



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



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Summary

This deliverable reports on the numerous dissemination and standardization activities carried out during the first year of the ResumeNet project. These activities include:

- the set-up and maintenance of the public Web site (for external use) and Wiki pages (for daily internal use);
- the submission of research papers for publication in scientific conferences and journals of the field;
- a series of presentations of the project in scientific workshops, symposia, as well as events organized by the European Commission such as the ones coordinated by the FP7 FIREWorks Coordination Action;
- the organization of a Dagstuhl seminar in April 2009 by part of the project consortium;
- the use of additional communication channels (e.g., newspapers, university magazines, poster presentation) to publicize the project's concepts and objectives;
- the launch of collaboration with institutions carrying out resilience-related activities in Europe, US, and Pacific region;
- the contribution of ResumeNet to the "Focus Group on Future Networks", a focus group newly constituted by the Study Group 13 ("Future networks including mobile and NGN") of the International Telecom Union's standardization sector (IUT-T).

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1. Web site and Wiki

Since the World Wide Web is a major dissemination channel, our first efforts in the project have been devoted to the creation of the Web site. Following the planning described in the project's Description of Work document [DoW], the site (<http://www.resumenet.eu>) became operational less than two months after the official start of ResumeNet, i.e., in mid-October 2008.

A major revision of its pages has been realized recently, i.e., in July 2009. Besides the main page containing basic information (e.g., duration of the project, contract number), the website content has been structured along six components:

1. Project: after a descriptive passage of ResumeNet main directions (framework, mechanisms, experimentation), each technical work package of the project is presented, followed by a reminder of its six-step strategy (D^2R^2+DR), and a link to download material summarizing the project scope and objectives.
2. Consortium: partner institutions making up the consortium are quoted, together with a short description of each of them.
3. People and Roles: this area displays the names and a short biography of i) members of the different committees acting among the project; ii) members of the Advisory Board; iii) researchers contributing to ResumeNet.
4. Results: the outcomes produced by the project consortium are listed in this section through five categories, i.e., Deliverables, Presentations (in scientific workshops, conferences, or meetings), Scientific papers (in journals or conference proceedings), Standards (results obtained in the framework of standardization groups), Publicity (e.g., in newspaper articles).
5. News and Events: past events where ResumeNet members have taken dissemination actions, as well as upcoming ones, are summarized in this area.
6. Related Activities and Projects: this section describes briefly EU and other international projects, whose scope lies close to the ResumeNet area of interests.

The Wiki pages for the Consortium's daily work have also become effective in early October 2008. This private area is the zone used by all ResumeNet members to organize administrative, logistical, and technical tasks. In addition to the Wiki, an SVN server is hosted in ETHZ for the collaborative production of all kinds of dissemination material including deliverables, reports, posters, and publications.

2. Publications

As quoted in the DoW, "Academic publications play an essential role to provide confidence to the outcomes of the project. Furthermore, it can be a starting point in the research area for further interest and discussion about the project topics and will lead to a higher degree of acceptance of new technologies. The transparency, given by academic publications, may be the enabler to trigger further interest of industries, provider and users to get acceptance for implementation of the project ideas in new products and services to establish resilience in the future Internet".

Although the project has only completed the first year of its lifetime, research work out of it has been submitted, and, in some cases, accepted and published, to scientific conferences and journals. Likewise, significant work has been published out of research work carried out after the project proposal submission (submitted to the EC in October 2007, the project has been approved in December 2007 and could have begun during Q2 2008. Its launch was postponed to September 1st 2008 upon request of the Consortium for logistical constraints). The full set of publications/submissions is listed below, followed by a short description of their contents and their links to ResumeNet.

2.1. Magazines

- D. Hutchison, and J.P.G. Sterbenz, "*ResiliNets: resilient and survivable networks*," ERCIM News 77, April 2009

The ResiliNets initiative is an umbrella for a number of projects in resilient future Internet architecture. It aims to understand and improve the resilience and survivability of computer networks, including the Internet. This article describes the ResiliNets initiative, the D2R2+DR strategy and gives an overview of the work being carried out within the ResumeNet project (as an example project that has emerged from ResiliNets). Furthermore, the PoMo and GpENI projects are described in the article, including their relationship with resilience. The ResumeNet project has been placed in context of the ResiliNets initiative and other US-based research projects, seeking to make the research community aware of the project and our resilience strategy.

2.2. Journals

- Z. Fadlullah, T. Taleb, M. Guizani, and N. Kato, "*DTRAB: Combating against attacks on encrypted protocols through traffic-feature analysis*," to appear in ACM/IEEE Transactions on Networking (paper accepted with major revisions)

The unbridled growth of the Internet and the network-based applications have contributed to enormous security leaks. Even the cryptographic protocols, which are used to provide secure communications, are often targeted by diverse attacks. Intrusion Detection Systems (IDSs) are often employed to monitor network-traffic and host-activities which may lead to unauthorized accesses and attacks against vulnerable services. Most of the conventional misuse-based and anomaly-based IDSs are ineffective against attacks targeted at encrypted protocols since they heavily rely on inspecting the payload-contents. To combat against attacks on encrypted protocols, an anomaly based detection system by using strategically distributed Monitoring Stubs (MSs) is proposed. Various attacks against cryptographic protocols have been categorized. The MSs, by sniffing the encrypted traffic, extract features for detecting these attacks and construct normal usage behaviour profiles. Upon detecting suspicious activities due to the deviations from these normal profiles, the MSs notify the victim servers, which may then take necessary actions. In addition to detecting attacks, the MSs can also trace back the originating network of the attack. This unique approach is called DTRAB, since it focuses on both detection and trace back in the MS level. The effectiveness of the proposed detection and trace back methods are verified through extensive simulations and Internet datasets. The work described in this paper fits well with tasks 2.2 and 2.3 of the ResumeNet project.

- A. Feldmann, S. Fischer, N. Kammenhuber, and B. Vöcking, "*Management of variable data streams in networks*," in 'Algorithmics of Large and Complex Networks' (J. Lerner, D. Wagner, and K. Zweig, Eds.), Lecture Notes in Computer Science, Volume 5515, Springer Verlag, 2009

This paper presents a dynamic theoretical model of selfish, adaptive behaviour in routing networks that quickly converges to a stable solution. Based on this model, REPLEX, a flexible distributed algorithm for dynamic traffic engineering, is designed. Simulations confirm quick oscillation-free convergence and significant performance improvements. Dynamic traffic engineering renders a network more robust against sudden changes in traffic patterns, e.g., due to DDoS attacks or flash crowds. The REPLEX algorithm presented in this paper will be developed further in WP3 to be suitable for overlay networks, and to cater for other optimization metrics.

- M. Karaliopoulos, "*Assessing the vulnerability of DTN data relaying schemes to node selfishness*", accepted for publication in IEEE Communication Letters, September 2009

This letter analytically assesses the vulnerability of two popular data relaying alternatives, the unrestricted and two-hop relay schemes, to node selfishness. Network nodes may behave selfishly often due to some resource preservation policy, in particular when they are constrained with respect to energy or/and storage space. The results suggest that the performance advantage of unrestricted relaying over two-hop relaying decreases both with the number of selfish nodes and the intensity of their selfishness, irrespective of whether nodes defer from relaying deterministically or probabilistically. The proposed model can be used to quantify the vulnerability of the two relaying schemes to node selfishness but also drive remediation actions against it. This work feeds into task 1.2 of ResumeNet, where a risk assessment approach has been introduced for assessing the impact of several challenges to network normal operation. Analytical modelling is one of the ways to obtain hints about the actual performance degradation due to challenges, in particular when measurement data are hard to obtain. The challenge addressed in this paper is the node selfishness and the network scenario corresponds to the second case study of the project, which is subject of experimentation in WP4.

- M. Sifalakis, M. Fry and D. Hutchison, "Event detection and correlation for network environments", accepted for publication in IEEE Journal on Selected Areas in Communications - Special issue on "Recent Advances in Autonomic Communications", 2009

Networks with desirable self-* properties should be more adaptable to changing conditions and would enable greater flexibility and functional scalability to support resilient operation. A necessary condition for realising these benefits is a heightened level of network awareness; this requires not merely the capacity to monitor the system and network state, but also the ability to characterise the operational environment and its dynamic shifts. This article presents the design framework and initial evaluation of an Information Sensing system that aims to enable awareness through an integrated event detection-correlation mechanism. In the context of systems resilience, it can be used for operational awareness and it offers a more lightweight solution than traditional active database-oriented event systems. It has better performance than log-post analysis processing and its design enables a distributed detection facility. This is fundamental for network-level context awareness and for leveraging decision making and respective action taking, with regard to resilient operation as planned in ResumeNet.

- P. Van Mieghem, J. Omic, and R. Kooij, "*Virus spread in networks*", IEEE/ACM Transactions on Networking, Vol. 17, No. 1, February 2009, pp. 1-14

This paper presents a method for the computation of the so-called epidemic threshold for virus spread in computer networks. Below this threshold, which is uniquely determined by the topological properties of the graph representing the network, the virus dies out exponentially fast. Above the threshold, the virus persists in the network. Simulation results validate our analytical findings. In the framework of ResumeNet, the method can be used to design computer networks that are robust with respect to the spread of viruses.

2.3. Conferences

- A. Jabbar, J.P. Rohrer, A. Oberthaler, E.K. Çetinkaya, V.S. Frost, and J.P.G. Sterbenz, "*Performance comparison of weather disruption-tolerant cross-layer routing algorithms*", in Proc. of 28th IEEE Conference on Computer Communications (INFOCOM), Rio de Janeiro, Brazil, April 19-25, 2009

With growing demand for high-speed access to mobile handheld devices, there is a significant cost benefit in deploying fixed wireless-mesh networks for backhaul access. However, enabling reliable broadband access over high-frequency radios (such as millimetre-wave networks) poses a fundamental challenge due to weather disruptions in general and rain attenuation in particular. An analysis of the impact of precipitation on millimetre-wave mesh networks based on radar measurements of real storms in the Midwest US is presented in this paper. Furthermore, two novel algorithms that use physical-layer information to optimize routing at the network layer are compared: P-WARP (Predictive Weather-Assisted

Routing Protocol) and XL-OSPF (Cross-Layered Open Shortest Path First). Finally, simulation studies to compare the performance of the proposed protocols and evaluate the dependability of the end-user service during weather disruptions are presented. This paper applies the ResumeNet resilience principle of context-awareness, self-organisation, autonomic behaviour, and adaptability to a resilient cross-layered routing mechanism.

- J. Omic, A. Orda, and P. Van Mieghem, "*Protecting against network infections: a game theoretic perspective*", in Proc. of IEEE 28th IEEE Conference on Computer Communications (INFOCOM), Rio de Janeiro, Brazil, April 19-25, 2009

In this paper, the existence of a Nash equilibrium for the protection optimization game is determined and its properties are characterized. It is shown that its quality, in terms of overall network security, largely depends on the underlying topology. In the framework of ResumeNet, these results can be used to estimate the network protection in highly heterogeneous network of autonomous decision makers.

- J. Omic, R. E. Kooij, and P. Van Mieghem, "*Heterogeneous protection in regular and complete bi-partite networks*", in Proc. of IFIP Networking, Aachen, Germany, May 11-15, 2009

In this paper, a method for the computation of the so-called epidemic threshold for virus spread in computer networks is presented. This paper extends the previous results (see section 2.2) in the sense that in the previous paper, the infection process and the curing process were assumed to be homogeneous over all links, and nodes, respectively, while in this work, both processes are heterogeneous. Simulation results validate the analytical findings. In the framework of ResumeNet, the method can be used to optimise curing strategies against computer viruses.

- Z. Fadlullah, T. Taleb, N. Nasser, and N. Kato, "*Exploring the security requirements for quality of service in combined wired and wireless networks*", in Proc. of ACM IWCMC'09, Leipzig, Germany, June 21-24, 2009

In the modern era of Internet, providing Quality of Service (QoS) is a challenging issue, particularly in resource constrained wireless networks with delay-sensitive multimedia traffic. Real-time and multimedia services are now available to end-users over wired networks, Wireless Local Area Networks (WLANs), and Wireless Personal Area Networks (WPANs). While the usual trend is to provide the best possible QoS for these services, it is also imperative to deploy security requirements along with the QoS parameters. It is argued in this paper that the existing approaches for including security parameters (such as encryption/decryption key lengths) with QoS parameters (e.g., end-to-end delay requirements) lead to further security risks and consequently fail to provide an adequate solution. Through simulations, the pitfalls of integrating delay and security support in the contemporary approaches are pointed out. QoS2, a framework integrating both quality of security and QoS, in order to provide possible solutions for solving these problems, is envisioned. The effectiveness and strength of this approach are demonstrated via simulation. The work described in this paper corresponds to task 2.1 of the ResumeNet project.

- N. Kheir, H. Debar, N. Cuppens-Boulahia, F. Cuppens, and J. Viinikka, "*Cost evaluation for intrusion response using dependency graphs*", in Proc. of IFIP International Conference on Networks and Service Security (N2S), Paris, France, June 24-26, 2009

The evaluation of attack and response impacts on target IT systems is still a challenging task. System architectures include multiple services with complex dependencies between them. The high rate of service dependencies thus increases the impact evaluation challenge as the latter is not restrained to the only component being attacked, but it often spreads to its dependent services. This paper contributes to the impact evaluation process for security incidents through the proposal of a systematic modelling and treatment of system dependencies. It evaluates the effect of security incidents using service dependency graphs. It defines security-related properties which are used to propagate impacts in a dependency graph and thus to quantify the real cost of a security incident. The results shown in this paper best fit to the response selection challenge in ResumeNet. The paper proposes selection criteria for countermeasures,

which are based on their impact on the system. This approach may be implemented in order to provide metrics for response selection, which can be used by the decision module within the ResumeNet project.

- N. Kheir, H. Debar, F. Cuppens, N. Cuppens-Boulahia, and J. Viinikka, "*A service dependency modelling framework for policy-based response enforcement*", in Proc. of DIMVA, Milan, Italy, July 9-10, 2009

Malicious and accidental failures both require rapid measures to be taken in order to remediate the system and eliminate the impacts of those failures. It is argued that the management of those remediation alternatives at the level of security policies provides a better granularity, and best fits to the dynamic system constraints. Meanwhile, the high complexity in today's network and information systems renders the dynamic management of those policies a difficult process. Elementary access control rules, which are carefully tightened during the system design time, need to be dynamically updated during system run-time, ending up with an enormous number of access control rules which are difficult to be managed. This paper develops a formal approach for modelling system architectures and the dependencies between services within those architectures. It also provides a formal process for handling the dependency model. It thus bridges the gap between the abstract policy definition and the concrete system architecture. The approach presented in this paper facilitates the inline management of security policies since those will be more abstract and less dependent on the concrete system architecture. This approach will become a main component of the remediation process studied in the task 2.3 of ResumeNet.

- M. Schoeller, T. Taleb, and S. Schmid, "*Neighbourhoods as an abstraction for fish-eye state routing*", in Proc. of IEEE PIMRC, Tokyo, Japan, September 13-16, 2009

This paper presents a routing scheme based on metric dependent neighbourhoods to calculate the forwarding graph. The proposed routing scheme supports aggregation of this metric related information while disseminating routing updates to retain scalability. Simulation results with an exemplary metric based on link stability information show the feasibility of this aggregation approach and the improvement with respect to node reachability and reliable communication in self-organizing wireless networks. In the framework of ResumeNet, this routing algorithm can be used as a resilient routing component in ad-hoc wireless networks.

- F. Hugelshofer, P. Smith, D. Hutchison, and N.J.P. Race, "*OpenLIDS: a lightweight intrusion detection system for wireless mesh networks*", in Proc. of 15th Annual International Conference on Mobile Computing and Networking (MobiCom), Beijing, China, September 20-25, 2009

Wireless mesh networks (WMNs) are being used to provide Internet access in a cost efficient manner. Typically, consumer-level wireless access points with modified software are used to route traffic to potentially multiple back-haul points. Malware infected computers generate malicious traffic, which uses valuable network resources and puts other systems at risk. Intrusion detection systems can be used to detect such activity. Cost constraints and the decentralised nature of WMNs make performing intrusion detection on mesh devices desirable. However, these devices are typically resource constrained. This paper describes the results of examining their ability to perform intrusion detection. Our experimental study shows that commonly-used deep packet inspection approaches are unreliable on such hardware. A set of lightweight anomaly detection mechanisms as part of an Intrusion Detection System (IDS), called OpenLIDS is implemented. It is shown that even with the limited hardware resources of a mesh device, it can detect current malware behaviour in an efficient way. This paper relates to Task 2.2 on challenge detection, and introduces some of the constraints of performing intrusion detection in multi-hop wireless mesh networks, as investigated in WP4. The results can be used as a basis for further work on distributed challenge detection, as one may view OpenLIDS as a component of a larger distributed detection system that looks at specific challenges, i.e., attacks, at certain layers of the protocol stack.

- T. Taleb, Z. Fadlullah, M. Schoeller, and K. Letaif, "*A connection stability aware mobility management scheme*", in Proc. of IEEE WiMOB, Marrakech, Morocco, October 12-14, 2009

Exploiting the cooperative diversity paradigm in Partner-based Hierarchical MIPv6 (PHMIPv6) promises an acceleration of the handoff management operation by relaying some signalling over a selected partner node prior to the actual handover to the new access point. For this purpose, a suitable partner node, that stays in communication range for sufficient time until the signalling in the pre-handoff phase, is finalized, should be selected. This paper shows that using the Link Expiration Time (LET) metric to select the partner node can significantly improve handovers in Mobile IP (MIP) networks. The basis of this new metric is the relative position and the relative speed of the mobile node to the potential partner nodes. The presented algorithm features a node selection algorithm for reliable communication for hand-off preparation. Mechanisms to be proposed in WP2 and WP3 should benefit from such a cooperative behaviour, seen as a fundamental principle for resilient networking.

2.4. Workshops

- N. Kammenhuber, "*Dynamic traffic engineering in the future (?) Internet*", in Proc. of 3rd GI-ITG/KuVS Workshop on the Future Internet, Munich, May 28th, 2009

The REPLEX algorithm for dynamic traffic engineering (DTE) is extremely flexible, as it can operate on almost any routing infrastructure, and accommodate arbitrary optimization metrics, being thus perfectly suited for application in future networks. DTEg renders a network more robust against sudden changes in traffic patterns, e.g., due to DDoS attacks or flash crowds. The algorithm presented in this paper will be developed further in WP3 to be tailored for overlay networks and cater for other optimization metrics.

- R. Bruncak, P. Smith, D. Hutchison, and J. P.G. Sterbenz, "Towards multilevel resilience for future networking," in Proc. of 10th Annual Postgraduate Symposium on The Convergence of Telecommunications, Networking & Broadcasting (PGNet), Liverpool, UK, June 22-23, 2009

Resilience will be a property of future networks. Networks will be able to provide and maintain an acceptable level of service while the infrastructure is facing significant challenges. This paper aims to progress the understanding of the multilevel resilience approach. This work introduces some of the issues that are under investigation in Task 1.5 on multi-level resilience. In short, it describes the need for multi-level resilience and provides a brief survey of the previous work carried out in this area.

- J.P. Rohrer, R. Naidu and J.P.G. Sterbenz, "*Multipath at the transport layer: an end-to-end resilience mechanism*", in Proc. of International Workshop on Reliable Networks Design and Modeling (RNDM), St. Petersburg, Russia, October 12-14, 2009

As society's dependence on network technology increases, the need for resilience and survivability in these services becomes increasingly apparent. Since the user experience is ultimately determined by the dependability of the end-to-end service, the transport layer is one area where this issue can be addressed. This paper introduces a resilient multipath selection algorithm, which obtains multiple end-to-end paths in the WAN context through cross-layer interaction with lower layers of the network. This cross-layer interface is provided by a thin internetwork protocol (PoMo), which supports heterogeneity at trust and policy boundaries. The result is a more resilient end-to-end service provided to applications by taking advantage of redundancy in the underlying physical network. The efficiency tradeoffs of the multipath approach is evaluated on two topologies, a synthetic one and one corresponding to a tier 1 ISP's backbone network. This paper applies ResumeNet design principles of redundancy, diversity, and cross-layering to network and transport protocol design.

- J.P. Rohrer, A. Jabbar and J.P.G. Sterbenz, "*Path diversification: a multipath resilience mechanism*", in Proc. of 7th IEEE International Workshop on the Design of Reliable Communication Networks (DRCN), Washington, DC, USA, October 25-28, 2009

Path diversification is a new mechanism that can be used to select multiple paths between a single ingress and egress node pairs using a quantified diversity measure to achieve maximum flow reliability. The path diversification mechanism is targeted at the end-to-end layer but can be applied at any level for which a path discovery service is available, e.g., intra-realm routing or inter-realm routing. Path diversification also takes into account higher level requirements for low-latency or maximal reliability in selecting appropriate paths. Using this mechanism will allow future internetworking architectures to exploit naturally rich physical topologies to a far greater extent than is possible with shortest-path routing or equal-cost load balancing. This paper describes the path diversity metric and its application at various aggregation levels. This metric is then applied to the path diversification process in the context of several real-world network graphs to assess the gain in flow reliability. This paper applies ResumeNet design principles of redundancy and diversity to network topology design.

2.5. Ongoing work

In addition to the publications listed above, there are four papers submitted or whose submission is within the next month, covering work done in the project.

- C. Doerr, P. Smith, and D. Hutchison, "*Network heterogeneity and cascading failures - an evaluation for the case of BGP vulnerability*", submitted to IWSOS 2009, Zürich, Switzerland, December 9-11, 2009
- M. Fry, P. Smith, and D. Hutchison, "*Effective detection and remediation for network resilience*", to be submitted to Computer Communications, Elsevier
- N. Kammenhuber, A. Fessi, and G. Carle, "*Resilience: resistance of the network against adverse influences*", to be submitted to Informatik Spektrum, Special Issue on "Future Internet", Springer-Verlag – in German
- M. Schoeller, P. Smith, and D. Hutchison, "*On risk management for resilient networked systems*", to be submitted to IEEE Network

3. Presentations

Contributing to, and participating in, dissemination events organized by the European Commission is part of ResumeNet commitments. To this end, several presentations on various aspects of the project have been given, mainly in the context of the Future Internet Conference events, organized regularly by EC and FIRE project clustering activities coordinated by the FIREWorks Coordination Action.

- B. Plattner, "*Resilience and survivability for future networking: framework, mechanisms, and experimental evaluation*", SAC-FIRE Workshop, Turin, Italy, March 5th 2008
- B. Plattner, "*FP7 ResumeNet STREP - Resilience and survivability for future networking: framework, mechanisms, and experimental evaluation*", The Future of the Internet, Bled, Slovenia, April 2nd 2008
- M. Karaliopoulos, "*ResumeNet*", Poster presented at FIRE launch event, Paris, France, September 10th 2008
- M. Schoeller, "*ResumeNet*", Flyer dropped at ICT 2008, Lyon, France, November 25-27, 2008

- B. Plattner, "*How good is the future Internet ?*", Future of the Internet Conference, Prague, Czech Republic, May 11-13, 2009
- J.P.G. Sterbenz, D. Hutchison, B. Plattner, D. Medhi, B. Ramamurthy, and C. Scoglio, "*GpENI and ResiliNets: international collaboration in GENI, FIND, and FIRE*", Invited talk at the 2nd GENI-FIRE Workshop, Seattle, WA, USA, July 13th 2009

ResumeNet has also been presented in the framework of scientific workshops and symposiums through the presentations listed below.

- D. Hutchison and C. Edwards, "*QoS: (still) a grand challenge?*", Invited talk at IWQoS 2008, Twente, Netherlands, June 3rd 2008
- P. Smith and D. Hutchison, "*Towards resilient networked systems with self-organizing mechanisms*", Abstract presented at IWSOS, Vienna, Austria, December 10-12, 2008
- J.P.G. Sterbenz, "*Dynamic and adaptive architectures for network resilience*", Keynote address at 2nd ICC Winter Workshop on Complexity in Social Sciences, Lisboa, Portugal, January 10th 2009
- B. Plattner, "*Resilience and survivability for future networking: framework, mechanisms, and experimental evaluation*", NetArch Symposium (on the 40th Anniversary of the 1st RFC), Monte Verità - Ascona, Switzerland, March 16-19, 2009
- J.P.G. Sterbenz, D. Hutchison, A. Jabbar, J.P. Rohrer, and E. Çetinkaya, "*Resilience, survivability, and heterogeneity in the postmodern Internet*", Invited presentation at the 4th International Conference on Future Internet Technologies, Seoul, June 17-19, 2009
- P. Smith, M. Schoeller, and D. Hutchison, "*Understanding risk for network resilience*", Multi-Service Networks, Abingdon, UK, July 9-10, 2009
- J.P.G. Sterbenz, D. Hutchison, B. Plattner, D. Medhi, B. Ramamurthy, C. Scoglio, A. Jabbar, J. P. Rohrer, and E. Çetinkaya, "*Postmodern resilience and international collaboration in GpENI*", Multi-Service Networks, Abingdon, UK, July 9-10, 2009

Download link: <http://www.resumenet.eu/results/presentations>

4. Dagstuhl seminar organization

"Schloss Dagstuhl - Leibniz Centre for Informatics" is the world's premier venue for seminars and workshops in the area of computer science and informatics. It enables the international elite, promising young researchers and practitioners alike, to gather together to discuss their views and research findings [DAGSTUHL]. The Centre promotes fundamental and applied research, continuing and advanced academic education, and the transfer of knowledge between those involved in the research side and application side of informatics.

The key instrument for promoting research is the Dagstuhl Seminars, which bring together internationally renowned leading scientists for the purpose of exploring a cutting-edge informatics topic. The friendly and open climate at the conference Centre promotes a culture of communication and exchange among the seminar participants.

Following the organization in July 2007 of a 3-day seminar about "*Resilient and survivable networks, infrastructure, and services*" by some of ResumeNet partners, a 4-day seminar was held in 2009 (14 April – 17 April), covering a broader scope subject: "Perspectives Workshop: *Architecture and design of the future Internet*". The ResumeNet partners who arranged this event are TUM, ULANC, ETHZ, and Kansas University [ADFI].

This seminar brought together thirty seven experts from Europe, North America, and Asia to discuss the way ahead for the Internet. It was broadly agreed that three aspects are crucial: technological, economic, and societal/political. This was a theme brought out in the opening session and re-visited during the closing discussion. There were seven sessions in all:

1. Introduction, problem space
2. Programme perspectives (USA, EC, Asia)
3. Network essentials (naming/addressing, routing, mobility, ...)
4. Network properties (security, resilience, performance, ...)
5. Management, policy, economic, green (and other) issues
6. Architecture (evolution v/s revolution, virtualization, testbeds, ...)
7. Breakout groups and closing discussion

The outcomes of the five breakout groups¹ and the conclusions offered during the closing discussion are summarized below. These breakout groups are as follows:

- i. Sacred cows
- ii. Management issues
- iii. Social, economic, green, etc.
- iv. Programmability and virtualization
- v. Personalization and context for Future Internet

Each group reported back in the final plenary session and a closing discussion followed.

Group (i) covered the IP address architecture, routing structure, TCP and the end-to-end argument, dumb core and smart edges, as the 'sacred cows' of the current Internet, and debated three things: layering principles, and whether there's a need for management & control; re-routing as the primary approach to failure recovery, and whether overlays solve all problems; and virtual circuits (CO/CL). Several of the comments indicated that we seem to be re-visiting these topics yet again, but, perhaps in the light of new application or user needs (such as resilience), this is actually appropriate. Also, we don't yet know best how to make the right choices from the above sets.

Group (ii) offered some basic observations and issues that still require study: nested control loops, and stability provision; humans in the (control) loop – or not; knowledge and the amount of data required to produce satisfactory management – how to do inferences (we still don't know how).

Group (iii) covered a range of topics including the digital divide – which exists in all countries, the balance between security and privacy, network neutrality as a growing concern (or not), how to be 'greener' in networking, and the cultural and objective differences between academic and industry (for example ISPs) – where there will always be some tension.

Group (iv) was concerned with whether programmability is now having its time, for example with the advent of multiple cores and the prospect of virtualization. Associated research imperatives include router architecture, protocol architectures for massive parallelism, and the architecture of networks where the

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¹ There is a separate summary of the presentations in sessions 1-6

main routers have multiple cores. A comment that arose was: could virtualization be used as a solution to deal with 'interference' in networks (with respect to network neutrality)?

Group (v) asked questions about personalization and context in the Future Internet: what is the typical usage; will virtual and physical worlds become more integrated, raising possible issues of privacy, social exchange, etc.); which application areas will need further support, e.g., emergency, mobile video streaming, using social relationships to support communities, using public transport to support mobile users, etc. Context was defined variously as what's 'around', situation awareness, and it was agreed that context-modeling is an upcoming issue.

It is finally worth noticing two ResumeNet presentations during this seminar:

- G. Popa, "*Analytically estimating the impact of node misbehaviours on the throughput of wireless multihop networks*"
- M. Schöller, "*Understanding challenges and their impact on network resilience*"

Download link: <http://www.resumenet.eu/results/presentations>

5. Publicity

In addition to the communication channels described earlier, ResumeNet has exploited other means (e.g., regular newspapers and University magazines) to raise society awareness of its scope and objectives.

On the occasion of the NetArch 2009 Symposium, ResumeNet coordinator (Prof. B. Plattner) has described the project's concepts and objectives in the article "*Internet 2.0 - Renovation oder Neubau ?*" published in "Neue Zürcher Zeitung", one of the oldest and most prestigious Swiss newspapers.

Likewise, "ETH Life", the magazine of ETH Zurich, has recently hosted an interview of Prof. B. Plattner, where ResumeNet is discussed in the context of the broader Future Internet topic.

Download link: <http://www.resumenet.eu/results/publicity>

Finally, it is worth mentioning a considerable collective effort of the consortium allocated in Q2 2009 to update and enhance the initial poster describing ResumeNet strategy and goals, as presented in Sep 08 and Nov 08 during the FIREWorks events (see section 3). This new improved version is available now on the Web site.

Download link: <http://www.resumenet.eu/project/brief>

6. Further impact

During the past 12 months and through personal contacts and web-site visibility, ResumeNet has attracted the interest of various players, in Europe and beyond the European borders, who approached the project Consortium, asking for some form of collaboration. Moreover, links have been established with communities carrying out similar activities elsewhere in the world.

The first of these cases is in the USA, where through the activities of J. Sterbenz at Kansas University, ResumeNet now has a connection with NSF GENI and other research activities. This is informing our work both in the scientific efforts on resilience (for example metrics) and in testbeds: we are discussing the possibility of using an extension of the GpENI testbed into Europe within the ResumeNet project.

Secondly, the project was approached by Dr Peyam Pourbeik of DSTO, the Australian Defence Science and Technology Organisation (<http://www.dsto.defence.gov.au/>), who expressed interest in ResumeNet. This led to a visit by Dr Pourbeik to both ULANC and ETHZ during September 2009. As a result, we have identified several possible strands for exchanging results and, perhaps, collaboration. This will next be followed up by M. Fry at the University of Sydney, who will investigate the possibility of some joint activity within the context of Australian funding. M. Fry has also recently recruited a PhD student to work on ResumeNet. This student has just been awarded a scholarship by NICTA, the Australian national ICT research institute (<http://www.nicta.com.au/>): it has been indicated to NICTA that this may be an entry point to developing a relationship with ResumeNet.

Thirdly, in the UK, the national regulator OFCOM is proposing work on computer network resilience within the context of the Digital Britain report, and ULANC has been approached for possible assistance with this work because of its ResumeNet and related research on resilience. Also, the UK company QinetiQ (similar in many ways to the Australian DSTO) has recently been in contact with ULANC to explore joint work on resilient systems.

Finally, strong interest to the project was expressed by the delegation of the National University of Defense Technology (NUDT) of China during their visit to the ETHZ in summer 2009. The delegation included Prof. Zhiying Wang (Vice Dean of the Network Engineering Department of NUDT) and Prof. Ming Xu (Head of Network Engineering Department). As a result, the work of a PhD student (Wenping Deng) from NUDT, who is guest at the Computer Engineering and Networks Laboratory of ETHZ from Nov 2008 to Nov 2009, has been oriented towards the scope of the project. More specifically, the student's work focuses on robustness control methods for inter-domain routing systems and is viewed as the link between ResumeNet and similar activities to be launched in NUDT.

7. Contribution to standardization work

The project Consortium has very good understanding of the challenges related to standardization and outlined very early its standardization strategy [DoW]; namely, that the impact of ResumeNet on standardization is primarily expected to happen *indirectly*, potentially via a Specific Support Action (SSA) and/or a Coordinated Action (CA) within FIRE. Nevertheless, the project has also invested resources on *direct* standardization actions. Such is the case with the ITU-T Focus Group on Future Networks.

Since its inception in 1865, the International Telecom Union has played a leading role in the most universally-recognized info communications standards, brokering industry consensus on the technologies and services that form the backbone of the world's largest, most interconnected man-made system [ITU_T]. In 2007 alone, its standardization sector (ITU-T) has produced over 160 new and revised standards (ITU-T Recommendations), covering everything from core network functionality and broadband to next-generation services like IPTV.

In the framework of ITU-T, Study Group 13 ("Future networks including mobile and NGN") leads the work on standards for next generation networks². Convergence is a key word in this field. Built upon the Internet Protocol, the convergence between networks and/or technologies such as public switched telephone network, digital subscriber line, cable television, wireless local area network and mobile technologies is a task that many believe is impossible without the development of global standards [SG13].

SG13 has established in January 2009 a "Focus Group on Future Networks" to share the discussion on future networks and ensure global common understanding about these networks with collaboration and

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²NGN refers to the move from circuit switched to packet based networks that many operators worldwide will undertake in the next few years. It will mean reduced costs for service providers who will in turn be able to offer a richer variety of services.

harmonization with relevant entities and activities [FG_FN]. By collaborating with worldwide future network (FN) communities (e.g., research institutes, forums, academia), this focus group aims to:

1. collect and identify visions of FN, based on new technologies,
2. assess the interactions between FN and new services,
3. familiarize ITU-T and standardization communities with emerging attributes of FN,
4. encourage collaboration between ITU-T and FN communities.

The inaugural meeting of FG-FN was held on 29 June - 3 July in Lulea (Sweden), i.e., the same week as the conference "*FIRE and Living Labs – Future Internet by the people*". ResumeNet, through a talk by M. Schoeller entitled "*Network resilience as a prime feature of future networks*", has contributed to this collection and identification of future networks visions, by means of a presentation on resilience terminology and the ResumeNet strategy.

Download link: <http://www.resumenet.eu/results/standards>

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