Sparsely Synchronized Traffic Flow Characteristics Transfer in Distributed Simulation of Road Traffic

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Introduction and Motivation

- Traffic simulation – an important tool for analysis and control of traffic networks
- Simulation of a large network still problematic
  - Great amount of computational power required for “faster-then-real” time execution
  - Often multiple simulation runs needed
- Speedup of the simulation by its adaptation for distributed computing environment
- Main bottleneck – inter-process communication
- Design of an efficient communication protocol

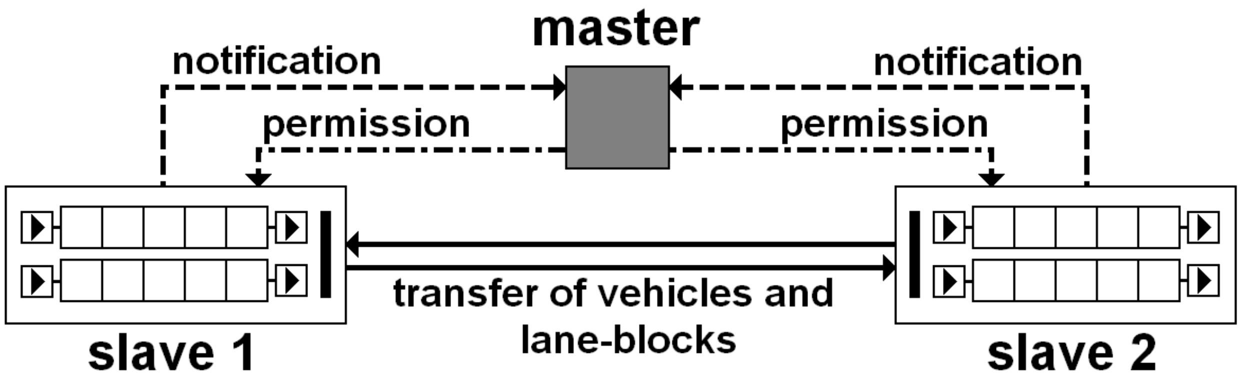
Simulation of Road Traffic

- Communication protocol intended for discrete microscopic time-stepped traffic simulators
  - Simulation subdivided as a sequence of equally-sized time step (each step one second long)
  - Each particular vehicle considered in the simulation
  - Each vehicle has its own position, direction, speed, and acceleration
- Communication protocol tested on Java Urban Traffic Simulator (JUTS) developed at our department

Inter-process Communication

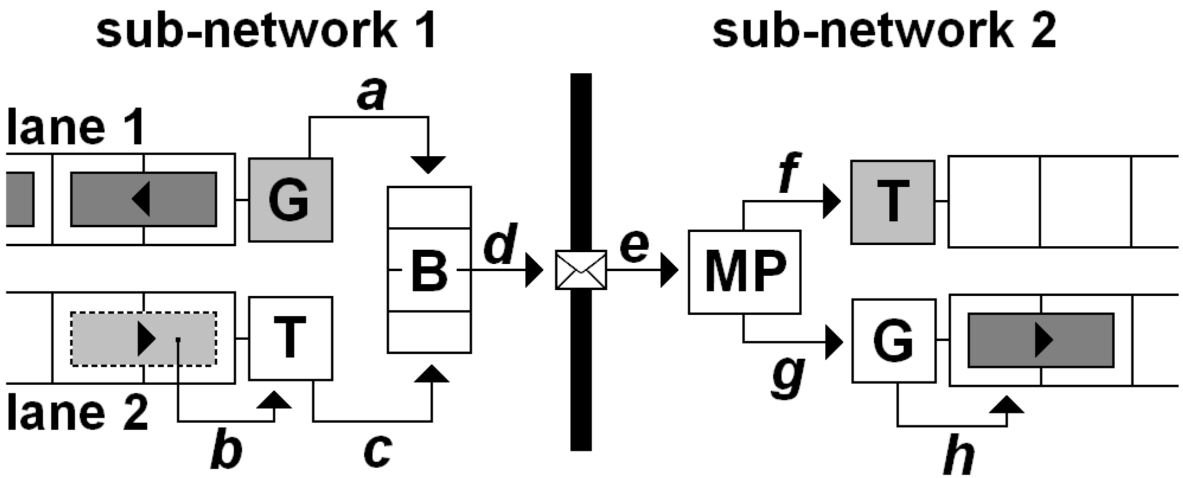
- Simulation in distributed computing environment
  - Divided into process performed on particular nodes of the distributed computer
  - Each process simulates a part of traffic network (a traffic sub-network)
- Communication protocol
  - Most important issue of the distributed simulation
  - Transfer of vehicles between the sub-networks
  - Synchronization of the simulation (guarantees the correct mutual running of the processes)

Master-Slave Approach



- Master-slave approach most commonly used in distributed simulations of road traffic
  - One master, number of slave processes
  - Master synchronizes the simulation
  - Each slave process performs simulation of one assigned traffic sub-network

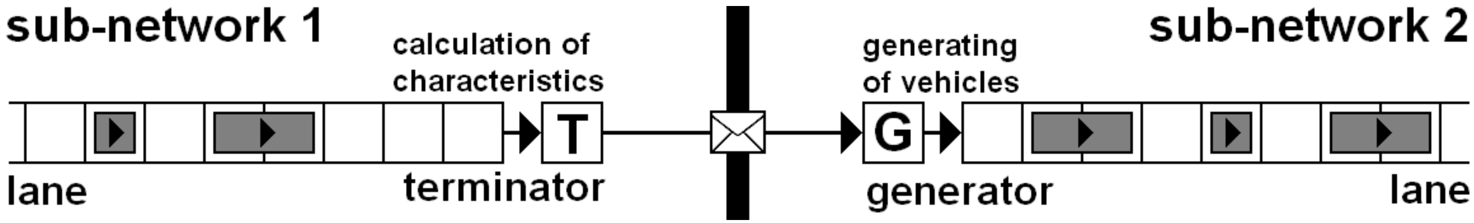
JUTS Standard Protocol (SCP)



T - terminator, G - generator, B - buffer,
MP - message processing

- Based on master-slave approach
- All vehicles determined for one neighbouring sub-network sent in one message
- Reference communication protocol

Flow Characteristics Transfer



- Transfer of traffic flow characteristics instead of particular vehicles
  - Characteristics (vehicle density, mean speed, vehicle lengths) calculated by terminator
  - Vehicles created by generator according to the received characteristics
  - Characteristics sent only if they change
- Terminated and generated flows not identical
  - Slightly different vehicle count and delay

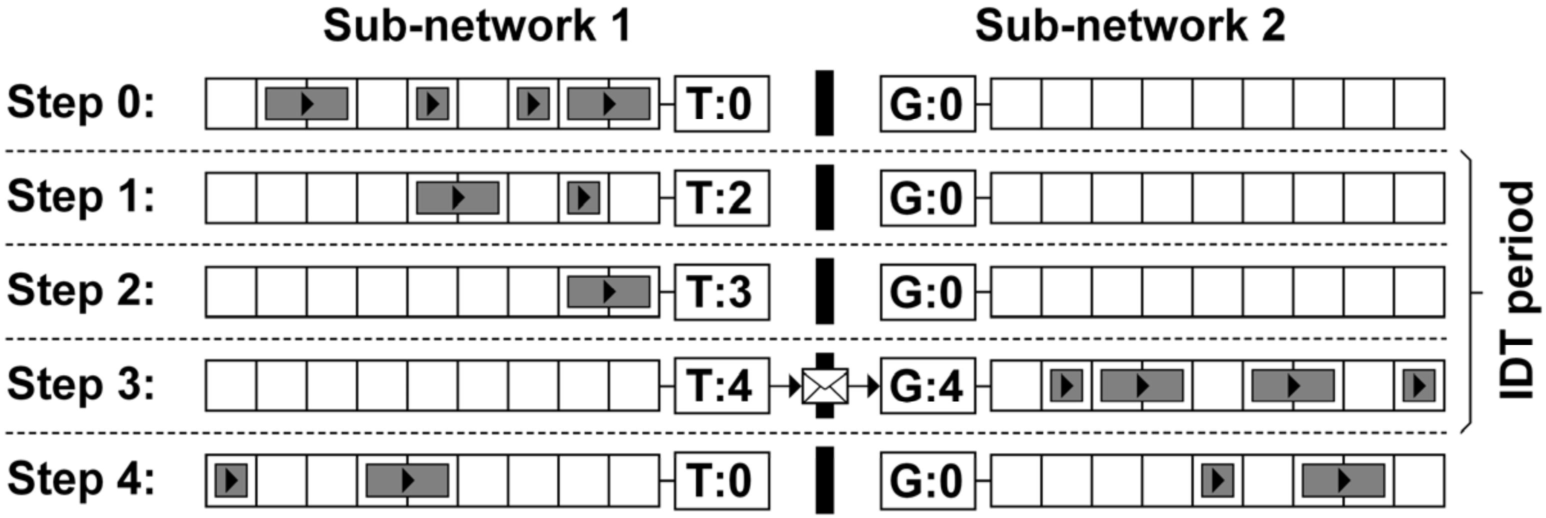
Sparsely Synchronized Transfer I

- Sparsely Synchronized Characteristics Transfer (SSCT)
  - Improves the features of the characteristics transfer
  - All characteristics updates sent regularly once every several time steps
  - Reduction of number of messages necessary for the vehicle transfer
  - Reduction of number of synchronization messages
  - Synchronization performed only in steps, in which the characteristics updates are transferred
  - Inter-Dispatching Time (IDT) – The time period between two synchronizations

Sparsely Synchronized Transfer II

- Enables to improve the fidelity of the characteristics transfer
  - Vehicle count difference and delay can be minimized
  - Vehicle density replaced by the number of vehicles terminated within the last IDT period
  - The same number of vehicles generated at the beginning of the following IDT period
  - Virtually identical numbers of the terminated and the generated vehicles
  - Vehicles immediately shifted in the lane according to the distance traveled during the IDT period

Sparsely Synchronized Transfer III



- Number of messages sent:

$$N_{SSCT} = \frac{N_{SCP}}{T_{IDT}} = \frac{2p + \sum_{i=1}^{p} n_i}{T_{IDT}}$$

Results I

- Performance of the SSCT tested and compared to the performance of the SCP
- Traffic network decomposed into 2, 4, and 6 sub-networks
- Each sub-network simulated by one slave process on one node of distributed computer
- The length of the IDT period from 1 to 16 time steps
- Observed parameters – sent messages count and communication time

Results II

	2 sub-networks		4 sub-networks		6 sub-networks	
IDT period length [steps]	Messages count	Time [ms]	Messages count	Time [ms]	Messages count	Time [ms]
N/A	5897	2395	14821	3849	22262	4984
1	6000	2481	16000	4075	24000	5626
2	3000	1756	8000	2721	12000	3685
4	1500	1266	4000	1856	6000	2590
8	750	980	2000	1401	3000	1840
16	374	754	996	1039	1494	1361

- For IDT period longer than one step, SSCT shows significantly better results
- Messages count savings up to 93 %
- Communication time up to 71 %

Future Work

- Distributed synchronization
  - Focus on distributed synchronization mechanisms instead of centralized master-slave
  - Utilization of the messages between the neighbouring slave processes for synchronization purposes
- Intensive testing of the communication protocols we developed
  - Testing on other similar simulators of road traffic
  - Determine the speedup of the distributed simulation for large traffic networks (near-linear in ideal case)

Conclusion

- Described an efficient communication protocol for distributed traffic simulation – *sparsely synchronized characteristics transfer (SSCT)*
- Significant communication savings
  - Savings of the sent messages count up to 93 % in comparison with the SCP
  - Savings of the communication time up to 71% in comparison with the SCP
- Tested on JUTS system, should be applicable also for other similar traffic simulators