DEVS-Based Modeling and Simulation For Intelligent Transportation Systems

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- Case Study : I^3D^2 Traffic Simulation System
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Background : Intelligent Transportation Systems

✍ Motivation :

To maximize utilization rate of existing traffic equipments to reduce traffic congestion problems.

Background :
Research trends for ITS

- **Conventional :**
  - H/W-oriented (electronic, mechanical, civil engineering approaches)
- **Current :**
  - There is a limitation in reducing traffic congestion from extending of existing traffic facilities.
  - S/W-oriented approach is necessary for ITS
  - ITS(Intelligent Transportation Systems)
    - ATIS (Advanced Traveler Information System)
      - user-oriented
      - used for efficient traffic guidance
    - ATMS (Advanced Traffic Management System)
      - operator-oriented
      - used for traffic system optimization

Background : Why Modeling and Simulation

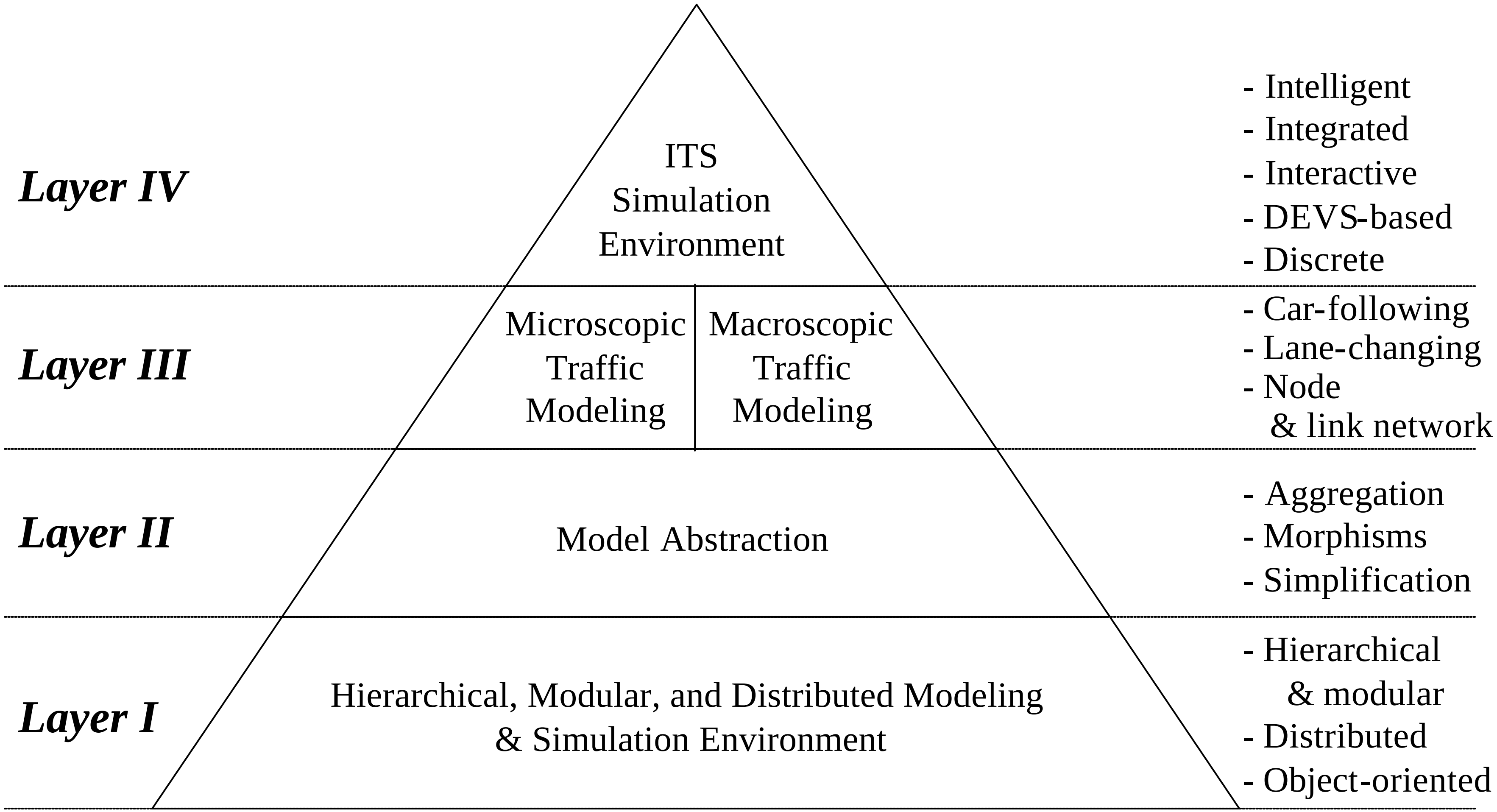
- **for ATMS**
  - control policy analysis (efficiency, reliability).
  - forecasting of congestion propagation depending on traffic accident, road construction .....
  - optimal signal control algorithm generation.
  - feasibility study of traffic effect.
- **for ATIS**
  - forecasting traffic congestions.
  - dynamic travelling path finding.
  - virtual driving.

Background :
Conventional vs. DEVS Simulation

- **Conventional Traffic Simulation Approach**
  - mathematical analytic approach.
  - Mostly microscopic-oriented (where each car is separately injected to the road).

- **Discrete Event Simulation Approach**
  - support both microscopic & macroscopic.
  - provide hierarchical, modular system development environment.
  - fit the dynamic characteristics of traffic system where state transition occurs when light signal change (event).
  - allow level of abstraction

Layered approach for designing ITS simulation

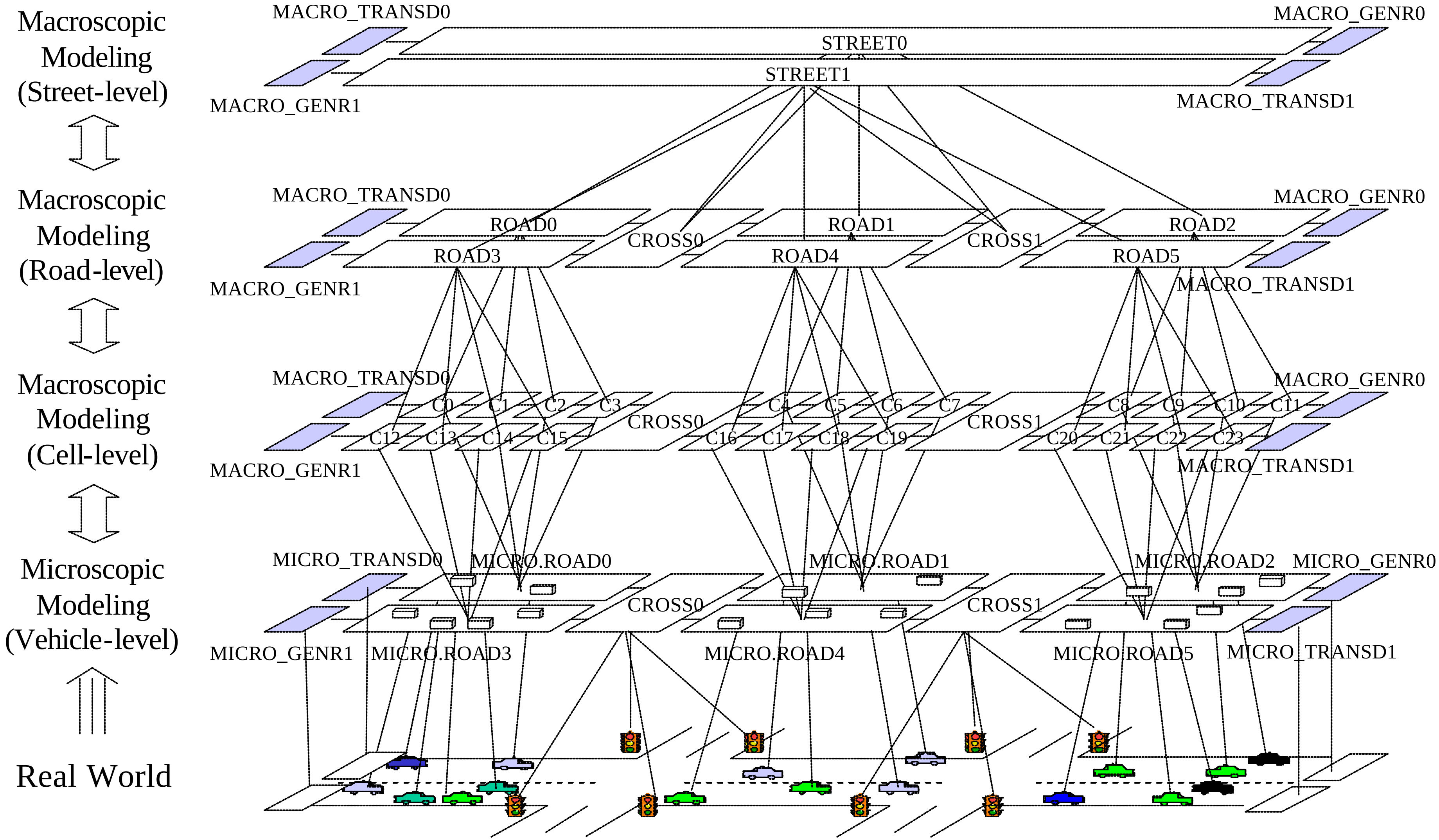


Layer I : Hierarchical, Modular and Distributed Modeling & Simulation

- **System Entity Structure / Model Base**
  - Proposed by Zeigler
  - support hierarchical, modular discrete event modeling and simulation environment
  - system entity structure
    - AI-based tree-link knowledge representation scheme that combines the decomposition, taxonomic, and coupling relationships.
  - model base
    - Contains models that are procedural in character, expressed in DEVS(Discrete Event System Specification) formalism

- **DEVS/HLA**
  - DEVS/HLA based distributed simulation environment
  - use of multiple computers for model execution is fast becoming the predominant form of simulation

Layer II : Model Abstraction

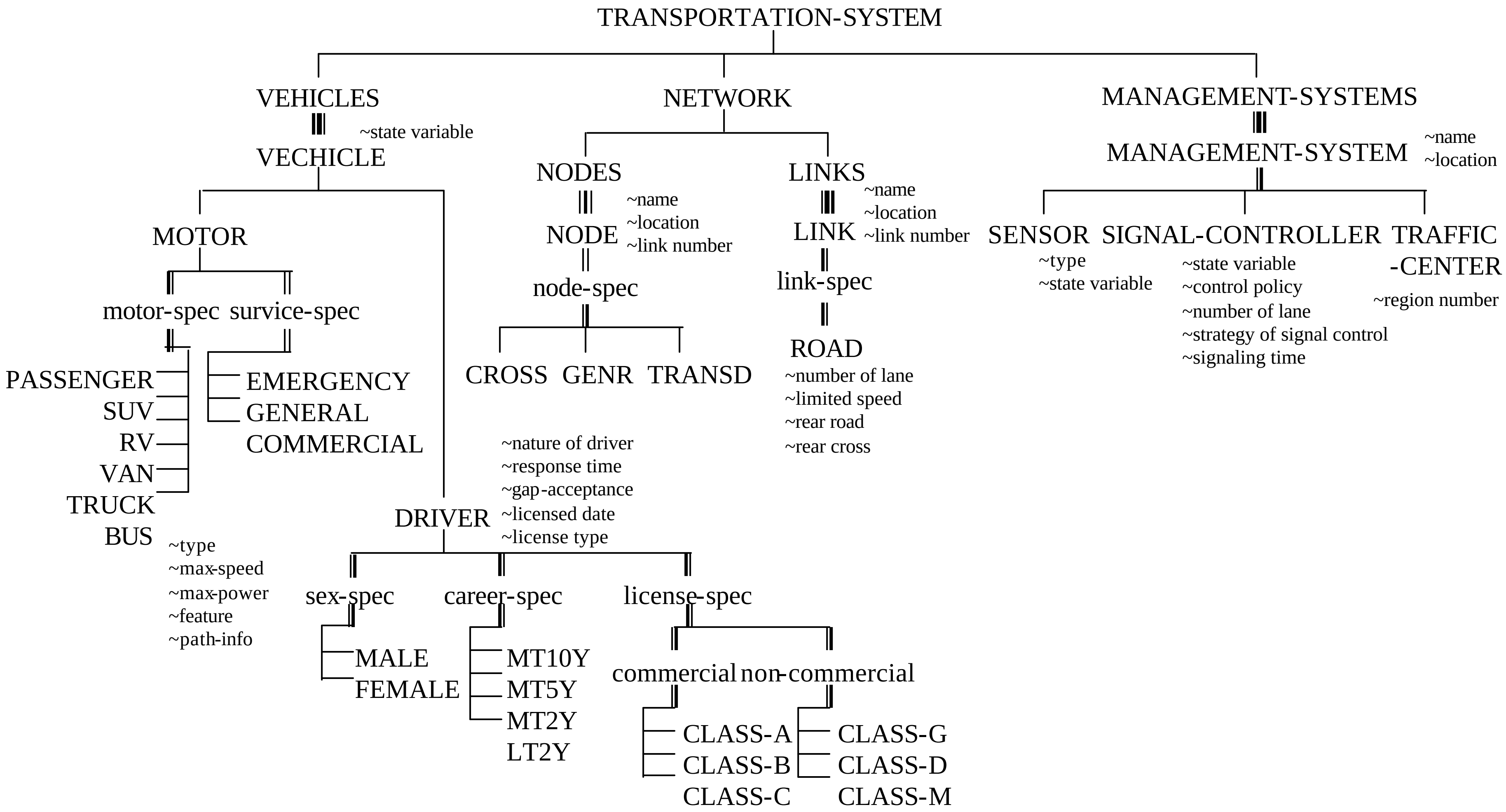


Layer III : Microscopic and Macroscopic Traffic Modeling

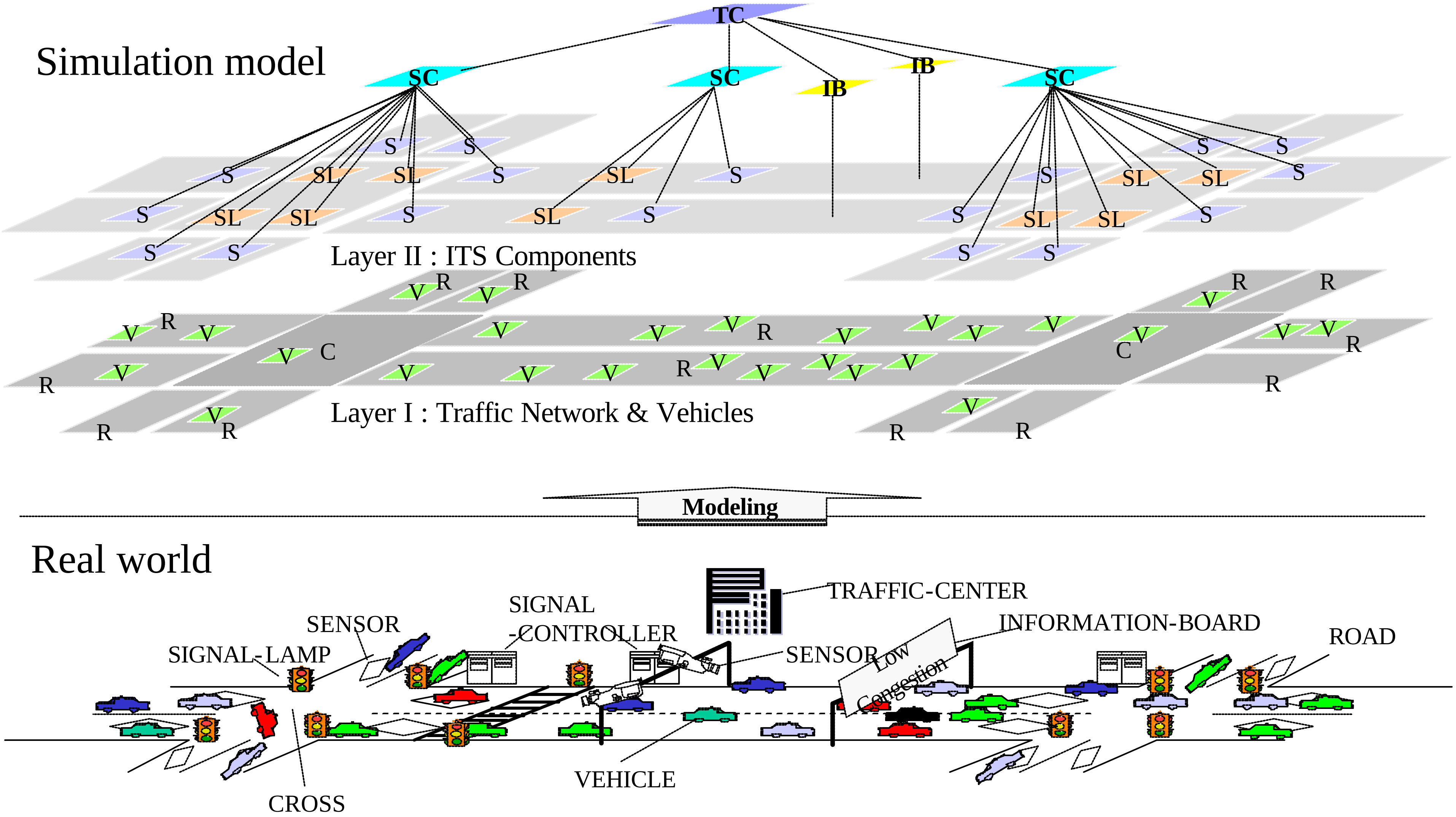
- **Microscopic Simulation Model**
  - Based on the discrete-time approach
  - Generally applied and analyzed by the *car-following* model & the *lane changing* model. so as to trace the behavior of each vehicle at every time period.
    - Car-following
      - study of which how the driver of a following vehicle try to conform with the behavior of the lead vehicle
    - Lane-changing
      - the core of multi-lane microscopic traffic model in company with the car-following model
      - relatively complex because of the intervention of driver's characteristics and decision making

- **Macroscopic Simulation Model**
  - Can be abstracted from the microscopic model, consists of nodes and links
    - CROSS, TRANSD (Transducer), GENR (Generator), ROAD

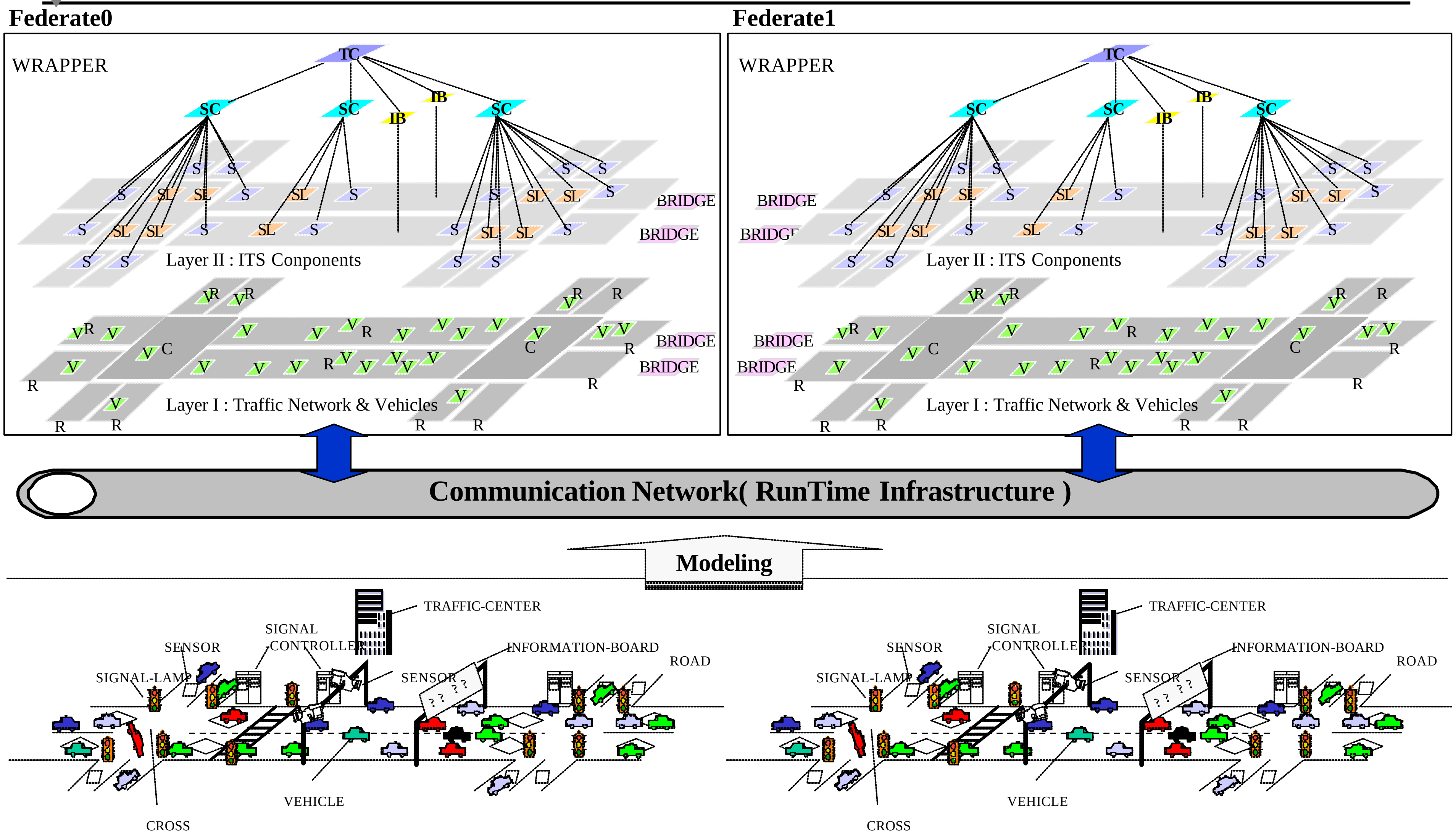
SES of Transportation Systems



Conceptual Diagram of Traffic Modeling



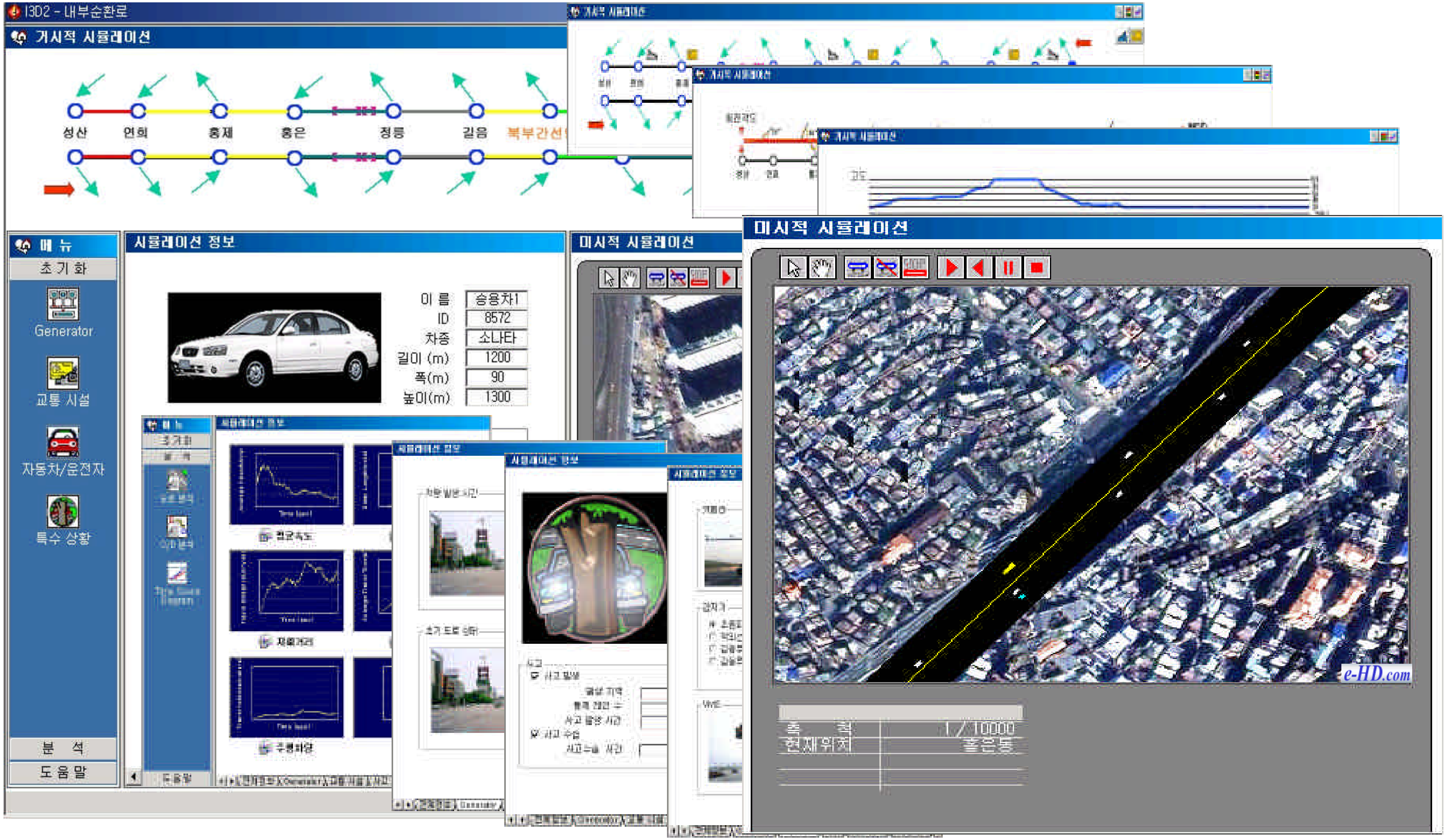
Conceptual Diagram of DEVS/HLA based Distributed Traffic Modeling



Layer IV : ITS Simulation Environment

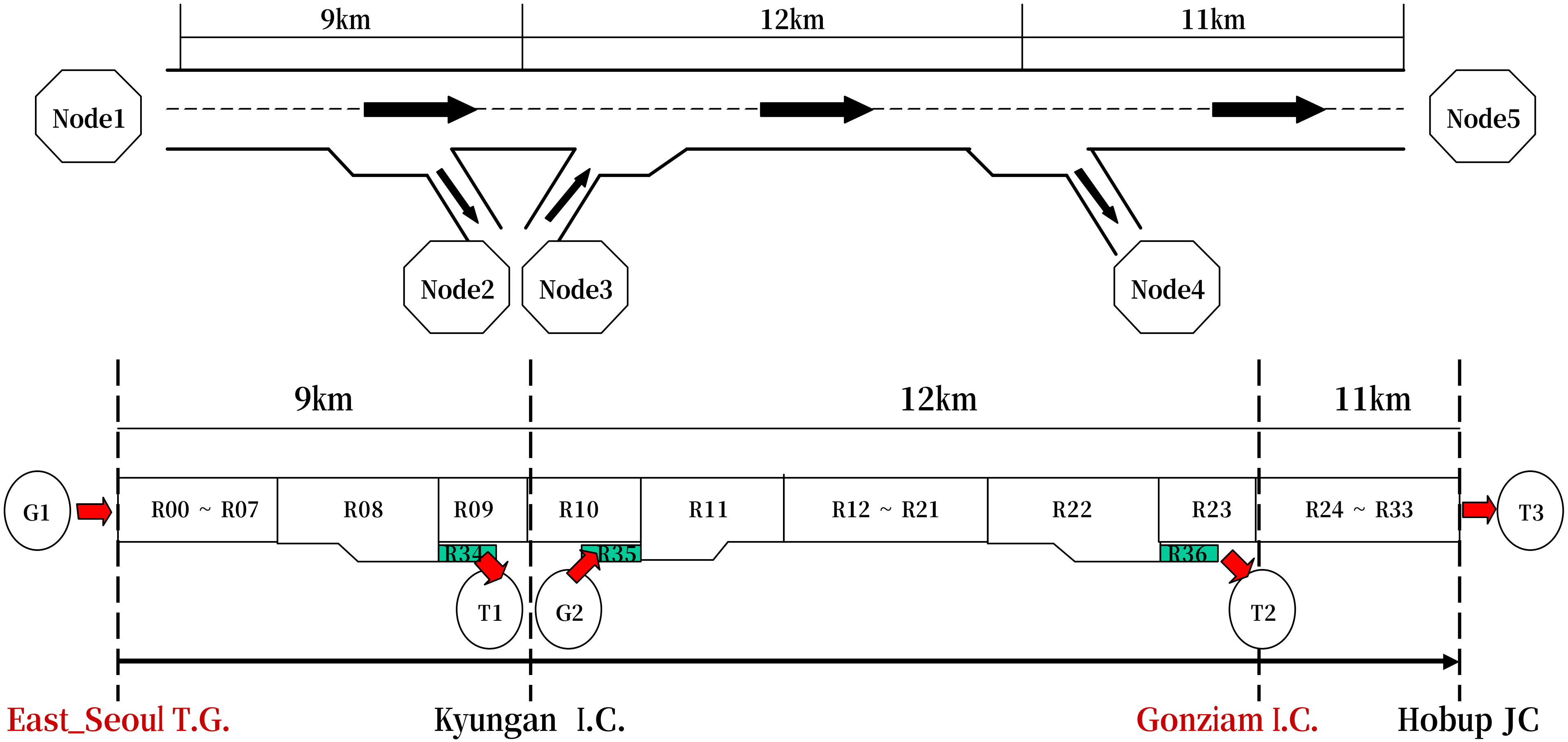
- I^3D^2 Traffic Simulation System

Layer IV : ITS Simulation Environment
- NaeBu Freeway Traffic Simulation System



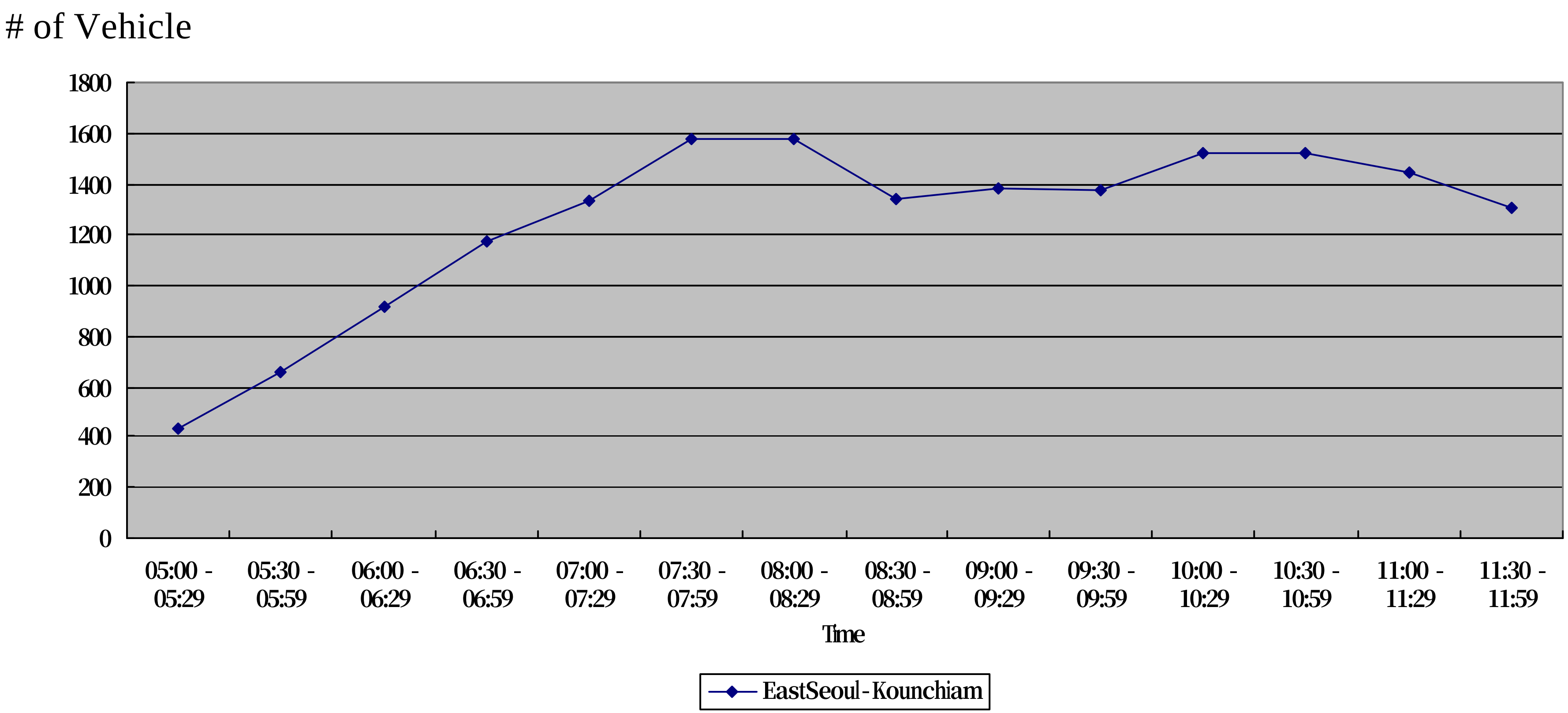
Performance Analysis

✍ Simulation Model Structure of JOONGBOO Highway



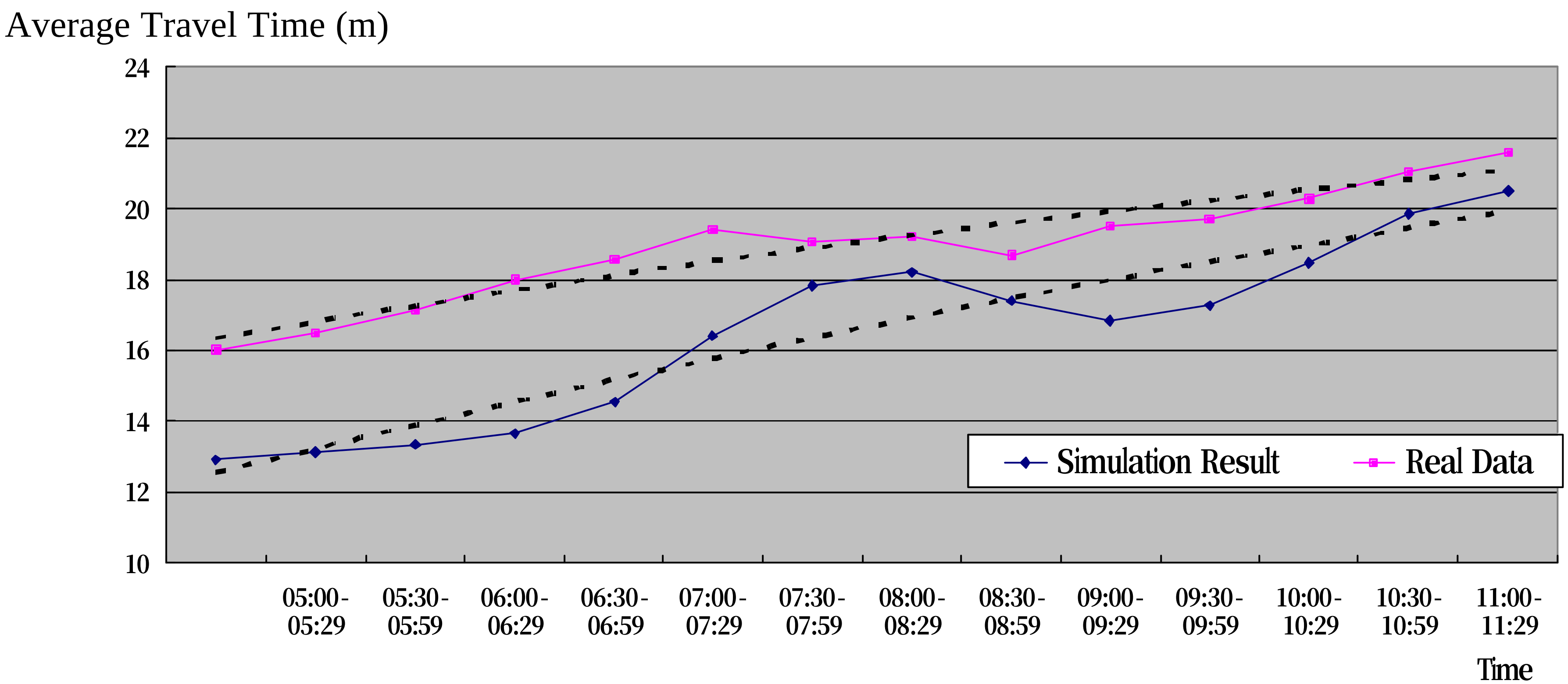
Generating amount of vehicles

- The amount of vehicles generated between East Seoul T.G. and Gonziam I.C. according to collected real data.
  - Real Data : Thursday, May. 31. 2001. am 05:00 ~ pm. 12:00



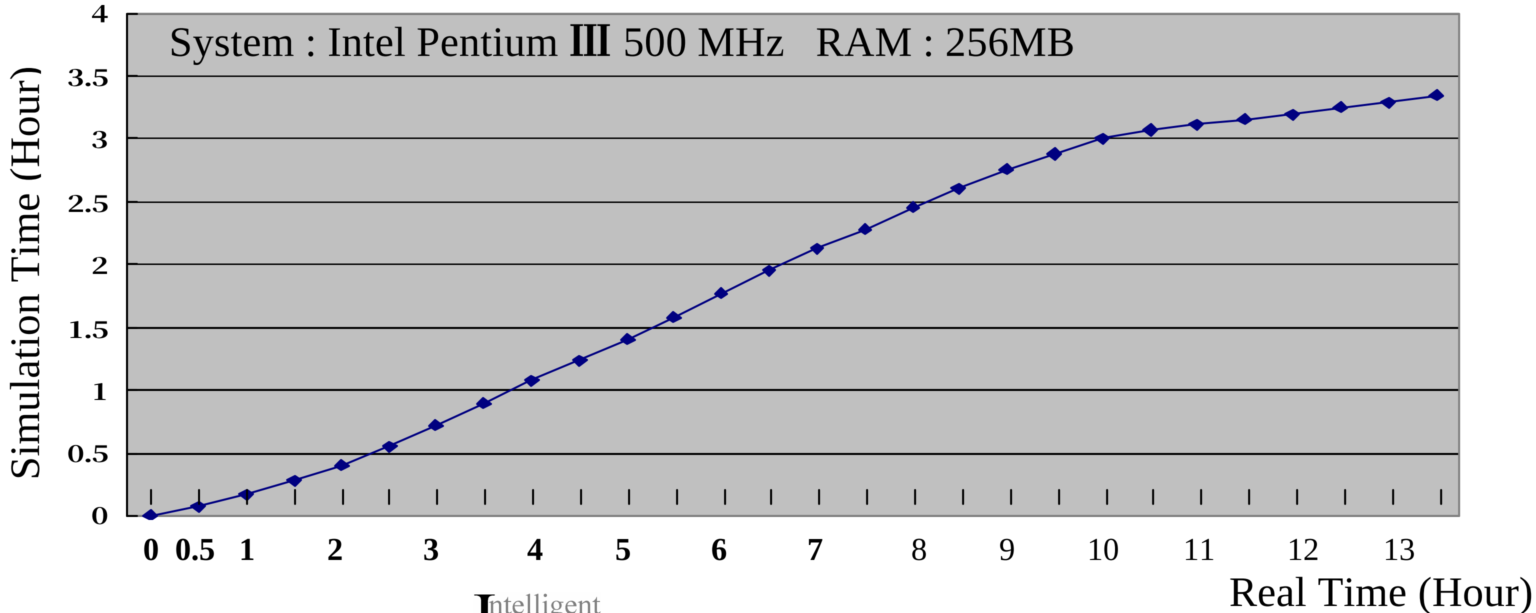
Traffic model's ability to express

- Average travel time of vehicles that drive from East Seoul T.G. to Gonziam I.C according to time period.
  - Although this has a little faster average travel time than real data, comprehensive traffic phenomena are expressed effectively.



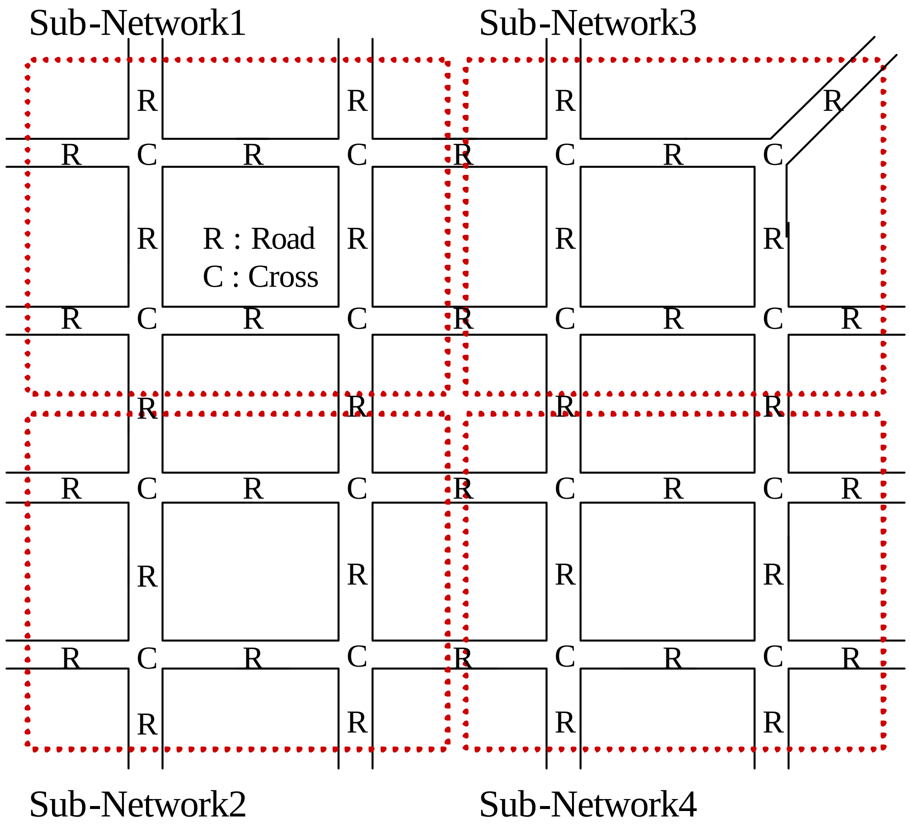
Processing Time of Simulation

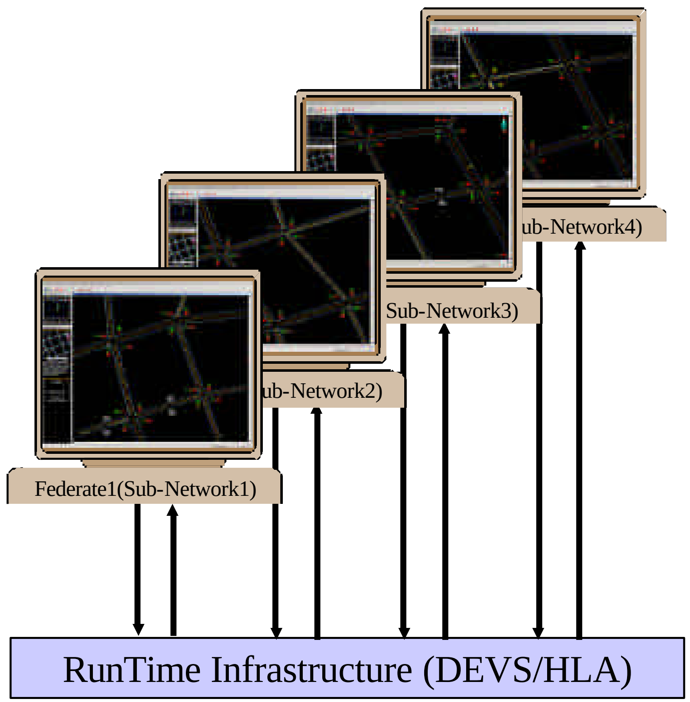
- The result of simulation for 13 hours in 32Km block of JOONGBOO Highway.
  - about four times faster than real-time.
- But, processing time of simulation should be about 6 to 7 times faster than real-time (by Transportation Engineering)
  - Only so, it is efficient to apply the analysis of real world's traffic phenomena to real world



Distributed Simulation

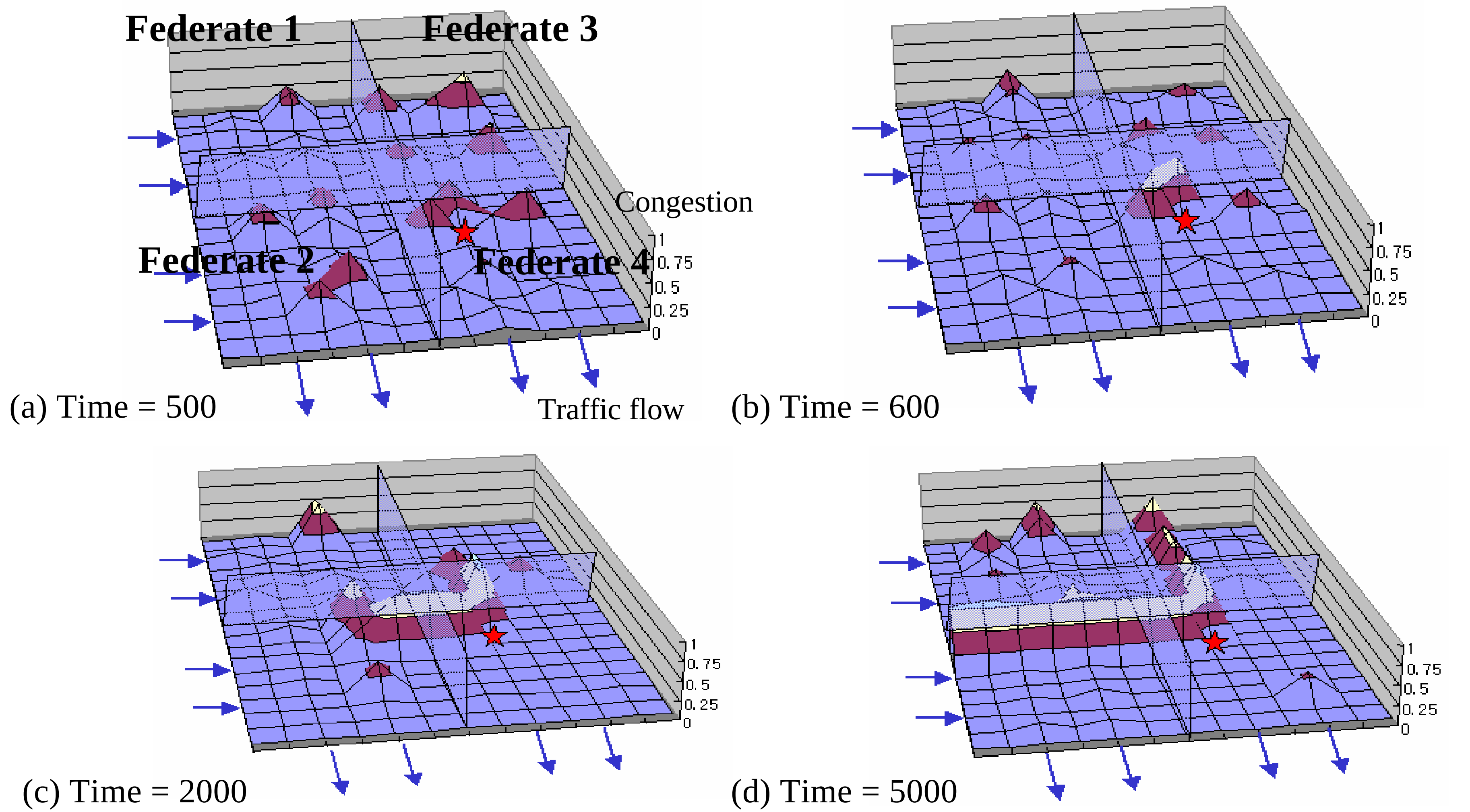
✍ Decomposition concept of the large scale traffic network





Distributed Simulation Result (Abnormal)

✍ Distributed Traffic Simulation Result(abnormal situation)



(a) Time = 500

(b) Time = 600

(c) Time = 2000

(d) Time = 5000

Conclusions

- DEVS-based design methodology for the traffic simulation system has been discussed.
- Discrete event modeling technique can be employed to describe macroscopic model.
- Level of abstraction supports an coherent integration between microscopic and macroscopic traffic modeling
- Four-layered approach provides a convenient means for evaluating the alternative signal control strategies at the operating level of ATMS as well as for generating the simulation-based forecasting information for ATIS.
- I^3D^2 traffic simulation system has been successfully implemented and tested
- Finally, it is showed whether DEVS/HLA-based distributed simulation technique can be applied to traffic simulation field effectively.

Some Problems of Our research

- To consider scalability of traffic simulation, DEVS/HLA-based distributed simulation is applied.
- There is a doubt if it effectively enhances the performance
  - The stabilized system structure non-sensitive to fluctuation of objects is necessary.
  - Enhancement of distributed processing speed of DEVS/HLA is required.
    - Reduce the size and frequencies of message for Distributed Traffic Simulation.
    - Apply Predictive Quantization Multiplexer method to Distributed Traffic Simulation.

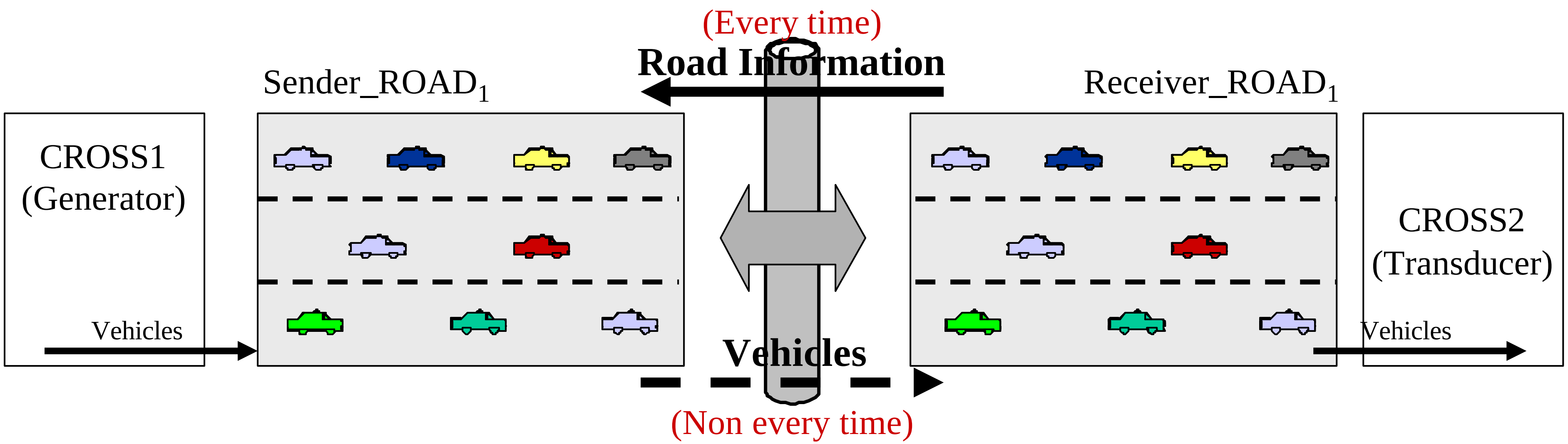
Future Works

- Objective
  - Performance Enhancement on DEVS/HLA based Distributed Traffic Simulation

- Idea
  - Uses the Predictive Quantization Multiplexer method and performs the effective message filtering and compression between two Roads in distributed environment.
  - Performs Distributed Traffic Simulation with reasonable communication overhead.
  - This idea is based on proposed Methodology by Prof. Bernard P. Zeigler et al.

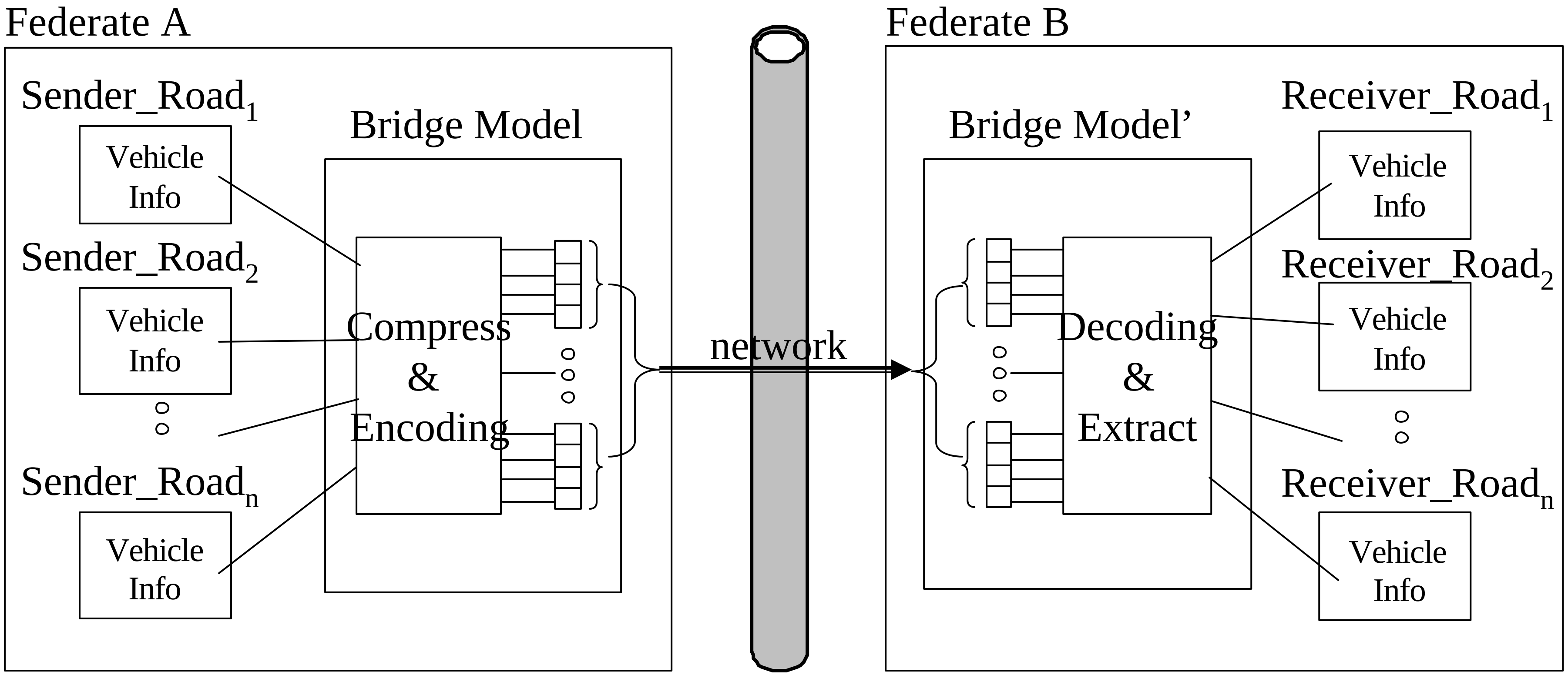
Data Communication of Distributed Traffic Simulation Envir.

- Vehicle Information
  - transfers the information only when vehicles move to connected federate. But, there are relatively lots of information transferred.
- Road Information
  - transfers information of the front road every time. But it has less data amount at one time than vehicle information.



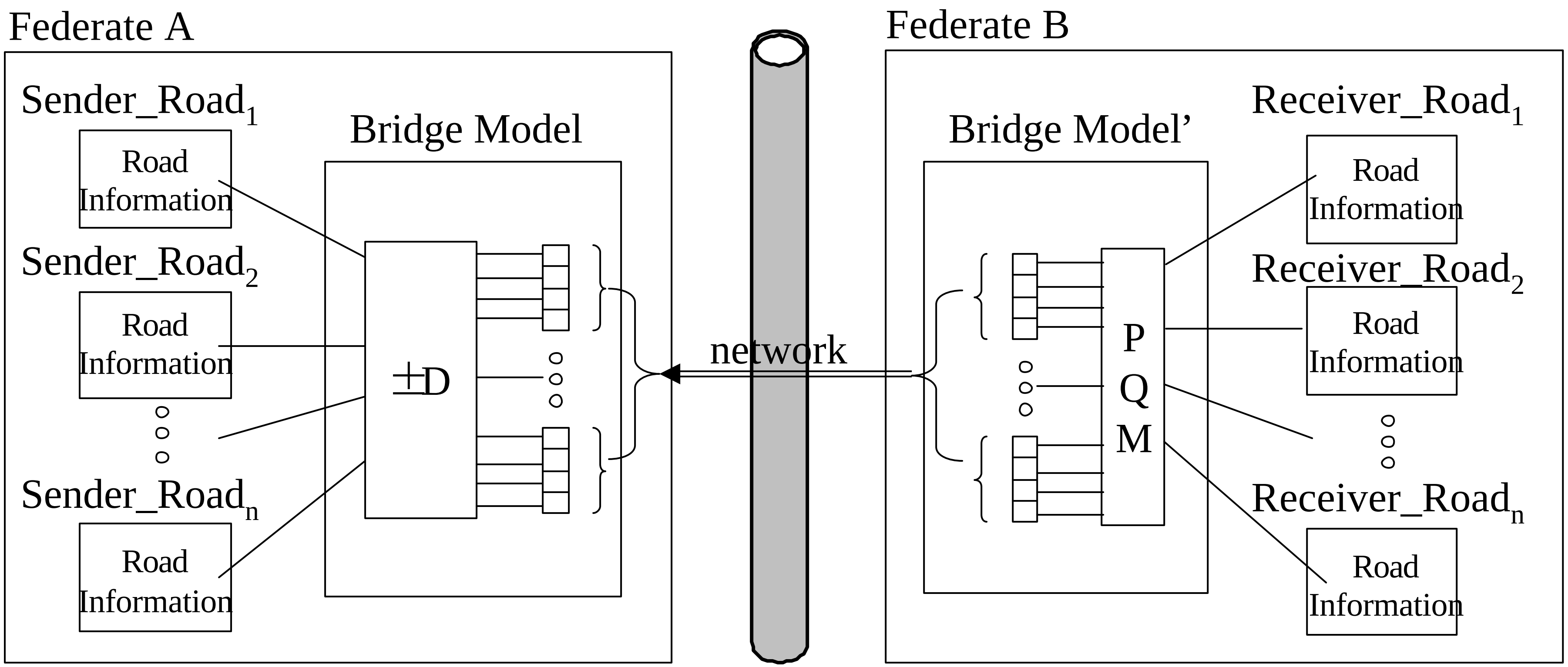
Moving of Vehicle Information

- Method that minimizes individual variables in each vehicle information is necessary.
- Individual transmission method of vehicle information is multiplexed and transferred.



Moving of Road Information

- As road information requires update of continuous information, Predictive Quantization Multiplex method should be used.



The End

Thank you very Much!