Hierarchical routing system using Ant Based Control

Henrik Dibowski

Delft University of Technology

Dresden University of Technology

July 21, 2003

Delft

Contents

- Introduction
- Ant Colony Optimization
- Ant Based Control
- Hierarchical network
- Hierarchical routing system
- Adaptations of the ABC-algorithm
- Evaluation and Recommendations

Introduction (1)

Hierarchical routing system using Ant Based Control:

Routing vehicles by using

- a hierarchical network
- dynamic data
- Ant Based Control algorithm

Introduction (2)

Goals:

- Design a model of a hierarchical network
- Design a model for the Hierarchical routing system
- Adapt the ABC-algorithm
- Validate the Hierarchical routing system

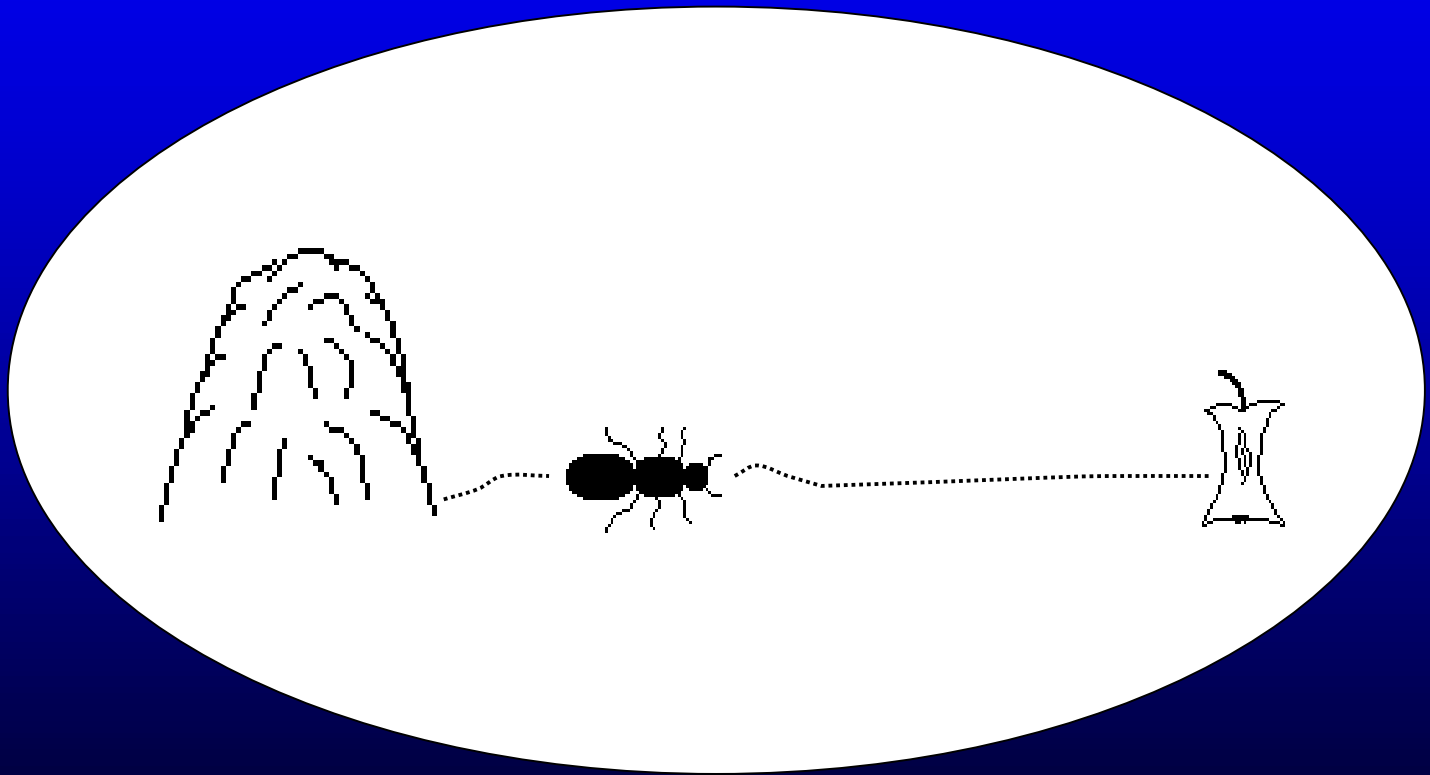
Introduction (3)

Features:

- Navigation of vehicles in cities and to other cities
- Avoiding congestions by routing along the shortest route in time
- Better exploitation of the road capacity

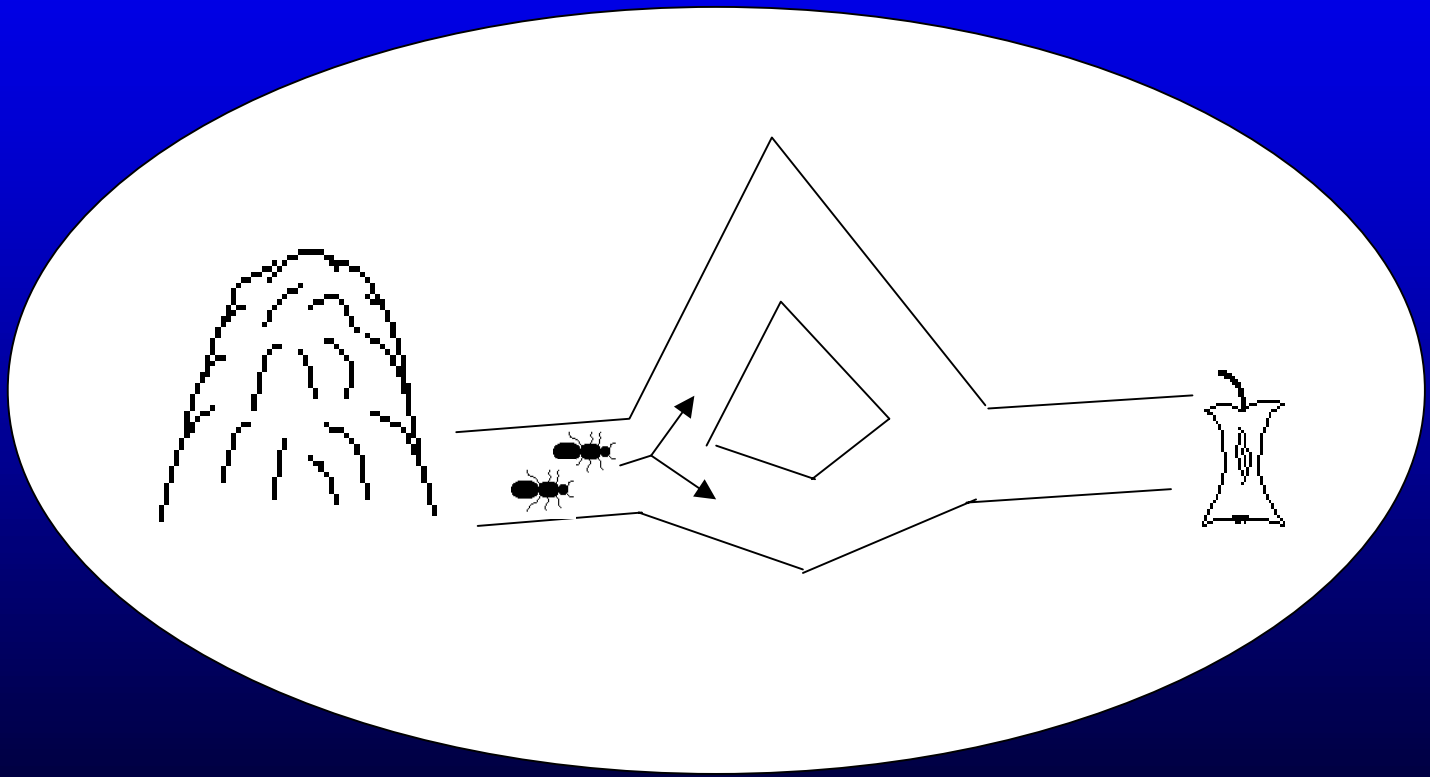
Ant Colony Optimization (1)

Natural ants find the shortest route



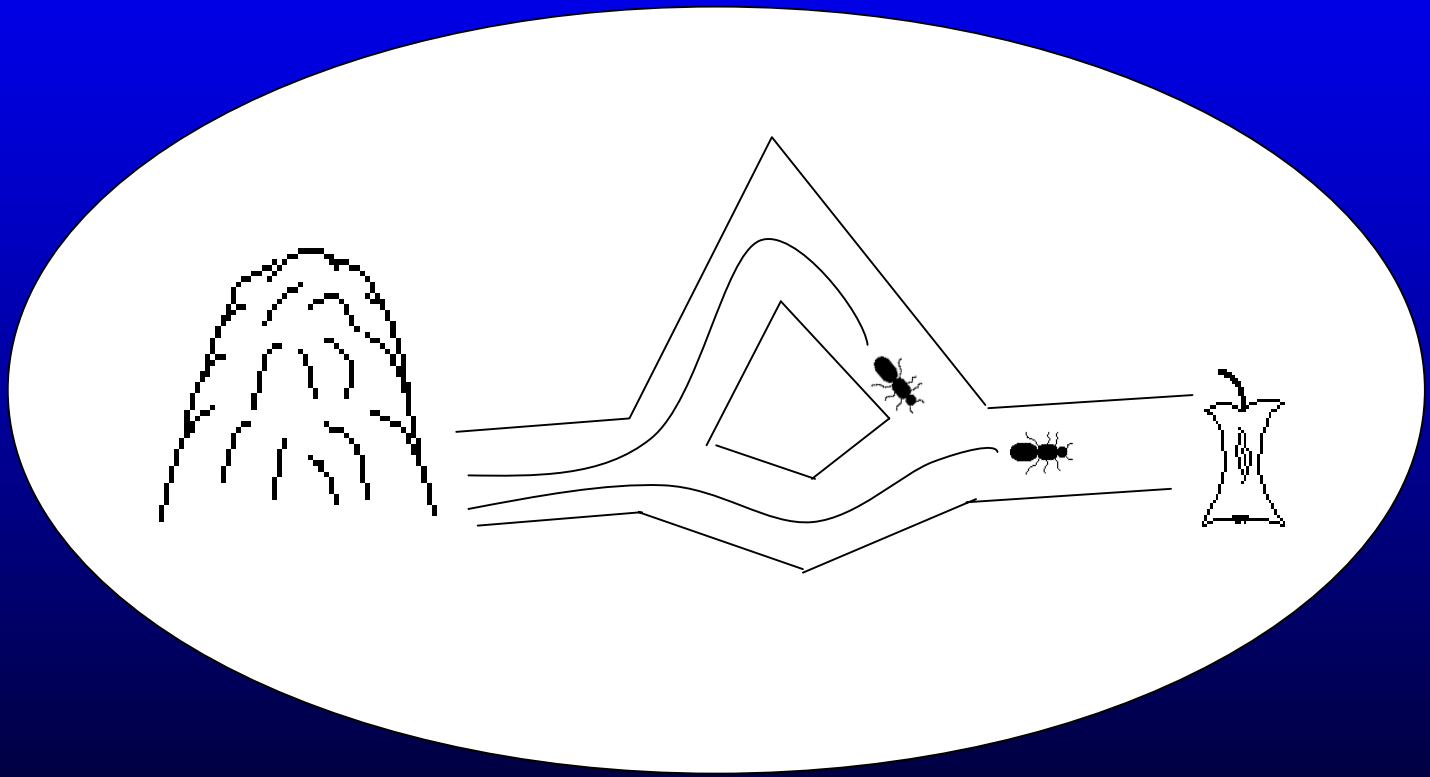
Ant Colony Optimization (2)

Choosing randomly



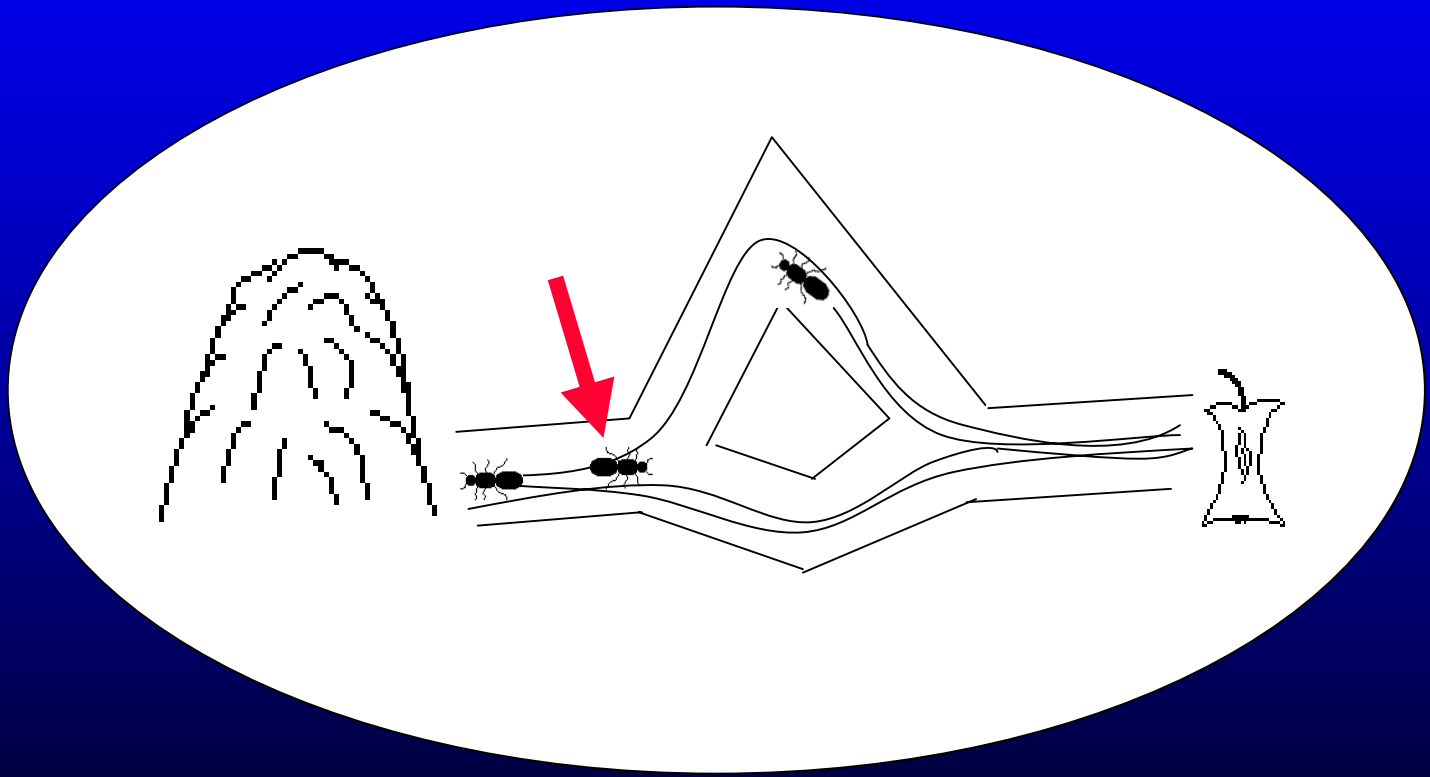
Ant Colony Optimization (3)

Laying pheromone



Ant Colony Optimization (4)

Biased choosing



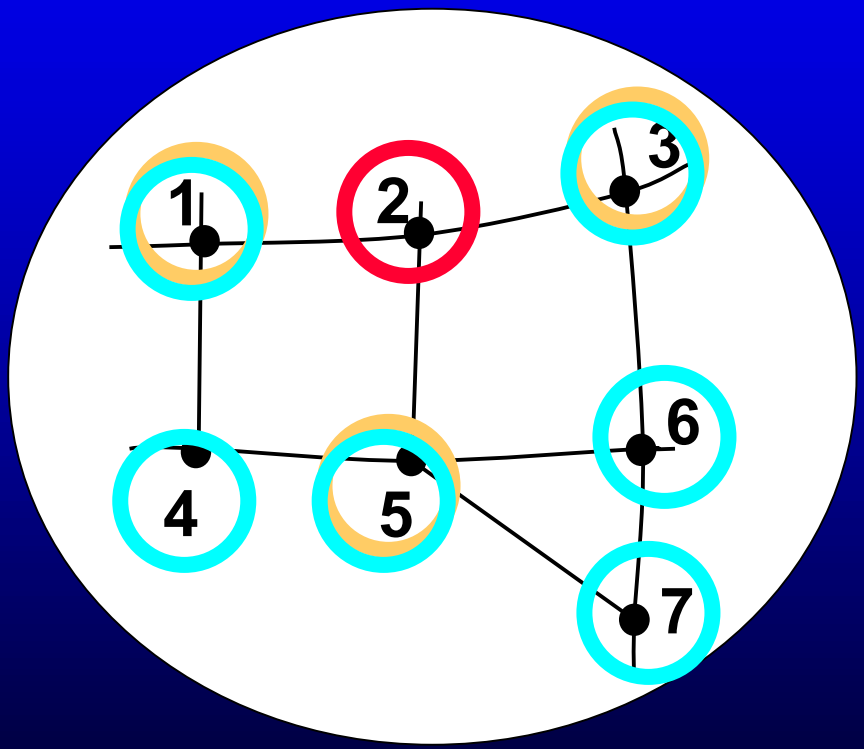
Ant Based Control (1)

The ABC-algorithm:

Derived from the behaviour of ants:

- Ants → Intelligent agents
- Pheromone → Routing tables
- Different pheromone for every destination
- Decentralized, suitable for dynamic data

Ant Based Control (2)



Routing table

Destination ↓ | Next →	1	3	5
1	0.89	0.05	0.06
3	0.03	0.90	0.07
4	0.44	0.19	0.37
5	0.08	0.05	0.87
…	…	…	…

Ant Based Control (3)

Forward agents

- Generated regularly from every node with random destination
- Choose route according to probabilities
- Store route and travel times
- Transform to backward agent when arriving at the destination

Ant Based Control (4)

Backward agents

- Move back from destination to source
- Use reverse path of forward agent
- Update the probabilities for going to this destination
- Are killed at the source

Ant Based Control (5)

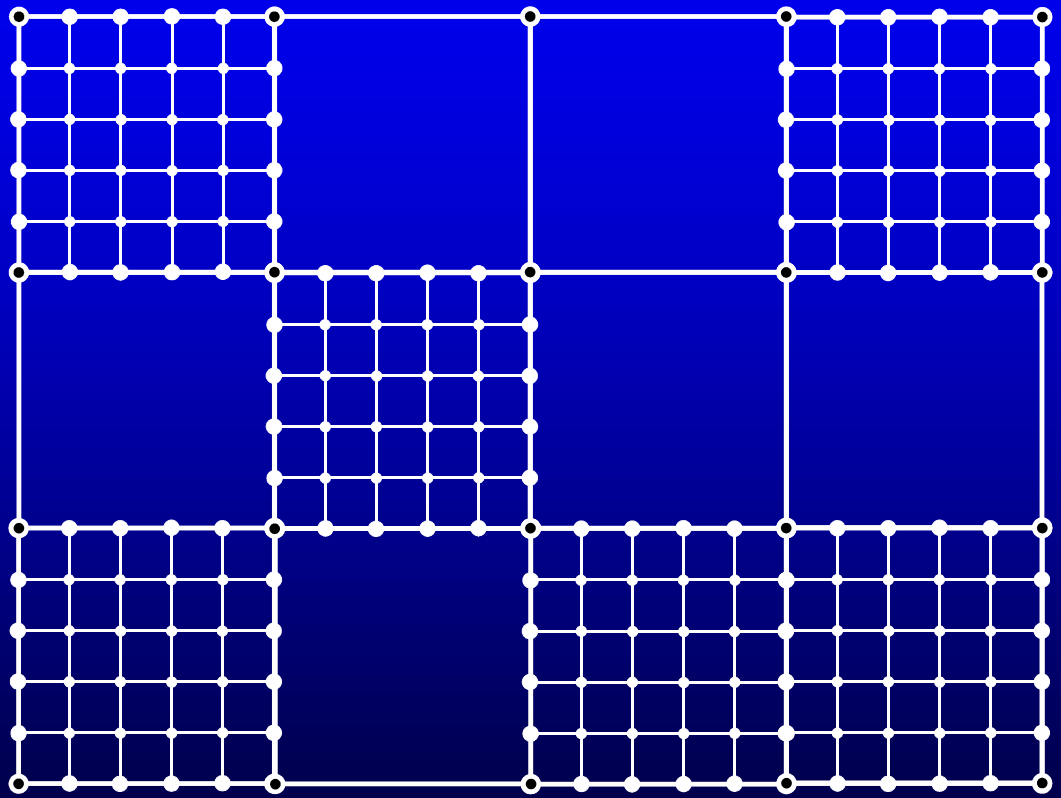
Updating probabilities

- Probability for choosing the node the forward agent chose is *incremented:*

$$\Delta P = \frac{A}{t} + B$$

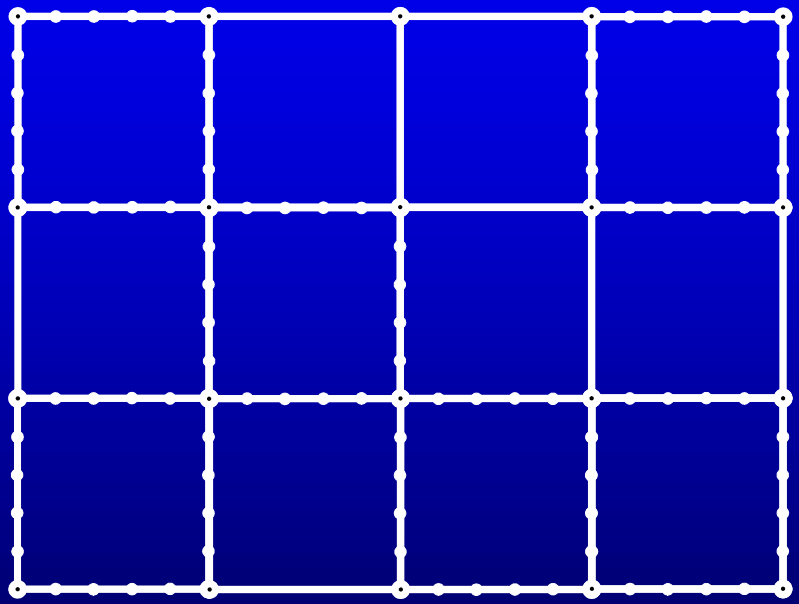
- Probabilities for choosing other nodes are slightly *decremented*

Hierarchical network

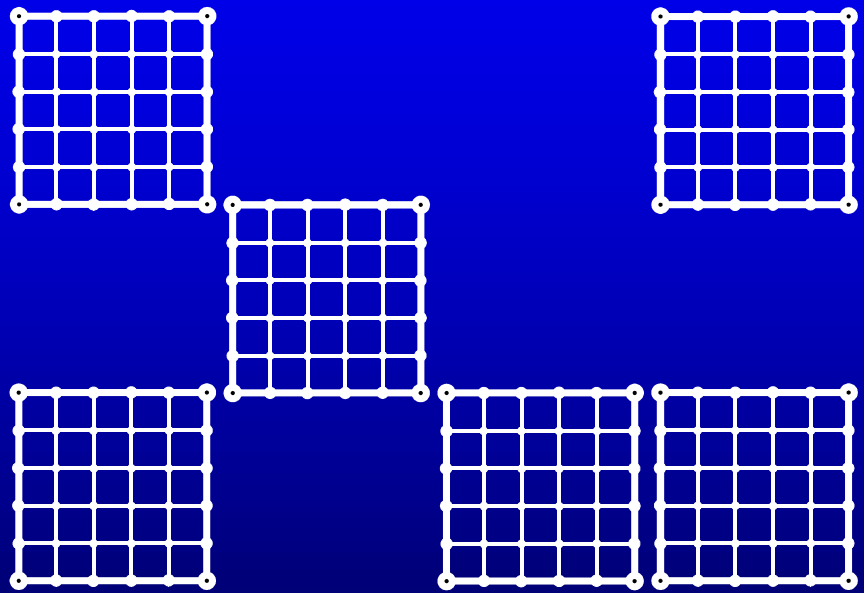


street
motorway
intersection
slip road, departure
motorway intersection

Hierarchical network

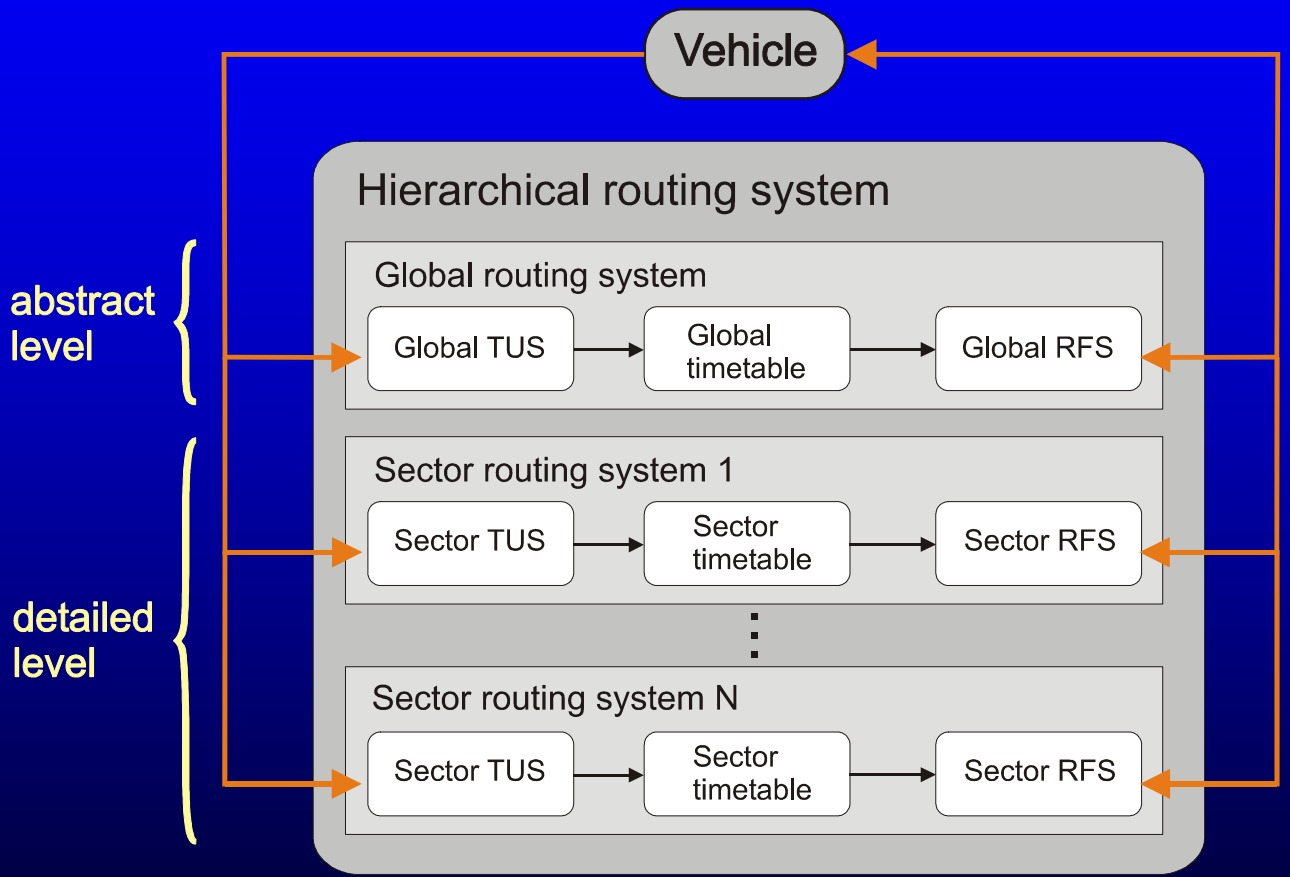


Abstract level



Detailed level

Hierarchical routing system (1)

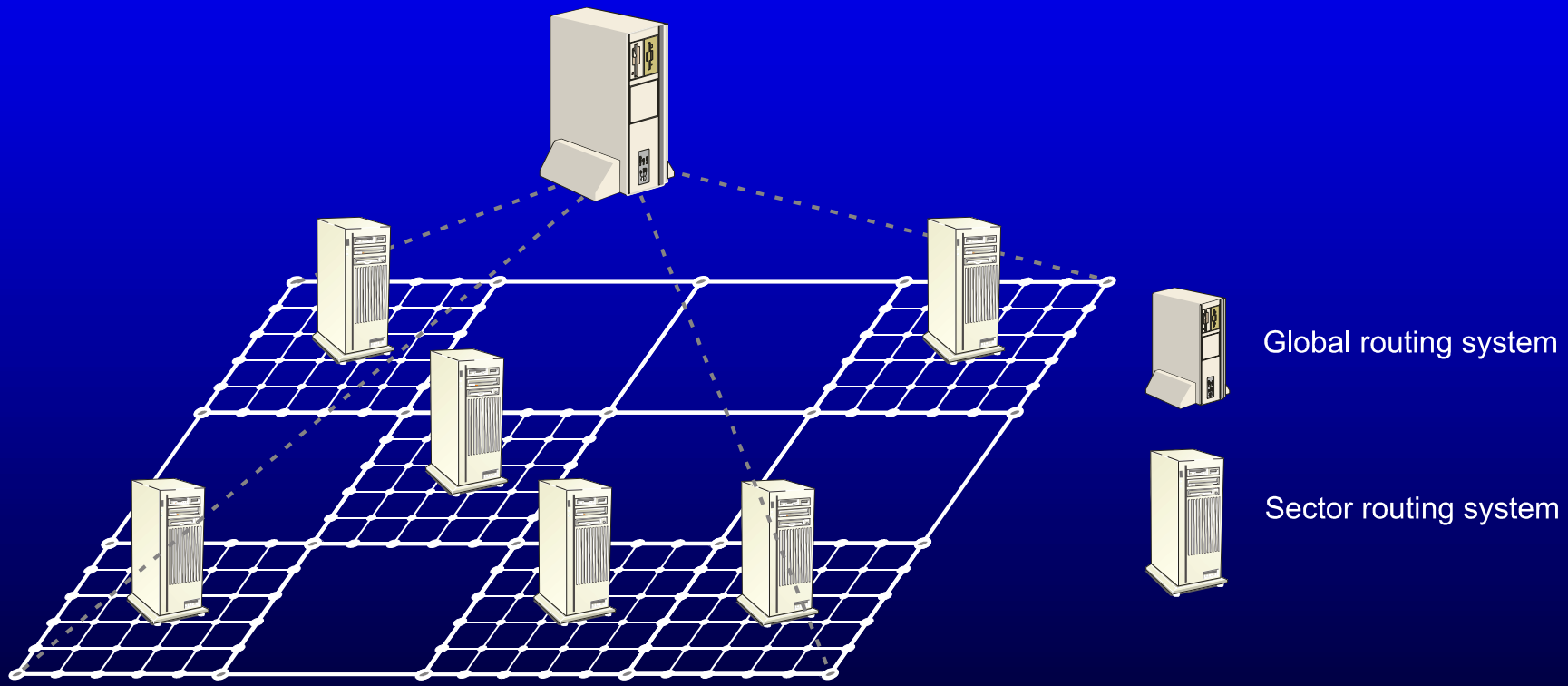


TUS: Timetable updating system

RFS: Route finding system

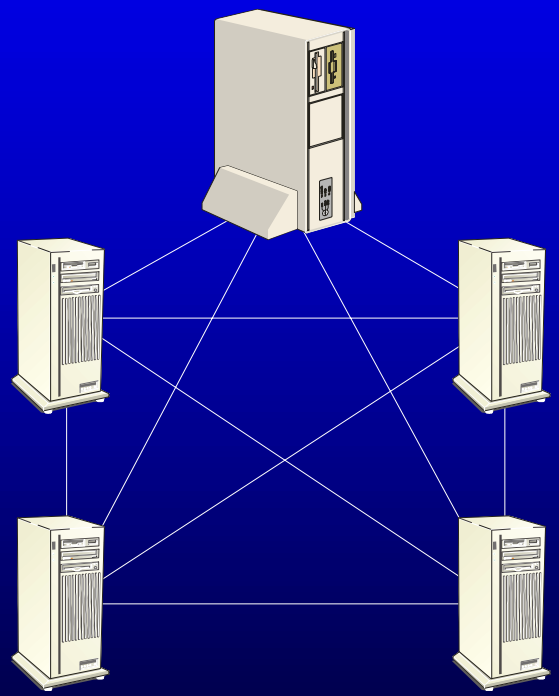
Hierarchical routing system (2)

Distribution



Hierarchical routing system (3)

Communication



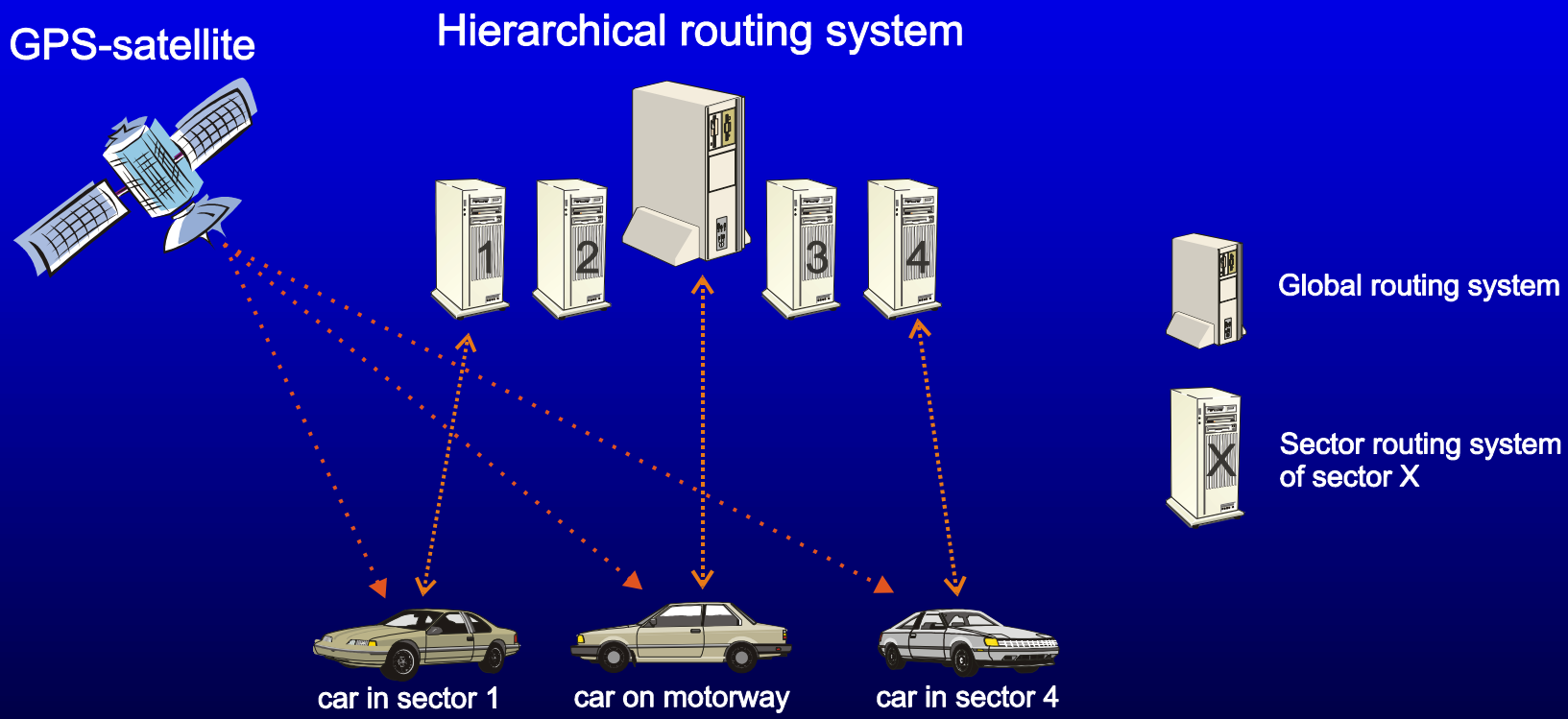
Via Internet or
Wide Area Network

Global routing system

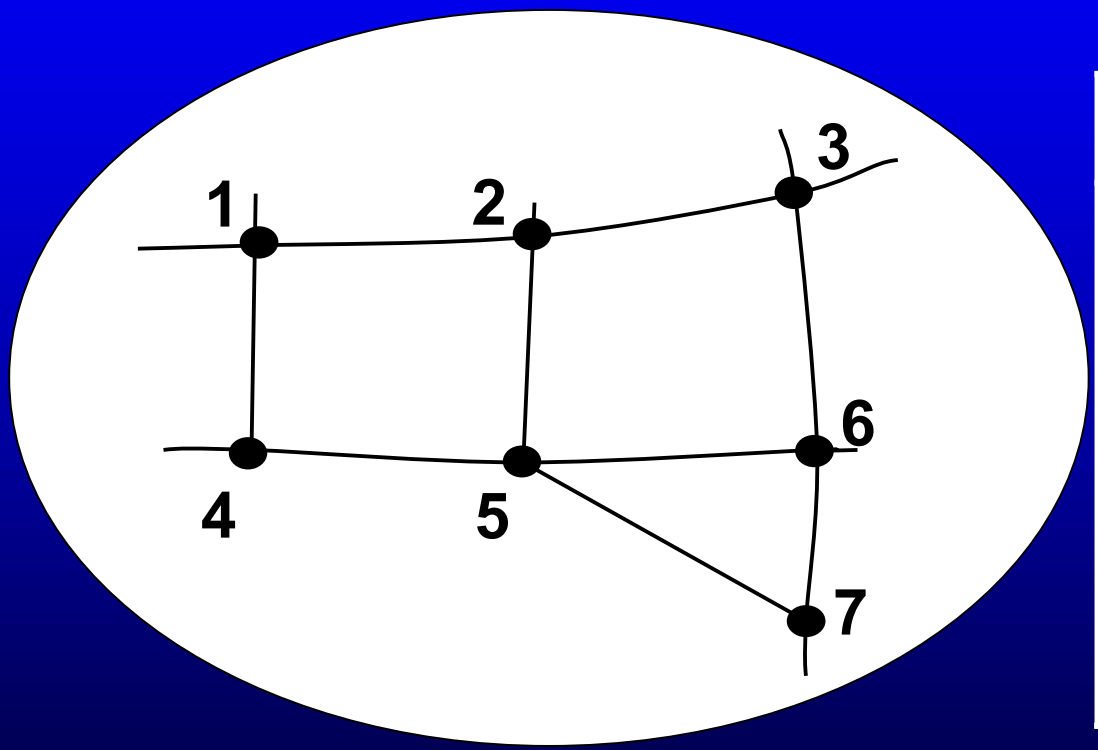
Sector routing system

Hierarchical routing system (4)

Vehicle connection



Timetable updating systems (1)

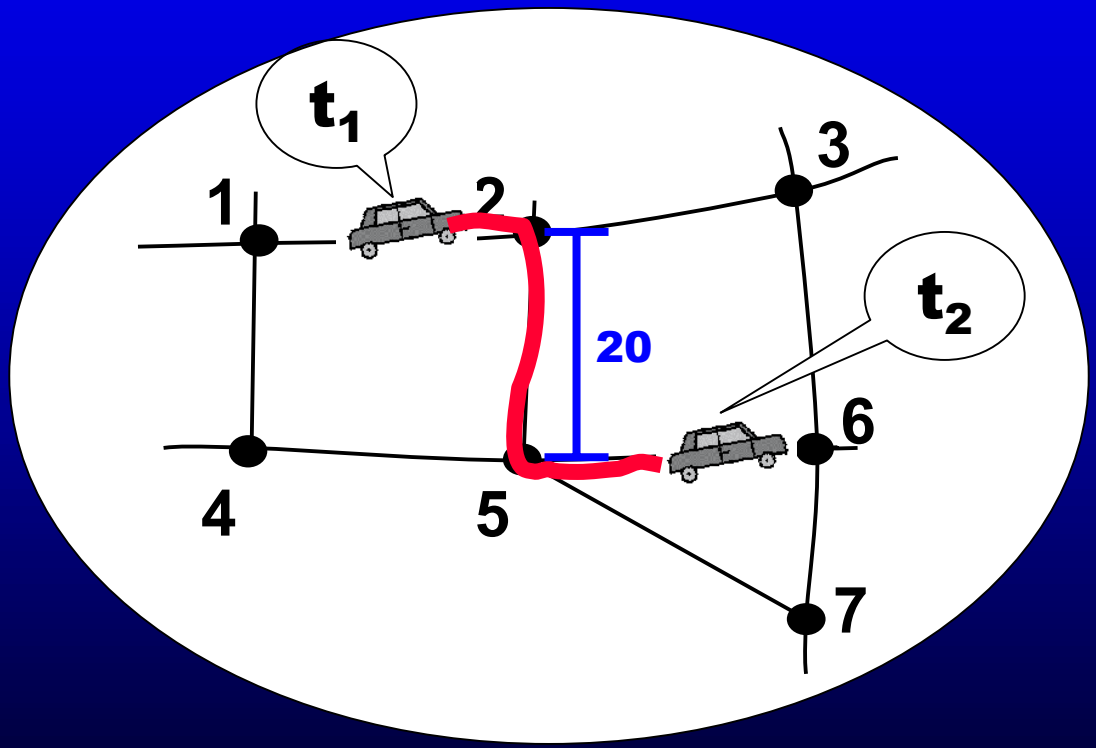


Timetable

	1	2	4	5	…
1	-	12	15	-	…
2	11	-	-	18	…
4	14	-	-	13	…
5	-	18	14	-	…
…	…	…	…	…	…

Timetable updating systems (2)

Update information from vehicles



TU Delft

Route finding systems (1)

Route optimization

- Every RFS has its own agents and routing tables
- Routing tables only contain nodes for the corresponding network
- Agents only optimize routes within the corresponding network

Route finding systems (2)

Route computation

- Vehicles are routed along the path with highest probability
- Routes within a network are computed by one RFS
- Routes which start in a network and end in another network are computed as composed route by two or three RFS

Route finding systems (3)

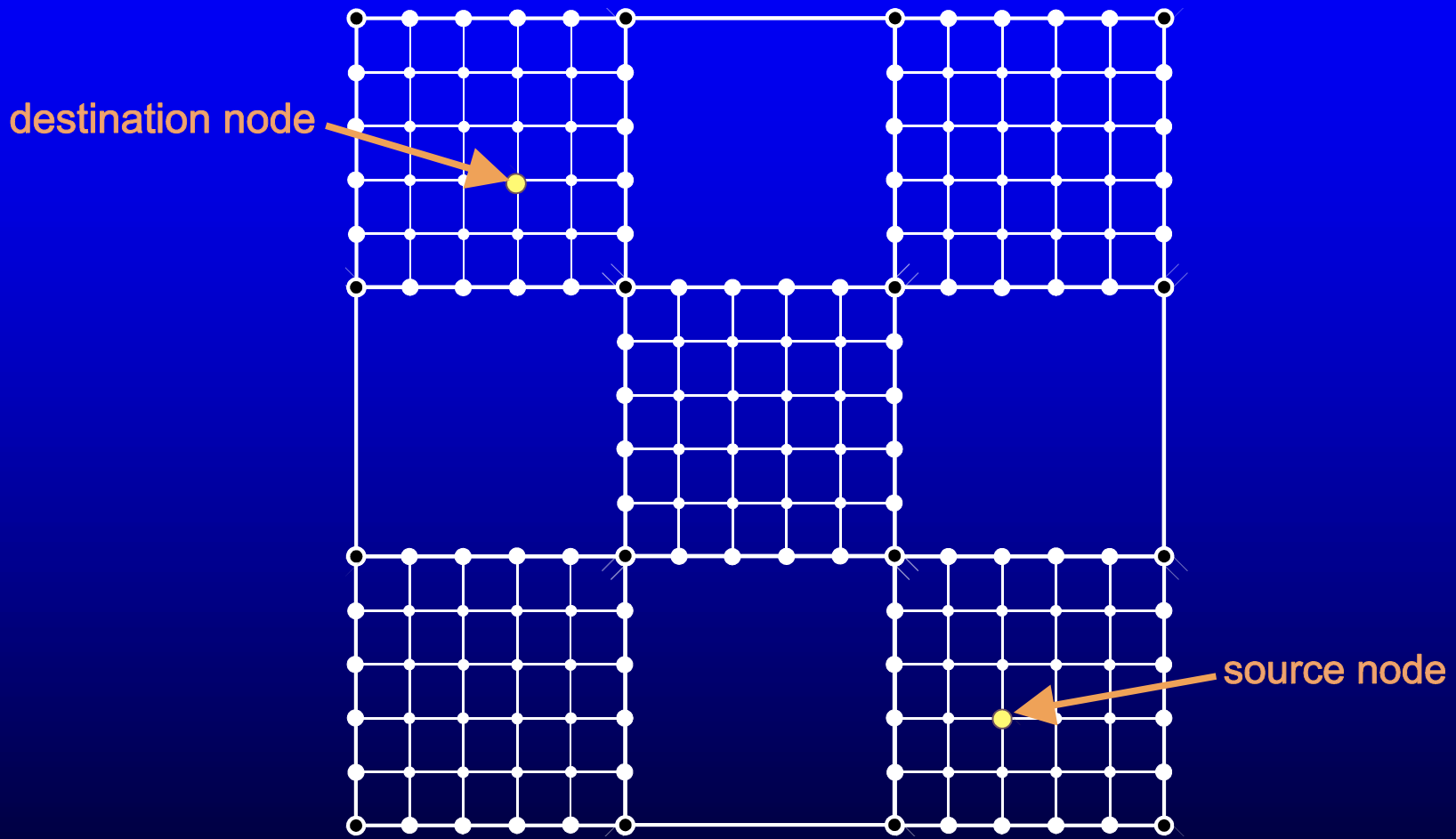
Composed route

Strategy:

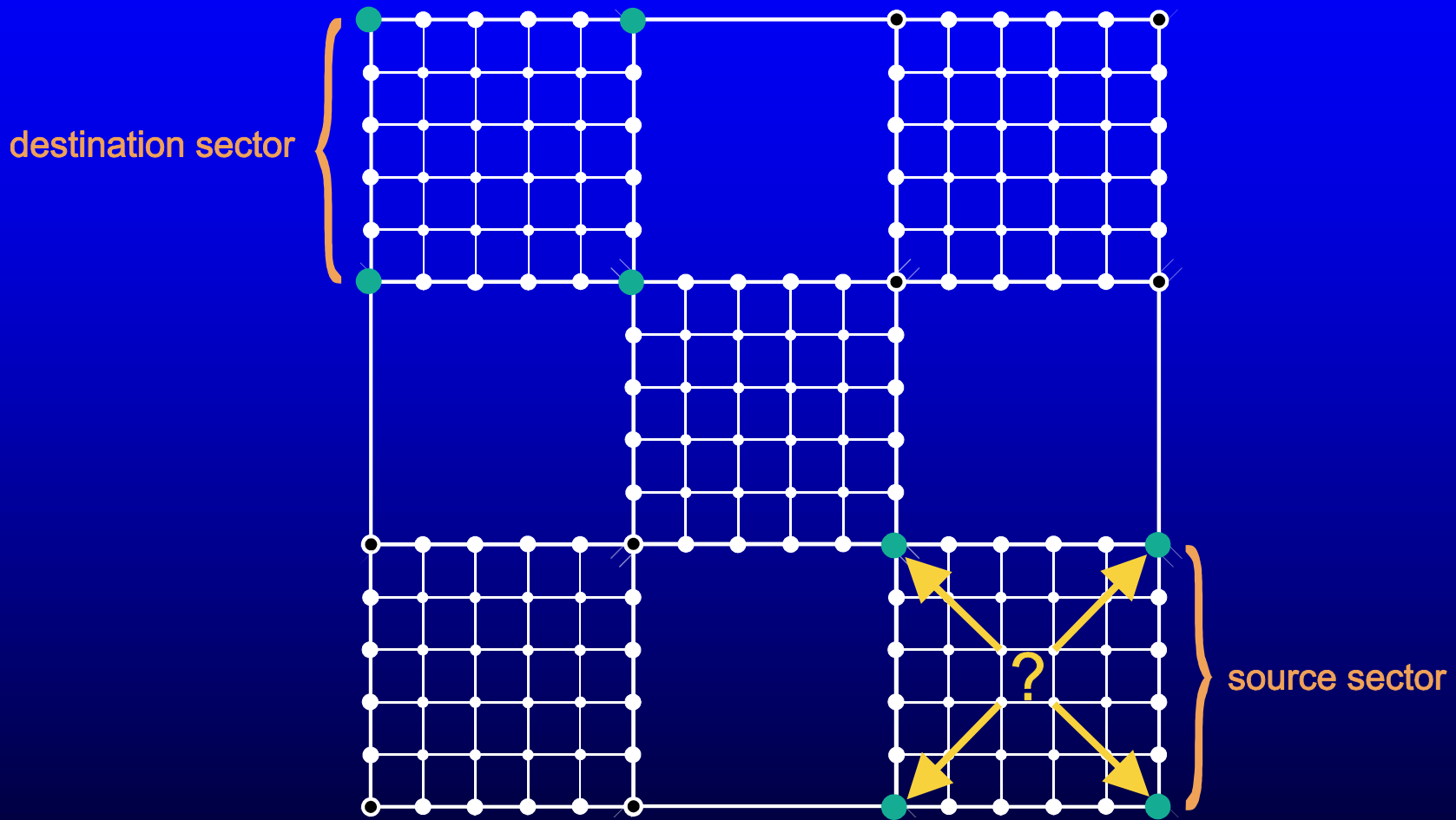
- Use the motorway to reach another sector
- Route vehicles in shortest time to the destination sector:

time to reach motorway
+
time to reach destination sector
→ minimum

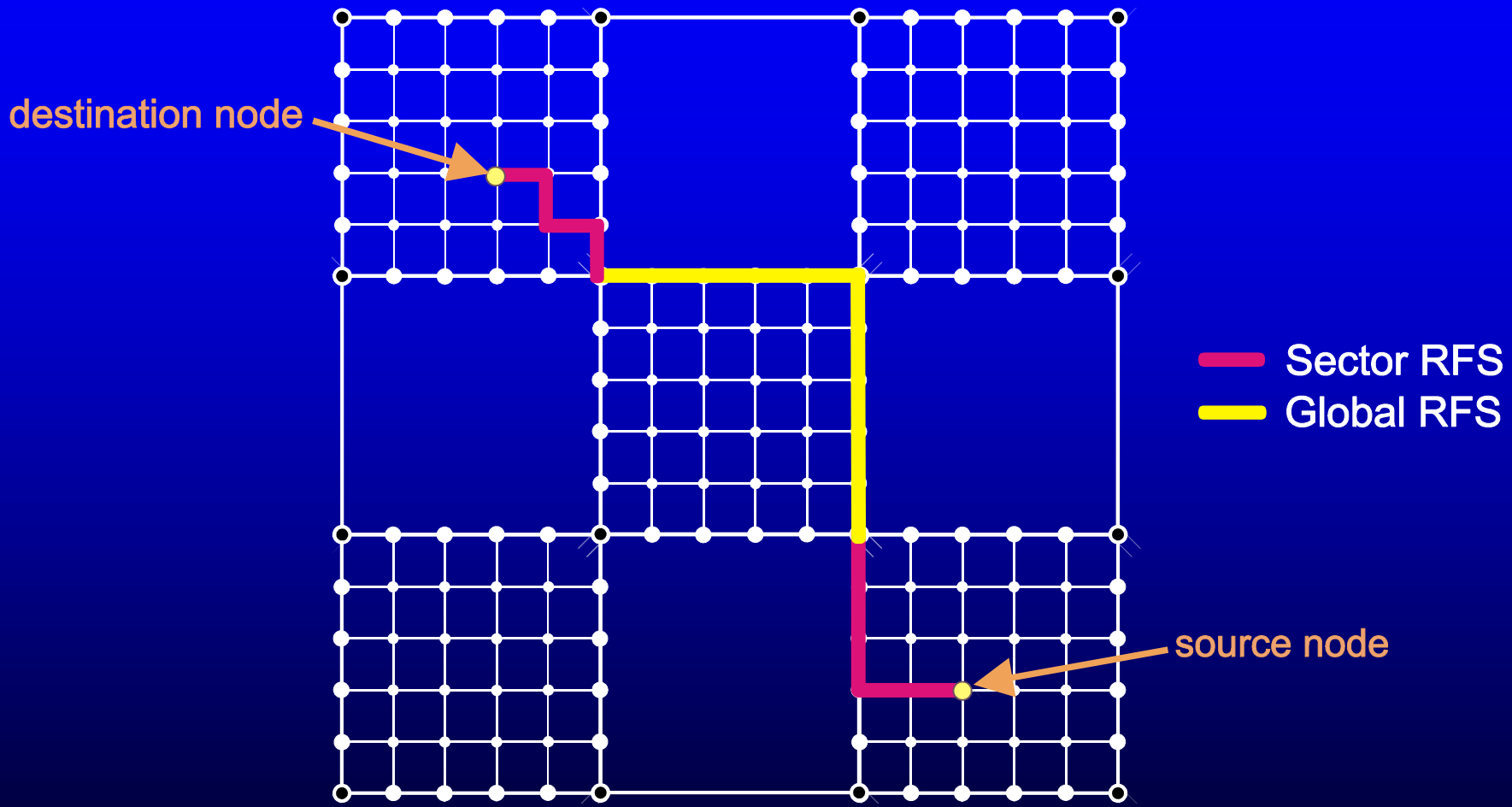
Route finding systems (4)



Route finding systems (4)



Route finding systems (4)



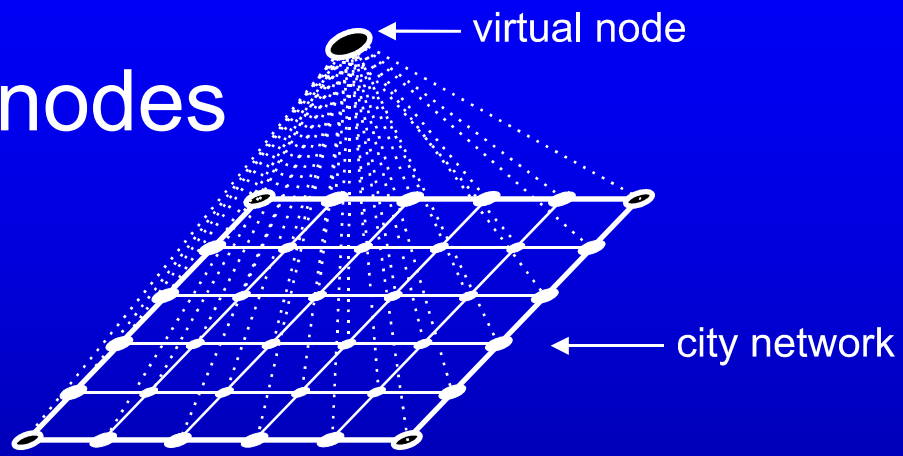
Adapting the ABC-algorithm (1)

Necessary Adaptations

- Introduction of Virtual nodes
- Expansion of the routing tables with Time columns
- Introduction of Time agents

Adapting the ABC-algorithm (2)

Virtual nodes



- Represent a sector
- Routing tables of the Global RFS are expanded with rows for the virtual nodes
- Update with same backward agents
- Vehicles with destination in another sector are routed to the virtual node

Adapting the ABC-algorithm (3)

Time columns

Destination ↓ | Next →	1	3	5	Time
1	0.89	0.05	0.06	13 s
3	0.03	0.90	0.07	21 s
4	0.44	0.19	0.37	43 s
5	0.08	0.05	0.87	9 s
…	…	…	…	…

Adapting the ABC-algorithm (3)

Time columns

- Contain time values which represent the travel time along the path with highest probability
- Global RFS: routing tables for motorway intersections
- Sector RFS: all routing tables, only time values for motorway intersections

Adapting the ABC-algorithm (4)

Time agents

- Fill the time columns with time values
- Generated regularly at nodes with time columns, destination is node from the time column
- Follow route with highest probability and collect travel time
- Update time value in time column of source node

Adapting the ABC-algorithm (5)

Message passing

- From Global TUS to Sector TUS:
  time estimates for motorway ring
- From Global RFS to Sector RFS: reduced routing tables of motorway intersections
- From RFS to other RFS and back:
  route request for composed route

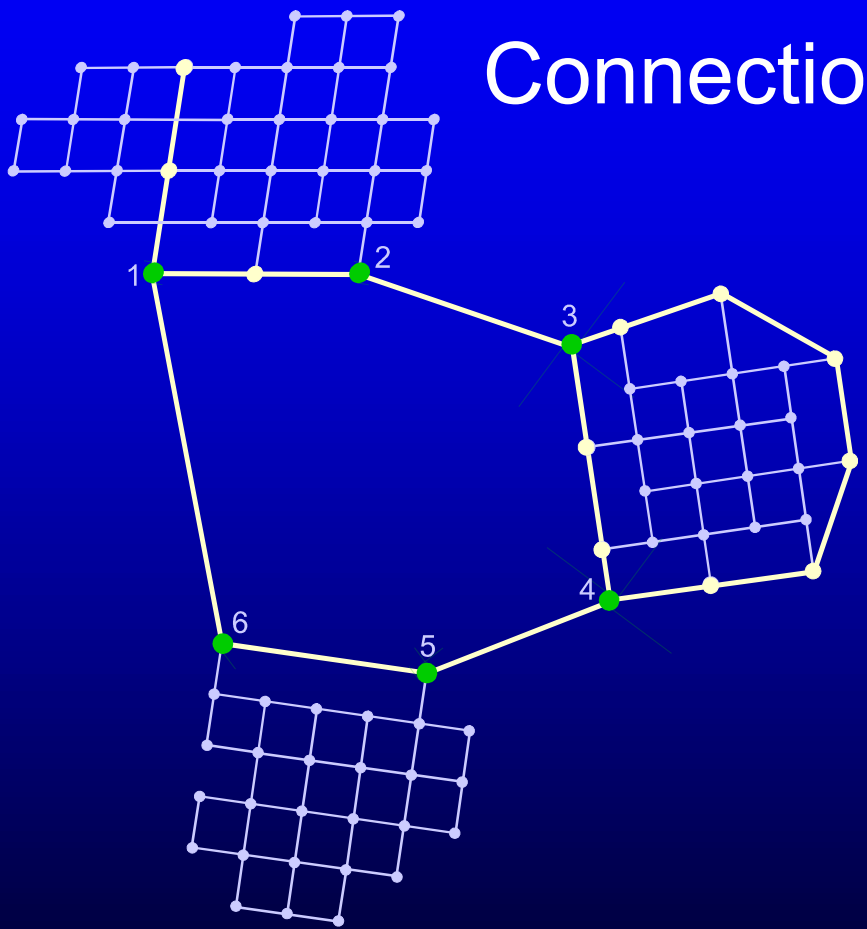
Evaluation (1)

Applicability for realistic traffic networks

- Hierarchical routing system is applicable
- Only necessary adaptation: use connection points instead of motorway intersections
- Connection point: nodes to leave or enter a sector

Evaluation (2)

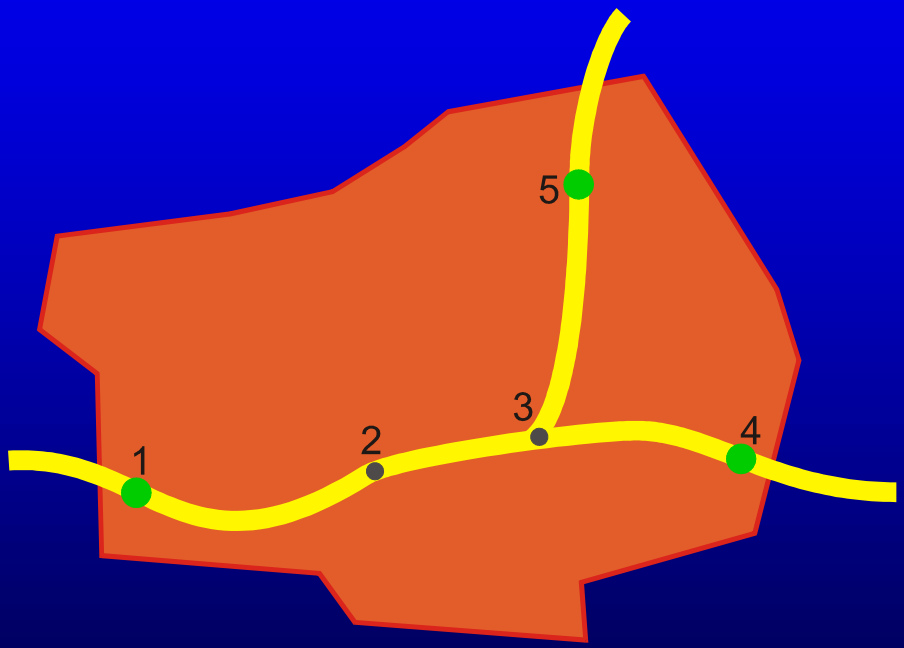
Connection points



street
motorway
intersection
slip road/departure
or motorway intersection
connection point

Evaluation (2)

Connection points



Evaluation (3)

Optimality

- ABC-algorithm is not optimal for individual drivers
- Further restriction of the optimality by the hierarchy and strategy:

  RFS restricted to their networks

  motorway is used to go to other sectors

Evaluation (4)

Characteristics

- Distributed design and ABC-algorithm ensure high scalability
- Hierarchical routing system is able to work in real time
- High robustness against failures

Recommendations

- TUS:

  Consider different speeds of vehicles

  Use other sources for dynamic data such as TMC, Traffic monitoring systems, GSM…

- RFS:

  Update probabilities using earlier found routes compared to new route

Questions?