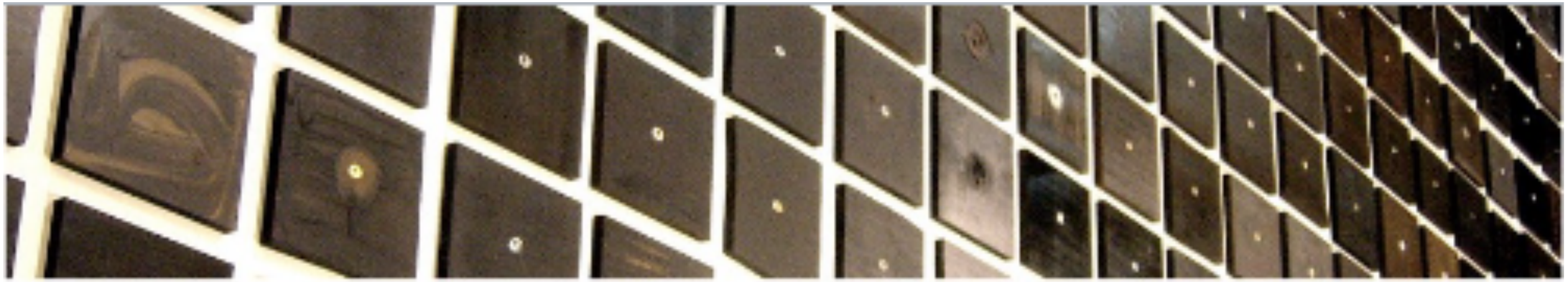

UiO : Universitetet i Oslo

TEK5110

L10 Wireless Systems

Josef Noll

Secretary General and Co-Founder at BasicInternet.org, Professor at UiO, Head of Research at Movation

Oslo Area, Norway | Telecommunications

Current	Basic Internet Foundation, University Graduate Studies (UNIK), University of Oslo (UiO), Movation AS
Previous	MobileMonday, Telenor R&I, Telenor R&D
Education	Ruhr University Bochum

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PhD Fellow at Eye Networks AS

Oslo, Oslo, Norway

Information Technology and Services

Current	Eye Networks AS
Previous	Høgskolen i Oslo og Akershus, State Organization for Registry of Deed & Property, Karaj Islamic Azad University
Education	University of Oslo (UiO)

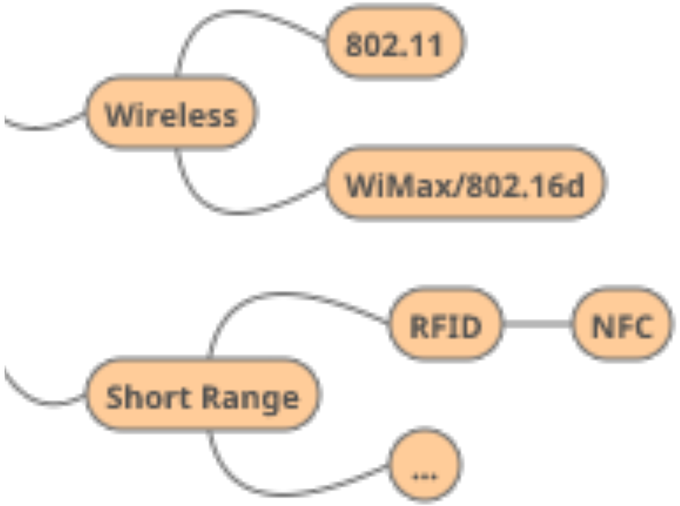
TEK5110 - Before we start

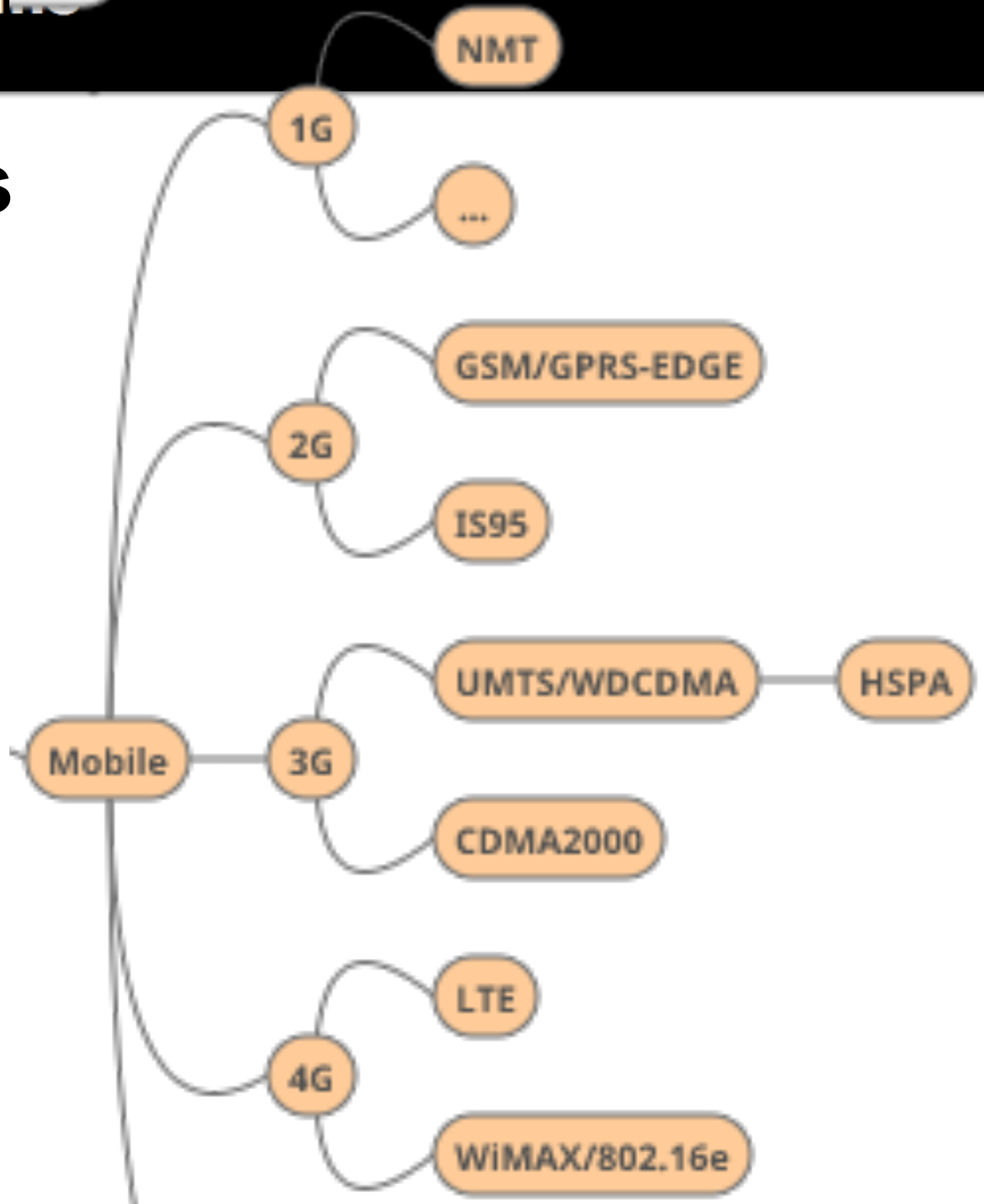
- Questions to L9 - Mobile Systems?
- Hands-on Mikrotik - your experience?
- Questions to group work?

Recall:
-
4G, 5G and refarming

Mobile and Wireless Systems

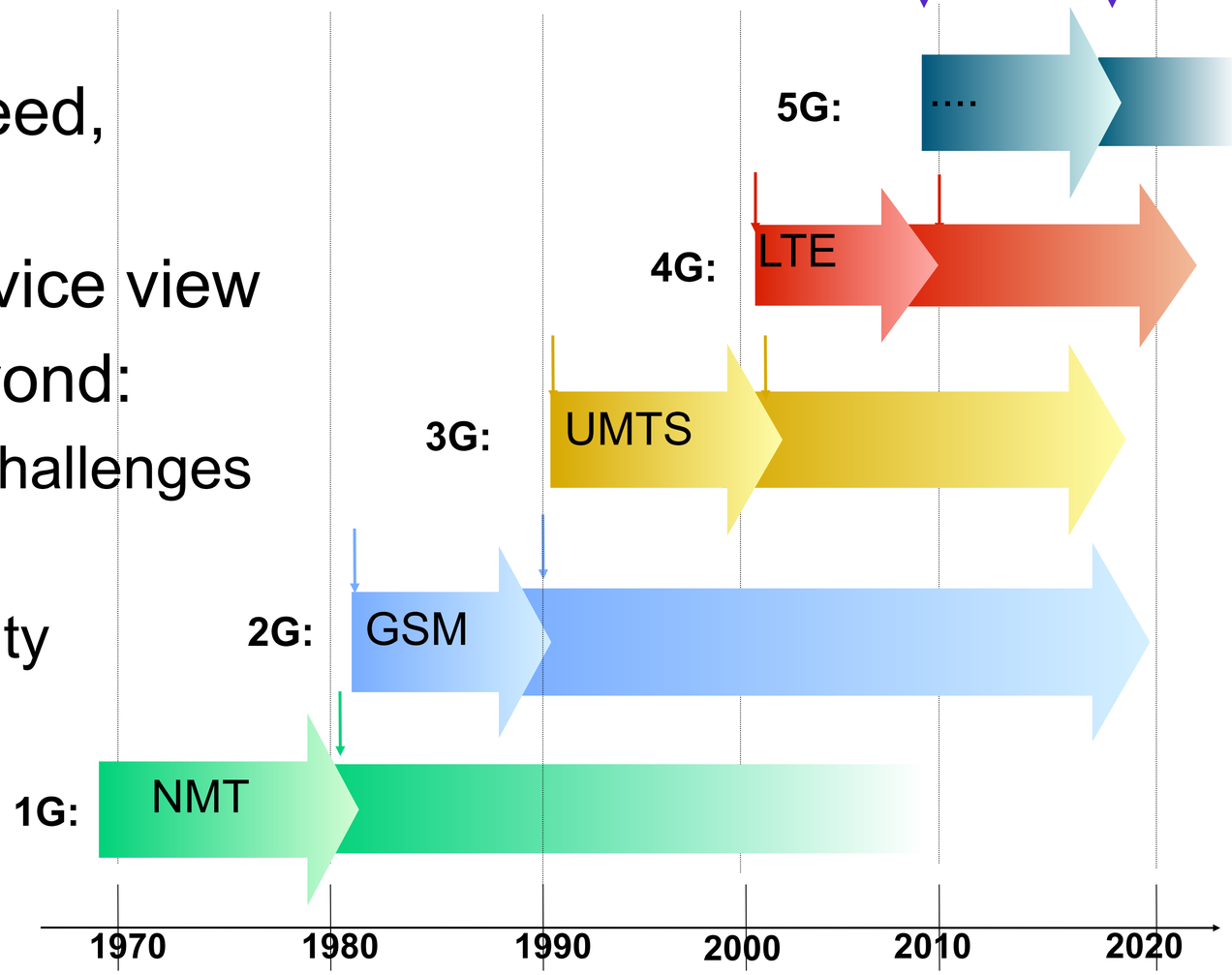
- https://drive.google.com/file/d/0B2fQNOmvY08oOVp1RXVJaFNkSEk/view?usp=sharing





5G: Speed, Bandwidth, latency and much more

- 1G-3G: Speed, flexibility
- 3G-4G: service view
- 5G and beyond:
  - Business challenges
  - ownership
  - sustainability



Service & Sustainability

Seamless integration

Security,

Sustainability

Mobile broadband services

Web, Multimedia, Communications

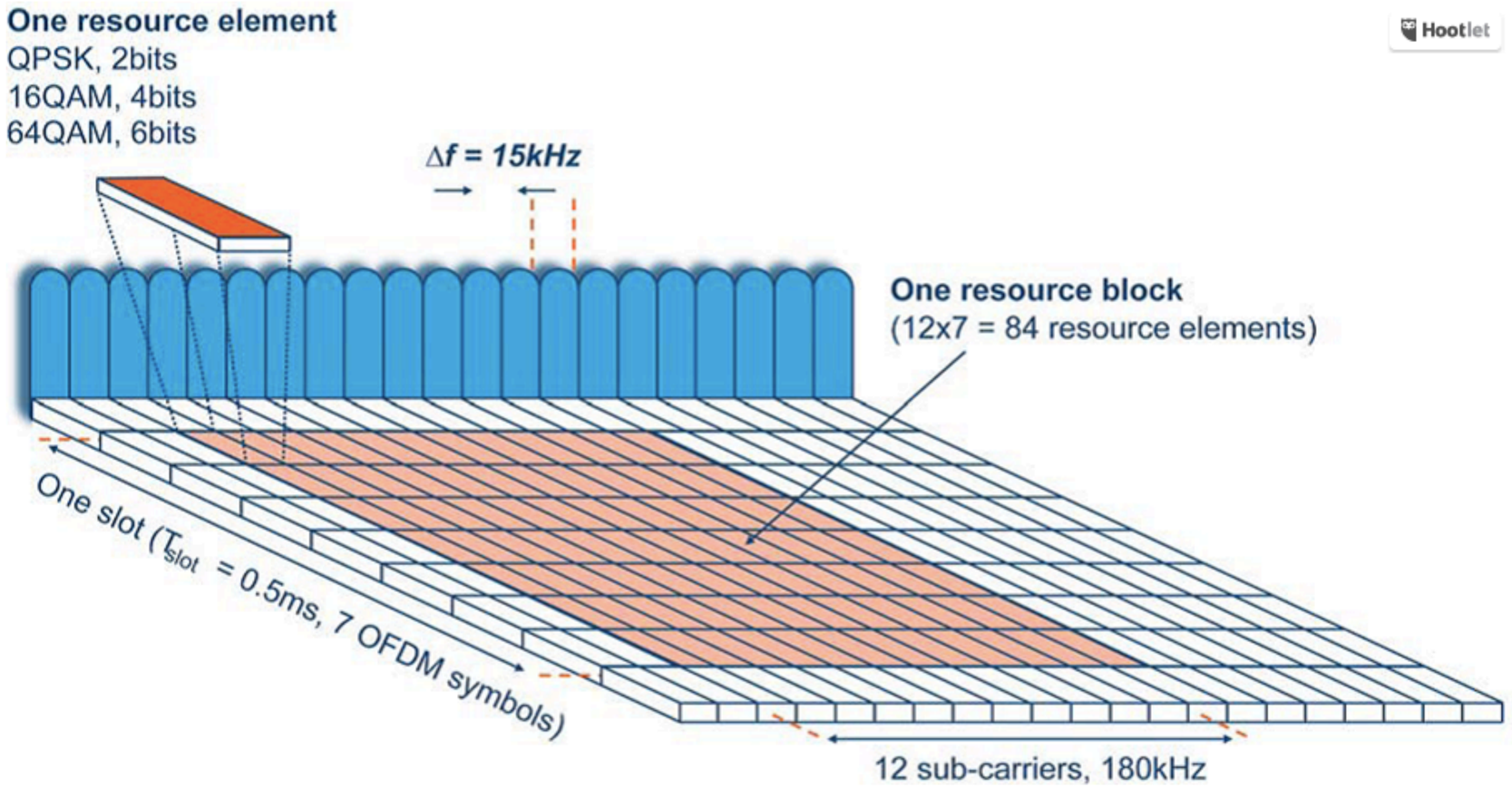
Mobile telephony, SMS, FAX, Data

Mobile telephony

[adapted from Per Hjalmar Lehne, Telenor, 2000]

4G resource allocation

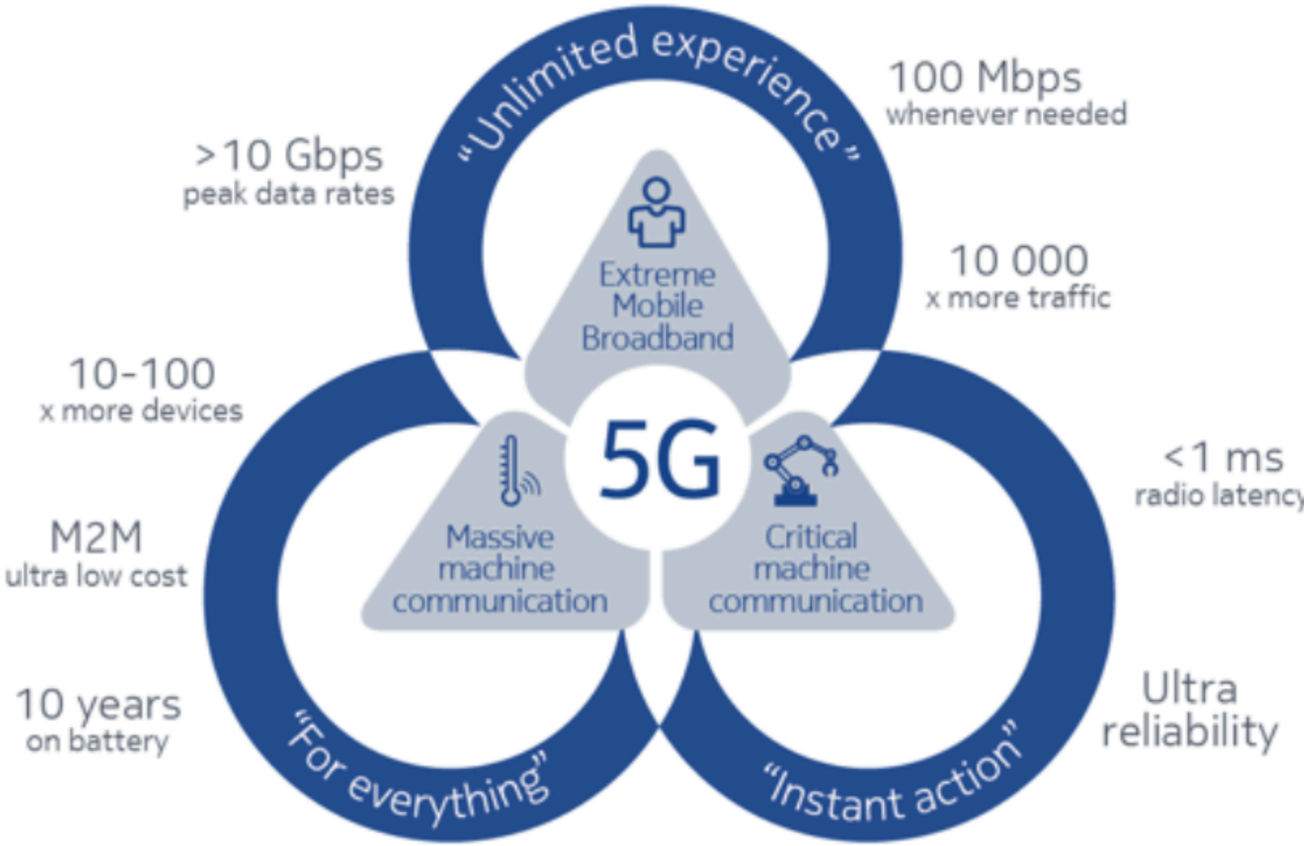
- OFDM
- frequency
- time
- code



https://irisxyan.wordpress.com/category/technology/lte-4g/

5G Ultra Reliable, Low Latency

- Application areas
  - process industry, alarm, wireless-connected vehicles
  - latency <1 ms, <10 ms,... in process control
  - 99.99997% uptime, delivery within 5 ms
- #5GforAll
  - radio interface: Large cell low mobility sites (low density rural areas)
  - freemium model for access (freemium = free + premium)
- Missing aspects in 5G
  - interface mobilehome network
  - application-specific routing (service quality)
  - interference with unlicensed technologies



[source: Nokia https://networks.nokia.com/5g/get-ready]

5G Air Interface

- Scalable **OFDM**-based 5G NR air interface
  - ➡ Scalable numerology, scalable slot duration (efficient multiplexing of diverse latency and QoS requirements)
  - ➡ Frequency localisation
  - ➡ lower power consumption
  - ➡ Asynchronous multiple access
- Flexible slot-based 5G NR framework
  - ➡ Self-contained slot structure (independently decode slots and avoid static timing relationships across slots)
  - see: https://www.5gtechnologyworld.com/the-basics-of-5gs-modulation-ofdm/

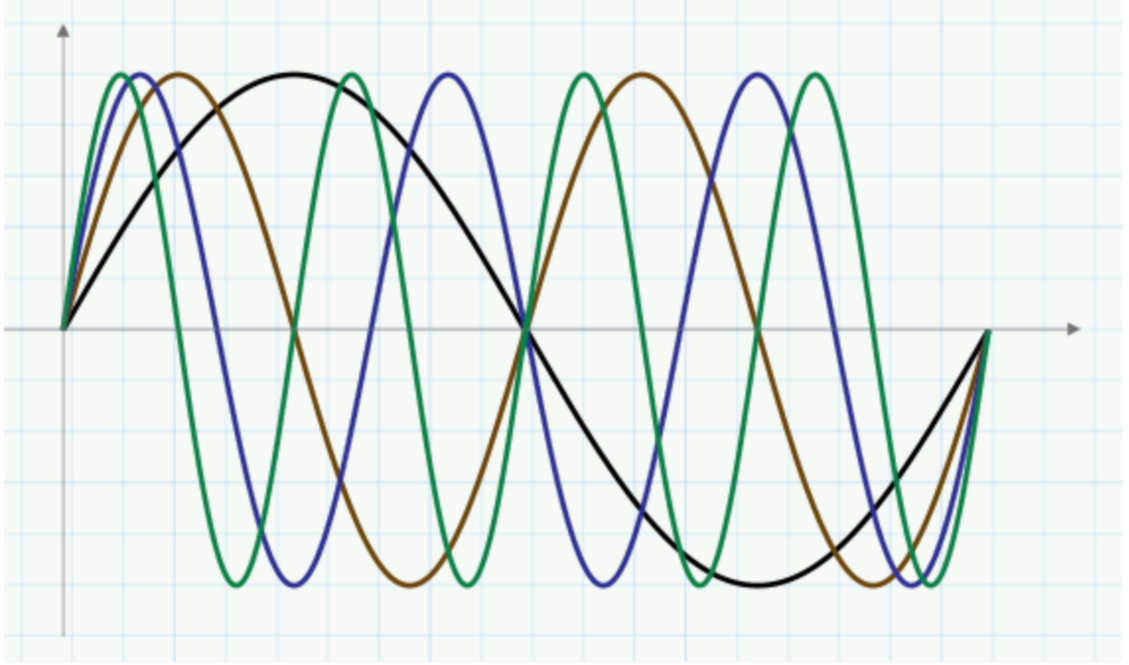


Figure 3. This OFDM signal contains four carriers spaced apart by ⊠f corresponding to f0, f1, f2, f3.

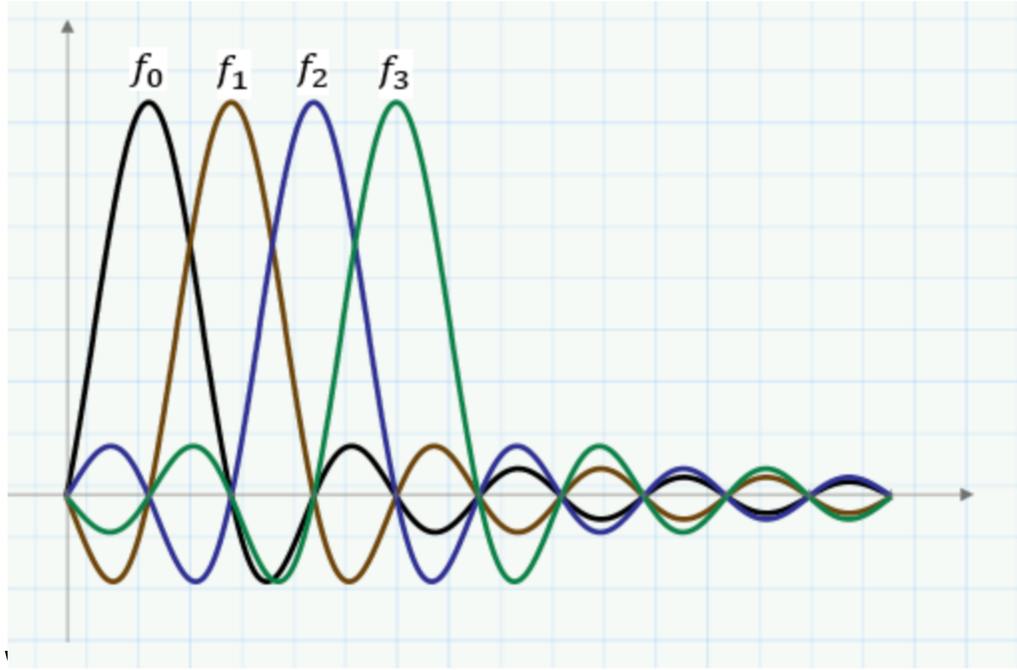


Figure 4. Frequency domain representation of a four-carrier OFDM signal

5G Channel coding

- Channel coding
  - Advanced ME-LDPC channel coding
  - more efficient than LTE Turbo code, 4x at Code rate (R)=0.65, 5 at R=0.9
- **3x increase** in **spectrum efficiency**
  - explicit 3D beam forming with up to 256 antenna elements
  - typical 3.8x increase from 4x4 MIMO to 5G NR Massive (256 antennas) MIMO (52 Mbps to 195 Mbps)
- Large BW opportunity for mmWave
  - 5G NR sub-6GHz (3.4-3.6 GHz)
  - 5G NR mmWave (e.g. 24.25-27.5 GHz, 27.5-29.5 GHz)

5G Challenges

- require:
- overcome significant path loss in bands above 24 GHz
- robustness: innovation to overcome mmWave blockage from hand, body, walls, foliage - non-LOS is a problem
- Device size/power integration into a mobile
- Dense network topology and spatial reuse (150-250m distance)
- colocation of 28 GHz on LTE channels

Network refarming

- Mobile frequencies
- GSM bands in 800 – 900 MHz and 1800 – 1900 MHz
- UMTS bands are typically within the 1900/2100 MHz frequencies;
- LTE is found at (450)/700/1900/2100/2400/2650 MHz in the spectrum.

- Refarming: new frequency distribution for 2G, 3G, 4G, 5G
  - ➡ What is the optimum combination?

- see: https://www.gsma.com/spectrum/wp-content/uploads/2012/07/refarmingcasestudysweden900mhz20111129.pdf

Coverage - LTE 450 MHz

- Band 31, limited bandwidth of 2 x 10 MHz
- Ovum: http://450alliance.org/wp-content/uploads/2014/07/Ovum-LTE450-presentation.pdf

Technical pros and cons of LTE450

Cons:

- Limited bandwidth
- Interference challenge (5Mhz guard band between the uplink and downlink)
- Limited ecosystem
- So far standardized for Brazil only

Pros:

- Propagation - covers more territory with fewer base stations than higher bands
- Cost is appealing for covering large rural areas.
- Technical issues are being addressed
- Clear evidence of vendor interest in supporting LTE450.

Frequency (MHz)	Cell radius (km)	Cell area (km2)	Relative cell count
450	48.9	7521	1
850	29.4	2712	2.8
950	26.9	2269	3.3
1800	14.0	618	12.2
1900	13.3	553	13.6
2500	10.0	312	24.1

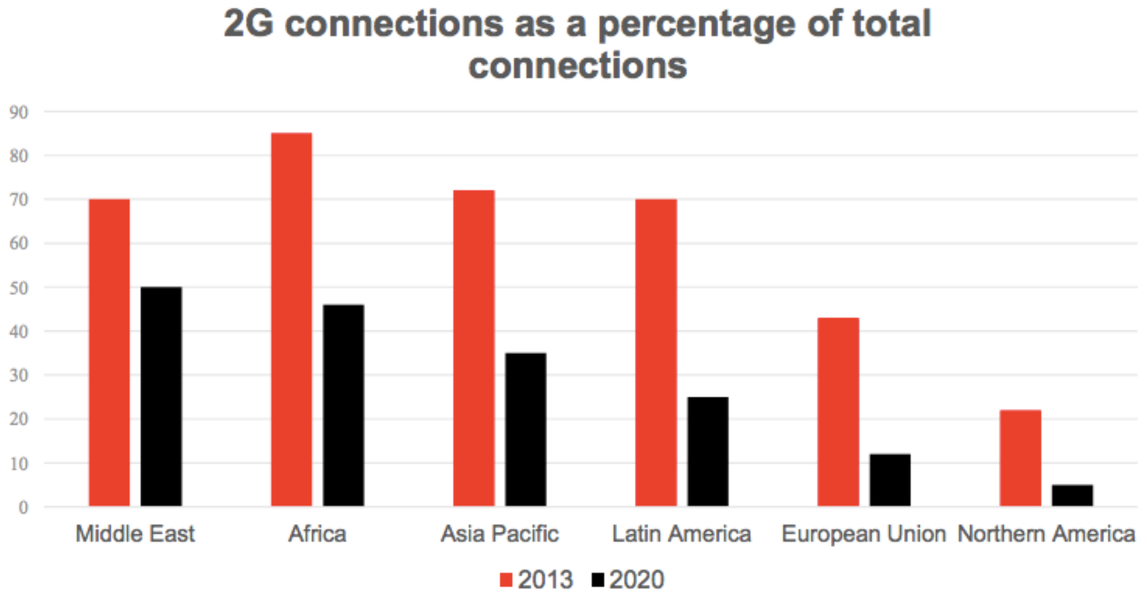
Theoretical comparison of base station coverage at different spectrum bands. This performance is based on flat terrain, tower mounted amplifier with radio 60 meters above ground, and no interference

The challenge of area coverage

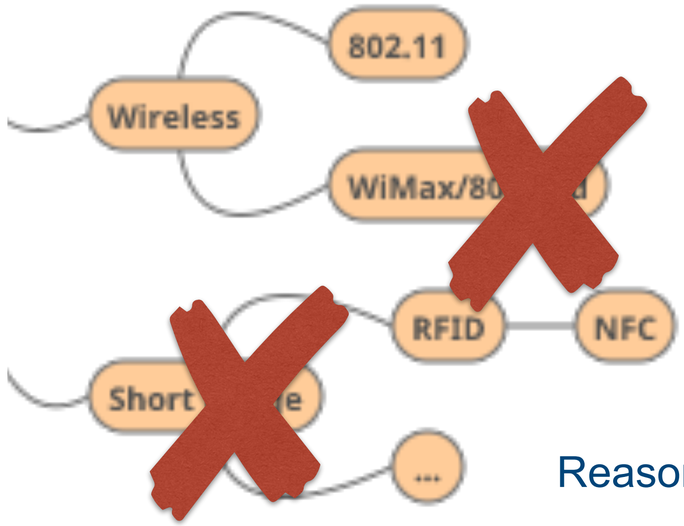
- Land area Norway, 385.178 km^2 - 7500 basestasjons
  - http://www.mynewsdesk.com/no/telenor/pressreleases/sjekk-naar-du-faar-4g-der-du-bor-1399662

- Tanzania 947,303 km^2 = 3 x Norway,
- Mali 1.240.000 km^2 = 4 x Norway
- DR Congo 2.345.000 km^2 = 8 x Norway

- Economy in building Wireless Broadband
  - #5Gforall - *Discuss*



Wireless Systems
- contactless: RFID, NFC
- Sensor: ZigBee, BLE, 6LoWPAN



Reason: short range

Short Range Technologies

- 802.15.4 standard, with 802.15.5 defining mesh networking
  - ZigBee
  - WirelessHART - wired HART (highway addressable remote transducer) - automation and industrial control
  - ISA100.11a - International Society of Automation (ISA)
    - industrial control, adds channel hopping, variable time-slot multiplex options, and mesh networking
  - 6LoWPAN - Internet Engineering Task Force (IETF)
    - 128-bit addresses IPv6. Header compression and address translation
    - compressed packets to fit 802.15.4 packet frames

https://www.electronicdesign.com/what-s-difference-between/what-s-difference-between-ieee-802154-and-zigbee-wireless

IEEE family of 802 standards

- 802.3 wired Ethernet
- 802.11 WLAN (Wi-Fi)
- 802.15 wireless personal area networks (WPANs), e.g.
  - 802.15.1 Bluetooth,
  - 802.15.3 ultra-wideband (UWB) technologies,
  - 802.15.4 low-data-rate WPANs
  - 802.15.6 is for body area networks (BAN).
- 802.15.4 low-data-rate, extended life, low power
  - 802.15.4a/b, basic standards definign
    - radio technology (PHY)
    - media access control (MAC) control
  - 802.15.4c China, 802.15.4d Japan,
  - 802.15.4e focus on industrial applications,
  - 802.15.4f for active (battery powered) radio-frequency identification (RFID) uses,
  - 802.15.4g for smart utility networks (SUNs), e.g.Smart Grid.

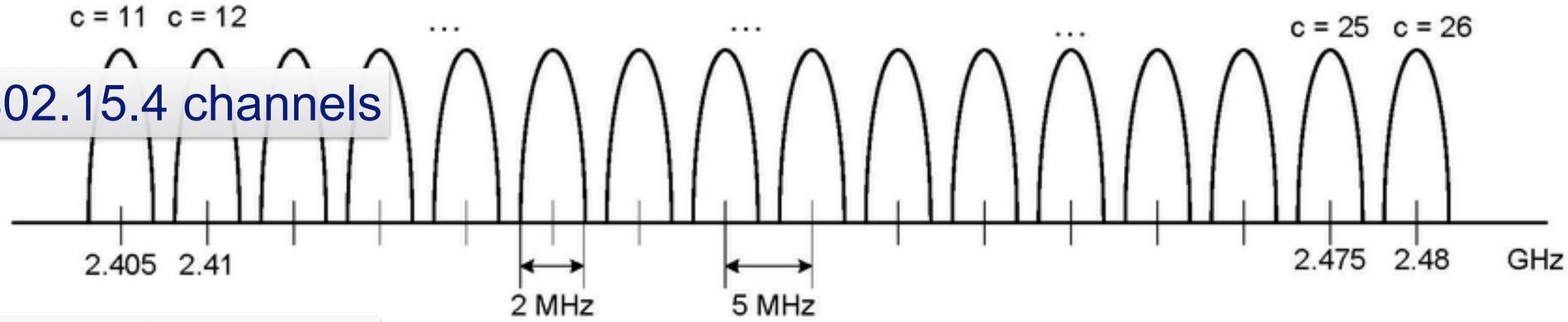
802.11 Physical layer (PHY) standards

Standard	Band(GHz)	Bandwidth(MHz)	Modulation Scheme	Antenna Technologies	Maximum data rate (new standards - roughly)	Coverage
802.11	2.4	22	DSSS, FHSS	N/A	2 Mb/s	Indoor (20m)
802.11b	2.4	22	DSSS	N/A	1, 2, 5.5, 11 Mb/s	Indoor (35m)
802.11a	5, 3.7	20	OFDM	N/A	6, 9, 12, 18, 24, 36, 48, 54 Mb/s	Indoor (35m)
802.11g	2.4	20	DSSS, OFDM	N/A	OFDM - 6, 9, 12, 18, 24, 36, 48, 54 Mb/s DSSS - 1, 2, 5.5, 11 Mb/s	Indoor (38m)
802.11n	2.4, 5	20, 40	OFDM	MIMO (4x4), SISO (1x1)	7.2 - 72.2, 15-150, 600 Mb/s	Indoor (70m)
802.11ad	60	2160	SC, OFDM	Beamforming (MIMO > 10x10)	7 Gb/s	(< 5m)
802.11ac	5	20, 40, 80, 160	OFDM	MIMO (8x8) / MU-MIMO	7.2-96.3, 15-200, 32.5-433.3 Mb/s, 3.2 Gb/s	Indoor (30m)

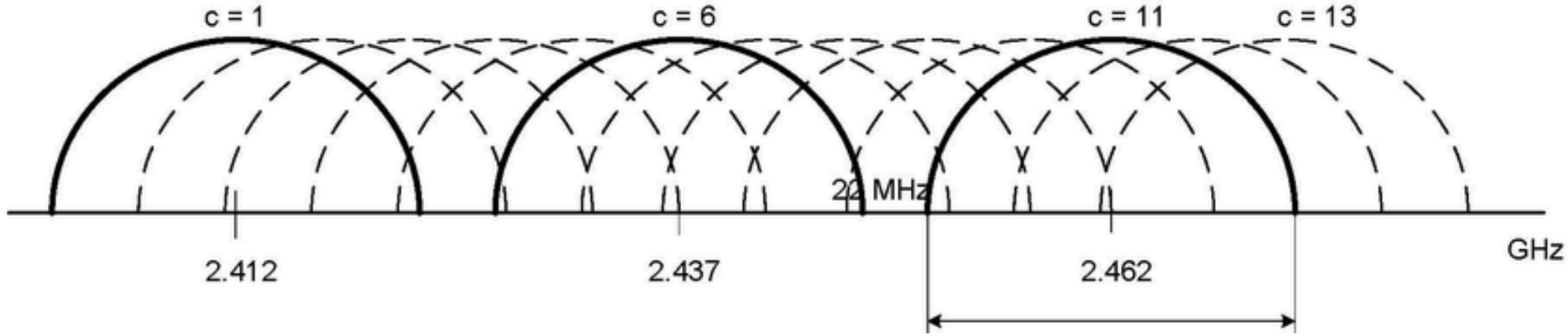
[Source: https://phonexicum.github.io/infosec/wifi.html]

802.11 frequency assignments - 2.4 GHz

802.15.4 channels

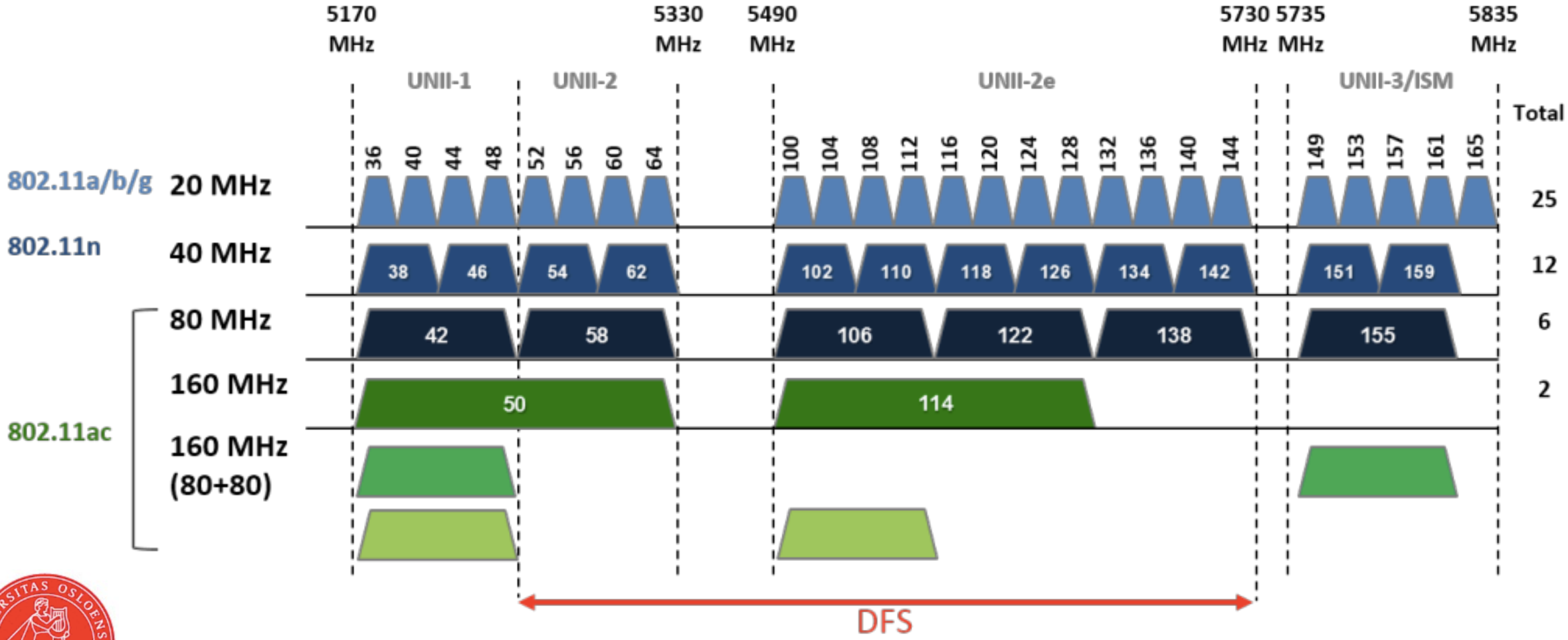


802.11g channels



[Source: https://www.researchgate.net/figure/Frequency-channels-of-IEEE-80211g-and-802154-in-the-24-GHz-band_fig4_271741147]

802.11 frequency assignments - 5GHz



[Source: https://phonexicum.github.io/infosec/wifi.html]

Upcoming Topics

Upcoming Topics / To do for next week

Upcoming Topics

- L11 Basic Internet Infrastructure

To Do:

- Group work: Present specific plans
  - what do you want to achieve?
  - what is the outcome?

Goal oriented approach