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Study of Active Subscription Control Parameters in Large-Scale Smart Spaces

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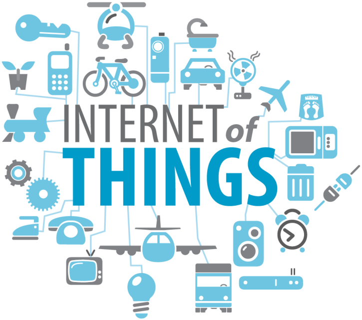
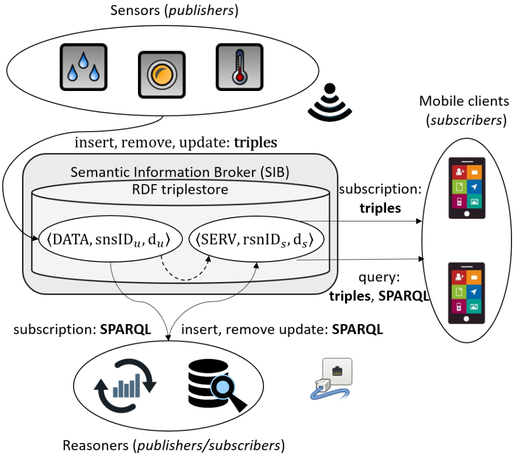
IoT Concept

- Surrounding physical objects become digitalized, interconnected, and connected to Internet resources
- Localized IoT environments appear in many application domains (room, building, city, healthcare, tourism, . . .)
- Functional heterogeneity of devices as well as many low-capacity computers (consumer electronics, embedded devices, smartphones, Wi-Fi routers, . . .)
- Fundamental problem:
  large multi-party interaction



Smart Spaces: The Smart-M3 Platform

- SSpace: created in IoT env. for multi-party information sharing and service construction
- SIB: Semantic Information Broker for shared content
- RDF data representation model: semantic interoperability and ontology-driven programming
- Subscription: Event detection overhead on SIB



Novel Design and the Applications of Smart-M3 Platform in the Internet of Things: Emerging Research and Opportunities, book by D. Korzun, A. Kashevnik, S. Balandin (IGI Global, 2017)

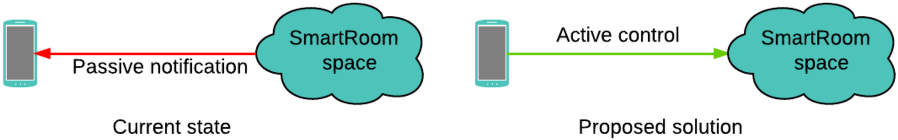
Reference Application Model

Interaction of many low-capacity and heterogeneous devices

- Defined roles of agents running on devices:
  1. Sensor: regular data provision (raw data sensing)
  2. Reasoner: data processing to deduce information (service construction)
  3. Client: information access and presentation (service delivery)
- Possible case studies:
  - SmartRoom System: Analysis of participants activity in the collaborative work
  - e-Tourism Services: Situational multimedia presentation of available descriptions for the studied cultural heritage object
  - Patient's m-Health environment: Assistance based on continuous monitoring of the patient and current surrounding

Delivery Guarantee Problem

- Subscription Problems:
  - Broker (SIB) does not check delivery for already sent notifications
  - Subscription is high expensive operation for SIB performance
  - In mobile clients:
    - the subscription is affected by losses of notifications
    - fault tolerance is essentially affected due to the specifics of wireless network communication (Wi-Fi, 3G, etc.)
- Solution:
  - Active control by a mobile client itself by replacing subscription



Korzun D., Pagano M., Vdovenko A. Control strategies of subscription notification delivery in smart spaces. In: Vishnevsky V., Kozyrev D. (eds.) Distributed computer and communication networks (DCCN). CCIS 601, pp. 40–51. Springer (2016)

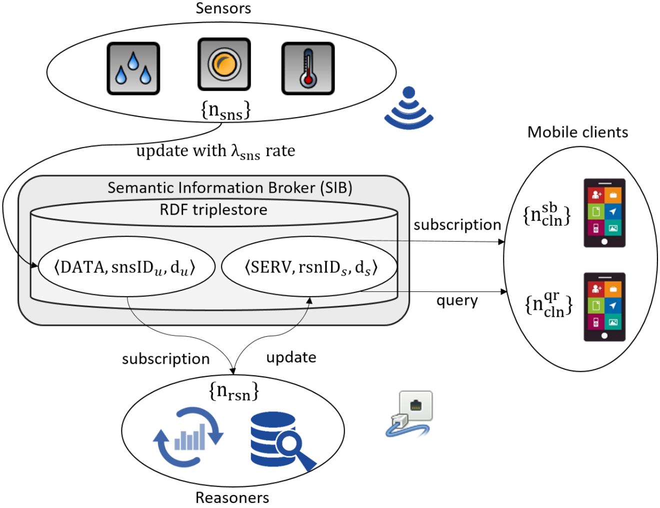
Active Control Strategy

- Active notifications: t_i can be controlled by the client
- Adaptive strategy (adaptation to losses): increasing and decreasing the t_i check interval due to observable losses k_i

$$t_{i+1} = \begin{cases} t_i/\alpha, & k_i > 0 \\ t_i + \delta, & k_i = 0 \end{cases}$$

- Sequence of multiplicative decreases X_n possesses the Markovian property with assuming that aggregated periods S_n forms renewal process
- Analytical estimations for:
  - $T_{pred} \leq \alpha\sqrt{\frac{2\delta}{\lambda^*(\alpha^2-1)}}$ — the expected length of check interval before a multiplicative decrease,
  - $N_{pred} \leq \alpha\sqrt{\frac{2\delta(\alpha+1)}{\lambda^*(\alpha-1)}}$ — the number of consecutive growths,
  - K — metric for different types of a loss flow.

Simulation Testbed 1/2



- Each agent is simulated within a separate thread on a moderate capacity machine
- SIB is hosted on a moderate-capacity machine in the same local network
- To construct the service each reasoner subscribes on data of several sensors
- To deliver the service each client subscribes on several services

Simulation Testbed 2/2

Agents implemented in Python 2.7 with Smart-M3 PythonKPI library

Functional role	Capacity	Device specification
SIB host machine	network connection with all participants	CPU Intel Core i3, CPU 1.90 GHz, RAM 4Gb, wired connection with 100 Mbps, Ubuntu 15.10
Sensors KP	10^4 agents	CPU Intel Dual Core, CPU 2.60 GHz, RAM 2Gb, wired connection with 100 Mbps, XUbuntu 16.04
Reasoner KP	10^2 agents	CPU Intel Core i5, CPU 1.70 GHz, RAM 6Gb, wireless connection with 21 Mbps, Ubuntu 15.10
Mobile Client KP	10^3 agents	CPU Intel Core i5, CPU 2.50 GHz, RAM 3Gb, wireless connection with 21 Mbps, XUbuntu 16.04
Reference agents	3 agents $\lambda_{\text{sns}} = 1.5$ client $t_0 = 3$	CPU Intel Core i5, CPU 2.50 GHz, RAM 3Gb, wireless connection with 21 Mbps, XUbuntu 16.04

Evaluation Objectives

I T_{pred} vs T_{exp} as average of X_n

II N_{pred} vs N_{exp} as average of growth event

III K the average number of losses before decrease ($K_{\text{Poisson}}, K_{\text{bulk loss}}, K_{\text{Bernoulli}}$)

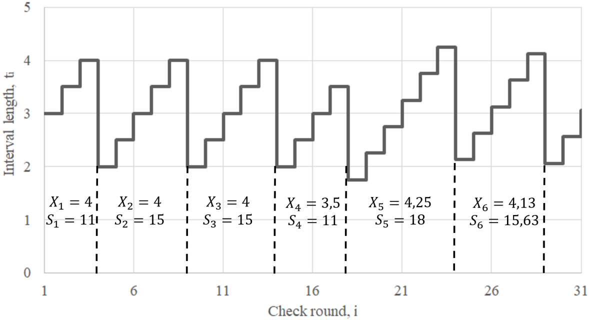
IV Client request rate λ_{cl} and total losses percent

$$t_{i+1} = \begin{cases} t_i/\alpha, k_i > 0 \\ t_i + \delta, k_i = 0 \end{cases}$$

$$X_n = t_j \text{ if } t_{j+1} = t_j/\alpha$$

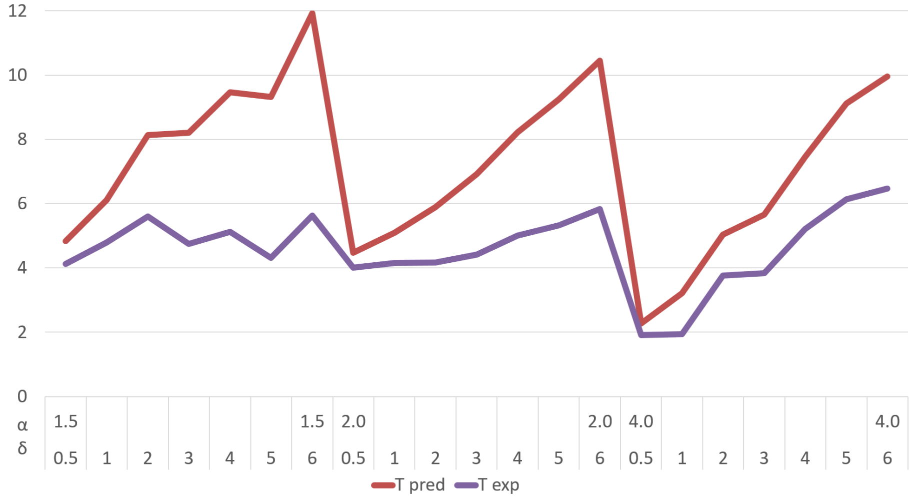
$$S_n = \sum_{i=j}^{m} t_i, m : k(m) > 0$$

$$\alpha = 2, \delta = 0.5$$



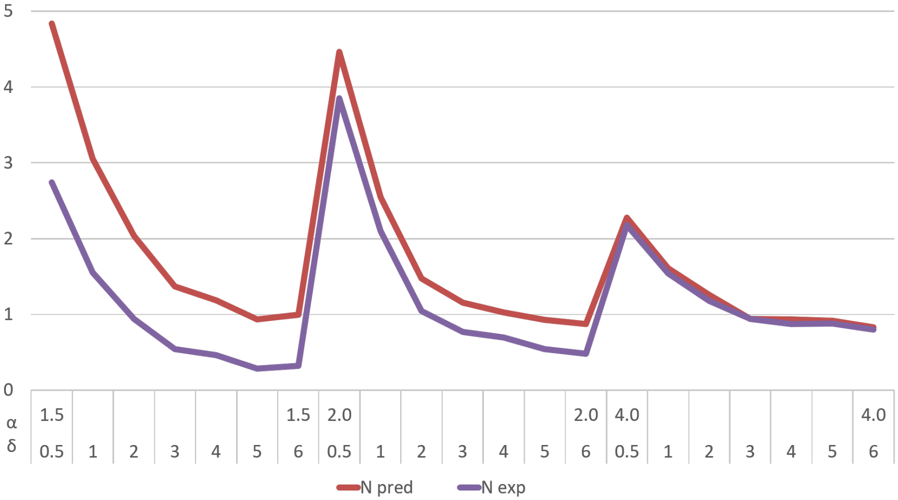
Objective I: Length of interval

Expected length of t_i before a multiplicative-decrease



When $\delta > 3$ for $\lambda_{\text{sns}} = 1.5$ the estimation give much bigger values than experimental

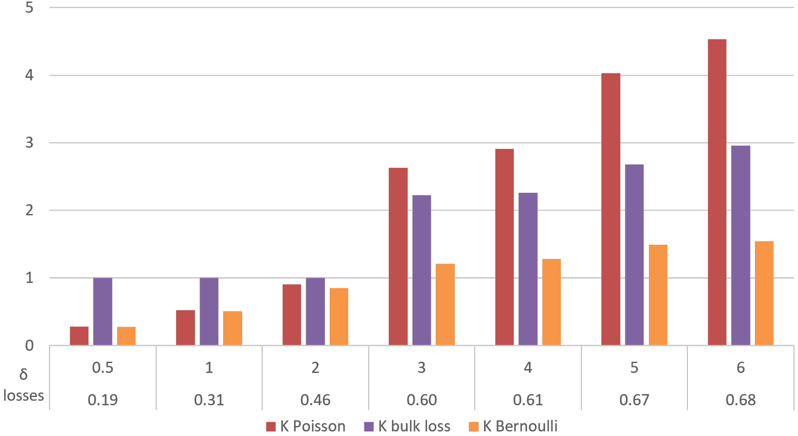
Objective II: Number of consecutive growth



Estimation provides a high bound for experimental values in most of cases

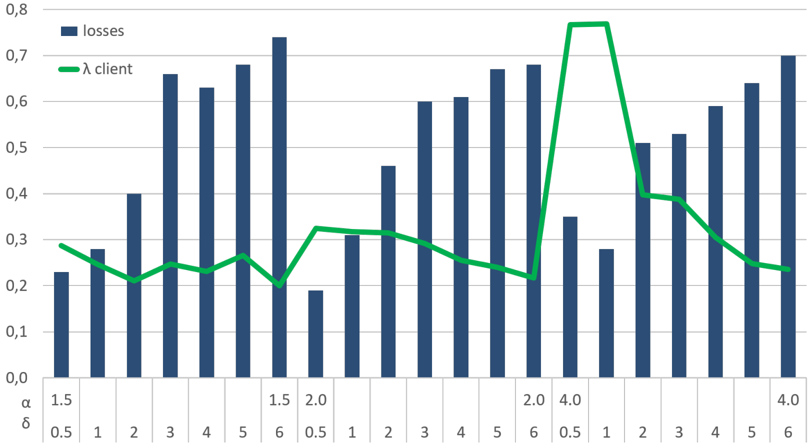
Objective III: Average number of losses

1. $K_{\text{Poisson}} \approx \lambda T_{\text{pred}}$ (losses provided by low intensity sources independently can be approximated by Poisson flow)
2. $K_{\text{bulk loss}} = \sum_{n=0}^{\infty} p_n$ (average losses number on decrease event)
3. $K_{\text{Bernoulli}} \approx \lambda_{\text{cl}} Tp$ (losses probability connected with client request rate)



Objective IV: Client request rate and losses

Behaviour of λ_{cl} for different values of δ and α and interdependence of losses percent at all intervals



Higher rate leads to smaller percent of losses

Too big control parameters values leads to worse losses percent

Conclusion

- Use of active control instead of subscription to improve performance in large-scale smart spaces
- Analytical estimations for:
  - The expected length of check interval before a multiplicative decrease,
  - The number of consecutive growths,
  - Metric for different types of a loss flow.
- Testbed for simulation of Large-Scale IoT environment
- Experimental evaluations of estimations demonstrated that they could be used for tunning parameters of the active control

Thank you! Now it’s time for your questions

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