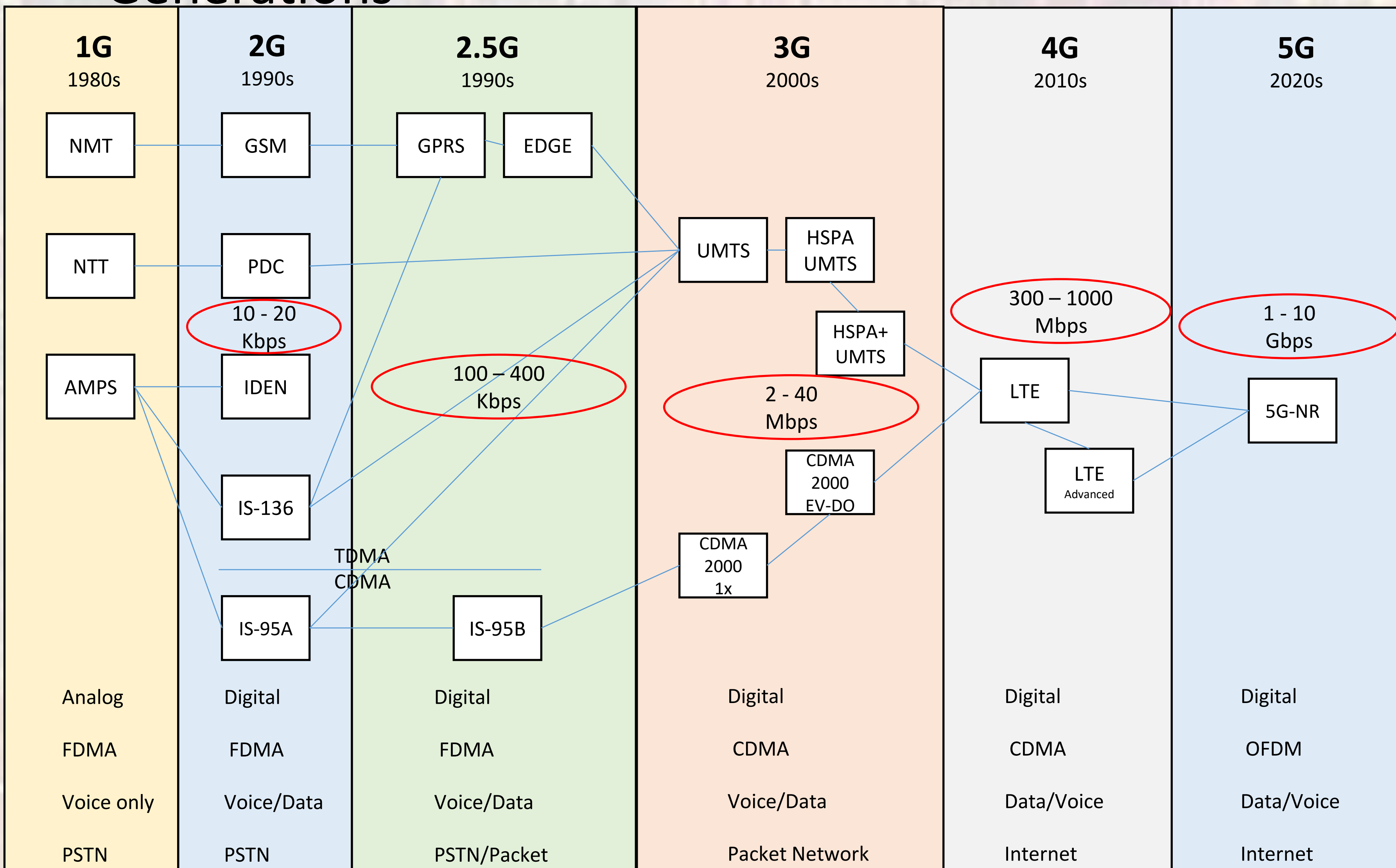
Cellular Background

Last updated 4/18/24

Cellular - Background

- Generations

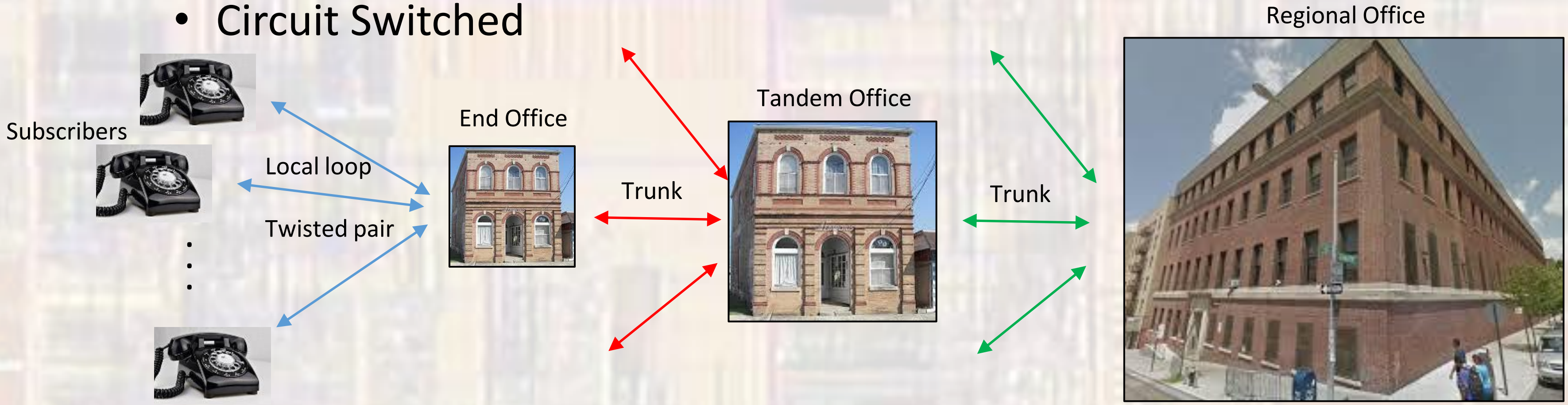


Cellular - Background

- POTS
  - Plain Old Telephone Service
  - ca. 1877 → mid 1980's in US
  - Still used in many countries

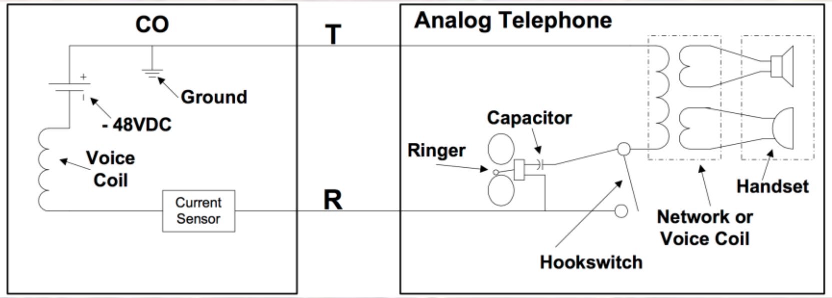
  - Wired analog communication
    - 2 wires – local loop
    - Full duplex
    - Circuit Switched

src: nationalww2museum.org

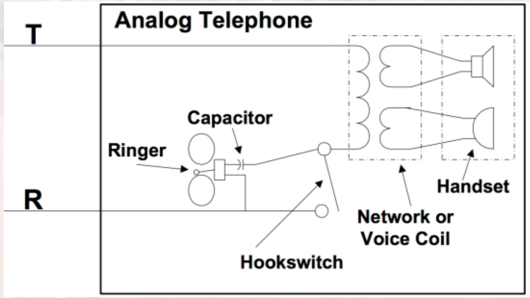


Cellular - Background

- POTS – Electrical Operation
  - T – tip line
  - R – ring line
  - CO – central office



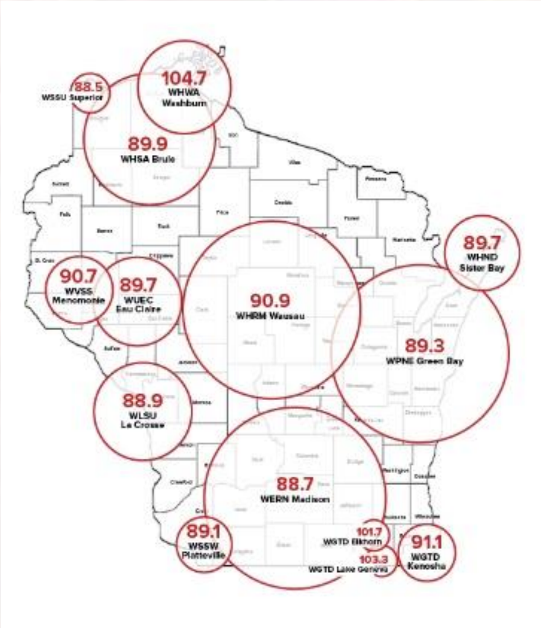
- Outgoing call
  - Pick up handset → Hook switch → closed
  - Current flows → sensed by the current sensor
    - CO generates a dial tone on the line
    - CO connects digit decoder to the line
  - CO connects calling line to Receiving line
    - Voice coil and speaker signals transferred between handsets



- Incoming call
  - CO generates a ring signal
  - Answered → Hook switch → closed
  - Current sensor stops the ring and connects the lines
    - Voice coil and speaker signals transferred between handsets

Cellular - Background

- Broadcast Radio
  - Transmit only
  - Line of sight



- Earliest radio-phones
  - 1946
  - FM – push to talk
  - Single high-powered transmitter
  - Several smaller receive locations
    - https://youtu.be/xDy2tHCPdk8 (10 minutes – sorry about the ads)
  - Very limited subscriber numbers
    - Wide BW signals, narrow available BW → few channels

Cellular - Background

- Tx/RX sequencing
  - Simplex
    - Receive or transmit only
    - Garage door opener
    - Pagers
    - Broadcast radio and TV
  - Half duplex
    - non- simultaneous Rx/Tx
    - Walky-talky
  - Full duplex
    - Simultaneous Rx/Tx (effectively)
    - Cellular

Cellular - Background

- Mobile Radio
  - Full Duplex Methods

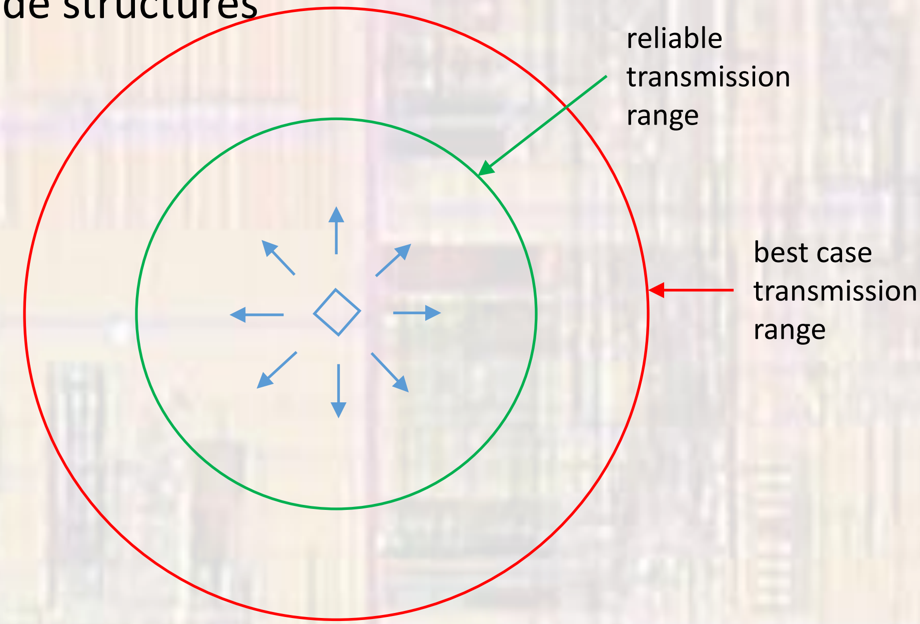
    - FDD – Frequency Division Duplex
      - Separate frequencies used for transmit and receive

    - TDD – Time Division Duplex
      - Send and receive “packets” separated in time
      - Requires the information sent/received is small compared to the channel's capacity
      - Requires “real time” information to be low BW compared to the packet BW

    - Terms
      - Station to user – forward channel - downlink
      - User to station – reverse channel - uplink

Cellular - Background

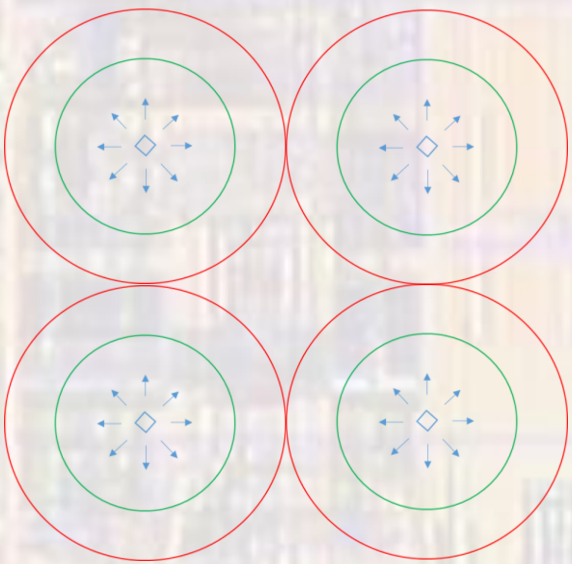
- Cellular
  - Transmitter
    - Fixed location
    - Range dependent on transmission power
    - Range varies with
      - Atmospheric conditions
      - Geographic topology
      - Man made structures



Cellular - Background

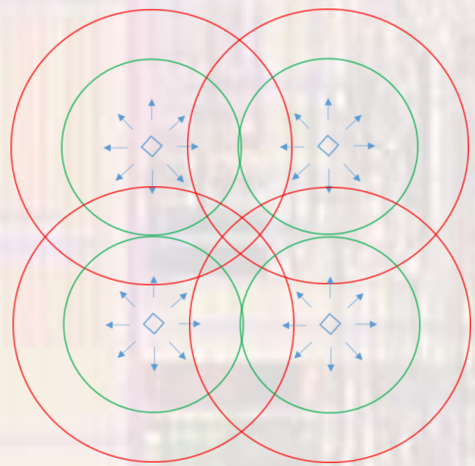
- Cellular
  - Transmitter Positioning
    - Common frequency

Common Frequency



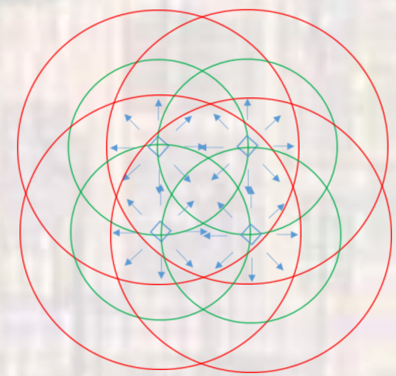
No interference
GAPS !

Common Frequency



Interference !
GAPS !

Common Frequency

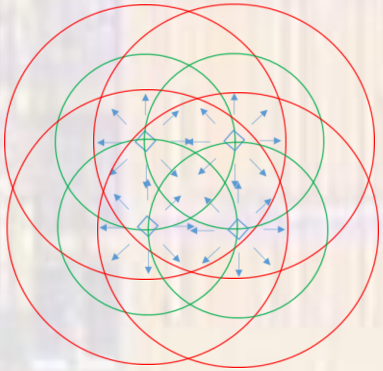


INTERFERENCE !
No gaps

Cellular - Background

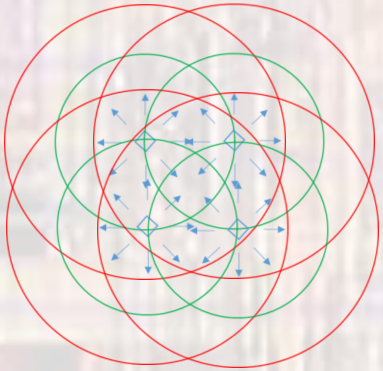
- Cellular
  - Transmitter Positioning
    - Non-common frequencies

4 frequencies



No interference
No gaps

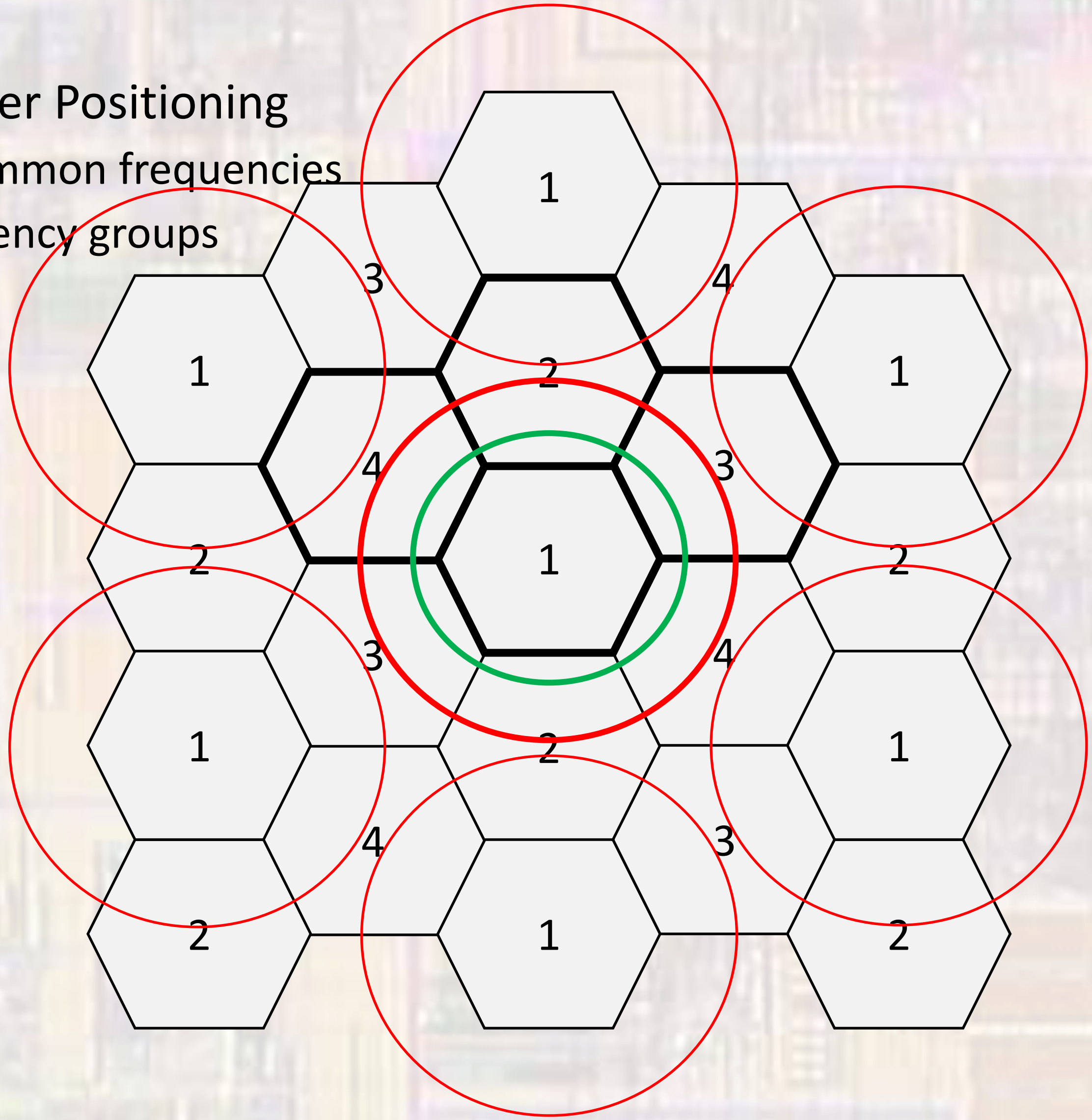
64 frequencies
16 per transmitter (co-channels)



No interference
No gaps

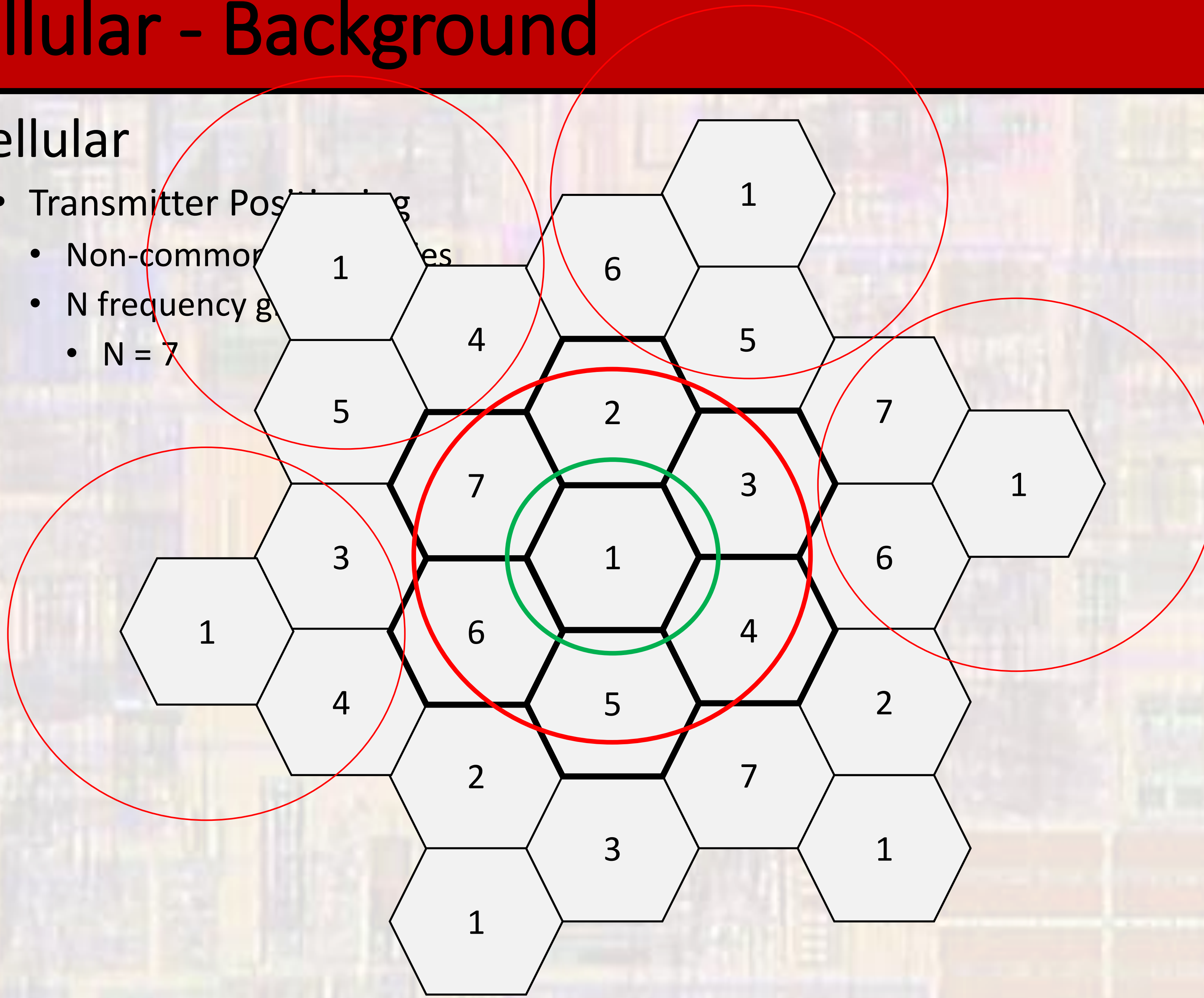
Cellular - Background

- Cellular
  - Transmitter Positioning
    - Non-common frequencies
    - N frequency groups
      - N = 4

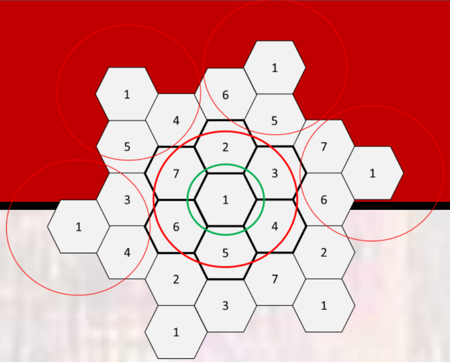


Cellular - Background

- Cellular
  - Transmitter Pos g
    - Non-commo es
    - N frequency g
      - N = 7



Cellular - Background



- Cellular
  - Transmitter(s)
    - D – distance between cell centers using the same frequencies(channels)
    - R – radius of a cell
    - N – number of cells in a pattern
      - N = 1, 3, 4, 7, 9, 12, 13, 16, 19, … $N = I^2+J^2+(IxJ)$ I, J = 0, 1, 2, …
    - $D/R = (3N)^{1/2}$
    - Example:
      - Assume 5 co-channels/cell, 25 users/channel at one time, desire to support 625 users in a $25km^2$ area (circular)
      - With a N = 9 system, what would the value of D be?
      - 625 users, 25/channel → 25 channels → 5 cells
      - $5 \times 2*PI*R^2 = 25km^2$ → R = 0.89km
      - D = 4.64km

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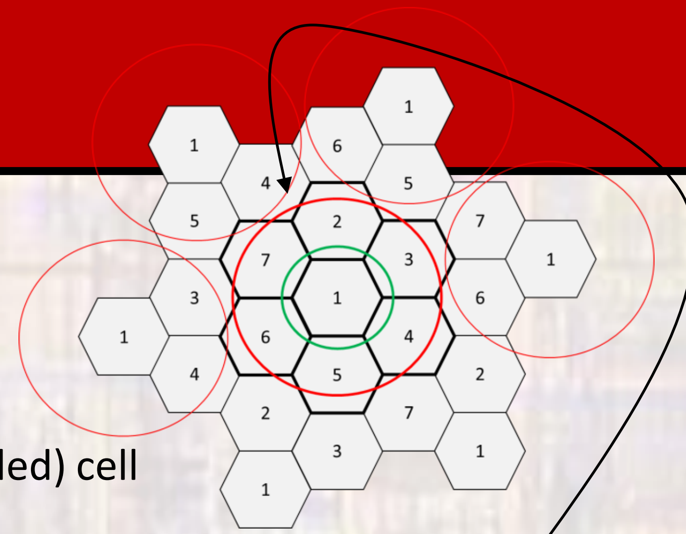

- Capacity expansion
  - Add new channels to a cell
    - Assign unused frequencies
  - Frequency borrowing
    - Assign channels from an adjacent (less loaded) cell
    - Can be done dynamically
    - Can impact the broader reuse pattern
      - Cell 1 borrows from cell 4 – may impact the next nearest cell 4
  - Cell splitting
    - Shrink the footprint
      - More cells in a given area → more capacity
    - More towers
    - More handoffs
  - Cell sectoring
    - Break the cell into radial sectors (3 or 6 typically)
    - Each sector can use all (most) co-channels independently
      - ~3x or 6x capacity
    - Requires directional antennas