Real-time Wireless Control via Ultra-Wideband (UWB) Communication

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Motivation

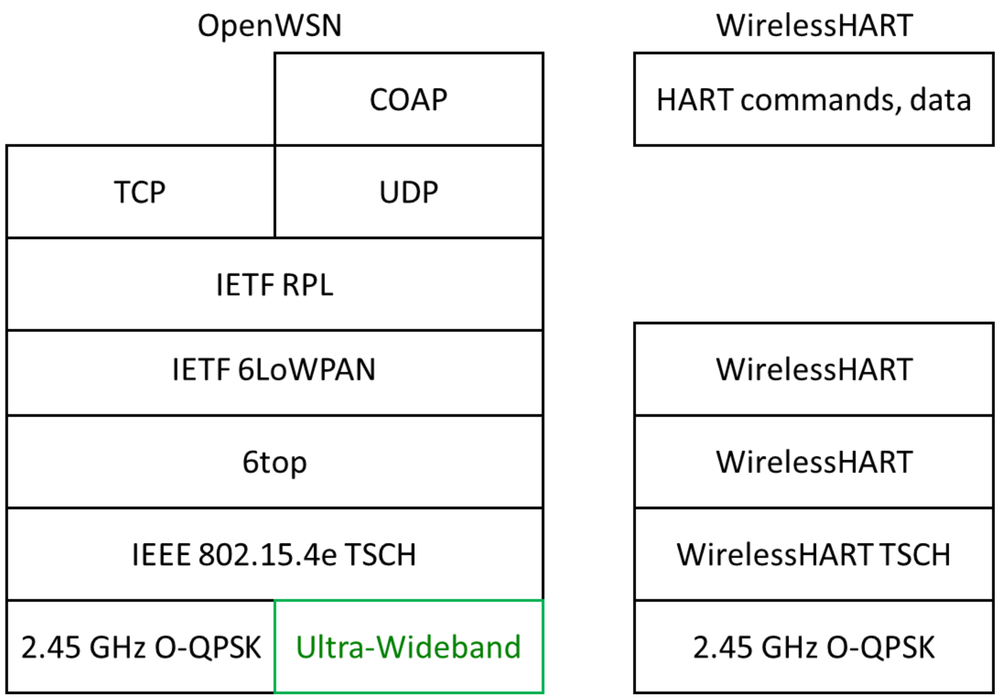
- Wireless control networks can be installed and modified much faster and with a lower cost compared to wired networks.
- Experience is that wired networks have “0 bit error rate”.
- Reliability of wireless networks for control is a concern, especially for safety-critical applications.
- UWB is a potentially more reliable wireless communication platform in the presence of noise and interference.

Hardware

DecaWave DW1000 UWB transceiver
DecaWave EVB1000 evaluation board
IEEE 802.15.4-2011 compliant
Data Rate: 110, 850, 6810 kbps
Range: up to 290 m

WirelessHART SmartMesh SDK
Based on IEEE 802.15.4-2006 2.4 GHz
O-QPSK physical layer
Data rate: 250 kbps

Software



- WirelessHART is an existing industrial wireless communication standard, based on 2.4 GHz radio.
- OpenWSN is an open-source IPv6 networking stack based on IEEE 802.15.4e time slotted channel hopping (TSCH)
- We have adapted OpenWSN to operate on an UWB physical layer on the DecaWave EVB1000 evaluation board.

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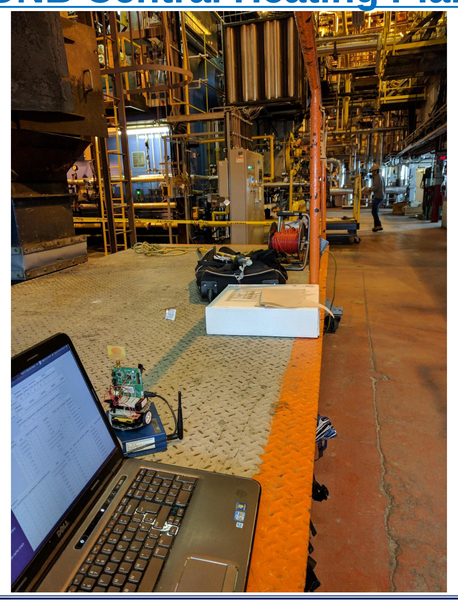
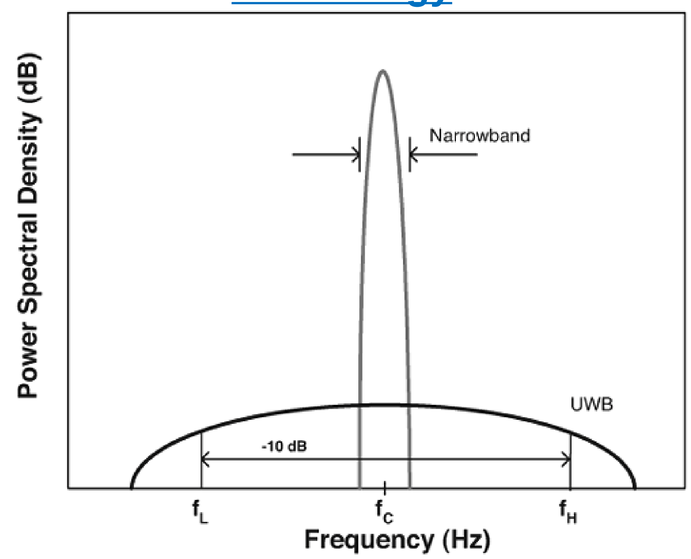


Technology



Experimental Results

UWB information bit error ratio (IBER) in an industrial environment:

Data Rate (kbps)	Mote #1	Mote #2	Mote #3	Mote #5
110	3.51×10^{-6}	4.74×10^{-6}	1.15×10^{-5}	3.71×10^{-7}
850	9.67×10^{-5}	7.63×10^{-5}	4.19×10^{-4}	2.90×10^{-6}
6810	2.71×10^{-1}	7.50×10^{-3}	5.07×10^{-1}	9.87×10^{-5}

Communication reliability (% of packets successfully acknowledged)

Environment	UWB OpenWSN	WirelessHART
Office	95.55%	72.21%
Industrial	54.40%	84.55%

Average upstream packet latency

Environment	UWB OpenWSN	WirelessHART
Office	134 ms	314 ms
Industrial	149 ms	486 ms

IEC 61508 Safety Integrity Level (SIL)

SIL	Probability of dangerous failure per hour (PFH)	Probability of dangerous failure on demand (PFD)
1	$\geq 10^{-6}$ to $< 10^{-5}$	$\geq 10^{-2}$ to $< 10^{-1}$
2	$\geq 10^{-7}$ to $< 10^{-6}$	$\geq 10^{-3}$ to $< 10^{-2}$
3	$\geq 10^{-8}$ to $< 10^{-7}$	$\geq 10^{-4}$ to $< 10^{-3}$
4	$\geq 10^{-9}$ to $< 10^{-8}$	$\geq 10^{-5}$ to $< 10^{-4}$

Relationship between bit error probability Pe and dangerous failure rate $\Lambda_{SL}(Pe)$:

$$\Lambda_{SL}(Pe) = R_{CRC}(Pe) \times v \times m$$

$R_{CRC}(Pe)$ is the probability of an undetected error by the CRC w.r.t. Pe
v is the number of safety messages per hour, and m is the number of recipients

Conclusions

- UWB bit error rate is suitable for communication in systems targeting SIL 3.
- UWB is more reliable than WirelessHART at shorter distances (10-13 m).
- UWB range for reliable communication may be shorter than WirelessHART.
- WirelessHART loses fewer end-to-end packets than OpenWSN/UWB.
- OpenWSN/UWB achieves lower latency than WirelessHART.

[1] IEEE Standard for Local and metropolitan area networks--Part 15.4: Low-Rate Wireless Personal Area Networks (LR-WPANs)," in *IEEE Std 802.15.4-2011*, Sept. 5 2011