Probabilistic Event Dropping for Intermittently Connected Subscribers over Pub/Sub Systems

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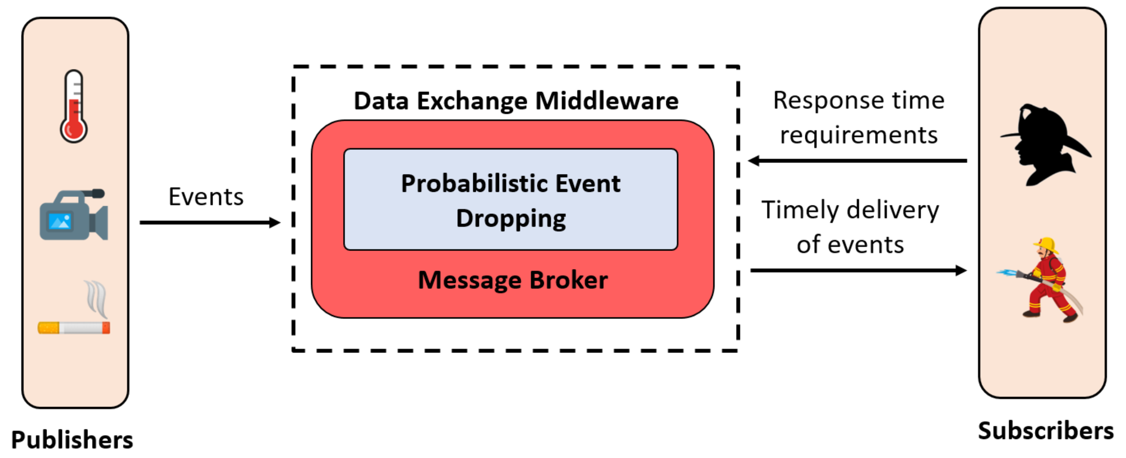
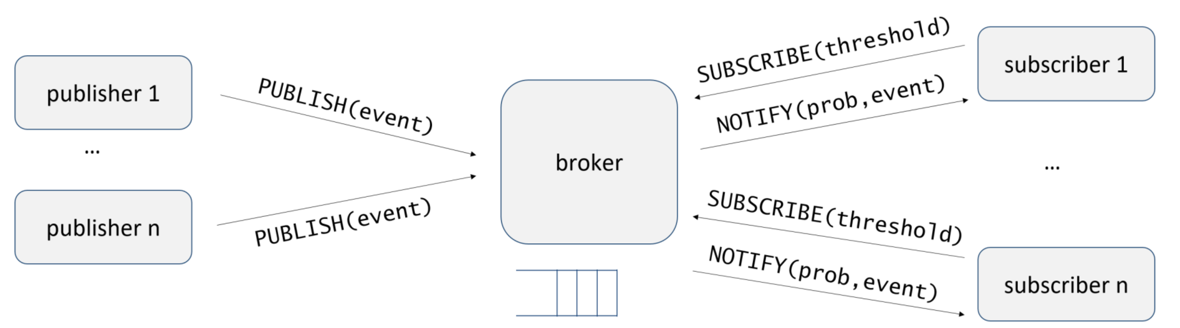
Motivation

- Our main goal is to ensure the delivery of mission critical data in Internet of Things (IoT) applications with a certain level of Quality of Service (QoS).
- We introduce a pub/sub mechanism for probabilistic event dropping by considering the stakeholders' intermittent connectivity and QoS requirements.



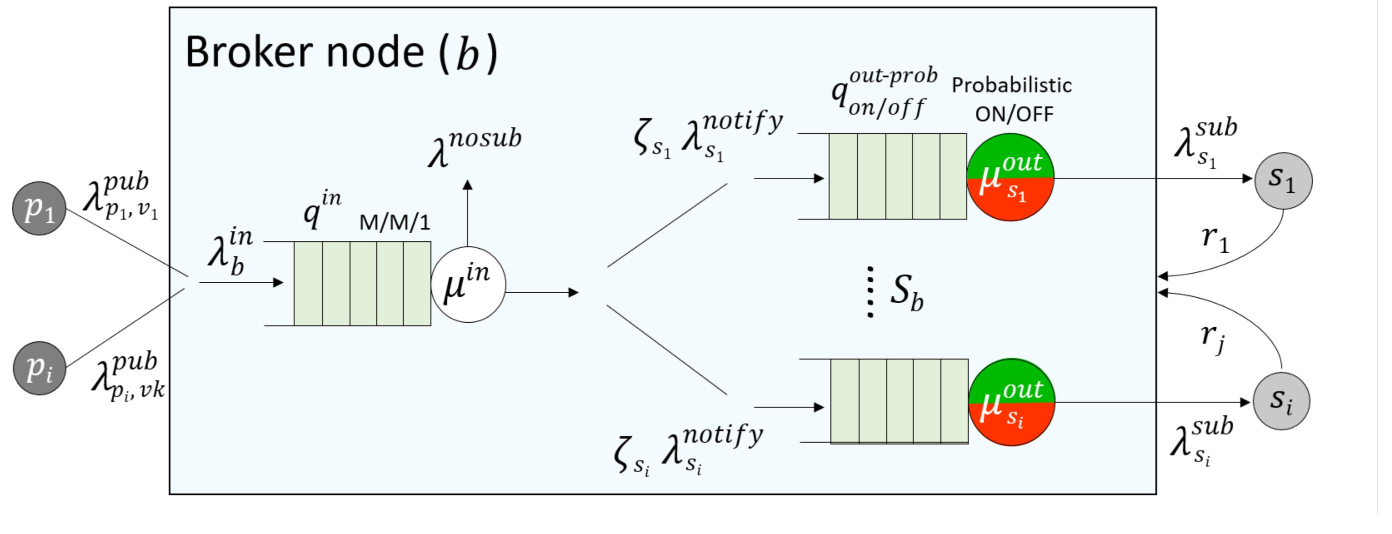
Pub/Sub System with Probabilistic Event Dropping



- In pub/sub, multiple peers interact via an intermediate broker.
- Subscribers subscribe their interest for specific topics to the broker using a threshold time period.
- Publishers produce events characterized by a specific topic to the broker.
- The broker matches received events with subscriptions and delivers each event to interested subscribers using a join probability which is estimated based on the subscribers' threshold.

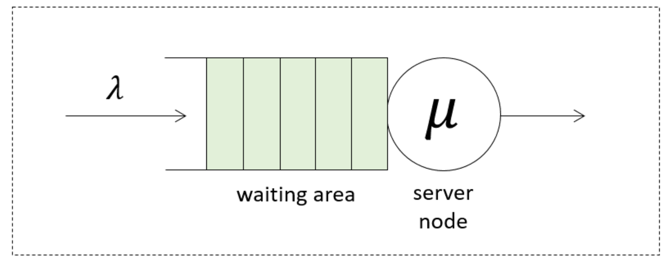
Pub/Sub Formal Model

- To formalize the probabilistic pub/sub mechanism we rely on our previous experience [1,2,3] where we model pub/sub systems with different characteristics as network of queues.

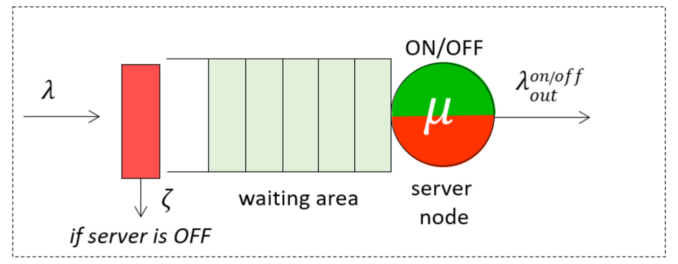


$$\Delta_{s_i} = \Delta_{q^{in}} + \Delta_{q^{prob}_{on/off}}$$

- M/M/1 queue:



- Probabilistic ON/OFF queue:

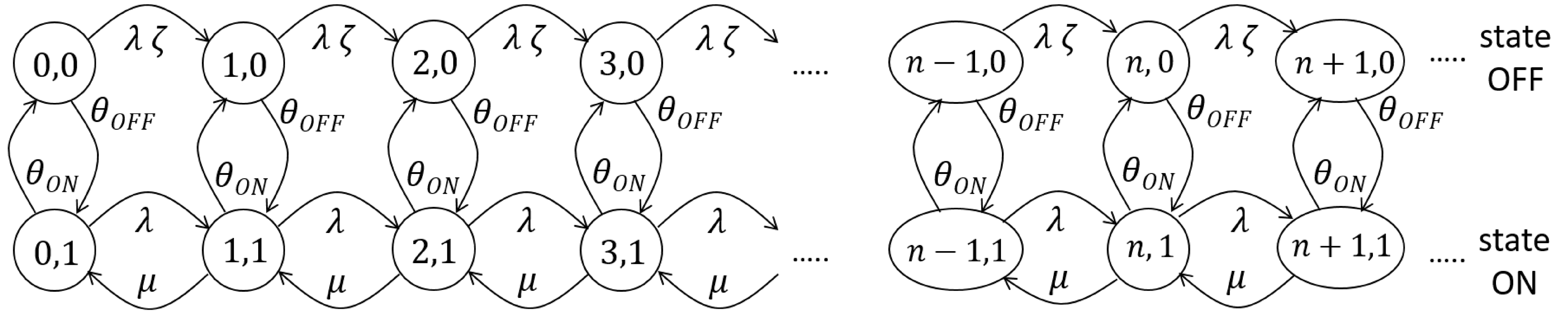


- Model variables and shorthand notation:

Variable(s)	Definition/Description
$v_k \in V$, $r_j \in R$	event topics and subscriptions
$p_i \in P$, $s_i \in S$	publishers and subscribers
$\lambda^{pub}_{p_i,v_k}$, λ^{in}_b, λ^{nosub}	publication rate, input b's rate, subscriptions drop rate
$\lambda^{notify}_{s_i}$, $\lambda^{sub}_{s_i}$	s_i's notification rate, s_i's delivery rate
ζ_{s_i}, S_b	join probability, $\lvert S\rvert$ subscribed in b
μ^{in}, $\mu^{out}_{s_i}$	processing rate, transmission rate
$T^{s_i}_{\mathrm{ON}}$, $T^{s_i}_{\mathrm{OFF}}$	average connected period, average disconnected period
Δ_{s_i}, $\Delta^{Thr}_{s_i}$, Ξ_{s_i}	s_i's response time, s_i's threshold, s_i's delivery success rate

Probabilistic ON/OFF Analytical Model

- The probabilistic ON/OFF model is described as a 2D Markov chain:



- Server ON probability:

$$P_{server}(ON) = \sum_{n=0}^{\infty} P_{n,1} = \frac{\theta_{\mathrm{OFF}}}{\theta_{\mathrm{ON}} + \theta_{\mathrm{OFF}}}$$

- Server OFF probability:

$$P_{server}(OFF) = \sum_{n=0}^{\infty} P_{n,0} = \frac{\theta_{\mathrm{ON}}}{\theta_{\mathrm{ON}} + \theta_{\mathrm{OFF}}}$$

- The global balance (GB) equations of the 2D Markov chain:

$$\text{State}(0,0): \theta_{\mathrm{ON}} P_{0,1} - (\lambda\zeta + \theta_{\mathrm{OFF}}) P_{0,0} = 0$$
$$\text{State}(0,1): \theta_{\mathrm{OFF}} P_{0,0} + \mu P_{1,1} - (\lambda + \theta_{\mathrm{ON}}) P_{0,1} = 0$$
$$\text{State}(1,0): \lambda\zeta P_{0,0} + \theta_{\mathrm{ON}} P_{1,1} - (\lambda\zeta + \theta_{\mathrm{OFF}}) P_{1,0} = 0$$
$$\text{State}(1,1): \lambda P_{0,1} + \mu P_{2,1} + \theta_{\mathrm{OFF}} P_{1,0} - (\lambda + \mu + \theta_{\mathrm{ON}}) P_{1,1} = 0$$
...
$$\text{State}(n,0): \lambda\zeta P_{n-1,0} + \theta_{\mathrm{ON}} P_{n,1} - (\lambda\zeta + \theta_{\mathrm{OFF}}) P_{n,0} = 0$$
$$\text{State}(n,1): \lambda P_{n-1,1} + \mu P_{n+1,1} + \theta_{\mathrm{OFF}} P_{n,0} - (\lambda + \mu + \theta_{\mathrm{ON}}) P_{n,1} = 0$$
...

- We use the matrix-geometric method to solve efficiently the 2D Markov chain (quasi-birth death processes).
  - Average number of events in the system (server + queue):

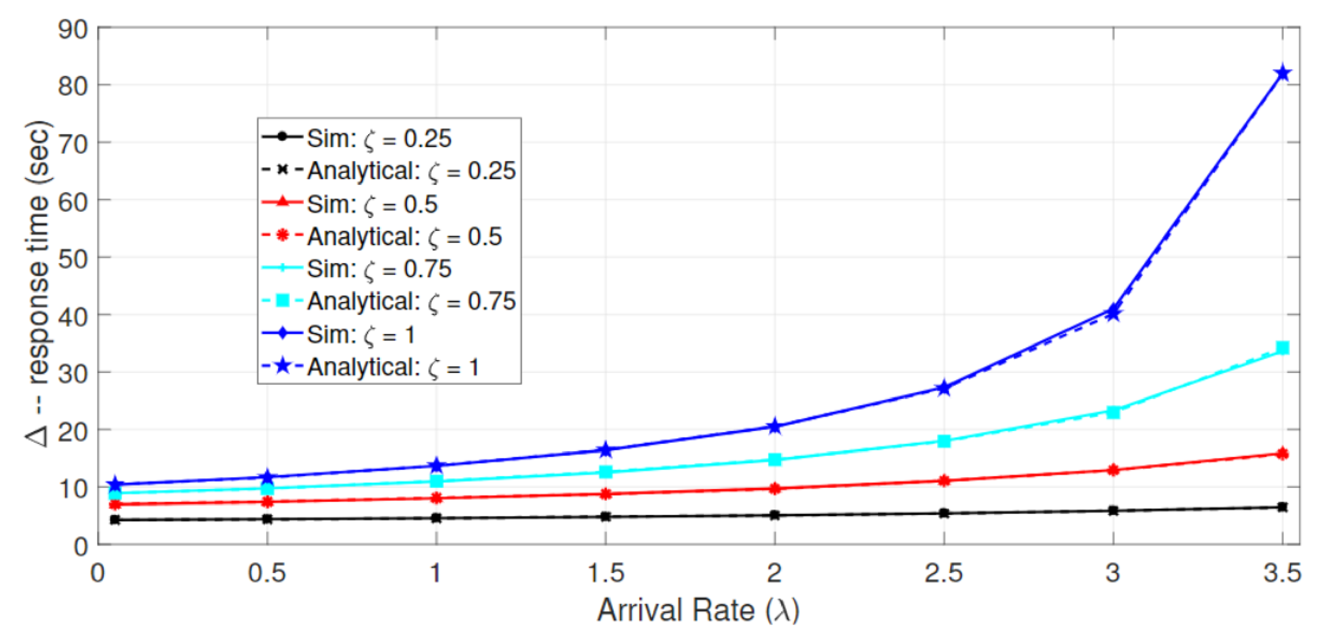
$$E(n)_{on/off} = \sum_{n=0}^{\infty} n (P_{n,0} + P_{n,1})$$

  - Average response time of events in the system (server + queue):

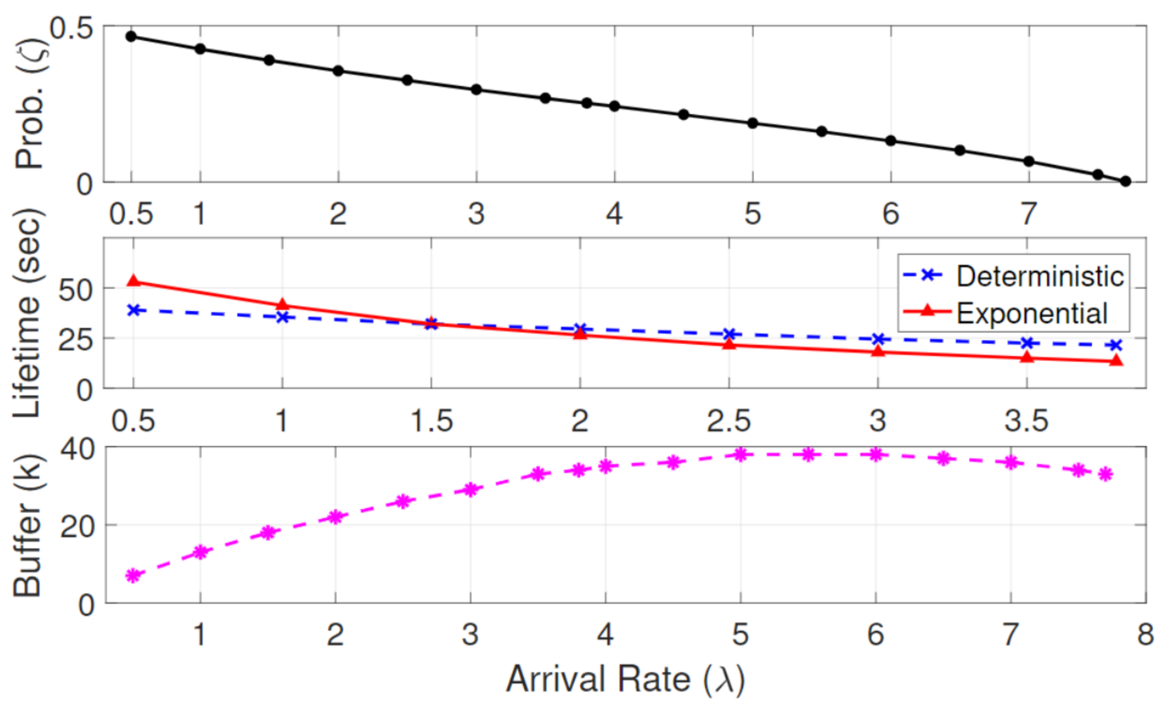
$$\Delta_{q^{prob}_{on/off}} = \frac{E(n)_{on/off}}{\lambda_{eff}}$$

Experiments

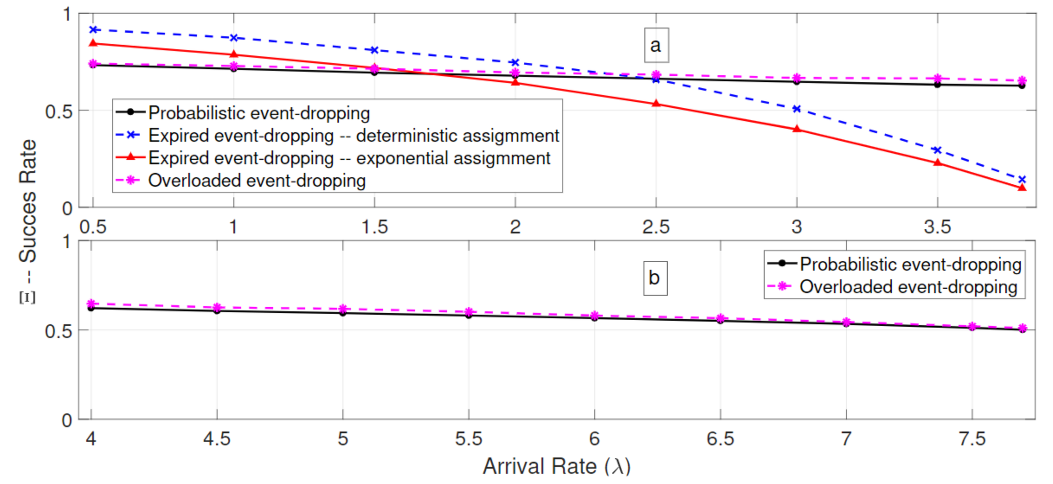
- Probabilistic ON/OFF model validation:



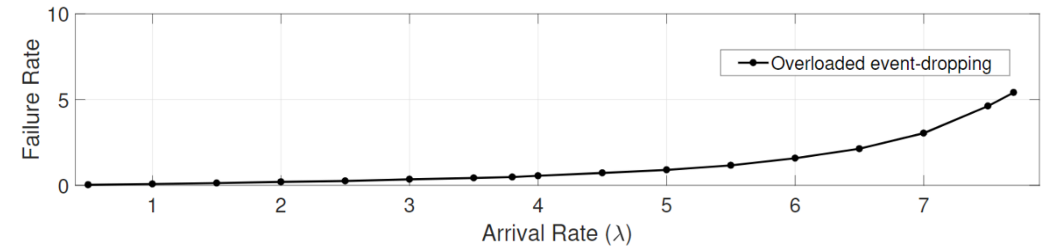
- Varying k, lifetime and ζ parameters to compare delivery success rates of the probabilistic ON/OFF model:



- Comparison of different event dropping mechanisms for $\Delta_{s_i} = \Delta^{\mathrm{Thr}}_{s_i} = 7$ sec:



- Failure rates during ON periods:



Future Work

- Our next steps include:
  - ✓ Implementing a prototype of the proposed pub/sub mechanism
  - ✓ Relying on [4] to extend our approach to dropping events based on both the stakeholders' intermittent connectivity as well as the events' importance.
  - ✓ Using a real dataset to validate our analytical model and evaluate our proposed mechanism.

Bibliography

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