

# Introduction to Mobile Wireless Networks

**Tommy Svensson**

*(Full) Professor, PhD, Leader Wireless Systems*

*Communication Systems Group*

*Department of Electrical Engineering*

*Chalmers University of Technology, Sweden*

*[tommy.svensson@chalmers.se](mailto:tommy.svensson@chalmers.se)*

*EDIT building, floor 6, room 6413*

*[www.chalmers.se/en/staff/Pages/tommy-svensson.aspx](http://www.chalmers.se/en/staff/Pages/tommy-svensson.aspx)*



**CHALMERS**

Partly based on lecture slides by Fredrik Brännström, SSY145 Wireless Networks VT17.

# Outline

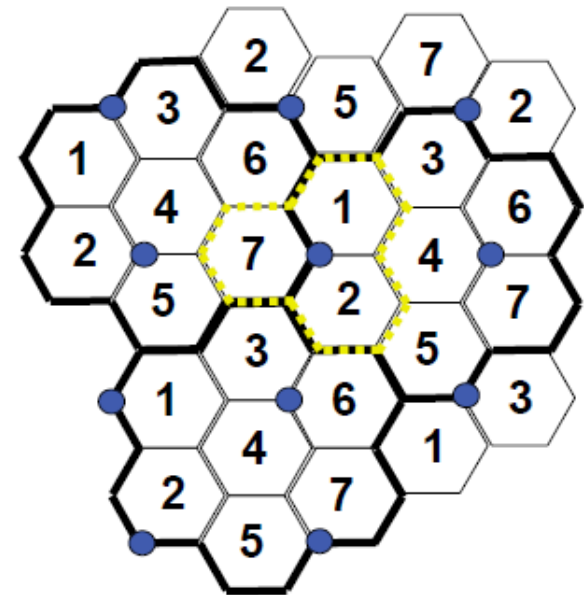
- **Brief history, Cellular Systems**
  - ❑ **1G, 2G, 3G**
  - ❑ **FDMA, TDMA, CDMA**
- 4G and advanced wireless access technologies
  - ❑ OFDM/OFDMA
  - ❑ MIMO
- Visions of 5G (and beyond)

# Brief history

- 1864: James Clerk Maxwell predicts radio waves
- 1886: Heinrich Rudolph Hertz demonstrates the existence of radio waves
- 1896: Guglielmo Marconi invented the wireless telegraph
- Also in 1890s: Nikola Tesla, Alexander Stepanovich Popov, and others demonstrate different forms of wireless communications
- Marconi gets the credit for attempting wireless communications (1909 Nobel prize in Physics)

# Cellular Systems

- System resources (frequency, time) are limited. How can we reuse them and keep interference at low level?
- Cellular is a good idea! Radio signals attenuate with distance, interference can be kept low
  - Resources can be at least partially reused in every cell
  - Significant breakthrough, introduced in 1947 by AT&T
- Sophisticated handovers that would not drop the call



# 1G Cellular Systems (1)

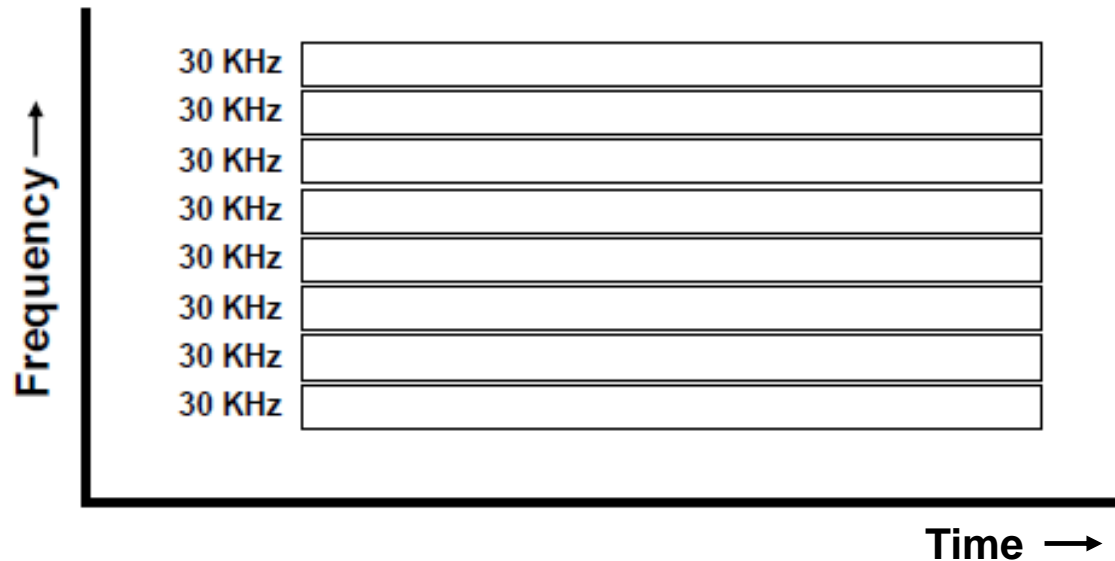
- Analog systems (1980s)
- Supported only "plain old telephony services" (POTS)
- Incompatible standards
  - NMT (*Nordic countries*), AMPS (*USA*), TACS (*UK*), Radiocom 2000 (*France*), C-450 (*West Germany*), RTMI (*Italy*), J-TACS (*Japan*)

# 1G Cellular Systems (2)

- Bulky, mainly car-borne equipment
- Inconsistent voice quality due to high inter-user interference
- Spectrally inefficient
  - low achievable bits/sec/Hz
  - 1G is based on Frequency Division Multiple Access (FDMA)

# 1G Cellular Systems - FDMA

FDMA - Frequency Division Multiple Access



# 2G Cellular Systems

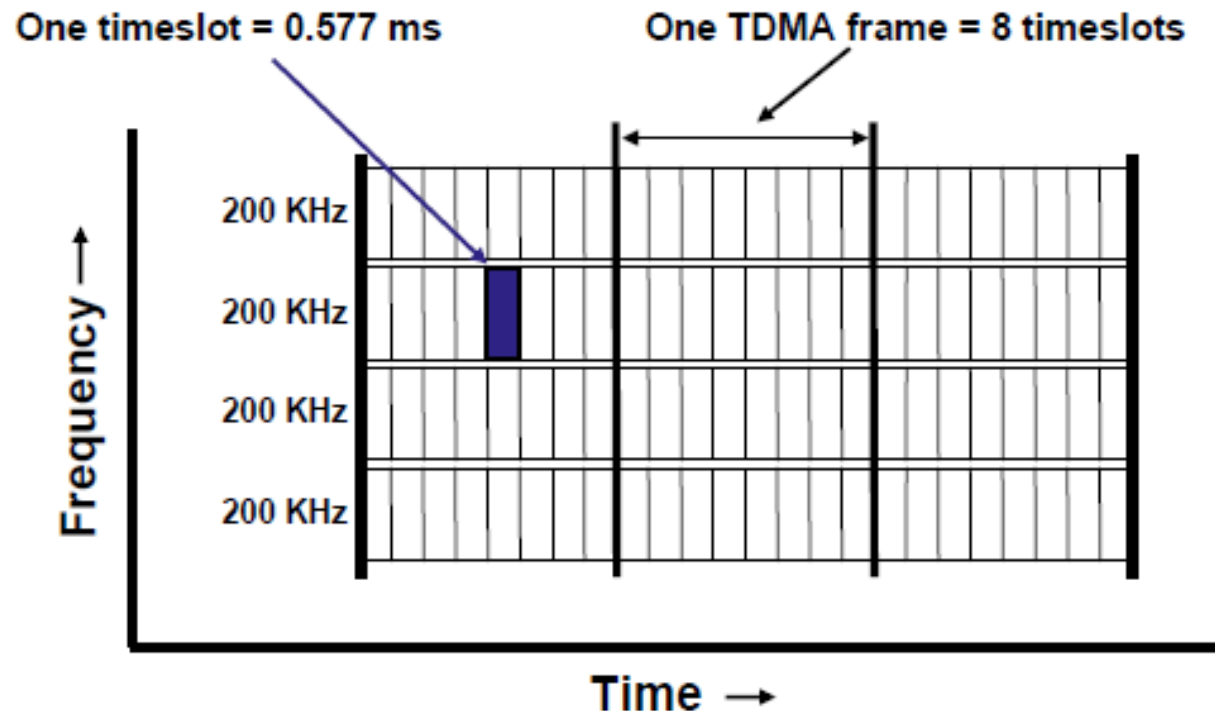
- 1980s: to face the problems of 1G, development of 2G systems started
- 2G leverages digital technology
  - Speech compression and signal processing
- Increased capacity and QoS
- 2G systems:
  - GSM (Europe): based on TDMA/FDMA
  - IS-95 and IS-136 (*USA*): based on CDMA
  - PDC (*Japan*): based on TDMA/FDMA
  - PHS, DECT (cordless phones): based on TDMA/FDMA



# 2G - GSM

- Global System for Mobile communications (GSM)
  - Launched in 1992
  - Joint European effort which started in 1982
  - Based on TDMA and FDMA
  - 900 MHZ band
- Supports voice services and basic data services (SMS)
- GSM is the dominant world standard today
  - Well defined interfaces
  - Many competitors resulting in good prices

# GSM –TDMA / FDMA



# 2G/3G – CDMA (1)

- Although GSM is based on TDMA/FDMA, IS-95 and IS-136 (D-AMPS) are based on CDMA
- Code Division Multiple Access:
  - All users share the same frequency band.
- Most success in the USA and also Korea
- Advantage: easy migration to 3G since they both use the same modulation

# 2G/3G- CDMA (2)

- Spread spectrum modulation
  - Original developed for the military
  - Resists jamming and many kinds of interference
  - Modulation is hidden from those without the spreading code
  - With wide bandwidth robust links possible by harnessing frequency diversity
- All users share the same block of large spectrum
  - Drawback: Interference due to Near-far-problem
- All 3G radio standards based on CDMA
  - CDMA 2000, W-CDMA, and TD-SCDMA

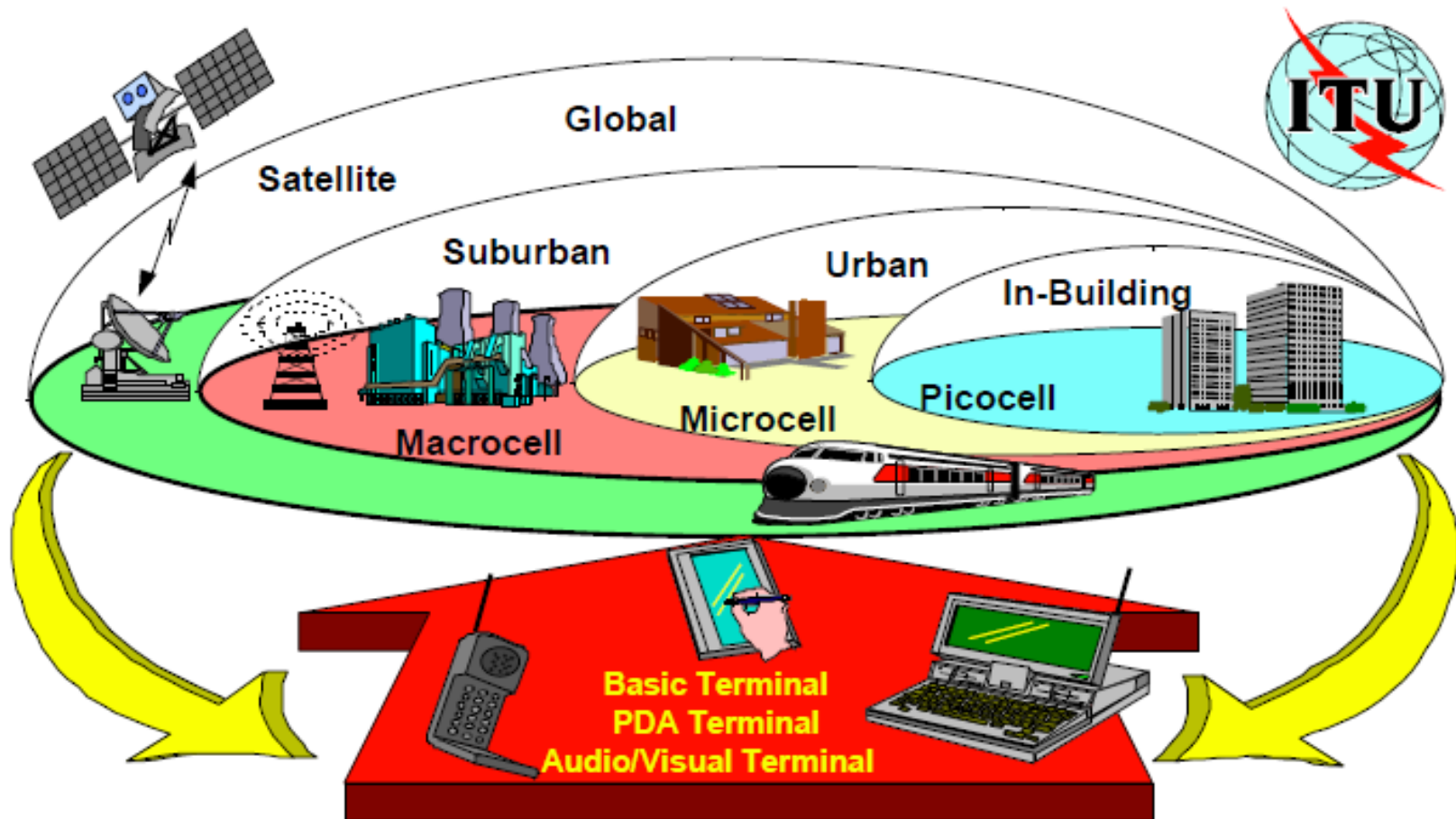
# 2G - GSM Evolution

- GSM supported voice and low data rate packet services (peak 9.6 kbit/s)
  - Need for supporting packet oriented services of higher rates
- General Packet Radio Service (GPRS) was the first step, marked as 2.5G
- Enhanced Data Rates for GSM Evolution (EDGE) was a further significant evolution, marked as 2.75G

# The 3G Vision

- High data rates for packet oriented services
- Universal global Roaming (1 standard and not several)
- Multimedia traffic (voice, data, video)
- High spectral efficiency
- Data-centric architecture
- 3G is based on CDMA

# The 3G Vision (2)



PDA: Personal Digital Assistant

# 3G Radio Technology Today

- **UMTS** (Universal Mobile Telephone service): based on Wideband CDMA (W-CDMA)
- **CDMA 2000**: based on Multi-Carrier CDMA
- **TD-SCDMA**: Time Division Synchronous CDMA



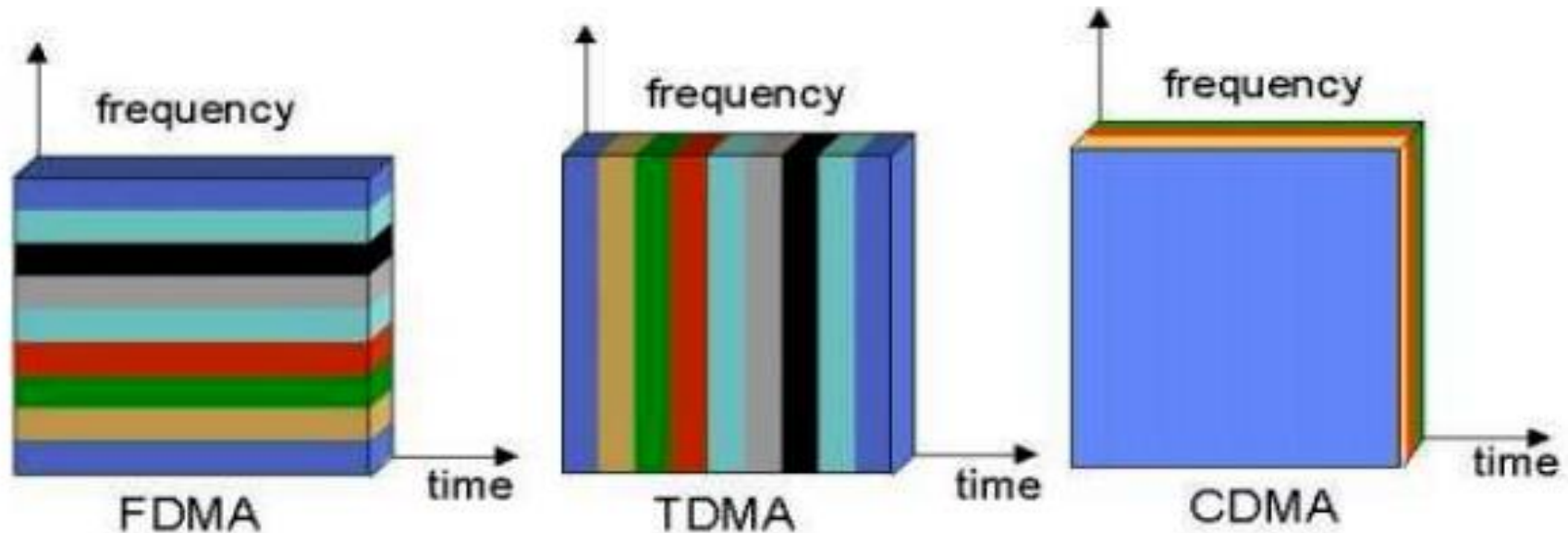
# 3G - UMTS

- Market leader
- GSM evolution path: leveraged GSM's dominant position
- Requires substantial BW each way
- Slow start but now leading
  - Since it was building on GSM's 80% market share.

# 3G - CDMA 2000

- Evolution of original Qualcomm CDMA (IS-95)
- Better migration from 2G to 3G
  - CDMA operators do not need additional spectrum
  - Higher data rates than UMTS, at least at first
- Could not compete with GSM's critical mass

# 1G, 2G, 3G Multi-Access Technologies



Courtesy of Petri Possi, UMTS World

# Outline

- Brief history, Cellular Systems
  - ❑ 1G, 2G, 3G
  - ❑ FDMA, TDMA, CDMA
- **4G and advanced wireless access technologies**
  - ❑ **OFDM/OFDMA**
  - ❑ **MIMO**
- Visions of 5G (and beyond)

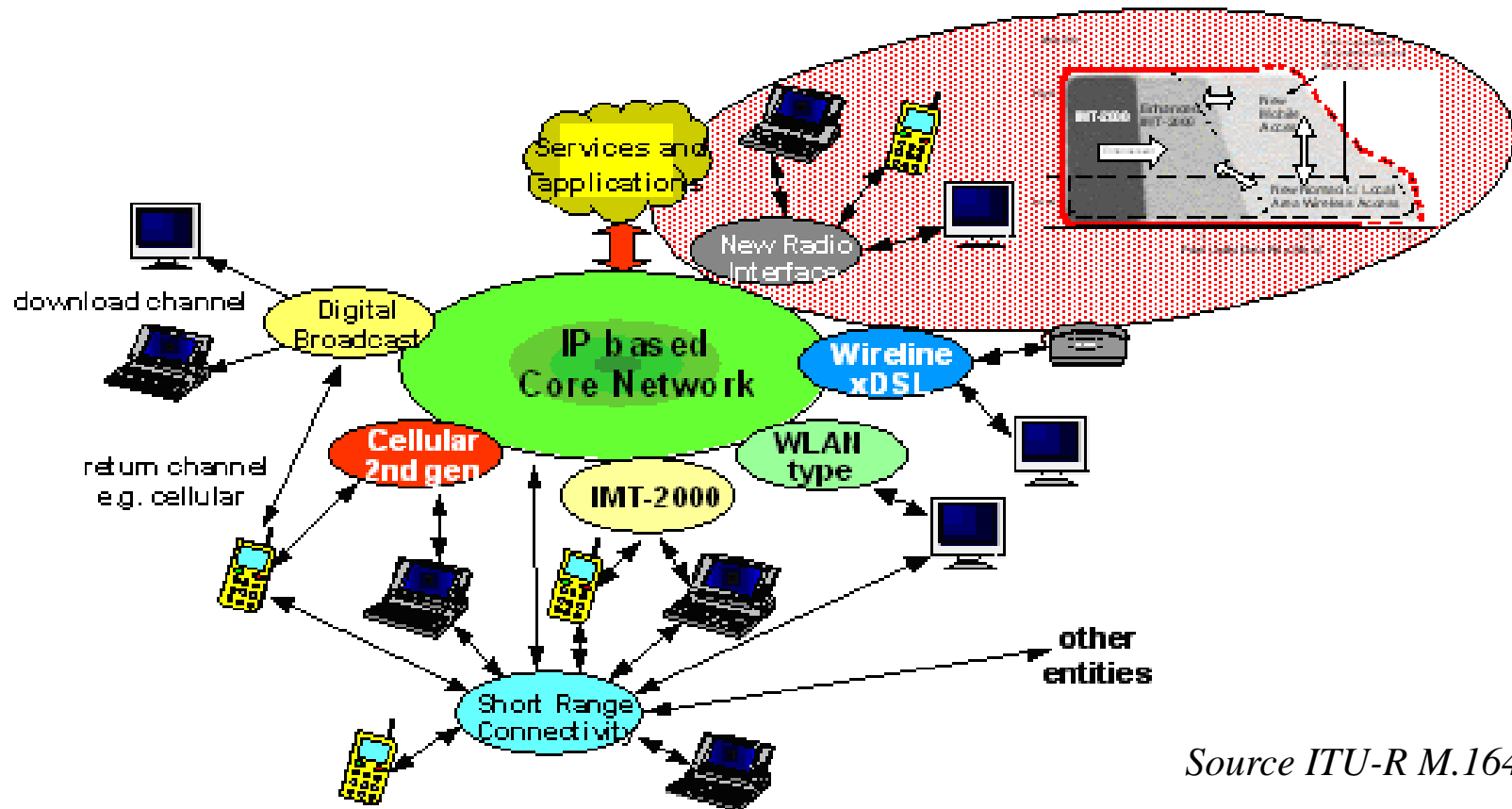
# Shortcomings of 3G

- 3G was accompanied by huge financial investments for spectrum acquisition
- It was less successful commercially than anticipated
  - Enhanced GSM (mainly EDGE) provided sufficient rates for a range of applications
  - UMTS did not greatly outperform EDGE
- Need for evolution!
  - HSPA was a first attempt, marked as 3.5G

# Why 4G?

- Mobile subscribers use a range of applications requiring different QoS level and ubiquitous coverage
- 4G requirements
  - Very high peak rates and spectral efficiency
  - Fairness, especially for cell-edge users
  - Easy deployment
  - Ability to co-exist with legacy technologies

# ITU-R Vision for Systems Beyond 3G



Source ITU-R M.1645

Integrate existing and evolving access systems on a *packet-based* platform to enable cooperation and interworking.

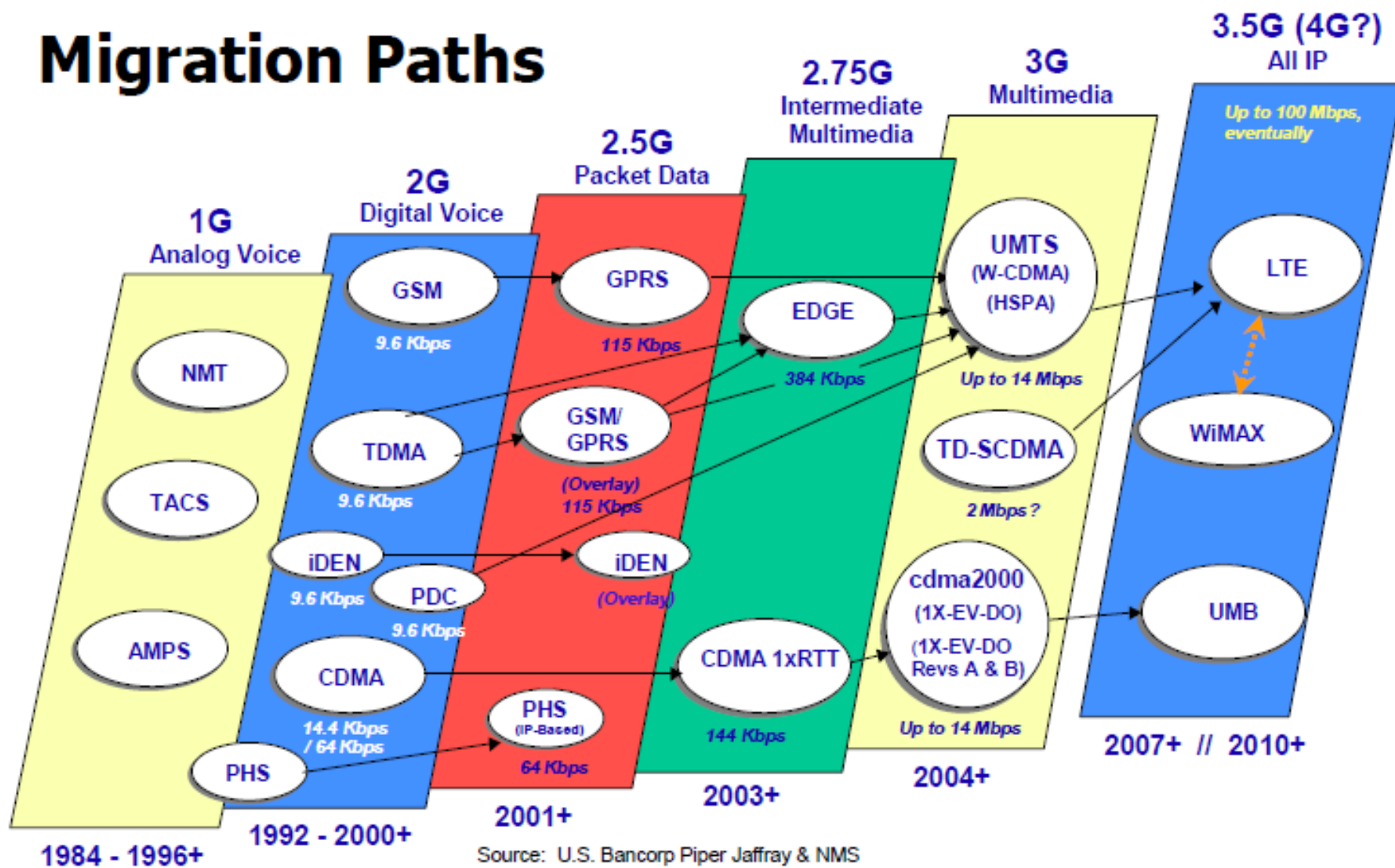
“Optimally connected anywhere, anytime”

# Towards 4G - LTE

- Sophisticated multiple access schemes
  - Downlink: OFDMA with cyclic prefix (CP)
  - Uplink: single carrier FDMA with CP
- Adaptive modulation and coding
  - QPSK, 16QAM, and 64 QAM.
- MIMO spatial multiplexing techniques
  - $(2, 4, \text{or more}) \times (2, 4 \text{ or more})$  downlink and uplink



# Migration Paths

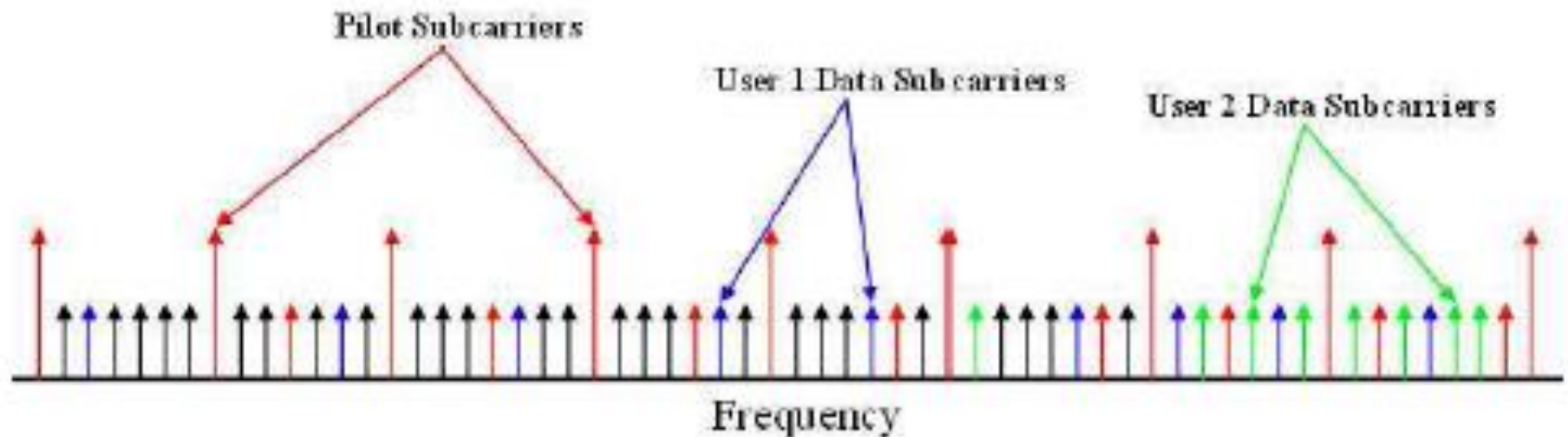


# OFDM and OFDMA

- OFDM: Orthogonal Frequency Division Multiplexing:
  - Multiple subcarriers that are assigned to a user
  - CP is used to eliminate ISI
  - Vary bits per subcarrier based on instantaneous SNR
- OFDMA: Orthogonal Frequency Division Multiple Access
  - The subcarriers are assigned to multiple users
  - Optimization of frequency and time

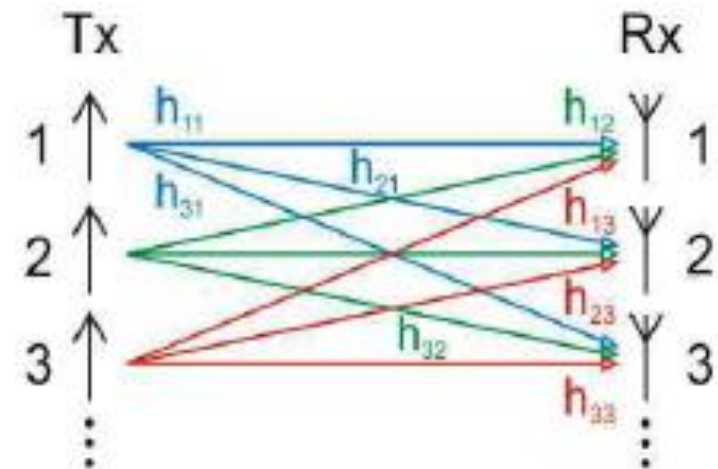
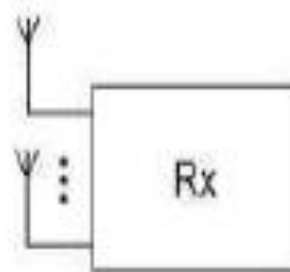
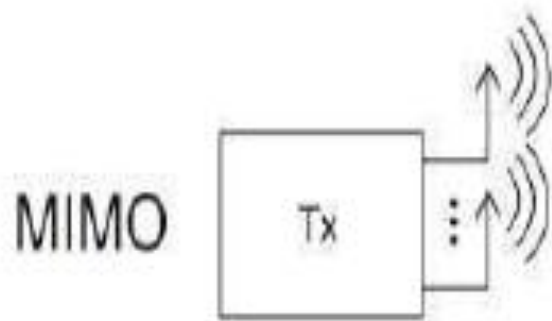
# OFDMA

- Dynamically allocate user data to sub-carriers based on instantaneous data rates and varying subcarrier capacities
- Highly efficient use of spectrum



# 4G Technology - MIMO

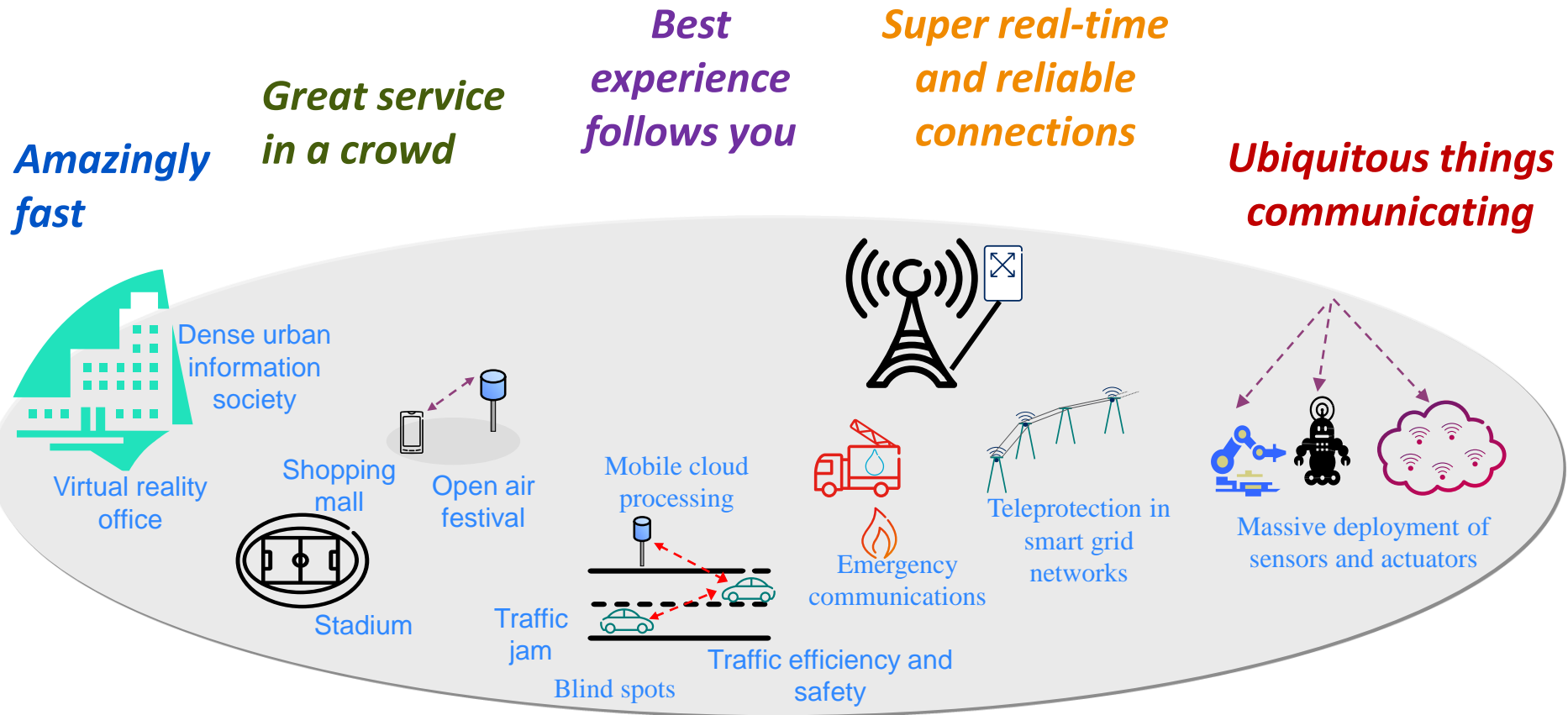
- Multiple-Input Multiple-Output antenna technologies
- Multiple path improve reliability and/or increase spectral efficiency.



# Outline

- Brief history, Cellular Systems
  - ❑ 1G, 2G, 3G
  - ❑ FDMA, TDMA, CDMA
- 4G and advanced wireless access technologies
  - ❑ OFDM/OFDMA
  - ❑ MIMO
- **Visions of 5G (and beyond)**

# METIS Scenarios and Test Cases



Source: METIS Deliverable D1.1 “Scenarios, requirements and KPIs for 5G mobile and wireless system”, <https://www.metis2020.com/>

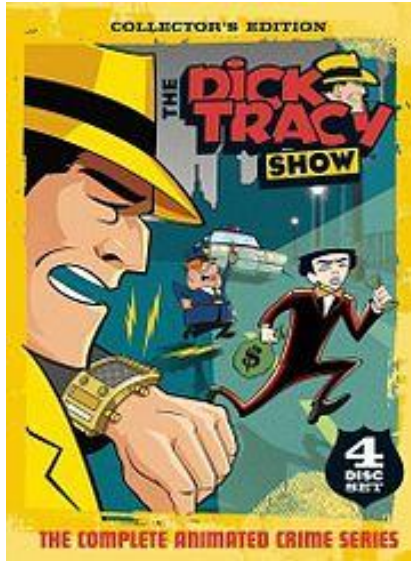
# 8 Use Cases in mmMAGIC



[https://bscw.5g-mmagic.eu/pub/bscw.cgi/d54427/mmMAGIC\\_D1.1.pdf](https://bscw.5g-mmagic.eu/pub/bscw.cgi/d54427/mmMAGIC_D1.1.pdf)



# Power of Visions - Dick Tracy Comic Strip



Dick Tracy (originally Plainclothes Tracy), a square-jawed, hard-hitting, fast-shooting, and intelligent police detective. Created by Chester Gould, the strip made its debut on October 4, 1931, in the Detroit Mirror. [Wikipedia]



# James Bond - Tomorrow Never Dies – BMW Car Chase



<http://www.youtube.com/watch?v=qKAME9fAA-4&feature=youtu.be&t=4s>

# General Motors' EN-V concept



<https://www.youtube.com/watch?v=0tiHwzGsotA>

# Eureka - SARAHA



The house SARAHA (Self Actuated Residential Automated Habitat) implements "ambient intelligence".



Eureka is an American science fiction television series that premiered on Syfy on July 18, 2006. The fifth and final season ended on July 16, 2012.  
[Wikipedia]

<http://www.youtube.com/watch?v=O8Jm-AIRqwQ&feature=youtu.be&t=2m11s>

# Internet -> Mobile Internet -> ...

**-> Robustness, Low latency => Internet of Skills!**



SSY145 – Wireless Networks, March 23, 2020



# Recap: Next steps in the Course

- Each student choose your four preferred Project Topics, with priority 1 (highest), 2, 3, and 4 (lowest).
  - The Project topic priority list should be submitted in Canvas to: "Quizzes>>Surveys>>Submit your priority list" no later than **13:00 on Wed March 25** (in less than two days!).
- **10:00-11:45 Thu March 26**, Zoom 9259762080, direct: <https://chalmers.zoom.us/j/9259762080>, "Academic Technical Writing", Kathryn Strong Hansen, *Centre for Language and Communication*
  - Preferably book your consultation time directly on Thu March 26 in the lecture break.
- Read your Chalmers emails and Canvas messages and check the latest Course-Memo! There will be updates on the Guest lecturers schedule.

