}$**
  - $P_0 = e^{-G}$
- **Throughout** $S = Ge^{-G}$
- **Maximum throughput (S_{max})**
  - $S' = 0$
  - $e^{-G} - Ge^{-G} = 0$ → maximum at → $\boldsymbol{G = 1}$
  - $\boldsymbol{S_{max}} = 1e^{-1} = \mathbf{0.368}$



Carrier sensing

Sense (listen) channel before transmit



Reduces collision probability by awareness of the channel wrt ALOHA

- Collisions not totally eliminated due to signal propagation delay
- Vulnerable period shortened to only propagation time

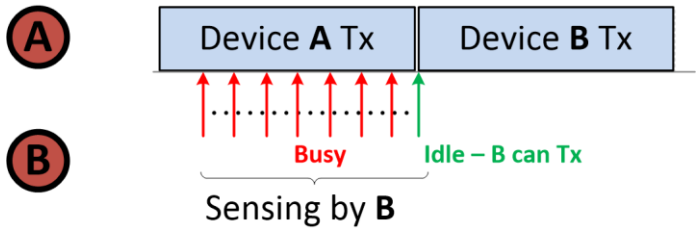
Types of **Carrier Sensing Multiple Access** (CSMA) methods

- **1-persistent**
- **Non-persistent**
- **p-persistent**

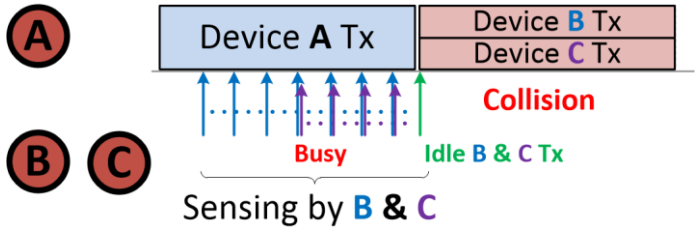
1-persistent CSMA

Principle

- If **busy**, then **keep continuously sensing** and **wait until it is idle**
- If **channel is idle, transmit**



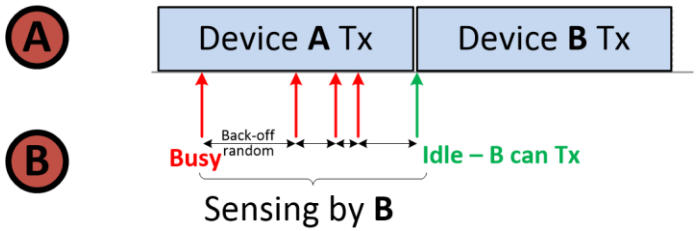
- All **waiting devices transmits at the same time** after channel becomes idle
  - **Collision**
    - Anytime two devices are willing to start transmission during busy channel
    - Channel propagation problem – channel seems idle, but other device already transmits
    - **Wait random time** and try again



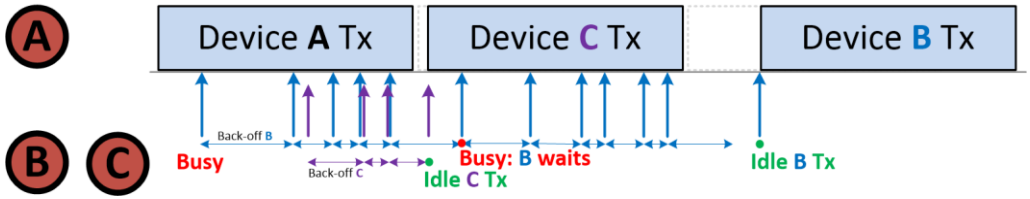
Non-persistent CSMA

Principle

- If channel is **busy, listen again after a random back-off time** interval
- If channel is **idle, transmit**



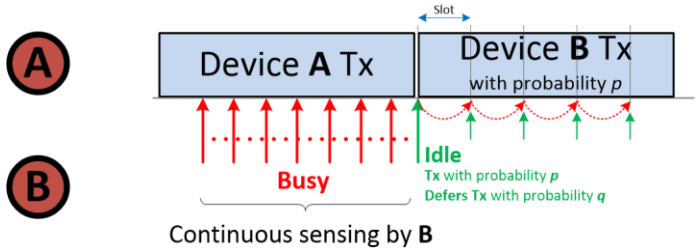
- **Waiting devices** (most likely) **sense at different times**
  - **Lower collision probability**
  - **Longer delay** wrt 1-persistent
    - Channel may remain idle even if data is ready



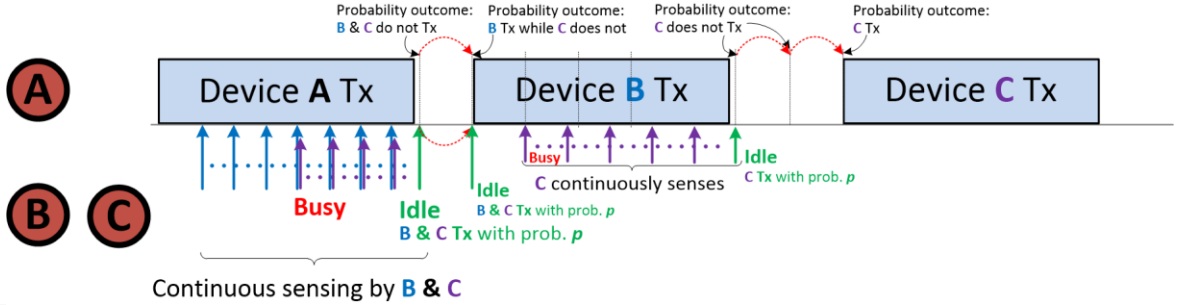
p-persistent CSMA

Principle

- Slotted time (channel)
- If channel is **busy**, **wait** until idle
- If channel is **idle**, **transmit with probability p**
  - Defer transmission to next slot with probability $q = 1 - p$



- **Waiting devices senses till channel is idle**
  - If idle **transmit only with probability p** → lower probability of collision than 1-persistent
  - Low p → low probability of collision, but longer waiting time
  - High p → higher probability of collision, shorter waiting ($p = 1$ … 1-persistent)



CSMA – collision detection

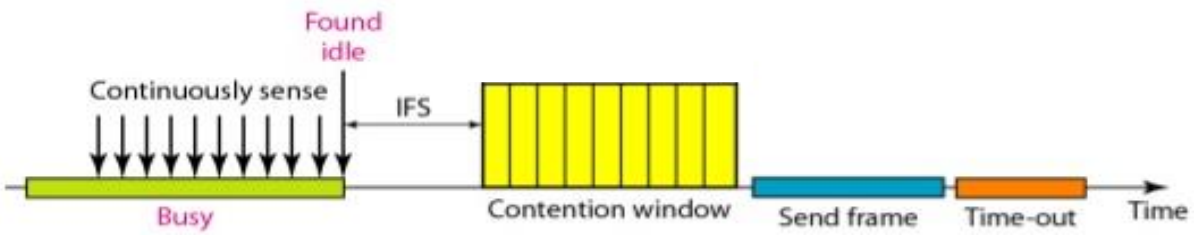
CSMA/Collision Detection (CD)

- Based on CSMA, i.e., sense before transmit
- **Collision**
  - **Detection** (e.g., by signal level measurement)
  - All devices **abort transmission** to avoid wasting resources
- **Problem in wireless**
  - **Half-duplex operation** (cannot listen when transmitting)
  - Transmission power >> Received power

CSMA – collision avoidance

CSMA/Collision Avoidance (CA)

- **Sense** before transmit
- If channel is busy, wait
- If channel is **idle**, **wait Inter Frame Space** (IFS)
  - Mitigate signal propagation issue (~μs)
- If channel is still **idle**, **wait for Contention Window**
  - Random duration (in slots) to reduces collision probability
- **Send frame**
- **Wait for ACK**
  - In not received within **Time out**, then repeat the procedure



Smak Inc., "Wireless Application protocols" 2012

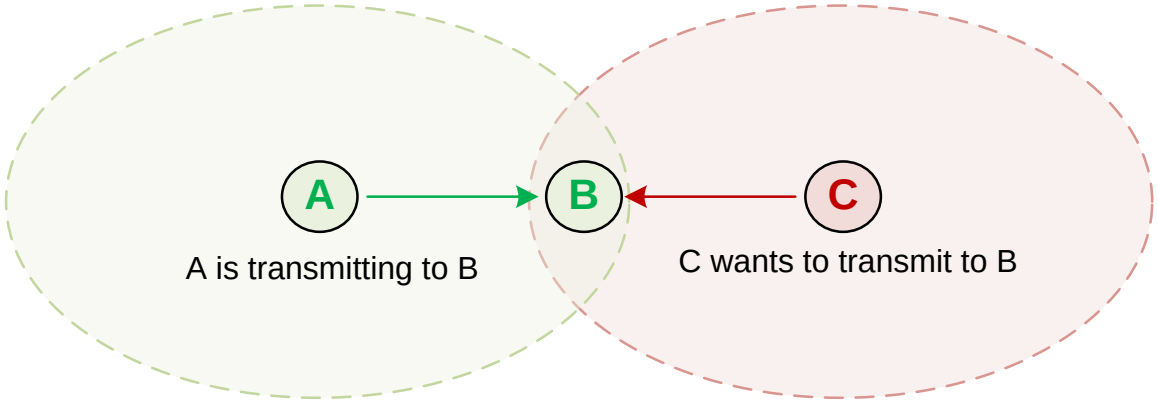
Limitations of CSMA in wireless

- **Hidden node problem** (increase amount of collisions for all CSMAs)
- **Exposed node problem** (reduces bandwidth utilization for all CSMAs)

Hidden node problem

Hidden node

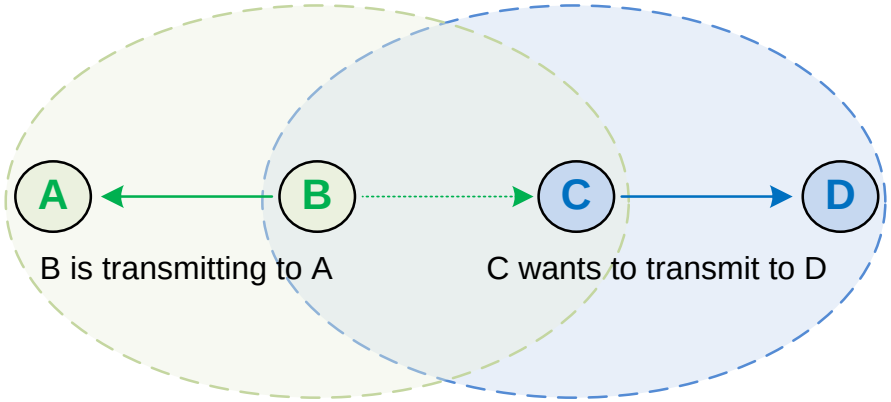
- Node close to communicating pair, **within** range of **destination node**, but **out** of range of **source node,** willing to communicate with the destination node
- **Cannot hear ongoing communication → collision**
- **Example:**
  - ***A* and *C* in communication range of *B***
    - *A* and *C* can communicate with *B*
  - ***A* and *C* out of communication range of each other**
    - *A* and *C* cannot communicate with each other
  - ***A*** transmits to ***B***, but ***C*** does not hear it (too far from ***A***)
  - ***C*** sees the channel idle and transmits to ***B*** → **collision**



Exposed node problem

Exposed node

- Node close to communicating pair **within** range of **source node**, but **out** of range of **destination node,** willing to communicate with another node
- Hear ongoing communication → do not transmit even if it could → **wasting bandwidth**
- **Example:**
  - ***A* and *C* in communication range of *B***
  - ***A* and *C* out of communication range of each other**
  - ***B*** transmits to ***A***; and ***C*** wants to transmit to ***D***
  - ***C*** hears **B→A** communication, and thus stays idle
  - ***C*** cannot reach ***A*** (it is too far) so ***C*** could transmit to ***D*** → **wasting bandwidth**



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