Leveraging Analysis and Experimentation to Develop Robust Solutions for Wireless in Factory Automation

A report of the
UM-ERC/RMS 4th Annual Network Performance Workshop held on May 13th 2009

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Deepak Sharma, James Moyne and Dawn Tilbury

Contact us at: erc-wireless@umich.edu

Executive Summary

The Engineering Research Center for Reconfigurable Manufacturing Systems at the University of Michigan held the 4th annual network performance workshop. The *goals of the workshop* were to determine barriers to implementation of wireless on the factory floor and outline applied research that could be contributed by universities to help overcome these barriers, focusing in research associated with analysis and experimentation of industrial wireless solutions.

Dr. James Moyne from the University of Michigan introduced the scope and goals for the workshop and the highlighted the background and results of a few of the past and current projects undertaken by ERC in collaboration with industry leaders. The presentation summarized the successes in research in wireless industrial automation at ERC to date and stressed the need to develop testing and analysis techniques for further research in wireless automation. Dr. Penny Chen from Yokogawa gave the keynote talk on applying wireless technologies to industry automation. Her talk illustrated the wide variety of applications in industrial automation for which wireless technology is needed and pointed out the need for more stringent requirements on co-existence, reliability, interoperability and security on the wireless communication protocols being developed. Armin Glaser from Pilz automation provided an overview of challenges in applying wireless to safety systems and provided details on a proprietary wireless communication protocol being developed by Pilz. The wireless protocol uses a proprietary modulation and hopping sequence (physical layer). Dhananjay Anand from ERC/RMS spoke about the performance of wireless networks and precision time synchronization. Key ideas presented were wireless protocols performance testing and analysis and precision time synchronization over networks. The talk concluded with a panel discussion on issues hindering deployment of wireless technologies on the plant floor and the role university research needs to play to tackle some of these issues

Key Takeaways

- *Standardization* of wireless automation protocols and technologies is needed.
- Wireless automation solutions are being provided by vendors such as Siemens, ABB and Pilz. Some of these are proprietary solutions that are being proposed for niche applications (e.g., Pilz for safety); a mapping of the wireless application space to a minimal set of (hopefully open) protocols is needed.
- Planning of wireless infrastructure is essential for manufacturing systems. *Pre and post* infrastructure diagnostics tools need to be developed.
- Significant work has been done by ERC/RMS in developing *performance metrics* for wireless protocols such as 802.11g and Bluetooth; the ERC/RMS will be publishing a comprehensive catalog of wireless system analysis providing data on the impact of factors (e.g., power, distance, interference) on wireless performance, focusing on WiFi and Bluetooth
- More analysis needed to analyze *wireless jitter* and packet loss so as to enable deterministic control
- Low-level time-stamping of sensor data with *time synchronization* may help provide precise control over wireless networks

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Introduction

The Engineering Research Center for Reconfigurable Manufacturing Systems at the University of Michigan held the 4th annual network performance workshop on May 13th 2009 to discuss best possible analysis and experimentation techniques to develop robust industrial wireless solutions, identify issues hindering the development of wireless automation and discuss how University of Michigan could help facilitate the adoption of wireless systems.

Summary of Presentations

1. University of Michigan – Overview

   Dr. James Moyne – University of Michigan, ERC/RMS

   Dr. James Moyne from the University of Michigan introduced the scope and goals for the workshop and the highlighted the background and results of a few of the past and current projects undertaken by ERC in collaboration with industry leaders. The presentation summarized the successes in research in industrial networks at ERC/RMS to date including development of networking best practices in Industrial Ethernet and wireless networking and development of network partitioning techniques for safety, control and diagnostics. Dr. Moyne emphasized the need for the automation industry to identify challenges with the current wireless technologies which can be addressed by university research. Some of the potential challenges include development of optimized protocol stack, a secure/safe physical layer, understanding delay and delay jitter of wireless systems, developing tools to determine wireless performance a priori and to optimize wireless designs, and developing networked control systems that utilize time stamp information.

2. Applying Wireless Technologies to Industrial Automation

   Dr. Penny Chen – Yokogawa IA Global Marketing

   Dr. Penny Chen from Yokogawa gave the keynote talk on applying wireless technologies to industry automation. Her talk illustrated a wide variety of applications in industrial automation for which wireless technology is needed providing a strong business case and listing key challenges. Some of the key challenges mentioned in wireless implementation include non standard wireless services, high entry cost due to lack of infrastructure, reliability of connection for control and security of data. Wider adoption of wireless in industrial automation will require more stringent quality of service from the network in terms of time delays and jitter and will need to meet other requirements such as co-existence, reliability, interoperability and security. Such emerging requirements have forced need for standardization of wireless automation and communication technologies across industry. She highlighted the efforts being done by International Society of Automation in developing these standards. Some of the groups working on wireless automation include ISA100.12 (WirelessHART Convergence Group) and ISA100.15 (Wireless Backhaul Backbone Network Group). She concluded by providing a future vision of wireless applications in industrial automation where an integrated wireless solution is provided, creating isolated subnets of devices from corporate networks, laptops,

phones, sensors, tracking devices etc, and at the same time allowing seamless and secure movement of data.

3. Market Leadership through Technology Leadership
   Armin Glaser - Pilz Automation, United States
   Armin Glaser from Pilz automation provided an overview of challenges in applying wireless to safety systems and introduced a new wireless communication protocol developed by Pilz called *induraNET p*. An automation grade safety system requires a very robust communication infrastructure. Key challenges in developing a wireless solution include reliability, robustness and coexistence. A very important point was made that the existing protocols do not meet these requirements for implementation in safety systems. The protocol uses the ISM band of 2.4 GHz but implements a proprietary modulation and hopping sequence called Coexistence Frequency Management which allows it to coexist with 802.11a/b/g and Bluetooth. InduraNET p also uses special antenna characteristics to provide high reception quality and reliable connection. Applications of the protocol include AGVs, Robotic palletiser, production lines etc.
4. Performance of Wireless Networks for Automation and Control
   Dhananjay Anand – UM, ERC/RMS
   Dhananjay Anand from ERC/RMS presented on performance of wireless networks and precision time synchronization. Key results presented were wireless protocol performance testing and analysis and precision time synchronization over networks. Time delays and jitter were shown for 802.11 a/b/g (Wi-Fi) and Bluetooth, providing metrics for quality of service of the network. Wi-Fi showed a mean round trip delay of 2-3 milliseconds while Bluetooth showed a roundtrip delay of 35-40 milliseconds. Increasing interference in the medium significantly reduced wireless network performance because of increased jitter. Even though both Wi-Fi and Bluetooth showed degraded performance, Bluetooth performed better than Wi-Fi with a smaller increase in jitter. A key idea presented was the significant impact protocol stack implementations have on time delays in wireless communication. Experiments conducted at Underwriters Laboratories showed that multipath interference has a large effect on time delays and jitter. The other aspect of presentation described the need for time synchronization for accurate low level time stamping of sensor data, a necessary requirement for precise estimation and control over networks. Network Time Protocol (NTP) and Precision Time Protocol (IEEE 1588) were compared as two time synchronization protocols. Experiments done at ERC/RMS showed when these protocols can be applied.

Panel Discussions

The panel discussion focused on issues hindering deployment of wireless technologies on the plant floor and the role university research needs to play to tackle these issues.

- Thomas Boenig from ABB talked about the current level of wireless technologies in factory automation and the future. He forecasted that by 2014 wireless will become a commodity. He illustrated the major concerns in wireless deployment including the fear of unknown, lack of standards and cost barriers. University

focus is needed to compare available wireless technologies using test cases and communicate success stories to potential users.

- Raj Rajani from Siemens mentioned the need for sophisticated modeling and simulation technology for wireless automation. He also described the need for pre- and post-deployment site survey tools for wireless devices on plant floor. Some tools for site survey have already been developed by Siemens. He also pointed out the lack of reliability in wireless communication due to which deterministic control is difficult to achieve.
- The final panelist, Mike Reed from Ford Motor Company, provided the requirements on wireless automation developed by USCAR. These requirements include 10 ms RPI (Requested Packet Interval), deterministic response time, high density operations and non-interference with existing wireless infrastructure.

Key Challenges in Implementation of Wireless Automation

The panel discussion identified the key challenges faced in the implementation of wireless automation on plant floor where applied research from *university* can contribute. The challenges have been listed in the order of importance as voted by workshop participants

1. Interoperability and coexistence of protocols – Development of wireless protocol standards for automation and development of integrated solution for IT, control, diagnostics and safety. Mapping of existing open protocols to the requirements space to see, for example, if a small set of open protocols (e.g., WiFi, Bluetooth and HART) can address needs in manufacturing automation.
2. Handling communication jitter and packet-loss – Identifying causes of jitter and packet-loss and developing solutions which minimize non-determinism in wireless communication.
3. Throughput – Developing protocols and devices (switches, routers) to handle and provide for higher throughput.
4. Diagnostics – Developing tools for pre- and post-deployment diagnostics for wireless infrastructure
5. Control over networks using time stamping
6. Education
7. Preplanning
8. Reliability

The key challenges mentioned above will act as guideline for the research being done at ERC/RMS.

Conclusion

It is evident that significant advantages are present in moving certain aspects of communication and control to wireless systems. Though products are being developed to meet the requirements, there are no clear directions and standards. Based on the consensus developed in the workshop, ERC/RMS will focus on interoperability and

coexistence of wireless networks and will work with different organizations such as USCAR to develop best practices for wireless automation, and to map existing common open networks into the wireless automation requirements space. Also ERC/RMS will work on better understanding of quality of service in wireless networks and developing solutions to minimize jitter and packet loss. Longer term we will work to aid the paradigm shift to control over networks leveraging time synchronization and time stamping.

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- Dr. Penny Chen (Yokogawa IA Global Marketing)
- Armin Glaser (Pilz Automation)

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Complete presentations can found at
http://erc.engin.umich.edu/news/network_workshop_may2009.html

Appendix-A

Name	Affiliation/Company	E-Mail
Julien Amelot	NIST	Julien-amelot@nist.gov
Dhananjay Anand	U-M	danand@umich.edu
Thomas Boenig	ABB	thomas.boenig@de.abb.com
Penny Chen	Yokogawa	penny.chen@us.yokogawa.com
Jim Gilsinn	NIST	James-gilsinn@nist.gov
Armin Glaser	Pilz	a.glaser@pilz.de
Aaron Hammer	Siemens	Aaron.hammer@siemens.com
Don Henry	Chrysler-IT	Dh67@chrysler.com
Eric Hollister	Pilz	e.hollister@pilzusa.com
Greg Irwin	Chrysler-AME	gwi@chrysler.com
Bruce Jones	Controls-Rockwell	Bcjones7777@gmail.com
Richard Kluth	Siemens	Richard.kluth@siemens.com
Ya-shian Li-Baboud	NIST	Ya-shian.li-baboud@nist.gov
Luis Lopez	Ford-PTO Controls	llopez@ford.com
Jim McAlpine	Ford-AMTD	jmcalpin@ford.com
Jason McLees	Phoenix Contact	jmclees@pheonix.com
James Moyne	U-M	moyne@umich.edu
Jonathan Parrott	ODVA	jparrott@odva.org
Raj Rajani	Siemens	Rajesh.rajani@siemens.com
Mike Read	Ford-IT	mread@ford.com
Warren Schwanky	Ford-PTO Mfg	wschwank@ford.com
Deepak Sharma	U-M	deepaks@umich.edu
David Sidebottom	General Motors – PT	David.sidebottom@gm.com
Dawn Tilbury	U-M	tilbury@umich.edu
Larry Vavro	Chrysler-AME	lmv1@chrysler.com
Russ Wootton	Chrysler-ITM	rww@chrysler.com
Gary Workman	GM-CCRW	Gary.c.workman@gm.com
Mark Woudenberg	Summit Automation	mwoudenberg@summitautomation.com
Chengyin Yuan	GM	Chengyin.yuan@gm.com
Tom Zerona	Rockwell Automation	trzerona@ra.rockwell.com