

# Armando L. Caro, Ph.D.

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## Experience

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**BBN Technologies**  
**Scientist**  
**Senior Scientist**

**Cambridge, MA**  
**9/2005 - 2/2010**  
**2/2010 - Present**

### **Content Access System for the Combat-Agile Distributed Environment (CASCADE)**

**3/2012 - Present**

I am the Content Management Lead for the CASCADE project, which is sponsored by DARPA under the Content-Based Mobile Edge Networking (CBMEN) program. BBN is developing a content-oriented networking stack for Android devices that incorporates data mining and machine learning techniques to provide efficient distribution of content in mobile ad hoc networks. Proactive caching mechanisms employ user preference models to predict future content needs. Community detection techniques are used to automatically adapt the content replication and distribution approach based on network connectivity and discovered user interest groups.

### **Predictive Content Delivery (WildCard)**

**5/2011 - Present**

I am the Principal Investigator for the WildCard project, which is sponsored by ONR. BBN is investigating predictive content delivery techniques for mitigating network bottlenecks and reducing user-perceived latencies. The goal is to strategically pre-position content in anticipation of users' needs to more effectively utilize limited bandwidth resources and mitigate intermittent connectivity.

### **Survivable Policy Influenced Networking: Disruption-tolerance through Learning and Evolution (SPINDLE)**

**12/2006 - 5/2010**

I was the Principal Investigator for the SPINDLE project, which was sponsored by DARPA under the Disruption Tolerant Networking (DTN) program. BBN is developing DTN technologies that enable access to information when stable end-to-end paths do not exist and network infrastructure access cannot be assured. DTN technology makes use of persistence within network nodes, along with the opportunistic use of mobility, to overcome disruptions to connectivity.

### **Policy-based Information centric Reliable Ad hoc Network (PIRANA)**

**12/2007 - 5/2011**

I was the Routing Lead for the PIRANA project, which is sponsored by DARPA under the Wireless Networking after Next (WNaN) program. BBN is developing scalable, adaptive, ad hoc networks which exploit very inexpensive, yet flexible software radios. Innovative aspects of the program include the incorporation of DTN technology for disconnected operation, dynamic spectrum access for finding and exploiting any available frequencies rather than using pre-allocated frequencies, and exploitation of multichannel MIMO.

### **Self-forming Extensible luNar EVA network (SELENE)**

**2/2008 - 6/2011**

I was the Principal Investigator for BBN's effort in the SELENE project, which was sponsored by NASA to develop the SELENE network for the Human Lunar Outpost. BBN was investigating a hybrid routing algorithm combining Mobile Ad Hoc Networks (MANETs) and Disruption Tolerant Networks (DTNs) for networking EVA radios in the Human Lunar Outpost.

**Adaptive Distributed Radio Open-source Intelligent Network (ADROIT)**

**1/2006 - 11/2006**

I was the Configuration Management Lead and a key developer for the ADROIT project, which was sponsored by DARPA under the Adaptive Cognition-Enhanced Radio Teams (ACERT) program. BBN was building an open-source software-defined data radio, intended to be controlled by cognitive applications. The goal was to create a system that enables teams of radios, where each radio has its own cognitive controls and the ability to collaborate with other radios, to create cognitive radio teams that dynamically adapt in real-time to environmental conditions.

**Protocol Engineering Lab (PEL), University of Delaware  
Graduate Research Assistant**

**Newark, DE  
6/1998 - 5/2005**

**End-to-End Fault Tolerance Using Transport Layer Multihoming**

My dissertation investigated transport layer techniques that improve end-to-end fault tolerance and throughput. Often, access links (for both clients and servers) are a single point of failure for end-to-end reachability. Routing protocols (in particular, BGP) may also take a significant amount of time (often tens of minutes) to converge on a new route when a link failure is detected. Multihoming support at the transport layer addresses both types of failures by allowing a transport layer session to bind multiple IP addresses at each endpoint. This feature provides both endpoints with multiple paths with which to communicate, and thus the ability to failover to an alternate path when a path failure occurs. I investigated multihoming retransmission policies and failover thresholds with the Stream Control Transmission Protocol (SCTP). A key contribution of my dissertation was a new SCTP retransmission policy that was incorporated into a revised SCTP specification (RFC 4960), which obsoletes the original specification (RFC 2960).

**Nokia Research Center  
Research Intern**

**Helsinki, Finland  
Summer 2001**

**SCTP Simulation Studies**

I lead the development of an SCTP model for the ns-2 network simulator. I evaluated SCTP and PR-SCTP for protocol correctness and performance, and worked with the PR-SCTP authors to correct protocol errors in the specification.

**Telcordia Technologies  
Research Intern**

**Morristown, NJ  
Summers 1999 & 2000**

**ITSUMO QoS**

**Summer 2000**

The Internet Technologies Supporting Universal Mobile Operations (ITSUMO) project was a collaboration between Telcordia Technologies and Toshiba Research formed in February 1999 to develop IP-centric access systems integrating voice, data, and multimedia services for mobile devices. I co-designed the dynamic service level agreement/specification negotiation protocol and the diffserv-based QoS architecture. I implemented a complete prototype of the architecture, and demonstrated that mobile hosts could roam freely between domains while transmitting and receiving video and voice at the negotiated QoS.

**ITSUMO Secure Registration**

**Summer 1999**

I implemented a unified authentication mechanism for an open source implementation of DHCP and Mobile IP.

### ReMDoR

I co-designed and co-developed an interactive Remote Multimedia Document Retrieval (ReMDoR) client-server system. The motivation for ReMDoR was to demonstrate the practical benefits of using a partially ordered and partially reliable transport service for multimedia communications. ReMDoR interfaced with our lab's Universal Transport Library (UTL) to dynamically choose among several experimental transport protocols.

### Journal Publications

1. G. Troxel, et al. Enabling Open-source Cognitively-Controlled Collaboration Among Software-Defined Radio Nodes. *Computer Networks*, March 2008.
2. A. Caro, P. Amer, R. Stewart. Retransmission Policies for Multihomed Transport Protocols. *Computer Communications*, June 2006.
3. A. Caro, P. Amer, R. Stewart. Rethinking End-to-End Failover with Transport Layer Multihoming. *Annals of Telecommunications*, 61(1-2), January-February 2006.
4. A. Caro, J. Iyengar, P. Amer, S. Ladha, G. Heinz, K. Shah. SCTP: A Proposed Standard for Robust Internet Data Transport. *IEEE Computer*, 36(11):56-63, November 2003.
5. P. Amer, S. Iren, G. Sezen, P. Conrad, M. Taube, A. Caro. Network-Conscious GIF Image Transmission over Internet. *Computer Networks*, 31(7):693-708, April 1999.

### Conference Publications

1. G. Troxel, et al. Cognitive Adaptation for Teams in ADROIT. *IEEE Global Telecommunications Conference (GLOBECOM)*, November 2007.
2. R. Krishnan, et al. The SPINDLE Disruption-Tolerant Networking System. *IEEE Military Communications Conference (MILCOM)*, October 2007.
3. G. Troxel, et al. Adaptive Dynamic Radio Open-source Intelligent Team (ADROIT): Cognitively-controlled Collaboration among SDR Nodes. *First IEEE Workshop on Networking Technologies for Software Defined Radio (SDR) Networks*, Reston, VA, September 2006, Invited.
4. A. Caro, P. Amer, R. Stewart. Retransmission Schemes for End-to-End Failover with Transport Layer Multihoming. *IEEE Global Telecommunications Conference (GLOBECOM)*, Dallas, TX, November 2004.
5. S. Ladha, P. Amer, A. Caro, J. Iyengar. On the Prevalence and Evaluation of Recent TCP Enhancements. *IEEE Global Telecommunications Conference (GLOBECOM)*, Dallas, TX, November 2004.
6. A. Caro, P. Amer, R. Stewart. End-to-End Failover Thresholds for Transport Layer Multihoming. *IEEE Military Communications Conference (MILCOM)*, Monterey, CA, November 2004.
7. A. Caro, P. Amer, R. Stewart. Transport Layer Multihoming for Fault Tolerance in FCS Networks. *IEEE Military Communications Conference (MILCOM)*, Boston, MA, October 2003.
8. S. Ladha, P. Amer, A. Caro. On The Evaluation of Transport Protocols for FCS Networks. *IEEE Military Communications Conference (MILCOM)*, Boston, MA, October 2003.

9. A. Caro, P. Amer, J. Iyengar, R. Stewart. Retransmission Policies with Transport Layer Multihoming. *IEEE International Conference on Networking (ICON)*, Sydney, Australia, September 2003.
10. J. Iyengar, A. Caro, P. Amer, G. Heinz, R. Stewart. Making SCTP More Robust to Changeover. *International Symposium on Performance Evaluation of Computer and Telecommunication Systems (SPECTS)*, Montreal, Canada, July 2003.
11. P. Conrad, A. Caro, P. Amer. ReMDoR: Remote Multimedia Document Retrieval over Partial Order Transport. *ACM Multimedia*, Ottawa, Canada, September 2001.
12. P. Conrad, G. Heinz, A. Caro, P. Amer, J. Fiore. SCTP in Battlefield Networks. *IEEE Military Communications Conference (MILCOM)*, Washington, DC, October 2001.
13. J.C. Chen, A. Caro, A. McAuley, S. Baba, Y. Ohba, P. Ramanathan. A QoS Architecture for Future Wireless IP Networks. *IASTED International Conference on Parallel and Distributed Computing and Systems (PDCS) 2000*, Las Vegas, NV, November 2000.
14. S. Iren, P. Amer, A. Caro, P. Conrad, G. Sezen, M. Taube. Network-Conscious Compressed Image Transmission over Battlefield Networks. *IEEE Military Communications Conference (MILCOM)*, Boston, October 1998.
15. P. Conrad, P. Amer, M. Taube, G. Sezen, S. Iren, A. Caro. Testing Environment for Innovative Transport Protocols. *IEEE Military Communications Conference (MILCOM)*, Boston, October 1998.
16. P. Amer, S. Iren, G. Sezen, P. Conrad, M. Taube, A. Caro. Network-Conscious GIF Image Transmission over Internet. *International Workshop on High Performance Protocol Architectures (HIPPARCH)*, London, June 1998.
17. P. Conrad, P. Amer, E. Golden, S. Iren, R. Marasli, A. Caro. Transport QoS over Unreliable Networks: No Guarantees, No Free Lunch! *IFIP International Workshop on Quality of Service (IWQOS)*, New York, NY, May 1997.

## **IETF RFCs**

1. R. Stewart, I. Arias-Rodriguez, K. Poon, A. Caro, M. Tuexen. Stream Control Transmission Protocol (SCTP) Specification Errata and Issues. RFC 4460, April 2006.

## **Public-domain Software**

1. A. Caro and J. Iyengar. SCTP module for ns-2 Network Simulator. <http://www.isi.edu/nsnam/ns>
2. A. Caro. webAlbum. <http://www.armandocaro.net/software>

## **Education**

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**Ph.D. in Computer and Information Sciences**

**August 2005**

University of Delaware

**Advisor:** Prof. Paul D. Amer

**Dissertation:** *End-to-End Fault Tolerance Using Transport Layer Multihoming*

**M.S. in Computer and Information Sciences**

**May 2000**

University of Delaware

**B.S. with Distinction in Computer and Information Sciences**

**May 1998**

University of Delaware

**Thesis:** *ReMDoR 2.0: Remote Multimedia Document Retrieval Over Partially-Ordered, Partially-Reliable Transport Protocols*

## **Professional Societies**

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- ACM
- IEEE Senior Member

## **Security Clearance**

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Top Secret

## **Languages**

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English, Spanish

## **References**

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Available upon request