DISASTER RESILIENCE IN COMMUNICATION NETWORKS: PART 2

Michele Nogueira

Piotr Chołda

Deep Medhi

Robert Doverspike

We experience society's growing dependence on electronic communication networks in every aspect of our lives. With this comes the expectation that communication networks are readily available all the time. Networking protocols are designed to address some simple failures, such as when a packet is dropped, a retransmission occurs, or the size of the transmission window is adjusted to accommodate congestion. Similarly, routing protocols have the functionality to route around a failure. That is, communications networks have certain built-in resilience for certain specific types of failure situations. Furthermore, networks can be designed with backup paths and capacity to protect against a failure as part of critical infrastructure protection.

A disaster in a communication network is generally understood as a massive set of failures that can affect performance to the point where the degradation appreciably affects our lives. It should be noted that not all disasters are visible to end users. A disaster such as a hurricane, which encompasses a geographic area, can severely affect the communication network in the geographic area and beyond; in such a case, end users may be aware of the disaster through news reports. On the other hand, if a major disaster occurs at a large-scale data center, users from a very wide geographical region may notice degraded performance, but may not be aware of the actual event that occurred. Examples are over-the-top video provided by data centers that experience failures or with the peering locations that interface these data centers with the Internet. Millions of video customers have been affected over large areas of a country in such cases, but no environmental disaster is present. As another example, a software attack that cripples the network is a virtual disaster that will not be directly visible to end users.

It is infeasible and impractical to design and deploy hardened structures, equipment, and transmission facilities that never fail and can withstand any disaster. Therefore, the approach is to design and provide mechanisms that can recover and react to disasters. Thus, the scope of disaster resilience is that a network recovers from a disaster with an acceptable level of performance by a set of mechanisms. Such mechanisms can be either proactive, reactive, or a combination thereof. Usually, proactive approaches include redundancy in a cost-effective manner; hence, the network is sufficiently reliable to address a failure or an attack. In the case of reactive approaches, the network may react by rerouting through backup capacity, or, in some cases, by rapidly deploying ad hoc networking capability. Thus, reactive approaches may include emergency communication mechanisms during and after a disaster. The latter are an emerging and exciting approach that we have highlighted in this Feature Topic.

While much research in the past few decades focused on network resiliency, most of this work limited itself to isolated or very localized failures. When a disaster occurs, the ability of the network to recover to a reasonably acceptable performance level is a challenging problem. Thus, this Feature Topic sought submissions that covered the topic of disaster resilience from a broader perspective than had ever been attempted in the past.

The Feature Topic on Disaster Resilience in Communication Networks attracted 72 submissions. The review process resulted in identifying nine papers for publication. The first part of the Feature Topic was published in October 2014 and included four articles. The second part, in this issue, contains five articles. These five articles not only address the problems of disaster resilience in general, but also propose original and new mechanisms to support communications in case of a massive disaster.

We briefly summarize below the articles included in this issue.

The first article, "Network Adaptability to Disaster Disruptions by Exploiting Degraded-Service Tolerance" by S. Sedef Savas, M. Farhan Habib, Massimo Tornatore, Ferhat Dikbiyik, and Biswanath Mukherjee, considers a disaster recovery system that assumes service differentiation (i.e., various levels of the quality provided to the clients). The authors elaborate on methods of provisioning diverse service classes from this viewpoint. According to their approach, a high level of network adaptability is feasible when it is extremely needed, which is in catastrophic events.

The second article, "Enabling Disaster Resilient 4G Mobile Communication Networks" by Karina Gomez, Leonardo Goratti, Tinku Rasheed, and Laurent Reynaud, elaborates on the virtualization of a mobile network. The virtualization is treated as a tool supporting flexibility in the reaction to disaster events and avoiding problems with the infrastructure provider. Additionally, the authors propose a distributed device-to-device communication scheme inspired by resilient tactical networking enabling the provision of high-quality transmission in the vicinity of the areas affected by catastrophes, fires, floods, and so on.

The third article, "EmergeNet: Robust, Rapidly Deployable Cellular Networks" by Daniel Iland and Elizabeth M. Belding, describes a concept of a small-scale portable cellular network that can be deployed very quickly in case of necessity. The network is designed to enable the use of basic services (e.g., messaging and voice calls based on Skype), bypassing commercial networks. Due to this idea, the network can be used by anybody in the disaster area, no matter whether or not the user is subscribed. Only a GSM phone is necessary.

The fourth article, "Exploiting the Use of unmanned Aerial Vehicles to provide Resilience in Wireless Sensor Networks" by Jó Ueyama, Heitor Freitas, Bruno S. Faiçal, Geraldo P. R. Filho, Pedro Fini, Gustavo Pessin, Pedro H. Gomes, and Leandro A. Villas, is the only article strictly focusing on communications that does not support human interaction directly, as it deals with the networks of sensors. The covered system involves relays carried by unmanned aerial vehicles, presenting a very original and promising contribution supported by broad experimental studies.

The fifth article, "Network Virtualization for Disaster Resilience of Cloud Services" by Isil Burcu Barla Harter, Dominic A. Schupke, Marco Hoffmann, and Georg Carle, presents a system establishing resilient virtual networks to be configured automatically when recovery of data flows carried inside clouds is awaited. Specifically, the authors consider the problem of choosing a proper technological layer in which recovery should be provided depending on the type of failure to bypass.

Assembling a Feature Topic on this challenging and important topic was truly a rewarding experience. We would like to thank again all the authors for their contributions to this Feature Topic and all the reviewers for volunteering their valuable time, helping to motivate the authors to make their contributions better and better.

BIOGRAPHIES

MICHELE NOGUEIRA is a professor of computer science at the Federal University of Paraná, where she has been since 2010. She received her doctorate in computer science from the Université Pierre et Marie Curie — Sorbonne Universités, Laboratoire d'Informatique de Paris VI (LIP6), in 2009. She was a visiting professor at Université Paul Sabatier and a visiting researcher at Georgia Institute of Technology in 2013 and 2009, respectively. Her research interests include wireless networks, security, and dependability. She has worked on providing resilience to self-organized and wireless networks by adaptive and opportunistic technologies such as cognitive radio. She was one of the pioneers in addressing survivability issues in self-organized wireless networks, the article "A Survey of Survivability in Mobile Ad Hoc Networks" being one of her prominent scientific contributions. She was a recipient of academic scholarships from the Brazilian Government during her undergraduate and graduate years, and of international grants such as from the ACM SIGCOMM Geodiversity program. She is also an Associate Technical Editor for *IEEE Communications Magazine* and the *Journal of Network and Systems Management*.

PIOTR CHOŁDA obtained a doctorate in telecommunications in 2006 from AGH University of Science and Technology. He then joined the Department of Telecommunications there, and now works as an assistant professor. He specializes in design of computer and communications networks. Recently, he has focused on risk-based communications networking. He is the coauthor of 16 refereed journal papers and three conference tutorials. He was a Technical Program Committee (TPC) Co-Chair of Communications QoS, Reliability and Modeling Symposium at ICC 2011, and NOMS 2014. He is a member of the Editorial Board for *IEEE Communications Surveys & Tutorials* and Editor the Book Reviews column in *IEEE Communications Magazine*.

DEEP MEDHI is a curators' professor in the Department of Computer Science and Electrical Engineering at the University of Missouri-Kansas City (UMKC). He received his B.Sc. in mathematics from Cotton College, Gauhati University, India; his M.Sc. in mathematics from the University of Delhi, India; and his Ph.D. in computer sciences from the University of Wisconsin-Madison. Prior to joining UMKC in 1989, he was a member of technical staff at AT&T Bell Laboratories. He was an invited visiting professor at the Technical University of Denmark, a visiting research fellow at Lund Institute of Technology, Sweden, a research visitor at the University of Campinas, Brazil, under the Brazilian Science Mobility Program, and served as a Fulbright Senior Specialist. He is currently Editor-in-Chief of Springer's *Journal of Network and Systems Management*, and is on the Editorial Boards of *IEEE/ACM Transactions on Networking*, *IEEE Transactions on Network and Service Management*, and *IEEE Communications Surveys & Tutorials*. He was an Associate Technical Editor of *IEEE Communications Magazine* from 2006 to 2010. His recent IEEE activities include serving as a TPC Co-Chair of IEEE NOMS 2010, General Chair of IEEE CloudNet 2013, and Vice-Chair of the Committee on Network Operations and Management (CNOM). He is coauthor of the books *Routing, Flow, and Capacity Design in Communication and Computer Networks* (Morgan Kaufmann/Elsevier, 2004) and *Network Routing: Algorithms, Protocols, and Architectures* (Morgan Kaufmann/Elsevier, 2007).

ROBERT DOVERSPIKE [F] received his undergraduate degree from the University of Colorado, and his Master's and Ph.D. degrees from Rensselaer Polytechnic Institute (RPI). He began his career with Bell Labs and, upon divestiture of the Bell System, went to Bellcore (later called Telcordia). He returned to AT&T Labs (Research), where he is now executive director of network evolution research. He has made extensive contributions to the field of optimization of multi-layered transmission and switching networks, and pioneered the concept of packet transport in metro and long distance networks. He also pioneered work in spearheading the deployment of new architectures for transport and IP networks, network restoration, and integrated network management of IP-over-optical-layer networks and software defined networking. He has over 1500 citations of his books and articles over diverse areas/publications such as telecommunications, optical networking, mathematical programming, *IEEE Communications Magazine*, IEEE Communications Society, operations research, applied probability, and network management. He holds many professional leadership positions and awards, such as an INFORMS Fellow, member of the Optical Society of America, co-founder of the INFORMS Technical Section on Telecommunications, OFC Steering Committee, DRCN Steering Committee, and Associate Editor for the *Journal of Optical Communications and Networking*.