

## Wireless Networks

### Background:

- ❑ # wireless (mobile) phone subscribers now exceeds # wired phone subscribers!
- ❑ computer nets: laptops, palmtops, PDAs, Internet-enabled phone promise anytime untethered Internet access
- ❑ two important (but different) challenges
  - communication over wireless link
  - handling mobile user who changes point of attachment to network

## Outline

### 1. Introduction

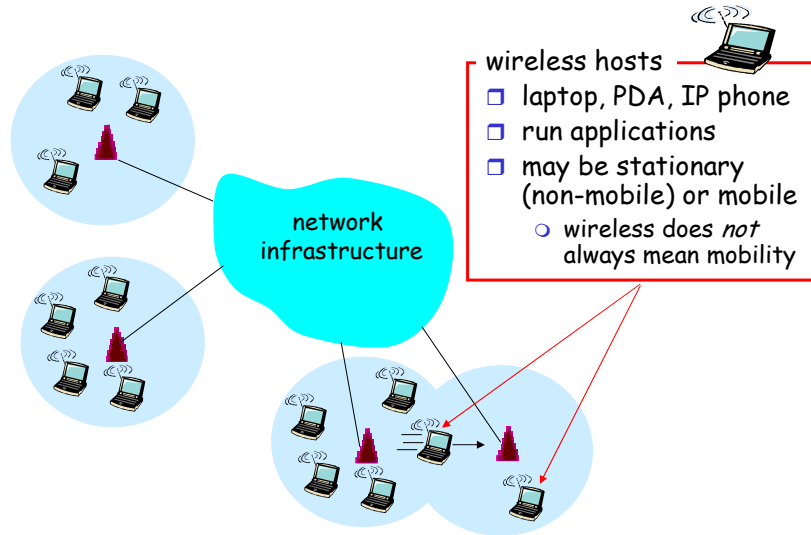
2. Wireless link characteristics and PHY Layer design.

3. Multiple access and interference management:

- IEEE 802.11 wireless LANs ("wi-fi")
- cellular standards (eg. GSM, CDMA)

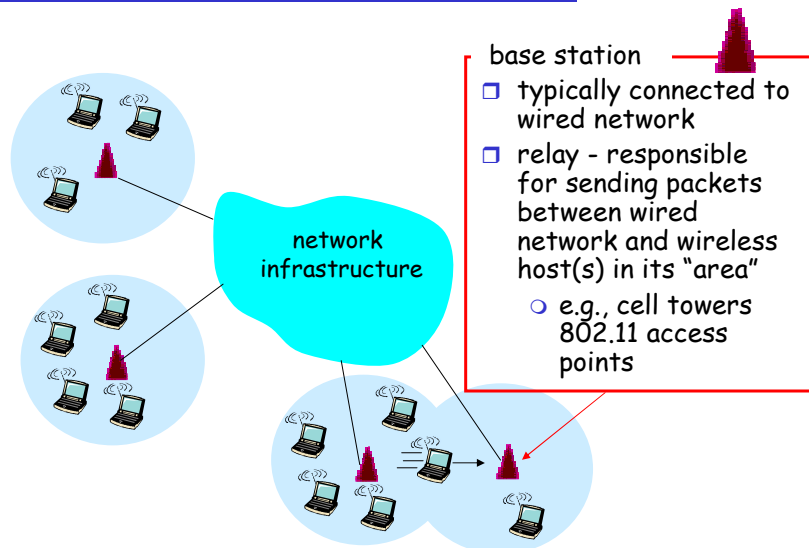
4. Mobility management

## Elements of a wireless network



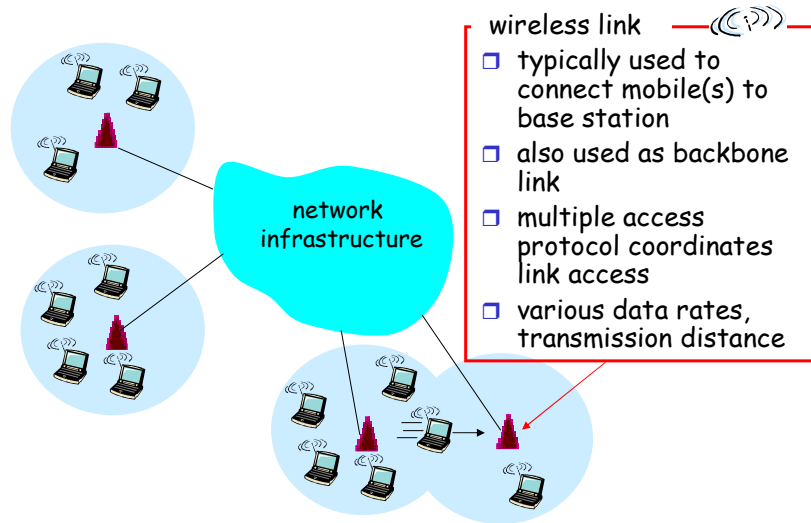
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## Elements of a wireless network



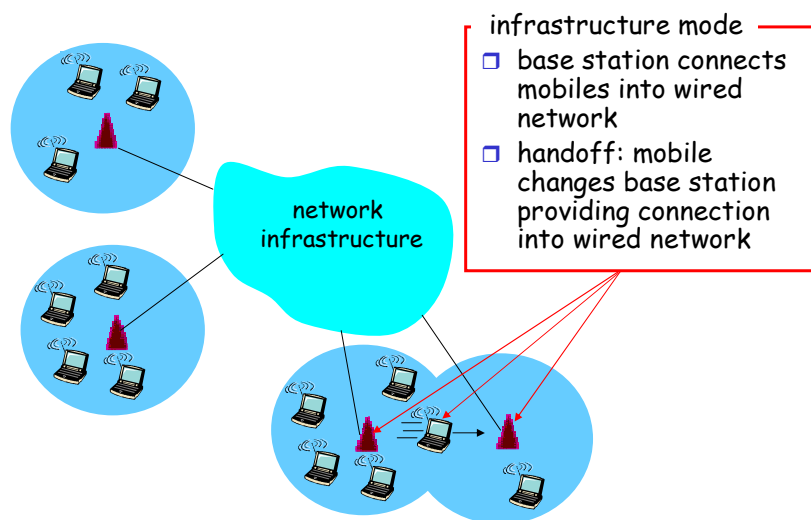
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## Elements of a wireless network



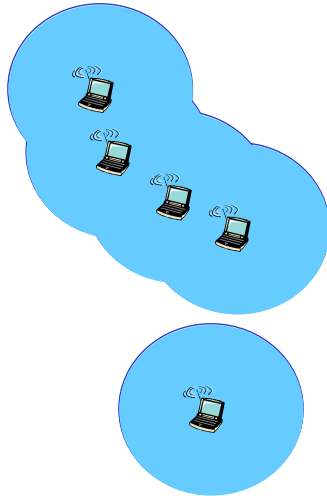
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## Elements of a wireless network



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## Elements of a wireless network



### Ad hoc mode

- ❑ no base stations
- ❑ nodes can only transmit to other nodes within link coverage
- ❑ nodes organize themselves into a network: route among themselves

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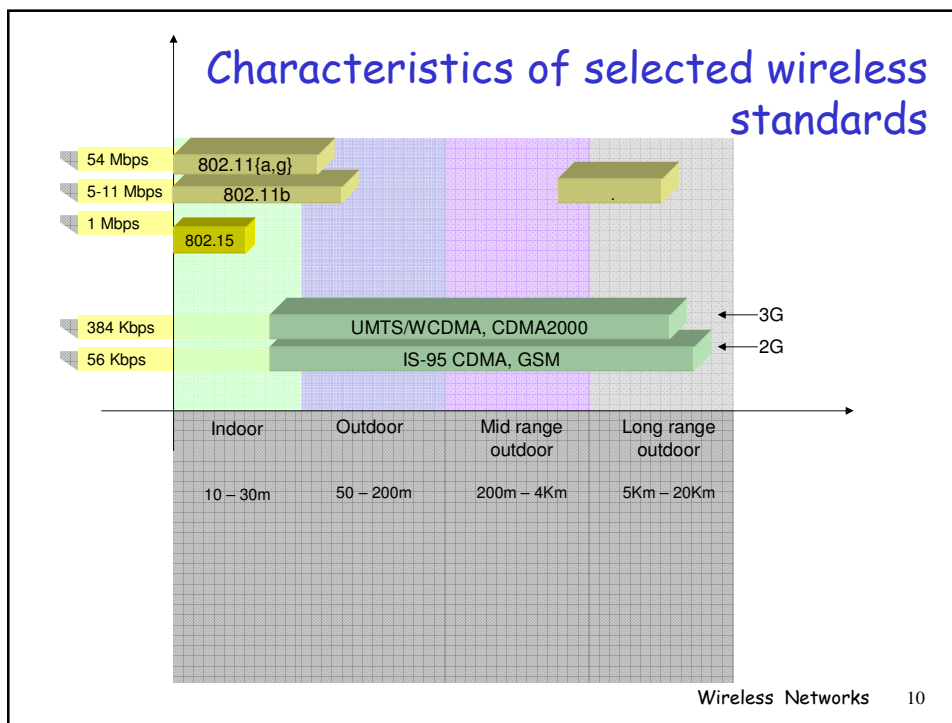
## History

- ❑ Cellular concept (Bell Labs, early 70's)
- ❑ AMPS (analog, early 80's)
- ❑ GSM (digital, narrowband, late 80's)
- ❑ IS-95 (digital, wideband, early 90's)
- ❑ 3G/4G systems for wireless data (UMTS, CDMA 2000)
  
- ❑ Explosive growth of 802.11 WiFi Lan in past 5 years.

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## Wireless Link: Key Parameters

- ❑ Carrier frequency  $f_c$  : 900 Mhz or 1.9 GHz for cellular. 2.4 Ghz or 5.3 Ghz for 802.11.
- ❑ Transmission bandwidth  $W$  : 200 kHz for GSM, 1.25 MHz for CDMA, 83.5 MHz for 802.11b, divided into 3 channels.
  - Determines the symbol rate.
- ❑ Data rate  $R$  bps: eg. 11 Mbps for 802.11b.
- ❑ Range.



## Cellular vs Wi-Fi

- ❑ Cellular: wide area coverage, proprietary networks, more coordination between BSs.
- ❑ Wi-Fi: local area coverage, "last link" for the Internet, little coordination between APs
- ❑ Cellular: licensed (and expensive) spectrum (around 900 MHz and 1.9 GHz)
- ❑ Wi-Fi: unlicensed (free) spectrum (2.4 GHz and 5.3 GHz)
- ❑ Cellular: high mobility
- ❑ Wi-Fi: low or no mobility

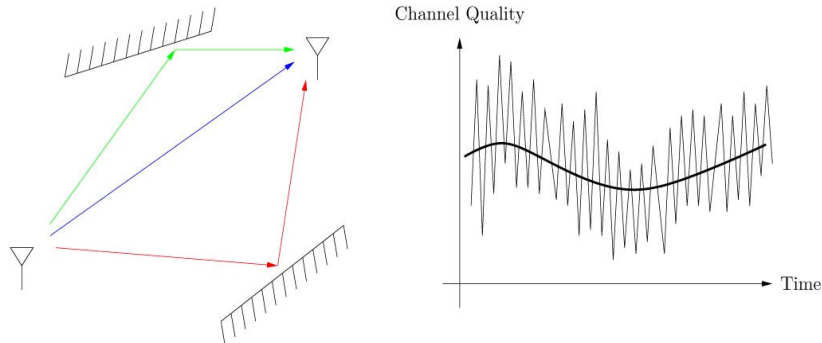
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## Wireless Link Characteristics

- **decreased signal strength:** radio signal attenuates as it propagates through matter (path loss)
- **multipath fading:** constructive and destructive interference of multiple signal paths from transmitter to receiver.
- **interference:**
  - Between different users in a cell.
  - Between users across different cells
  - From external sources in unlicensed bands (eg. your microwave oven)

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## Wireless Channel



Channel varies at two spatial scales:  
large scale  
small scale (multipath fading)

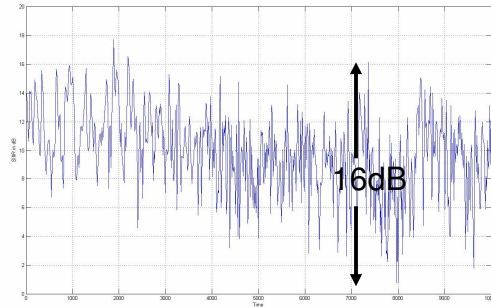
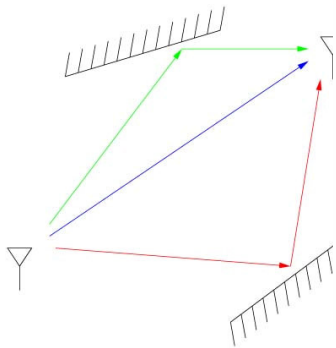
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## Large-scale channel variations

- ❑ In free space, received power attenuates like  $1/r^2$ .
- ❑ Can also experience shadowing by objects
- ❑ Important for cell site/access point planning:
  - Coverage
  - Frequency reuse

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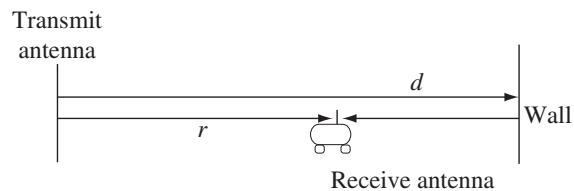
## Small-scale multipath fading



- Multipath fading due to **constructive** and **destructive** interference of the transmitted waves at very high carrier frequency.

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## Example



- Difference in phases of direct and reflected waves:

$$\frac{2\pi}{\lambda}[(2d - r) - r] + \pi = \frac{4\pi}{\lambda}(d - r) + \pi$$

where  $\lambda$  is the wavelength of the signal.

- Movement of  $\lambda/4$  goes from a peak to a valley. (this is 0.3m at frequency 900 MHz)

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