

Mobile: Separate channel

Signalling

802.11: min. common BW = 2 Mbit/s

Signalling: 2 Mbit/s



128 Mbit/s



2 Mbit/s



Every lecture is recorded and available at:

- > <mms://lux.unik.no/UNIK4700-JN/UNIK-20170822.wmv>
- > <mms://lux.unik.no/UNIK4700-JN/UNIK-20170829.wmv>
- > replace 20170722 with the lecture date

UNIK 4700

recording

if a lecture is missing,
ask Kaja Mossenad

Interference reduction

↳ mobile network

↳ Wifi

hot spot



capacity limited

Near - far

→ network operated



high power

"bad apple"

1) AP coordinated

2) Mesh

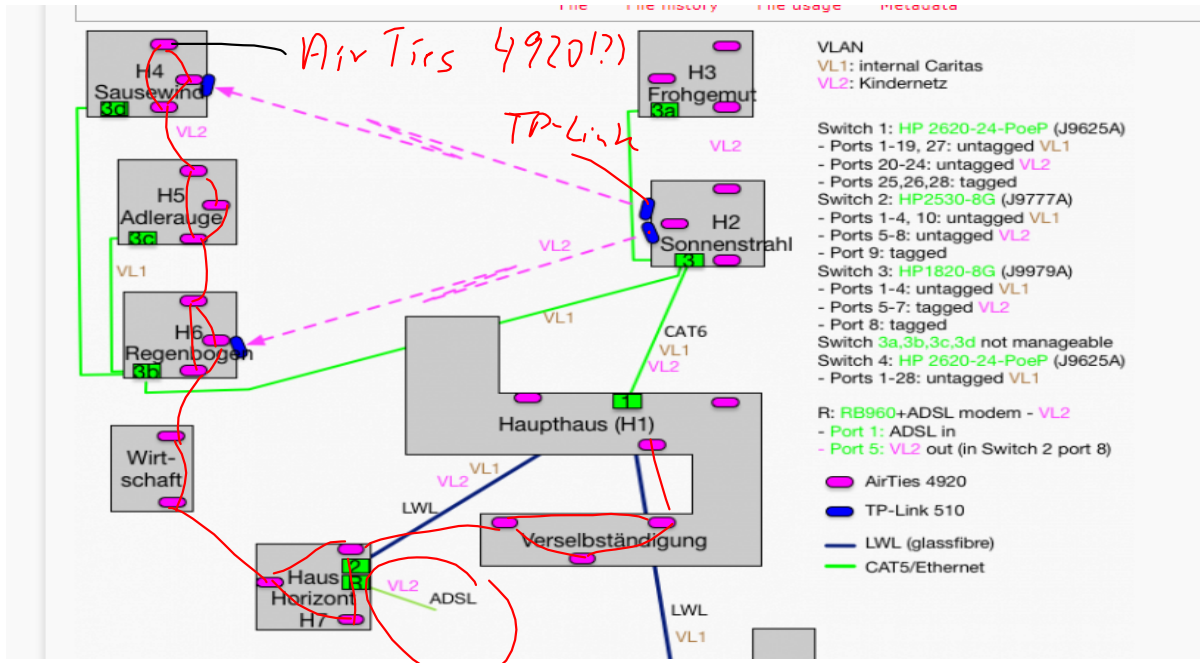
2. mesh



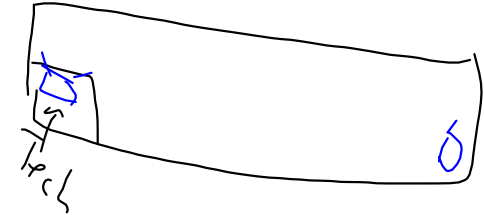
1. handover

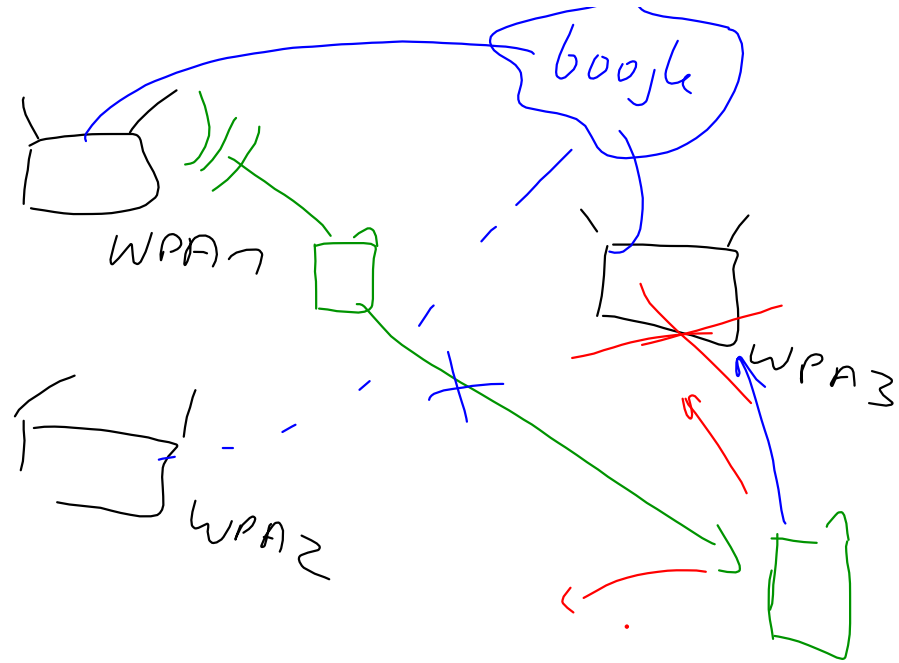
- device operated





Eye Networks.no
 Eye Saas.no
 Managed Wif:





Google

AP

information transmission channel with additive white, Gaussian noise. This capacity is given by an expression often known as "Shannon's formula": $C = W \log_2(1 + P/N)$ [bits/s] with W as system bandwidth, and $P/N = \frac{P}{N_0 W}$ in case of interference free environment, otherwise $N_0 W + N_{\text{interference}}$, where $N_0 = k_B T_K$ with k_B as Boltzmann constant and T_K as temperature in Kelvin.

power amplifier

noise factor = 10

1)

Capacity

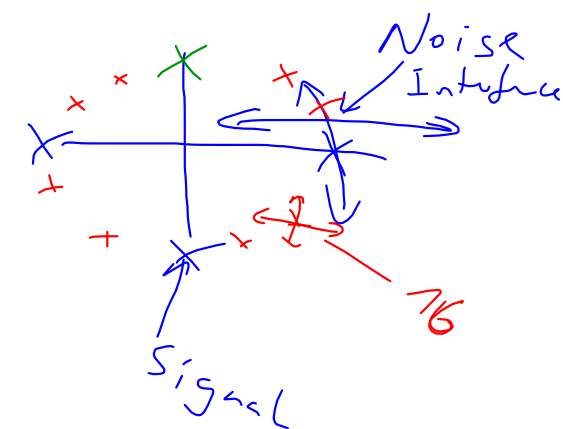
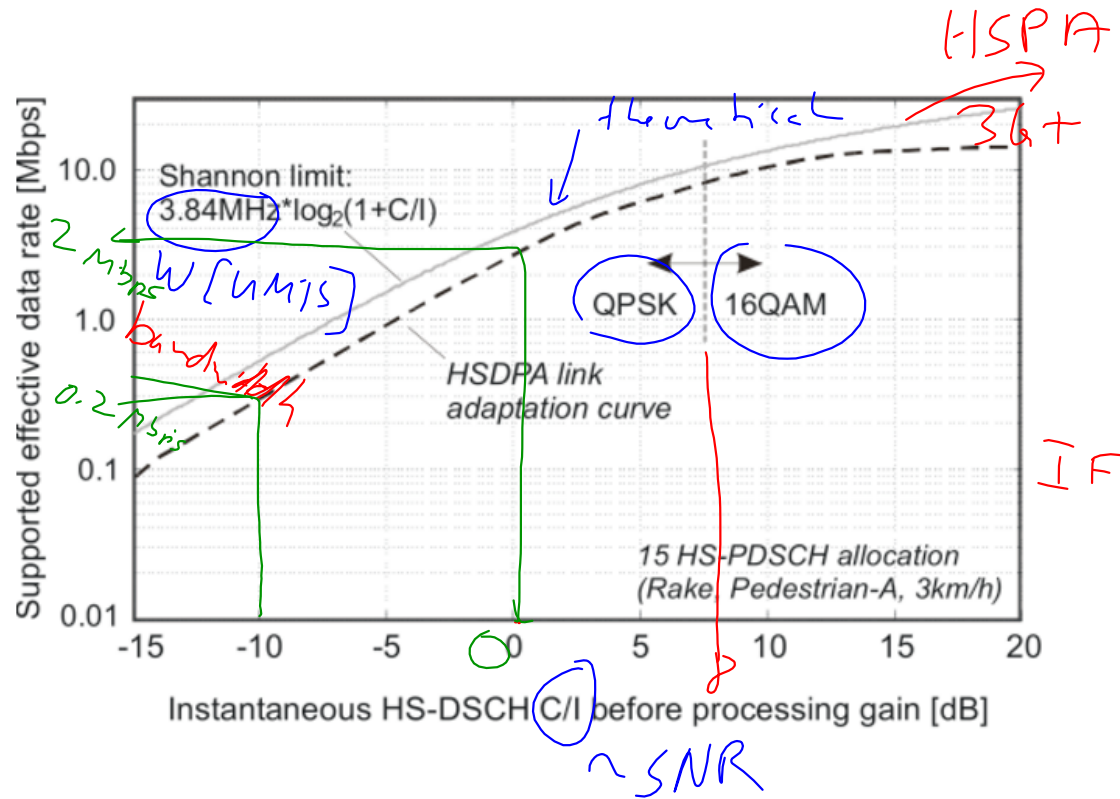
~ Bandwidth

2)

Capacity

~ $\log(\text{SNR})$

Sensitivity ~ -95 dBm WLAN
 -704 dBm GSM
 -776 dBm UMTS



IF SNR > 8, then 16QAM, then

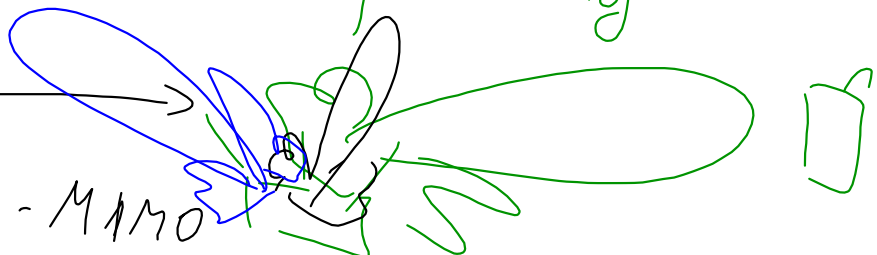
MIMO

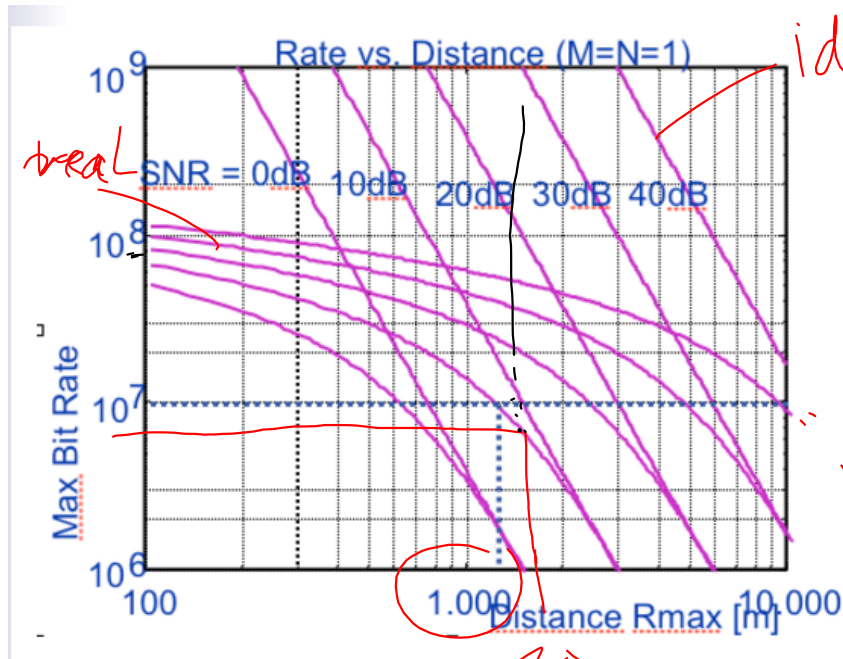
→ beam forming

802.11n

new = Multi-MIMO

→ "real MIMO" analyse & consider multiple paths





ideal

real

$$R_{max} = \log_2(1 + SNR)$$

$$R_{max} = \log_2$$

[Source:

$$SNR = 10dB$$

$$R_{max} = 7.5 km \rightarrow 7 Mbit/s$$

$$SNR = 40dB$$

$$R_{max} = 7.5 km$$

$$Bitrate < 100 Mbit/s$$

1.5 km UMTS
+ typical cell size

yields the wave equation:

$$\frac{\partial^2 \vec{E}}{\partial t^2} - c_0^2 \cdot \nabla^2 \vec{E} = 0$$

$$\frac{\partial^2 \vec{B}}{\partial t^2} - c_0^2 \cdot \nabla^2 \vec{B} = 0$$

with $c_0 = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 2.99792458 \times 10^8 \text{ m/s}$

[Source: Wikipedia]

Medium

$$v_{\text{speed}} = \frac{c}{\sqrt{\mu \epsilon}}$$

$$\mu = \mu_0 \cdot \mu_r$$

$$\epsilon = \epsilon_0 \cdot \epsilon_r$$

speed of light
 $\left(\approx \right) \text{E} \frac{\text{m}}{\text{s}}$

Voice: scalar

Wave: $E_x - H_y$

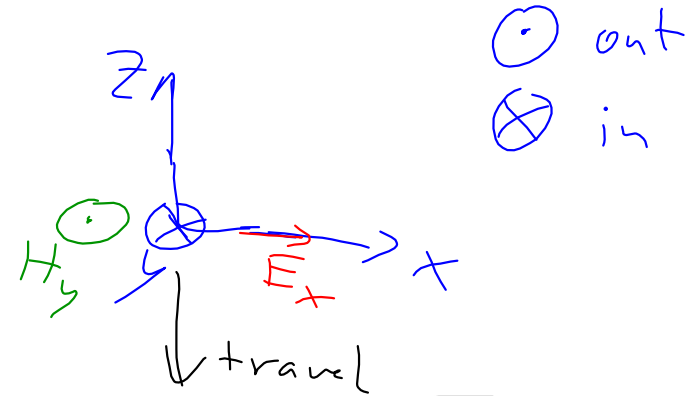
where

direction

→ $\vec{r} = (x, y, z)$ and $\vec{k} = (k_x, k_y, k_z)$ so?

- j is the imaginary unit
- $\omega = 2\pi f$ is the angular frequency, [rad/s]
- f is the frequency [1/s]
- $e^{j\omega t} = \cos(\omega t) + j \sin(\omega t)$ is Euler's formula

with the group velocity (free space = speed of light) $c = \frac{c_0}{n} = \frac{1}{\sqrt{\mu\epsilon}}$ and the refractive index $n = \sqrt{\frac{\mu\epsilon}{\mu_0\epsilon_0}}$



free space resistance

$$Z_0 = \frac{E}{H} \sim 377 \Omega$$

antenna cable
50Ω, 75Ω

Free space propagation next week

Presentation

30 min slot : 20 min pres + 10 min discussion

> Internet of Things & Cognitive Radio

Topics

> 5G security and ~~mobility~~ ^{heterogeneity} challenges : Haroon

> Device to device communication challenges and opportunity : Magnus

> Location variability in satellite communication : Hani

> Modelling wireless propagation : Maxime

> Mobile broadband performance measurements : Cise

> 5G network slicing : Georgios

Questions / Open Issues
 13:27-14:00
 14:00-14:30
 14:45-15:15
 19 Sep 2017
 19 Sep 2017

→ 15:15 - 15:45

13:30-14:00

break 14:30-14:45

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