

Performance Analysis of IEEE 802.15.4 Contention Free Period through Real-Time Industrial Maintenance Applications

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Outline

- 1 Context
 - Industrial environment
 - Wireless networks
- 2 IEEE 802.15.4
 - Overview
 - Channel access methods
 - Performances
- 3 Performances Analysis
 - Automation of industrial processes
 - Superframe usage
 - Configuration example
 - Performances comparison

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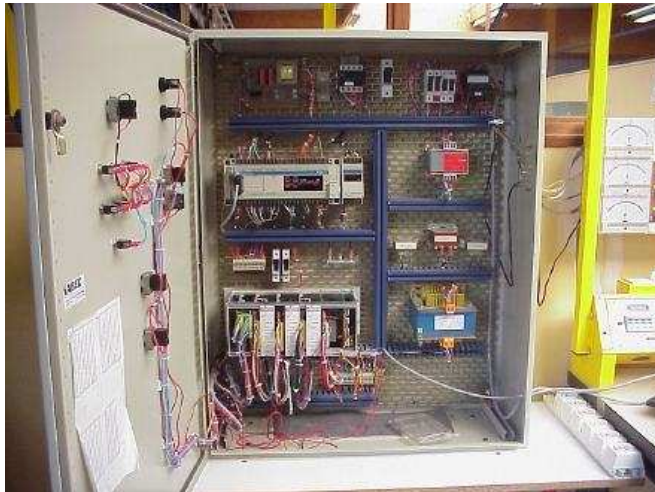
Industrial environment



Industrial environment



Industrial environment



Industrial wireless networks

What for ?

• Advantages :

• Drawbacks :



Industrial wireless networks

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 - industrial expectation
 - cost-reduction
 - architecture management
 - new services → mobility
 - standardization

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Wireless networks

		Bluetooth 	ZigBee
IEEE Standard	802.11a/b/g (1999)	802.15.1 (2002)	802.15.4 (2003)
Transmission rate	11–54 Mb/s	1 Mb/s	250 Kb/s
Network Type	WLAN	WPAN	WPAN
Range	300 m	10–100 m	10–100 m
Devices	32	7	65 000
Memory size	1 Mb +	250 Kb +	4–64 Kb
Battery life	hours	days	years

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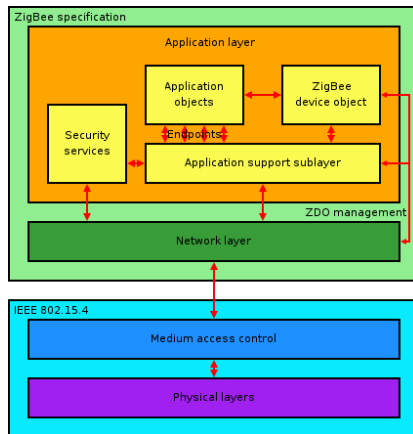
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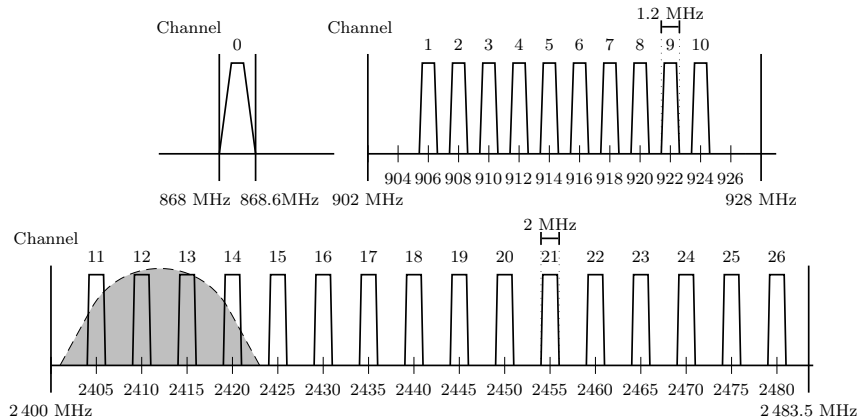
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IEEE 802.15.4 vs ZigBee



IEEE 802.15.4 \neq ZigBee

Frequency bands



Modulations

Frequency bands	Modulation	Transmission Rate
868–868.6 MHz	BPSK	20 kb/s
	BPSK+ASK	250 kb/s
	O-QPSK	250 kb/s
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Channel access methods

There are **two** medium access modes :

Non-Synchronized

Medium access relies on CSMA/CA^a.

^aCarrier Sense Multiple Access with Collision Avoidance

Synchronized

Network coordinator sends regularly beacon frames.

Between beacon frames, medium access is part in two phases :

- CSMA/CA
- Reserved time slots (Guaranteed Time Slots or GTS)

It may be followed by a period of inactivity → power saving.



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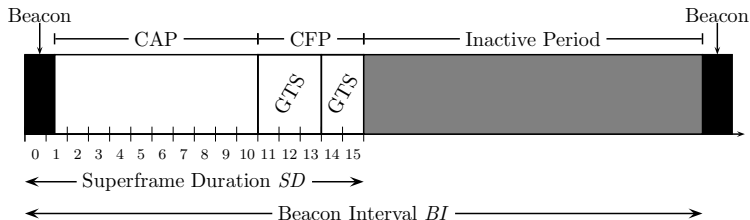
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Synchronized mode



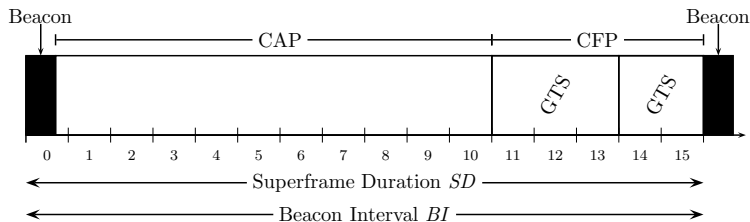
$$SD = aBaseSuperframeDuration \cdot 2^{SO} \quad (1)$$

$$BI = aBaseSuperframeDuration \cdot 2^{BO} \quad (2)$$

$$0 \leq SO \leq BO \leq 14 \quad (3)$$

Superframe Order \leq Beacon Order

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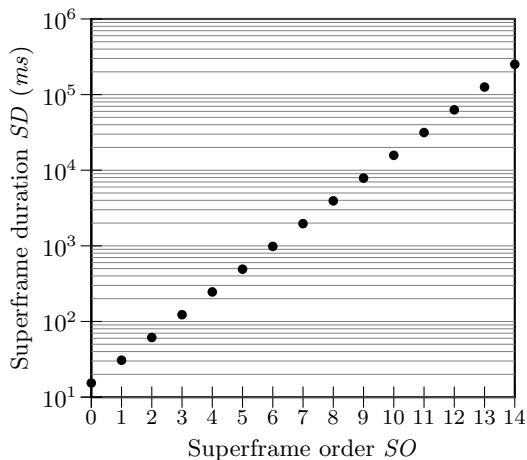
Superframe Order = Beacon Order

As we are looking for performances, we don't consider inactive period.



Superframe Duration SD

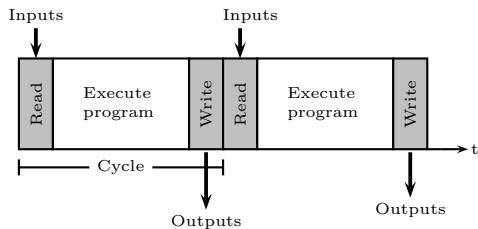
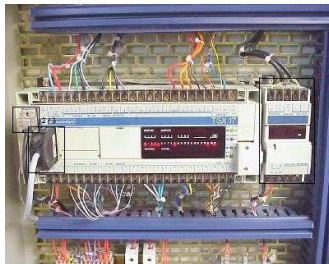
SO	SD
0	15.36 ms
1	30.72 ms
2	61.44 ms
3	122.88 ms
⋮	⋮
13	125.8 s
14	251.6 s



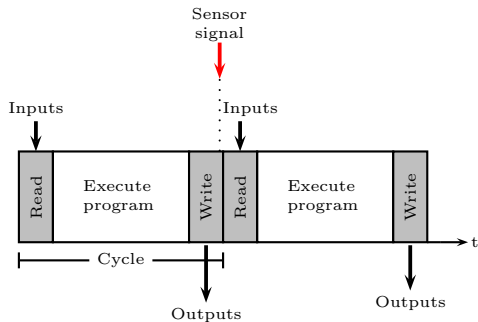
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Programmable Logic Controller (PLC)

Cyclic mechanism :

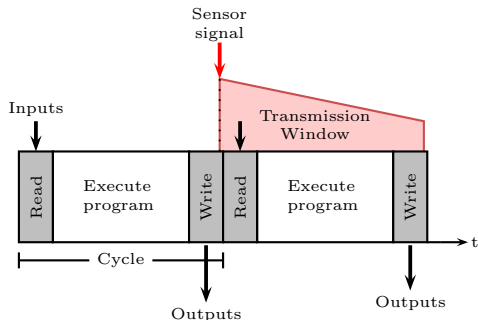
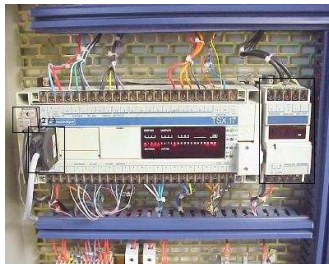


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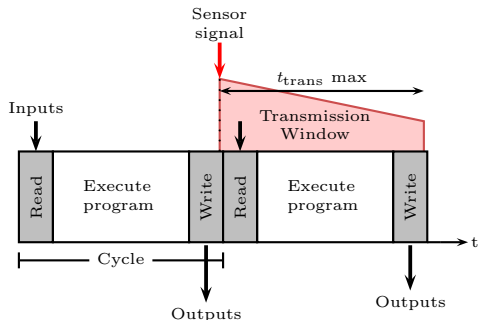
transmission duration < cycle duration

Programmable Logic Controller (PLC)



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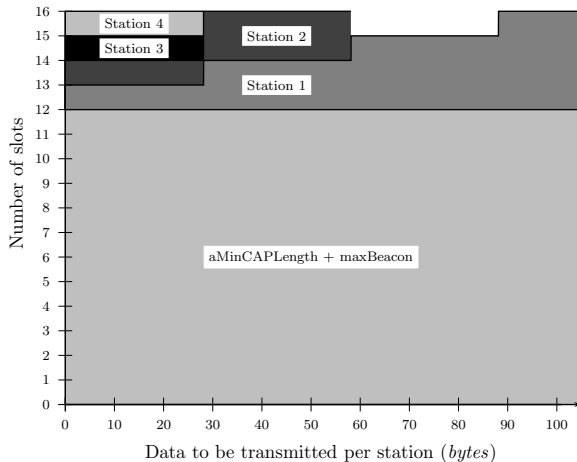
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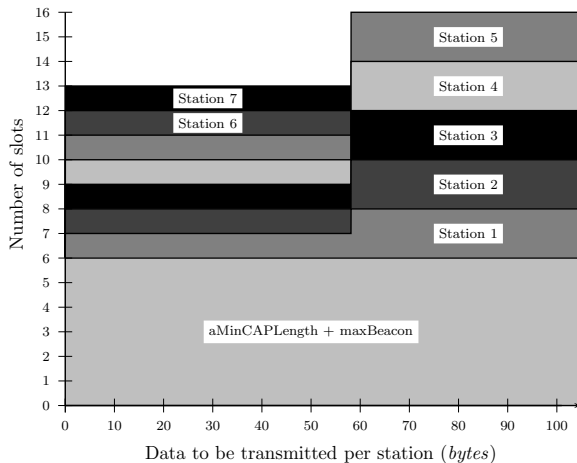
Superframe usage

$$SO = 0$$



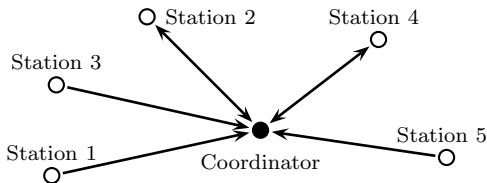
Superframe usage

$$SO = 1$$



Configuration example

A network composed by a coordinator and 5 related devices.



Station	Sent data	Received data	Period
n° 1	1 byte	-	40 ms
n° 2	8 byte	-	40 ms
n° 2	-	16 bytes	100 ms
n° 3	4 bytes	-	60 ms
n° 4	8 bytes	4 bytes	60 ms
n° 5	16 bytes	-	100 ms

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- $SO = 1$ satisfies example's requirements as Superframe Duration equals 30.72 ms (only if transmission is not acknowledged).
- In case of acknowledgement, Superframe Order must at least satisfy $SO > 2$. Then $SD > 61.44$ ms \rightarrow it doesn't fulfil requirements.

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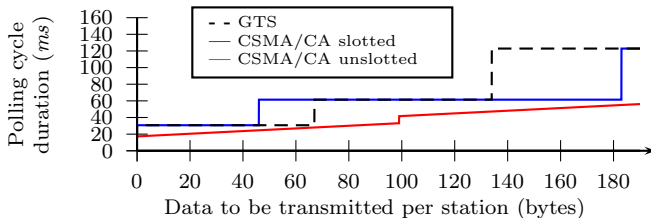
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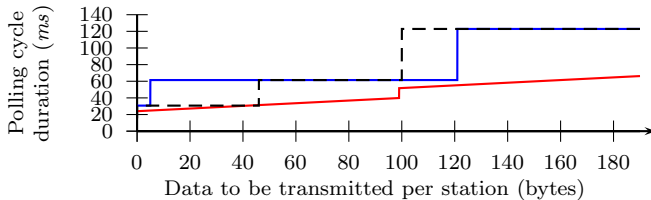
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Comparison : GTS vs CSMA/CA



(a) unacknowledged



(b) acknowledged

Conclusion

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- IEEE 802.15.4 may satisfy some industrial real-time requirements (monitoring, maintenance, ...) as long they support some limitations :
 - Number of devices ≤ 7 ($\ll 65000$)
 - PLC response time $< 15,36$ ms

Prospects

- Examine different industrial wireless technologies (Wireless HART, ISA SP100, ...)
- Advise some adaptations of wireless networks in order to satisfy industrial requirements in terms of response time, reliability, fiability,

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Questions ?

