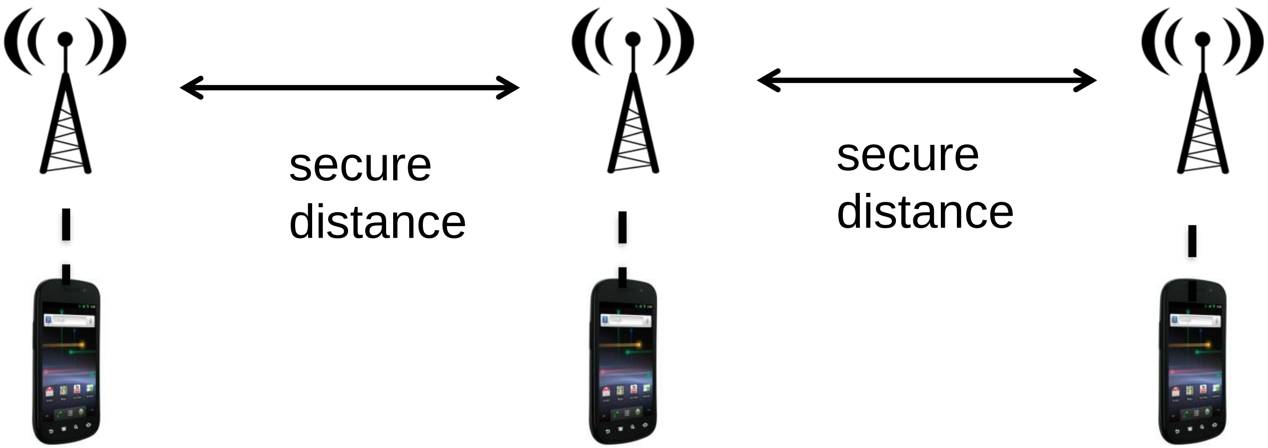
Medium Access
with
Fixed Assignment

Medium Access

- How can we reduce interferences between senders?
- Only allow one sender at a time?
  - Yes, that’s possible but only for a small number of senders
- We need to control medium access, but allow concurrent medium usage → Multiplexing
- We will see now different solutions that do fixed assignments of resources to the senders

Space Division Multiple Access (SDMA)

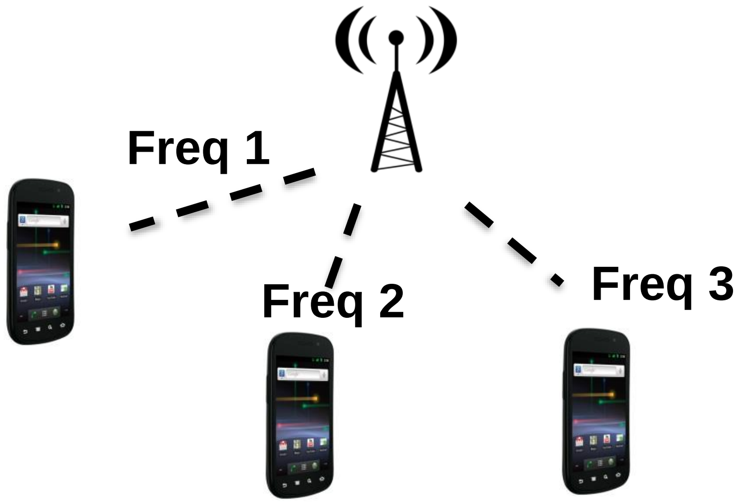
- As name suggests, the idea is to divide *space* so that devices do not interfere
- Basis of cellular networks (mobile phone networks)



- Simple to implement. But:
  - Pure SDMA would require huge a secure distance between stations
  - You need one base station for each end device!
- Only practicable when combined with other multiplex methods

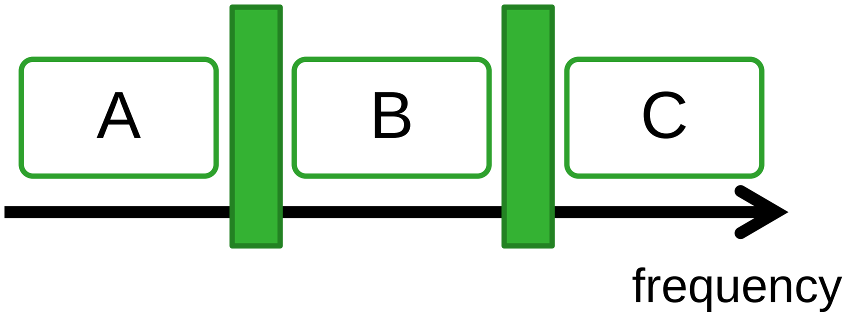
Frequency Division Multiple Access (FDMA)

- Frequencies permanently assigned to transmission channels
- Example: broadcast radio



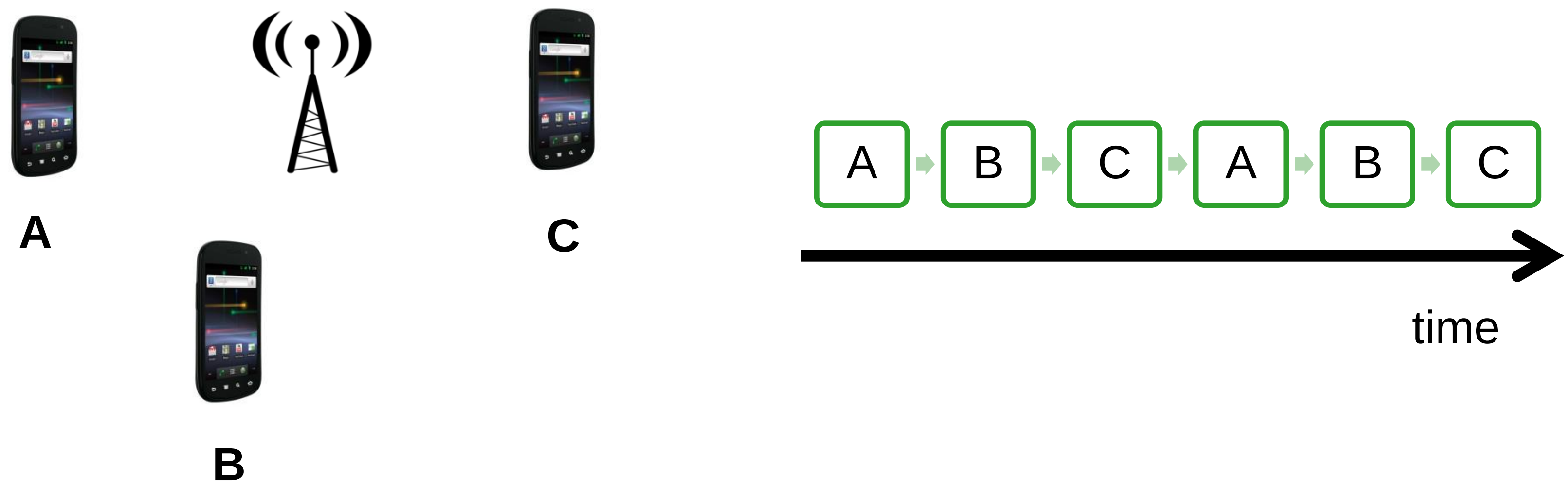
Frequency Division Multiple Access (FDMA)

- Would require one frequency per station! Not feasible if number of stations is large.
- Requires exact frequency filtering with "guard-bands" between adjacent channels to be more robust against interferences



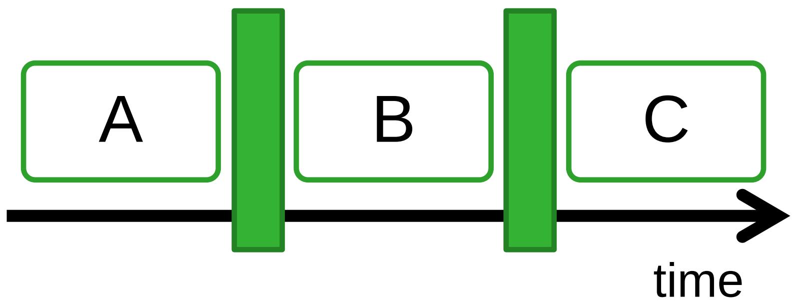
Time Division Multiple Access (TDMA)

- Time is divided into slots and only one station per slot can access medium



Time Division Multiple Access (TDMA)

- Simple hardware!
  - All stations send on same frequency
  - Time division can be done in software
- Requires synchronisation between stations
  - Exact timing with “guard-times” (extra-time) between slots to be more tolerant against timing variations



Practical Considerations

- SDMA not useful alone
- TDMA requires precise timing and all devices must use the same clock
- FDMA requires precise frequency filters
- TDMA and FDMA are sensitive to external interferences
- TDMA and FDMA require coordination: Who assigns the frequencies and timeslots to the senders?

- These and other considerations make Code Division Multiple Access (CDMA) interesting
- Here, we will only explain the <u>basic</u> idea behind CDMA.

Code Division Multiple Access (CDMA)

- CDMA allows all stations to send at the same time on the same frequency band
- Idea:
  - Each sender uses a different *code* that is applied to the data stream
  - If the receiver knows the code it can decode the data
  - It’s like two persons, one speaking French, one speaking English, in the same room, talking at the same time.
- Typically implemented in hardware

CDMA Example

- Sender A wants to send source bit X = "1"
  - Code used by A: Y = 010011
  - Output signal X*Y = (-1 +1 -1 -1 +1 +1)
    (a zero-bit in the data or the code is represented as -1)
- Sender B wants to send bit "0"
  - Code used by B: 110101
  - Output signal: (-1 -1 +1 -1 +1 -1)
- "In the air", both signals are superimposed:

  (-2 0 0 -2 +2 0) = (-1 +1 -1 -1 +1 +1) + (-1 -1 +1 -1 +1 -1)
- The receiver can extract the data from sender A from the superimposed signal, provided it knows A's code:
  (-2 0 0 -2 +2 0) * 010011 = 2 + 0 + 0 + 2 + 2 + 0 = 6
  (inner product, again using -1 for "0" in the code)
- Result is (much) greater than 0 $\rightarrow$ Original bit sent by A was "1"

Spreading in CDMA

- The "-1" and "+1" are called *chips* (to avoid confusion with the data bits "0" and "1").
- In our example, one data bit is represented by a sequence of six chips

  → *spreading factor* = 6

- The resulting signal needs six times more bandwidth than the original signal “1” and “0” from sender A and B. The original spectrum is *spread.*

Code Orthogonality

- The codes of the stations must be chosen carefully
- **Bad example:**
  - Station A uses code "1000"
  - Station B uses code "0100"
  - Station C uses code "1100"

→ Code of station C is linear combination of code of A and B

→ When A and B send a "1" data bit at the same time, it looks like C

- (In practice, a little bit more complicated because we have three possibilities for each station: -1, +1 and 0)

Practical Considerations on CDMA

- Real systems use much longer codes, resulting in larger distances between code words

  → Decoding of signal is more robust. Signals with small errors can be still decoded correctly.

- CDMA still needs coordination between stations:
  - The used codes must be sufficiently apart from each other. Alternative: Stations choose codes randomly.
  - Receiver needs to know codes.

- Senders have to adapt their transmission power, so that all signals have more or less the same strength at a receiver.
  - Implemented by letting the receiver send strength measurement information back to the senders