

# Outline

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2. State of the art

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5. x-Long paper

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# Why I started a PhD ?

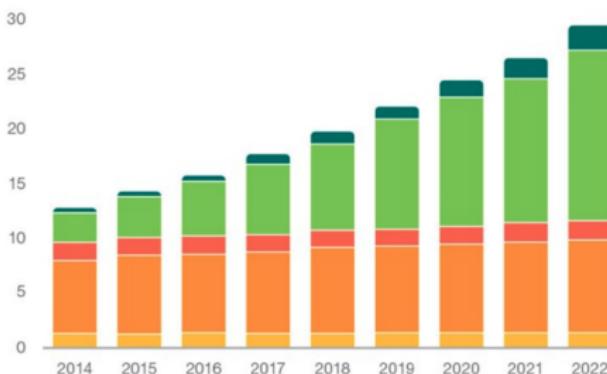
3 main reasons

- ➡ Research methodology lecture.
- ➡ Bac+5 in networking ? not really !
- ➡ Being paid to study and develop yourself !

# IoT devices

IoT devices are useless without a good communication capability

Connected devices (billions)



	2016	2022	CAGR
Wide-area IoT	0.4	2.1	30%
Short-range IoT	5.2	16	20%
PC/laptop/tablet	1.6	1.7	0%
Mobile phones	7.3	8.6	3%
Fixed phones	1.4	1.3	0%

16 billion      29 billion      10%



Figure 1. IoT devices [1].

# IoT applications requirements

Each application has its own communication requirements

Challenges/Applications	Grids	EHealth	Transport	Cities	Building
Resources constraints	✗	✓	✗	-	✗
Mobility	✗	-	✓	✓	✗
<b>Heterogeneity</b>	-	-	-	✓	✗
Scalability	✓	-	✓	✓	-
QoS constraints	-	-	✓	✓	✓
Data management	-	✗	✓	✓	-
Lack of Standardization	-	-	-	-	✓
Amount of attacks	✗	✗	✓	✓	✓
Safety	-	✓	✓	-	✓

Table 1. Main IoT challenges [2] [3]



Figure 2. IoT Applications.

# IoT platforms

IoT platforms is a chain of communication process

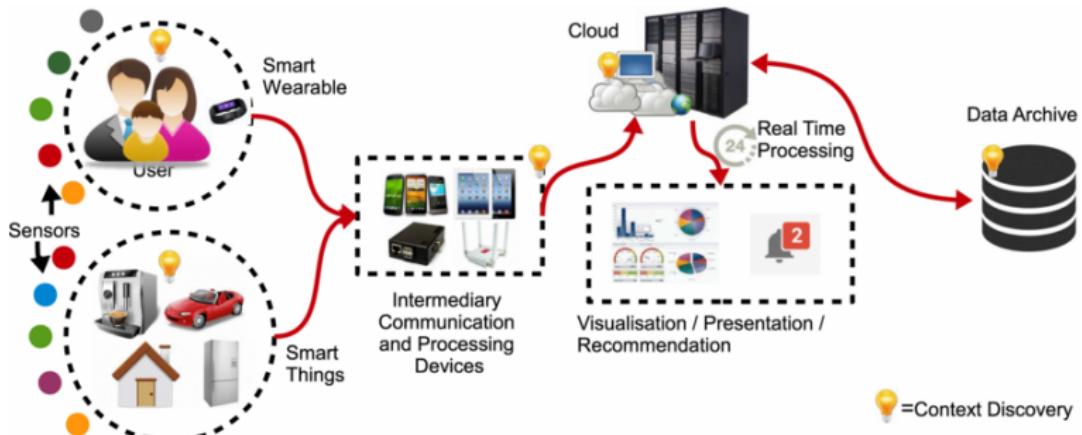


Figure 3. IoT platform.



Figure 4. IoT challenges.

# IoT applications requirements

## Context

Use Case	Packet rate [pkt/day]	Min success rate [Ps,min]	Payload Size [Byte]
Wearables	10	90	
Smoke Detectors	2	90	
Smart Grid	10	90	10-20
White Goods	3	90	
Waste Management	24	90	
VIP/Pet Tracking	48	90	
Smart Bicycle	192	90	
Animal Tracking	100	90	
Environmental Monitoring	5	90	
Asset Tracking	100	90	50
Smart Parking	60	90	
Alarms/Actuators	5	90	
Home Automation	5	90	
Machinery Control	100	90	
Water/Gas Metering	8	90	
Environmental Data Collection	24	90	
Medical Assisted Living	8	90	
Micro-generation	2	90	
Safety Monitoring	2	90	100-200
Propane Tank Monitoring	2	90	
Stationary Monitoring	4	90	
Urban Lighting	5	90	
Vending Machines Payment	100	90	
Vending Machines General	1	90	1K

Table 2. Application requirements for the use cases of interest [4] [3].

# IoT wireless communication

Wireless communication performance need to be evaluated to match applications requirements

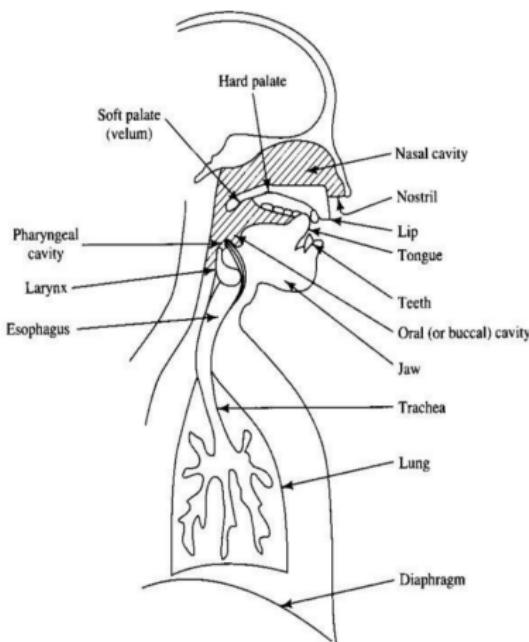


Figure 5. Human voice.

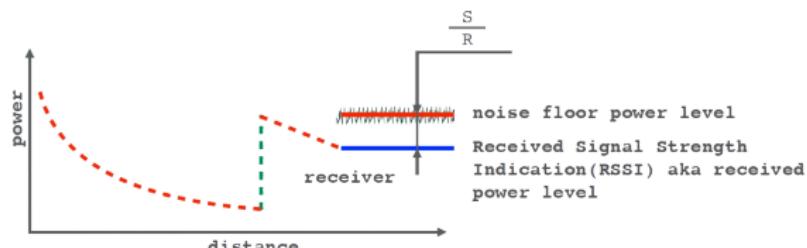


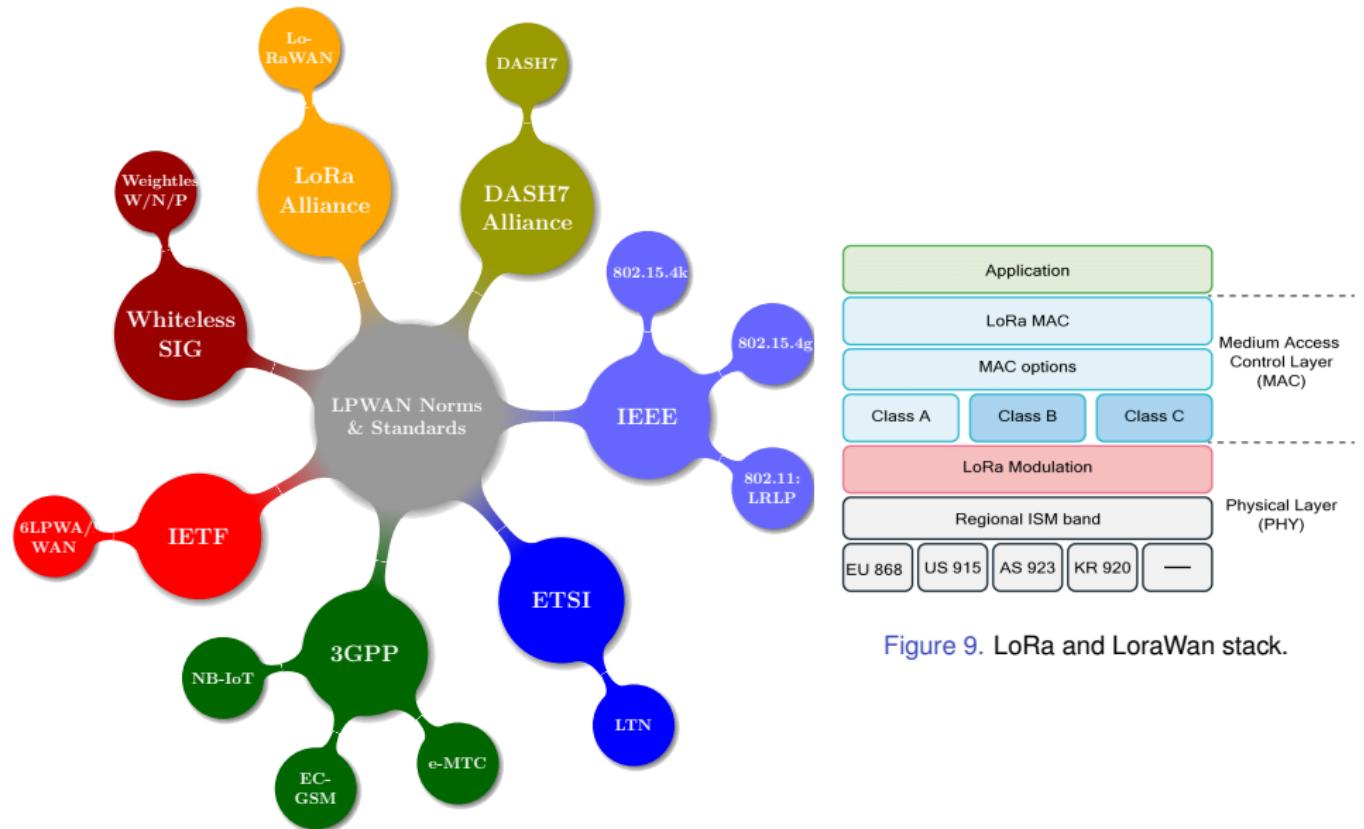
Figure 6. SNR & RSSI.



Figure 7. Time on air.

# IoT wireless communication

Exp: LPWAN in a new technology that satisfy IoT applications requirements



# Problematic

Network configuration is the problem number one actually

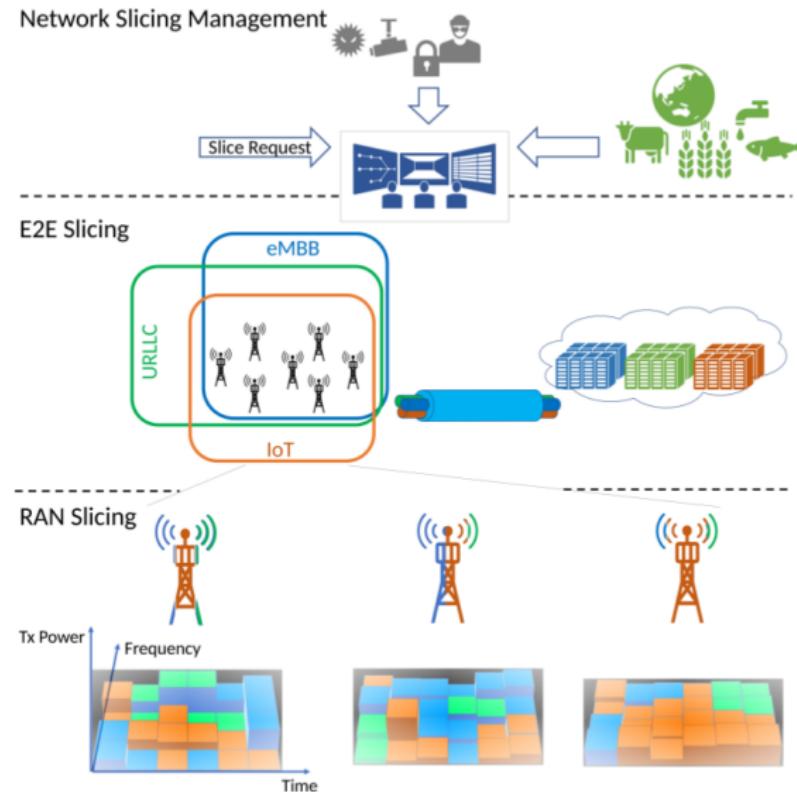


Figure 10. Key barriers in adopting IoT in the industry [5].

# Problematic

Network configuration is the problem number one actually

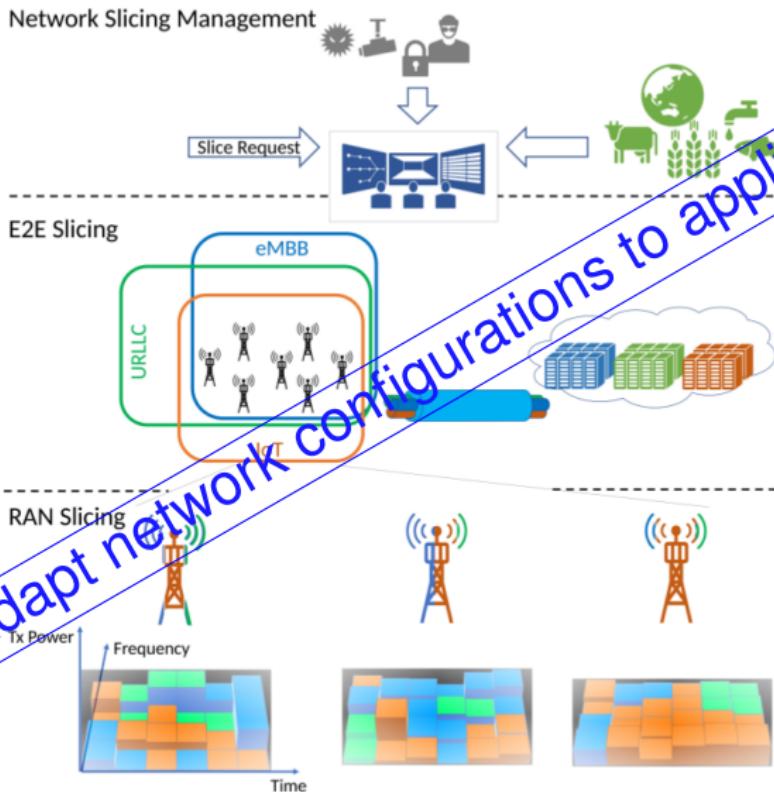


Figure 10. Key barriers in adopting IoT in the industry [5].

## Problematic

Where is the problem ?

- ➡ Some network configuration are static and not adaptive to the application
  - ⇒ Decision and optimisation problem..
  - ⇒ Various network access
  - ⇒ Various configuration of each network access
  - ⇒ Lack of selection tools
- ➡ Users have to select the network and the application
  - ⇒ How to select the **best** network.
  - ⇒ How to select the network required by the application.

# Network slicing

Exp: 4G/5G, Content provider (GAFA) want to be directly connected to users devices

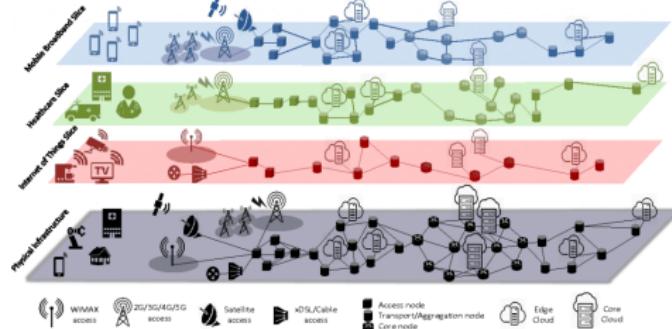


Figure 11. Network slicing [5].

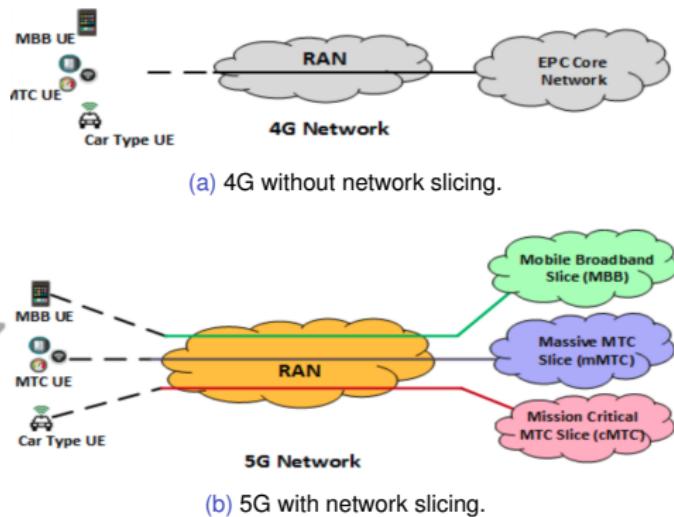


Figure 12. Network slicing concept [6].

# Conclusion

In the future, network administration function will disappear and will be replaced by a slice orchestrator

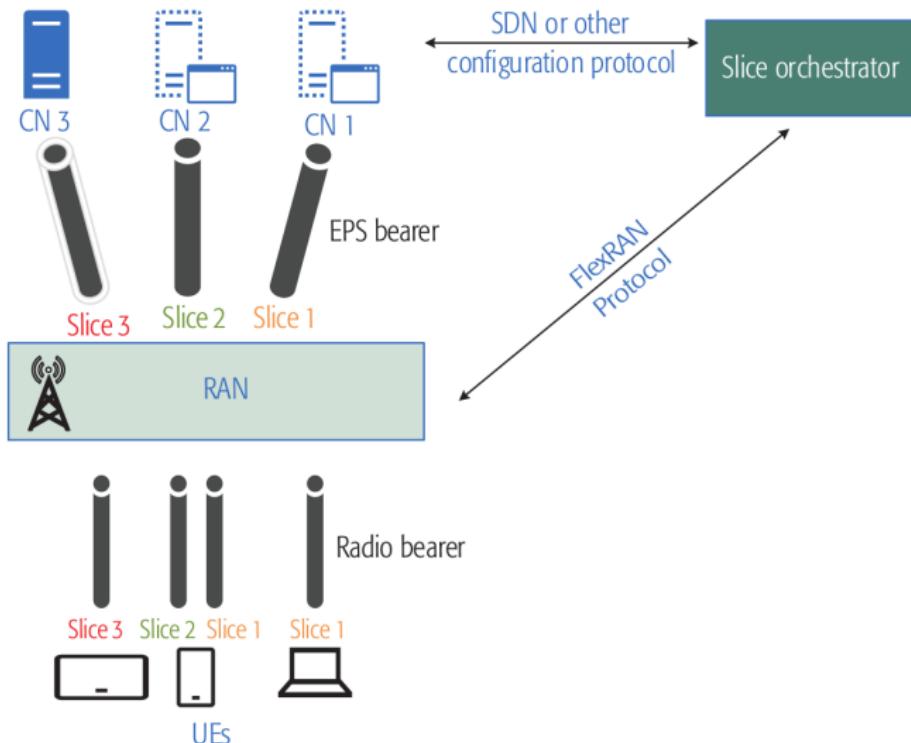


Figure 13. Slice orchestrator [7].

# Conclusion

In the future, network administration function will disappear and will be replaced by a slice orchestrator

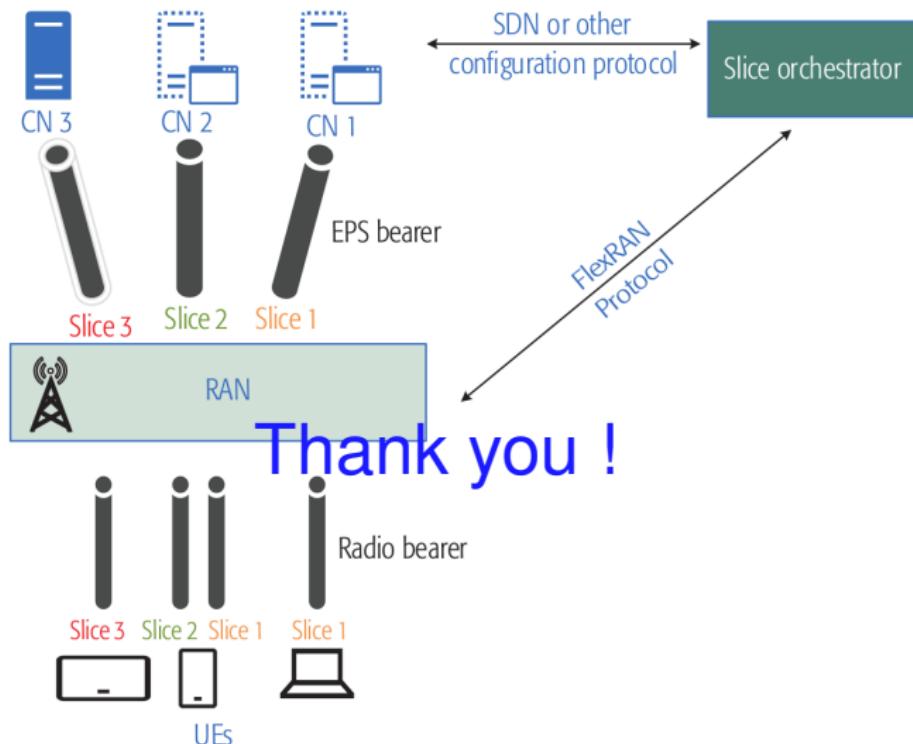


Figure 13. Slice orchestrator [7].

# Challenges

Where is the difficulty ?

- ➡ jh
  - ➡ Allow heterogeneous network to communicate
  - ➡ QoS Analysis
  - ➡ Threats
- ➡ How to select the **best** access point
  - ➡ Allow heterogeneous network to communicate
  - ➡ QoS Analysis
  - ➡ Threats
- ➡ Reasonable and acceptable delay before the decision appears.
- ➡ Cope with the different view points and goals of the operators and the users.
- ➡ React to the changing environment conditions.
- ➡ Allow any type of inputs and to be applicable to any type of ANs.
- ➡ Handle the increasing number of RATs and the large number of criteria.

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## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 3. An example table.

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## Discussion

- ➡ a
- ➡ b

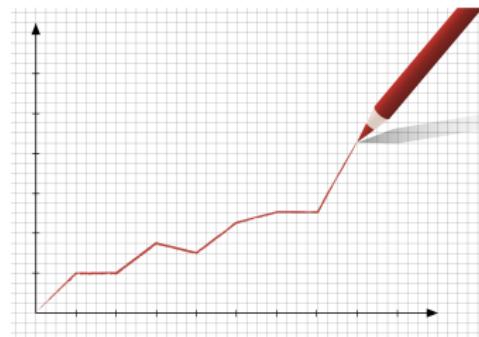


Figure 14. .

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# Problem statement

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- ➡ a
- ➡ b

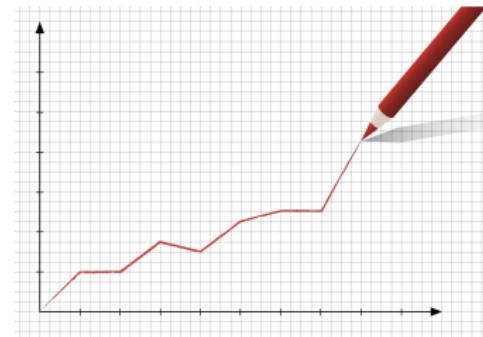


Figure 15. .

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## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 4. An example table.

## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 5. An example table.

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... (step 1)

Methods



... (step 2)

Methods



## ... (step 3)

### Methods



... (step 4)

Methods



# Results

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# Experimentation

## Experimentation

- ➡ a
- ➡ b

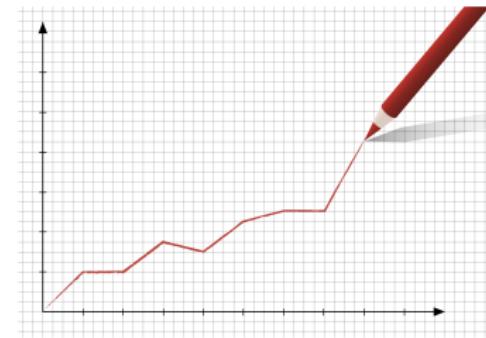


Figure 16. .

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## Comparison

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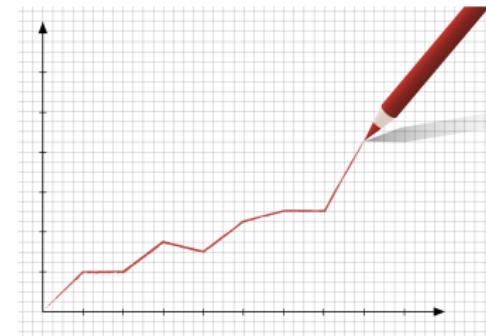


Figure 17. .

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## Discussion

- ➡ a
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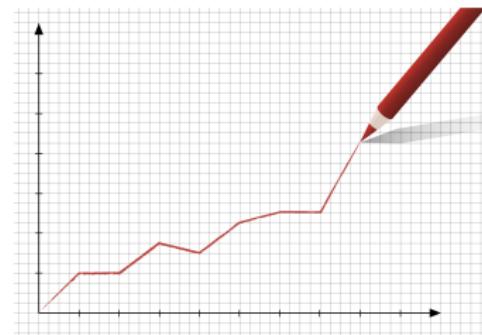


Figure 18. .

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# Problem statement

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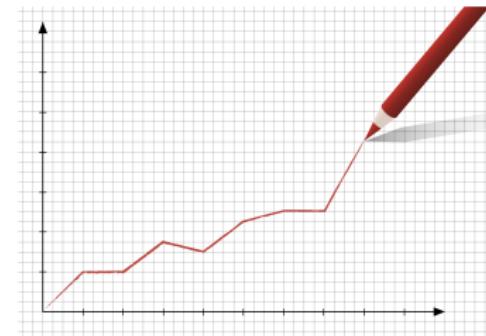


Figure 19. .

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## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 7. An example table.

## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 8. An example table.

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### Methods



... (step 4)

Methods



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## Experimentation

- ➡ a
- ➡ b

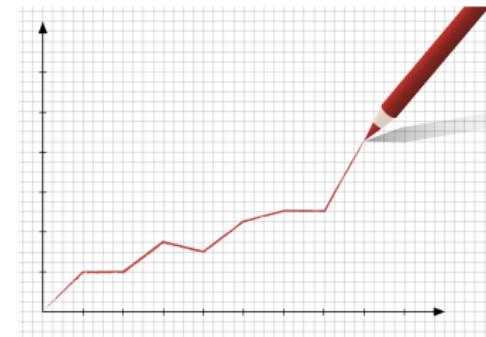


Figure 20. .

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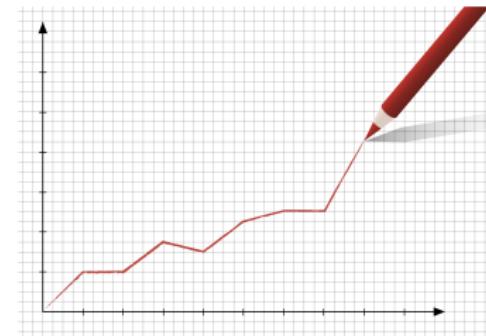


Figure 21. .

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## Discussion

- ➡ a
- ➡ b

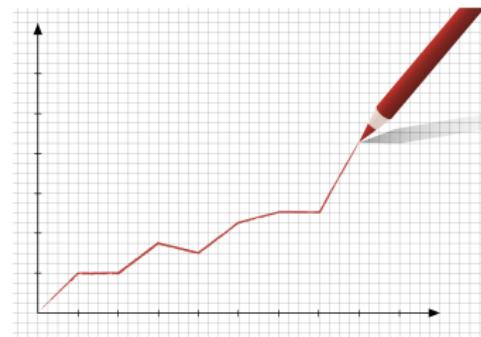


Figure 22. .

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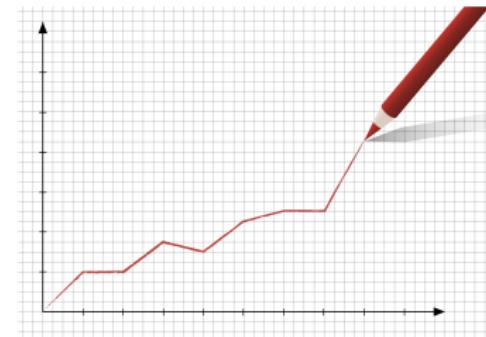


Figure 23. .

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## Related work

### Comparison

Paper	A1	A2	A3	A4
[8]				

Table 10. An example table.

## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 11. An example table.

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... (step 1)

Methods



## ... (step 2)

### Methods



## ... (step 3)

### Methods



## ... (step 4)

### Methods



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## Comparison


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# Experimentation

## Experimentation

- ➡ a
- ➡ b

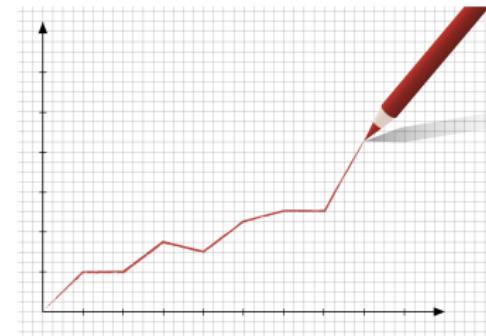


Figure 24. .

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## Comparison

- ➡ a
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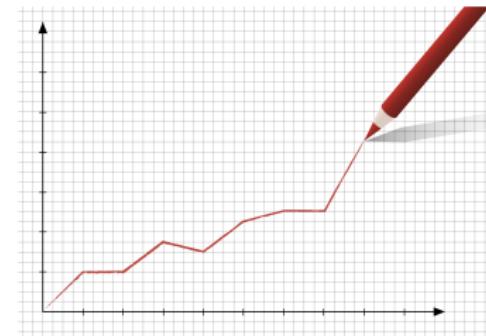


Figure 25. .

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## Discussion

- ➡ a
- ➡ b

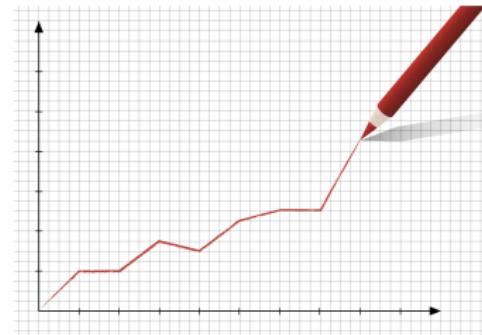


Figure 26. .

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# Problem statement

Introduction<sup>2</sup> ?

## Parameters

- Bandwidth ( $BW$ )
- Spreading Factor ( $SF$ )
- Coding Rate ( $CR$ )
- Transmission Power ( $Tx$ )

## Metrics

- Receiver Sensitivity ( $RS$ )
- Signal Noise Rate ( $SNR$ )
- Data Rate ( $DR$ )
- Air Time ( $AT$ )
- Payload length ( $PktL$ )

Setting	Values	Rewards	Costs
$BW$	7.8 $\rightarrow$ 500kHz	$DR$	$RS, Range$
$SF$	$2^6 \rightarrow 2^{12}$	$RS, Range$	$DR, SNR, PktL, Tx$
$CR$	4/5 $\rightarrow$ 4/8	Resilience	$PktL, Tx, AT$
$Tx$	-4 $\rightarrow$ 20dBm	$SNR$	$Tx$

Table 13.<sup>1</sup>

<sup>1</sup>M. Cattani, C. Boano, and K. Römer, " An Experimental Evaluation of the Reliability of Lora Long-Range Low-Power Wireless Communication ", *Journal of Sensor and Actuator Networks*, vol. 6, no. 2, p. 7, 2017, 00042.

<sup>2</sup>dimartino\_internet\_2018.

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# Multi-Armed-Bandit Algorithm

## Related work

- ➡ Arms:  $K = 1, \dots, K$
- ➡ Decision:  $T = 1, \dots, T$
- ➡ Reward:  $X_t^k$  with  $\mu_t^k = E [X_t^k]$ 
  - ➡ Best reward:  $X_t^*$  with  $\mu_t^* = \max \mu_t^k, k \in K$

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# Genetic Algorithm

Related work [alkhawlani\\_access\\_2008a](#)

- ➡ Heterogeneous wireless network: (RAT 1 ,RAT 2 ,...,RAT n)
- ➡ Criteria up to i ( $c_1, c_2, \dots, c_i$ ) the operators, the applications, and the network conditions.
- ➡
- ➡ The different sets of scores ( $d_1, d_2, \dots, d_i$ ) are sent to the MCDM in the second component.
- ➡ GA component assigns a suitable weight ( $w_1, w_2, \dots, w_i$ )

# Genetic Algorithm

## Related work

- S = SF12, BW125, 4/8, 17 dBm
- Input:
  - Problem:  $f(x) = \max(x^2)$ ,  $x \in [0, 32]$ 
    - \*  $x_1 : 01101_b$
    - \*  $x_2 : 11000_b$
    - \*  $x_3 : 01000_b$
    - \*  $x_4 : 10011_b$
- Method: Genetic algorithm
  - Generate a set of random possible solution
  - Test each solution and see how good it is (ranking)
    - \* Remove some bad solutions
    - \* Duplicate some good solutions
    - \* Make small changes to some of them (Crossover, Mutation)
- Output:
  - $x_1 : 01101$  (169) (14.4)
  - $x_2 : 11000$  (576) (49.2)
  - $x_3 : 01000$  (64) (5.5)
  - $x_4 : 10011$  (361) (30.9)

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# Marcov chain

Related work

$$V(s, \pi) = \mathbb{E}_s^\pi \left( \inf_{k=0}^{\infty} \gamma^k \cdot r(s_k, a_k) \right), s \in \mathbb{S} \quad (1)$$

$$r(s_k, a_k) = G_k \cdot PRR(a_k) \quad (2)$$

$$\pi^* = \arg \max_{\pi} V(s, \pi) \quad (3)$$

$$PRR = (1 - BER)^L \quad (4)$$

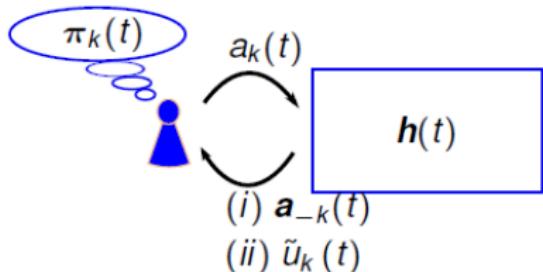
$$BER = 10^{\alpha e^{\beta SNR}} \quad (5)$$

# Marcov chain

Related work

Learning Iterative Steps:

- **Choose** action  $a_k(t) \sim \pi_k(t)$ .
- **Observe** game outcome, e.g.,  
 $a_{-k}(t)$   
 $u_k(a_k(t), a_{-k}(t))$ .
- **Improve**  $\pi_k(t+1)$ .



Thus, we can expect that:  $\forall k \in \mathcal{K}$ ,

$$\pi_k(t) \xrightarrow{t \rightarrow \infty} \pi_k^* \quad (1)$$

$$\bar{u}_k(\pi_k(t), \pi_{-k}(t)) \xrightarrow{t \rightarrow \infty} \bar{u}_k(\pi_k^*, \pi_{-k}^*) \quad (2)$$

where,  $\pi^* = (\pi_1^*, \dots, \pi_K^*)$  is a NE strategy profile.

Figure 27..

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# Game theory

## Related work

- ➡ Players:  $K = \{1, \dots, K\}$
- ➡ Strategies:  $S = S_1 \times \dots \times S_K$ 
  - ➡  $S_k$  is the strategy set of the  $k^{\text{th}}$  player.
- ➡ Rewards:  $u_k : S \rightarrow R_+$  and is denoted by  $r_k(s_k, s_{-k})$ 
  - ➡  $s_{-k} = (s_1, \dots, s_{k-1}, s_{k+1}, \dots, s_K) \in S_1 \times \dots \times S_{k-1} \times S_{k+1} \times \dots \times S_K$

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## ... (step 2)

### Methods

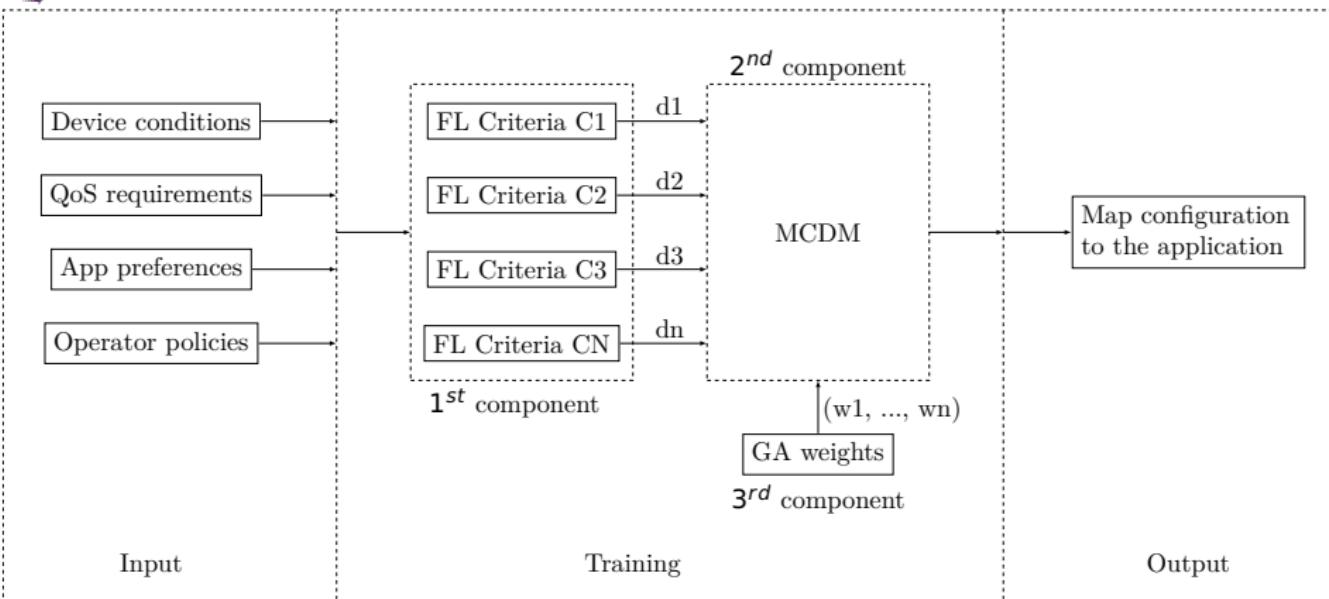


Figure 28. HH.

## ... (step 3)

### Methods



## ... (step 4)

### Methods



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# Contribution

## Contributions

- ➡ **Use cases (Application Requirements)**
  - Smart building: Voice, Images, Text.
- ➡ **Environments**
  - Rural/Urban
  - Static/Mobile
  - Temperature
- ➡ **Scenarios**
  - Application protocol (MQTT, COAP, XMPP)
  - Network protocol (Star, Mesh)
  - MAC protocol (LoRaWan, Sigfox, ...)
- ➡ **Input:**
  - Service QoS metrics requirements
  - MAC configuration (SF, CR, BW, ...)
  - Network QoS metrics

- ➡ **Algorithms:**
  - MADM
    - \* Ranking methods
    - \* Ranking & weighted methods
  - Game theory
    - \* Users vs users
    - \* Users vs networks
    - \* Networks vs network
  - Fuzzy logic
    - \* as a score method
    - \* another theory
  - Utility function
    - \* 1
    - \* 2
- ➡ **Outputs:**
  - Ranked networks

# Technical choice

## Implementation

- ➡ ZOLERTIA RE-MOTE
  - ➡ Low consumption component
  - ➡ ADC port for placing sensors on it
- ➡ CONTIKI OS
  - ➡ Operating system for wireless and low power development
  - ➡ Support for newer standards (6LowPAN, RPL, CoAP, MQTT)
- ➡ 6LowPAN
  - ➡ Based on IPv6 and IEEE 802.15.4
  - ➡ IPv6-based network with low power consumption
  - ➡ Ability to create a mesh network
- ➡ Sending packages
  - ➡ UDP in the 6LowPAN network
  - ➡ MQTT between the cloud platform and the router

# Experimentation

## Experimentation

- ➡ a
- ➡ b

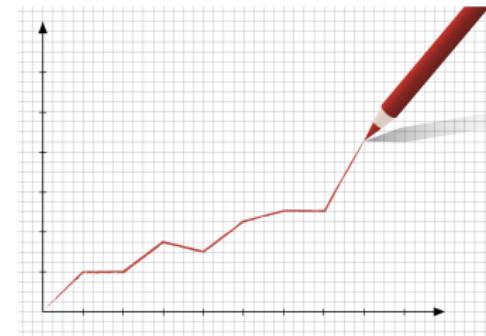


Figure 29. .

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# Results

## Comparison

- ➡ a
- ➡ b

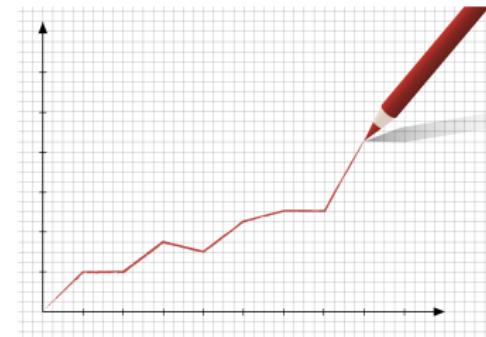


Figure 30. .

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## Discussion

- ➡ a
- ➡ b

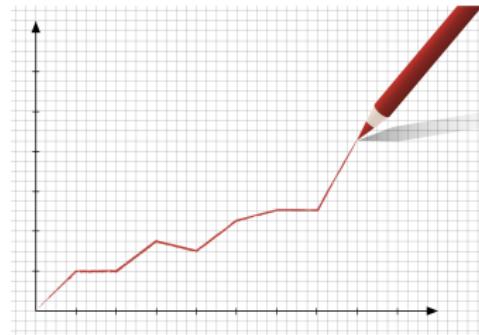


Figure 31..

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# Problem statement

## Introduction

- ➡ a
- ➡ b

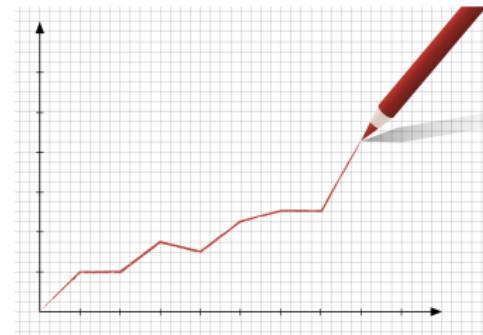


Figure 32. .

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## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 14. An example table.

## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 15. An example table.

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... (step 1)

Methods



... (step 2)

Methods



## ... (step 3)

### Methods



## ... (step 4)

### Methods



# Results

## Comparison


Table 16

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# Experimentation

## Experimentation

- ➡ a
- ➡ b

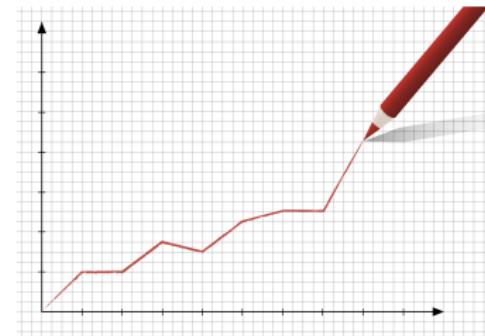


Figure 33. .

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# Results

## Comparison

- ➡ a
- ➡ b

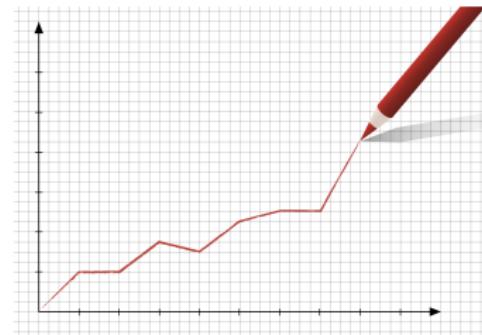


Figure 34. .

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## Discussion

- ➡ a
- ➡ b

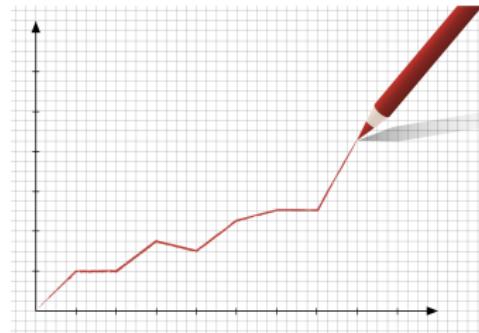


Figure 35. .

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# Problem statement

## Introduction

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- ➡ b

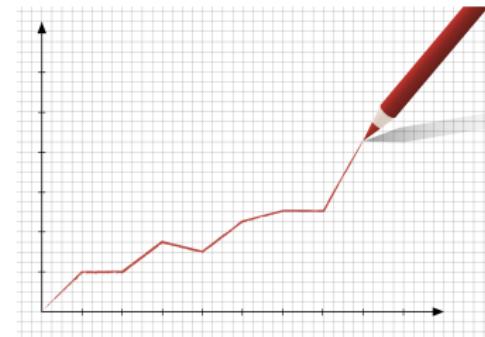


Figure 36. .

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## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 17. An example table.

## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 18. An example table.

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... (step 1)

Methods



... (step 2)

Methods



... (step 3)

Methods



... (step 4)

Methods



# Results

## Comparison


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# Experimentation

## Experimentation

- ➡ a
- ➡ b

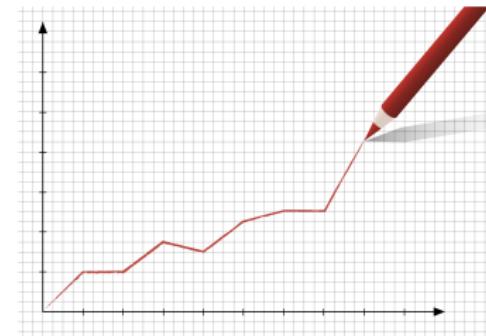


Figure 37. .

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# Results

## Comparison

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- ➡ b

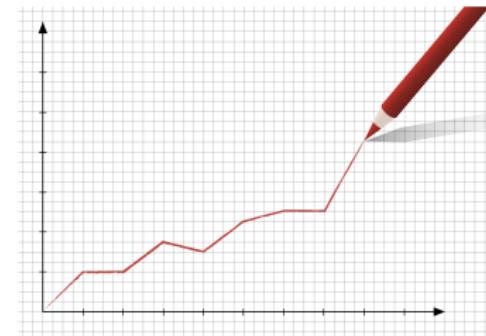


Figure 38. .

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## Discussion

- ➡ a
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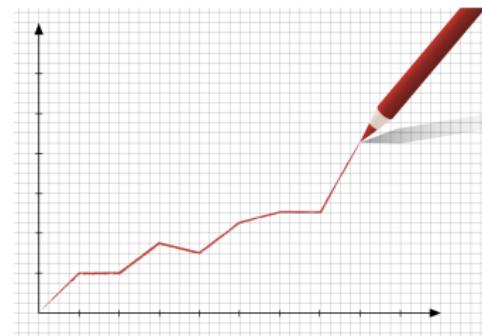


Figure 39. .

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# Problem statement

## Introduction

- ➡ a
- ➡ b

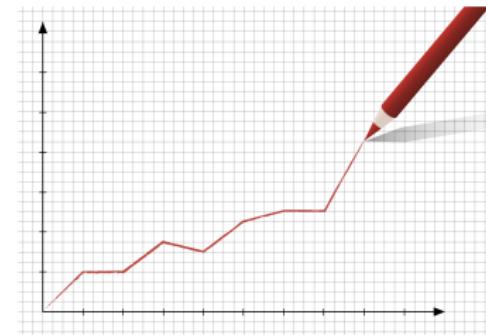


Figure 40. .

# Outline

1. Introduction

2. State of the art

3. x-Testbed

4. x-Sentilo

5. x-Long paper

6. Genetic Algorithm For LoRa  
Transmission Parameter Selection

7. Emergency Evacuation  
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8. Template

9. UTLC

10. Conclusion

11. Survey Platforms

1. Problem statement
2. Related work
3. Contagion process
4. Experimentation
5. Results exploitation
6. Discussion

## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 20. An example table.

## Related work

### Comparison

Paper	A1	A2	A3	A4

Table 21. An example table.

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6. Discussion

... (step 1)

Methods



... (step 2)

Methods



## ... (step 3)

### Methods



... (step 4)

Methods



# Results

## Comparison


Table 22



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- 4. Experimentation**
5. Results exploitation
6. Discussion

# Experimentation

## Experimentation

- ➡ a
- ➡ b

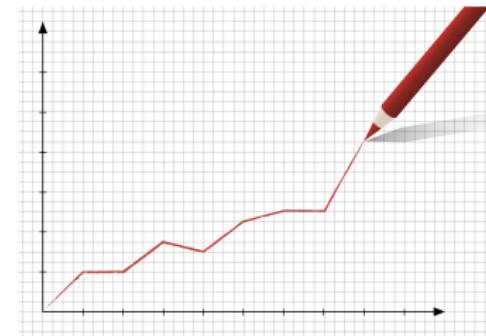


Figure 41. .

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- 5. Results exploitation**
6. Discussion

# Results

## Comparison

- ➡ a
- ➡ b

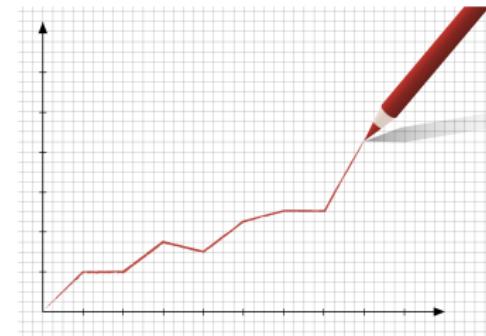


Figure 42. .

# Outline

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4. Experimentation
5. Results exploitation
- 6. Discussion**

## Discussion

- ➡ a
- ➡ b

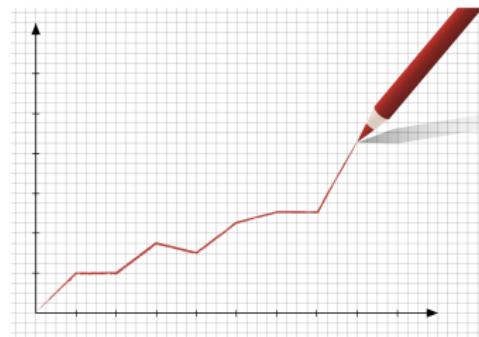


Figure 43. .

# Outline

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# Conclusion

Our main goal was

- ▶ .
- ▶ .

Our main contribution was

- ▶ .
- ▶ .

Our main results was

- ▶ .
- ▶ .

# Future Challenges

## Conclusion

Our future goal was

- ▶ .
- ▶ .

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