Outline

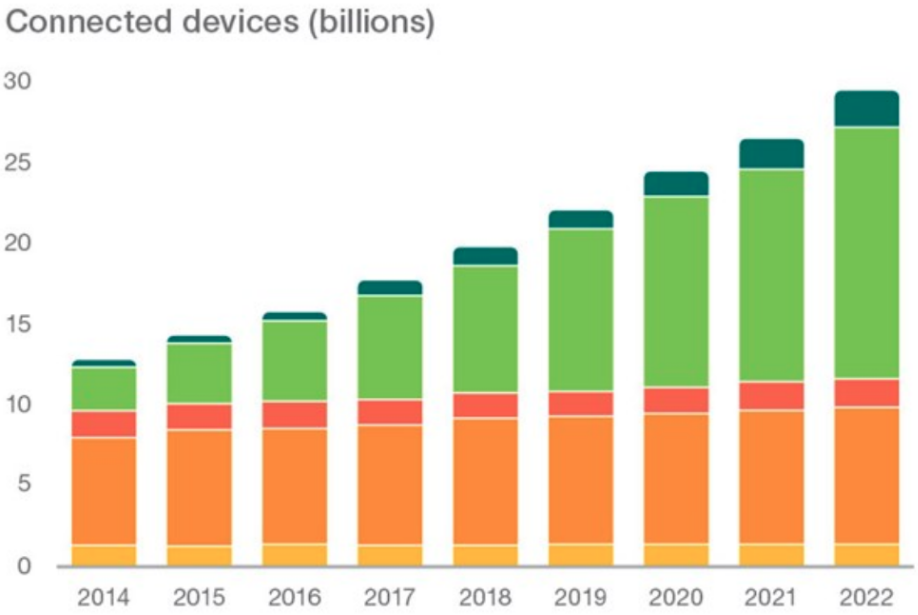
Why I started a PhD ?

3 main reasons

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

IoT devices

IoT devices are useless without a good communication capability



	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%

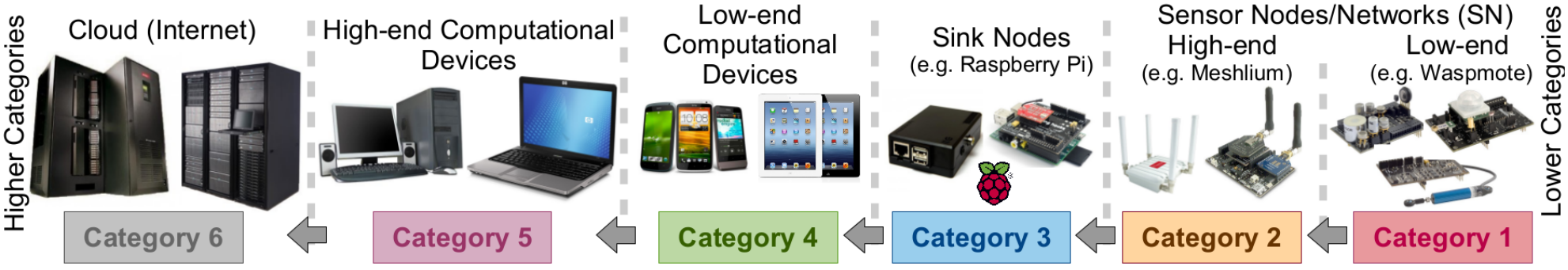


Figure 1. IoT devices [1].

IoT applications requirements

Each application has its own communication requirements

Challenges/Applications	Grids	EHealth	Transport	Cities	**Building**
Resources constraints	✗	✓	✗	-	✗
Mobility	✗	-	✓	✓	✗
Heterogeneity	-	-	-	✓	✗
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

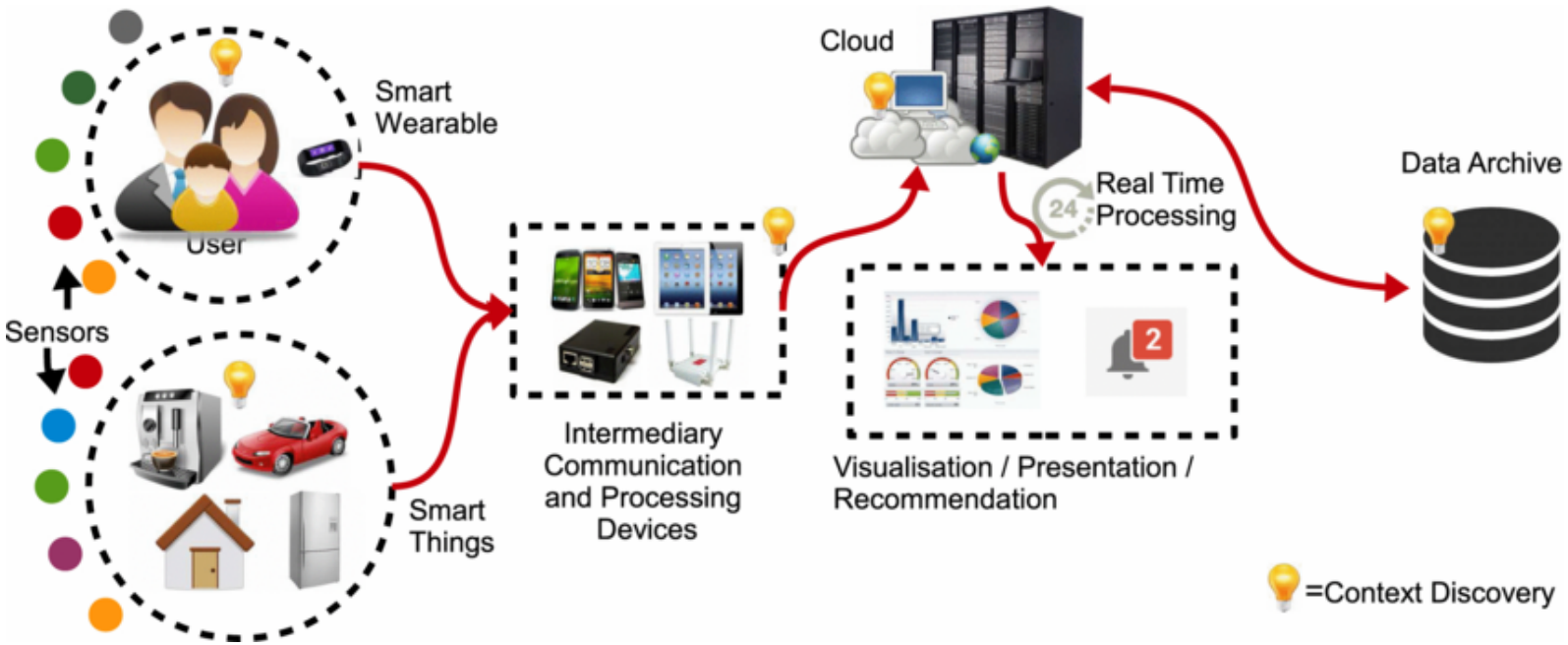


Figure 3. IoT platform.

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

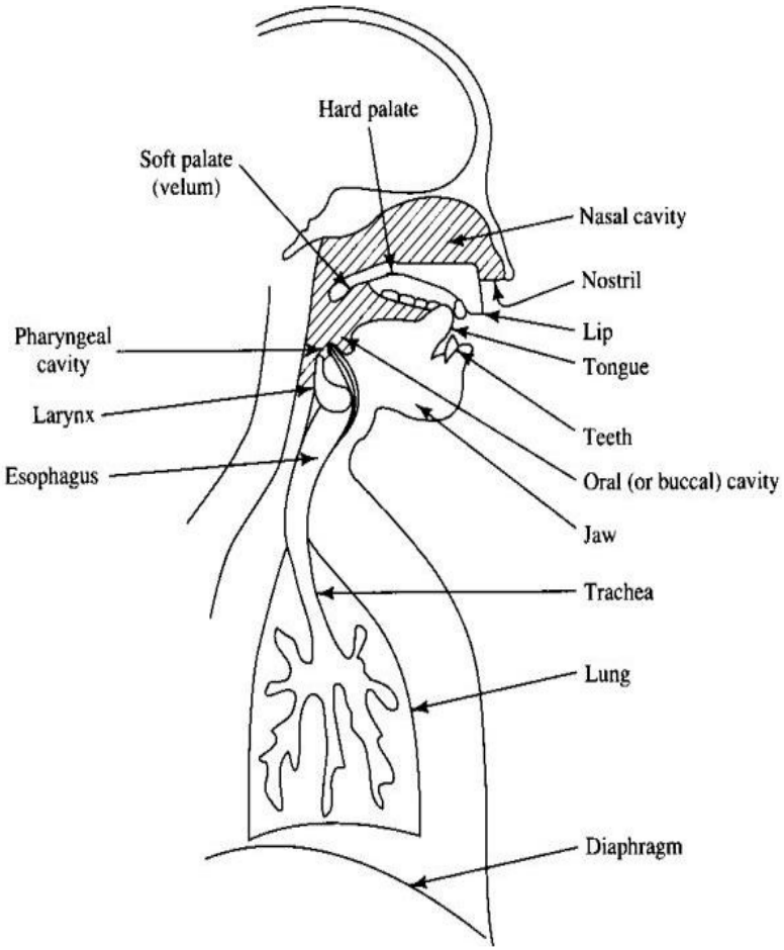


Figure 5. Human voice.

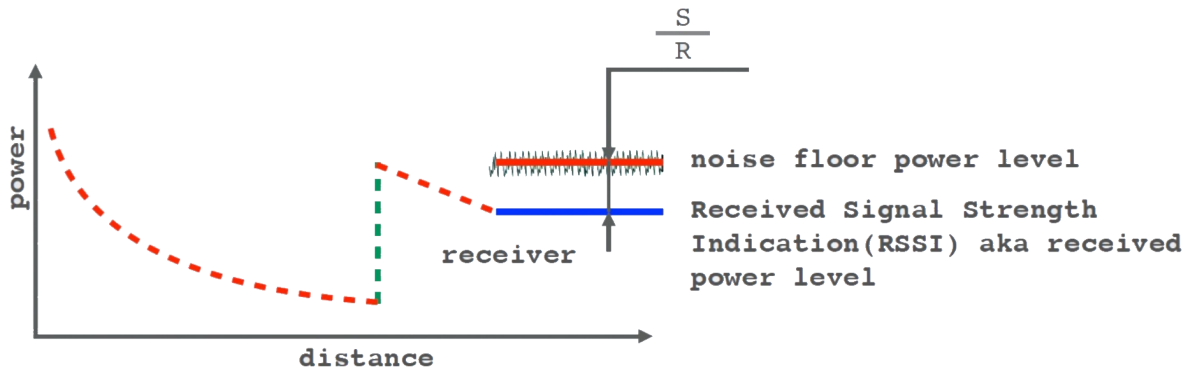


Figure 6. SNR & RSSI.

Figure 7. Time on air.

Problem statement

Introduction[2] ?

- 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 ➠ 500*kHz*	*DR*	*RS*, Range
SF	2^6 ➠ 2^{12}	*RS*, Range	*DR*, *SNR*, *PktL*, *Tx*
CR	$4/5$ ➠ $4/8$	Resilience	*PktL*, *Tx*, *AT*
Tx	-4 ➠ 20*dBm*	*SNR*	*Tx*

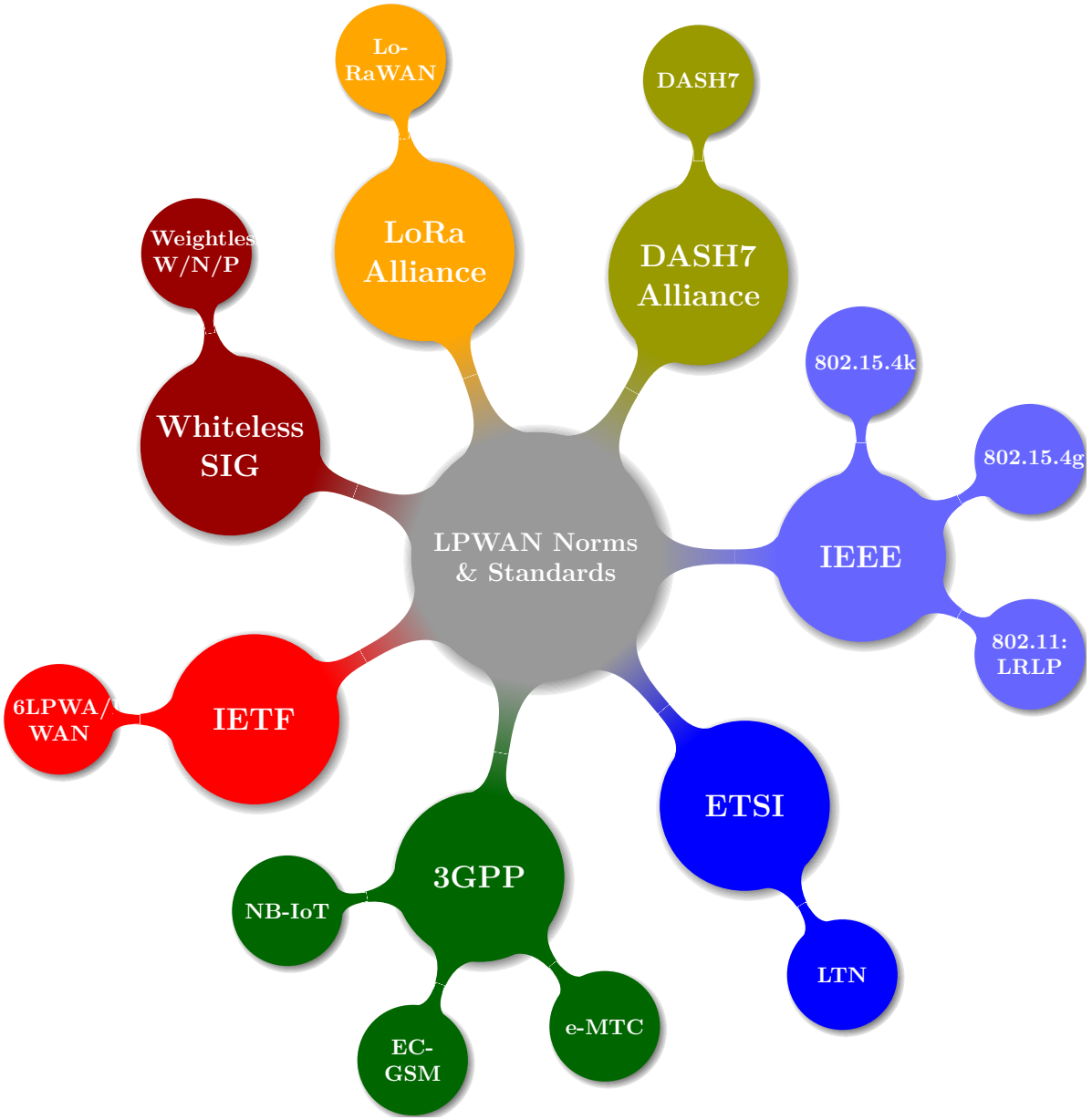
Table 3. [1]

[1] 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.

[2] **dimartino_internet_2018**.

IoT wireless communication

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



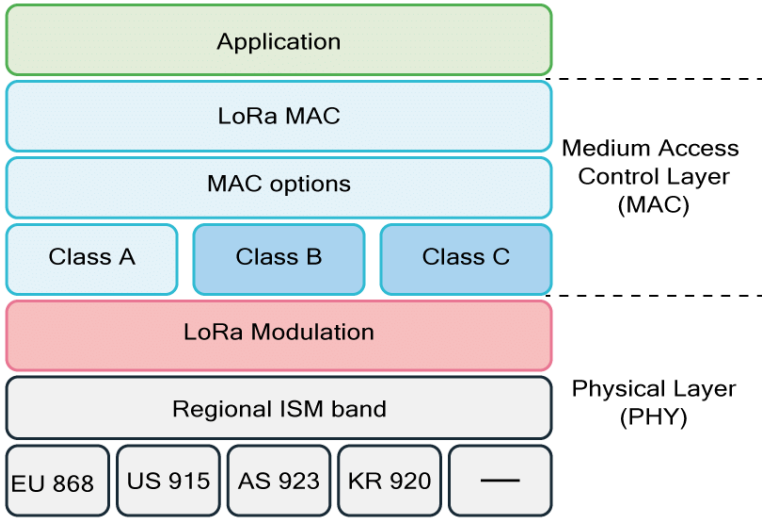


Figure 9. LoRa and LoraWan stack.

Problematic

One size fits all problem: 1) Many configurations, 2) Diversity of service requirements

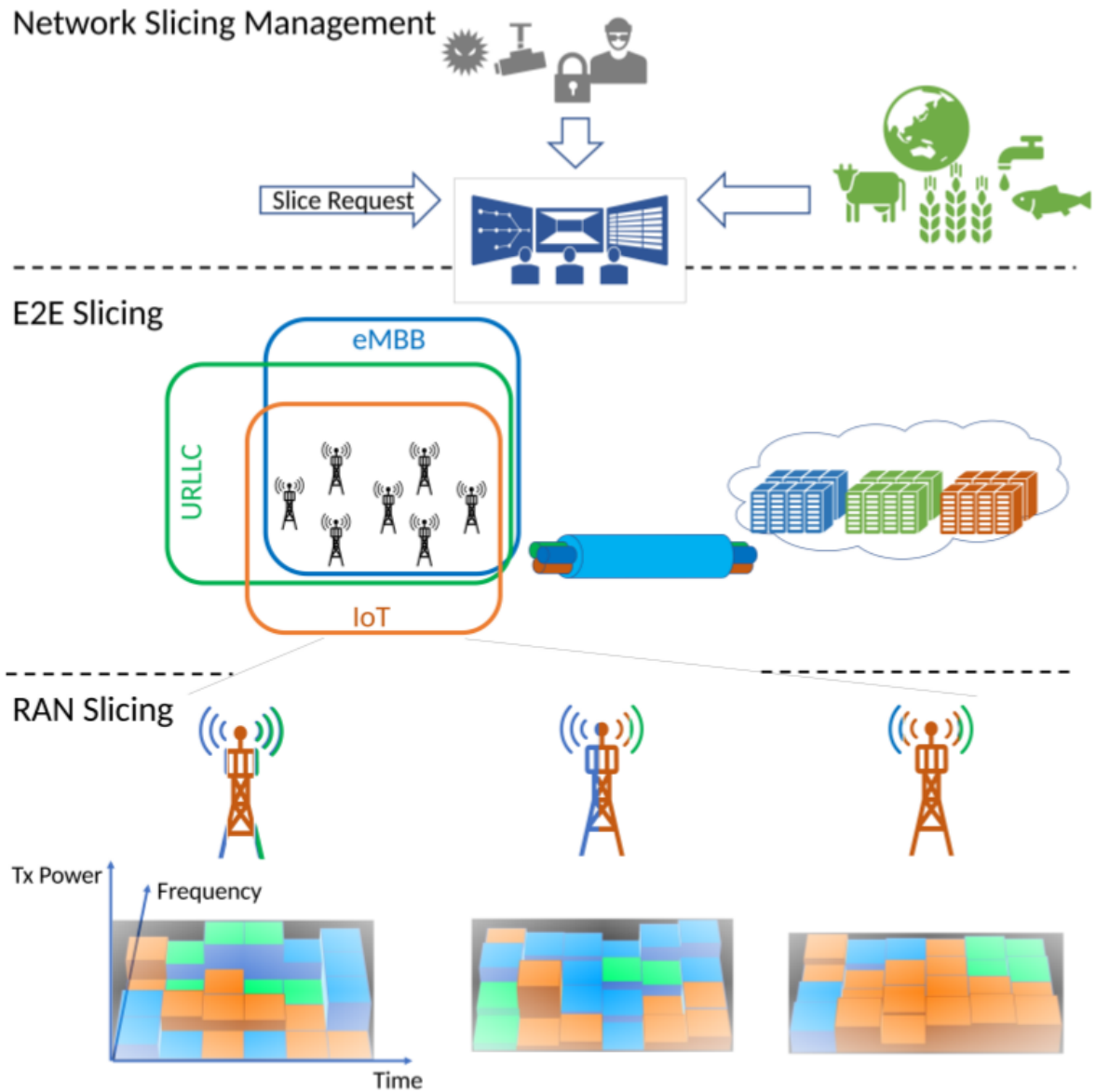
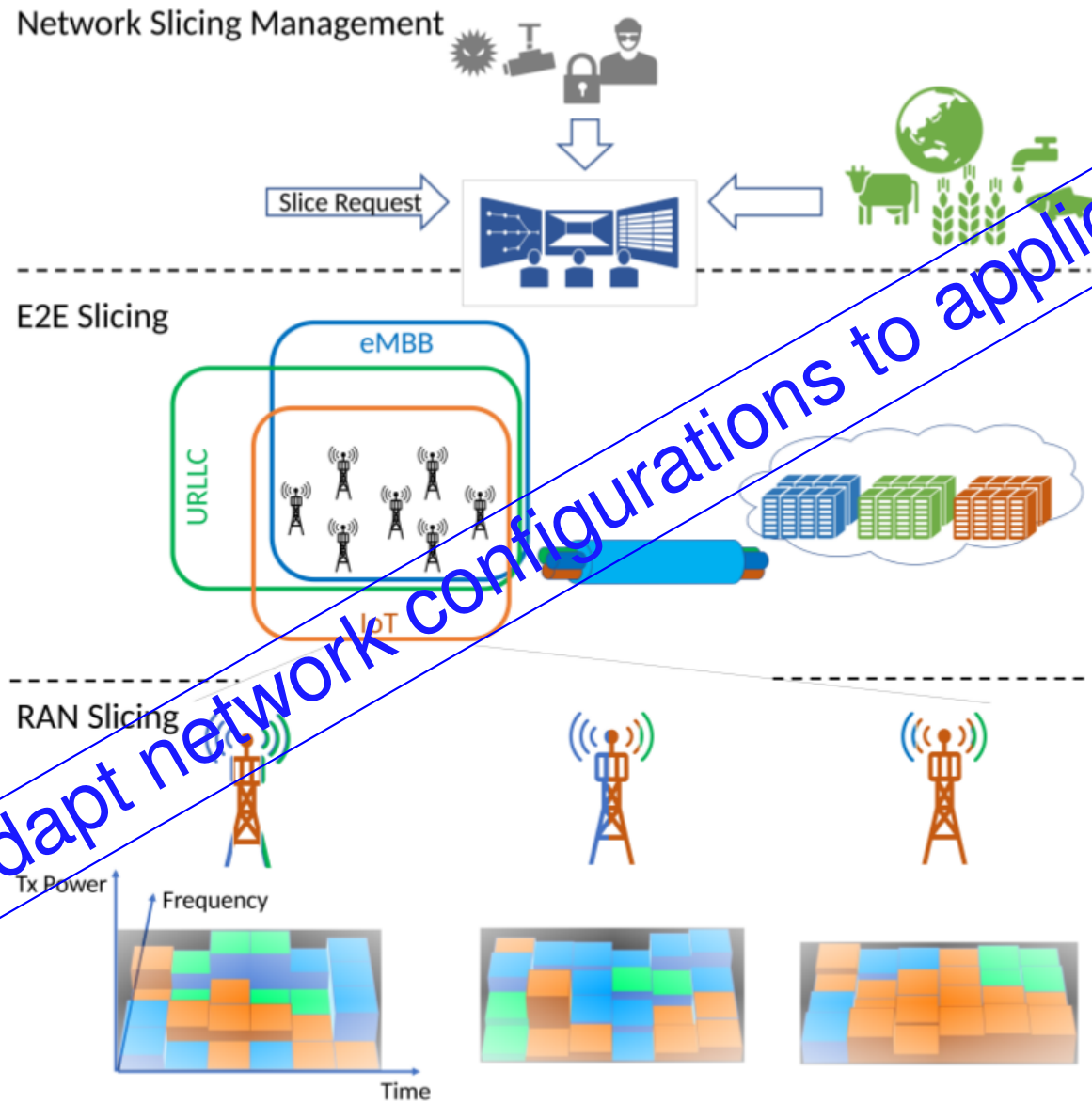


Figure 10. Key barriers in adopting IoT in the industry [6].

Problematic

One size fits all problem: 1) Many configurations, 2) Diversity of service requirements



How to adapt network configurations to applications ?

Figure 10. Key barriers in adopting IoT in the industry [6].

Problematic

Where is the problem ?

- Some network configuration are static and not adptive to the application
  - Decision and optimisation problem..
  - Various network acces
  - Various configuration of each network acces
  - Lake 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.

End-to-end Network slicing

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

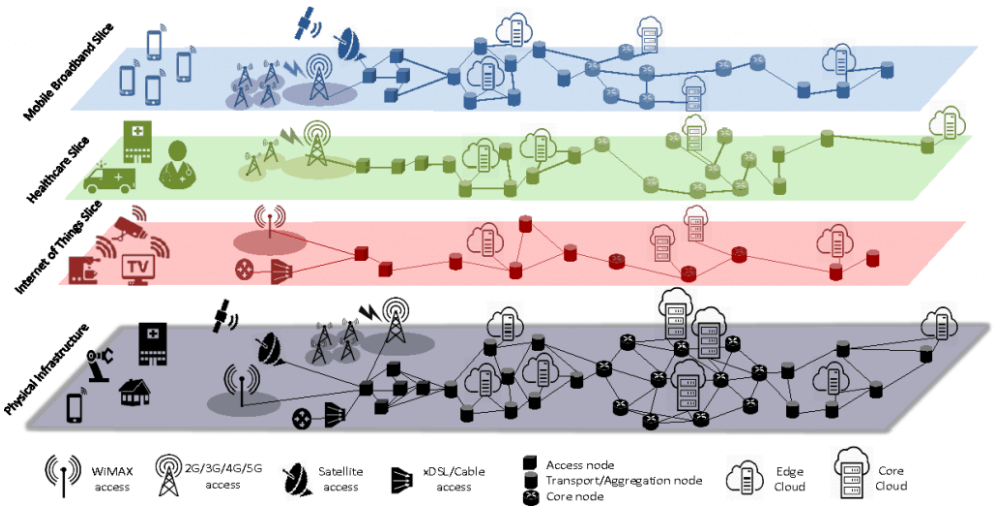
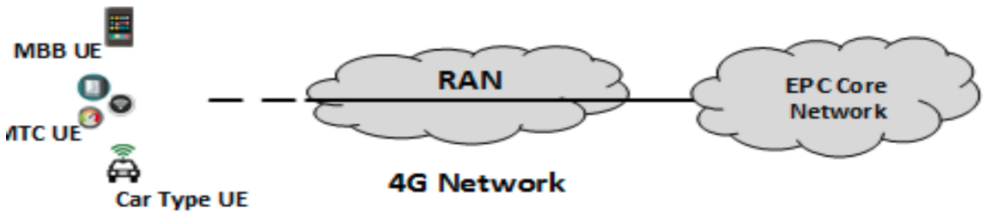
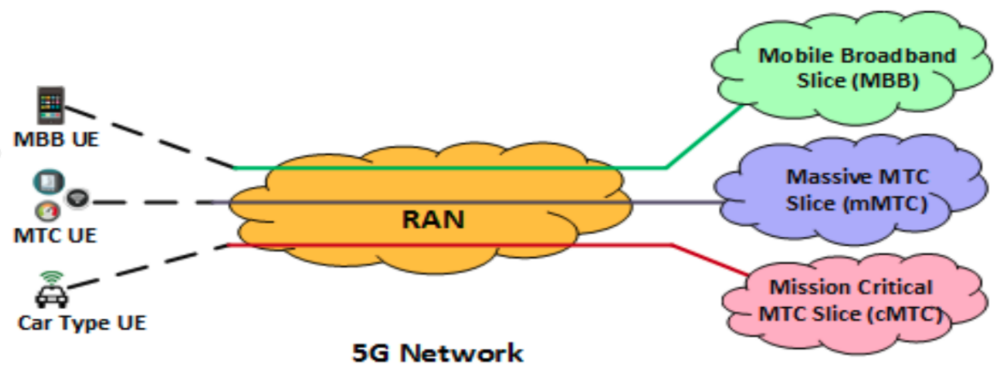


Figure 11. Network slicing [6].



(a) 4G without network slicing.



(b) 5G with network slicing.

Figure 12. Network slicing concept **sama_servicebased_2016**.

Conclusion

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

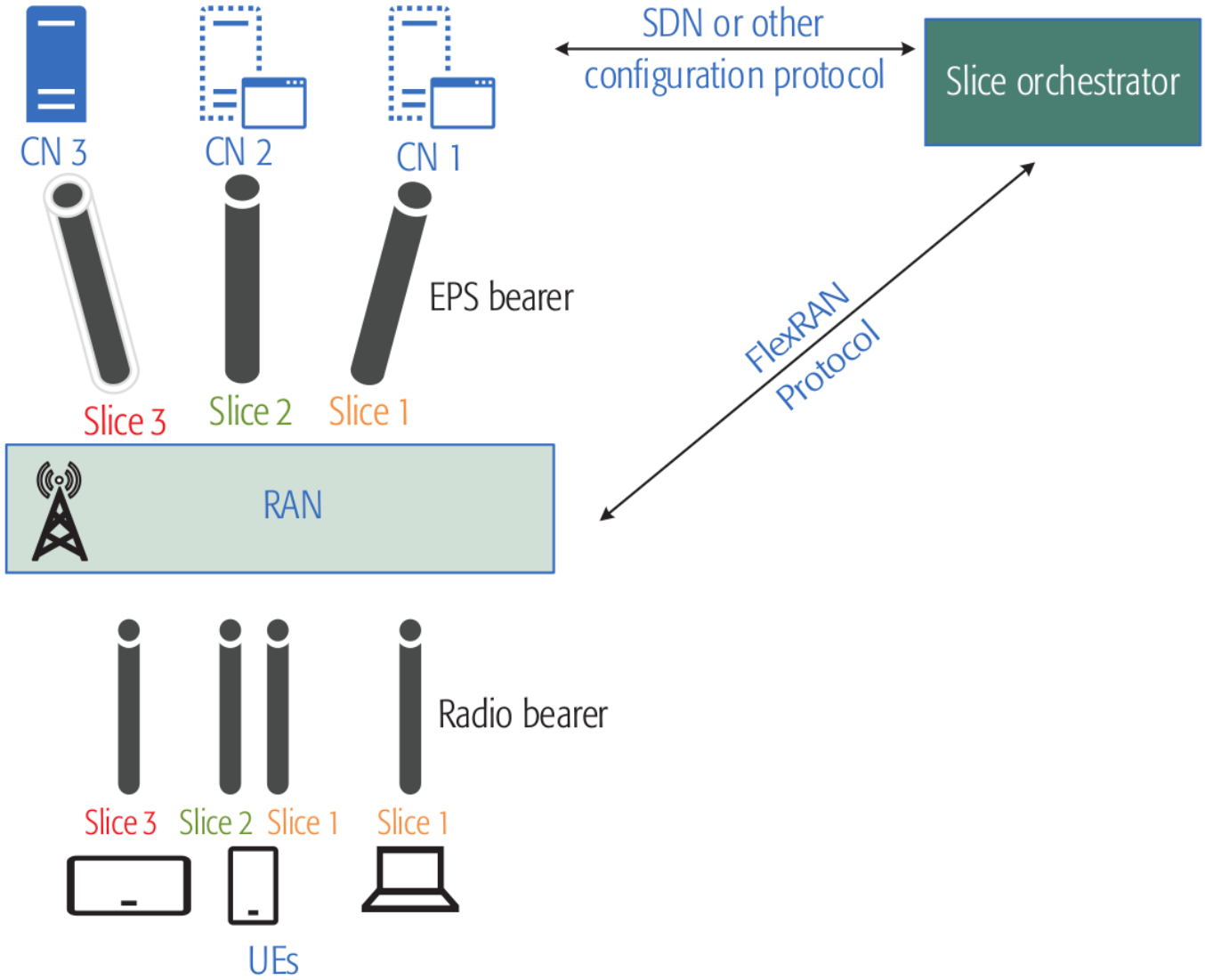


Figure 13. Slice orchestrator [7].

Conclusion

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

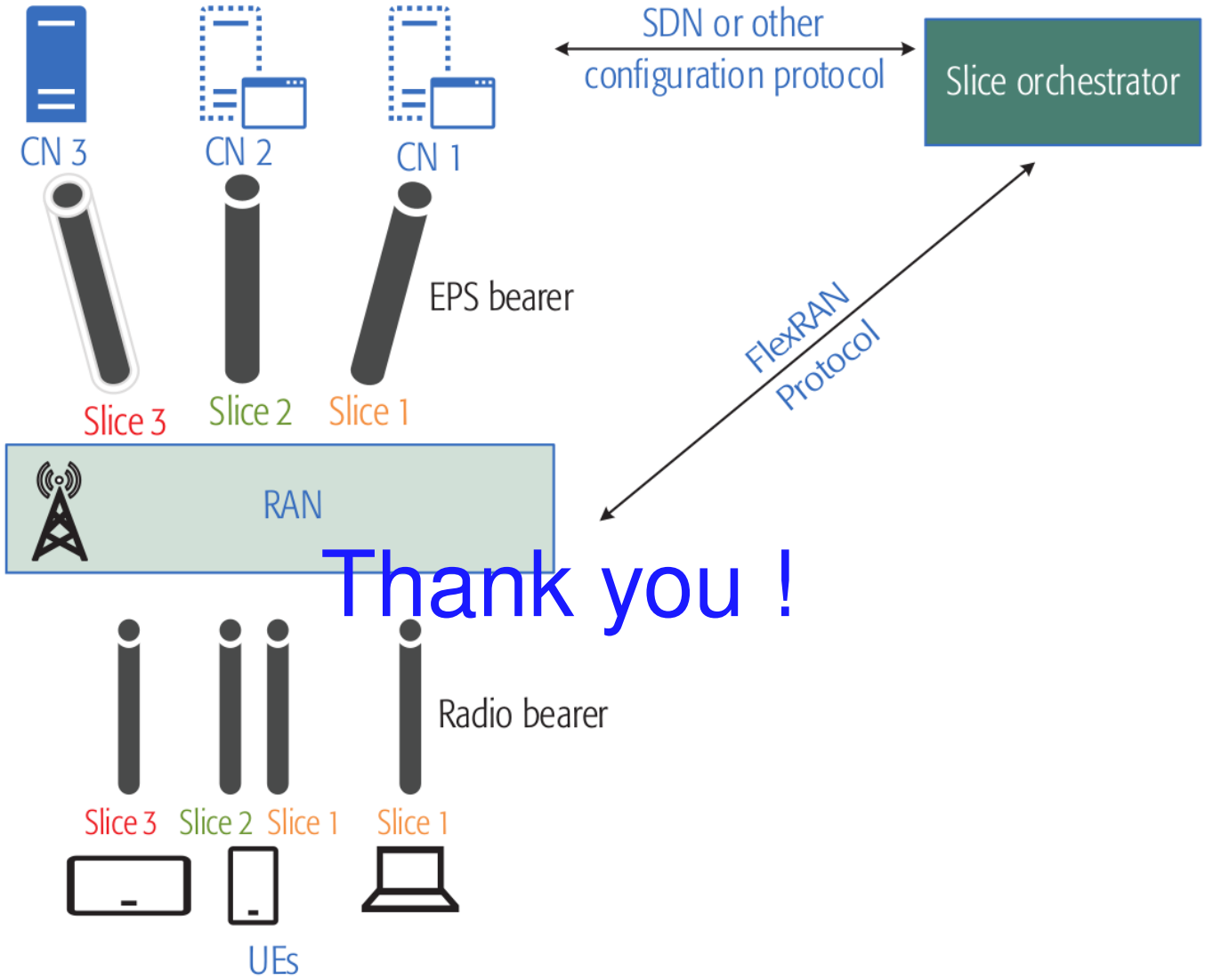


Figure 13. Slice orchestrator [7].

Contribution

Contributions

- **3 Applications**
  - Voice, Images and Text transmission.
- **3 Environment conditions**
  - Rural/Urban
  - Static/Mobile
  - Temperature
- **6 Scenarios**
  - Application protocol (MQTT, COAP, XMPP)
  - Network protocol (Start, Mesh)
  - MAC protocol (LoraWan, Sigfox, ...)
- **6 algorithms**
  - ..
  - ..
  - ..
- **Inputs:**
  - QoS metrics:
    - User metrics: Cost
    - Network metrics: Receiver sensitivity, SNR, DR, Air time, Payload length.
  - MAC configuration (SF, CR, BW, Tx)
- **Outputs:**
  - (SF_i, CR_j, BW_k, Tx_l)

Outline

Outline

Outline

Outline

Multi-Armed-Bandit Algorithm

Related work

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

Outline

Genetic Algorithm

Related work **alkhawlani_access_2008a**

- **N** transceiver configurations: $(x_1, ..., x_n)$
- **I** QoS metrics $(m_1, ..., m_i)$. ex: the operators, the applications, and the network conditions.
- **I** weights $(w_1, ..., w_i)$ are sent to the MCDM in the second component.
- GA component assigns a suitable weight (w 1 ,w 2 ,...,w i)

Genetic Algorithm

Related work

Evaluation function

Define the number of parameters	{SF, Tx, CR, BW}
Define the target QoS	{RSSI, SNR, delay, PDR, RTD}
Define evaluation function	Score(SF, Tx, CR, BW) -> {RSSI, SNR, delay, PDR, RTD}

Parameters

Define a population of individuals (solutions)	6720
Define probabilities of crossing and mutating	0.5, 0.2
Define the number of generations	60

Generations

Select individuals randomly	$\{SF_i, Tx_i, CR_i, BW_i\}^{random}$
Clone, crossover and mutate this individuals	$\{SF_{i+1}, Tx_{i+1}, CR_{i+1}, BW_{i+1}\}^{random}$
Evaluate the offspring with an invalid Fitness	$\text{Score}(SF_{i+1}, Tx_{i+1}, CR_{i+1}, BW_{i+1})$

(Crossover, Mutation)

Remove some bad solutions
Duplicate some good solutions
Make small changes to some of them

Outline

Marcov chain

Related work

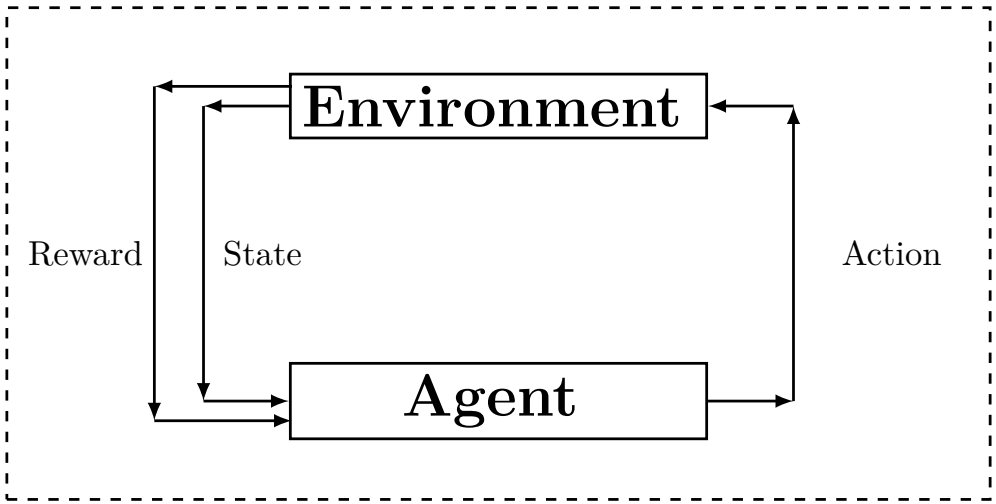


Figure 14. qlearning.

Outline

Marcov chain

Related work

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

$$r(s_k, a_k) = G_k \cdot PRR(a_k) \tag{2}$$

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

$$PRR = (1 - BER)^L \tag{4}$$

$$BER = 10^{\alpha e^{\beta SNR}} \tag{5}$$

Marcov chain

Related work

Learning iterative steps:

- **Choose** action $a_k(t) \sim \pi_k(t)$
- **Observe** game outcome
  - $a\_k(t)$
  - $u_k(a_k(t), a\_k(t))$
- **Improve** $\pi_k(t+1)$

Thus, we can expect that ∀k ∈K

$$\pi_{k(t)} \xrightarrow{t \longrightarrow \infty} \pi_k^* \tag{6}$$

$$u_k(\pi_k(t), \pi\_k(t)) \xrightarrow{t \longrightarrow \infty} u_k(\pi_k^*, \pi^*\_k) \tag{7}$$

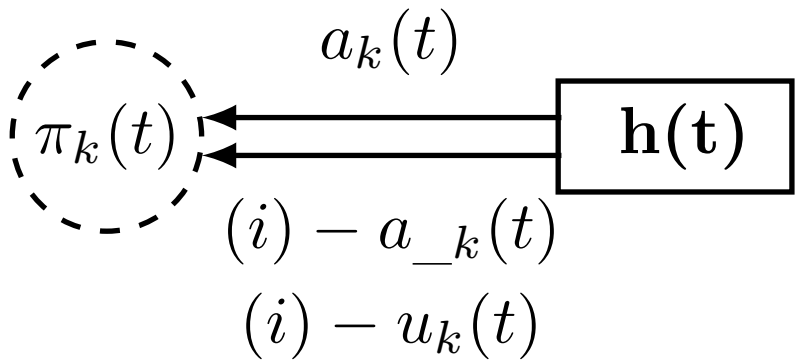


Figure 15. .

Where:

- $\pi^* = (\pi_1^*, ..., \pi_k^*)$ is the NE strategy profile

Outline

Outline

Outline

Game theory

Related work

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

Outline

Discussion

- a
- b

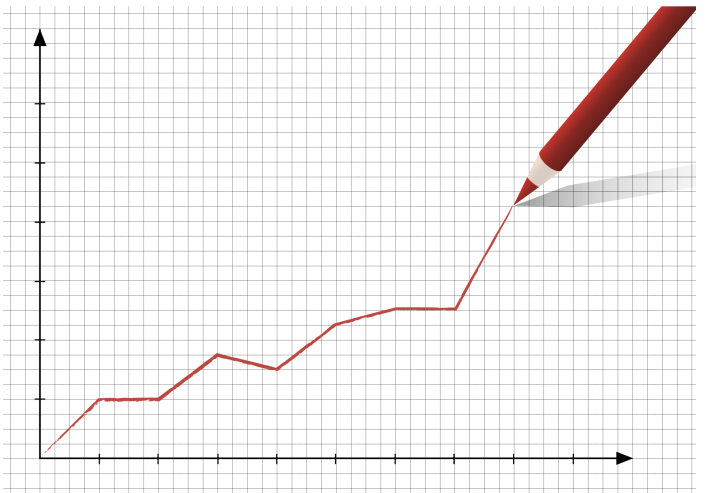


Figure 16. .

Outline

Outline

Problem statement

Introduction

- a
- b

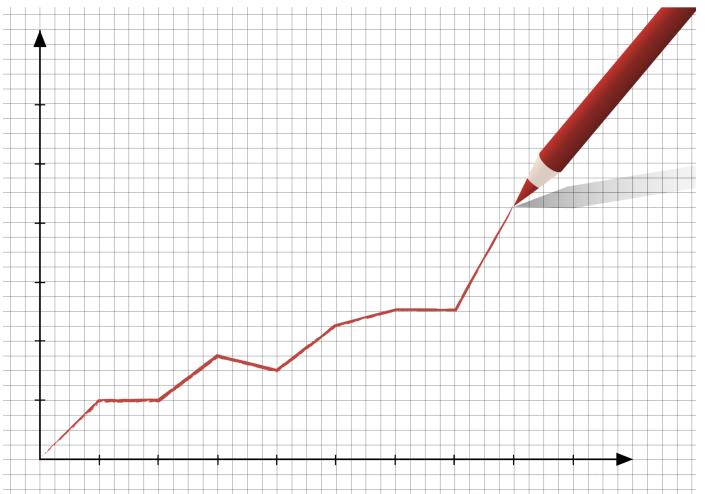


Figure 17. .

Outline

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.

Outline

... (step 1)

Methods

... (step 2)

Methods

... (step 3)

Methods

... (step 4)

Methods

Results

Comparison

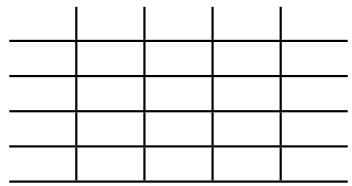


Table 6

Outline

Experimentation

Experimentation

- a
- b

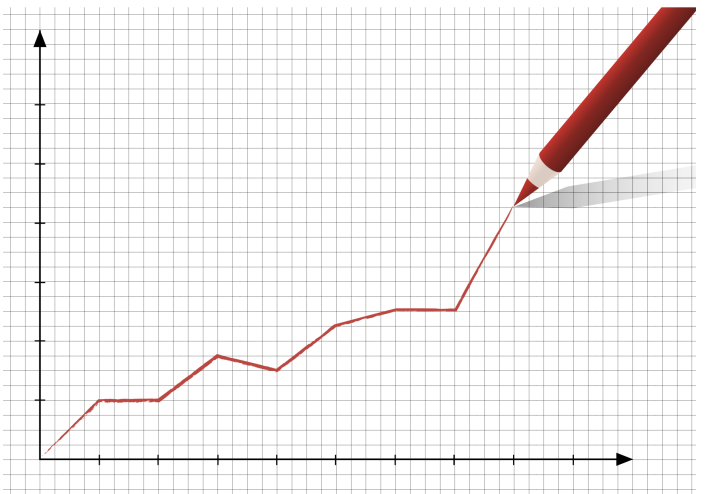


Figure 18. .

Outline

Results

Comparison

- a
- b

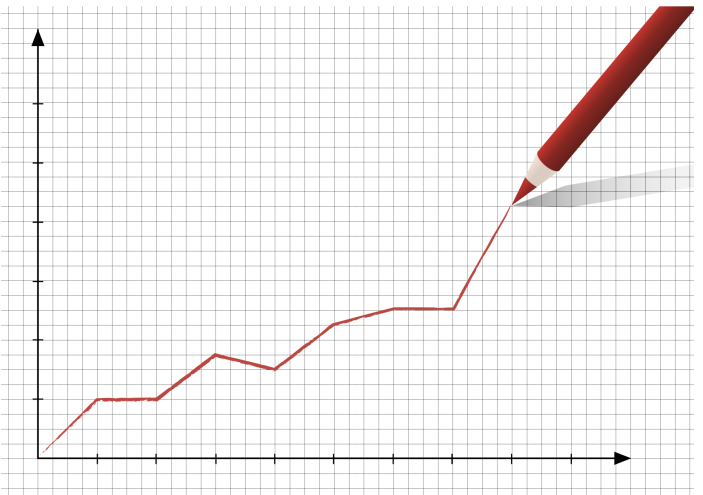


Figure 19. .

Outline

Discussion

- a
- b

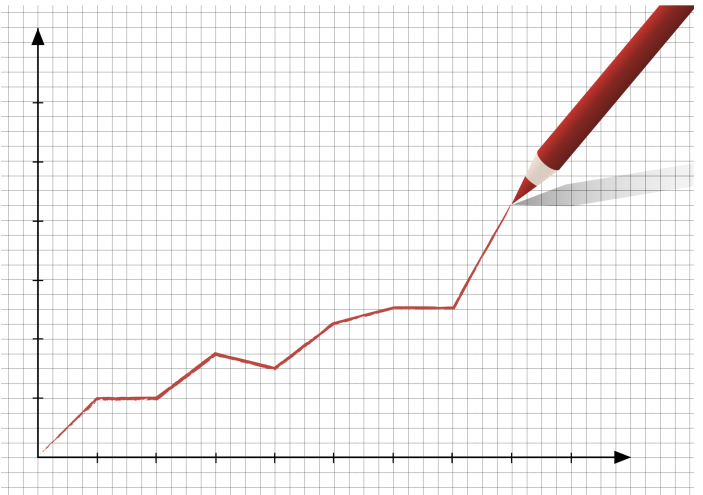


Figure 20. .

Outline

Outline

Problem statement

Introduction

- a
- b

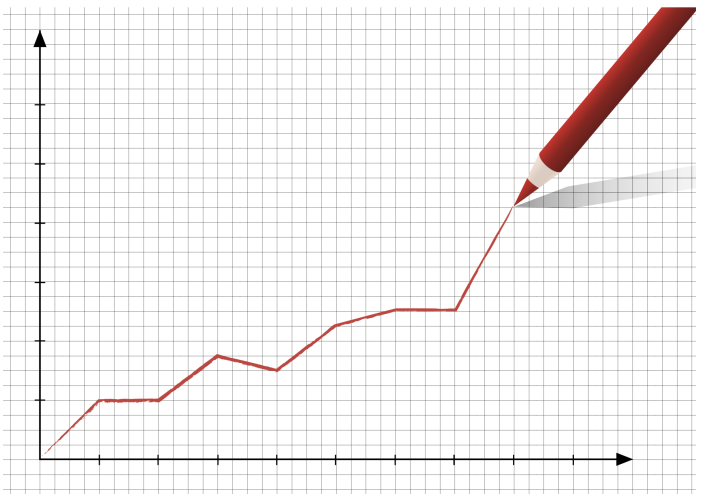


Figure 21. .

Outline

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.

Outline

... (step 2)

Methods

... (step 3)

Methods

... (step 4)

Methods

Results

Comparison

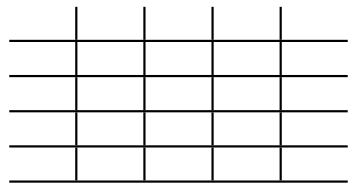


Table 9

Outline

Experimentation

Experimentation

- a
- b

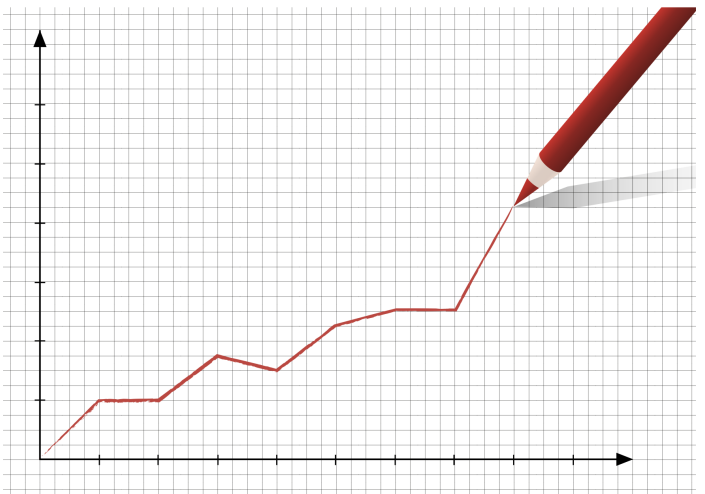


Figure 22. .

Outline

Results

Comparison

- a
- b

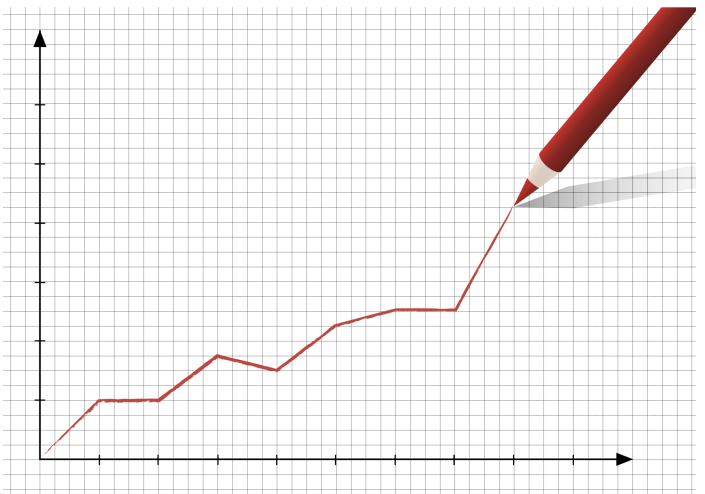


Figure 23. .

Outline

Discussion

- a
- b

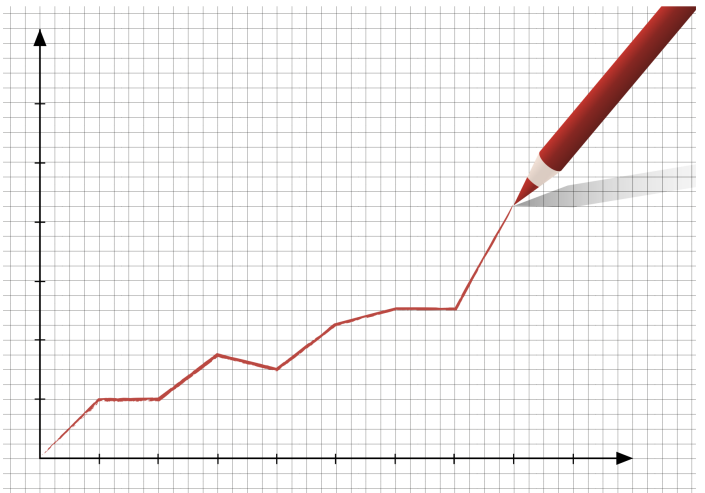


Figure 24. .

Outline

Outline

Problem statement

Introduction

- a
- b

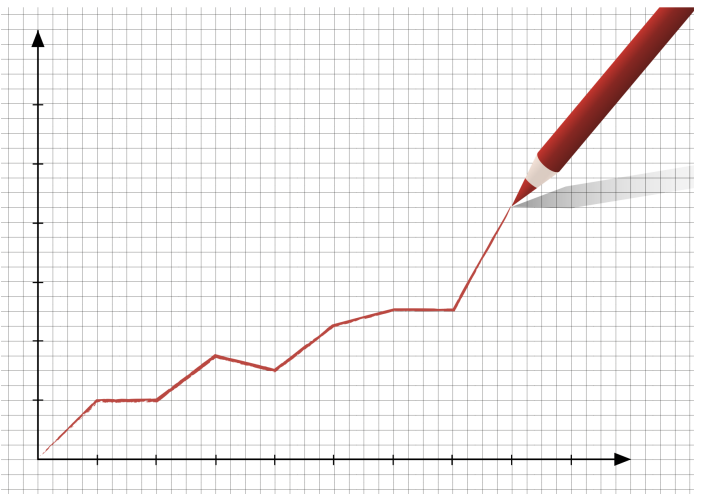


Figure 25. .

Outline

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.

Outline

... (step 1)

Methods

... (step 2)

Methods

... (step 3)

Methods

... (step 4)

Methods

Results

Comparison

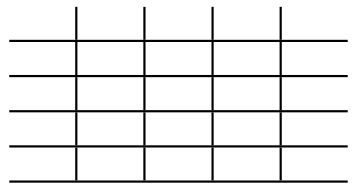


Table 12

Outline

Experimentation

Experimentation

- a
- b

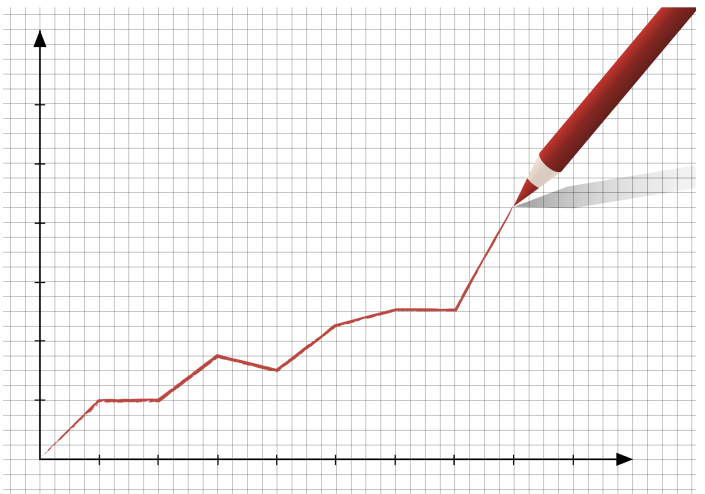


Figure 26. .

Outline

Results

Comparison

- a
- b

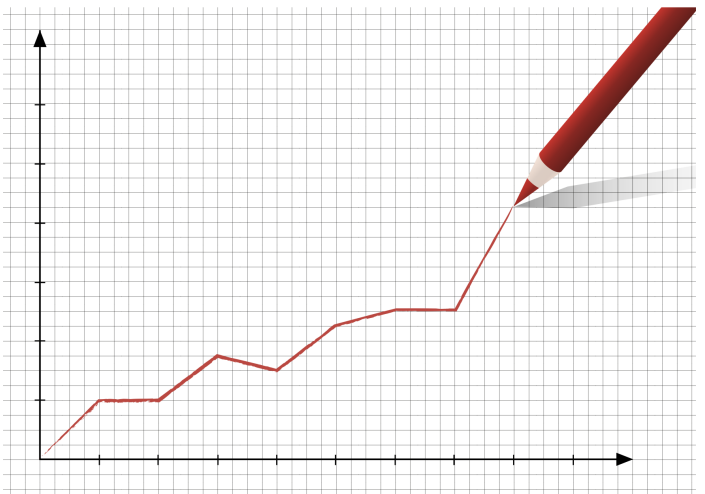


Figure 27. .

Outline

Discussion

- a
- b

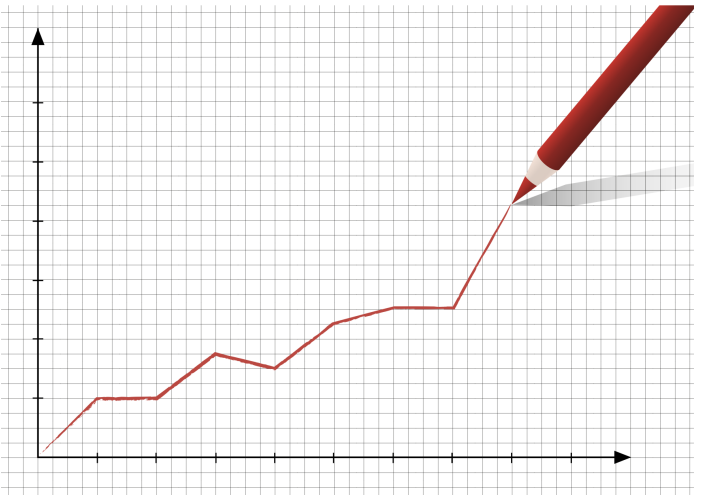


Figure 28. .

Outline

Outline

Outline

Outline

Outline

... (step 2)

Methods

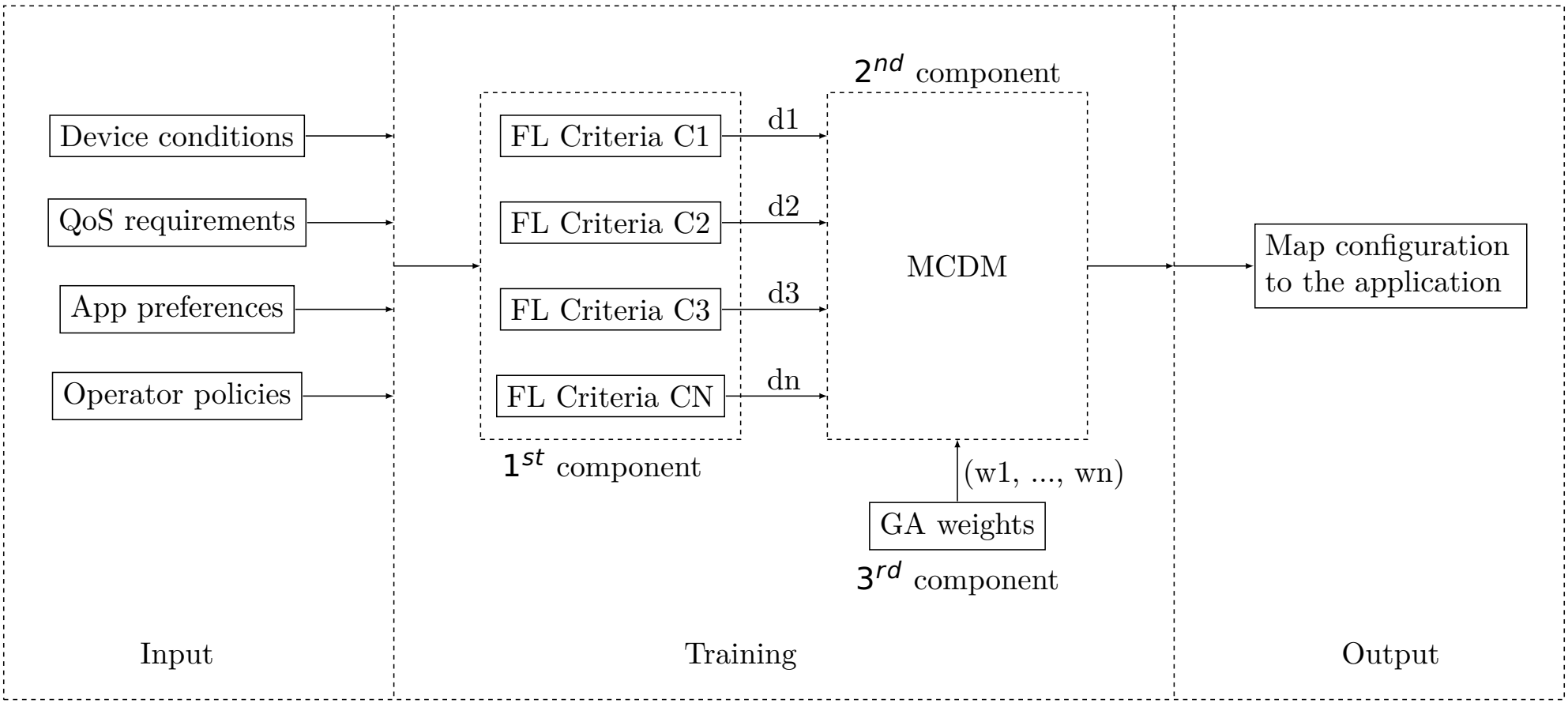


Figure 29. HH.

... (step 3)

Methods

... (step 4)

Methods

Outline

Experimentation

Experimentation

- a
- b

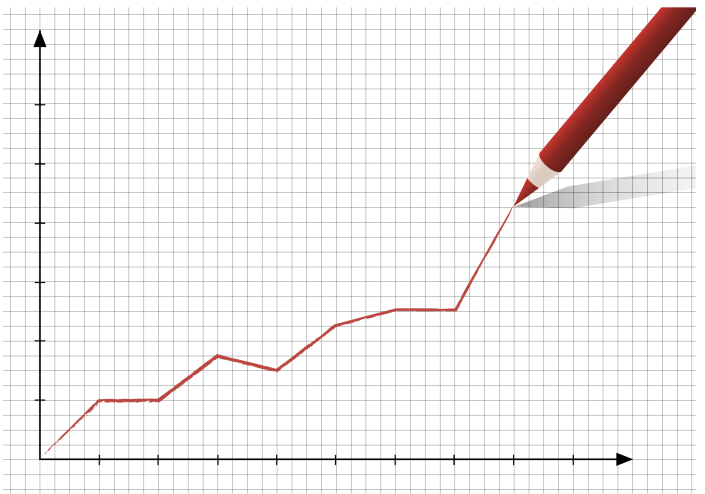


Figure 30. .

Outline

Results

Comparison

- a
- b

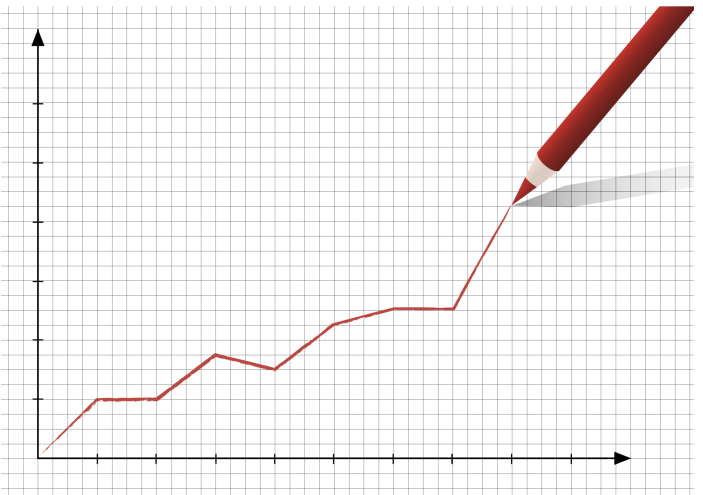


Figure 31. .

Outline

Discussion

- a
- b

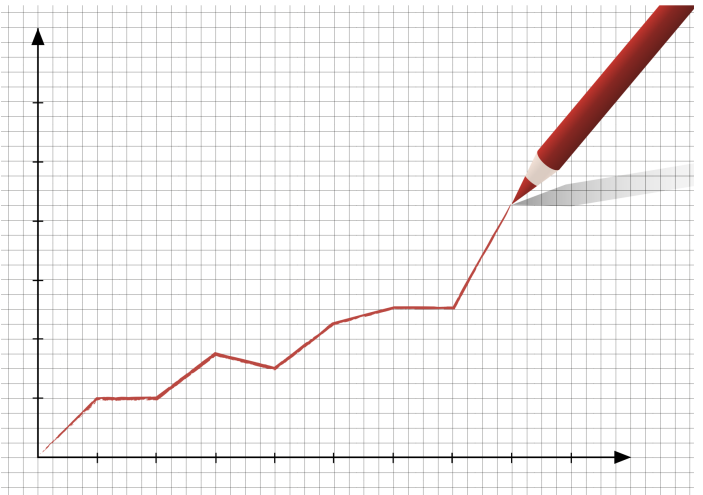


Figure 32. .

Outline

Outline

Problem statement

Introduction

- a
- b

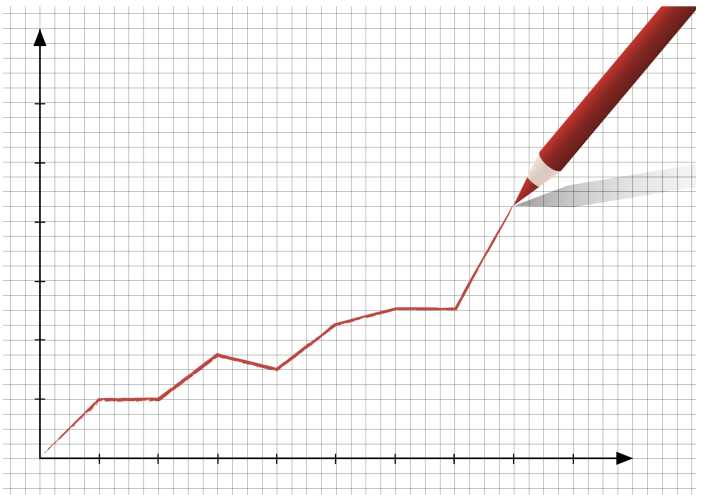


Figure 33. .

Outline

Paper	A1	A2	A3	A4

Table 13. An example table.

Related work

Comparison

Paper	A1	A2	A3	A4

Table 14. An example table.

Outline

... (step 1)

Methods

... (step 2)

Methods

... (step 3)

Methods

... (step 4)

Methods

Results

Comparison

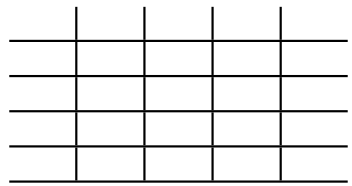


Table 15

Outline

Experimentation

Experimentation

- a
- b

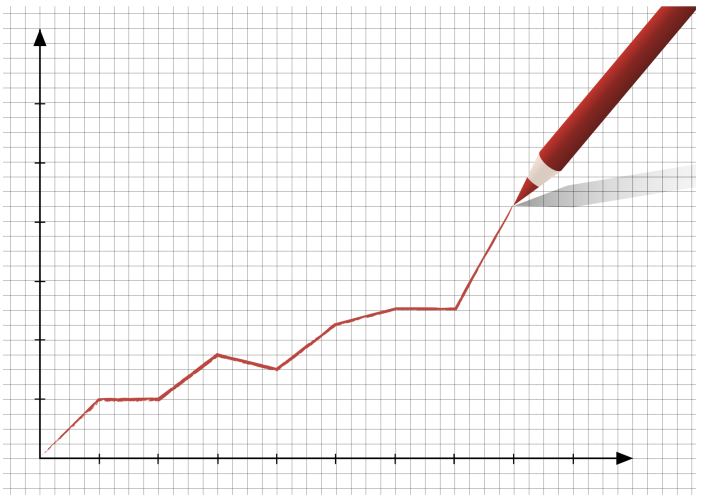


Figure 34. .

Outline

Results

Comparison

- a
- b

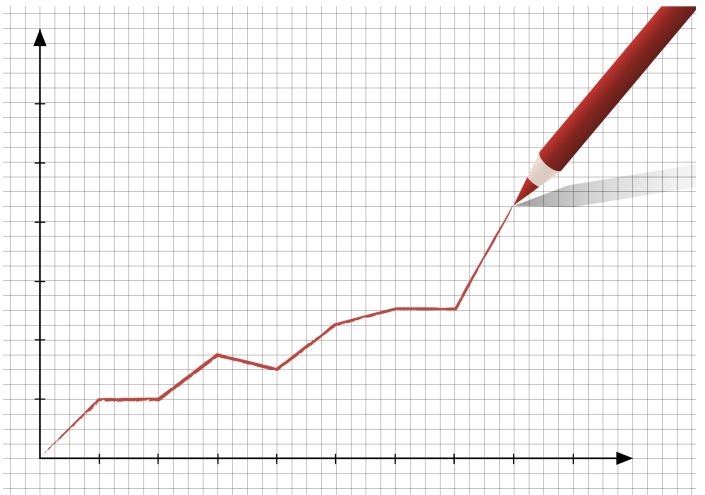


Figure 35. .

Outline

Discussion

- a
- b

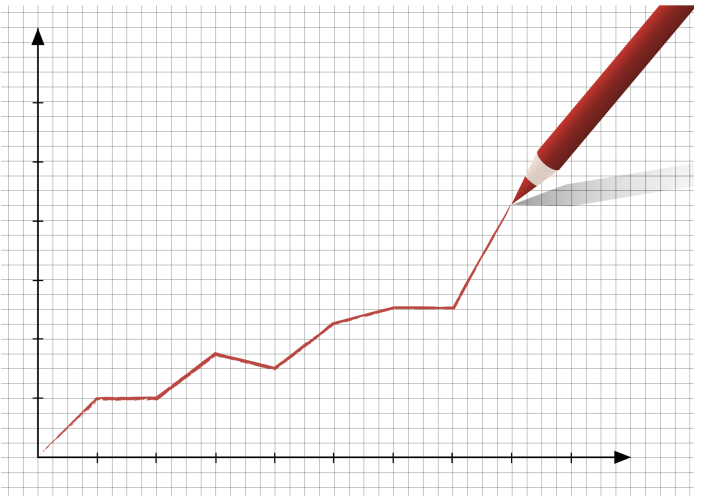


Figure 36. .

Outline

Outline

Problem statement

Introduction

- a
- b

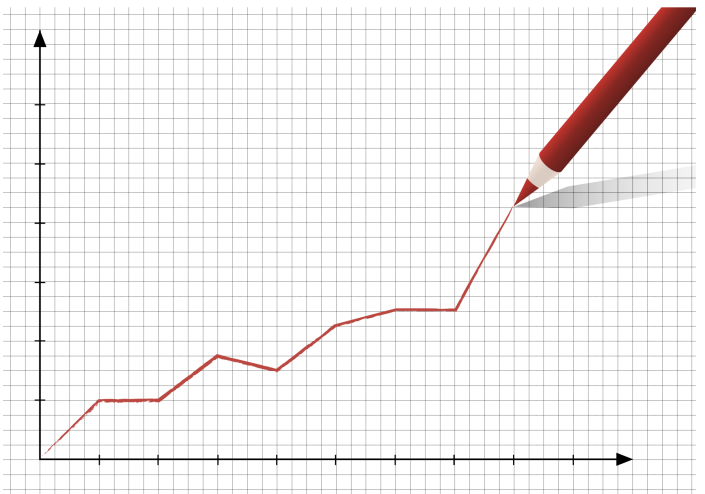


Figure 37. .

Outline

Related work

Comparison

Paper	A1	A2	A3	A4

Table 16. An example table.

Related work

Comparison

Paper	A1	A2	A3	A4

Table 17. An example table.

Outline

... (step 1)

Methods

... (step 2)

Methods

... (step 3)

Methods

... (step 4)

Methods

Results

Comparison

Table 18

Outline

Experimentation

Experimentation

- a
- b

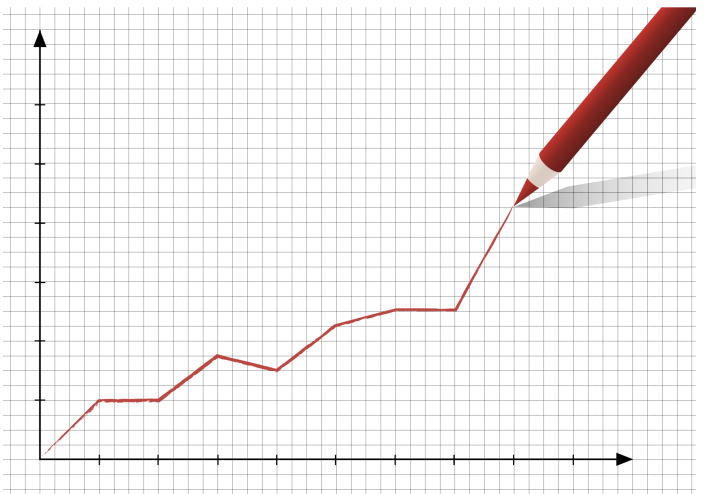


Figure 38. .

Outline

Results

Comparison

- a
- b

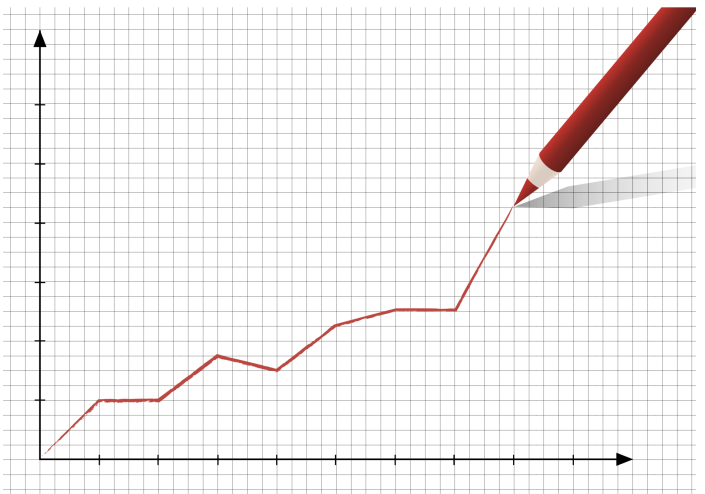


Figure 39. .

Outline

Discussion

- a
- b

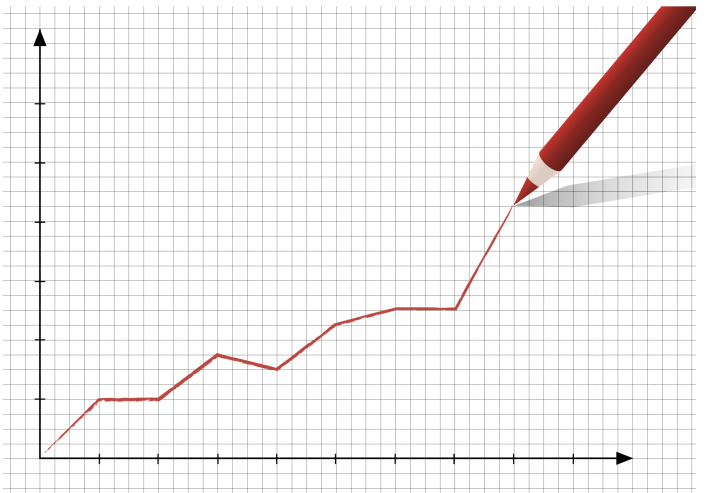


Figure 40. .

Outline

Outline

Problem statement

Introduction

- a
- b

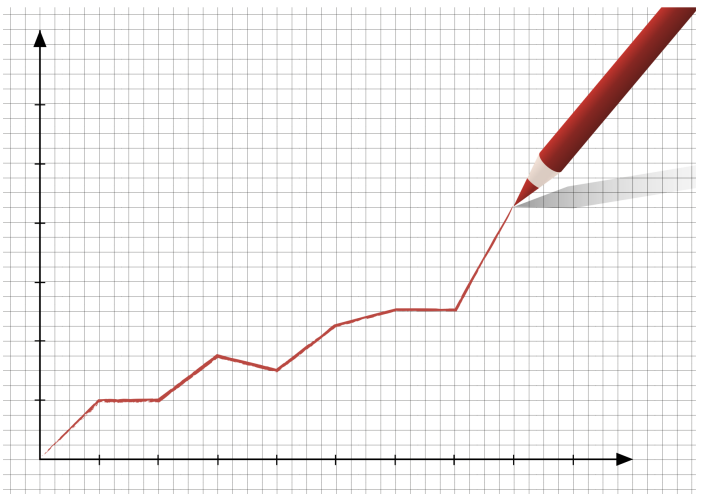


Figure 41. .

Outline

Related work

Comparison

Paper	A1	A2	A3	A4

Table 19. An example table.

Related work

Comparison

Paper	A1	A2	A3	A4

Table 20. An example table.

Outline

... (step 1)

Methods

... (step 2)

Methods

... (step 3)

Methods

... (step 4)

Methods

Results

Comparison

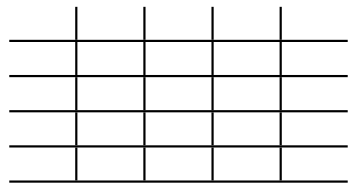


Table 21

Outline

Experimentation

Experimentation

- a
- b

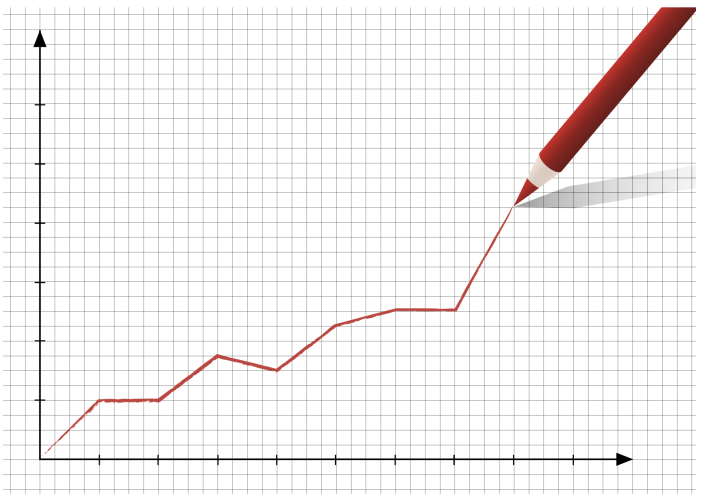


Figure 42. .

Outline

Results

Comparison

- a
- b

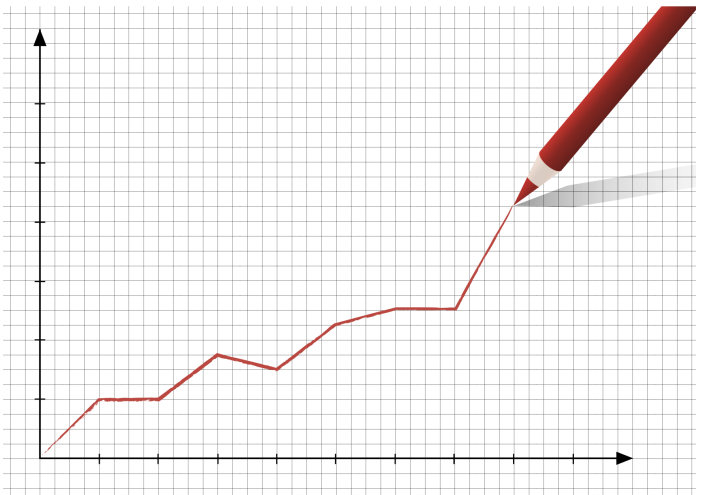


Figure 43. .

Outline

Discussion

- a
- b

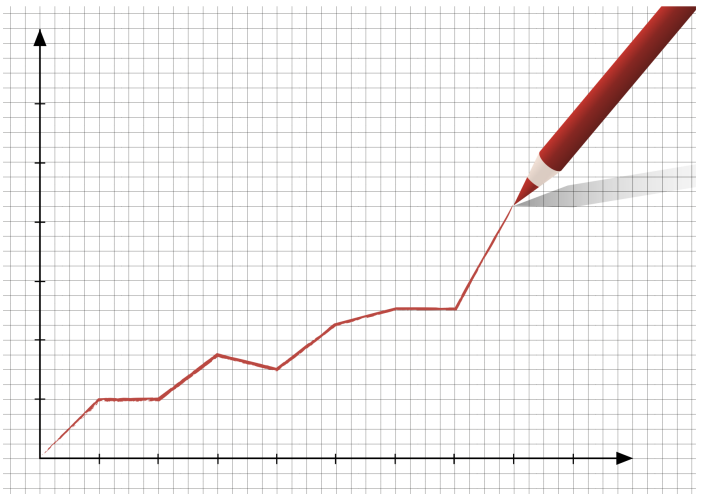


Figure 44. .

Outline

Conclusion

Our main goal was

- .
- .

Our main contribution was

- .
- .

Our main results was

- .
- .

Future Challenges

Conclusion

Our future goal was

- .
- .

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