Sélection d'interface de communication dans les réseaux de capteurs multi-technologies

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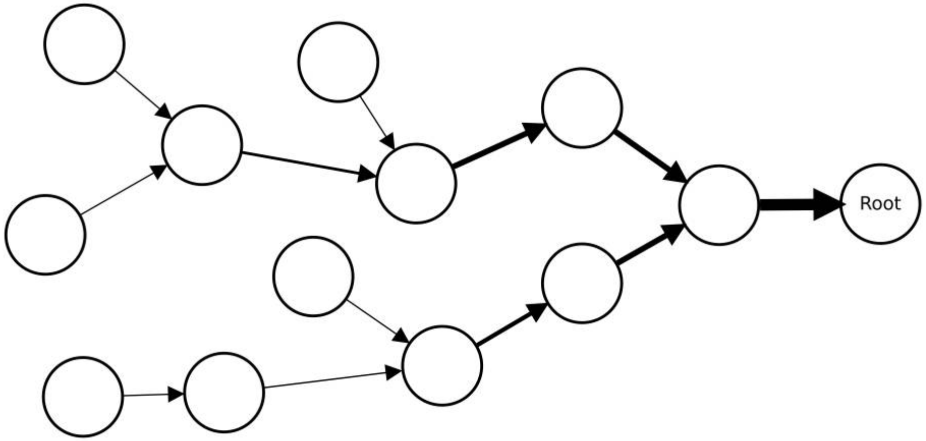
Wireless Sensor Networks (WSN)

- Multi purpose tool for data acquisition
  - Environmental monitoring
  - Video camera surveillance
  - ...
- Energy self-sufficiency (batteries)
- Usually based on a single wireless communication technology

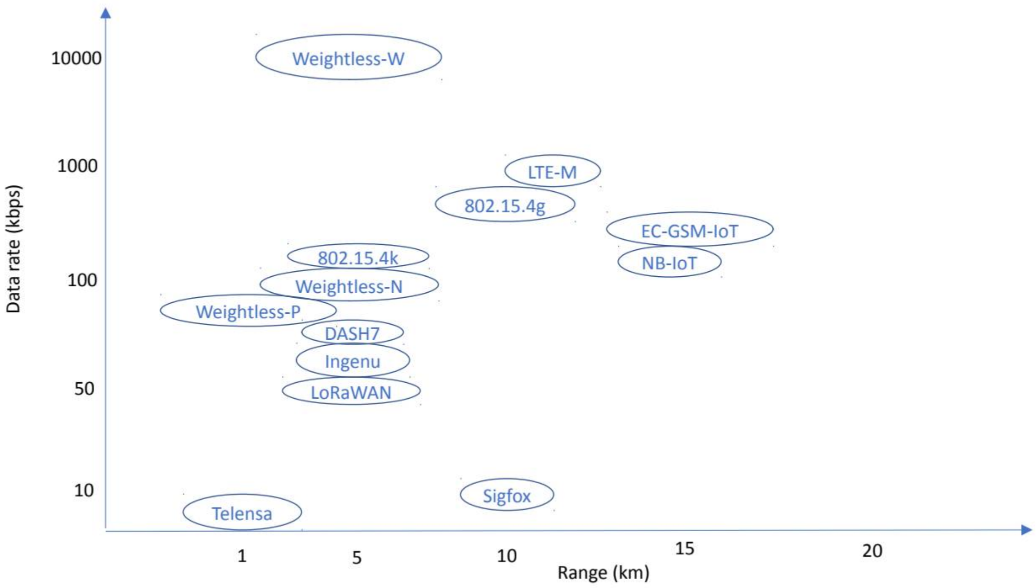
Thus

- Technology's capabilities limit deployments
  - Coverage
  - Throughput
  - Latency
  - Range
  - ...



Many communication technologies

- ISM based technologies
  - WiFi
  - Bluetooth
  - LoRaWAN
  - Sigfox
  - ...
- Operators based technologies
  - Sigfox
  - LTE-M & NB-IoT
  - ...



But

- No base station → no internet access
- Operators not present in every country
- Technologies restrictions limit multiple uses

Sencrop's case study

- Manufactures and sells autonomous weather stations
- Sigfox based
  - > Simple deployment
  - > Long range ([10 – 40] km)
  - > Low power consumption (~ 50 mA in TX mode)

At the price of

  - > Coverage holes
  - > Operators disfunctions
  - > Low throughput ([100 - 600] bps)
  - > Message number threshold (12B payload ; ≤ 140 / day)

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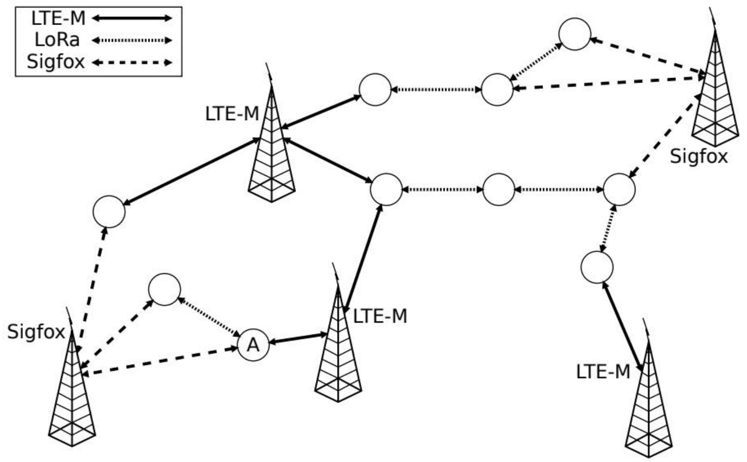
Multi-technologies WSN

- Best technology selected as a function of the data type
  - > Monitoring → low power consumption
  - > Alarm → fast communication
  - > ...
- If the selected technology operator is down / not present → switch

Thus

- We need a method to select the best fitted technology
- Problem known as Network Interface Selection (NIS)



Multiple Attribute Decision-Making (MADM) methods

- Most common tools to tacke NIS
- Takes a decision matrix as input
  - Several alternatives
  - Judged on several criterias
  - To which are associated weights
- Applies a method to it
  - Simple Additive Weighting (SAW)
  - Weighted Product Method (WPM)
  - ...
- Produces a ranking of the alternatives

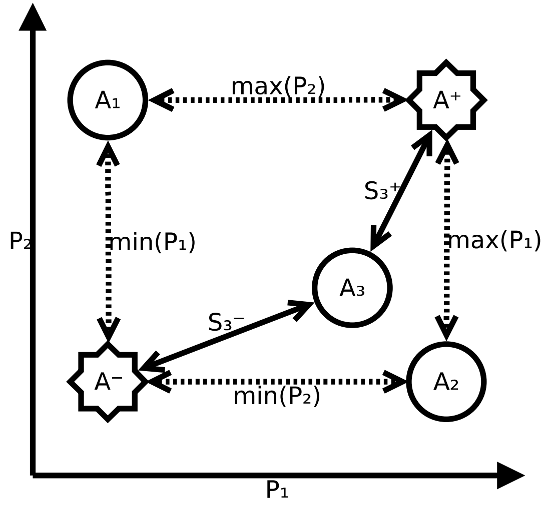
	P_1 w_1	P_2 w_2	...	P_m w_m
A_1	x_{11}	x_{12}	...	x_{1m}
A_2	x_{21}	x_{22}	...	x_{2m}
...	...	...	...	...
A_n	x_{n1}	x_{n2}	...	x_{nm}

Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

- One of the most used and studied MADM methods
- Compare alternatives based on
  - Ideal positive alternative
  - Ideal negative alternative
  - Mathematical distances between alternatives and ideals

But

- Resource intensive computations
- Rank reversal



Rank reversal

- Caused by the « Euclidean » normalization
- Ranking is altered when the set of alternatives changes
  - > Removing worst alternatives can alter the top of the ranking

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{n} x_{ij}^2}}$$

Example

- Ranking → [A1, A3, A2, A4]
- If A4 is removed, ranking should be [A1, A3, A2]
- But ranking → [A3, A2, A1]

	P_1	P_2	P_3
A_1	1.024537	7.828443	8.650221
A_2	4.226149	0.09865402	4.673396
A_3	8.026353	5.455392	2.536936
A_4	1.700537	1.398855	0.7656412

Rank reversal free & lighter TOPSIS

- Rank reversal is caused by the normalization method
  - > Normalize values based on the whole set of values

Thus

- We propose a different normalization method
  - > Simplified computations
  - > Based on absolute bounds
- The application layer expresses needs
  - > Absolute bounds
  - > Weights

Algorithm 1 Lightweight normalization

Require: x_{ij} the raw value of each attribute j for each candidate i

```
for each attribute P_j do
    if P_j is an upward attribute then
        B_j^+ is the upper bound of P_j
        r_ij = x_ij / B_j^+
    else if P_j is a downward attribute then
        B_j^- is the lower bound of P_j
        r_ij = B_j^- / x_ij
    end if
end for
return r_ij the normalized value of x_ij
```

Complexity reduction

- Modification of the normalization allows further simplification of the TOPSIS method
  - Trivial ideal alternatives construction
  - Quicker distances computation
- For a decision matrix of size *nm*
  - 5*mn* – 2 operations spared

$$A^{+}=[v_1^{+}\dots v_m^{+}]$$
$$A^{-}=[v_1^{-}\dots v_m^{-}]$$
$$v_j^{+}=Argmax\{v_{ij}, i=1,\dots,n\}$$
$$v_j^{-}=Argmin\{v_{ij}, i=1,\dots,n\}$$

→

$$A^{+}=[1\dots1]$$
$$A^{-}=[0\dots0]$$

⇒

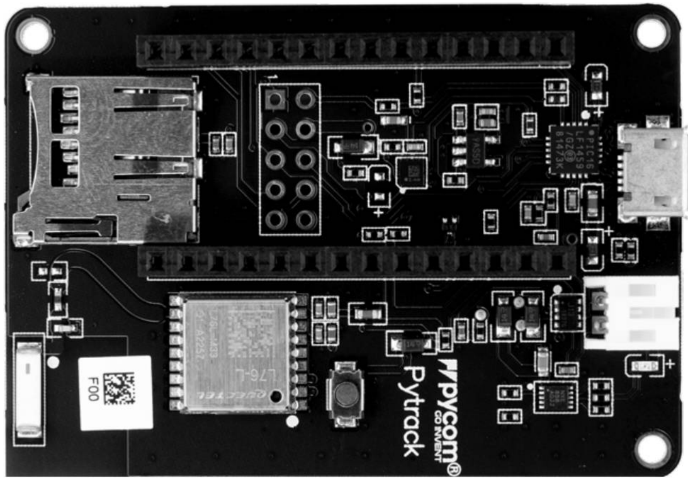
$$S_i^{+}=\sqrt{\sum_{j=1}^{m}(v_j^{+}-v_{ij})^2}$$
$$S_i^{-}=\sqrt{\sum_{j=1}^{m}(v_j^{-}-v_{ij})^2}$$

→

$$S_i^{+}=\sqrt{\sum_{j=1}^{m}(1-v_{ij})^2}$$
$$S_i^{-}=\sqrt{\sum_{j=1}^{m}v_{ij}^2}$$

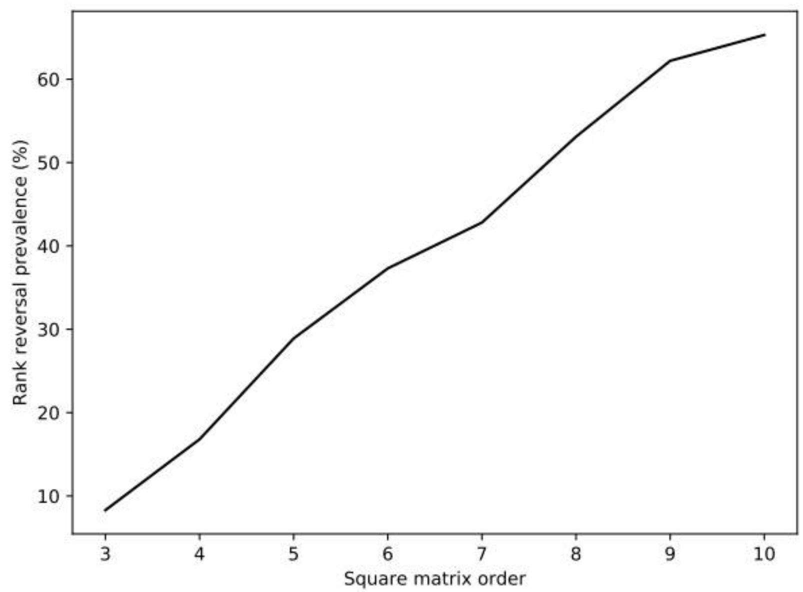
Experiments’ hardware

- FiPy modules from Pycom
  - Offers WiFi, BLE, LoRa, Sigfox, LTE-M & NB-IoT technologies
  - MicroPython implementation
- Coupled with Pytrack expansion board



Rank reversal prevalence

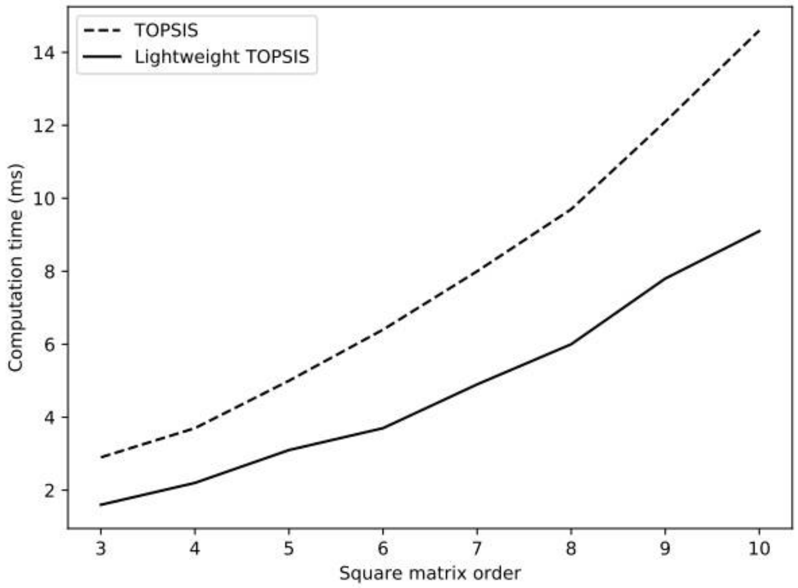
- Experimental protocol
  > TOPSIS on random matrix
  > Random alternative removal
  > TOPSIS on resulting matrix
  > Comparison between rankings
- Results highly dependent on the decision matrix size
  > Population of 1000 experiments / matrix order
  > The bigger → the most frequent is rank reversal
  > 5*5 matrix → reversal in 30% of experiments
- If NIS happens periodically, this is considerable



Proposition evaluation

- TOPSIS vs lightweight TOPSIS
  - > Measurements of time needed for algorithms completion
  - > Weights determined based on the data requirements
  - > Quantification of the rankings similarity
    - TOPSIS does not embed an objective comparison referential
- Population of 7000 experiments
- Mean speed up of 38%
- Ranking similarity in 82% of the experiments
- For a 5*5 matrix
  - > 4.79 ms vs 2.96 ms
  - > 0.05 ms standard deviation
  - > 448 µJ saved per TOPSIS run
    - 68 mA max & 3.6 V
    - Based on the FiPy CPU data-sheet

	Energy	Delay	Cost
$W_{monitoring}$	0.6	0.1	0.3
W_{alarm}	0.1	0.8	0.1



Conclusion

- Multi-technologies WSN can overcome classical WSN deployment limitations
- The MADM TOPSIS is an interesting method to make the NIS on devices
- Our proposition
  - > Eliminates rank reversal
  - > Reduces complexity, which in turn reduces energy consumption
  - > Without sacrificing the ranking quality

Ingoing future work

- Extend the NIS method to multi-technology route selection

Thank you for your attention! Any questions?

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