Modeling and Performance Evaluation of a Manual Logon System for Electronic Fee Collection

VDE/ITG-Workshop: Communication Applications for Logistics: Maut, Telematics & More
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Contents

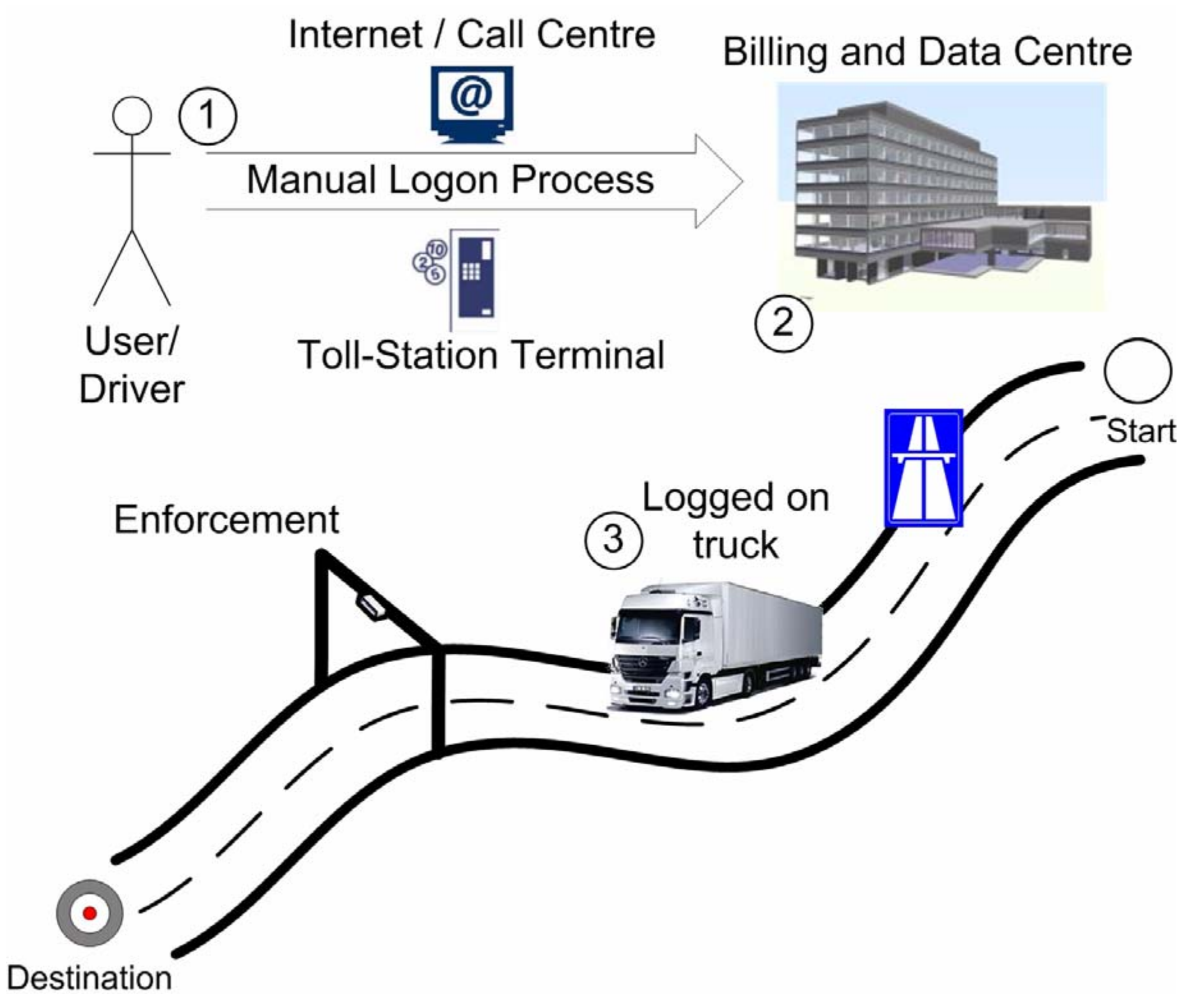
- TollCollect’s logon process and system architecture
- Modeling aspects
- Performance evaluation
- Backoff Algorithm

German Toll Collection System "TollCollect"

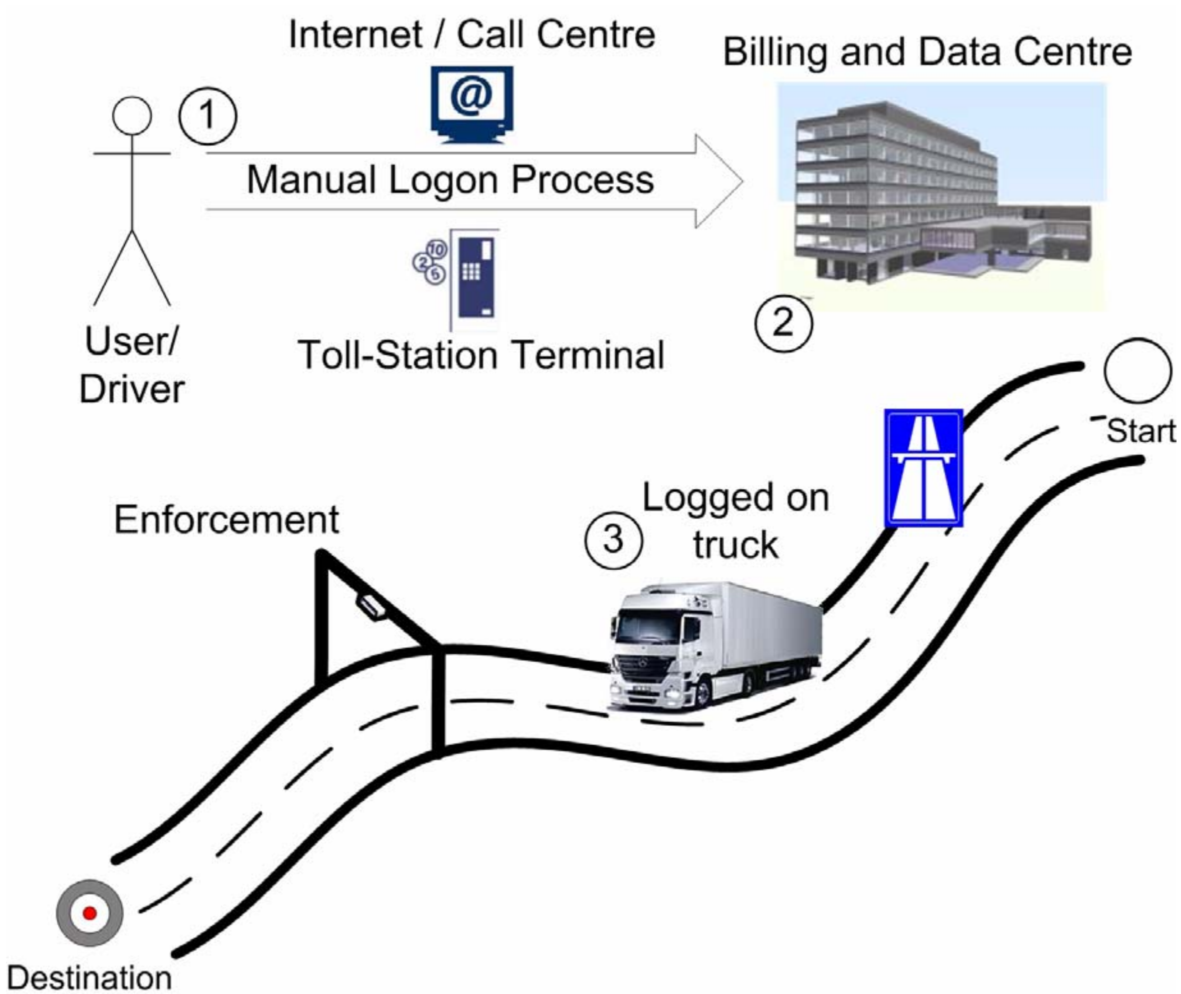
- 2005, Germany introduced an Electronic Fee Collection System (EFC)
- Global navigation satellite system and cellular network (GNSS/CN)
- Currently > 700,000 registered users
  By 2012, might grow to over 9 million in Europe
- Three approaches for payment

Automatic Logon	Manual Logon	
On-board unit	Internet and Call Centre	Toll-Station Terminal
• > 460,000 (July 2005)		• approx. 3600 terminals
• approx. 80% revenue	• marginal and declining	• approx. 400 frequently used terminals • approx. 400 rarely used terminals

TollCollect's Manual Logon Process for EFC



TollCollect's Manual Logon Process for EFC



- **Billing data records have to be transferred quickly for enforcement**

➥ **System behavior after failure or outage is critical**

Manual Logon Process

Challenging Scenarios

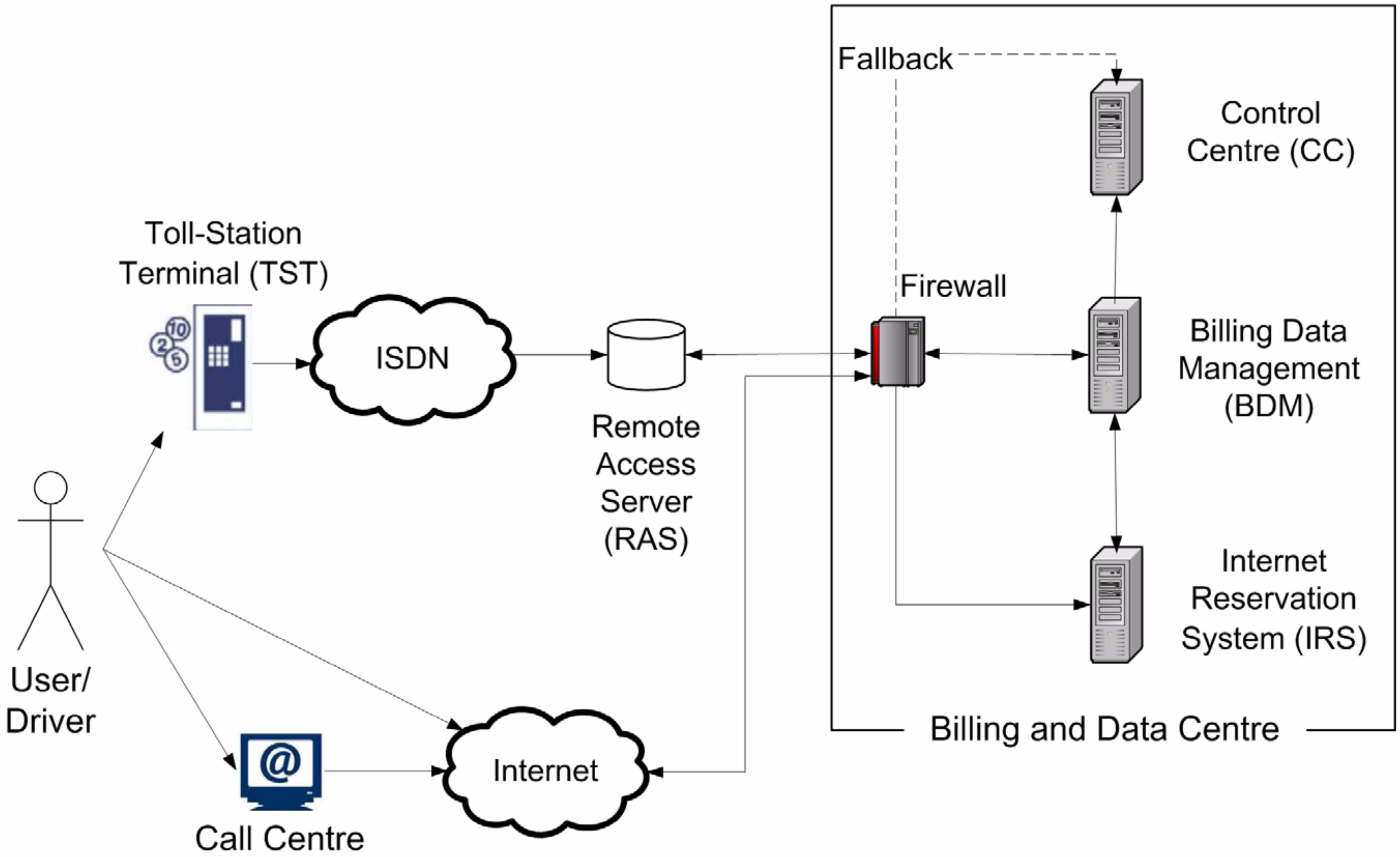
- **System failure or breakdown of key components**
  - Billing and Data Centre
  - Remote Access Server (RAS)
- **Overload situation**
  - Breakdown of the automatic GNSS/CN EFC system
  - Specific and unexpected peaks

➡ **Financial losses and negative standing for the operator**

Aim of this work

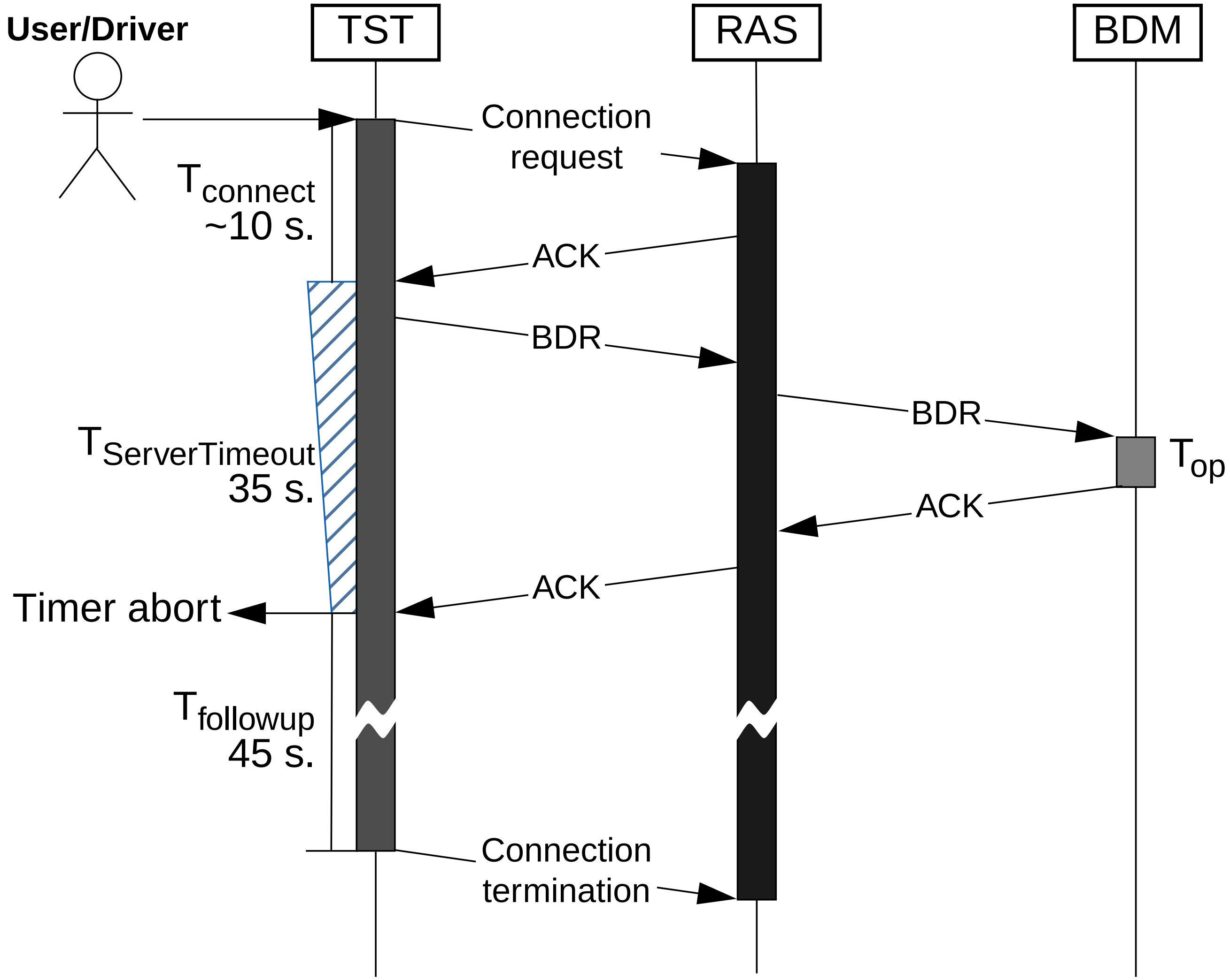
- **Model and evaluate the overall manual logon process regarding performance and scalability**
- **Optimize the algorithm and parameters for transmission of billing data records after system outage**

Terminal-based EFC system architecture



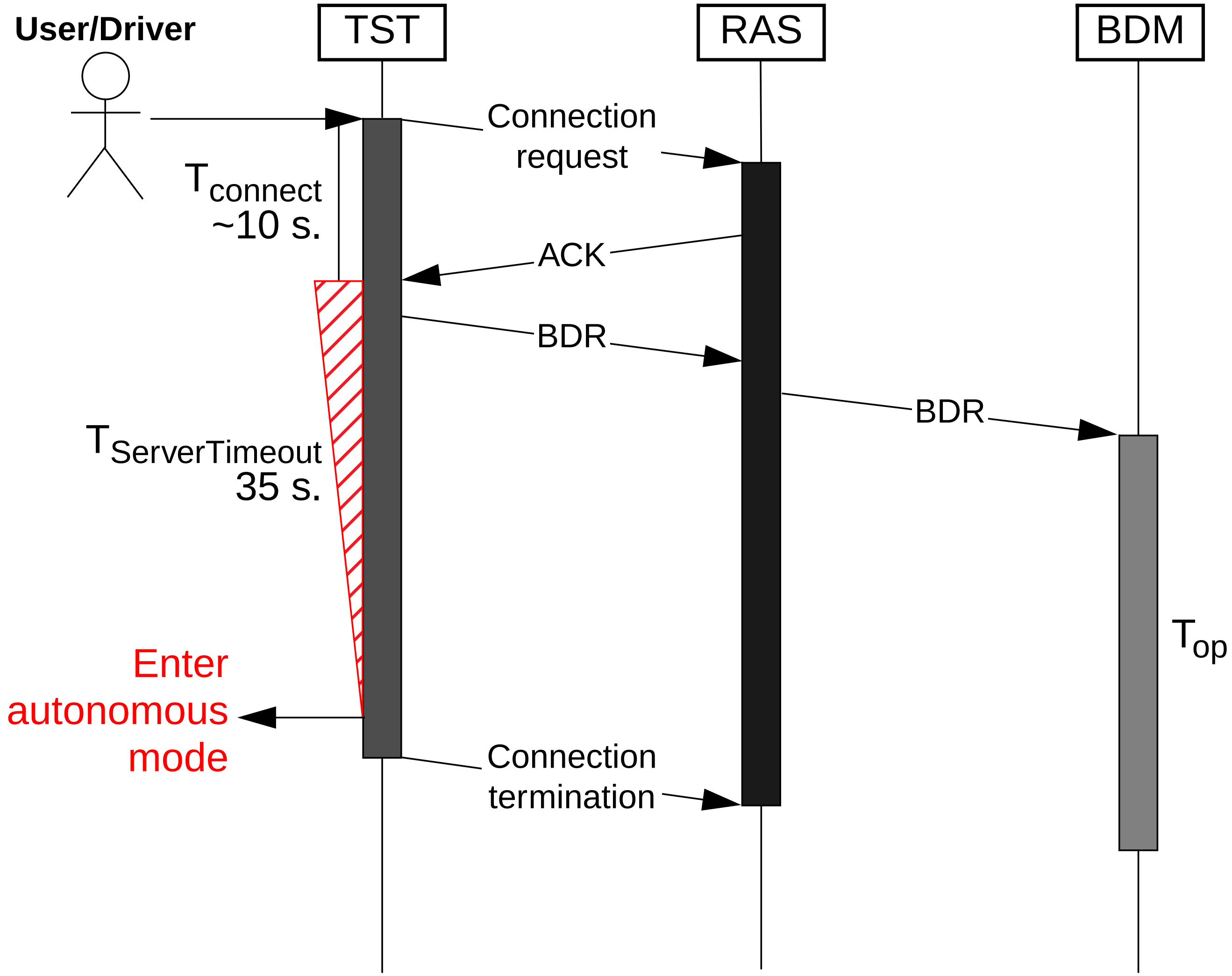
Normal operational mode

Failure-free billing data records (BDR) delivering

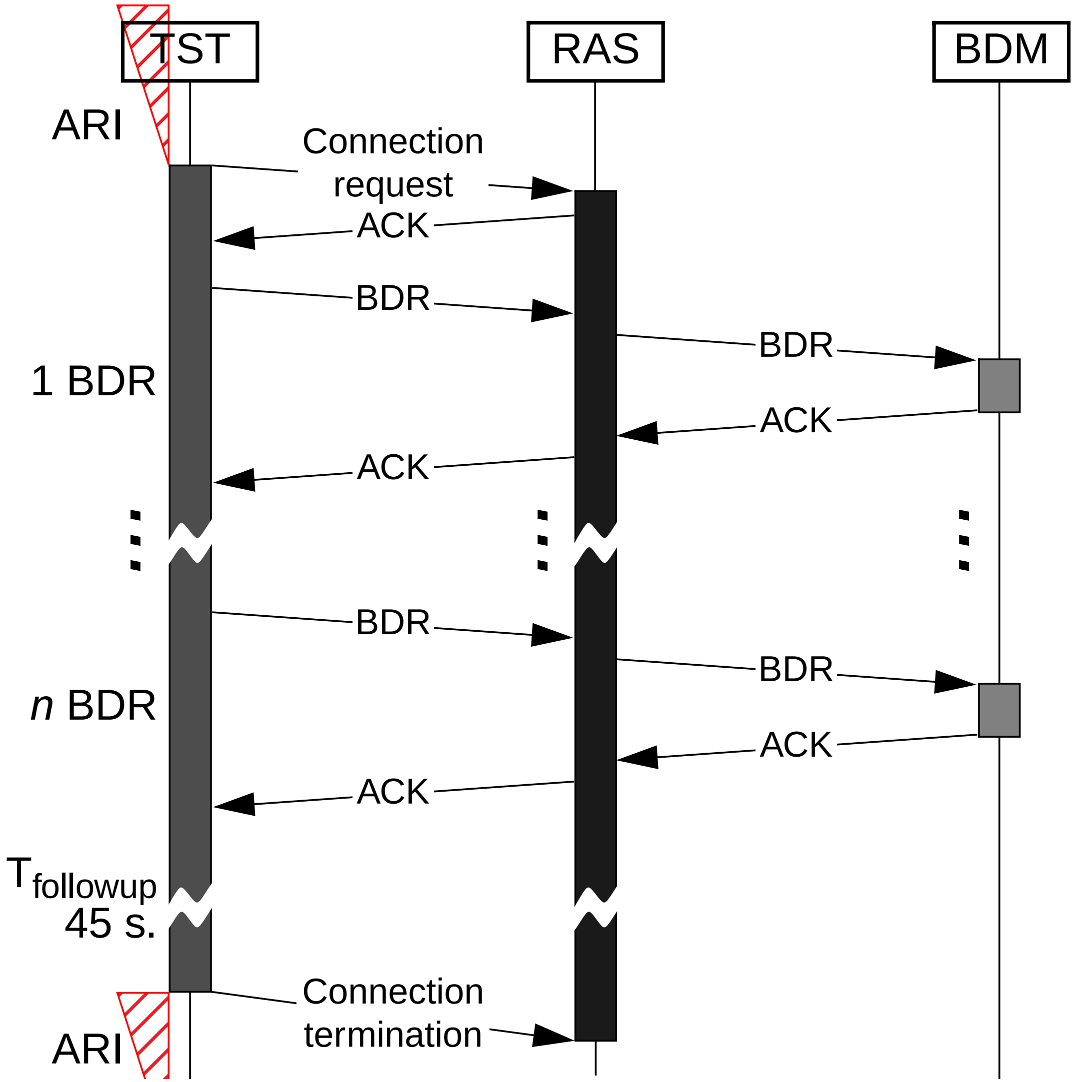


Autonomous mode

Erroneous connection establishment



Billing data records (BDR) delivering



Parameters

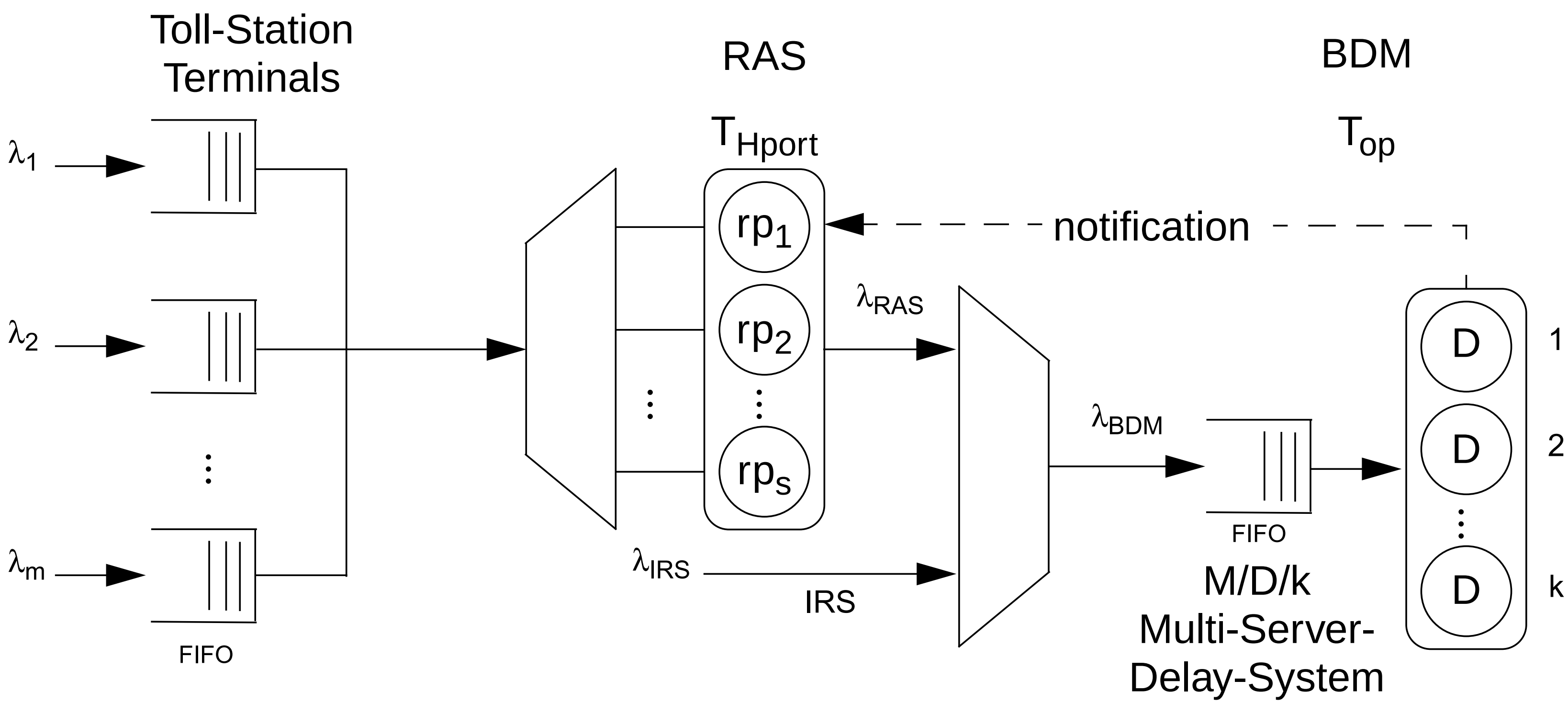
- AutoReconnectInterval ARI
- AutoSendInterval ASI
- Number of delivered BDRs n
- Time to transfer one BDR t_{BDR}

Relations

$$n = \begin{cases} 1 & ASI < t_{BDR} \\ \frac{ASI}{t_{BDR}} & ASI \geq t_{BDR} \end{cases}$$

Modeling the terminal-based EFC system

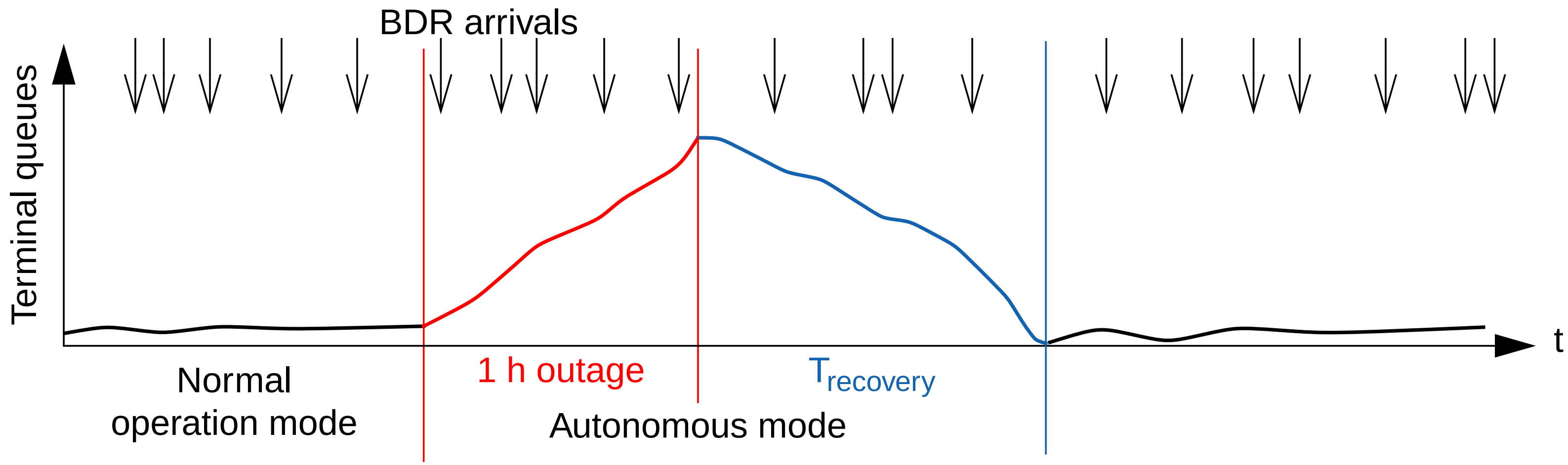
Open queueing network



- *Frontend* comprises the terminals and the RAS
- *Backend* represents the BDM as a M/D/k-Multi-Server-Delay-System

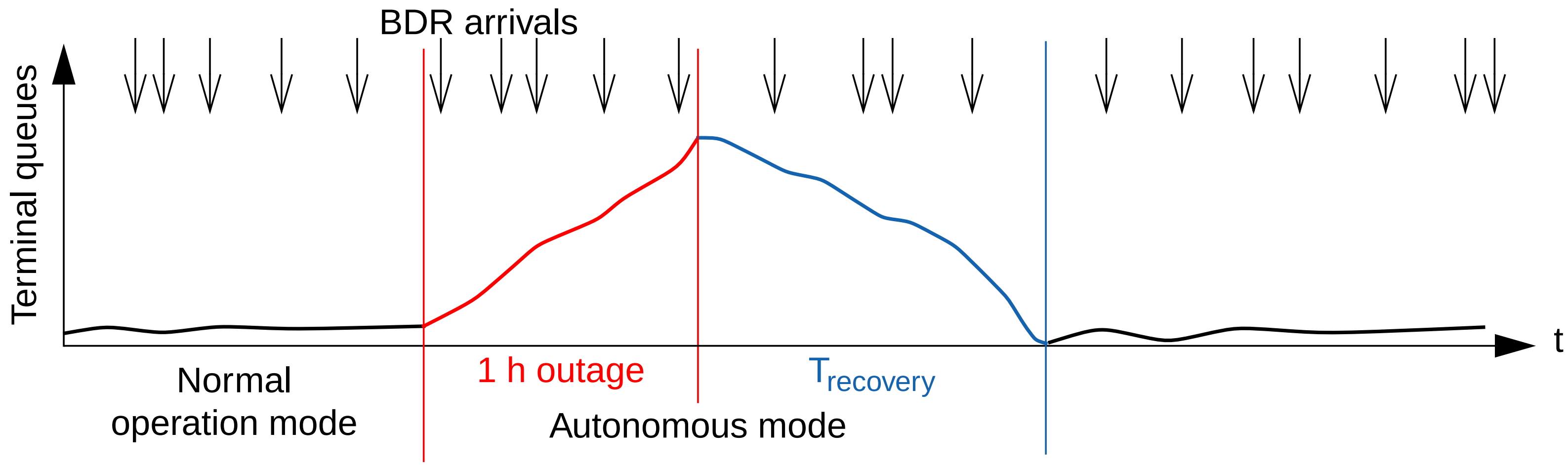
Performance evaluation

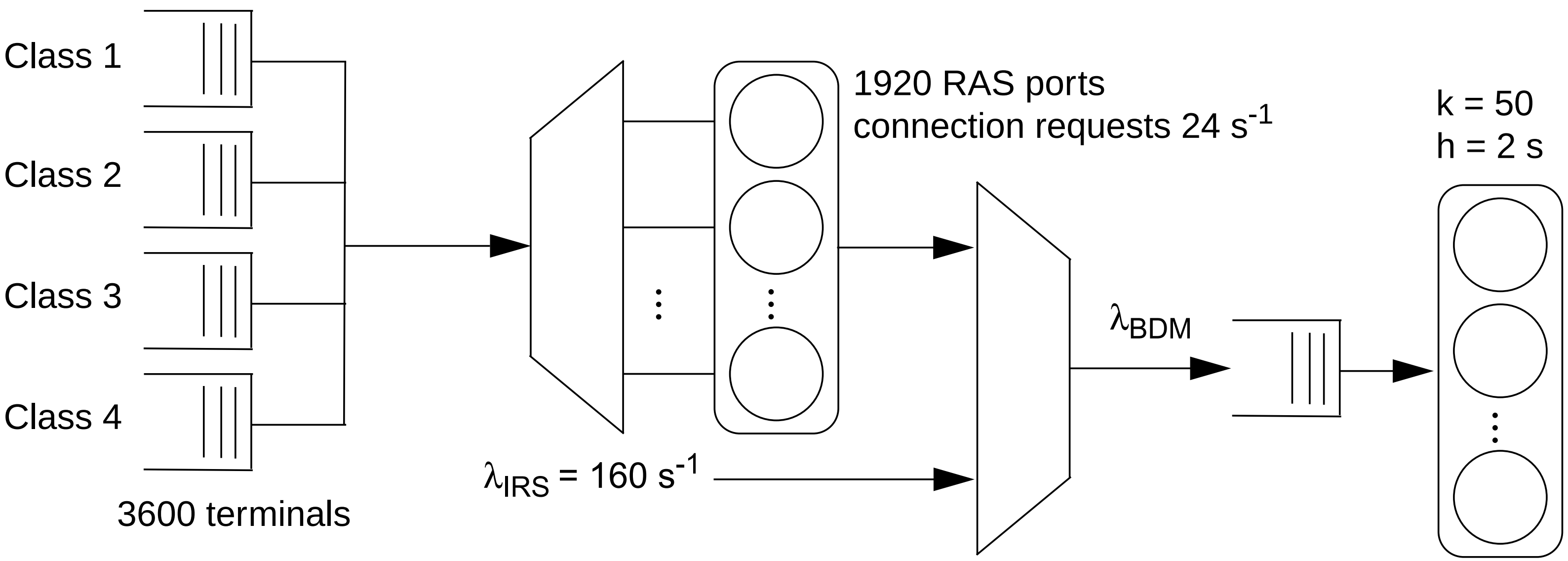
Scenario



Performance evaluation

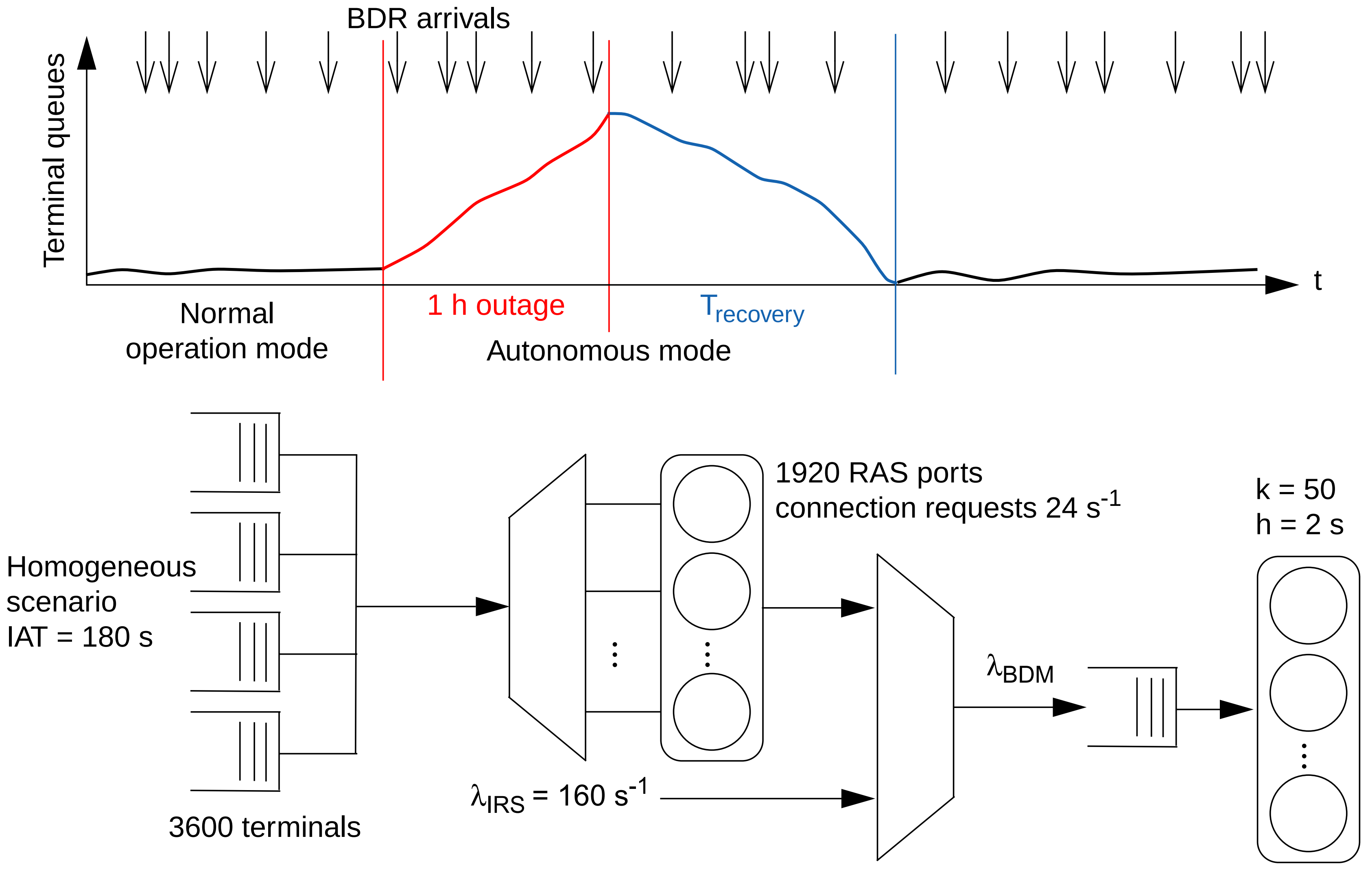
Scenario





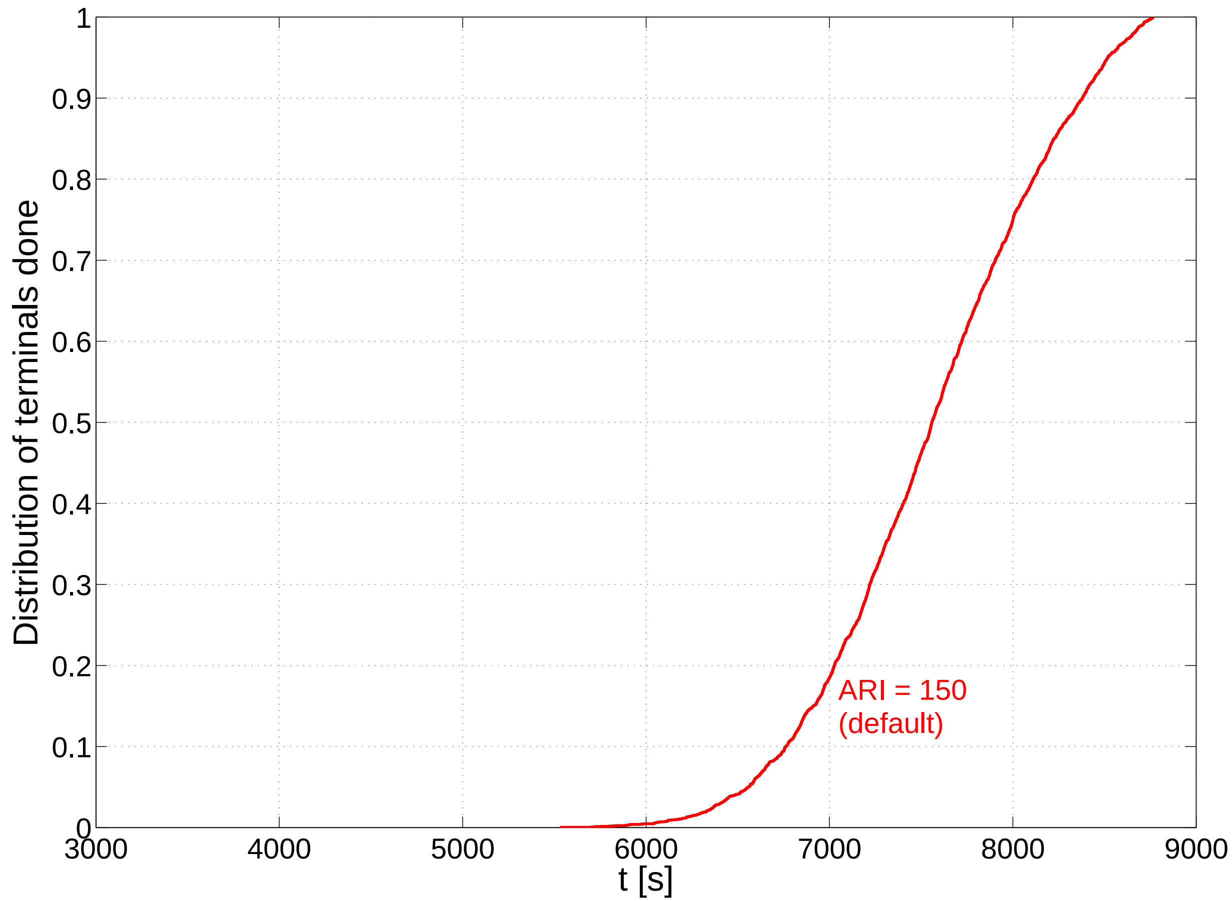
Performance evaluation

Scenario



Performance evaluation

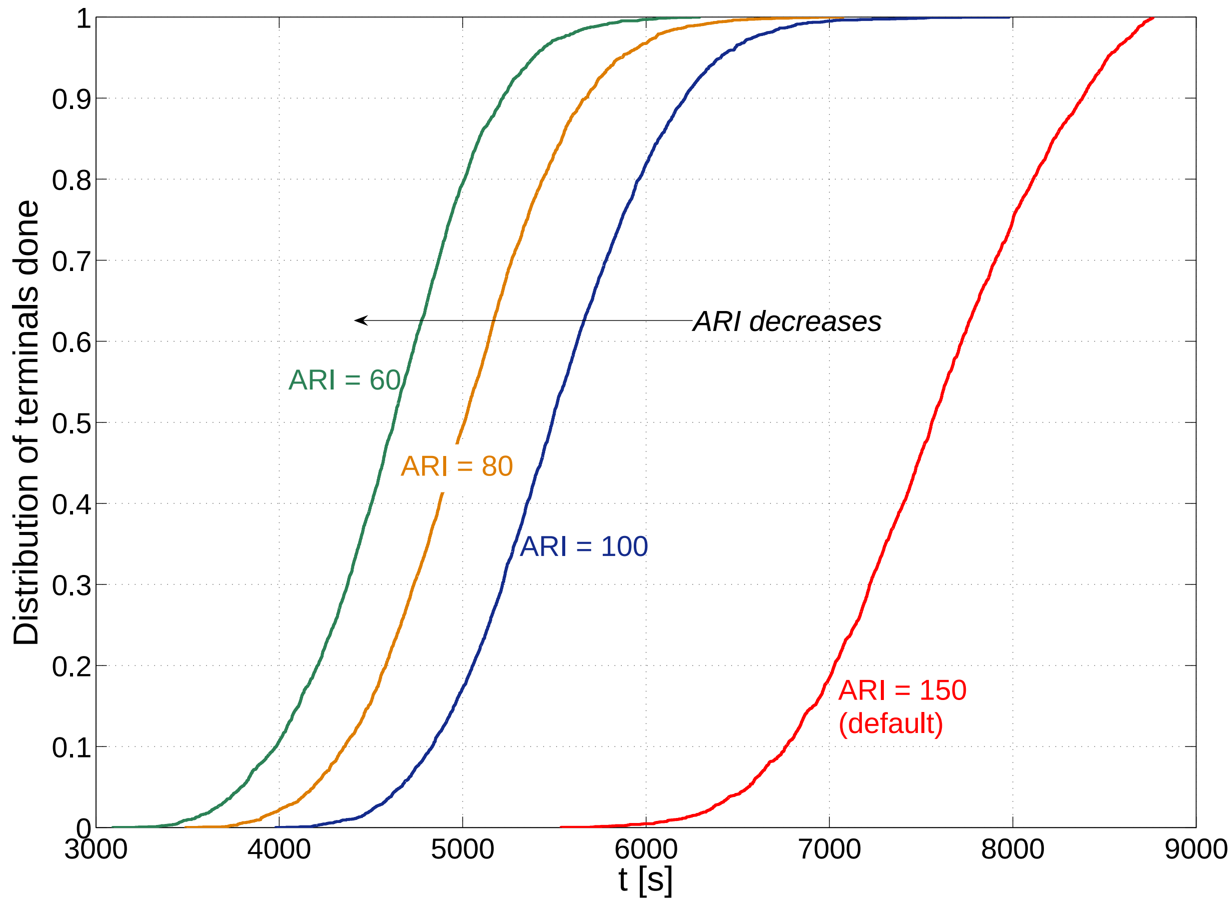
CDF of the queue processing (n = 1)



- With default configuration (ARI = 150 s) approximately $T_{recovery}$ = 2.5 h

Performance evaluation

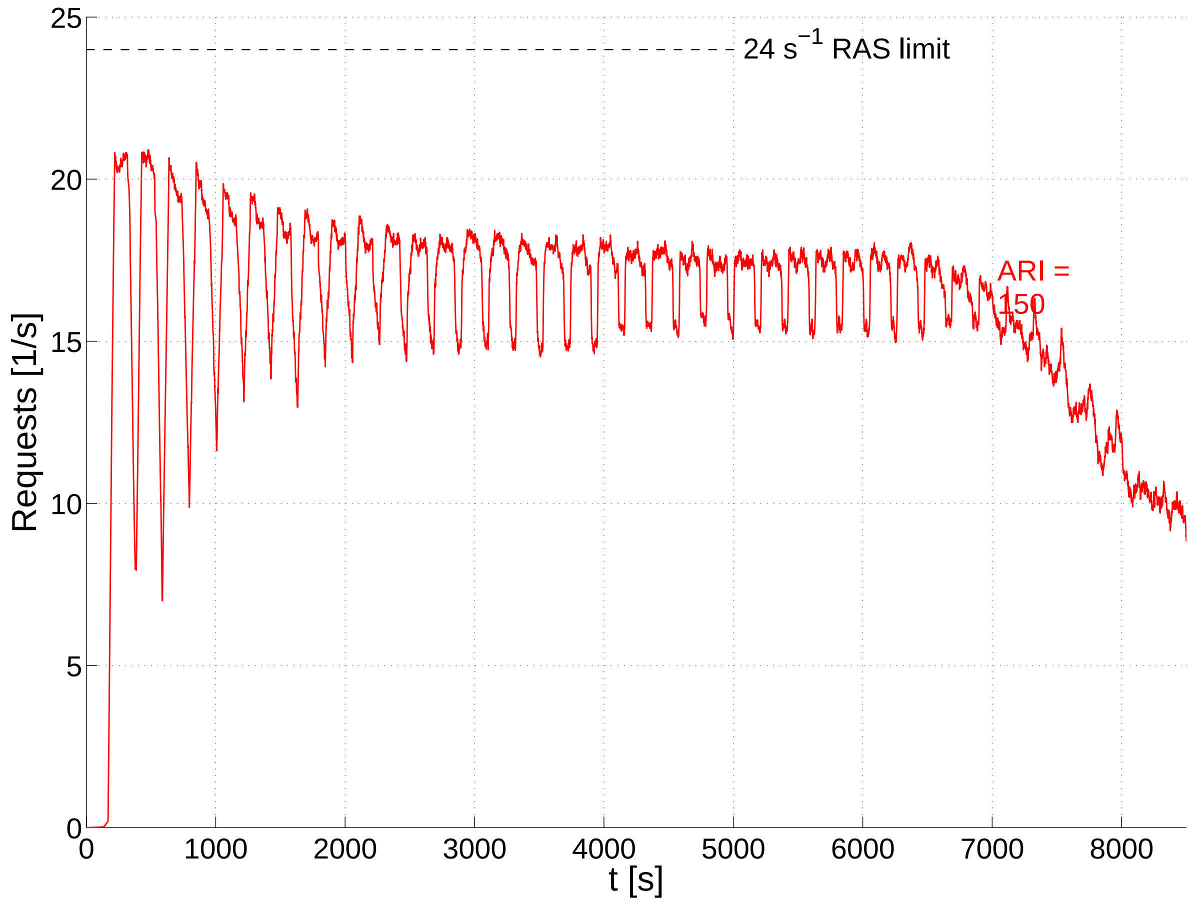
CDF of the queue processing (n = 1)



➡ Decreasing ARI values reduce $T_{recovery}$

Performance evaluation

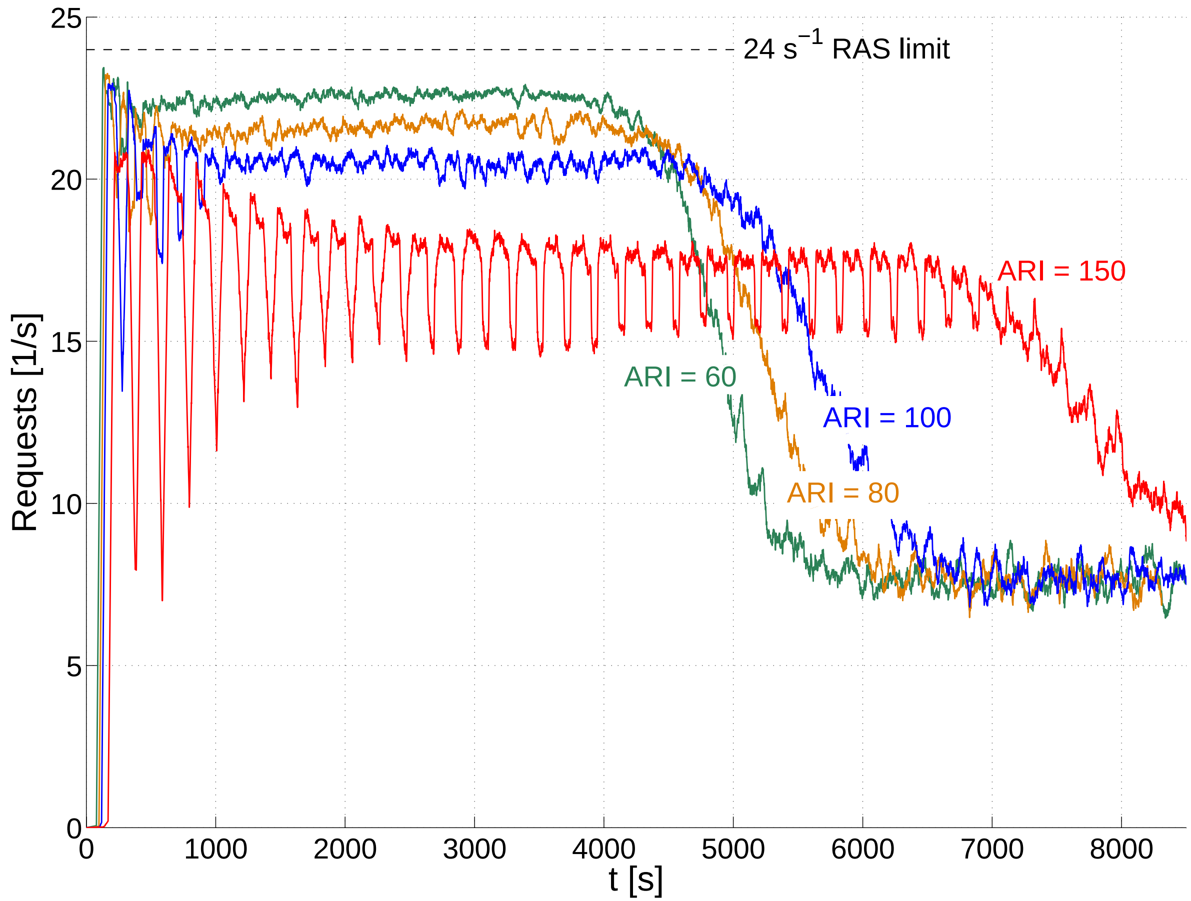
BDM utilization (n = 1)



- ARI = 150 s can not utilize the BDM continuously

Performance evaluation

BDM utilization (n = 1)



➥ Smaller ARI values are feasible due to *RAS boundary*

Backoff Algorithm (1)

So far, deterministic approach

- ARI and n are constant values for all terminals
- Periodic system behavior → possible instability
- Default of the recovery algorithm is too restrictive
  - ➥ The parameters after an outage are not optimal

➥ Challenge: improvement and optimization of the algorithm and parameters

➥ Aim: minimization of the recovery duration with controlled BDM load

Backoff Algorithm (2)

New approach for the backoff algorithm

Initial configuration in the autonomous mode ARI_0=150 s, n_0=2

Failure-free case Connection to RAS could be established successfully

$$ARI_{i+1} = ARI_0 + \frac{ARI_i}{2} \qquad n_{i+1} = \begin{cases} n_i \cdot 2 & \text{if } 2n \le q_l \\ q_l & \text{else} \end{cases}$$

Failure case Connection to RAS could not be established

$$ARI_{i+1} = \begin{cases} ARI_i - \frac{ARI_i}{2} & \text{if } \left(ARI_i - \frac{ARI_i}{2}\right) \ge ARI_0 \\ ARI_0 & \text{else} \end{cases}$$

$$n_{i+1} = \begin{cases} \frac{n_i}{2} & \text{if } \frac{n_i}{2} \ge n_0 \\ n_0 & \text{else} \end{cases}$$

Conclusion and outlook

- Modeled the manual logon process (users and system)
- Evaluated the recovery process in the autonomous mode
- Introduced a new approach for the backoff resolution

➥ Default manual logon process works stable,
but is restrictive after an outage

- System behaviour depending on different downtime scenarios
- Optimization of the Backoff Algorithm to minimize RAS and BDM utilization
- Make the Backoff Algorithm dependant on state of
  - terminal queue
  - BDM
- Evaluate heterogeneous scenarios

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