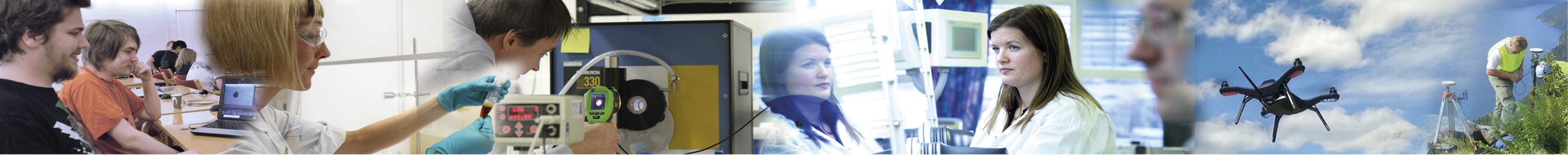

UiO : Department of Technology Systems
University of Oslo

“Digital Inclusion for a Better World”, Tsinghua University, 8Mar2021

Mobile Developments - From 1G to 5G

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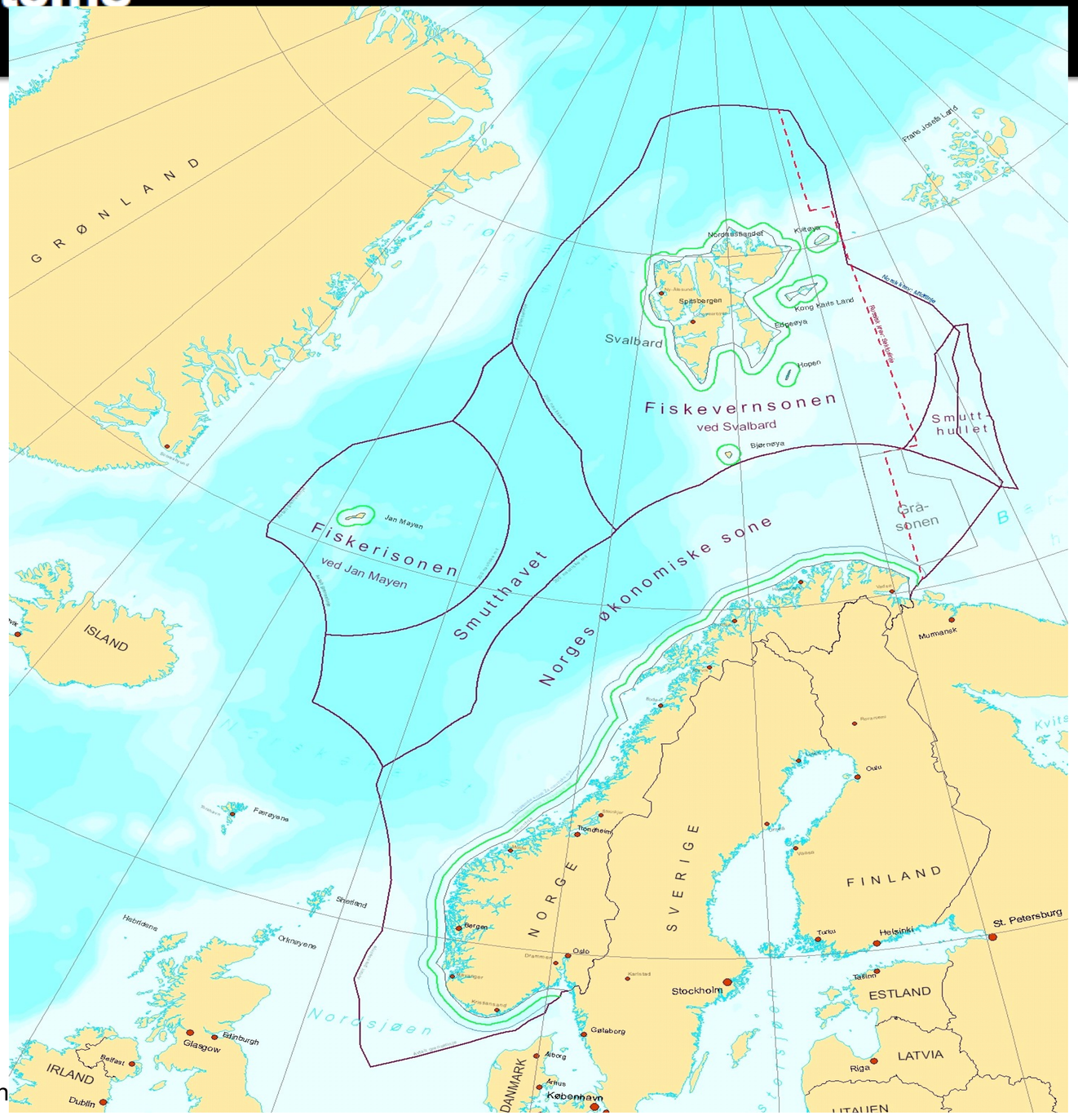
The Nordics (Scandinavia++)

- Demanding customers
- Trusted authorities
- Competitive landscape
- Open Interfaces

- Large distances
- costly infrastructure
- high labour costs



The Internet and Scandinavia

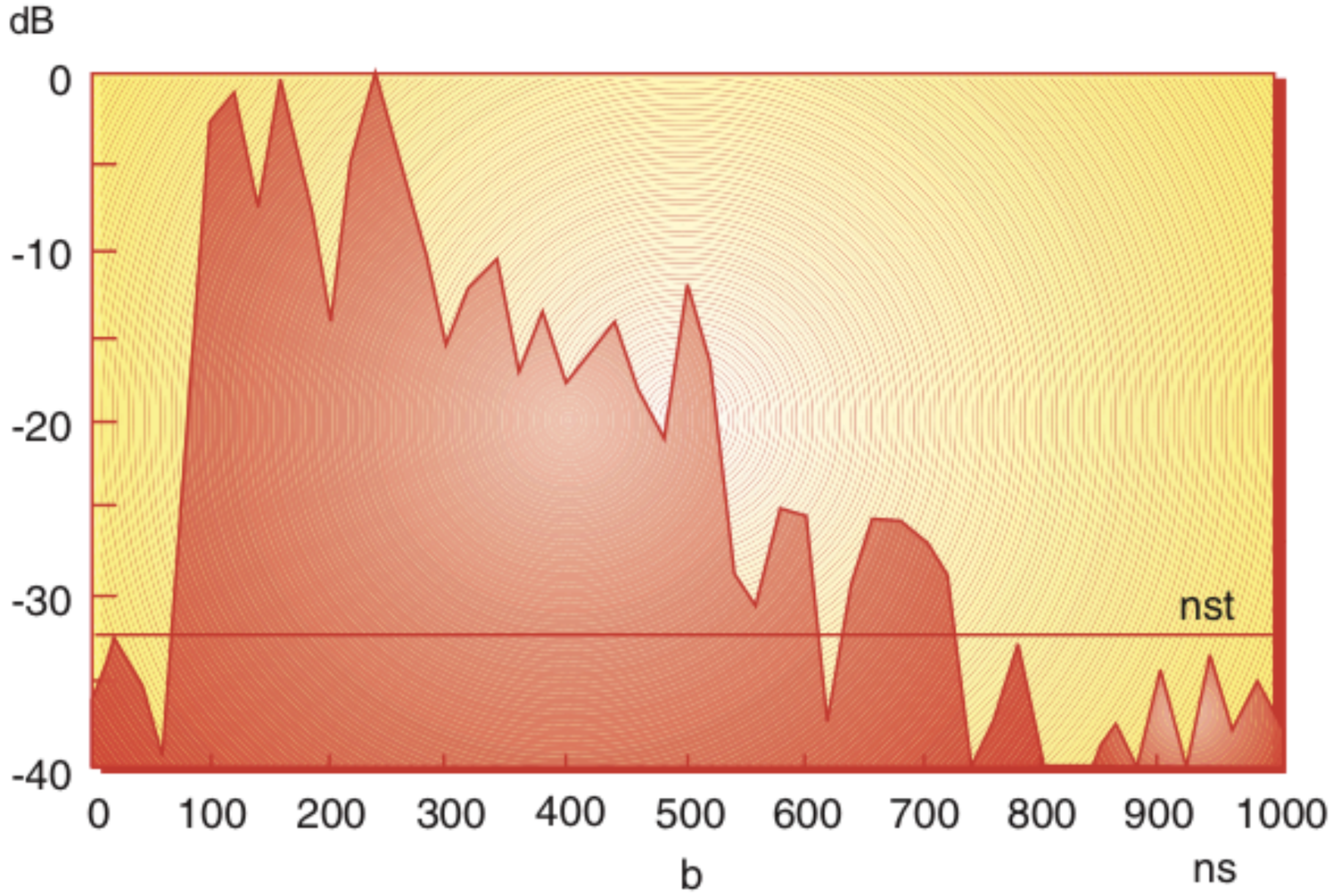
- The first connection of Arpanet outside of the USA (and Hawaii) was to **Scandinavia** (Kjeller, June 1973)
- List_of_Internet_pioneers [Wikipedia]
  - Yngvar Lundh, Paal Spilling
- Application development
  - .php, OpenSource, Linux, Skype, Spotify
  - OperaSoftware, FAST Search
  - Nokia, Ericsson
  - Telenor, TeliaSonera
- Mobile Internet:
  - GSM
  - Adaptation

How did we measure the quality of the mobile network

Impulse Response, Urban Measurements

- 1950 MHz, Oslo.
- Output power 25 dBm

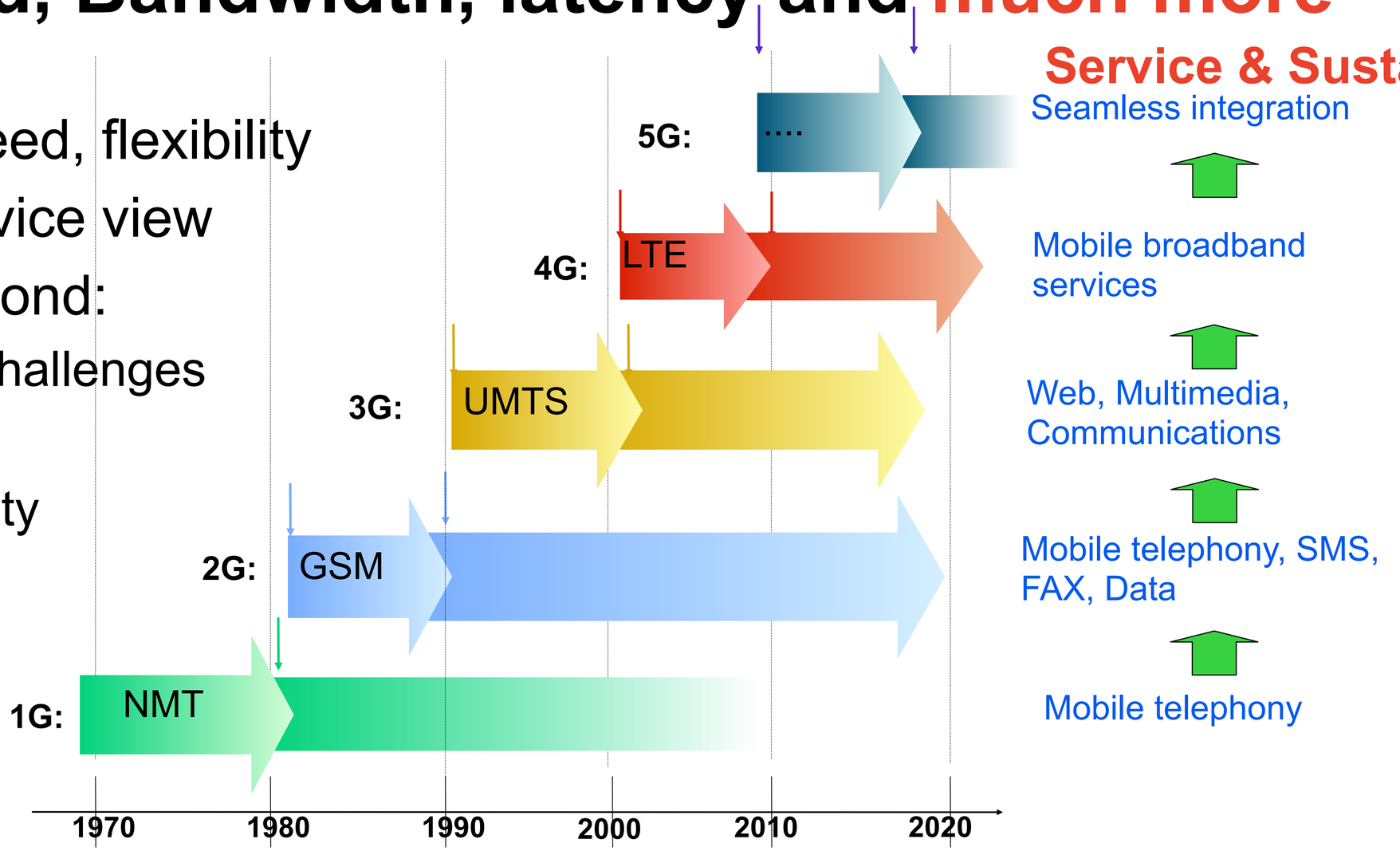
- Q (all impulse responses):
  - describe characteristics of reflection
  - from delay, calculate reflection factor and free space attenuation
  - why almost equal distribution?
  - Physical effects?



[Source:R Rækken, G. Løvnes, Telektronikk]

5G: Speed, Bandwidth, latency and much more

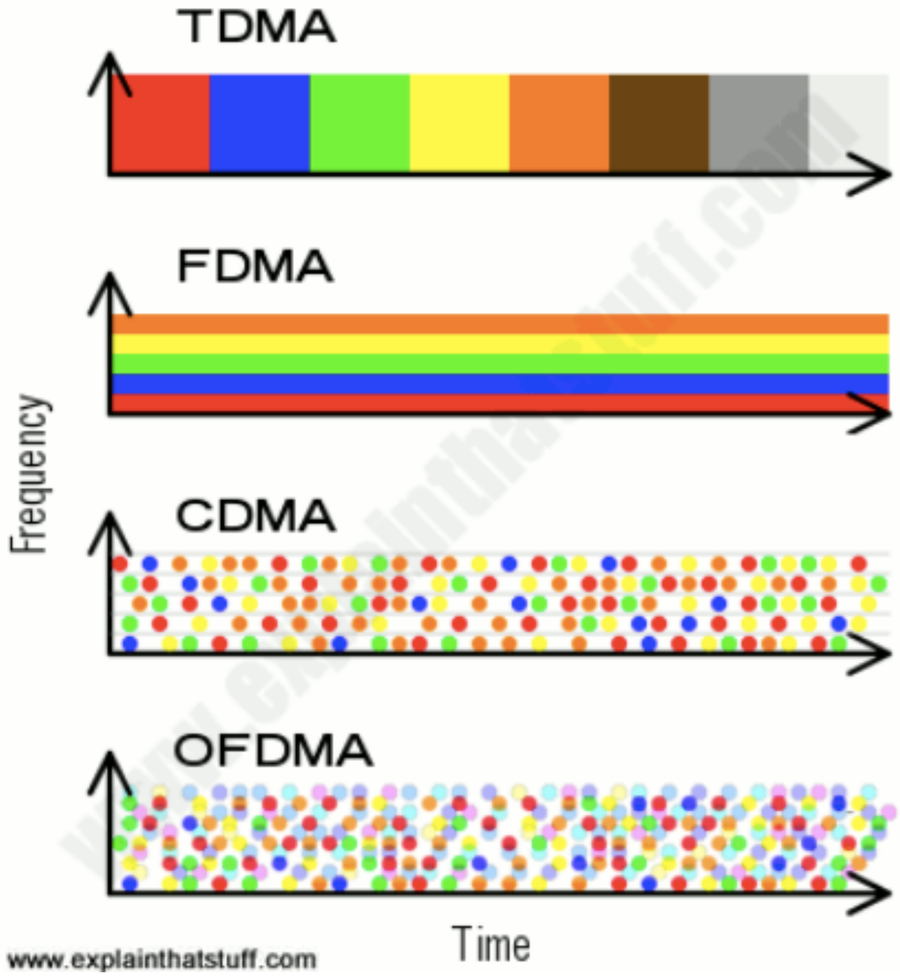
- 1G-3G: Speed, flexibility
- 3G-4G: service view
- 5G and beyond:
  - Business challenges
  - ownership
  - sustainability



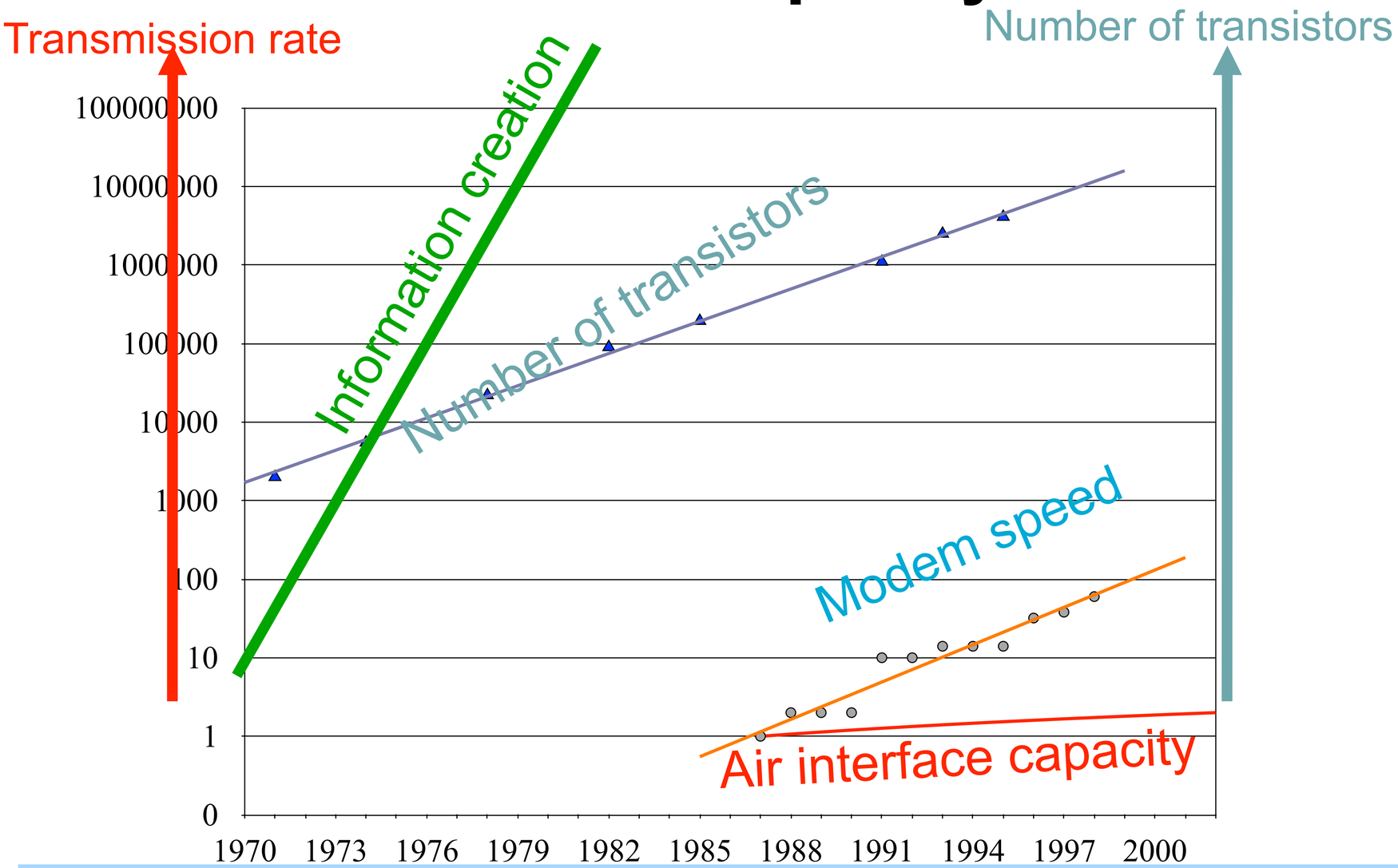
[adapted from Per Hjalmar Lehne, Telenor, 2000]

Main differences 2G-5G

- Coverage/Range (2G, 4G)
- Capacity (3G, 4G, 5G)
- Security (2G, 3G, 4G,…)
- Radio technology
  - ➡ frequency, time, code
  - ➡ allocation
- Internet of Things (4G, 5G)
- Control systems (5G)
  - ➡ latency, reliability



Moore's law in 'air interface capacity'



- Air interface capacity is the most valuable resource

2G Mobile systems: GSM (IS 95 - USA)

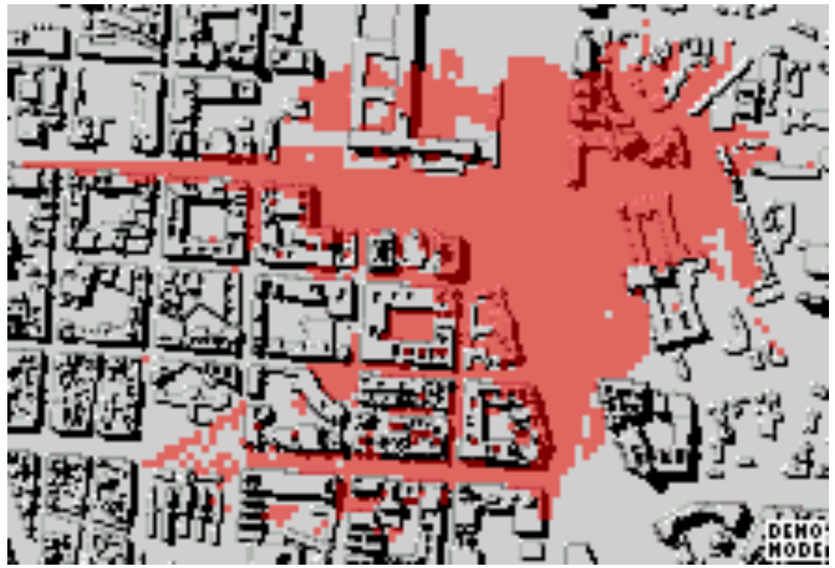
- Developed in the late 1980s, deployed 1992.
  - Norway a key developer and inventor
- Today: Coverage 80% of world population (5+ billion users), gsmworld.com.
- GSM security goal: “as secure as the wire”
- GSM network consists of several network elements
  - Radio Subsystem (RSS)
    - Base station Subsystem (BSS)
    - Mobile Equipment (ME) (cell phone/handset)
  - Network and Switching Subsystem (NSS) – core network
  - Operation Subsystem (OSS)

[source: Lars Strand, UiO]

Mobile systems: 3GPP

- Third generation partnership project (3GPP)
  - Structured in releases
- Includes mobile technologies like:
  - UMTS (3G) – Telenor in 2001, terminated in 2021
  - LTE (not 4G) – Netcom 2010, Telenor 2012.
- Building on and evolved from GSM
  - Upgrade path: GSM -> WCDMA (Europe, Asia), IS 95 -> CDMA 2000 (USA)
  - Backward compatible with a system with weaker security is undesirable – but commercial reality dictated otherwise

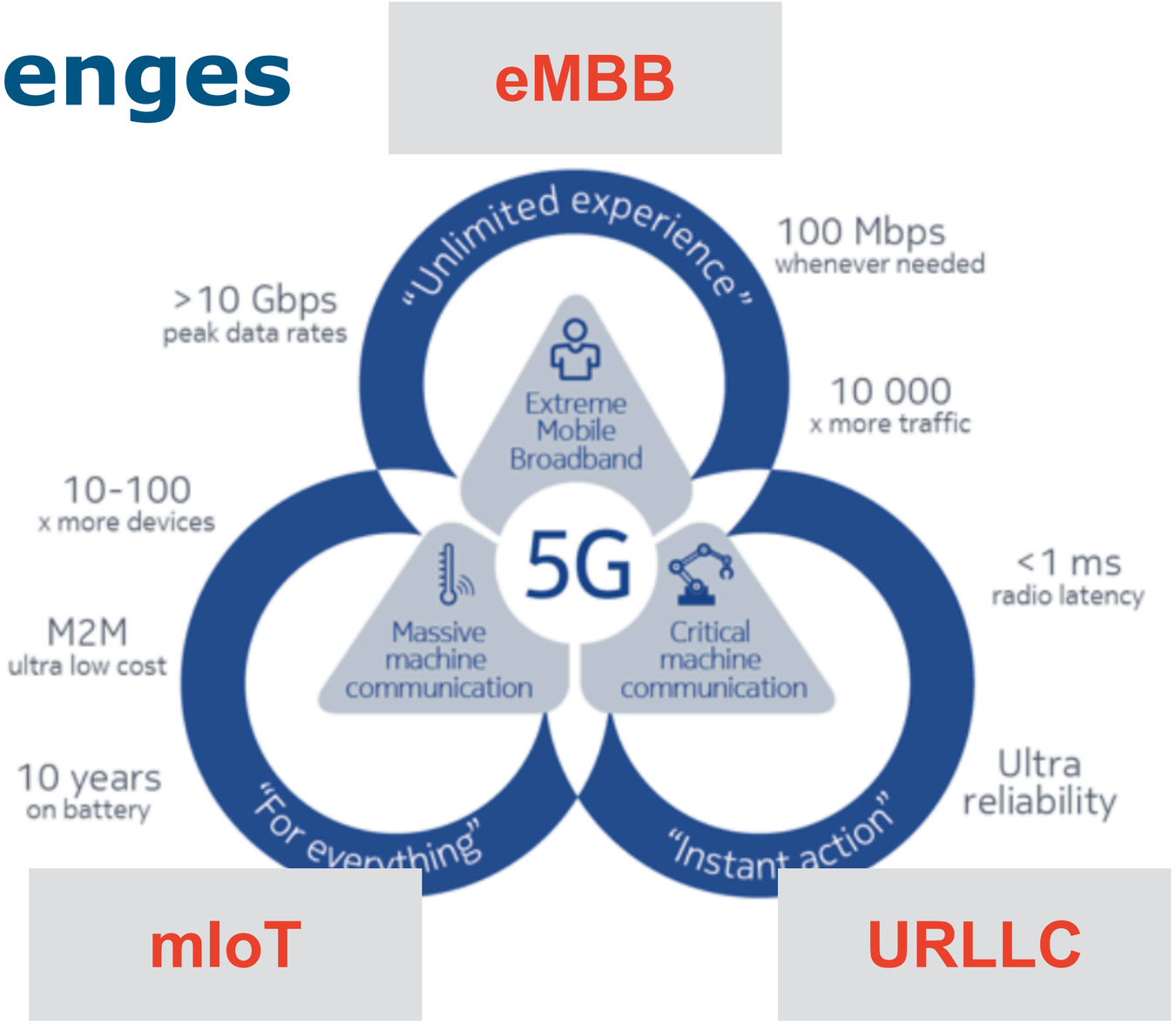
Evolution: "Nobody" thought about co-existence



[adapted from: Lars Strand, UiO]

5G: Industrial Challenges

- enhances Mobile Broadband
- massive IoT
- ultra Reliable, Low Latency communication



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

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 mobile-home network
  - application-specific routing (service quality)
  - interference with unlicensed technologies