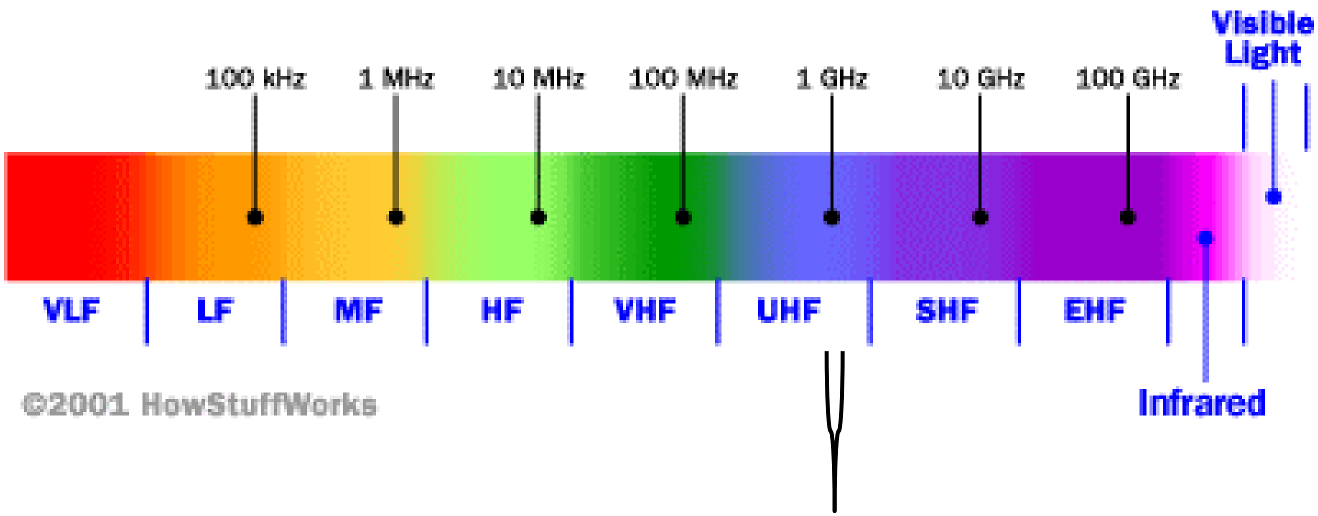
ICSE 6222: Mobile Tel. Tech

History of Mobile Data Networks

- Remember that phones were originally designed for calls

Cellular Network Basics

- There are many types of cellular services; before delving into details, focus on basics (helps navigate the “acronym soup”)
- Cellular network/telephony is a *radio*-based technology; radio waves are electromagnetic waves that *antennas* propagate
- Most signals are in the 850 MHz, 900 MHz, 1800 MHz, and 1900 MHz frequency bands

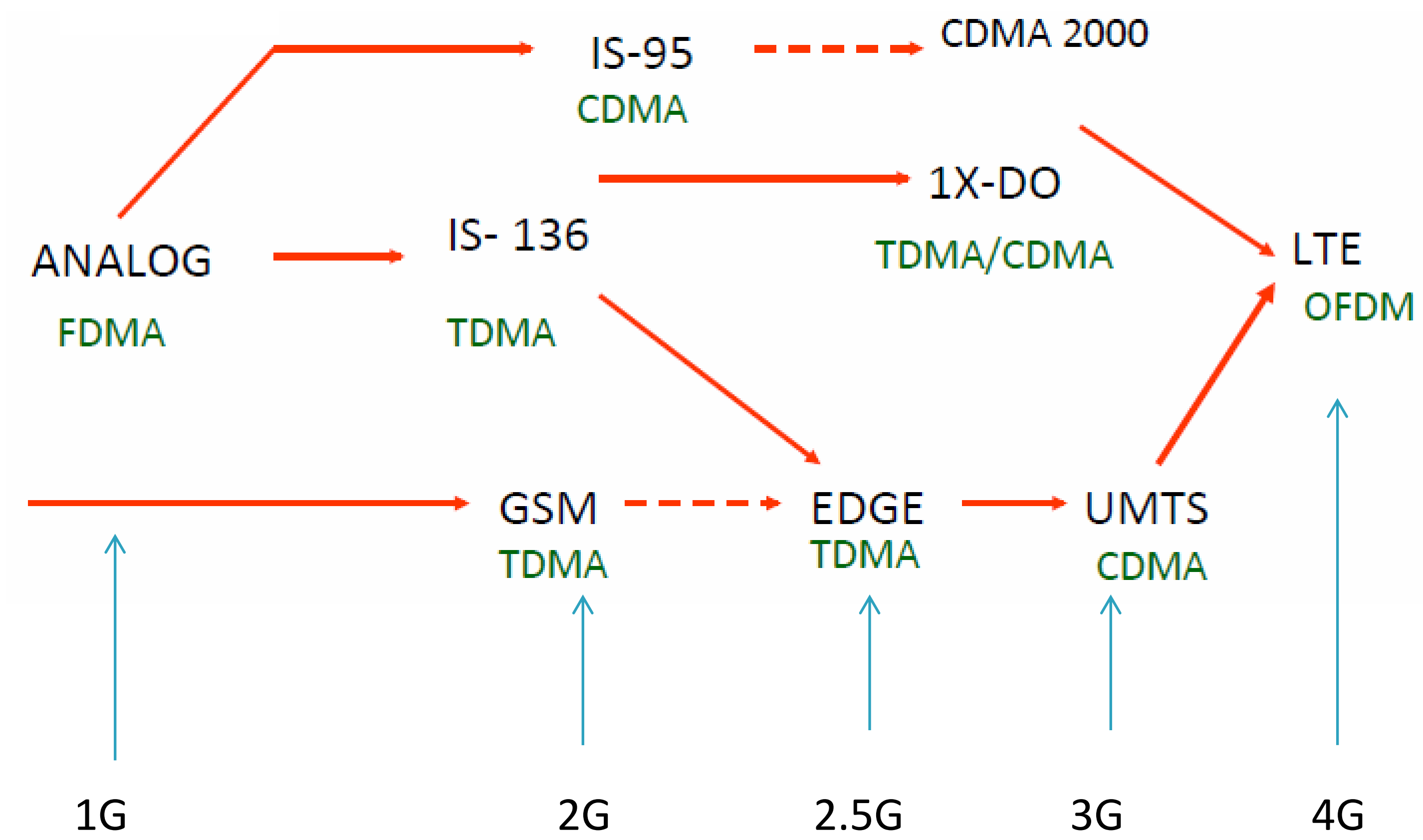


Cell phones operate in this frequency range (note the *logarithmic* scale)

Cellular Network Generations

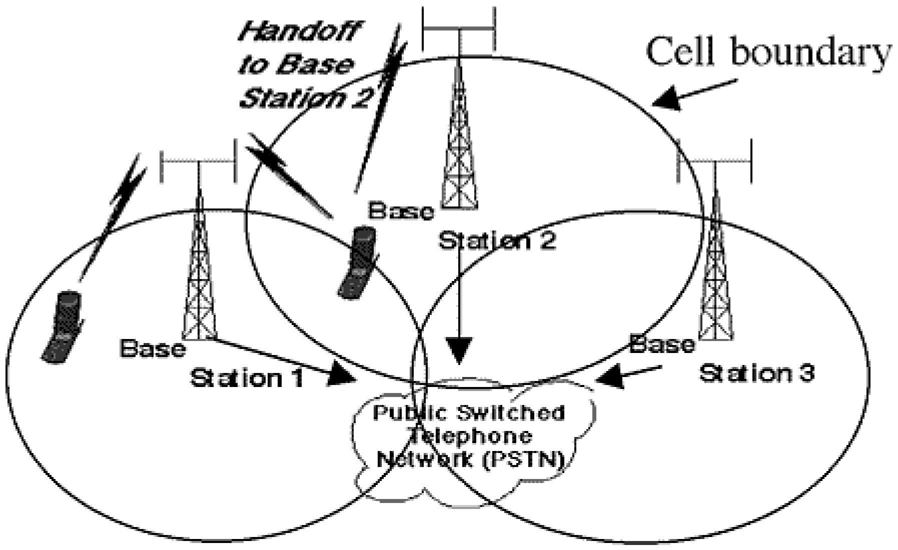
- It is useful to think of cellular Network/telephony in terms of *generations*:
  - 0G: Briefcase-size mobile radio telephones
  - 1G: *Analog* cellular telephony
  - 2G: *Digital* cellular telephony
  - 3G: *High-speed* digital cellular telephony (including *video telephony*)
  - LTE (4G): IP-based "anytime, anywhere" voice, data, and multimedia telephony at *faster* data rates than 3G

Evolution of Cellular Networks



Cellular Network

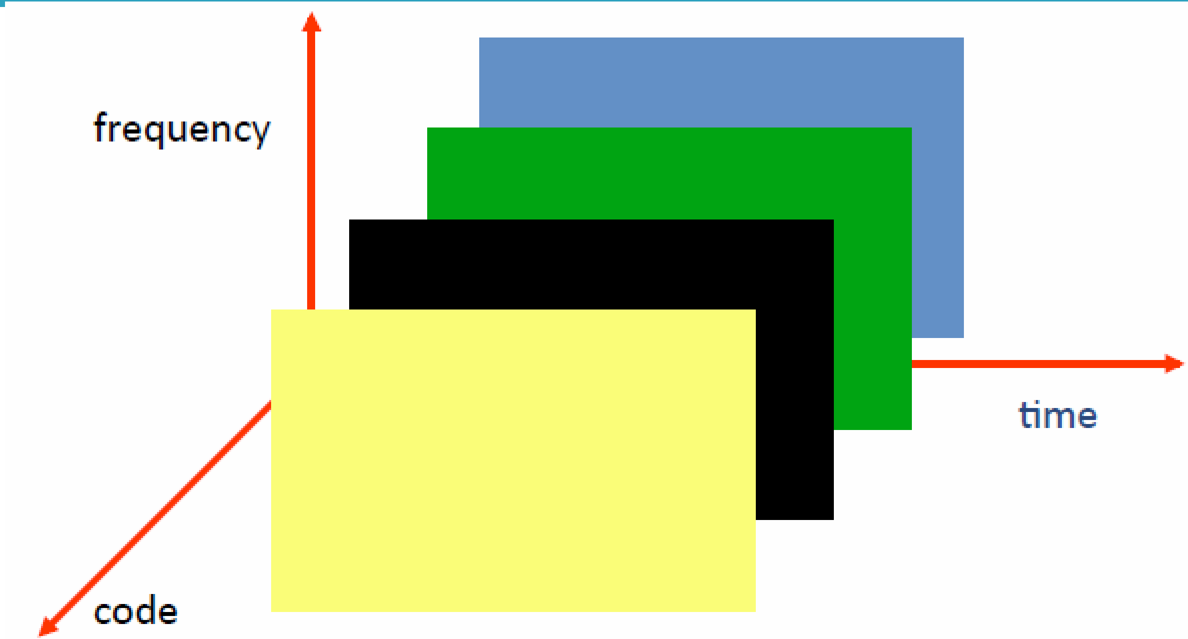
- Base stations transmit to and receive from mobiles at the assigned spectrum
  - Multiple base stations use the same spectrum (spectral reuse)
- The service area of each base station is called a cell
- Each mobile terminal is typically served by the 'closest' base stations
  - Handoff when terminals move



The Multiple Access Problem

- The base stations need to serve many mobile terminals at the same time (both downlink and uplink)
- All mobiles in the cell need to transmit to the base station
- Interference among different senders and receivers
- So we need multiple access scheme

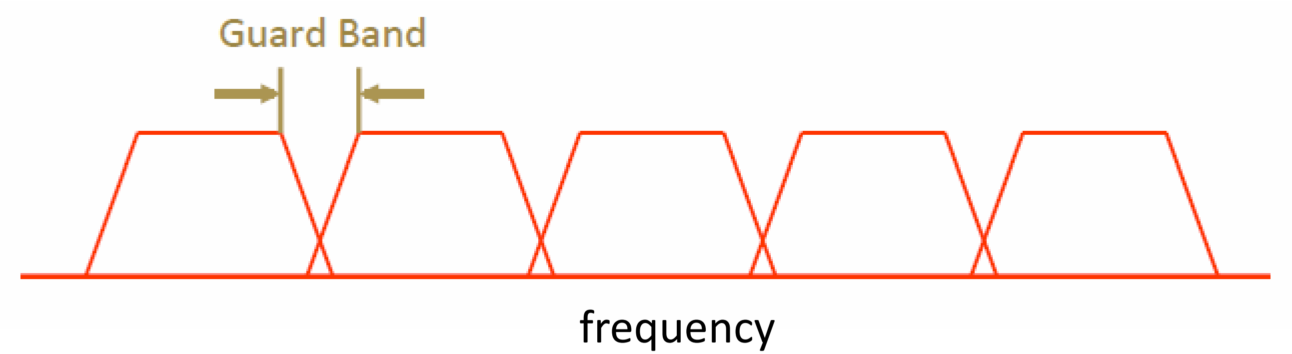
Multiple Access Schemes



3 orthogonal Schemes:

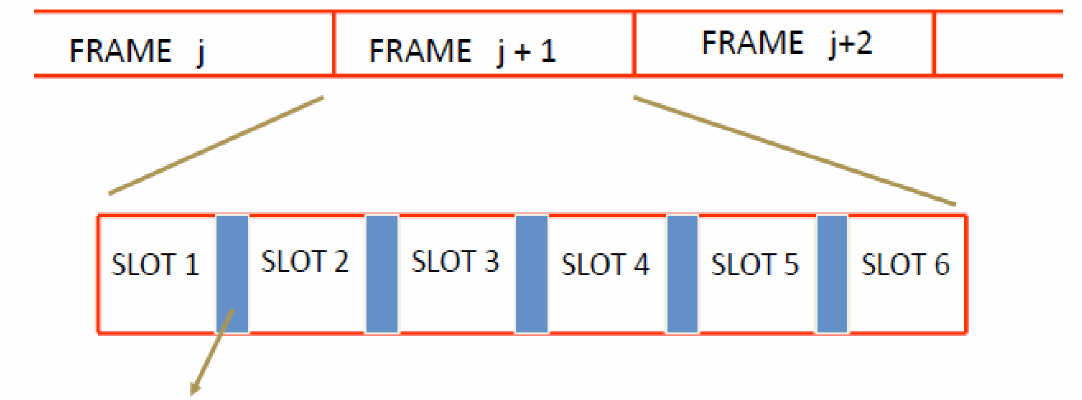
- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)

Frequency Division Multiple Access



- Each mobile is assigned a separate frequency channel for a call
- Guard band is required to prevent adjacent channel interference
- Usually, one downlink band and one uplink band
- Different cellular network protocols use different frequencies
- Frequency is precious and scare – we are running out of it
  - Cognitive radio

Time Division Multiple Access

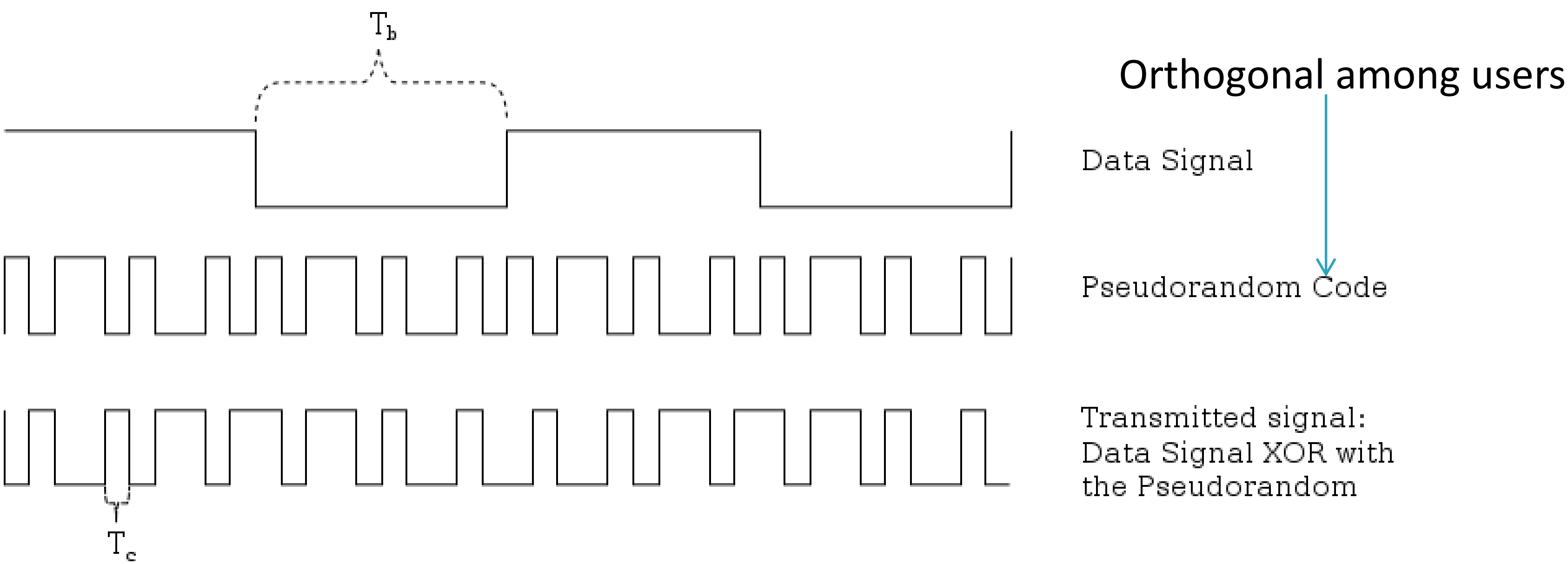


Guard time – signal transmitted by mobile terminals at different locations do no arrive at the base station at the same time

- Time is divided into slots and only one mobile terminal transmits during each slot
  - Like during the lecture, only one can talk, but others may take the floor in turn
- Each user is given a specific slot. No competition in cellular network
  - Unlike Carrier Sensing Multiple Access (CSMA) in WiFi

Code Division Multiple Access

- Use of orthogonal codes to separate different transmissions
- Each symbol of bit is transmitted as a larger number of bits using the user specific code – Spreading
  - Bandwidth occupied by the signal is much larger than the information transmission rate
  - But all users use the same frequency band together



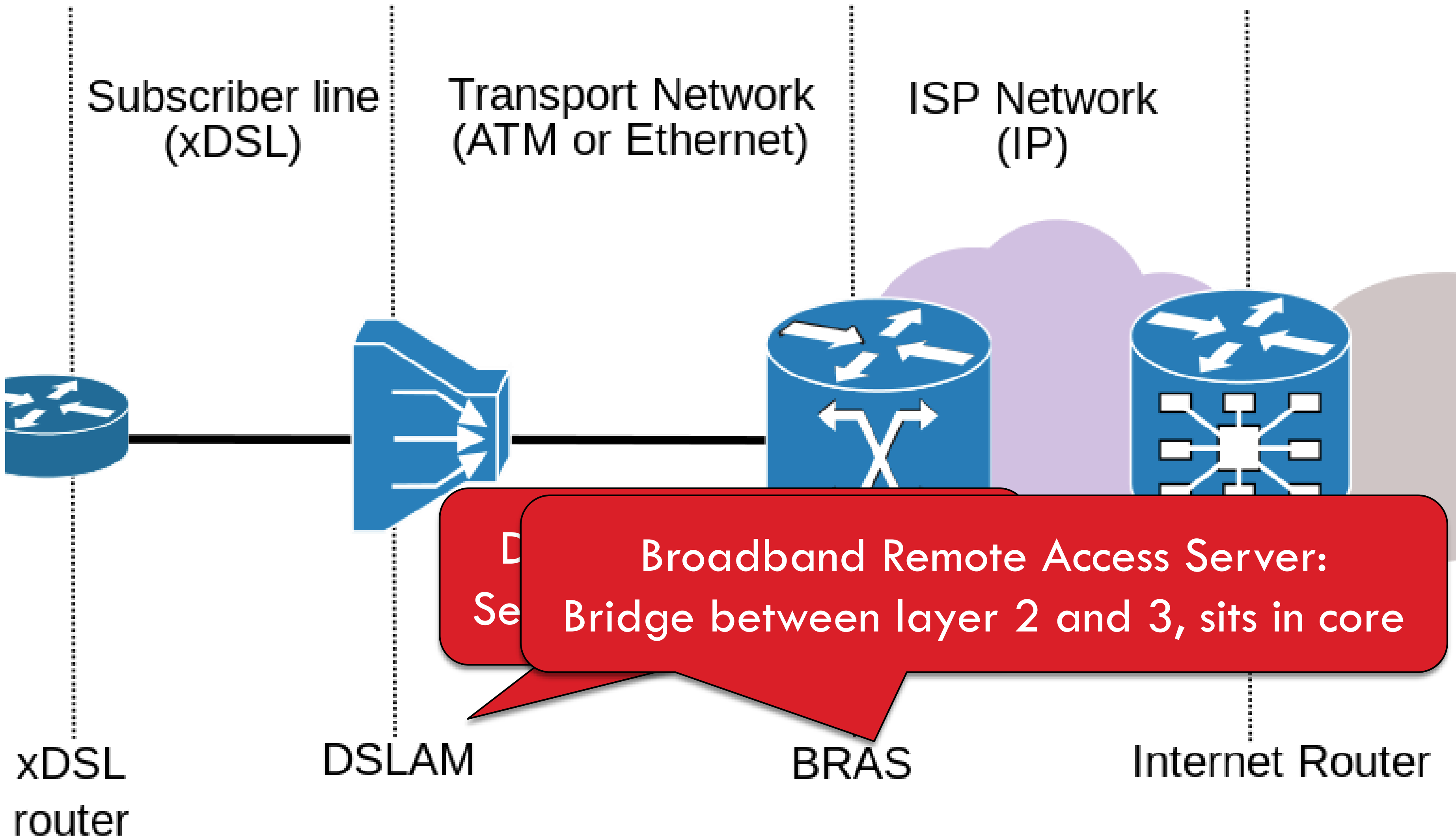
Why am I telling you this?

The performance we get out of cell networks is intimately tied to network design

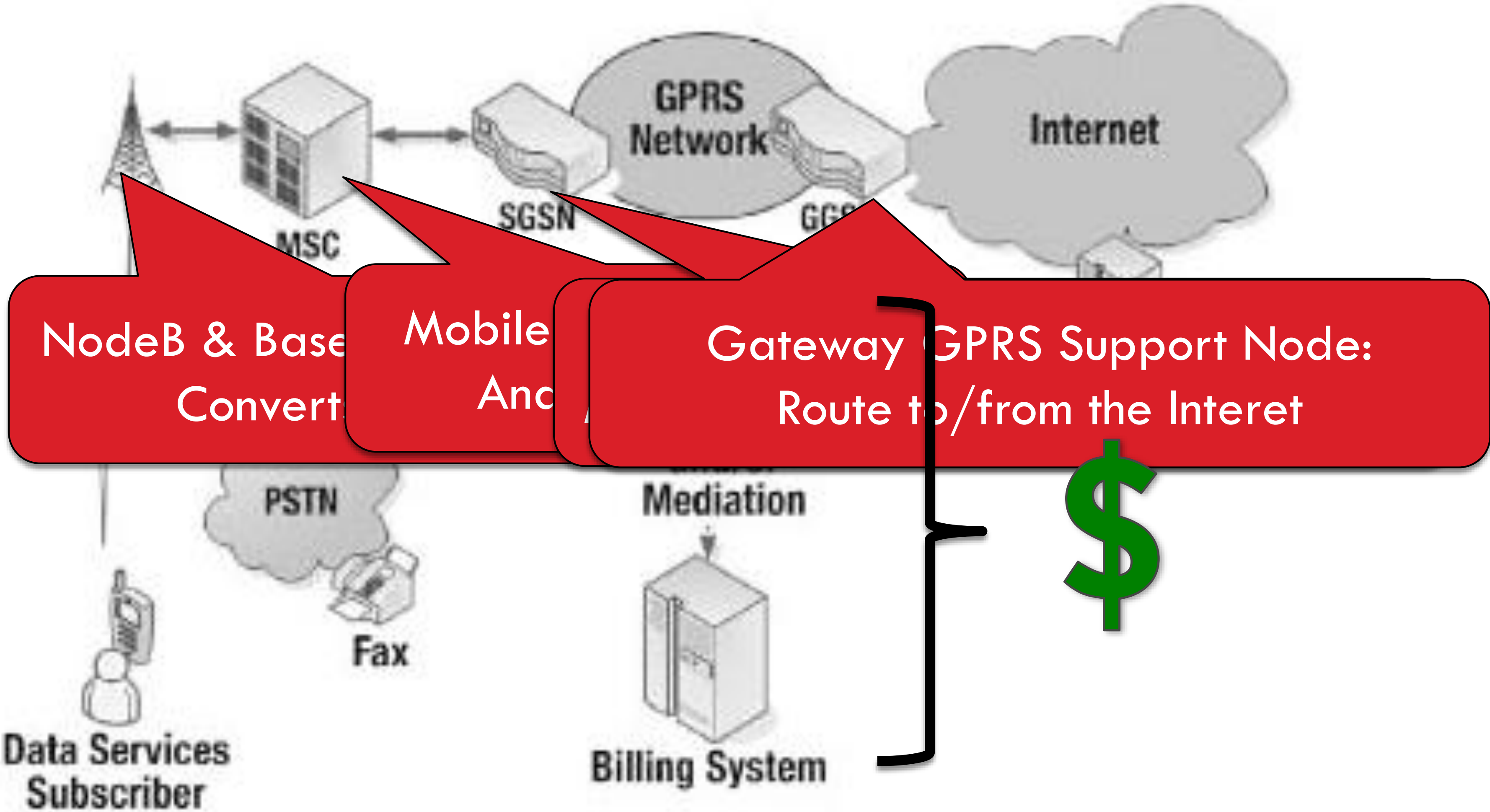
- …and cell networks (pre-LTE) were not designed for IP

- Instead, optimized for
  - Circuit-switched
  - Low bitrate (calls/text)
  - Charging customers, allowing connections from any cell provider

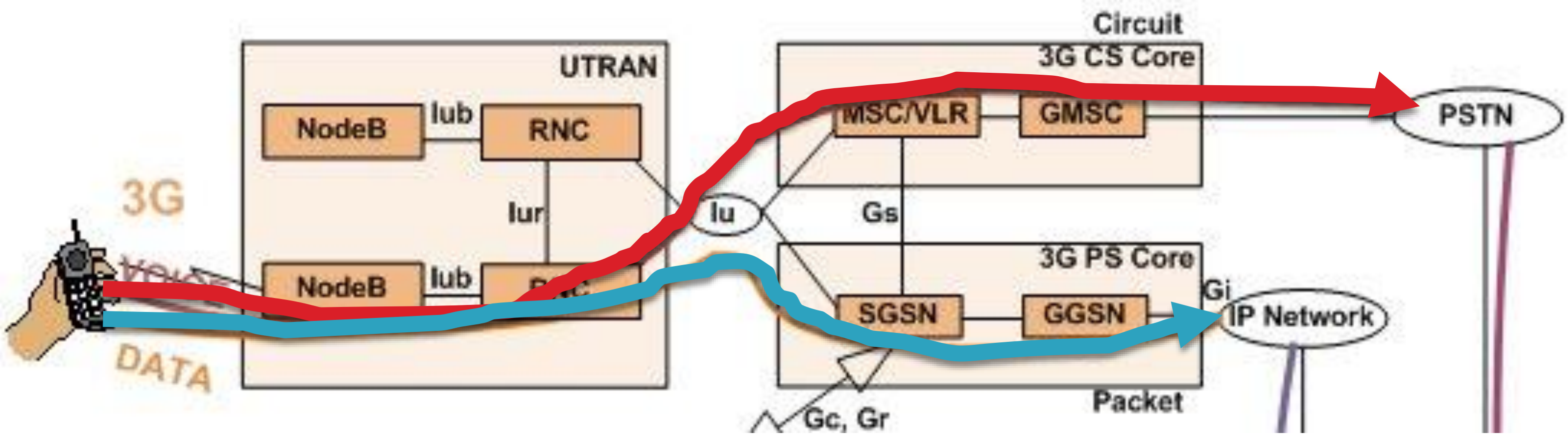
Wired networks are relatively simple



“Simplified” view of 3G



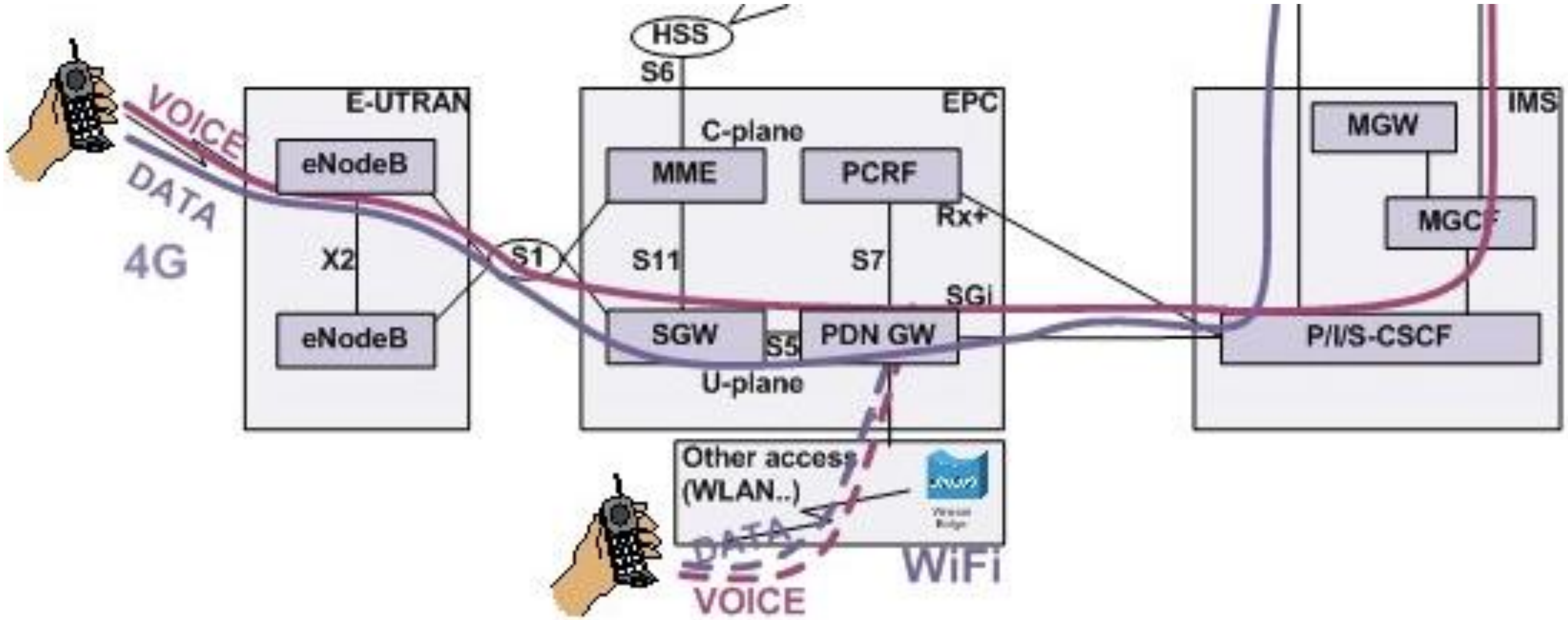
Packet switched vs circuit switched



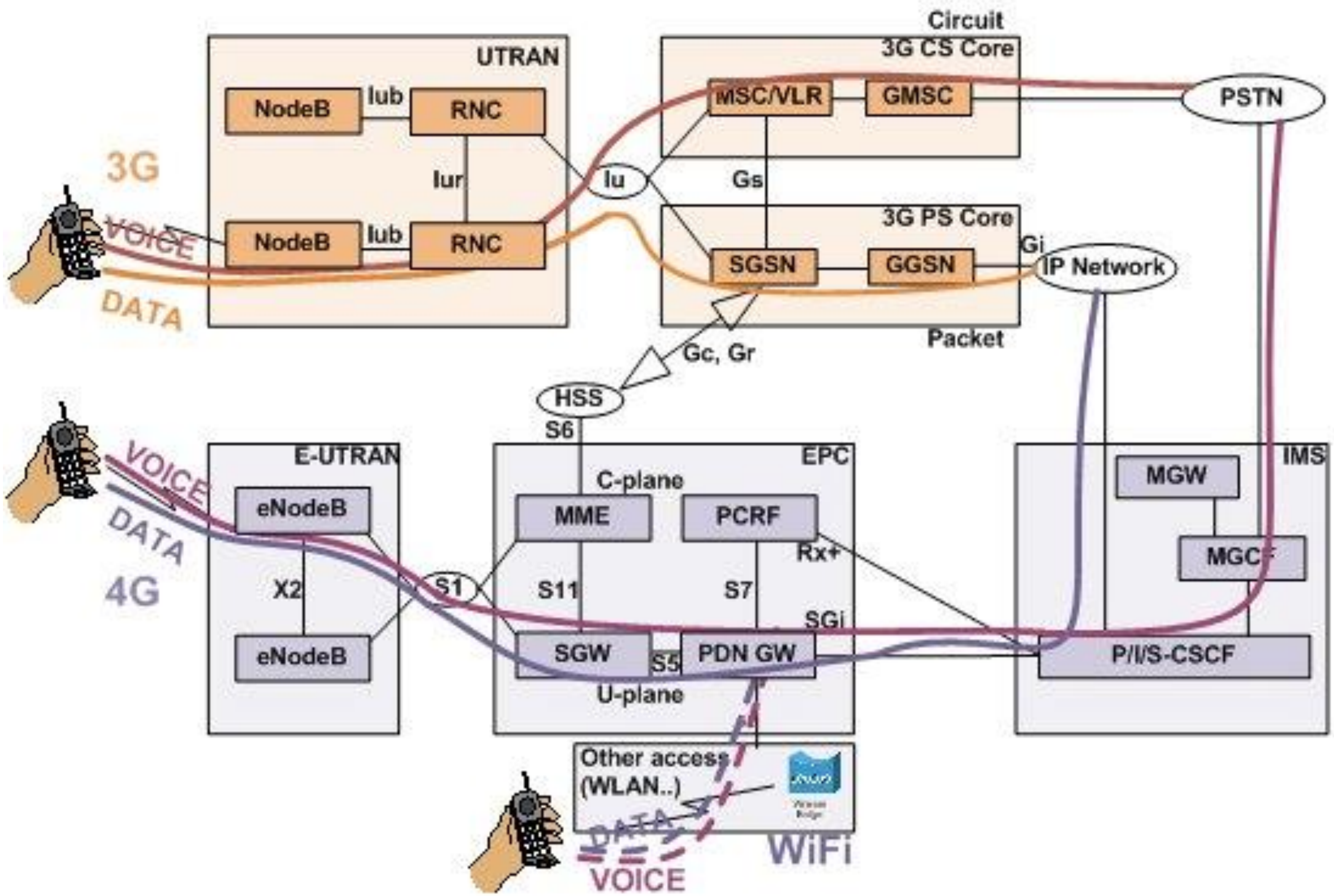
- 3G and earlier maintains two data paths
  - Circuit switched: Phone calls (8kbps) and SMS/MMS
  - Packet switched: All IP data

Packet switched vs circuit switched

- LTE uses "all in one" approach
  - Everything over IP, including voice
  - S-GW (Serving Gateway) replaced SGSN, P-GW replaces GGSN

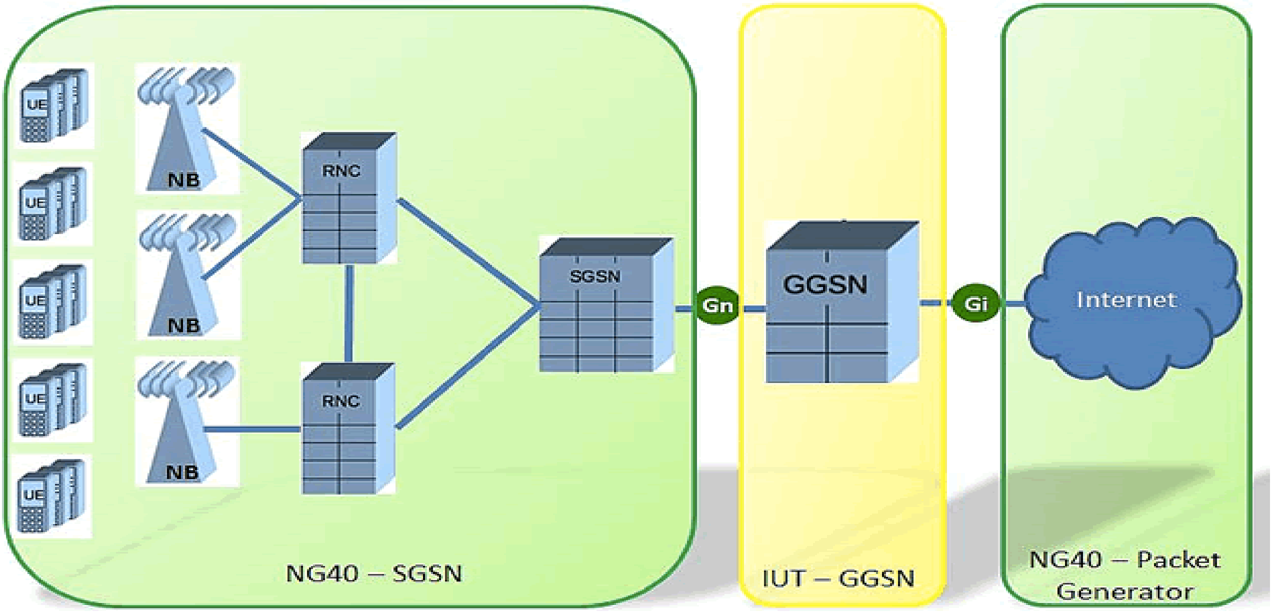


Backward compatibility

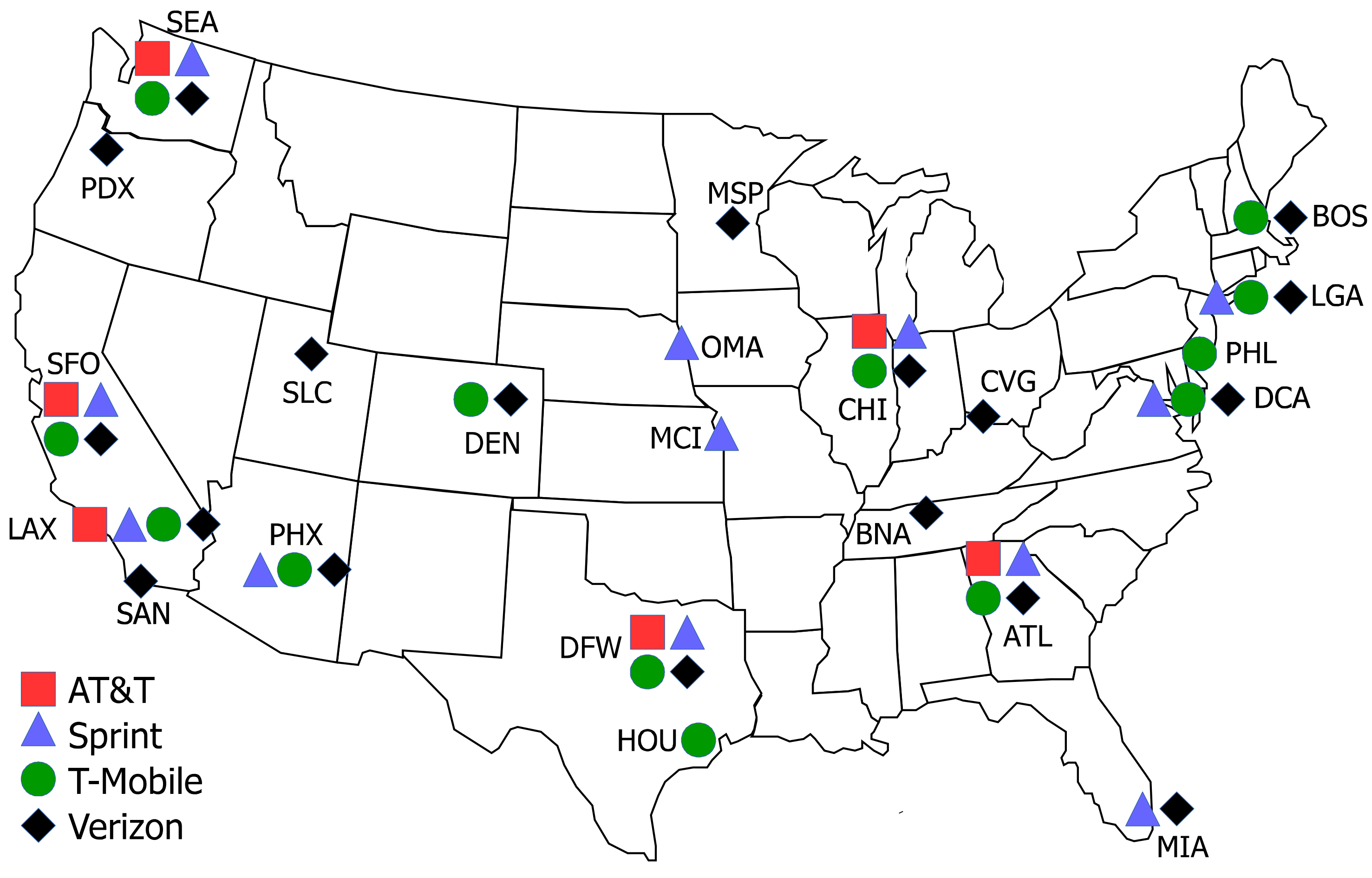


Mobile Architecture in practice

- RNC/NodeB: 1000s
- SGSNs/S-GWs: 10s or 100s
- GGSN/P-GWs: < 10
  - Why is this a problem?

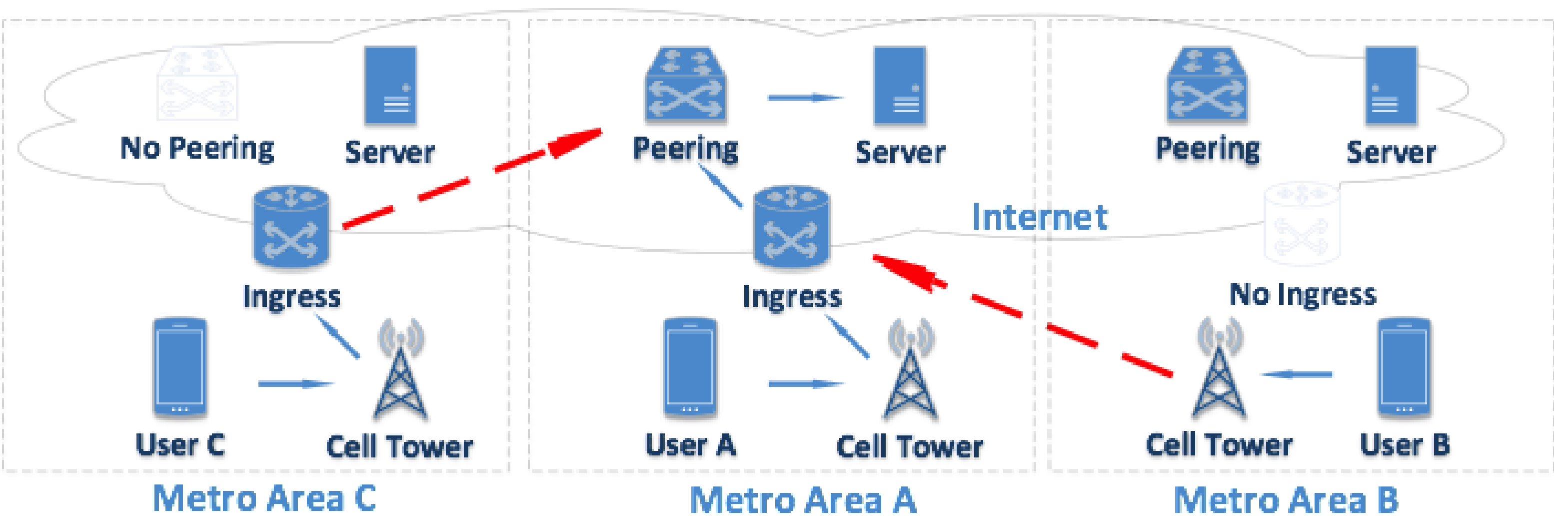


Very few GGSNs for a large region

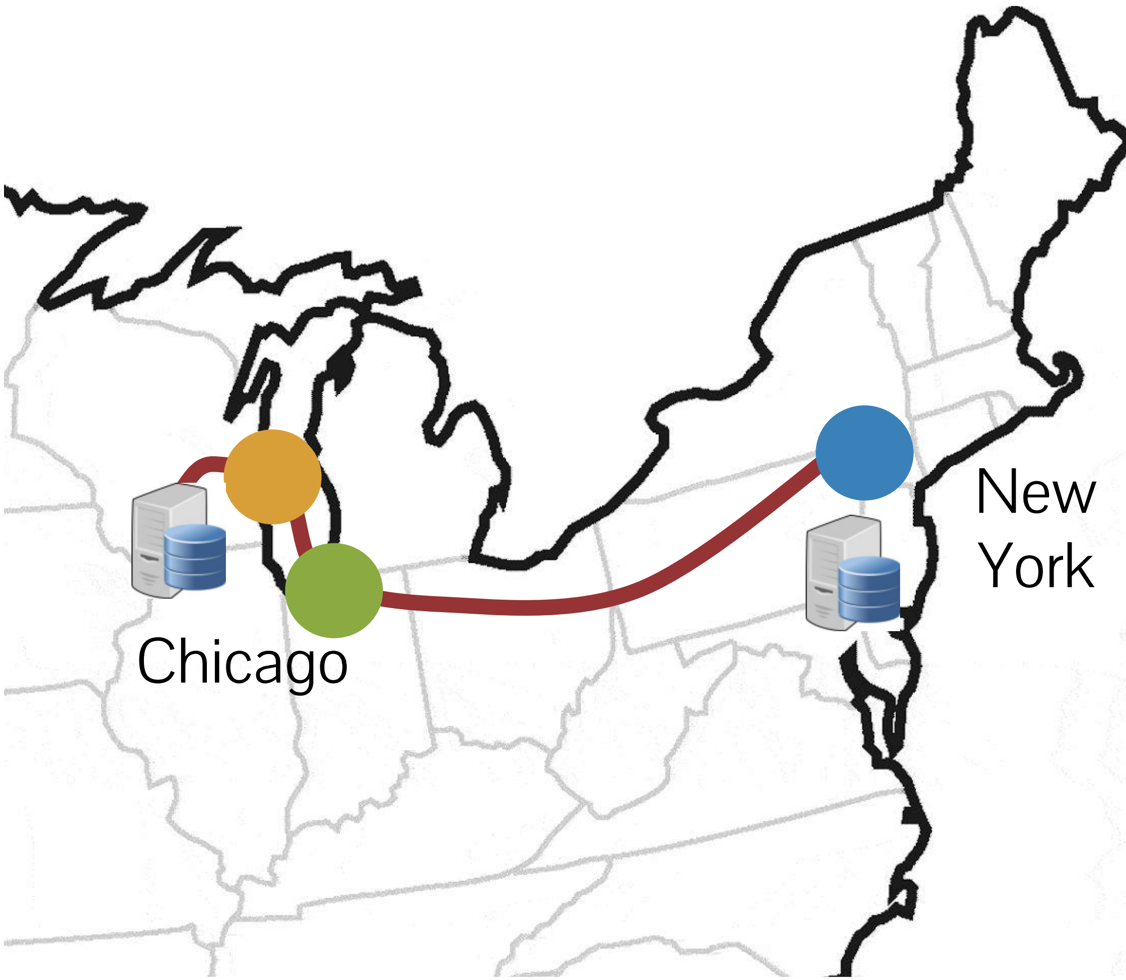


Implication: Path Inflation

- Path inflation: Two nearby hosts are connected by a geographically circuitous IP path
  - Can be caused by
    - Carrier path
    - Interdomain policy
    - Lack of nearby peering points



Path Inflation Example: Ingress



AT&T New York traffic enters public Internet in Chicago area

1074km extra distance

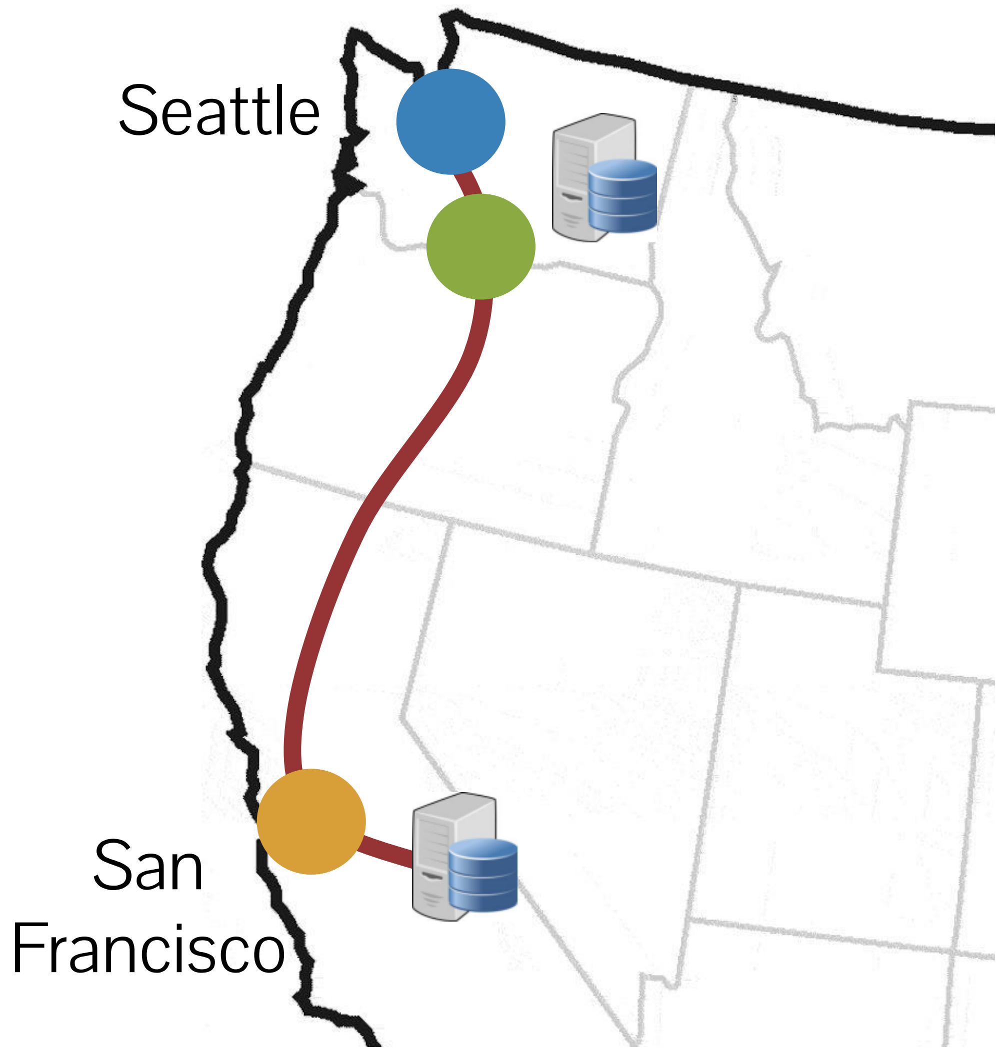
16ms extra latency

Path Inflation Example: Peering

AT&T Seattle traffic enters Google's network in Bay area

1089km extra distance

16ms extra latency



Inflation breakdown for AT&T

Area	Count	Fraction Inflated	Cause(s)	Extra distance	Extra PLT
San Francisco	7759	1.00	Ingress, Peering	4200km	315ms
Seattle	303	1.00	Peering	2106km	158ms
New York	2720	1.00	Ingress	2148km	161ms

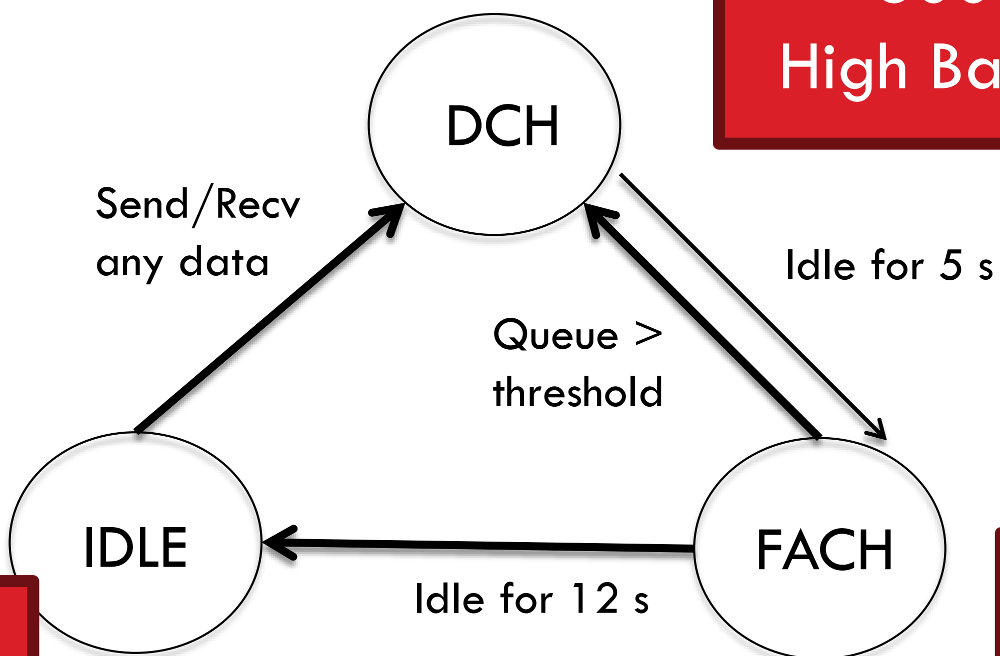
Wireless/Radio Issues

- Conflicting goals
  - IP application assume "always on" connectivity
  - Radio consumes large amounts of power
  - How to balance the two?

- Compromise in UMTS networks: 3 power states
  - Idle: No data channel, only paging, almost no power
  - FACH: Shared, low-speed channel, low power
  - DCH: Dedicated channel, high speed, high power

Issues with this approach

- State promotions have promotion delay
- State demotions incur tail times



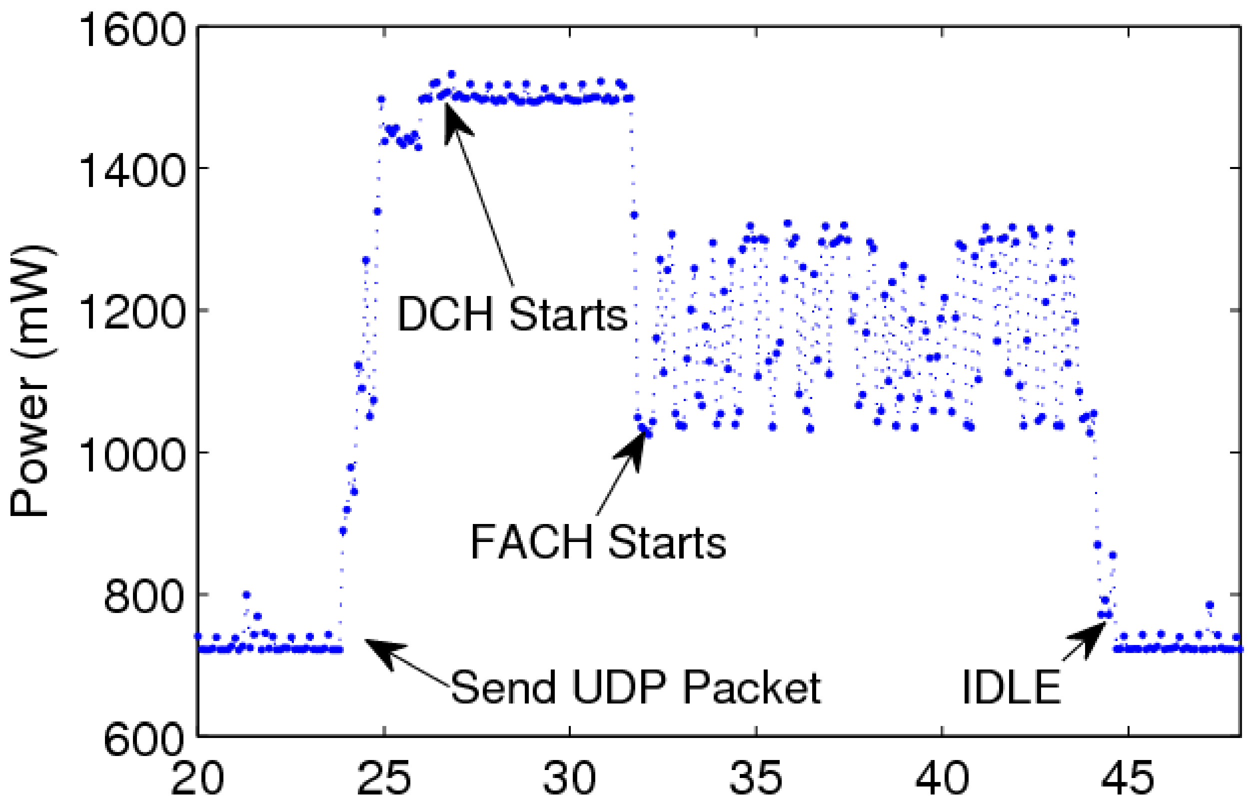
800 mW
High Bandwidth

460 mW
Low Bandwidth

No Power
No BW

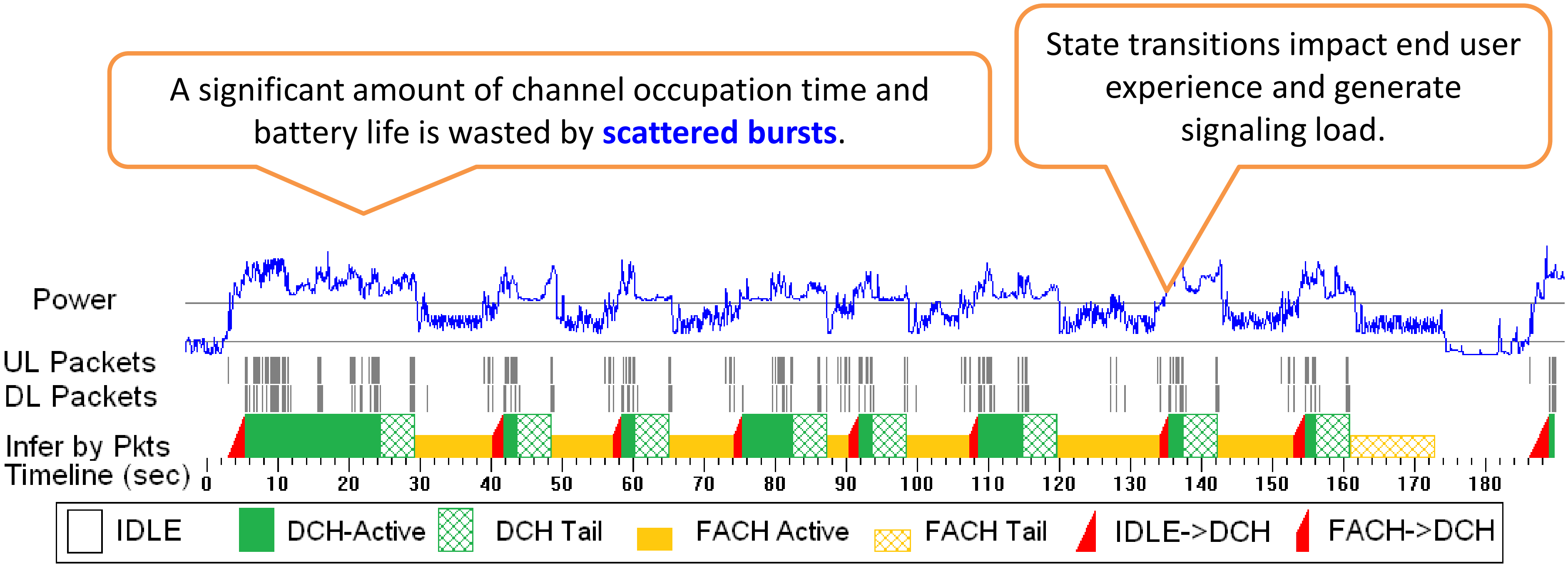
Delays add up…

- Delay to send a packet
- Delay to save power



… to inefficiency

- Inefficient radio utilization (34% power/channel)



Analysis powered by the ARO tool

LTE Key Features

- Uses Multi-input Multi-output (MIMO) for enhanced throughput
- Reduced power consumption
- Higher RF power amplifier efficiency (less battery power used by handsets)
- Lower latency to get access to the medium

- Performance sometimes better than WiFi!

Middleboxes in Mobile Networks

- Carrier-grade NAT
  - Devices often assigned private IPs
  - Firewalled connections
- Content optimizers
  - Split TCP connections
    - Why?
  - Compression and caching
  - Other strange behavior
- **How might we measure these?**

- **Mobile networks**