ICWMC Tutorial - Valencia - Sept 2010

Collaborative Radio for 5G Mobile and Wireless Communications

represented by:
Josef Noll, Professor
University of Oslo/UNIK
josef@unik.no

on behalf of the
Center for Wireless Innovation Norway
CWI Norway (http://cwin.no)

.... and the Internet

- Research and Education at Kjeller
- Close relation to FFI, IFE, NILU,...
- Prof. from Univ. of Trondheim and Oslo

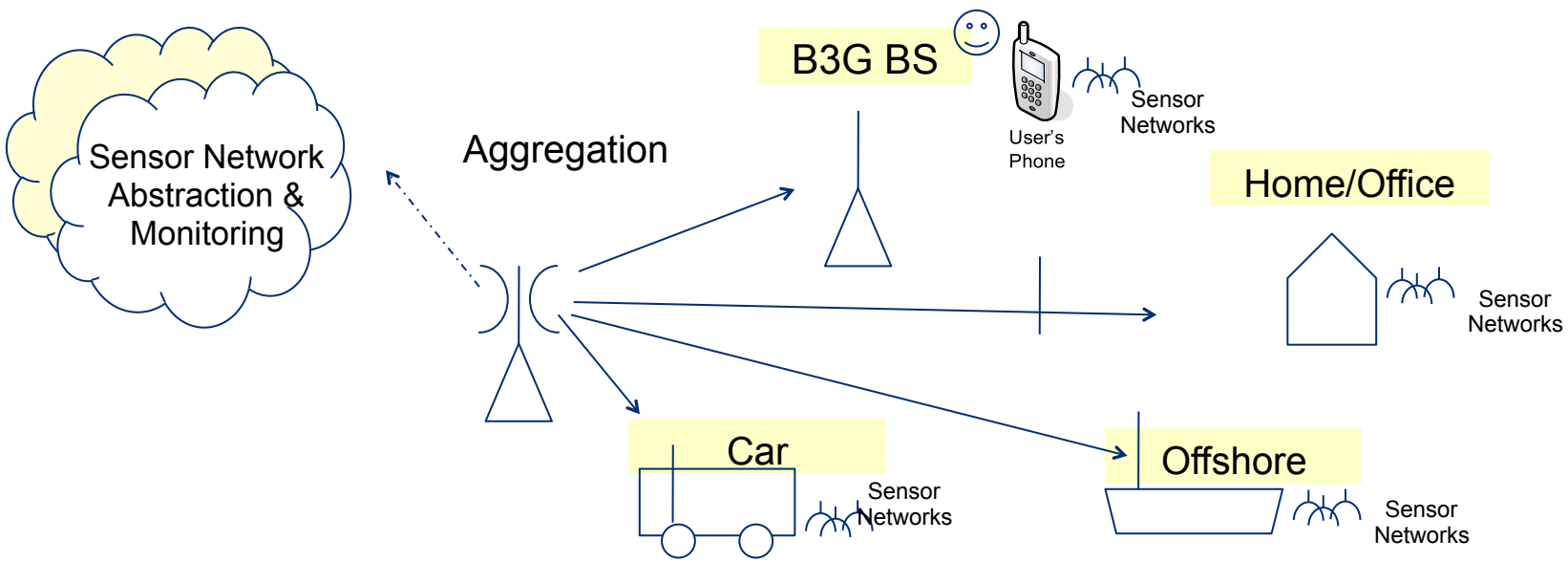
- The building where the Internet (Arpanet) came to Europe in June 1973

Source: Wikipedia

> 1971 (at which point 23 hosts, at universities and government research centers, were connected to the ARPANET); 29 by August, 1972, and 40 by September, 1973.
>
> At that point, two satellite links, across the Pacific and Atlantic Oceans to Hawaii and Norway (NORSAR) had been added to the network. From Norway, a terrestrial circuit added an IMP in London to the growing network.

Center for Wireless Innovation

A facilitator for industry and seven research institutions to form strategic partnerships in wireless R&D



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Content

- Introduction
- Generation aspects of mobile and wireless communications
- Drivers for 5G communications
- Focus: Radio coverage
- Focus: Seamless authentication
- Business aspects
- Conclusions

Content

- Introduction
- Generation aspects of mobile and wireless communications
  - Applications for 5G
  - Radio, Capacity and Coverage
  - Network aspects
- Drivers for 5G communications
- Focus: Radio coverage
- Focus: Seamless authentication
- Business aspects
- Conclusions

Postulation

"Let the user own his own network, and your revenue as a Telecom operator will increase"

Postulation

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Stoneage:

- A phone is related to a household
- The PC/Laptop belongs to your company
- Your Mobile Phone is owned by your company

still remaining

- The Network is owned by an operator

but

- An operator can't charge for mobile costs

SMS versus **video**

The Requirements Of Changing Industry - Services

Services will grow in multiplicity, diversity and richness of content

✓New services with the Internet at the heart the services - **Internet a network** with extreme mobility, ubiquity, personalization, adaptivity, video addiction and surprising applications as yet unimagined

✓ Ubiquitous **ultra broadband** communications

✓New ecosystem & new players and value chain, New business and revenue models

✓ Digital Connected world: digital Infrastructure & digital content and in particular **Digital Home** continues to grow

✓More powerful and **enabled devices -** Changes on the shape, size, capability and price

Users will grow in importance

✓Customer delight is absolutely essential

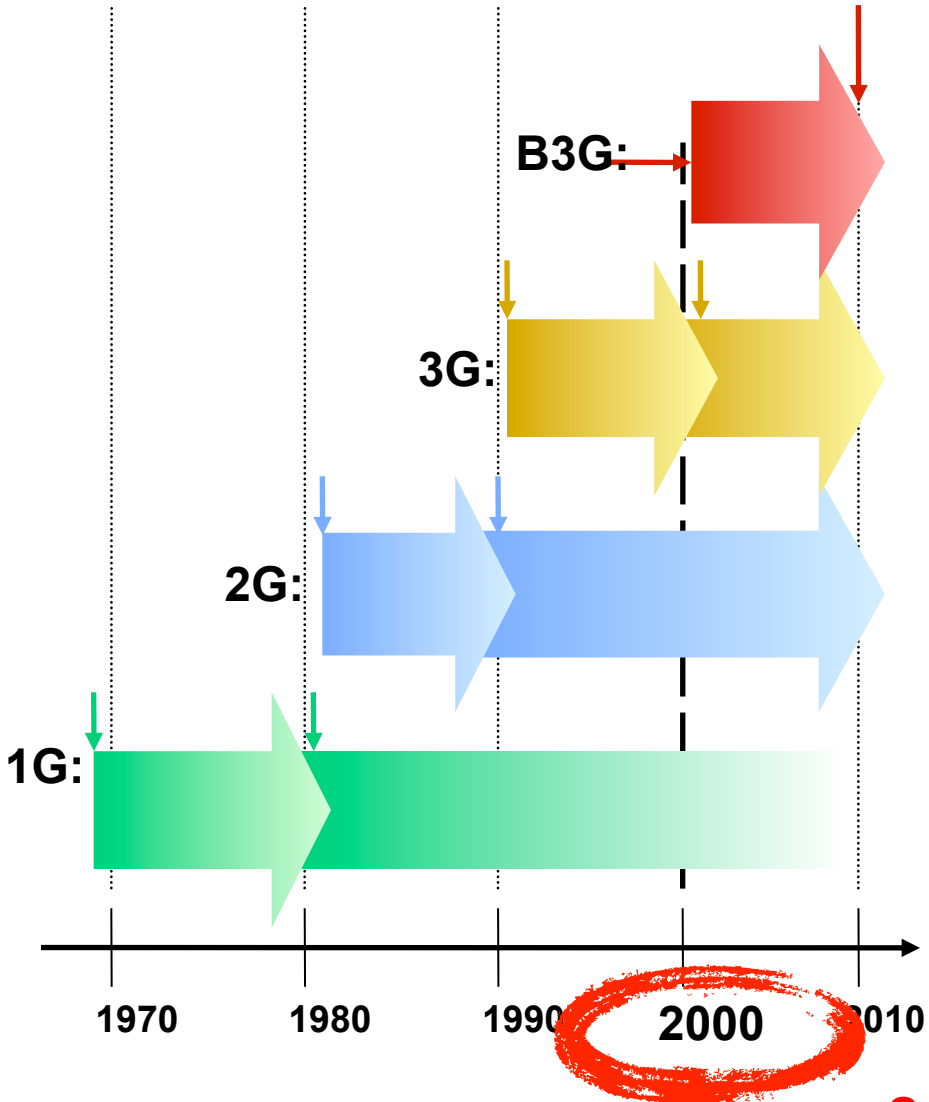
✓Adopting new habits (e.g. social media)

✓More demanding on the quality, interactivity, personalisation, sharing, immersive content experience, virtualization **YET lower price**

Simplicity for users and shift of complexity to networks

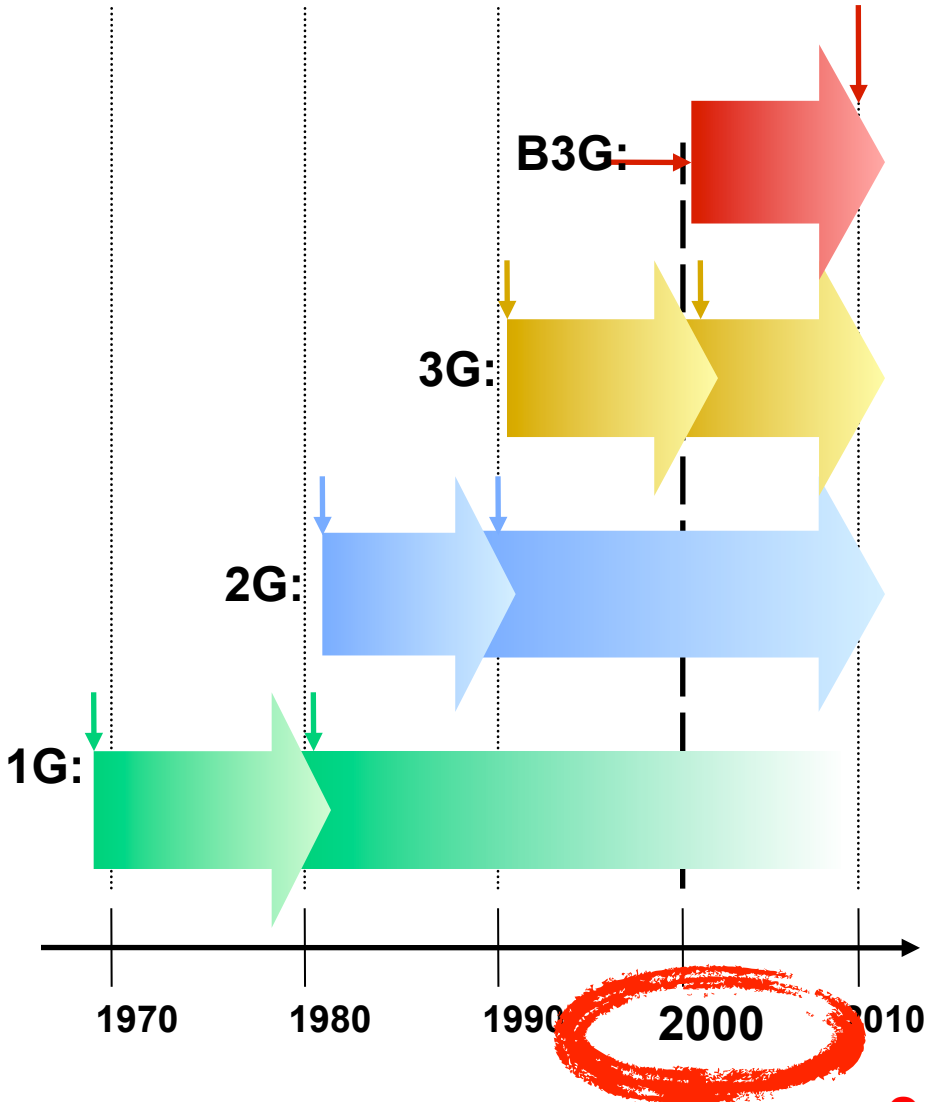
[source: Sharam G Niri, 2010]

Service development on Mobile Phones



Original: B3G study, Jan 2001

Service development on Mobile Phones



Personalised broadband wireless services

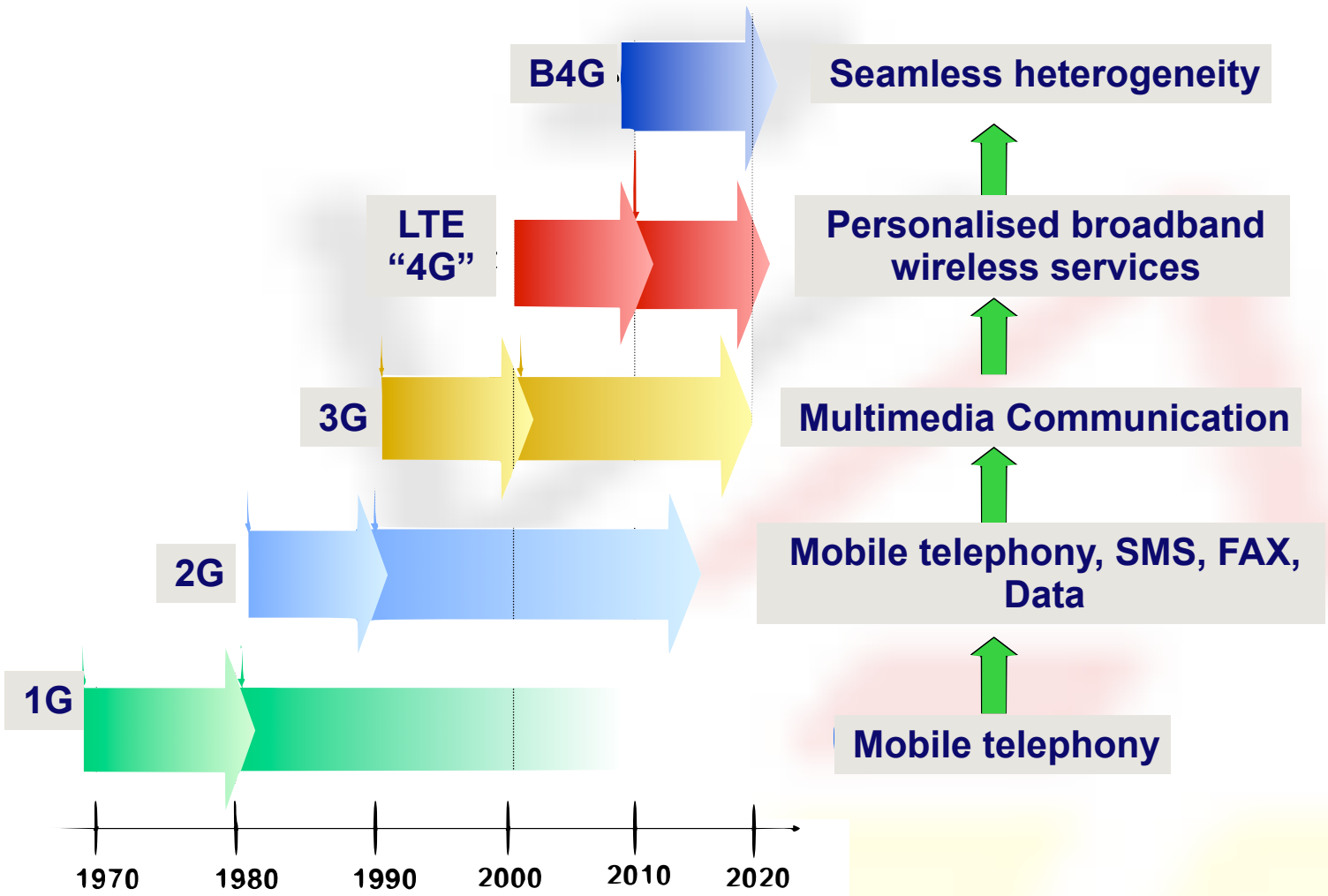
Multimedia communication

Mobile telephony, SMS, FAX, Data

Mobile telephony

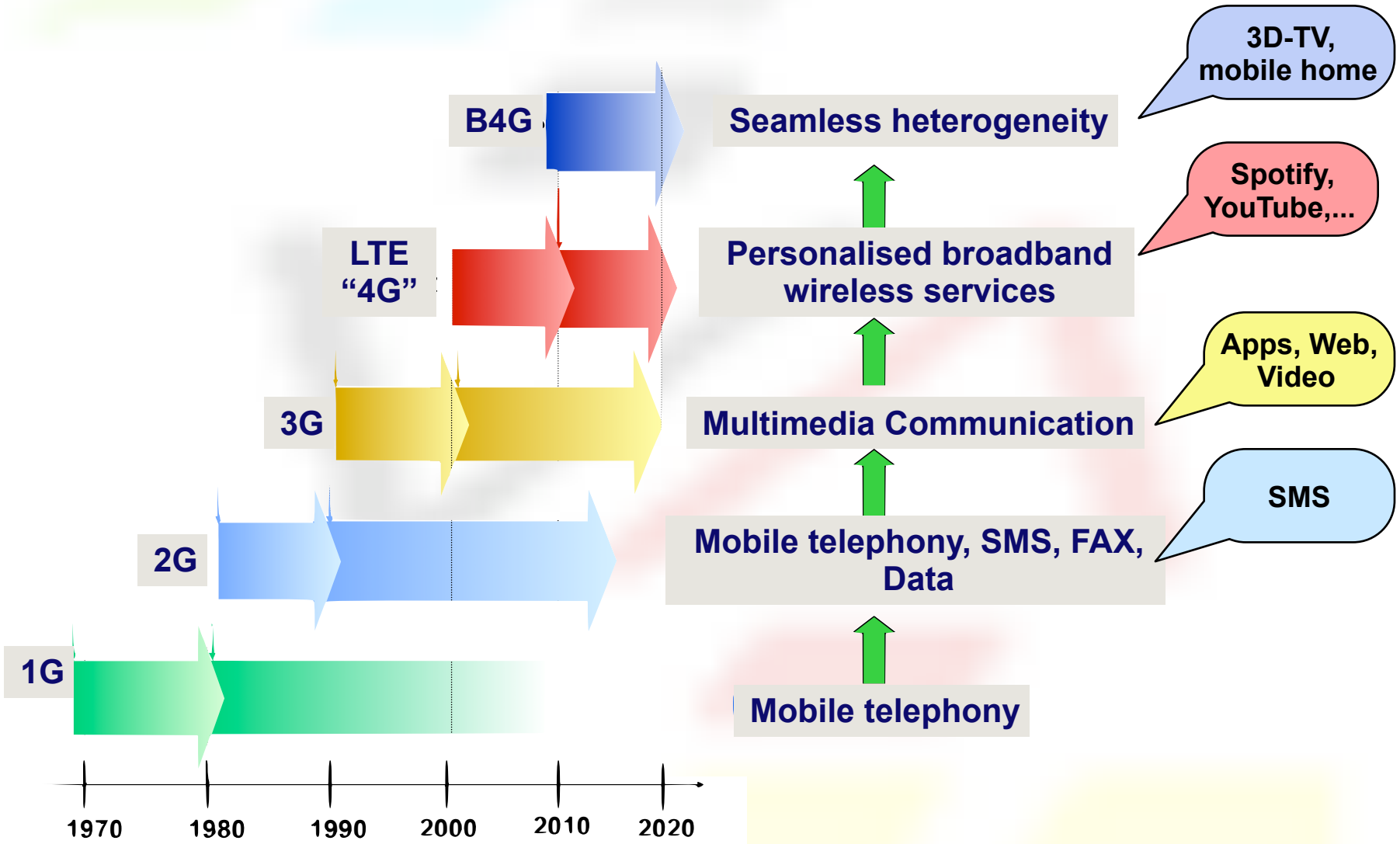
Original: B3G study, Jan 2001

Beyond 4G - the heterogeneous network



"It is all about service delivery"

Beyond 4G - the heterogeneous network



"It is all about service delivery"

Development of cellular systems

Generation	System	Comments
1G	NMT/ AMPS	•Analog voice •FDMA
2G	GSM IS-95 PDC	•Digital modulation/voice centric •Advance security and roaming •TDMA/ narrowband CDMA
3G	UMTS/WCDMA CDMA2000 TD-SCDMA	•IMT-2000 introduces global standard •Global roaming and wideband CDMA
4G	*3GPP LTE* *Mobile WiMAX* *3GPP2 UMB*	•Future Mobile Systems (IMT-A) •100 Mbps for (mobile usage) and 1 Gbps for (nomadic/stationary usage)

Key features of IMT-Advanced

- a high degree of commonality of functionality worldwide while retaining the flexibility to support a wide range of services and applications in a cost efficient manner;
- compatibility of services within IMT and with fixed networks;
- capability of interworking with other radio access systems;
- high-quality mobile services;
- user equipment suitable for worldwide use;
- user-friendly applications, services and equipment;
- worldwide roaming capability;
- enhanced peak data rates to support advanced services and applications (100 Mbit/s for high and 1 Gbit/s for low mobility were established as targets for research).

Future Mobile systems

- Increased capacity
  - higher bandwidth (GSM: 200 kHz; UMTS 3.84 MHz, LTE 20 MHz)
  - Advanced modulation and coding: QPSK, M-QAM
  - Multi-antenna technology: MIMO
- Better spectral efficiency
  - OFDM/OFDMA (orthogonality reduces bandwidth)
- Lower latency
  - complete IP-architecture
- Multimedia traffic
  - enhanced for quality of service (QoS)

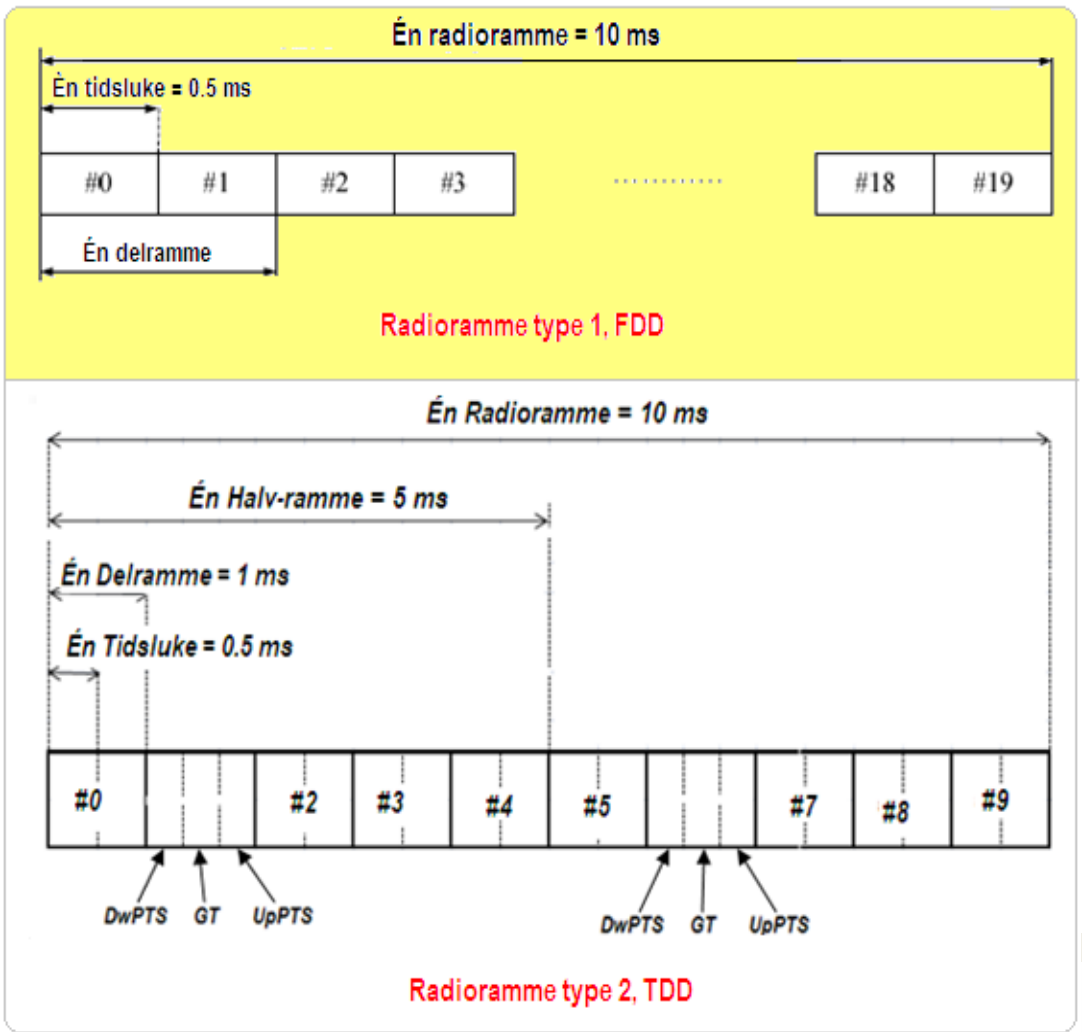
3GPP LTE	
Release 99(2000)	UMTS/CDMA
Release 5(2002)	HSDPA
Release 6(2005)	HSUPA
Release 7(2007)	DL MIMO, IMS(IP Multimedia Subsystem), better real-time support (VoIP, games, streaming)
Release 8(2008)	Long Term Evolution (LTE)
Release (2010?)	LTE-Advanced

IEEE 802.16 (WiMAX)	
802.16(2001)	LOS (10 – 66 GHz)
802.16a(2003)	Support for 2 – 11 GHz
802.16d(2004) enhanced 802.16a	Basic standard for fixed WiMAX
802.16e-2005 (2005)	Support for mobility and asymmetric link
802.16™-2009	Combined standard for fixed and mobile WiMAX
802.16m (3Oct 2009)	802.16 submission as IMT-A RIT-candidate for ITU-R

LTE versus Mobile WiMAX

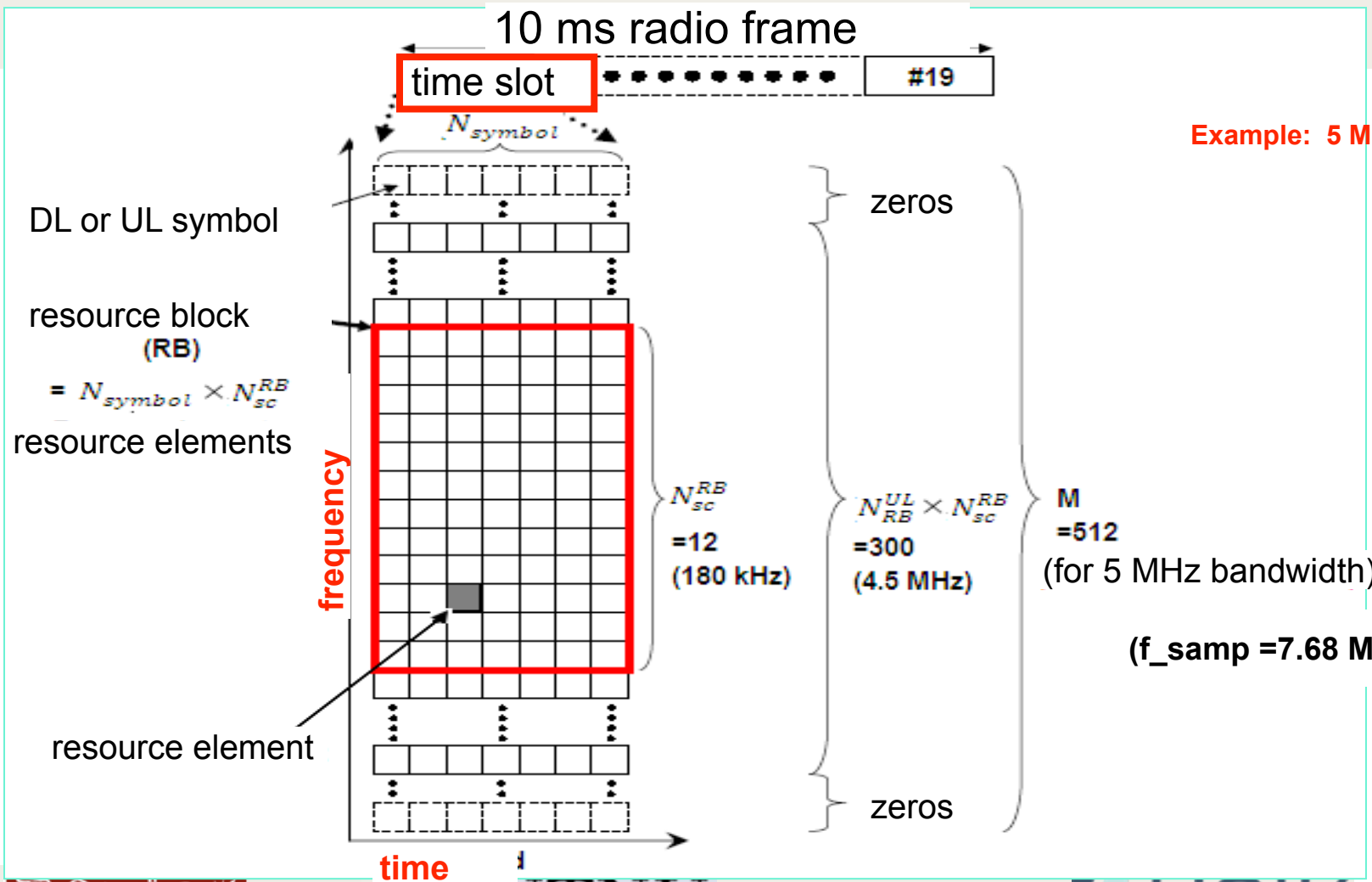
Parameter	3GPP LTE	Mobile WiMAX
Channel bandwidth [MHz]	1.4, 3, 5, 10, 15 og 20	5, 7, 8.75, 10 og 20 (802.16m)
DL access method	OFDMA	OFDMA
UL access method	SC-FDMA	OFDMA
Duplex	FDD og TDD	TDD, (FDD inkludert i 802.16m)
Subcarrier hopping	Ja (per time slot)	Ja
Subcarrier placement	**localised**, distributed	localised, **distributed**
Data modulation	QPSK, 16-QAM og 64-QAM	QPSK, 16-QAM og 64-QAM (optional for UL)
FFT size	128, 256, 512, 1024, 1536, 2048	512, 1024, 1024, 1024 og 2048
channel coding	CC, CTC (R=1/3)	CC, CTC (R=1/2), BTC (optional)
Subcarrier spacing [kHz]	**15**, 7.5 (only for extended CP)	10.94 (for 5, 10 and 20 MHz BW)
Multi antenna technology	Multi-layer precoded space multiplexing	space multiplexing, STC, Beam-forming
Top data rates: DL/UL [Mbps] (SISO)	86.4 / 55.5 (1 lag)	64.8 / 28.2 (measured values for 20 MHz og 64QAM)

LTE radio frame structure



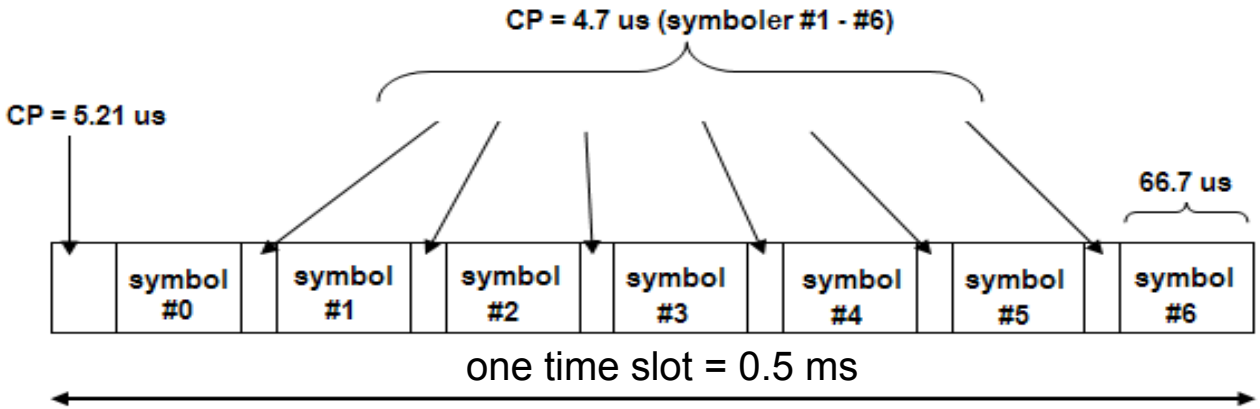
- Two LTE radio frame structures
  - Type 1, FDD
  - Type 2, TDD
- Radio frame length: 10 ms
- Subframe length: 1 ms
- Length of one time slot: 0.5 ms
- ** Dw-/UpPTS → Downlink-/ Uplink Pilot Time Slot,
- GT→ Guard Time (switching points between DL Tx and UL Tx)

LTE time slot and resource block



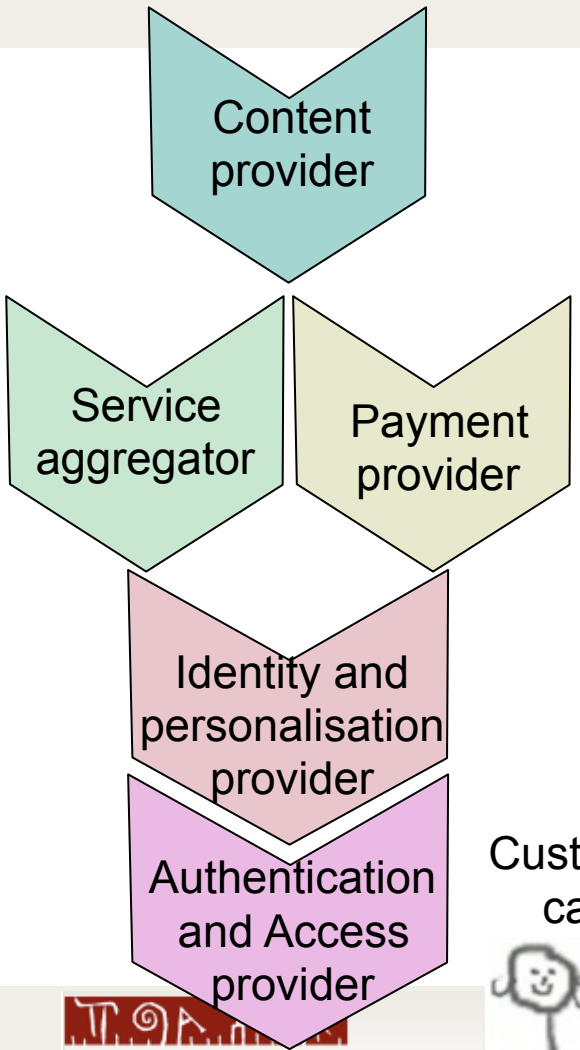
LTE time slot and resource block

LTE symbol with normal cyclic prefix (CP) in one time slot:



bandwidth [MHz]	1.4	3	5	10	15	20
FFT	128	256	512	1024	1536	2048
symbol/time slot	7					
Δf	15 kHz					
# subcarriers	72	180	300	600	900	1200
# PRB	6	15	25	50	75	100

5G business entities



Customer care

- Media,
- Banks, Service providers
- Telecom, Corporate, Home

Service aggregator

- Convenient interfaces
- Ease of use

Identity and personalisation provider

- Convenience
- Trust

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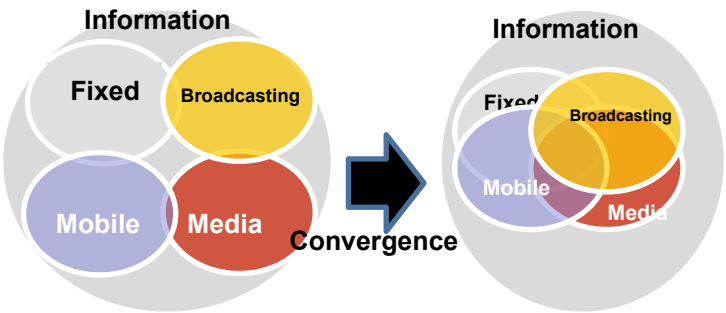
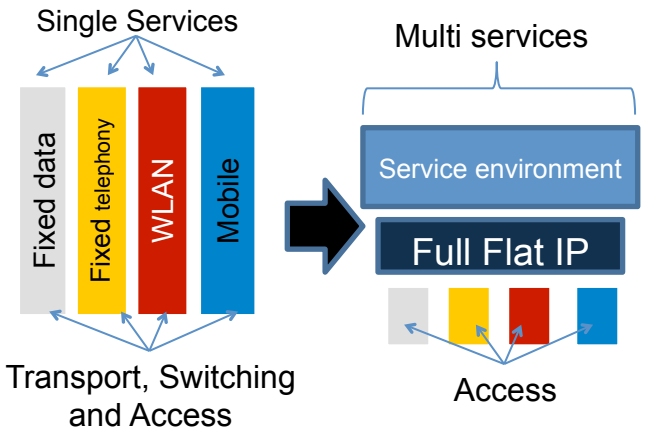
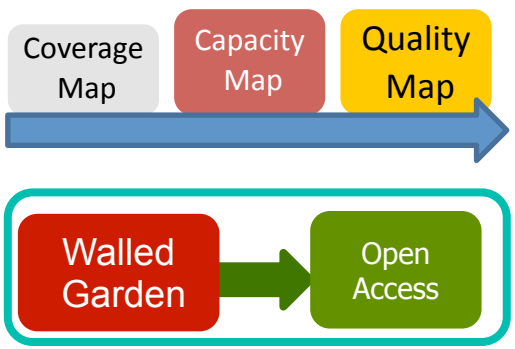
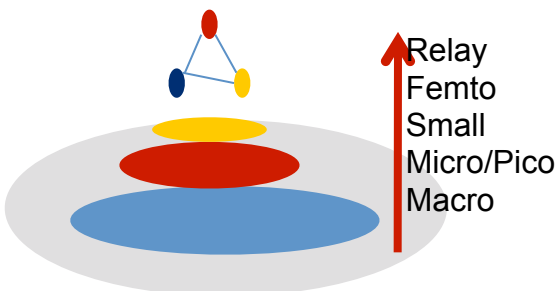
The Requirements Of Changing Industry - Networks

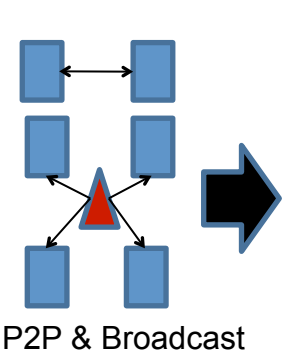
- ✓Blurring boundaries - convergence of telecommunication, information, broadcasting and media and publishing technologies
- ✓Change of vertical NWs for single service to horizontal NWs for multi service
- ✓Hyper connectivity (P2p, M2M)
- ✓New network deployment options
- ✓Walled Garden will change to Open Networks
- ✓High capacity and pipes with intelligent plumbing that could incorporate sophisticated quality control capability
- ✓Self managed and automated networks
- ✓Communication fundamentally delivered through SW on standards / generic HW

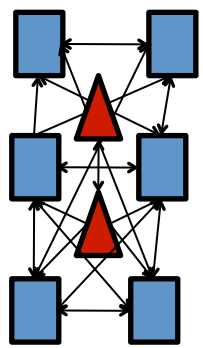










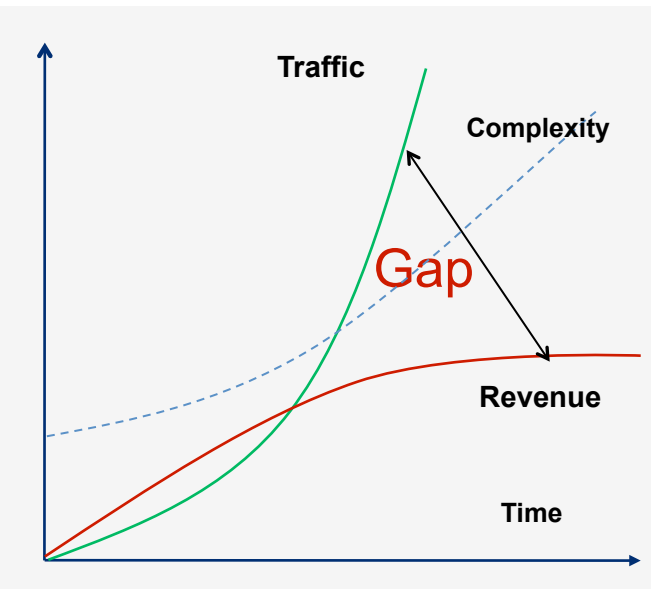


Next generation networks will grow in technical complexity

[source: Sharam G Niri, 2010]

Diverged Traffic & Revenue Growth

- ✓ **From Kilo (10^3) bytes to Tera (10^{12}) and Zeta (10^{21}) bytes**
- ✓ Global ubiquitous Internet-based solution with hyper Connectivity
- ✓ Hundred-fold increase in network flow brought by mass terminals and mass digital content, and the thousand-fold, increase in traffic flow on mobile networks
- ✓ Users are spending more time on the phone & internet
- ✓ Average household spending on communication falls
- ✓ Consumer pay less while getting better value -> they pay ~30% less than 5 years ago
- ✓ Significant growth in traffic while slow in revenue
- ✓ User experience at risk
- ✓ What do we do with a surging traffic
  - Limit/control it?
  - Turn it to revenue?
  - Bring the cost of it down?



Cost reduction is a very critical aspect of the future networks. Telecom seems to be the only sector delivering price decrease

[source: Sharam G Niri, 2010]

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- Introduction
- Generation aspects of mobile and wireless communications
- Drivers for 5G communications
  - Device aspects
  - Form factor
  - Diversity
  - Power
  - Network authentication
- Focus: Radio coverage
- Focus: Seamless authentication
- Business aspects
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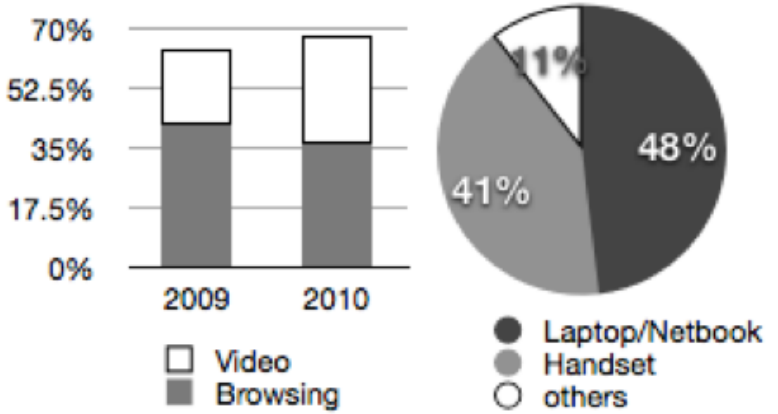
B4G - the service aspect

- Can mobile operators provide sufficient bandwidth at home/in the office?

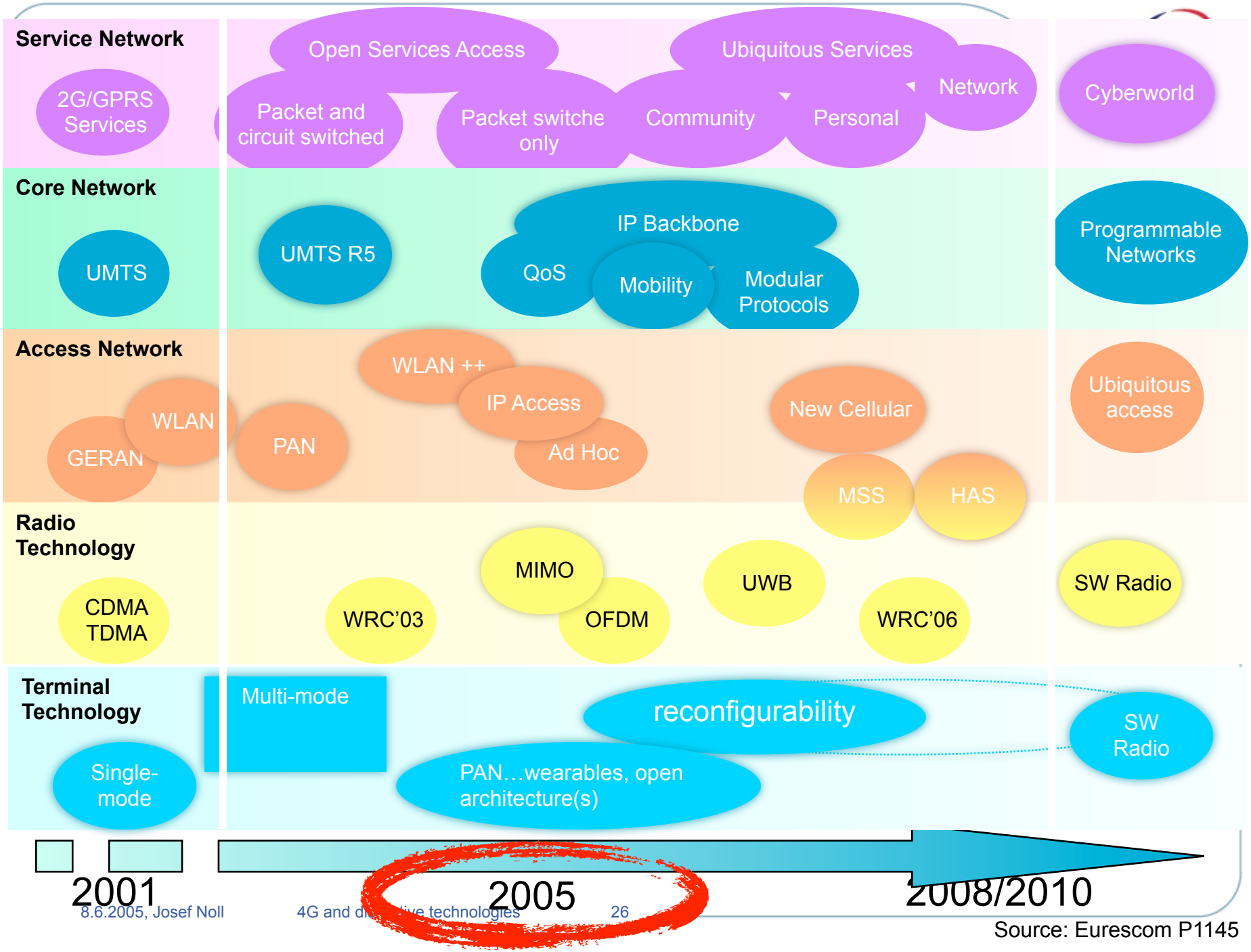
- Service experience from mobile broadband/LTE roll-out
  - 70-80% of all mobile broadband users are inside a building
  - fixed services like TV, video, streaming are more dominant
  - USA today: more data/apps traffic than voice traffic



[source: J. Waring, 2010]

- Mobile modems are part of home/business infrastructure
  - iPad, set-top box, TV, projector
  - iPhone (AppStore), Android: Widgets, Applets
  - streaming: YouTube, Spotify, mobile-TV,

Revenue does not relate to bandwidth

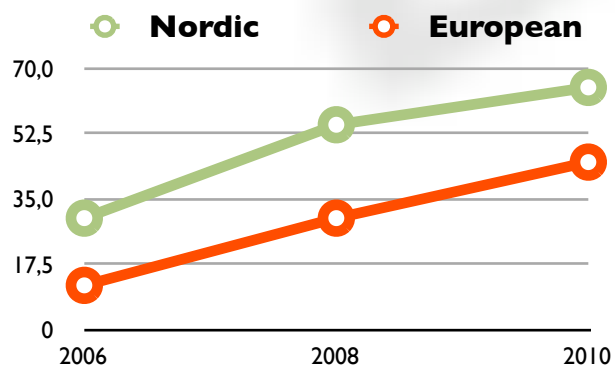


Source: Eurescom P1145

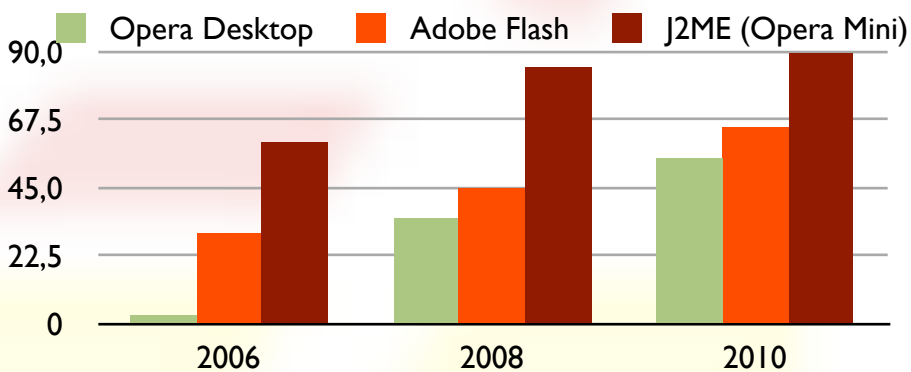
Mobile Market

- Mobile workforce: 40-70 % of a group in different locations
- 90 % of the employees away from HQ

- 2006:
  - 1020 million mobiles
  - 209 million PCs
- 4 Billion people with mobile in 2009
- Q4/2006: > 30 % smartphones in Norway
  - 20-30 % smartphones by 2009.



Smartphone penetration [%] in Europe and the Nordic



Handset functionality in market share [%] for the Nordic market

["Mobile Phone Evolution", Movation White paper, May 2007]

Device Fragmentation

source: Svein Therkelsen, mBricks, 2008

(handsets, operating system, security and network technologies)

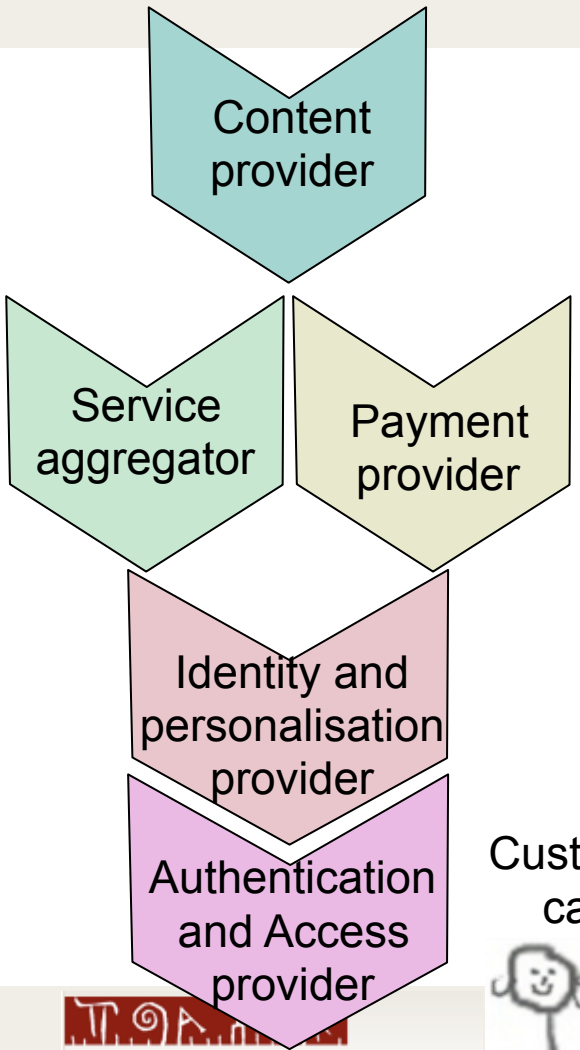
notebooks, **other** form factors, TV, STB

OS X, Android, S60, Linux - **html7, applets**

login, OTP, EAP-SIM, -AKA,....

802.11, .16, LTE++, **frequency**

5G business entities



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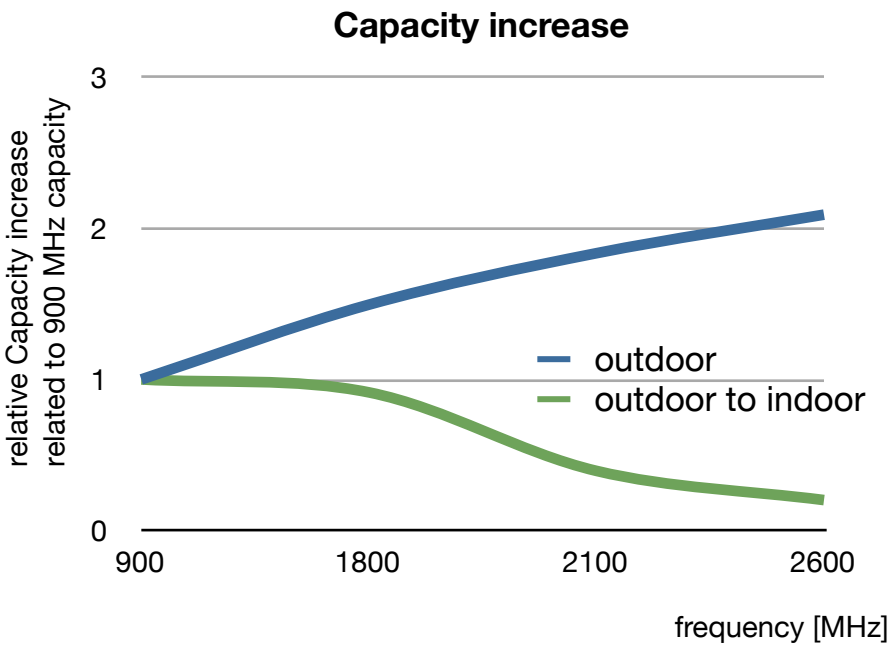
- Drivers for 5G communications
- Focus: Radio coverage
  - Interference in Beyond 3G systems (HSPA, LTE, 5G)
  - Radio dilemma: range, capacity, frequency
  - Network capacity and cell capacity
  - Interference limited coverage
  - Serving indoor users
  - Femtocells
- Focus: Seamless authentication
- Business aspects
- Conclusions

5G access - radio dilemma

Authentication and Access provider

- Access challenge: More bandwidth with less revenue
- The radio dilemma
  - frequency ↑, bandwidth ↑
  - frequency ↑, range ↓
  - ~~outdoor to indoor~~

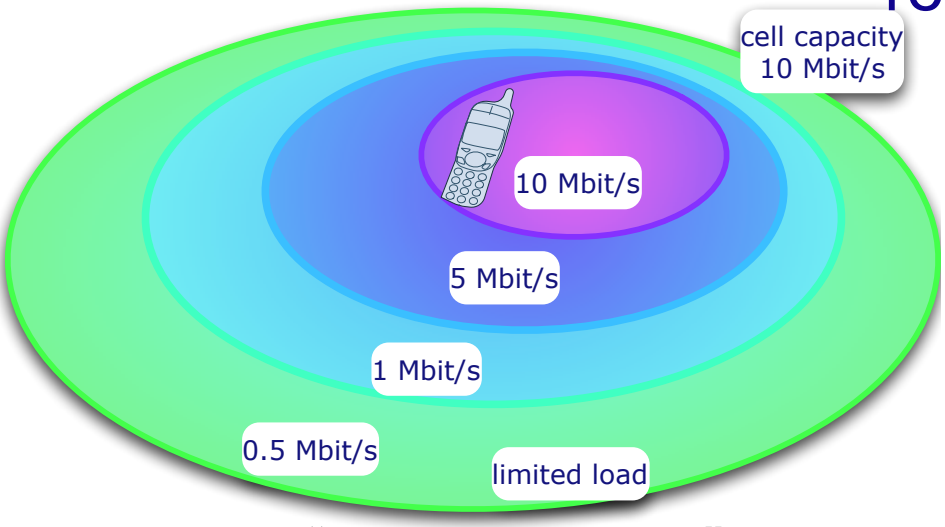
frequency [MHz]	Capacity increase	Attenuation (dB)	Capacity increase
900	100 %	12	100 %
1800	149 %	13	91 %
2100	183 %	17	40 %
2600	209 %	20	20 %



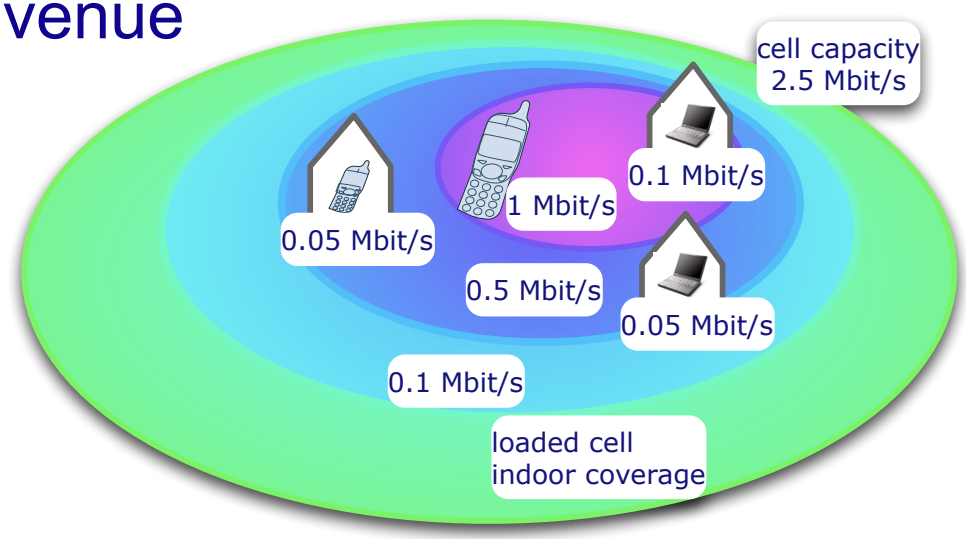
5G access - business considerations

Authentication and Access provider

- The radio dilemma
  - outdoor to indoor
- The business dilemma
  - 5G access is expensive (range)
  - changing access means loosing revenue



"coverage cell"



"70-80% indoor usage"

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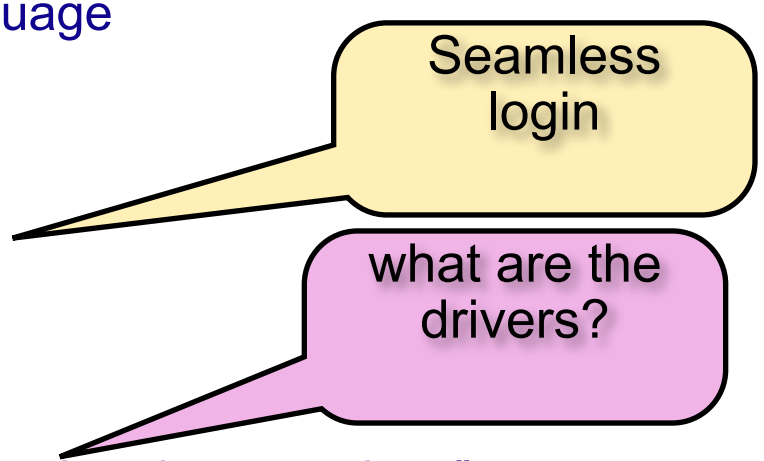
5G aspects

- Bandwidth requirements come from other form factors (notebook, portable 3D cinema)
- Assuming standardisation of application language
  - convertable widgets
  - web technologies (SAWSDL, html7)
- Seamless authentication
  - “My driver license on the information road”
- “Indoor coverage can’t be satisfied through outdoor base stations”
  - cooperating networks
- Variability of wireless sensors, devices, and systems
  - information on communication capabilities
  - power consumption and interference



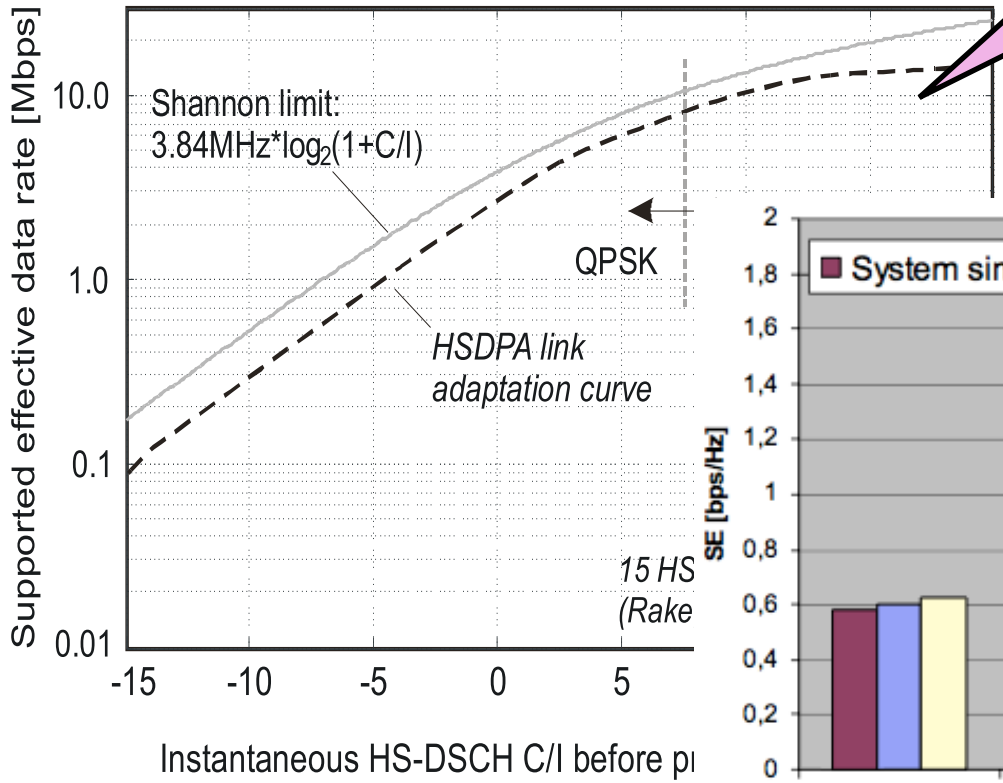
5G radio - System benefits for approaching Shannon?

WCDMA/HSDPA with 5 MHz bandwidth very competitive technology, as performance is rather close to the Shannon li

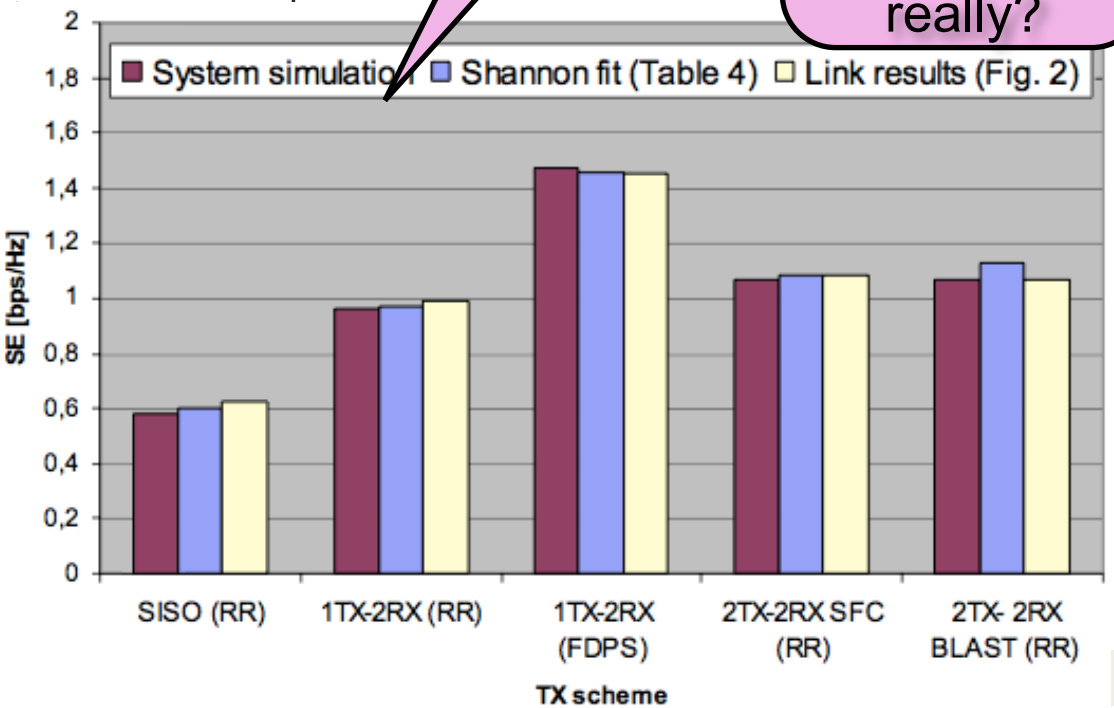
3G - HSDPA

4G - LTE

5G , really?

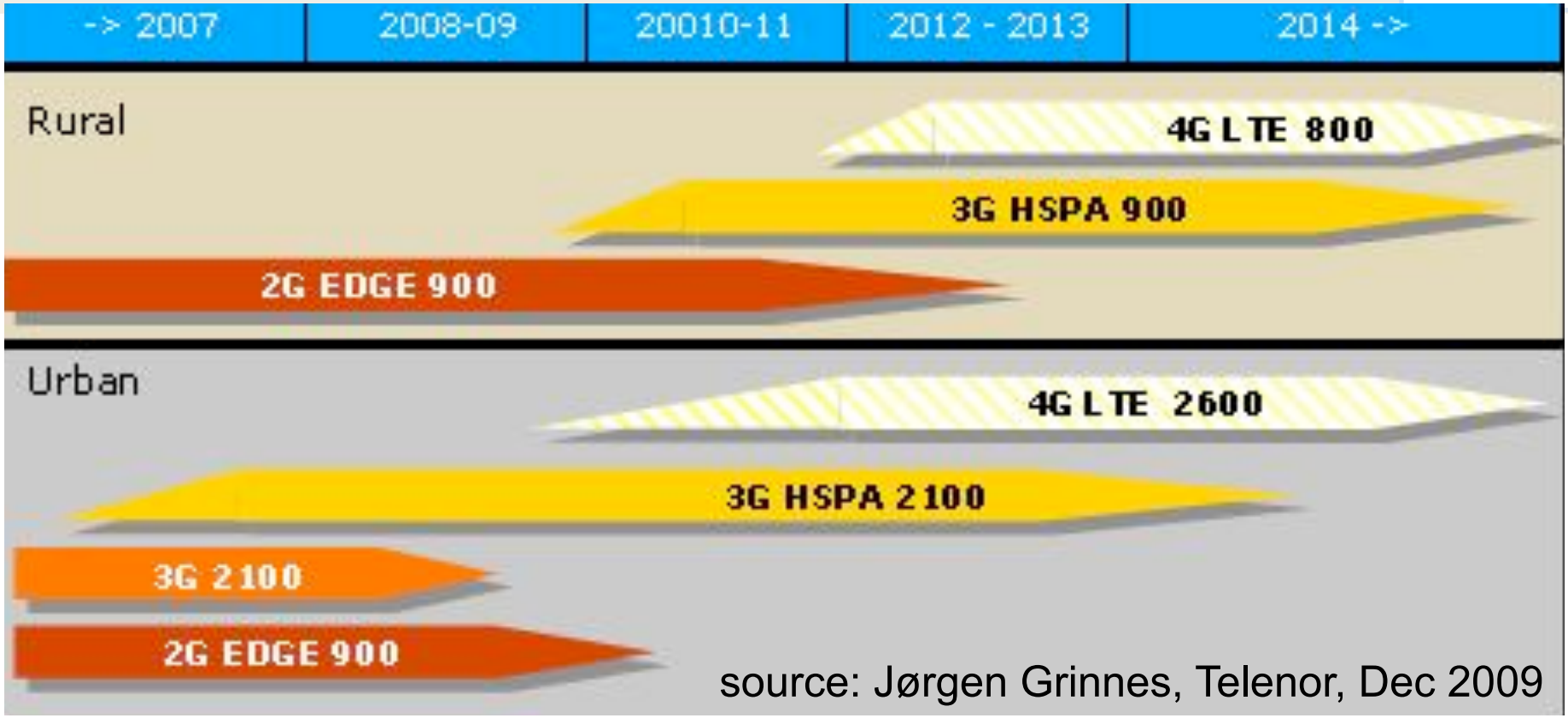


[source: WCDMA for UMTS, 3rd edition]



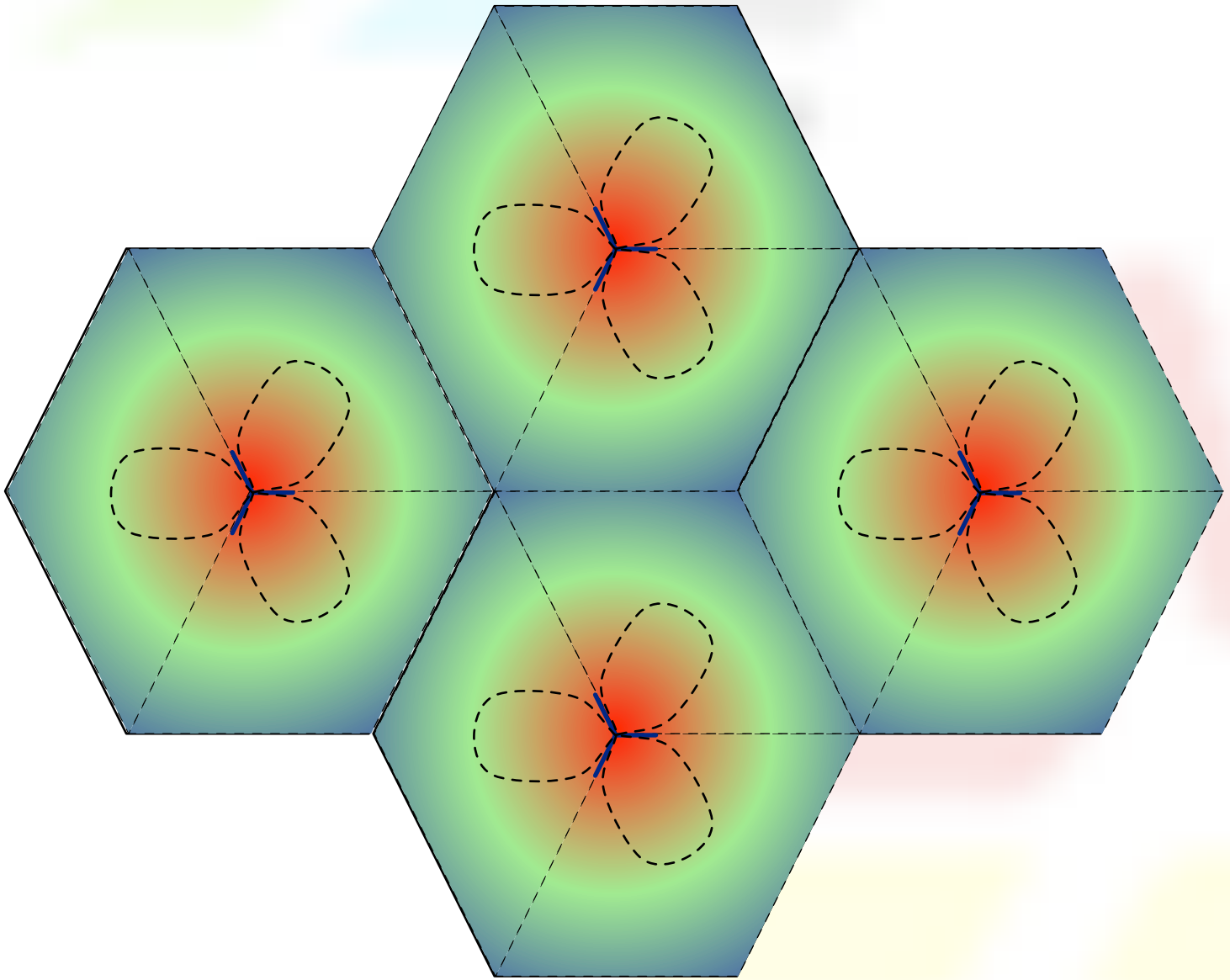
[source: Preben Mogensen, et al., 2007]

Telenor expectations



- Norwegian Post/Tele Reguator has opened for “cognitive radio” (April 2010)

LTE radio dimensioning



Aggregated data rate

> 65 Mbit/s

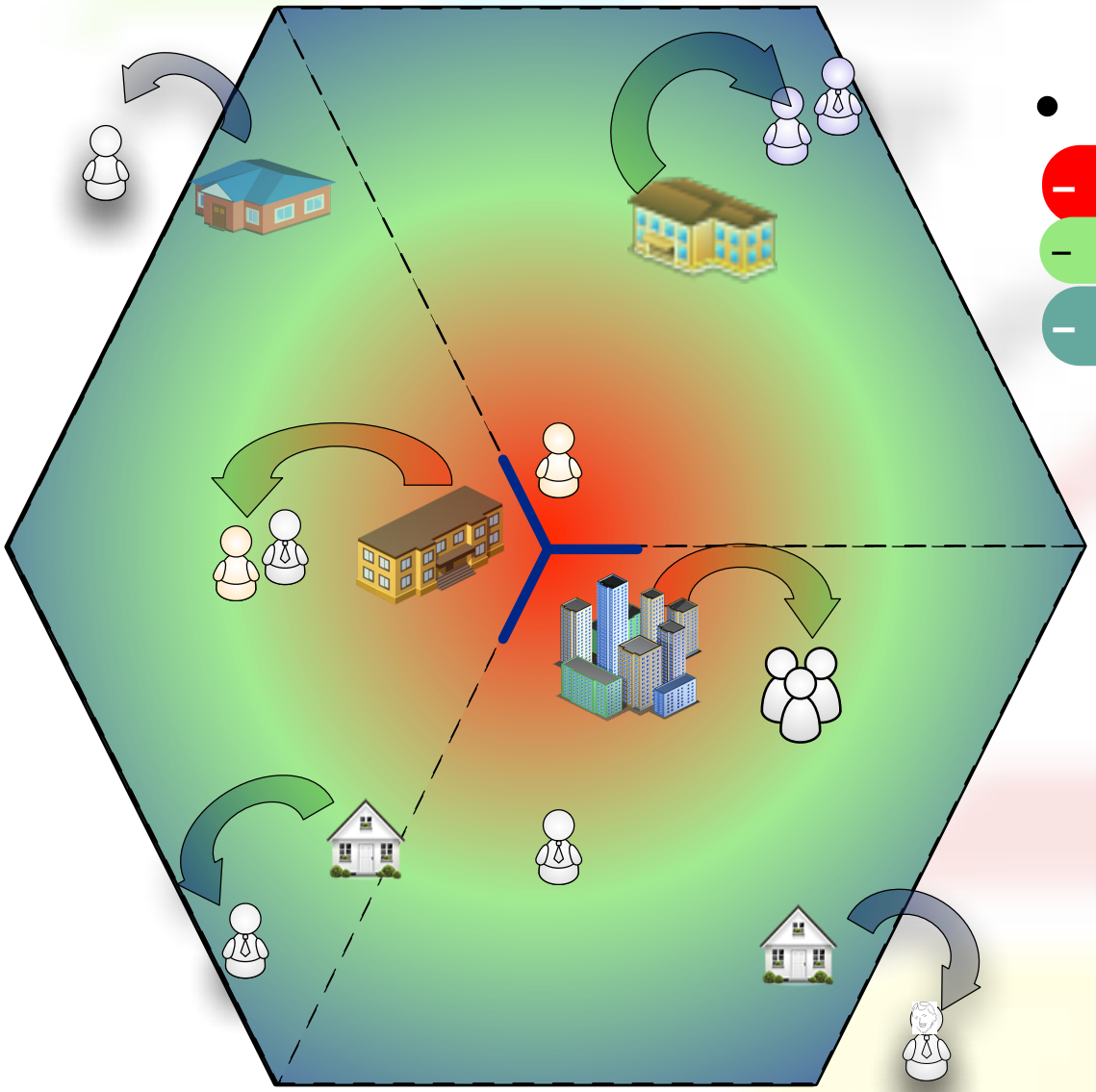
> 20 Mbit/s

> 7 Mbit/s

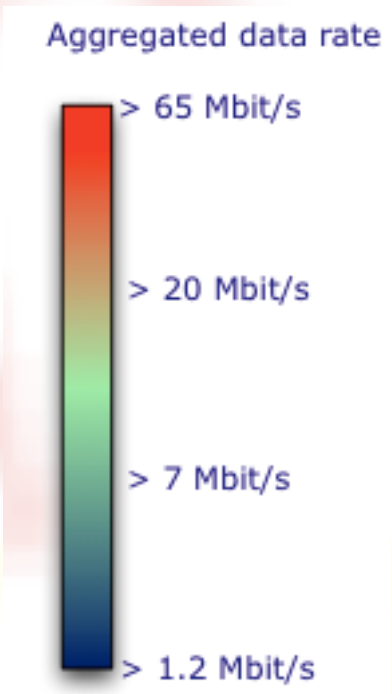
> 1.2 Mbit/s

Interference at the edge of the network, can be resolved through intelligent frequency reuse

Real network usage

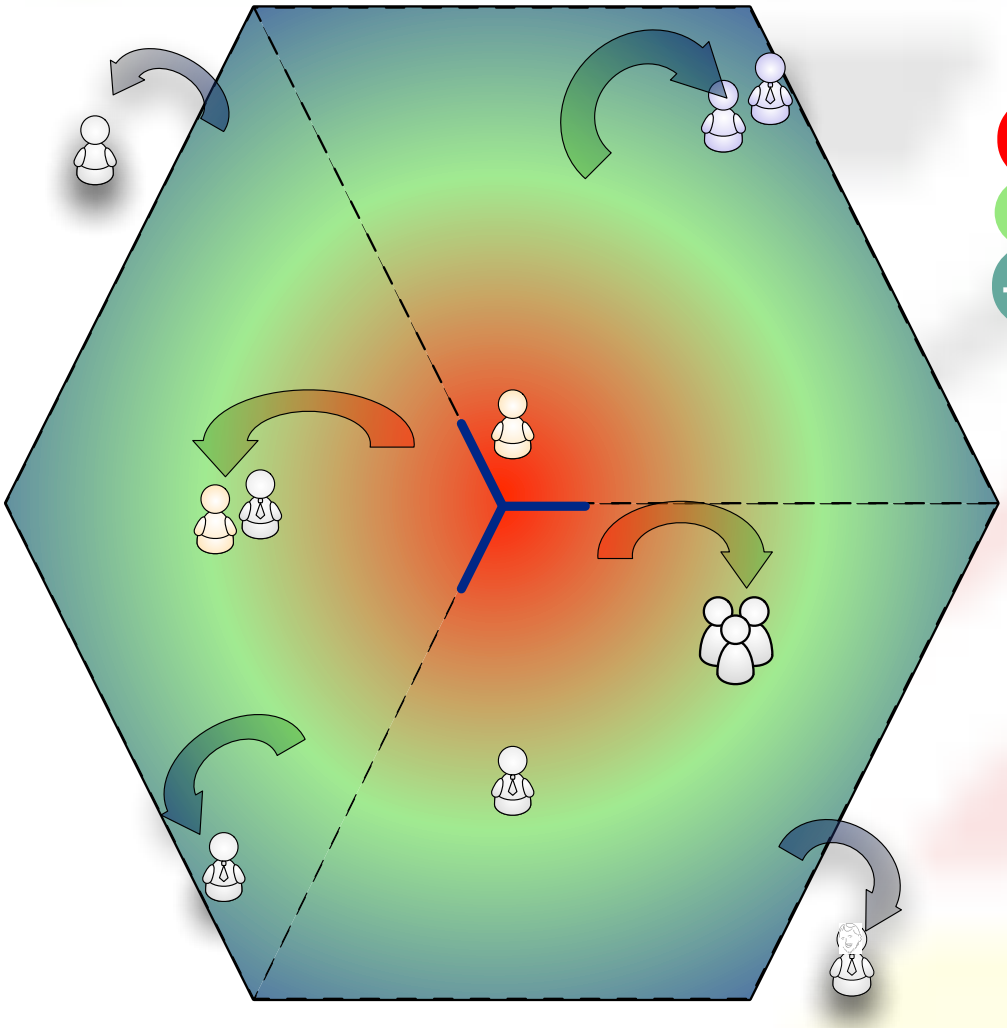


- Coverage [Motorola 2009]
  - **38% of users > 20 Mbit/s**
  - 32% of users 7...20 Mbit/s
  - **30% of users 1.2...7 Mbit/s**



70% indoor users means 30% reduction of cell capacity, and only 45% of satisfied users

Indoor dilemma



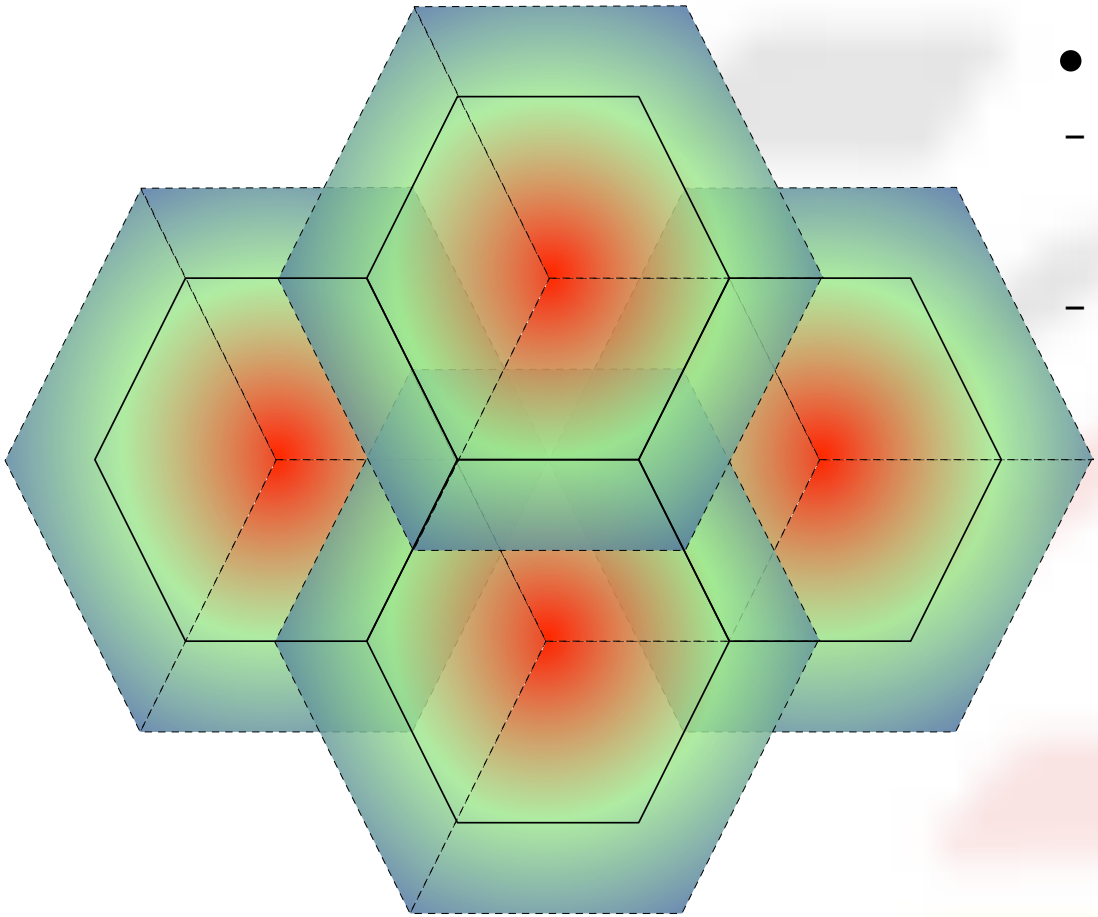
- Out ---> Indoor
  - **38% of users > 20 Mbit/s** — **16%**
  - 32% of users 7...20 Mbit/s — **17%**
  - **30% of users 1.2...7 Mbit/s** — **32%**

35%

- Indoor coverage
  - 70-80% of traffic from indoor
  - decreased signal quality
  - users experience less bandwidth than promised
  - 35% of users out of service coverage
  - Operators has up to 30% reduced cell capacity

70% indoor users means 30% reduction of cell capacity, and only 45% of satisfied users

Alt 1: Over-dimensioning

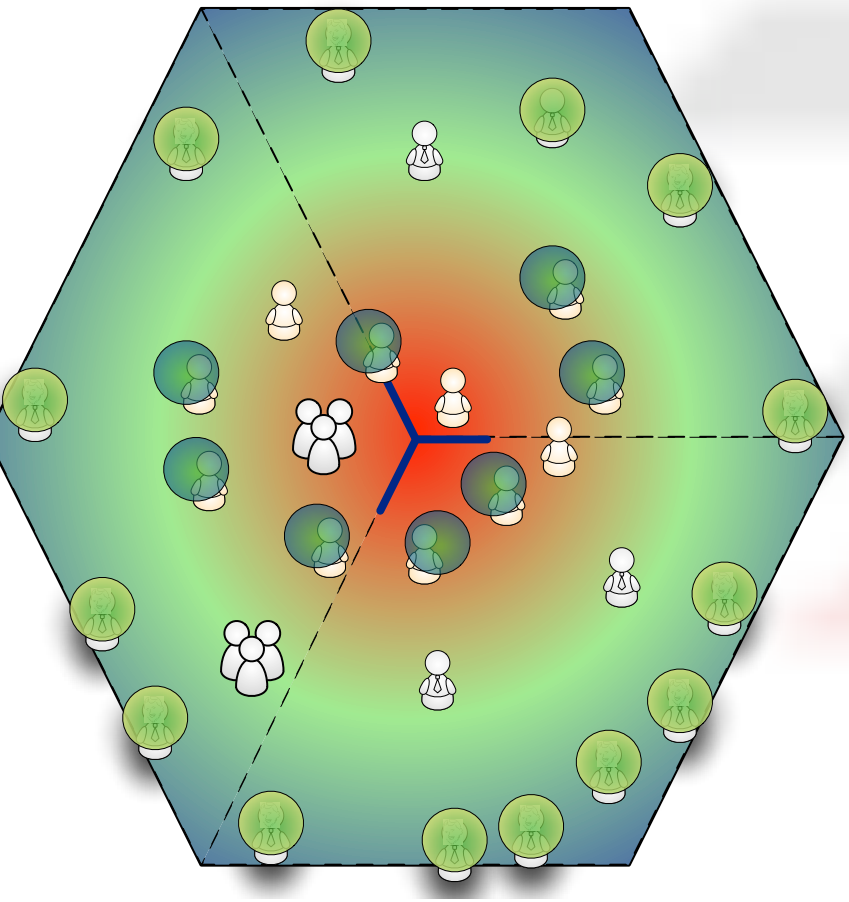


- Increase of Tx
  - 10 dB increased Tx -> 70% increased coverage
    - cell overlap causes interference
  - total network capacity is reduced

Over-dimensioing costs too much network capacity

Alt 2: Operator owned Femtocells

16% 17% 32% 35% service availability without femtocells



- Operator-owned femtocell
  - operator-owned
    - full QoS control
    - enable hand-over
  - equipment
  - transmission
  - installation and deployment cost
  - site acquisition or rental cost
  - operation and maintenance cost

- Customer perspective
  - DnBNOR, FFI.... provide only "Telenor" coverage?
  - WLAN hotspot: "freedom to select"

Femtocells: from Coverage to Capacity to Quality Network

Radio, Femtocell

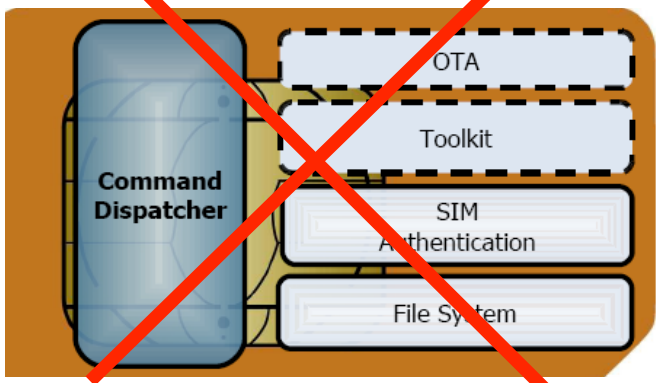
protitability?

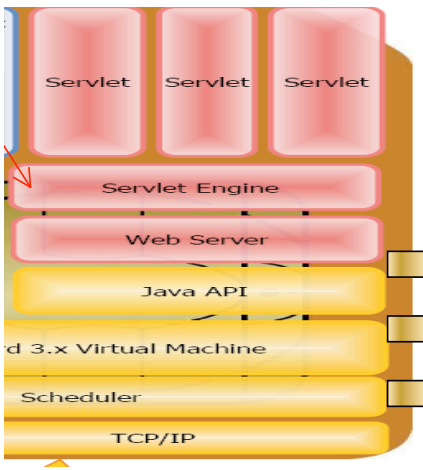
customer-owned femtocells?

Content

- Introduction
- Generation aspects of mobile and wireless communications
- Drivers for 5G communications
- Focus: Radio coverage
- Focus: Seamless authentication
  - Seamless Network access
  - Mobility
  - Authentication mechanisms
  - Future SIM as authenticator
- Business aspects
- Conclusions

Seamless login through Future SIM





Plus ETSI SCP
3 new phys IFs:

12 Mb/s USB

NFC (SWP)

telenor

- To comply with 3G networking requirements (USIM)
  - Security features (algorithms and protocols), longer key lengths
  - GSM uses EAP SIM: client authentication
  - UMTS uses EAP AKA: Mutual authentication
  - 5G interconnects based on EAP AKA(?)

- 3rd party identities
  - ISIM application (IMS)
  - private user identity
  - one or more public user identities
  - Long term secret

Source: Judith Rossebø, Telenor

Content

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  - Collaborative approach,
  - Near Field Communication (NFC) as an example
- Conclusions

Postulation

"Let the user own his own network, and your revenue as a Telecom operator will increase"

User-owned home BS

- Home base station (BS)
  - 70-80% indoor usage
  - voice produced on 3G
  - mainly data usage with application-based hand-over
    - "break than make"
  - provision to all customers, "home authentication"
  - "0%" OpEx costs for operators

- Maintenance cost reduction
  - 12 %/year for an operator-owned
  - user owned: 2 %/year customer maintenance support

User-owned home femtocell

- Conditions
  - spectrum ownership: 2600 GHz should be "unlicensed" (NPT, EU,...)
  - alternative: "Give away" guard band spectrum
  - adaptive signal adaptation

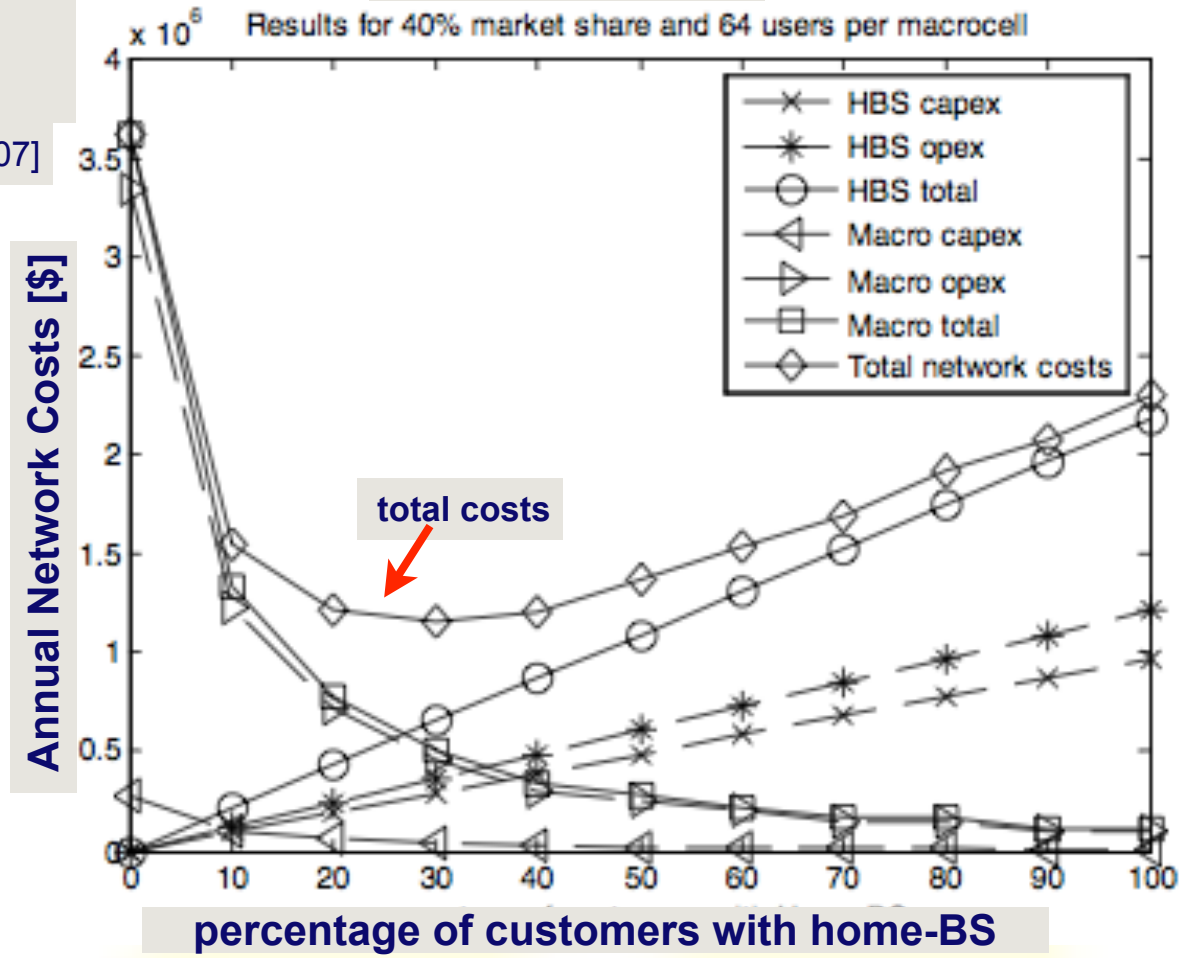
- Collaborative business
  - known from NFC - "trusted service manager" (TSM)
  - trust relation and "prosumer" approach

Alt 2: User-owned home BS

OpEx and CapEx calculations based on "free provisioning" of home base stations

[source: H. Claussen, 2007]

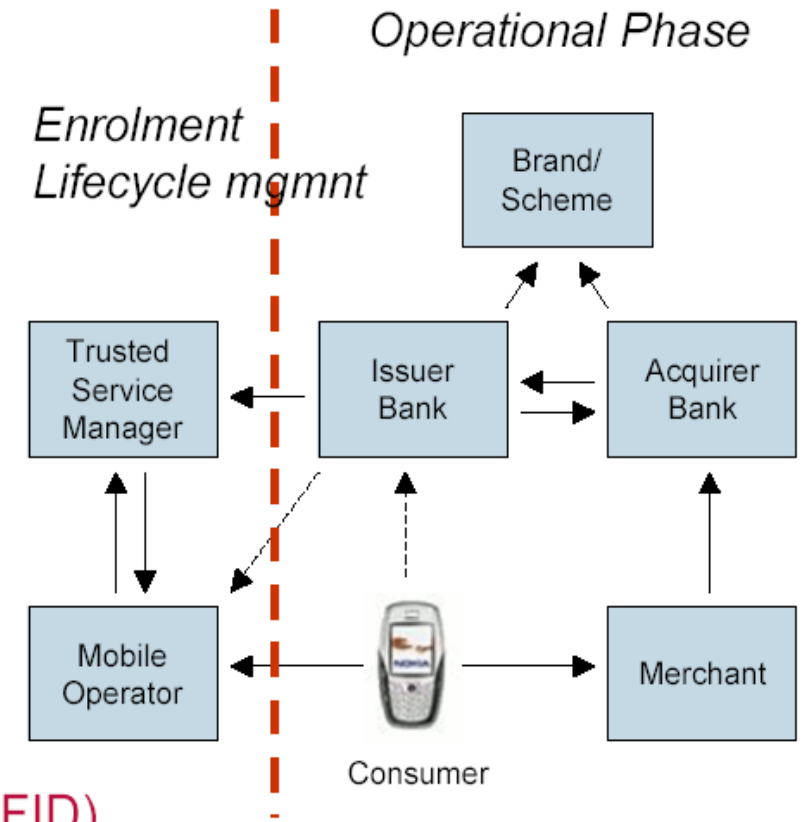
40% market share



Total network cost reduction more than 70% with user-owned base stations

Ecosystem: for NFC
The collaborative business model

- Principle Stakeholder
  - Consumer
- Key Stakeholders
  - Banks
  - Mobile Operators
  - Merchants
- Supporting Stakeholders
  - Card Associations
  - Transaction Service Providers
  - Mobile Handset Manufacturers
  - Technology Providers (NFC & RFID)
  - Third Parties (Application/Platform Providers)



– Telenor and DnB NOR establishes TSM Nordic AS in April 2008

Source : Mobey Forum Ltd. + Bent Bentsen, 2008

DnB NOR

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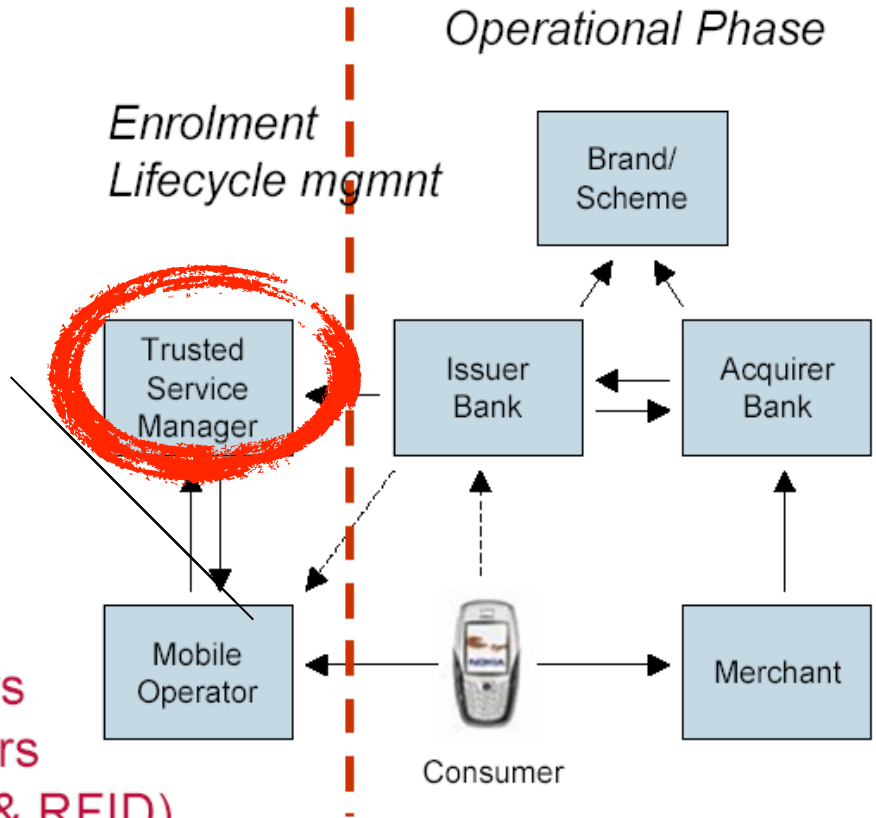

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The secure element: SIM card

Seamless login

Authentication and Access provider

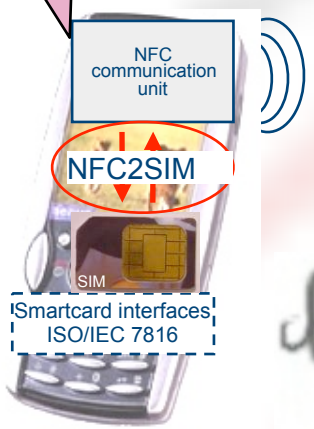
Identity and personalisation provider

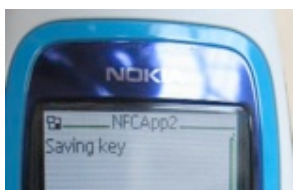
Service aggregator

Send key and credentials

Send info to recipient

Send service to phone





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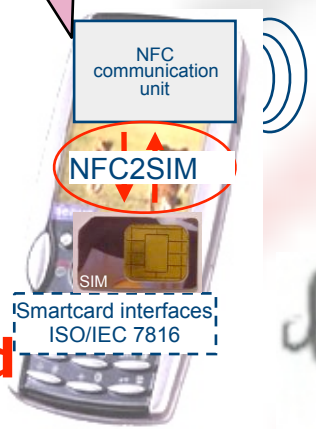
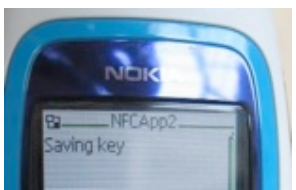
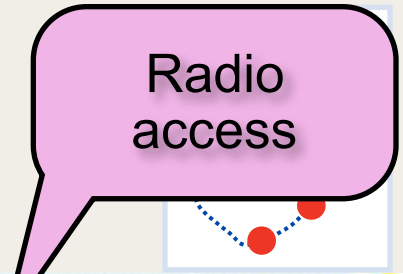


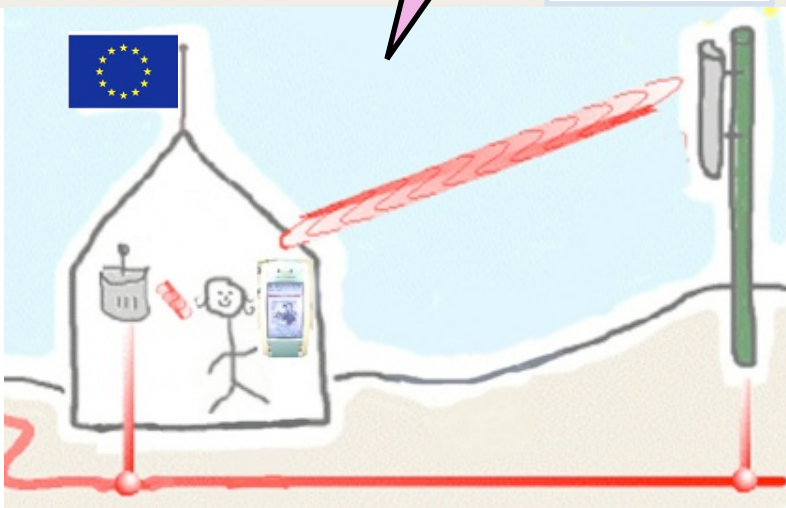


- SIM is secure element
  - controlled environment
  - over-the-air update
  - open for applications
- **SIM will be owned by user?**
  - managed by trusted third party

Drivers for collaborative access networks



- Heterogenous networks
  - Different entities
  - reduced revenue
  - **"Collaborative Business Model"** for seamless wireless access
- The user as the driver
  - reduced costs
  - reduced electromagnetic radiation
- Enabler
  - Operators
  - National authorities
  - EU commission



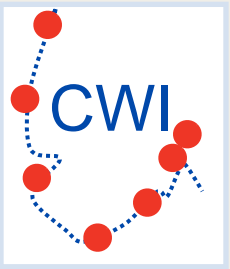
Conclusions

- 70-80% of 3G/"4G" from indoor users

	outdoor	out/inn
>20 Mbit/s	38 %	16 %
7-20 Mbit/s	32 %	17 %
1.2-7 Mbit/s	30 %	32 %
		-35%

- Femtocell
  - effective if >30% penetration
  - limited user experience "where is my operator"
- User-provided Femto
  - "no maintenance"
  - requires trust relations
- Collaborative Radio

Thanks to



My colleagues at UNIK

- **Mohammad Mushfiqur Rahman Chowdhury** for 5G discussions and calculations
  - see his presentation on Friday 25.9.2010
- **Arlindo Bengui André** for LTE work

My colleagues at CWI

- **Frank Reichert** for comments on 5G

Our cooperation partners at CTIF (Aalborg University)

- **Ramjee Prasad** for initiating the “5G discussion”

Our industrial partners

- **Bjørn Amundsen** from Telenor for discussions on coverage and capacity
- **Per Hjalmar Lehne** from Telenor for generations
- **Bent Bentsen** from DnB NOR for the information on Payment and TSM Nordic
- **Truls Berg** from Movation for mobile usage data
- **Linda Firveld** from MobileMonday for femtocell industrialisation
- **Shahram G Niri** from NEC for collaborative discussions

My Telecom colleagues from various Eurescom projects

- and many, many more....