

# Performance Modeling of the Middleware Overlay Infrastructure of Mobile Things

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MiMove  
Middleware on the Move



# Middleware Protocols in the IoT

- Devices and protocols:



DPWS

CoAP

MQTT

ZeroMQ

XMPP

....

Streaming

Async

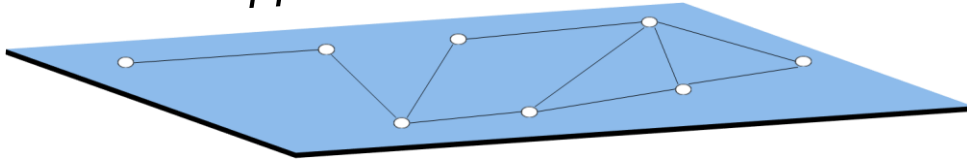
Sync

Pub/Sub

....

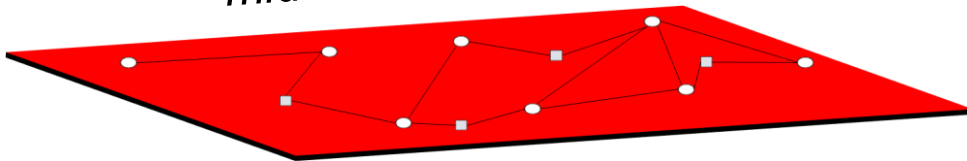
# IoT Interactions across Multiple Layers

*application layer*



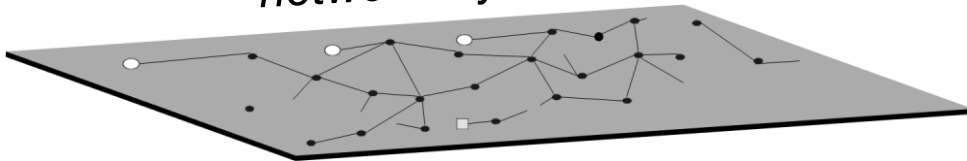
- Things interact with each other by relying on the middleware-layer protocols
- Things may receive data on a voluntary basis (e.g., to save energy)
  - *app-layer disconnections*

*middleware layer*



- Each (IP-based) protocol implements its own QoS features on top of UDP/TCP
- Protocols deal with network issues (e.g., wireless disconnections)
  - *mdw-layer disconnections*

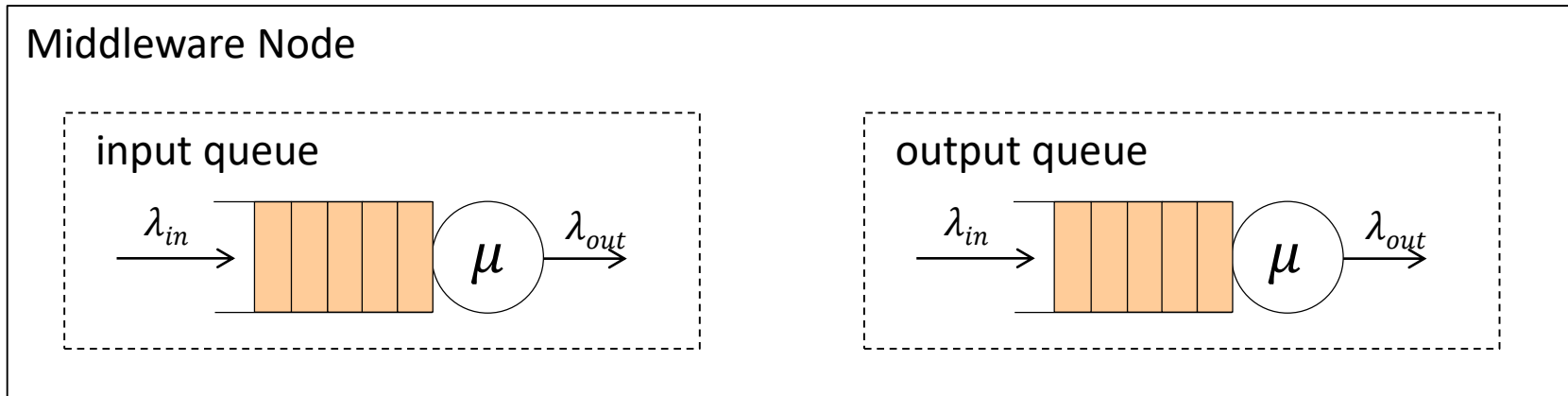
*network layer*



- Data are routed through the physical network, which consists of physical routers and links

# Middleware-layer Performance Modeling

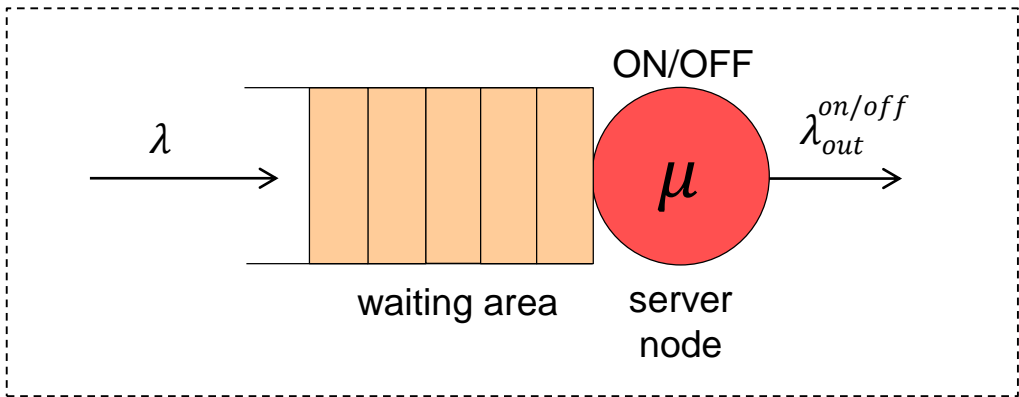
- We model a middleware node using simple input and output queues:



- An input queue is used to represent the processing of received data
- An output queue is used to represent the transmission of data
- The service rate of output queues model the network transmission delay

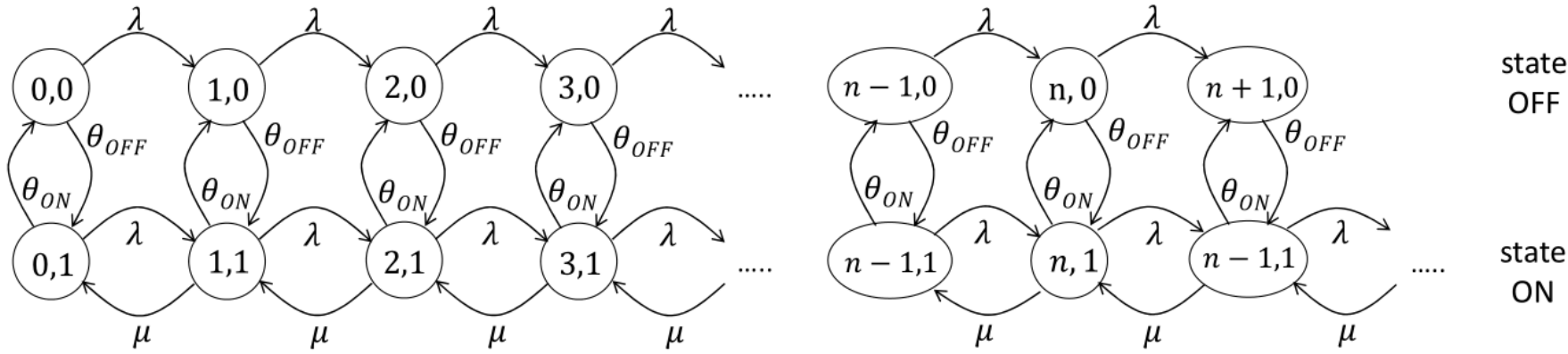
# Middleware Model for Mobile peers

$\theta_{ON}$



$\theta_{OFF}$

- 2-D Markov chain:
  - solving the global balance equations



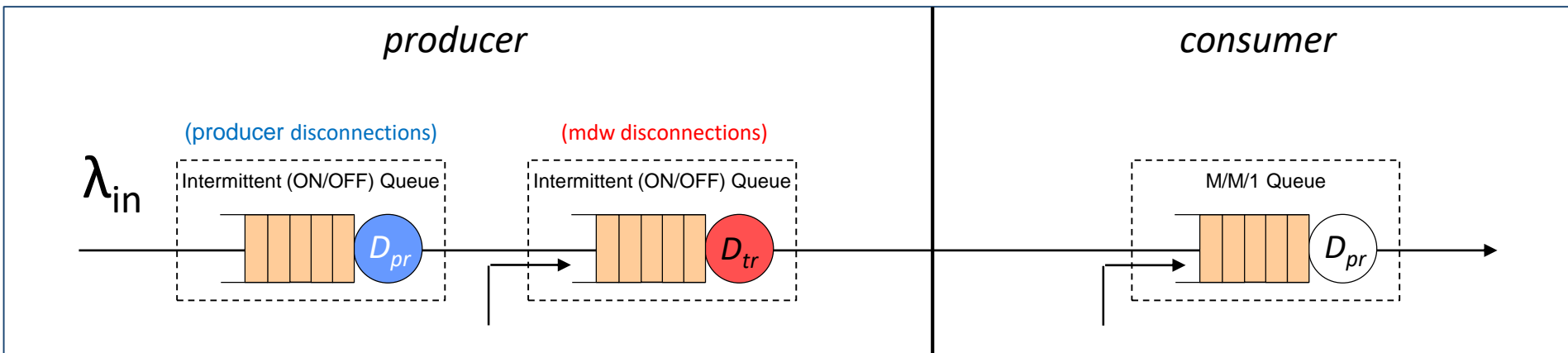
$$E(n)_{on/off} \approx \frac{\rho' + \rho_{OFF} P_{server}(OFF)}{1 - \rho'} \quad T_{on/off} = \frac{E(n)_{on/off}}{\lambda}$$

# Performance Model for Streaming Interactions

- Data Streaming (DS) Communication Style:



- Performance model (reliable) for DS:



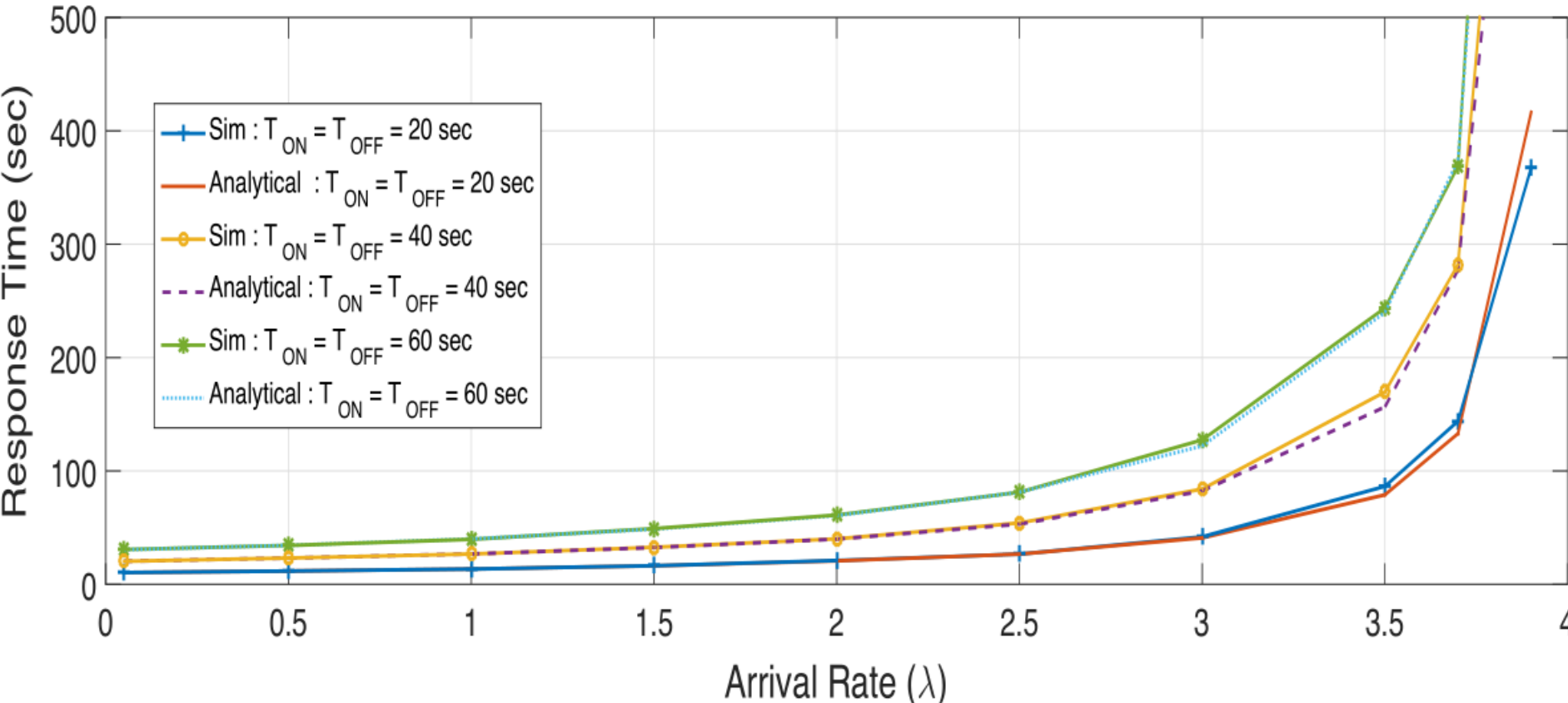
# Evaluation Results

- JINQS:
  - open source simulator for Queueing Network Models
- We extend JINQS and we have developed MobileJINQS<sup>1</sup>:
- We validate the ON/OFF queueing center through:
  - probability distributions for arrival rates and ON/OFF connectivity
  - arrival rates using the D4D dataset<sup>2</sup>
  - ON/OFF connectivity traces collected in the metro of Paris<sup>2</sup>
- Simulate and validate end-to-end response times in DS

<sup>1</sup> <http://xsb.inria.fr/d4d#mobilejinqs>

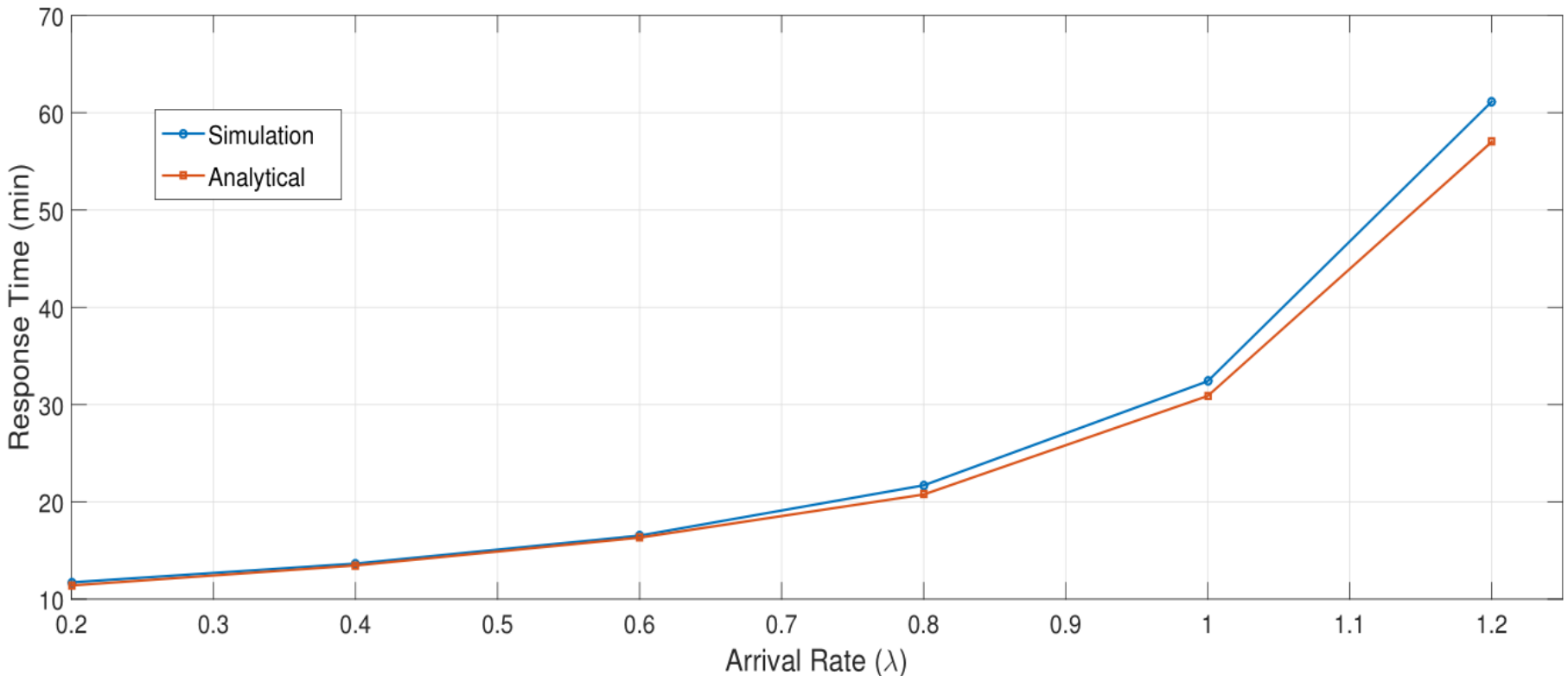
<sup>2</sup> G. Bouloukakis et al., Timeliness Evaluation of Intermittent Mobile Connectivity over Pub/Sub Systems. 8th ACM/SPEC International Conference on Performance Engineering (ICPE), 2017

# ON/OFF queueing center validation: Estimated vs. Simulated Response Time





# End-to-end Response Times in DS



- App-layer disconnections:

- $T_{ON} = 1$  min
- $T_{OFF} = 10$  min

- Mdw-layer disconnections<sup>1</sup>:

- $T_{ON} = 4.8$  min
- $T_{OFF} = 1.3$  min

# Next steps

- Future work:
  - Apply lifetime periods to each published event.
  - Deal with unreliable infrastructures for middleware Internet of Things protocols.
  - Introduce models that evaluate the interoperability effectiveness of Things employing heterogeneous protocols.

# Thank you

*informatics mathematics*  
*Inria*

