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FACULTY OF ENGINEERING AND ARCHITECTURE

IDLAB - DEPARTMENT OF INFORMATION TECHNOLOGY (INTEC)
ELECTROMAGNETICS GROUP

LORA NETWORKS BASED ON SYSTEM-INTEGRATED TEXTILE SIW ANTENNAS: AN OVERVIEW

Thomas Ameloot, Patrick Van Torre and Hendrik Rogier

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INTRODUCTION

INTRODUCTION

Internet of Things:

Wireless sensor networks deployed **over larger and larger areas**

Sub-GHz frequency bands:

+ Superior radio wave propagation properties
- Lower frequencies => larger antennas

Middle ground:

868 MHz ISM BAND ⇒ Several standards available:

LoRa™

sigfox

DASH7

GOAL

What challenges are we facing when using low-power sensor networks for body-centric communication?

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MORE SPECIFICALLY

Is LoRa a valuable option for body-centric communication?

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- Improving wireless performance
  - Receiver diversity
  - Parameter optimization
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WEARABLE LORA HARDWARE

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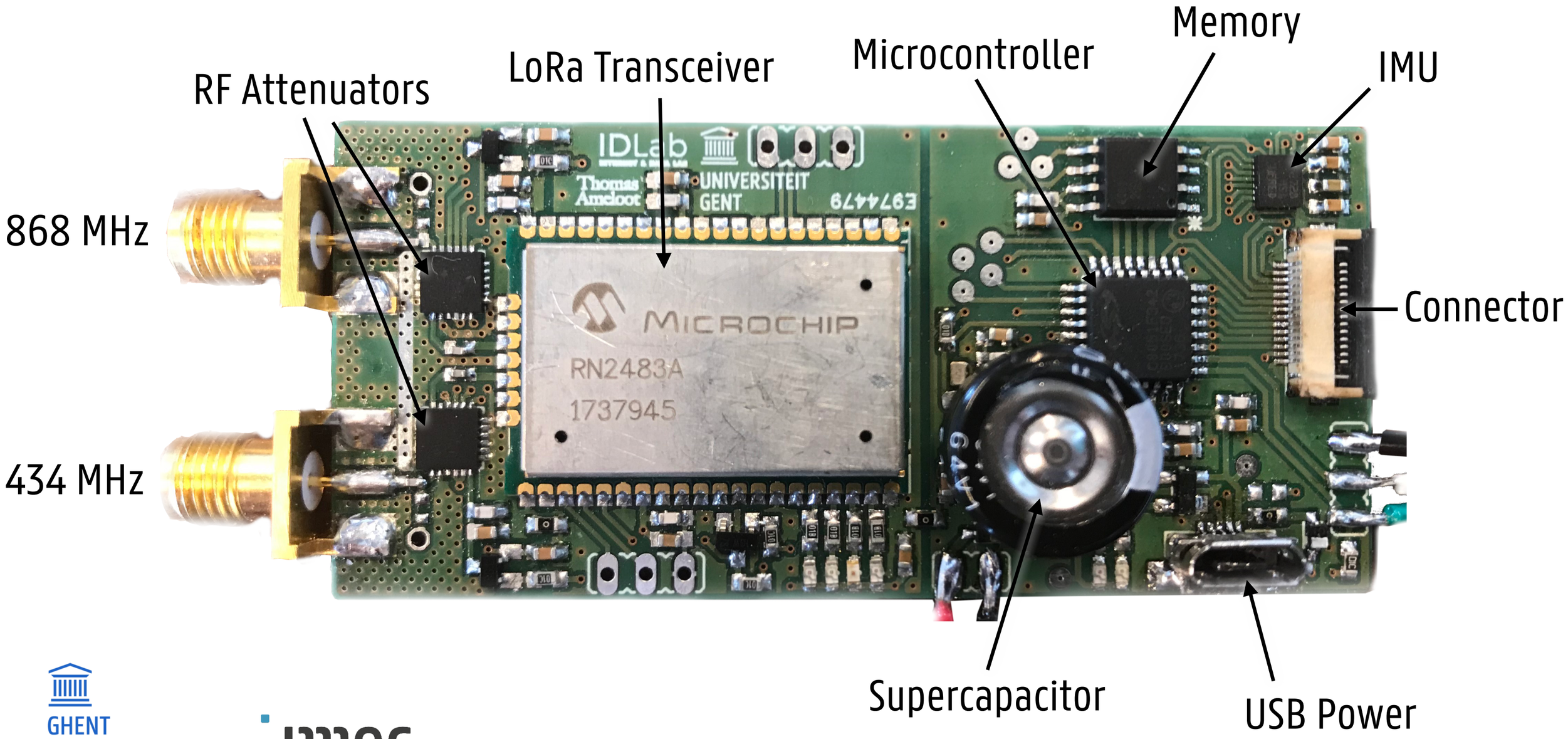
CUSTOM LORA SYSTEM



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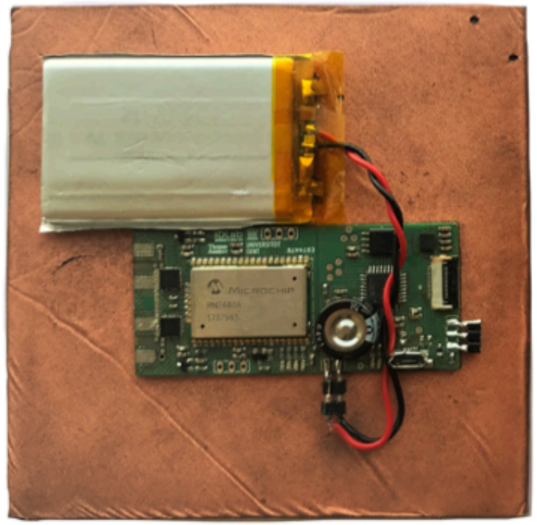
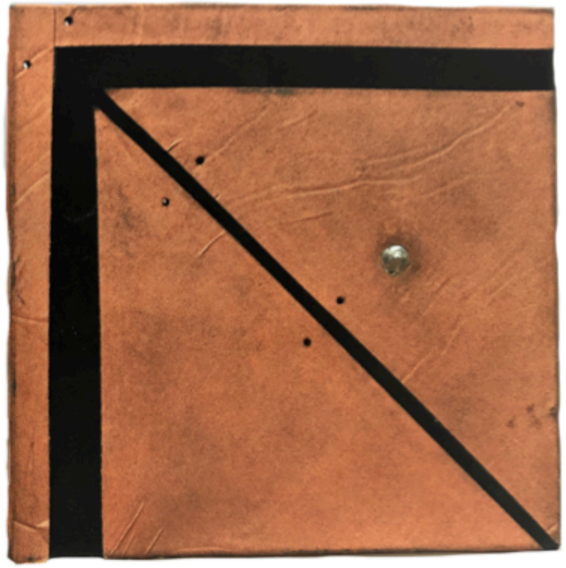
WEARABLE LORA HARDWARE

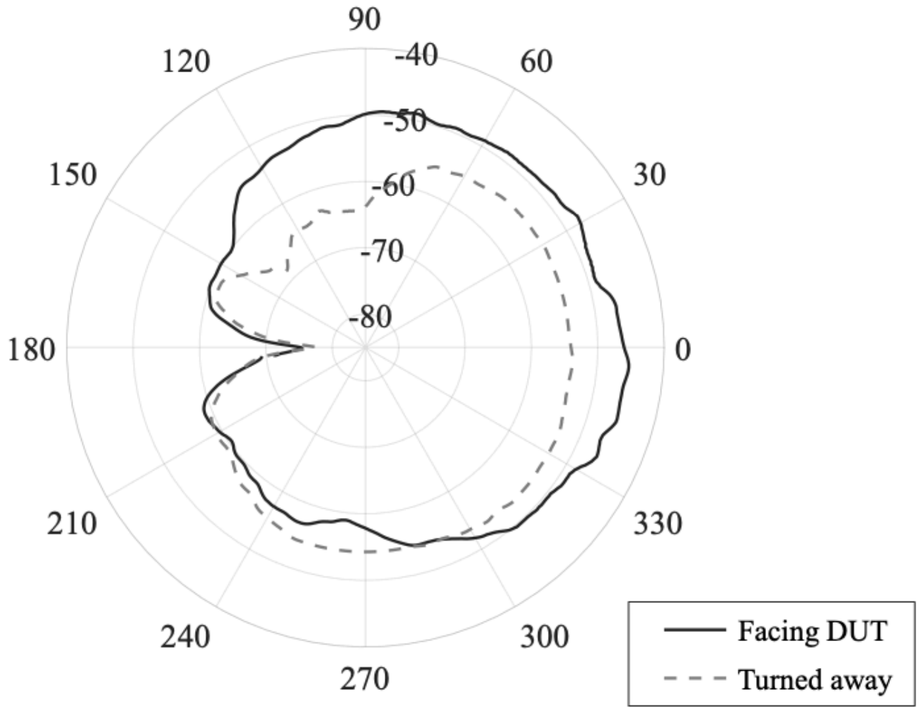
Electronic circuit integrated onto textile

Substrate Integrated Waveguide (SIW) antenna





Size: 112 x 112 x 4 mm



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CHANNEL CHARACTERIZATION STRAGTEGIES

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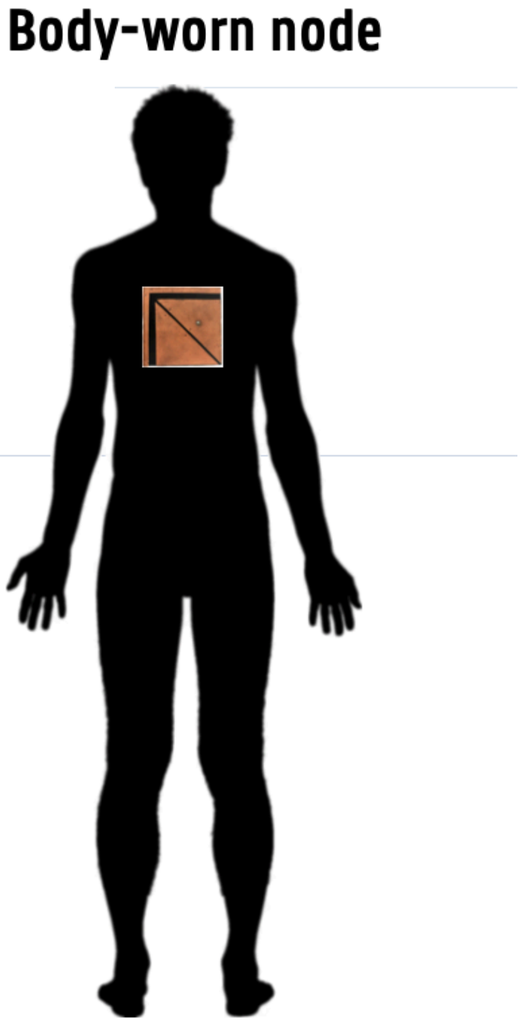
MEASUREMENT STRATEGY

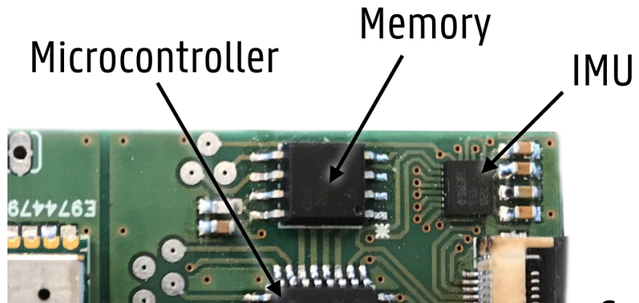
- TX: Base-station (body-to-base-station) or test person (body-to-body)
- RX: Always test person
- TX and RX synchronised through internal clocks

- Short packets sent continuously
  - Spreading factor (SF) of 7:

    ⇒ high repetition rate = high probing rate

- Signal-to-noise ratios & timestamps recorded in flash memory





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BODY-CENTRIC LORA PERFORMANCE

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BODY-CENTRIC LORA NETWORKS

- Body-to-body

  vs

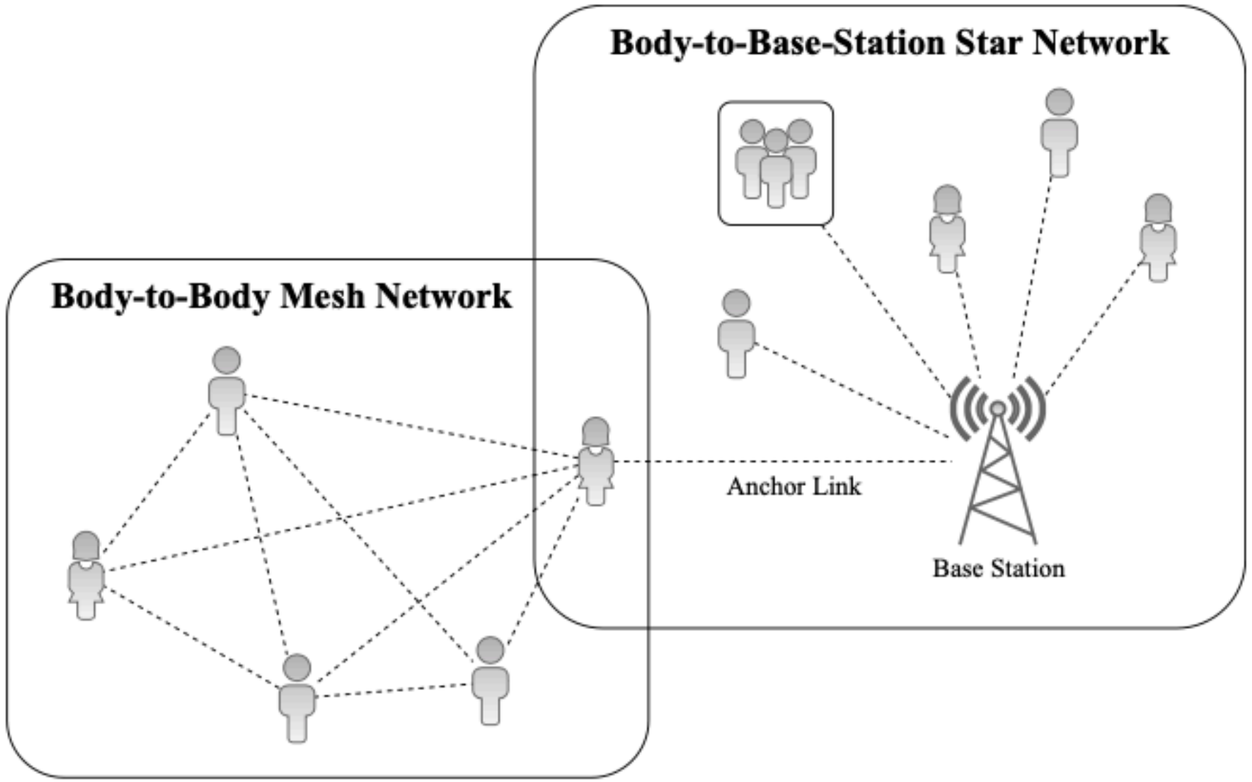
- Body-to-base-station

- Indoor

  vs

- Outdoor

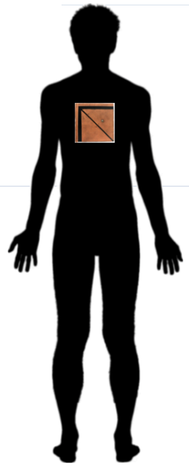
An example



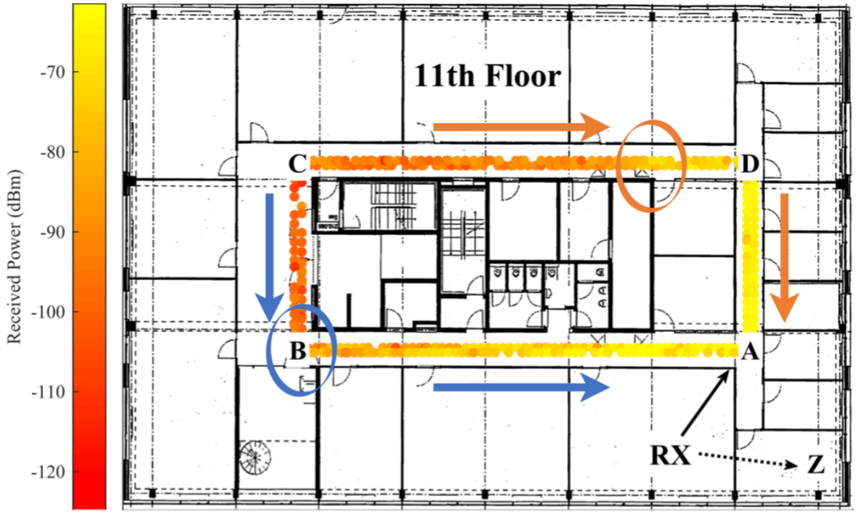
INDOOR BODY-TO-BODY

Walking TX

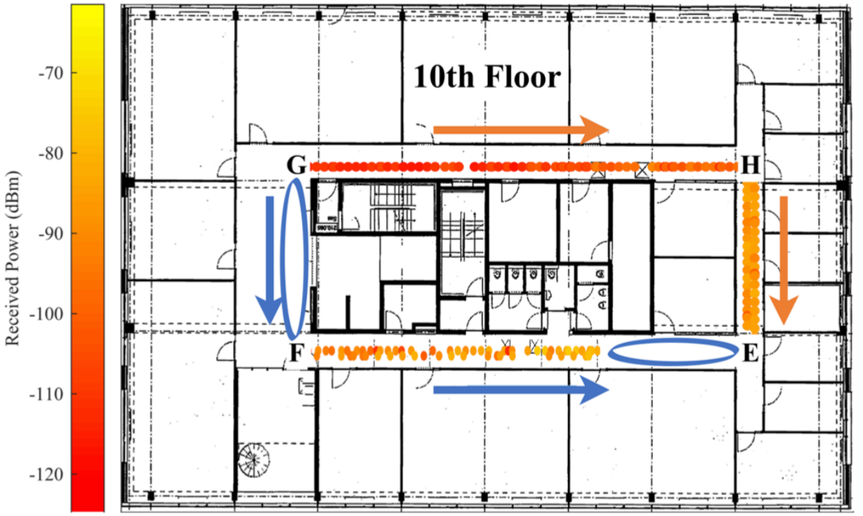
Body-worn node



Nodes on same floor



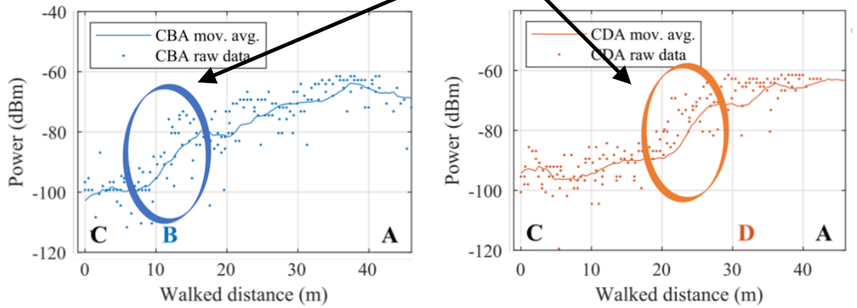
Nodes on different floors



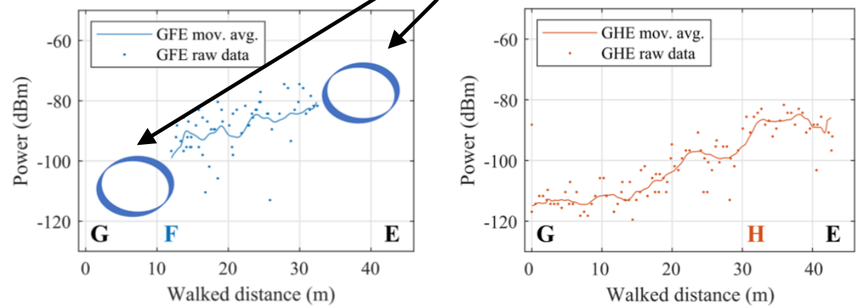
Static RX

Body-worn node

Influence of concrete core



Significant packet loss



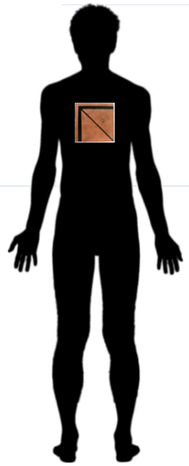
[11] T. Ameloot, P. Van Torre, and H. Rogier. Indoor Body-to-Body LoRa Link Characterization. In *2019 9th IEEE-APS Topical Conference on Antennas and Propagation in Wireless Communications*, September 2019.

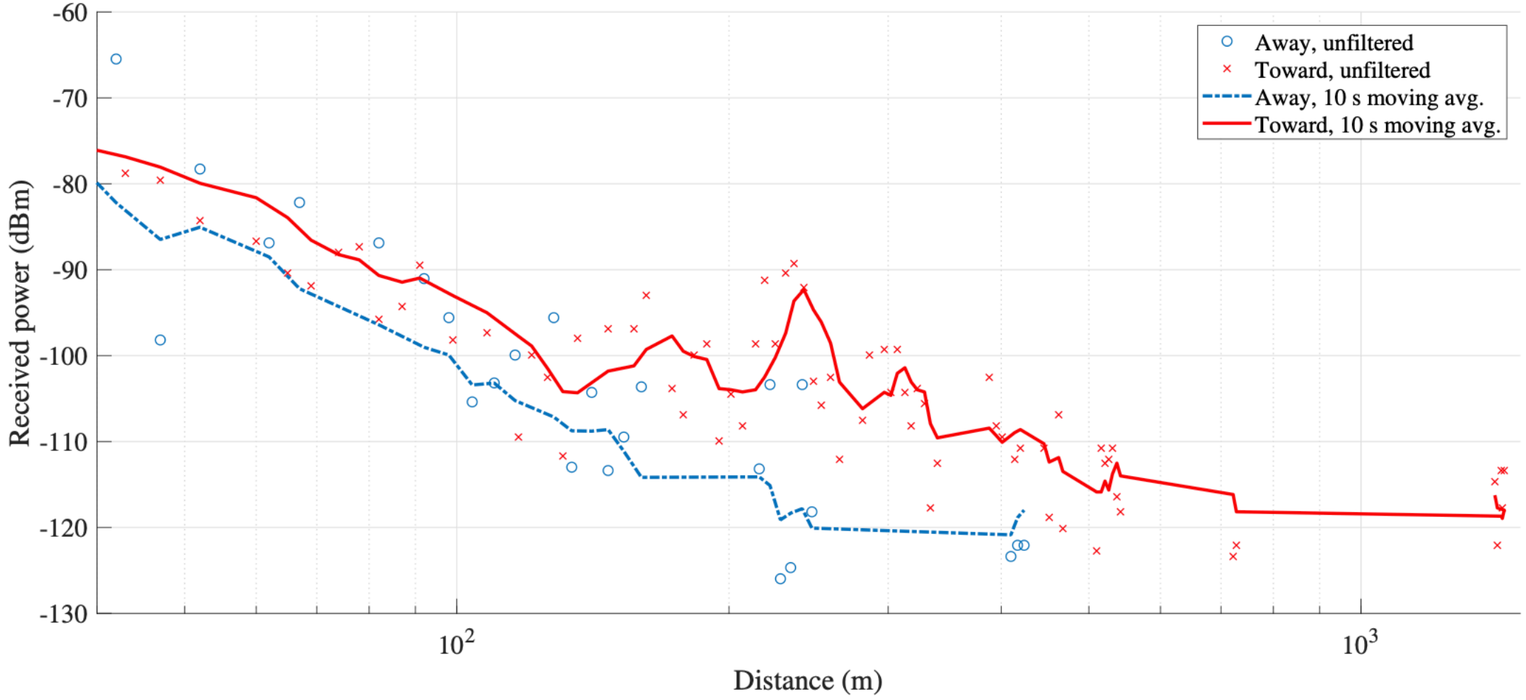
OUTDOOR BODY-TO-BODY

Range test: pointing nodes toward and away from each other

Walking TX

Body-worn node





Walking RX

Body-worn node

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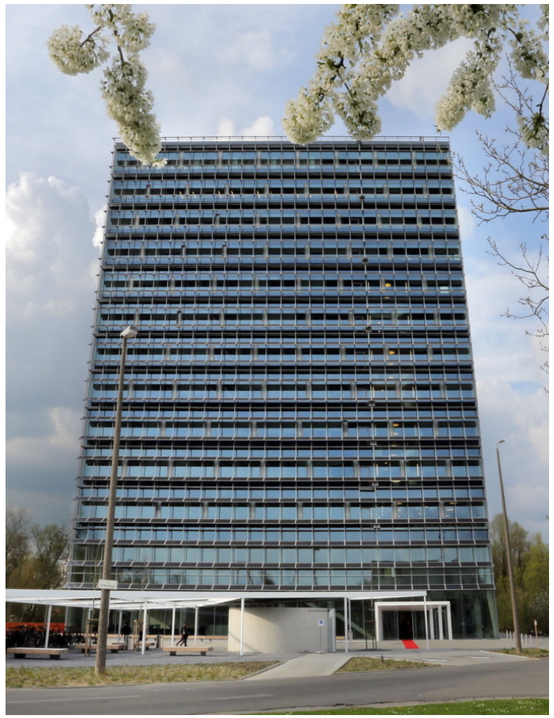
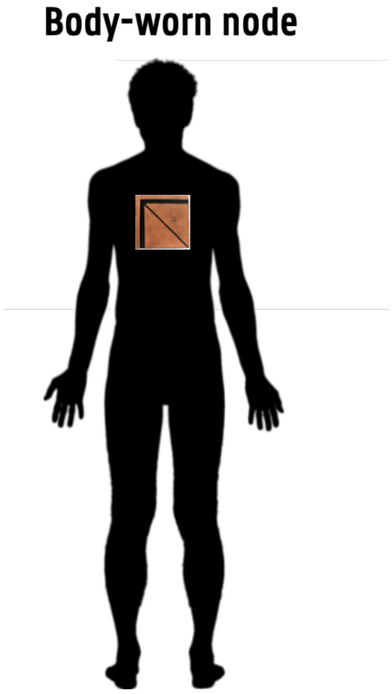
[12] P. Van Torre, T. Ameloot, and H. Rogier. Long-range body-to-body LoRa link at 868 MHz. In *2019 13th European Conference on Antennas and Propagation (EuCAP)*, pages 1–5, March 2019.

OUTDOOR BODY-TO-BASE-STATION





→ Test person moving in the larger area around base-station on top of 52m office building

Results

[10] T. Ameloot, P. Van Torre, and H. Rogier. LoRa Base-Station-to-Body Communication with SIMO Front-to-Back Diversity. *submitted to IEEE Transactions on Antennas and Propagation*.

→ Now available in Early Access on IEEE Explore

IMPROVING BODY-CENTRIC LORA PERFORMANCE

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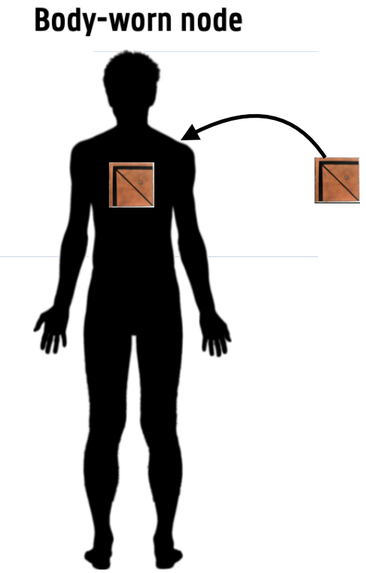
OUTDOOR BODY-TO-BASE-STATION: DIVERSITY

- Nodes on the front and back of the body:
- Fixed base-station:



- SIMO front-to-back diversity:
  - Selection combining (SC): significant link improvement w.r.t. SISO
  - Maximum ratio combining (MRC): limited improvement w.r.t. SC

Results

[10] T. Ameloot, P. Van Torre, and H. Rogier. LoRa Base-Station-to-Body Communication with SIMO Front-to-Back Diversity. *submitted to IEEE Transactions on Antennas and Propagation*.

→ Now available in Early Access on IEEE Explore

EXPERIMENTAL PARAMETER OPTIMIZATION

- Focus on spreading factor
- Trade-offs between:
  - Data-rate and coverage
  - Data-rate and probing rate
    - → Important for channel estimation
      - → Important for SF decision

[16] T. Ameloot, P. Van Torre, and H. Rogier. Experimental Parameter Optimization for Adaptive LoRa Modulation in Body-Centric Applications. In *Accepted for 2020 14th European Conference on Antennas and Propagation (EuCAP)*, March 2020.

SPREADING FACTOR VS EFFECTIVE CHANNEL THROUGHPUT

Optimal SF for highest channel throughput depends on SNR

SNR Range	Optimal SF
] −7 , ... [	7
] −9 , −7]	8
] −11, −9]	9
] −12, −11]	10
] −13, −12]	11
] ... , −13]	12

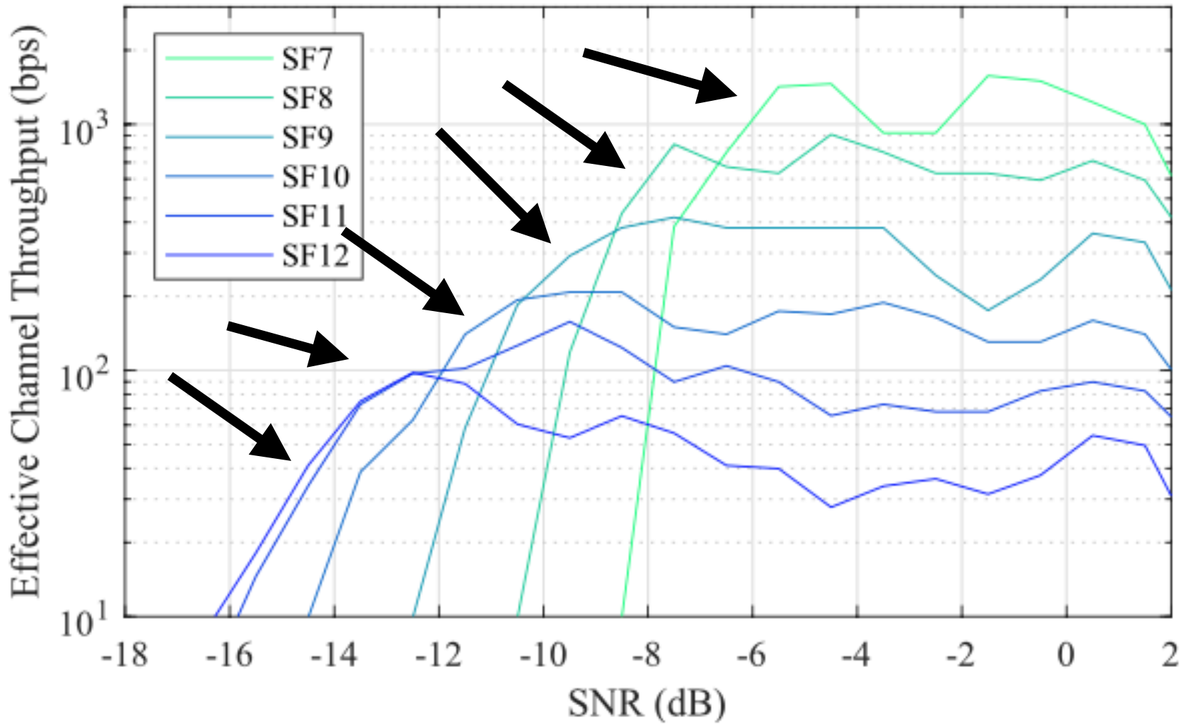


Fig. 7: Effective channel throughput as a fuction of the SNR (for continuous bursts with packet size = 1 byte).

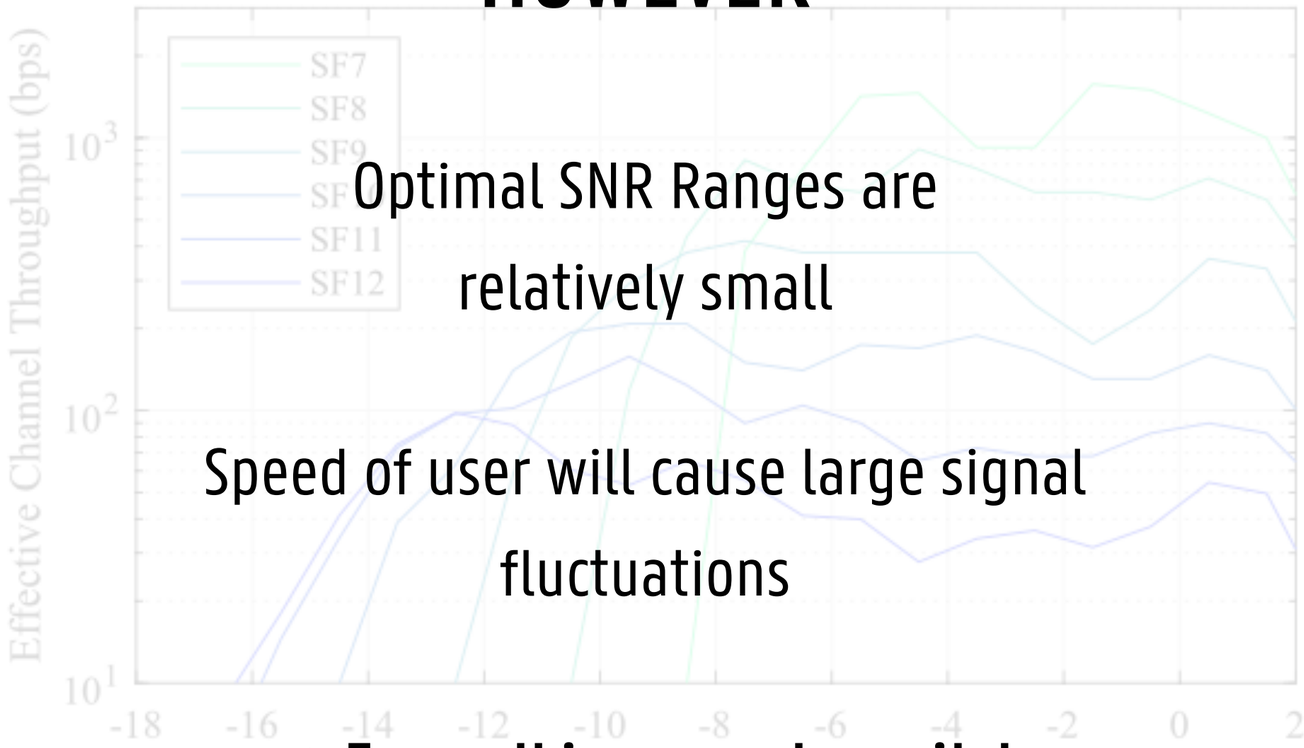
[16] T. Ameloot, P. Van Torre, and H. Rogier. Experimental Parameter Optimization for Adaptive LoRa Modulation in Body-Centric Applications. In *Accepted for 2020 14th European Conference on Antennas and Propagation (EuCAP)*, March 2020.

EFFECTIVE CHANNEL THROUGHPUT

Best channel throughput depends on SNR

SNR Range	Optimal SF
] −7 , ... [	7
] −9 , −7]	8
] −11, −9]	9
] −12, −11]	10
] −13, −12]	11
] ... , −13]	12

HOWEVER



Optimal SNR Ranges are relatively small

Speed of user will cause large signal fluctuations

⇒ For walking speeds: switch between 2 or 3 spreading factors

[16] T. Ameloot, P. Van Torre, and H. Rogier. Experimental Parameter Optimization for Adaptive LoRa Modulation in Body-Centric Applications. In *Accepted for 2020 14th European Conference on Antennas and Propagation (EuCAP)*, March 2020.

CONCLUSIONS

CONCLUSIONS

- Pro's:
  - Excellent propagation performance (indoor & outdoor) vs current solutions
  - Solid strategies exist to further improve performance (diversity & SF switching)

- Con's:
  - Low data-rate
  - Latency

All things considered:

LoRa = very good option for long-range body-centric communication

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