Estimating the Safety Function Response Time for Wireless Sensor Networks

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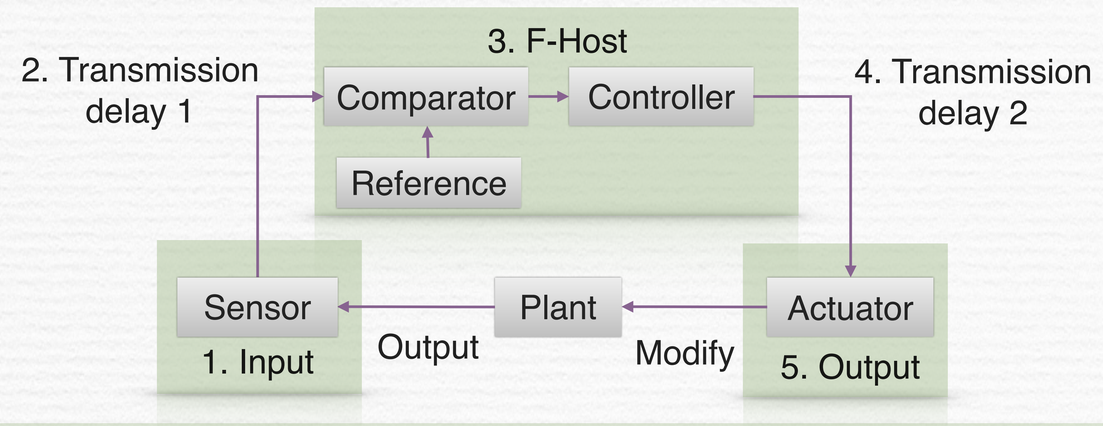
Motivation

- Explore safe use of wireless communications in industrial control networks.
- Extend Safety Function Response Time (SFRT) to include multiple input and multiple output (MIMO) systems with wireless communication channels.
- Improve SFRT modelling of communication channels.

Network Entities Implementing a Feedback Control Loop



MAC Modes Introduced in the IEEE 802.15.4e Standard

Mode	Application	Major requirement	Topology	Medium access	Synchronization	Discovery
TSCH	Process automation	Network robustness	Any	CSMA-CA, guaranteed, channel hopping	Frames in defined timeslots	TSCH enhanced beacons
LLDN	Factory automation	Very low latency, high cyclic determinism	Star, many devices	TDMA, GTS	Beacons, superframes	Discovery state beacons
DSME	Industrial, commercial, healthcare	Deterministic latency, flexibility	Any, many devices	Multi-channel, multi-superframes, GTS	Beacons from time synchronization parent	DSME enhanced beacons

A Model for Safe Feedback Control over Wireless Networks

- Merge the architecture and safety requirements of the IEC 61784-3-3 standard with the communication protocol defined in the standard.

The set of network entities $E = \{Input, F\text{-}Host, Output, TD\}$

$$SFRT = \sum_{i \in E} WCDT_i + \max_{i \in E}(WDTime_i - WCDT_i)$$

$WCDT_i$ is the worst case delay time of entity i, and

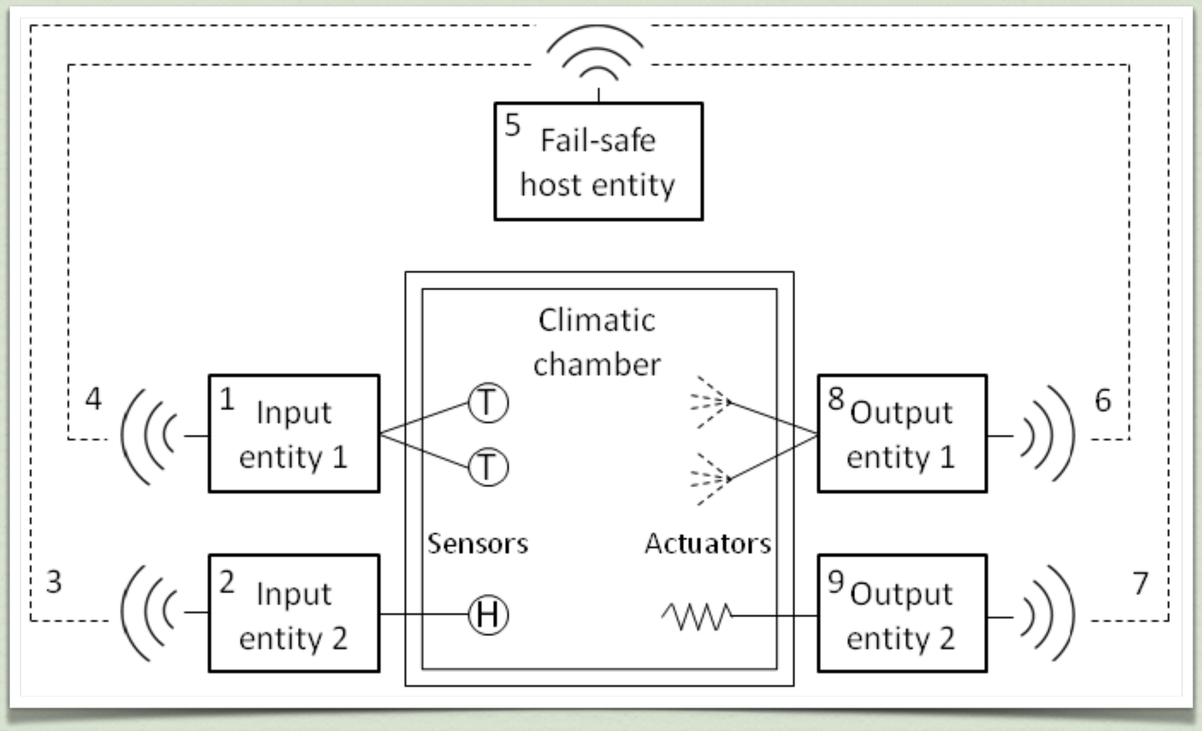
$WDTime_i$ is the watchdog time of entity i.

For a transmission delay entity i; $WCDT_i = N_{ts} L_{ts}$

N_{ts} is the number of timeslots in the slotframe, and

L_{ts} is the total length of one timeslot.

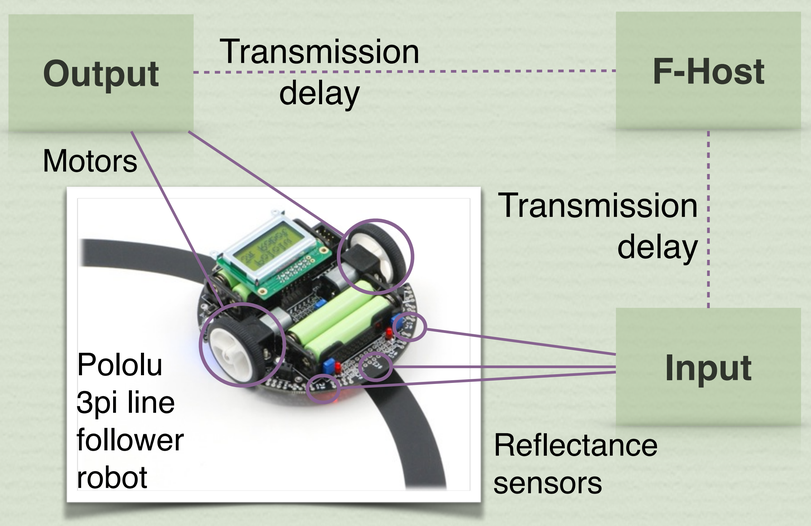
- Example of a dual control loop of temperature and humidity

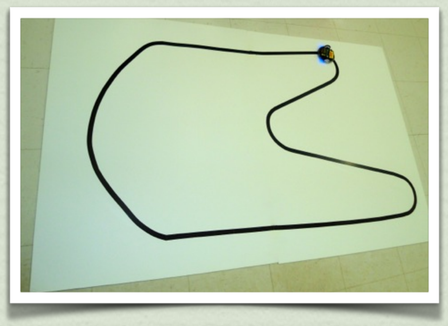


Stimuli and Responses for Entities Implementing a Feedback Control Loop

Network entity	Stimulus	Response
Input	New sensor reading(s)	Packet with new sensor reading(s) generated
Transmission delay	New packet ready to be transmitted	Packet successfully received by destination
Fail-safe host	Packet with new sensor reading(s) successfully received	Packet with new corrective action(s) generated
Output	Packet with new corrective action(s) successfully received	Corrective action(s) implemented

Methodology





References:
- IEC 61784-3-3 - Industrial communication networks - Profiles - Part 3-3: Functional safety fieldbuses - Additional specifications for CPF 3, International Electrotechnical Commission (IEC), 2010.
- IEEE Standard for Local and Metropolitan Area Networks - Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs) - Amendment 1: MAC sublayer, IEEE Standards Association, April 2012

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