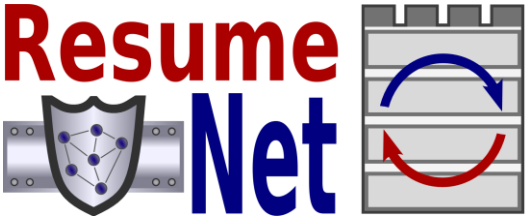
Resilience and Survivability for future networking: framework, mechanisms, and experimental evaluation



5th Periodic Progress Report (September 2010 – February 2011)

PROJECT PERIODIC REPORT

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Publishable summary

The research work carried out in the context of the ResumeNet project proposes a systematic architectural approach to Internet resilience that attempts to maximize interoperability with legacy network components. In ResumeNet, we understand resilience as the ability of the network to provide and maintain an acceptable level of service in the face of various faults and challenges to its normal operation. Our definition of resilience is a superset of commonly used definitions for survivability, dependability, fault-tolerance, and performability.

Our approach to understanding and implementing resilience in future networks evolves gradually within the project lifetime from the more abstract aspects of strategy and framework towards the more practical implementation issues. At the highest level of abstraction the desired functionality of resilient networks is summarized in the six-step strategy D^2R^2+DR (Defend, Detect, Remediate, Recover, Diagnose and Refine). These straightforward Ds and Rs effectively order the required resilience functionality with respect to the nature of the different actions, i.e., proactive (preventive) vs. reactive, but also, more importantly, their timing: Detect, Remediate and Recover outline the shorter-term control loop in the operation of resilient networks, whereas Diagnose and Refine compose the outer, longer-term control loop.

A Framework for Architecture, Policies and Metrics
In engineering networked systems that are able to carry out these six operations, we need a good understanding of several concepts. Within ResumeNet this work is undertaken in the context of WP1 (framework) and involves a number of fundamental aspects.

We have developed a risk management based approach for assessing and classifying challenges to network operation. The rationale is that the monetary and computational resources available for resilience are expected to be finite. Therefore, we need to understand the high impact challenges a networked system will face, so that defensive and remediation measures should primarily address those challenges.

Defining resilience metrics is of critical importance. Technical University Delft and Kansas University have been working on a multilevel framework that can assess the network resilience, as viewed by different layers of the protocol stack. Starting from the physical topology resilience, analysis and simulation are combined to get a view of how higher layers may attenuate or accentuate the impact of challenges on network performance, as this is experienced from different network functions and assessed from different viewpoints (e.g., user vs. network operator).

With respect to policies, we have investigated the features of three significant policy-based management frameworks – Ponder2, XACML and Or-BAC – that could be used for resilience. We found a number of useful features, which are described in the deliverable D1.3. Moreover, in a publication in AIMS 2010, we described the application of policies to a resilience case study: high traffic volume challenges to an ISP's infrastructure.

Finally, our work on understanding the various approaches to information sensing and sharing continues, with a strong cross-layer dimension embedded to it. Joint work between Kansas Univ. and Lancaster Univ. on exploring the trade-offs associated with performing error control in different ways, given distinct application requirements, has continued with the implementation of a number of error control mechanisms. We have explored the use of context information to better understand the nature of a challenge. The utility of the various information sources discussed is shown in a number of case studies.

Making the Network More Resilient

ResumeNet is pursuing five different defensive measures on different layers of the protocol stack. The first approach is looking at "topological conditions for collaboration in wireless mesh network". The goal is to provide defensive measures to the network layer to protect the distributed system from maliciously behaving nodes, i.e., forwarding selfishness. A protocol leveraging these results is currently under development as a WP4 work item. The second approach focuses on "optimization models for resilient network design". The developed optimization model outputs a network topology, which balances resilience and monetary costs. "Diversity in topology and end-to-end mechanisms" is the third measure under investigation, which has three main thrusts: the identification and characterization of multiple reliability modes; path diversification, a heuristic approach to selecting multiple end-to-end paths for simultaneous or failover use; and the modelling of physical topologies, network attacks and challenges. The fourth approach is looking at integrating QoS with Quality of Security (QoS^2). This defensive measure balances quality of service versus quality of security using a multi-attribute decision making algorithm. The algorithm was evaluated for an IPTV service environment. The fifth defensive measure investigates the required protection each node has to provide to protect the overall system from malware. A model of the spreading process has been developed and applied with different configurations.

With respect to challenge detection, an extensive literature study and consolidation effort had to be performed first since this has been a research topic for several years. Based on these results, ResumeNet partners have been pursuing four different research threads. The first thread addresses challenge detection in wireless mesh networks, focusing on interference. The second research area is about challenge detection in opportunistic networks, where the detection task is severely hindered by episodic connectivity. The third research item evolves around an information storage and sharing architecture to support challenge detection and fault analysis. The last research item, closely related to the third one, draws on the proposed information storage mechanisms to autonomously self-refine the challenge detection architecture.

The last task in WP2 is concerned with the adaptation that is necessary to remediate the network once challenges are detected. ResumeNet partners have investigated three different scenarios to extract requirements for such a system adaptation. Based on these requirements, an architecture for network resilience has been derived. Further investigations have been focusing on technologies for this resilience architecture: remediation strategies using adaptation of access control policies, remediation strategies using obligation policies to adapt the system configuration and specialized optimizers supporting the remediation selection process. As mentioned earlier, in the final year of the project, system evolution and refinement of the resilience architecture is being investigated. In a similar fashion to our research on the adaptation framework, we are taking a bottom-up approach, building on a number of case studies. Our aim is to define a general interface to allow interaction between the two (inner and outer) control loops. The results of our investigations will be reported in deliverable D2.4b at the end of the project.

Towards Resilient Services

The focus of activities WP3 is on service resilience. The general approach is to use techniques that can provide abstractions from the underlying hardware resources and thus can proactively (Defence) improve the resilience of services. These techniques are, more specifically: a) P2P; b) overlay-based end-to-end connectivity; and c) virtualisation.

P2P signalling is used to provide resilient lookup of a communication partner (IP and port), e.g., for VoIP call, or a web session. Protocols used for this purpose today are, e.g., DNS or SIP while the actual data is transported subsequently using, e.g., HTTP or RTP. For the SIP case, we follow a supervised P2P approach with endpoints as peers and a central authority as a server. We have provided a quantitative reliability model based on reliability theory and traces from the Skype

network. For the DNS case, we have evaluated the suitability of P2P networks for resolving DNS Fully Qualified Domain Names (FQDN) and came across hot spot problems. However, we are currently learning from DNS deployment, notably the usage of IP anycast for reaching DNS servers, and want to apply IP anycast as a resilience mechanism to maximize service availability over the network.

The next resilience mechanism in WP3 is overlay-based end-to-end connectivity. At the data plane (e.g., HTTP or RTP) if the end-to-end communication using TCP/IP between the two endpoints is disrupted, then overlay-based end-to-end connectivity comes into place. A P2P overlay network is used for providing end-to-end connectivity as a failover. Additionally, services can be hosted in virtualised environments. Hosting services in virtualised platforms is a Defence itself, (since it provides isolation and thus better security), but is also an enabler for the migration of services as a Remediation and Recovery strategy. In this context, the costs and implications of different migration techniques are currently being investigated.

While work in WP3 has a strong focus on defence, i.e., proactive resilience mechanisms put in place before challenges occur, the remaining three steps of the inner loop (Detect, Remediate and Recover) at the service level are among the contributions of France Télécom in the project. This task is integrated with the overall challenge identification architecture in WP2. It reuses results from WP1, notably the work on policies, to select and apply remediation mechanisms. And finally, the results of this task flow into the experimentation activities in WP4.

Experimental Validation

The evaluation of both principles and mechanisms is carried in WP4 out via analysis and experimentation. Four case studies have been defined to exemplify the application of the framework in concrete service provision scenarios. They represent a well-balanced mix of networking paradigms with both short-term and longer-term potential for commercial exploitation such as Wireless Mesh Networks, Delay Tolerant Networks, and Internet of Things. Experiments are carried out on testbeds; some of them are in-house experimentation facilities, deployed or enhanced for the needs of the project (e.g., ETH Zurich TikNet, Uppsala Haggle testbed), whereas others are larger-scale facilities made available to the research community via dedicated projects (e.g., Planetlab and its European counterpart, Planetlab Europe).

During the first two years of the project, significant effort was devoted to the more detailed specification of the experimentation scenarios and the respective testbed development work, where appropriate. This work is directly influenced by the progress made on the framework (WP1) and mechanism (WP2-WP3) aspects of the project. In parallel, the activities in WP4 have supported the activities of the EU FIREWorks Coordination Action[1] via compilation of two versions of two light deliverables on the federation requirements and the links between research and experimentation in ResumeNet. Now in the final year of the project, our activities in this work package are fully underway and will be reported at the end of the project.

Impact

ResumeNet has devoted considerable effort to the dissemination of its results:

1. The project Web site and Wiki pages are operational since November 2008 (http://www.resumenet.eu/), and are regularly updated with the latest project news and results.

[1] http://www.ict-fireworks.eu/

2. ResumeNet has been presented, with the use of flyers, posters[2], or slide sets, in various venues including magazines; scientific conferences and workshops; events organized by the European Commission (SAC/FIRE Workshops, FIRE Launch Event, ICT 2008-2010).
3. ResumeNet has been closely monitoring the activities of the Future Internet Assembly, supporting the coordination activities of FIREWorks, and participating in the meetings of the FIRE Expert Group. The project has also invested resources on direct standardization actions. Such is the case with the ITU-T Focus Group on "Future Networks", established in January 2009 by Study Group 13 ("Future networks including mobile and NGN").
4. Members of the project published nine papers in prestigious journals, three magazine articles and 34 articles in peer reviewed conferences or workshops. Six more articles were submitted for publication.
5. ResumeNet also has an impact on education in the involved academic institutions, with six Bachelor theses and eleven Master theses on-going or completed. Fourteen Doctoral theses are on-going and two were completed in 2010.

Throughout the project lifetime, exchanges have also taken place with EU projects carrying out activities on network resilience: Contacts have been made to various projects, including the FP6 Network of Excellence ReSIST (http://www.resist-noe.org/, the FP7 Coordination Action AMBER (http://amber.dei.uc.pt/), and the FP6 Integrated Projects ANA (Autonomic Network Architecture) and Haggle. Recently, ResumeNet partners supported the UniverSelf (www.univerself-project.eu) project by filling in a questionnaire, along with other liaison activities. Furthermore, a half-day common meeting was in Liège (Belgium) with the ECODE project (www.ecode-project.eu), during which partners from each consortium presented their respective work.

Finally, ResumeNet has come to the attention of ENISA, the European Network and Information Security Agency, which works on behalf of the EU Institutions and Member States in response to security issues of the European Union. ResumeNet was invited to present its work during their 1st Workshop on "Network and service resilience metrics and measurement frameworks". Furthermore, ResumeNet project outcomes described in our deliverables have been cited in technical reports produced by ENISA.

http://www.resumenet.eu

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[2] The latest version of ResumeNet's poster is available now in the public Web site.

Contents

1. Project objectives for the period

Making progress on research work on experimentally validating the project's results: Since M24 of the project, much of the focus of the project has been on experimentation in WP4. This was reflected in the comments we received from the reviewers at the second review in Brussels. In particular, the reviewers asked for a short additional deliverable that describes in greater detail than previously reported various aspects of our experimentation plans. A draft version of this deliverable was presented to the reviewers ahead of our PCC meeting in Liège, at which the document played an important role in our discussions. A final version of the deliverable was submitted to the reviewers for comments mid-February. Activities within WP4 are now being pursued at full-effort and we anticipate these to be reported successfully at the project end.

Initiation of activities on the outer loop of the D^2R^2+DR strategy: During this reporting period activities in Task 2.3 turned to the diagnosis and refinement phases of the resilience strategy, with the proposed activities in this area being reported in deliverable D2.4a. This task has taken a "bottom-up" approach to gaining insights into learning for resilience, by using a number of case studies. The results of these activities will be published in D2.4b, at the end of the project.

Reporting of activities on resilient overlays: This activity is investigating algorithms for providing resilient overlays for both signalling and data traffic. The observation is that these forms of traffic have different resilience requirements, e.g., signalling traffic tends to be low bandwidth and require low-latency and loss, whereas data traffic may have higher bandwidth requirements and could tolerate higher losses. Broadly speaking, the approach taken, called Perco-Pastry, constructs a geographically aware substrate overlay used for signalling, out of which overlays are derived for sending data traffic. The motivation for this work and the initial approach taken is described in D3.4, which was due in this reporting period. This is an interim deliverable; the outcome of this activity will be finally reported at M36 in D3.1c.

Concerns from the previous review: As with the previous review, we have chosen to codify the reviewer's remarks, allowing us to track progress toward satisfying them.

A theme that emerged strongly from the review regarded the importance of the experimentation activities in evaluating the project's outcomes, which lead to the requirement to produce an extra deliverable (see above). As a project, we will continue to monitor progress closely in WP4, e.g., via bi-weekly WP meetings, to ensure the targets set for the activities in WP4 are met.

Another concern that emerged from the review related to the maturity of the architectures developed in Tasks 2.2 and, in particular, 2.3 of the project. Work is on going to improve the maturity of this work, including carrying out further simulations of the multi-stage and policy-driven approach to resilience discussed in the deliverables D2.2b and D2.3b. Furthermore, we anticipate being able to make statements regarding approaches to implementing the architecture.

Based on comments made at the second review, we are continuing to seek opportunities to demonstrate the multi-level nature of the approach we have taken to resilience. In particular, we aim to demonstrate how our approach is applicable beyond layers two and three of the OSI protocol stack. The outcomes of this activity will be described in deliverables that are due at the end of the project.

Finally, a number of reviewer's comments related to specific items they would like to see discussed in the final versions of the deliverables produced by the project. These have been noted, and in particular, we aim to address these comments in the two major final project deliverables: D1.5c on the resilience strategy and D6.5, the final project report.

2. Work progress and achievements during the period

2.1. WP1: Framework for resilience and networking

Officially, many of the activities within WP1 have ended, with outcomes from this WP being evaluated and results fed back from WPs 2, 3 and, in particular, 4. These results will be reported in the final versions of the deliverables due for this WP. Correspondingly, Task 1.1 on the resilience strategy, is still running to collate these results. Additional activities, proposed in an amendment to the DoW, have been started in Task 1.3 on resilience metrics, with effort from TUM and TUDelft, and activities in Task 1.5 on multi-level resilience, lead by UP, have begun. The outcomes of these activities will be reported in the final metrics deliverable, and a new deliverable (D1.6), respectively.

2.1.1. Per-task summary of progress towards objectives

Task 1.1 Strategy for resilient networking

During this reporting period, activities within Task 1.1 have included further development of a magazine article that was submitted to the IEEE Communications Magazine Network and Service Management Series. Furthermore, within Task 1.1, we have been investigating how current research in the area of Situational Awareness (SA) relates to our on-going work on challenge detection and identification in WPs 2 and 3. In particular, we are interested in understanding further if models of SA may help us to understand how better decisions could made regarding remediation and recovery. We anticipate outcomes from this investigation to appear in the final strategy document, due M36.

Task 1.3 Resilience metrics

In a new subtask (1.3.4) added by TUM (see "Amendments to Description of Work" document), we started to analyse the robustness and usability of existing real-world certificate infrastructures. To this end, we are conducting an analysis of the certificates handled by the hierarchical X.509 PKI infrastructure as it used by modern browsers for SSL and TLS. Our methodology includes both active crawls and passive monitoring of SSL/TLS connectivity. The X.509 investigation is complemented by an analysis of the decentralized web of trust graph for PGP/GPG keys that can be accessed via key servers. This activity is currently being continued (beyond Feb. 2011). The outcome will be provided in D1.2b (end of August 2011).

Previous results and insights from measuring resilience (Task 1.3) and resilience mitigation strategies (Task 2.1/2.3) determined that there can exist a high correlation and interdependency between metrics, which would limit the development of efficient optimizing strategies for network resilience. In order to further quantify the behavior and relations of resilience metrics, a new work item was added by TUD to experimentally evaluate the correlations, sensitivity and responses of metrics to system parameter changes based on the example of VoIP by use of statistical regression models and data mining techniques. This activity is currently ongoing and the results be reported in D1.2b (end of August 2011).

Task 1.5 Cross-layer optimisation and multi-level resilience

During the last six months there has been work carried out on cross-layer challenge detection. In particular, the topic of distributed correlated network monitoring has been investigated. Several network monitoring tools have been investigated for their applicability to the ResumeNet architecture. The ability to correlate between events plus the distributed operation of monitoring agents have been identified as critical building blocks for reliable challenge detection. Next steps

will focus on integration with identification engines like the Chronicles Recognition System (CRS). This work is going to be reported in D1.6, due at the end of the project.

2.1.2.WP1 Main Output

The following summarises the main output from WP1 during this reporting period:

- Submission of an article to the IEEE Communications Magazine Network and Service Management Series.

2.1.3.Deviations from the time plan and suggestions for correction

As mentioned earlier, new sub-tasks have been added to the activities in WP1, namely in Tasks 1.3 and 1.5. The task descriptions are outlined in a request for amendments to the description of work. Results from these activities will be presented in the final metrics deliverable, and a new one.

2.2. WP2: Network-level resilience

2.2.1.Per-task summary of progress towards objectives

Task 2.1 Defensive Measures

This task was concluded with the end of the second year and activities have ceased since then. The final results were reported in D2.1b.

Task 2.2 Challenge Detection

In response to reviewer's comments from the second project review, activities to improve the maturity of the architectural work carried out have been continuing. In particular, we have continued to develop aspects of the policy-driven resilience simulator, including the ability to import collected flow data into the simulation environment and produce packet-level events. The intention is to improve the realism of the simulations. This facility and the ability to couple the simulator with the Ponder2 policy framework will form the basis of continued work. Our efforts on improving the maturity of the architecture work will be reported in D1.5c, due in M36 of the project.

Furthermore, ULg has been working on a Python implementation of the SkipTree peer-to-peer protocol for a lab environment. SkipTree had been identified in D2.2b as the most promising solution for an aggregation-capable overlay that would meet the requirements for DISco. We intend to use this prototype to validate the concepts on VoIP SPIT being investigated in Task 2.3 on longer-term evolution.

Task 2.3 Adaptation and Evolution Framework

The activities in this task have moved from adaptation to evolution for the last period of the project. We have defined five scenarios for investigations in D2.4a which was delivered Nov. 2010. These scenarios are expected to inform us about details of the required functionality of the outer control loop of the general ResumeNet strategy. The variety of scenarios reaching from network level mechanisms, e.g., multi-path protection schemes and challenge backtracking, up to application level mechanisms, e.g., SPIT (Spam over VoIP service) and virtual machine migration, should enable us to define general interface to allow interaction between the two control loops. The results of our investigations will be reported in the update deliverable D2.4b at the end of the project.

2.2.2.WP2 main output

The following summarises the main output from WP2 during this reporting period:

- Submission of Deliverable D2.4a.

- Preparation of a paper on Challenge-aware Multi-path Protection Schemes for submission to DRCN 2011 in March.

- Preparation of a paper on multi-stage policy-driven challenge identification and remediation for submission to DRCN 2011 in March.

2.2.3. Deviations from the time plan and suggestions for correction

Activities in T2.2 on Challenge Detection have been extended into year 3 of the project as a reaction to the review comment on the maturity of the architecture work. In collaboration with T2.3, both task will further evolve and evaluate the proposed architecture.

2.3. WP3: Service-level resilience

2.3.1. Per-task summary of progress towards objectives

Task 3.1: Resilient services framework

Task 3.1 is an umbrella task for WP3 and is an on-going task during the whole WP3 period. It has been coordinating the activities with other WPs as well as within WP3. The next deliverable of this task will be D3.1c (end of August 2011) which describes the ResumeNet final resilient service architecture.

Task 3.2: Secure application of P2P and overlay networks for resilient service provision

According to the time plan, this task was finished by the end of August 2010. The results on P2P signalling for resilient services (SIP and DNS) were also described in D3.3 (delivered in August 2010). Nevertheless, the results of this task, particularly the analysis of the DNS deployment today motivated to a new additional activity (as mentioned in the last project review): the analysis of the potential benefits of IP anycast for resilient services. IP anycast has been deployed to achieve failover between DNS server nodes reachable under the same IP address but located in different geographic locations. We are currently in the process of analysing the generic applicability of IP anycast for resilient services. For this purpose, we use traces collected at anycast nodes of DNS root servers and correlate these traces with BGP data collected from various BGP routes views. The results will be reported in D3.1c (end of August 2011).

Task 3.3: Management and security of virtualization services

The main focus in T3.3 during the reporting period has been the modification of the vCPI (virtual Component Programming Interface) software to the ResumeNet requirements. The vCPI has been developed in the AutoI project as a software to manage and monitor virtual resources. In the context of ResumeNet, some modifications were necessary to make use of it. The vCPI was originally implemented as a software to manage virtual routers and virtual links. In particular, the functionality to manage virtual links is considered useful for T3.3, since the creation of virtual links can be used to restore network connectivity after wide area migration of a virtual service. Still, some of the vCPI concepts had to be adapted to support virtual services, as planned in T3.3. This work will be documented in D3.1c.

Task 3.4: Detection, Remediation and Recovery at the Service Level

As mentioned in the previous progress reports, this task is about the application of Detection/Remediation/Recovery (DR^2) phases of ResumeNet's D^2R^2+DR strategy at the service level. A framework is being built for detecting challenges threatening a service, remediating harms caused by these challenges and recovering to a normal situation.

A service resilience framework should have a generic design in order to be applicable to different services. To this end, a good understanding of the notion of service is mandatory. Thus, the first step in this work consists of identifying what is a service and what are the service attributes concerned by resilience. Another issue is the difference between resilience at the service level, compared to other levels, e.g., network.

The resilience framework should also take into consideration methods used to keep a service resilient, metrics needed to assess the service resilience, challenges threatening a service, and service attributes that can be affected by these challenges. Thus, results from previous works like challenge taxonomy in T1.2 and resilience metrics in T1.3 are currently being used.

Thus, the work during this reporting period consists of:

- an investigation of the notion of service used in different communities (business, IT, telecommunication, …),
- a resilience analysis in different layers (physical, network, application) and different fields (industry, business, computing, telecommunication, …),
- the application of resilience to the service level by designing a generic framework to ensure security and dependability of any kind of services,
- a study of the chronicle recognition system (CRS), the mechanism we intend to use for event correlation to detect challenging situations.

Task 3.5: Overlay-based end-to-end connectivity

As mentioned in previous progress reports, this task aims at maintaining end-to-end IP connectivity using an overlay as a failover technique. It is intended for cases where IP (i.e., underlay) connectivity is disrupted in a way such as a host can only reach parts of the Internet, e.g. due to major BGP convergence problems. It was agreed by June 2010 that TUM takes over the contribution of NEC in this task. Thus, two additional researchers in TUM (Ralph Holz, Stephan Günther) have become active (part time) in this task since October 2010. Thus, this task's activity has greatly increased in the past months.

First, we focused on the following activities: We refined our requirements analysis and design for the intended overlay framework. This resulted in the design and implementation of *Perco-Pastry*, an overlay-based routing algorithm that we developed based on our observations and our use case scenarios that relate to tackling connectivity issues (described in D3.4). Second, we extended our method for estimating a host's geographical location based on RTT measurements. This is a useful feature for detecting paths and nodes within an overlay that seem to differ on the grounds of IP addresses, but actually share the same geographical location of nodes. Our framework design, including Perco-Pastry and IP geolocation, has been described in D3.4 (delivered by end of February 2011). Both Perco-Pastry and IP geolocation are subject to ongoing research and fine-tuning. The final results of our activities in T3.5 will be reported in D3.1c (end of August 2011).
2.3.2.Deviations from the time plan and suggestions for correction

The most relevant deviation in the time plan of WP3 is the extension of activities in this WP beyond the originally planned end date M30 (i.e., end of Feb. 2011) by six months to M36 (end of August 2011). This fits well with the overall project extension from M36 to M40.

More precisely, the following activities are continued beyond Feb. 2011.

- Activities in T3.2 have been extended beyond the original plan (investigation of P2P signalling) to include analysis of IP anycast. The extension of WP3 allows to benefit from this additional activity and to document the results in the final deliverable.
- To ensure the scientific quality of the results of T3.4, a new PhD student joined FT in January 2011. She is working among others on CRS (see details above). The results will be documented by end of August 2011 (M36) in D3.1c.
- As for T3.5, the ResumeNet consortium agreed on how to shift the resources from NEC in this task to other partners. This resource shift was approved by the reviewers and the PO in the 2nd review at the beginning of November 2010. Right away, TUM has allocated additional human resources starting from November 2010 to fulfil the work taken over from NEC in Task 3.5. D3.4 ("Overlay-based Connectivity", M30) provides intermediate results in this task. The final results of T3.5 will be documented in D3.1c by end of August.

2.4. **WP4: Experimentation with resilient networking** Per-task summary of progress towards objectives

In the experimentation part of the project, the aim is to exemplify our approach to resilience in concrete study cases. Work Package 4 (WP4) has been structured around study cases, which are effectively combination of {networking technology, service provision scenario, challenge set} tuples. The four scenarios are:

1. Forwarding Selfishness in Wireless Mesh Networks (w)
2. Content Dissemination in Opportunistic Networking (o)
3. Cooperative Session Initiation Protocol (s)
4. Publish-Subscribe Platform for Smart Environments (p)

Each one assesses a subset of the D^2R^2+DR strategy aspects and the concepts/mechanisms realizing it.

The main focus has been on improving the testbeds and initiating the experimentation activities. This work is directly influenced by the progress made on the framework (WP1) and mechanism (WP2-WP3) aspects of the project.

The tasks enumerated below have been thoroughly discussed in D4.1b. Reviewers have also requested a more concrete technical description of these tasks, along with detailed work plan. This request has resulted in the creation of a special deliverable containing the additional information, document which has been sent to the reviewers at the end of February.

Task 4.1: Wireless Mesh Networks

This task focuses on examining forwarding incentives in wireless mesh networks. In particular, it verifies the impact that the use of network coded traffic has on the incentive structure. For this purpose, the in-house testbed has been upgraded, and the software for network coding has been developed.

A comprehensive set of experiments is currently being devised. These are designed to test the hypothesis that network coding makes it unattractive for nodes to drop packets, as they may contain data of interest for themselves. Theoretical background work (estimating the cooperation from flow dependency graphs) has already been published.

A new semester thesis has been started on the topic of randomized network coding. It will answer a set of practical questions related to the performance of network coding under adverse conditions.

Task 4.2: Opportunistic Networking

A more complex scenario, Task 4.2 brings together all the research questions addressing opportunistic networks, in particular forwarding selfishness and detecting selfishness, the use of metrics, optimality of congestion control algorithms based on locally available information. The testbed allows emulating a mobile opportunistic network and conducting repeatable tests in a controlled and easy to manage environment.

The following items have been addressed during the last reporting period and are a part of the ongoing research:

1. Master thesis on the resource allocation problem (what should be kept in buffers). The goal of this work is to compare different resource allocation algorithms (drop packets according to frequency, popularity, consider different buffer sizes etc.)
2. Comparison of the 2-hop scheme proposed by the DTMC model. At the moment there is a discrepancy between simulation results and model.
3. Ongoing work to evaluate metric envelopes for the case when nodes/links are removed. Here a practical problem is enumerating all possibilities, which leads to state explosion.

Task 4.3: Service-Level Resilience

This task is about experimenting with the concepts developed in close cooperation between TUM and UP in WP3. In the last reporting period, TUM and UP have been working on integrating the activities on P2P signalling for VoIP and virtualisation. Particularly, on Jan. 21st 2011, a meeting took place at the University of Passau to discuss the integration. The final goal is to provide a resilient VoIP signalling service which additionally provides the flexibilities of modern services running in a cloud.

To achieve this goal different techniques have been investigated for the migration of a VM and establishing the connectivity between a SIP server and clients after successful migration. TUM has been working on extending the Cooperative SIP (CoSIP) signalling framework to support notification about migration events in the P2P network, while UP has been working on using layer-2 tunnels for re-establishing connectivity. This will lead to a comparison between the two approaches which will be documented in the upcoming deliverable D4.2b ("Final report on experimental evaluation of resilient networks").

Moreover, UP has been working on the necessary modifications of the virtualisation management software (identified in T3.3). These have been implemented in the last reporting period. This included a modification of the virtualisation backend from XEN to KVM. Though requiring a significant amount of effort, this work has been completed, with the current software stack now being compatible to the G-Lab / ProxMox / KVM infrastructure. Management of virtual services and interconnection of virtual services with virtual links is now possible. This work will enable extensive experimentation with Virtual Machine migration in WP4 / T4.3 during the upcoming months. The results will also be documented in D4.2b.

Task 4.4: Communicating Objects' Data Platform

As stated in the WP4 Special Deliverable, this task is about a publish-subscribe platform, which is a very loosely coupled architecture allowing, e.g., people and objects in an Internet of Things to exchange data without the need to know each other.
This experiment aims to validate the D^2R^2 part of ResumeNet resilience strategy through our testbed starting by the detection of the challenges threatening the platform. To this end, we have begun studying the architecture of this platform in detail to find its vulnerabilities. As a first step, we have identified four challenges that may harm the platform: brute force attack and sniffing attack aiming to detect the users or administrator passwords, the objective being to change different entitlements in order to access unauthorized data (confidentiality component of security),

or publish false messages (integrity aspect of security); denial of service attack, where hackers intend to render the service unavailable; and, finally, equipment failures that may damage the quality of service delivered by the platform or even render the service unavailable.

To avoid the problem of password theft, we have proposed to use the technique of one-time password to authenticate people using the platform. With this method, we avoid replaying attacks but are still vulnerable to what is named "session hijacking attack", where attackers exploit a valid session or session key (e.g., session token or cookie) to gain unauthorized access to services. Investigation is going on for this matter, as well as the identification of other potential sophisticated challenges.

2.5. WP5: Dissemination and exploitation of projects results and standardization activities Per-task summary of progress towards objectives

Publications
The main dissemination activities during this report period are focused on publications involving, for some of them, an internal collaboration among different ResumeNet partners. Research work carried out of the project has been presented in scientific journals/magazines and conferences/workshops/other scientific contexts, or publicized internally, as listed below.

Journals
• A. Fischer, J.F. Botero, M. Duelli, D. Schlosser, X. Hesselbach, and H. De Meer, "ALEVIN - A framework to develop, compare, and analyze virtual network embedding algorithms", Electronic Communications of the EASST (Proc. of the Workshop on Challenges and Solutions for Network Virtualization (NV), Kiel, Germany, March 10 2011), Vol. 37, 2011, pp. 1-12
• J.P.G. Sterbenz, E.K. Çetinkaya, M.A. Hameed, A. Jabbar, S. Qian, and J.P. Rohrer, "Evaluation of network resilience, survivability, and disruption tolerance: analysis, topology generation, simulation, and experimentation - invited paper", to appear in Telecommunication Systems Journal (Springer)

Conferences and workshops
• M.A. Hameed, A. Jabbar, E.K. Çetinkaya, and J.P.G. Sterbenz, "Deriving network topologies from real world constraints", IEEE GLOBECOM Workshop on Complex and Communication Networks (CCNet), Miami, FL, USA, December 2010, pp. 415–419
• J.P.G. Sterbenz, E.K. Çetinkaya, M.A. Hameed, A. Jabbar, and J.P. Rohrer, "Modelling and analysis of network resilience (invited paper)", 3rd IEEE International Conference on Communication Systems and Networks (COMSNETS), Bangalore, India, January 2011
• A. Schaeffer-Filho, P. Smith, and A. Mauthe, "Policy-driven network simulation: a resilience case study", 26th ACM Symposium on Applied Computing (SAC), Taichung, Taiwan, March 21-24, 2011
• C. Doerr, "Parallelized network-driven analysis of network systems on commodity hardware", IEEE International Conference on Networking, Sensing and Control, Delft, Netherlands, April 11-13, 2011

Presentations
• M. Schöller, "Resilience and survivability in communication networks: strategies, principles, and survey of disciplines", Karlsruhe Institute for Technology, Germany, November 22, 2010
• A. Fischer, "Resilience in networks: elements and approach for a trustworthy infrastructure", Future Internet Assembly, Ghent, Belgium, December 16-17, 2010
• M. Schöller, "Network virtualization - An enabler for network resilience?", Karlsruhe Institute for Technology, Germany, February 09, 2011

Publicity

• C. Lac, E. Gourdin, and B. Delosme, "ResumeNet: networks and services resilience", Orange Innovation Division Intranet, November 2010 (in French)

Ongoing work
In addition to the publication listed above, there are 6 papers submitted, covering work done in the project.

• E.K. Çetinkaya, D. Broyles, A. Dandekar, S. Srinivasan, and J.P. G. Sterbenz, "Modelling communication network challenges for Future Internet resilience and survivability: a simulation-based approach", submitted to Telecommunication Systems Journal (Springer)
• W. Deng, M. Karaliopoulos, W. Mühlbauer, P. Zhu, X. Lu, and B. Plattner, "Using k-fault tolerance to characterize the resilience of Internet AS graph", submitted to Computer Networks (Elsevier)
• G. Popa, F. Legendre, M. Karaliopoulos, and E. Gourdin, "Avoiding interference improves collaboration in multi-hop networks", to be submitted to IEEE Transactions on Mobile Computing
• P. Smith, M. Schöller, A. Fessi, M. Karaliopoulos, C. Lac, D. Hutchison, J.P.G. Sterbenz, and B. Plattner, "Network resilience: a systematic approach", submitted to IEEE Communication Magazine
• E. Gourdin, J. Omic, and P. Van Mieghem, "Optimization of network protection against virus spread", submitted to 8th International Workshop Design of Reliable Communication Networks, Krakow, Poland, October 10-12 2011
• T. Jung, D. Ernst, S. Martin, M. Nassar, and G. Leduc, "Towards SPIT filters with optimal performance guarantees", submitted to 5th International Conference on Autonomous Infrastructure, Management and Security (AIMS), Nancy, France, June 13-17 2011

Further impact-making activities
Another aspect of dissemination work is constituted by liaison activities with other FP7 projects. ResumeNet has filled a questionnaire launched by UniverSelf (www.univerself-project.eu) in November 2010, as well as a description of our objectives and results has been provided to some partners of this project launched recently, for its potential applicability to autonomics for future networks. A half-day common meeting was organized on February 3rd 2011 in Liège (Belgium) with ECODE (www.ecode-project.eu), during which partners from each consortium have presented their respective work which could be potentially interesting for the other project.

As mentioned in the previous project periodic report (D6.4d), ENISA, the European Network and Information Security Agency, has invited ResumeNet to present its work during their 1st Workshop on "Network and service resilience metrics and measurement frameworks". This event was held in Brussels (Belgium) on December 1st 2010. Representing the consortium, Dr. Christian Doerr (TU Delft) has described ResumeNet results and the metrics work done in WP1. As a lot of attention was generated by the assistance for the project, ENISA is seeking for further collaboration.

Two ResumeNet partners have attended the Future Internet Assembly event held on December 16-17 2010 in Ghent (Belgium): Andreas Fischer from U. of Passau (Germany) has seized the opportunity to present the objectives and results obtained so far by ResumeNet in the Smart Infrastructures session.

Within the IU-ATC project (www.iu-atc.com), Lancaster U. (UK) leads, together with IIT Madras (India), the theme 4 on "Security and resilience monitoring for NGNs"[3]. Within this theme, a distributed measurement and control system to detect the onset and remediate the effects of abnormal network behaviour is designed. Further, the potential of cross-layer synergy between the application and the network layers, and the correlation of temporal performance metrics at different points in the network (routers, hosts) to provide fast detection and recovery is

[3] Other partners of this theme are U. of Ulster, BT and NMS Works

investigated. The detection mechanism will be based on real-time analysis of traffic arrival rate at different points in the network and the way this is aggregated towards the target(s), using control-theoretic approaches. Appropriate remediation strategies will also be developed for different classes of anomalies detected. We will study the impact of efficient information exchange between the infrastructure and the application layers, and the combination of local and remote control enforcement for fast remediation. Another point of investigation is the use of policies in the context of the D^2R^2+DR control loop and autonomic network management for resilient networks.

Lancaster U. is also collaborating with British Telecom within the context of IU-ATC on more end-system specific issues related to cyber security and resilience. In this context, two joint studentships in the area of "Malware detection and prevention based on application-specific behavioural monitoring", and "Adaptive intrusion detection systems" have recently been advertised.

We have already cited in D6.4d the invitation issued by Lancaster U. to Dr. Mixia Liu from Lanzhou U. of Technology (China). She has joined Lancaster U. on a Chinese government grant in December 2010 for one year to work on items related to machine learning in resilient networks.

Finally, we have also mentioned in D6.4d the visit of Prof. David Hutchison from Lancaster U. planned for the end of 2010 in Australia. This visit took place in December 2010, and provided an opportunity to present the latest work in ResumeNet to the Military Communications research group at the Defence Science and Technology Organisation (DSTO) in Adelaide. Significant interest was raised through the discussion, leading to an agreement of the two groups to maintain contact.

Contribution to standardization work
ResumeNet's contribution to the "Focus Group on Future Networks", issued from the study group 13 of ITU-T, is included in the final document entitled "Draft Deliverable on Future Networks: Objectives and Design Goals" (reference: TD-WP5-132). As local regulation rules are contained in it, the document is going through the Traditional Approval Process (country vote) at the moment.

Dr. Marcus Schöller from NEC (Germany) has also contributed to another ITU publication entitled "Project descriptions on Future Networks" (reference: TD-WP5-104).

2.5.2.Deviation in the time plan and the WP structure from the technical annex

No deviation from the work planned in the DoW is to be reported during the first six months in this third year of ResumeNet WP5 activities.

3. Deliverables and milestones tables

3.1. Deliverables (excluding the periodic and final reports)

Table 3.1: Deliverables

Del. no.	Deliverable name	WP no.	Lead beneficiary	Nature	Dissemination level	Delivery date from Annex I	Delivered	Actual / Forecast delivery date	Comments
1.1	Understanding of challenges and their impact on network resilience	1	NEC	R	PU	M6	✓	22/10/2009	Delivered before end of M7 to allow inclusion of risk-assessment approach in the document.
1.2a	Defining metrics for resilient networking (Interim)	1	TUDelft	R	PU	M18	✓	26/02/2010	Delivered on time
1.3a	Politics for resilience (Interim)	1	NEC	R	PU	M18	✓	18/03/2010	Delivered with a short delay
1.4	Cross-layer optimization and multilevel resilience	1	ULANC	R	PU	M24	✓	15/10/2010	Delivered with a short delay
1.5a	First interim strategy document for resilient networking	1	ULANC	R	PU	M12	✓	05/10/2010	Delivered with a short delay
1.5b	Second interim strategy document for resilient networking	1	ULANC	R	PU	M24	✓	24/09/2010	Delivered with a short delay
2.1a	First draft on defensive measures for resilient networks	2	FT	R	PU	M15	✓	05/12/2010	Delivered with a short delay

Table 3.1: Deliverables (continued)									
Del. no.	Deliverable name	WP no.	Lead beneficiary	Nature	Dissemination level	Delivery date from Annex I	Delivered	Actual / Forecast delivery date	Comments
2.1b	Defensive measures for resilient networks	2	TUDelft	R	PU	M24	✓	20/09/2010	Delivered with a short delay
2.2a	First draft on new challenge detection approaches	2	ULg	R	PU	M18	✓	05/03/2010	Delivered with a short delay
2.2b	New challenge detection approaches	2	ULg	R	PU	M24	✓	24/03/2010	Delivered with a short delay
2.3a	First draft on the remediation, recovery, and measurement framework	2	ULANC	R	PU	M18	✓	05/03/2010	Delivered in time
2.3b	Remediation, recovery, and measurement framework	2	NEC	R	PU	M24	✓	24/03/2010	Delivered with a short delay
2.4a	First draft of the learning framework for resilient networks	2	NEC	R	PU	M26	✓	14/12/2010	Delivered with a short delay
3.1a	Taxonomy of P2P, Overlays and Virtualization techniques with respect to service resilience	3	UP	R	PU	M12	✓	02/10/2009	Delivered with a short delay
3.1b	Resilient Service Architecture	3	TUM	R	PU	M20	✓	11/05/2010	Delivered with a short delay
3.2	Service Surveillance	3	FT	R	PU	M22	✓	20/07/2010	Delivered with a short delay

Table 3.1: Deliverables (continued)									
Del. no.	Deliverable name	WP no.	Lead beneficiary	Nature	Dissemination level	Delivery date from Annex I	Delivered	Actual / Forecast delivery date	Comments
3.3	P2P overlays and virtualization for service resilience	3	TUM	R	PU	M24	✓	20/09/2010	Delivered with a short delay
3.4	Security and Control concepts for resilient services	3	TUM	R	PU	M30	✓	11/03/2011	Delivered in time
4.1a	Federation Requirements (Interim)	4	ETHZ	R	PU	M6	✓	09/04/2009	Light deliverable in response to the delayed request for inputs from FIREWorks
4.1b	Federation requirements (Final)	4	ETHZ	R	PU	M18	✓	26/03/2010	Delivered with a short delay
4.2a	Interim report on experimental evaluation of resilient networking	4	UU	R	PU	M24	✓	08/10/2010	Delivered with a short delay
WP4-DS	Special deliverable on WP4 experimentation plans (final)	4	ETHZ	R		M30	✓	21/02/2011	Delivered in time
5.1	ResumeNet website and Wiki pages	5	ETHZ	O	PU	M2	✓	10/2008	Delivered in time
5.2a	Yearly reports on dissemination activities	5	ULANC	R	PU	M12	✓	02/10/2009	Delivered in time
5.2b	Yearly reports on dissemination activities	5	ULANC	R	PU	M24	✓	20/09/2010	Delivered with a short delay
5.3a	Exploitation Plans (Interim)	5	FT	FT	CO	M24	✓	24/09/2010	Delivered with a short delay

Table 3.1: Deliverables (continued)									
Del. no.	Deliverable name	WP no.	Lead beneficiary	Nature	Dissemination level	Delivery date from Annex I	Delivered	Actual / Forecast delivery date	Comments
6.1	Project Management Guidelines	6	ETHZ	R	PP	M2	✓	31/10/2008	Delivered in time
6.2a	Links between research and experimentation (Interim)	6	ULANC	R	PU	M6	✓	09/04/2009	Delivered with a short delay
6.2b	Links between research and experimentation (Final)	6	ULANC	R	PU	M18	✓	28/03/2010	Delivered with a short delay
6.3	Report on technical work in WP2 and WP3 during first year	6	ETHZ	R	PU	M12	✓	05/10/2009	Delivered with a short delay

3.2. Milestones

Table 3.2 Milestones

#	Milestone name	Work package no	Lead beneficiary	Delivery date from Annex I	Achieved Yes/No	Actual / Forecast achievement date	Comments
1.1	First view on resilience metrics and classes definition	1	TUDelft	M18	Yes	M18	Deliverable D1.2a
1.2	Policy definition and SLA-like resilience requirements formulation	1	NEC	M18	Yes	M18	Deliverable D1.3a
2.1	First demonstrator of the optimization tool for resilient network topologies	2	FT	M22	Yes	M22	Software on SVN
2.2	First Prototype of the Adaptation and Evolution Framework	2	NEC	M24	Yes	M24	Software on SVN
3.1	Specification of the role of P2P overlays and virtualization in providing resilient services	3	TUM	M24	Yes	M24	Deliverable D3.3
5.1	Website and Wiki pages set up and operational	5	ETHZ	M2	Yes	M2	

4. Project management

The basic concern of the management team during the first half of the third and last year of the project lifetime was to address the reviewer's comments of the second project review and to finalise the amendment document, which includes several changes to the DoW.

The second project review took place on the European Commission's premises in Brussels, Belgium at the beginning of November 2010. The reviewers were generally positive about the ResumeNet project and all Deliverables were accepted. They valued the work made to address the issues raised at the first project review. The whole consortium's effort towards an integration of the individual research streams was much appreciated, however, the reviewers suggested for the final reporting period to further bolster the integration of the individual components, mainly through exploitation of the results of planned experimental activities.

In order to complete a third and successful last project year the reviewers expect the consortium to provide the following three additional documents:

i. A precise description of the experimental activities
(WP4-DS: deadline 28.02.2011, delivered on time)

ii. A unique and comprehensive document presenting the project's technical approach, solutions, and lessons learnt
(Can be part of D1.5c, deadline: end of the project)

iii. A document shedding light on the project's attempts to exploit the currently available FIRE experimental facilities in light of their identified shortcomings, the results if these attempts, and the project's view on extension of such facilities that would be required to fulfil the project's requirements.
(Deadline: end of the project)

Proposed changes to the DoW (pending amendment)

1. Transfer of RTD budget between ResumeNet partners

i. NEC Europe Ltd. requested to withdraw from WP3 "Service level resilience" and release the resources assigned to the research on "Overlay-based resilient end-to-end transport" (Task 3.5). The ResumeNet PCC agreed that this budget and tasks will go to partners TUM, TUDelft and Passau. The later proposed a significant extension of the original workplan with the help of the additional resources. Details are described in a separate document requesting an amendment to the DoW (Amendment 1).

ii. University of Liège (ULg) has determined that the budget figures for their involvement in the project were too elevated. ULg is therefore willing to transfer €32,000.00 to other partners to enable their increased participation in the project. TUM, TUDelft and Passau each proposed to do additional work with this budget within tasks 1.3.5, 1.5 and 1.3, respectively. Details of this transfer can be found in the Amendment 1 document.

2. No cost extension

The ResumeNet project requests a time extension, without additional EC contribution, until the end of December 2011 (M40). All members of the consortium voted unanimously in favour of a project extension at the February 2011 PCC meeting in Liège. In case of approval by the EU the deadline of Deliverables D1.6, D2.4b, D4.2b, D5.2c, D5.3b and D6.5 will be shifted to M40.

3. Changes in the ResumeNet management

Since September 2010, Dr. Merkouris Karaliopoulos is no longer involved in the technical management of the ResumeNet project, as he accepted a position at University of Athens, Greece at this date. However, given that his research will be relevant to the ResumeNet theme and his involvement so far in the project, the proposal is to engage him in the ResumeNet activities as a scientific advisor affiliated to partner 1, ETH Zürich.

In this way, partner 1 can charge costs for travel to ResumeNet meetings for Dr. Karaliopoulos. He will become the third person with a similar role in the project; the other two are Prof. Michael Fry from University of Sydney, Australia, and Prof. James Sterbenz, from Kansas University, US, both visiting researchers to the Lancaster University (Partner 2). The Project Coordination Committee voted unanimously in favour of this change during the Paris Meeting (September 30, 2010).

Dr. Merkouris Karaliopoulos was Work Package Leader of WP4 in the first 2 years of the project. This task will be taken over for Year 3 by Gabriel Popa of ETH Zürich, who was involved in WP 4 from the beginning of the project. The Project Coordination Committee voted unanimously for Gabriel Popa to be WP4 leader in Year 3 during the Paris Meeting (September 30, 2010).

Dr. Paul Smith from Lancaster University (partner 2) has been assisting with project coordination activities during a stay at ETH Zürich from November 2010 until the end of February 2011. This has accounted for 40% of his time on the project during this period. On his return to Lancaster University, he will continue to assist in coordination activities until the end of the project. ETHZ (partner 1) will transfer a corresponding amount of his budget to ULANC (partner 2).

4. Other Cost Anomaly

The ResumeNet budget as agreed in the GPF and Annex1 contains budget figures in the "Other" cost column. It was recently discovered that this is not in compliance with the funding guidelines, as stated in the guide for applicants for the appropriate call (FP7-ICT-2007-2):

"*STREPs in the ICT Theme do not include a cost category "Other". Dissemination activities (normally foreseen in a STREP project) may be classified under "RTD" or "Management". Activities such as IPR protection or the preparation of an exploitation plan may be classified under "Management". Activities such as training, coordination or the commercial exploitation of results should not be included in a STREP project.*"

This budgeting mistake went unnoticed during the negotiations. The project officer agreed that (in order to remedy this issue) shifts between budget categories are not a problem as long as the project keeps the overall cost envelope. Accordingly, we will claim all future cost (except

management cost) as RTD cost, i.e., the expenditures budgeted in the "Other" column will effectively be shifted to the RTD column, while maintaining the overall project budget. In the previous cost claims (which were made before the problem was discovered), costs in the "Other" category were already claimed by different partners. Where necessary, adjustments to the respective previous periods will be made in the final cost claim by these partners, such that in the end no cost will have been claimed in the "Other" category.

Other tasks of the project management team during this period:

- The **synchronization of the whole Consortium** on the project activities (management issues, communication on the scientific level and synchronization of the work between all partners) was mainly achieved through bi-weekly phone conferences (every other Thursday) and emails through the ResumeNet mailing list. Minutes of the phone conference were made available to all consortium members via the internal part of the project homepage, which has constantly been updated during the project period. Additionally, regular phone conferences are held at WP-level or even at task-level.

- **Project monitoring.** Project process (deliverables, milestones) was monitored according to the process described earlier with the result that all deliverables were delivered in time or with a minimal delay.

- **Organization of physical meetings.** To monitor and coordinate the overall project work and also for discussion and workshops within individual WPs, two plenary meetings took place during the past half year: the sixth plenary meeting in Paris, France, 28 September – 1 October 2010 (including the second advisory board meeting on October 1st, 2010) and the seventh plenary meeting in Liège, Belgium, 1-3 February 2011. In addition, several WP-meetings took place, either face-to-face or as phone conferences. The list of meetings scheduled for the rest of the project lifetime is given below:

Table 4.1: Physical meetings envisaged over the next 6 months of the project

Meeting	Context (scope)	Date	Location/ Host
8th Project plenary meeting	The tri-annual plenary project meeting	16-18 May 2011	Passau, Germany / (University of Passau)
9th Project plenary meeting	The tri-annual plenary project meeting	Fall 2011	Location and Host will be decided at the Passau meeting
3rd annual review meeting	Review meeting + brief project TPM group meeting to plan work after the review	January 2012	Zurich, Switzerland (ETHZ)

5. Explanation of the use of the resources

Omitted from this version of the deliverable.