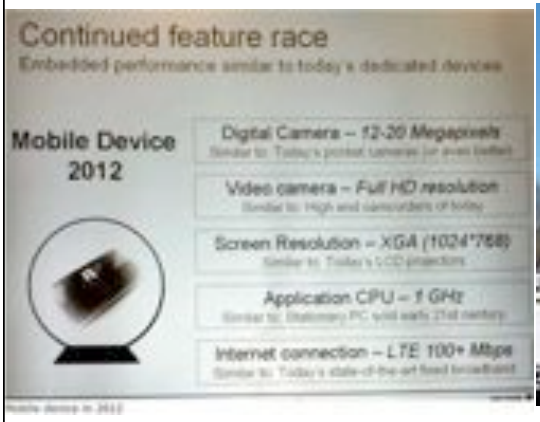
Lecture 12: Multimedia over Wireless Networks

Wireless

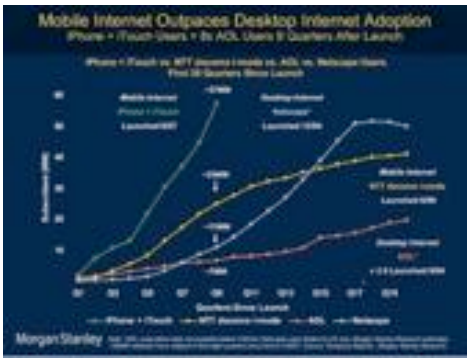
Roadmap

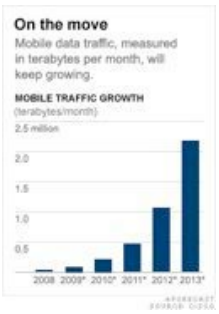
It Won't Stop..



Many Ways to Stay Connected

The Trend: Mobile Rules





Mobile Media Usage Among US Mobile Phone Users, by Operating System, September 2009 (% of respondents in each group)

	Mobile media	E-mail	News/ info browser	Any app	Social networking	IM
Apple	94%	87%	80%	83%	58%	43%
Android	92%	63%	80%	82%	52%	46%
Smartphone	80%	70%	65%	59%	43%	37%
Non-smartphone	26%	12%	14%	13%	8%	10%

Note: three-month average ending September 2009
Source: comScore Inc., "Android: Crashing the Smartphone Party" as cited in press release, December 17, 2009
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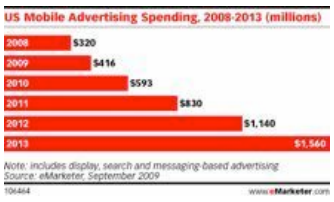
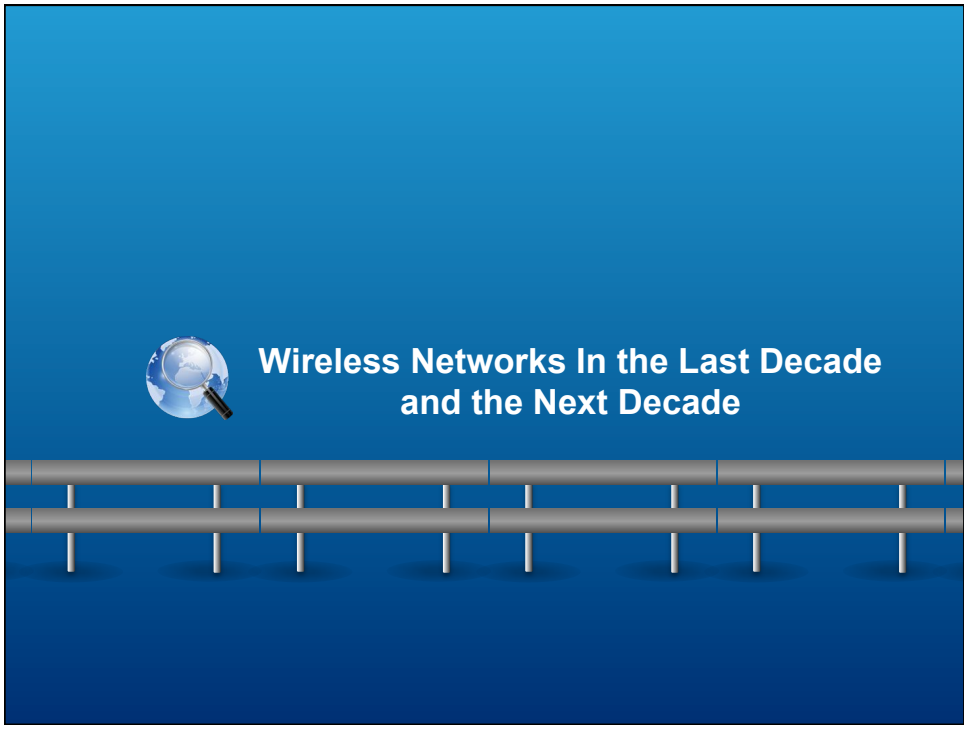
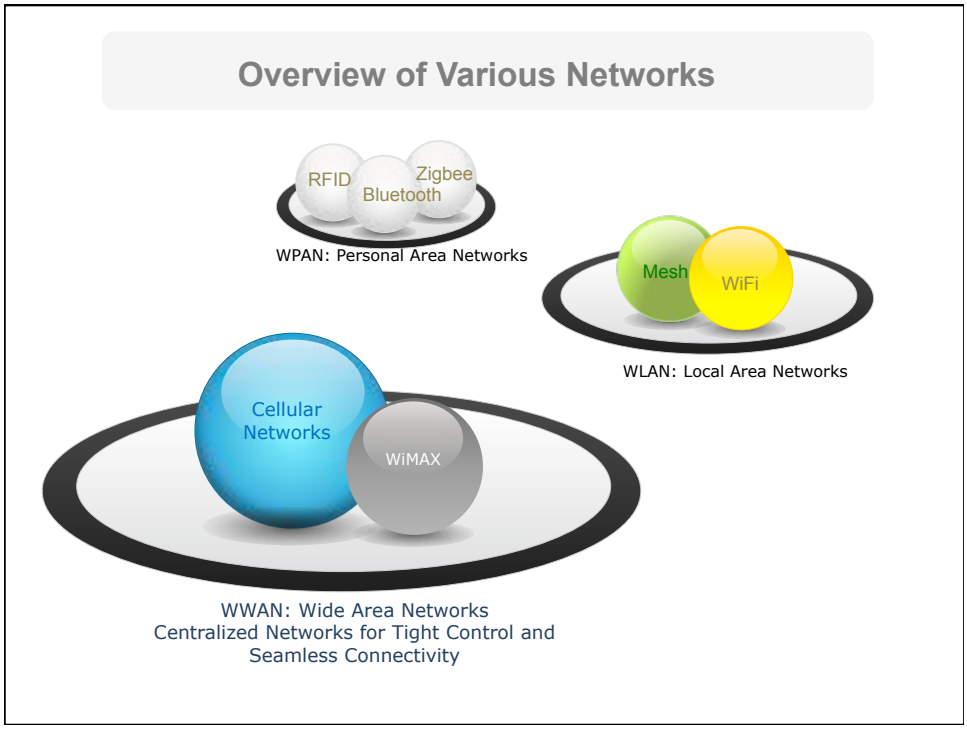
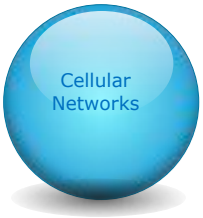


Today's Lecture

- How do wireless systems work?
- Coolest/newest trends
- Artifacts of wireless transmissions
- Impact on media delivery

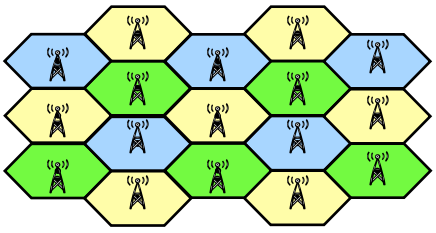

Wireless Networks In the Last Decade
and the Next Decade

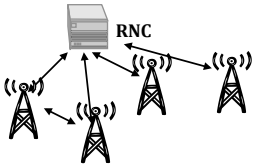

Overview of Various Networks
RFID
Zigbee
Bluetooth
WPAN: Personal Area Networks
Mesh
WiFi
WLAN: Local Area Networks
Cellular
Networks
WiMAX
WWAN: Wide Area Networks
Centralized Networks for Tight Control and
Seamless Connectivity



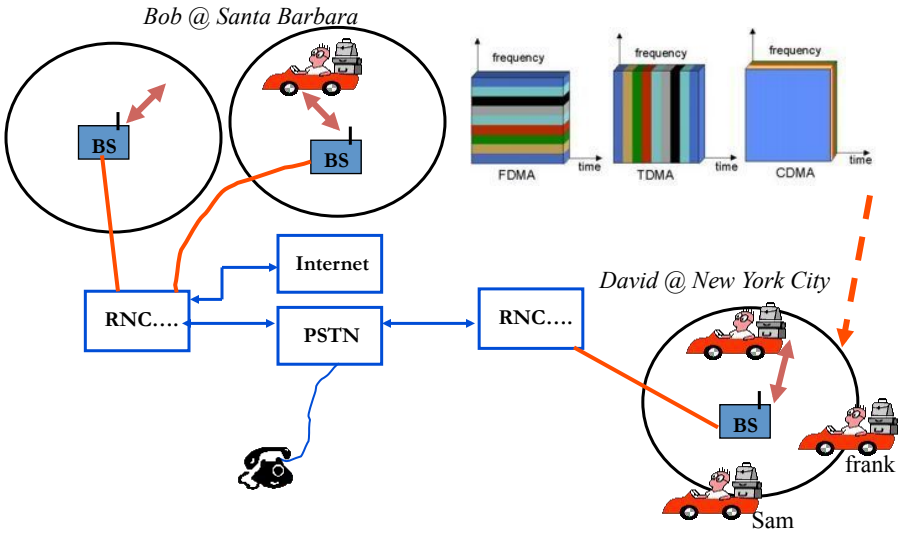
Cellular Network Overview

- Providing continuous, anywhere, anytime communication
- Geographic region divided into cells
- Frequencies/timeslots/codes reused at spatially-separated locations (shown as different colors)
- Operate in licensed spectrum (additional cost)
- Radio network controllers coordinate among base stations to connect users

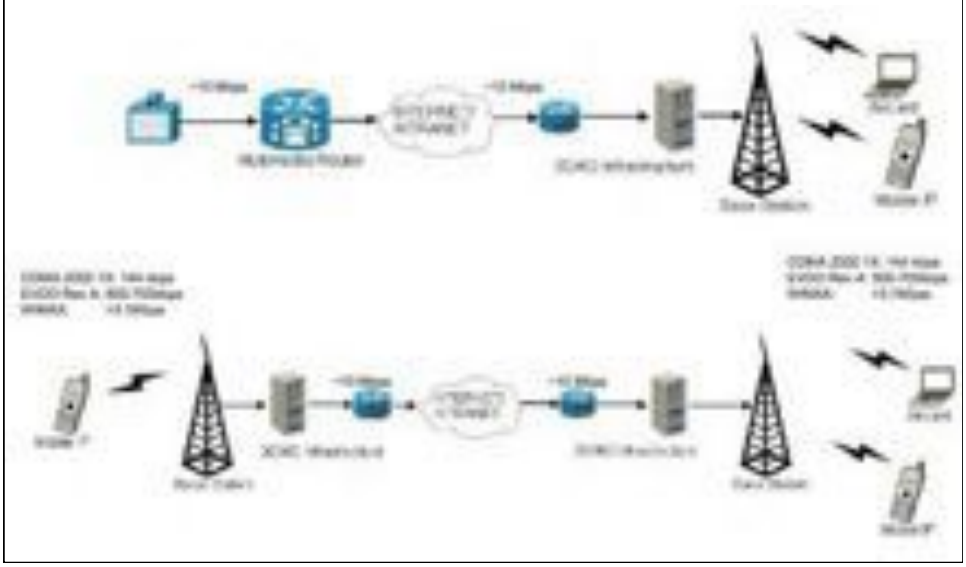




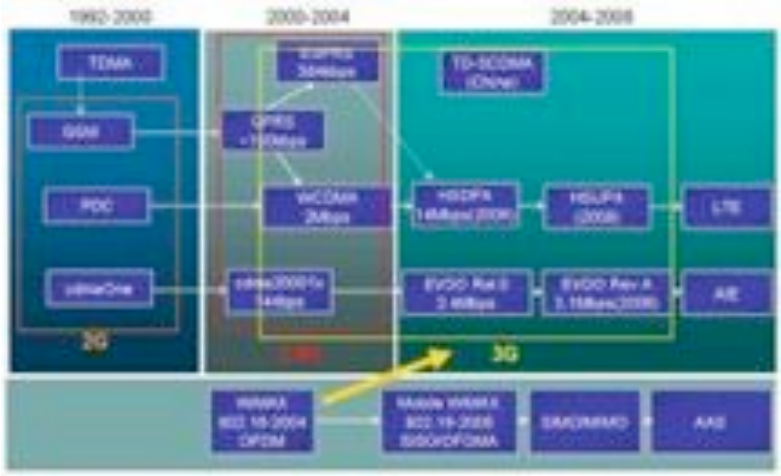
Providing Continuous Connectivity



Transmission Path in 3G/4G

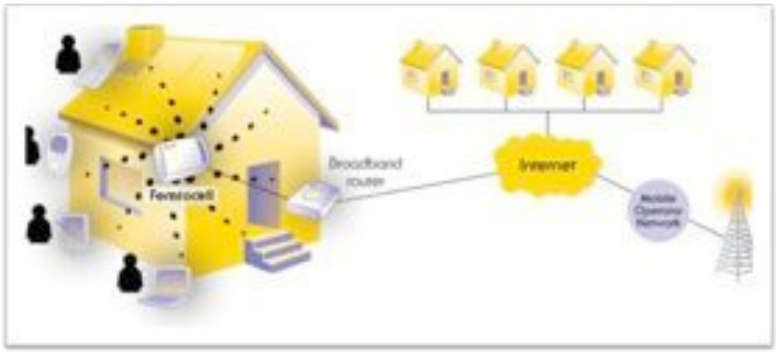


Cellular Network Evolution



Hot Topic: Femtocell

- low-power wireless access points that operate in licensed spectrum to connect standard mobile devices to a mobile operator's network using the customer's DSL or cable broadband connection.
- about the size of the typical desktop Wi-Fi router – and can be deployed in a home or office.



Hot New Mobile Apps

- More exciting mobile applications into **hyberspaces**

Opportunities and Challenges

- Smartphones merge computers, cameras, radio and communications.
- Conventional voice-only → email access → web browsing → rich media data applications
- High volume, delay sensitive, location-aware

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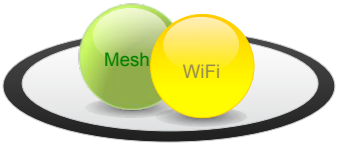
WiFi



WLAN: Local Area Networks
Decentralized network architecture
Self-organizing, flexibility, low cost
NOT designed for Mobility (Seamless Connectivity)
Multiple standards
Using Unlicensed Bands

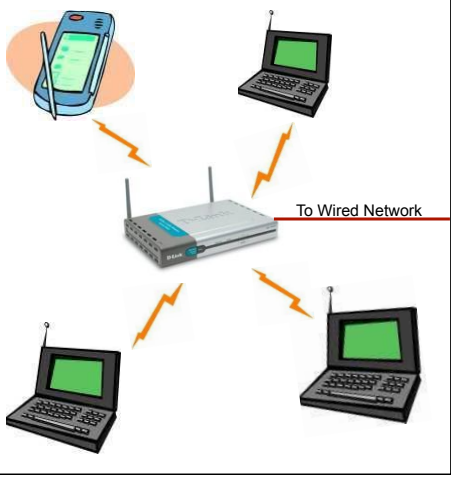
(Free) WiFi Everywhere

- WiFi at Starbucks, Borders, MacDonald's, Airports, Trains, Airplanes, Parks, Shopping Malls

- WiFi enabled memory cards, VoIP phones etc.

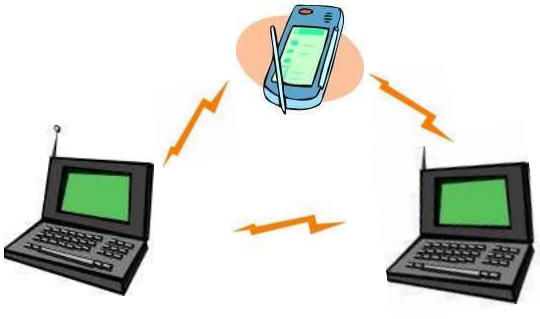
WiFi Infrastructure Mode

- An Access Point (AP) as the hub of a "star topology."
- Any communication has to go through AP.
- Multiple APs can be connected together and handle a large number of clients.
- Used by the majority of WLANs in homes and businesses.



WiFi Ad Hoc Mode

- **Ad-Hoc mode:** Peer-to-peer setup where clients can connect to each other directly.
- Generally not used for business networks.



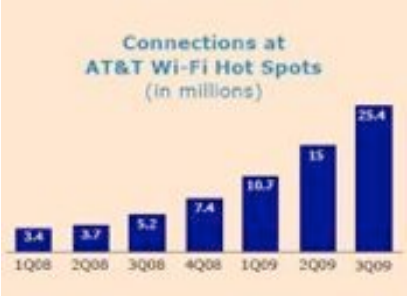
WiFi's CSMA, Listen before Talk..

- No central control on medium access
- Rely on CSMA/CA protocol to avoid collision of transmissions
- Will come back to this soon…

Existing WiFi Devices as the path to Internet

- **Mesh networks:** WiFi mesh nodes scattered over the coverage area; interconnected into a mesh using the same WiFi technology as do the end-user clients in connecting to the mesh nodes themselves
- **No more costly backbone DSL, Cable etc.**
- Workaround, multihop backhaul
- Self-organize, low cost
- Community networks

2009 Community WiFi Reborn



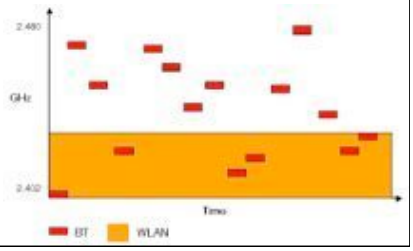
- Theories that municipal Wi-Fi would kill the telcos and cellular business proved wrong.
- Cellular carriers are experiencing a 100x or more increase in 3G data usage (thanks to iPhone), so users are suffering
  - Lose customers or Offload data traffic to another network (WiFi)
- Cellular carriers are rolling out Citywide WiFi networks for a fraction of the cost of 4G networks
  - Only Free for Cellular Users..
  - Better QoS control
  - Better security

Hot Topics: WiFi Vehicular Networks

Personal Area Networks

WPAN: Personal Area Networks

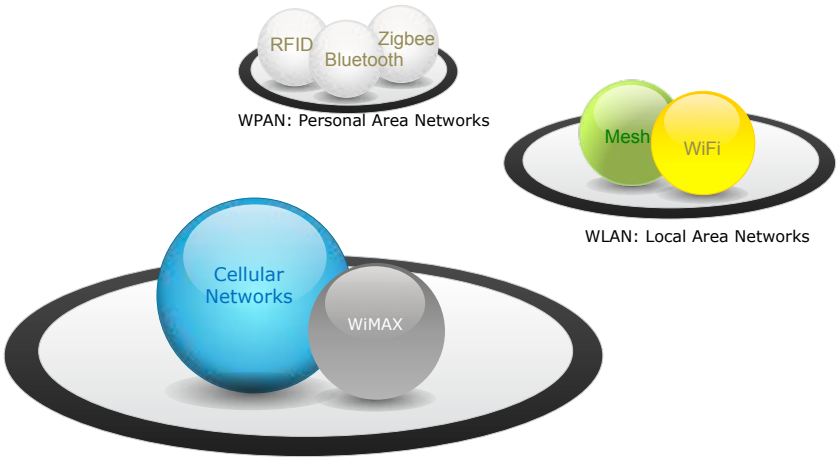
Short-range transmissions,
very low cost



ZigBee (Sensors)

- Low-cost, low-power, wireless mesh networking
- Home Entertainment and Control — Smart lighting, advanced temperature control, safety and security, movies and music, Water sensors, power sensors, energy monitoring, smoke and fire detectors, smart appliances and access sensors
- Mobile Services — m-payment, m-monitoring and control, m-security and access control, m-healthcare and tele-assist
- Commercial Building — Energy monitoring, HVAC, lighting, access control

Summary of Various Networks



WPAN: Personal Area Networks

WLAN: Local Area Networks

WWAN: Wide Area Networks
Centralized Networks for Tight Control and Seamless Connectivity

Wireless Transmission 101

What Happens After We Cut the Wire?

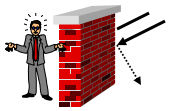
Wireless Radio Transmission

Propagation in free space always like light (straight line)

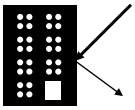
Receiving power proportional to $1/d^2$
(d = distance between sender and receiver)

Receiving power additionally influenced by

- fading (frequency dependent)
- shadowing
- reflection at large obstacles
- scattering at small obstacles
- diffraction at edges



shadowing



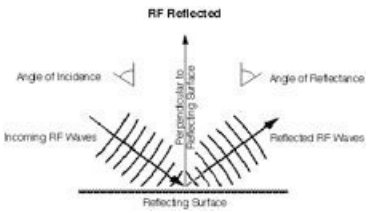
reflection

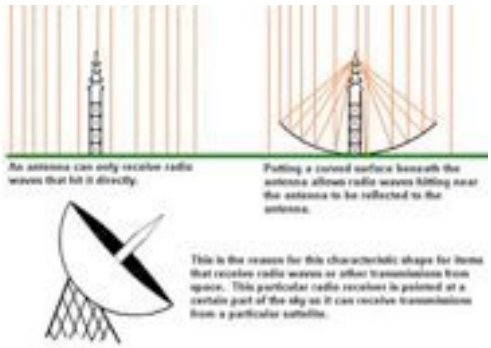
scattering

diffraction

The Physics of Radio Propagation

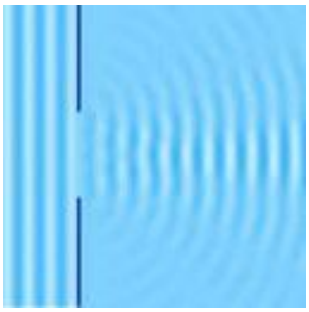
- Reflection
  - Propagating wave impinges on an object which is large compared to wavelength
  - E.g., the surface of the Earth, buildings, walls, etc.

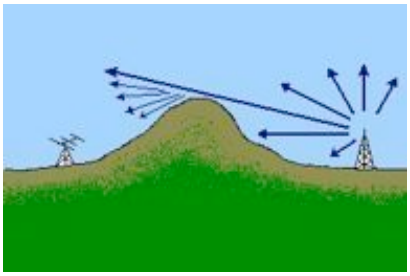




The Physics of Radio Propagation

- Diffraction (shadowing)
  - Radio path between transmitter and receiver obstructed by surface with sharp irregular edges
  - Waves bend around the obstacle, even when line of sight (LOS) does not exist





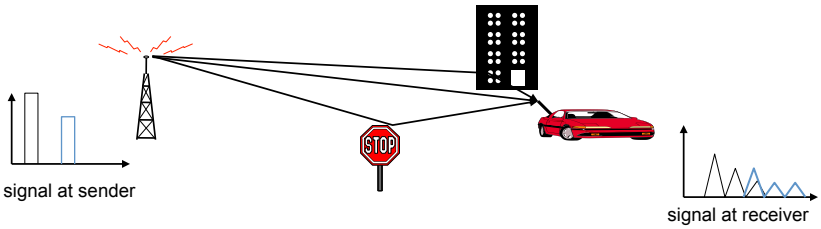
The Physics of Radio Propagation

- Scattering
  - Like diffraction, but at objects smaller than the wavelength of the propagating wave
  - E.g., foliage, street signs, lamp posts
  - The most difficult to capture

scattering

Multi-Path Propagation

Signal can take many different paths between sender and receiver due to reflection, scattering, diffraction



Time dispersion: signal is dispersed over time

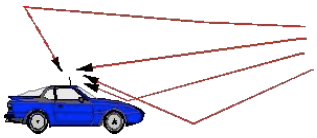
➔ interference with "neighbor" symbols, Inter Symbol Interference (ISI)

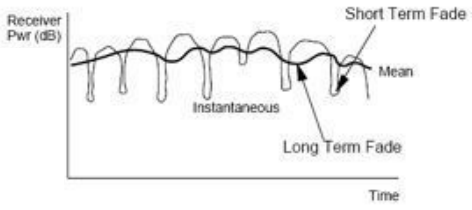
The signal reaches a receiver directly and phase shifted

➔ distorted signal depending on the phases of the different parts

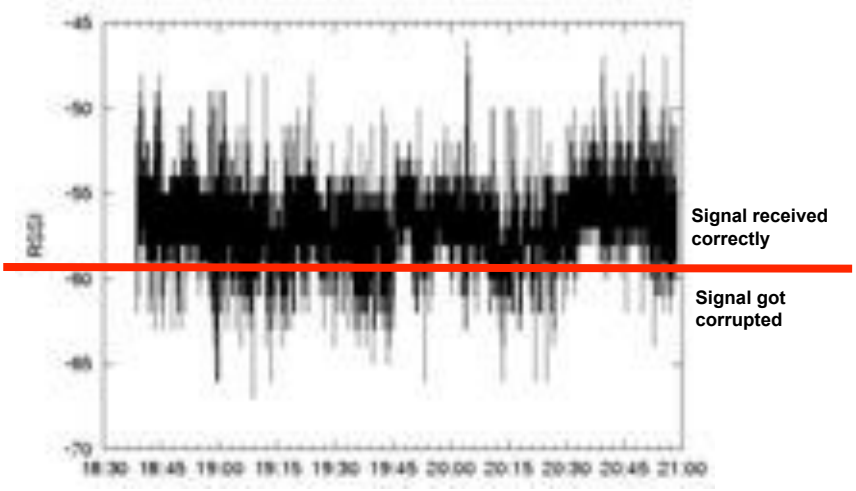
The Impact of Mobility

- Mobility creates fluctuations of signal
- Large scale fades
  - Attenuation: in free space, power degrades by $1/d^2$
  - Shadows: signals blocked by obstructing structures
- Small scale fades
  - Multipath effects:
    - Rapid changes in signal strength over a small area or time interval
  - Even when mobile is stationary, the received signals may fade due to movement of surrounding objects!



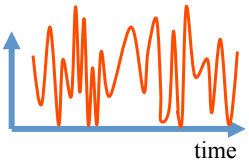


Received Signal Over Time



Why Wireless is Harder than Wired Networks

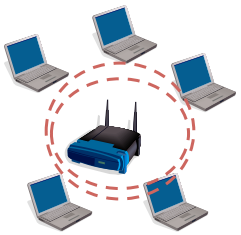
- Time-varying, often unpredictable channel quality
  - Nature of radio propagation, mobility, dynamic environment
- Interference
  - Broadcast nature → interference

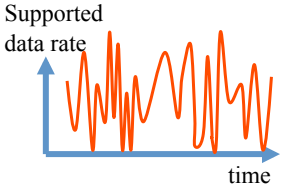


Lots of packet errors and losses, time-varying bandwidth, delay, jitter ☹

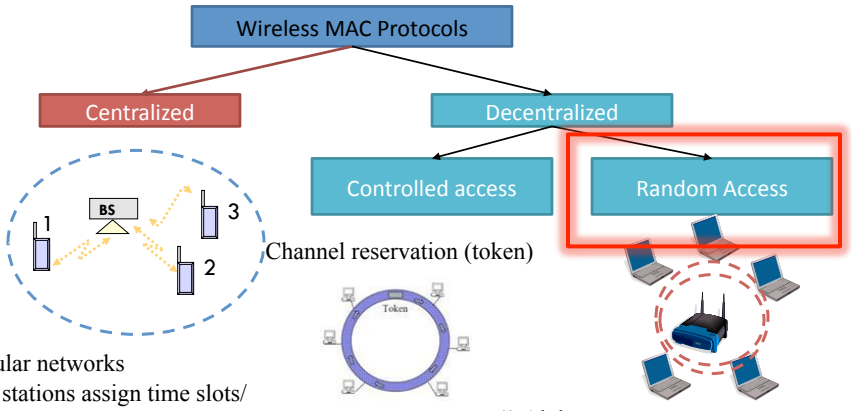
Wireless MAC

- Avoid interference
- Provide fairness
- Schedule users and adapt transmission rate to channel variations to improve throughput
- **Select Frequency/Power/Rate**





MAC Categories



Channel reservation (token)

Cellular networks
base stations assign time slots/
frequencies/codes to users
TDMA, FDMA, CDMA

1) Aloha
2) 802.11, CSMA/CA
3) TDMA, FDMA

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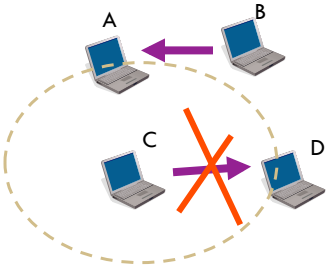
Random Access

- Random Access vs. Controlled Access
  - No fixed schedule, no special node to coordinate
  - Distributed algorithm to determine how users share channel, when each user should transmit
- Challenges: two or more users access the same channel simultaneously → Collisions
- Protocol components:
  - How to detect and avoid collisions
  - How to recover from collisions

WiFi/802.11/CSMA: Carrier Sensing Medium Access

- Sense before transmitting
  - Channel idle: transmit
  - Channel busy: defer transmission to avoid collisions



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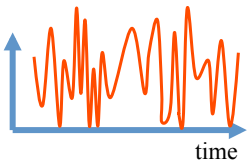
  * Nature of radio propagation, mobility, dynamic environment

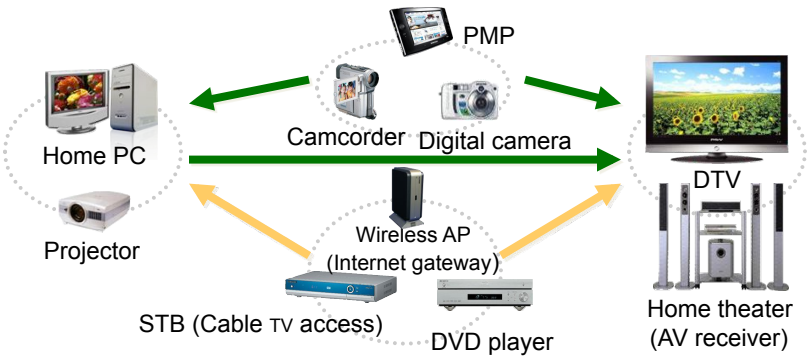


* Interference
  * Broadcast nature → interference (not always harmful)

Lots of packet errors and losses, time-varying bandwidth, delay, jitter ☹

Wireless Media Delivery

Use Cases



- Many applications including …
  - Delivering multiple HD streams to several receivers
  - Displaying stored digital contents from media servers to display devices
  - Browsing contents in distributed devices through big screen TVs

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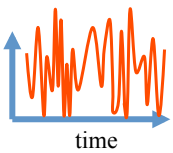
Use Cases

- Public Safety

Video over Wireless Challenges

- Hey, it is wireless
  - Interference, path loss
  - Limited number of channels in unlicensed bands
  - Channel characteristics constantly change (dynamic)



- Medium access non-deterministic (802.11 is originally designed for data)
- While latency and jitter is minimal in a wired network, wireless networks are quite different
  - Uncertain about the medium due to propagation and interference
  - Extremely susceptible to errors, which ultimately result in packet losses and packet errors.
  - A 20% to 40% packet loss is not uncommon.

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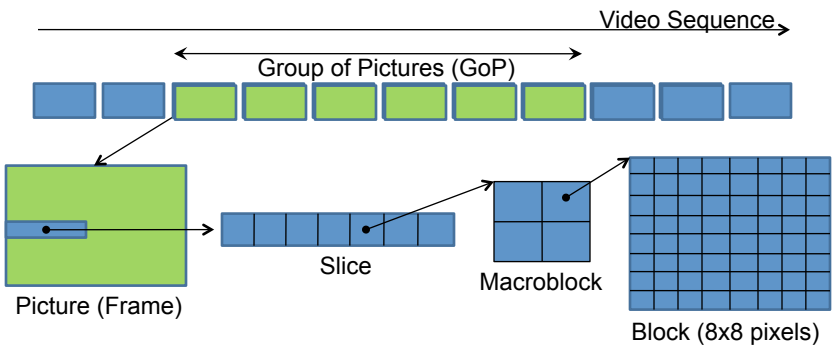
Packet Loss In Wireless Networks

- Packet loss in wireless networks may be due to
  - Bit errors
  - Handoffs
  - Congestion (rarely)
  - Reordering (rarely, except for certain types of wireless nets)

How would this affect video delivery?

Another Look at Video:
Not all bits are created equal



- Intra (I) frames, Predicted (P) Frames or Bidirectional (B) Frames.
- MPEG-2 typically uses one I-frame followed by 15 P/B frames to make up a GOP.

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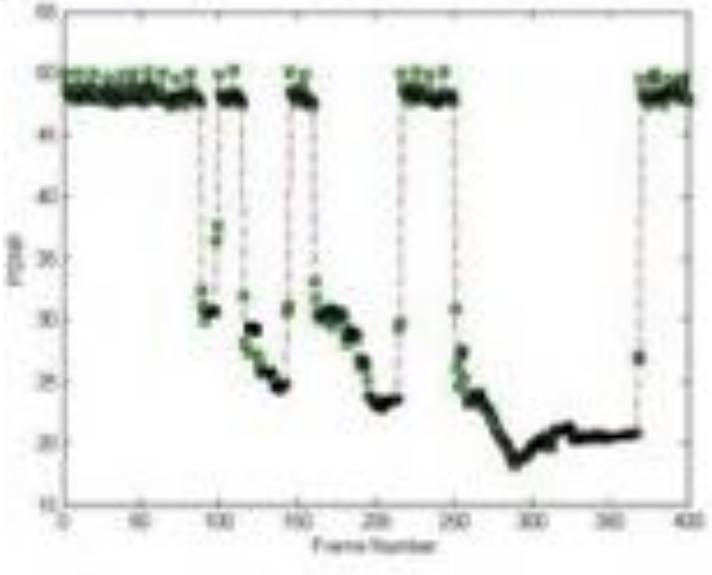
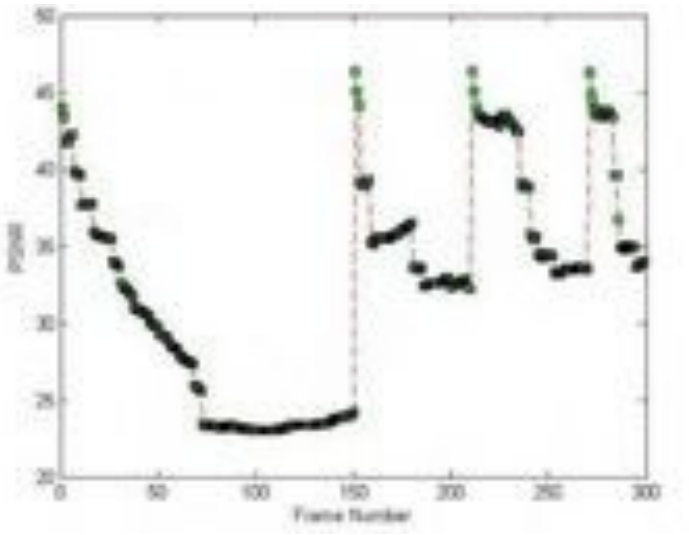
Packet loss

- If one packet is lost this will affect other correctly received packets
- Therefore the propagation effects of a packet loss can be significant
- Single packet error typically corresponds to the loss of a small frame (P/B) or the loss of a part of a big frame
- Burst packet loss – significant degradation

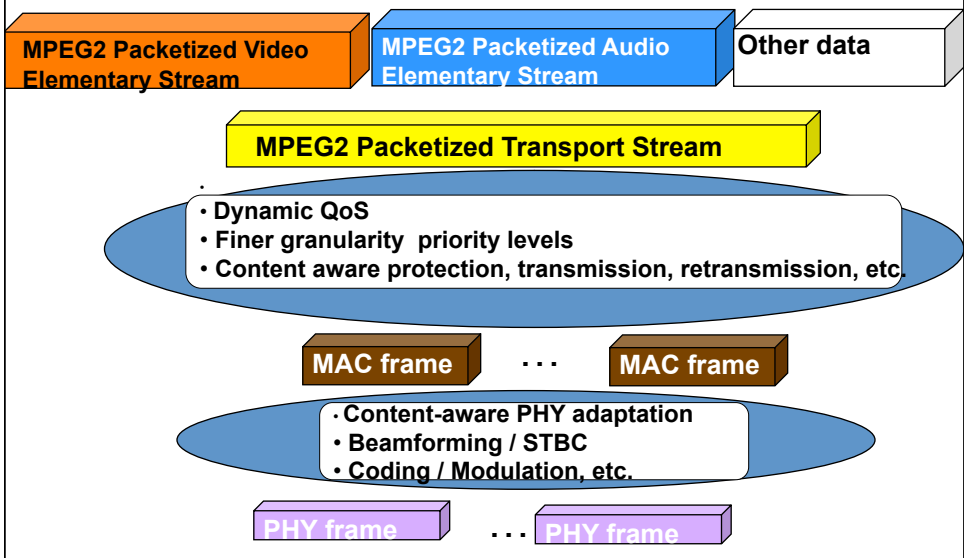
Examples of Wireless Video Delivery



Examples of Wireless Video Delivery



Possible solutions: Illustration



How can the Network Help?

- MAC-level techniques
  - Selective Repetition to mitigate packet loss
  - Smart packet drop
  - Finer prioritization among streams and within one stream
  - Content-specific methods
  - QoS policy (establishing, monitoring, adaptation)
- Inter-Layer communication (Vertical interaction)
  - PHY-MAC
  - MAC-higher layers

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Summary of Today's Learning

- Wireless/Mobile is the future
- Get to know different wireless networks
- The physics behind wireless transmissions
- Wireless artifacts and their impact on media transmissions
- How can networks help to minimize losses and errors?
- How can media adapt to wireless environments?