

- Interference
  - 12Sep2014 - Wave Propagation ✓
  - 19Sep2014 - Radiation equation, Antennas
  - 26Sep2014 - Propagation models: Yun Ai
  - 26Sep2014 - Frequency range and type of wireless communications - Raul
  - GSM and UMTS (cell breathing)
  - 17Oct2014 - LTE - Solomon
  - 17Oct2014 -Voice in LTE - Mikhail Yakubovich
  - 10Oct2014 - WiFi long range standards - Mohsen
  - 10Oct2014 - WiMAX - Qihaoli
  - 10Oct2014 - Security in NFC - Seraj
- 
- Part II assignments
- Cell capacity, System capacity
  - Mobility
  - Basic Internet (free access to basic information (text & pictures) on the Internet)
  - inverse MVNO: the customer owns the access network
  - WLAN system for video communication
  - ... (any other topic which you might find interesting)
  - Ali Zaher: RFID/NFC

①

$$P_R = P_T G_T G_R \cdot \left( \frac{\lambda}{4\pi R} \right)^2$$

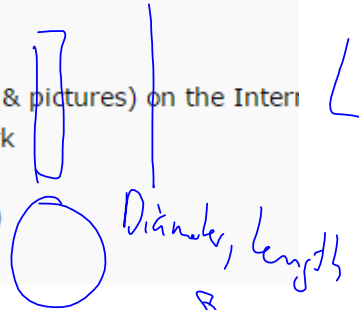
Basics of Comm.

②

Shannon Capacity

Path Loss L  
free space

$$L = \left( \frac{c}{2\pi f R} \right)^2$$



passive repeater

$$G_{ant} \sim \left( \frac{D}{\lambda} \right)^2 = \left( \frac{Df}{c} \right)^2$$

$$G_{ant} \sim f^2$$

### Radiation Equation

$$P_R = P_T G_T G_R \left(\frac{\lambda}{4\pi R}\right)^2$$

$f = 900 \text{ MHz}$   
 $f = 1800 \text{ MHz}$

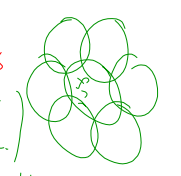
$\times 2$

$$P_{R, 1800} = P_{R, 900} \cdot 4 \cdot 4 \cdot \frac{1}{4}$$

### Spectrum

new spectrum 400-762 MHz  
 $f = 900 \text{ MHz } 6M$   
 Applies  
 1800 GSM  
 2700 4MIS  
 2655 LTE

- Why not higher frequencies?
- interference with obstacles
  - technology (more complicated at 2.6 GHz...)
  - theoretical versus real path loss
  - obstacles  $\times 1$
  - coverage decrease



$f_s = 900 \text{ MHz}$   
 $f_c = 1800 \text{ MHz}$



$\times 1$  obstacle

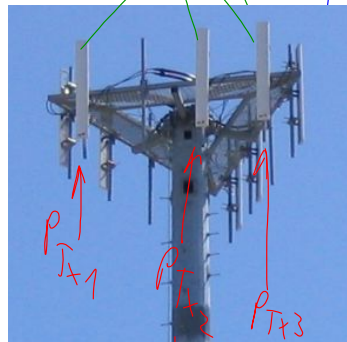
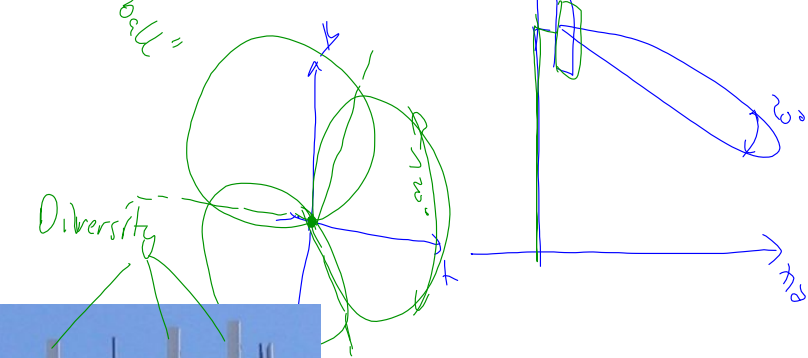
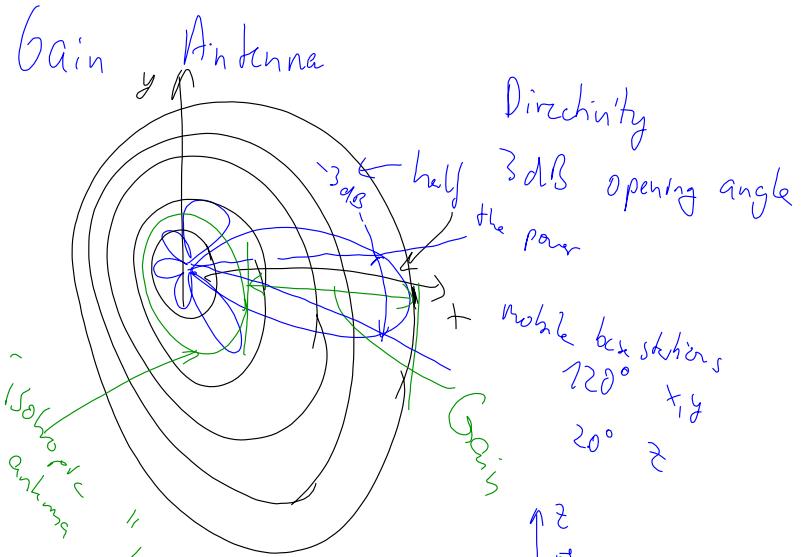
length  $L \sim \frac{\lambda}{2}$

$$\frac{\lambda}{70} \leq L \leq 2.3 \lambda$$

$\frac{\lambda}{2} (900 \text{ MHz}) \sim 15 \text{ cm}$   
 $\frac{\lambda}{2} (1800 \text{ MHz}) \sim 8 \text{ cm}$

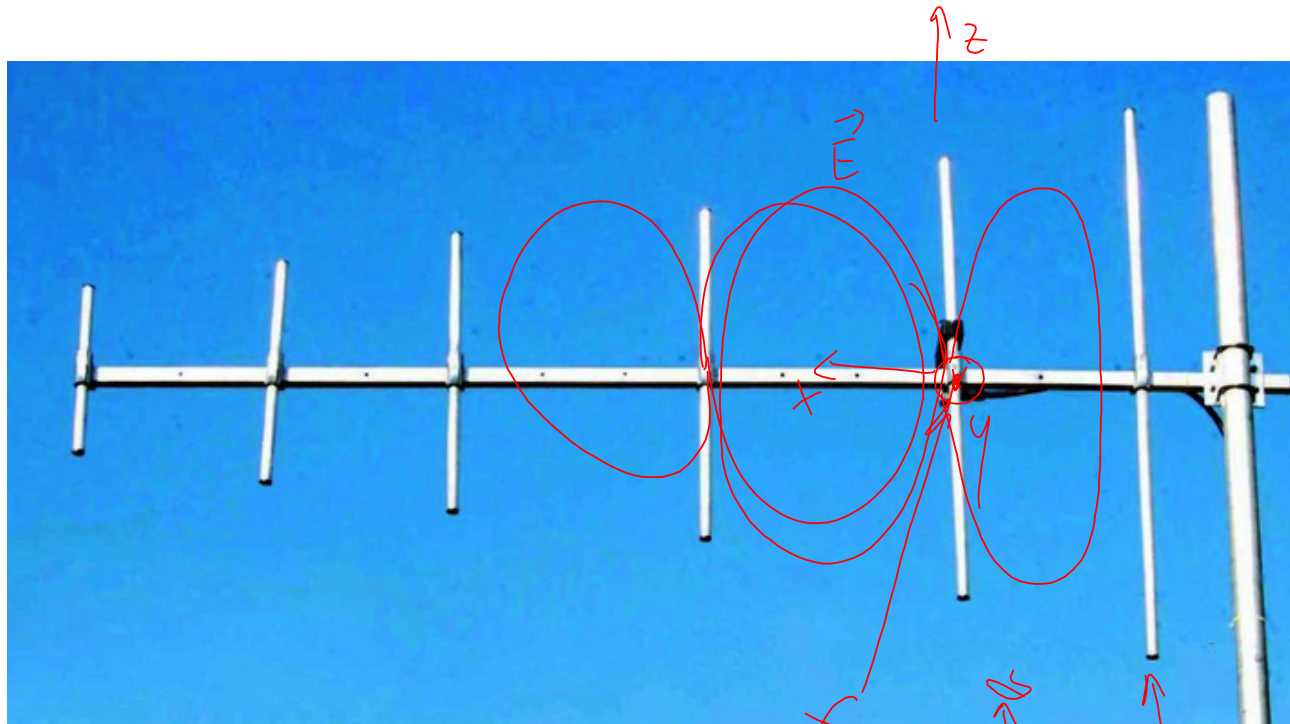
$$\lambda_{900 \text{ MHz}} = \frac{30 \text{ cm}}{f [\text{GHz}]} \approx 30 \text{ cm}$$

1800 MHz: Objects: 1.6 cm --- 8 cm --- 50 cm  
 trees, branches, leaves (canopies)  
 house: walls  
 person



How many antennas?  
- induction

increase power and interference

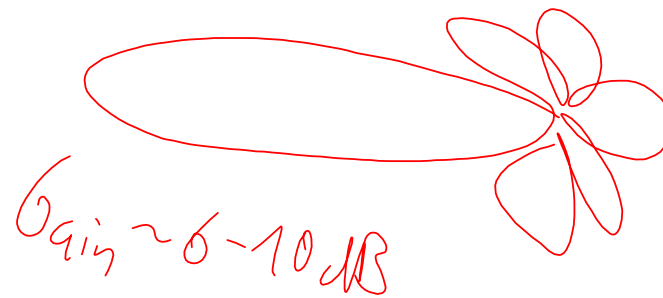


Group factor

power feed



blocking reflector



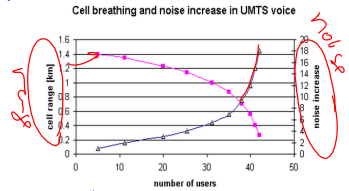
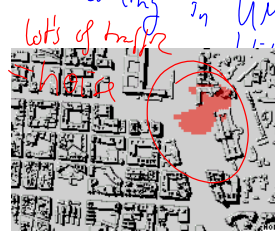
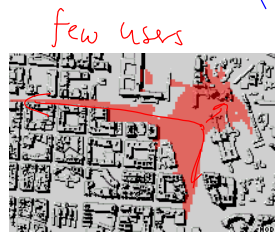
Technology

NFC "contact"

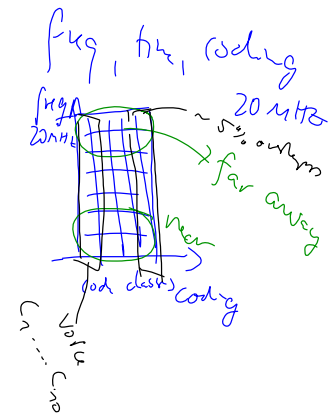
Bluetooth, ANT+ 1-20 m (Bluetooth 20dBm ~ 100m)

Wifi: 2.4 GHz MIMO

5.1--5.4 GHz bundling of frequencies  
 LTE \*2 (cell breathing in UMTS) 20 → 40 MHz → 100 MHz



\*LTE



increase interference

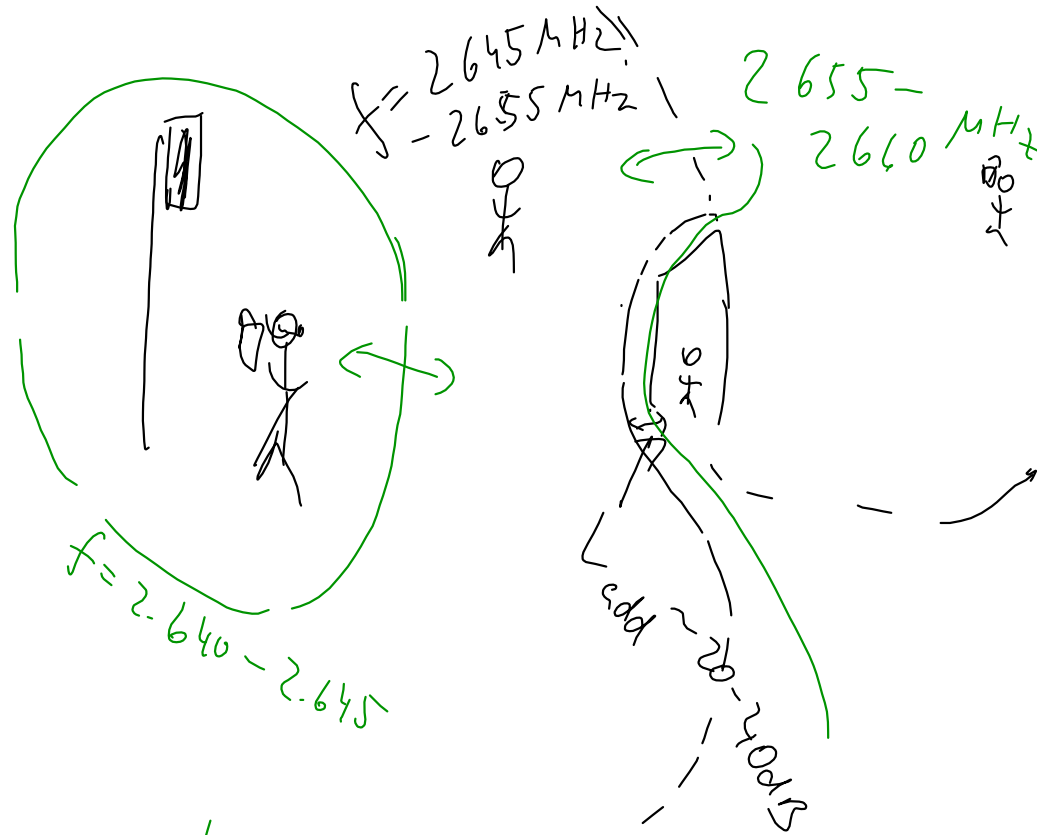
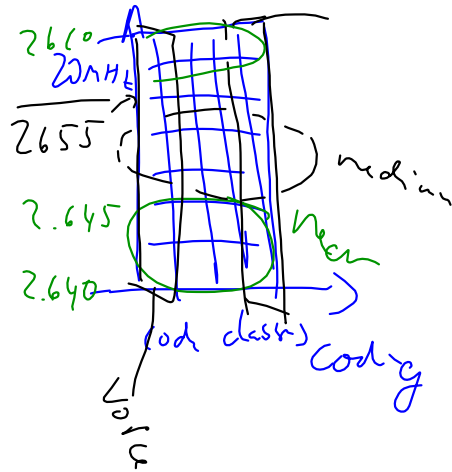
Code: overlapping

voice ~ 30% overlap

data-streaming < 5% overlap

- ftp ~ 10% overlap

# LTE operation



type of service

Part II assignments

- Cell capacity, System capacity
- Mobility
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◦ traffic model

$$C = B_w \log_2(1 + SNR)$$

← bandwidth

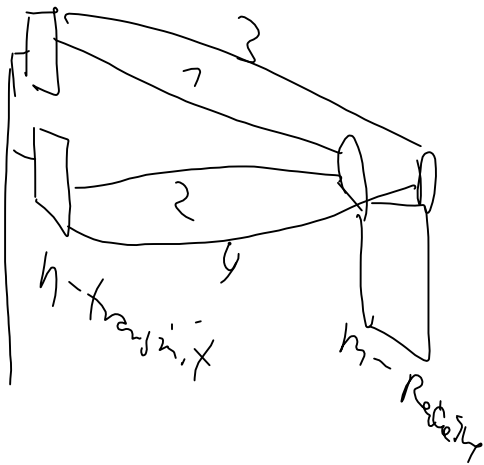
double  $B_w$

→ double Capacity

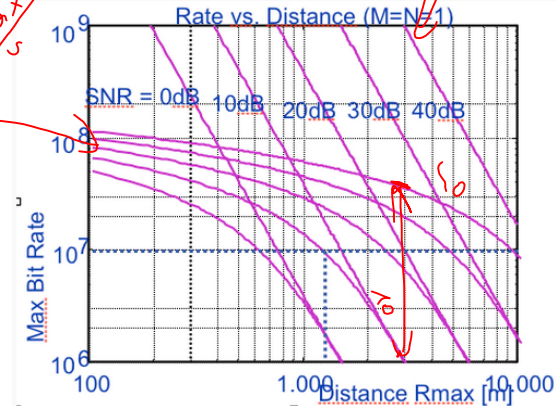
Example increase SNR

SNR = 10 → 40 → increase capacity  
 (= 10<sup>6</sup> → 5 · 10<sup>7</sup> bit/s)

MIMO  $M < n \times m$



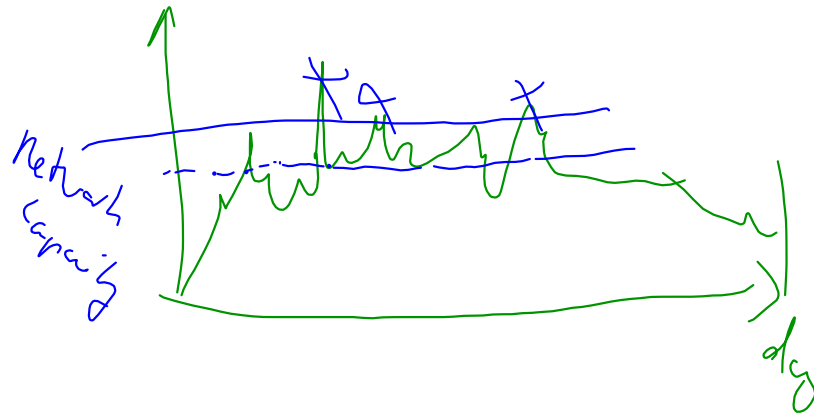
ideal  
 Max Bit Rate  
 10<sup>9</sup>  
 10<sup>8</sup>  
 10<sup>7</sup>  
 10<sup>6</sup>  
 SNR = 0dB 10dB 20dB 30dB 40dB  
 100 1.000 10.000  
 Distance Rmax [m]



# Traffic model

- users      example: 15 phone 0900-1600
- type of service      ↳ 5 --- 10 hrs
- timeline

total traffic

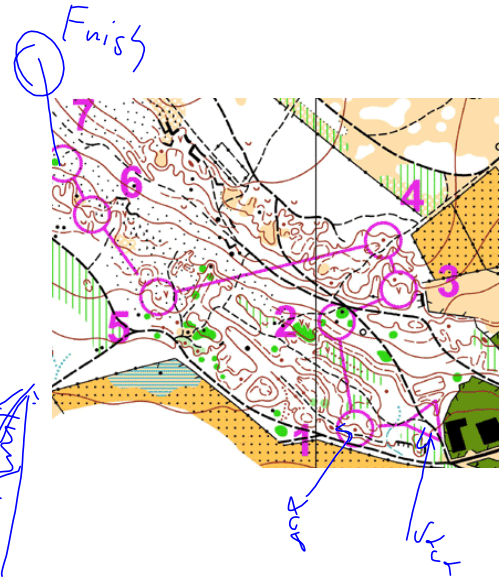
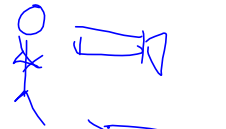




# Video in WLAN



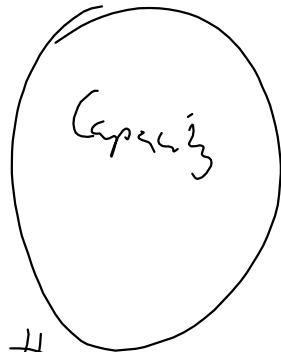
Capacity ?  
# 5, 10 cameras  
distance  
direct antennas



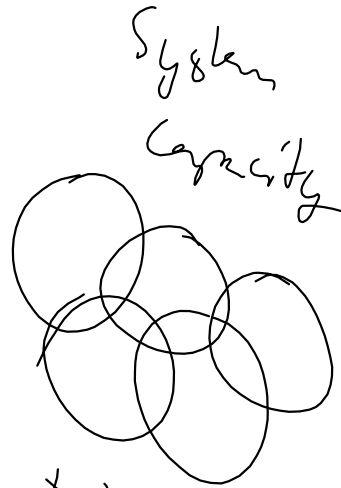
office/home network  
surveillance

Cell / System Capacity

Outcome



# users  
traffic



System  
Capacity

Interference

typical numbers  
20 Mbit/s --- 5 users

Mobility

a) Mobile mobility  
GSM/UMTS/LTE

b)

Mobile IP

c)

Handover  
simulation  
(matlab code)

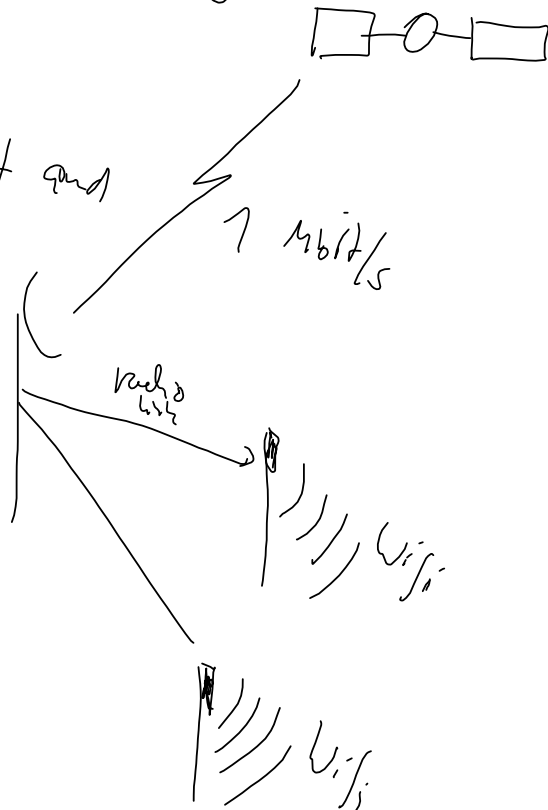
CWi. univ. no

# Basic Internet.org

- Only transmit compressed text and pictures

- Opera Mini

- typical Web 70-30 KByte



a) # users

b) traffic mix  
basic (compressed) + normal users

| Google stats on web pages                        |           | Mean   | Min  | Tail 1% (10% av Top Sites has 38 kB) |       |        |        |        | Median | 60     | 70     | 80 |
|--|-----------|--------|------|--------------------------------------|-------|--------|--------|--------|--------|--------|--------|----|
| KB Per Page                                      | Top Sites | 312.04 | 0.00 | 38.15                                | 40.44 | 119.28 | 145.51 | 176.23 | 208.38 | 275.48 | 377.16 |    |
|  | All Sites | 320.24 | 0.00 | 21.82                                | 54.15 | 90.76  | 131.30 | 177.47 | 234.67 | 310.51 | 428.73 |    |
| Conclusion: sites without video have 38 - 150 kB |           |        |      |                                      |       |        |        |        |        |        |        |    |

compression = 80-90%

animation, video

invers Mobile Virtual Network Operator (MVNO)

does not have a network  
only auth., billing

chess  
talkmore  
djuice } networks  
Netcom  
Telcelor



U.S.I.O

build their own access network



- increased capacity
- better quality

Small cells

2 weeks to presentation

24.10 today

31. Oct (?) 5 min pres. of your topic  
7. Nov presentation ...

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◦ traffic model

i MVNO

keywords: company/organization  
own their access network  
user-owned networks

1) i MVNO  
my focus

5 min "difference to MVNO"

2) presentation

"what is the buzz mode"  
30%

3) simulate

buzz model  
30% pres  
40% sim