Special Topics

CS 168 – Fall 2024 – Discussion 14

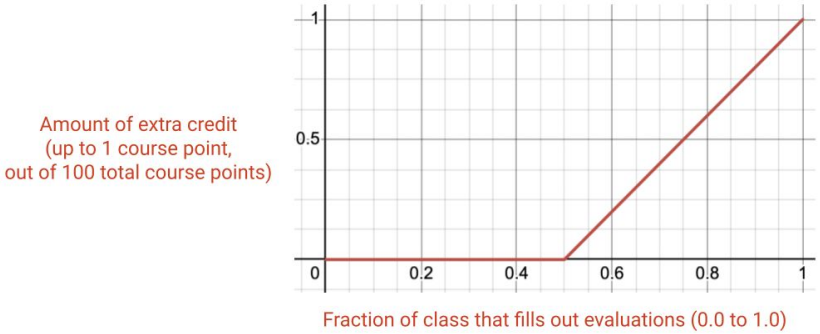
Agenda

- Logistics
- Wireless Overview:
  - What is it?
  - What is different about wireless?
- Medium Access Control
  - CSMA
  - RTS/CTS
  - MACA/MACAW
- Cellular:
  - Architecture
  - Actions (Discovery, Attachment, Handover, Roaming)

Logistics

- Final exam is on **Wednesday, December 18, 8am–11am** PT
  - If you have any requests, such as an alternate time, DSP accommodations, left-handed desk, etc., please fill out the final exam logistics form before **Monday, December 9**
  - You can bring two 8.5" × 11" cheat sheets, each two-sided
  - all lectures, discussions, projects, and homeworks — including Special Topics — are included in the exam scope
- Please fill out course evaluations for extra credit!
- This is the final week for discussions

Extra credit = $2x - 1$, where x is fraction of class that fills out evals (0.0 to 1.0)



Wireless Overview!

What is wireless communication?

- Transmit information without contact (e.g. with EM waves)

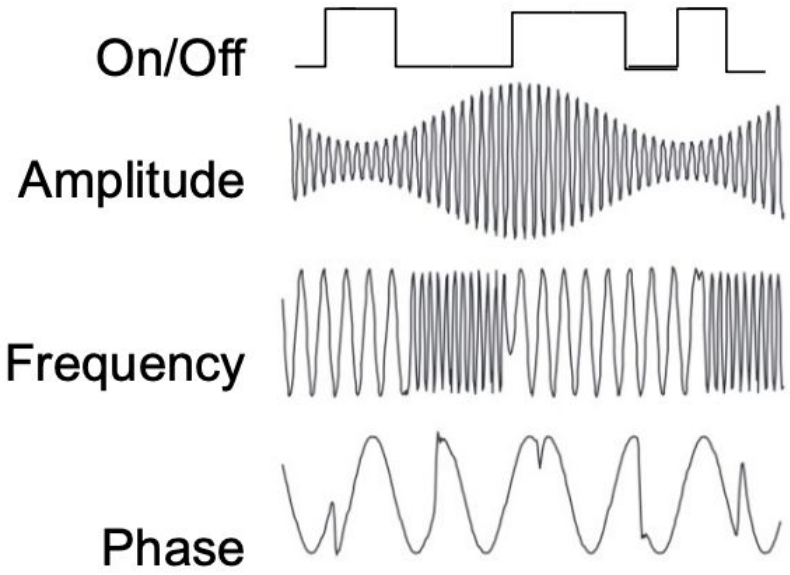
How is wireless different from wired?

Wireless ...

- is a fundamentally shared medium
- signals attenuate significantly with distance
- environments can change rapidly
- packet collisions are hard to detect

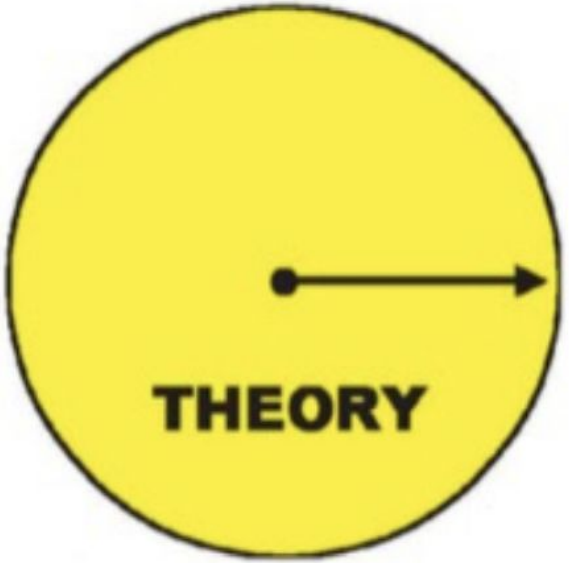
How is data encoded?

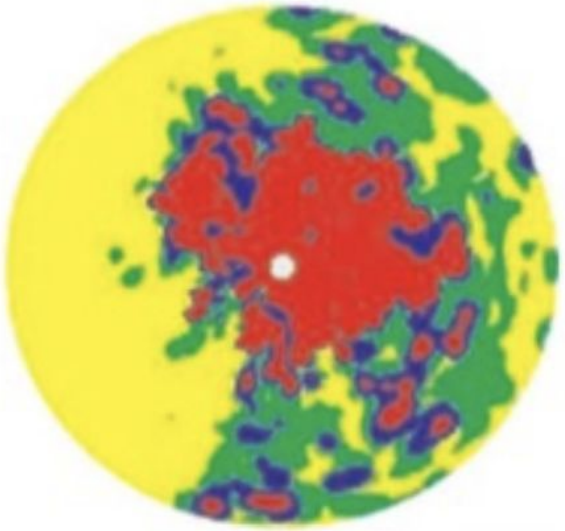
Physical Layer Modulation: Physical variations in signals map to digital values (i.e. 1 or 0)



The wireless medium is messy

Details out of scope!! Check out EE117, EE 121, EE122





Medium Access Control

How to share the same transmission technology?

Key problem: wireless collisions are often unexpected (highly mobile, dynamic environment) and hard to detect (failure is the only indication)

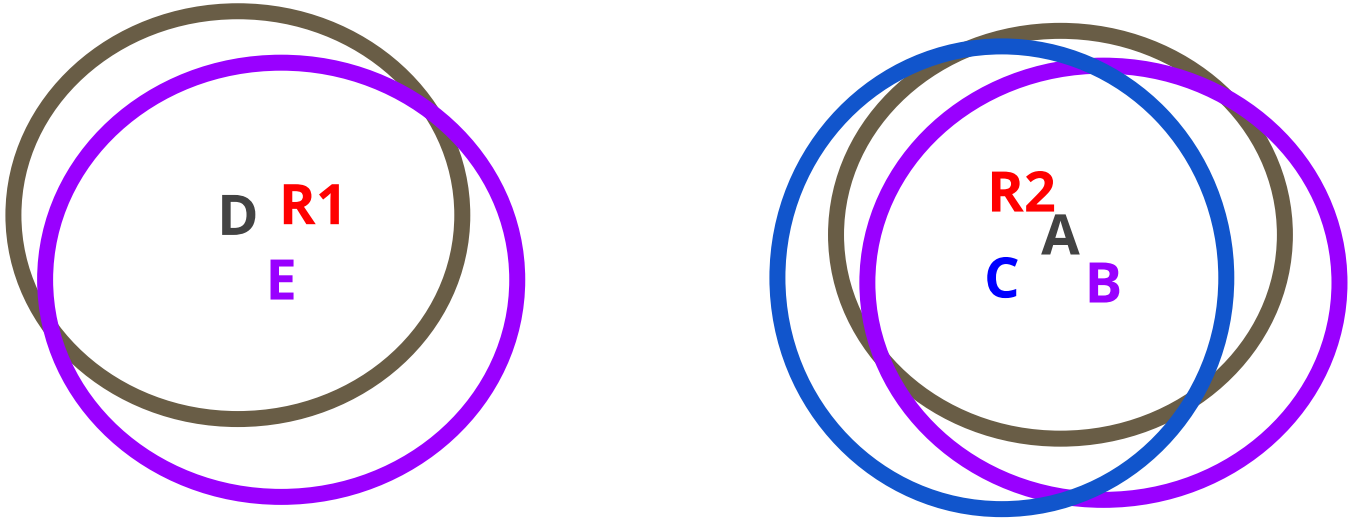
How do we deal with a lack of reliability in networks?

- end-to-end principle, ensure reliability at endpoints
- retransmit if no ack
- coordination

Carrier Sense Multiple Access (CSMA)

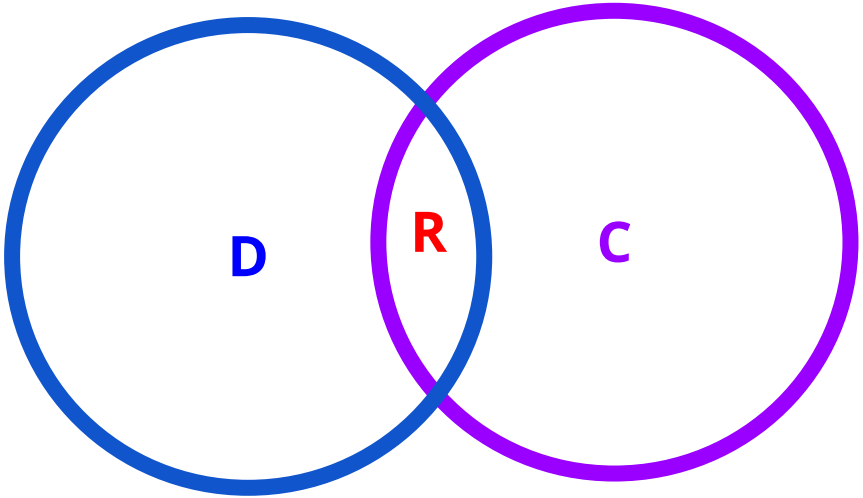
Key idea: listen for others on the medium and don't transmit if busy

- Works great when ranges of involved transmitters/receivers are all overlapping or completely disconnected



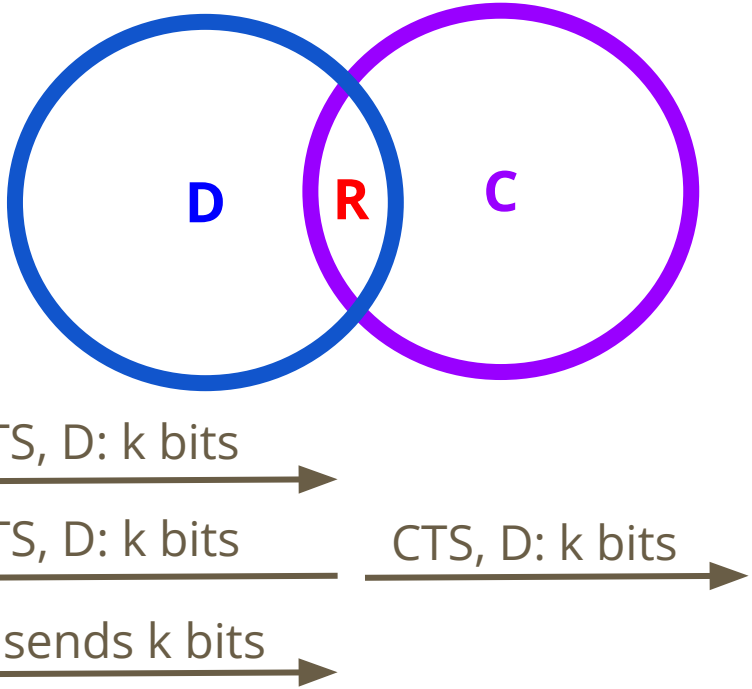
Hidden Terminal Problem

- A problem: two transmitters can’t hear each other



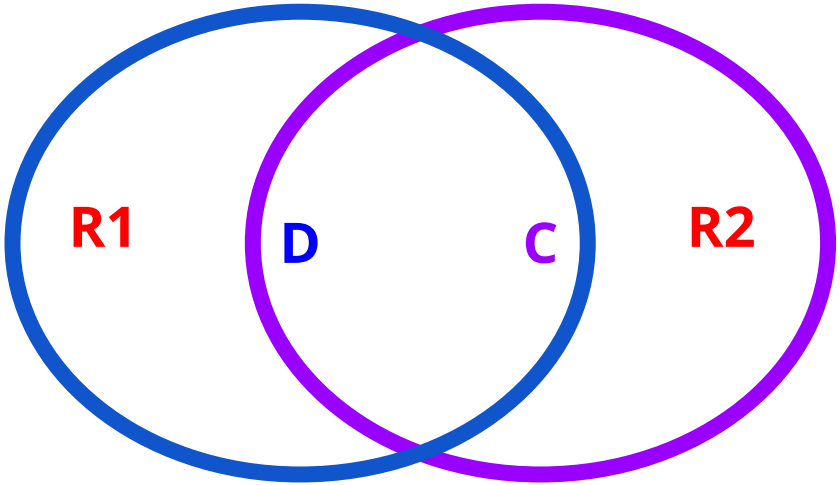
Request to Send / Clear to Send (RTS/CTS)

- Key idea: send a request-to-send and wait for a clear-to-send before transmitting



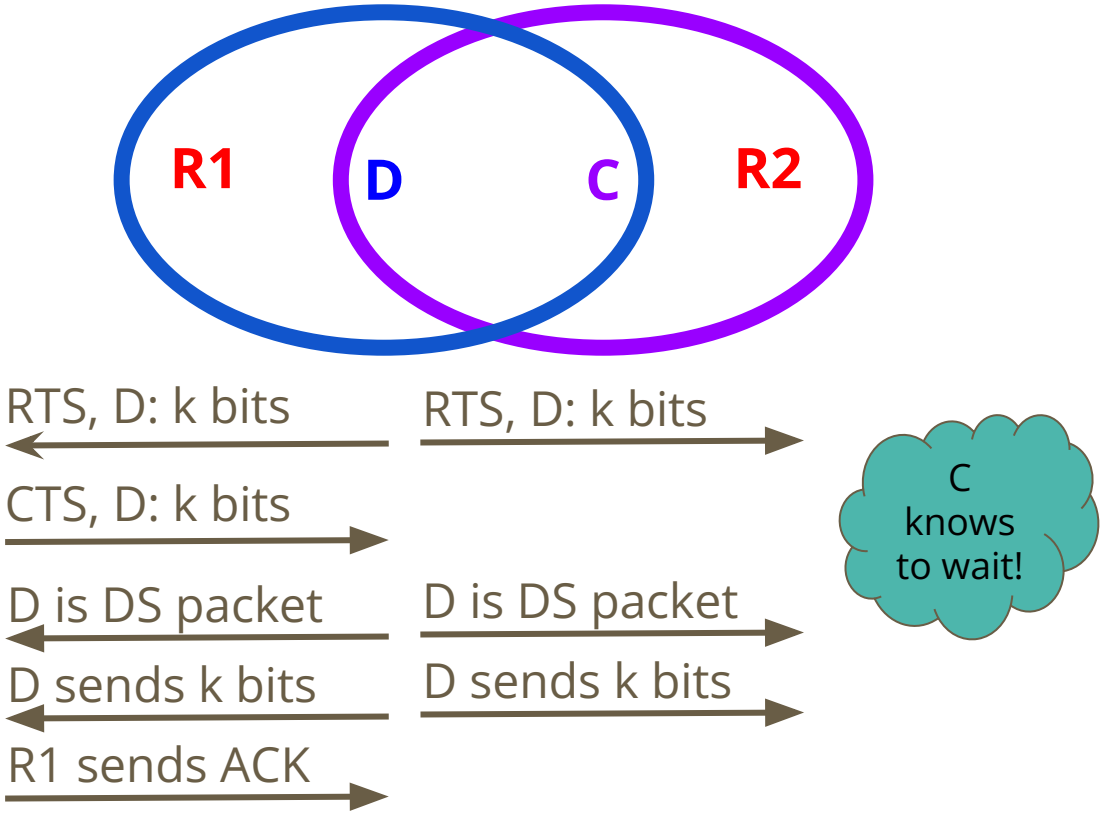
Exposed Terminal Problem

- Another problem: ‘safe’ transmissions could be blocked since D and C hear each other transmitting



Multiple Access with Collision Avoidance for Wireless (MACAW)

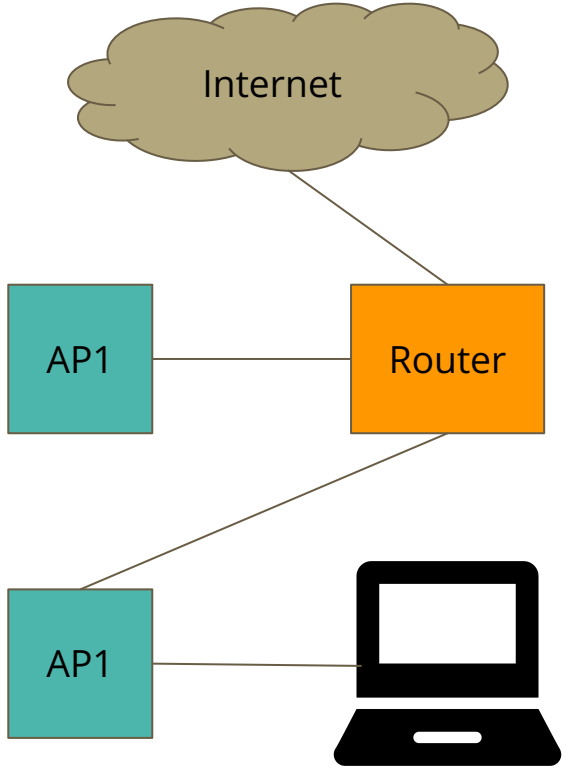
Key idea: Use RTS/CTS, but add backoff to deal with RTS collisions and reliability by using acks and a data sending indicator



WiFi

How does WiFi (802.11) work?

- Designed for a limited area (i.e. home)
- Access points (APs) set to a channel
- APs broadcast beacon messages with SSID (Service Set Identifier) and MAC Address periodically
- Hosts scan all channels to discover APs
- Hosts associate with AP



How does WiFi (802.11) work?

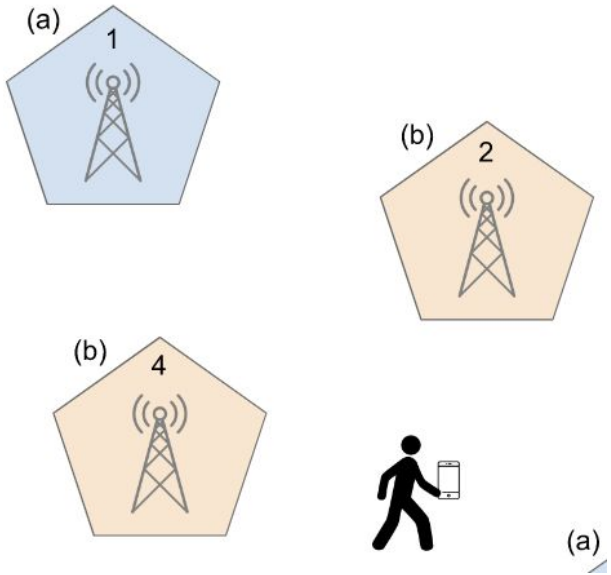
- Essentially uses CSMA (this is over simplified but details are out of scope)
- RTS/CTS is an optional feature (mainly used for large data transfers)

- Why would WiFi not use a full MACAW protocol all the time?

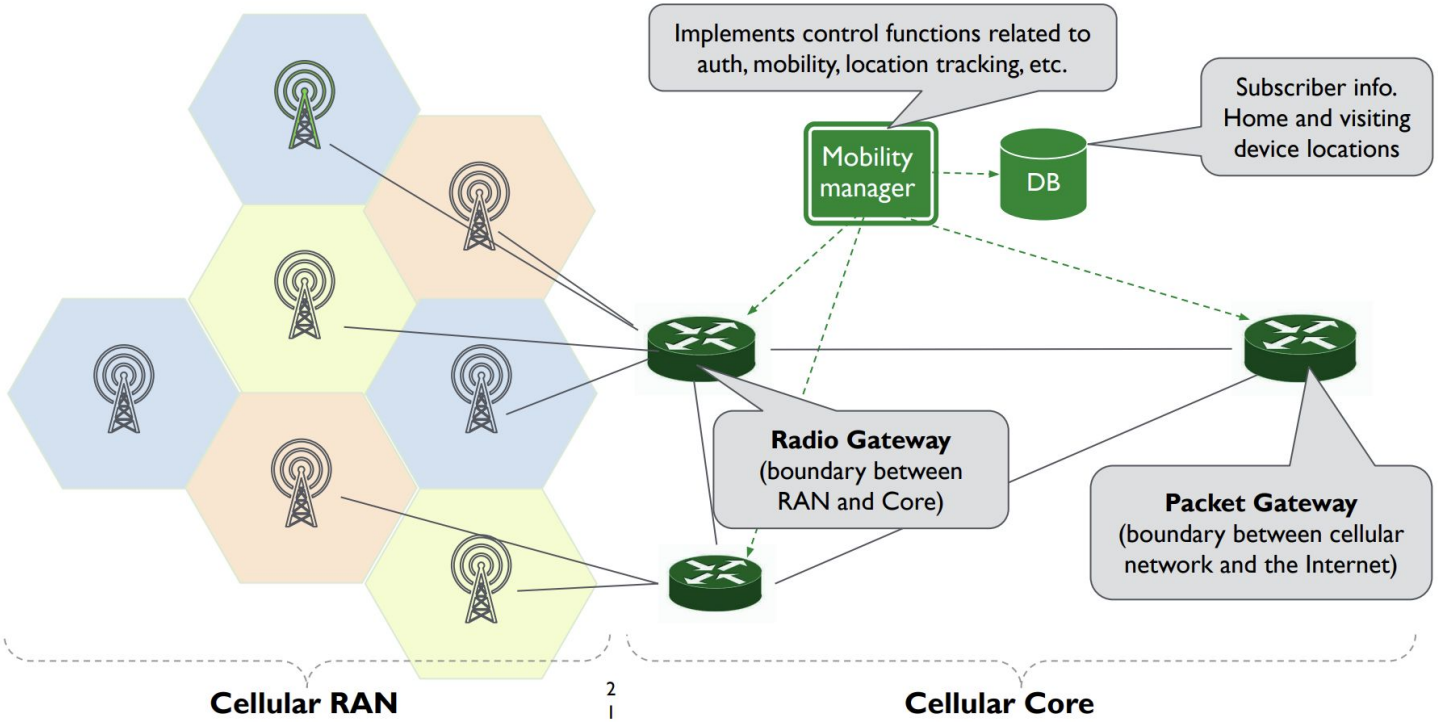
Cellular

How does cellular work?

- Key goal: Mobility
- Authentication and accountability are also first order goals
- Two Major Components:
  - Cellular Radio Access Network (RAN): between devices and cell towers
  - Cellular Core: between gateways and internet

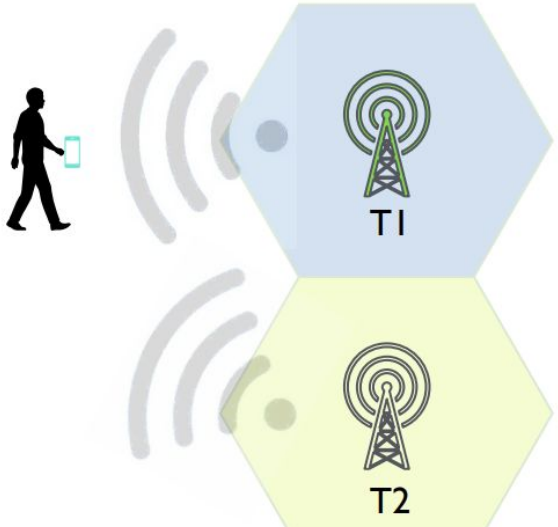


How does cellular work?



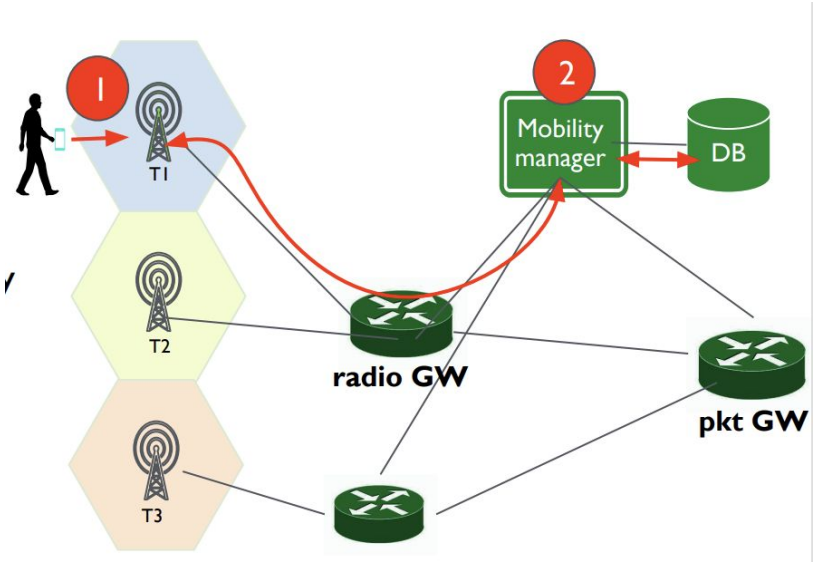
Discovery

- Towers transmit periodic “hello”s which ID the operator
  - Network operator for these towers are included in the message. Why?
- Device picks the best tower based on signal strength



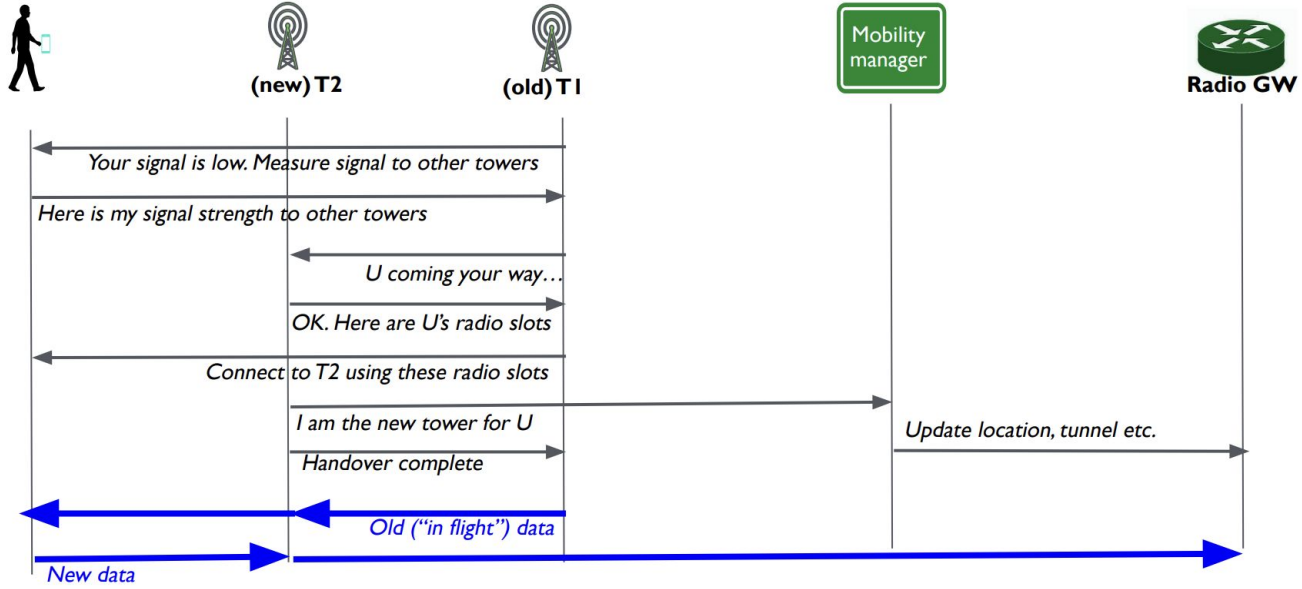
Attachment

- Device sends “attach request” to tower with best signal strength owned by operator.
- Request is processed/authenticated by the mobility manager
  - Mobility Manager stores User Device’s International Mobile Subscriber Identity (IMSI) and subscriber plan to database



Handover

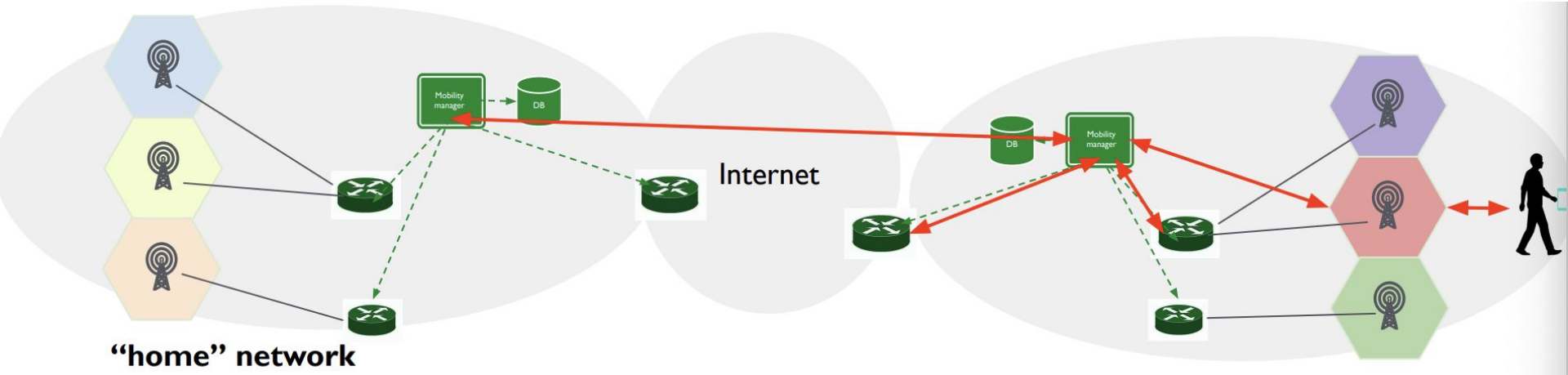
- Cooperatively done between U,T1,T2,mobility manager, radio gateway



Acknowledgements: adapted from Raj Jain's lectures

Roaming

- Mobility manager in the “visited” network has to check with the “home” network mobility manager for authentication.
- Can either route data through home network packet gateway or visited network packet gateway



Aside - Machine Learning + Wireless Networking Research!

https://shonenmind.github.io/EE290-Final-Project/

- Using machine learning models for more efficient 5G communication systems
- **Beamforming**: concentrating waves toward a specific receiving device's antenna, rather than spreading them out in all directions
  - Higher signal quality
  - Less Power consumption
  - Increased range of data transmission
- Train a neural network to pick the best directions our antennas should concentrate transmitting data

Worksheet

Feedback Form: https://tinyurl.com/cs168-disc-fa24

1. Wireless is a fundamentally shared medium.

Solution: True. The wireless medium is a shared physical space instead of wired infrastructure.

2. The path loss of a wireless transmission is always the same in all directions.

2. The path loss of a wireless transmission is always the same in all directions.

Solution: False. Obstacles and reflections mean that the reality of wireless transmission is messy and non-uniform.

3. In cellular networks, the nearest tower to the user configures the specific routers to establish a path from the user to the Internet.

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Solution: False. It is the job of the mobility manager, not the tower, to establish a path from the user to the rest of the internet.

4. When picking a tower to configure with, the user picks the tower (belonging to its operator) that is closest to the user in terms of distance.

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Solution: False. The user measures the signal strength to different towers, and picks the tower (belonging to its operator) with the best signal, not the least distance.

5. When towers periodically broadcast hello messages in order to be discovered, they include their network operator in these broadcast messages.

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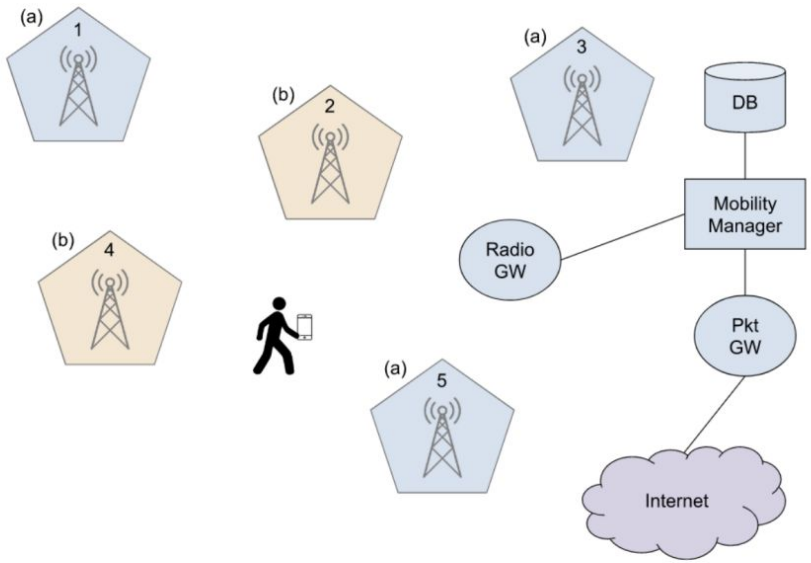
Solution: True. The reason they do this is so that only users who registered with the same network provider can connect to the tower.

In the following cellular architecture, the user is registered with the cellular operator (a) shown in blue and labeled with (a). As the user moves around the area, they discover and transfer data using different cellular towers.



1. The user device is registered with operator (a), and gets the following beacons from the different towers with different received signal strength indicators (RSSI).

Tower	RSSI	Operator
1	-75dBm	(a)
2	-23dBm	(b)
3	-84dBm	(a)
4	-32dBm	(b)
5	-42dBm	(a)

dBm range: 0 to -100

Closer value is to 0, the greater the noise level

(a) Which tower should the user device connect to?

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Solution: The user should connect to the tower with the highest signal strength that is in the administrative domain that they have signed up for. In this case, tower 5 has the highest dBm for operator a

(b) What entity in the cellular core processes the attach request from the user device?

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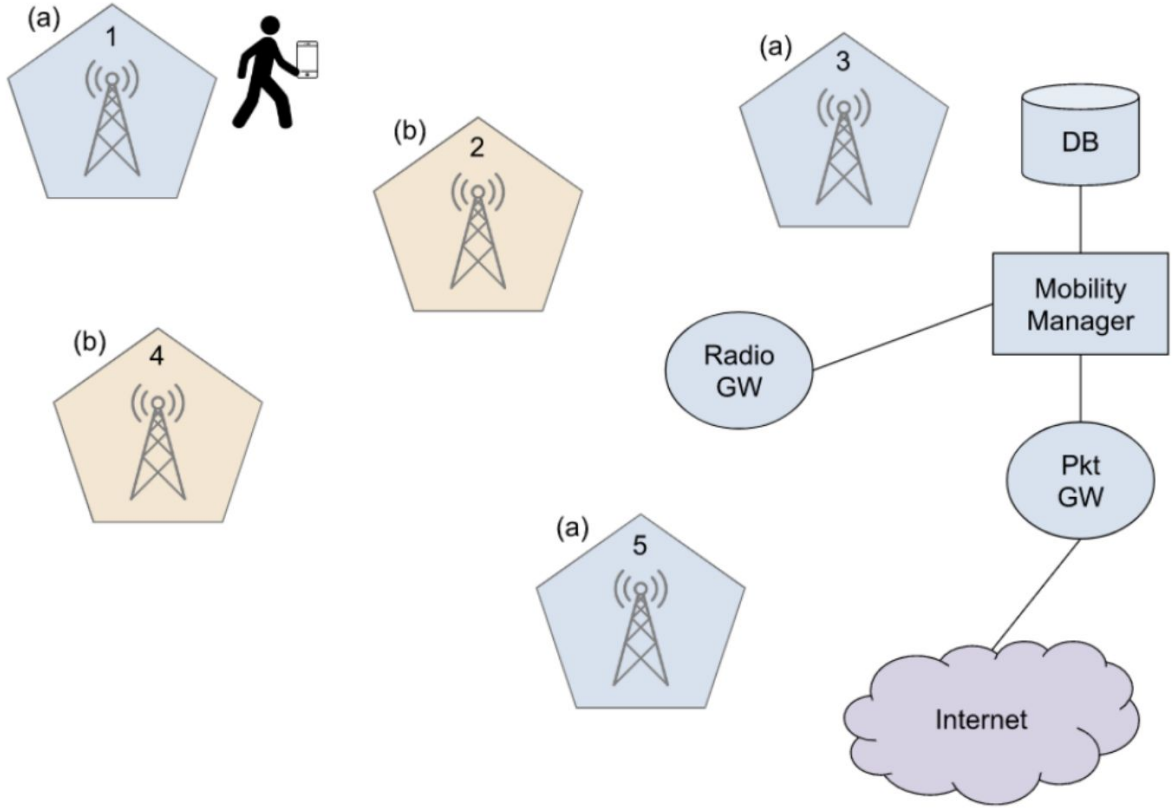
Solution: The mobility manager processes the attach request by checking to make sure the user exists in the database, and providing authentication.

2. Now the user moves as shown below and a handoff to tower 1 must occur.



(a) Who participates in the handoff? Circle all that apply.

i. User Device
ii. Packet Gateway
iii. Tower 1
iv. Old Tower (from part 1)
v. Tower 4
vi. Mobility Manager

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Solution: i., iii., iv., vi.

(b) Who initiates the handoff?

i. User Device
ii. Packet Gateway
iii. Tower 1
iv. Old Tower (from part 1)
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(b) Who initiates the handoff?

i. User Device
ii. Packet Gateway
iii. Tower 1
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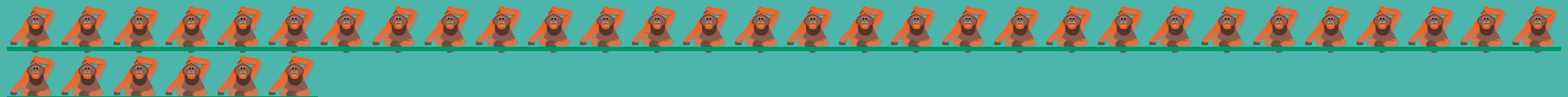
Solution: iv.



3 Wireless

Consider the following hosts attempting to talk with each other using the Multiple Access Collision Avoidance (MACA) protocol from class. You may assume that when a host transmits a message, the message travels radially outward from that host at a uniform velocity.

Notably, if Host D transmits a message, then after one second, both Host C and Host E hear the message, and after two seconds, both Host B and Host F hear the message, and so on. All hosts are equidistant from each other.

1. Suppose after not hearing any messages being transmitted for a while, Host E wants to start the process for transmitting a message to Host G at time $t = 0$.

   (a) What is the first thing that Host E transmits, and why does this first step help reduce collisions?

1. Suppose after not hearing any messages being transmitted for a while, Host E wants to start the process for transmitting a message to Host G at time $t = 0$.

   (a) What is the first thing that Host E transmits, and why does this first step help reduce collisions?

Solution: The first thing Host E will do is transmit a Request to Send (RTS) packet that contains the length of the data it wants to send to Host G. This is to ensure that other hosts near Host E's range won't send anything, as every host that hears this packet will wait for one time slot before sending out their own packets.

(b) How does this first step differ from what would happen through the Carrier Sense Multiple Access (CSMA) approach?

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Solution: Since Host E waited for a while already, it would then immediately transmit its data to Host G (in reality in all directions, but meant for Host G). CSMA does not use any RTS or CTS packets, but instead automatically transmits data after waiting for some time to see if any other hosts are transmitting data.

2. Suppose Host G has received Host E's message from the "first step" of the previous part.

   (a) What packet does Host G now transmit to Host E, and what is the significance of this packet?

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   (a) What packet does Host G now transmit to Host E, and what is the significance of this packet?

Solution: Host G now transmits a Clear To Send (CTS) packet that contains the length of the data Host E wants to transmit to Host G. This packet, once it reaches Host E, ensures Host E that it is clear to transmit its data to Host G, but it also ensures that everybody else in range of the receiver stays quiet during this time, so as to avoid collisions at the receiver.

(b) Suppose Host A wants to transmit data to Host H at the same time that Host G receives E's "first step" message. By MACA rules, is Host A able to do this?

Solution: Yes, because Host G will receive Host E's RTS packet at time $t = 2$. At that point, Host A would not have heard Host E's RTS packet (since Host A is further away from Host E than Host G is to Host E). Therefore, in Host A's perspective, it is free to transmit an RTS packet to H.

(c) Suppose Host E has now received the packet from Host G. Why can Host E now transmit the data and be assured that collisions at Host G are unlikely to occur?

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Solution: Host E can now transmit the data, and the CTS message from Host G now ensures that all the hosts in Host G's close range, like Hosts H, I, and F, will be quiet while Host E now transmits its data to Host G.