The Network of Excellence Euro-NF and its Specific Joint Research Projects

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Abstract

This article presents the European FP7 Network of Excellence "Euro-NF" (Networks of the Future) and reviews its set of activities. Specific attention is paid to the concept of Specific Joint Research Projects (SJRP), a series of small but focused projects, integrating at least three Euro-NF partners and targeting joint seminal work, publications as well as full-size follow-up projects. Further to the description of the SJRP concept, a set of three selected SJRP from different areas are presented in detail with respect to motivation, goal, contents, results, and impact.

1   Introduction

Euro-NF (2008–2012) [1] is a Network of Excellence (NoE) from the ICT Call 1 of the European Framework Programme (FP) 7. It involves 35 partners from 16 countries, coordinated by Daniel Kofman, Télécom ParisTech, France, and funded by the European Union with 4.8 MEUR. Euro-NF is the follow-up of the NoEs Euro-NGI (2003–2006) and Euro-FGI (2006–2008). In the same spirit as its predecessors, it targets challenges in Networks of the Future (NF), amongst others design principles (clean slate versus evolutionary); the merging of physical and digital world (based on connected objects); the emergence of virtualisation and programmability of network resources; and the empowerment of end users and their transition into "prosumers". Observing the ever-growing complexity of networking scenarios in combination with a plethora of technical and socio-economical boundary conditions, Euro-NF took a broad approach in gathering key European experts with a sufficiently wide range of competences in order to address the challenges in NF, and to present a major support for the European society [2].

In view of these challenging tasks, Euro-NF has devised a Joint Programme of Activities (JPA) that will be presented briefly in Section 2. The Specific Joint Research Projects that have been "invented" within Euro-NGI and shown to be a very successful instrument of joint focused (and strategic) research work are introduced in Section 3. Sections 4 to 6 describe a set of three selected SJRP in detail with respect to motivation, goal, contents, results, and impact. Section 7 concludes the article.

2   Euro-NF's Joint Programme of Activities

Euro-NF features a set of Integration Activities (IA), Joint Research Activities (JRA) and Spreading of Excellence Activities (SEA), the most relevant ones in the context of this article will be presented in the following subsections.

2.1   Integration Activities

"These activities are designed for integrating researchers in the network by providing them with the tools and facilities they need, and the means to learn together and to exchange information" [2]. They include

- A **Knowledge Map** to provide a global cartography of issues related to the architecture, design and engineering of the Network of the Future, and to map the efforts of the Euro-NF partners on this global map;
- Efforts to coordinate **sharing and development of software tools and platforms**;
- Web-based **collaboration tools**;
- A **mobility program** for researchers within the network, ranging from short-term visits and attendances of technically sponsored conferences to long-term visits that are spanning over several months;
- A **Ph.D. course program**, involving more than 20 courses;
- Yearly **summer schools** on topics related to the Joint Research Activities;
- **Internal workshops**;
- Yearly **plenary meetings**.

2.2   Joint Research Activities

"With the aim of integrating research activities performed by its partners, Euro-NF concentrates the JRA on mapping the scientific developments with the future networking needs" [2]. The JRA are split into three complementary areas:

1. **Future Network and Services Architectures**, with work packages on horizontal and vertical integration of access technologies; metro and core architectures; new networking paradigms; overlays for network control and support of evolved services infrastructures; and new service architectures.
2. **Traffic engineering, Routing, Planning, Optimization and related quantitative methods**, with work packages on reliable and efficient communication in self-organized networks; Traffic Engineering, mechanisms and protocols for controlled bandwidth sharing; QoS in multiservice multitechnology wireless networks; routing and traffic management in a multi-provider context; design of optimal highly dependable networks; Measurements and Traffic Awareness; and advanced quantitative methods.
3. **Socio-economic aspects**, with work packages on Internet governance: towards a new cooperation model; Service Level Agreements (SLAs), pricing, Quality of Experience; cost models; and trust, privacy and security.

Furthermore, the **Specific Joint Research Projects** (see Section 3) belong to the JRA.

2.3 Spreading of Excellence Activities

"Euro-NF considers that the dissemination of knowledge and the steady supply of skilled staff are key factors for the sustainability of European excellence for Future Networks' design and engineering" 11. Thus, Euro-NF is running a set of SEA, a selection of which is presented below:

- **Ph.D. courses** and **summer schools** are even open to non-partners;
- Since 2005, Euro-NGI/FGI/NF's **flagship conference "NGI"** has been arranged on a yearly basis;
- The **EuroView** workshop, traditionally held in Würzburg, attracts global attendance;
- **Open workshops**;
- Joint work with the European Commission, amongst others the coordination within the **Future Internet Cluster**; joint organisation of the **Future Internet Cluster Workshops** (FICW) three times per year since March 2010; and involvement in the **Future Internet Assembly** (FIA) Steering Board and FIA activities.

3 Specific Joint Research Projects

Networks of Excellence are not supposed to conduct research as such, but to integrate research efforts of their partners. During the course of Euro-NGI, it became obvious that specifically targeted project with marginal funding (10 KEUR per partner) advance new approaches beyond the pre-defined JPA, boost the work within related JRA work packages and provide new links between those.

Specific Joint Research Projects (SJRP) aim at improving knowledge in targeted topics considered of main importance, with a significant innovation potential and not sufficiently covered at present. They should be sharply focused, preferably on disruptive ideas on the networks of the future, and designed to gain new knowledge and explore the need for more research effort, anticipating scientific and technological needs (that, for example, could motivate the proposal of FP7 projects in future calls). Those projects furthermore aim at shaping collaboration between participants (institutions), where new constellations of participants that have not collaborated so far are especially encouraged. In particular, joint publications should be targeted. External partners might be invited, given that their competence is needed and not available within NoE itself.

The SJRP started within Euro-NGI (one call), continued within Euro-FGI (one call) and culminated within Euro-NF (five calls). During Euro-NF, 23 SJRPs were carried out so far (four calls), while the

Call 5-project proposals are currently under evaluation. The placement of the so-far carried out SJRP on the Euro-NF JRA matrix [2] is shown in Figure 1.
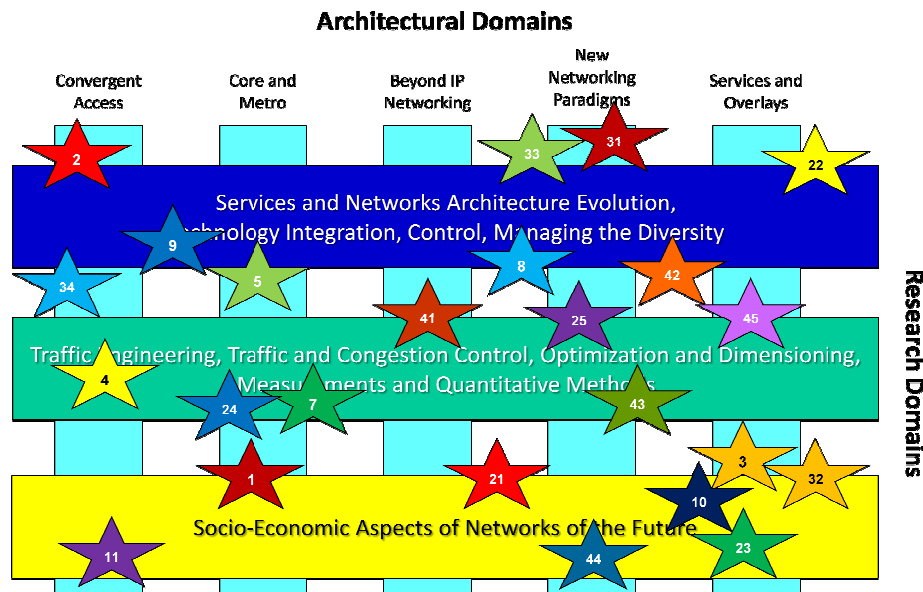

Figure 1. Placement of the SJRP from calls 1 to 4 on the Euro-NF JRA matrix [2].

In addition to the SJRP, two "Specific Joint Development and Experimentation" (SJDE) projects were implemented. The overall concept of SJDE, belonging to Integrating Activities, is very much alike that of SJRPs, while SJDEs focus on a phase between research and innovation. Due to the software development and implementation work required by this type of projects, the budget per partner was increased by 50 %.

On average, an SJRP produces three joint papers, ranging from top journals to workshops, and three knowledge map entries. SJRP have fed initiatives and ideas into Integrated Projects (IP), Specific Targeted Research Projects (STREP), other NoEs and COST Actions, as well as other SJRPs.

In order to provide a view of topics and approaches, the following three sections present three examples of SJRP from the first three calls, covering all JRA areas.

4   The SJRP QoEWeb

The SJRP "Quality of Experience and User Behaviour Modelling for Web Traffic" (QoEWeb) was one of the ten projects from the first call. It focused on JRA 3 and involved four Euro-NF partners.

4.1   Motivation and Goals

Increasingly many ICT solutions, services and applications, use the web browser as well-known and well-understood user interface. Typically, such services work in an interactive manner, i.e. the user performs some *action* (clicks on some link or button, or enters some information) and needs to wait for the response. As long as the latter arrives within a certain time horizon, e.g. within the reaction time of one second, the user feels the system to react immediately. However, long or heavily varying response times upon user action make the user suffer. The question is now: How patient is a user in such a case, i.e. how does her perception sink with time and the number of actions performed in case of bad network conditions? This question needs to be related to the type of application, which

means considering the expected performance for a fixed web page, a video, a request to a search engine, etc.

Quality of Experience (QoE) combines user perception, experience and expectations with non-technical and technical parameters such as application- and network-level QoS. While the ITU standards focus on service quality towards the end user, the IETF's understanding of QoS relates to the capabilities of the network to provide packet transfer in a better-than-best-effort way. While the ITU view on QoS is user-centric, the IETF view on QoS is network-centric. This raises the question of how network-level QoS measurements and control relate to the user perception of a service which is addressed within the SJRP "QoEWeb: Quality of Experience and User Behaviour Modelling for Web Traffic" [3] for the web traffic domain.

From an Internet Service Provider or Network Operator point of view, the main application is to detect performance problems (based on user perception) on their network. In case of trouble, they can apply tools to localize, diagnose and correct the problem. These tools build on network measurements (QoS), which need to be linked to user perception (QoE). Hence, relationships between QoE and QoS have to be derived and formulated as QoE-QoS mappings cf. [4]. However, there may also be psychological influence factors, which cannot be directly influenced by the provider, but which are key influence factors on the user perceived quality. Therefore, it is necessary to investigate such factors, like the memory effect, and draw conclusions on appropriate QoE modelling [5]. Such models help to investigate future Internet mechanisms from a user-centric point of view. One approach for handling multidimensional QoE metrics to improve web service provisioning are reputation systems [6].

4.2 A Generic Quantitative Relationship between QoE and QoS

In the context of the QoEWeb project, we derived a generic QoE-QoS relationship [4] based on the following observations. The QoE of the outcome of the transmission of a website as a function of QoS disturbances is split in several areas, separated by thresholds x_1 and x_2. For a vanishing QoS disturbance in area 1, i.e. in case of a transparent network, the user considers the QoE to that of the reference denoted as QoE value 5 in Figure 2.
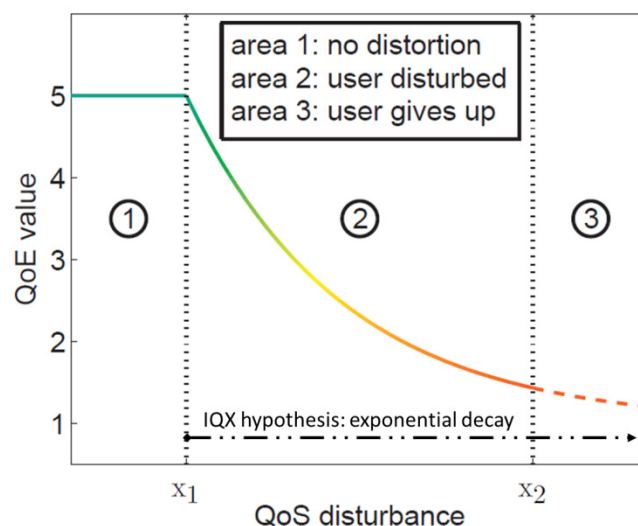

Figure 2. General shape of the QoE-QoE mapping.

A slight growth of the QoS disturbance may not affect the QoE at all. For instance, small delays and delay variations are not perceived by the user when browsing in the Internet. Thus, even if web pages would be delivered faster than what is given by threshold x_1, the user would not matter. This

allows an ISP or service provider to reduce costs without decreasing the users' fidelity. When the QoS disturbance exceeds a certain threshold x_1, i.e. in area 2, the QoE level cannot be maintained any more. As the QoS disturbance grows, the QoE and the user satisfaction sinks. In case of a high QoE, a certain additional QoS disturbance might have a considerable impact on the QoE, while for low QoE, that particular additional QoS disturbance might not be that critical any more. This generic relationship is formulated as IQX hypothesis which postulates the **I**nterdependency between **Q**oE and QoS to follow an e**X**ponential function. As soon as the QoS disturbance reaches another threshold x_2, the transmission of the web page is unacceptable or the web service might stop working because of technical constraints such as timeouts. A user might give up using the service at that point, indicated by the dashed line in Figure 2.

4.3 The Memory Effect and Its Implications on Web QoE Modeling

Besides technical influence factors, psychological factors like expectations or experiences play an important role in the overall QoE. However, the existing QoE models mostly consider only the current stimuli, i.e. the actual service environment and conditions, and do not consider such temporal dynamics or historical experiences of the user's satisfaction while consuming a certain service. In particular, psychological factors like the memory of a user or the popularity of contents are often not taken into account. In order to fill this gap, QoEWeb aims at a QoE model which takes into account such temporal dynamics on the example of web traffic. In a research continuation of the QoEWeb project within COST Action "TMA" [7], the memory effect was introduced in [5] to the field of Web QoE modeling. The results of three web browsing user studies show that, although the current QoS level clearly determines resulting end-user quality ratings, there is also a visible influence of the quality levels experienced in the past. In particular, we found that in addition to the current QoS level the user experienced quality of the last downloaded web page has to be taken into account. This implies that the memory effect needs to be adequately reflected in corresponding QoE models. One approach is the novel two-dimensional hidden Markov model proposed in [7]. The hidden states describe the internal system state while the emission describes the observed user ratings. The hidden states do not include only the current QoS settings in terms of page load time, but also a second state to capture the previous download time. This way, we obtain a memory Markov model to "remember" the past system states. The emission from a hidden state reflects the individual user rating on a certain rating scale. The resulting hidden memory Markov model can be easily used for example in simulations to derive the Web QoE for advanced future networking mechanisms.

4.4 QoE-based Reputation Models for Future Web Service Provisioning

In [6], we present a new approach for estimating QoE for web services by means of reputation systems. The presented framework is a generic architecture proposal for reputation systems which provide mechanisms to manage subjective opinions in a web society and yield general scoring of particular users' behaviour as well as service and network reliability. This multidimensional nature of QoE metrics can be handled by reputation systems, which produce a time and context related scoring on the users, service and network operator. The application of the reputation systems for QoE assessment faces the challenges of adaptation QoE metric features into the data collection module with a need of definition how the input measurements are correlated with a user behaviour and service context. This part is not clearly covered in literature and drives a new research areas related to the QoE user behaviour modelling. The usage of reputation may be a beneficial for service providers in terms of SLAs fulfilment or retaining QoE on the satisfaction level for users sharing the same network or service resources. In the scope of advantages of application the reputation systems for QoE evaluations there are an ability to support decision making systems and adapt web services or networks for retaining QoE on a satisfactory level.

4.5 Impact of QoEWeb

The project QoEWeb was successful in terms of fostering new collaboration and discussions on highly relevant topic, in particular regarding the QoE of future interactive services. The project participants proved to be a good match in terms of their expertise in the context of QoE and the applied methodology for QoEWeb (active and passive measurements, statistical analysis, modelling and performance evaluation) as well as the different view points on QoE. The partners of QoEWeb – that are University of Würzburg, Blekinge Institute of Technology, France Telecom SA and Warsaw University of Technology – could disseminate the knowledge gained within this Euro-NF SJRP to other projects like SmoothIT and G-Lab. Members of QoEWeb are now joining a QoE special interest group (SIG) within the framework of the COST Traffic Monitoring and Analysis (TMA) action and are actively participating in the COST QUALINET action [8]. This allows to continue discussions beyond QoEWeb e.g. on models or test methodologies for user perceived quality of future interactive services, for example in the Dagstuhl seminar [9] or in the Euro-NF workshop on "Quality of Experience (QoE)" collocated with 21st International Teletraffic Congress (ITC 21) - Traffic and Performance Issues in Networks of the Future [10].

5 The SJRP RISKASIP

The SJRP "Risk assessment methods for IP networking" (RISKASIP) was one of the five projects from the second call. Its point of gravity lies within JRA 2, and it involved three Euro-NF and one external partner.

5.1 Motivation and goals

As the role of the networking infrastructure in the modern society has grown tremendously and is still growing, the awareness of the seriousness of its failures is gradually awakening. RISKASIP was motivated by the observation that in fact also the scientific methods needed for assessing the risks inherent in this infrastructure are only emerging. Four EuroNF teams with interests in different aspects of network dependability started collaboration through RISKASIP: VTT, who had been developing a broad approach to the dependability of IP networks in the Finnish IPLU project (2006) and its follow-ups (see http://iplu.vtt.fi), URM2, who had recently expanded its interests to the analysis of economic issues and risk theory, NTNU, who had worked on various network dependability issues for more than a decade, and co-operated with UNINETT and other operators on collecting and analysing dependability and risk-related field data, and AGH, who had a strong research record on network reliability and recovery.

The notion of risk combines two quantities: the probability of an unfortunate event, and the amount of loss it incurs. The challenge of a risk theory is to analyse and combine these both in an intelligible manner to facilitate the comparison of the importance of various risks, and subsequent decision-making. RISKASIP focused on generic building blocks of methods for assessing networking risks: (i) probabilistic modelling of joint failures, (ii) techniques for estimating and measuring failures and losses in networks, and (iii) principles of combining them into a novel risk theoretic framework.

5.2 Modelling of Dependence

RISKASIP's work in the first topic focused on a reliability theoretical model of dynamical dependence, where a reliability system was described as a set of jointly stationary on/off processes, one per component. The dependence between components failures is modelled by letting the stochastic intensity of a component failure depend positively on the set of components that are down already. Thus, the failure of a component has a "stochastically causal" effect on the remaining components.

On the other hand, the failure durations can have arbitrary distributions, which is important for allowing the realistic possibility of very long downtimes. Details will be provided in reference [13].

5.3   Failure Estimation

As regards failure estimation, most of the work has centred on a rich, and rare in its kind, set of network failure data, provided by the Norwegian university backbone operator UNINETT. The analysis of this data set has provided valuable experience and insights. Although one of the insights was that failure data produced by the usual network management systems has often very serious defects hindering their effective use for research purposes, it was possible to extract results for research papers. In particular, correlations between failures were found to be pronounced in both time and space, and it was shown that the geographical distance has a significant impact to the dependence [12]. As a part of this work, methods for obtaining the correlation of failures and recoveries of network elements were investigated. Additionally, RISKASIP had access to operational data related to dependability and risk from a cellular operator obtained during approximately three years, and to NTNU's own accurate (10 ms granularity) measurements on IP packet delays between Norway and China.

5.4   Concept of Risk-Aware Networking

Most importantly, RISKASIP produced an extensive white paper [11] that argues for the recognition of *risk-aware networking* as a multidisciplinary paradigm that should be promoted as a whole as well in practice as in research. Dependable networks should be designed having in mind not only the frequency of failures, but also their severity to clients. The novelty of this approach is threefold, covering methodologies (a proposed system approach), techniques, and operational aspects. In particular, RISKASIP recognized the following challenges on the way to risk-aware networking:

- design, planning and assessment taking into account risk of reliability thresholds of SLA violation;
- proper risk assessment;
- risk-aware data collection and modelling.

Additionally, a number of techniques for quantification and reduction of risks are discussed in the white paper. They are of both theoretical and practical nature: survivability mechanisms, extensions to network reliability modelling to embrace risk metrics, and guidelines related to the data collection in order to obtain meaningful information for the network design stage. Some of the suggestions and insights were related to the practical side of networking: the complexity of the relation between networking parties (e.g., mutual responsibilities and accountability), practical aspects of data collection, and the often ignored impact of human factors on recovery, reliability and risk.

5.5   Impact of RISKASIP

The main impact of RISKASIP will be connected with the concept of risk-aware networking introduced in its white paper [11]. If the proposed approach finds support, it will lead to substantially deeper collaboration of network operators, researchers and regulators for the avoidance and mitigation of the otherwise increasing risks related to network failures.

6   The SJRP VDTN

The SJRP "Vehicular Delay-Tolerant Networks" (VDTN) belongs to the four projects from the third call. It had its main links to JRA 1 "Future Network and Services Architectures", and it involved three Euro-NF partners.

6.1   Motivation

Delay-Tolerant Networks (DTNs) [14] are networks that enable communication where connectivity issues like sparse and intermittent connectivity, long and variable delay, high latency, high error rates, highly asymmetric data rate, and even no end-to-end connectivity exist. Instead of working end-to-end, in DTNs, a message-oriented overlay layer called "Bundle Layer" employs a store, carry and forward message switching paradigm that moves messages from node to node, along a path that eventually reaches the destination. The idea is to "bundle" together all the information required for an application transaction, minimizing the number of round-trip exchanges, which is useful when the round-trip time is very large.

Vehicular Delay-Tolerant Networks (VDTNs) [15], [16] are DTN-inspired networks where vehicles communicate with each other in order to disseminate data using data bundles (aggregation of datagrams) as a data unit. Some of the potential applications for these networks include road safety, traffic monitoring, driving assistance, entertainment, advertisements, delivering non real-time Internet connectivity such as file transfer [17] or Web access [18] to rural/remote communities or catastrophe-hit areas, and gathering information collected by vehicles such as road pavement defects. VDTNs are part of a family of opportunistic, self-organized, and autonomous networking area that have arisen from the wide use of wireless communications, where network disruptions are common.

6.2   The VDTN approach

The Euro-NF SJRP VDTN [19] worked on VDTNs following an IP over VDTN architecture approach, as illustrated in

Figure 3. The bundle layer is placed below the network layer instead of over the transport layer as in the DTN architecture. The objective is to route large size bundles instead of small size IP packets. This results in fewer packets processing and routing decisions, which can be translated to less complexity, lower cost, and energy savings. The VDTN architecture uses out-of-band signaling, based on the separation of the control plane and data plane. The Bundle Aggregation and De-aggregation (BAD) layer aggregates incoming IP packets into bundle messages that are transferred in the data plane and de-aggregated at the destination. The Bundle Signaling Control (BSC) layer provides a signaling protocol for use at the connection setup phase. The nodes exchange control information to discover each other's characteristics and prepare the data transfer to occur in the data plane.

6.3   Results

A simulation tool, called VDTNsim [20], and a laboratory testbed, called VDTN@Lab [21], were developed to support research studies related with the development, experimentation, and performance evaluation of protocols, algorithms, services, and applications for VDTNs.

Figure 4 shows the VDTN@Lab prototype. The testbed uses Lego Mindstorm NXT robotic cars with notebooks or PDAs for emulating mobile nodes and laptops or desktops for emulating relay nodes and terminal nodes.

Several routing mechanisms were tested in combination with different bundle scheduling and dropping policies [22], as well as several bundle fragmentation mechanisms [23], [24]. It was shown that the use of routing mechanisms that control the number of bundle copies circulating in the network contributes to reducing congestion and improving quality of service parameters such as delivery ratio and delay. It was also shown that scheduling and dropping policies that take into account the remaining lifetime of bundles use the network more efficiently, as more network resources are used for the transmission of bundles that still have a high probability of reaching their

destination and less network resources are used for bundles that already have a low delivery probability. Finally, it was shown that the use of reactive fragmentation mechanisms, which dynamically adapt the bundle fragment size to the duration of each radio contact between nodes, provide a more efficient use of the rather short contact opportunities in a highly dynamic network such as a vehicular network.

Web browsing and file transfer applications for VDTNs were developed and their performance assessed in the testbed [17], [18]. The applications work properly, showing that non-real time Web browsing and files transfer applications can be deployed on VDTN networks. The use of content storage and retrieval mechanisms, where bundle copies still stored in the network can be used as a network cache for subsequent application requests, also provides a significant performance improvement for applications.
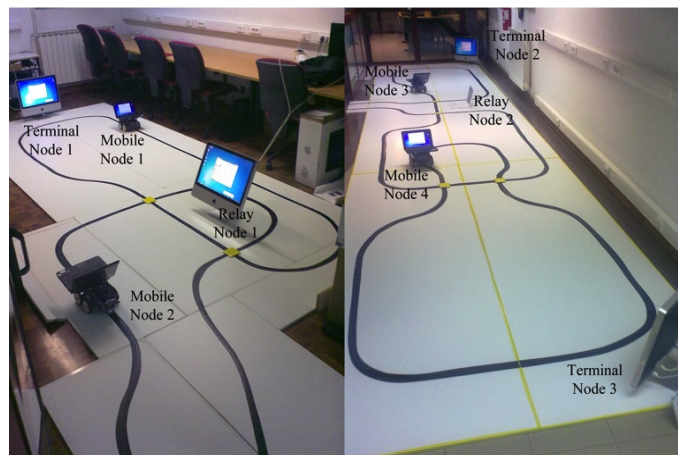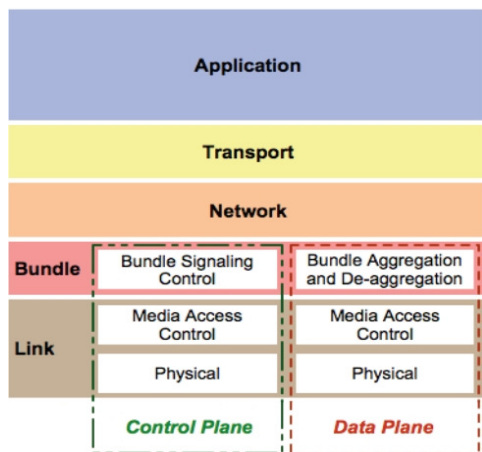
Figure 3. Vehicular delay-tolerant networks architecture.

Figure 4. Photos of the vehicular delay-tolerant network laboratory testbed.

6.4   Impact of VDTN

Assuming the evolution of vehicular communications and their real deployment, VDTNs can have a strong impact in the future because may provide users many services and applications in an easy and comfortable way. This technology may be integrated in cars, deployed in their embedded aboard computers, offering ubiquitous services and applications to the users, such as, traffic information and advertisements.

For the future, our plans go through the development of network management approaches for VDTNs, evaluating them through the VDTN@Lab testbed. Bundles aggregation and de-aggregation will also be considered. In parallel, efforts are going on to create a mature Real VDTN Testbed in cooperation with a car manufacturer.

7   Conclusions

This article provided an overview of the European Network of Excellence Euro-NF, with specific focus on the Specific Joint Research Projects (SJRP) being characteristic for this network and its predecessors EuroNGI and EuroFGI. The SJRP were considered to be successful in integrating researchers from different Euro-NF partners around a sharply demarcated set of tasks, yielding joint publications; boosting the work within the related research-oriented work packages; and providing initiatives to new projects. Thus, the quite limited amount of seed funding – 10 KEUR per partner

and project – yielded considerable multiplication effects with regards to follow-up projects and continued joint work. Three SJRPs were presented in detail to provide impressions of typical contents and results of this originally EuroNGI/FGI/-NF-specific instrument, which in the meantime has been applied successfully by other initiatives and projects.

References

[1]   Euro-NF Homepage, www.euronf.org. [Online].

[2]   D. Kofman, "Network of Excellence (NoE) proposal, ICT Call 1, FP7-ICT-2007-1, Anticipating the Network of the Future - From Theory to Design, Euro-NF"

[3]   QoEWeb Project. (2009) "QoEWeb: Quality of Experience and User Behaviour Modelling for Web Traffic." [Online]. http://www3.informatik.uni-wuerzburg.de/research/projects/qoeweb/

[4]   M. Fiedler, T. Hoßfeld, and P. Tran-Gia, "A Generic Quantitative Relationship between Quality of Experience and Quality of Service," in IEEE Network Special Issue on Improving QoE for Network Services, Vol. 24, No. 2, pp 36–41, March–April 2010.

[5]   T. Hoßfeld, R. Schatz, S. Biedermann, A. Platzer, S. Egger, and M. Fiedler, "The Memory Effect and Its Implications on Web QoE Modeling," in Proc. 23rd International Teletraffic Congress (ITC 2011), San Francisco, USA, 2011.

[6]   T. Ciszkowski, W. Mazurczyk, Z. Kotulski, T. Hoßfeld, M. Fiedler, and D. Collange, "Towards Quality of Experience-based Reputation Models for Future Web Service Provisioning," Special Issue of the Springer Telecommunication Systems Journal: Future Internet Services and Architectures – Trends and Visions, Vol. 47, March 2011.

[7]   T. Hoßfeld, "Time Dynamic Modeling of Quality of Experience (QoE) for Web Traffic," Cost TMA Action IC0703 "Data Traffic Monitoring and Analysis: theory, techniques, tools and applications for the future networks," October–December 2010. [Online]. http://www.tma-portal.eu/

[8]   COST QUALINET Action IC1003. (2011) "European Network on Quality of Experience in Multimedia Systems and Services." [Online]. http://www.qualinet.eu/

[9]   M. Fiedler, K. Kilkki, and P. Reichl, "From Quality of Service to Quality of Experience," Germany Schloss Dagstuhl – Leibniz-Zentrum für Informatik, Ed.: Dagstuhl Seminar Proceedings 09192, 2009.

[10]   Euro-NF Workshop, "Quality of Experience Workshop," in combination with 21st International Teletraffic Congress (ITC 21), Paris, France, September 2009. [Online]. http://www.i-teletraffic.org/index.php?id=112

[11]   P. Chołda, E. Larsen Følstad, B.E. Helvik, P. Kuusela, M. Naldi, and I. Norros, "Towards risk-aware communications networking," submitted for publication.

[12]   A.J. Gonzalez, B.E. Helvik, J.K. Hellan, and P. Kuusela, "Analysis of dependencies between failures in the UNINETT IP backbone network," in Proc. IEEE 16th Pacific Rim International Symposium on Dependable Computing [PRDC2010], October 2010.

[13]   I. Norros, P. Kuusela, J. Lapuyade-Lahorgue, and M. Naldi, "On reliability modeling with stationary on/off processes," preprint.

[14]   V. Cerf, S. Burleigh, A. Hooke, L. Torgerson, R. Durst, K. Scott, K. Fall, and H. Weiss, "Delay-Tolerant Networking Architecture," RFC 4838, April 2007, [Online]. Available: http://www.rfc-editor.org/rfc/rfc4838.txt.

[15]   V.N.G.J. Soares, F. Farahmand, and J.J.P.C. Rodrigues, "A Layered Architecture for Vehicular Delay-Tolerant Networks," in Proc. Fourteenth IEEE Symposium on Computers and Communications (ISCC'09), Sousse, Tunisia, July 5–8, 2009, pp. 122–127.

[16]   P. Rogério Pereira, A. Casaca, J.J.P.C. Rodrigues, Vasco N. G. J. Soares, Joan Triay, Cristina Cervelló-Pastor, "From Delay-Tolerant Networks to Vehicular Delay-Tolerant Networks," in IEEE Communications Surveys & Tutorials, accepted for publication. ISSN: 1553-877X. DOI: 10.1109/SURV.2011.081611.00102.

[17]   J.N. Isento, J.A. Dias, J.C. Neves, V.N.G.J. Soares, J.J.P.C. Rodrigues, A. Nogueira, and P. Salvador, "FTP@VDTN - A File Transfer Application for Vehicular Delay-Tolerant Networks," in Proc. International Conference on Computer as a Tool (EUROCON 2011) and 8th Conference on Telecommunications (ConfTele 2011), IST Congress Center, Lisbon, Portugal, April 27–29, 2011.

[18]   J.A. Dias, J.N. Isento, M.P. Pereira, Bruno M. Silva, Vasco N. G. J. Soares, Joel J. P. C. Rodrigues, Paulo Pereira, Augusto Casaca, Cristina Cervelló-Pastor, and Javier Gallego, "WWW@VDTN - A Web Browsing Application for Vehicular Delay-Tolerant Networks," in Proc. 16th IEEE International Workshop on Computer-Aided Modeling Analysis and Design of Communication Links and Networks (CAMAD 2011), Kyoto, Japan, June 10–11, 2011.

[19]   J.J.P.C. Rodrigues, J.A. Dias, J.N. Isento, B.M. Silva, V. Soares, N. Magaia, P.R. Pereira, A. Casaca, C. Cervelló-Pastor, J. Gallego, "The Vehicular Delay-Tolerant Networks (VDTN) Euro-NF Joint Research Project," in Proc. 7th Euro-NF Conference on Next Generation Networks (NGI 2011), Kaiserslautern, Germany, June 27–29, 2011. ISBN: 978-1-4577-0916-6. DOI: 10.1109/NGI.2011.5985871.

[20]   V.N.G.J. Soares, F. Farahmand, and J.J.P.C. Rodrigues, "VDTNsim: A Simulation Tool for Vehicular Delay-Tolerant Networks," in Proc. 15th IEEE International Workshop on Computer-Aided Modeling Analysis and Design of Communication Links and Networks (IEEE CAMAD 2010), Miami, FL, USA, December 3–4, 2010, pp 101–105.

[21]   J.A. Dias, J.N. Isento, V.N.G.J. Soares, F. Farahmand, and J.J.P.C. Rodrigues, "Testbed-based Performance Evaluation of Routing Protocols for Vehicular Delay-Tolerant Networks," in Proc. IEEE Globecom 2011 Workshop on (MCS 2011), Houston, TX, USA, December 05, 2011.

[22]   J.A. Dias, J.N. Isento, V.N.G.J. Soares, and J.J.P.C. Rodrigues, "Impact of Scheduling and Dropping Policies on the Performance of Vehicular Delay-Tolerant Networks," in Proc. IEEE International Conference on Communications (IEEE ICC 2011), Communication Software, Services and Multimedia Applications Symposium (CSMA), Kyoto, Japan, June 05–09, 2011.

[23]   V.N.G.J. Soares, F. Farahmand, and J.J.P.C. Rodrigues, "Performance Analysis of Scheduling and Dropping Policies in Vehicular Delay-Tolerant Networks," in International Journal on Advances in Internet Technology, ISSN: 1942-2652, Vol. 3, No. 1&2, 2010, http://www.iariajournals.org/internet_technology/.

[24]   J.A. Dias, J.N. Isento, J.J.P.C. Rodrigues, P.R. Pereira, and J. Lloret, "Performance Implications of Fragmentation Mechanisms on Vehicular Delay-Tolerant Networks," in Proc. 11th International Conference on Telecommunications for Intelligent Transport Systems (ITST-2011), St. Petersburg, Russia, August 23-25, 2011, pp. 436–441.