

1a: $P_{receive}$

1b: SNR ($P_r - P_{sen} - 20dB$)

create a table with R, f, P_r , SNR, Capacity, typical industrial values

calculate Shannon capacity

Shannon II

$$C = B \log_2 \left(1 + \frac{S}{N} \right)$$

↑ Bandwidth
↑ P_{sens}
↑ P_{noise}

↑ $P_{sens} + P_{rad}$
↑ 20dB

↑ results from $\frac{P_{sens}}{P_{noise}}$

① theoretical result

② check against literature (operating conditions)

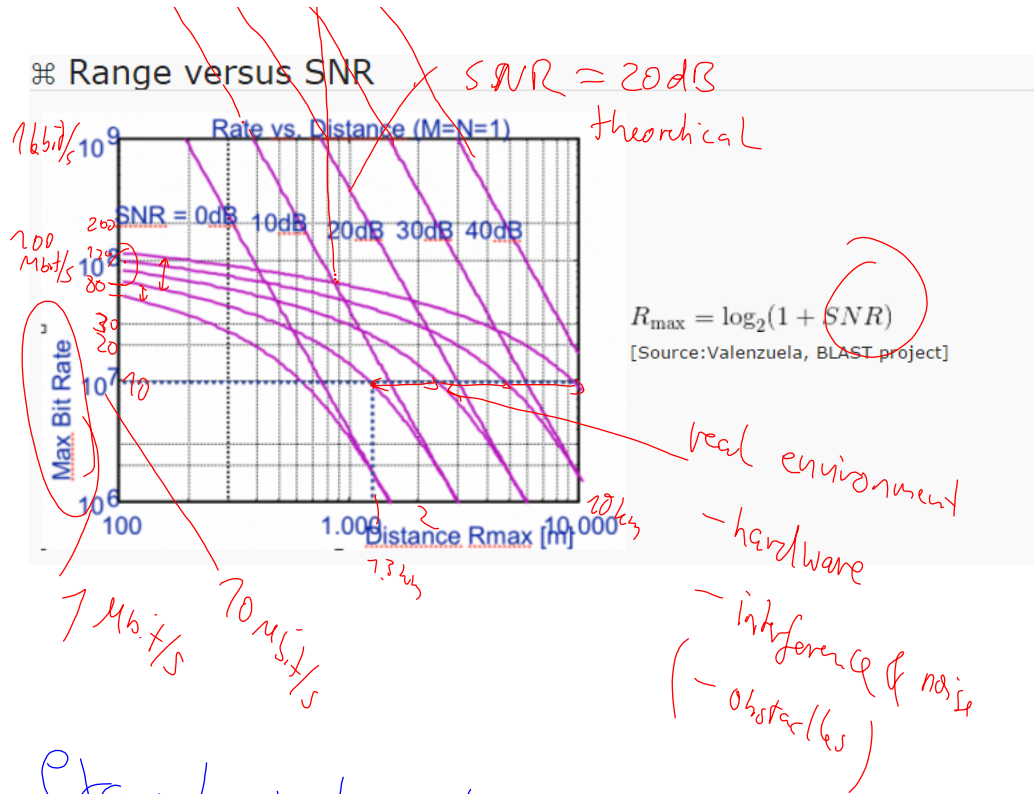
III ③ analyze the difference

GSN
4ms
LTE
WIFI

Bandwidth	
P_{sens}	-104
P_{noise}	-116
LTE	-110
WIFI	-95

Difference cable vs wireless

analyse diff: Shannon versus real systems (check with typical values in Literature)

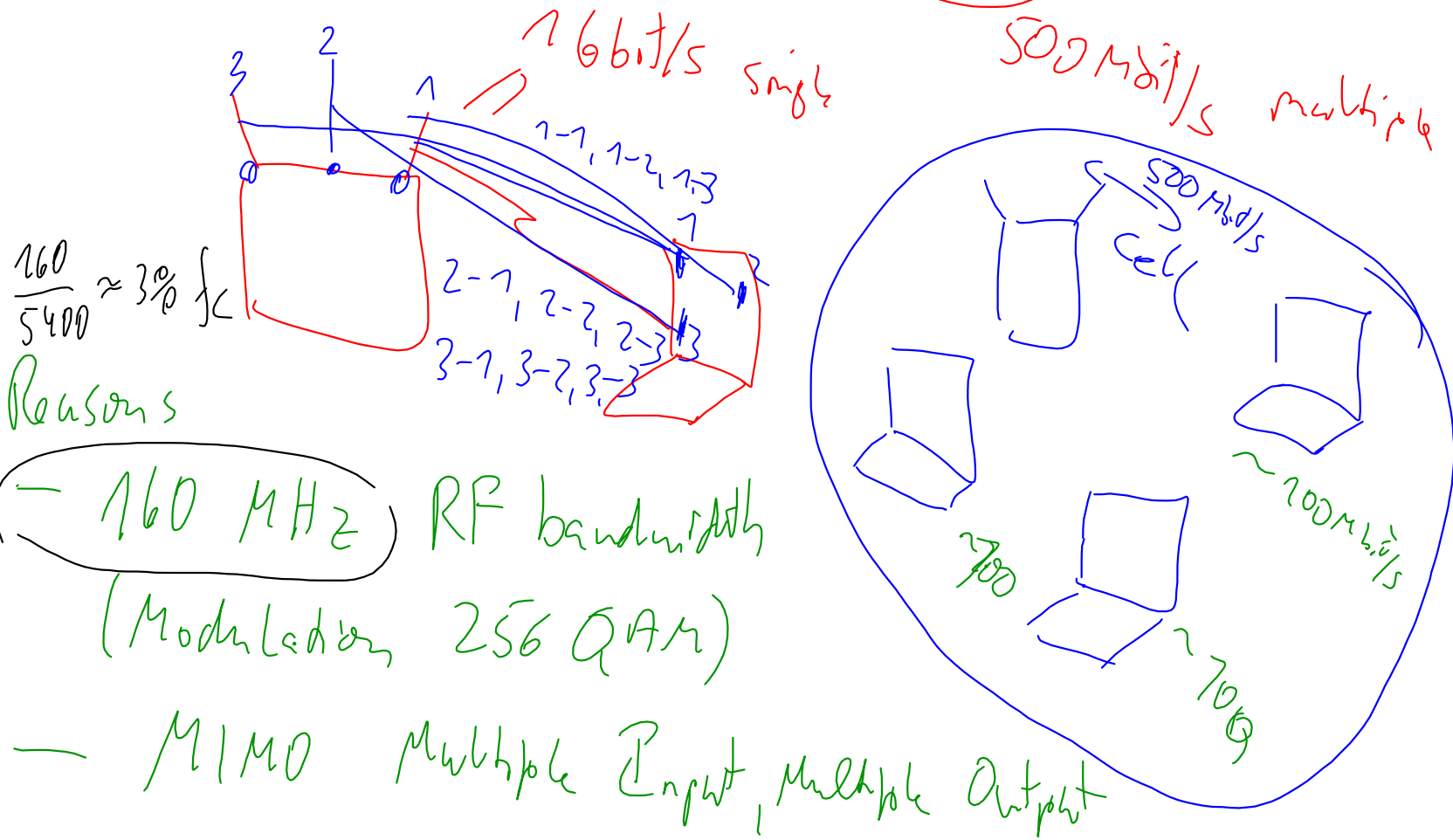


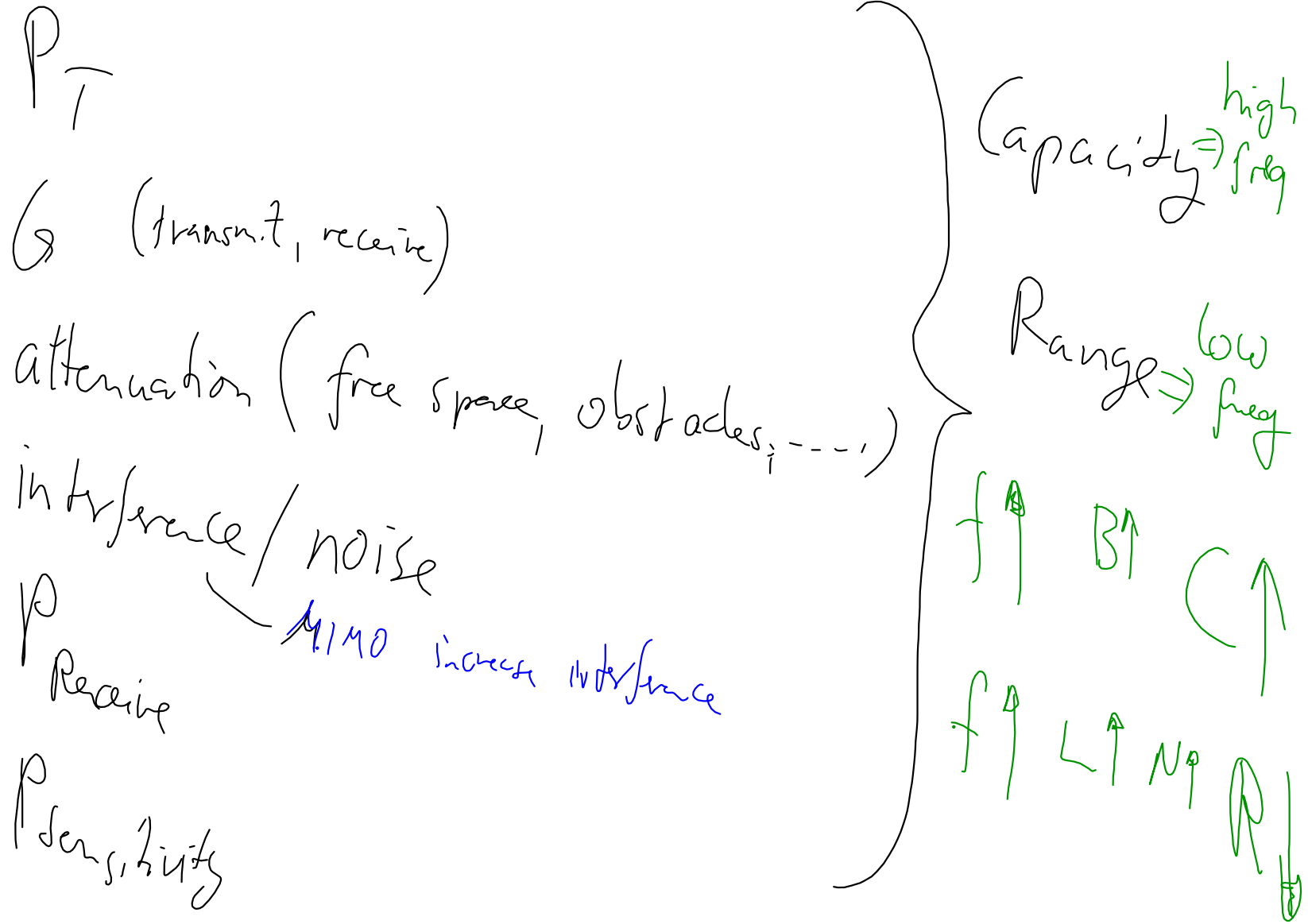
Example real system:

\uparrow SNR = 30dB \sim Capacity increase 50% / short range
 \downarrow SNR = 30dB \sim Range increase \rightarrow 70% (1.3 \rightarrow 10km)

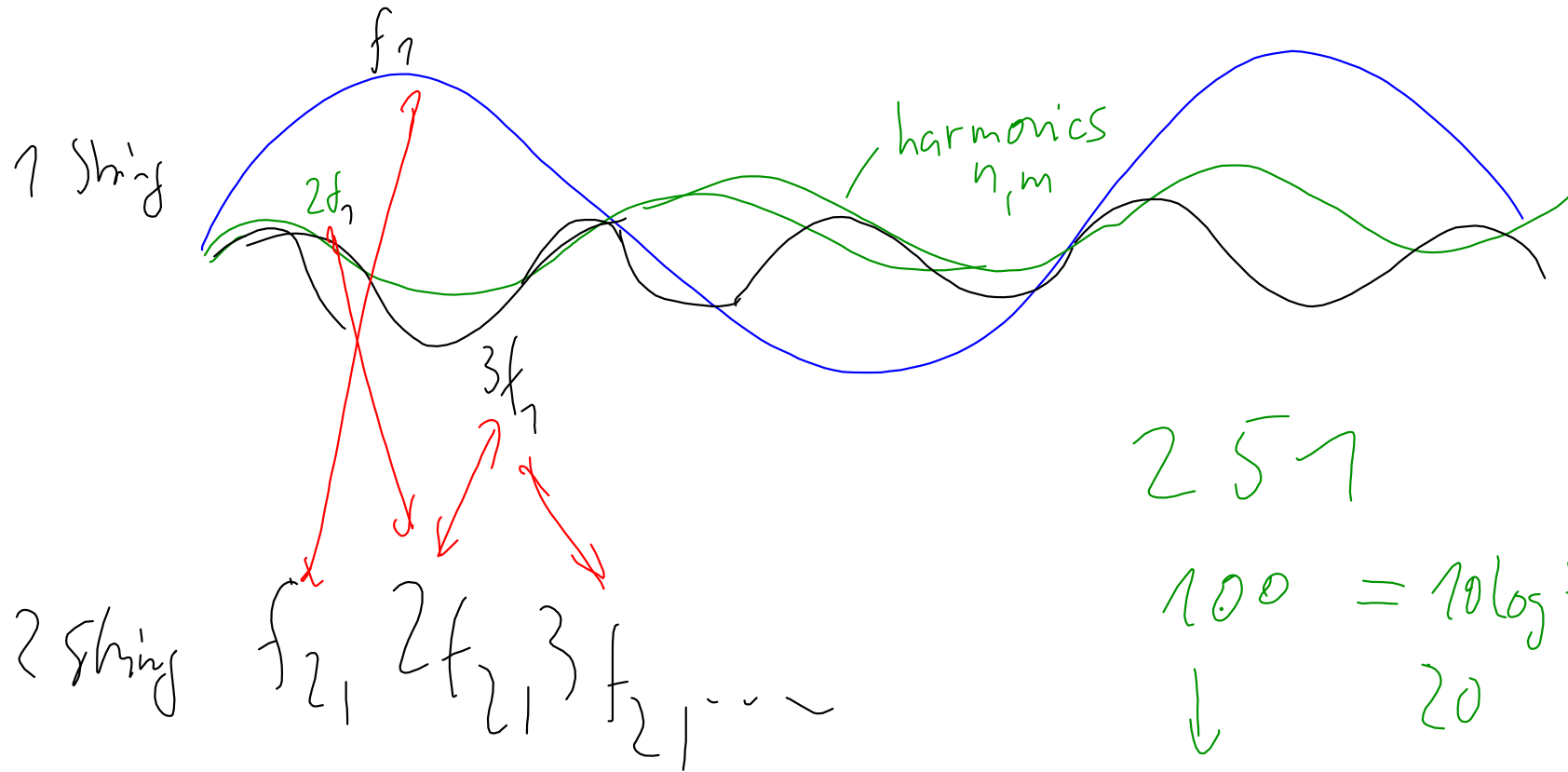
IEEE 802.11ac is a wireless networking standard in the 802.11 family (which is marketed under the brand name Wi-Fi), developed in the IEEE Standards Association process.^[1] providing high-throughput wireless local area networks (WLANs) on the 5 GHz band.^[1] The standard was developed from 2011 through 2013 and approved in January 2014.^{[1][2]}

This specification has expected multi-station WLAN throughput of at least 1 gigabit per second and a single link throughput of at least 500 megabits per second





Intermodulation = $n f_1 \pm m f_2$



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$$100 = 10 \log E_2$$

$$\downarrow \quad 20$$

$$200 + 2 \quad + 3$$

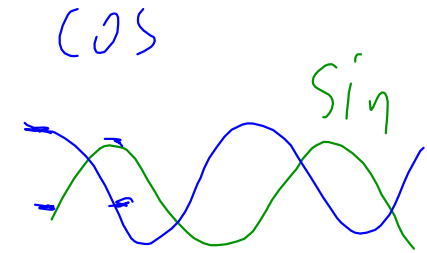
$$\sim 24 \text{ dB}$$

512 steps

Power/Voltage

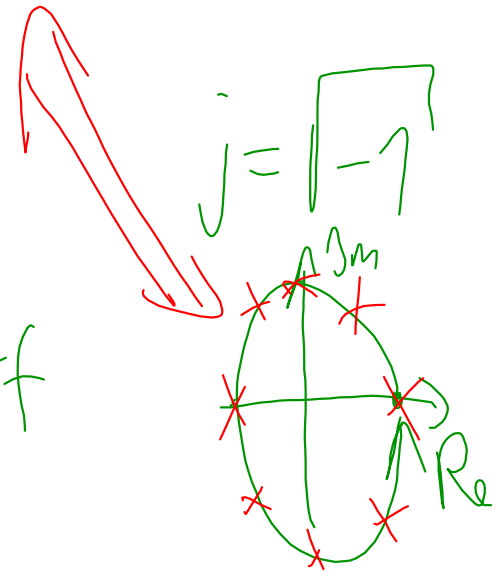


$$\begin{array}{c|c|c} \frac{1V}{0V} & \begin{array}{c} 1 \\ 0.5 \\ 0 \end{array} & \begin{array}{c} 1V \\ 0.9 \\ \vdots \\ 0.2 \\ 0.1 \end{array} \end{array}$$



Electromagnetics

$$\vec{E} = E_0 e^{-j\omega t} \quad \text{201f}$$



Challenge

$$f_c = 4.5 \text{ MHz} \quad B = 3 \text{ MHz}$$

unrealistic for
real system



$$\frac{B}{f_c} = 0.75$$

Real system: filter, amplifier, receiver linearity

$$B \sim \frac{1}{20} f_c$$

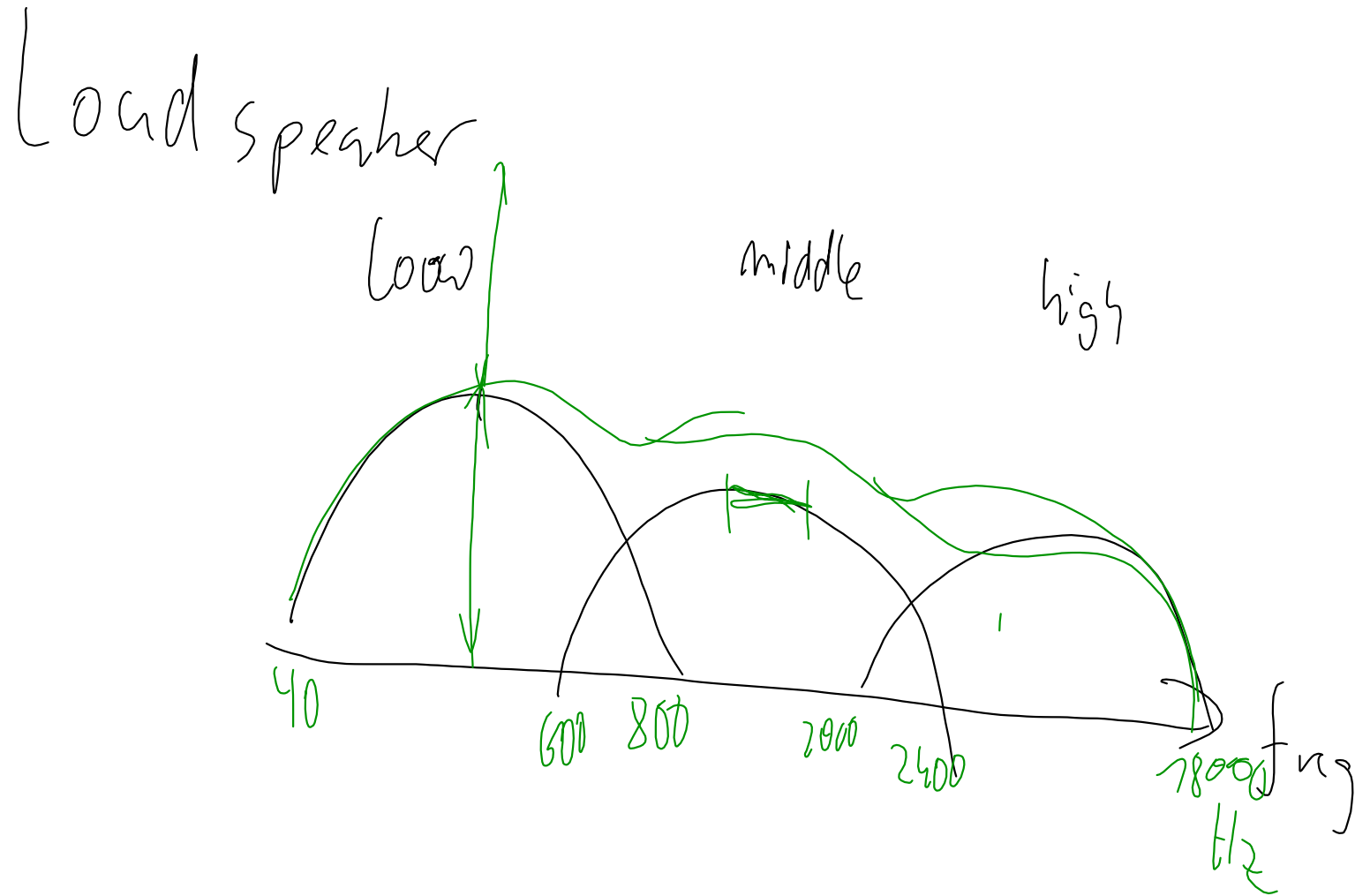
$$900 \text{ MHz} \sim B \sim 90 \text{ MHz}$$

$$802.11a$$

$$5.4 \text{ GHz}$$

$$\sim B \sim 540 \text{ MHz}$$

ac



Future Networks

- refarming: LTE at 800 MHz
- Digital Divide (TV frequencies)
- Basic Internet - Business model of information

Refarming
 Today 450 ICE WCDMA 400-762 MHz TV-band
 Moble 900 GSM
 1800 GSM
 2200 WCDMA
 → 2650 LTE

450 ICE LTE
 900, GSM + LTE
 2800, LTE
 2700 WCDMA, LTE
 2650 LTE

(2013 Apple LTE)

Apple's iPhones 5c and 5s support more LTE bands in Europe

September 10, 2013 | By Anne Morris

SHARE Apple unveiled two new iPhones to replace the iPhone 5 on Tuesday, the lower-cost iPhone 5c and higher-end iPhone 5s, and to the relief of Apple fans across Europe the new smartphones will now support LTE Bands 7 (2.6 GHz) and 20 (800 MHz), as well as LTE Band 3 (1800 MHz).



8 antenna
 Apple: easy rec. update
 - (USA) network provision
 - already used (3G)

typical R C

total avail. bandwidth

Coverage 450
outdoor → indoor

Coverage 900
outdoor → indoor

Capacity 1800

Capacity P 2700

hot-spot 2650

6 MHz operator = 5 MHz LTE + 1 MHz GSM

12 MHz operator (25 MHz carrier) = 2x5 + 2x10 MHz LTE
3 operators

25 MHz / 4 operators

LTE flexibility

B = 2, 5, 10, 20, 40 MHz

cell-breathing

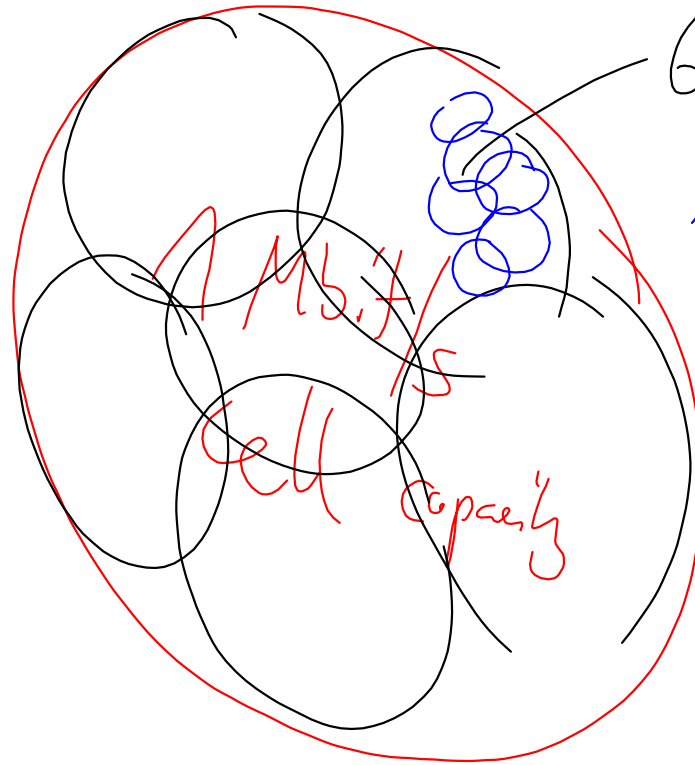


no traffic
heavy traffic
3G traffic ↑
noise ↑
R_{avg}, coverage ↓
UMTS
B = 5 MHz (3.8 MHz)

Typical Cell

UMTS

3 x 5MHz
(3.8MHz)



6x capacity

100x capacity

- cost

(-interference)

- Mobility
handover

Basic Internet.org

35 min pres

5 min pause

58% mobile coverage in Africa

- Why Universities, not rural

- Tanzania

- DR Congo - no Internet

not affordable

↳ funding

Questions understanding

Questions challenges

Buz

Investment

CAPEX

Operational

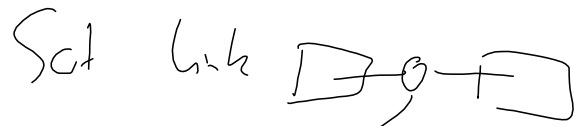
OPEX

Return of Investment

ROI

- free basic ~ 5% BW
- funding "infrastructure" CAPEX \leftarrow not proven \leftarrow "tax"
- vouchers ~ 95% BW \leftarrow income

- users:
 - 80% smartphones
 - 75% males \leftarrow smartphone \leftarrow Oper Mini
 - 25% women
 - ? tablets
 - ? PC/laptop
- Information
 - Univ. \rightarrow PC \leftarrow fitted "network admin" responsible
 - India buy health centre, schools 77-78k\$
 - sell stacks
- hotspots
- health centre
 - tablet
 - PC



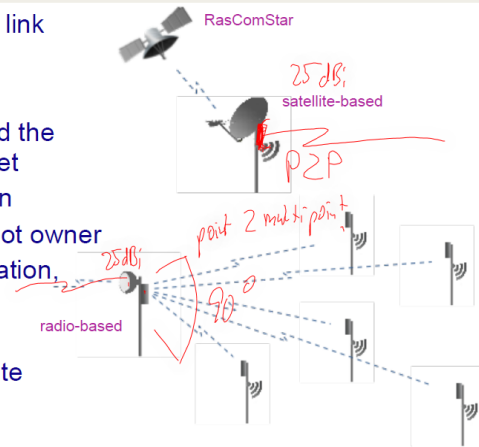
1 mp3 = $\frac{\text{low}}{\sim 3-5 \text{ MB}}$

2500 kbit/month
 $7 \text{ Mbit/s} = 777 \text{ kByte/s}$
 $\sim 7 \text{ MByte/m.h}$

Basic Internet provision through Partners



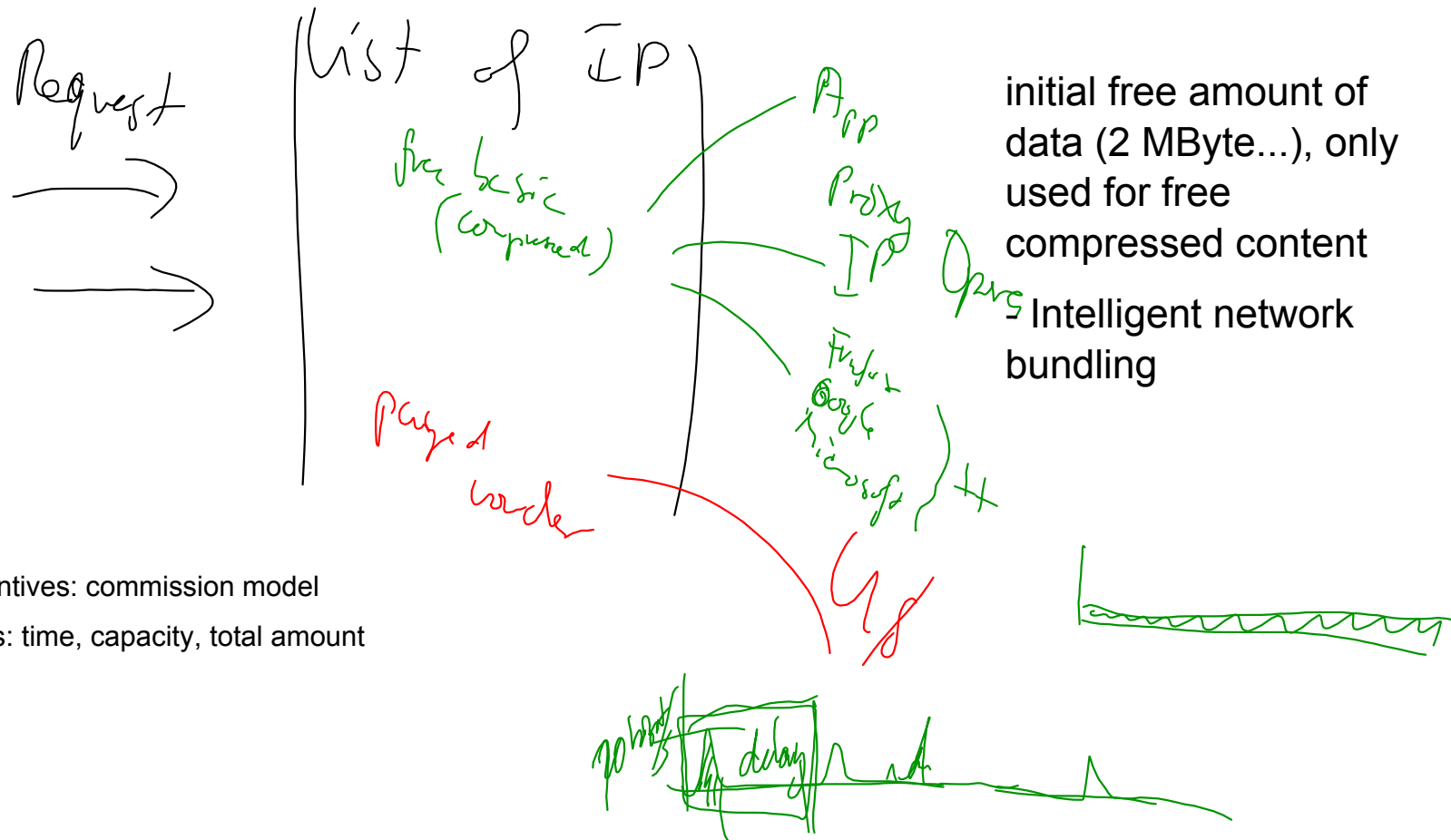
- Satellite, radio or mobile link
 - local roll-out
 - with partners in Africa
- Mobile Operators: extend the reach, prepare the market
- CSR: increase innovation
- Own deployment: hot-spot owner
- AID organisations: education, health information
- Sponsored access
- Higher education: educate teachers



Firefox - Browser -> proxy?

- ?? (filter by IP)

off-line vs online content



incentives: commission model
 apps: time, capacity, total amount