Submitted on: 10/05/2009
Principal Investigator: Ramachandran, Umakishore
Organization: GA Tech Res Corp - GIT
Submitted By:
Ramachandran, Umakishore - Principal Investigator
Title:
ITR/SY: A Distributed Programming Infrastructure for Integrating Smart Sensors

### Project Participants

<table>
<thead>
<tr>
<th>Name</th>
<th>Worked for more than 160 Hours</th>
<th>Contribution to Project</th>
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<tbody>
<tr>
<td>Ramachandran, Umakishore</td>
<td>Yes</td>
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<tr>
<td>DeWeerth, Stephen</td>
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<td>Mackenzie, Kenneth</td>
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<td>Starner, Thad</td>
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<td>Hutto, Phil</td>
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<td>Wolenetz, Matt</td>
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<td>Rehg, James</td>
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<td>Abowd, Gregory</td>
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<tr>
<td>Jain, Ramesh</td>
<td>Yes</td>
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**Senior Personnel**

- **Name:** Ramachandran, Umakishore
  - **Contribution to Project:**

- **Name:** DeWeerth, Stephen
  - **Contribution to Project:**

- **Name:** Mackenzie, Kenneth
  - **Contribution to Project:**

- **Name:** Starner, Thad
  - **Contribution to Project:**

- **Name:** Hutto, Phil
  - **Contribution to Project:**

- **Name:** Wolenetz, Matt
  - **Contribution to Project:**

- **Name:** Rehg, James
  - **Contribution to Project:**

- **Name:** Abowd, Gregory
  - **Contribution to Project:**

- **Name:** Jain, Ramesh
  - **Contribution to Project:**
**Contribution to Project:**
Prof. Jain leads the Event Web project that is one of the driving applications for our MediaBroker work. He has considerable expertise in media processing and automated 'event' detection. Professor Jain holds joint appointments in CoC and ECE and holds the Rhesa S. Farmer, Jr. Distinguished Chair in Embedded Experiential Systems within the College of Computing.

**Name:** Yu, HeonChung
**Worked for more than 160 Hours:** No

**Contribution to Project:**
Prof. Yu is on the faculty at Korea University in Seoul, S. Korea. He is on sabbatical for a year starting January 2004 and is spending this time in residence at the College of Computing at Georgia Tech. His research fault-tolerance and resource scheduling in grid systems. He is working with us on our efforts to dynamically support offloading of computationally intensive sensor processing on a computation grid.

**Post-doc**

**Name:** Kumar, Rajnish
**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Rajnish graduated in Fall 2006. I have hired him as a research scientist to work on aspects of the project particularly with respect to deployment of the technologies developed in real application scenarios.

**Name:** Singh, Rahul
**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Dr. Singh is a post-doc working with Ramesh Jain. He has been coordinating the Event Web project from Prof. Jain's side.

**Name:** Nakazawa, Jin
**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Jin joined the project in Fall 2004 and is working to help define and implement the next generation of MediaBroker infrastructure, with a focus on supporting distributed consumer applications in smart homes.

**Graduate Student**

**Name:** Agarwalla, Bikash
**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Bikash is one of the primary developers and maintainers of Stampede and D-Stampede. He is involved in a variety of aspects of the project, including work on leveraging grid resources for compute intensive sensor processing. He spent 9 months working at HP Labs in Palo Alto. His proposal based on his recent Streamline research received 2nd prize in the 2005 IBM North America Grid Scholars Challenge.

**Name:** Huneycutt, Chad
**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Chad works with Josh Fryman on the SoftCache infrastructure for supporting ubiquitous embedded network systems.

**Name:** Fryman, Josh
**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Josh works primarily with researching solutions for ubiquitous embedded network systems that can benefit from network-level cache architectures to reduce resource requirements on client devices.

**Name:** Wilson, Chuck
**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Chuck Wilson has graduated from Georgia Tech with a PhD.

Name: Harel, Nissim
Worked for more than 160 Hours: Yes
Contribution to Project:
During the scope of this project, Nissim has worked with Hasnain Mandviwala to research adaptive rate control mechanisms for streaming applications.

Name: Mandviwala, Hasnain
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Angelov, Yavor
Worked for more than 160 Hours: Yes
Contribution to Project:
Worked on compute-intensive processing, parallelization. Graduated from Masters program and now works at Microsoft.

Name: Hilley, David
Worked for more than 160 Hours: Yes
Contribution to Project:
On-line Television Channel Recommender project. Funding from PURA award from Georgia Tech as ugrad. Is now in the Masters program and continues extensive work on the project, video feature extraction algorithms. Working with Prof. Irfan Essa. He is also working with Bikash Agarwalla and Nova Ahmed on integrating his application-level algorithms with grid infrastructures.

Name: Shin, Junsuk
Worked for more than 160 Hours: Yes
Contribution to Project:
Abstraction migration in Stampede
Funding from this project

Name: Lee, Jeannie
Worked for more than 160 Hours: Yes
Contribution to Project:
Audio-based location system on top of Stampede. Funding from this project. Student graduated with a Masters at the end of Spring 2003.

Name: Jeong, Namgeun
Worked for more than 160 Hours: Yes
Contribution to Project:
Stampede.NET project. Partial funding from this project. Namgeun is soon to complete his PhD and has been working at the Federal Reserve Bank in Atlanta.

Name: Song, Xiang
Worked for more than 160 Hours: Yes
Contribution to Project:
Stampede.NET project. Partial funding from this project. Xiang Song worked with Raj Kumar at HP labs summer 2004. His contributions have led to project growth, attracting undergraduate student involvement.

Name: Sharma, Rajat
Worked for more than 160 Hours: Yes
Contribution to Project:
Stampede.NET project
Partial funding from this project.
Student has graduated with a Masters at end of Spring 2003.

Name: Pack, Derick
Worked for more than 160 Hours: Yes
Contribution to Project:
Derick just completed his Master's thesis on an architecture for Event Web. He has done a large amount of implementation and integration of the current system.

Name: Liu, Bin
Worked for more than 160 Hours: Yes
Contribution to Project:
Bin is a PhD student working with Prof. Jain's group. He is exploring streaming database issues such as synchronization and query optimization. Working with James Kim and Matt Wolenetz, Bin assisted in the study of using MediaBroker to support EventWeb queries that has resulted in a journal publication.

Name: Ahmed, Nova
Worked for more than 160 Hours: Yes
Contribution to Project:
She is the student managing the group working on the middleware system. She worked on developing the key ideas of the system such as virtual readers, virtual paths and a simulation based study prior to the actual system implementation using C and MPI based communication among system components. Later she worked on the load management ideas to enhance the system and evaluated the real experimental testbed using RFID readers and tags.

Name: Edwards, Ken
Worked for more than 160 Hours: Yes
Contribution to Project:
Ken worked with us as an undergraduate on the TvWatcher project and is in the Master's program in the College of Computing at Georgia Tech. He has worked on resource monitoring and the information subsystem of the grid infrastructure in service of our grid scheduling research.

Name: Wei, JinPing
Worked for more than 160 Hours: Yes
Contribution to Project:
JinPing completed a 'mini-project' related the DFUSE work and was supervised by PhD students Rajnish Kumar and Matthew Wolenetz. This project was the primary outcome of special 'research orientation' course required of all incoming PhD students in the College of Computing at Georgia Tech.

Name: Urazov, Vladimir
Worked for more than 160 Hours: Yes
Contribution to Project:
He worked on a java based implementation of the middleware system. It includes the major system components called virtual readers and their communication mechanism using virtual paths. He also contributed in the project in the simulation based evaluation of the system.

Name: Lillethun, David
Worked for more than 160 Hours: Yes
Contribution to Project:
Dave joined the project in Fall 2004 and has made good progress with the MediaBroker infrastructure to support the EventWeb continuous query application. Working with Bin Liu and Matt Wolenetz, he has successfully demonstrated the working combination and good performance of EventWeb and MediaBroker, resulting in a journal publication. He is currently working with the group to design and develop the next generation of MediaBroker infrastructure.

Name: Paul, Arnab
Worked for more than 160 Hours: Yes
Contribution to Project:
Arnab has worked closely with the project along with Rajnish Kumar to generate published research in the area of efficient code dissemination (FBcast) and remote authentication (LAWN). Arnab recently received his doctorate and is now pursuing a post-doc at Dartmouth.

Name: Mohapatra, Dushmanta
Worked for more than 160 Hours: Yes

Contribution to Project:
Assisted senior graduate student and research scientist to gather performance data for camera sensor network.

Name: Muthu, Chidambaran
Worked for more than 160 Hours: Yes

Contribution to Project:
Worked on service composition algorithm.

Name: Richardson, Jahmeilah
Worked for more than 160 Hours: Yes

Contribution to Project:
She worked on the project as an SAIC scholars program offered by COC. She was from an HCI background and thus contributed to the project by doing usability survey of our system as well as several other RFID based systems that are mentioned in commercial websites.

Name: Ryu, MungYung
Worked for more than 160 Hours: Yes

Contribution to Project:
machine learning techniques for anomaly detection

Name: Yusuf, Lateef
Worked for more than 160 Hours: Yes

Contribution to Project:
Opportunistic networking

Name: Kim, Hyojun
Worked for more than 160 Hours: No

Contribution to Project:
Virtualization techniques for mobile devices

Name: Kumar, Jatin
Worked for more than 160 Hours: No

Contribution to Project:
Virtualization techniques for mobile devices, MS project

Name: Shim, Sang Min
Worked for more than 160 Hours: No

Contribution to Project:
Face detection algorithm implementation as an MS student

Name: Choi, Taeil
Worked for more than 160 Hours: No

Contribution to Project:
Network simulation assistance in the ASAP project

Undergraduate Student
Name: Talat, Zaib
Worked for more than 160 Hours: Yes
Zaib Talat has graduated from the program with a BS in Spring 2003.

**Name:** King, Joseph

**Worked for more than 160 Hours:** No

**Contribution to Project:**

**Name:** Post, Ansley

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Ansley has graduated and is now going to Grad School at Rice University.

**Name:** Bagrak, Ilya

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Media broker project.
Funding from PURA award from Georgia Tech.
Ilya won CoC Outstanding Undergraduate Research Assistant and was awarded Honorable Mention in the CRA nomination.
He now attends graduate school at Berkeley.

**Name:** Modahl, Martin

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Media Broker Project
Funding from PURA award from Georgia Tech as a ugrad.
Has completed Masters program.
During his Masters, he worked on Event Web with federated Mediabroker as base. Since graduation, he has pursued embedded systems application development in industry.

**Name:** El-Helw, Ahmed

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
On-line Television Channel Recommender project.
Funding from PURA award from Georgia Tech.
Ahmed implemented the text correlation engine, web browser pop-ups, and web service interfaces. He has entered the Masters program and continues work on the project.

**Name:** Graciano, Ryan

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Ryan was part of a group of students developing Java-based Sensor Lab infrastructure during the summer of 2004. He received one hour of research credit and developed a Mediator and GUI for control of PTZ cameras.

**Name:** Kim, James

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
James was part of a group of students developing Java-based Sensor Lab infrastructure during the summer of 2004. He developed a Mediator for the ER1 mobile robot. In addition, James continued implementation of the MediaBroker Federation architecture begun by Martin Modahl for his Senior Design project in Fall 2004. He was heavily involved in developing a component necessary to wrap the MedaBroker API to make it usable by the EventWeb application. This work has resulted in a journal publication.

**Name:** Thomas, Robert

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
Robert was part of a group of students developing Java-based Sensor Lab infrastructure during the summer of 2004 and will
continue into the Fall of 2004. Robert developed a Mediator for the Versus Tech RF/IR badge tracking system deployed within the College. In addition, Robert developed a Mediator for scrolling marquee signs and developed the Registry used for device discovery and for download of Mediator proxies (bytecodes).

Name: Whitehurst, Jason

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Jason Whitehurst is working with Phillip Hutto and Xiang Song on the Stampede.NET project.

Name: Courtoy, James

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
JD Courtoy is working with Phillip Hutto and Xiang Song on the Stampede.NET project.

Name: Adkisson, Kevin

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Member of our Systems Summer Hackfest 2005 group. He is working on developing a Stampede.NET demo.

Name: Horrigan, Seth

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Member of our Systems Summer Hackfest 2005 group. He is working on the cyberforaging project (offloading computations from wireless to nearby wired surrogates).

Name: Mentonelli, Paolo

**Worked for more than 160 Hours:** Yes

**Contribution to Project:**
System support for RFID; worked for course credit.

Name: Pattillo, Ricky

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Member of our Systems Summer Hackfest 2005 group. He is working on the cyberforaging project (offloading computations from wireless to nearby wired surrogates).

Name: Phillips, Bill

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Member of our Systems Summer Hackfest 2005 group. He is working on the uMiddle project (pervasive computing interoperability framework), focusing on a UPnP Media Renderer for streaming a/v content.

Name: Rivard, Nate

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Member of our Systems Summer Hackfest 2005 group. He is working closely with Jin Nakazawa, Bin Liu and Eric Sample on the next generation of MediaBroker (MB++). He is currently focusing on integrating Rendezvous/Bonjour capabilities into MB for advanced naming and lookup.

Name: Sample, Eric

**Worked for more than 160 Hours:** No

**Contribution to Project:**
Member of our Systems Summer Hackfest 2005 group. He is working us on the next generation of MediaBroker (MB++).
Implement the database backend for MediaBroker++. Worked for course credit.

Name: Heim, Gabriel
Worked for more than 160 Hours: Yes
Contribution to Project:
Hierarchical Wireless Sensor Networks; worked for course credit.

Name: Reiss, Charles
Worked for more than 160 Hours: Yes
Contribution to Project:
Hierarchical Wireless Sensor Networks; supported by NSF REU supplement.

Name: Lotfi, Puyan
Worked for more than 160 Hours: Yes
Contribution to Project:
Hierarchical Wireless Sensor Networks; worked for course credit.

Name: Gilliland, Scott
Worked for more than 160 Hours: Yes
Contribution to Project:
Hierarchical Wireless Sensor Networks; worked for course credit.

Name: Ukah, Echezona
Worked for more than 160 Hours: Yes
Contribution to Project:
System support for RFID; supported by REU supplement.

Name: Worsham, David
Worked for more than 160 Hours: No
Contribution to Project:
System support for RFID; supported by REU supplement.

Name: Young, Sam
Worked for more than 160 Hours: Yes
Contribution to Project:
Sam worked on MobiGO which is a system for supporting seamless mobility in a ubiquitous computing environment.

Name: Slaughter, Michael
Worked for more than 160 Hours: Yes
Contribution to Project:
He worked on the project as an SAIC scholars program offered by COC. He is a first year undergraduate student and was new to research based work. He contributed to the project first by getting an idea of what is going on the system and then developing a simple graphical representation of the deployed graph in the system. He presented in the Undergraduate Research Symposium, 2007 on behalf of our group.

Name: McCauley, Michael
Worked for more than 160 Hours: No
Contribution to Project:
summer hackfest implementing camera sensor network code

Name: Woo, Joseph
Worked for more than 160 Hours: No
Contribution to Project:
summer hackfest implementing camera sensor network code

Name: Parker, Robert
Worked for more than 160 Hours: No
Contribution to Project: summer hackfest implementing camera sensor network code
Name: McCawley, Matthew
Worked for more than 160 Hours: Yes
Contribution to Project: NSF REU support; scalable multiparty video conferencing system
Name: Stebar II, Brian
Worked for more than 160 Hours: Yes
Contribution to Project: NSF REU support; scalable multiparty video conferencing system
Name: Whitehead, Brandon
Worked for more than 160 Hours: Yes
Contribution to Project: NSF REU support; Scalable stream fusion
Name: DeRosa, Michael
Worked for more than 160 Hours: Yes
Contribution to Project: NSF REU support; Scalable stream fusion
Name: Rowsell, Brent
Worked for more than 160 Hours: Yes
Contribution to Project: NSF REU support; Active RFID system benchmarking
Name: Butler, Stewart
Worked for more than 160 Hours: Yes
Contribution to Project: NSF REU support; GuardianAngel middleware for unobtrusive monitoring using passive RFID

Technician, Programmer
Name: Brennan, Sean
Worked for more than 160 Hours: Yes
Contribution to Project: Sean is a staff member of the campus computing group (OIT) at Georgia Tech. He has been assigned part-time to work on a prototype of the Event Web system featuring campus seminars and other events at Georgia Tech. He has done extensive work provisioning and setting up specialized facilities on campus to accommodate the Event Web system.

Other Participant
Name: Essa, Irfan
Worked for more than 160 Hours: Yes
Contribution to Project: He is a Co-PI on the award
Name: Yip, Man
Worked for more than 160 Hours: No
Contribution to Project: implemented active RFID system with robots for navigation

Research Experience for Undergraduates
Name: Crowell, Zachary
Worked for more than 160 Hours: Yes
Contribution to Project:
Zach worked on the Event Web project for a semester and the TVWatcher project for another semester. He has graduated and is working at Microsoft.

Years of schooling completed: Other
Home Institution: Same as Research Site
Home Institution if Other: 
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2004 2003
REU Funding: REU supplement

Name: Caudill, Harrison
Worked for more than 160 Hours: Yes
Contribution to Project:
Harrison worked for two semesters with other undergraduates developing a prototype sensor-based, pervasive computing application - the Future Library which involved tracking of library resources and associated interfaces for interacting with the system.

Years of schooling completed: Junior
Home Institution: Same as Research Site
Home Institution if Other: 
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2003
REU Funding: REU supplement

Name: McCorkle, Eric
Worked for more than 160 Hours: Yes
Contribution to Project:
Eric worked for two semesters with other undergraduates developing a prototype sensor-based, pervasive computing application - the Future Library which involved tracking of library resources and associated interfaces for interacting with the system.

Years of schooling completed: Junior
Home Institution: Same as Research Site
Home Institution if Other: 
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2004
REU Funding: REU supplement

Name: Chen, Simon
Worked for more than 160 Hours: Yes
Contribution to Project:
Simon was part of a group of students developing Java-based Sensor Lab infrastructure during the summer of 2004. Simon worked on a Mediator for the Berkeley Motes and the XML command channel.

Years of schooling completed: Sophomore
Home Institution: Same as Research Site
Home Institution if Other: 
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2004
REU Funding: REU supplement

Name: Shanks, Thomas
Worked for more than 160 Hours: Yes
Contribution to Project:
Thomas was part of a group of students developing Java-based Sensor Lab infrastructure during the summer of 2004. Thomas implemented a Mediator for interfacing with tv-tuner video capture cards. This involved extending the source code for the Java Media Framework from Sun.

- **Years of schooling completed:** Sophomore
- **Home Institution:** Same as Research Site
- **Home Institution Highest Degree Granted (in fields supported by NSF):** Doctoral Degree
- **Fiscal year(s) REU Participant supported:** 2004
- **REU Funding:** REU supplement

Name: Sheridan, Rex

**Worked for more than 160 Hours:** Yes

Contribution to Project:
Rex was part of a group of students developing Java-based Sensor Lab infrastructure during the summer of 2004. He developed Mediators for wireless temperature sensors and developed a gui-based control panel demo application in Java using the SWT widget set and the Java Media Framework. Rex coordinated integration.

- **Years of schooling completed:** Junior
- **Home Institution:** Same as Research Site
- **Home Institution Highest Degree Granted (in fields supported by NSF):** Doctoral Degree
- **Fiscal year(s) REU Participant supported:** 2004
- **REU Funding:** REU supplement

Name: Boyer, Garrett

**Worked for more than 160 Hours:** Yes

Contribution to Project:
Garrett worked on some hardware issues and received a PURA Award in Spring 2004.

- **Years of schooling completed:** Junior
- **Home Institution:** Same as Research Site
- **Home Institution Highest Degree Granted (in fields supported by NSF):** Doctoral Degree
- **Fiscal year(s) REU Participant supported:** 2004
- **REU Funding:** REU supplement

Name: Snyder, Luke

**Worked for more than 160 Hours:** Yes

Contribution to Project:
Luke worked on hardware issues and received Third Place in the Undergraduate Research Symposium in Spring 2004.

- **Years of schooling completed:** Sophomore
- **Home Institution:** Same as Research Site
- **Home Institution Highest Degree Granted (in fields supported by NSF):** Doctoral Degree
- **Fiscal year(s) REU Participant supported:** 2004
- **REU Funding:** REU supplement

Name: Caban, Jose

**Worked for more than 160 Hours:** Yes

Contribution to Project:
Jose has worked with initial reimplementation and debugging of the Family Intercom application that helps drive the development of MediaBroker infrastructure. He discovered, with Vladimir Urazov and Matt Wolenetz, several issues specific to the Family Intercom application that have previously prevented good performance.
Years of schooling completed: Junior
Home Institution: Same as Research Site
Home Institution if Other: 
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2005
REU Funding: REU supplement
Name: Dalton, Steven
Worked for more than 160 Hours: Yes
Contribution to Project:
Steve worked on wireless sensor network project. His contribution was in the realm of using cameras with embedded processors.

Years of schooling completed: Junior
Home Institution: Same as Research Site
Home Institution if Other: 
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2007
REU Funding: No Info
Name: French, Robert
Worked for more than 160 Hours: Yes
Contribution to Project:
He worked on developing a java based emulation framework. It can deploy number of emulated RFID readers given a graph based layout of the deployment of the readers and provide the system with several tunable parameters that show similar behavior as real RFID readers. The major parameters are: number of readers, reader accuracy level, number of tags per time unit etc.

Years of schooling completed: Other
Home Institution: Same as Research Site
Home Institution if Other: 
Home Institution Highest Degree Granted(in fields supported by NSF): Doctoral Degree
Fiscal year(s) REU Participant supported: 2007
REU Funding: REU supplement

Organizational Partners

HEWLETT PACKARD
1) Stampede was developed jointly with DEC, which was bought by Compaq, and now merged with HP
2) Kath Knobe of HP Cambridge Research Lab is an active partner on the project
3) Ramachandran (PI) has had consultative arrangement with the Cambridge Research Lab
4) Grad students working with Ramachandran have done summer internships at HP Cambridge Research Lab, and HP Labs in Palo Alto, CA

Microsoft Corporation
Funding for Stampede.NET project.

Intel Corporation
Dr. Kath Knobe, Cambridge Research Lab and Santa Clara

Reservoir Labs., Inc.
Dr. Ken Mackenzie works with us on the project; provide rstream software
Samsung Electronics Corporation
Supported a device virtualization project under STAR center between Georgia Tech and Samsung Electronics Corp.

Other Collaborators or Contacts
Kath Knobe, Intel
Raj Kumar, HP Palo Alto Research
Ken Mackenzie, Reservoir Labs
Sang-bum Suh, Samsung
Ilpyung Park, Samsung
Junghyun Yoo, Samsung

Activities and Findings
Research and Education Activities:
See attached PDF file (Section Activities and Findings)

Findings:
See attached PDF file (Section Activities and Findings)

Training and Development:
See Attached PDF file (subsection Training and Development)

Outreach Activities:
See attached PDF file (subsection entitled Outreach)

Journal Publications
Books or Other One-time Publications

Web/Internet Site
URL(s):
http://www.cc.gatech.edu/~rama/ubiq-presence/
Description:
Research artifacts
Pointers to pubs

Other Specific Products
Contributions
Contributions within Discipline:
See attached PDF file (Section Contributions)

Contributions to Other Disciplines:

Contributions to Human Resource Development:
See attached PDF file (Section Contributions)

**Contributions to Resources for Research and Education:**

See attached PDF file (Section Contributions)

**Contributions Beyond Science and Engineering:**

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**Conference Proceedings**

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**Categories for which nothing is reported:**

Any Journal
Any Book
Any Product
Contributions: To Any Other Disciplines
Contributions: To Any Beyond Science and Engineering
Any Conference
As we observed at the time of filing the annual report in August 2008, that was really a final report on the project. The only unexpended funds at that time was the remaining in the category of REU for which NSF had given a one-year extension. Therefore, we present the work done with the undergraduates in the following section and then reproduce the contents of the annual report from August 2008 for the sake of completeness of this final report.

Work done with Undergraduates in 2008-09

ASAP System

This is a mature project that provides a middleware framework for situation awareness applications incorporating high bandwidth sensors such as cameras and low bandwidth sensors such as RFID. There is more description of this work in the body of the annual report, which follows this section. Several undergraduates were employed on this project during this NCE year and benefited tremendously from the exposure. It is worth noting that two of the students (Matthew McCawley and Brian Stebar II) who worked collaboratively on this project received The 2009 College of Computing Outstanding Undergraduate Research Award for their work in developing a scalable multi-party video conferencing system while receiving the REU funding from this research project. A third student (Steve Dalton) completed an undergraduate thesis on a research topic related to this NSF funded project. Steve was also the recipient of The 2007 College of Computing Outstanding Undergraduate Research Award for the research he did on this project.

   Work Description: Distributed Feature Extraction Using Cloud Computing Resources: The goal of this project was to construct a cloud processing system that will be integrated into the distributed camera surveillance network (ASAP). The ASAP system uses a heterogeneous wireless sensor network
to collect and prioritize multiple video data streams. ASAP performs the stream processing using only the in-network computational resources. This limitation on the availability of computational resources has restricted the number of interesting applications that can be implemented. By using cloud resources to move computations out-of-network the project aimed to facilitate the construction of more computationally complex applications in the ASAP system.

Currently, Steve is a PhD student at UIUC.

Learning Outcome: Cloud computing framework, ASAP, distributed systems integration

Research Outcomes:
(a) UG thesis: Distributed Feature Extraction Using Cloud Computing Resources, May 2009
(b) The 2007 College of Computing Outstanding UG Research Award
(c) Code and documentation to be used in ongoing research


Work Description: Scalable video conferencing: The goal of this project was to build an efficient stream server for multi party video conferencing. The project explored at designing prioritization and parallelization strategies for efficient bandwidth and computation management on the stream server. One example of bandwidth optimization is to control video quality based of participants based on their social network structure. Matthew looked at the web-based interface to the above system.

Learning Outcome: Actionscript and Flex programming framework, Web architecture, Distributed systems integration

Research Outcomes:
(a) The 2009 College of Computing Outstanding UG Research Award
(b) Judges’ First Place Award at 2009 College of Computing Undergraduates Research Opportunities in Computing (UROC) contest for their entry entitled “Scalable Multiparty Video Conferencing.”


Work Description: Scalable video conferencing: The goal of this project was to build an efficient stream server for multi party video conferencing. The project explored at designing prioritization and parallelization strategies for efficient bandwidth and computation management on the stream server. One example of bandwidth optimization is to control video quality based of participants based on their social network structure. Brian looked at supporting multiple simultaneous room capability in the system.

Learning Outcome: Actionscript and Flex programming framework, Flash media server, Web architecture, Distributed systems integration

Research Outcomes:
(a) The 2009 College of Computing Outstanding UG Research Award
(b) Judges’ First Place Award at 2009 College of Computing Undergraduates Research Opportunities in Computing (UROC) contest for their entry entitled “Scalable Multiparty Video Conferencing.”


Work Description: Scalable stream fusion: The goal of this project is to build a system for dynamic switching and stitching of multiple camera streams connected to a desktop.

Learning Outcome: Microsoft Directshow architecture and programming, Multimedia encoding and decoding process, Red5 open source flash media server architecture.


Work Description: Scalable stream fusion: The goal of this project is to build a system for dynamic switching and stitching of multiple camera streams connected to a desktop. Michael was responsible for exploring Xuggle system for its stream management capability and how it can be used for our project purpose.

Learning Outcome: Microsoft Directshow architecture and programming, Multimedia encoding and decoding process, Xuggle and Red5 system integration.

RFID Middleware

More details on this sub-project is also in the body of the annual report that follows this section. Several undergraduates have worked on this sub-project through the life of the NSF award. The following list
includes the 2 students who worked on the RFID middleware in 2008-09 during the NCE period of this award.

1. **Brent Rowswell (January 2008 to December 2008):**
   Work Description: The student has done extensive evaluation of the active RFID system performance in an indoor environment. He has designed and evaluated set of experiments that considers an indoor environment using active RFID technology. He has also developed some theoretical searching procedures to aid the mobility in an active RFID enabled environment.
   Learning Outcome: The student learned and contributed to programming active RFID system and conducting early experiments in the use of this technology for object localization in an indoor environment.

2. **Stewart Butler (May 2009 to present):**
   Work Description: The student worked on developing a prototype environment that mimics an assisted living center using passive RFID tags and readers. He specifically developed a python based prototype to evaluate a small scale performance of the system. He also helped in evaluation and writing of a scholarly paper on the system named GuardianAngel.
   Learning Outcome: The student learned how to design a localization system for an indoor environment using passive RFID, as well as how to calibrate the system for unobtrusive monitoring of objects in such an environment.
   Research Outcome: The student also participated as a co-author in the writing of a paper [6] to a prestigious conference venue (IEEE Percom 2010).

**Annual Report from August 2008 reproduced below**

The research undertaken in this proposal is integrating sensing hardware, embedded processing and distributed system support to build a seamless programming infrastructure for ubiquitous presence applications. Fundamental invention and integration of techniques spanning programming idioms and runtime systems for distributed sensors, and building blocks for embedded processing are expected as the primary intellectual contributions of the proposed research. Interfacing these technologies to emerging applications on the one end and novel off-the-shelf sensors at the other end are secondary goals of the proposed research.

We have made the following contributions through this research:

- definition of an elaborate system architecture for prototyping sensor-based distributed applications covering distributed programming paradigm and data fusion
- issues that pertain wireless sensor networks including protocol stack, security issues, and code dissemination
- use of the technologies to construct prototype of complex cyber physical application for situation awareness

**1 Activities and Findings (This Past Year 2007-08)**

First we summarize the research accomplishments this past year followed by those in the previous years in Chronological order.

**1.1 Research and Education**

**1.1.1 Systems Technologies to support Sensor Based Distributed Computing**

1. **e-SAFE: An Extensible, Secure and Fault Tolerant Storage System.** In an ubiquitous setting it is important to ensure the integrity of remote access to information from mobile devices. This research resulted in using erasure codes to simultaneously assure the security of remote access to file systems as well as the fault tolerance when the requested data can be reconstructed even when there is partial communication in remote communication. The work [3] is part of the dissertation of Dr. Arnab Paul [38] who was supported by this award and appeared in the First IEEE International Conference on Self-Adaptive and Self-Organizing Systems, Boston, Mass., USA, July 9-11, 2007.
2. **StampedeRT**: Programming Abstractions for Live Streaming Applications. Stampede is a programming system for distributed computing that is at the heart of this research. The principles behind this programming system is part of the dissertation of Dr. Sameer Adhikari [2], a student supported on this award. StampedeRT represents a new twist on this programming model to support live streaming applications. It was presented at the 27th International Conference on Distributed Computing Systems (ICDCS), 2007, and represents a part of the dissertation work of David Hilley, a student working on this project but supported by an IBM Fellowship.

3. **On Improving the Reliability of Packet Delivery in Dense Wireless Sensor Networks.** Reliable communication is essential in distributed sensing and this research work investigates techniques for improving the reliability for packet delivery and appeared in 16th International Conference on Computer Communications and Networks (ICCCN 2007), August 2007 [53]. It also represents a part of the dissertation work of Junsuk Shin, a student supported by this award.

4. **Memory Optimizations for Distributed Streaming Applications.** Sophisticated sensors such as cameras generate significant amounts of data. It is important to ensure that the resources are managed to contain the amount of memory resources used in streaming applications involving such high bandwidth sensors. This research uses the information in the application task graph to reduce the resource requirements in streaming applications [19, 18]. It is part of the dissertation work of Dr. Nissim Harel [17] who was supported by this award.

5. **MobiGo and Chameleon: Supporting Seamless Mobility.** Supporting user mobility seamlessly is important. This research devised techniques for application level (MobiGo) [58] and system level (Chameleon) [60] seamless mobility of a user in a distributed setting. This research represents part of the dissertation work of Dr. Xiang Song [55] who was supported by this award.

6. **Streamline: Scheduling Streaming Applications in a Wide Area Environment.** One of the premises for the project as a whole is that ambient computing infrastructure is ever available to support distributed sensing applications. This work [5] discusses a heuristic for efficiently scheduling streaming applications on a computational grid, and represents a part of the dissertation work of Bikash Agarwalla.

7. **ASAP: A Camera Sensor Network for Situation Awareness.** As a canonical example of sensor based distributed computing, we have built a camera sensor network for video based surveillance. The mockup uses typical security threats that may occur in an airport setting. This work was presented in the 11th International Conference On Principles Of Distributed Systems (OPODIS’07), Guadeloupe, French West Indies, December 17-20th, 2007. It also represents a part of the dissertation work of Junsuk Shin, a student supported by this award.


### 1.2 Training and Development

Needless to say, graduate students pursuing their doctorate are the primary focus of training and development. Please see Section 3.1 for a complete list of students at all levels who are alumni of this project.

Graduate students associated with the project have been benefiting from internships in leading research labs. In the spring of 2008, Dave Lillethun interned at Microsoft Research in Cambridge, England. In the summer of 2008, David Hilley was interning at IBM Almaden, Mung Yung Ryu was interning at Motorola Labs, and Lateef Yusuf was interning at QualComm. Dushmanta Mohapatra spent 2 semesters as an intern at AMI Corp., and Junsuk Shin is currently (in Fall 2008) interning at Microsoft Research, Redmond, Washington.

We continue to attract bright and interested graduates and undergraduates to research projects in our group. Undergraduate participation in research within the College is facilitated by the excellent UROC program ([www.cc.gatech.edu/program/uroc](http://www.cc.gatech.edu/program/uroc)), coordinated by Professor Amy Bruckman. A variety of institute-wide programs are also available ([www.undergraduateresearch.gatech.edu](http://www.undergraduateresearch.gatech.edu)) including a special fund sponsored by the president of Georgia Tech (PURA) and several NSF-sponsored projects. Since we associate these UGs to work with graduate students, it serves as a valuable tool for training our
graduate students in serving as mentors and student advisors. In this past year, we have entertained a number of UG students as researchers in our lab. They include:

- Michael S. Slaughter (worked with Nova Ahmed on RF$^2$ ID project in Fall 2007 and Spring 2008).
- Man Fung Yip (an exchange from Hongkong who worked with Nova Ahmed on RF$^2$ ID project in Spring 2008).
- Matthew Wesley McCauley, Joseph Woo, and Robert Parker (worked with Junsuk Shin on ASAP project in Summer 2008).

1.3 Outreach

Professor Ramachandran has concluded negotiations with Samsung Electronics Corporation to establish a joint-center at Georgia Tech for carrying out collaborative research of mutual interest to Samsung and Georgia Tech. Under this agreement, Samsung will fund a number of research projects that had their roots in the ITR award. One such project is MobiGo that supports seamless mobility in a ubiquitous setting. A second one (to be carried out by PI Professor Irfan Essa) involves Non Photo-realistic Rendering. The joint-center will have engineers from Samsung visiting on a year-round basis and working closely with the faculty and students in the College of Computing. So far, the agreement has resulted in funding 5 research projects at Georgia Tech. Please visit http://www.star.cc.gatech.edu.

We are in communication with the City of Baton Rouge and their department of Homeland Security. They are interested in serving as a beta-site for the camera sensor network technology we have developed for video-based surveillance.

We have similar ongoing dialogue with the IT department of the Hartsfield-Jackson International Airport in Atlanta to deploy our camera sensor network.

1.3.1 Research Commercialization

Georgia Tech has active interest in research commercialization. Venture lab is an entity that identifies research work in Georgia Tech that are worthy of consideration for commercialization. The SensorStack dissertation work performed by one of the students (Rajnish Kumar) funded by this ITR award has been chosen for research commercialization. We have developed an architecture for priority aware situation awareness with the SensorStack at its core. Potential application of this technology includes airport surveillance and critical infrastructure protection. Rajnish Kumar, research scientist, has been hired expressly to oversee the development of these technologies for application in such scenarios.

1.4 Activities and Findings in previous Years

The research in previous years have resulted in the generation of a number of technologies for distributed sensing. Here are few highlights:

- Distributed Programming idioms including the Stampede [48] and D-Stampede [1] programming systems.
- Middleware for data fusion called DFuse [28, 45], and a sophisticated yellow pages for match-making of sensors and actuators to applications called MediaBroker [34, 47].
- Technologies for making our programming infrastructure available on a variety of platforms including .NET [56].
- Technologies for marrying ambient HPC infrastructure with distributed sensing [4].
- Middleware for increasing the reliability of RFID deployments [7].

We also initiated a number of activities including the formation of a sensor lab that allows undergraduates to come and experiment with sensing technologies, and outreach to industries and potential consumers once this kind of technology matures.

All of these activities are well documented in the annual reports of the previous years. Rather than itemize the activities and findings from previous years, we simply present the web pointers to the previous years

- Web URL for the project: http://www.cc.gatech.edu/ rama/ITR-PROJECT/
2 Publications and Products

2.1 Publications

See the references at the end of this document for publications that appeared in the period that covers this project.

2.2 Web Site

Please visit the project web site at http://www.cc.gatech.edu/rama/ITR-PROJECT/

3 Contributions

The activities we have undertaken in this project have resulted in a significant number of publications and software artifacts. These are listed in the references at the end of this report.

3.1 Human Resource Development and Student Placement

In the course of this project, every year roughly 10 graduate students worked on the project on an average. In addition, we hosted at least half a dozen undergraduates on the project, either as RAs supported by the REU program or for course credit. Students at all levels, who are alumni of this project, are sought after for summer internships by leading industries and get very good placements when they graduate.

As a direct result of this grant, we have graduated the following students who are well placed in industries and/or academia:

1. Zack Kurmas: Graduation Date: 8/2004
   Thesis title: “Generating and Analyzing Synthetic Workloads using Iterative Distillation”
   Position: Assistant Professor, Department of Computer Science & Information Systems, Grand Valley State University, Michigan.

2. Sameer Adhikari: Graduation Date: 12/2004
   Thesis title: “Programming Idioms and Runtime Mechanisms for Distributed Pervasive Computing”
   Position: Intel Corp., Portland

3. Arnab Paul: Graduation Date: 5/2005
   Thesis title: “Application of Error Correcting Codes to Distributed and Pervasive Computing”
   Position: Intel Corp., Portland

4. Josh Fryman: Graduation Date: 8/2005
   Thesis title: “Power management in embedded devices”
   Position: Intel Corp., Santa Clara

5. Matthew Wolenetz: Graduation Date: 8/2005
   Position: Microsoft Corp.
6. Nissim Harel: Graduation Date: 12/2006
   Thesis title: “Memory Optimizations for Distributed Stream-based Applications”
   Position: Jambool - Startup

7. Hasnain Mandviwala: Graduation Date: 12/2008
   Thesis title: Capsules: Expressing Composable Computations in a Parallel Programming Model
   Position: Software Engineer Ask.com

8. Rajnish Kumar: Graduation Date: 12/2006
   Position: Research Scientist II, Georgia Tech

9. Xiang Song: Graduation Date: 08/2008
   Thesis title: “Seamless Mobility in Ubiquitous Computing Environments”
   Position: Microsoft Corp.

There are several more students at advanced stages of their dissertation research who have been funded by this award including, and expected to finish in the next 9-12 months:

1. Bikash Agarwalla
2. Nova Ahmed
3. David Hilley

Alumni of this project at MS and BS level include:

1. Kirill Mechitov, BS 2001, Grad Student UIUC
2. Durga Devi Mannaru, MS 2001, IBM Research Triangle Park, NC.
3. Ansley Post, BS 2002, Grad Student Rice U.
4. Rajat Sharma, MS 2003, Verizon Wireless
5. Zaib Talat, BS 2003
6. Ilya Bagrak, BS 2004, Grad Student UC-Berkeley
7. Martin Modahl, MS 2004
8. Sam Young, BS 2007, Amazon
9. Steven French, BS 2007, Microsoft
10. Vladimir Urazov, MS December 2007, Citadel Investment Group

During the course of the award, we also entertained one post-doctoral visitor (Dr. Jin Nakazawa, Keio University, Japan, Oct 2004–October 2005; and one sabbatical visitor Professor HeonChang Yu, Associate Professor, Korea University, Seoul, S. Korea, Jan 2004–Jan 2005.

3.2 Software
Students working Dr. Ramachandran’s group, developed a toolchain for Federal Reserve Bank, Atlanta, that allows scheduling applications on a cluster. The tool chain is built using the Stampede programming system, which was developed in this project. This tool-chain called EcoSys [49] is used by the economists at Federal Reserve Bank, who are domain experts in their area for utilizing cluster computing resources.

3.3 Impacting Education
The research artifacts from the project have found their way into graduate courses and we have had significant undergraduate participation in project-related research. We have funded a number of undergraduates through the REU supplement attached to this ITR grant, sponsored a number of independent undergraduate research projects for course credit (CS 4903), and have sponsored capstone senior design projects (CS 3901) that each result in a poster presentation at the annual Undergraduate Research Symposium.

The ITR project has reinforced the connectedness of hardware and software and the need to train students in system architecture quite early in their undergraduate preparation. With this in mind, Professor Ramachandran embarked on writing a set of course notes [46] for use in the sophomore level course on systems and networks. The course notes were well received by the students. In Spring 2006, he has signed a contract with Addison-Wesley to have the book published as a textbook. A custom edition is already in use at Georgia Tech [46], and a regular edition is expected in Spring 2009. A paper describing the pedagogical approach
underlying this textbook is appeared in WCAE 2007 [50].

4 Special Requirements

We have received permission from the Program Director (Dr. Helen Gill) for expending the remaining REU funds in the project by August 2009.

References


