THE GPRS ERA AT COMNETS - WORLD LEADERS IN STANDARDISATION, IMPLEMENTATION AND DEPLOYMENT

Peter Stuckmann, Götz Brasche, and Peter Decker

and some info on FP7☺

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Verwaltungsrat

Europäische Kommission

GD Informationsgesellschaft und Medien

European Commission
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Outline

- ComNets leading early research in cellular packet radio
- GPRS Standard based on ComNets Research
- ComNets has been leader in traffic engineering and deployment rules
- Future of packet radio and opportunities in FP7

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ComNets leading early research in cellular packet radio

- 1991: ComNets presenting basic ideas at Mobile Radio Conference Nizza (predecessor of today's Mobile World Congress):

  [1] Walke, B. and Mende, W. and Decker, P. and Crumbach, J.:Performance of CELLPAC, a packet radio protocol proposed for the GSM mobile radio network. In Proceedings of Mobile Radio Conference 1991, p.p. 57-63, Nizza, France, 11/1991

- 1991-1997: Design, prototype implementation and performance evaluation of MAC protocols for the GPRS air interface

  [2] G. Brasche: Evaluation of a MAC Protocol proposed for a General Packet Radio Service in GSM, in Proceedings of IEEE Personal, Indoor and Mobile Radio Communications (PIMRC '96), Taipei, Taiwan

- 1997: ComNets publishing the first major research article in IEEE ComMag on GPRS leading to international recognition:

  [3] Brasche, G. and Walke, B. Concepts, Services and Protocols of the New GSM Phase 2+ General Packet Radio Service. IEEE Communications Magazine, Volume 35, Issue 8, Aug. 1997

- First generation **GPRSIM** simulation tool as the basis

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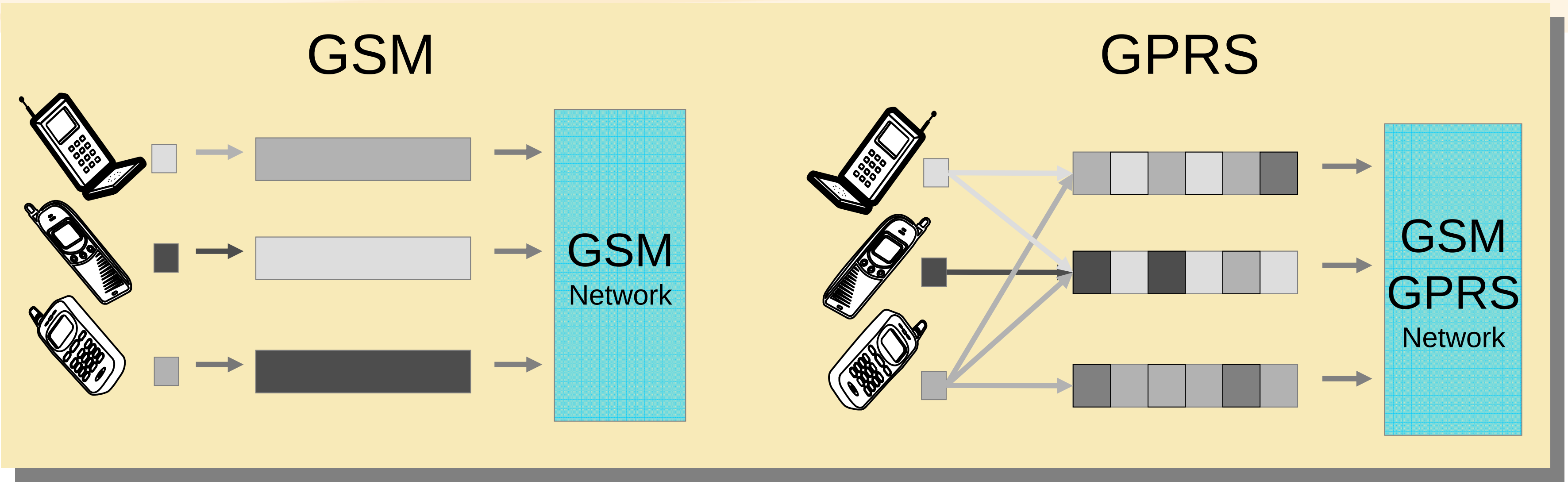
From Circuit-switched to Packet-switched



Benefits for User:

- Higher Data Rates
- Always on
- Volume-based charging

Benefits for Operator:

- Multiplexing/efficiency gain
- Smooth integration into GSM infrastructure
- Capacity-on-demand principle

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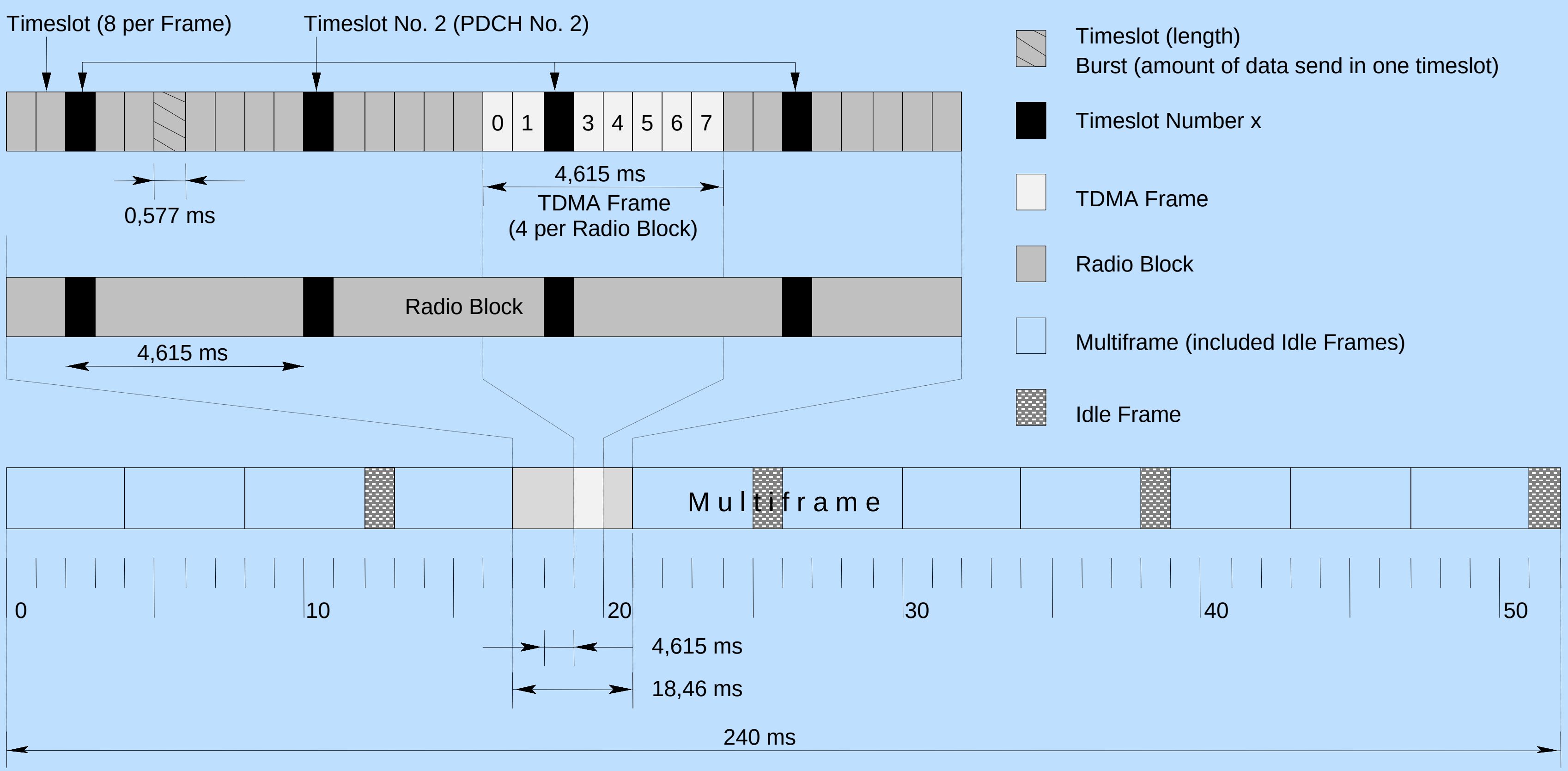
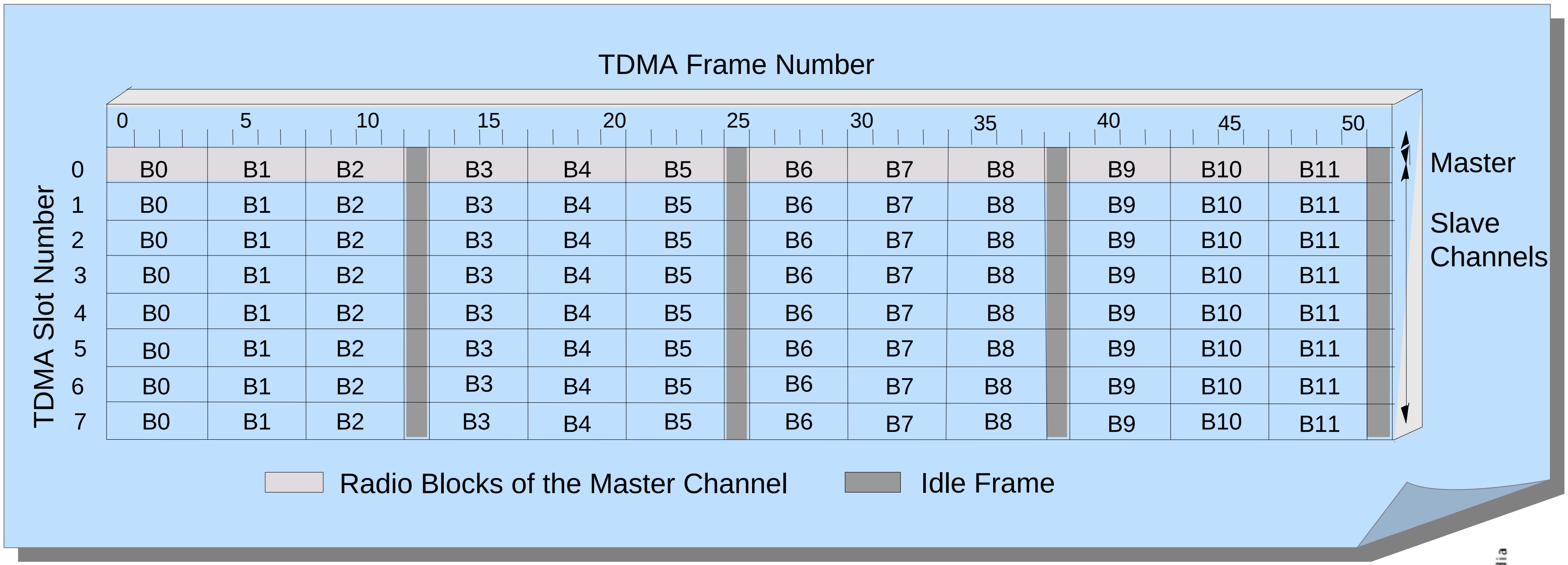
GPRS 52-Multiframe Structure



Four consecutive TDMA Frames are combined in one Radio Block

GPRS Channel Structure



Two types of Packet Data Channels:

- Master Channels (used for broadcast of basic system information)
- Slave Channels

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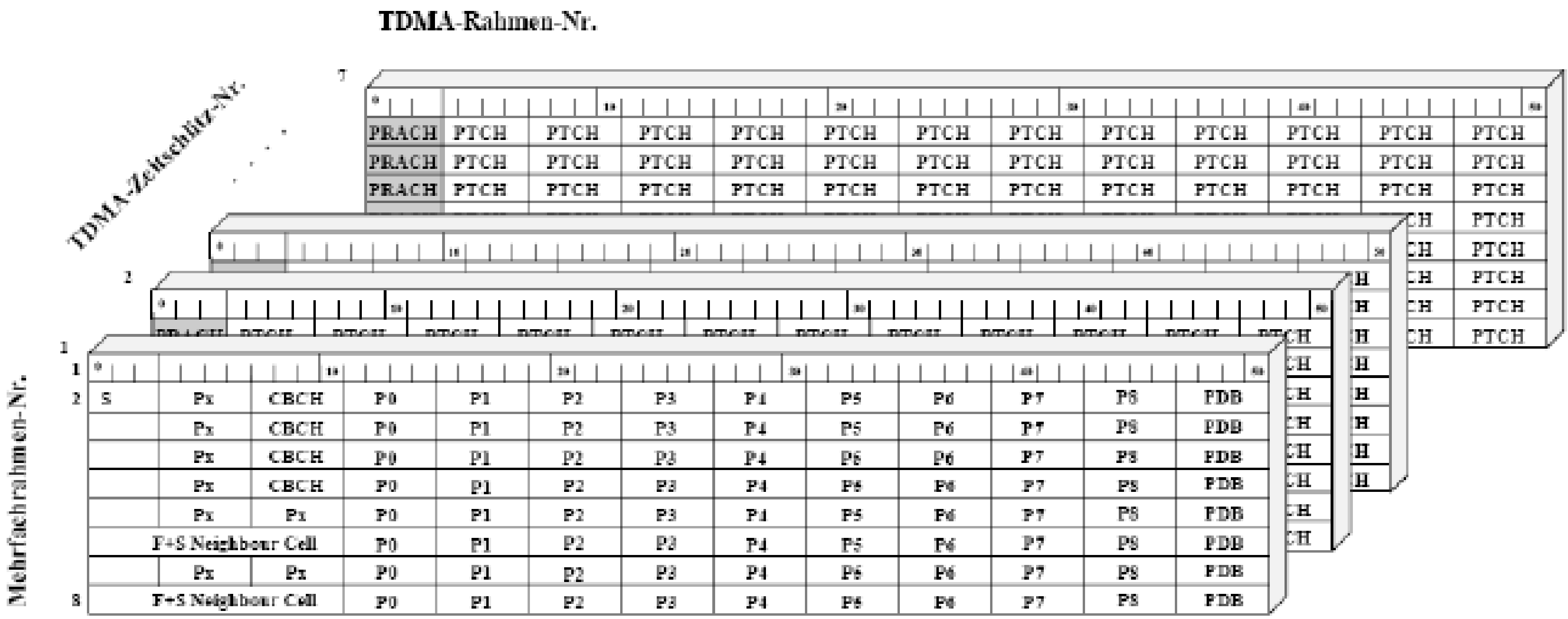
Remember: master slave dynamic rate access (MSDRA) - Initial Idea for GPRS frame structure



Source: Brasche, G. and Walke, B. Concepts, Services and Protocols of the New GSM Phase 2+ General Packet Radio Service. IEEE Communications Magazine, Volume 35, Issue 8, Aug. 1997 Page(s):94 - 104

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Typical simulation results at that time [2]

C. Simulation Results

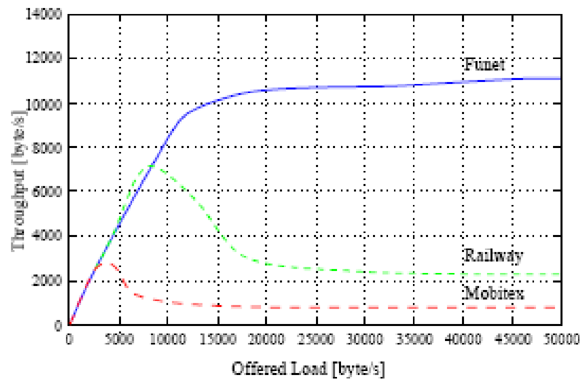

Figure 12: *Throughput with SS Assignment*

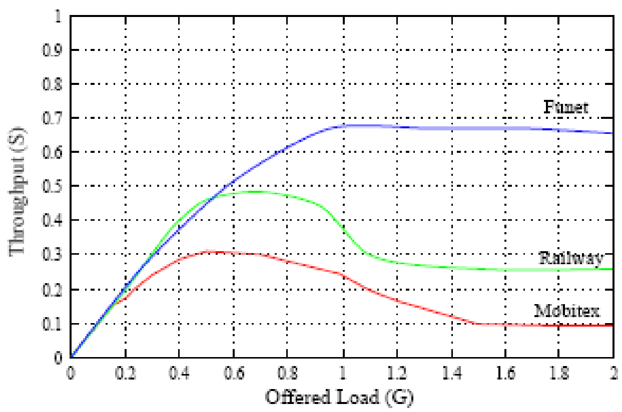

Figure 13: *Throughput with MS Assignment*

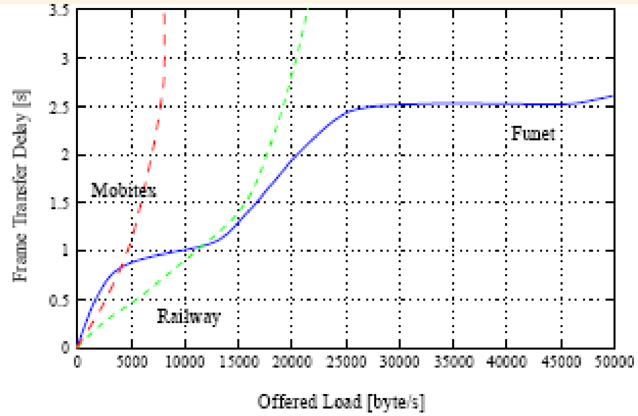

Figure 15: *Frame Transfer Delay Single Slot*

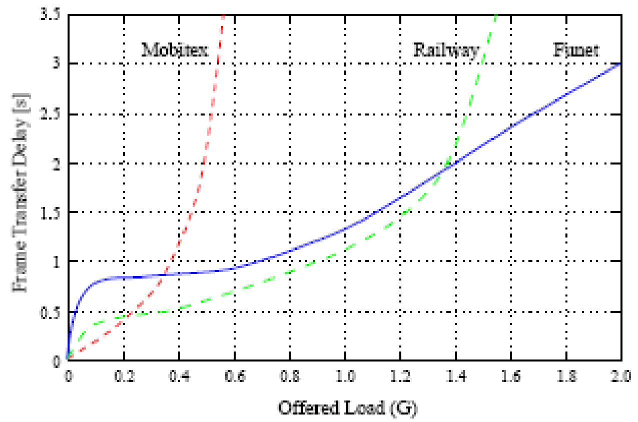

Figure 16: *Frame Transfer Delay Multi Slot*

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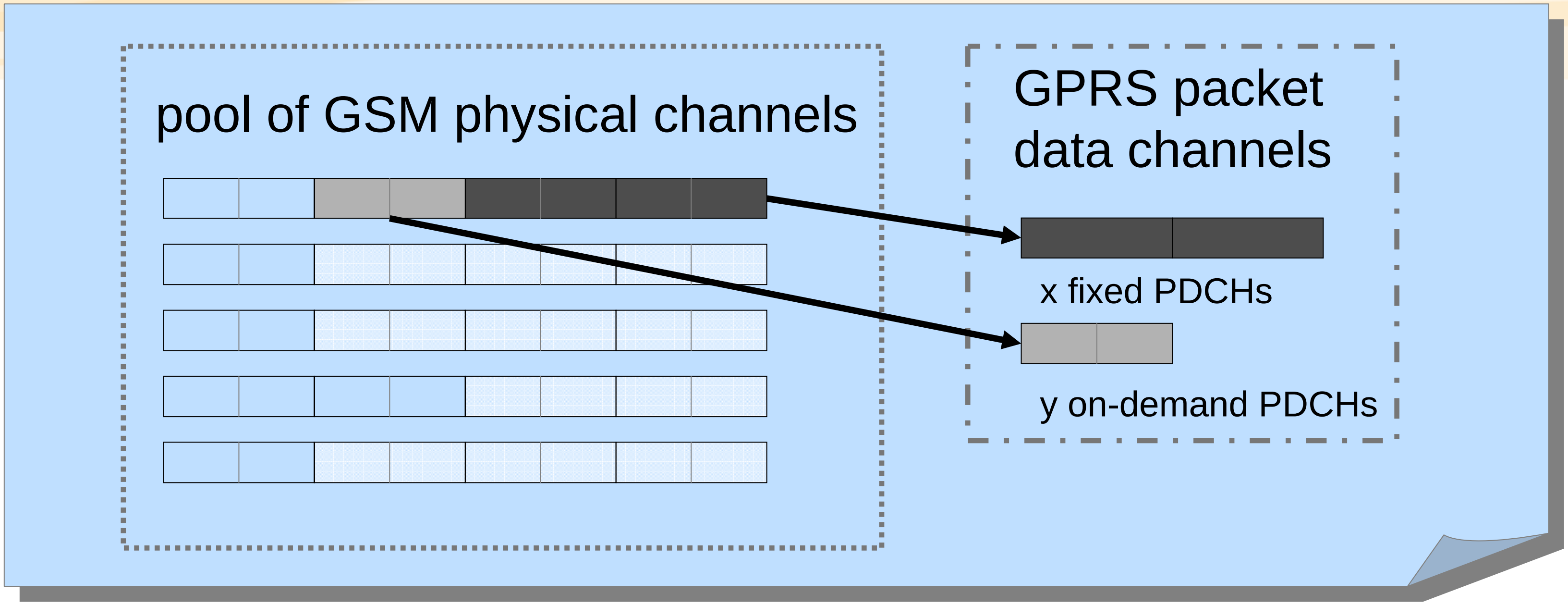
Assignment of GSM Channels for GPRS



- **Packet Data Channels** (PDCHs) assigned out of pool of GSM physical channels
- **Fixed PDCHs** are permanently available
- **On-demand PDCHs** only available if not used for GSM circuit-switched traffic

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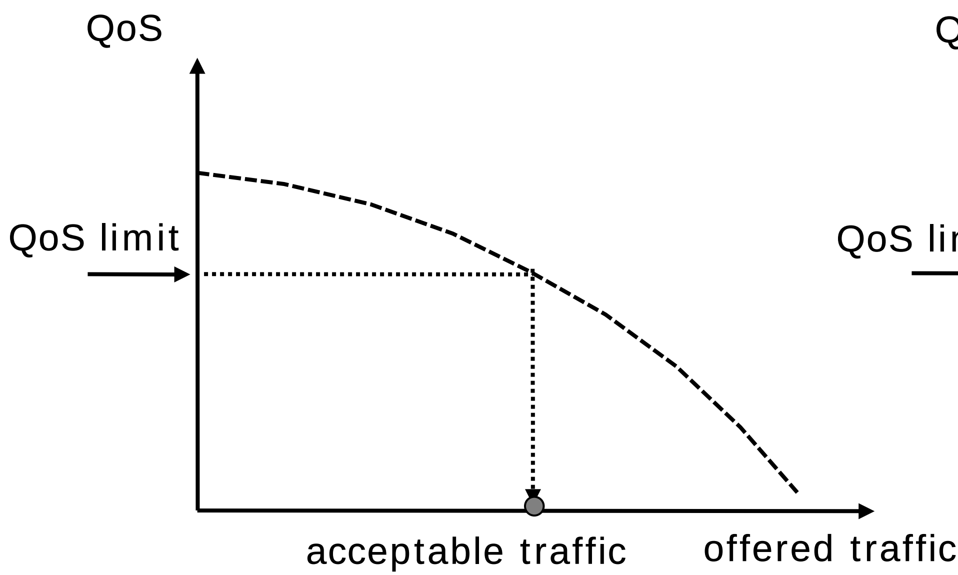
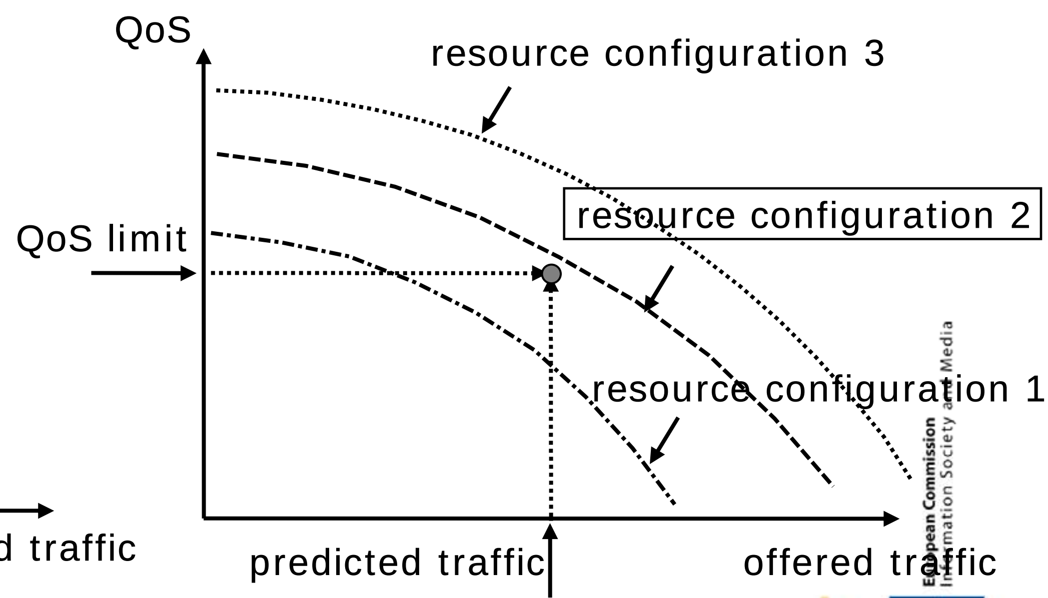
Dimensioning Approach

- Dimensioning graphs for application-specific performance measures
- Valid for the cell and load scenarios of interest
- Applicability: only based on user number/ traffic volume in the busy hour
- Accuracy: derived from realistic models for the protocol stacks, traffic patterns and radio channel





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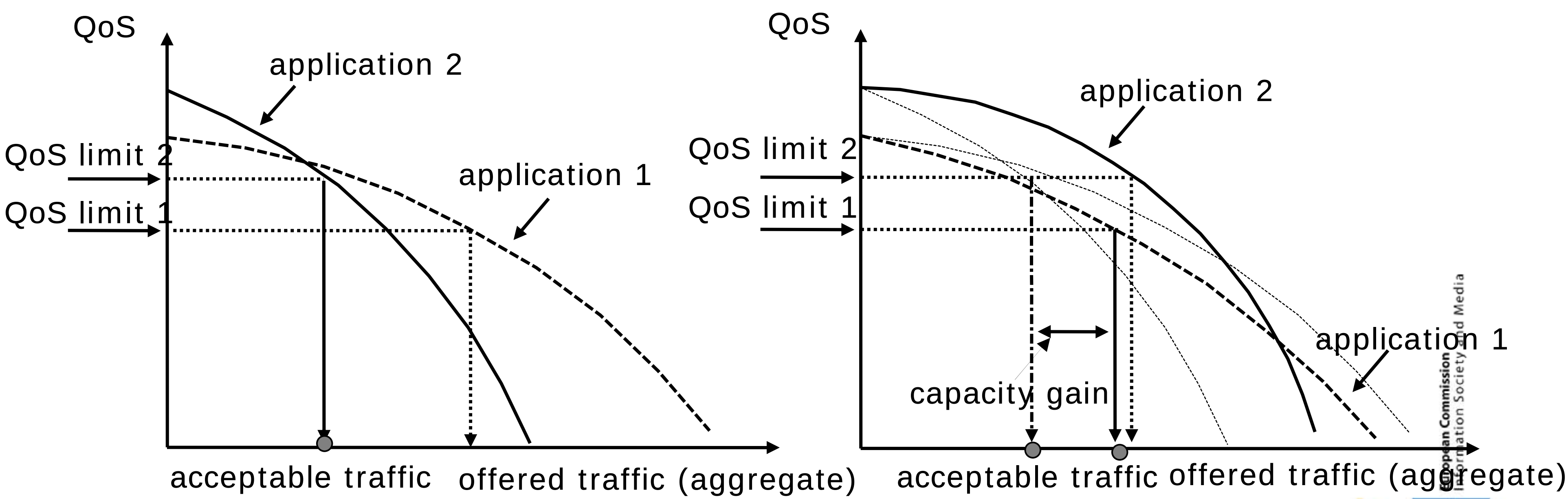
Traffic Management

- Increase performance for best-effort services
  - Coupled RLC/MAC implementation considering urgency of RLC blocks for MAC scheduling
  - MAC scheduler considering link quality
- Support application-specific QoS (class differentiation on MAC level)
  - Priority queuing
  - Fairer scheduling algorithms introducing weights for traffic classes



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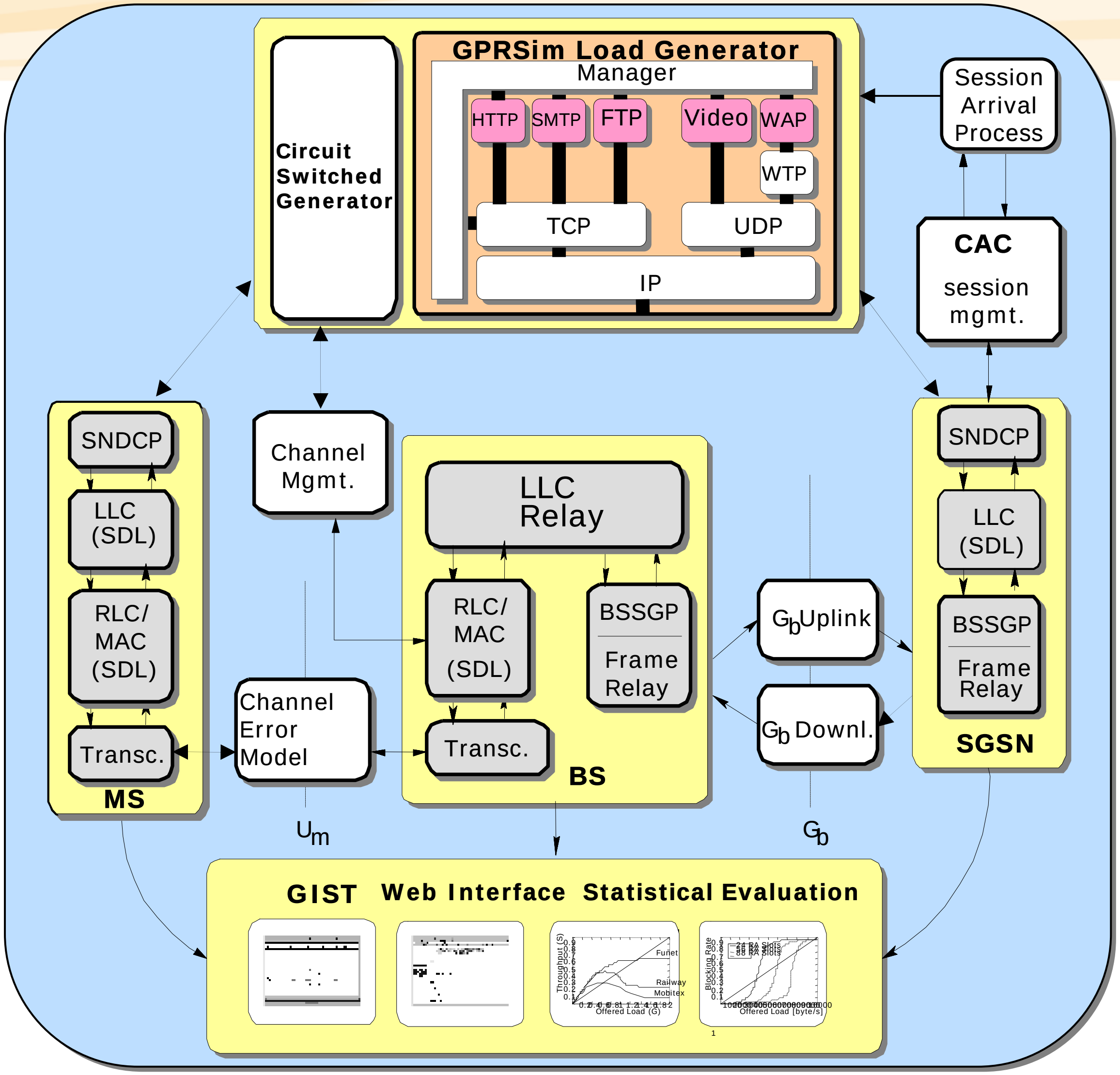
Multimedia Traffic Modelling

- Aim
  - definition of user profiles
  - characterization of sessions
- Predicted applications for mobile users
  - Internet (WWW, e-mail, FTP)
  - Wireless Application Protocol (WAP)
  - Streaming (Video & Audio)
  - Video-Conferencing, VoIP
- Methodology
  - Use measurement results for fixed Internet from literature
  - Perform own measurements
  - Use standardized models (e.g. UMTS 30.03)
  - Use market prediction studies

GPRSIM – The Second Generation



- Event-driven Simulator based on C++ and SDL
- Prototype implementations of protocol stacks at
  - *Mobile Station* (MS)
  - *Base Station* (BS)
  - SGSN
- Stochastic traffic models to generate well-defined traffic load
- Channel and mobility models
- Evaluation and graphical representation
- Validation by measurement

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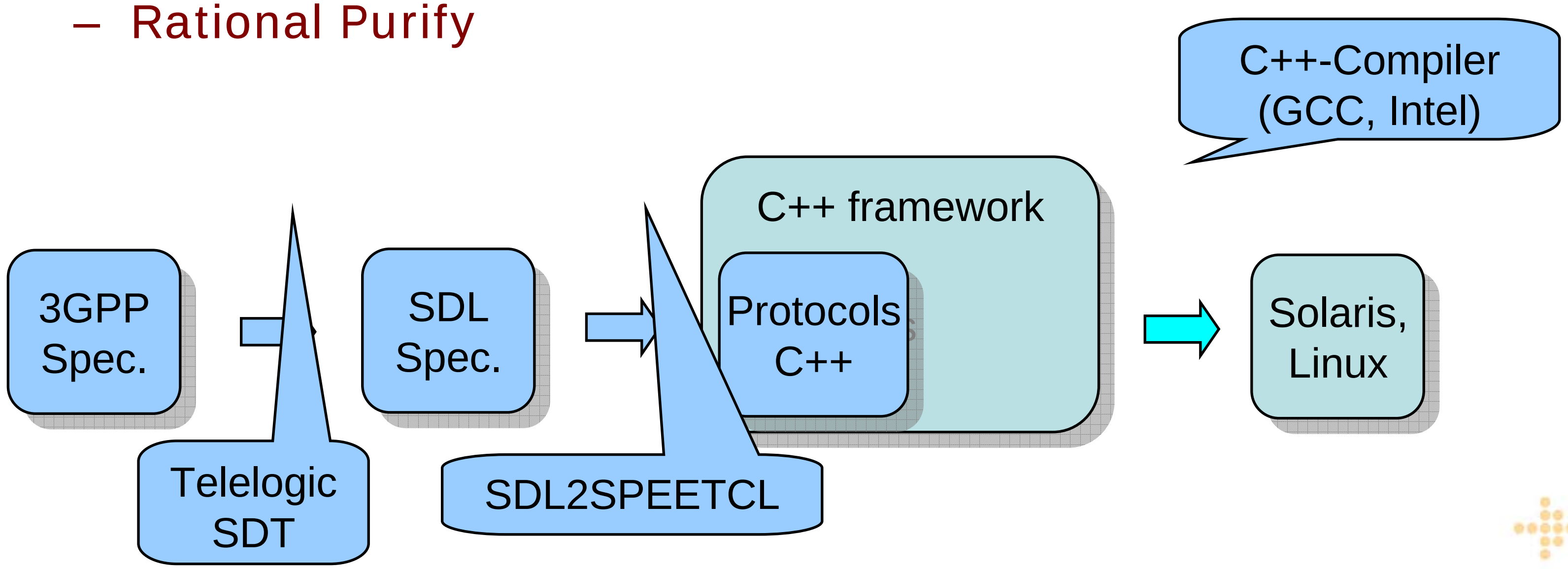
Development Framework

- Specification of protocols and application models in SDL/GR
  - Telelogic SDT
- Generation of C++-Code from SDL/PR specification
  - ComNets/Aixcom SDL2SPEETCL
- Code generated from SDL spec. embedded into C++ framework
  - GNU tools (emacs, gdb, CVS)
  - Rational Purify



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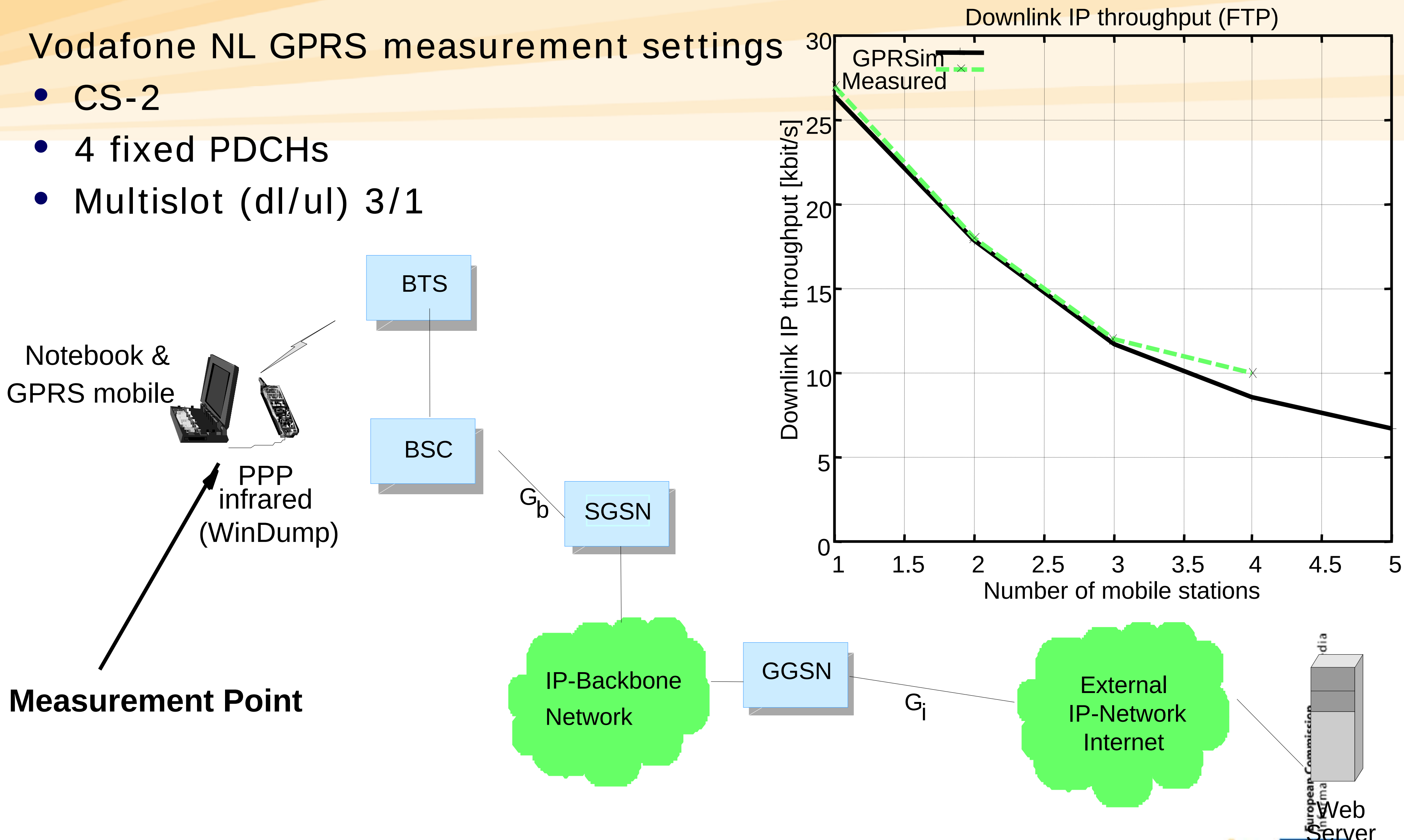
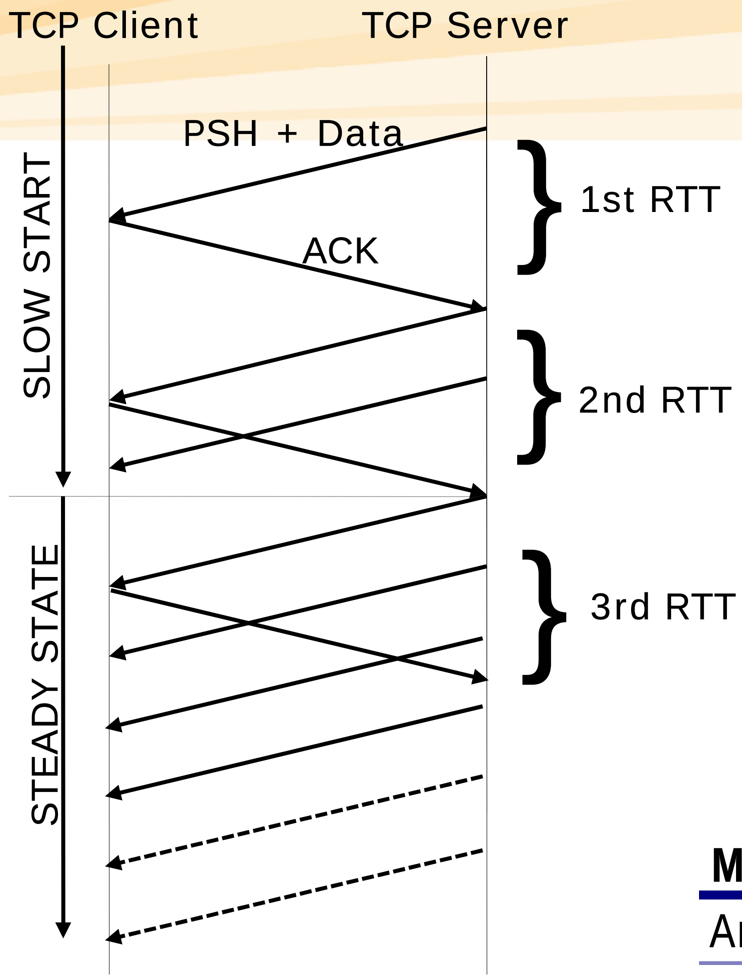
Validation II (Measurement)

Vodafone NL GPRS measurement settings

- CS-2
- 4 fixed PDCHs
- Multislot (dl/ul) 3/1



Validation I (Analytical TCP Model, Meyer2001])



Transmission time t for a file of size F:

$$t(F) = N_{SS}(RTT + TBF_{setup}) + \frac{(F - B_{SS})}{R_{TCP}} + D_{LCH}$$

Transition to steady state with the number of Round-trip periods N_{ss}:

$$RTT \leq \frac{W_{init} MSS}{R_{TCP}} k_{SS}^{N_{SS}} \quad \Leftrightarrow N_{SS} = \left\lceil \frac{\log\left(\frac{R_{TCP}(RTT + TBF_{setup})}{W_{init} MSS}\right)}{\log(k_{ss})} \right\rceil$$

Amount of data B_{ss} transmitted in slow start:

$$B_{SS} = W_{init} MSS \left(\frac{1 - k_{SS}^{N_{SS}}}{1 - k_{SS}} \right)$$

Model	WWW (3700 byte)	e-mail (1 kbyte)
Analytical	14.9 kbit/s	22.7 kbit/s
Simulation	17.2 kbit/s	22.9 kbit/s

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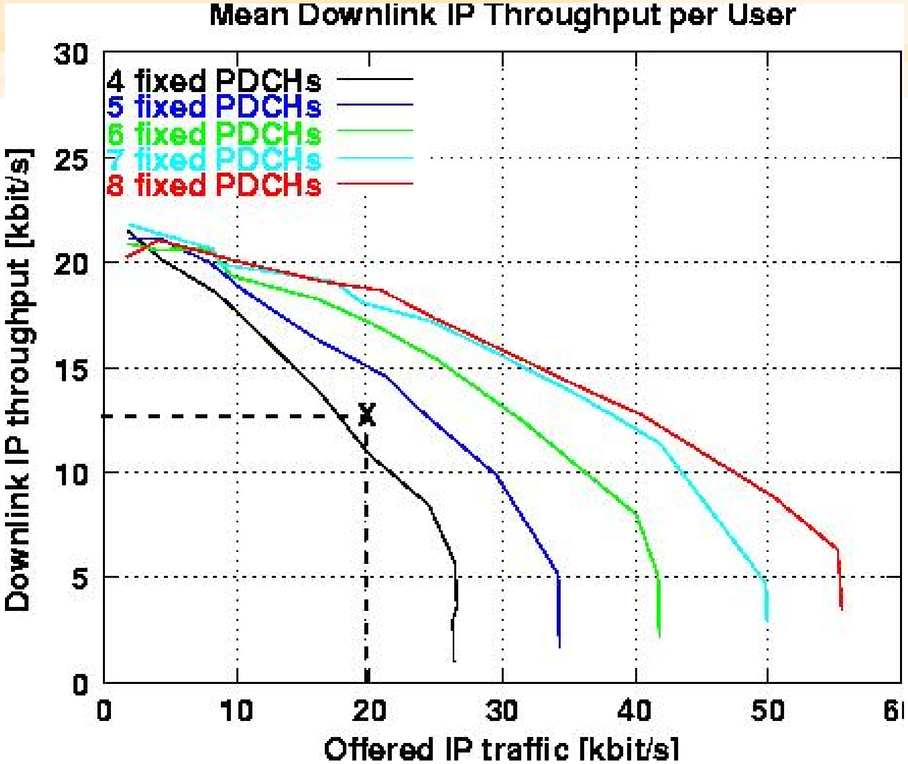
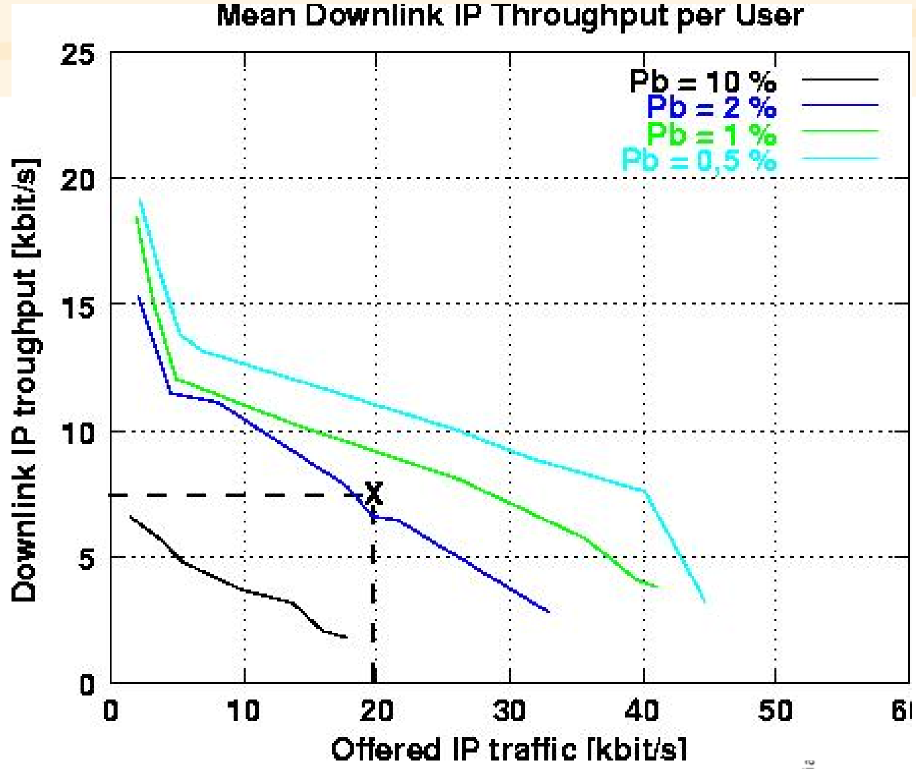
Dimensioning for Fixed and On-demand PDCHs





- Dimensioning graph for fixed PDCHs based on the performance for different resource configurations over the offered IP traffic
- Dimensioning graph for on-demand PDCHs based on the performance for different coexisting speech loads over the offered IP traffic

Conclusions: Main Contributions

- Development of a comprehensive GPRS/EDGE emulation tool for radio interface performance analysis and capacity planning
- Identification and development of traffic models for existing and future mobile applications
- Comprehensive performance analysis for GPRS and EDGE networks considering a wide range of applications and system parameters
- Derivation of radio resources traffic engineering rules for the cost-effective evolution of cellular packet radio networks
- Development and performance evaluation of advanced QoS management algorithms for cellular packet radio networks
- Book publication “The GSM Evolution” (Wiley 2002)
- 2 journal publications
- More than 20 conference papers
- 1 patent on QoS management in mobile radio networks

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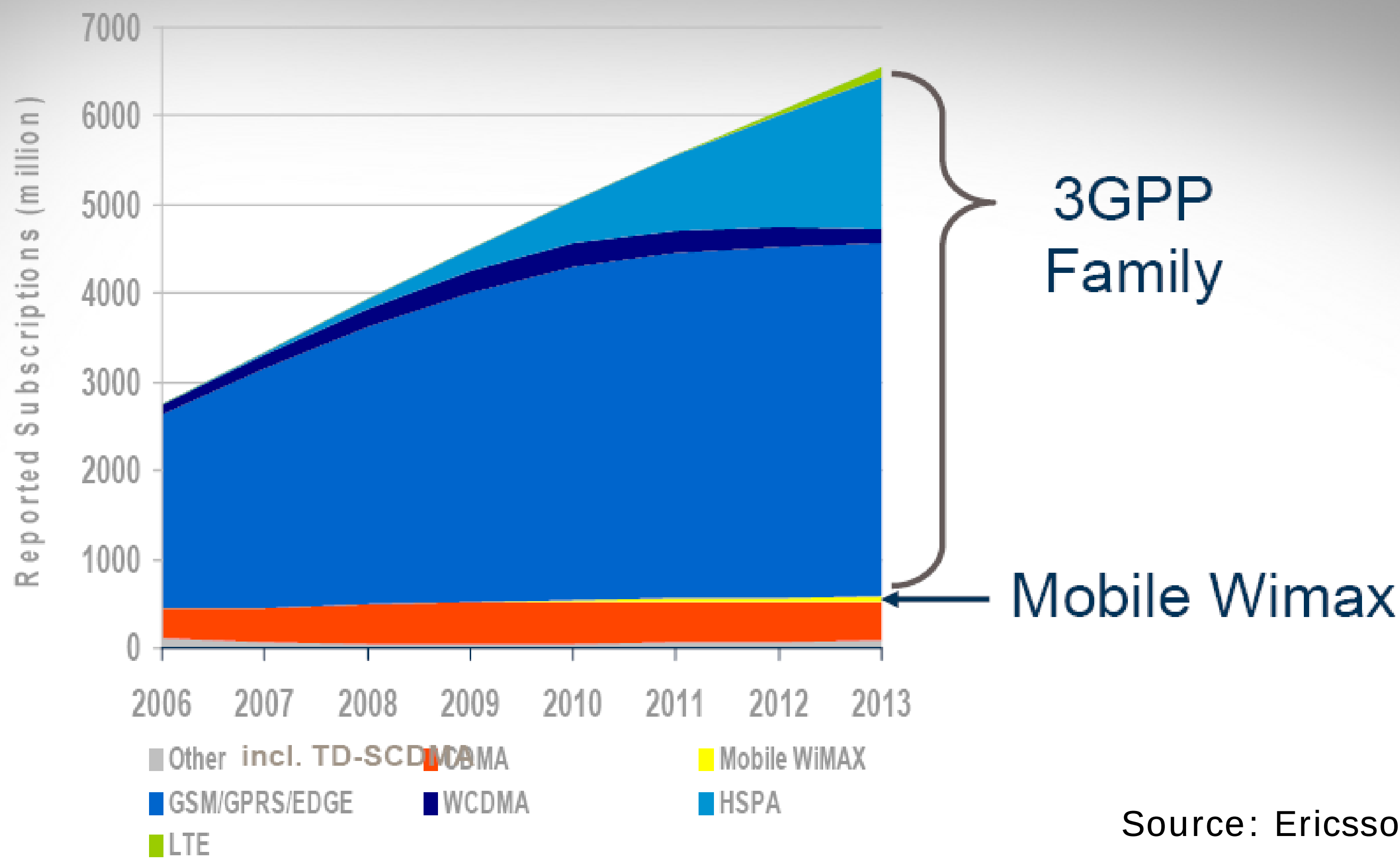
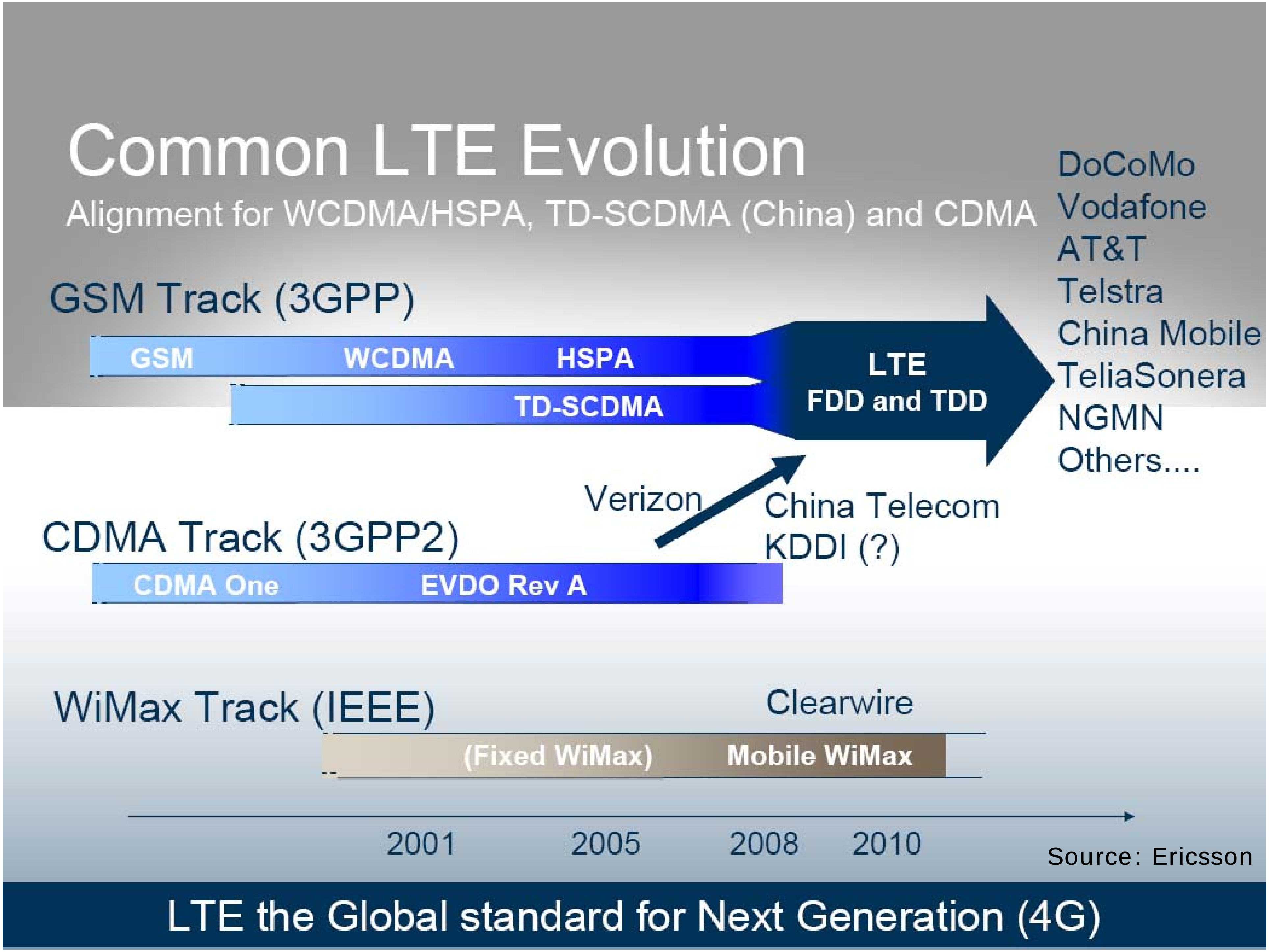
Reported mobile subscriptions

By system standard, 2006-2013



Source: Ericsson

GSM, WCDMA/HSPA and LTE dominance gives economy of scale


Common LTE Evolution
Alignment for WCDMA/HSPA, TD-SCDMA (China) and CDMA
GSM Track (3GPP)
GSM
WCDMA
HSPA
TD-SCDMA
LTE
FDD and TDD
DoCoMo
Vodafone
AT&T
Telstra
China Mobile
TeliaSonera
NGMN
Others....
Verizon
China Telecom
KDDI (?)
CDMA Track (3GPP2)
CDMA One
EVDO Rev A
WiMax Track (IEEE)
Clearwire
(Fixed WiMax)
Mobile WiMax
2001
2005
2008
2010
Source: Ericsson
LTE the Global standard for Next Generation (4G)

Research - Multiple Wireless Futures

- **Next-generation wireless LAN** – emerging radio technologies (802.11n, MIMO), improved MAC layer protocols, multicasting, hybrid cellular/WLAN, security
- **Ad-hoc mesh networks** – use of different radio technologies, spectrum coordination, self-organization, scalable/secure routing protocols, cross-layer, QoS support
- **Cognitive radio networks** – interference avoidance methods, networks with multiple radio PHY's, forming adaptive networks, discovery protocols, cross-layer routing
- **Sensor networks** – power efficient protocols, hierarchical topologies, data aggregation and information flows, content-aware routing, service API's, real-world applications
- **Pervasive networks** – heterogeneous radio technologies, integration of sensors with WLAN/cellular, dynamic binding protocols, closed loop control applications...
- **Future cellular networks** – alternative radio technologies (WiMax, 4G), open interface for new network and transport protocols, new services (location-aware, media, etc.)

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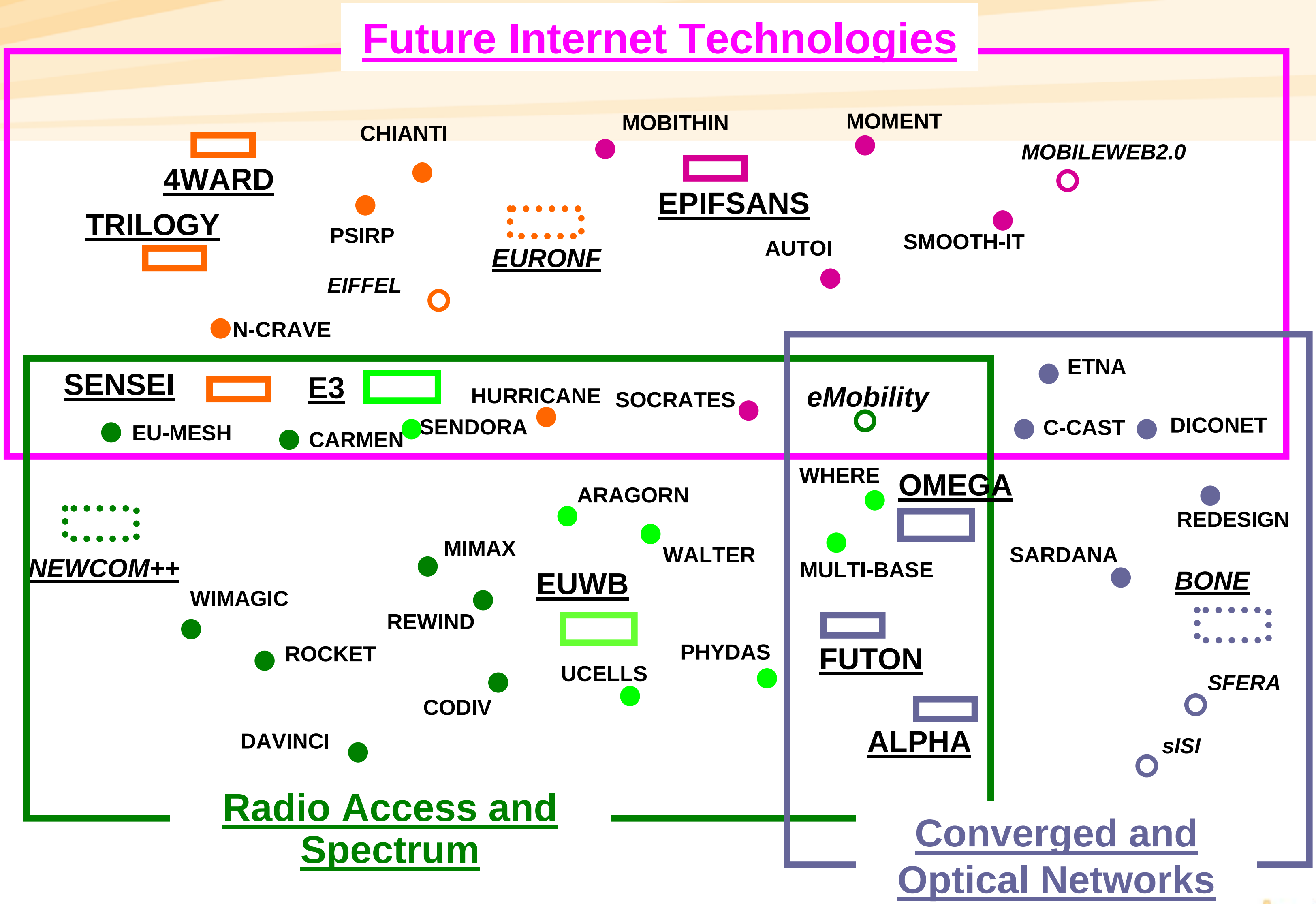
FP7 Future Networks Project Portfolio
(funding: 200 M€)



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Cluster Radio Access & Spectrum

- Innovative radio transmission technologies
  - Filter bank based multi-carrier transmission (FBMC)
  - Non-binary wireless communications based on innovative low-density parity-check (LDPC) codes
- Future radio network system concepts
  - Enhancement of WIMAX technology (relaying, mesh, energy-efficiency)
  - Sensor and actuator networks
- Flexible spectrum management
  - Next-generation cognitive radio networks (prototyping, standardisation)
  - Sensor-assisted and location-based cognitive radio
  - Decentralised cognitive radio and cognitive networks
- Spectrum overlay (UWB)
  - Projects on UWB may significantly impact the regulation process about the ultra-wide band regime

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Where do we stand?

- Behind us:
  - FP7 ICT Call 1 for proposals in 2007-08
  - ~200 M€ of EU funding,
  - 48 projects launched (out of 173 proposals received)
- Ahead of us
  - WP 2009-10 Objective 1.1: ~190 M€ funding
  - Call 4 ~110 M€ funding
  - Call 5 ~80 M€ funding

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Enabling Europe to shape and master the 2015-20 ICT landscape

Three major technology and socio-economic transformations that Europe can and should lead:

- Future Internet (FI)
- Alternative paths to ICT components and systems
- ICT for sustainable development

In addition, main mid-to-long term drivers for ICT research priorities remain valid

- 'more for less' - more *functionality and performance* at lower cost
- *scalability, adaptability and learning* capabilities of ICT systems
- *reliability and security*
- higher volumes and more complex *digital content and services*
- *innovation from the use of ICT* in ever more challenging applications

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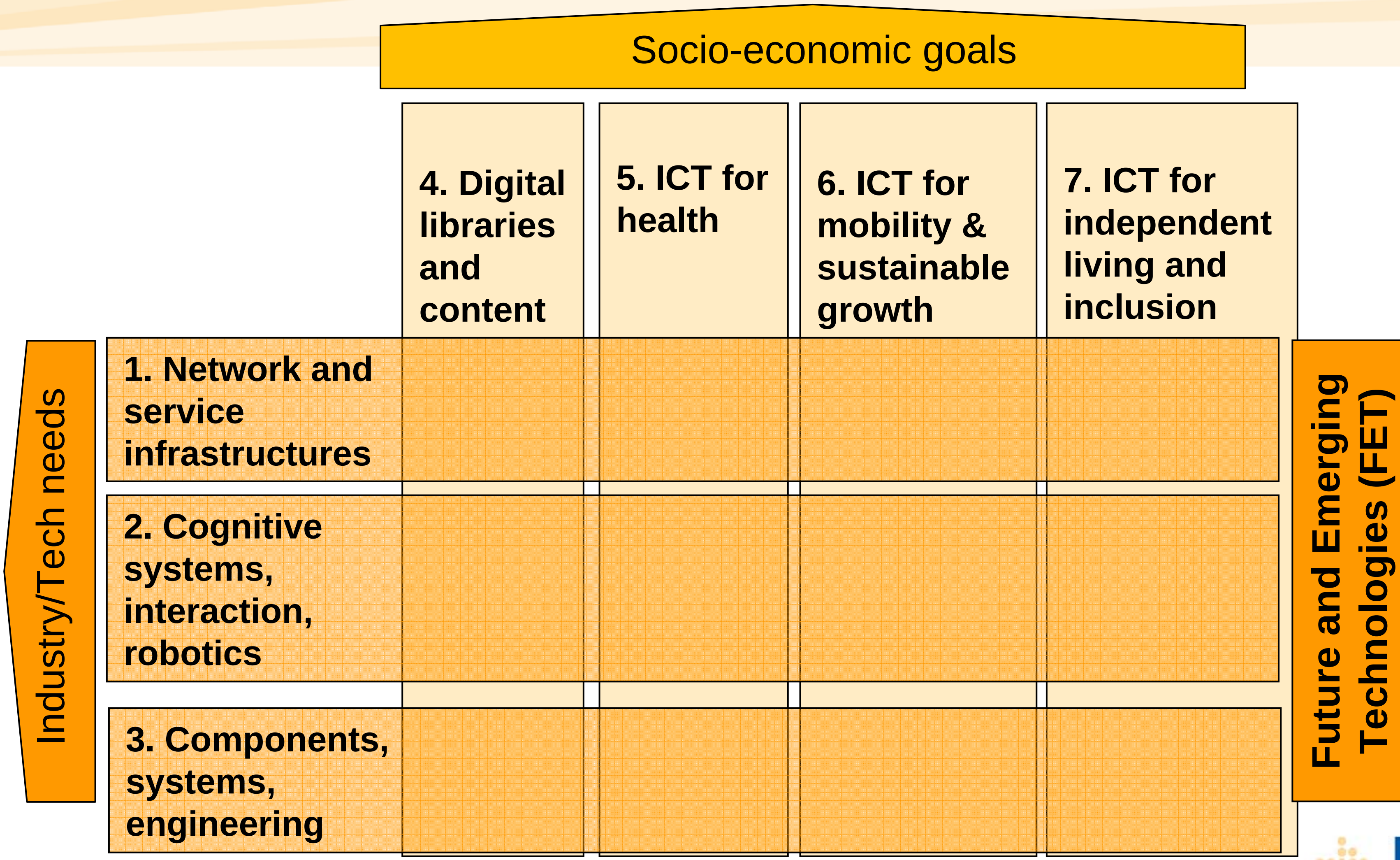
ICT in FP7: *7 Challenges + FET*



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Funding schemes

Collaborative projects (CP):

- 'small or medium-scale focused research actions' (STREP): specific research objective in a sharply focused approach
- 'large-scale integrating projects' (IP): comprehensive 'programme' approach / include a coherent and integrated set of activities dealing with multiple issues

- Both instruments play an important and complementary role
- Objective is to support a <u>balanced portfolio</u>:
  - focused and agile scientific and technological exploration through STREPs
  - concentration of efforts - where needed - through IPs
- Indicative budget distribution per instrument specified for each objective
- Overall aim is to ensure that <u>about half of the support for Collaborative Projects is delivered through IPs and about half through STREPS</u>

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Challenge 1: Future Internet as a federating research theme

Challenge

Making the Internet
- mobile/broadband
- manageable/scalable/QoS/QoE
- secure, and trustworthy
- 3D enabled

- Virtualised resource, ad-hoc application design
- Enabling novel applications (RFID/sensor based)
- Social Internet, Net is the database, search
- Understand Internet "behaviours" (federated testbeds)

- Standards, International Co-operation.....

Approach

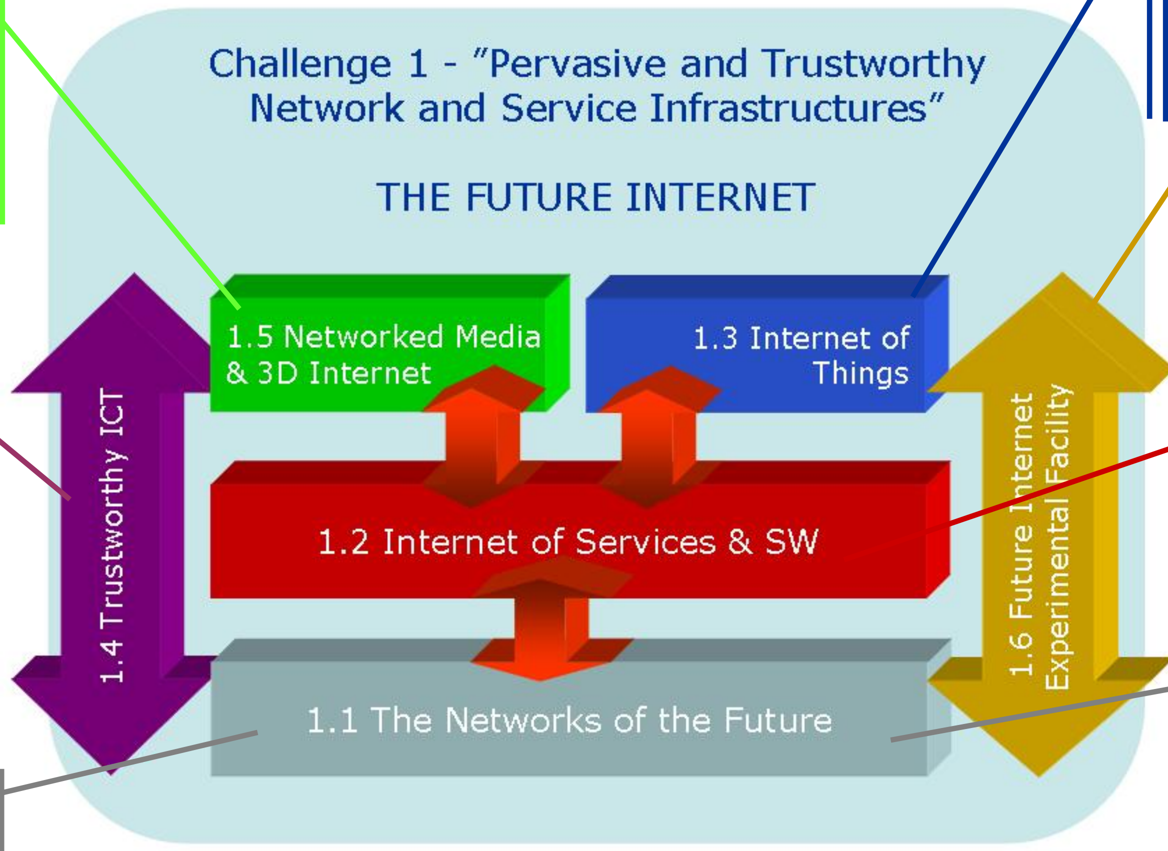
- Developing the technological and architectural foundations of the FI
- Further building the Future Internet Assembly
- Support to reinforced co-operation with EU national initiatives
- International co-operation with regions having FI initiatives
- Leveraging EU assets, industrial drive

Pervasive and Trustworthy Network and Service Infrastructures

Call 4
80 M€
IP/STREP/
NoE/CSA

Call 5
90 M€
IP/STREP
/NoE/CSA

Call 4
110 M€
IP/STREP



Call 5
37 MEuro
>2IPs/
STREP/CSA

Call 5
50 MEuro
IP/STREP
/CSA

Call 5
110 MEuro
IP/STREP
/CSA

Call 5
80 MEuro
IP/STREP
/NoE/CSA

Target outcomes (I)

The Network of the Future (IP/ Strep)

Call 4

Spectrum-efficient radio access to Future Networks

- next-generation mobile radio technologies
- cognitive radio and network technologies
- novel radio network

Converged infrastructures in support of Future Networks

- ultra high capacity optical transport networks
- converged service capability across heterogeneous access

Call 5

Future Internet Architectures and Network Technologies

- novel Internet architectures and technologies
- flexible and cognitive network management

Coordination/ Support actions and Networks of Excellence (NoE, CSA)

Internet of Services, Software and Virtualisation (IP / Strep)

Service Architectures and Platforms for the Future Internet

- service front ends
- open, scalable, dependable service platforms
- virtualised infrastructures

Innovative Service / Software Engineering

- service / Software engineering methods and tools
- verification and validation

Coordination and support actions (CSA)

Internet of Things and Enterprise environments (> 2 IPs / Strep)

Architectures and technologies for an Internet of Things

- architectures and technologies using open protocols, which enable novel Internet-based applications
- optimised technologies covering distribution of intelligence
- architectural models

Future-Internet based enterprise systems

- software platforms
- interoperability
- dynamic ecosystems

International co-operation and co-ordination (CSA)

Target outcomes (II)

Trustworthy ICT

Trustworthy Network Infrastructures (IP)
•novel architectures with built-in security / dependability / privacy
•trustworthy management of billions of networked devices

Trustworthy Service Infrastructures (IP)
•adaptability, interoperability, scalability and dynamic composition of services
•identity management for persons, tangible objects and virtual entities

Technology and Tools for Trustworthy ICT (Strep)
•Understanding threat patterns for pro-active protection
•user-centric and privacy preserving identity management
•management and assurance of security, integrity and availability
•assurance and assessment of trustworthiness

Networking, Coordination and Support (NoE, CSA)

Networked Media and 3D Internet

Content aware networks and network aware applications (IP/Strep)
•networking and delivery of multimedia content and services
•video coding, multi view point coding, 3D coding

3D Media Internet (IP/ Str/NoE)
•technologies for 3D content representation
•commercial or social applications, beyond games

Networked search and retrieval (IP/ Strep)
•heterogeneous information sources
•including physical world event information
•search capabilities across distributed media systems and P2P networks

Immersive media experiences (IP/ Strep/NoE)
•higher frame rates, wider colour gamut, higher contrast, higher resolution, 3D capabilities, immersive environments
•optimised end-to-end architectures

Support measures (CSA)
dissemination, roadmaps, international co-operation

FI experimental facility and experimentally-driven research

Building the Experimental Facility and stimulating its use (IP)
•prototype of the FIRE experimental facility
•'open coordinated federation of testbeds'
•large scale experimentation
•direct involvement of user communities
1/ FIRE Components:
operational prototype facility
2/ FIRE Users:
open calls; results must be of mutual interest

Experimentally-driven Research (Strep)
•iterative cycles of research, design and large-scale experimentation
•Future Internet as a complex system (holistic vision)
•definition of relevant metrics
•taking into account energy, low cost, environmental or socio-economic aspects

Coordination actions (CSA)
•EU-level / MS
•international co-operation/ standardisation
•co-ordination of experience research and user-driven open innovation

Next steps

- 22 October 08: Final WP to ICTC for opinion
- November 08: WP adoption
- November 08: ICT Call 4 launch (DL: 1 April)
- 25 – 27 November 2008: ICT 2008 in Lyon
- 22 January 2009: ICT Proposer’s Day, Budapest
- July 09: ICT Call 5 launch (DL: 3 November)

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FP7 – ICT Proposers' Day

Budapest
22 January 2009

Obtain information

- Challenges and objectives of the Work Programme
- Instruments, contracts, rules for participation
- Around 100 Commission officials present

Network

- Meet researchers with similar or complementary research interests
- Form project consortia
- Follow-up of the ICT Event in Lyon

http://ec.europa.eu/information_society/events/budapest_2009

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More Information

- The ICT Future Networks web site
  http://cordis.europa.eu/fp7/ict/future-networks/

- Our bi-monthly newsletter:
  - Distributed via email (by subscription - free of charge);
  - Contains info on all activities in the field including calls for proposals, conferences, publications, etc.)