

# Preview of Award 0931195 - Final Project Report

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## Cover

Federal Agency and Organization Element to Which Report is Submitted:	4900
Federal Grant or Other Identifying Number Assigned by Agency:	0931195
Project Title:	CPS: Small: Dynamically Managing the Real-time Fabric of a Wireless Sensor-Actuator Network
PD/PI Name:	Michael D Lemmon, Principal Investigator Xiaobo S Hu, Co-Principal Investigator
Recipient Organization:	University of Notre Dame
Project/Grant Period:	09/01/2009 - 08/31/2014
Reporting Period:	09/01/2013 - 08/31/2014
Submitting Official (if other than PD\PI):	N/A
Submission Date:	N/A
Signature of Submitting Official (signature shall be submitted in accordance with agency specific instructions)	N/A

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## Accomplishments

### \* What are the major goals of the project?

Wireless sensor-actuator networks (WSAN) consist of numerous sensing and actuation devices that share information over an ad hoc wireless communication network. Examples of such systems include the national power grid, ground/air traffic networks, and water/gas distribution networks.

This project studies the implementation of feedback control algorithms over WSANs, particularly with regard to the management of large-scale networked systems such as the electric power grid or water distribution networks. Controlling such physical processes traditionally requires some type of hard real-time support. This means that each packet of feedback data must be serviced within a specified deadline to assure the overall control application's performance level. It has, in practice, been difficult to provide such guarantees in real-life wireless networks. This project will address that issue by developing algorithms that allow control applications and network servers to work together in maximizing application performance subject to firm or hard real-time service constraints.

### \* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities: 1) Project participant, Shengyan Hong, successfully defended his Ph.D. dissertation entitled "real-time scheduling in cyber-physical systems" in August 2014.

2) Dr. Lemmon participated in CPSweek April, 2014, Berlin Germany. Presentation at HiCONS 2014 conference.

3) Dr. Lemmon participated at the International Conference on Control and Automation, Taichung, Taiwan, June 2014

4) Dr. Lemmon gave invited presentation at 3rd annual Midwest Workshop on Control and Game Theory, Columbus, Ohio, April 2014

5) Dr. Lemmon gave invited presentation at Georgia Tech, March 2014.

Specific Objectives:

Significant Results:

Key outcomes or Other achievements:

**\* What opportunities for training and professional development has the project provided?**

Project completed training of one PhD student, Shengyan Hong, over the last year.

**\* How have the results been disseminated to communities of interest?**

Results from Dr. Lemmon's work on wireless sensor-actuator networks was presented at conferences (ICCA 2014, HICONS 2014) and

at invited talks at Georgia Tech and Ohio State University.

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## Products

### Books

### Book Chapters

### Conference Papers and Presentations

### Inventions

### Journals

Lichun Li and M.D. Lemmon (2013). Computational synthesis of event-triggers for MMSE state estimators with communication constraints. *IEEE Transactions on Control Systems Technology*. . Status = UNDER\_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

### Licenses

### Other Products

### Other Publications

### Patents

### Technologies or Techniques

### Thesis/Dissertations

Shengyan Hong. *Real-time Scheduling in Cyber-physical System*. (2014). University of Notre Dame. Acknowledgement of Federal Support = Yes

## Websites

*Dynamically Managing the Real-time Fabric of a Wireless Sensor-Actuator Network*

<http://www3.nd.edu/~lemmon/projects/NSF-08-611/>

Homepage for NSF project 931195

## Participants/Organizations

### What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Lemmon, Michael	PD/PI	1
Hu, Xiaobo	Co PD/PI	1
Wang, Zhao	Graduate Student (research assistant)	1

### Full details of individuals who have worked on the project:

#### Michael D Lemmon

**Email:** lemmon@nd.edu

**Most Senior Project Role:** PD/PI

**Nearest Person Month Worked:** 1

**Contribution to the Project:** Principal Investigator

**Funding Support:** University of Notre Dame (9 months), NSF (1 month), Accenture Project (1 month)

**International Collaboration:** No

**International Travel:** Yes, Germany - 0 years, 0 months, 4 days; Taiwan - 0 years, 0 months, 5 days

#### Xiaobo S Hu

**Email:** shu@cse.nd.edu

**Most Senior Project Role:** Co PD/PI

**Nearest Person Month Worked:** 1

**Contribution to the Project:** co-investigator

**Funding Support:** NSF

**International Collaboration:** No

**International Travel:** No

#### Zhao Wang

**Email:** zwang6@nd.edu

**Most Senior Project Role:** Graduate Student (research assistant)

**Nearest Person Month Worked:** 1

**Contribution to the Project:** studying wireless-actuator sensor networks and autonomous microgrid controls

**Funding Support:** Accenture Foundation - 2012-2013

**International Collaboration:** No

**International Travel:** No

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**What other organizations have been involved as partners?**

<b>Name</b>	<b>Type of Partner Organization</b>	<b>Location</b>
EmNet LLC	Industrial or Commercial Firms	South Bend Indiana

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**Full details of organizations that have been involved as partners:**

**EmNet LLC**

**Organization Type:** Industrial or Commercial Firms

**Organization Location:** South Bend Indiana

**Partner's Contribution to the Project:**

Facilities

Collaborative Research

**More Detail on Partner and Contribution:** EmNet LLC builds and deploys wireless sensor-actuator networks that are designed to operate in harsh environments for extended periods (2-3 years) of time. This company has provided wireless networking equipment used in their WSANs as well as technical details regarding customer needs.

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**Have other collaborators or contacts been involved? No**

## Impacts

**What is the impact on the development of the principal discipline(s) of the project?**

The results from this project advanced our understanding of the way in which variations in wireless network quality-of-service impact the performance of networked control systems.

**What is the impact on other disciplines?**

Nothing to report.

**What is the impact on the development of human resources?**

In 2014, this project completed the training of one PhD student, Shengyan Hong.

**What is the impact on physical resources that form infrastructure?**

Nothing to report.

**What is the impact on institutional resources that form infrastructure?**

Nothing to report.

**What is the impact on information resources that form infrastructure?**

Nothing to report.

**What is the impact on technology transfer?**

Nothing to report.

**What is the impact on society beyond science and technology?**

Nothing to report.

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## Changes/Problems

### **Changes in approach and reason for change**

Nothing to report.

### **Actual or Anticipated problems or delays and actions or plans to resolve them**

Nothing to report.

### **Changes that have a significant impact on expenditures**

Nothing to report.

### **Significant changes in use or care of human subjects**

Nothing to report.

### **Significant changes in use or care of vertebrate animals**

Nothing to report.

### **Significant changes in use or care of biohazards**

Nothing to report.