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

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and some info on FP7

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Europäische Kommission
GD Informationsgesellschaft und Medien
• 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
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):

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

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

• First generation GPRSIm simulation tool as the basis
• ComNets leading early research in cellular packet radio
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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
GPRS 52-Multiframe Structure

Four consecutive TDMA Frames are combined in one Radio Block
### GPRS Channel Structure

**Master Channels** (used for broadcast of basic system information)

**Slave Channels**

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**Two types of Packet Data Channels:**
- Master Channels
- Slave Channels
Remember: master slave dynamic rate access (MSDRA) - Initial Idea for GPRS frame structure

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
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

Diagram:
- QoS vs. offered traffic
- QoS vs. predicted traffic
- Resource configurations 1, 2, 3
- QoS limits
- Acceptable traffic vs. offered traffic
- Predicted traffic vs. offered traffic
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
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
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

3GPP Spec.
Telelogic SDT
SDL Spec.
SDL2SPEETCL

C++ framework

Protocols C++

Solaris, Linux

C++-Compiler (GCC, Intel)
Validation II (Measurement)

Vodafone NL GPRS measurement settings

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

Downlink IP throughput [kbit/s]

Number of mobile stations

GPRS simulation

Measured

IP-Backbone Network

External IP-Network

Internet

Measurement Point

Notebook & GPRS mobile

PPP infrared (WinDump)
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 $N_{ss}$:

$$RTT \leq \frac{W_{init} \cdot MSS}{R_{TCP}} k_{SS}^{N_{ss}} \quad \Leftrightarrow \quad N_{ss} = \left\lfloor \log \left( \frac{R_{TCP} (RTT + TBF_{setup})}{W_{init} \cdot MSS} \right) \frac{1}{\log(k_{ss})} \right\rfloor$$

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

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

### Validation I (Analytical TCP Model, Meyer2001)

<table>
<thead>
<tr>
<th>Model</th>
<th>WWW (3700 byte)</th>
<th>e-mail (1 kbyte)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytical</td>
<td>14.9 kbit/s</td>
<td>22.7 kbit/s</td>
</tr>
<tr>
<td>Simulation</td>
<td>17.2 kbit/s</td>
<td>22.9 kbit/s</td>
</tr>
</tbody>
</table>
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

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

Source: Ericsson
Common LTE Evolution
Alignment for WCDMA/HSPA, TD-SCDMA (China) and CDMA

GSM Track (3GPP)
- GSM
- WCDMA
- HSPA
- TD-SCDMA

CDMA Track (3GPP2)
- CDMA One
- EVDO Rev A

WiMax Track (IEEE)
- (Fixed WiMax)
- Mobile WiMax

LTE FDD and TDD
- Verizon
- China Telecom
- KDDI (?)

DoCoMo
Vodafone
AT&T
Telstra
China Mobile
TeliaSonera
NGMN
Others....

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€)

Future Internet Technologies

Radio Access and Spectrum

Converged and Optical Networks
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
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
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
### ICT in FP7: 7 Challenges + FET

<table>
<thead>
<tr>
<th>Socio-economic goals</th>
<th>Industry/Tech needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>4. Digital libraries and content</td>
<td></td>
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<tr>
<td>5. ICT for health</td>
<td></td>
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<tr>
<td>6. ICT for mobility &amp; sustainable growth</td>
<td></td>
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<tr>
<td>7. ICT for independent living and inclusion</td>
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</tbody>
</table>

| 1. Network and service infrastructures |
| 2. Cognitive systems, interaction, robotics |
| 3. Components, systems, engineering |

### Future and Emerging Technologies (FET)
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 balanced portfolio:
  - 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 about half of the support for Collaborative Projects is delivered through IPs and about half through STREPS
## Challenge 1: Future Internet as a federating research theme

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Approach</th>
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<tbody>
<tr>
<td>Making the Internet</td>
<td>Developing the technological and architectural foundations of the FI</td>
</tr>
<tr>
<td>• mobile/broadband</td>
<td>• Further building the Future Internet Assembly</td>
</tr>
<tr>
<td>• manageable/scalable/QoS/QoE</td>
<td>• Support to reinforced co-operation with EU national initiatives</td>
</tr>
<tr>
<td>• secure, and trustworthy</td>
<td>• International co-operation with regions having FI initiatives</td>
</tr>
<tr>
<td>• 3D enabled</td>
<td>• Leveraging EU assets, industrial drive</td>
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<tr>
<td>• Virtualised resource, ad-hoc application design</td>
<td></td>
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<tr>
<td>• Enabling novel applications (RFID/sensor based)</td>
<td></td>
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<tr>
<td>• Social Internet, Net is the database, search</td>
<td></td>
</tr>
<tr>
<td>• Understand Internet “behaviours” (federated testbeds)</td>
<td></td>
</tr>
<tr>
<td>• Standards, International Co-operation.....</td>
<td></td>
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</table>
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

**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)
- 22 January 2009: ICT Proposer’s Day, Budapest
- July 09: ICT Call 5 launch (DL: 3 November)
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
• The ICT Future Networks web site

• 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.)