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TrustS: Probability-based trust management system in smart cities

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Outline

- Context & motivation
- Model presentation
- Model formalization
- Trust management approach
- Basic experimental evaluation
- Conclusions and future work

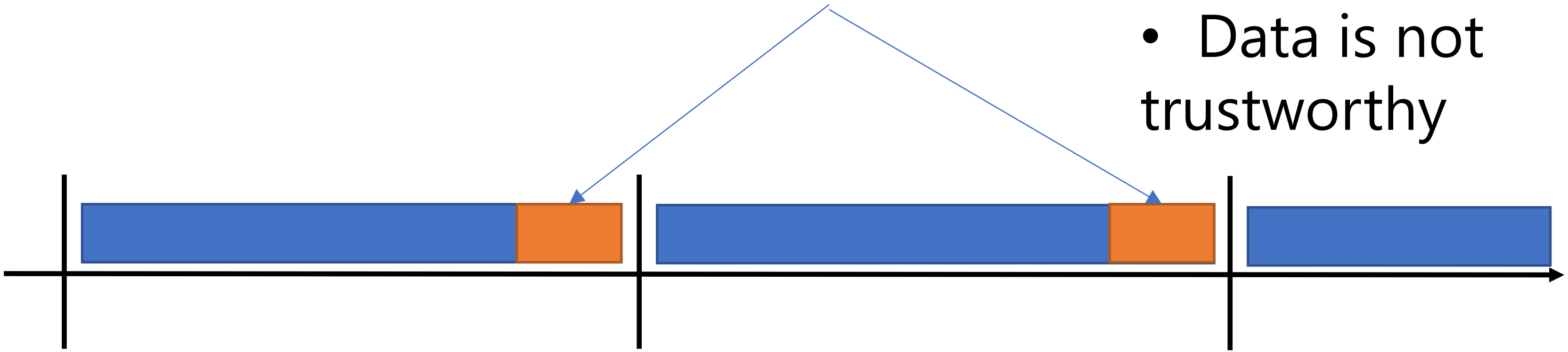
Context and motivation

- Smart sensor networks (parking sensors, bicycle parking sensors, traffic infrastructure sensors, smart road signs, etc) – a key concept of smart cities;
- Smart sensors are very heterogeneous - communication theologies and protocols; sensing features; capacities; capabilities; etc.
- One crucial aspect is the lifetime of sensors. Due to their heterogeneity, they are prone to malfunction;
- The problem that arises is the large amount of data generated by the sensors:
  - Heterogeneity;
  - Veridicity and veracity;
  - Velocity.

Context and motivation

- Data is innaaccurate
- Data is missing
- Data is not trustworthy

Period of time near maintenance



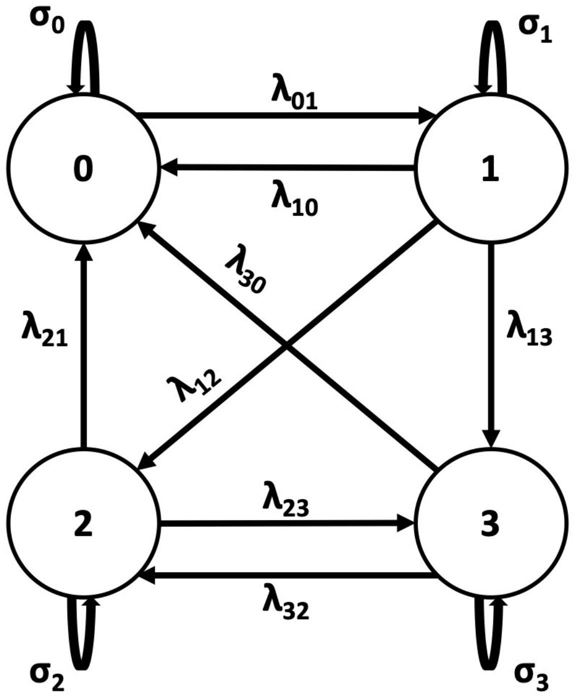
Maintainance

Maintainance

Proposed solution

- 0 - **DOWN** state;
- 1 - **UP** state;
- 2 - **UP SAFE** state – e.g. booting;
- 3 - **UP UNSAFE** state – e.g. boot error

(the device is restarting continuously).



Proposed solution - formalization

$$A = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 1 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 0 & 1 & 1 \end{bmatrix}$$

$$M = \begin{bmatrix} \sigma_0 & \lambda_{01} & 0 & 0 \\ \lambda_{10} & \sigma_1 & \lambda_{12} & \lambda_{13} \\ \lambda_{20} & 0 & \sigma_2 & \lambda_{23} \\ \lambda_{30} & 0 & \lambda_{32} & \sigma_3 \end{bmatrix}$$

A is the adjacent matrix

M is the transition matrix
M is a stochastic matrix.

Proposed solution - formalization

- We consider the random walk model , we define $\prod$ an initial distribution over I (state set) such that

$$\sum_{i \in I} \pi_i = 1.$$

$$\Pi^0 = \frac{1}{n}, \frac{1}{n}, \frac{1}{n}, \frac{1}{n}, n = |I|.$$

← First the random walk starts from a random state

$$\Pi^{k+1} = M\Pi^k$$

← We compute the state probility at each iteration

$$\Pi = M\Pi$$

Proposed solution - formalization

Markov Chain model presented is strongly connected, which means that each state can be reached from another state, thus it admits a stationary distribution that satisfies

$$\Pi = M\Pi$$

Next we solve the system for the stationary distribution of $\prod$ (power method).

$$\Pi = M\Pi$$

Algebraic solution

$$\pi_3 = \frac{E \times A}{B \times C + D \times A}$$

$$\pi_2 = \pi_3 \times \frac{B}{A}$$

$$\pi_1 = \pi_2 \times (\lambda_{20} + \lambda_{23}) + \pi_3 \times \lambda_{32}$$

$$\pi_0 = -\pi_1 \times \frac{\lambda_{10} - \lambda_{12} - \lambda_{13}}{\lambda_{01}}$$

Gauss method

$$A = \lambda_{20} \times \lambda_{13} + \lambda_{23} \times \lambda_{13} + \lambda_{12} \times \lambda_{23}$$

$$B = \lambda_{13} \times \lambda_{32} + \lambda_{12} \times \lambda_{30} + \lambda_{32} \times \lambda_{12}$$

$$C = \lambda_{20} \times \lambda_{01} + \lambda_{20} \times \lambda_{10} + \lambda_{01} \times \lambda_{12} + \lambda_{20} \times \lambda_{12} + \lambda_{01} \times \lambda_{13} + \lambda_{20} \times \lambda_{13}$$

$$D = \lambda_{30} \times \lambda_{01} + \lambda_{30} \times \lambda_{10} + \lambda_{01} \times \lambda_{12} + \lambda_{30} \times \lambda_{12} + \lambda_{01} \times \lambda_{13} + \lambda_{30} \times \lambda_{13}$$

$$E = \lambda_{01} \times \lambda_{12} + \lambda_{01} \times \lambda_{13}$$

Iterative solution

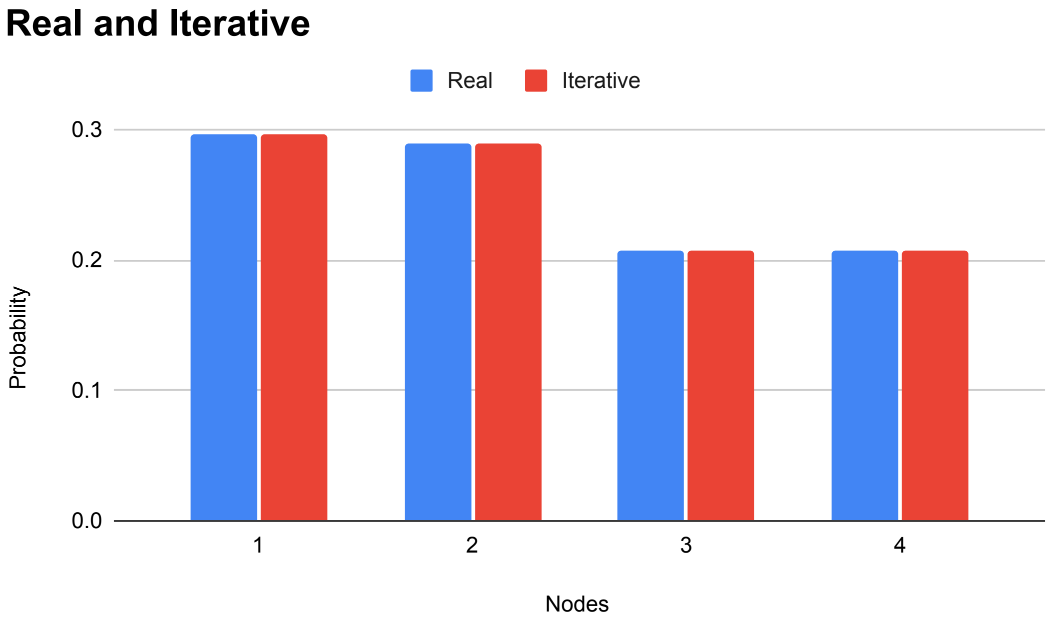
Algorithm 1 Iterative algorithm

$A \leftarrow$ adjacent matrix;
$M \leftarrow$ transition matrix;
$n \leftarrow size(A)$;
$\Pi_0 \leftarrow \frac{1}{n}, \frac{1}{n}, \frac{1}{n}, \frac{1}{n}$;
$converge \leftarrow false$;
while $converge == FALSE$ **do**
    $\Pi_{new} \leftarrow \Pi_0 \times M$;
    $norm \leftarrow \|\Pi_{new}\|$;
    $\Pi_{new} \leftarrow \frac{\Pi_{new}}{norm}$;
    if $\Pi_{new} - \Pi_0 < \epsilon$ **then**
        $converge \leftarrow true$;
    end if
    $\Pi_0 \leftarrow \Pi_{new}$;
end while

Validation of iterative algorithm

Input data:

State	Number of transitions	Transitions
1	2	1,2
2	4	1,2,3,4
3	3	1,3,4
4	3	1,3,4



Trust managemnt approach

- To the best of our knowledge, the majority of trust and reputation management solutions take into consideration the behaviour in time of the nodes.
- Our solution introduce a 4 state oriented graph that represents the states of the nodes from offline to online.

$$T_i{}^k = \alpha * \|\Pi_i\|_\infty = \alpha * \max(\Pi_i{}^k)$$

- Our approach is taking into consideration the largest magnitude among each distribution probability and reduces the probability the the maximal values

Experimental evaluation

- In Smart cities, infrastructure sensors are prone to malfunction especially when their lifespan is ending.

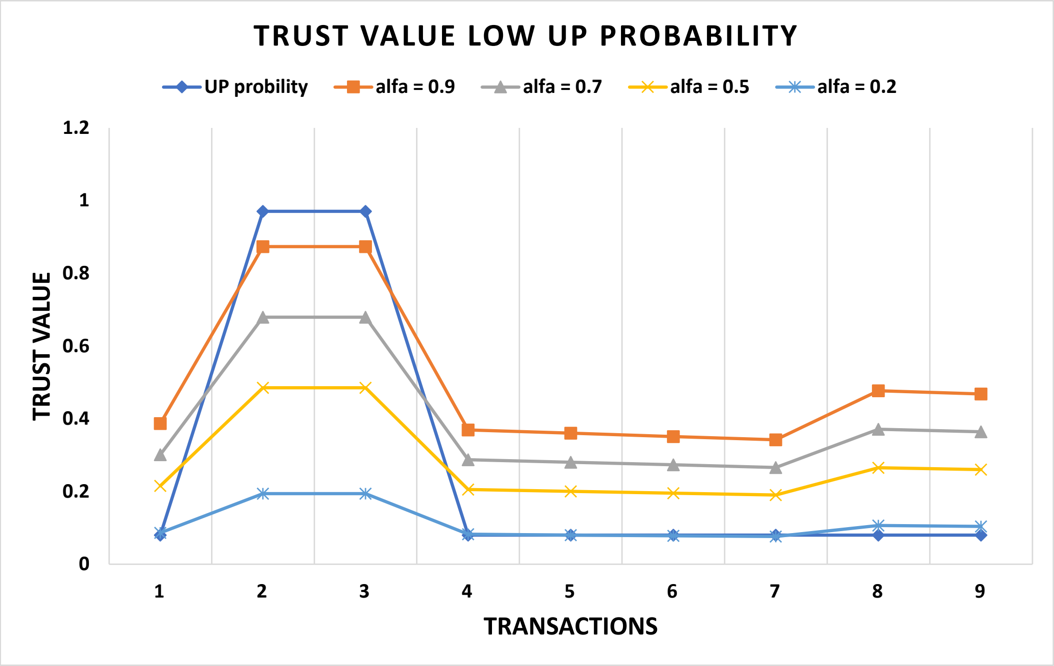
- Usually, replacing the sensors with new ones is difficult:
  - High cost;
  - Unplanned budget issues;
  - Lack of identical sensors (from the same manufacturer)

Experimental evaluation

- Experimental setup – we used analysed 10 transactions with different values of the scalar coefficient α

	$\boldsymbol{\alpha}$
1	0.2
2	0.5
3	0.7
4	0.9

Experimental evaluation

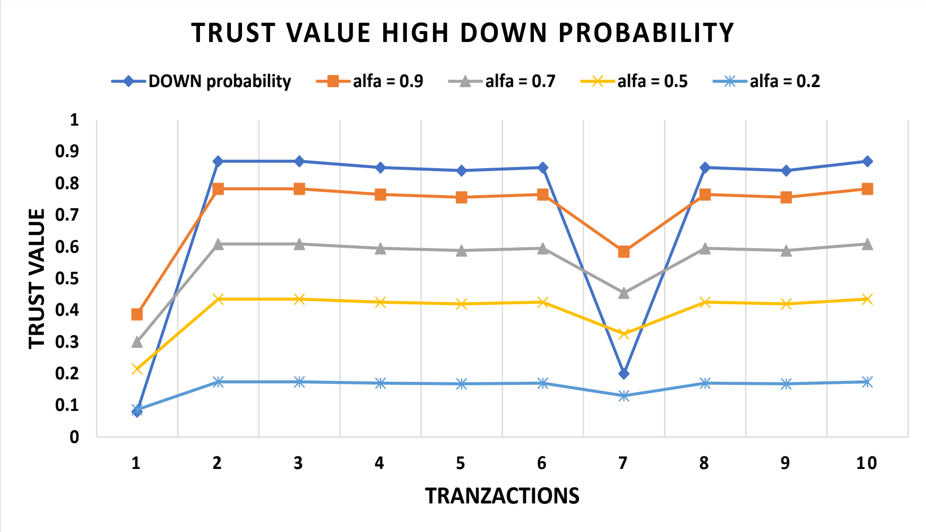


- The probability of a node to be in the UP State and suddenly changes to a DOWN STATE
- This indicates that a sensor

is likely to malfunction and the data generated is not trustworthy.

Experimental evaluation

- The probability to be in a DOWN state droop suddenly.
- This behaviour is rather an anomaly, than normal functionality of sensors.
- It this case, out solution shows the fact that the sensor is not failing and should not generate any triggers



Future work

- Integrate a lightweight cipher scheme in order to prevent external attacks;
- Evaluate our model against the Beta reputation system (from literature) in terms of:
  - response to state change,
  - time,
  - disruptive behavior,
  - model flexibility.
- Evaluate our model in real use-cases with real data sets.

Conclusions

- We propose a novel mechanism for trust management in smart cities based on Markov Chain with 4 state that combats internal attacks;
- We compute the stationary distribution of each node and compute the trust of each node in the system depending on the probabilities of being in one state and a trust coefficient α.
- We find out through empirical experimentation that the best value for the scalability coefficient α is 0.9.
- The obtained results show the fact that the proposed solution has a good precision for detection of a sudden state change making it feasible for smart-city sensors use cases.

Thank you