Estimating Safety Function Response Time for Wireless Sensor Networks

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Motivation

- To explore safe use of wireless communications in industrial control networks.
- Reduced wiring costs.
- Ease of field equipment reconfiguration and operation.
- Integration with IPv6 wireless networks.
- Additional redundancy easily added.

Industrial Automation Networks

An automation network is divided into different network layers. Each network layer runs a specialized protocol that satisfies the specific requirements of that network. In this context, energy for communications is assumed to be abundant.

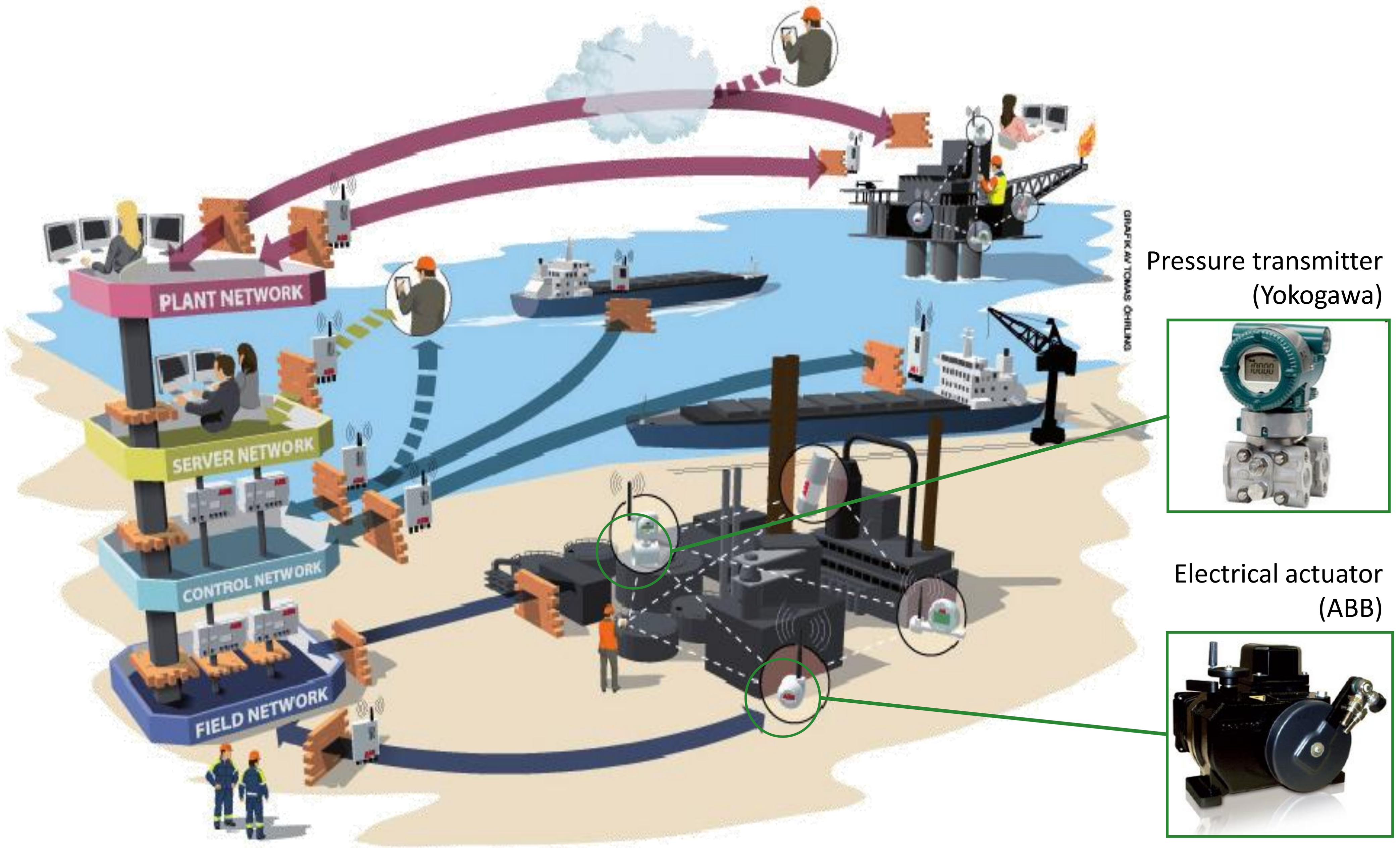

Figure 1: Automation networks are divided into different network layers (adapted from [1]).

Wireless Industrial Control Usage Classes

Type	Class	Description	Characteristic
Safety	0	Emergency action	Always critical
Control	1	Closed loop regulatory control	Often critical
	2	Closed loop supervisory control	Usually non-critical
	3	Open loop control	Human in the loop
Monitoring	4	Alerting	Short-term operational consequence (e.g. event-based maintenance)
	5	Logging and downloading / uploading	No immediate operational consequence (e.g. history collection, preventive maintenance)

Adapted from [2].

Wireless Industrial Communication Protocols

WirelessHART Protocol Stack

Application	WirelessHART
Transport	WirelessHART
Network	WirelessHART
Data Link	IEEE 802.15.4
Physical	IEEE 802.15.4

ISA 100.11a Protocol Stack

Application	ISA 100.11a	
Transport	TCP	UDP
Network	IPv6	
Data Link	IEEE 802.15.4	
Physical	IEEE 802.15.4	

6LoWPAN Protocol Stack

Application	Application protocols	
Transport	UDP	ICMP
Network	IPv6	
Adaptation	LoWPAN	
Data Link	IEEE 802.15.4	
Physical	IEEE 802.15.4	

Safety Function Response Time (SFRT)

The IEC 61784-3 standard [3] defines the SFRT as the:
"worst case elapsed time following an actuation of a safety sensor connected to a fieldbus, before the corresponding safe state of its safety actuator(s) is achieved in the presence of errors or failures in the safety function channel."

A first approach for estimating the SFRT was presented in [4] where the SFRT is computed as:

$$SFRT = \sum_{i=1}^{n} D_i + \max_{i=1,2,\ldots,n} (WD_i - D_i)$$

$\sum_{i=1}^{n} D_i$: total worst case delay time, where i represents a specific entity in the network such as sensor, actuator, bus, or host

$\max_{i=1,2,\ldots,n} (WD_i - D_i)$: maximum difference between an entity's watchdog time-out and worst case delay time

The worst case delay and the entity's watchdog time-out depend on the network topology and protocol.

Objectives

- How can the SFRT of a wireless network be defined?
- Can a software tool be written that automatically provides a SFRT map for a given wireless network?
- Which of the current industrial wireless protocols, if any, satisfy industrial requirements for the control usage classes?
- Can existing wireless industrial control protocols be incorporated in a tool that estimates the minimum SFRT a network can achieve?

Proposed Methodology

Design and implement a high speed control test setup with wired and wireless communication to study wireless network properties, such as round-trip latency and update frequency. These properties will be used to calculate the estimated SFRT of the network and compare wireless communication to wired communication.

References:

[1] J. Åkerberg. On Safe and Secure Communication in Process Automation. PhD thesis, Mälardalen University, School of Innovation, Design and Engineering, 2011.

[2] International Society of Automation (ISA). ISA-100.11a-2011 Wireless Systems for Industrial Automation: Process Control and Related Applications, May 2011.

[3] International Electrotechnical Commission (IEC). IEC 61784-3. Industrial Communication Networks - Profiles - Part 3: Functional Safety Fieldbuses - General Rules and Profile Definitions, 2010.

[4] J. Åkerberg, M. Gidlund, T. Lennvall, J. Neander, and M. Björkman. Efficient Integration of Secure and Safety Critical Industrial Wireless Sensor Networks. EURASIP Journal on Wireless Communications and Networking, 2011:100, 2011.

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