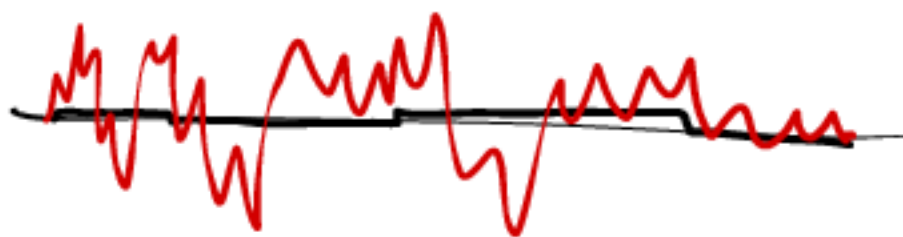
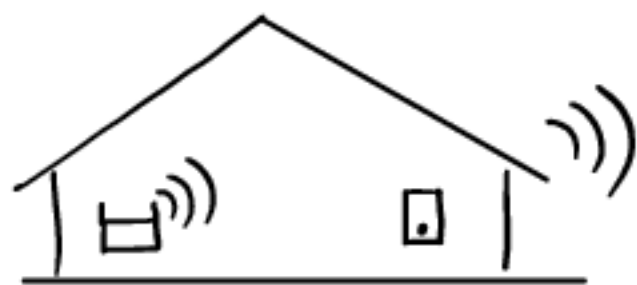


device or technology based on the Institute
of Electrical and Electronics Engineers (IEEE)
wireless communication standard 802.11
"The Standard for Wireless Fidelity"

⑫ So why not use Wifi when I am driving?



Motivates our next topic

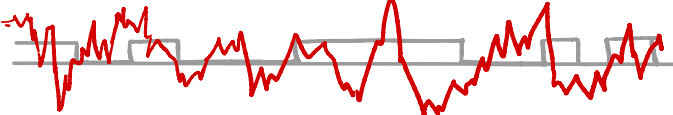
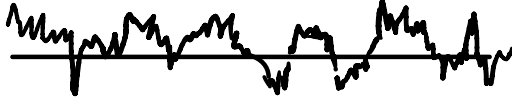


Cellular
Networks

① Connecting over long distances.



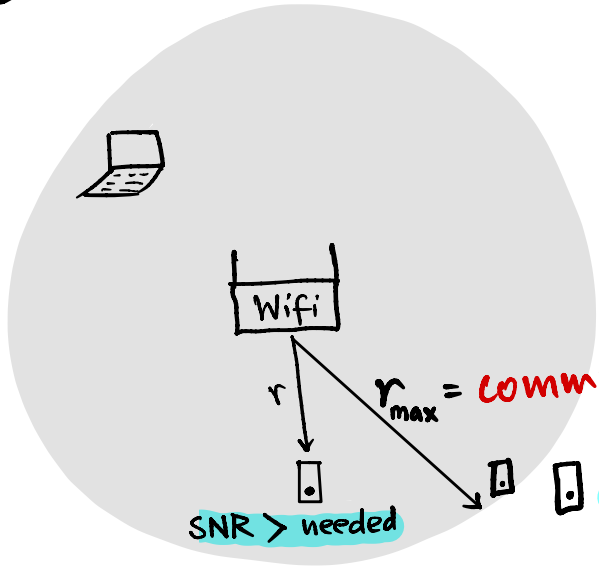
■ Difficult because → Power attenuates with distance → bit errors

Recall :  → 

■ What matters is the ratio : $\frac{\text{Received power of signal (S)}}{\text{Power of (noise (N) + interference (I))}}$

$$= \frac{S}{N + I} \quad \text{called SINR}$$

② Communication Range



■ Power attenuates $\frac{1}{r^2}$

■ Received power $S = \frac{\text{Transmit power}}{r^2}$

$P_t = \text{Transmitted power} = 100$

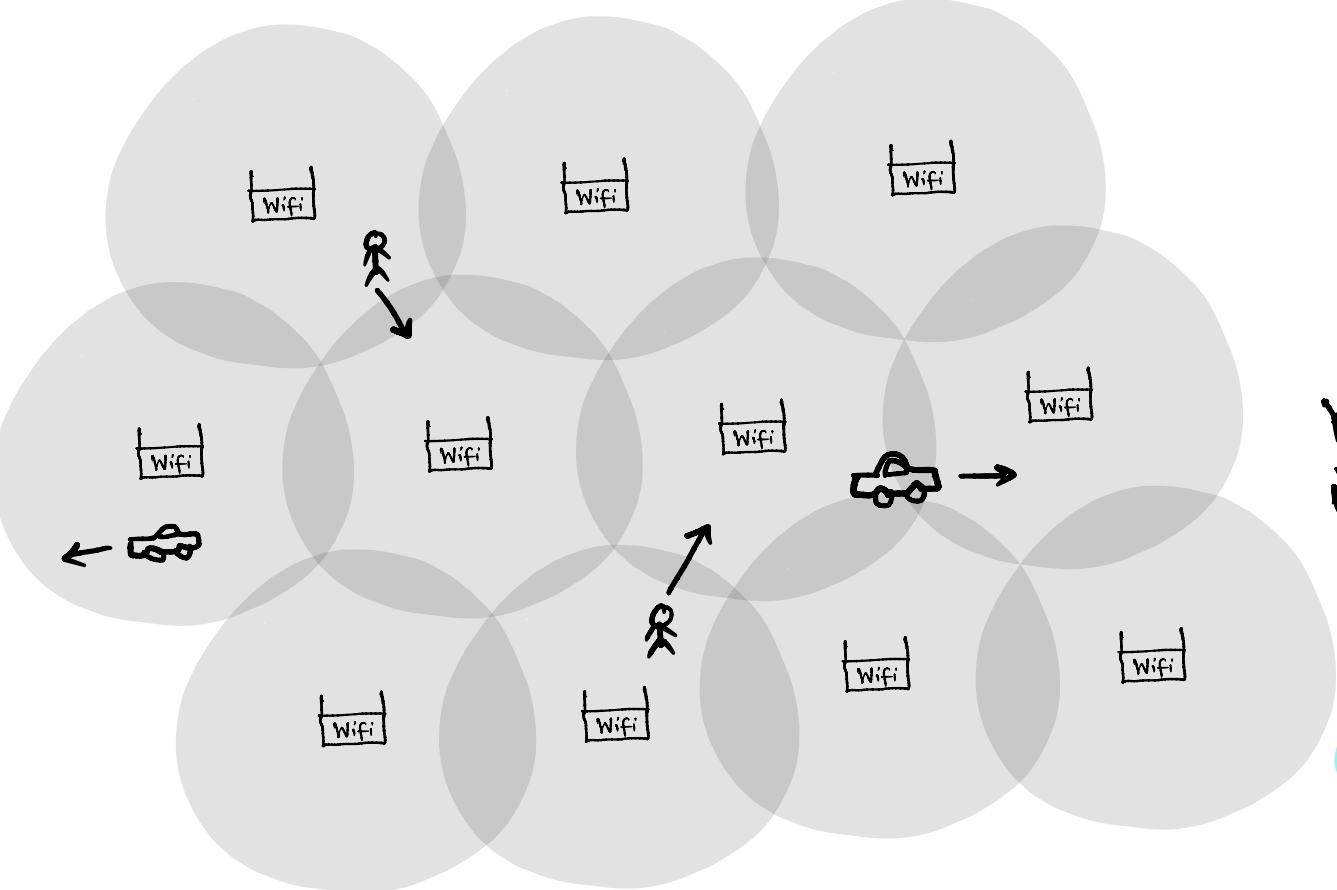
$N = \text{Noise power} = 3$

$I = \text{Interference} = 0$

$\text{SNR needed} = 1.33$

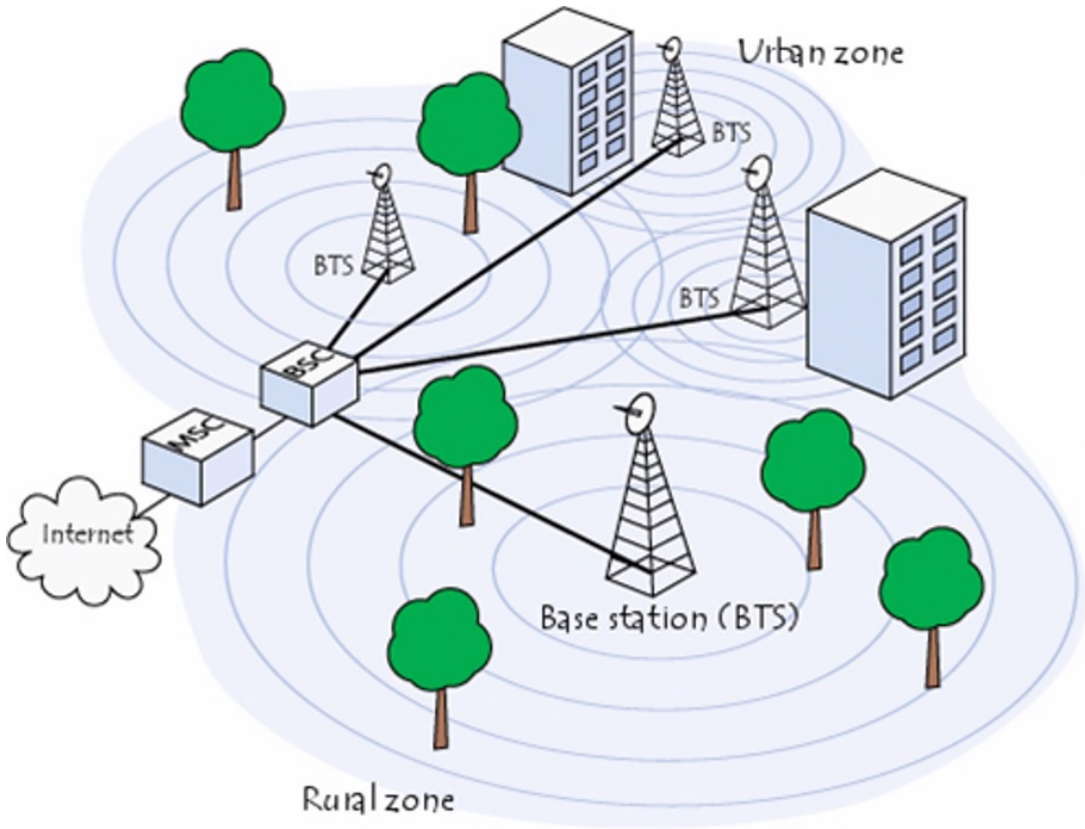
What is the communication range of wifi in this case?

③ Why not blanket cover the city with wifi?



Yes that's the idea with cellular networks ...

Except ...

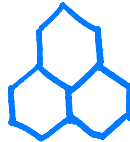


- Cell towers instead of Wifi boxes to send signals from a good height.

- All cell towers connected with wires

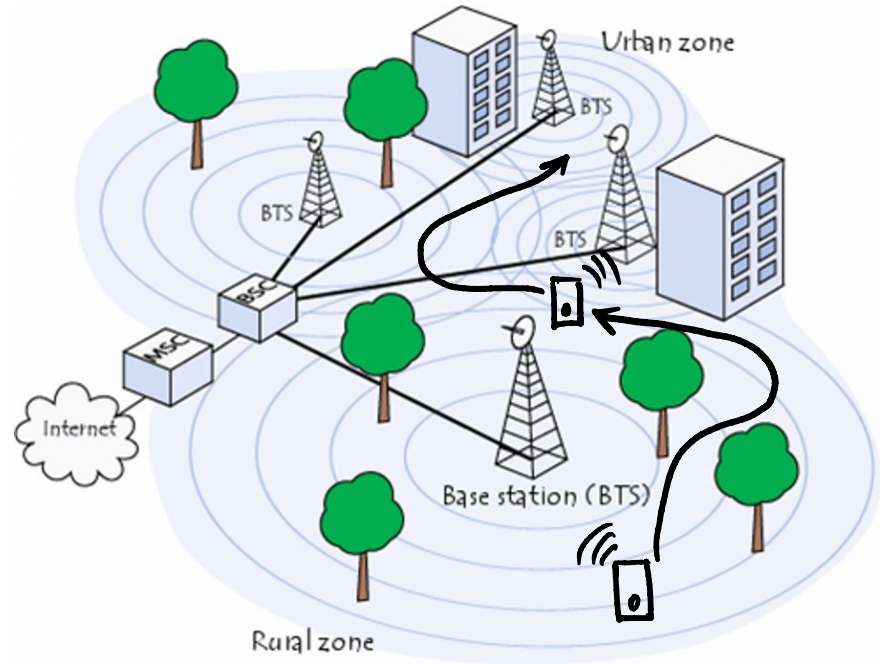
- Managed by a single administrator or company.

"cellular" because hexagonal cells can fully cover 2D space.



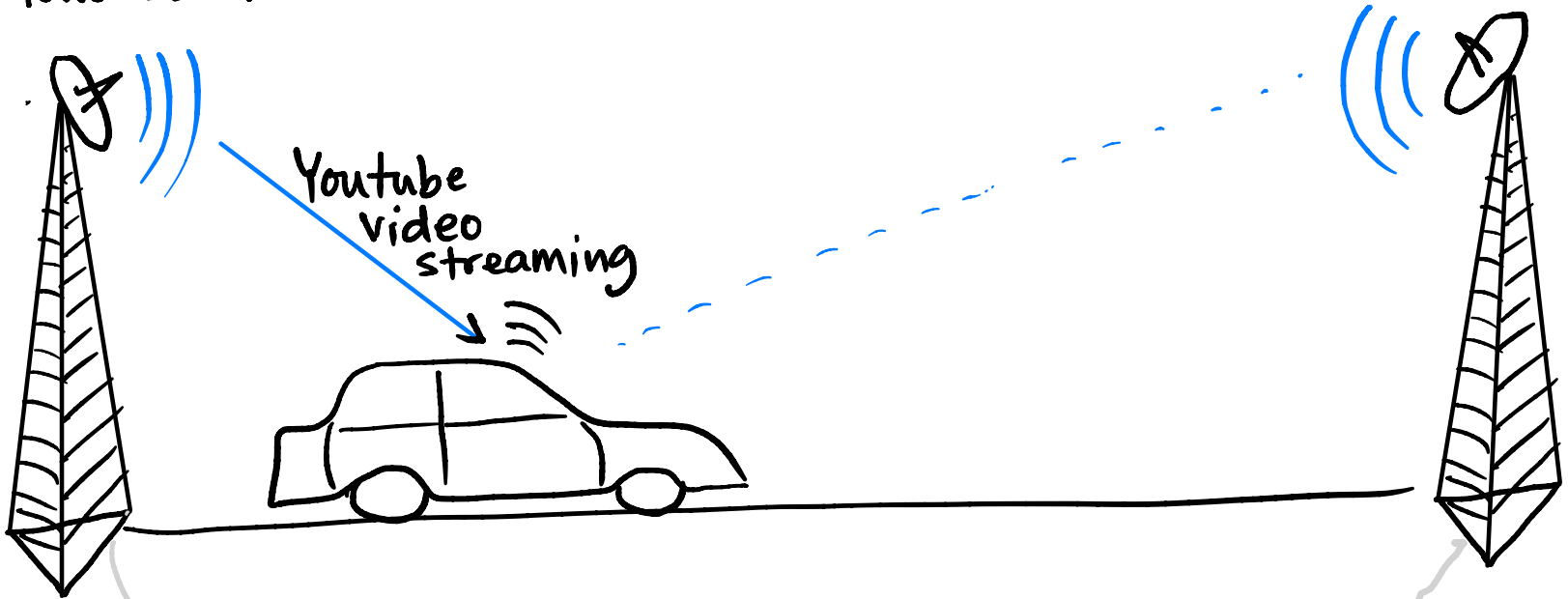
④ "Connected by wires & single admin" : What's The big deal

A: Mobility and Handoff
for continuous
connectivity.



tower ID: 15

ID: 18



Youtube
video
streaming

Mobile Switching Center

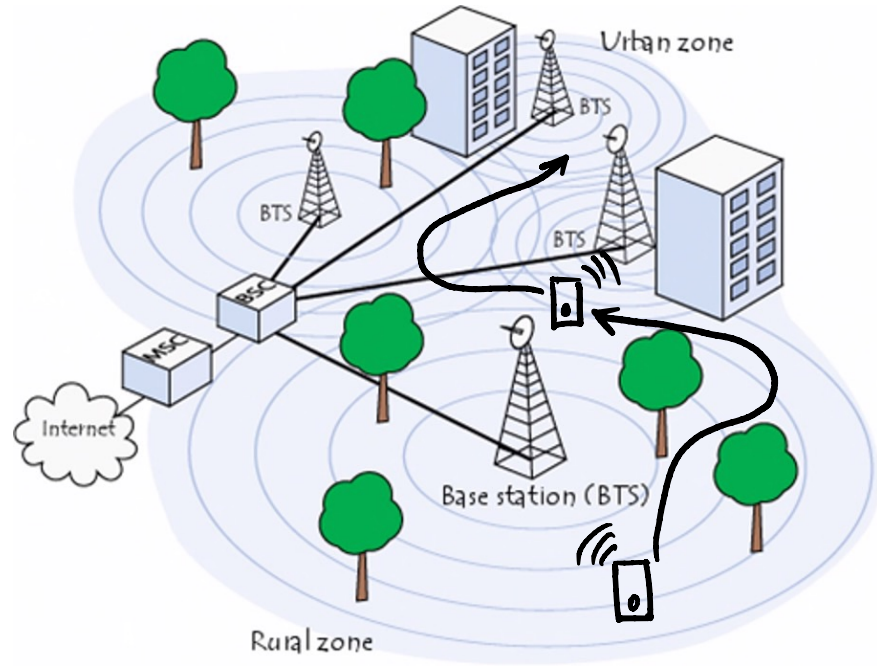
MSC

When should
the phone
switch towers?

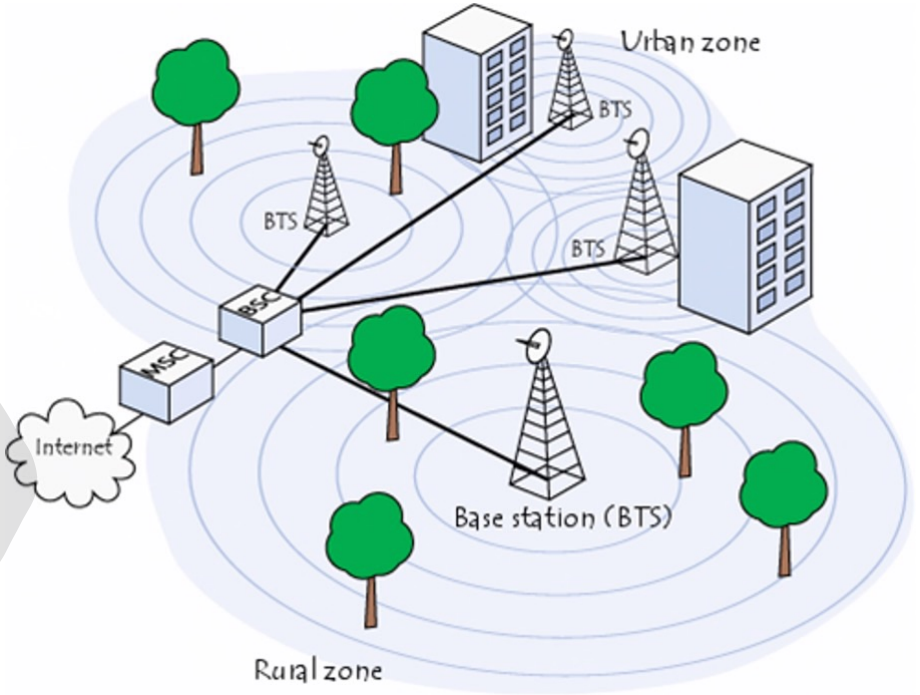
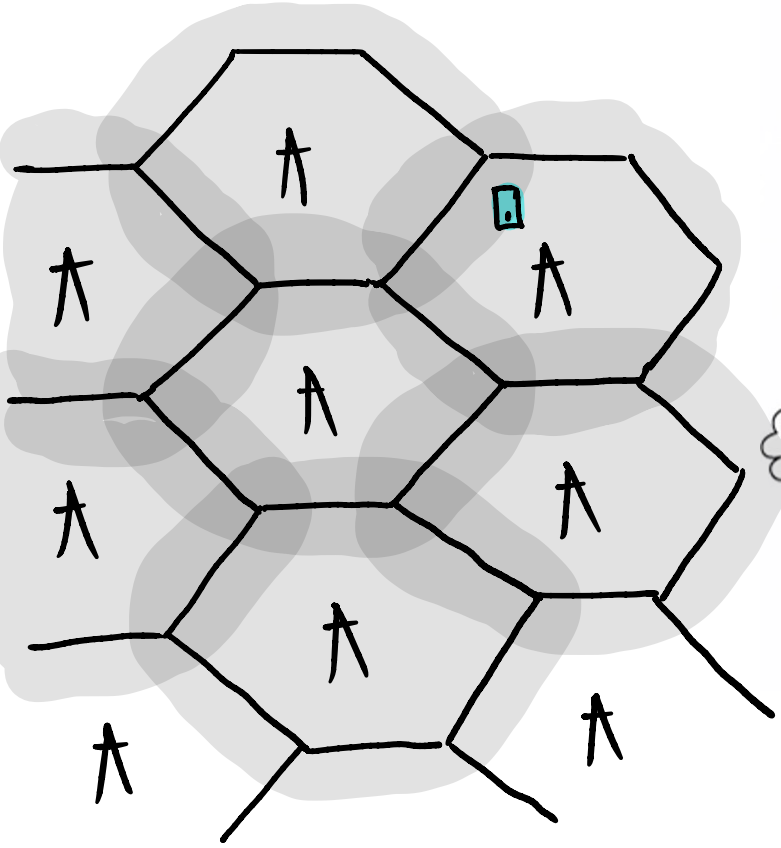
④ "Connected by wire & single admin" : What's The big deal

A: Mobility and Handoff for continuous connectivity.

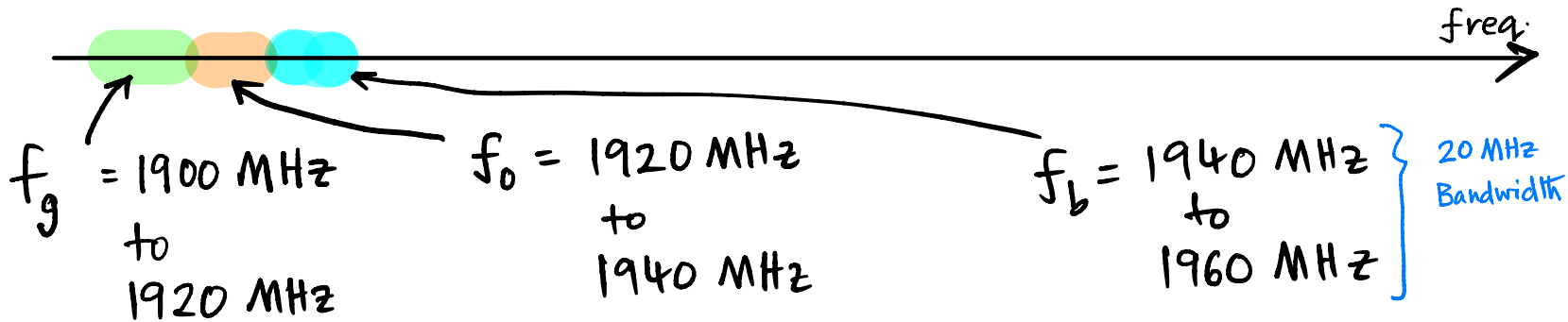
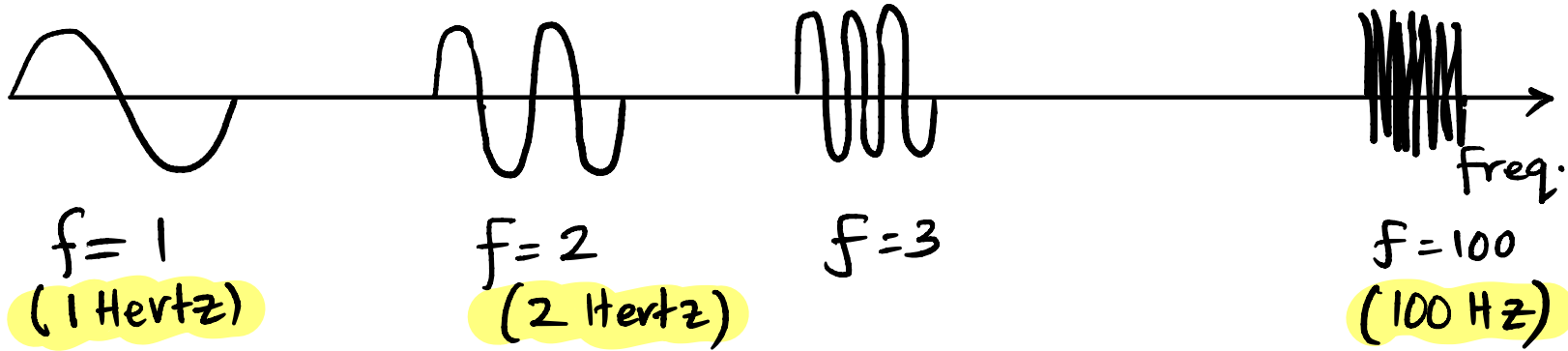
B. Billing and Accounting



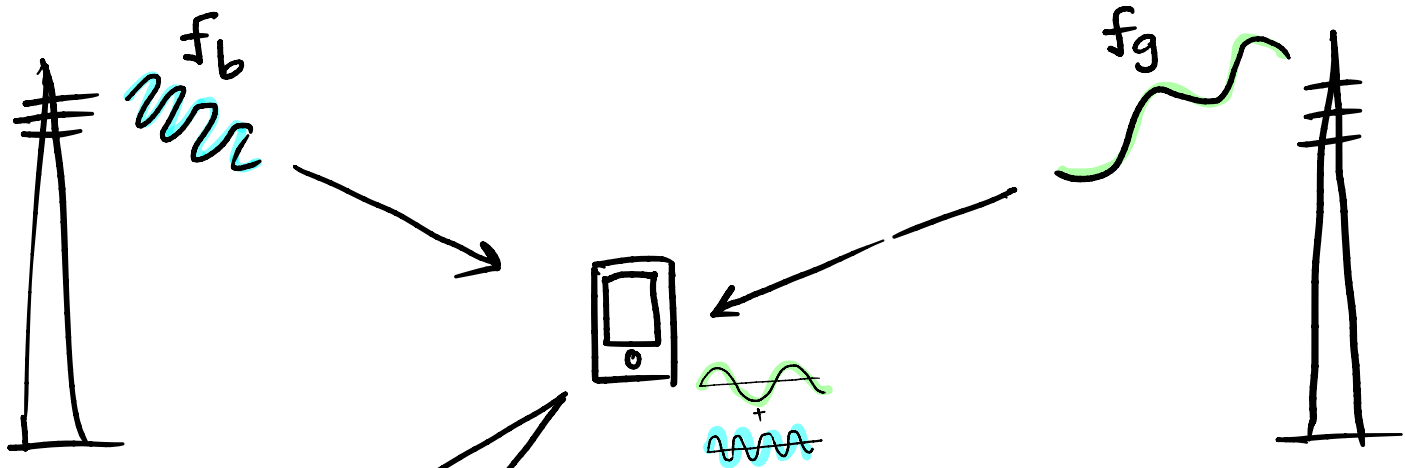
C. Scheduling



⑤ Understanding frequency and spectrum and Bandwidth

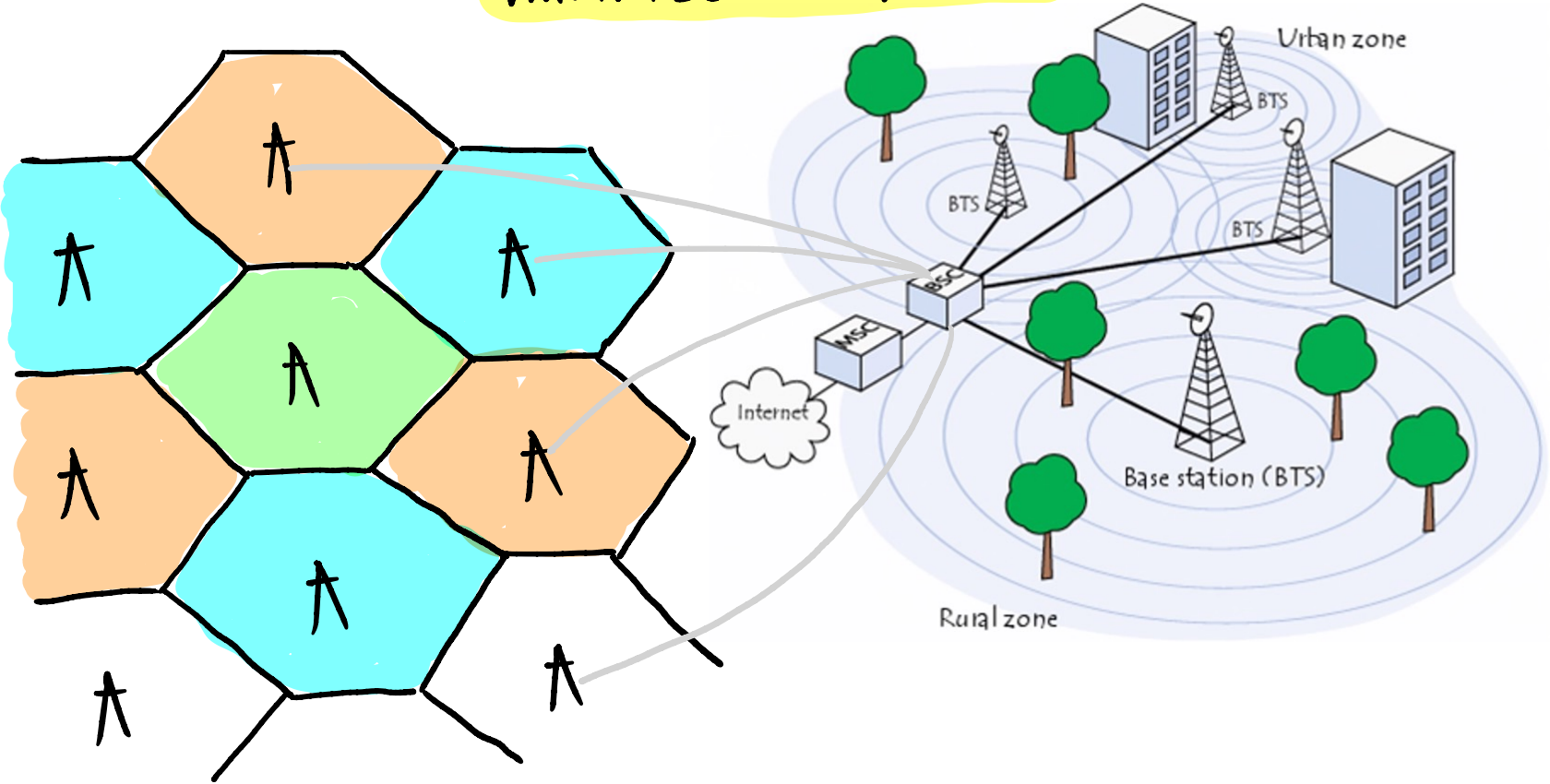


What happens if signal and interference are using different frequency bands?

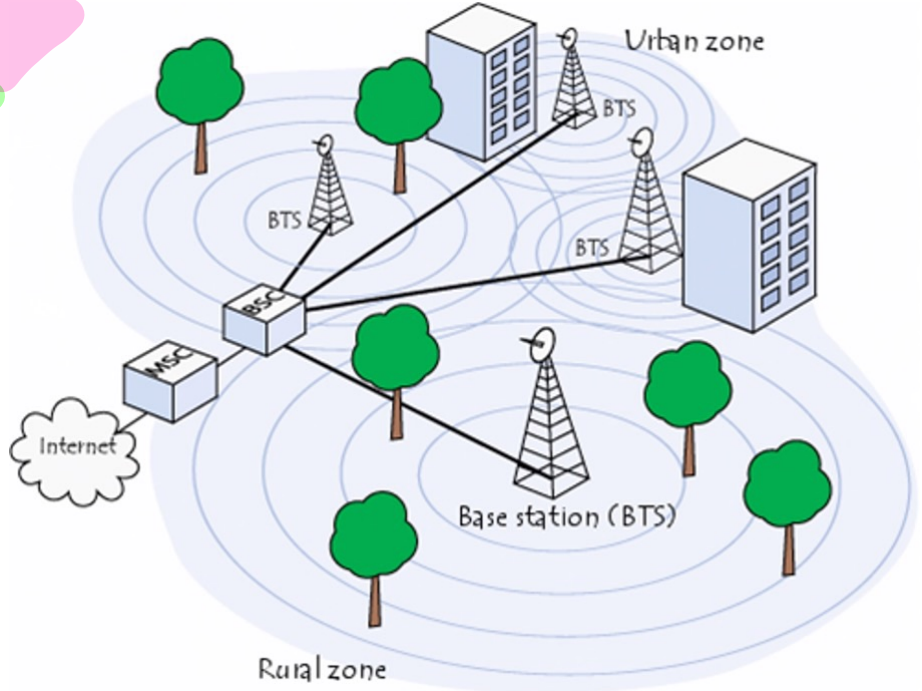
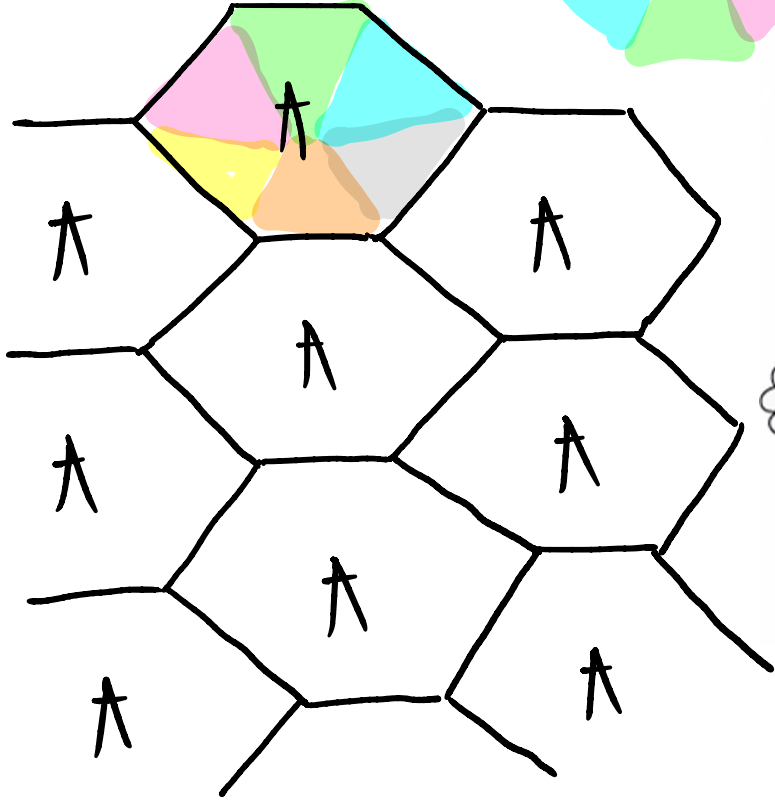
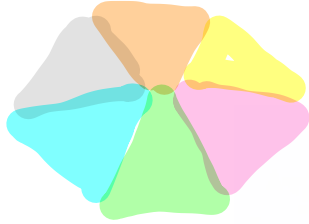


Aha!! No collision because they use different frequency bands.

c. Scheduling : Optimally assign frequency λ to each cell to minimize interference.

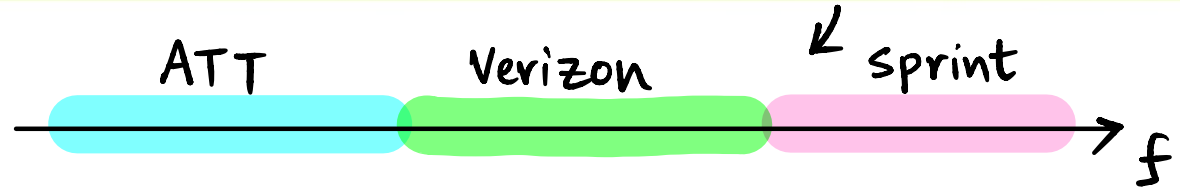
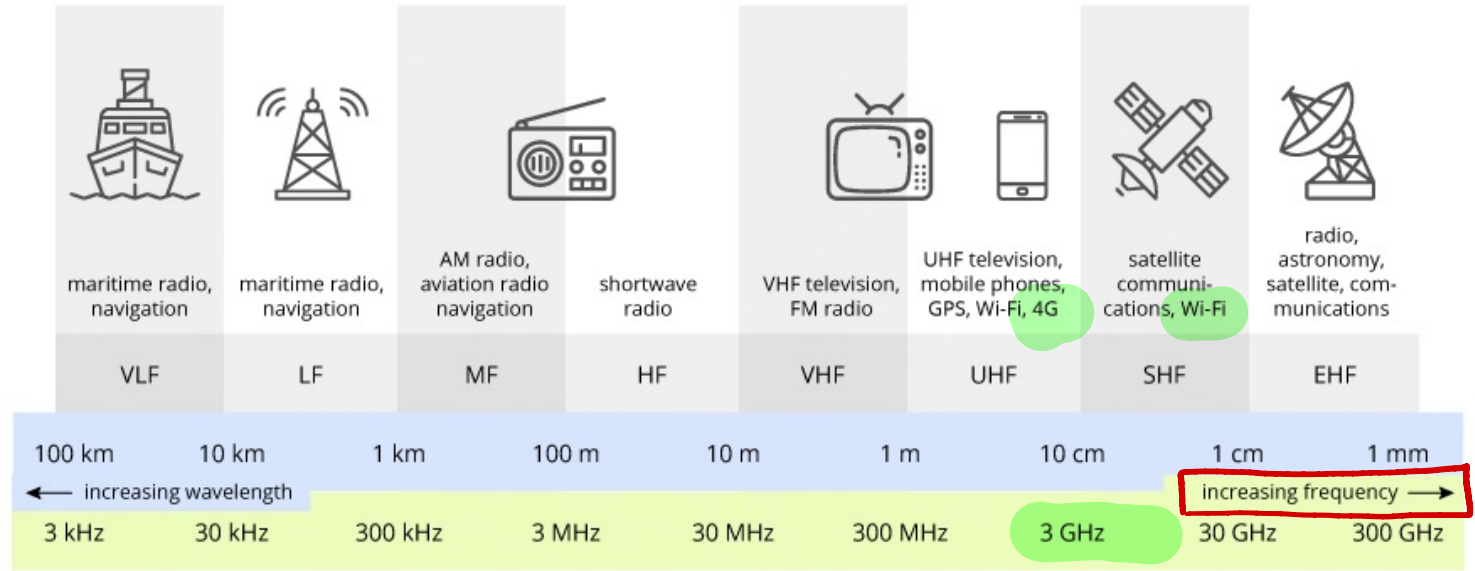


C. Scheduling



⑥ How to meet tremendous demand data & net. speed?

↳ Everyone needs spectrum or bandwidth ...
but where is free spectrum. It's so crowded!

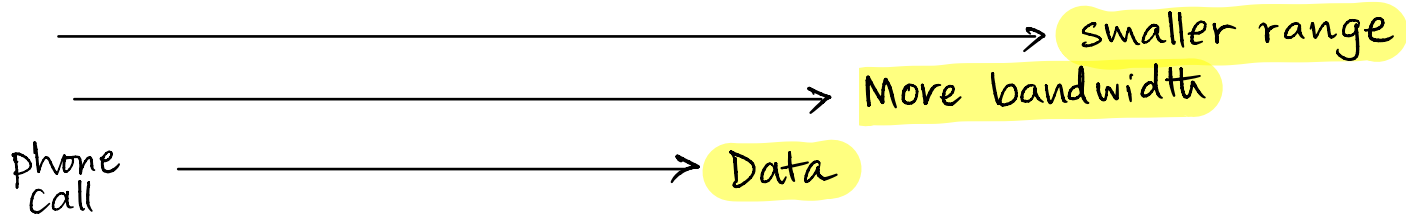


⑦ Generations of cellular technology : 1G/2G/3G/4G/5G

6 minutes to download a movie with 4G.

15 seconds to download same movie with 5G

Features	1G Analog	2G Dig.	3G	4G MIMO	5G
Start/Development	1970/1984	1980/1999	1990/2002	2000/2010	2010/2015
Technology	AMPS, NMT, TACS	GSM	WCDMA	LTE, WiMax	MIMO, mm Waves
Frequency	30 KHz	1.8 Ghz	1.6 - 2 GHz	2 - 8 GHz	3 - 30 Ghz
Bandwidth	2 kbps	14.4 - 64 kbps	2 Mbps	2000 Mbps to 1 Gbps	1 Gbps and higher
Access System	FDMA	TDMA/CDMA	CDMA	CDMA	OFDM/BDMA



Next generation : 5G + IoT

↳ Every medicine bottle has a tag ... connected to 5G
 Possible to track the medicine, Drones, Whales ...
 ↳ Every object starts getting connected. WOW!!

⑧ Cellular Network and Society

- (a) Radiation of nearby cell towers :
- (b) Distracted driving → accidents → deaths
- (c) Cellular network talk time = money in some countries
- (d) Education over cell phones for everyone .

Questions?

Coming up next lecture:
Internet