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OBJECTIVE A full-time position involving research and development in computer networking.

Ph.D. (Computer and Systems Eng.), **GPA 3.88/4.0**,
Rensselaer Polytechnic Institute, Troy, NY
Advisor: Prof. Shivkumar Kalyanaraman 05/2004
Topic: *Edge-based point-to-multipoint Quality of Service Provisioning*

EDUCATION **M.S.** (Computer and Systems Eng.), **GPA 3.8/4.0**,
Rensselaer Polytechnic Institute, Troy, NY
Advisor: Prof. Shivkumar Kalyanaraman 05/2001
Topic: *Dynamic Provisioning with Online Bandwidth Demand Estimation*

B.E. (Computer Eng.), **GPA 4.0/4.0**,
Karnataka Regional Engineering College (KREC),
Surathkal, India 07/1998

RESEARCH INTERESTS

Dynamic resource management, adaptive provisioning of network resources for application-aware Quality of Service, VPN architecture and characteristics, edge-based architectures for QoS.

Application-aware Networks at Nortel Networks, Billerica, MA, 05/2004-Present

RESEARCH PROJECTS

As networks evolve to become increasingly integrated with enterprise applications, there is a need for intelligent overlays that deliver flexibility in provisioning and management. I am part of a team credited with conception, design and implementation of a prototype middleware that allows applications to setup high-bandwidth paths on-demand. The middleware provides a high-level interface with the ability to bypass higher network protocol layers for a dedicated circuit-style path. In addition to significant contributions to the overall architecture, I am building the modules that incorporate topology information to discover cross-layer paths spanning network technologies (SONET, Ethernet) and administrative domains (including different control planes). With the help of popular application messaging protocols, the middleware allows any bandwidth-intensive application to have fine-grain control over when and what kind of network resources are provisioned. *Related demonstrations at Supercomputing 2004 and GlobusWorld 2005.*

Adaptive Provisioning for VPNs with the Hose Model at AT&T Labs Research and RPI, 06/03 – Present

Efficient provisioning of provider resources is the key to building scalable VPN services. While proposals like Point-to-Set and Hose Model provide the architectural framework, they do not specify the mechanisms to achieve demand-driven dynamic provisioning. I conceived and designed a set of measurement-based algorithms to achieve adaptive provisioning using existing SNMP-based measurement infrastructure. I built a new variant of the popular Entropy-based penalized least-squares approach that could quickly compute VPN traffic matrices. Using extensive measurement studies I demonstrated that key aspects of VPNs like structure and traffic matrices can be learnt and deployed in a provisioning architecture. I leveraged measurement insights to build a comprehensive simulation framework to quantify the value of traffic matrices to providers and customers. The results serve as design guidelines for architects wanting to build adaptive architectures. *Related papers published in SIGMETRICS 2004, IMC 2004 and INFOCOM 2005.*

A New Edge-based Point-to-Multipoint QoS Architecture at RPI, Troy, NY. 05/2002 – 05/2004

**RESEARCH
PROJECTS**

Traditional point-to-point QoS solutions do not tackle new enterprise networking realities like Virtual Private Networks (VPNs) where Service Level Agreements (SLAs) are typically point-to-multipoint in nature. Existing models to provision point-to-multipoint QoS rely on extensive core network support in terms of signaling and routing protocols. In my doctoral work, I build a new edge-based architecture, called Point-to-Set, that provides SLAs without requiring per-customer-endpoint signaling. I demonstrate a probabilistic admission model to realize high-confidence point-to-multipoint QoS assurances. I show that the parameters of the model are easily deduced using existing SNMP-based measurement information. The architecture has been implemented in the NS-2 simulator and evaluated with real packet traces. *Related Papers published in ICC 2002, QoSFIS 2003, SIGMETRICS 2004.*

Optimal allocation of edge network resources in Virtual Private Networks at AT&T Labs Research and RPI, 06/03 – 08/03

Assigning a VPN customer to a Provider Edge (PE) router involves allocating router resources and backhaul bandwidth costs. Clustering the endpoints of a customer on to the same PE yields savings in routing table sizes, but can result in higher backhaul costs and increased risk of outage. I formulated an optimization problem that captures the tradeoff between the cost of higher backhaul distances and risk of outage vis-à-vis lower routing table sizes. For synthetic datasets generated using distributions derived from customer data, I demonstrated that the optimization formulation can yield considerable gains over current heuristics given sufficient ISP points-of-presence. For the case where there is little flexibility with points-of-presence, heuristics quickly become the better alternative with increase in customer locations.

Probabilistic Delay Assurances using Edge-based components in a FIFO network at RPI, 05/2002 – 05/2003

Today's core network feature IP routers with simple FIFO queues with little or no per-flow scheduling capabilities. When flows are multiplexed on to a FIFO queue, the traffic distortions introduced in terms of increased burstiness have an adverse impact on delay bounds. Existing techniques to provide delay assurances either assume specialized scheduling in the core or the precise knowledge of the number of flows and their traffic characteristics, both of which are hard to come by in reality. I built a new framework to derive bounds on probability of violation of delay targets. I demonstrated that using simple shaping components at the edge of the network, one could enforce bounds on burstiness of flows so that delay assurances can be met with high confidence. Using numerical and packet simulations on a variety of topologies, I demonstrated delay assured services with FIFO core networks.

**RESEARCH
PROJECTS**

Route Fragility Coefficient – a new route selection metric for on-demand routing in mobile ad hoc networks at RPI, 09/2002-12/2002

Mobile ad hoc networks feature short-lived routes that expose transmissions to high loss rates. Along with a colleague, I invented a new metric that measures the quality of a path using a stateless and lightweight protocol mechanism. The Route Fragility Coefficient (RFC) measures the extent by which a path is contracting (nodes moving toward each other) or expanding in a mobile network. Employing NS-2 simulations we demonstrated that a variety of on-demand routing protocols like DSR, AODV and TORA could be upgraded to obtain substantial gains in throughput and reduction in control overhead. *Related paper published in IEEE ICON 2002.*

Built Network Traffic Management Components at Novell Bangalore, 07/98-07/99

- Designed components of RMON2 agent (Remote Network MONitoring MIB)
- Ported FDDI component of RMON agent from NetWare to NT 4
- Automated test software for testing RMON agents - Ethernet, FDDI packet generators.
- Enhanced a Java based network service monitor
- **Programming tools:** C/C++, Java
- **OS:** Windows NT 4, NetWare 4.x, 5.x

**INDUSTRY
EXPERIENCE**

Designed and Built Tool to Recreate Traffic from Packet Traces at Packeteer Inc., CA, 05/2000-08/2000

- Designed and built a tool to recreate network traffic from trace files
- Tool featured ability to spoof specific layers including the inter-packet times, accelerate or decelerate the traffic events etc.
- **Programming tools:** C, Packet Sockets Library on Linux
- **OS:** Linux kernel 2.2.18

WORK EXPERIENCE	• Research Engineer, Nortel Networks, MA	05/2004 – Present
	• Research and Teaching Assistant, RPI, NY	08/1999 – 05/2004
	• Summer Manager, AT&T Labs Research, NJ	06/2003 – 08/2003
	• Summer Intern, Packeteer Inc., CA	05/2000 – 08/2000
	• Software Engineer, Novell India	07/1998 – 07/1999

PUBLICATIONS

- **Refereed Conference (Published):**
 - **S. Raghunath**, S. Kalyanaraman, K.K. Ramakrishnan, "Trade-offs in resource management for Virtual Private Networks," In *Proceedings of IEEE INFOCOM 2005*.
 - P. Wang, I. Monga, **S. Raghunath**, F. Travostino, T. Lavian, "Workflow Integrated Network Resource Orchestration", *GlobusWorld 2005*, Short Paper.
 - **S. Raghunath**, K.K. Ramakrishnan, Shivkumar Kalyanaraman, C. Chase, "Measurement based characterization and provisioning of IP VPNs," In *Proceedings of ACM Internet Measurement Conference (IMC) 2004*.
 - **S. Raghunath**, S. Kalyanaraman, K.K. Ramakrishnan, "Quantifying Trade-offs in Resource Allocation for VPNs", *ACM SIGMETRICS 2004*, Poster session.
 - **S. Raghunath**, S. Kalyanaraman, "Statistical Point-to-Set Edge-based QoS Provisioning", In *Proceedings of Quality of Future Internet Services (QoFIS)*, Springer-Verlag, LNCS-2811, 2003.
 - **S. Raghunath**, K. Chandrayana, S. Kalyanaraman, "Edge-Based QoS Provisioning for Point-to-Set Assured Services," *Proceedings of IEEE ICC*, NY, April 2002.
 - O. Tickoo, **S. Raghunath**, S. Kalyanaraman, "Route Fragility: A Novel Metric for Route Selection in Mobile Ad Hoc Networks," In *Proceedings of IEEE ICON*, Sydney, 2003

- **Refereed Journal (Submitted):**
 - **S. Raghunath**, K. Chandrayana, S. Kalyanaraman, "Edge-Based QoS Provisioning for Point-to-Set Assured Services," Submitted, 2005
 - **S. Raghunath**, K.K. Ramakrishnan, S. Kalyanaraman, "Measurement based characterization of IP VPNs," Submitted, 2005

SKILLS

LANGUAGES	<ul style="list-style-type: none"> • C, C++/STL, Java • BASH, AWK, PERL, Tcl/OTcl • AMPL, CPLEX • HTML, Ruby
SDKs	<ul style="list-style-type: none"> • BSD Sockets • J2EE, JMS, JDK, Swing
TOOLS	<ul style="list-style-type: none"> • MATLAB, MAPLE • MATHEMATICA • NS network simulator
PLATFORMS	Linux, Solaris, HP-UX, IBM AIX, Windows

NETWORKING TECHNOLOGIES

- MPLS, ASON
- SONET/SDH, RPR, Ethernet
- RFC 2547 VPNs, E-Line, E-LAN, VPLS
- BGP, OSPF, Traffic Engineering
- TCP/IP suite, SNMP, TL1
- Grid Computing, Globus toolkit, Web-services standards

PATENTS

- ***Resource Allocation and Admission Control for efficient provisioning of VPNs in the Hose Model.*** Patent Pending (with Dr. K.K. Ramakrishnan)
- ***BANANAS: A New Connectionless Traffic Engineering Framework for the Internet.*** (with Prof. S. Kalyanaraman et al) US Provisional Patent No. 60/356,032

PROFESSIONAL ACTIVITIES

- Member IEEE, IEEE Communication Society.
- Reviewer IEEE Infocom, IEEE Globecom, IEEE/ACM IWQoS, IEEE ICDCS, IEEE ICC, ACM Computer Communications, IEEE JSAC.

REFERENCES

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Additional references available on request.