

## Aniruddha Bohra

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### RESEARCH INTERESTS

Operating systems focussing on the network and storage subsystems, large scale data storage, network file systems, multimedia delivery protocols, availability and fault tolerance in computer systems and networks.

### EDUCATION

Ph.D., Computer Science, December 2007;  
“System Architectures Based on Functionality Offloading”  
Advisor: Prof. Liviu Iftode  
Rutgers University, Piscataway, NJ

M.S., Computer Science, Spring 2002;  
“TCP Server Architecture for SMP-Based Systems”  
Advisor: Prof. Liviu Iftode  
Rutgers University, Piscataway, NJ

B.E., Computer Engineering, Fall 1999  
Netaji Subhas Institute of Technology,  
Delhi University, New Delhi, India

### RESEARCH AND EXPERIENCE

*Founding member and Director  
Network Transport Division*

**Infinistreams Networks, Inc.**

**August 2009 – Present**

Part of a 4 member founding team of a startup, focused on building large scale virtualized CDNs optimized for multimedia delivery over the Internet. The Virtualized CDN leverages existing CDNs and uses client-side adaptation to deliver sustained high-bandwidth data delivery while reducing cost through load concentration and distribution. My role in the company is to design and implement the network transport protocol for a variety of platforms including Microsoft Windows and embedded systems running Linux and FreeBSD Operating Systems.

*Research Staff Member,  
IP Networks and Distributed Systems*

**NEC Labs America**

**February 2005 – Aug 2009**

Jan 2008 —  
Aug 2009

Researcher involved in the HydraStor project, a distributed content-addressable storage system and a file system for secondary storage. The goal of this project is to build a highly scalable, high throughput storage system built using commodity off the shelf components. The first generation of this product is already available in the market.

My role in this project was two fold. First, I worked on improving the sequential throughput for HydraFS over NFS. HydraFS is a high-throughput file system but some operations, most notably `fsync` operations have high latencies. This leads to a very low throughput over NFS. I developed eager-writeback and page-laundering that tries to avoid issuing NFS `COMMIT` requests without violating correctness and durability guarantees. With these modifications, the throughput increased by more than 4 times for sequential write workloads, the primary workload for backup systems.

Second, I worked on a QoS and management framework for HydraStor. As part of this framework, I developed a content centric performance test suite to allow effective performance evaluation. Using this framework, I designed and implemented a size-based NFS request scheduling framework for the LinuxOS.

Feb 2005 —  
Dec 2007 —  
Researcher involved in the Grid Networking (GriN) project, which studies the wide area network protocols to take advantage of spatial and temporal diversity in the Internet. The goal of the project is to improve transfer times for large point-to-point and point-to-multipoint transfers.

Contributed to the development of a data dissemination framework for high-bandwidth point-to-multipoint transfers using multiple application-level multicast trees. Techniques to support real-time data dissemination for live media streaming have also been developed. Results reported for experiments using a wide-area network testbed have demonstrated more than two-fold improvement in performance.

Applications of the technology include Wide-Area File Systems, Wide-Area backups, and online stream Replication. Two papers related to this project have been published. Additionally, two patents have been filed and are currently under consideration.

Feb 2005 —  
Dec 2007 —  
Research team member for the resource allocation framework under the next generation wireless mesh project. The goals of the resource allocation is to improve throughput and fairness in Wireless LAN for spectrum and spatial resources. The key idea is to impose time-slots over the Carrier Sense Media Access/Collision Avoidance (CSMA/CA) IEEE802.11 MAC framework. These time slots are then scheduled according to a resource specific policy.

Contributed to a study evaluating the impact of channel hopping, where clients and access points periodically change channels to improve fairness across a dense, unplanned wireless network. Provided initial system design and implementation for the system and evaluated the performance in the presence and absence of a malicious client which attempts to jam all communication across the WLAN. By periodic channel hopping, the system was able to avoid jamming, supporting up to 70% throughput in presence of a jammer and with minimal loss of throughput without a jammer. A paper discussing the technology has been published.

*Research Assistant,  
Distributed Computing Laboratory*

**Rutgers University**

**1999 – 2004**

Dec 2005 —  
Present —  
Research team member for FileWall, which offloads the enforcement of file system policies to an external file system proxy. This system interposes on the client-server path and implements policies through message transformation. It also allows administrators to define file system policies using a high-level language without modifying the client and the server. FileWall can be used to define monitoring, access control, maintenance, and semantic policies which extend the network file systems. Two papers describing FileWall have been published.

Dec 2003 —  
Dec 2005 —  
Research team member for Backdoors, a system architecture for non-intrusive remote healing. Backdoors proposes a novel approach for non-intrusive monitoring, recovery, and repair of computer systems by offloading this functionality to a remote monitor. It takes advantage of Remote Memory Communication (RMC) which enables an alternative path for a remote monitor to observe and modify the memory of a remote system. Techniques for remote recovery of internet service sessions and repair of computer systems have been proposed for Backdoors.

Dec 2001 —  
Dec 2003 —  
Research team member for Service Continuations, which provides system support for migrating live Internet service sessions. Service Continuations provides support for high-availability in Internet Services by migrating TCP/IP connections to alternative servers transparent to the client applications. Web-services and streaming media services which are critical to clients have been shown to benefit from the Service Continuation based session migration. A paper describing Service Continuations has been published.

Aug 1999 —  
Dec 2002 —  
Worked on offloading TCP/IP processing in a multiprocessor Operating System to improve performance of network servers. Designed an asymmetric Operating System (*TCP Server*) which dedicated a subset of processors to network processing. This study identified and characterized synchronization overheads and indirect overheads due to cache pollution in interrupt driven network processing and proposed a

hybrid interrupt-polling based approach. A paper has been published describing the TCP Server design and implementation.

*Summer Intern,  
Information Sciences Research Center*

**Bell Laboratories, Lucent Technologies**

**May 2000 – Sep 2000**

Studied the behaviour of various memory allocator (malloc) implementations in the context of a long-running file system developed at Bell Labs(Hummingbird), and a snapshot based storage service. The study found that different implementations of malloc result in varying degrees of fragmentation and the overheads of fragmentation are much worse for long running applications. A paper describing the research was published.

*Instructor, Computer Architecture*

**Rutgers University  
Sep 2003 – Dec 2003**

Taught the undergraduate course on Computer Architecture for a semester. Was responsible for defining the curriculum, teaching lectures, and administering examinations and projects for two sections. The course involved introducing the fundamental aspects of Computer Systems and its basic building blocks including hardware and Operating System components.

SERVICE

Reviewer for Architectural Support for Programming Languages and Operating Systems (ASPLOS), File and Storage Technologies (FAST), Usenix Annual Technical Conference, High Performance Computer Architecture (HPCA), High Performance Distributed Computing (HPDC), ACM Transactions on Computer Systems, IEEE Distributed Systems Online.

PUBLICATIONS

C. Ungureanu et. al. "A high-throughput Content Addressable File System" *8th Usenix conference on File and Storage Technologies, FAST 2010* To appear

A. Bohra, S. Smaldone, and L. Iftode "FileWall: A Firewall for Network File Systems" *Proceedings of IEEE Dependable Autonomic and Secure Computing, DASC 2007*, Baltimore MD, September 2007

A. Bohra and L. Iftode "Improving Network Stack Concurrency using TCPServers" *Proceedings of IEEE Network Computing and Applications, NCA 2007*, Cambridge MA, July 2007

A. Bohra, S. Smaldone, and L. Iftode "FRAC: Implementing Role-Based Access Control for Network File Systems" *Proceedings of IEEE Network Computing and Applications, NCA 2007*, Cambridge MA, July 2007

R. Kokku, A. Bohra, S. Ganguly, and V. Arun "A Multipath Background Network Architecture" *Proceedings of IEEE Infocom 2007*, Anchorage AK, April 2007

V. Navda, A. Bohra, S. Ganguly, and D. Rubenstein "Using Channel Hopping to Increase 802.11 Resilience to Jamming Attacks" *Proceedings of IEEE Infocom Minisymposium*, Anchorage AK, April 2007

J. Liang, A. Bohra, H. Zhang, S. Ganguly, and R. Izmailov "Minimizing Metadata Access Latency in Wide Area File Systems" *Proceedings of IEEE High Performance Computing HiPC'06*, Bangalore India, December 2006

F. Sultan, A. Bohra, P. Gallard, I. Neamtiu, S. Smaldone, Y. Pan, Neamtiu, and L. Iftode. "Recovering Internet Service Sessions from Operating System Failures." in *IEEE Internet Computing, ICSI-0116-0804 Special Issue - Recovery-Oriented Approaches to Dependability*, March/April 2005

A. Bohra, I. Neamtiu, P. Gallard, F. Sultan, and L. Iftode. "Remote Repair of Operating System State Using Backdoors." *Proceedings of First IEEE International Conference on Autonomic Computing (ICAC'04)*, New York NY, June 2004

F. Sultan, A. Bohra, I. Neamtiu, and L. Iftode. "Nonintrusive Remote Healing Using Backdoors." *Proceedings of First Workshop on Algorithms and Architectures for Self-Managing Systems (Self Manage'03)*, San Diego CA, June 2003

F. Sultan, A. Bohra, and L. Iftode. "Service Continuations: An Operating System Mechanism for Dynamic Migration of Internet Service Sessions". *Proceedings of IEEE Symposium on Reliable Distributed Systems, SRDS 03*, Florence Italy, October 2003

A. Bohra and E. Gabber. "Are Mallocs Free of Fragmentation?" *Proceedings of Usenix Annual Technical Conference, Freenix Track*, Boston MA, June 2001

TECHNICAL REPORTS A. Bohra, S. Rago, and C. Ungureanu "NFS Performance of Sequential Write Workloads" *July 2009, NEC Laboratories America Technical Report, Submitted for publication*

A. Bohra and C. Ungureanu "Using System Invariants Technology for HydraStor: A Developer's Perspective" *Dec 2008, NEC Laboratories America, Technical Report*

S. Smaldone, A. Bohra, and L. Iftode "Implementing Network File System Policies with FileWall" *Rutgers University, Department of Computer Science, Technical Report DCS-TR-605, Nov. 2006.*

A. Bohra, A. Baliga, and L. Iftode "Orion: Looking for Constellations in Physical Memory." *Rutgers University, Department of Computer Science, Technical Report DCS-TR-569, January 2005.*

F. Sultan, A. Bohra, and L. Iftode. "Autonomous Transport Protocols for Content-based Networks". *Rutgers University, Department of Computer Science, Technical Report, DCS-TR-479, March 2002.*

M. Rangarajan, A. Bohra, K. Banerjee, E. V. Carrera, R. Bianchini, L. Iftode, and W. Zwaenepoel. "TCP Servers: Offloading TCP/IP Processing in Internet Servers." Design, Implementation, and Performance, *Rutgers University Department of Computer Science Technical Report, DCS-TR-481, March 2002.*

PATENT  
APPLICATIONS

A. Bohra, S. Smaldone, and L. Iftode "System and Method for Controlling File System Access" Filed Oct 2008

R. Kokku, A. Bohra, S. Ganguly, and R. Izmailov "A Multipath Routing Architecture for Background Transfers" Filed March 2006

S. Ganguly, A. Bohra, R. Izmailov, Y. Kikuchi "CoDist: Coding Based Distribution of Large Datasets" Filed March 2005

TALKS

A Multipath Background Network Architecture. Rutgers Helsinki Workshop on Spontaneous Networking, Piscataway NJ, June 2006

FileWall: Implementing File Access Policies Using Access Context 1st Rutgers / Pierre and Marie Curie Workshop, Paris, May 2006

Split-OS : An OS Architecture for Clusters of Intelligent Devices, SOSOP Work in Progress Session, Banff Canada, October 2001

Effects of Interrupts on Multiprocessor Servers. New York Metropolitan Area Distributed Systems Workshop, IBM Watson Research Center, Hawthorne NY, 2000

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### REFERENCES

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