System Concept for 1 Gbit/s and Beyond

Tutorial IEEE 802 Plenary, Vancouver, November 2005

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Peter Egner	Telefunken Racoms
Guido Hiertz	RWTH Aachen

www.wigwam-project.com
Wireless Gigabit With Advanced Multimedia Support

WIGWAM - Consortium

Main Contractors

TECHNISCHE UNIVERSITÄT DRESDEN
VODAFONE CHAIR

ALCATEL

Infineon technologies

PHILIPS

SIEMENS

DAIMLERCHRYSLER

ihp

MEDAV
WIR VERSTEHEN DIE ZEICHEN DER ZEIT
KEEPING PACE WITH THE SIGNAL OF TIME

NOKIA

TELEFUNKEN RACOMS

Sub Contractors

- RWTH Aachen (Walke)
- TU Berlin (Wolisz)
- Humboldt-Univ. Berlin (Meffert)
- TU Cottbus (Weger)
- Univ. Erlangen (Weigel)
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- TU Karlsruhe (Wiesbeck)
- TU Karlsuhe (Zitterbart)
- TU Munich (Eberspächer)
- Univ. Ulm (Bossert)
- Univ. Ulm (Lindner)
- FhG HHI (Boche)
- FhG IZM (Sommer)

Sponsor

Bundesministerium für Bildung und Forschung

DLR

mobile internet

Project Duration

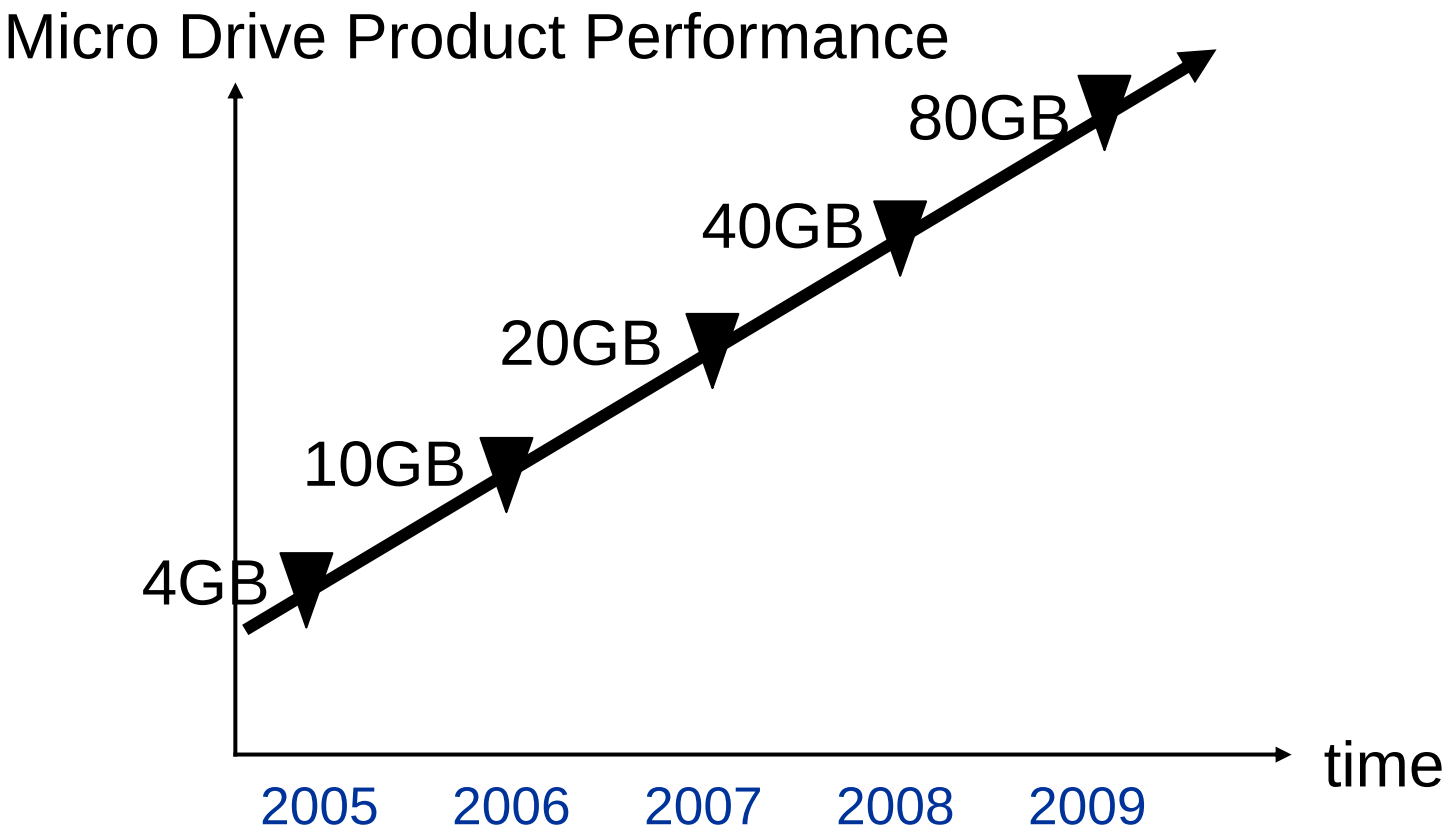
10/2003 - 3/2007

Aims

- Development of the **Enabling Technology** for a new air-interface with a maximum data transmission rate of **1 Gbit/s**
- Demonstration of **Key Components** and **Key Functionality**
- Contribution to **Standardization**
- Close cooperation

Data Communications
Thoughts & Trends

Mobile Memories: Driving Factor Within Terminals!



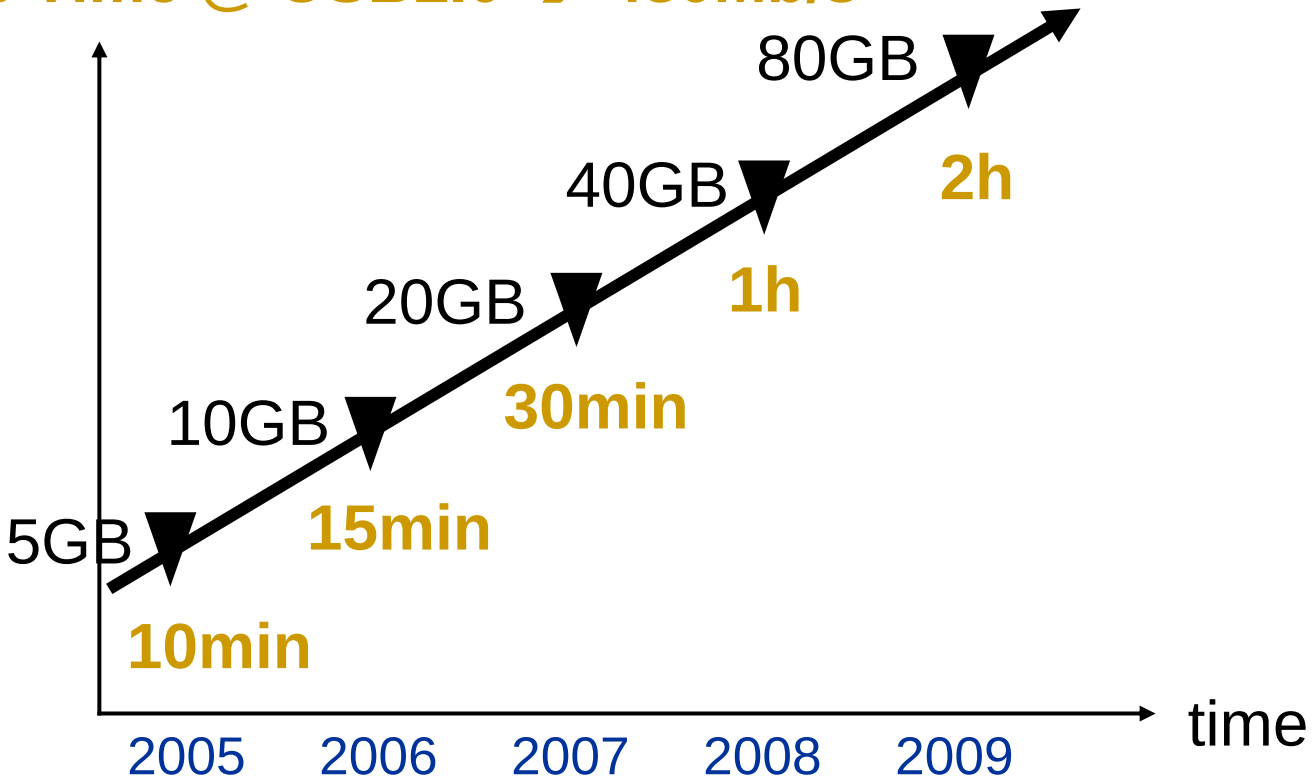
➔ “Unlimited demand for communications bandwidth”

What We Want (1): Moving Data

- Connectivity for moving data
  - From source to memory
  - From memory to destination
  - From memory to memory
- Cordless peer-to-peer

Moving The Data: Communications Bottleneck!

Sync Time @ USB2.0 ➔ 480Mb/s

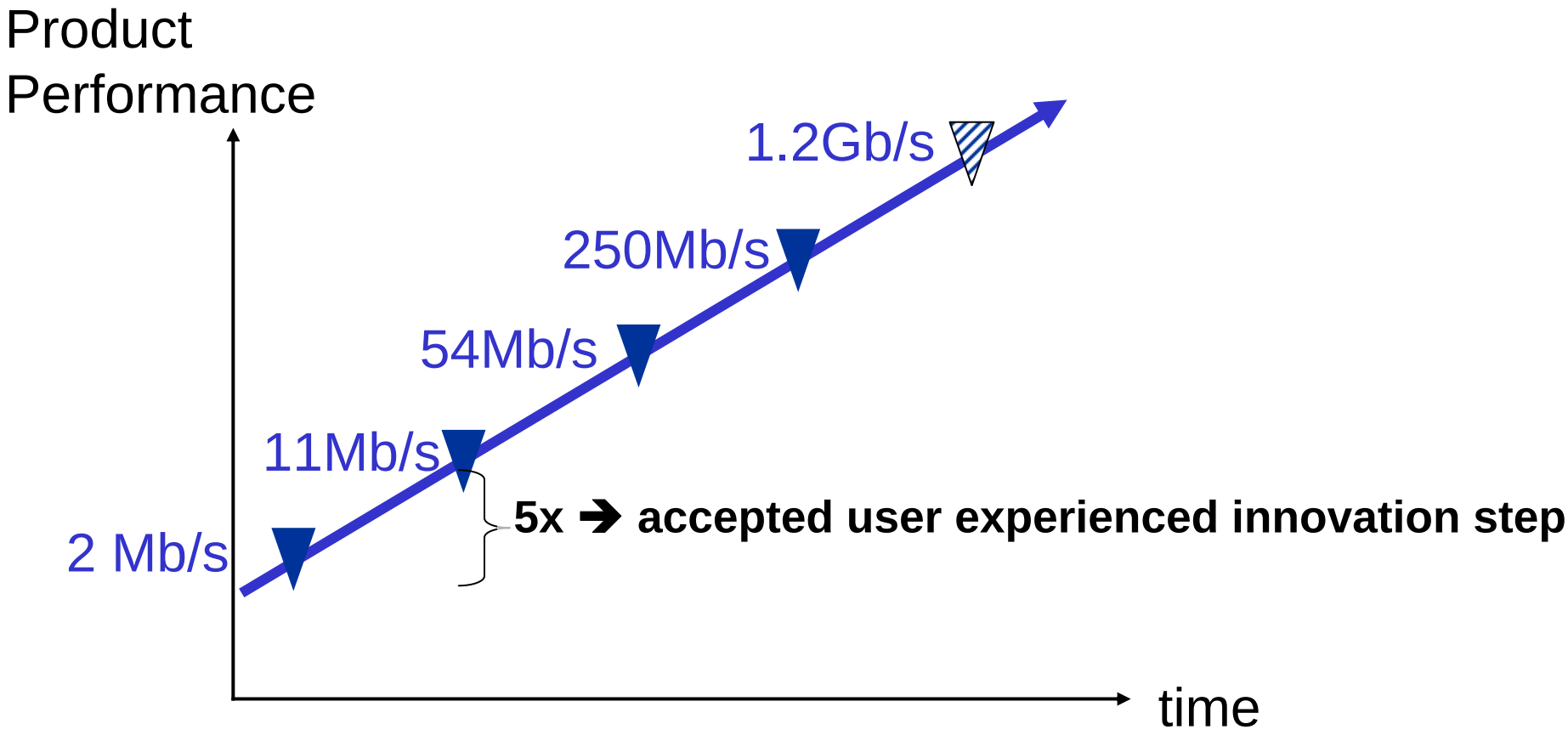


➔ “Unlimited demand for communications bandwidth”

What We Want (2): Sharing Data

- Sharing data
  - Connecting with local infrastructure
  - Connecting with fixed network
  - Client server environment
  - Connecting via shared access point
- A local area network

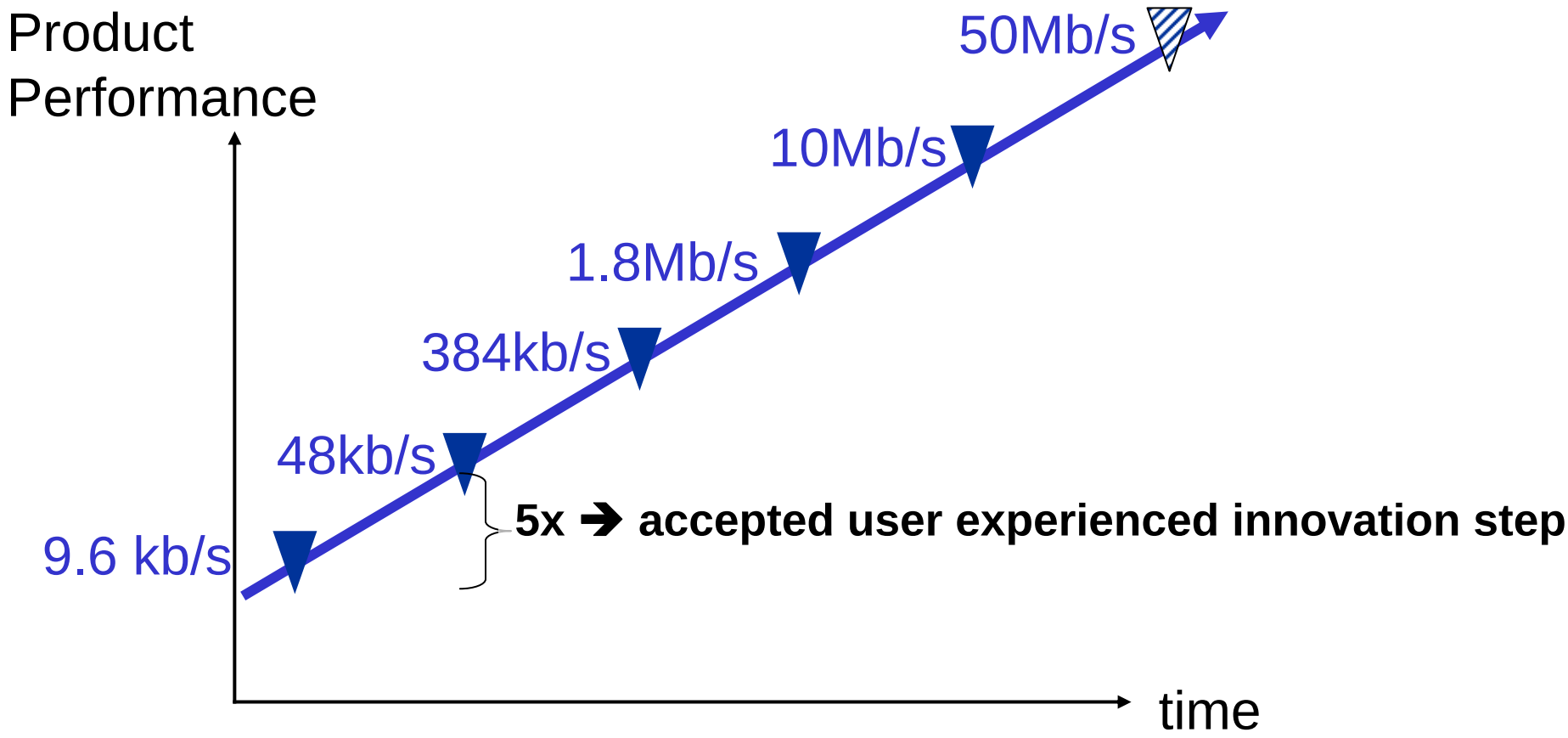
IEEE 802.11 WLAN History & Future



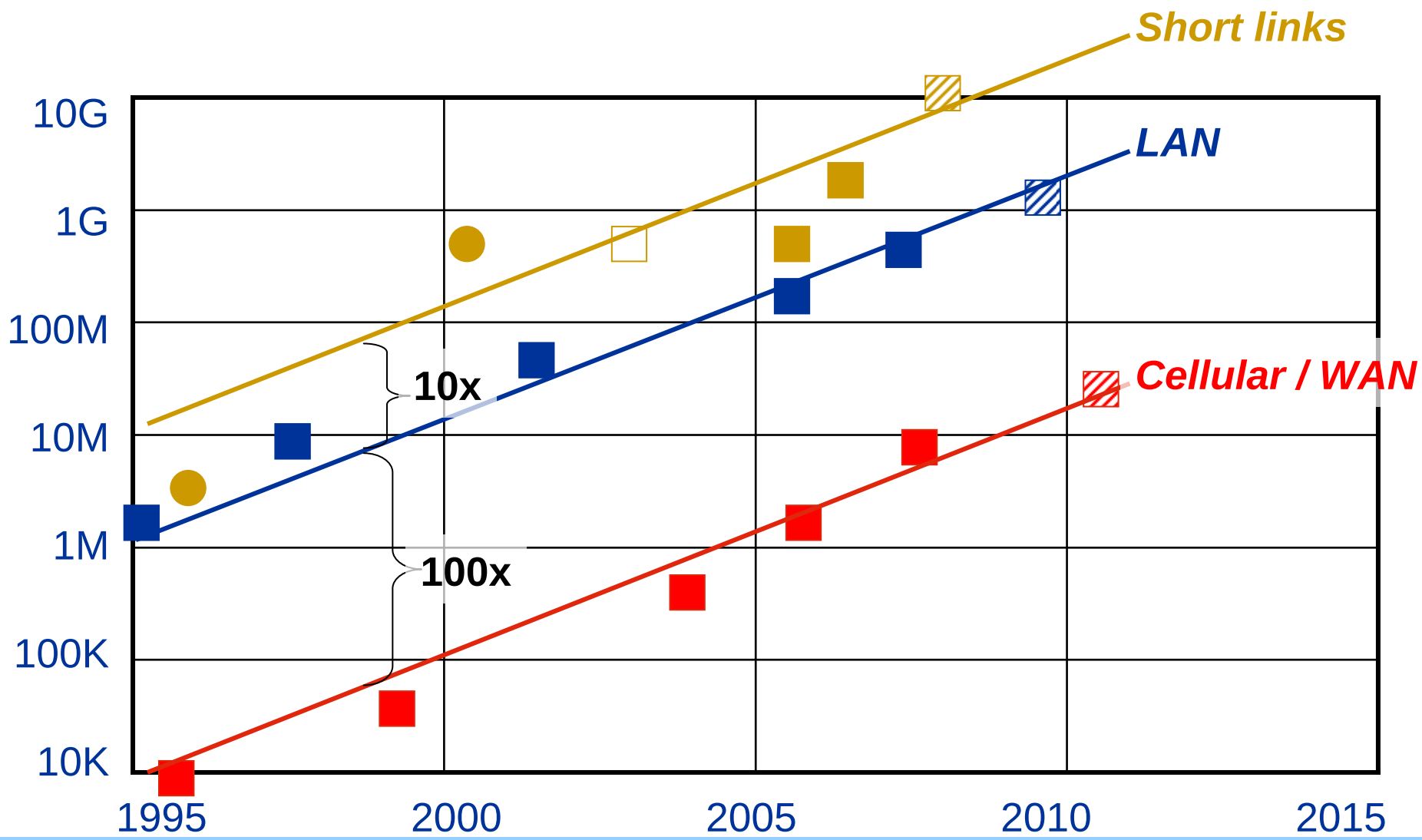
What We Want (3): Seamless User Experience

- Always connected
  - Roaming
  - Coverage
  - Accessibility
- A cellular wide area network

GSM/3GPP History & Future



Data Rates Over Time: 10x / 5yrs



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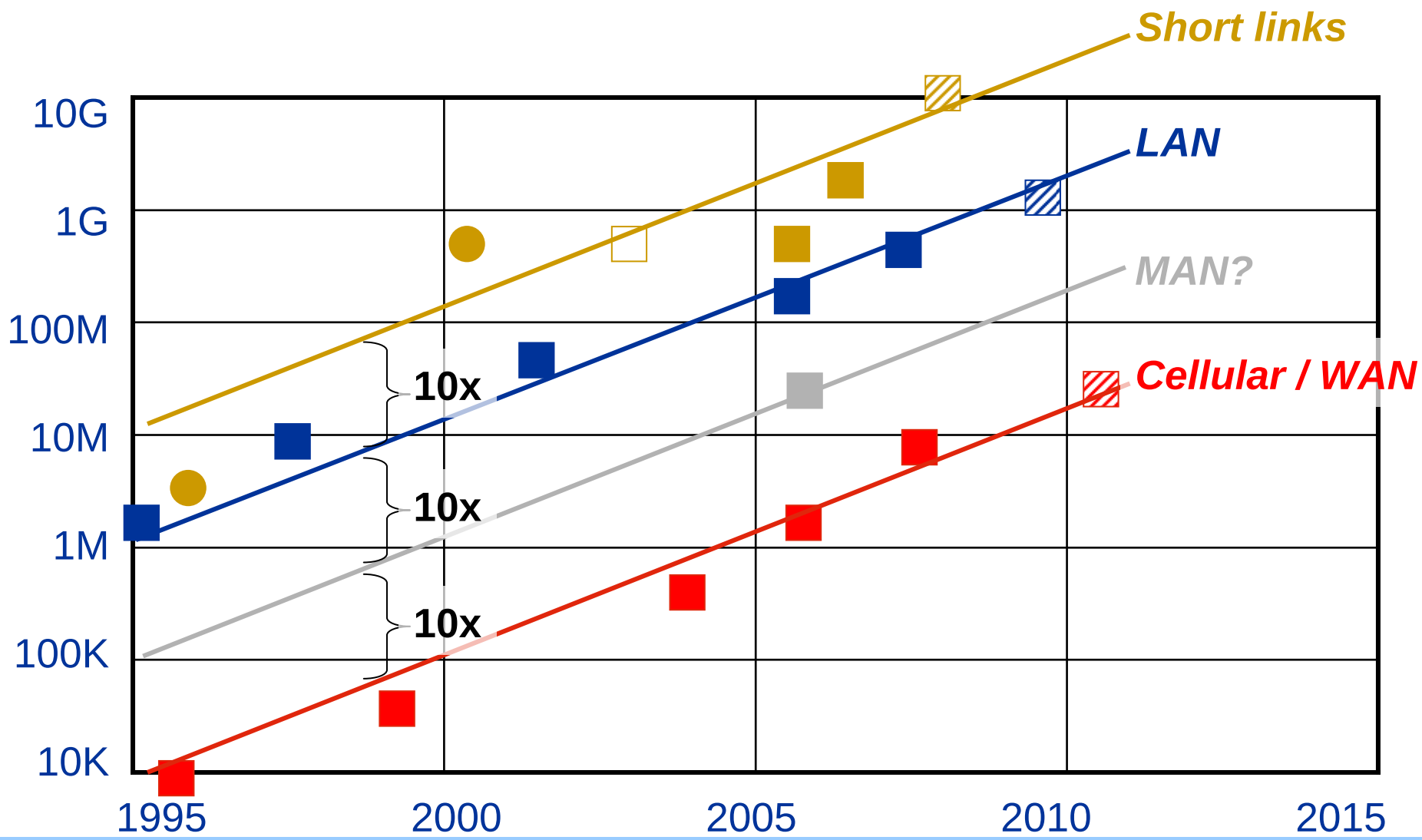


Classification

- **Short links**
  - One-to-one connections
  - Ease of use w/o mobility
  - 0.3-3m (1-10ft)
- **LAN**
  - Star connections of terminals to base with local coverage
  - Portability to low mobility
  - 3-30m (10-100ft)
- **MAN**
  - Hot-spot broadband networked coverage for metropolitan coverage
  - 30-300m (100-1000ft)
- **Cellular / WAN**
  - Network for full coverage and roaming
  - Mobility
  - 30-3000m (100-10kft)

Requirements

- Data rate of 1 Gbit/s wireless

1 Gb/s Data Rate

- Can it be done?

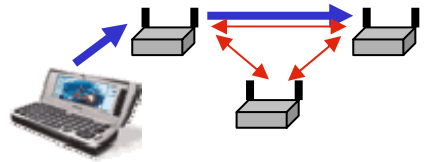
  in terms of …
  - RF performance
  - Base band processing power
  - Integration density
  - Protocols, radio resource management

Why WIGWAM???

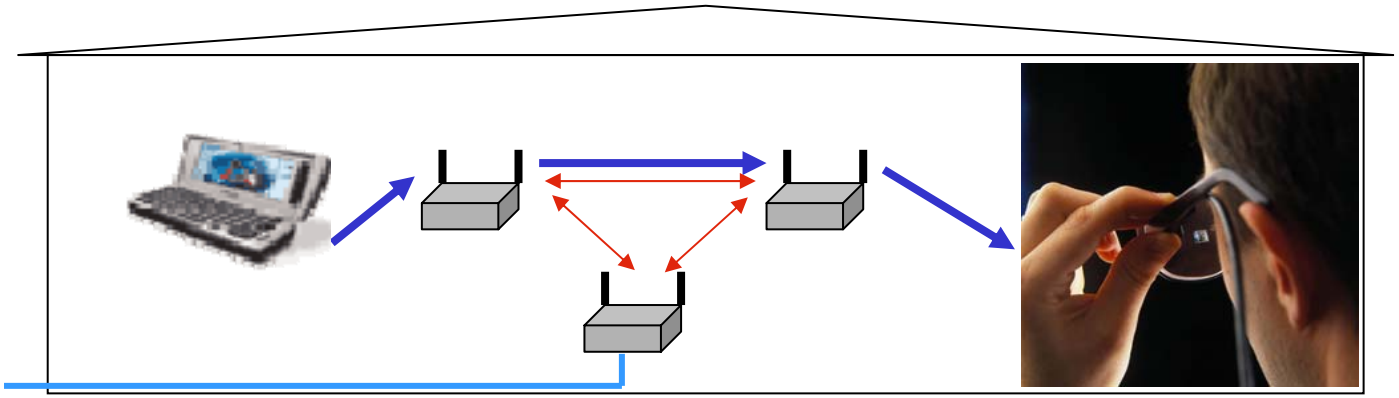
- Technological basis will be there.
- Therefore,
  - Gbit/s WLAN will happen around 2007-2009!
  - 2010: Broad commercial application
  - A standard and products cannot be held up!
- We do not want to watch passively,
  but want to contribute actively!

WIGWAM User Scenarios

- Definition of user scenarios in project phase I
  - 10/2003-03/2004
  - No technology or regulatory pre-assumptions
- Home scenario
- Office scenario
- Public access scenario
- High velocity scenario



1 Gbit/s at Home!



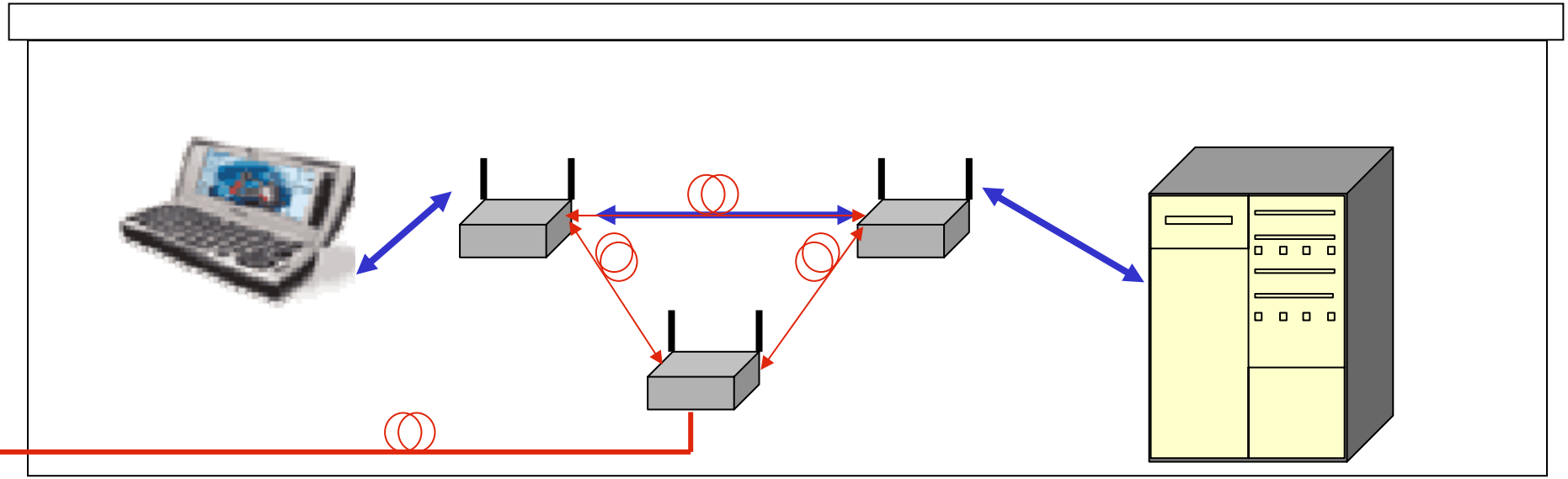
- Why 1 Gbit/s wireless?
  - Wireless connections follow wireline development !
  - Example: Wireline HDTV/H.264 rollout is gaining speed
    - 20 Mbit/s per application stream
    - 3 hops required ➔ 100 Mbit/s bandwidth per user
    - Multiple users/applications & bursty multimedia traffic

➔ >=1 Gbit/s required

Key Home Scenario Parameters

- Terminal Parameters
  - Velocity — 1 m/s (4km/h)
  - Size restriction — maximum miniPCI, better Flash-Card
  - Energy constraint — 0.5-2.0 Ah
  - Operating temperature — 0-50°C
- Traffic & MAC
  - Acceptable latency — 10 / 1000 ms
  - Delay jitter — < 1ms
  - Access points — asynchronous
- Features
  - Localization — no
  - Fallback — 802.11
  - Range — typ. 20m
- Channel
  - Typical delay — 0.3 μs
  - Delay spread — 0.015 / 0.03 μs
  - Channel exponent — 2.5 / 3.5
  - Doppler spread — 200 Hz (f_c = 5 & 60Ghz)

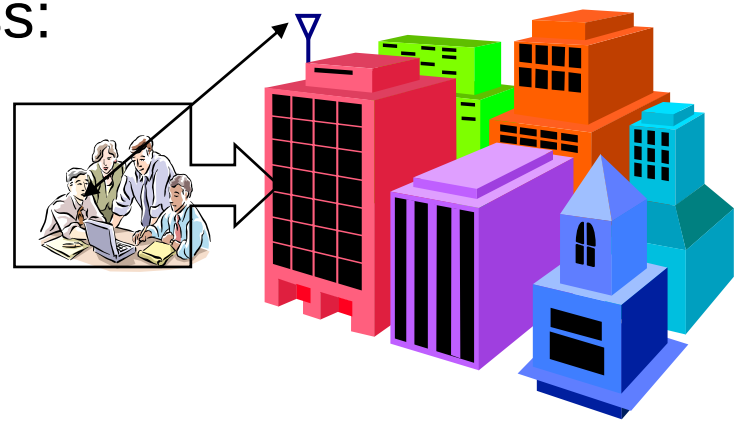
1 Gbit/s at the Office



we are used to: fixed 100 Mbit/s access:

- average on working day in 4-people-office: 1 Mbit/s
- peak in 4-people-office: 10 Mbit/s and more

→ very high “crest factor”



Key Office Scenario Parameters

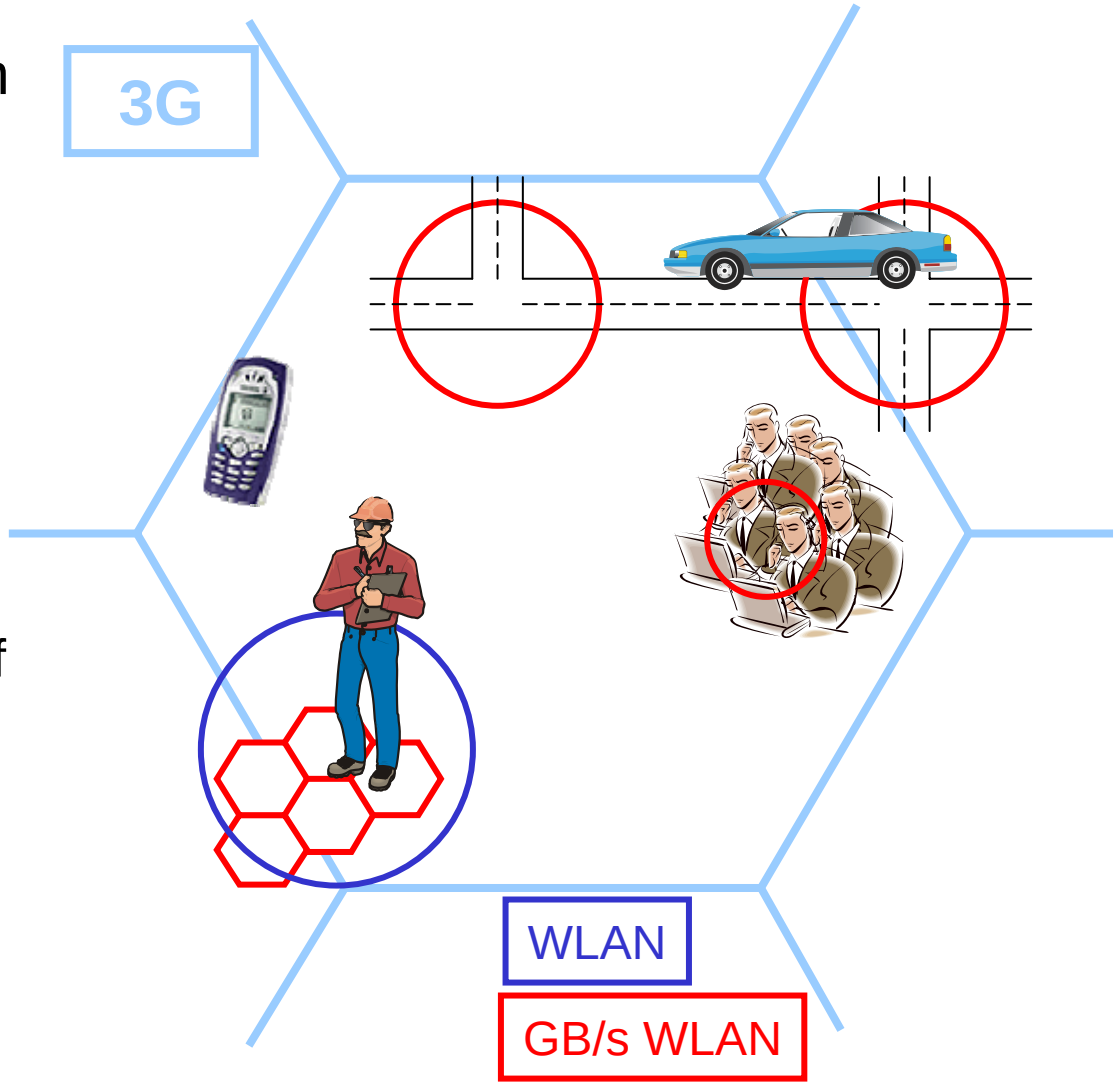
- Terminal Parameters
  - Velocity — 1 m/s (4km/h)
  - Size restriction — maximum miniPCI, better Flash-Card
  - Energy constraint — 0.5-2.0 Ah
  - Operating temperature — 0-50°C
- Traffic & MAC
  - Acceptable latency — 10 / 1000 ms
  - Delay jitter — < 1ms
  - Access points — asynchronous
- Features
  - Localization — no
  - Fallback — 802.11
  - Range — typ. 20m
- Channel
  - Typical delay — 1 μs
  - Delay spread — 0.15 / 0.3 μs
  - Channel exponent — 2.5 / 3.5 @ 5Ghz, 2.5 / 5.0 @ 60GHz
  - Doppler spread — 200 Hz (f_c = 5 & 60Ghz)

1 Gbit/s for Public Access?

"hot spots", e.g. lounges with

50 users at 80 m²

- connect "local" computers (100m range)
- Internet backbone provides best-effort service
- vertical & horizontal hand-off
- dramatic variation of max transmission bit rate during hand-off

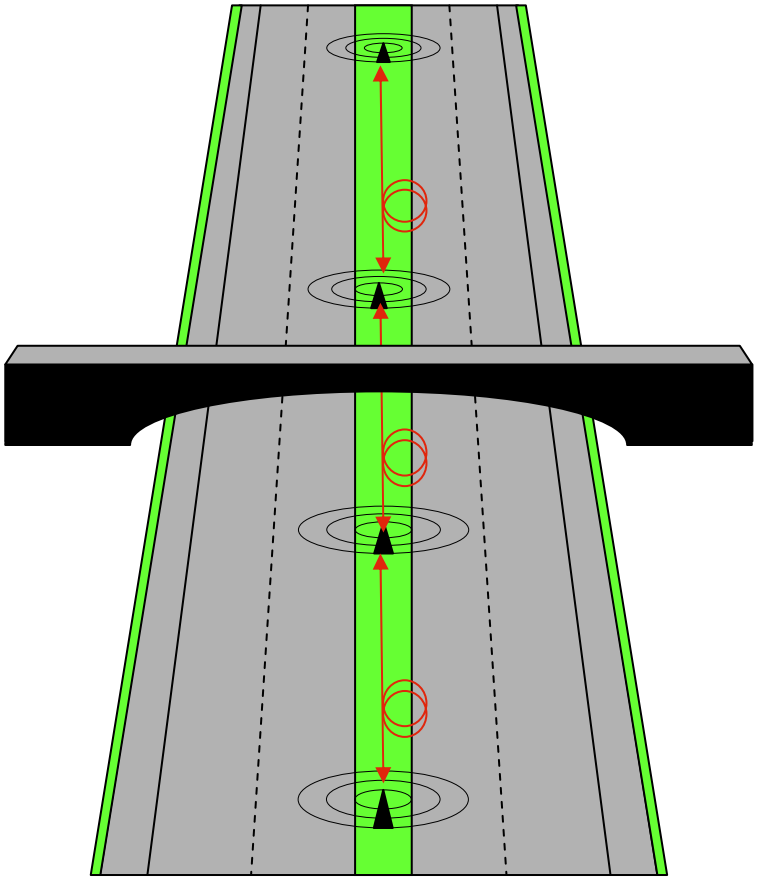


Key Public Scenario Parameters

- Terminal Parameters
  - Velocity — 0-5 km/h / 3-10 km/h / 60-100km/h
  - Size restriction — maximum miniPCI, better Flash-Card
  - Energy constraint — 0.6 Ah (PDA) – 6.0 Ah (laptop)
  - Operating temperature — -10°C – +50°C
- Traffic & MAC
  - Acceptable latency — 10 / 1000 ms
  - Delay jitter — 2-3ms streaming / 500ms packets
  - Access points — asynchronous
- Features
  - Localization — yes
  - Fallback — UMTS
  - Range — up to 500m
- Channel
  - Typical delay — 1 μs
  - Delay spread — 0.15 / 0.3 μs
  - Channel exponent — open
  - Doppler spread — 520 Hz (f_c = 5Ghz)

1 Gbit/s at High Velocity

- Freeway & Track information access



Key High Velocity Parameters

- Terminal Parameters
  - Velocity — 250 km/h – 600 km/h
  - Size restriction — ~ 1 liter
  - Energy constraint — “none”
  - Operating temperature — -40°C – +80°C
- Traffic & MAC
  - Acceptable latency — 10 / 100 ms
  - Delay jitter — 10/100 ms
  - Access points — asynchronous
- Features
  - Localization — yes (0.5m accuracy)
  - Fallback — GSM (UMTS)
  - Range — up to 3000m
- Channel
  - Typical delay — open
  - Delay spread — open
  - Channel exponent — 2 – 3
  - Doppler spread — 20 kHz (f_c = 5 & 38Ghz)

Some WIGWAM Features

- Frequency bands: **5 GHz** with extensions at 17,24,38 and **60 GHz**
- PHY/DLC Parameters
  - QoS enabled MAC: more than 1Gb/s cumulative user rate
  - Transmit power: 100/1000mW
  - Coding & modulation: OFDM, MIMO, LDPC-Codes, OFDMA/MC-CDMA, MC-SS Overlay
  - Transceiver size: MiniPCI or smaller
  - Antennas: minimum 2; 4x4
- Network Parameters
  - IP packet & streaming & VoIP network
  - Integration into 3GPP IMS (all IP) Core Network

Work Packages for Cross-Layer System Concept

System Concept	Hardware Platform	PHY	MAC DLC/RLC	Network Layer
TU Dresden With All Partners	Infineon DaimlerChrysler/ Uni Erlangen Telefunken IHP / FHG-IZM FhG-HHI, Uni Erlg. Nokia / Uni KA TUD	Siemens Telefunken / U Ulm FhG-HHI MEDAV / TU IL NOKIA TU-HH TUD	Philips Alcatel IHP TH AC Siemens / TU M Telefunken / TU B	Alcatel U KA Telefunken / TU B Philips / TH AC

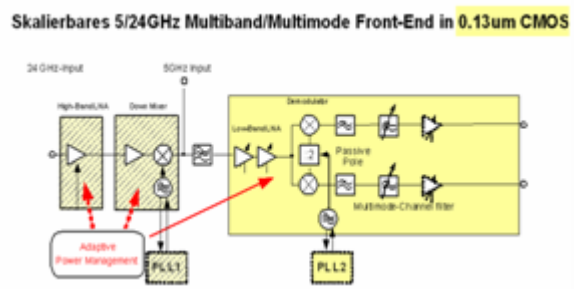
Work Package 2: Hardware Platform

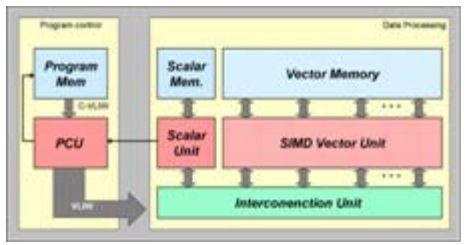
Infineon technologies
TECHNISCHE UNIVERSITÄT DRESDEN
ihp
DAIMLERCHRYSLER
TELEFUNKEN RACOMS
NOKIA

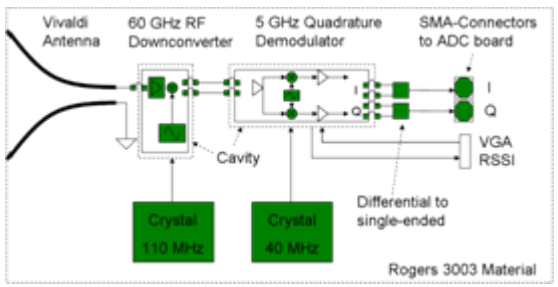
BB AFE Impairment Corrections

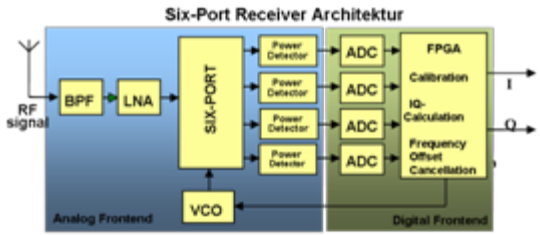
BB DSP Architectures

Analog Front End







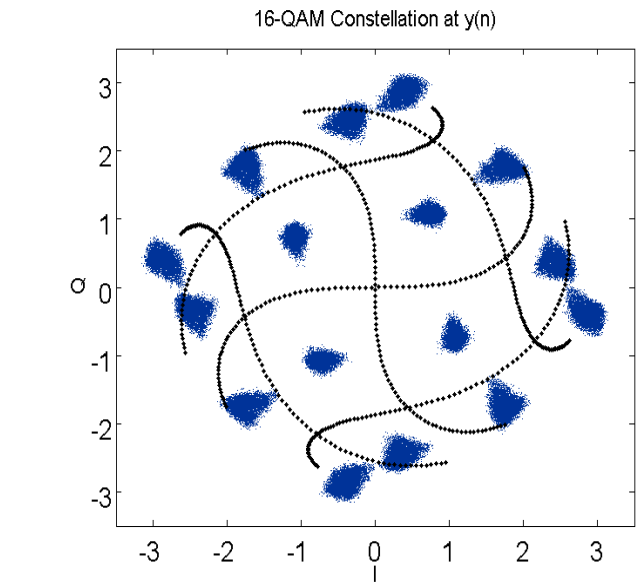


Work Package 2: Hardware Platform

BB AFE Impairment Corrections

BB DSP Architectures

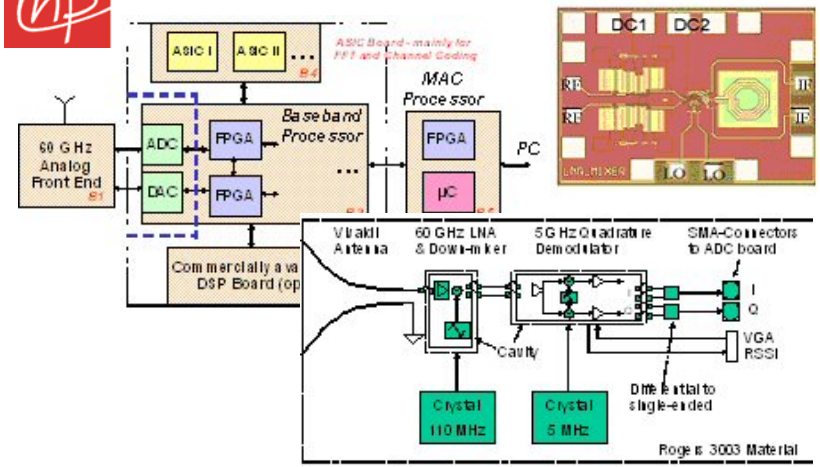
Analog Front End



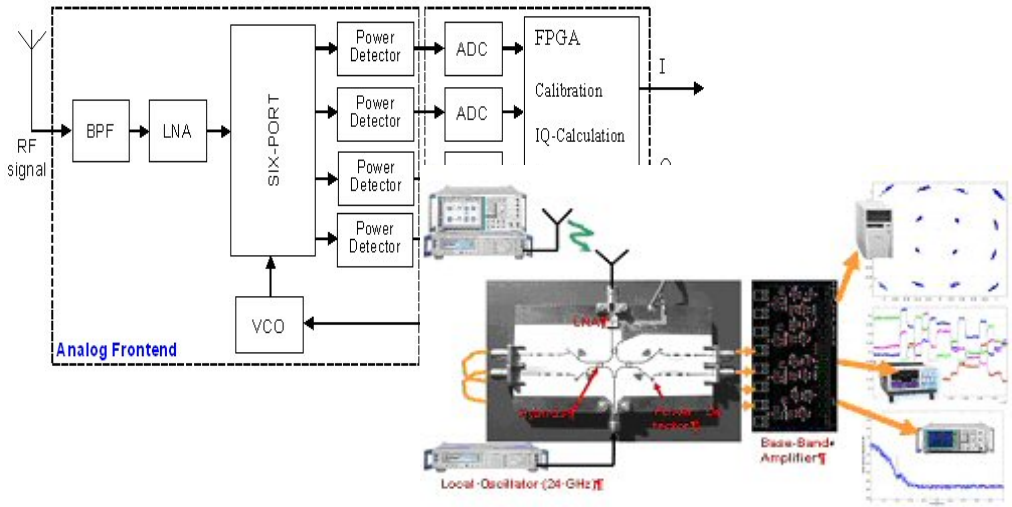
WP2: Hardware Platform

1.Generation Hardware-Demonstratoren beim Statusseminar Ulm, Juni 2005

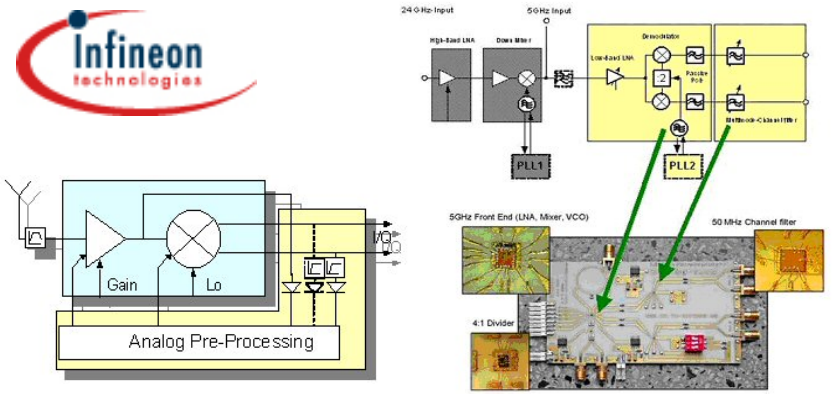
60GHz Demonstrator



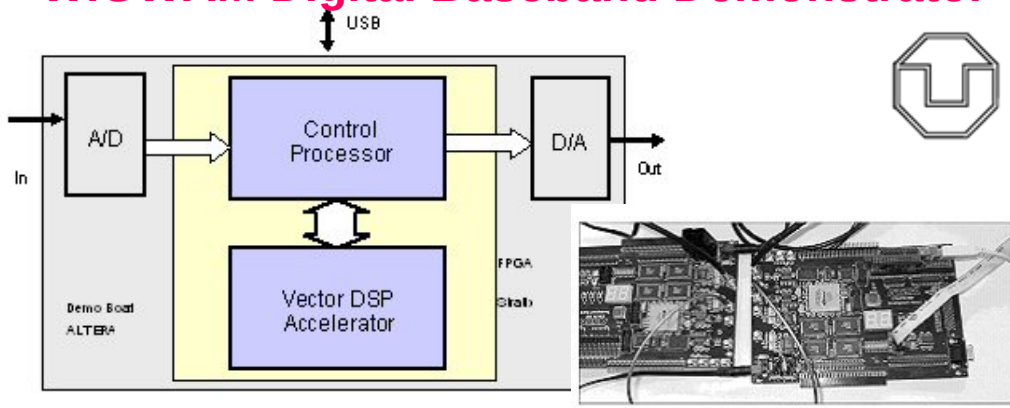
4GHz Six-Port



5/24GHz Multimode Receiver



WIGWAM Digital Baseband Demonstrator



Work Package 3: Physical Layer

SIEMENS NOKIA TELEFUNKEN RACOMS

MEDAV

TECHNISCHE UNIVERSITÄT DRESDEN

MAC Level PHY Specification

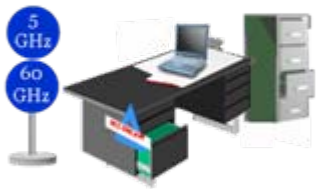
Channel Estimation and Synchronization

Modulation, Coding and MIMO

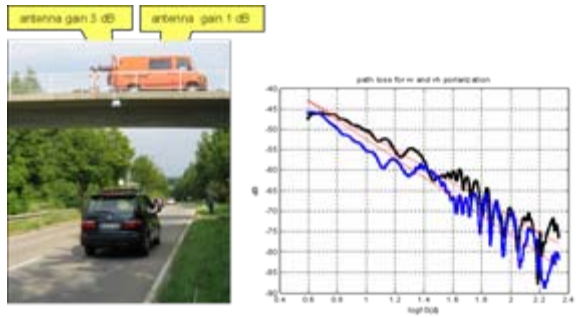
MIMO Measurement and Channel Modeling

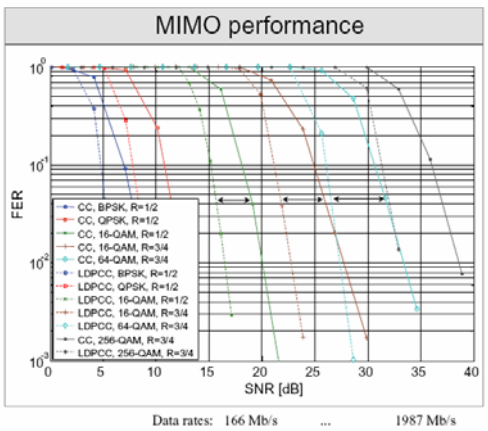
Public Access

Home / Office



High Velocity





Key PHY Features

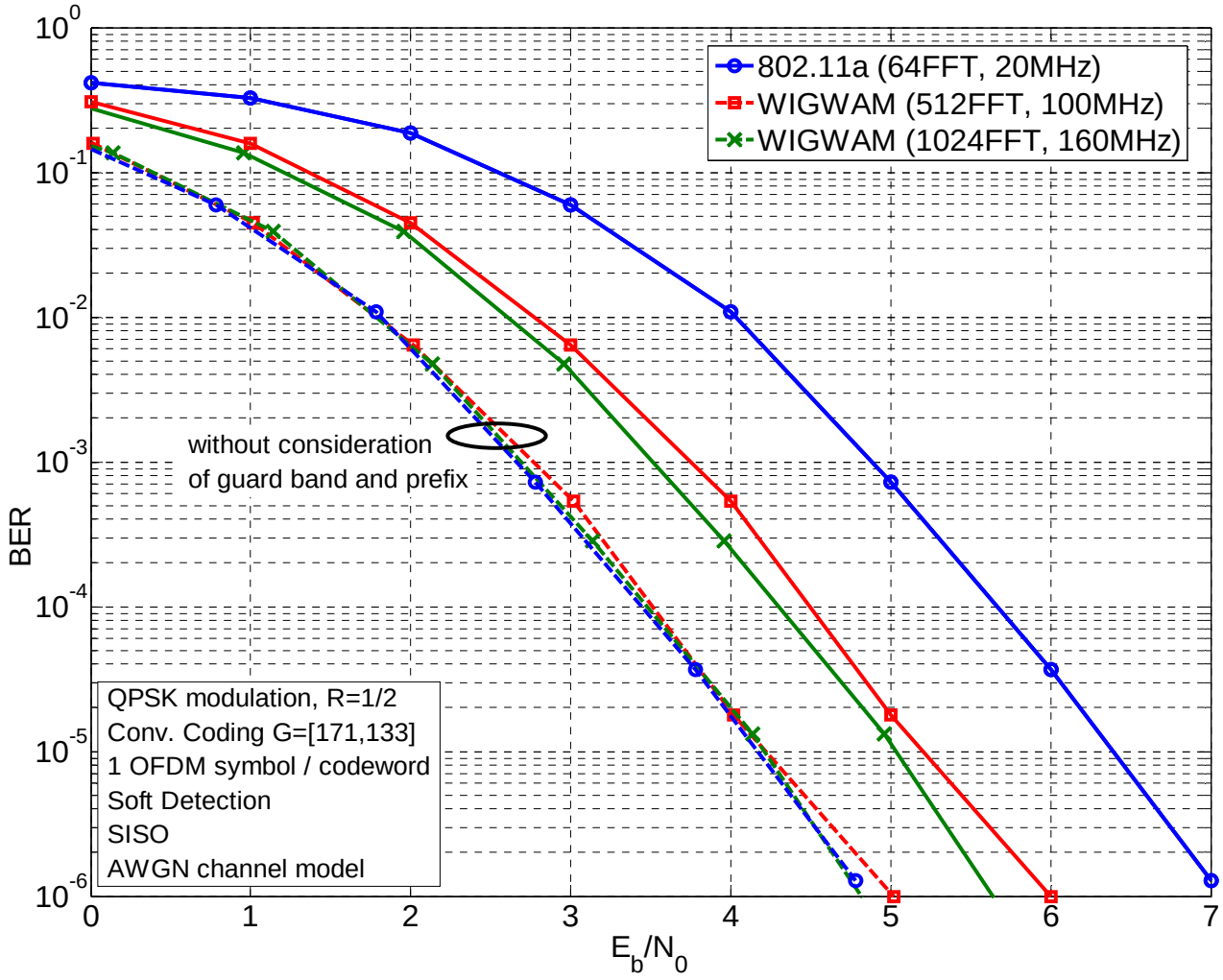
- Key features
  - OFDM system including OFDMA
  - n x 20 MHz (100 MHz), with OFDMA down to 1.25MHz
  - MIMO (up to 4x4) with adaptive concepts (with and without CSI @ Tx)
  - Advanced coding (LDPC, Turbo, Multi-Level Coding)
  - Multiple Access with competing concepts: OFDMA and MC-CDMA
  - Pilots with two competing concepts
    - Preamble for MIMO no longer as 802.11a/g
    - Superimposed (spread) pilots for delay shortening and capacity saving
  - Advanced scheduling (MIMO Multiuser)
  - System design based on extensive channel measurements @ 5 & 60 GHz

WIGWAM PHY Parameters

		Scenarios				
		Indoor/Office		Public Access	High Velocity	
		5 GHz	60 GHz	5 GHz	5 GHz	38 GHz
1	Bandwidth	100 MHz (*n* x 20 MHz)	500 MHz (400 MHz FFT)	80/100 MHz (n x 20 MHz)	40/50 MHz	40/50 MHz
2	Sampling time	6.25 ns	2.5 ns	6.25 ns	12.5 ns	12.5 ns
	Oversampling	1.6		2 / 1		
3	FFT Size	(512) / 1024	256	1024 / 2048	256	256
4	Freq.-Spacing	156.25 kHz	1.5625 MHz	78.125 kHz	312.5 kHz	312.5 kHz
5	TSymbol, eff	6.4 µs	640 ns	12.8 µs	3.2 µs	3.2 µs
6	TGuard	0.4 / 0.8 / 1.6 µs	<=160 ns	1.6 / 2.4 / 3.2 µs	0.4/0.8 µs	0.4/0.8 µs
7	Guard overhead	5.9%, 11%, 20%	<= 20%	11%/16%/20%	11%/20%	11%/20%
8	Symbol / frame	1 - 10				
9	Freq. Guard (TDMA)	3.75 MHz	100 MHz	3.75 MHz		
10	Interleaver size	1-10 OFDM sym.				

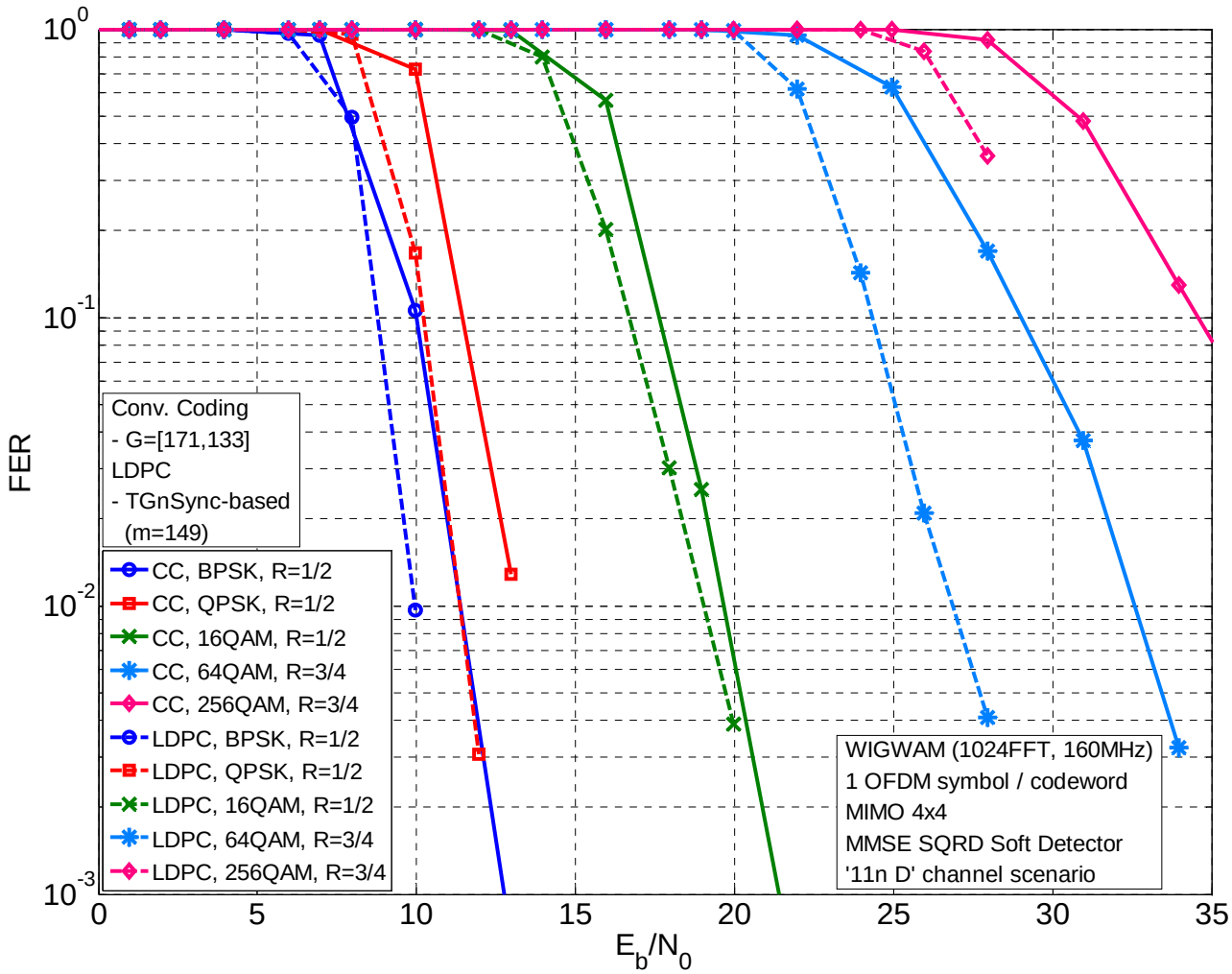
WIGWAM PHY - SISO Results

- WIGWAM home/office 5 GHz PHY with 596 carriers
- Transmission bandwidth 100 MHz
- Efficiency gain of 1 dB over 802.11a/g



4x4 MIMO: LDPC vs. CC

- WIGWAM home/office 5 GHz PHY with 596 carriers
- 4x4 MIMO
- Transmission bandwidth 100 MHz
- 802.11n D channel scenario (NLOS)
- Rx: MMSE SQRD
- LDPC gain higher than for SISO due to the larger codeword length



Link adaptation based on channel quality indicator

- Indicator dependent choice of modulation, coding, and MIMO concepts
- Analysis of different MIMO concepts dependent on available CSI:
  - Full channel knowledge @ Tx
    - Single stream ➔ MRC @ Tx (steering vector based on channel matrix)
    - Multiple streams ➔SVD MIMO spatial (SVD of channel matrix)
  - Partial channel knowledge @ Tx (channel cov. matrix available)
    - Single stream ➔ MRC BF (steering vector based on channel cov. matrix)
    - Multiple streams ➔ EigenBF (SVD based on channel cov. matrix)
  - No channel knowledge @ Tx
    - Single stream ➔ Space Time Coding (optional)
    - Multiple streams ➔ Spatial Multiplexing

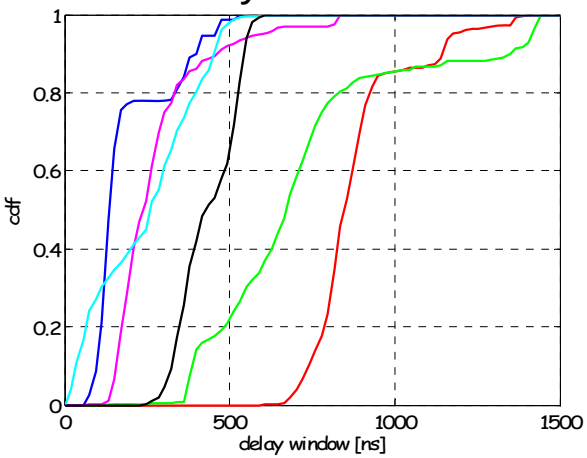
Channel Measurements

- Measurements by MEDAV, TU Ilmenau and Siemens
- Delay Dispersion, Angular Spread etc.

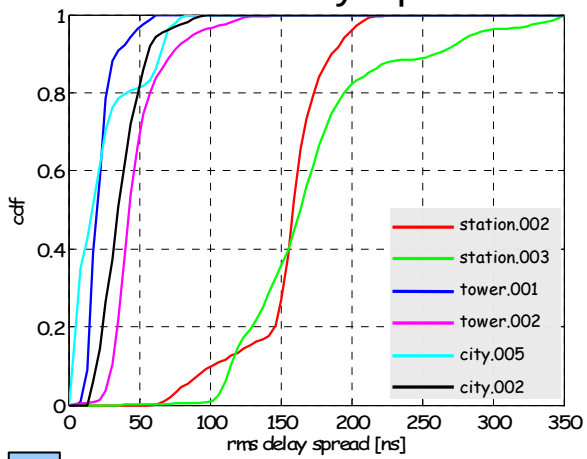
PHY design based on measurements

MIMO-Channel measurements
@ 5 GHz
- City (Munich)
- Railway Station
- Tower

Delay Window

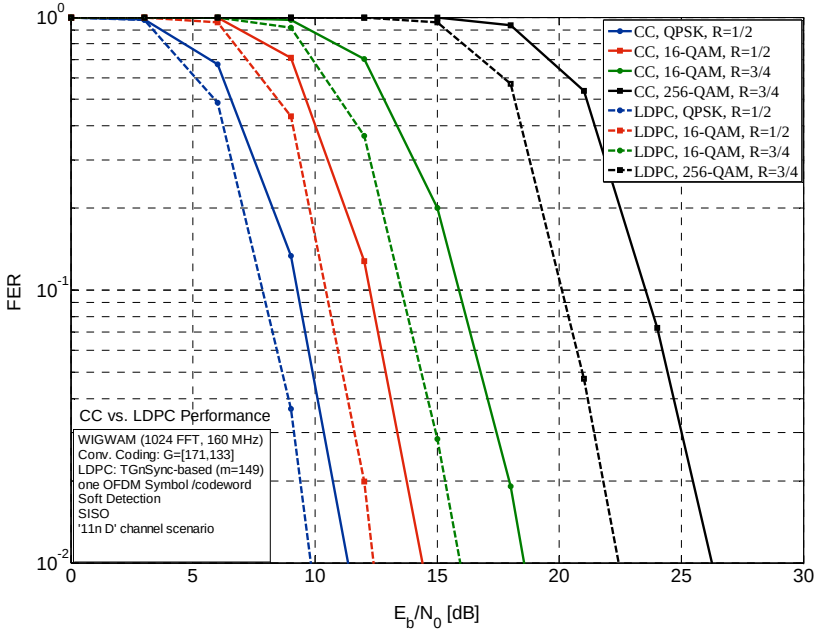


RMS Delay Spread



Definition of PHY parameters for WIGWAM scenarios based on actual measurements

FER-simulations of transmission modes with LDPC-Coding



Work Package 4: MAC / DLC / RLC

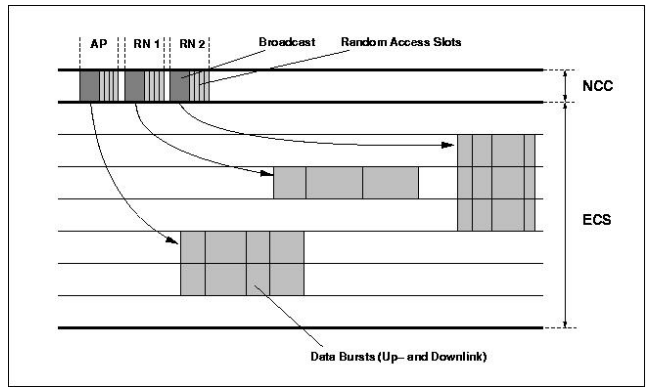
PHILIPS ALCATEL SIEMENS ihp TELEFUNKEN RACOMS

MAC

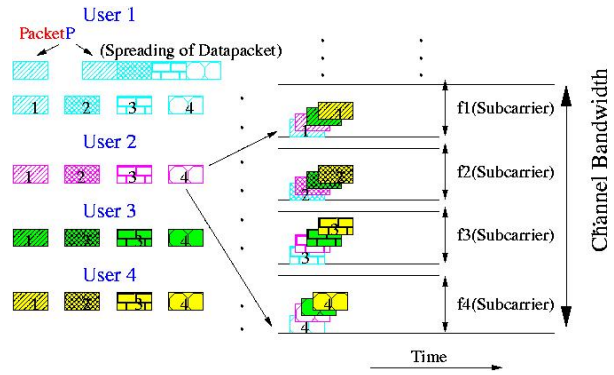
Centralized and Non-centralized Networks Multihop

Homogeneous Fast Handover Support / MxRRM

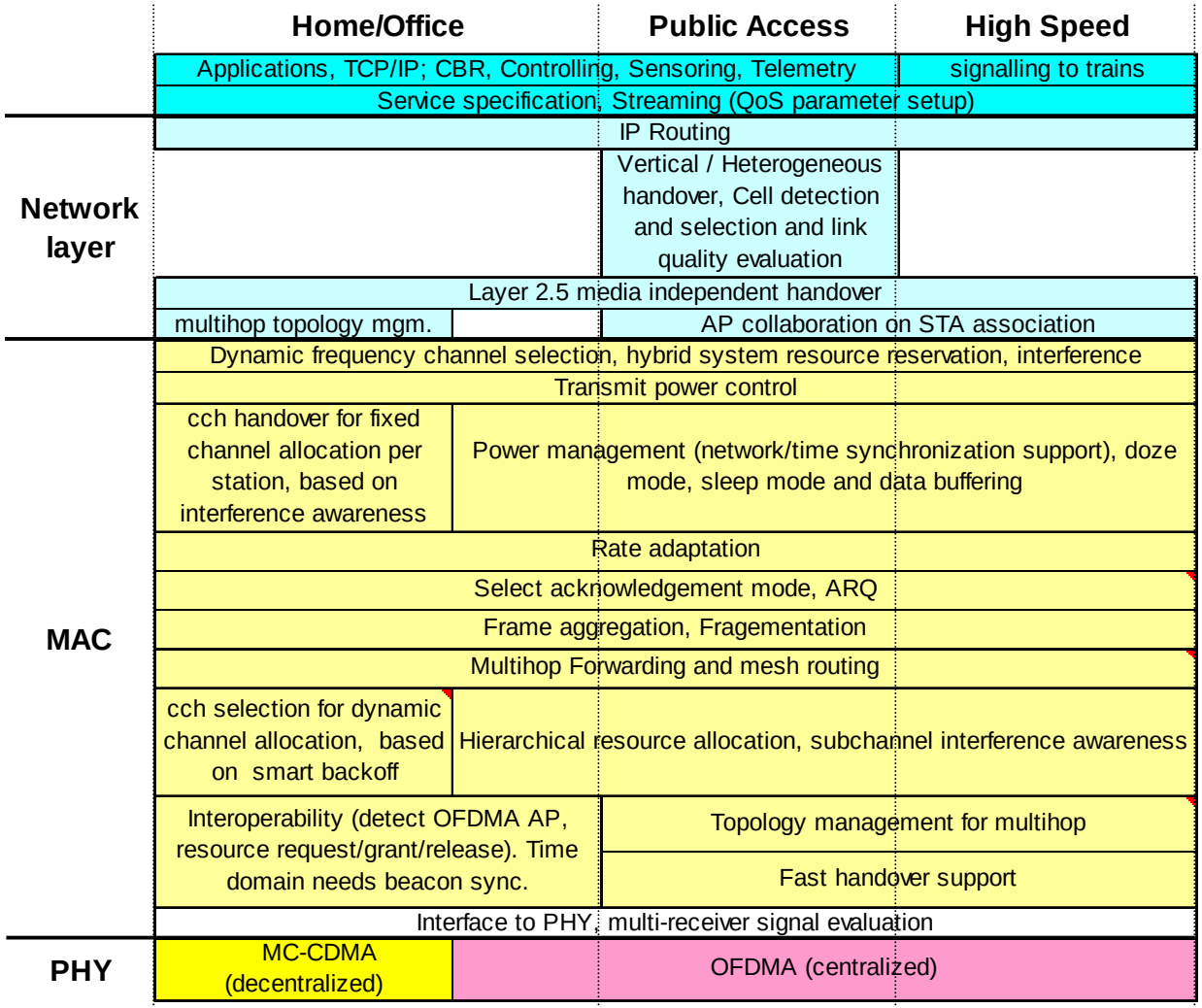
- OFDMA



- MC-CDMA

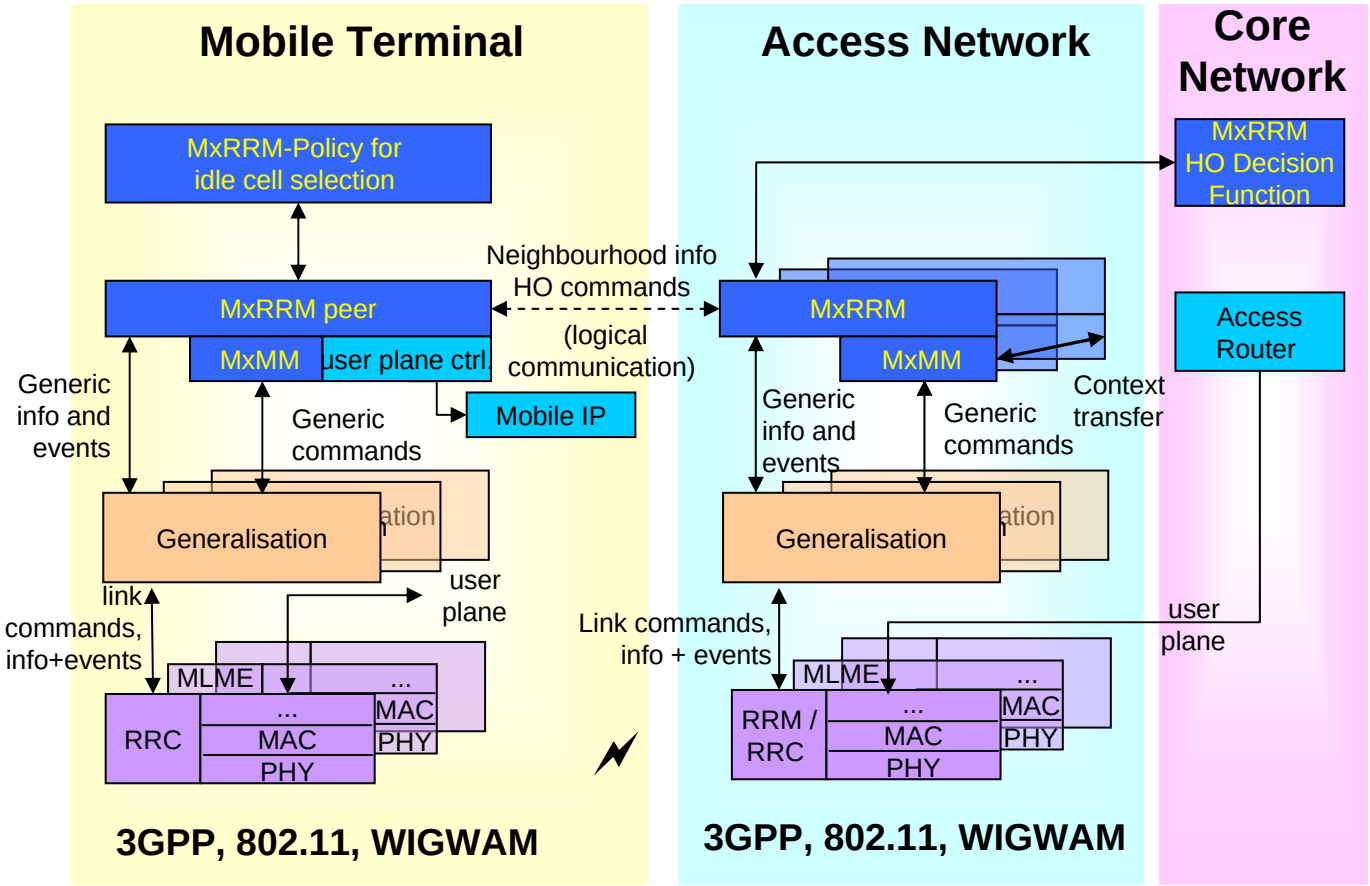


Work Package 4: Reference Architecture



WP4: Reference model for heterogeneous Hand-Over

Public access MxRRM/MxMM - MAC/PHY Interfaces



- Network side based HO decision (MxRRM)
- Heterogeneous mobility by MxMM functions
- Interworking layer for generalisation of radio specific measurements, events & commands
- radio technology specific interf. to lower radio layers

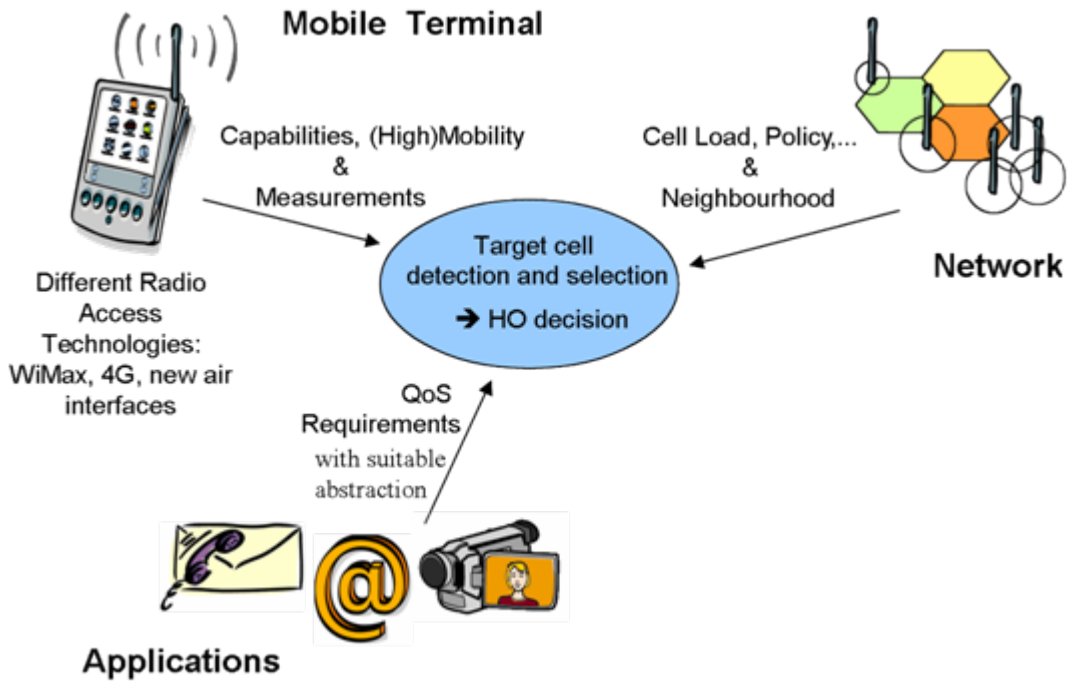
Work Package 5: Network Layer

ALCATEL
PHILIPS
TELEFUNKEN RACOMS

Mobility Management Architecture

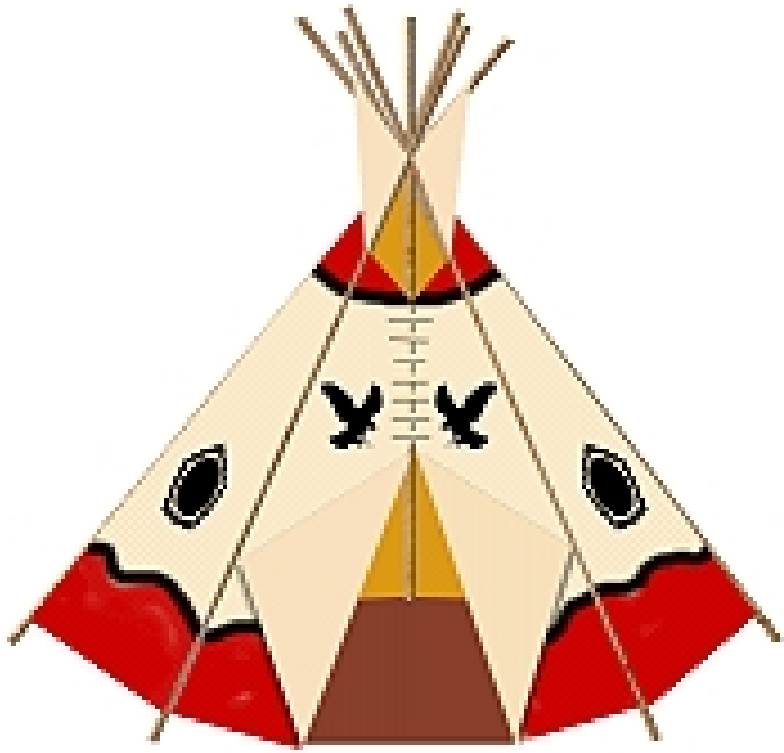
Mobility Management Protocols and Mechanisms

IP Layer Protocols



WIGWAM Demonstrators

- Alcatel: Heterogenous Handover
- DaimlerChrysler: Six-Port Receiver for mm-Wave
- IHP: Components for 60 GHz WIGWAM Demonstrator
- Infineon: 5/24 GHz Multiband/Multimode Front-End in CMOS
- MEDAV: UWB demonstrator with 60 GHz Frontend and test antennas
- Philips: Easy and Secure wireless home network
- Telefunken: Demonstrator High Velocity Scenario
- TU Dresden: Vector Baseband Processor



WIGWAM
Project End
2007

WIGWAM
System Concept
November '05

Thanks *!*

www.wigwam-project.com