

# BHARAT BHARGAVA

## 2003/04 Faculty Activity Report

Please return by Monday, March 15, 2004

- Activities should cover the period March 2003 – February 2004
- Publication should cover March 2002 – February 2004

### A. Teaching

Information about the courses taught will be obtained from departmental records. If your teaching preference is identical to that you gave last year, you can skip 1 and 2.

1. List four to five CS courses you enjoy teaching. Make sure you include undergraduate courses.
  - CS 348, 448, 541, 542, and 641
2. Among CS 180, 182, 240, 250, and 251, list at least one course you feel comfortable teaching. Please note that listing none implies that you are comfortable teaching any of these courses.
  - CS 251
3. Describe any major revision of existing courses you were involved in.
  - CS 542 (Distributed Database System) It required identifying specific topics that can lead to enhanced research activity at Purdue. The syllabus now includes mobile ad hoc nodes, wireless communications, privacy, and security. Projects that can match experimental facilities developed in research were initiated. In addition to seven in the past, five new projects are being implemented by students. They involved peer-to-peer data streaming, private data dissemination and evaporation. This will prepare students for other graduate courses in embedded systems, pervasive systems and integrate their material from networking and security sources. Some of these projects can result in students publishing research papers.

4. Describe courses or laboratories initiated.

- Mini-Raid communication software libraries have been updated for CS 542. Pastry, and Gnustream have been installed. PROMISE and CollectCast software developed in research is being used by four students in peer-to-peer projects in CS 542. Benchmarks, software, and experiments developed for use by students in projects such as tomography measurements, TERA system, and extended network simulator have been installed. ns2 has been upgraded with multicasting and ad hoc networking facilities. MobiEmu software that emulates mobile ad hoc networks has been obtained from Hughes Research Laboratories for experiments. Hacker and fraud behavior has been emulated. Some of these have helped undergraduate students for independent study projects.

5. Describe other teaching activities (e.g., summer conference courses, short courses).

- An informal seminar for undergrads/grads on mobile and wireless security is continuously offered in Fall/Spring. It is attended by three undergrads.
- Tutorial slides on Privacy/Security/Trust/Safety/Reliability have been developed. This will be offered in outreach activities to high schools, government agencies, and industry groups.

## **B. Supervision of students**

1. Give the names of students who completed their Ph.D. degrees under your supervision. Please indicate the level and type of support provided for each student (RA, TA, fellowship).

- Ahsan Habib, RA, funded by NSF, 100%.

2. Give the names of current Ph.D students supervised. For each student indicate whether pre-quals, post-quals, post-prelim, expected completion date, and level and type of support.

- Mohamed Mosaad Hefeeda Continuing Ph.D., May 2004, RA, post-prelim, funded by NSF, 100%.
- Yi Lu Continuing Ph.D., August/December 2004, RA, post-prelim, funded by DARPA and NSF, 100%.
- Yuhui Zhong Continuing Ph.D., December 2004, RA, post-prelim, funded by NSF, 100%.
- Weichao Wang Continuing Ph.D., May 2005, RA, post-qual II, funded by NSF, 100%.

- Gang Ding, RA, December 2005, passed quals in ECE, pre-quals in CS, funded by NSF, 100%.
  - Yunhua Lu, RA, December 2005, pre-quals, funded by NSF (100%, Spring, Summer 2003).
  - Issa M.I. Khalil, RA, Fall 2006, passed quals in ECE (50% support in Summer 2003).
  - Walid Ibrahim Khedr, RA, pre-quals.
  - Ahmet Burak Can, RA, pre-quals.
  - Maleq Khan, RA, post-qual II, (100% support in Spring, Summer 2003, now with Gopal Pandurangan since Fall 2003), funded by NSF.
  - Shan Lei, RA, post-qual, (100% support in Summer 2003, now with Dongyan Xu), funded by NSF.
  - Yu Dong, RA, post-qual II, (100% support in Spring 2004, student of David Yao), funded by NSF.
  - Jorge Ramos, RA, (Supplementary support for PRF grant, Summer 2003, student of Vernon Rego), funded by NSF.
  - Ruy de Oliveira, University of Bern in Switzerland (co-PhD advisor), 2005.
3. Ph.D. committee (post-candidacy) membership (provide a number). (Do not include chairmanships listed already).
- Three, including in Electrical and Computer Engineering and Industrial Engineering, External Examiner for PhD thesis of Yan Bai at University of British Columbia.
4. Number of preliminary examination committees you served on.
- Four
5. Individual graduate student projects supervised (including independent study courses). List student name and project title.
- Yunhua Lu, Fraud Formalization and Detection.
  - Shan Lei, Cellular-aided Mobile Ad hoc Networks.
  - Maleq Khan, Sensor Networks.
  - Issa M.I. Khalil, Key Management in Sensor Networks.

- Walid Ibrahim Khedr, Trust Management.
  - Ahmet Burak Can, Mobile Networks.
  - Gang Ding, Mobile Peer-to-peer and Multimedia over Wireless Networks.
  - April Savoy, Vulnerabilities Analysis.
  - Tamara Morris, Vulnerabilities in Microsoft Database Software.
  - Marin Vassilev Markov, Information Dispersion.
  - Anna Saputera, Trust Management.
6. Individual undergraduate student projects (including independent study courses) supervised. List student name and project title.
- Halima Ghafoor, Internet Experiments, supported by NSF.
  - Roger Elian, Wireless Networks, supported by NSF.
  - Marques Fulford, Networking Experiments, supported by NSF.
  - Anuj Puri, Cellular-aided Mobile Ad hoc Networks, supported by NSF in Summer 2003.
  - Steven Cadwallader, Web Interface for SQL.
  - Mathew Travis Muncy, Wireless Security.
7. Provide any additional information related to your interaction with students.
- Advisor of Indian Students Association (400 members).
  - Interact with undergraduate students to participate in SoS undergraduate research day.
  - Help minority students in retention in CS. Working closely with Regina Hicks in SoS. Obtained grants to support minorities from NSF.
  - Get students involved in research grants, publishing, presentations. Help grad students with contacts with other researchers. Examples: Hefeeda is now closely working with a top professor (Phil Afeche) of Northwestern in economics of P2P systems. Help Zhong to collaborate with Dr. Mohania (IBM manager), researchers at HP-Bristol, and Prof. Madria at UM-Rolla. Help Lu and Wang collaborate with research group at University of Bern and Cambridge University.
  - Help undergrad office with information about NSF REU, identify student projects, apply for grants. Meeting was held with SoS advisors.

I supported through NSF grant and educated several minority students about wireless networking, communications and got them to participate in the science undergraduate research day held in April 2003. Resulted in one research paper.

In the Spring/summer, 2003, every Friday we held meetings in Raidlab with all undergraduate students and for one hour to discuss research. I have connected them individually with a graduate student. They are given access to Raidlab and encouraged to use tools for communication experiments related to NSF grants. They are also learning tools for security in mobile communication. I have given lectures to incoming freshman through a program (SOAR) of SoS.

- I hold a formal meeting every Wednesday for one hour where graduate students present their ideas and discuss progress. The graduate students are taught the design of experiments and tools for conducting experiments. The following tools have been modified and developed and made available to graduate students working in Raidlab: mini-Raid, Communication Libraries, AG (Active Gateway), Network Probing tools, Web caching Software, Network Simulator, Linux OS, P2P (CollectCast, PROMISE) system software. Our students had four posters in e-enterprise center meeting and again in CERIAS annual meeting.
- I bring/invite researchers/industry managers to meet students in Raidlab in CS 542 class.
- I encourage students to attend conferences even if they do not have a research paper. A Postdoc and two students were sent to MobiCom in San Diego. Students have attended ACM Multimedia conference in Berkeley, IEEE Pervasive Computing Conference (PerCom) in Dallas, ACM SigComm in Germany, Future Trends in Distributed Systems in Puerto Rico, and NDSS in San Diego.
- Meet visiting admitted grad students.
- Available to students 24 hours via phone at home.
- Invite students to home for informal discussions.

### C. Research publications and presentations

Please include the names of all authors in the order in which they appeared in the publication; also include page numbers.

Publication should cover the time period **March 2002 – February 2004**.

1. Books, book chapters and book reviews.

- S. Madria, B. Bhargava, M. Mohania, S. Bhowmick. “Data and Transaction Management in a Mobile Environment”, Book Chapter in *Mobile Computing: Implementing Pervasive Information and Communication Technologies*, Kluwer Academic Publishers, Dec. 2002, pp. 139–166.
- I. Chung, B. Bhargava, S. Madria. “Taxonomy of Data Management via Broadcasting in a Mobile Computing Environment”, Book Chapter in *Mobile Computing: Implementing Pervasive Information and Communication Technologies*, Kluwer Academic Publishers, Dec. 2002, pp. 167–190.

2. Articles published in refereed journals. Distinguish between articles and correspondence items.

#### Published

- S. Madria, M. Mohania, B. Bhargava and S. Bhowmick, *Mobile Data and Transactions, Information Science Journal*, Vol 141, No 3-4, April 2002, pp. 279–309
- S. Madria, M. Tubaishat, B. Bhargava, Performance Evaluation of Linear Hash Structures in a Nested Transaction Environment, *Journal of Systems and Software*, Vol 63, No. 3, May 2002, pp. 59–79
- D. Yau and B. Bhargava. Heterogeneous CPU Services Using Differentiated Admission Control, *Journal of Multimedia Tools and Applications, special issue on QoS in Multimedia Networks*, Vol 17, July, 2002, pp 213–232
- A.Habib, S. Fahmy, S. Avasarada, V. Prabhakar, and B. Bhargava, On Detecting Service Violations and Bandwidth Theft in QoS Network Domains, *Computer Communications*, Elsevier, Vol. 26 Issue 8, May 2003, pp. 861–871.
- Y. Lu, B. Bhargava, W. Wang, Y. Zhong, and X. Wu, Secure Wireless Network with Movable Base Stations, *IEICE Transaction on Communications, IEICE/IEEE Joint Special Issue on Assurance Systems and Networks*, Vol. E86-B, No. 10, Oct. 2003, pp. 2922–2930.

- X. Wu, B. Mukherjee, G.-H. Chan, and B. Bhargava, Assuring Communications by Balancing Load in Cellular Networks, *IEICE Transaction on Communications, IEICE/IEEE Joint Special Issue on Assurance Systems and Networks*, Vol. E86-B, No. 10, Oct. 2003, pp. 2912–2921.
- A. Habib, M. Khan, and B. Bhargava, Edge-to-Edge Measurement-based Distributed Network Monitoring, *Computer Networks*, Vol. 44, Issue 2, Feb. 2004, pp. 211–233.
- M. Hefeeda, B. Bhargava, and D. Yau, A Cost-Effective Architecture for On-Demand Media Streaming, *Journal of Computer Networks*, Vol. 44, Issue 3, Mar. 2004, pp. 353–382.
- B. Bhargava, C. Shi, and Y. Wang, MPEG Video Encryption Algorithms, accepted for publication in *Multimedia Tools and Applications*
- B. Bhargava, X. Wu, Y. Lu, and W. Wang, Integrating Heterogeneous Wireless Technologies: A Cellular Aided Mobile Ad Hoc Network (CAMA), accepted for publication in *ACM Special Issues of the Journal on Special Topics in Mobile Networking and Applications (MONET)*
- X. Wu, G.-H. Chan, B. Mukherjee, and B. Bhargava, Mobile-Assisted Data Forwarding for Wireless Networks, accepted for publication in *IEEE/KICS Journal of Communications and Networks*

### Submitted

- I. Chung, B. Bhargava, S. Madria, Broadcasting for Data Management in Mobile Computer Systems, Submitted to *IEEE Transactions on Mobile computing* (Under revision)
- B. Bhargava, S. Wang, M. Khan, and A. Habib, Multimedia Data Transmission and Control using Active Networks, Submitted to *Special Issue on Activated and Programmable Internet, Journal of Computer Communications* (Under revision)
- A. Habib, S. Fahmy, and B. Bhargava, On Monitoring and Controlling QoS Network Domains, Submitted to *ACM Computer Communication Review*
- X. Wu, B. B. Mukherjee, and B. Bhargava, A Two-Step Paging Scheme in a Macrocell/Microcell Cellular Network, Submitted to *IEEE Transactions on Vehicular Technology*
- M. Hefeeda, A. Habib, D. Xu, B. Bhargava, and B. Botev, CollectCast: A Peer-to-Peer Service for Media Streaming, Submitted to *ACM/Springer Multimedia Systems Journal*.
- W. Wang, B. Bhargava, Y. Lu, and X. Wu, Defending Against Wormhole Attacks in Mobile Ad Hoc Networks, Submitted to *Wiley Journal on Wireless Communications and Mobile Computing*.

- X. Wu, B. Mukherjee, and B. Bhargava, A Crossing-Tier Location Update/Paging Scheme in Hierarchical Cellular Networks, Submitted to *IEEE Transactions on Wireless Communications*.
- X. Wu, G. Ding, and B. Bhargava, Improving Throughput by Link Distance Control in a Multi-Rate Ad Hoc Network, Submitted to *IEEE Journal on Selected Area in Communications (JSAC)*.
- Y. Lu and B. Bhargava, SAGA: Self-Adjusting Congestion Avoidance Routing Protocol for Ad Hoc Networks, Submitted to *IEEE Transactions on Mobile Computing (TMC)*.
- B. Bhargava, M. Jenamani, and Y. Zhong, Impact of Cheating on Online Auctions, Submitted to *International Journal of Co-operative Information Systems*.

3. Articles published in rigorously reviewed conferences with archival proceedings.

(These papers are 8 printed pages as per IEEE/ACM limit. Papers are on my website [www.cs.purdue.edu/homes/bb.](http://www.cs.purdue.edu/homes/bb.))

- A. Habib, B. Bhargava, and S. Fahmy, A Round Trip Time and Timeout aware Traffic Conditioner for Differentiated Services Networks, in *Proceedings of IEEE International Conference on Communications*, New York, April 2002.
- D. Xu, M. Hefeeda, S. Hambruch, and B. Bhargava, On Peer-to-Peer Media streaming, in *Proceedings of IEEE International Conference on Distributed Computing Systems*, Vienna, June, 2002
- B. Bhargava and Y. Zhang, Authorization Based on Evidence and Trust, in *Proceedings of DaWak-2002 conference*, Aix en Provence, Sept. 2002
- L. Bellatreche, L.Schneider, M. Mohania, and B. Bhargava, PartJoin: An Efficient Storage and Query Execution for Data Warehouses, in *Proceedings of DaWak-2002 conference*, Aix en Provence, Sept. 2002
- E. Maria, Y. Zhong, B. Bhargava, Pankaj, and S. Madria, Building User Role Profiles using a Clustering Algorithm, in *Proceedings of DaWak-2002 conference*, Aix en Provence, Sept. 2002
- F. Baumgartner, T. Braun, and B. Bhargava, Virtual Routers: A Tool for Emulating IP Routers, in *Proceedings of 27th Annual IEEE Conference on Local Computer Networks (LCN 2002)*, Tampa, USA, November, 2002.
- F. Baumgartner, T. Braun, and B. Bhargava, Design and Implementation of a Python-Based Active Network Platform for Network Management and Control, in *Proceedings of IFIP-TC6 4th International Working Conference(IWAN2002)*, Zürich, Switzerland, December 2002.
- W. Wang, Y. Lu, and B. Bhargava, On Vulnerability and Protection of Ad Hoc On-Demand Distant Vector Protocol, in *Proceedings of IEEE International Conference on Telecommunications*, Tahiti, Feb, 2003
- Y. Lu, W. Wang, and B. Bhargava, Hierarchical Structure for Supporting Movable Base Stations in Wireless Networks, in *Proceedings of IEEE International Conference on Telecommunications*, Tahiti, Feb, 2003
- A. Habib, M. Hefeeda, B. Bhargava, Detecting Service Violations and DoS Attack, in *Proceedings of Network and Distributed System Software (NDSS 2003)*, San Diego, Feb., 2003

- Y. Lu, W. Wang, Y. Zhong, and B. Bhargava, Study of Distance Vector Routing Protocols for Mobile Ad Hoc Networks, in *Proceedings of IEEE International Conference on Pervasive Computing and Communications (PerComm)*, Dallas, March, 2003
- W. Wang, Y. Lu, and B. Bhargava, Security in Routing Protocols for Mobile Ad Hoc Networks, in *Proceedings of IEEE International Conference on Pervasive Computing and Communications (PerComm)*, Dallas, March, 2003
- I. Chung, L. Lilien, B. Bhargava, and M. Mahoui, Autonomous Transaction Processing Using Data Dependency in Mobile Environments, in *Proceedings of International Workshop on Future Trends of Distributed Computing Systems (FTDCS '03)*, San Juan, Puerto Rico, May, 2003.
- M. Hefeeda and B. Bhargava, On-Demand Media Streaming Over the Internet, in *Proceedings of International Workshop on Future Trends of Distributed Computing Systems (FTDCS '03)*, San Juan, Puerto Rico, May, 2003.
- A. Habib, B. Bhargava, Network Tomography-based Unresponsive Flow Control, in *Proceedings of International Workshop on Future Trends of Distributed Computing Systems (FTDCS '03)*, San Juan, Puerto Rico, May, 2003.
- G. Ding, H. Ghafoor, and B. Bhargava, Error Resilient Video Transmission over Wireless Networks, in *Proceedings of 6th IEEE International Symposium on Object-oriented Real-time Distributed Computing*, Hakodate, Japan, May, 2003.
- X. Jiang, Y. Dong, D. Xu, and B. Bhargava, GnuStream: A P2P Streaming System Prototype, in *Proceedings of IEEE International Conference on Multimedia & Expo (ICME)*, Baltimore, July, 2003.
- B. Bhargava, Y. Zhong, and Y. Lu, Fraud Formalization and Detection, in *Proceedings of DaWak-2003 Conference*, Prague, Sept. 2003.
- X. Wu, B. Mukherjee, and B. Bhargava, A Low-Cost, Low-Delay Location Update/Paging Scheme in Hierarchical Cellular Networks, in *Proceedings of ACM International Workshop on Data Engineering for Wireless and Mobile Access (MobiDE)*, San Diego, Sept. 2003.
- M. Hefeeda, A. Habib, B. Botev, D. Xu, and B. Bhargava, PROMISE: A Peer-to-Peer Media Streaming System, in *Proceedings of ACM International Conference on Multimedia*, Nov., 2003.
- G. R. Murthy, M.S. Arunachalam, B. Bhargava, and E.G. Rajan, Random Fading Channels, in *Proceedings of International Conference on System, Cybernetics, and Informatics (ICSCI)*, Hyderabad, India, Feb. 2004.
- G. R. Murthy, M.S. Arunachalam, B. Bhargava, and E.G. Rajan, System Identification Approach to Echo Cancellation, in *Proceedings of International Conference on System, Cybernetics, and Informatics (ICSCI)*, Hyderabad, India, Feb. 2004.

- G. Ding and B. Bhargava, Peer-to-peer File-sharing over Mobile Ad hoc Networks, in Proceedings of *International Workshop on Mobile Peer-to-Peer Computing, Joint with International Conference on Pervasive Computing and Communications (PerComm)*, Orlando, Florida, March 2004.
  - P. Ruth, D. Xu, B. Bhargava, and F. Regnier, E-notebook Middleware for Accountability and Reputation Based Trust in Distributed Data Sharing Communities , in Proceedings of *2nd International Conference on Trust Management (Springer Verlag)*, London, UK, March 2004.
  - M. Jenamani, L. Lilien, and B. Bhargava, Anonymizing Web Services through a Club Mechanism with Economic Incentives, Submitted to *IEEE International Conference on Web Services, ICWS 2004*.
4. Other papers presented at conferences, symposia or workshops with published proceedings.
5. Other papers presented at meetings without published proceedings.
- B. Bhargava, Vulnerabilities and Fraud in Computer Systems, (Invited) in Proceedings of *the International Conference on Internet, Processing, Systems, and Interdisciplinary Research (IPSI), VIP Scientific Forum*, Sv. Stefan, Serbia and Montenegro, Oct. 2003 (CD-ROM Proceedings).
  - L. Lilien and A. Bhargava, From Vulnerabilities to Trust: A Road to Trusted Computing, in Proceedings of *International Conference on Advances in Internet, Processing, Systems, and Interdisciplinary Research (IPSI-2003)*, Sv. Stefan, Serbia and Montenegro, October 2003 (CD-ROM Proceedings).
6. Publications in other media.
- M. Hefeeda, A. Habib, and B. Bhargava, Cost-Profit Analysis of a Peer-to-Peer Media Streaming Architecture, *CERIAS Technical Report 2002-37*, Purdue University.
  - Y. Zhong, Y. Lu, and B. Bhargava, Dynamical Trust Production Based on Interaction Sequence, *Technical Report CSD-TR 03-006*, Department of Computer Sciences, Purdue University.
  - Y. Lu, Y. Zhong, and B. Bhargava, Packet Loss in Mobile Ad Hoc Networks, *Technical Report CSD-TR 03-009*, Department of Computer Sciences, Purdue University.

- M. Hefeeda, P. Afeche, and B. Bhargava, Economics of a Collaborative Peer-to-Peer Infrastructure for Content Distribution, *Technical Report CSD-TR 03-015*, Department of Computer Sciences, Purdue University.
- B. Bhargava, M. Jenamani, and Y. Zhong, Understanding the Impact of Shill Bidding in Online English Auctions, *Technical Report CSD-TR 03-036*, Department of Computer Sciences, Purdue University.
- M. Jenamani and L. Lilien, and B. Bhargava, Anonymizing Web Services through a Club Mechanism with Economic Incentives, *Technical Report CSD-TR 04-008*, Department of Computer Sciences, Purdue University.
- Y. Zhong, Y. Lu, and B. Bhargava, TERA: An Authorization Framework Based on Uncertain Evidence and Dynamic Trust, *Technical Report CSD-TR 04-009*, Department of Computer Sciences, Purdue University.
- G. Ding, X. Wu, B. Bhargava, and S. Lei, Simulation Study of a Cellular Aided Mobile Ad-hoc Network, *Technical Report CSD-TR 04-010*, Department of Computer Sciences, Purdue University.
- S. Potluri, P. Venkatayogi, and B. Bhargava, Behavior-based System for Generation of Security Solutions, *Technical Report, CSD TR 04-011*, Department of Computer Sciences, Purdue University.
- B. Bhargava, C. Farkas, L. Lilien, and F. Makedon, Trust, Privacy, and Security. Summary of a Workshop at the National Science Foundation Information and Data Management (IDM) Workshop, Seattle, September 14 - 16, 2003, *CERIAS Technical Report 2003-34*, Center for Education and Research in Information Assurance and Security, Purdue University.  
[https://www.cerias.purdue.edu/tools\\_and\\_resources/bibtex\\_archive/archive/2003-34.pdf](https://www.cerias.purdue.edu/tools_and_resources/bibtex_archive/archive/2003-34.pdf)  
 (Also on the web site of University of Washington set up for NSF.)

7. Invited presentations and keynote addresses at major conferences.

- Invited Speaker, 14th International Workshop on Mobile Distributed Database System, Prague, Sept. 2003.

8. Patents issued and software developed. Technology transfer efforts and industrial applications. Describe effort and impact.

We present six software tools that were developed in research laboratory.

- *Trust-Enhanced Role Assignment (TERA) Prototype.*

Trust-enhanced role assignment (TERA) prototype decides whether or not a user is authorized for an access based on the policies, the evidence, and the trust value for a user. It consists of several trust enhanced role mapping (TERM) servers and a reputation server.

A TERM server assigns roles to users based on the evidence and trust. It consists of a policy database and three components: trust information management, evidence rewriting, and role assignment. Dynamic trust information is maintained by the trust management component. The trust of a user is evaluated based on her behaviors. The evidence rewriting component computes the reliability of a piece of evidence from the TERM server's point of view. The reliability is determined by the trust of the evidence provider and her own opinions to the evidence. The role assignment component manages the policies and makes the role assignment decision based on evidence, trust, and policies. Each TERM server interacts with a role-based access control (RBAC) enhanced application server to provide role assignment information and obtain users' behaviors.

Every TERM server periodically submits users' trust information to the reputation server. When a TERM server encounters a new user or a user in a new context, it requests the reputation server to compute the personalized reputation of the user by using the specified reputation evaluation algorithm. If any TERM server had previous interactions with the user, a valid reputation value will return the requesting TERM server. This value is used as trust value for role assignment and access.

A user application is provided to simulate different user behaviors for experimental studies. A user can connect to and interact with any TERM server. Her behaviors can be generated manually or according to predefine behavior models: stable, repenting, cheating, smart cheater.

Using the TERA prototype, experiments are being conducted on evaluation of (a) behavior-based trust-building algorithms, (b) uncertain evidence handling mechanisms, and (c) personalized reputation calculation algorithms.

The TERA prototype and its demonstration are available at <http://www.cs.purdue.edu/homes/bb/NSFtrust>.

- *PRETTY*

Based on TERA, we are building a full scope prototype system called PRETTY (private and trusted system). PRETTY implements the research ideas in privacy-preserving data dissemination, quantification of the tradeoff between privacy and trust, and unified privacy metrics to provide quantitative assessment of the privacy level achieved by different techniques. PRETTY utilizes the server/client architecture. The client component of PRETTY consists of the user application, the credential manager, the evaluator of trust

gain and privacy loss, the privacy negotiator, and a set of privacy policies. The server component consists of the server application, the TERA server, the privacy negotiator, the set of privacy policies, the database, and the data disseminator. PRETTY provides a platform to simulate privacy violators and users with different levels of trust. It will serve as a testbed for experimental studies on (a) clean self-destruction and proximity-based evaporation for private objects, (b) effectiveness and efficiency of the probability-based and lattice-based privacy loss evaluation methods, and (c) evaluation of the dynamic mappings between trust levels and distortion levels.

- *Cellular Aided Mobile Ad Hoc Networks (CAMA).*

Cellular-Assisted Mobile Ad Hoc (CAMA) is a integrated network software for ad hoc mobile nodes that takes advantage of a cellular system. Cellular network works as a centralized control to handle the ad hoc network management of routing and security in a position-based routing algorithm. Experiments are conducted on throughput, cellular signaling, and robustness to imprecise position information.

Software has been developed to simulate this integrated architecture. The simulator is built upon ns2. In the link layer, the original program in ns2 for CSMA/CA medium access mechanism is used in our simulations. The module has been extended by including the function of link adaptation. The simulator determines the transmission rate by calculating the receiving signal-noise-ratio (SNR) instead of power. Simulator is developed to be able to accumulate the overall noise (including white noise and co-channel interference) at a receiving end when a packet arrives. The software is event-driven-based, and the receiving power and noise are attained whenever a new event such as a packet transmission or a control message transmission, occurs. This gives an updated radio environment for a realistic simulation scenario. The corresponding physical layer model includes the fading model and Doppler frequency effect. On the network layer, the software for position-based routing algorithm is built. A global controller is developed to simulate routing discovery, maintenance, and recovery. A virtual cellular channel model is mimic to evaluate the overhead on ad hoc/cellular signaling exchange.

- *CollectCast.*

A new network service called CollectCast has been designed and implemented. CollectCast serves the cooperative P2P applications that operate in a highly diverse and dynamic networks. CollectCast is a layer on top of a P2P lookup substrate and provides four services: (a) topology inference and labeling, (b) peer selection, (c) rate and data assignment, and (d) monitoring and adaptation.

The topology inference employs network tomography techniques to infer the performance (e.g., segment-wise loss rate and available bandwidth) of the underlying network with low overhead. Network tomography infers the internal characteristics of a network by only

probing it from the edge nodes. The adaptations on the basic inference techniques yield a small convergence time and low overhead, while maintaining the desired level of accuracy for the target streaming applications. The peer selection takes the set of candidate suppliers and the network performance as inputs. It uses this information to select the best senders for the streaming session. This is done by casting the selection problem as a maximization problem constrained by the input bandwidth of the receiver. The objective is to find the best subset of the candidates that will render the maximum aggregated rate at the receiver. An algorithm has been proposed to solve the maximization problem.

Multiple concurrently sending peers are coordinated by the rate and data assignment component of CollectCast. The assignment technique assigns each sender the appropriate rate and data based on the network performance information and sender's characteristics. To account for network dynamics and peer failures, the monitoring and adaptation component of CollectCast continually adjusts the sending rate of each sender, and switches failed senders by backups. Forward error correction (FEC) is used in an adaptive way to tolerate packet losses. The media data is divided into segments and each is FEC-encoded using a maximum predefined loss tolerance level. Periodically, the adaptation component determines the required loss tolerance level based on the *current* conditions of the network. Senders are then notified to send enough redundant packets to tolerate the current loss level. The components of CollectCast have been implemented.

- *PROMISE*.

PROMISE is a P2P media streaming system for video-on-demand applications. The system is built on top of CollectCast. PROMISE runs as an agent on each participating peer. We used Pastry as the P2P lookup substrate. Pastry returns a single supplying peer for each object lookup request, if the object exists in the system. We have modified Pastry to support multiple supplying peers for each lookup. These supplying peers form the candidate set for the peer selection algorithm.

PROMISE has been tested in both local and wide area environments. To test the code in the wide area environment, we have installed PROMISE agents on 15 nodes of the PlanetLab wide area test bed. The nodes chosen for the experiments are distributed over different geographic locations. The measurements include: (a) Packet-level performance, which considers the aggregate rate measured at the receiver and how it changes with the time; (b) Frame-level performance, which focuses more on the perceived quality by a user and quantified in terms of the number of frames that either miss their deadlines or lost; (c) The impact of changing the system parameters on the quality; and (d) How PROMISE handles peer failure and switching.

More information about the CollectCast and PROMISE is available at <http://www.cs.purdue.edu/homes/mhfeeda/promise/>.

- *Extensions to Network Simulator (ns2) with support for congestion avoidance, intruder identification, and wormhole attack detection in mobile ad hoc networks.*

Self-adjusting congestion avoidance (SAGA) protocol integrates the wireless channel spatial reuse with the multi-hop nature of ad hoc routing to reduce congestion. SAGA is a distance vector routing protocol that uses intermediate delay (IMD) instead of hop count as the distance. The use of IMD enables routing protocols to select routes that bypass hot spots where congestion is heavy. SAGA protocol is implemented as an extension of the network simulator ns2. It runs on each mobile node as an agent and performs routing functions. The implementation provides operations for delay estimation, routing table maintenance, routes advertisement, lazy route query, broken link handling, and packet forwarding. The implementation of the 802.11 MAC protocol is extended to provide a callback function for delay estimation. Experiments have been conducted through simulation to evaluate the performance of SAGA protocol and compare it with AODV, DSR, and DSDV protocols.

ns2 is extended with a new module and a set of interfaces that can be applied to simulate and investigate different kinds of attacks. Both internal and external attackers can be introduced into the network. The attackers communicate with the good nodes through the public channel. They are equipped with a dedicated channel that will not interfere with the public channel and can be applied to conduct wormhole attacks. The malicious node class now supports AODV and DSDV routing protocols. The implemented attacks include false sequence number, false distance vector, malicious broadcast, and wormhole attacks.

A generic end-to-end approach to defend against wormhole attacks is proposed. The mechanisms are implemented and investigated using ns2. To reduce the computation and storage overhead, schemes are designed to manage the information. The cell-based open tunnel avoidance (COTA) mechanism is implemented to enable the mobile nodes to achieve different tradeoffs between the overhead and the detection capability. Experiments are conducted using the extended simulation tool. Both false positive and false negative alarm ratios are examined. The extra communication overhead introduced by the wormhole detection mechanism is investigated.

PROMISE and CollectCast are being used in CS 542 and CS 641. The following institutions have requested copies of this software for research and course projects: University of Southern California, University of Notre Dame, Korean Institute of Technology at Korea, University of de Liege at Belgium, University of California at San Diego, University of Bologna at Italy, University of Tokyo at Japan, and University of Norway.

- GnuStream, multimedia streaming software.

- Research on Cellular Assisted Mobile Ad Hoc Networks (CAMA) and research on multimedia over mobile networks are of great value to Motorola. We are working with Jeff Bonta of Motorola in exploring commercial value. A nondisclosure agreement has been signed between Purdue and Motorola. We plan to use the software tool in the Pervasive System research seminar planned for Fall 2004.
- Efficient Multimedia Security Protocols. This series of protocols combine the encryption and compression algorithms. Have provided details and software to many requests from industry.
- Working closely with IBM in applying adaptability software scheme to the Autonomic Computing program. IBM Fellow Guru Rao has visited us twice under advise from IBM V.P. Nick Donofrio.
- Developed contacts and got funding at CISCO for research on trusted routing in mobile ad hoc networks. We have followed up with a meeting with the vice president John Wakerly.
- Exploring a DARPA grant with Raytheon Corporation and Hughes Research Laboratory.

#### D. Research

1. Briefly discuss your research highlights for the last year.

I am conducting research in security issues in mobile and ad hoc networks. This involves host authentication and key management, secure routing, and dealing with malicious hosts, adaptability to attacks, and experimental studies. Related research is in formalizing evidence, trust, and fraud. Applications in e-commerce and transportation security are being tested in a prototype system. I have proposed schemes to identify vulnerabilities in systems and networks, and assess threats to large organizations. I have developed techniques to avoid threats that can lead to operational failures. The research has direct impact on nuclear waste transport, bio-security, disaster management, and homeland security. These ideas and scientific principles are being applied to the building of peer-to-peer systems, cellular assisted mobile ad hoc networks, and to the monitoring of QoS-enabled network domains. More specifics are as follows:

- Research involves study of algorithm, protocol, and architecture design to improve quality of service (QoS) and security in wireless networks. Research topics include routing, security, and inter-networking in ad hoc/cellular integrated network; multi-rate communication and real-time service over multi-hop wireless connections; and location privacy in ad hoc networks.

- Research involves building peer-to-peer systems for multimedia streaming and video-on-demand applications. The system organizes peers in network-aware clusters that can allow for fast dissemination of multimedia files and control of traffic on the underlying network. The research develops mechanisms for distributing contents over the Internet in a cost-effective manner while achieving the desired quality of service. The study includes economic models, privacy issues, verification of integrity of packets received, and optimizations. This research extends peer-to-peer systems beyond file-sharing and distributed database applications.
- Research in developing distributed monitoring schemes that use edge-to-edge measurements and collect statistics of delay, loss, and bandwidth in Internet is underway. The objective is to reduce the overhead for core routers, deal with large scale network domains, and identify congested links to capture the misbehaving flows. Such flows violate service-level-agreements and inject excessive traffic that leads into denial of service attacks. The challenge is to investigate techniques to identify intruders and improve the performance for normal users. This research is being extended for wireless ad hoc networks.
- Research addresses privacy and trust issues from simple transaction based interactions to the most complex collaborations. This involves algorithms to evaluate privacy loss and trust gain, mechanisms for disseminating data without compromising privacy, and assessment metrics that measure the privacy. Guidelines are provided for a variety of applications for developing privacy policies, building trust, and determining strategies for disseminating data to known or new users.

The RAID laboratory at Purdue University has been equipped with facilities to conduct experimental studies in networking. They include network communication measurement experiments, analysis of communication infrastructure, adaptability experiments for distributed systems, and peer-to-peer systems. Experimental studies involve a variety of subjects in security: secure routing and intruder identification in mobile ad hoc networks, authentication and key management in mobile systems, privacy and trust assessment, prediction and tradeoffs, monitoring network domains to detect service violations and DoS attacks, and vulnerabilities and attacker behaviors.

2. Information on current and pending research grants will be distributed by the business office. If any entries are not correct, please contact the business office. Below list awarded or pending funding activities not showing up on the business office report. This could include proposals not requiring a budget going through CS business office, gifts not yet recorded, or internal funding coming to the department on 10-funds.

- “Purdue Center for Neuroproteomics Research and Technology Development”, submitted to NIH, \$7,166,028, (with Pak, Reginier, Xu), (2004 - 2009)
  - “The Regenstrief Institute for Healthcare Engineering: Applying the Principles of Engineering and Management for the Improvement of Healthcare”, submitted to Regenstrief Foundation, \$1,000,000 per year (with Joe Pekny and Charles Rutledge), (2004 - 2014) (Presentation was made by President Martin Jischke on March 3, 2004)
3. List post-docs/research associates supported (and their current status).
- Dr. Leszek Lilien (2002-2004), funded by NSF grant.
  - Dr. Xiaoxin Wu (2002-2004), funded by NSF grant.
  - Dr. Mamata Jenamani (2003-2004), funded by NSF grant.
  - Prof. Jun Wen (2004-2005), visiting scholar from China.
4. Provide names of faculty in other departments at Purdue you have research interactions with (we get asked for this information frequently).
- Carla Brodley (Electrical and Computer Engineering)
  - Fred Regnier (Chemistry)
  - William Pak (Biological Sciences)
  - Joseph Pekny (Chemical Engineering)
  - Robert Hannemann, Medical Doctor (Chemical Engineering/Biomedical Engineering, Visiting Professor)
  - Karen Chang (School of Nursing)
  - Victor Cicirelli (Psychological Sciences)
  - Catherine Rosenberg (Electrical and Computer Engineering)
  - Carla Brodley (Electrical and Computer Engineering)
  - Michael Zoltowski (Electrical and Computer Engineering)
  - Arif Ghafoor (Electrical and Computer Engineering)

### **E. Service**

List committees you served on and events/activities you were actively involved in. Include a brief statement as to your particular contribution.

## 1. Departmental committees

### (a) Graduate Committee:

- Informing members of the grad committee about excellent students and helping the students in applying to Purdue. I believe my efforts have made a difference in the batch of students accepted by our dept. I am making extra effort in ensuring that they decide to join Purdue.

### (b) Internal Advisory Board of CERIAS:

- Discuss proposals and plans for the security center.
- Writing a proposal for Science and Technology Center (NSF-STC), involving twenty faculty from seven universities.

### (c) Promotion Committee:

- Work on tenure cases of faculty, write reports.
- Work on supporting documents for a distinguished professor nomination.

## 2. Departmental activities and events

I have participated actively in two CERIAS proposals. I am involved in inviting visitors from industry and academics to create an intellectual environment at Purdue. Graduate students and postdocs from several universities have spent time in Raid laboratory. I am active in recruiting faculty and attend all department meetings.

## 3. School of Science

### (a) EPCC (Educational Policy and Curriculum Committee) of SoS

### (b) Member, School of Science Council

(c) *Horizon Program*: Mentor minority students, regular meetings with students and monthly meetings for 2 1/2 hrs per month in different locations.

(d) *Minority Affairs (Diversity) Committee*: In 2003, I attended all meeting of this committee and helped in developing a long range plan. I helped several minority undergraduate students in getting into research activities in our department.

(e) *Undergraduate Science Research Day Committee*: I have coordinated the efforts in CS dept on behalf of School of Science. In April, 2003 four (one from my lab) students had their projects presented from CS.

- (f) *Interdisciplinary Program in Geographical Information System*: Represent CS dept on this committee and advise students with courses in CS and other related depts. Serve on student committees.

4. University

- Active participant in the center for wireless systems and application (CWSA).

5. Professional (include Journal editorial boards and Conference program committees)

(a) *Editor of following Journals*:

- Journal of System Integration.
- International Journal of Multi-Media Systems: Tools and Applications.
- International Journal of Cooperative Information Systems.
- IEEE Transactions on Mobile Computing.
- Wiley Journal on Wireless Communications and Mobile Computing.
- International Journal of Computers and Applications.

(b) *Committee of the following conferences*:

- Technical Program Committee of the International Conference on Mobile Database and Computing, Melbourne, Feb., 2003.
- Technical Program Committee of IEEE International Conference on Data Engineering, Bangalore, March, 2003.
- Technical Program Committee of IIWAS International Conference on Information Integration and Web-based Applications & Services, Linz, Austria, August, 2003.
- Technical Program Committee of International Conference on Data Warehousing and Knowledge Discovery (DaWak-2003), Prague, Sept. 2003.
- Technical Program Committee of Mobile Data Management (MDM), Berkeley, Feb., 2004.
- Technical Program Committee of International Conference on Pervasive Computing, March 2004.
- Technical Program Committee of the First International Workshop on Mobile Peer-to-Peer Computing, Orlando, March 2004.
- Technical Program Committee of Third International Conference on Information Integration and Web-based Applications & Services, Linz, Austria, Aug. 2004.
- Technical Program Committee of International Conference on Data Warehousing and Knowledge Discovery (DaWak-2004), Spain, Sept. 2004.

- Technical Program Committee of International Conference on Mobile Distributed Data Management (MDDM), Spain, Sept. 2004.

(c) *NSF PI meeting*

Member of organizing committee and chair of sessions on Privacy, Trust, and Security in Information Data Management (IDM), Seattle, Sept. 2003 (a research report was produced for NSF).

6. Mentoring of faculty and students (in addition to graduate students you are supervising).

- Paid one month summer salary of Prof. Dongyan Xu. I supported several students working with other faculty.
- I am working with Prof. Xu, Prof. Li, and Prof. Nita-Rotaru and helping them with grants/proposals. I bring information about NSF, DoD opportunities to their attention. I gave them a briefing on the NSF PI meetings. I informed them of the review process in Trusted Computing program. I worked with Prof. Zoltowski and his student Terry Charbonneau. I am working with Prof. De of Krannert and his student Chetan on a Ph.D. proposal on P2P and Dist Database Systems. I helped Prof. Mohit Tawarmalani and Pankaj of Krannert. I am working closely with Steve Cain of Agriculture School.
- I have encouraged many minority students who needed advice or were discouraged in CS courses. I tried to find research money for them and got them to interact with the right faculty. I have arranged for their travel to meet faculty and graduate students in other universities.
- I have spent a large amount of time in mentoring CS students in understanding our curriculum (qualifier exams, requirements) and encouraged them to stay for Ph.D. I am active in recruiting efforts for new graduate students and in getting our current students internships and jobs at places where I have contacts.
- I have tried to develop research relationships with junior faculty by writing proposals and getting them involved in new proposals. Papers were written with Xu, Nita-Rotaru and Li.

7. Provide any additional information you feel is important relative to service.

I am helping several postdocs in building academic career. I believe I am providing leadership to the junior faculty. I nominated several of them to serve in the NSF panels and program committees. I have provided valuable information about funding opportunities and gave them information about the review process at NSF, Darpa, ARL. I have written joint proposals

with them. I am getting faculty involved in other university activities (in particular I invite them and accompany them to meetings with minorities and horizon program). I actively participate in grad committee, faculty meeting and SoS meetings.

## **F. Honors and Awards**

List any honors/awards you received. Provide a brief description if appropriate.

### 1. University

- Inducted in The Book of Great Teachers at Purdue

### 2. Professional

### 3. Other

- IEEE Technical Achievement Awards Committee, 2003
- Proposals for Database program, NSF, 2003.
- Career Awards for Networking program, NSF, 2003.

## **G. Other Information**

### 1. Describe your most significant accomplishments and future goals in teaching, research and service this past year. Refer to above entries, if appropriate.

- See the sections under teaching, research, and service.
- For multimedia courses, projects, and theses, we used software for stegnography, multimedia security protocols, web caching, and mobile agents, and employed commercial products from Nortel, Cisco, Ascend, and Lucent. We updated the mini-raid software that can be used by CS 542 students. Several software tools developed in our laboratory (C.8) and industry are being used by students in their projects. I am now in the process of developing a new course on Pervasive systems.

- In research, I have developed several new ideas for privacy and security in mobile wireless networks, vulnerabilities in database systems and networks, denial of service attacks, QoS monitoring and DiffServ, intruder identification under various models of attacks (including wormhole and gang attacks), fault-tolerant authentication, and detecting service violations in the Internet and mobile ad hoc networks. Trust and Fraud have been formalized. A series of experiments for adaptability for quality of service, P2P multimedia streaming, congestion in mobile ad hoc networks, and privacy and trust tradeoffs have been carried out. My research resulted in several successful new proposals. My work on vulnerability/threat assessment, security and privacy in databases have created new measures, tradeoffs, and practical schemes. Several prototype software are under development for experimental studies.
- Ideas of DiffServe and adaptability have generated funds from SwissNSF and NSF. Adaptability mechanisms are being investigated for dealing with failures, providing different quality of service/privacy/data access to different users, and providing different routing facilities to different packets. This effort is experimental and a lot of software infrastructure is being produced that will help in CS 542, CS 448, CS 348, CS 641, and Pervasive System courses. Applications to quality of healthcare are a special emphasis. Collaborations with Regenstrief Institute at IU Medical School are in progress.
- I participate actively in diversity committee, undergrad research day, grad committee, and help every minority students. I am passionate about helping students in need.
- I am active in recruiting new graduate students. For example, I worked hard to get Sarika Agarwal from UC Berkeley.

My future goals in teaching, research and service for the next year is as follows.

- Graduate two PhD students. Help students and postdocs in getting jobs.
- I am recruiting two more Ph.D. students and would like to work on graduate committee to update the curriculum (CS 348/448, CS 541/542/603). With Walid Aref and networking group, I like to set up a laboratory for Multimedia Systems courses. We have a proposal for equipment infrastructure funding that can help many laboratories (It was proposed for NSF and is in revision for Purdue's internal selection process for Fall 2004.). I worked on a University Research Fellowship from Motorola for Gang Ding and IBM fellowship for Weichao Wang. Plan to offer a seminar in pervasive systems that can lead to a new graduate course.
- In research, I like to collaborate with several systems faculty and develop large proposals for DoD and NSF. Raid laboratory facilities (software, experimental infrastructure, tools) are available to students of other faculty to create a good environment for experimental computer science. The direction of my research efforts in adaptable quality of service,

network measurements, multi-media communication, active networks and security are on my web page [www.cs.purdue.edu/homes/bb](http://www.cs.purdue.edu/homes/bb). With CERIAS, I want to work towards a large grant for the center.

- Write a DARPA grant on reconfigurable software for mobile ad hoc networks to deal with a variety of cyber attacks.
- Work on an ONR proposal on cellular/mobile networks.
- Collaborate and write proposals on networking with Mike Zoltowski in ECE.
- Collaborate with Joe Pekny - Regenstrief proposal.
- I like to bring more IEEE workshops and conferences at Purdue as part of my service activities. My major effort will be in getting industry funding for research and building the momentum for centers in CS dept and the CWSA wireless center.

2. In your opinion, what are the most significant challenges and problems facing the department?

- Improve Ranking.
- Retain and promote minorities.
- Retain CS students for Ph.D. theses. Help students in getting jobs in academia and industry.
- Improve graduate curriculum and improve required courses.
- Get a large interdisciplinary grant with SoS faculty/CERIAS.
- Identify and reward the best faculty and students.
- Retain/recruit the best faculty.
- Recruit interdisciplinary research faculty and students.