Cooperative Embedded Computing: Projects and Collaborations

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# **Embedded computers go outdoors**



Distributed object tracking over a large geographical area



Cars collaboration for a safer and more fluent traffic



# **Outdoors is different**

- Physical space defines execution context
- Volatile configurations
- Mobile ad-hoc networking
- Non-intrusive human-computer interfaces





#### **Quality of Result**



# **Outdoor Distributed Computing**

- Recent research in networked embedded systems
  - Hardware
  - Compilers
  - Software Engineering
  - Network Protocols
- Our focus
  - Programmability: How to program and execute distributed applications over networks of embedded systems?
  - Remote Healing: How to perform automatic system monitoring, diagnose, repairing remotely?

# **Our Research**

- NSF ITR grant ANI-0121416, 2001-2006
  - Faculty: Liviu Iftode(PI), Uli Kremer, Michael Hsiao
  - 10 graduate students: DisCo Lab, EEL
  - undergraduate students
  - visitors
- Contributions
  - Smart Messages
  - Spatial Programming
  - Spatial Views
  - Backdoors for Remote Healing
- Applications & Collaborations in Pervasive Computing
  - Vehicular Computing (IEEE PvC Special Issue, Oct 2006)
  - Smart Phones (IEEE PvC Special Issue, April 2005)



## **Spatial Programming at a Glance**



- Physical space mapped into a virtual address space to hide communication
- Outdoor distributed applications are programmed using spatial references
- Embedded systems named by their expected locations and properties
- Spatial programs migrate to access spatial references using Smart Messages

### **TrafficView Project**



Drivers can continuously monitor traffic in front of their cars farther than they can see



# Book taxis in dense urban areas using car-to-car communication





# Smart Phones as Universal Personal Servers



# Smart phones discover, load and execute various location-aware services





#### **IEEE Internet Computing, March-April 2005**



#### Recovering Internet Service Sessions from Operating System Failures

Current Internet service architectures lack support for salvaging stateful client sessions when the underlying operating system fails due to hangs, crashes, deadlocks, or panics. The Backdoors (BD) system is designed to detect such failures and recover service sessions in clusters of Internet servers by extracting lightweight state associated with client service sessions from server memory. The BD architecture combines hardware and software mechanisms to enable accurate monitoring and remote healing actions, even in the presence of failures that render a system unavailable.

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Liviu Iftode Rutgers University Critical Internet services such as ecommerce, online auctions, and banking run on complex, multi-tier architectures built with commodity (offthe-shelf) machines and operating systems. These stateful services are sensitive to server failures: active client sessions on these servers are lost, although the state associated with them might still be intact in a failed machine's memory.

We developed a recovery approach that exploits hardware and software redundancy in Internet service installations to reuse active clients' session state after OS failures (http://discolab. rutgers.edu/bda). Our lightweight, application-independent system provides both failure detection and recovery, for use with complex, multi-tier Internet services. The core of the system is the novel Backdoors (BD) architecture,<sup>1</sup> which uses commodity programmable network interface cards (NICs) with specialized firmware and OS extensions to provide remote access to lightweight application and OS state in a machine's memory without relying on its OS or processors. Using BD, machines in an Internet server cluster can cooperatively observe each other's health, detect failures, and take over client sessions from failed nodes.

In this article, we describe the BD architecture and our OS extensions for monitoring and recovery of service sessions. We have implemented a prototype in the FreeBSD 4.8 kernel, using Myrinet Lanai-XP programmable NICs (www.myri.com). The results from our experiments with the Rice University Bidding System (Rubis; http://rubis.objectweb.org), a cluster-based

#### To be presented at VANET-2005



# VITP: An Information Transfer Protocol for Vehicular Computing \*

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### Context-aware Migratory Services in Ad Hoc Networks

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#### **Context-Aware Migratory Service Applications**







# Conclusions



- Our collaboration model with EU partners has been very successful and mutually beneficial
  - Student exchanges (3 month- visits) are essential to bootstrap a collaborative project
  - Technical workshop to bring together the collaborating teams
  - At least two years necessary to complete a significant project
  - Seek additional funding to continue the projects if promising
- Collaborations with Hipeac/UPC, Barcelona and UPMC/LIP6, Paris are under way