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A Mobile Open Infrastructure Network Protocol (MOIN) for Localization and Data Communication in UWB Based Wireless Sensor Networks

2014 IEEE International Conference on Ultra-Wideband (ICUWB)
Paris, France

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3. September 2014

Outline

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- motivation and context
- related protocols
- MOIN protocol
- performance evaluation
- summary and outlook

Motivation

Context

- **Offshore operations:** part of research project SOOP - **S**afe **O**ffshore **OP**erations
- the aim is the contribution to the industrialization of offshore wind energy
- **today:** manual process monitoring (TETRA radio, visual, . . .)
- the goal was to develop a system architecture as base to generate an overview of the operation
- wireless sensor network (WSN) for communication and localization under harsh environmental conditions

SOOP
Sichere Offshore-Operationen

Dieses Projekt wird mit Mitteln des Europäischen Fonds für regionale Entwicklung gefördert.
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Niedersachsen

Motivation

Wireless Sensor Network

- most available protocols either focus on:
  - **localization or**
  - **communication**
- required is a combination of both; with following requirements
  - high precise ranging measurements
  - data communication for collected sensor data
  - dealing with harsh environments
  - implementation of a suitable network protocol for localization and communication
- due to harsh environments
  - the decision was made to use **Ultra Wideband (UWB)** as the right radio technology [4]
- approach can be easily mapped to a great number of similar problems and applications (Internet of Things, Smart Factories etc.)

Related protocols

IEEE 802.15.3 MAC

- supports additional physical layers such as Ultra Wideband (UWB)
- centralized beacon enabled protocol [1]
- based on a time-slotted superframe structure [3]

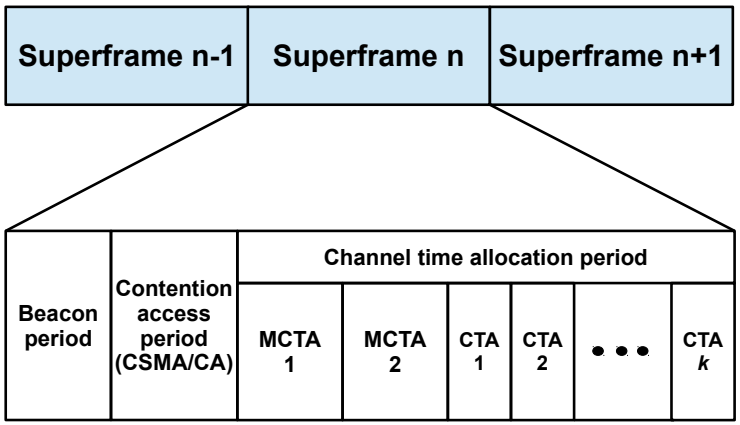


Figure : the IEEE 802.15.3 time-slotted superframe structure

Related protocols

PULSERS MAC (cf. [1],[3])

- supports peer-to-peer communication
- fulfill guaranteed requests with low latency
- ranging functionality with low power consumption

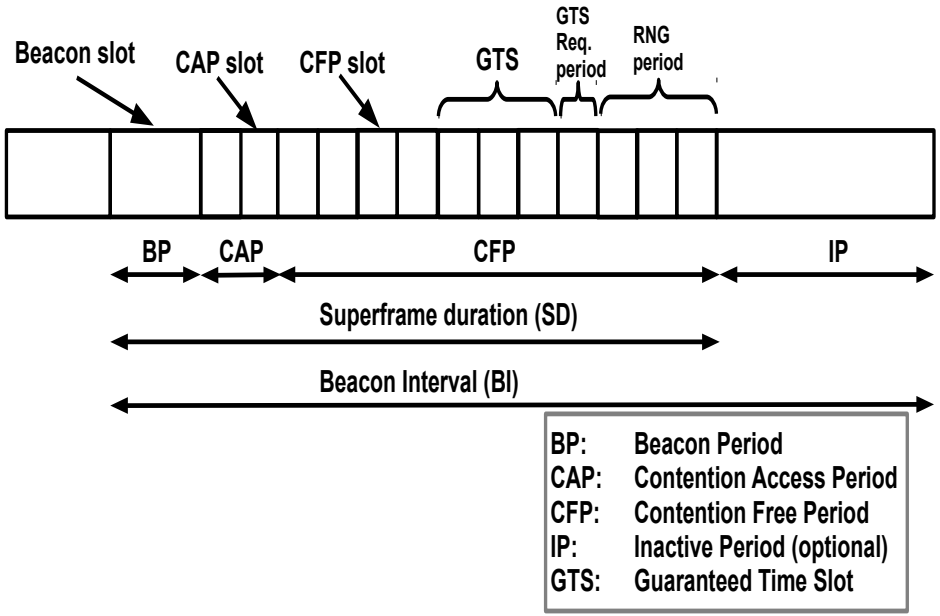


Figure : PULSERS MAC frame structure [1]

Network topology

Components

- Master
  - configures and coordinates the whole network via related Coordinators
- Coordinators
  - act as relay stations for their respective sensor domain
- mobile nodes (slave)
  - execute ranging measurements to calculate their positions and collect sensor data (temperature, acceleration etc.)
- anchor nodes
  - provide ranging measurements for mobile nodes

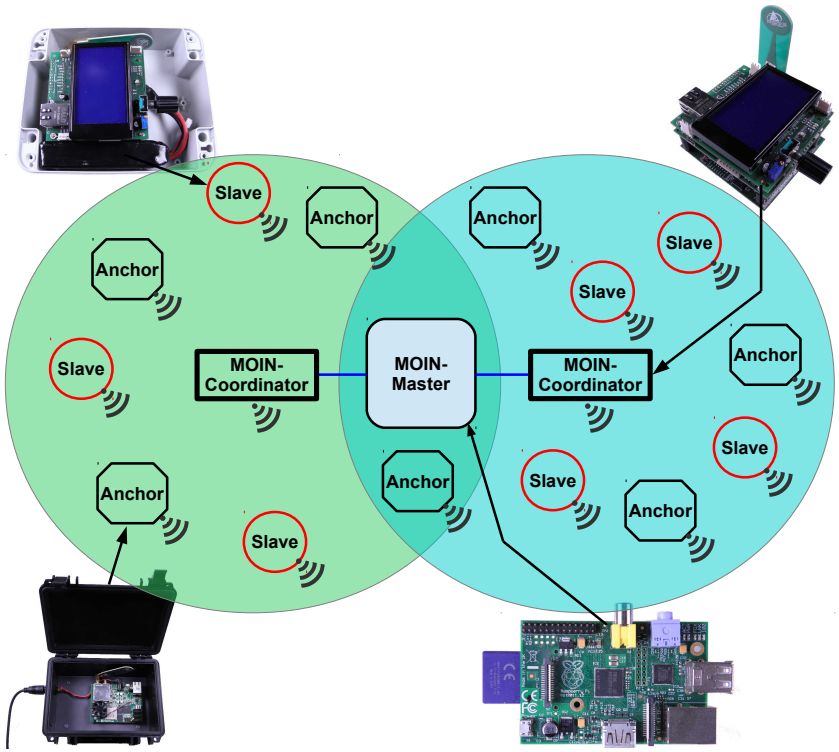


Figure : MOIN network topology

Protocol frame structure

Properties

- replaced contention access period by contention free period
- cause CSMA/CA could be a difficult task in UWB-WSNs [2]
- also it is not deterministic and unsuitable for time critical applications
- fully collision free and predictable multiple access
- combines TDMA and CDMA
- enables simultaneous channel access
- adaptive slot assignment

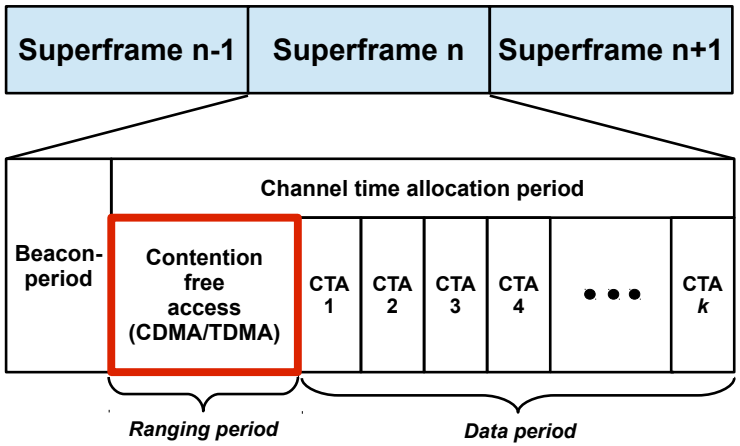


Figure : modified time-slotted superframe structure from the IEEE 802.15.3 MAC

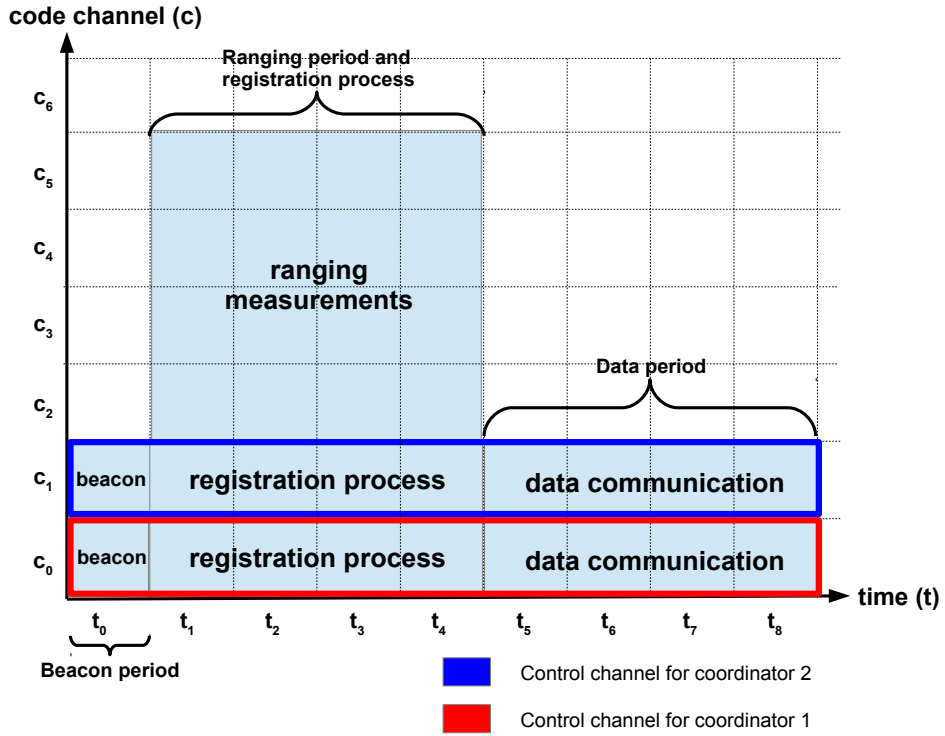
Slot configuration

Structure

- two-dimensional slot configuration
- m-time slots $*$ n-code channels
- Control channels for Coordinators
- handover between sensor domains

Different stages

1. beacon period
2. ranging period and registration process
3. data period



Slot duration

- ranging slot $= 45ms$
- data slot $= 25ms$

Example: Communication sequence

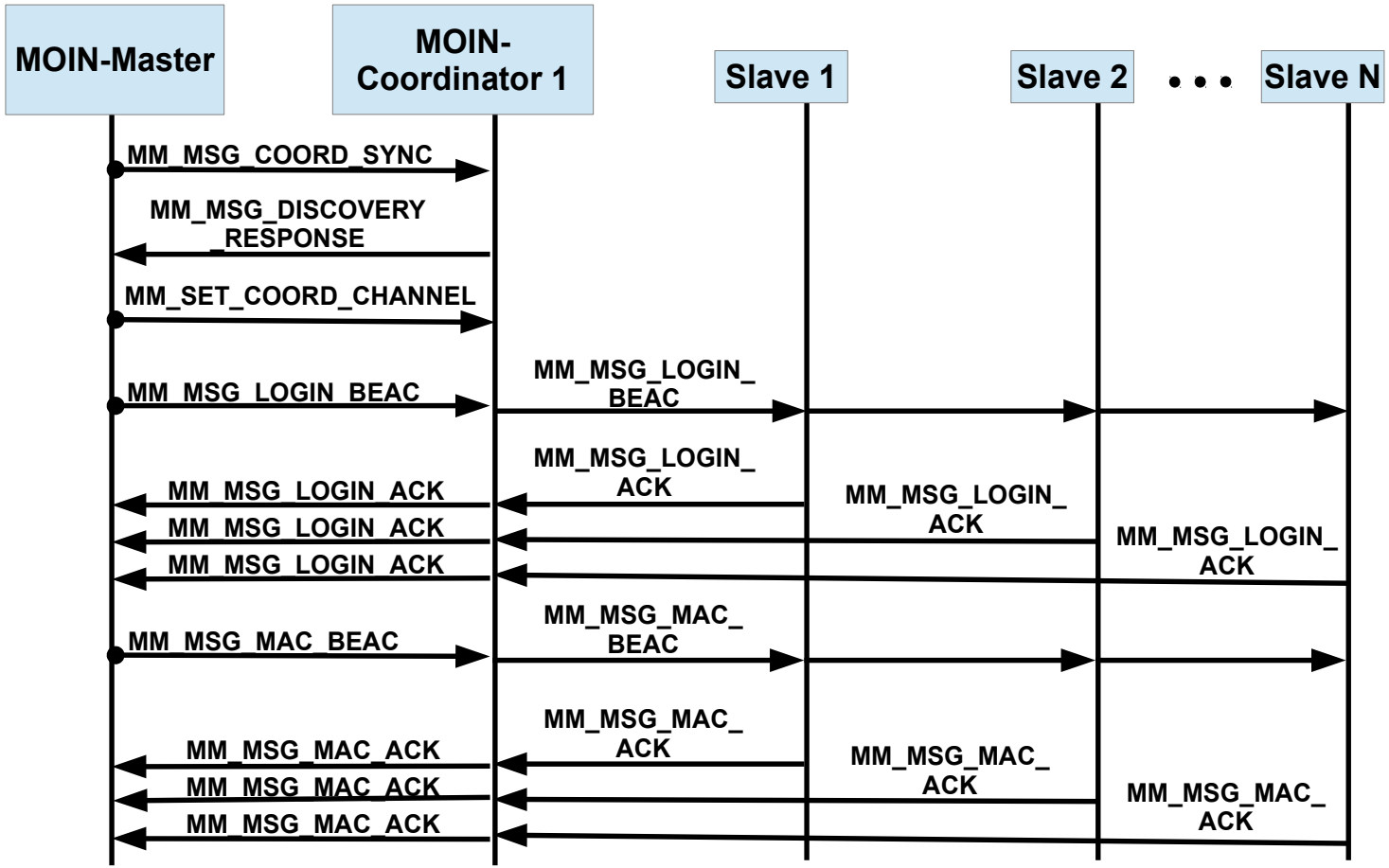
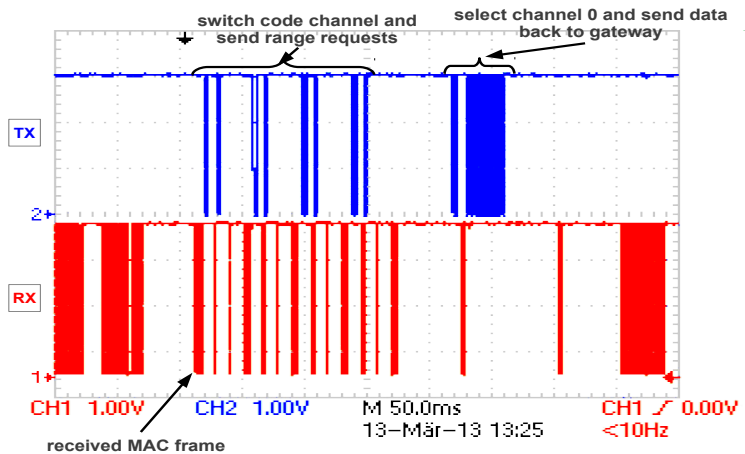


Figure : Communication sequence of MOIN components

Evaluation results

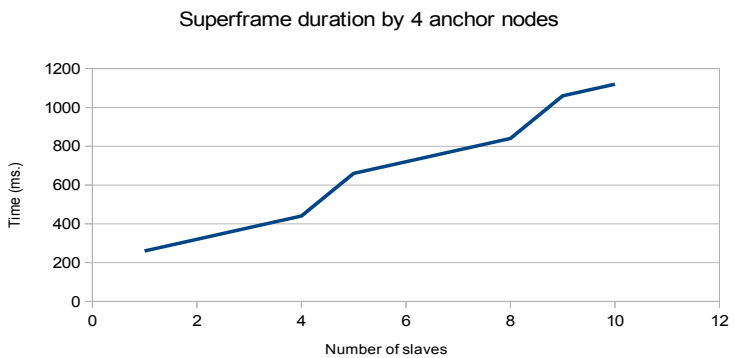
Network setup

- one Master
- one Coordinator
- five mobile nodes (slaves)
- four anchor nodes



Results

- totaltime of $564\ ms$
- update frequency of $\approx 1.8\ Hz$



Summary and outlook

The aim of the paper was to present a new efficient MAC protocol for UWB based WSNs which combines **localization** and **data communication** for industrial applications

Summary

- propose of an efficient MAC layer for industrial applications
- possibility of simultaneous channel access
- overcomes limitations of related MAC protocols
- scalable depending on the network configuration
- verification of performance by comparison to established methods (pure TDMA)

Outlook

- decreased power consumption by extended sleep modes in unused slots
- optimization of slot duration by faster channel switch and new available API of used radio modules
- integrate load balancing between sensor domains to decrease the duration of the data period

Literature

[1] L.X. Cai, Xuemin Shen, and J. Mark.
Efficient MAC protocol for ultra-wideband networks.
Communications Magazine, IEEE, 47(6):179 –185, june 2009.

[2] Fabrice Legrand, Isabelle Bucaille, Serge Héthuin, Luca De Nardis, Guerino Giancola, Maria gabriella Di Benedetto, Ljubica Blazevic, and et al.
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[3] Mohd Shahril and Izuan Mohd.
Finding the Optimal MAC Protocol for Low-Power High Data Rate Ultra-Wideband (UWB) Networks.
cms.livjm.ac.uk, pages 19–24, 2008.

[4] Thorsten Wehs, Manuel Janssen, Carsten Koch, and Gerd von Cölln.
System architecture for data communication and localization under harsh environmental conditions in maritime automation.
In *IEEE 10th International Conference on Industrial Informatics*, 2012.

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Duration of each superframe

The total time of each superframe is:

- $t_{sf} = B + R + D$
  - **B** is the duration of the beacon period $(\approx 40\ ms)$
  - **R** is the duaration of the ranging period

$$t_r = \begin{cases} ((m \ \mathbf{div}\ r) + 1) * r * t_{r_{slot}}\ , & m \neq r \\ \frac{m}{r} * r * t_{r_{slot}}\ , & (m \mod r) = 0 \end{cases} \quad (1)$$

  - **D** is the duration of the data period:

$$t_d = m * t_{d_{slot}}\ ,\ m > 0 \quad (2)$$

Example of slot assignment

Figure : Example of the adaptive slot assignment