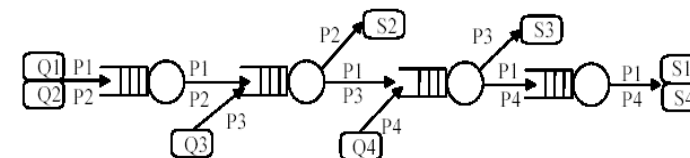




Multi-class signal flow model for inter-domain traffic flow simulation

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Overview

- Purpose of RTC-FSIM
- Comparison to state of the art
- General concepts behind RTC-FSIM
- The hierarchical Multi-class-model
- Demonstration
- Conclusion further work



Purpose of RTC-FSIM

An Environment for inter-domain modeling and simulation:

- Large scale inter-domain modeling with high level abstraction
- Efficient measurement based modeling
- Various possibilities to generate continuous rate input models
- Various visualization and analyzing opportunities
- Modularity and extendibility of the environment itself
- Inclusion of traffic classes and priority services to describe QoS issues



Comparison to state of the art

Simulation Techniques Model		event based	time slice driven	time continuous
DISCRETE	Packet	rare packet arrival – medium complex	high rate packet arrival – complex network	
	Fluid	rare rate – medium complex Propagation change	high frequency of rate changes Propagation change	
Fluid Rate Continuous				Differential Equations



Comparison of RTC-FSIM to fluid rate continuous simulators

- RTC-FSIM based on differential equations
- similar to the **Hybrid Discrete Continuous Flow [HDCF]** described by Melamed and Garcia. HDCF aimed at integrated discrete packet and continuous flow simulation, i.e. different abstraction levels
- **Project Maya (i.e. Next Generation modelling and simulation tools)** also hybrid packet and fluid simulation concept, it integrates packet level simulation for subnets and fluid for heterogeneous large scale abstraction.
- **ESPRIT project STAR [Gar01]**, combines queuing theory models and packet based simulation in a global decomposed traffic modelling environment -> difference to the RTC-FSIM basic model and HDCF differential paradigm is that the differential equation in this model describe the mean and not the actual buffer occupation.



General Concept of the RTC-FSIM

Simulation-Environment: Matlab - Simulink

Elementary queue system

with the use of a fluid model

Random processes:

- arrival rate $a(t)$
- service rate $b(t)$
- departure rate $d(t)$
- and inner system state (interpreted as the queue length) $z(t)$

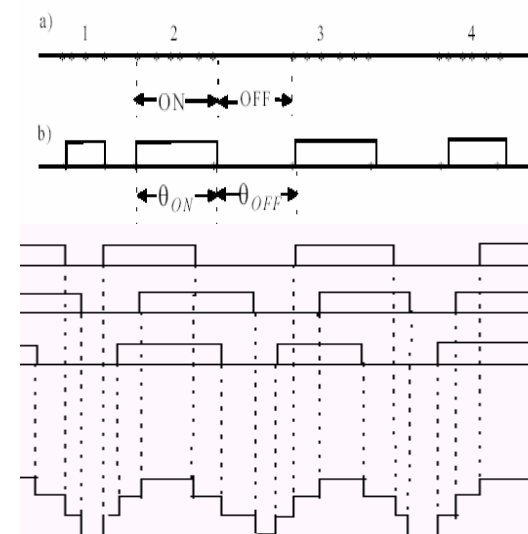
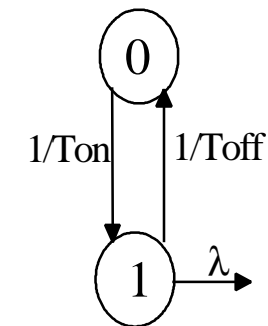
Rate & Time Continuous Fluid Simulation [RTC-FSIM]



Arrival rate process

- Superposition of ON/OFF processes with a per flow rate of λ and exponentially distributed ON and OFF phases

→ event oriented flow model



Rate & Time Continuous Fluid Simulation [RTC-FSIM]

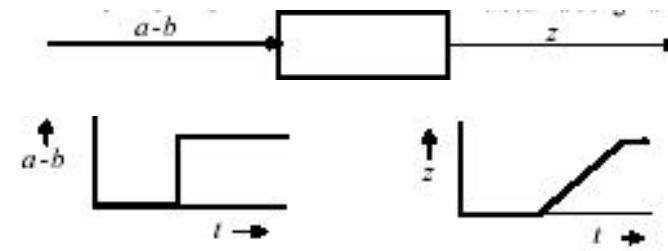


Signal Flow Model

- RTC-FSIM uses signals to get rid of events
- terms processes and signal are synonymous

Simplification is achieved by renouncing

- the event oriented simulation structure
- synchronous time-discrete sampling of signals





ON/OFF Arrival Process Generation:

- time rows of real traffic or event driven simulations
- with parameters from the given probability theory (mean ,variance,...)

needed calculations are done by Matlab

→input for SIMULINK (signal based environment)



Formulas for
Departure Rate
Inner System State

are derived from elementary waiting-loss
systems for each communication class



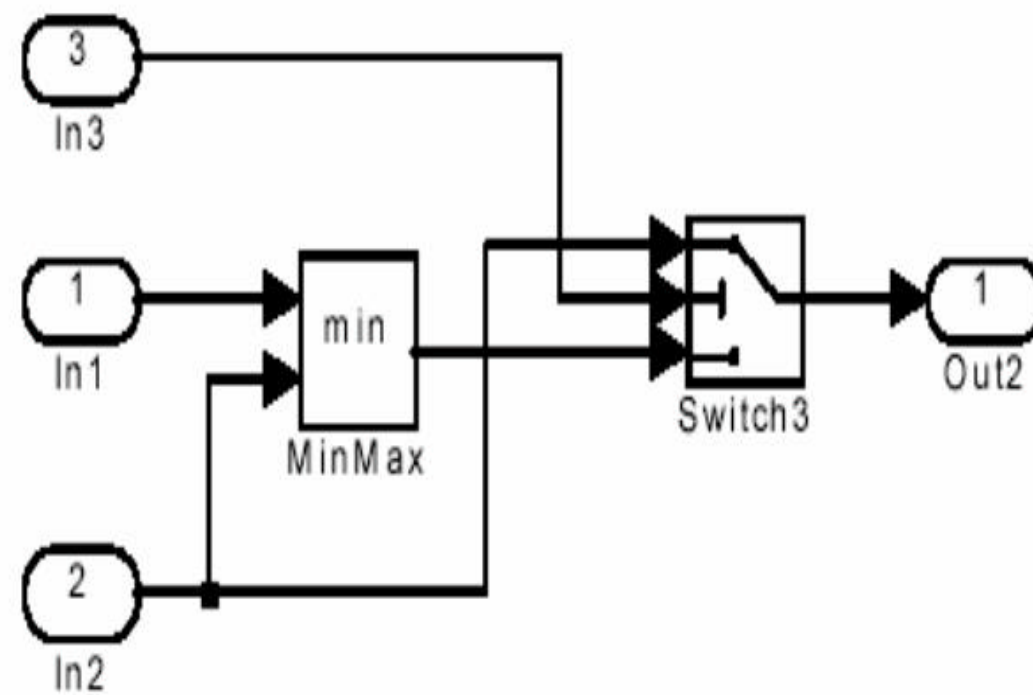
Departure Rate

- for a class K_{ij}
- in a station B_i

$$d_{ij}(t) = \begin{cases} \min\{a_{ij}(t), b_{ij}(t)\} & \text{if } z_{ij}(z) = 0 \\ b_{ij}(t) & \text{if } z_{ij}(t) > 0 \end{cases} \quad (i = 1, 2, \dots, M; j = 1, 2, \dots, K_i)$$



Departure Rate Signal Flow Plan



IN:

1:a(t)

2:b(t)

3:z(t)

OUT:

1:d(t)



Inner System State

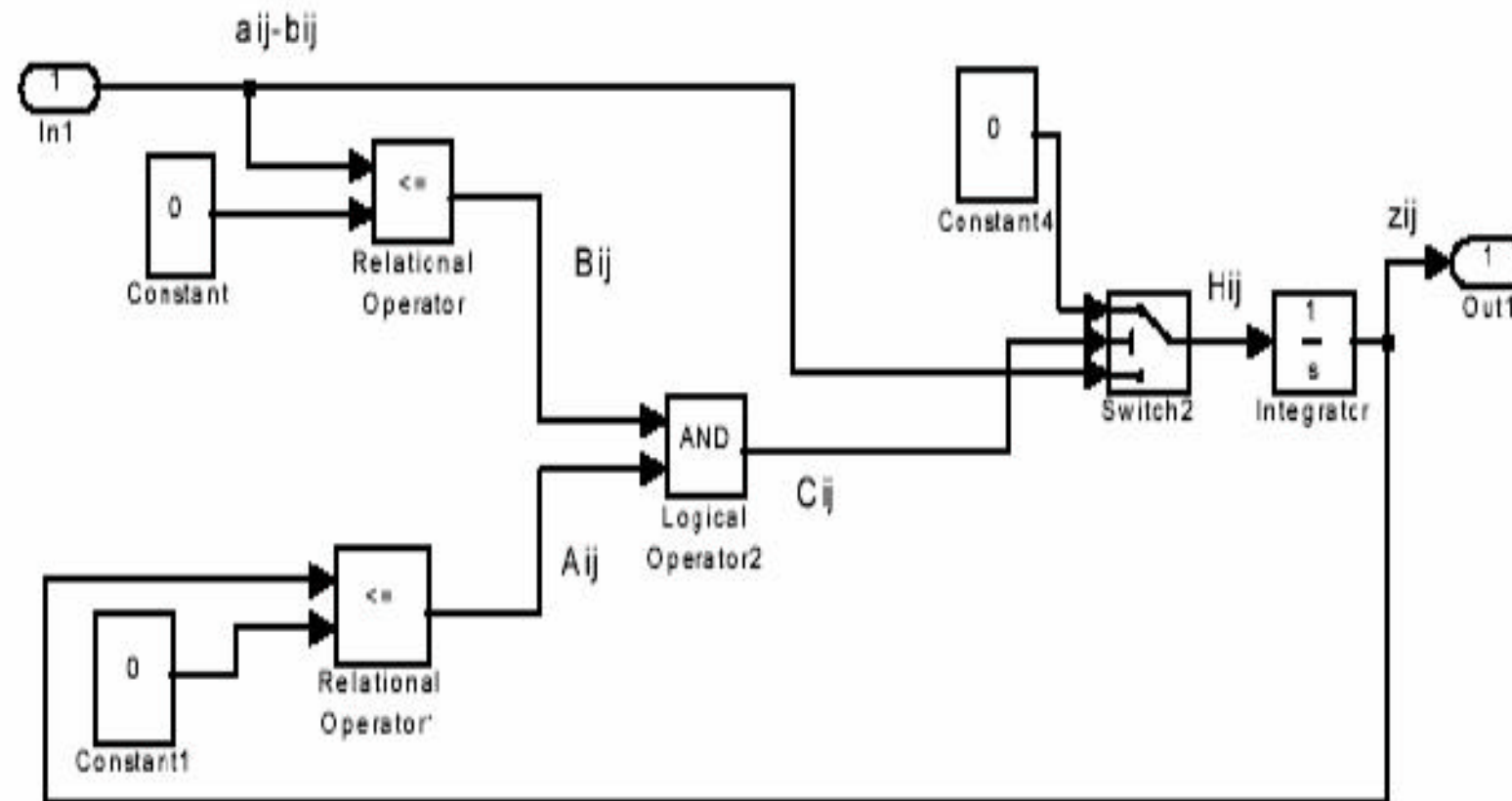
- for a class K_{ij}
- in a station B_i

$$\frac{dz_{ij}(t)}{dt} = \begin{cases} 0 & \text{if } z_{ij}(t) = 0 \text{ and } (a_{ij}(t) - b_{ij}(t)) \leq 0 \\ a_{ij}(t) - b_{ij}(t) & \text{else} \end{cases} \quad (i = 1, 2, \dots, M; j = 1, 2, \dots, K_i) \quad (1)$$



Rate & Time Continuous Fluid Simulation [RTC-FSIM]

Inner System Signal-State Flow Plan





Service rate states

- operational under condition G_{ij}

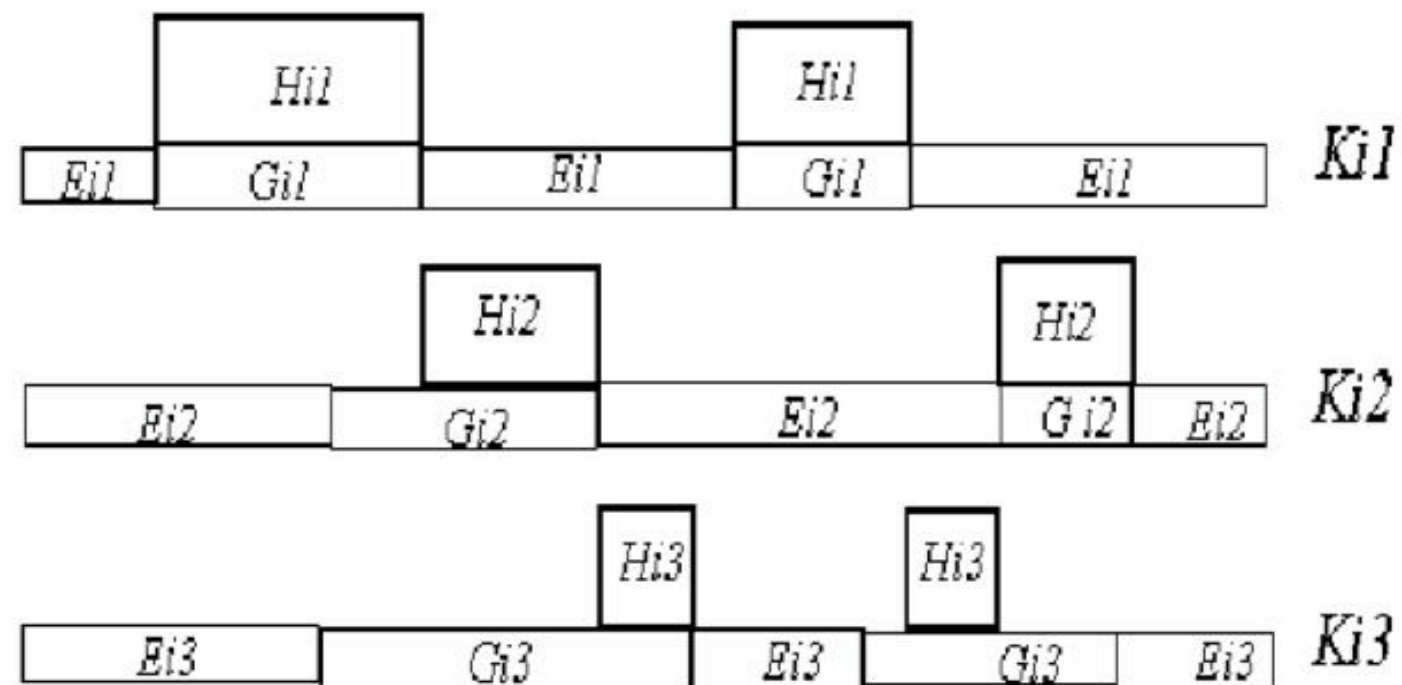
$$G_{ij}(t) = (z_{ij}(t) > 0) \text{ or } ((z_{ij}(t) = 0) \text{ and } (a_{ij}(t) > 0))$$

- unoperational under condition E_{ij}

$$E_{ij}(t) = (z_{ij}(t) = 0) \text{ and } (a_{ij}(t) = 0)$$



Service rate model for multi-class service station with priorities





Service rate

- for a class K_{ij}
- in a station B_i

$$b_{ij} = \begin{cases} b_i & \text{if } H_{ij} \\ 0 & \text{else} \end{cases} \quad (i = 1, 2, \dots, M; j = 1, 2, \dots, K_i)$$



Actual waiting times

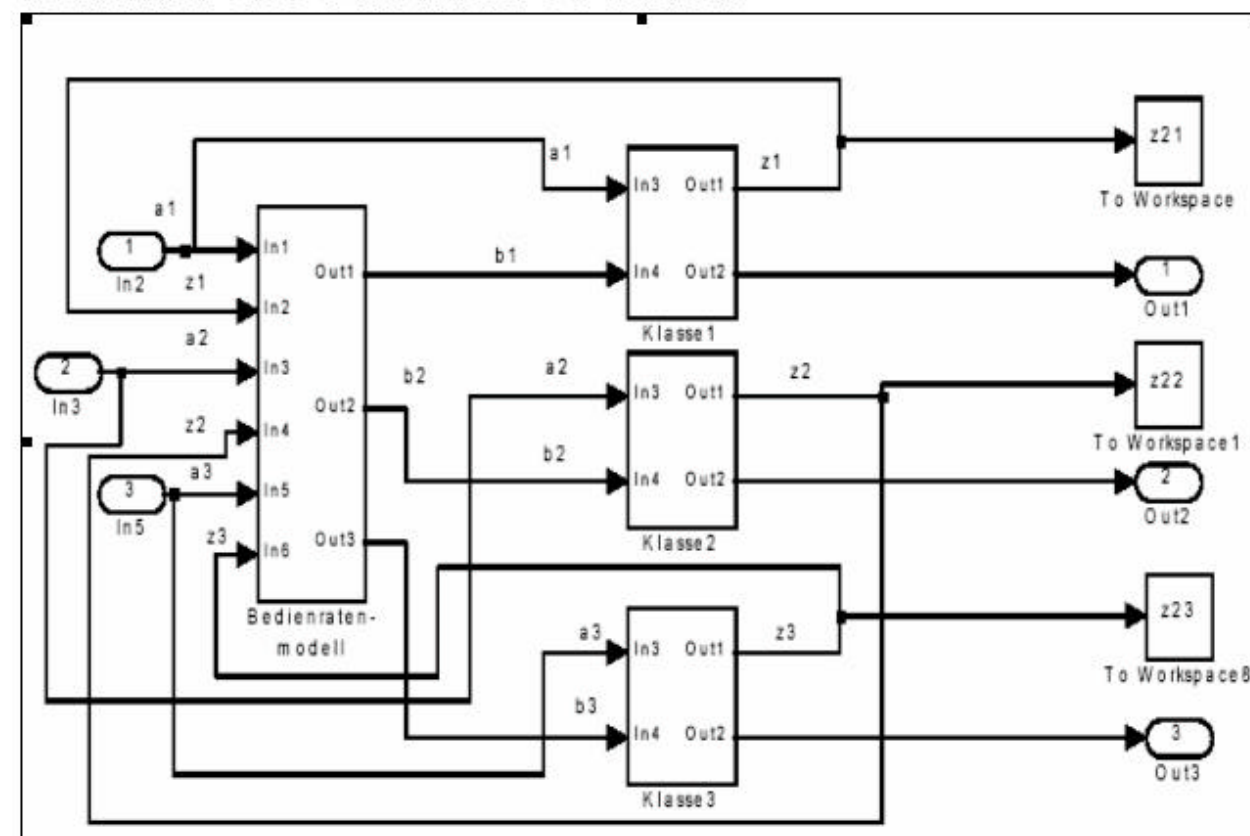
In a service station B_i with priorities

$$t_{wij} = \frac{\sum_{l=1}^j z_{il}}{b_i} \quad (i = 1, 2, \dots, M; j = 1, 2, \dots, K_i)$$



Rate & Time Continuous Fluid Simulation [RTC-FSIM]

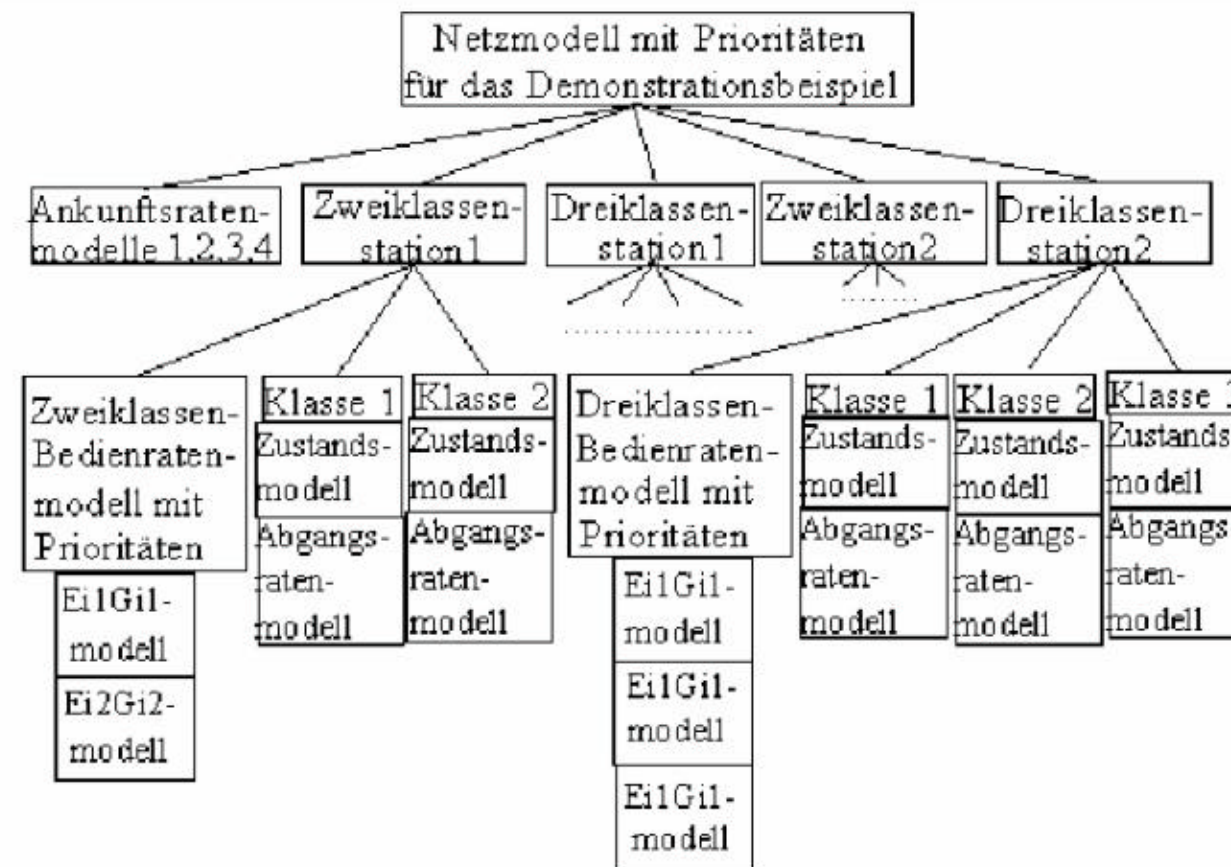
Signal Flow Chart of a three class model





Rate & Time Continuous Fluid Simulation [RTC-FSIM]

Design of more complex models





Demos

MATLAB & SIMULINK



Conclusion

- RTC-FSIM is intended to be well suited environment for Intermon

Future

- Measurements of real world traffic traces and their modeling
- enhancements on statistical parts for analysis
- design of practical scenarios
- integration into the policy based monitoring and measurement based modelling component of Intermon toolkit