IKR EmuLib

A Library for Seamless Integration of Simulation and Emulation

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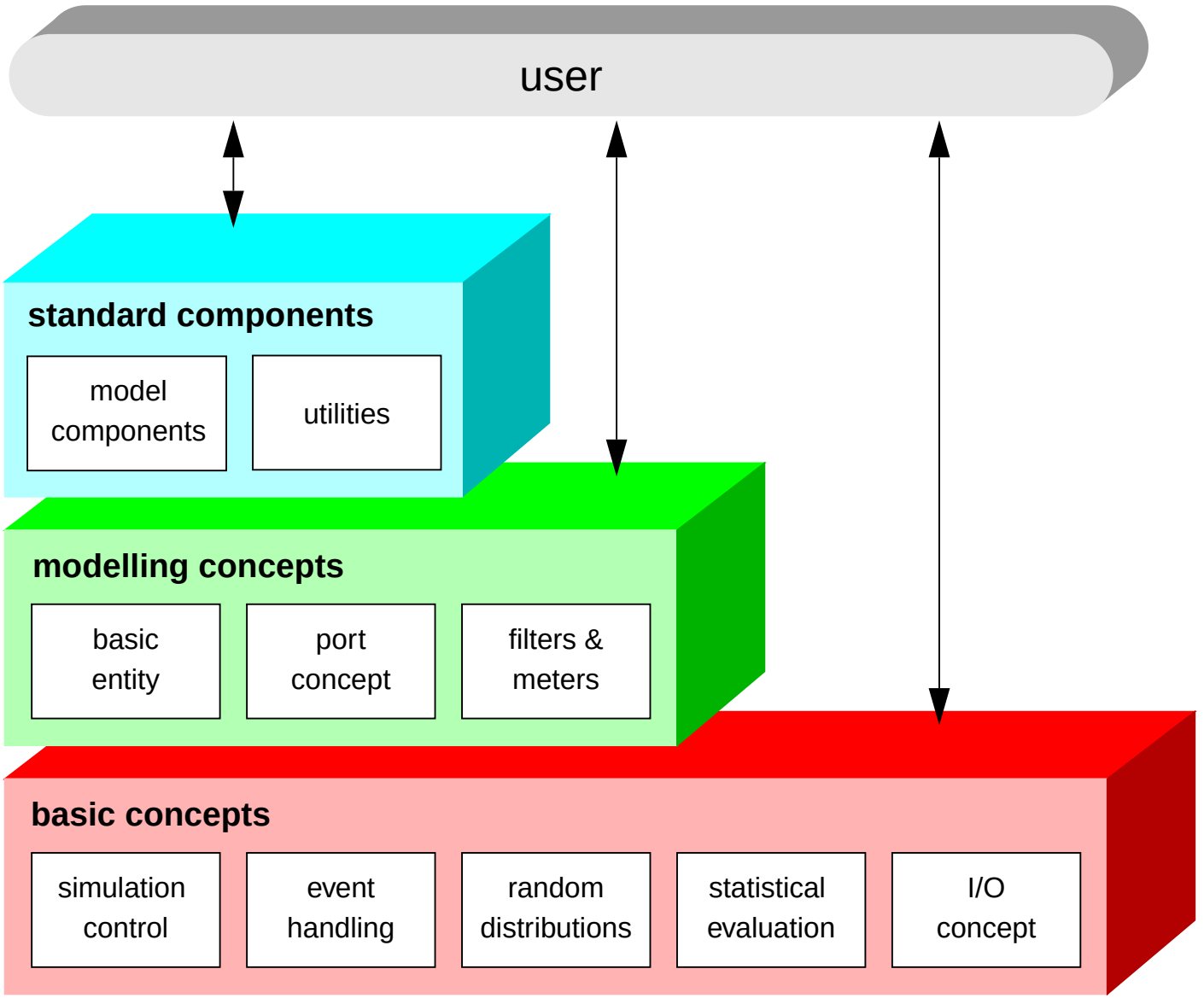
Outline:

- **Introduction of IKR SimLib**
- **Motivation of emulation approach**
- **Realization of IKR EmuLib**
- **Evaluation of accuracy**

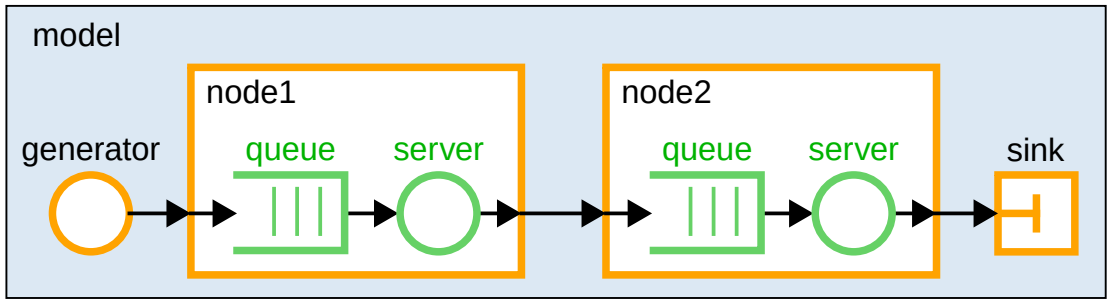
IKR SimLib

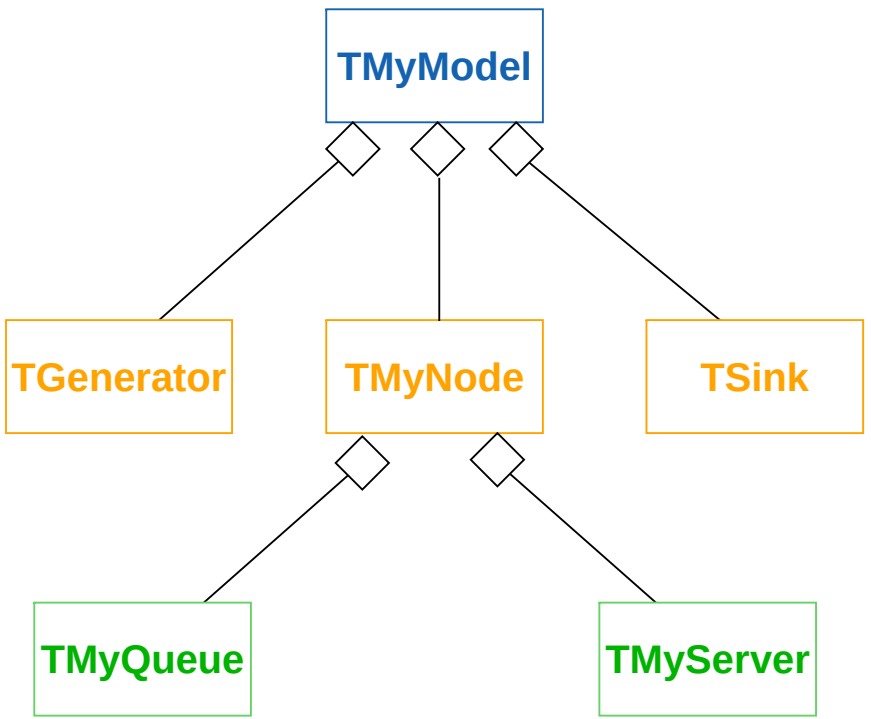
- **History**
  - origin: Pascal simulation library (1980ies)
  - object-oriented redesign in the context of a dissertation (1992)
  - since then continuously enhanced and improved
- **Implementation**
  - C++ class library
  - usage of additional libraries (e.g., container class library)
  - tested under various platforms: Linux, Solaris, CygWin
- **Main Features**
  - support for transformation of an abstract model into source code
  - control of event-driven simulation
  - random number generation (various distributions and source models)
  - statistical evaluation
  - reading parameter values and printing results

Basic Structure



Model Components: Object Hierarchy

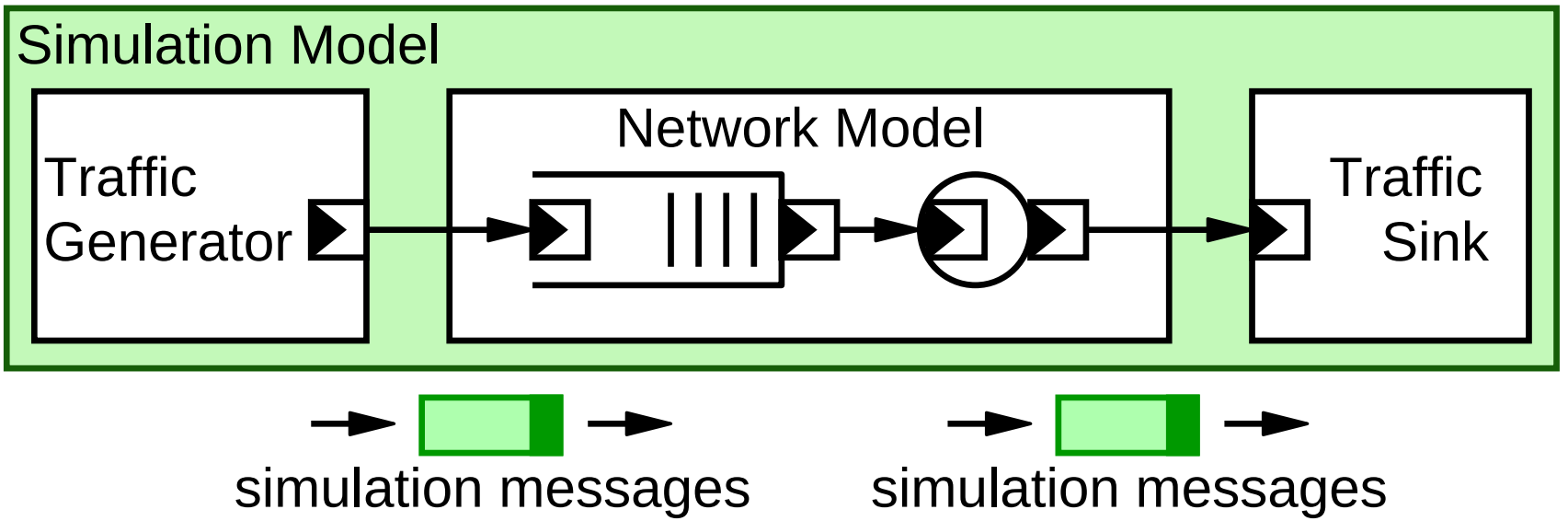




Decomposition support by

- **Hierarchy**
  - has-relationship
  - pointer to owner
- **Name Concept**
  - local name as attribute
  - identification of components
  - access via central component manager

Port Concept



Message exchange between model components via ports

- **distinction between input and output ports**
- **central port registration using owner address and port name**
- **connection of the ports using function call `Connect`**
- **communication via handshake protocol**

➥ **uniform interface for communication between model components**

Simulation vs. Emulation vs. Prototype

Simulation

- **fast and easy exploration of vast parameter space**
- **difficulty to model complex componentes & protocols**

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Prototype

- trustworthy results
- difficult setup, limited parameter space

Integrated Simulation and Emulation

Combined Simulation and Emulation

- simulative exploration of vast parameter space with approximate models
- emulative evaluation of selected parameter points with included real-world components

Design Objectives

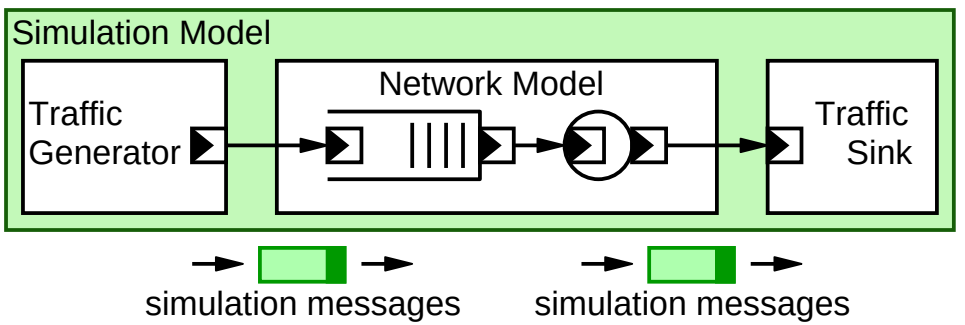
- Create emulation extension for existing simulation library
- Enable the reuse of existing simulation models
- Switch between simulation and emulation in zero time

➥ Seamless integration

Basic Idea

- **Implement emulation as an IP packet router**
- **Delay or drop IP packets according to model behavior**

➥ **Interfaces to model are traffic generators and traffic sinks**



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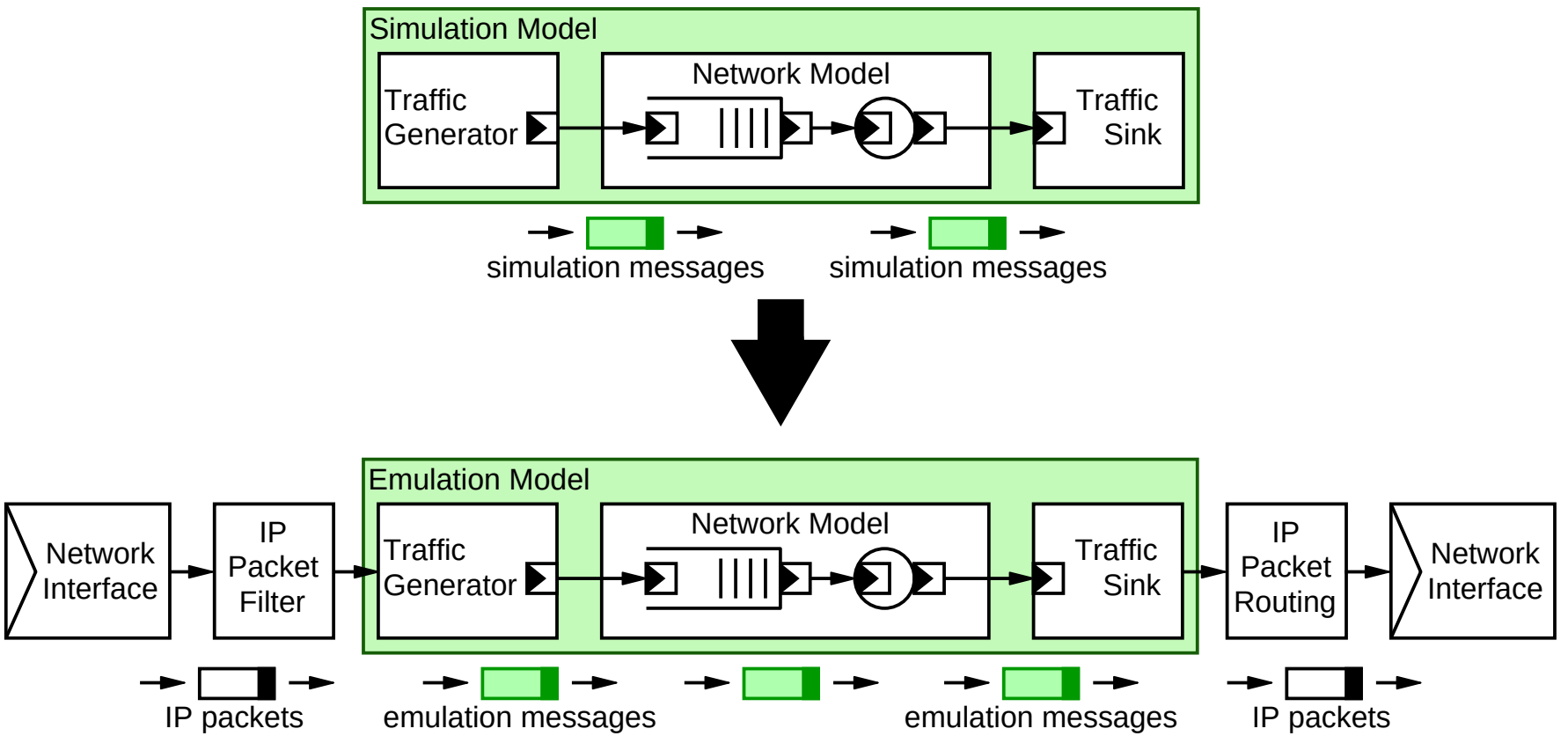
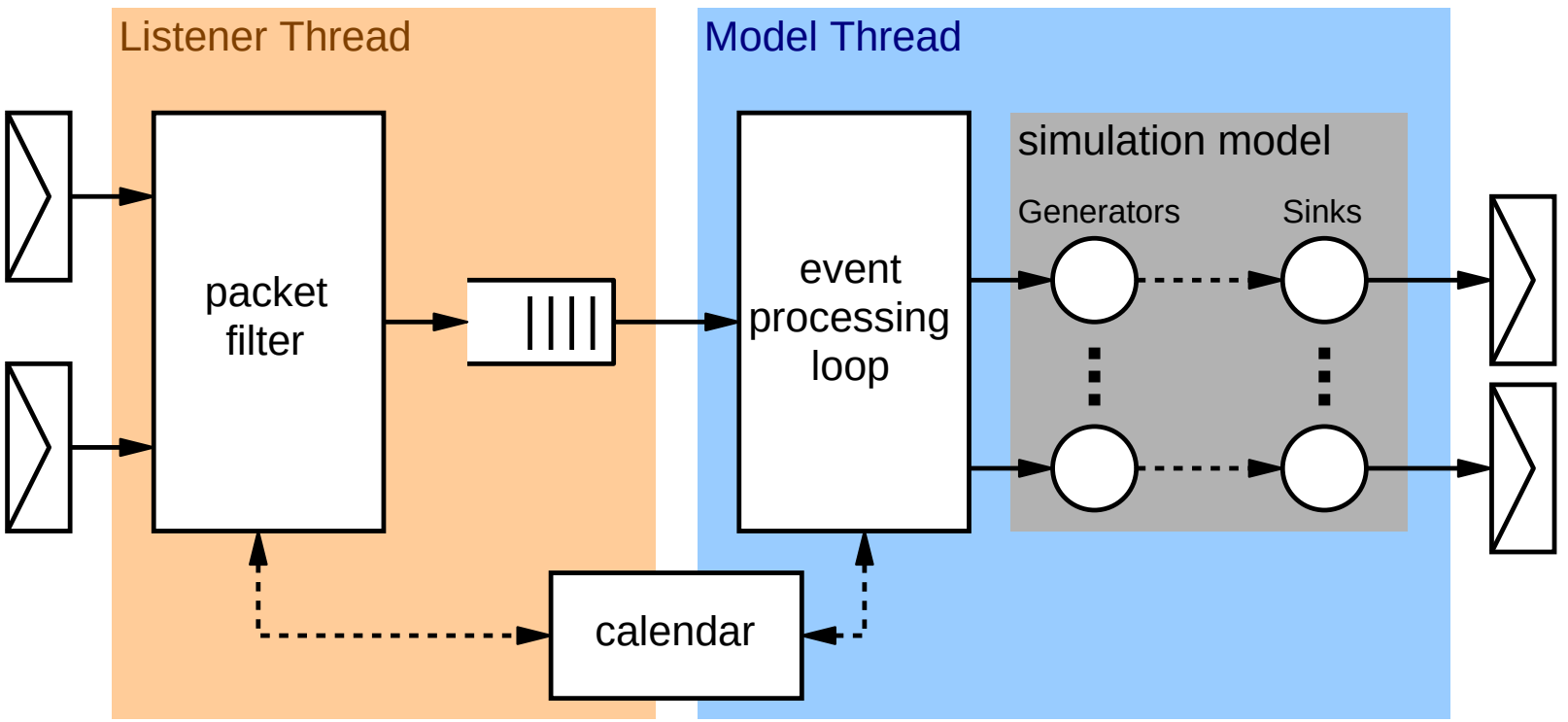


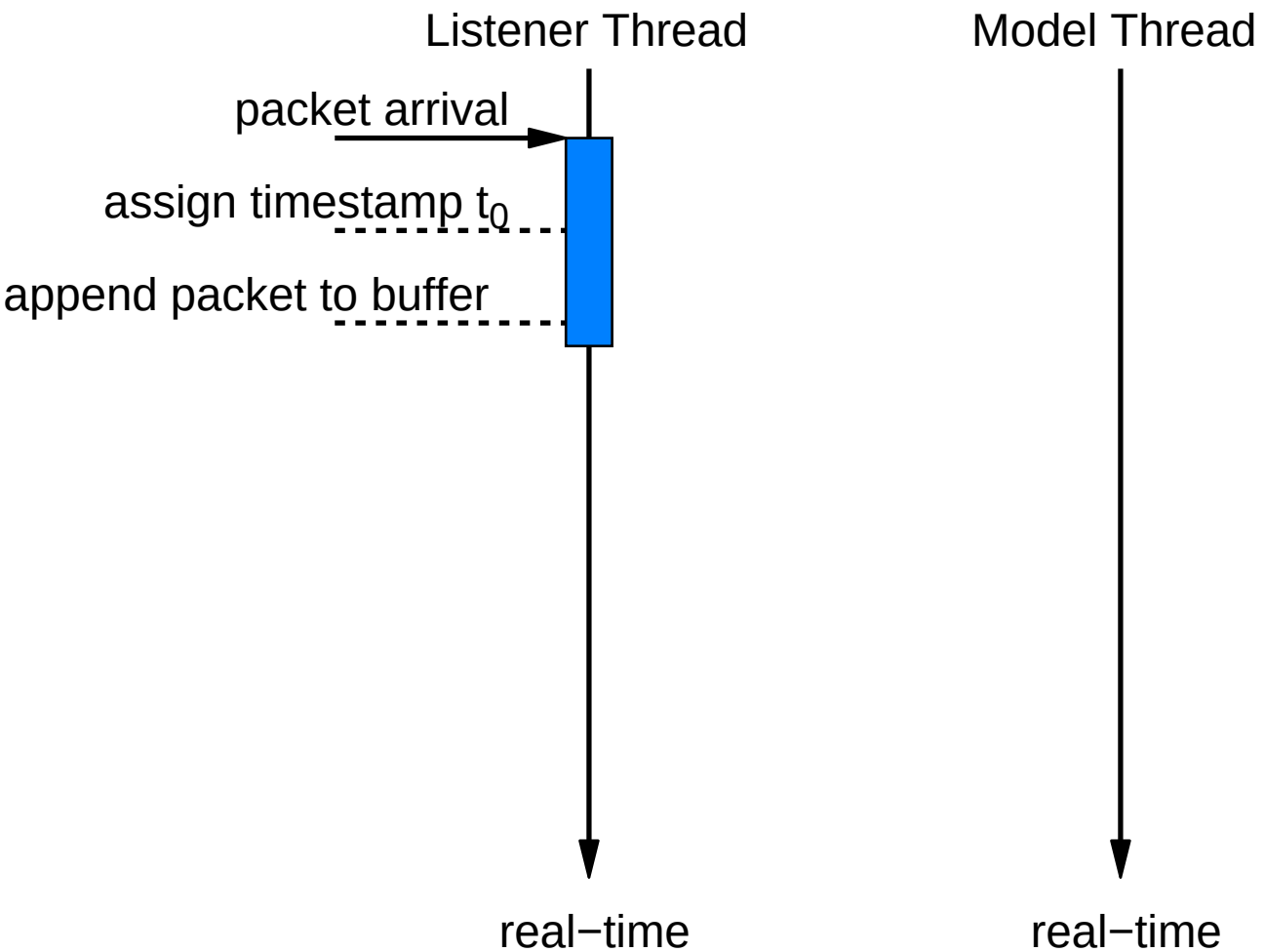
Realization I

Interface to network realized by multithreaded-design

- **Listener Thread**
  - reception of IP packets, filtering, time stamping, buffering
- **Model Thread**
  - encapsulation into simulation messages, model processing, transmission to network interface



Interaction between threads



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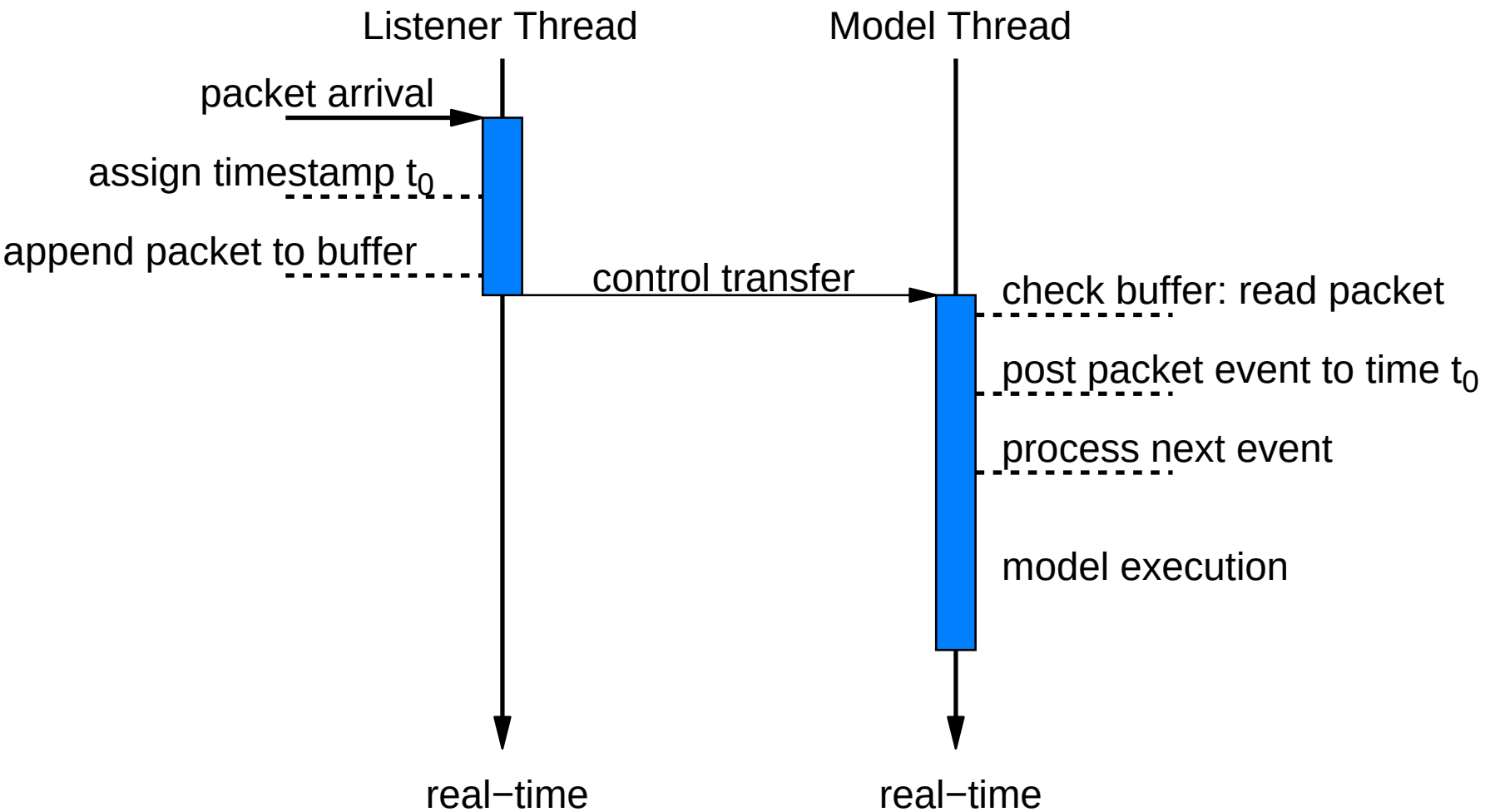

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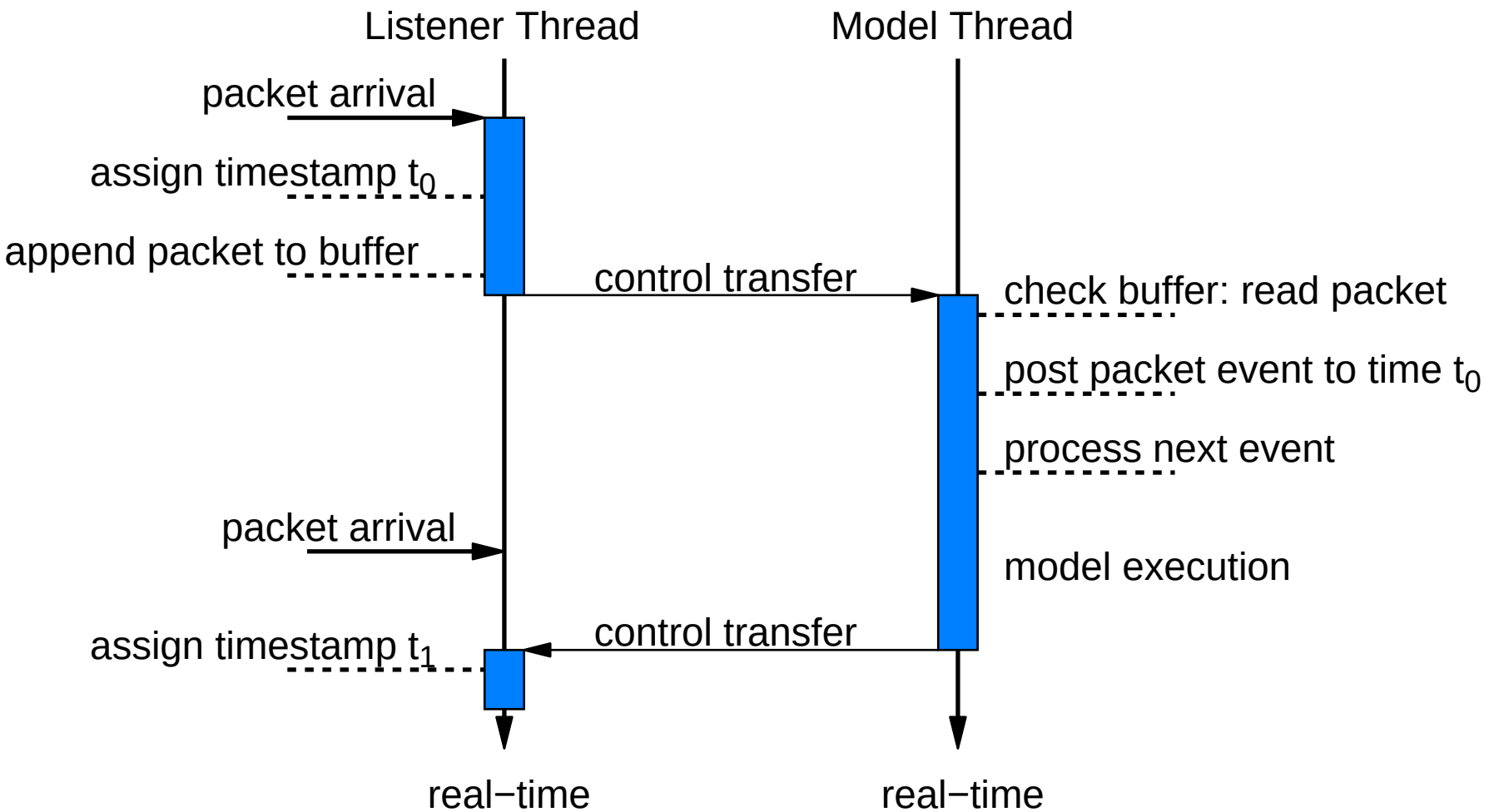

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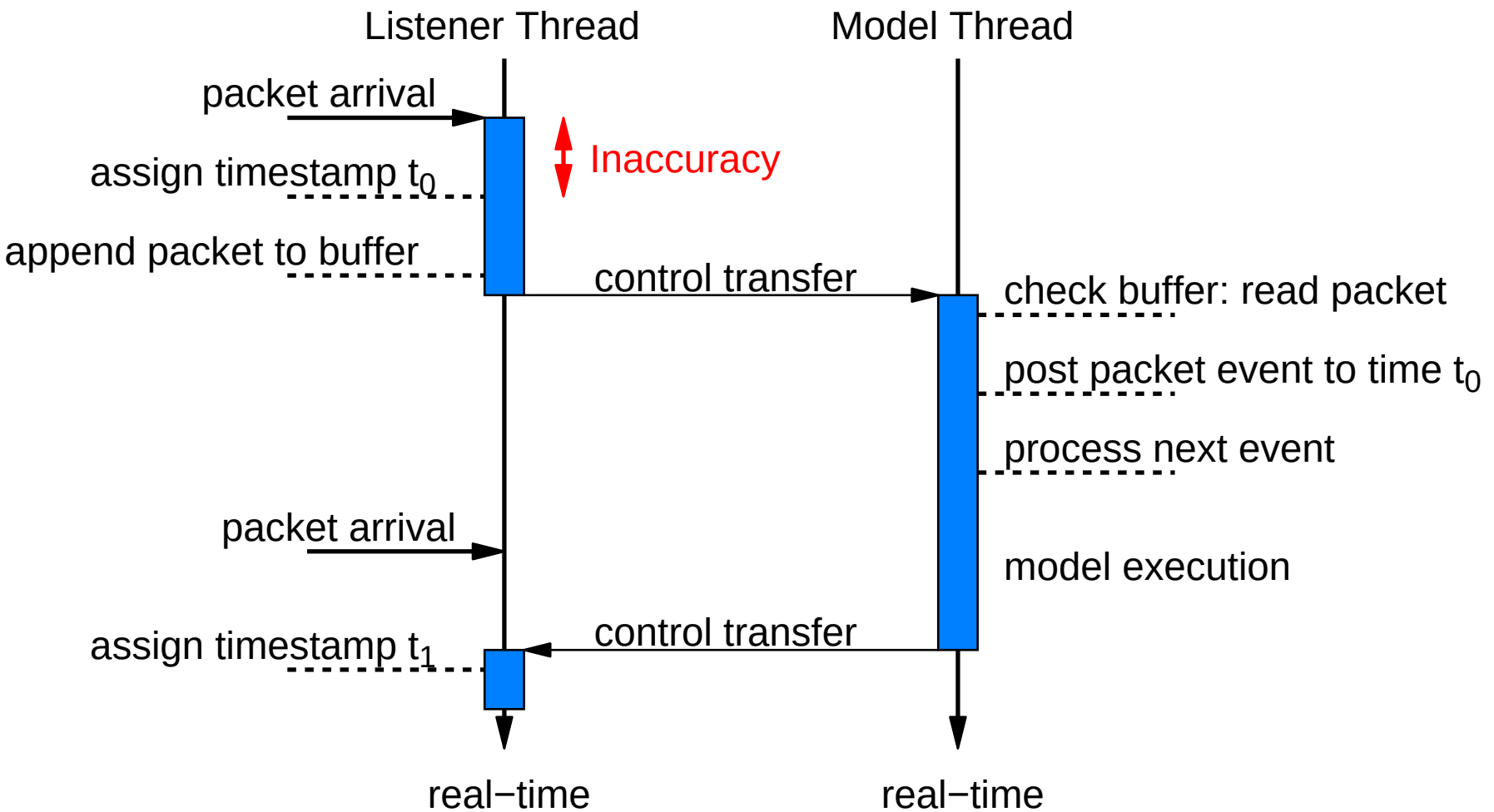

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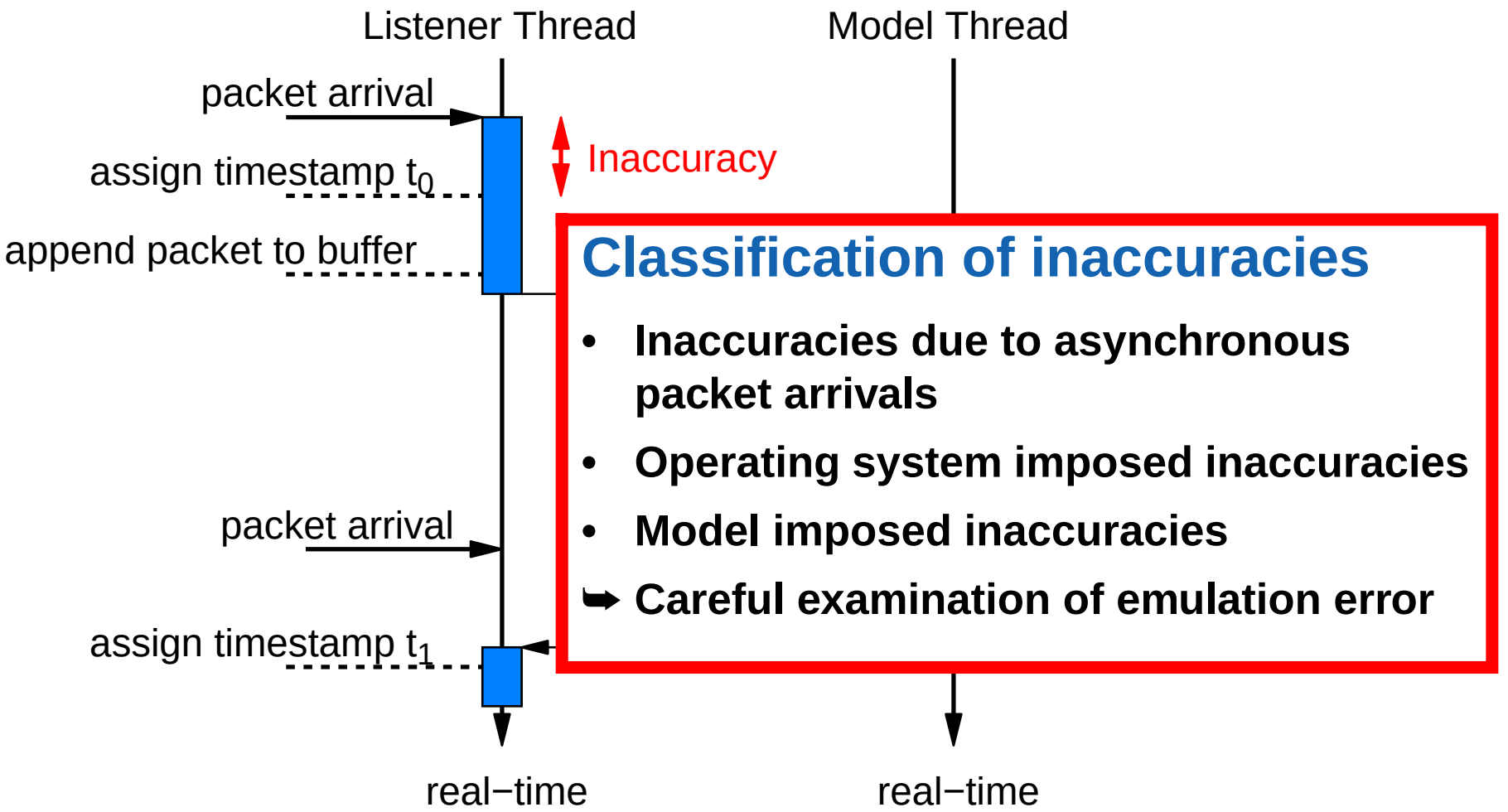
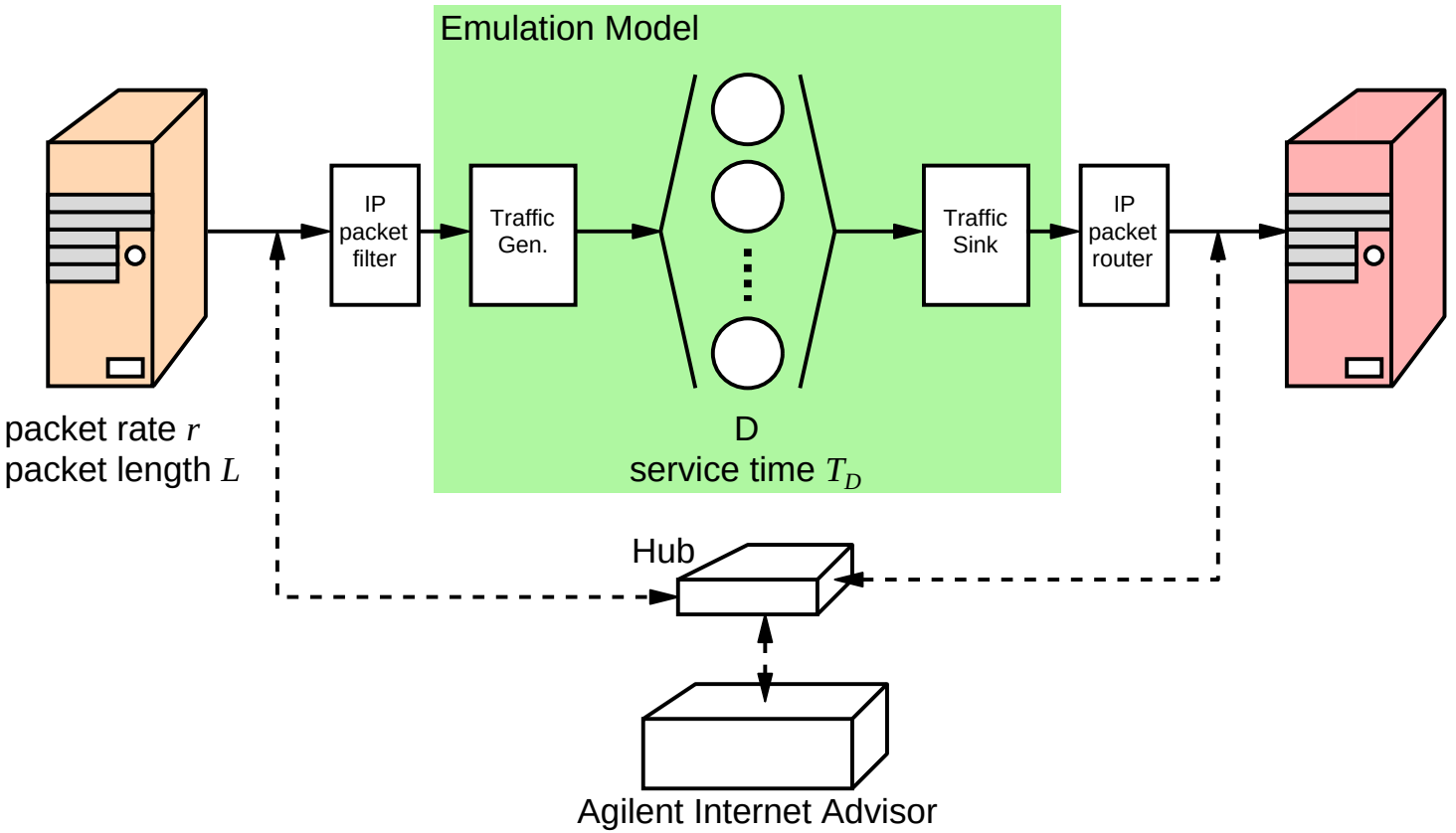


Classification of inaccuracies

- **Inaccuracies due to asynchronous packet arrivals**
- **Operating system imposed inaccuracies**
- **Model imposed inaccuracies**

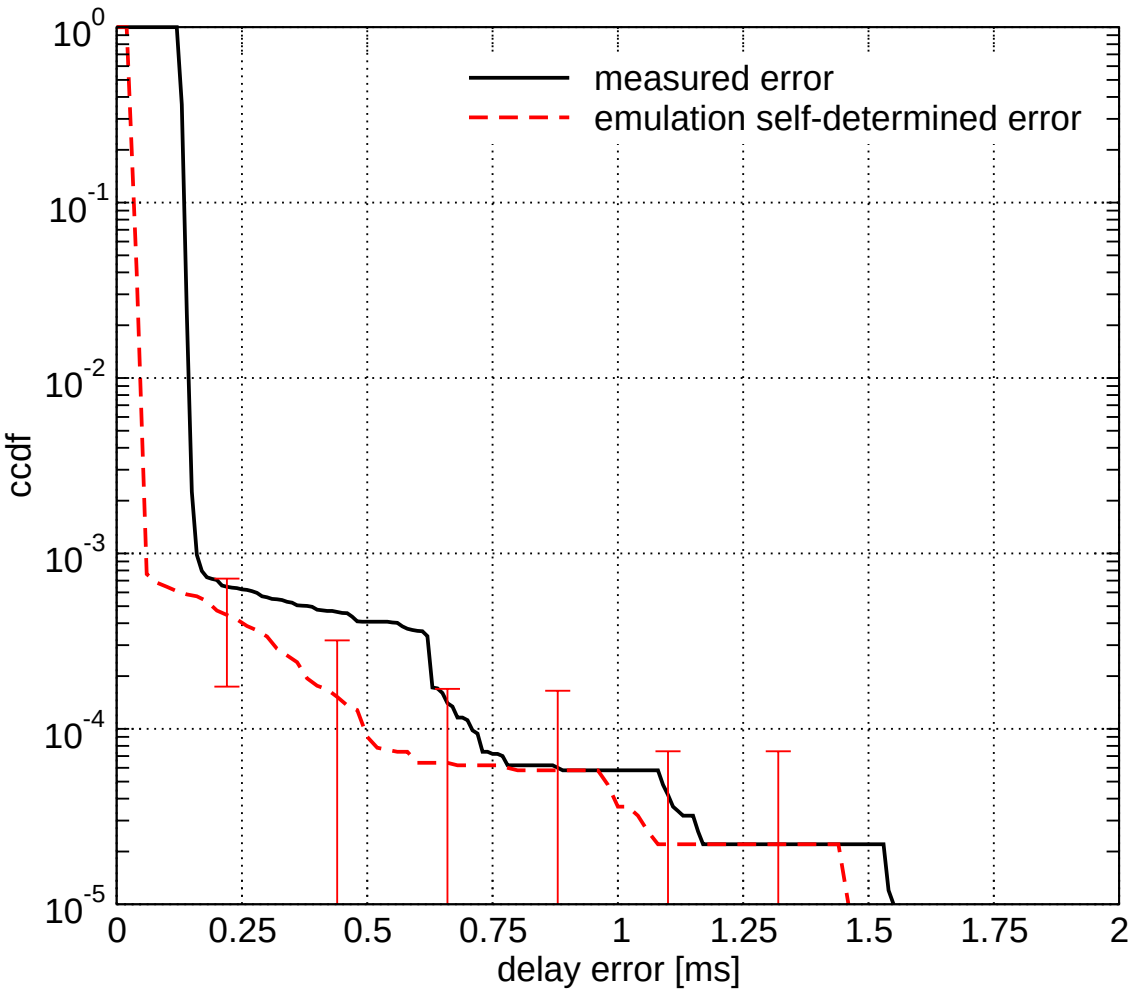
➥ **Careful examination of emulation error**

Measurement Setup



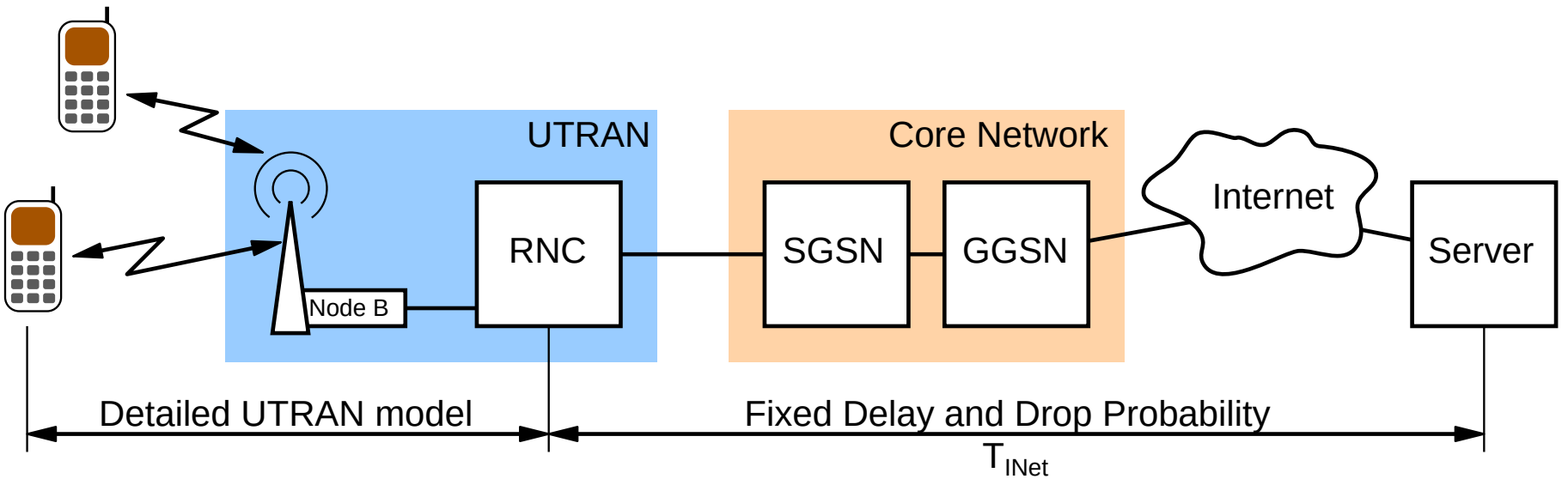
- **Constant rate UDP source**
- **Infinite server model with constant service time T_D = 10ms**
- **External measurement of delay error (Agilent Internet Advisor)**
- **Internal measurement of delay error (emulation self-determined error)**

Infinite Server Accuracy



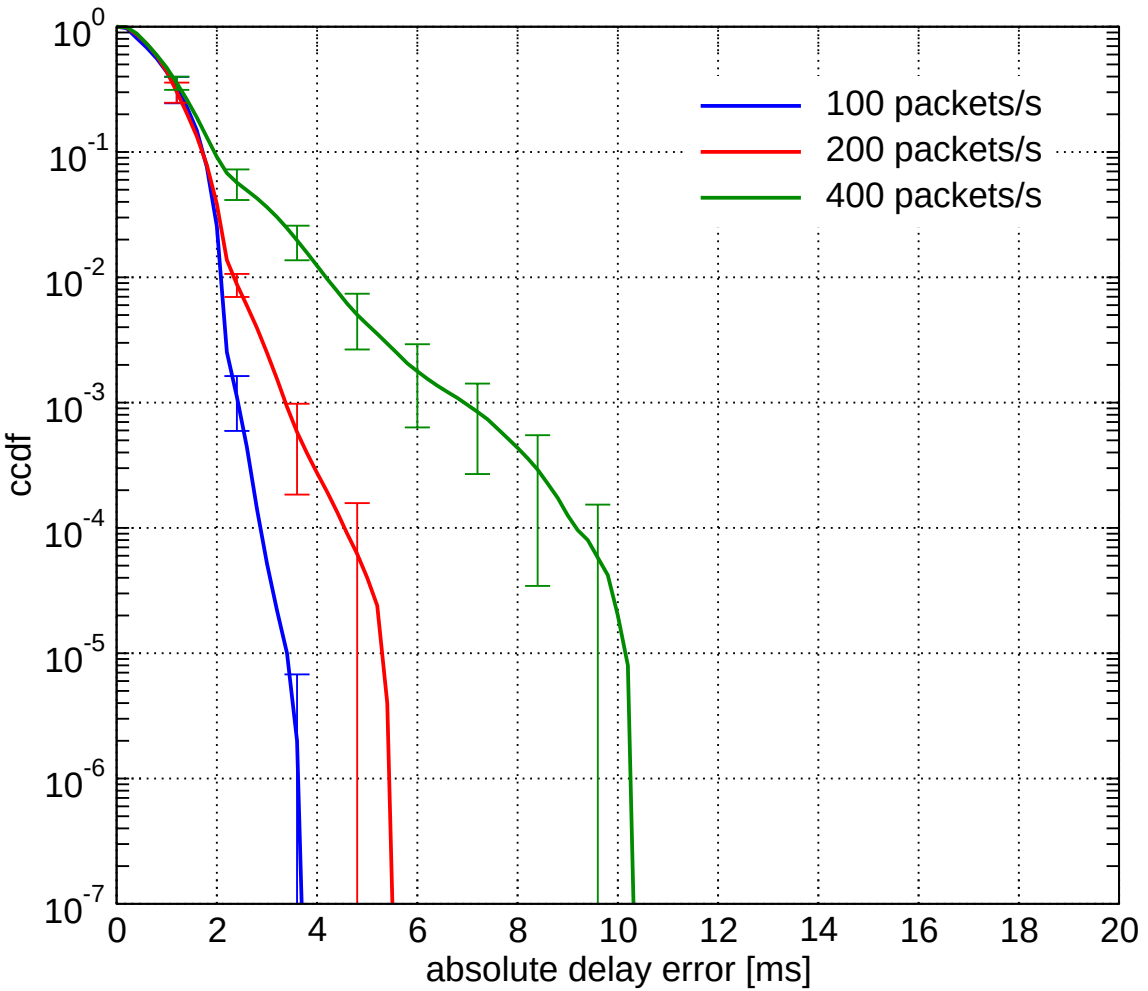
- **Excellent correlation between measured and self-determined error**
- **Only 0.1% of all packets have an error of more than 0.2 ms**

HSDPA Scenario



- **Detailled model of High Speed Downlink Packet Access (HSDPA)**
- **one emulated UDP traffic flow in downlink direction**
- **one simulated cross-traffic flow with TCP bulk data transfer in downlink direction**

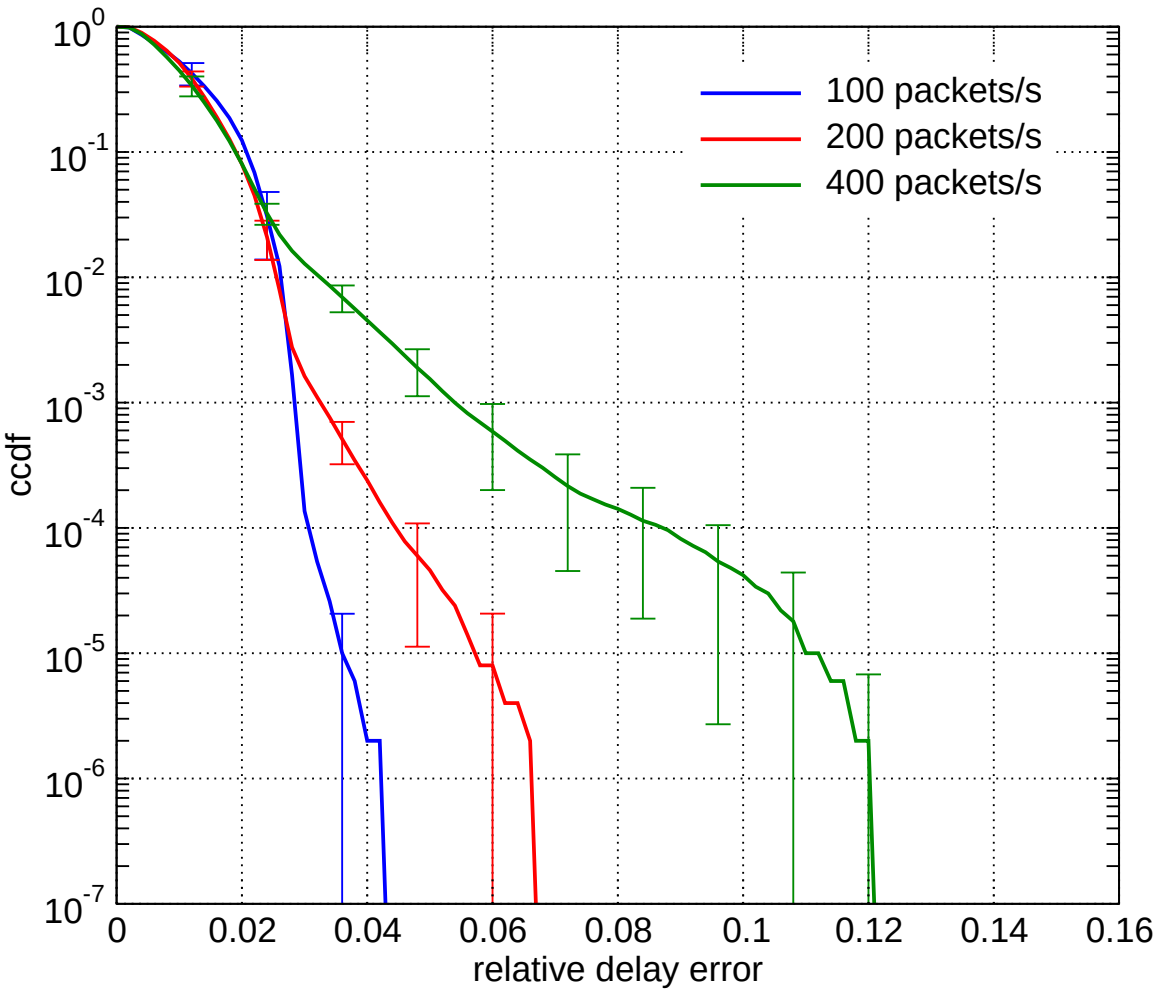
HSDPA Accuracy — Absolute Error



- **Only 1% of all packets have an error of more than 2-4 ms**
- **Higher absolute error due to model imposed inaccuracies**

➥ **Evaluate relative error**

HSDPA Accuracy — Relative Error



- **Very good relative error in low — medium load situations**
- **Only 0.1% of all packets have a relative error of more than 5%**

Conclusion

- **IKREmuLib: Integrated simulation and emulation environment**
- **Flexible usage through powerful filtering and routing possibilities**
- **Quick transition between simulation and emulation domain**
- **Efficiently combine simulated with emulated flows and components**
- **Good accuracy for models with delay on the order of tens of ms**

Outlook

- **Explore possibility for protocol interfaces**
- **Evaluate different strategies to enhance accuracy**