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Market Based Traffic Coordination

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Presentation at the Workshop 162 of the TRB Annual Meeting 2006
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The work presented was done while the speaker was affiliated to DaimlerChrysler Telematic Research
Part of this work was done in cooperation
with Wolfgang Spering (DaimlerChrysler) and William Coughlin (CEO Ford Global Technologies)

Market-Based Traffic Coordination

Target

Dynamic Route Navigation on Roads

Problem

Congestions shift from one road to another
because all drivers try to escape the same way

Suggested Solution

Coordinate drivers and make different suggestions

Problem

Drivers do not want to get domineered

Suggested Solution

Let drivers prioritize the routes
by different ratings that they give to the routes

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Target

Individual Dynamic Route Navigation on Roads

Application 1: Individual Route Guidance

Guide driver on most convenient route to his destination considering

- current traffic conditions
- individual priorities of guided driver
- compromise with priorities of other drivers

Application 2: Individual Road Clearance

Provide free lane for driver considering

- current traffic conditions
- individual speed priority for guided driver
- compromise with speed priorities of other drivers

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Target

Individual Dynamic Route Navigation on Roads

Application 1: Individual Route Guidance

Application 2: Individual Road Clearance

Objectives to be considered

Design coordination mechanisms with following properties:

- mechanism must not require active input of driver while he is driving
- driver‘s priorities should be considered
- overall optimum should be considered

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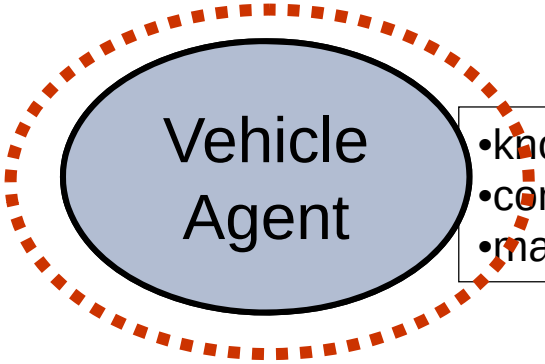
Concept

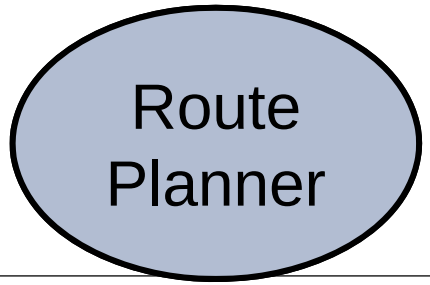
Auction Based Traffic Control (ABTC)

- for each vehicle:

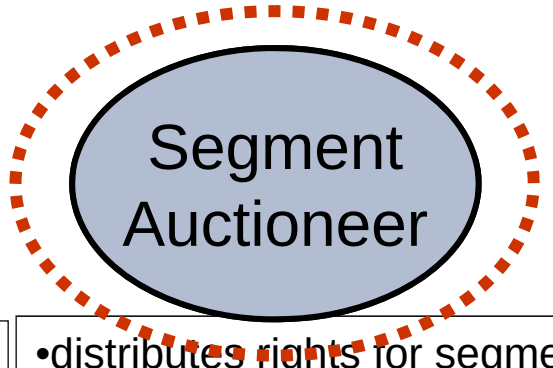


•knows individual strategies of driver
•communicates automatically with traffic control center
•may get new instructions from driver at any time

- for traffic control center:



•knows current traffic conditions
•accepts queries for routes from start to end and answers with several routes
•communicates impartial route properties

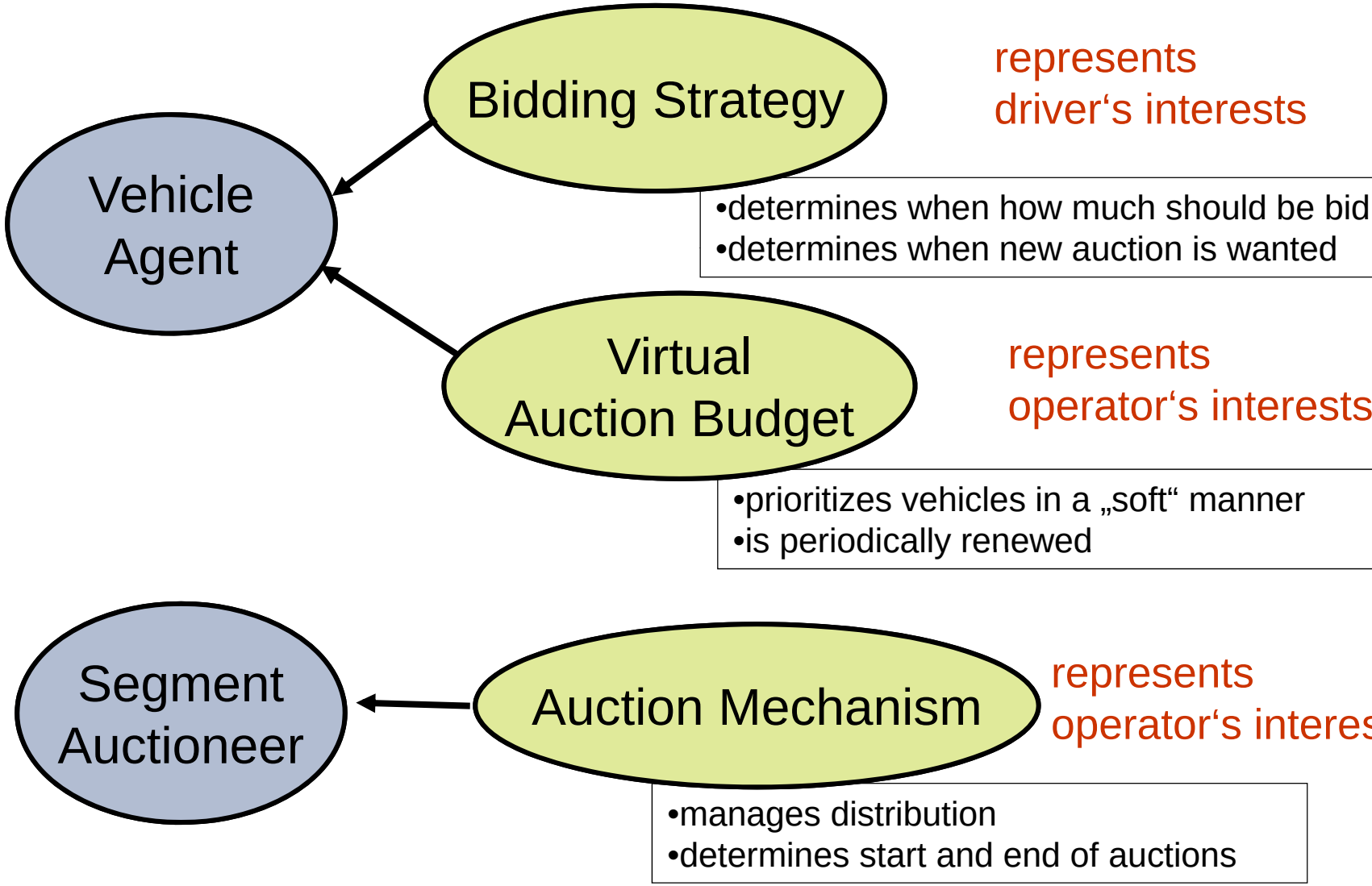


•distributes rights for segment usage via auctions

Market-Based Traffic Coordination

Concept

Auction Based Traffic Control (ABTC)



Performance of ABTC implementation

Tested Scenarios:

- several different digital maps for roads (from 200 up to 1200 road segments)
- different pairs (start, end) für the test vehicles
- different numbers of vehicles per hour (from 2000 up to 10000)

Issues of investigation:

1. How good were the results ?

- ca. 70 % of all vehicles got the most favored route

2. How fast was the computation ?

- auctions lasted between 30 sec and 2 min

Benefit of ABTC concept

Question examined:

What is the benefit of auction based coordination compared to traditional traffic guiding methods ?

Test:

Compare different percentages of auction based controlled vehicles among all vehicles

Results:

- for > 30 % auction based vehicles: visible improvements
- for > 50 % auction based vehicles: nearly optimal improvements

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Prime Application

Road Pricing

ABTC applies the following techniques:

Two kinds of auction budgets:

- virtual
  - for prioritizing the vehicle classes
- real
  - for charging the toll

Two possible toll concepts:

- Fixed Tolls
  - Buy a road by an auction using the virtual budget
  - Pay fixed fee for the actual usage
- Toll Ranges
  - Fix minimum and maximum fee for each segment
  - Buy segment by overbidding of minimum fee up to the maximum fee

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Test Results

Software employed

1) Simulation Tool PROROAD

(made by FZI Karlsruhe in commission of DC traffic research)

- **Traffic Simulation**
- **Route Computation**
- **„Traditional“ dynamic routing**

2) Implementation of AVIR concepts in Java

(by AVIR team)

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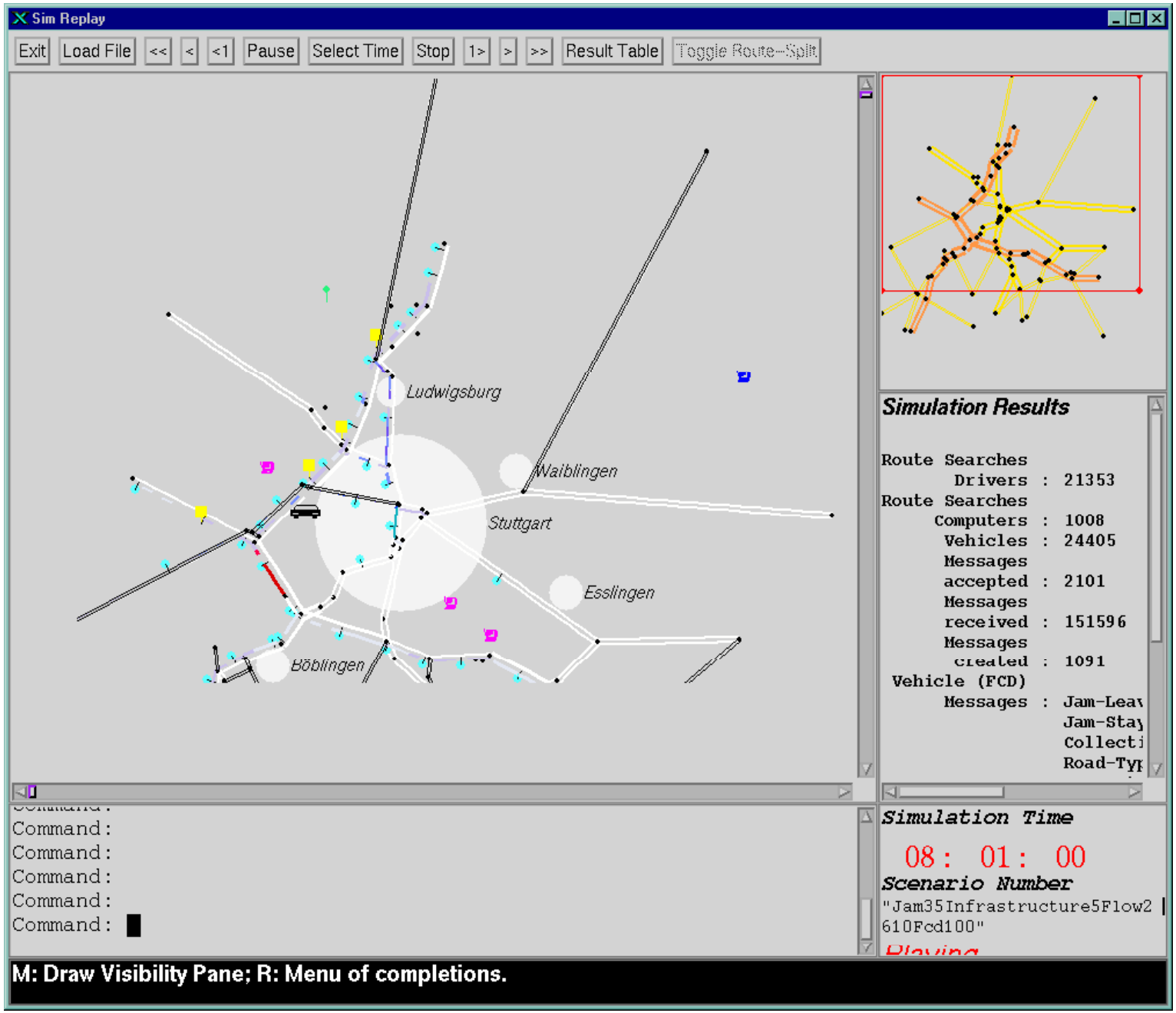
Simulation Tool PROROAD (made by FZI Karlsruhe)

Software Demonstration



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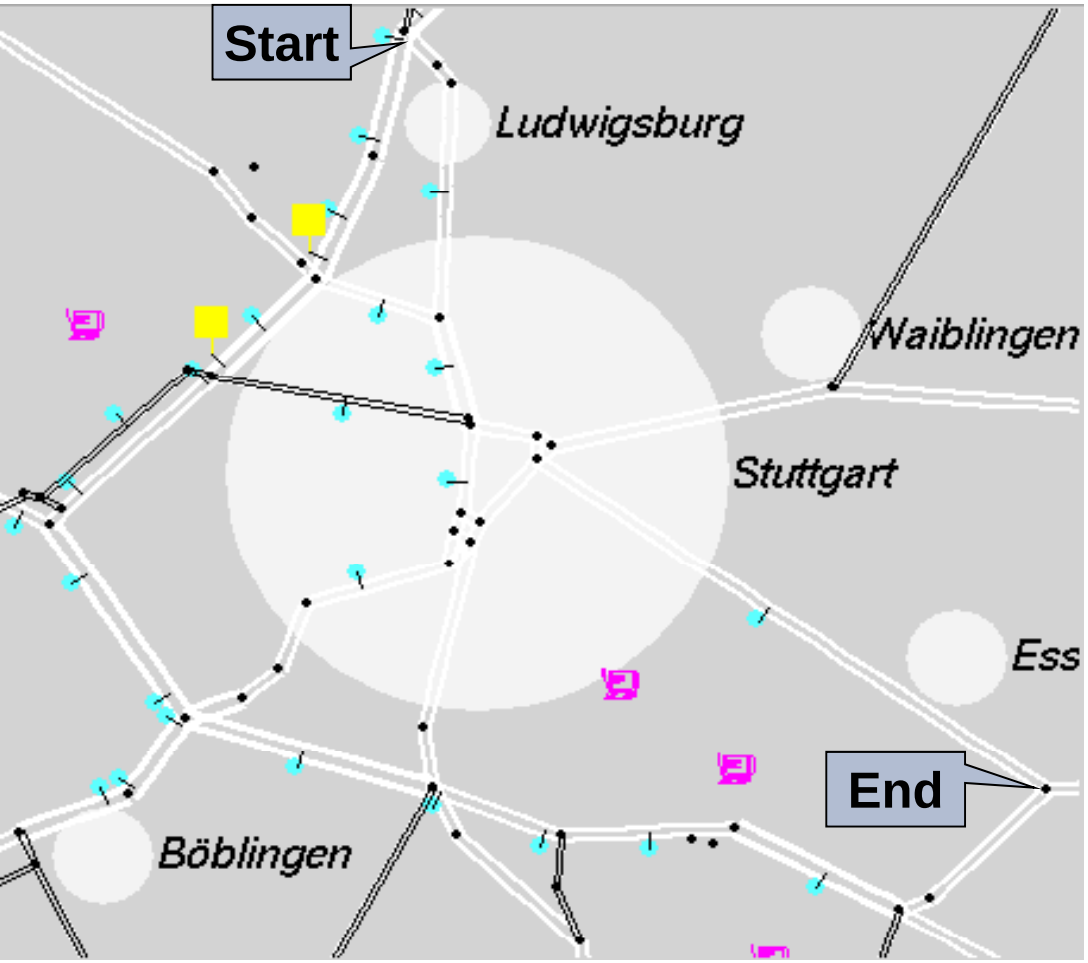

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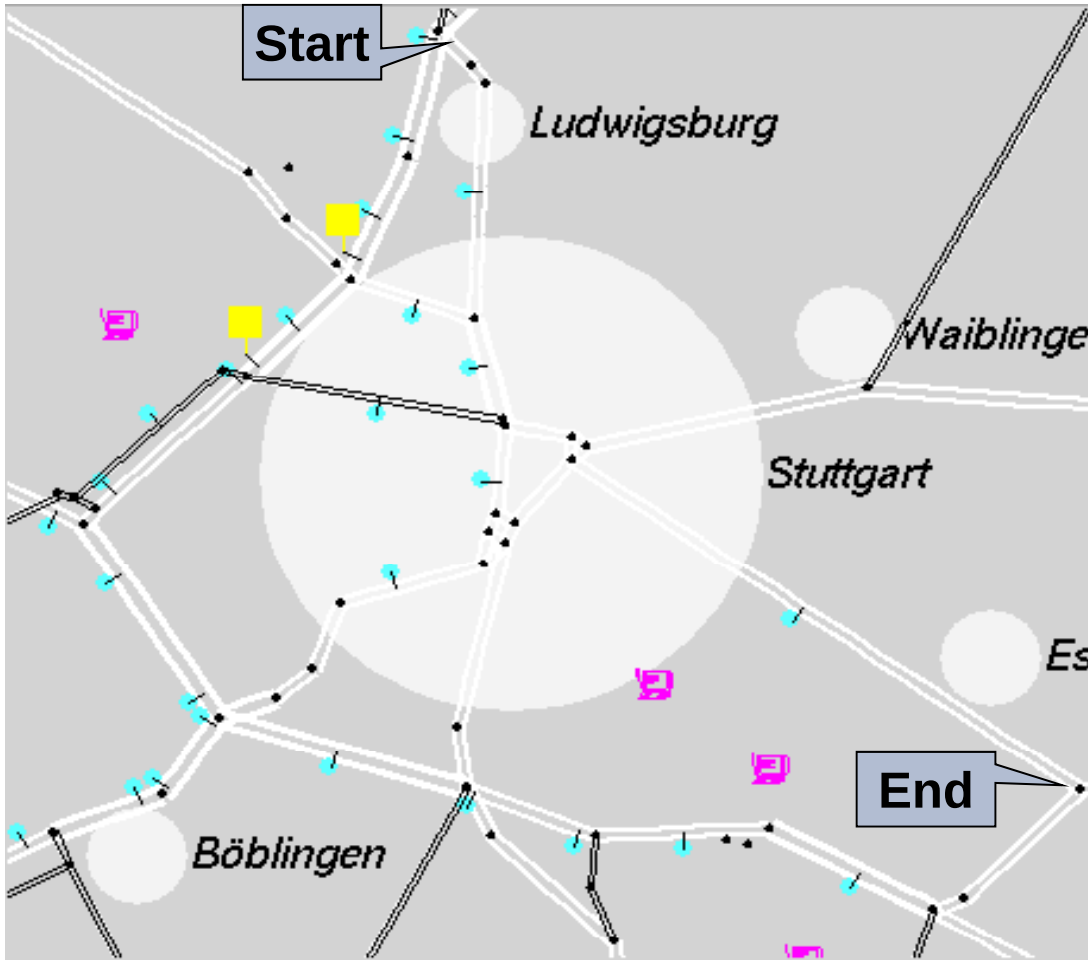

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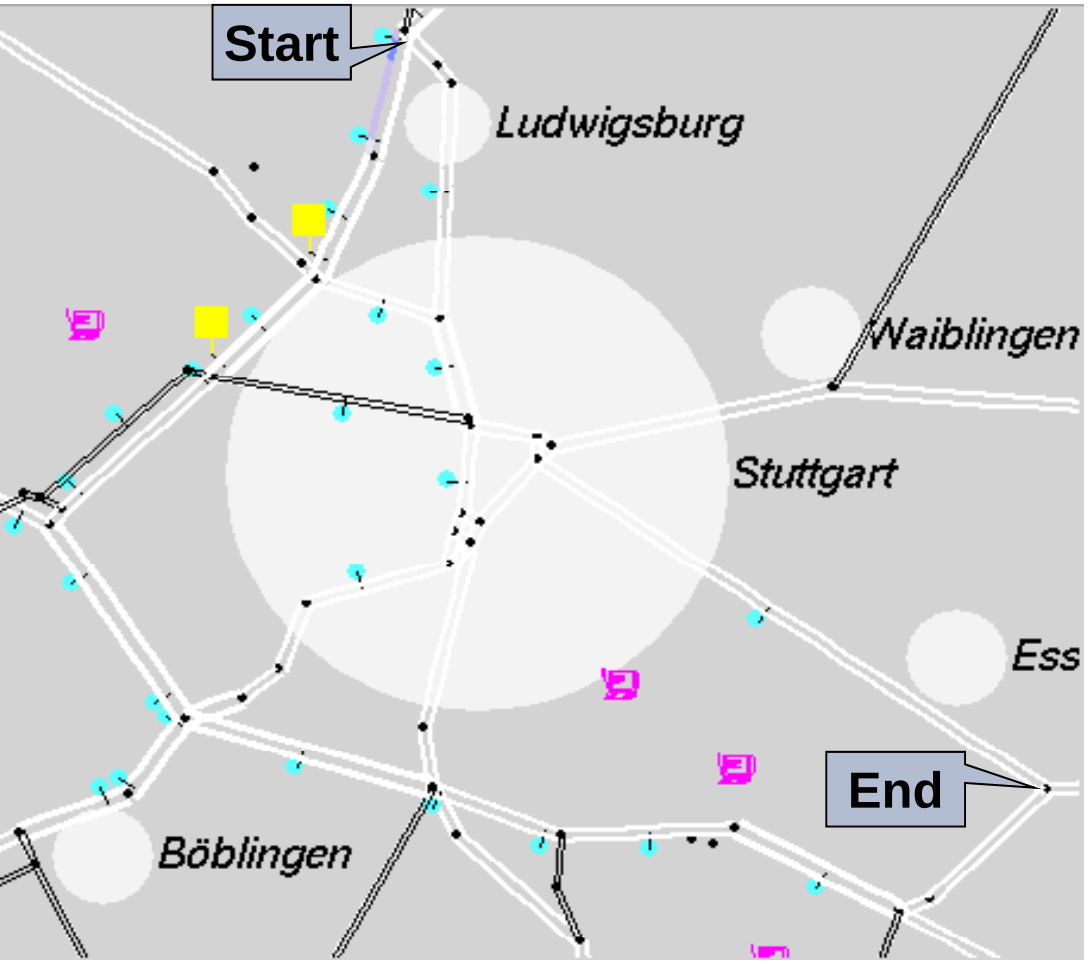

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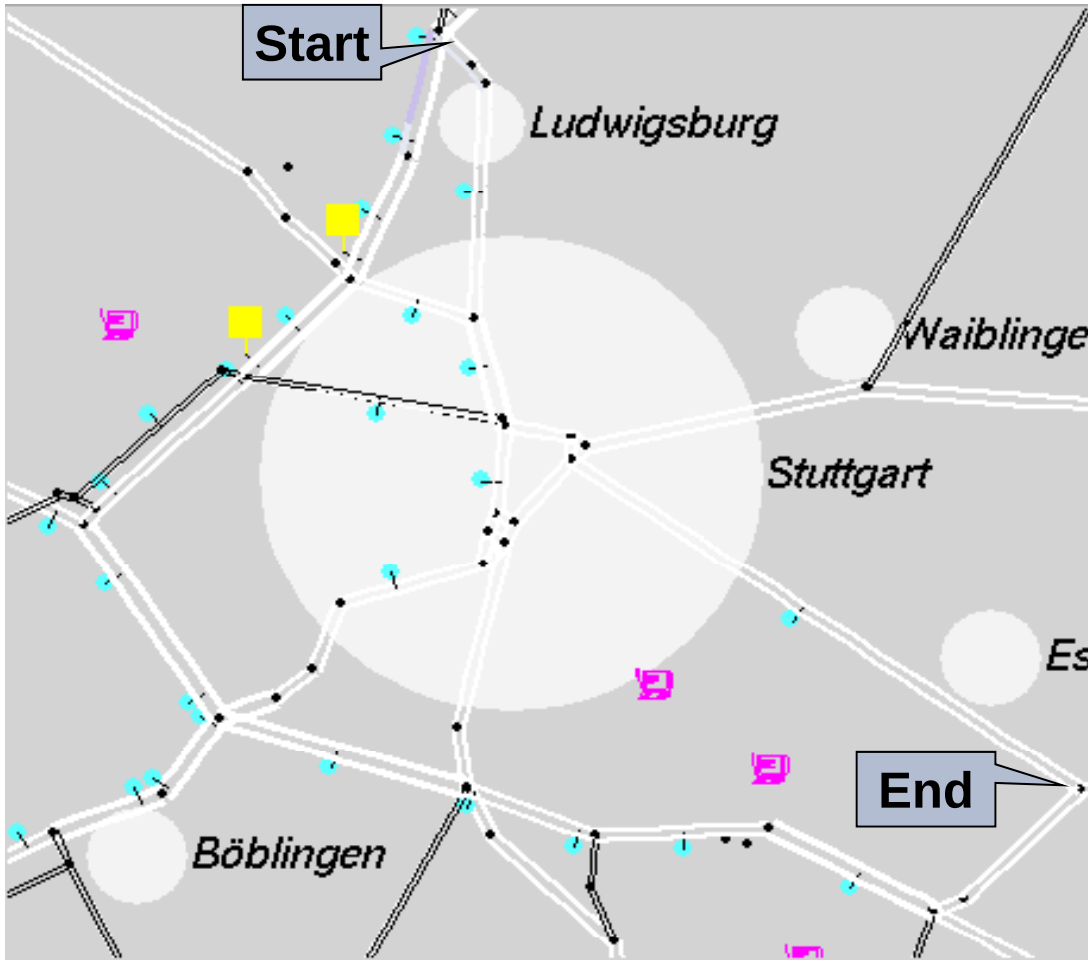

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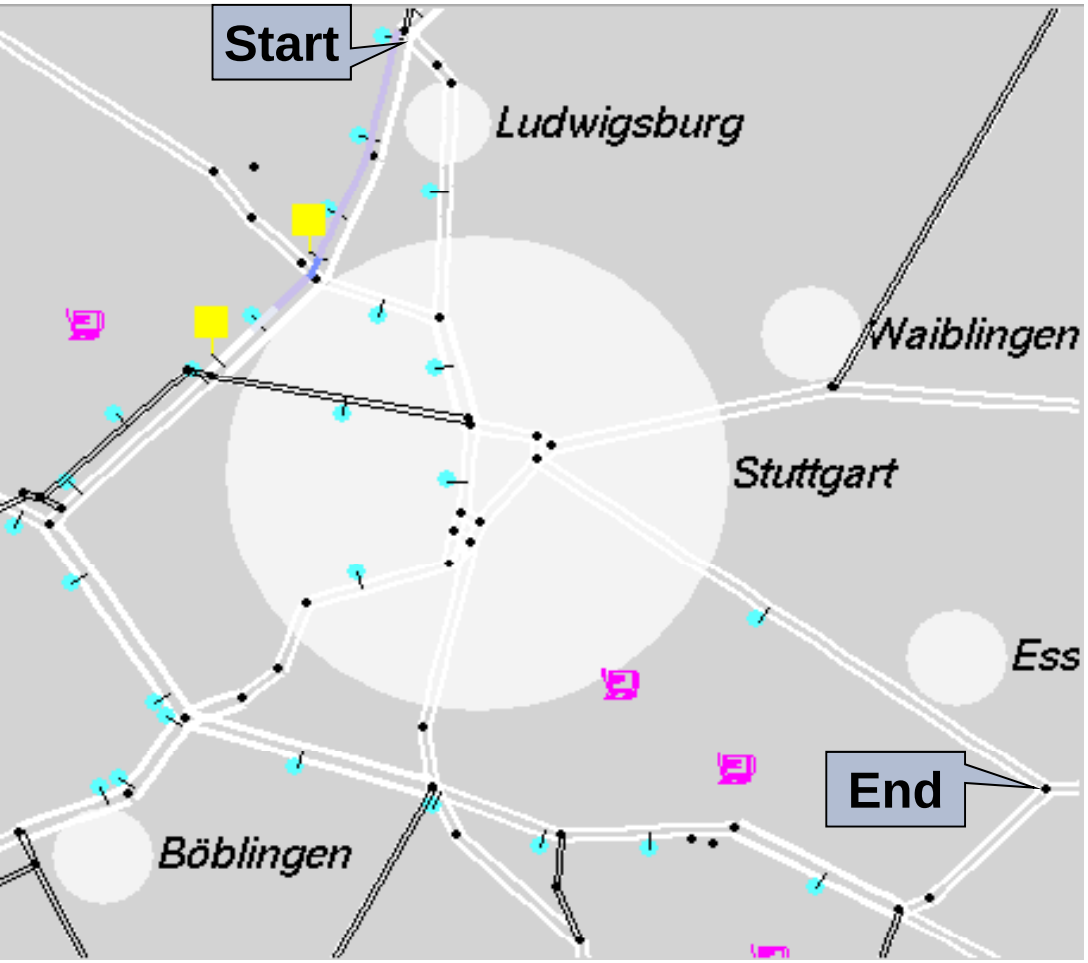

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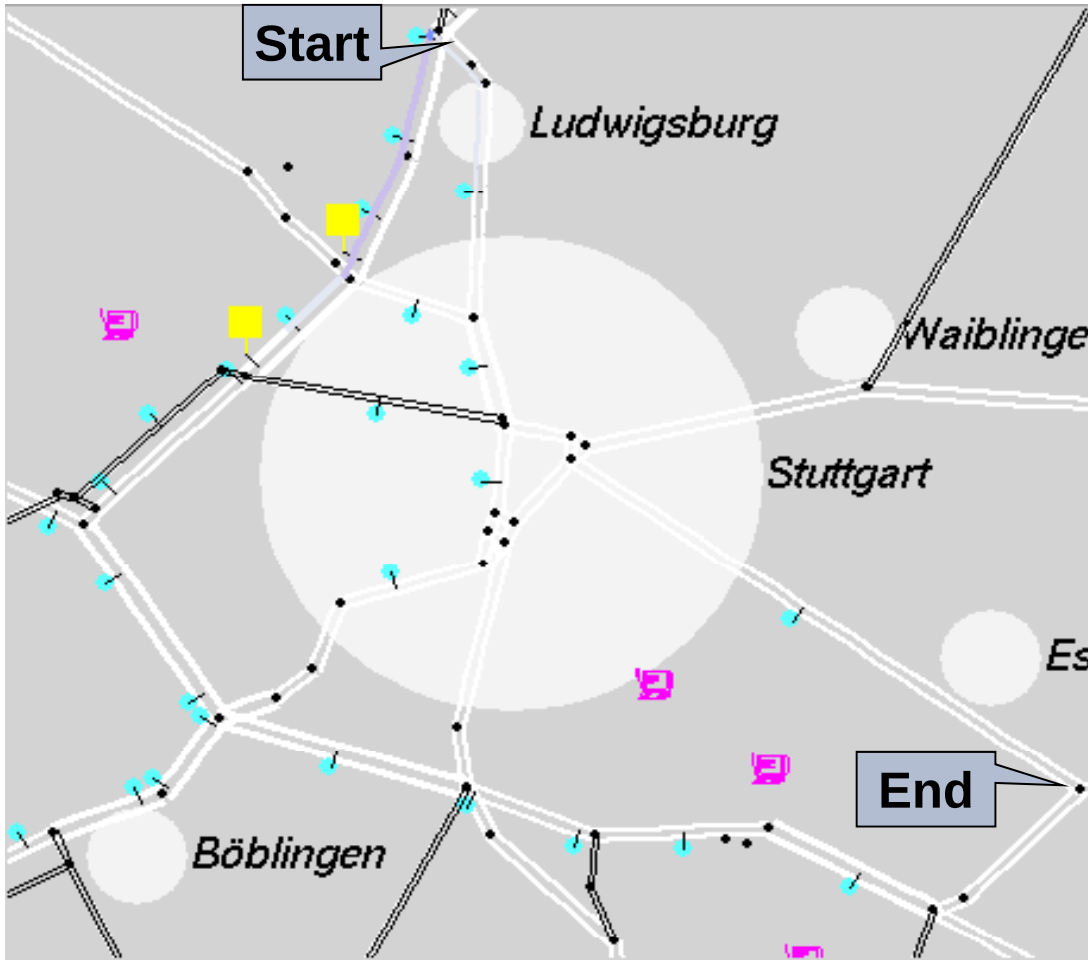

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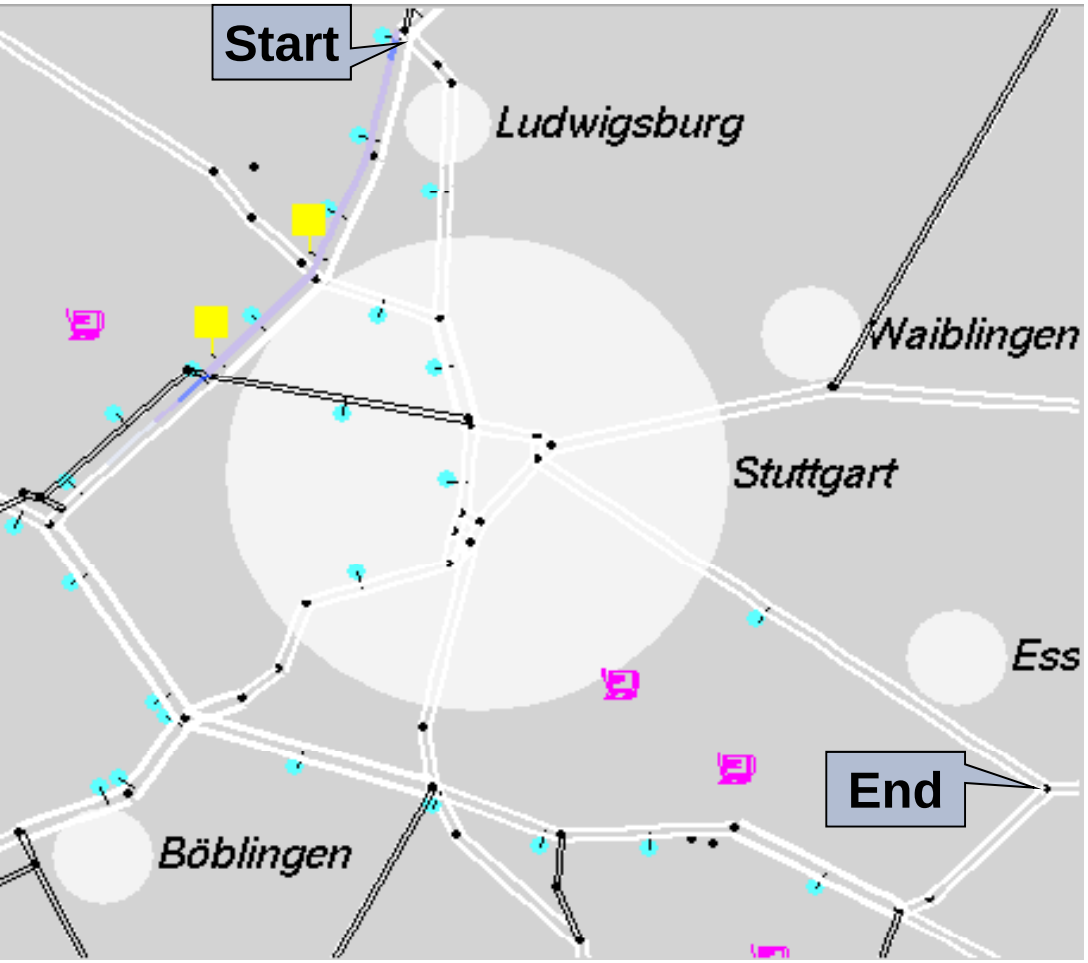

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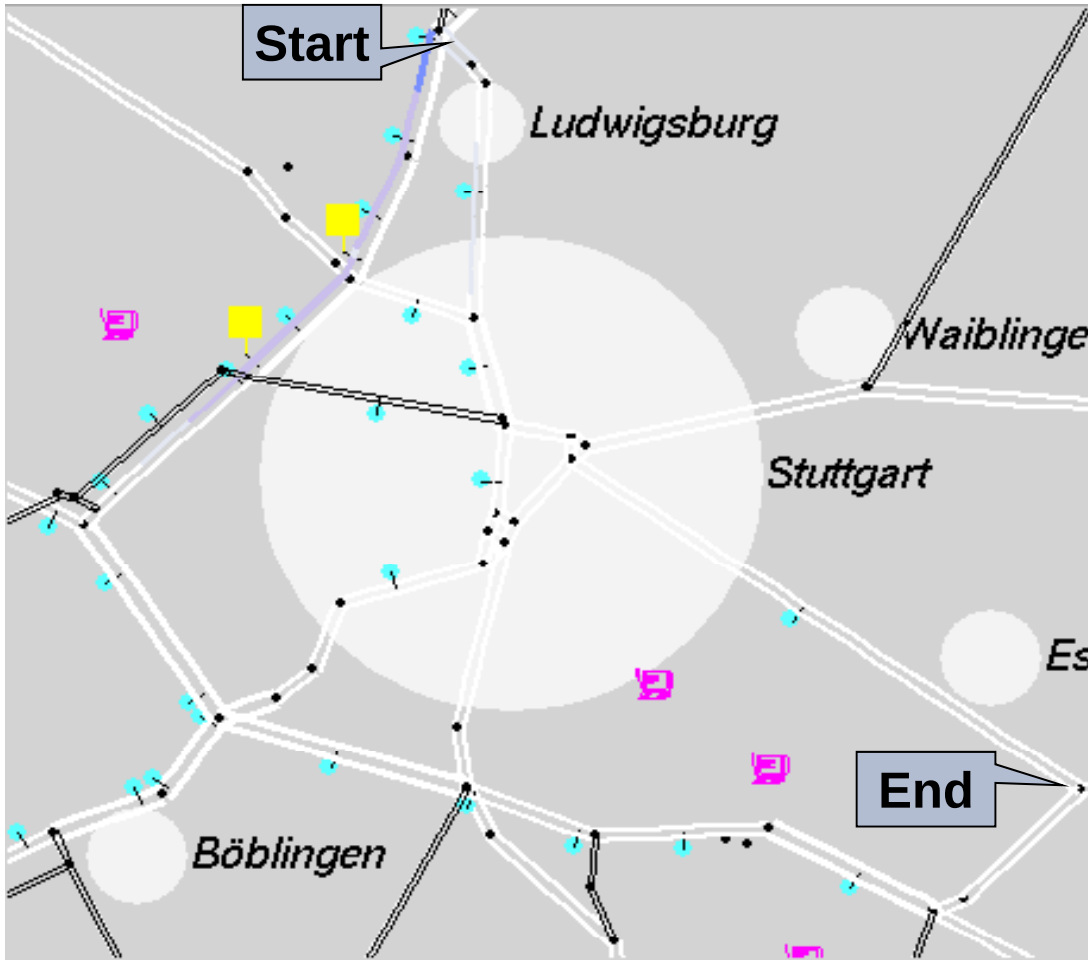

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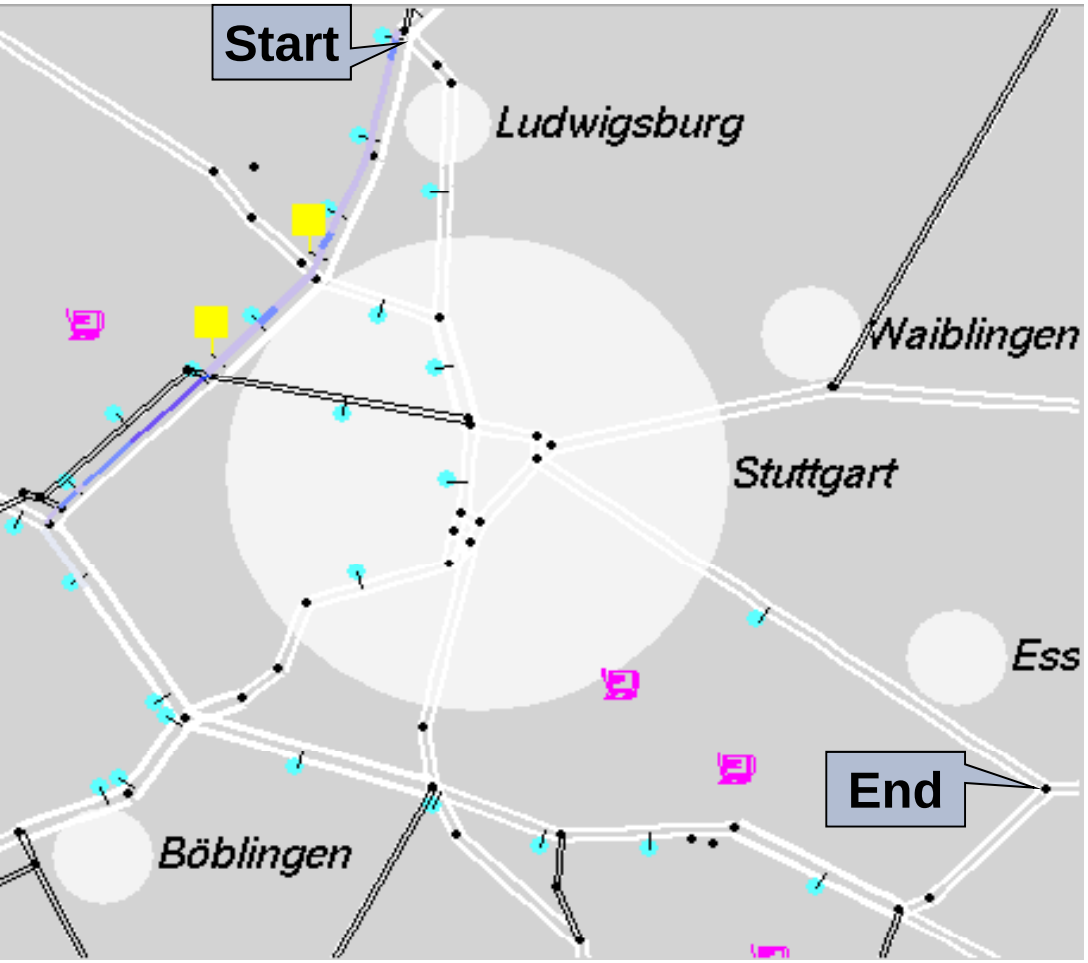

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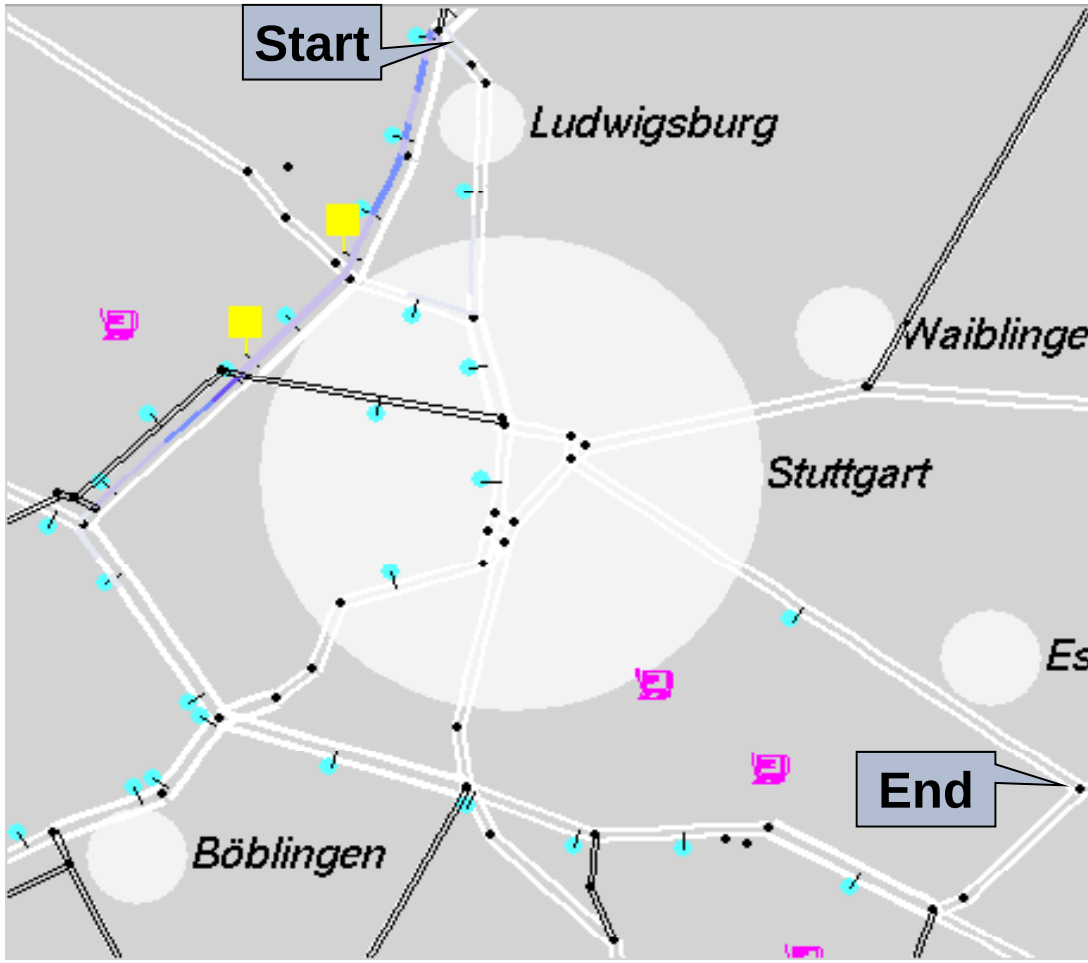

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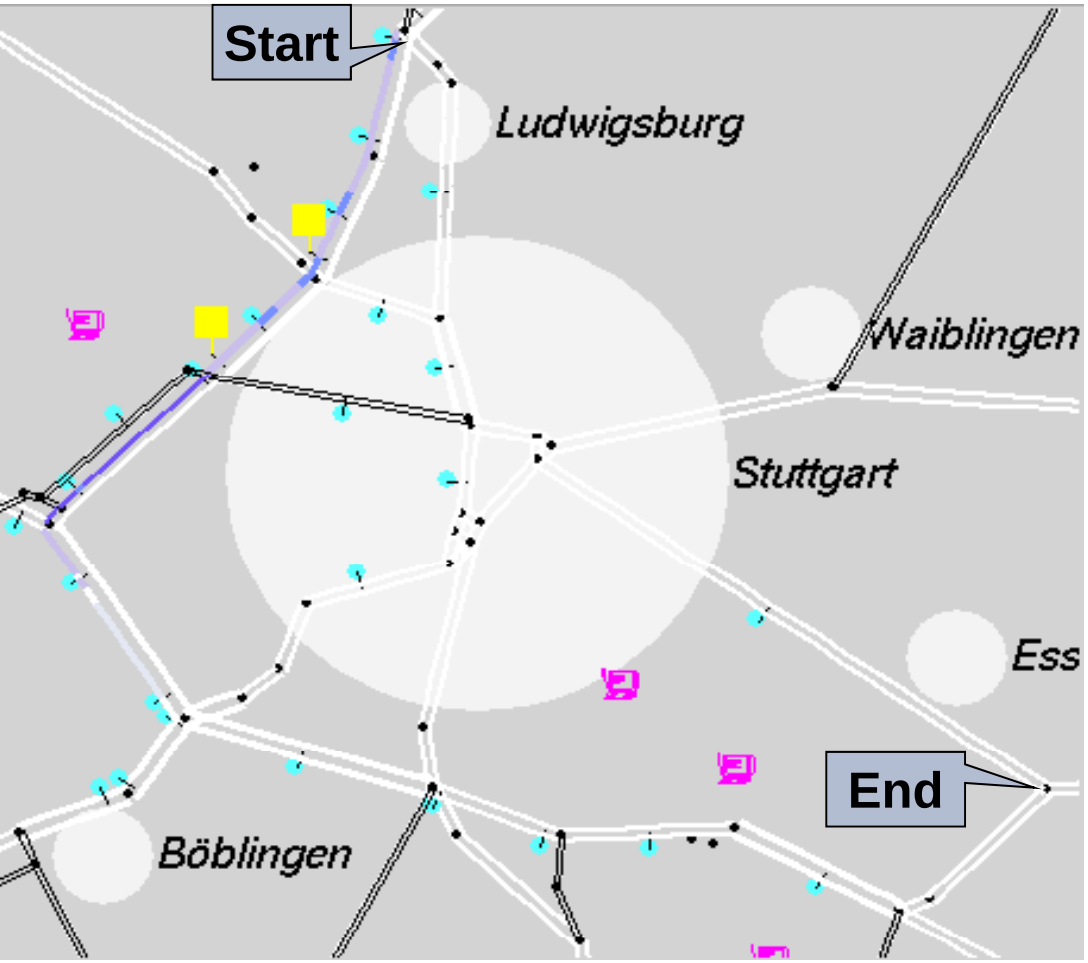

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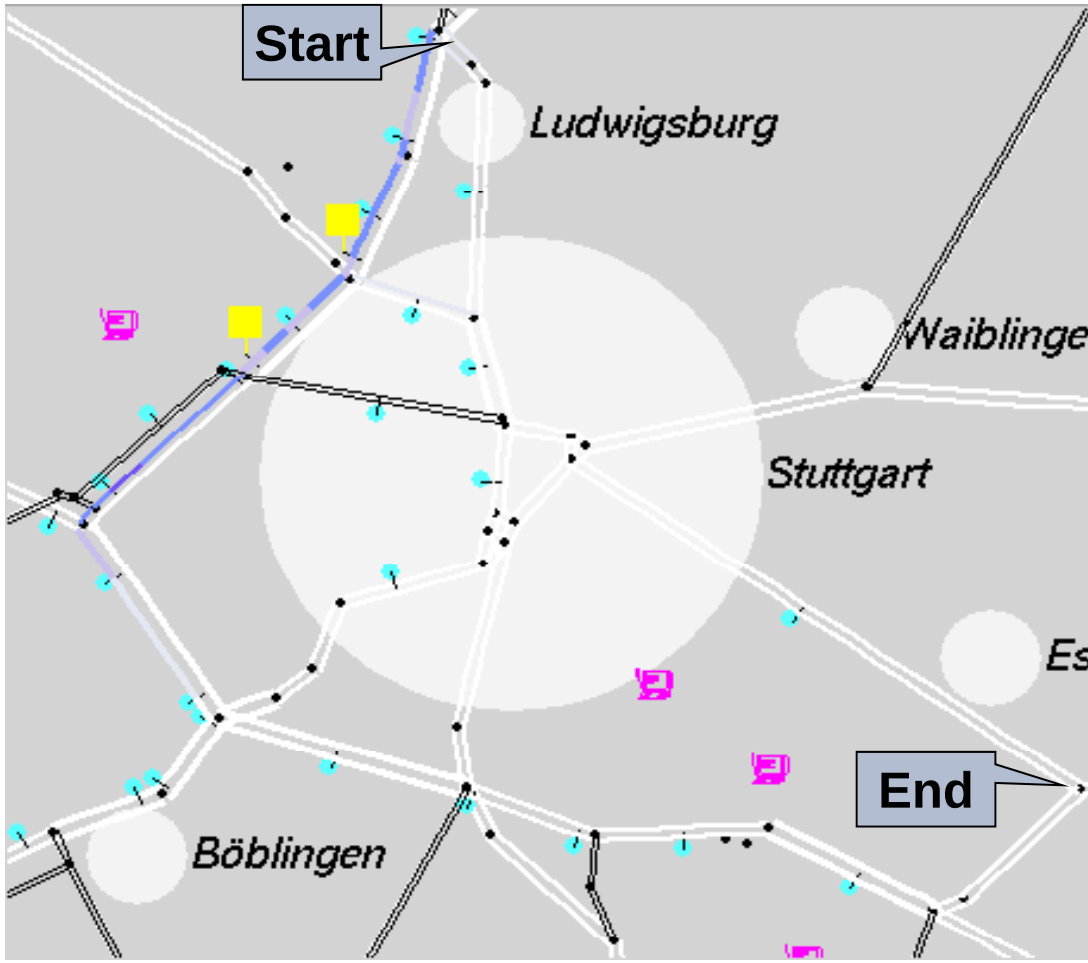

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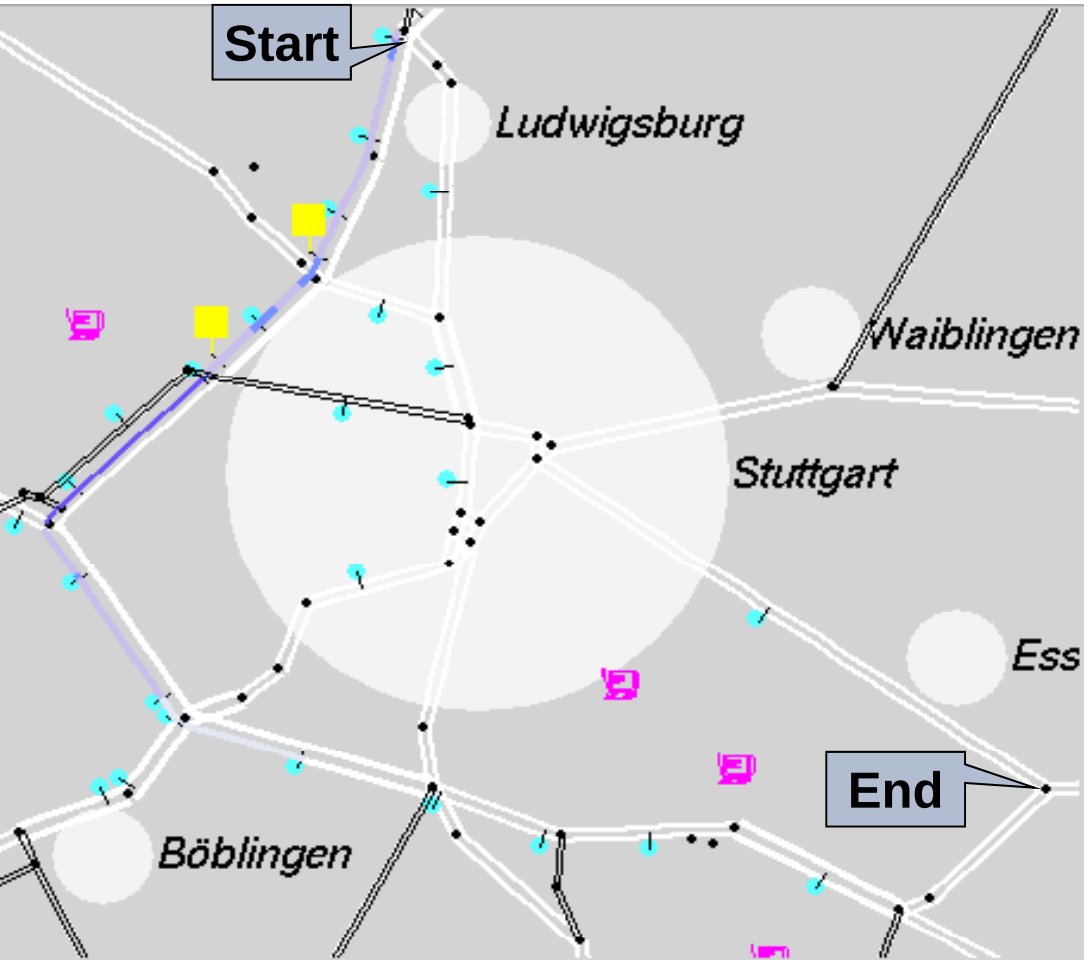

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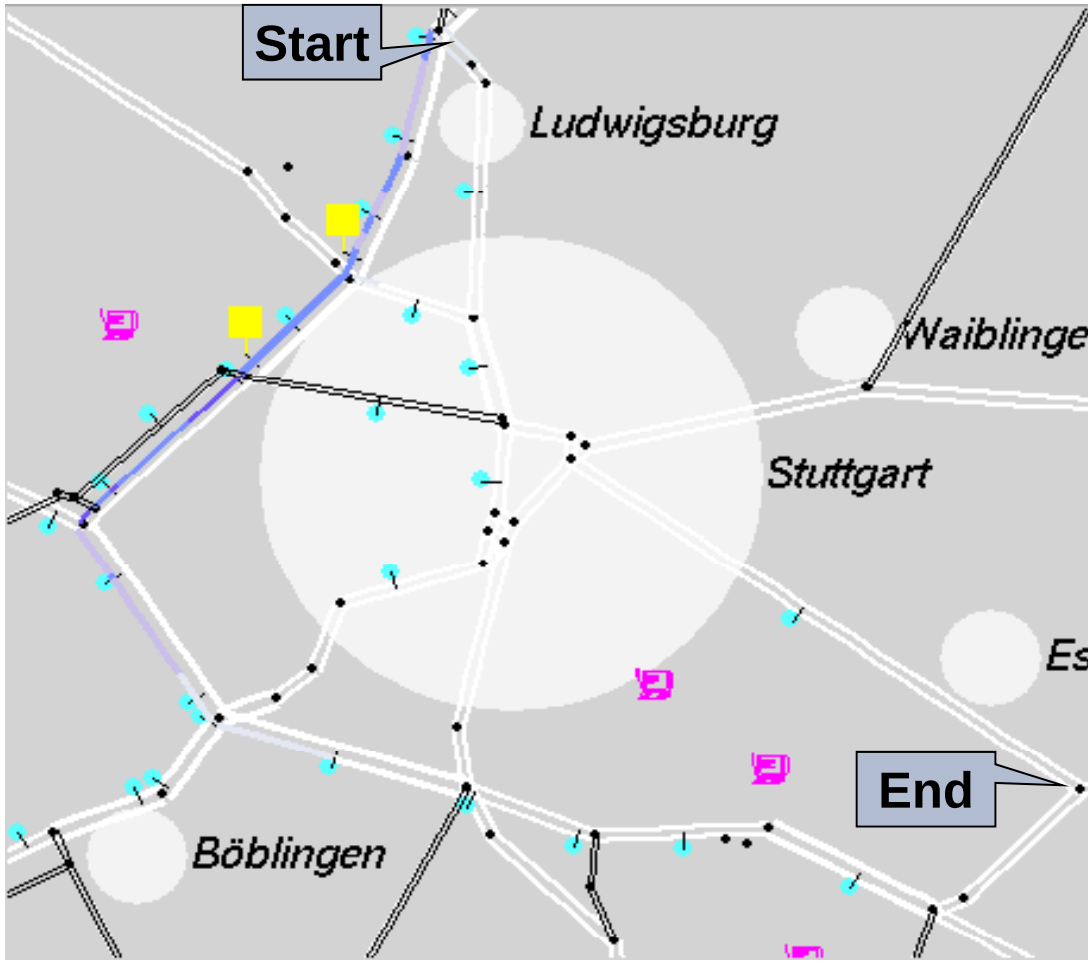

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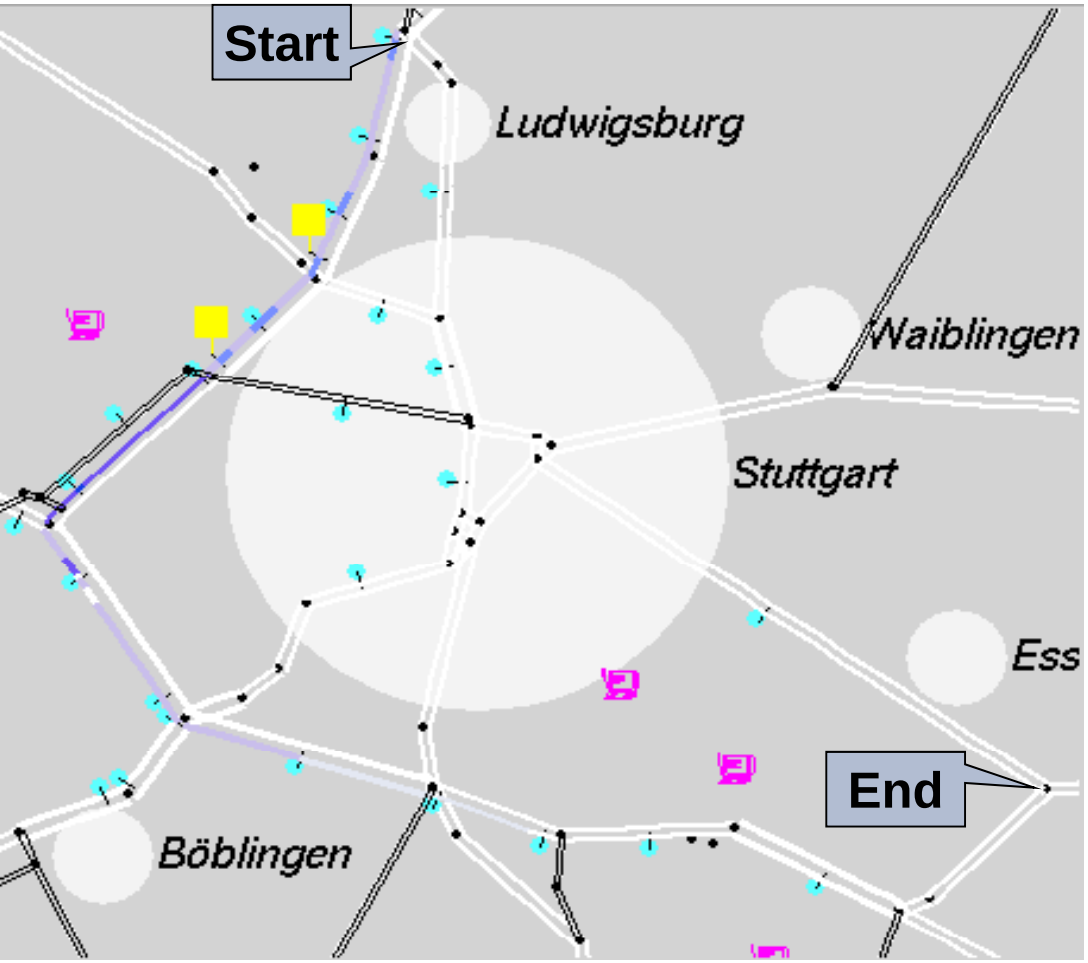

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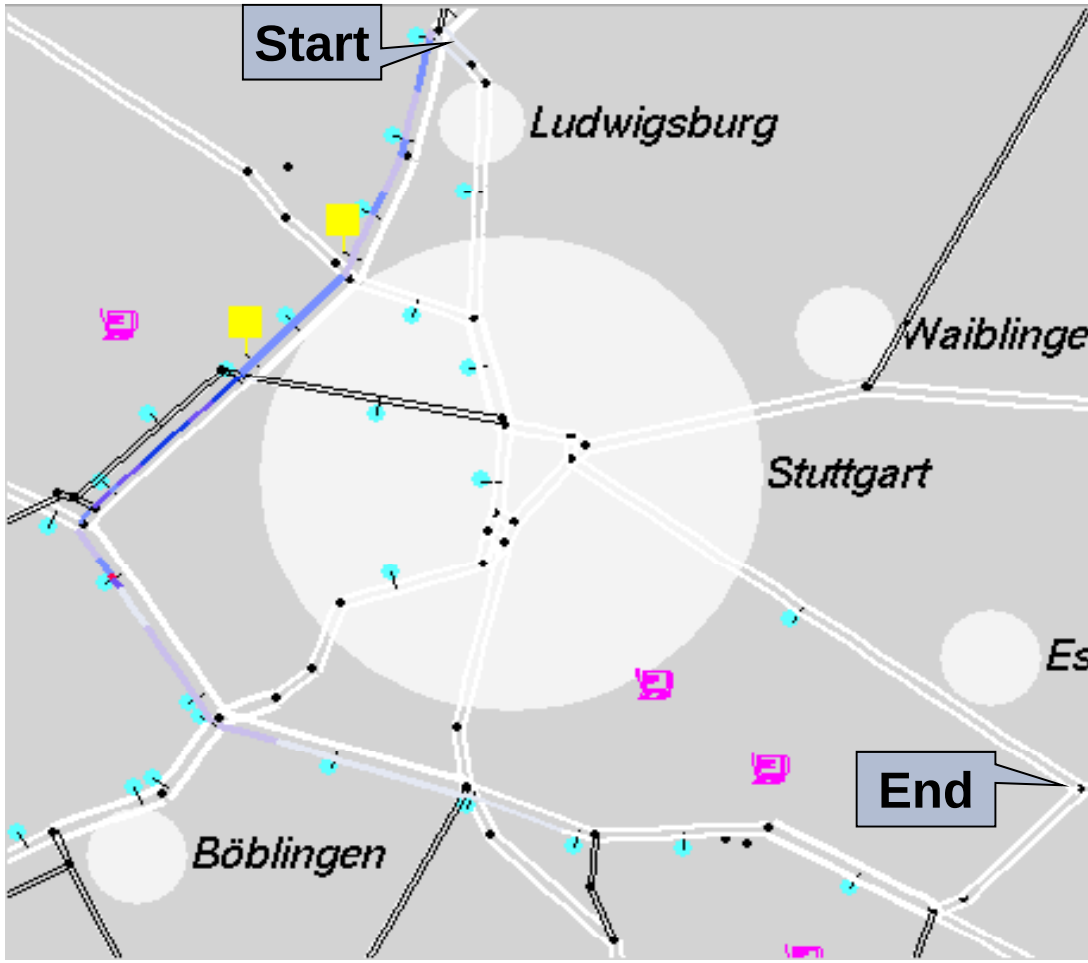

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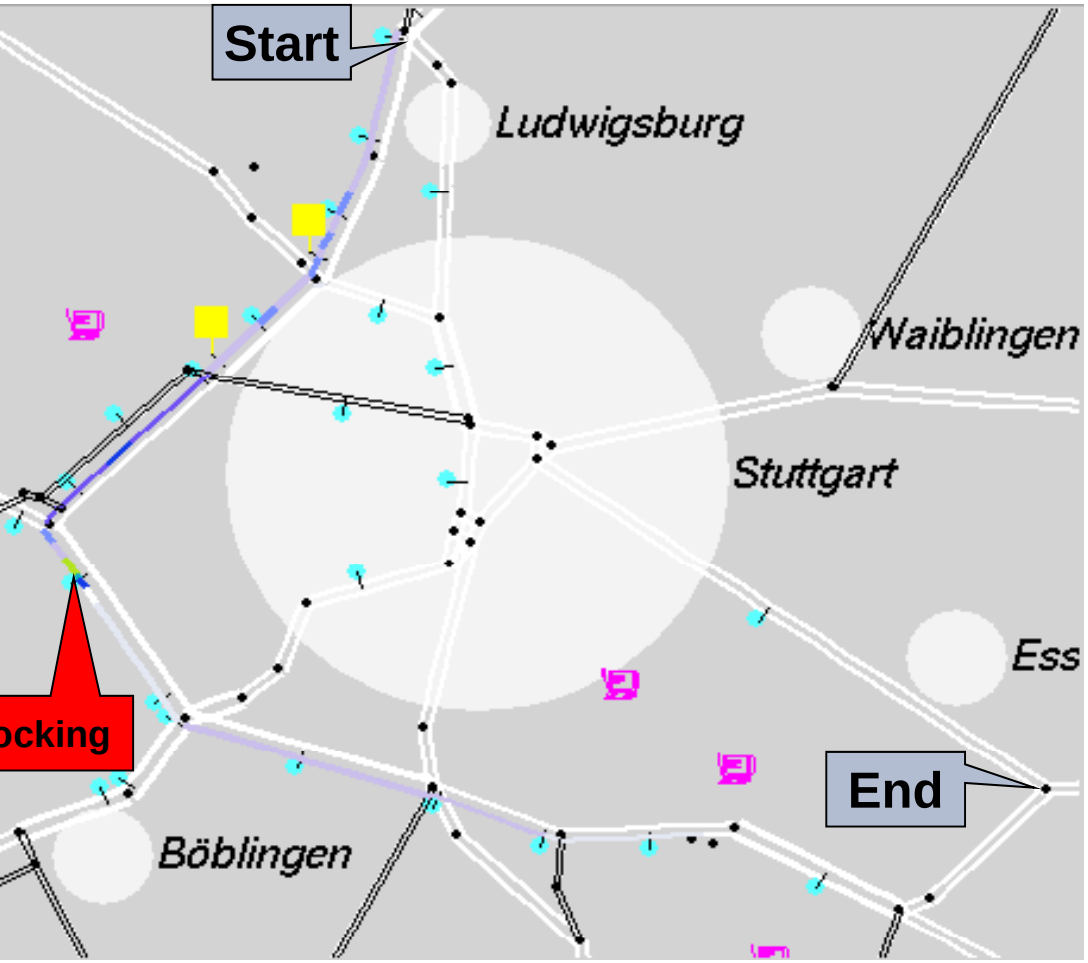

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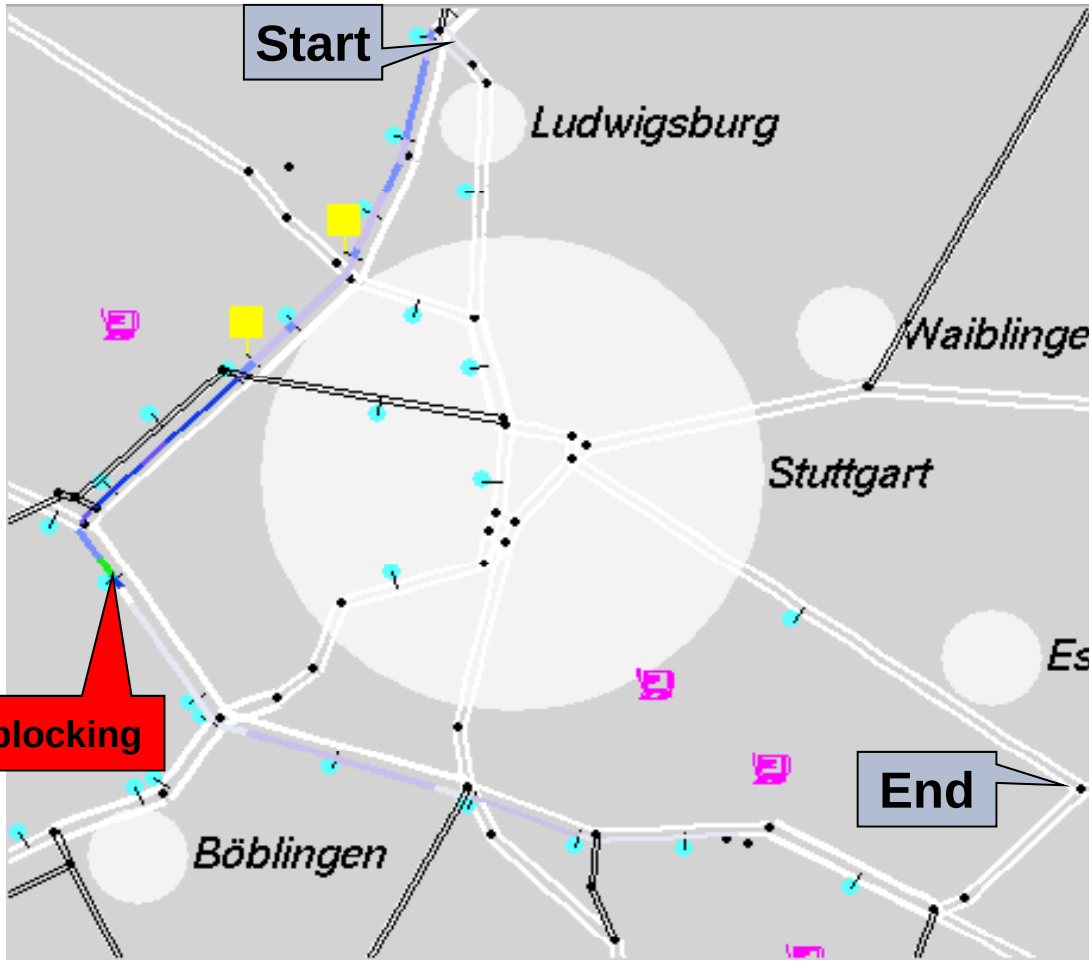

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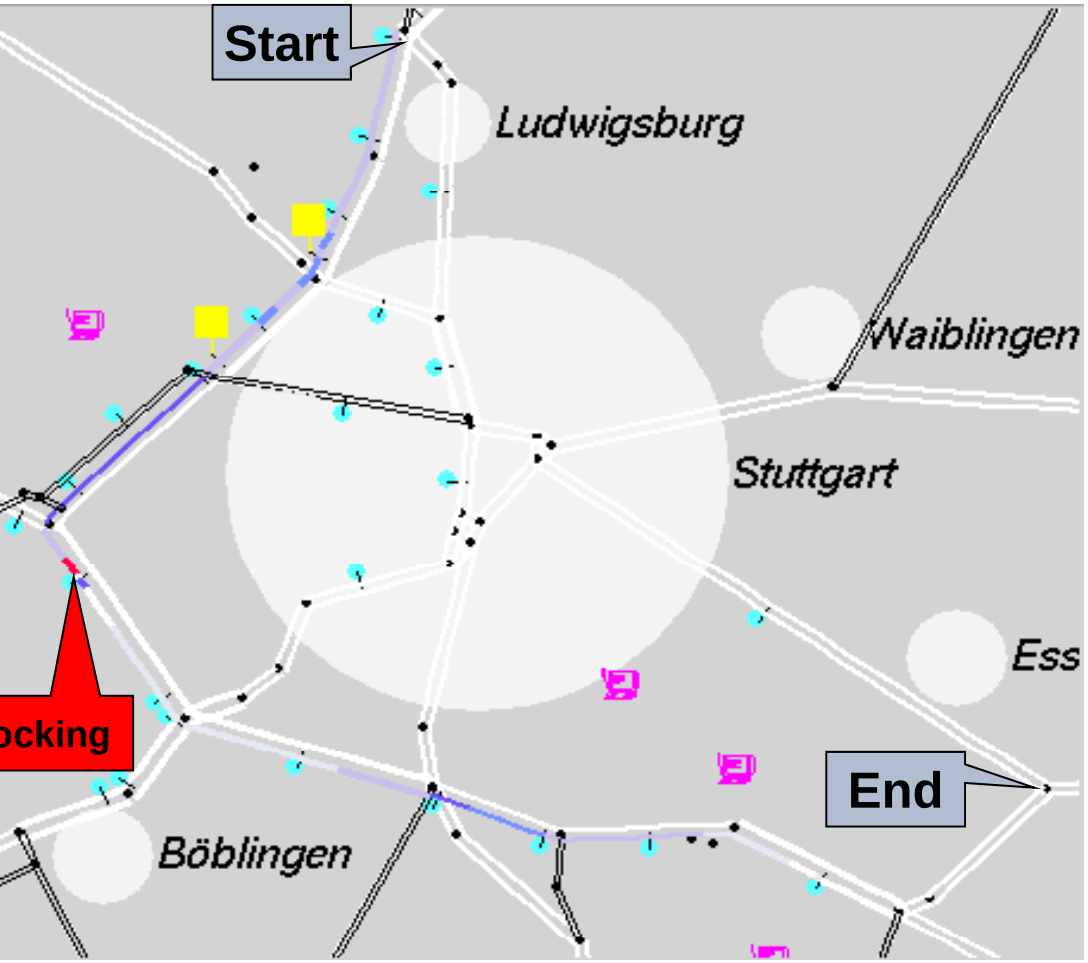

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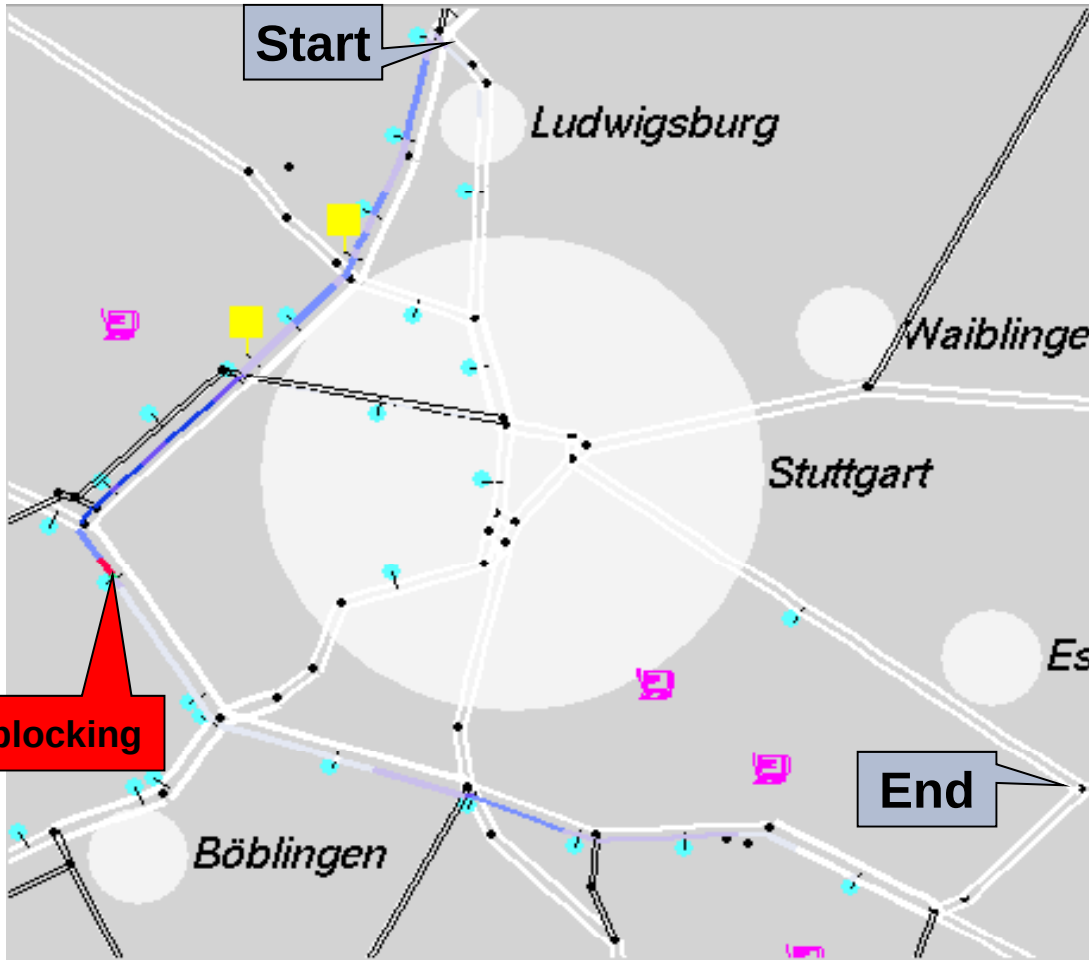

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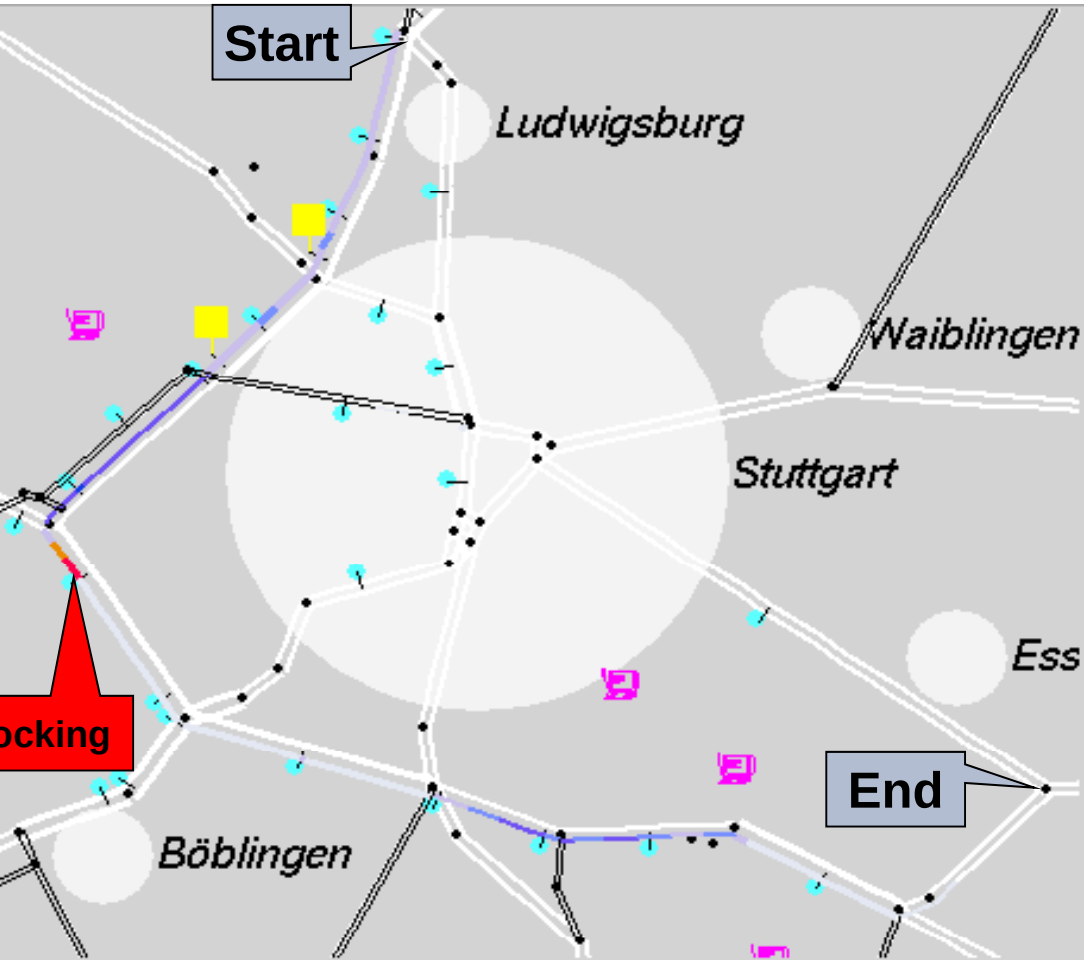

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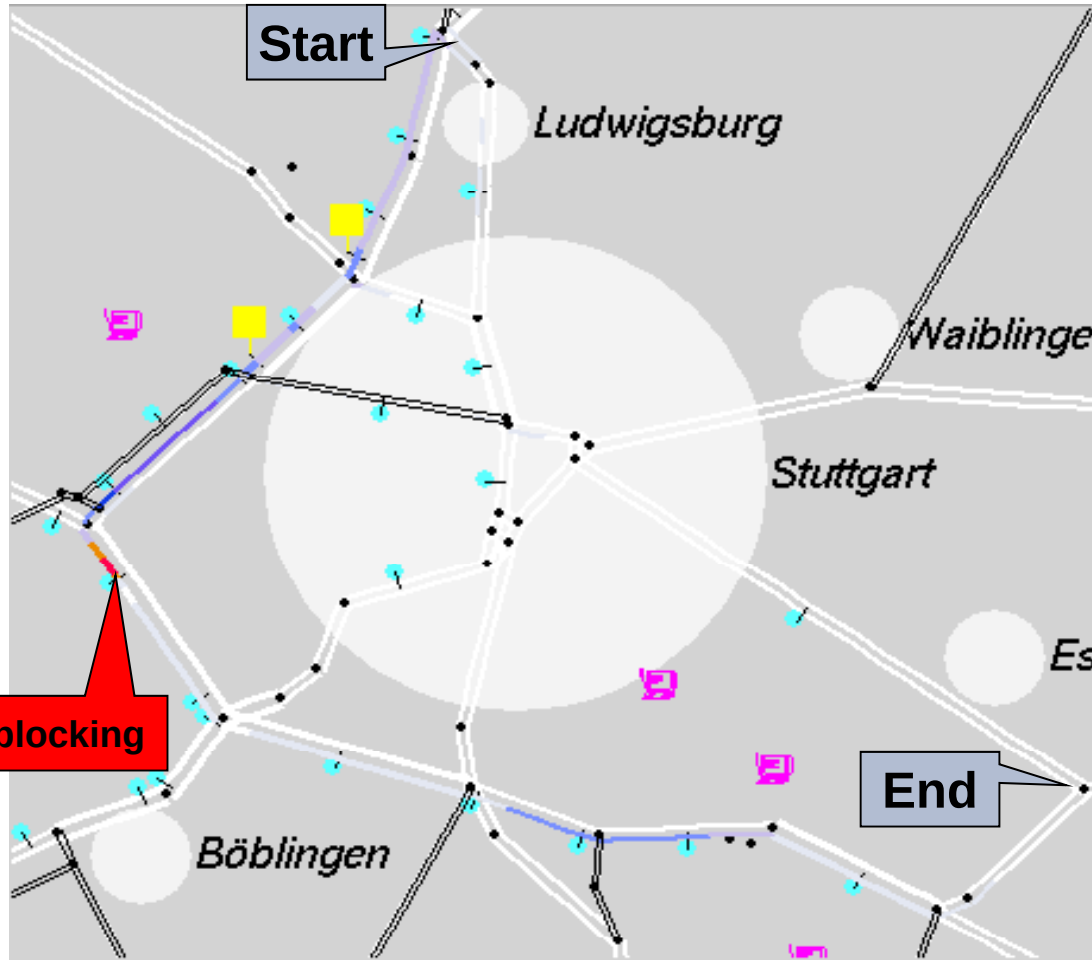

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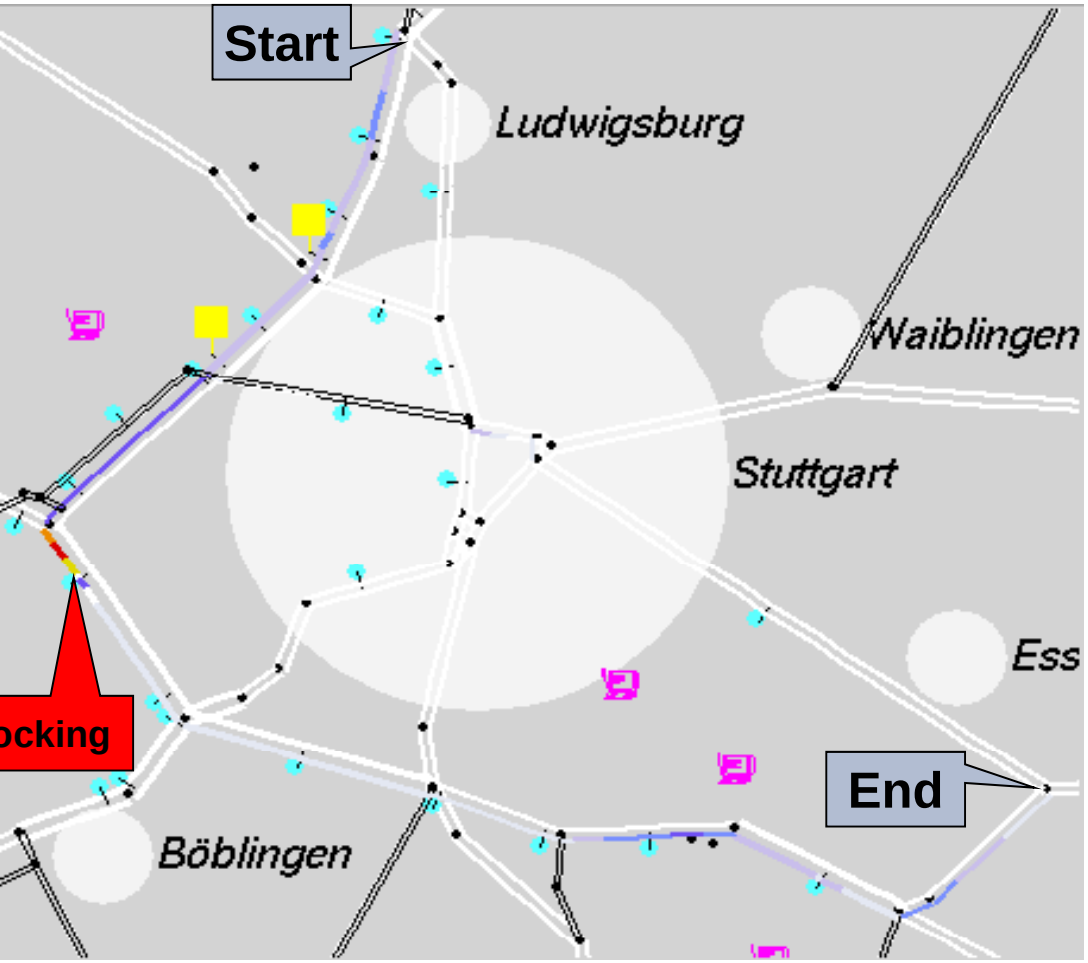

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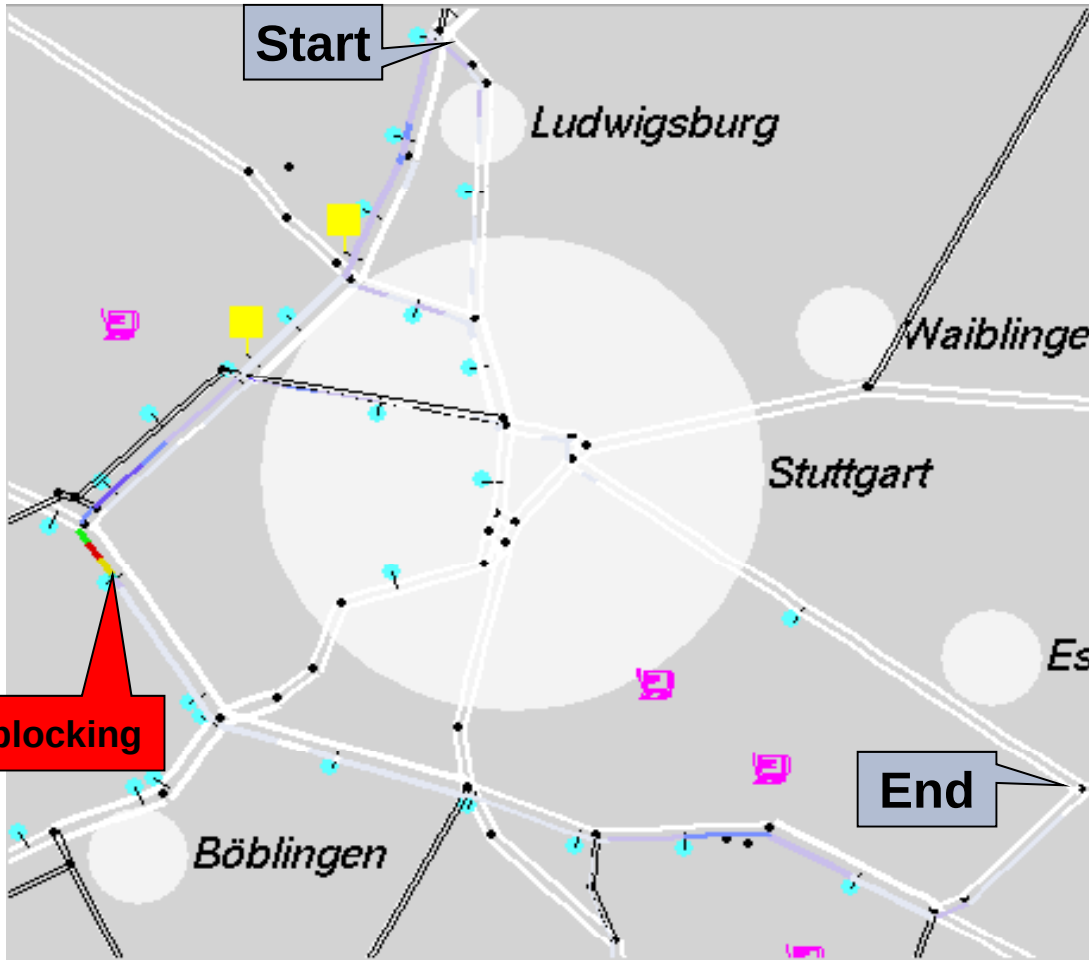

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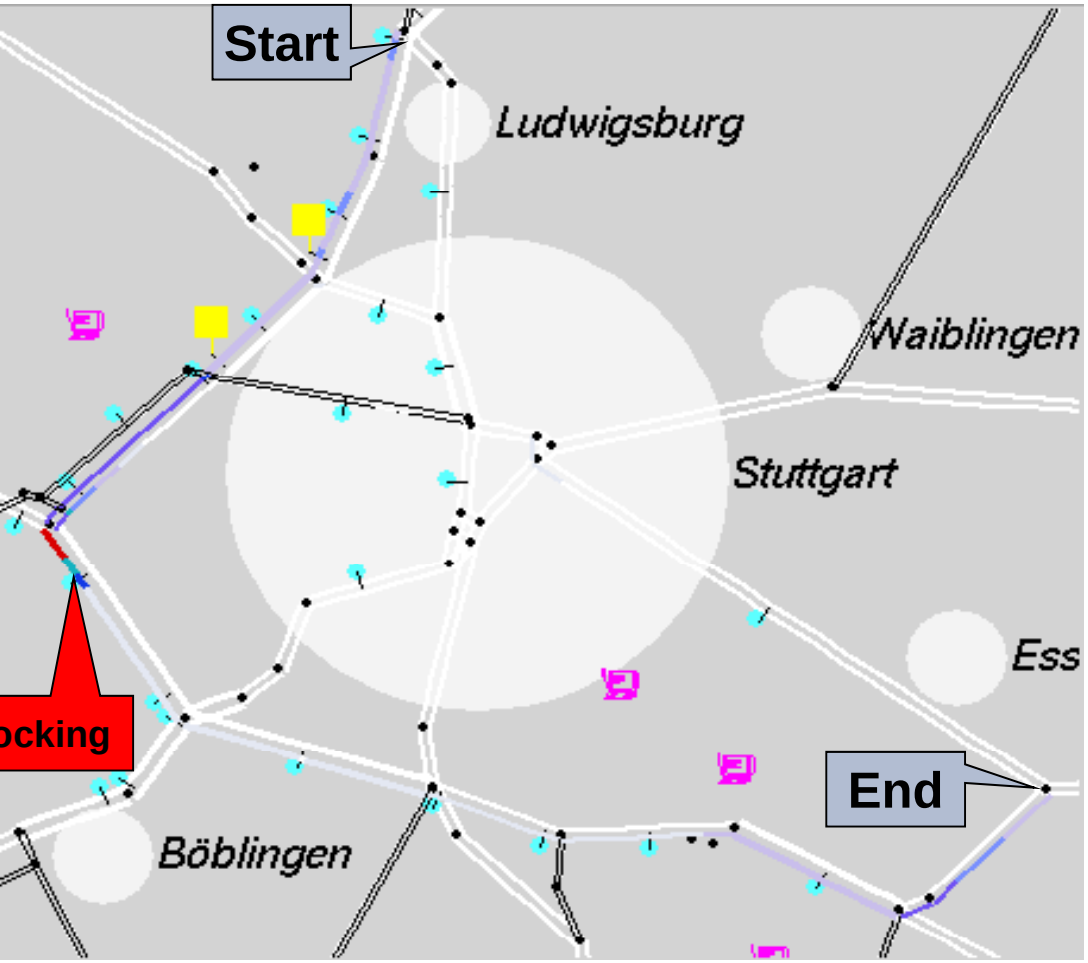

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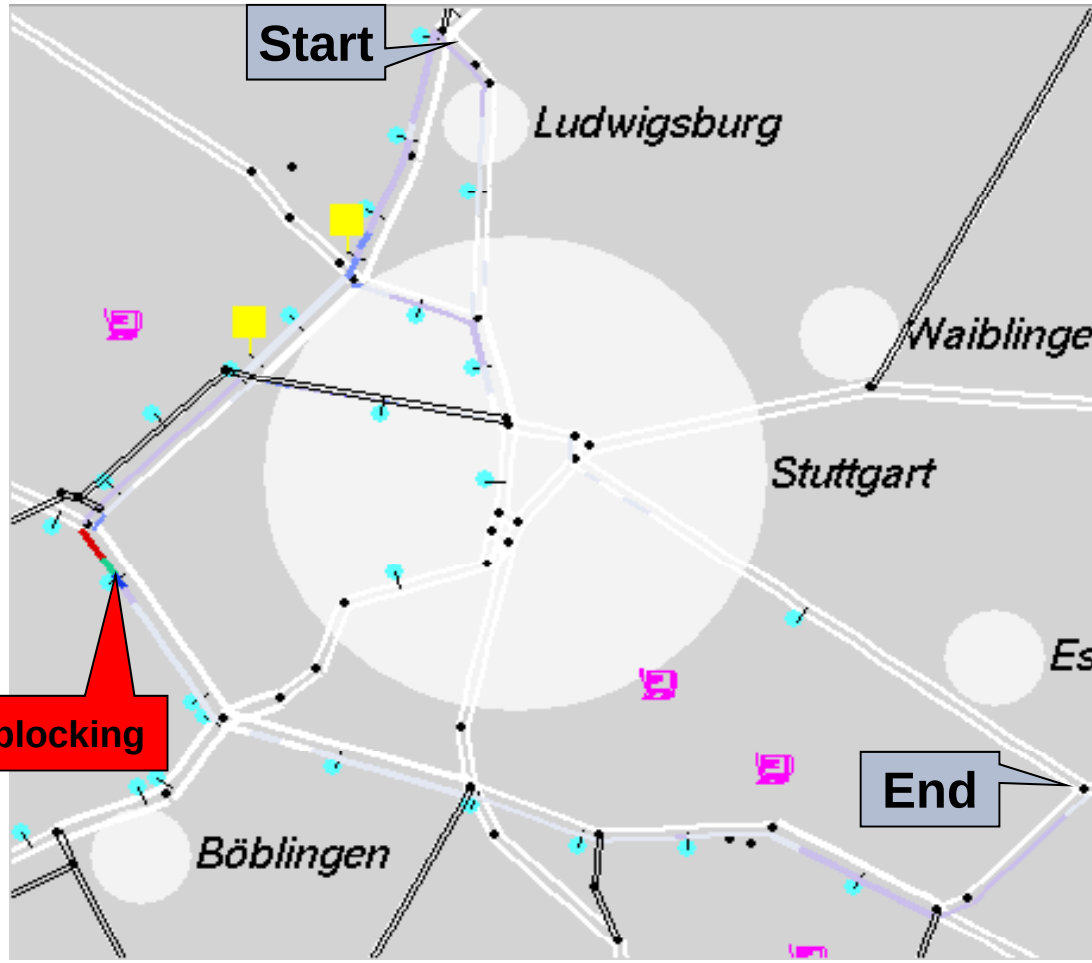

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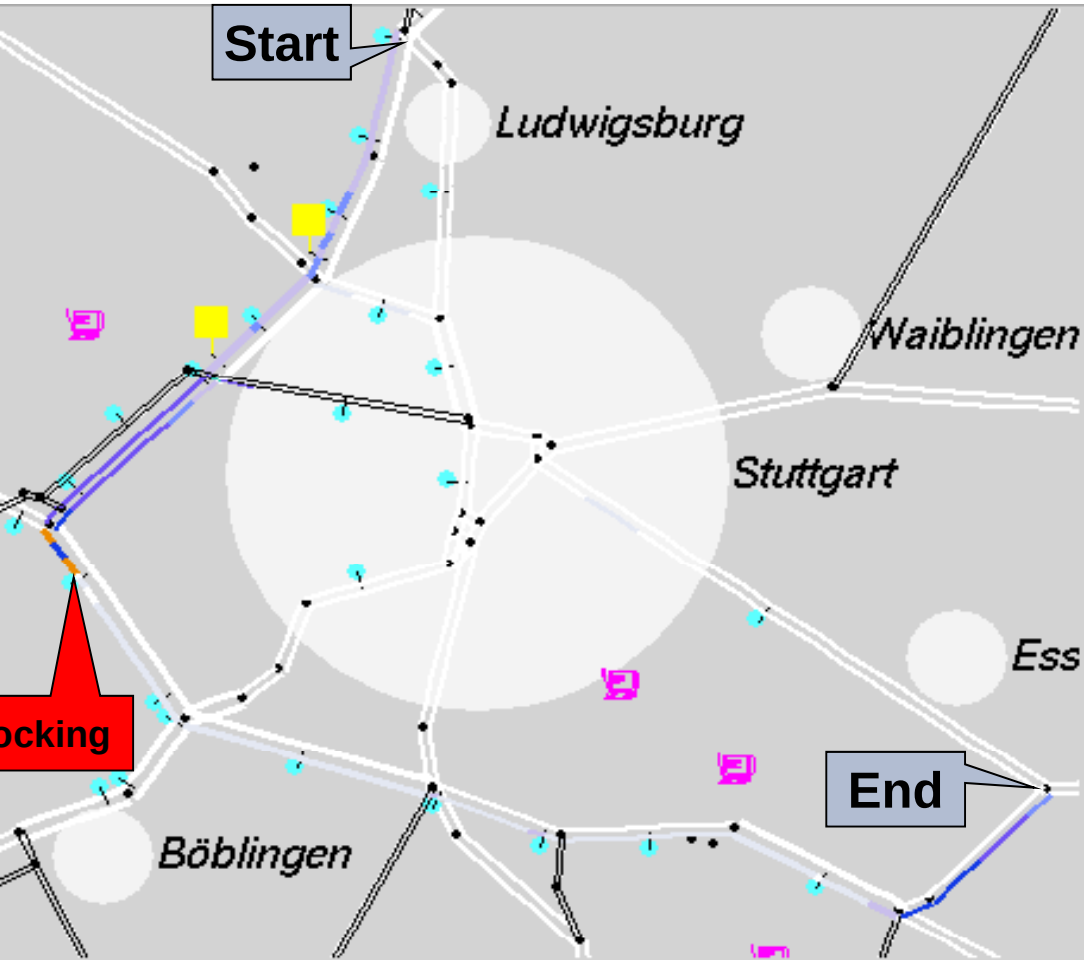

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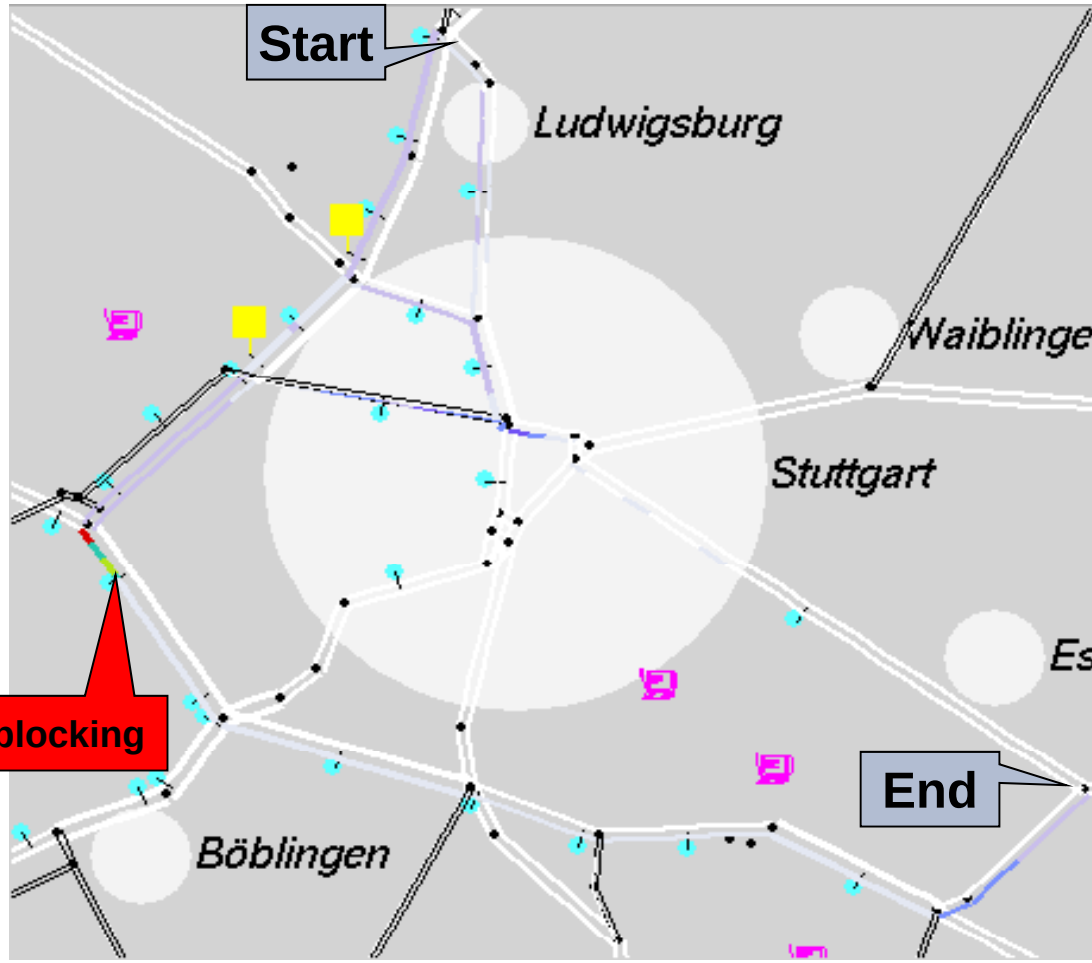

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Auction Based Traffic Control

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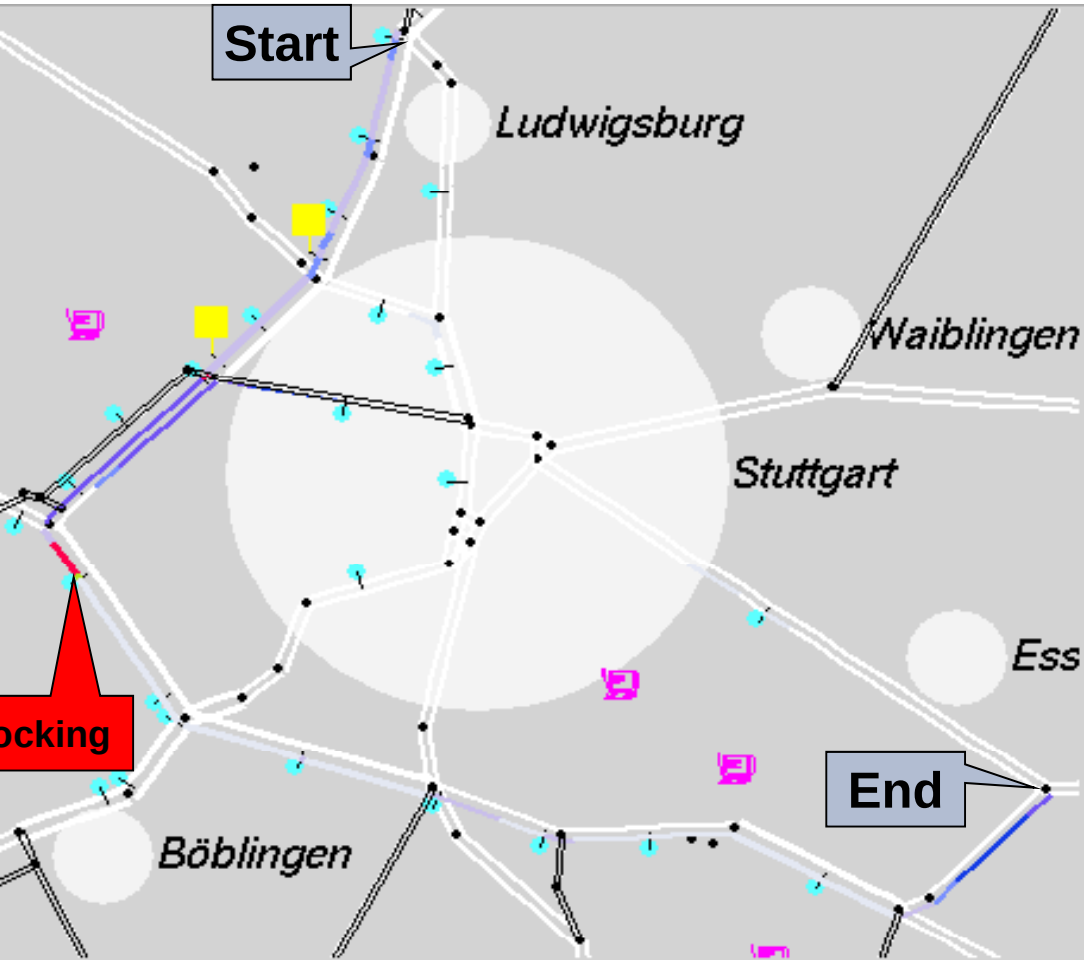

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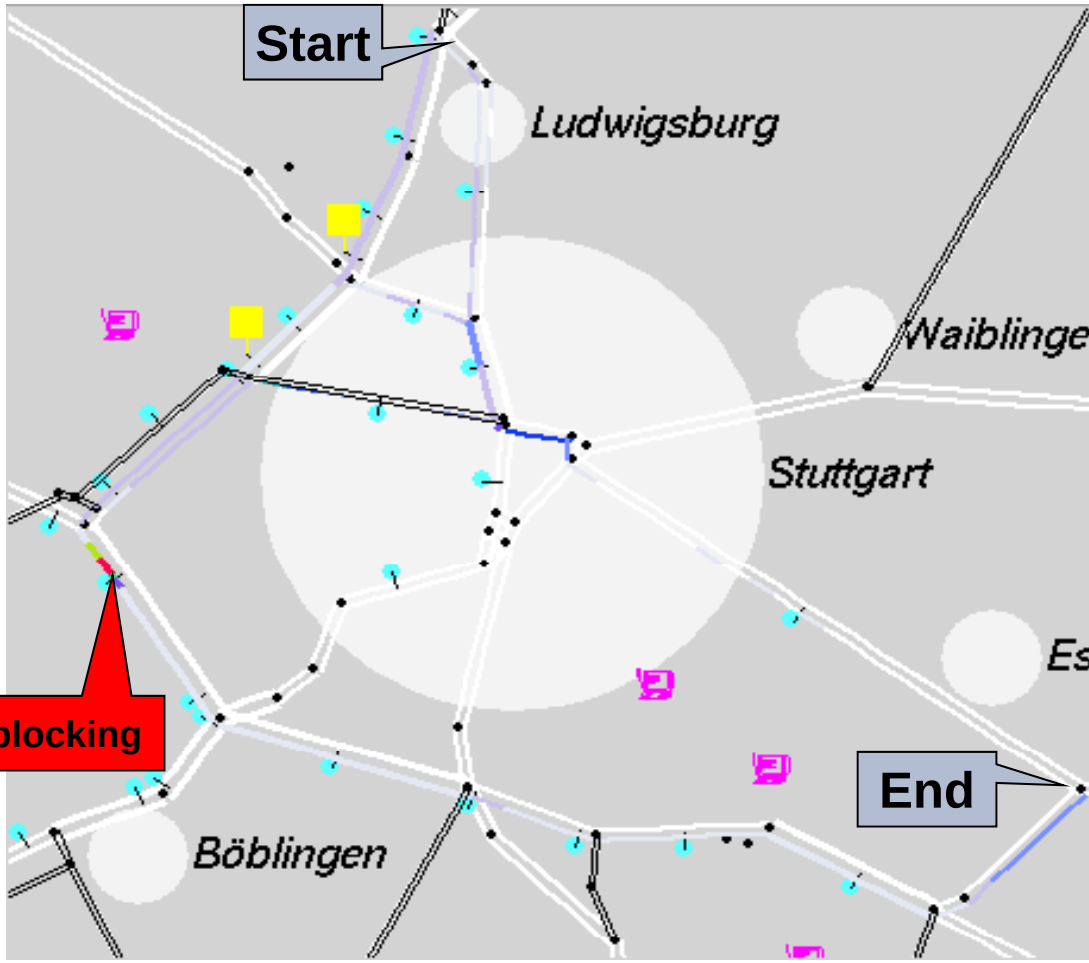

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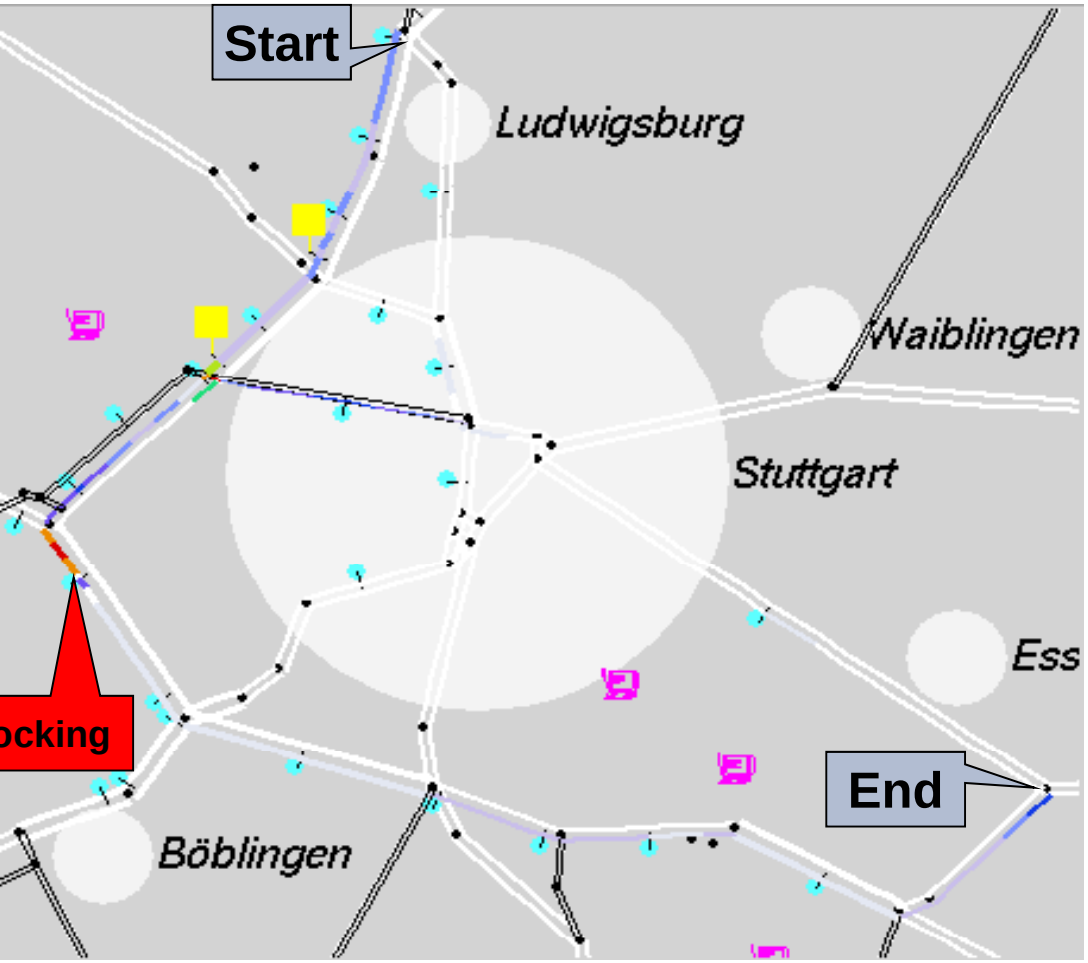

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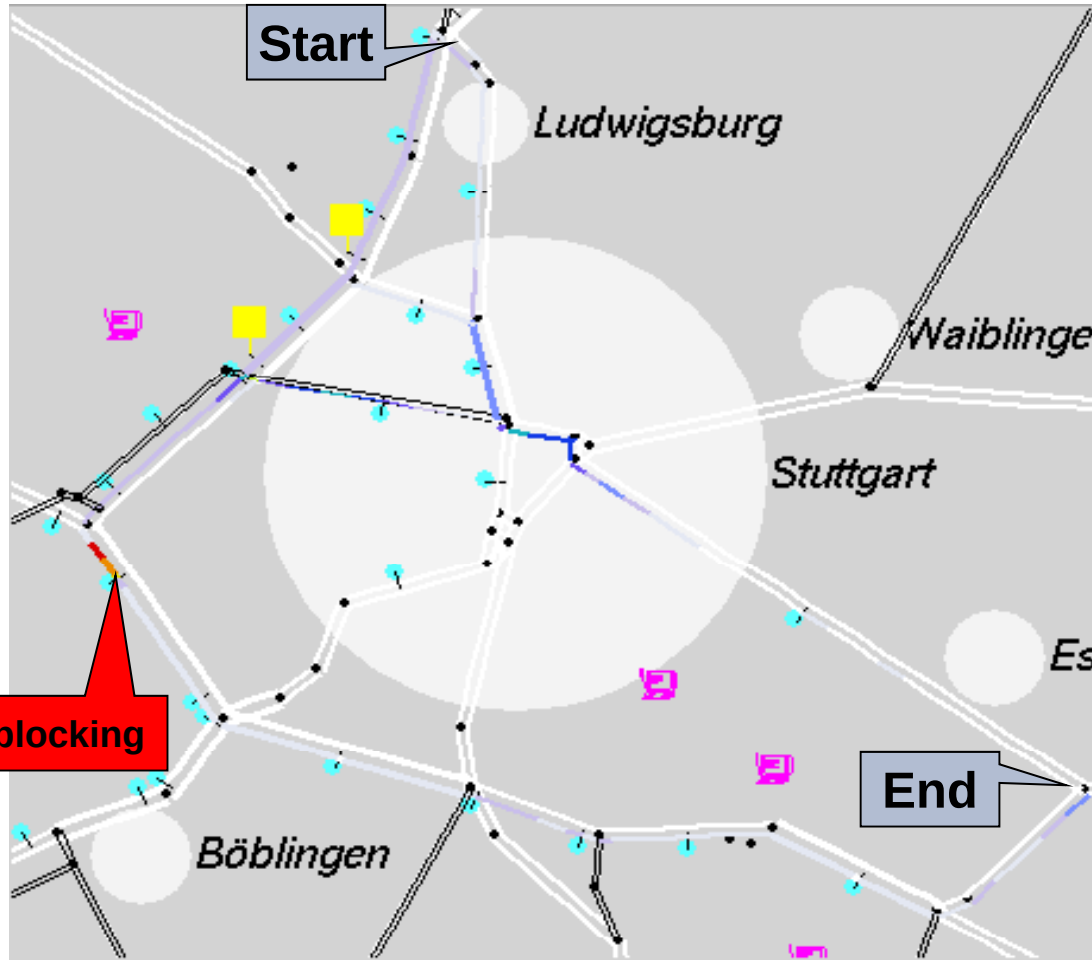

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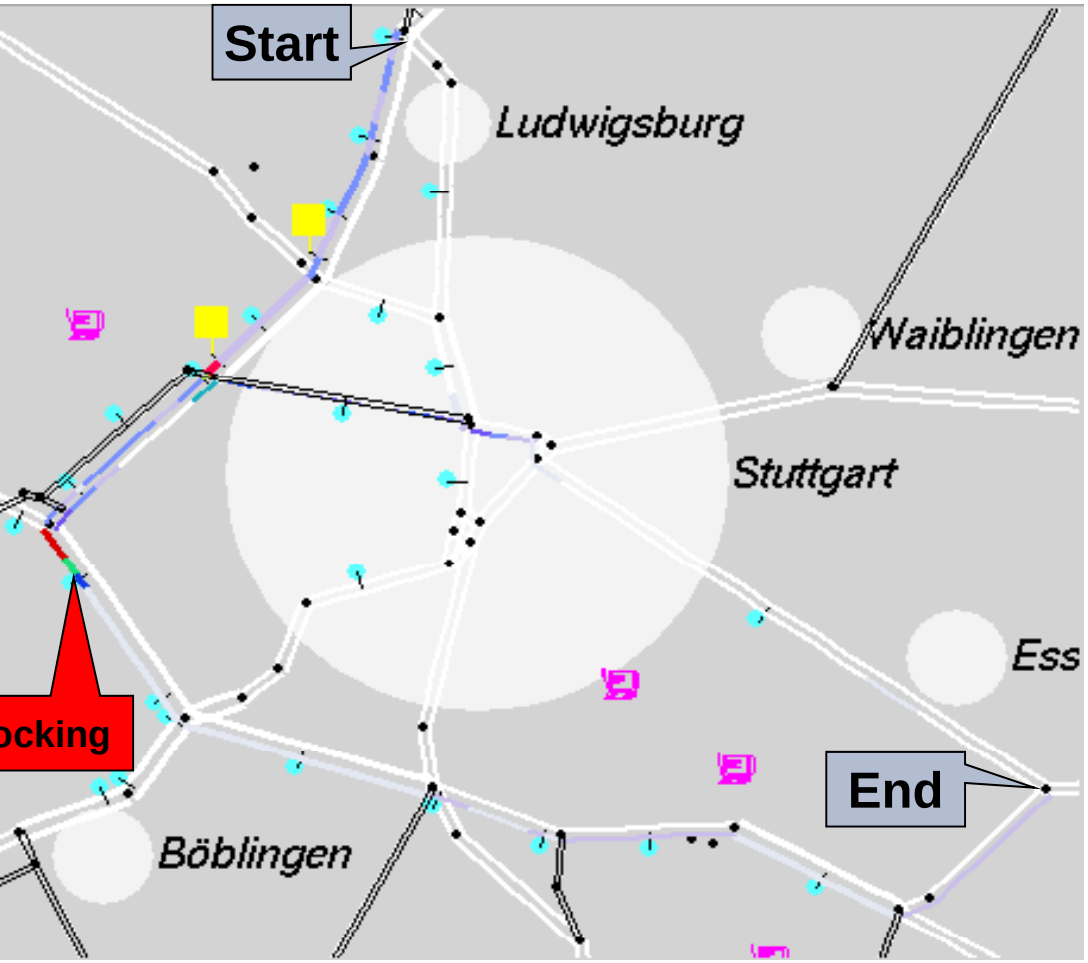

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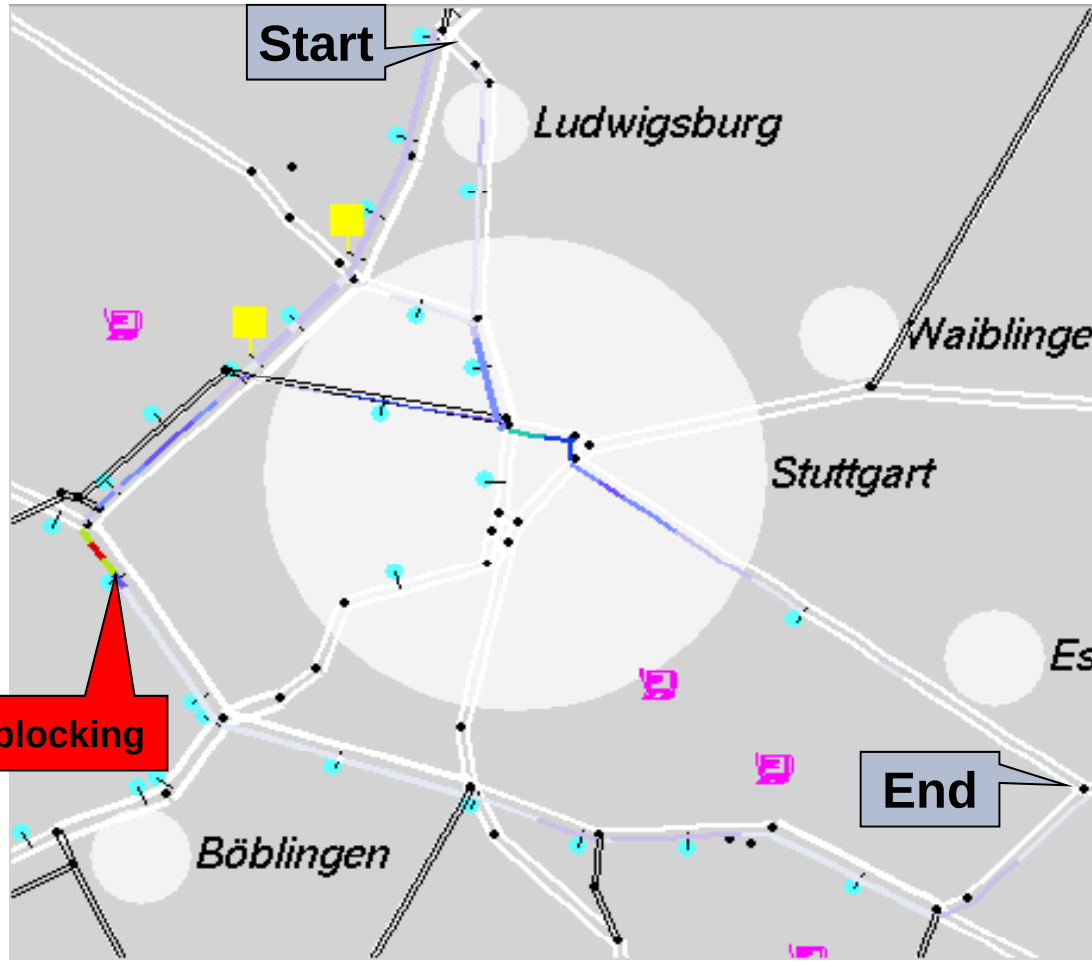

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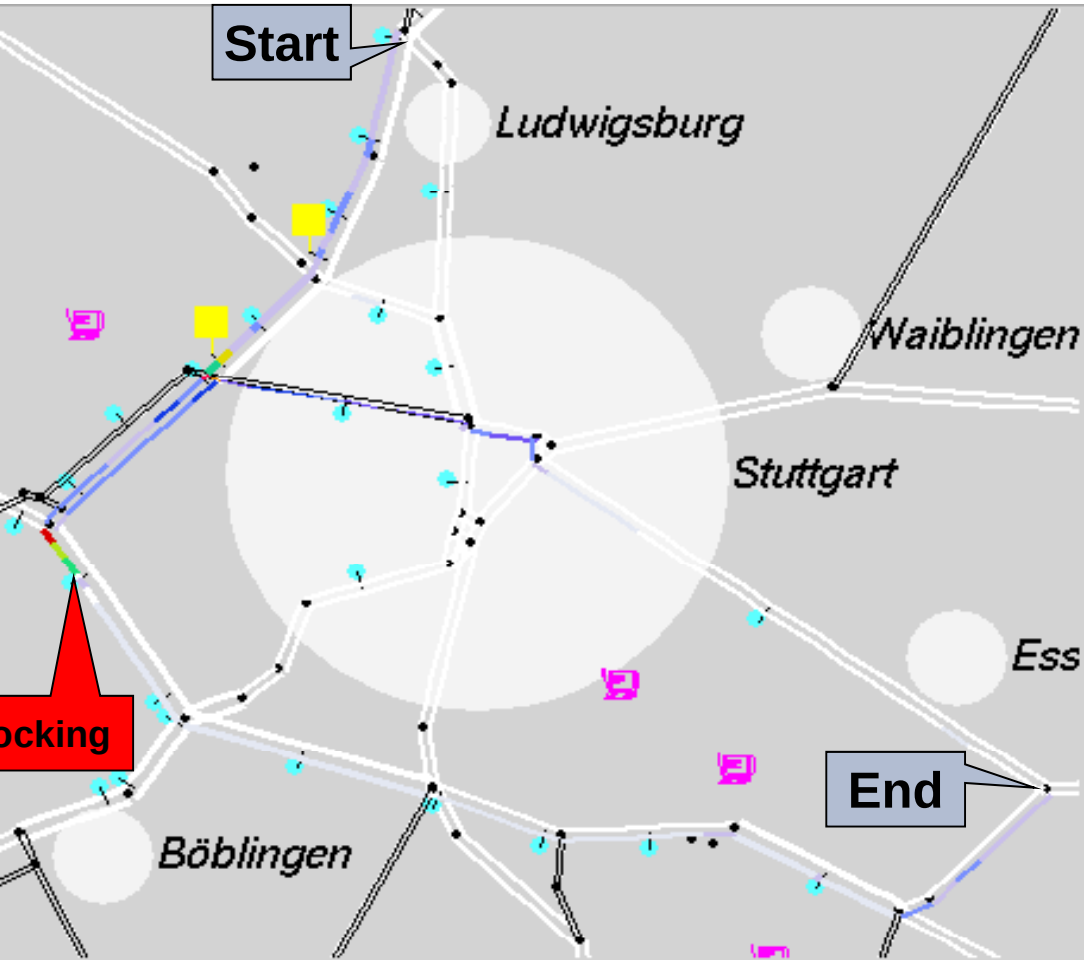

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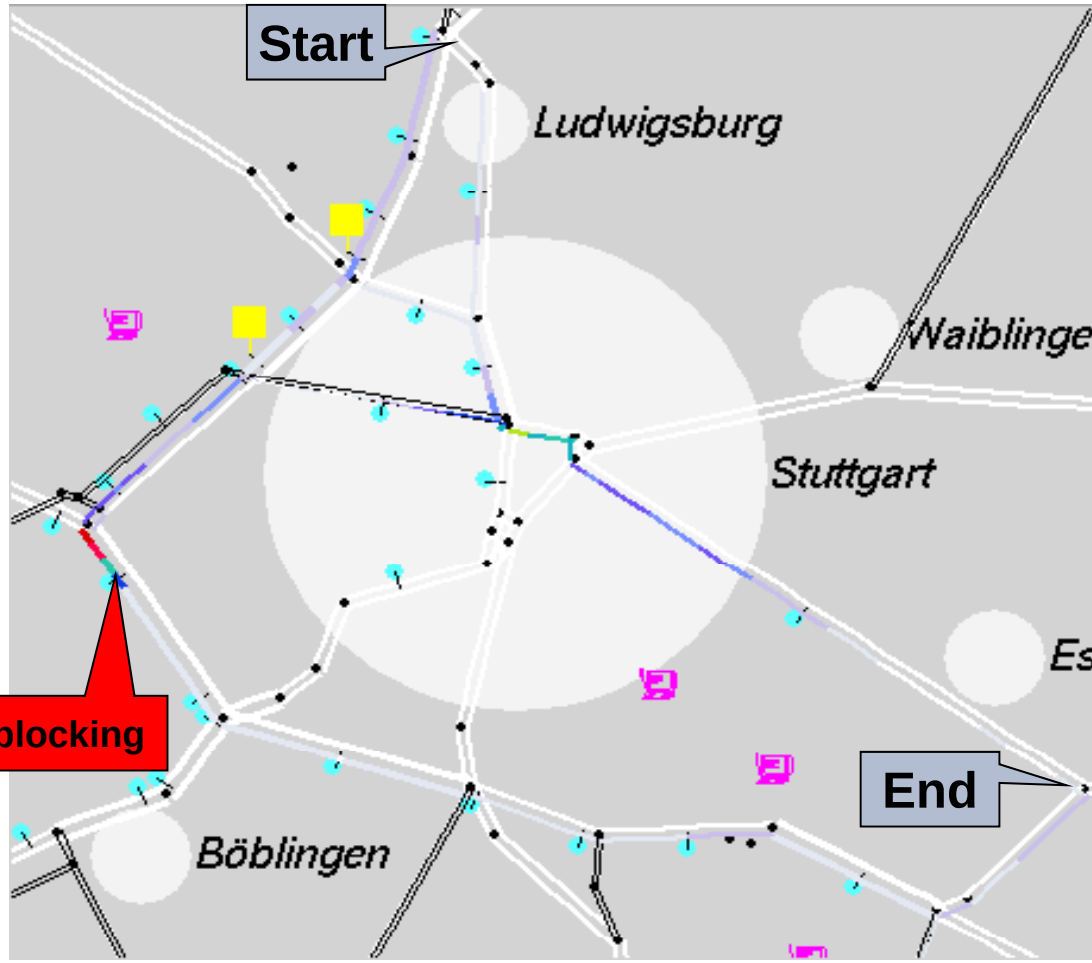

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Auction Based Traffic Control

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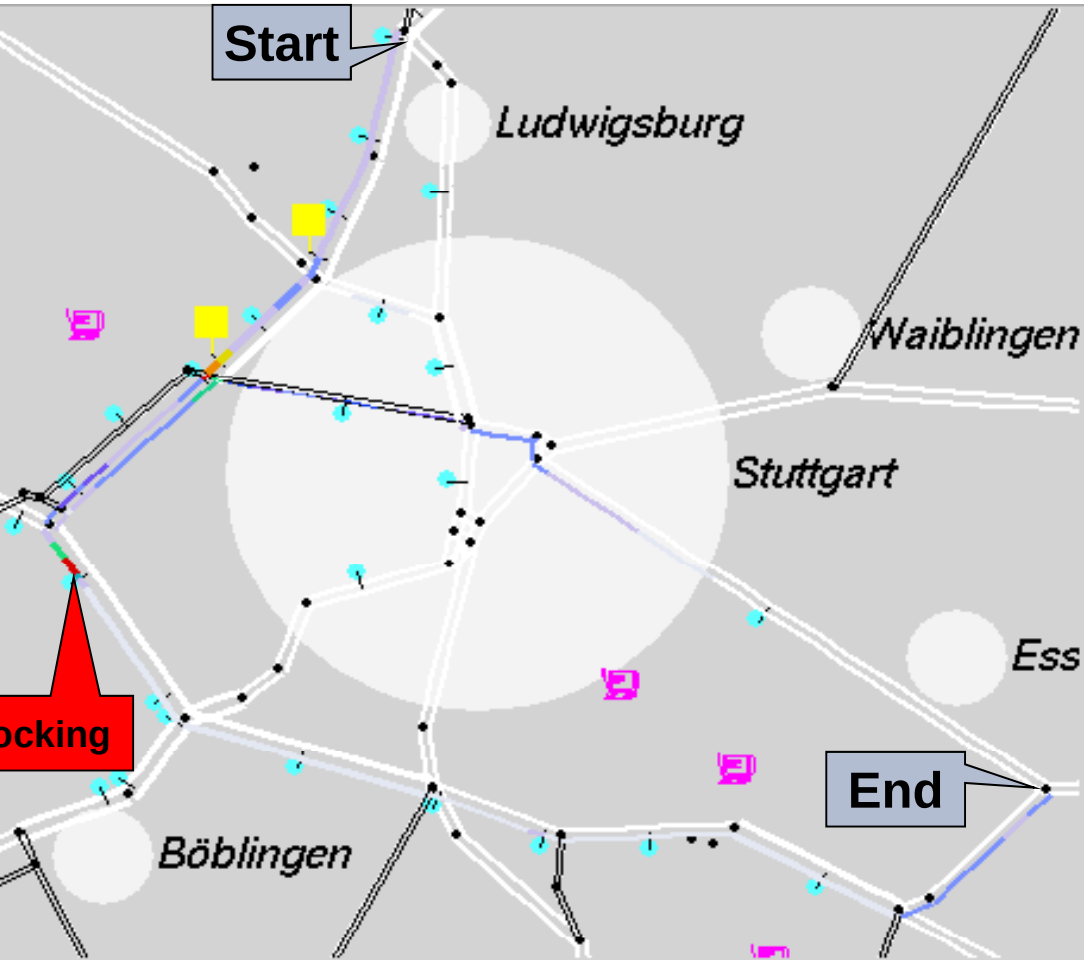

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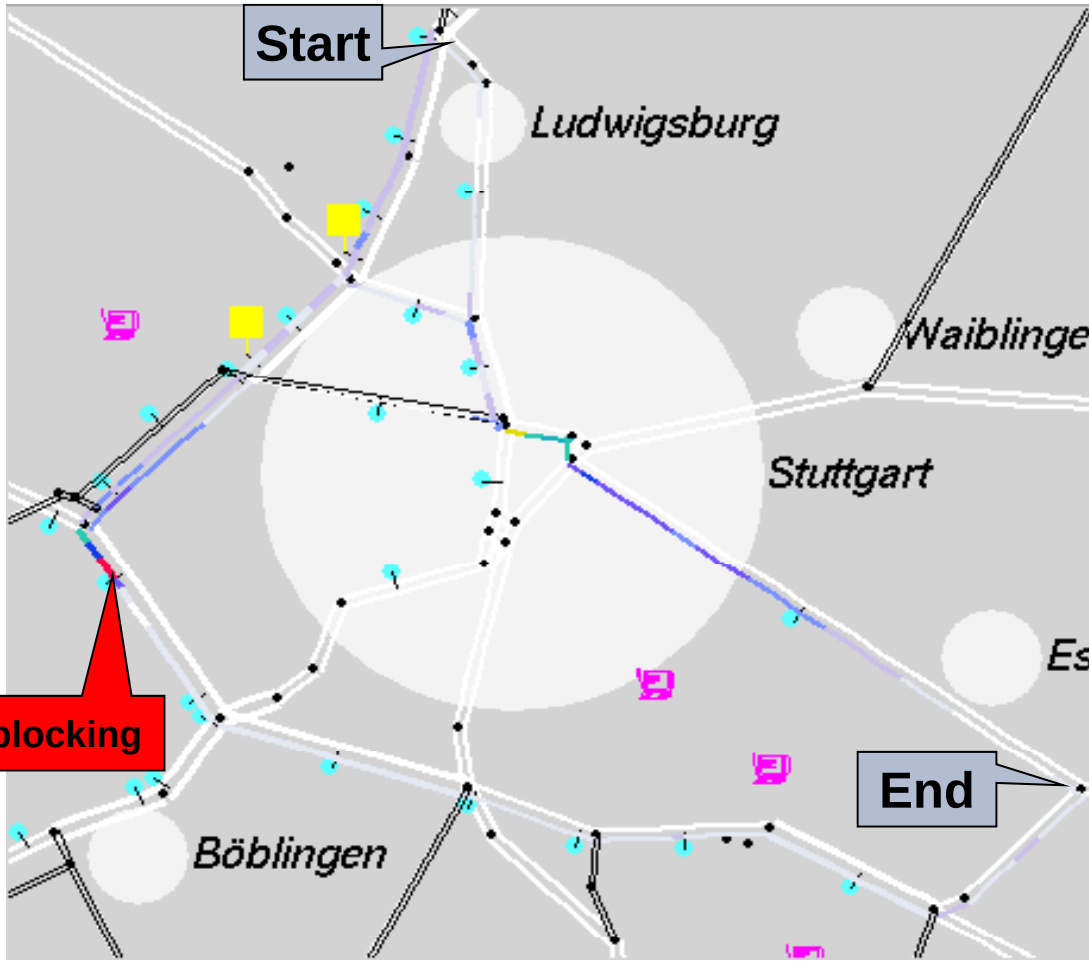

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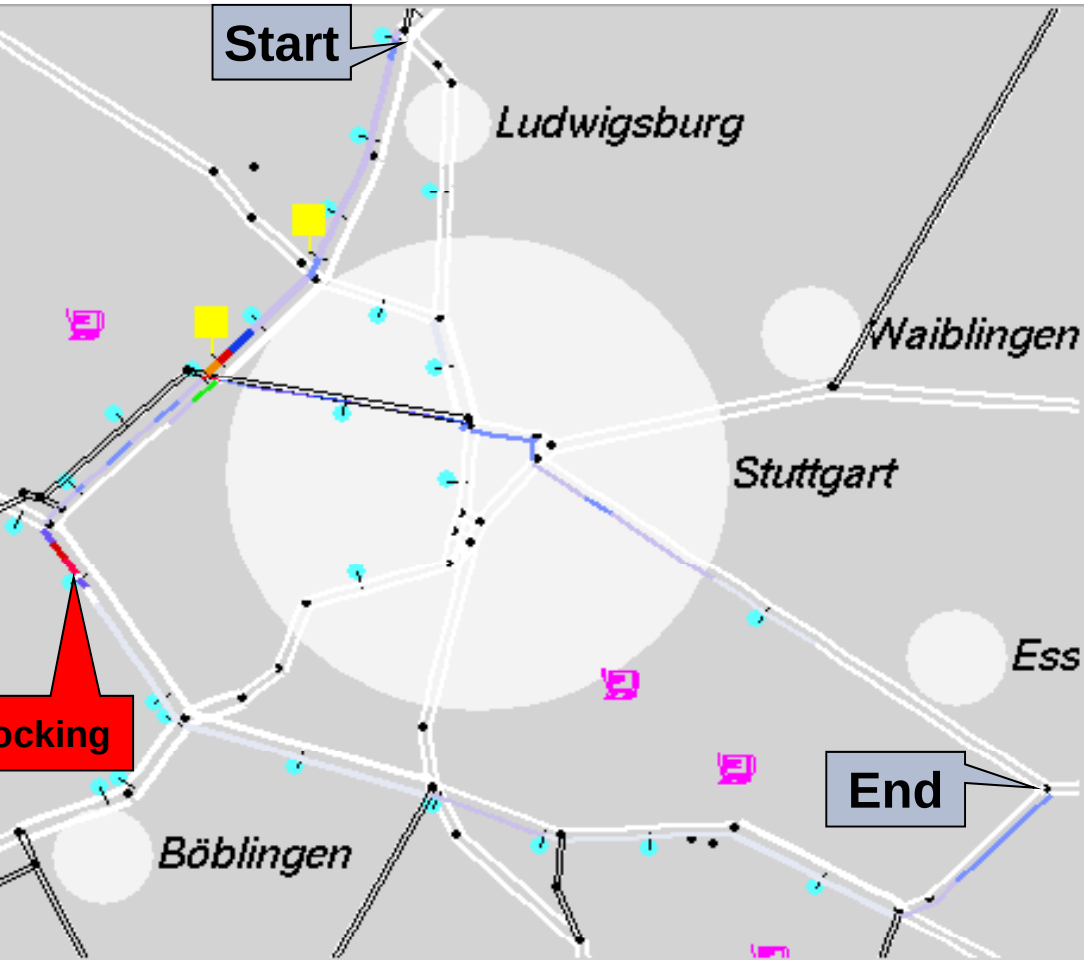
Auction Based Traffic Control

No Coordination



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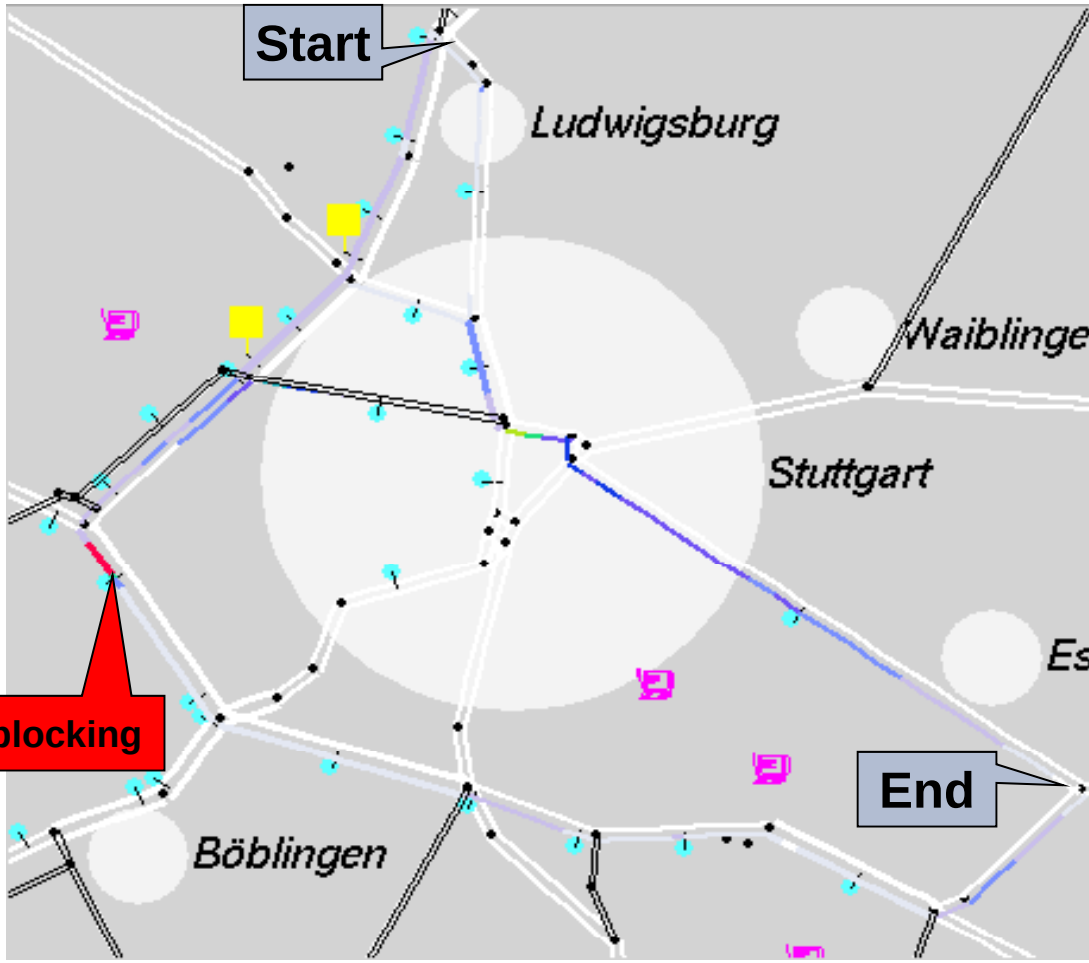

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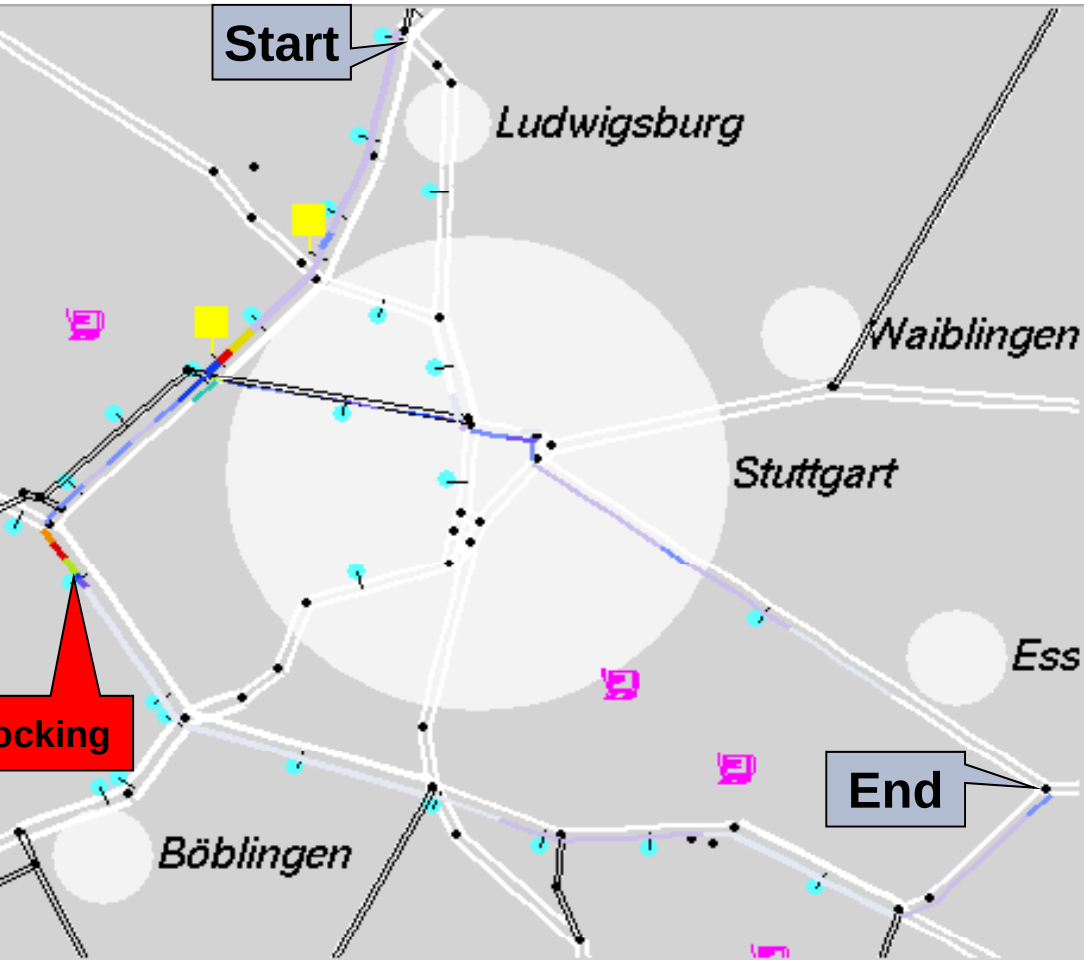
Market-Based Traffic Coordination

DAIMLERCHRYSLER

Auction Based Traffic Control

No Coordination



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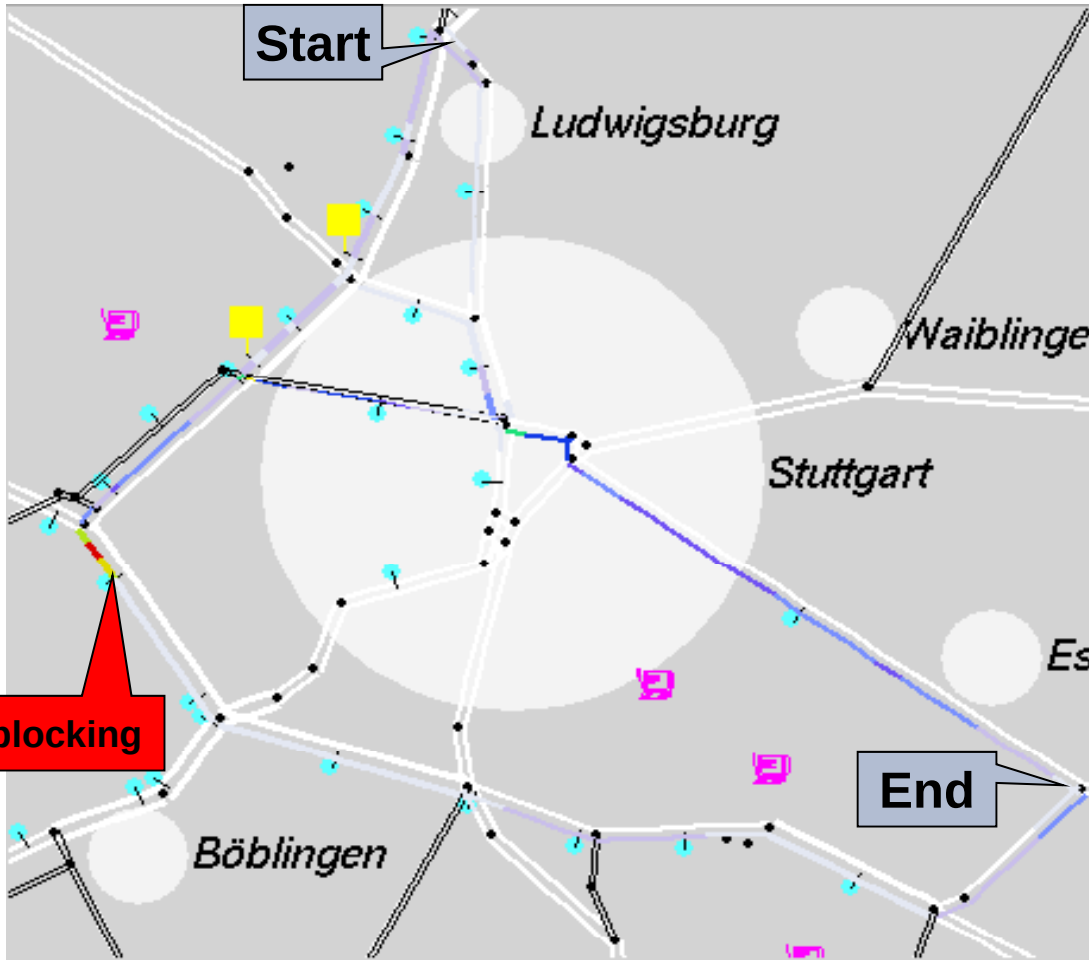

Time 08:00

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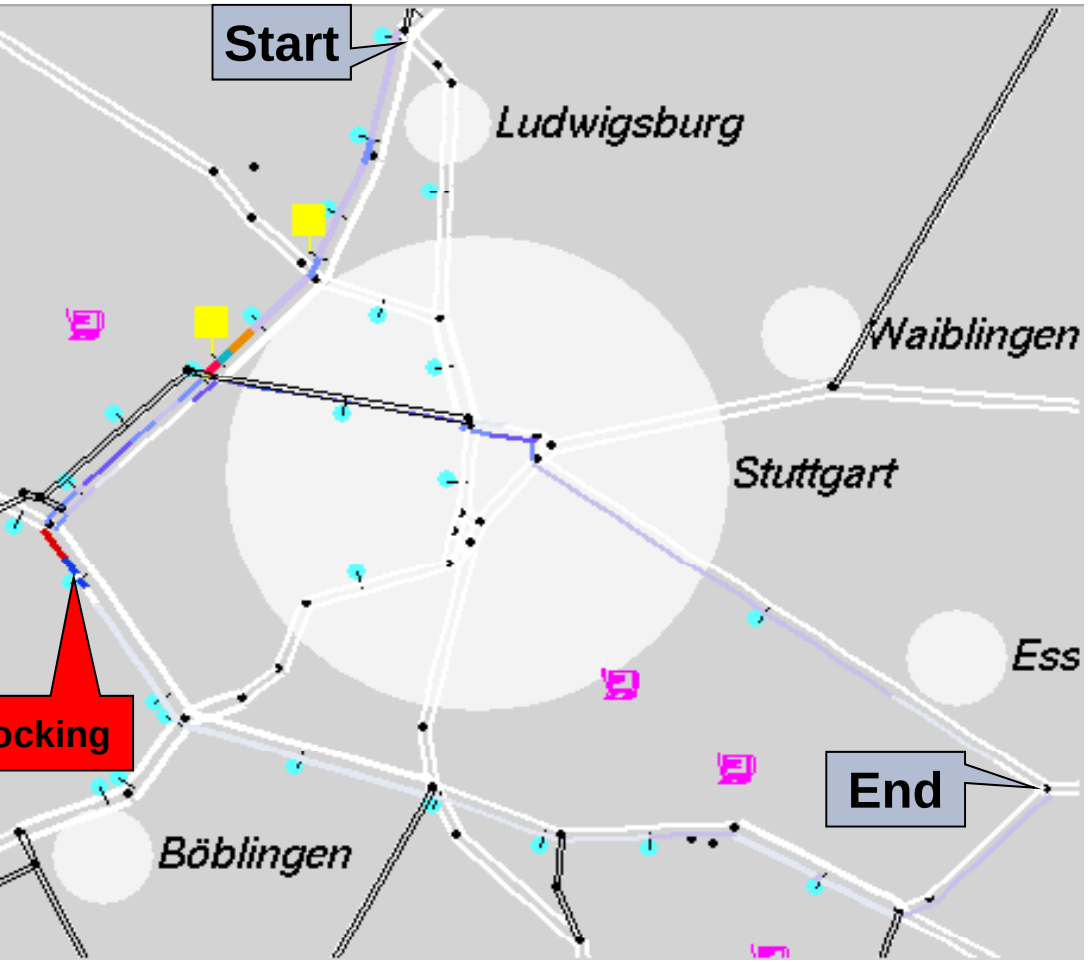
Market-Based Traffic Coordination

DAIMLERCHRYSLER

Auction Based Traffic Control

No Coordination



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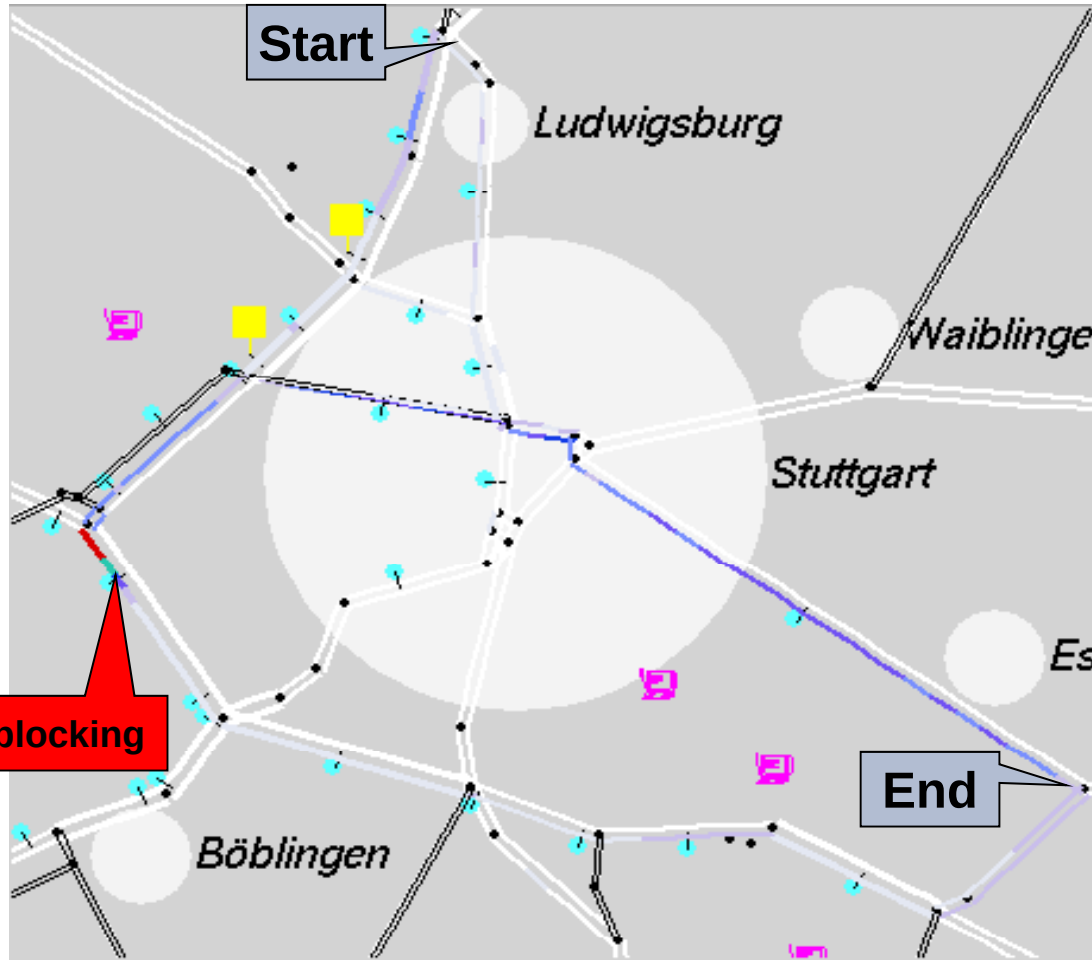

Time 08:03

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Market-Based Traffic Coordination

DAIMLERCHRYSLER

Auction Based Traffic Control

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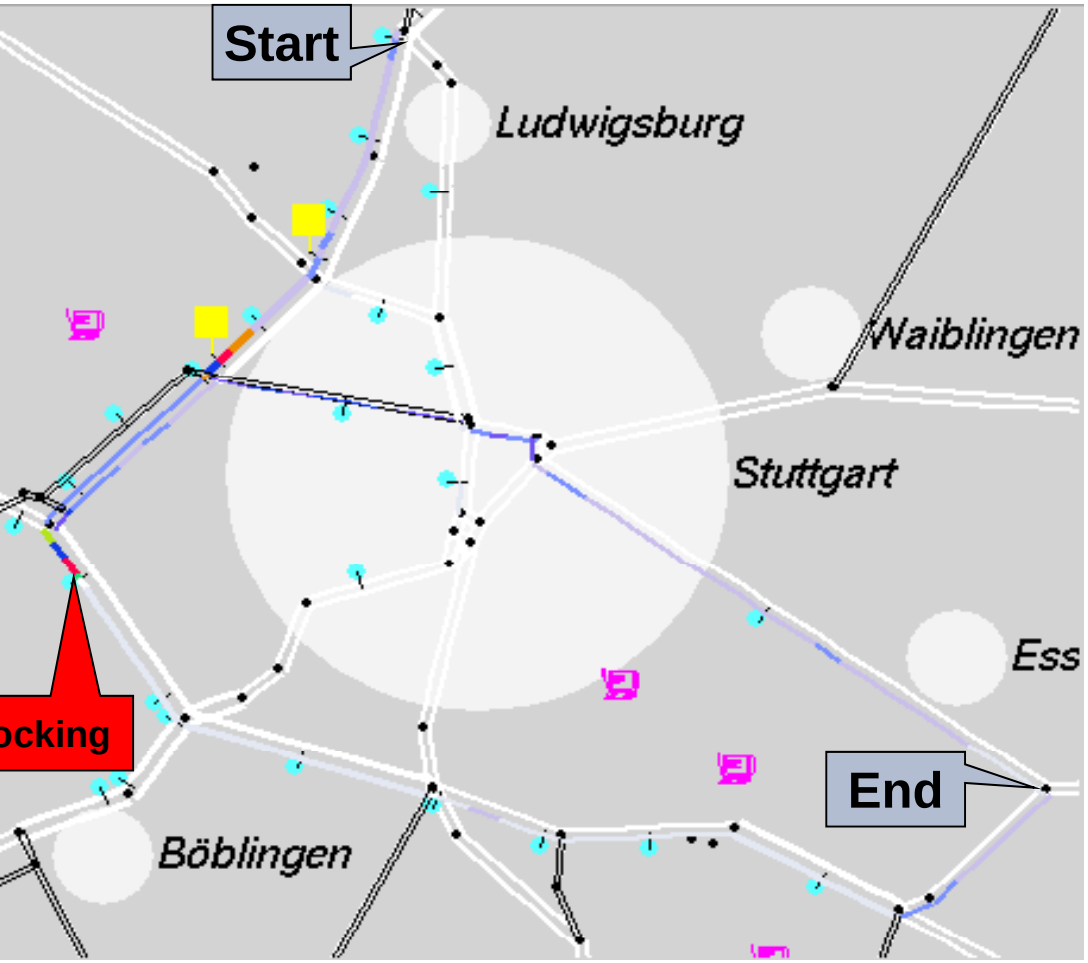

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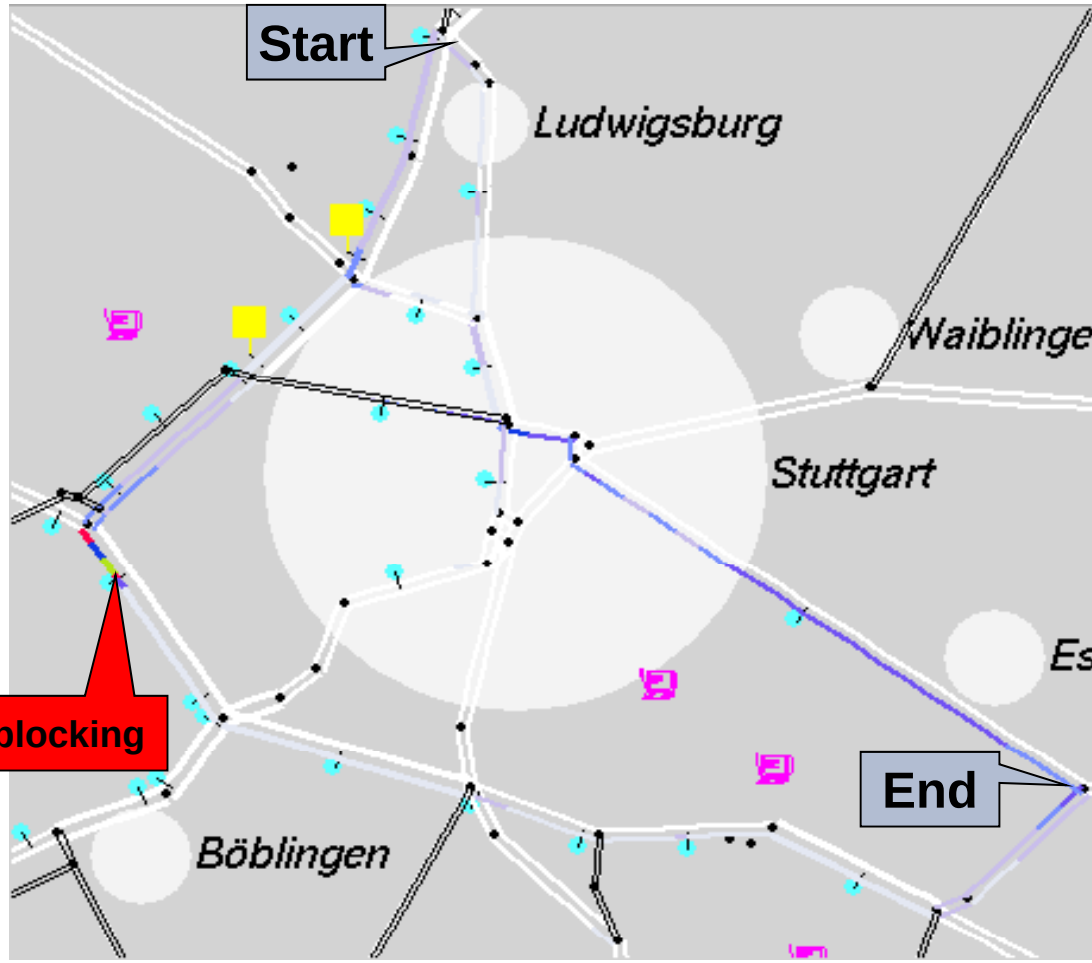

Time 08:06

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Market-Based Traffic Coordination

DAIMLERCHRYSLER

Auction Based Traffic Control

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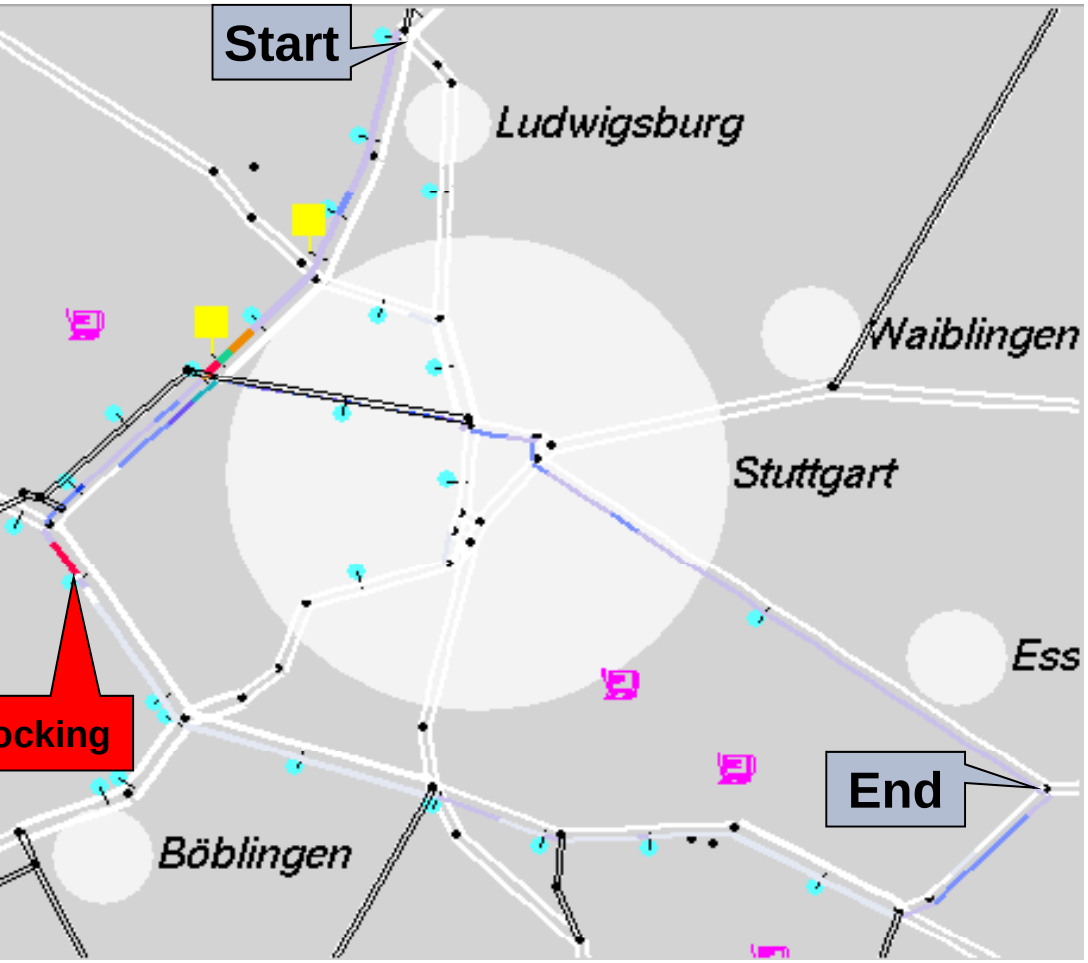

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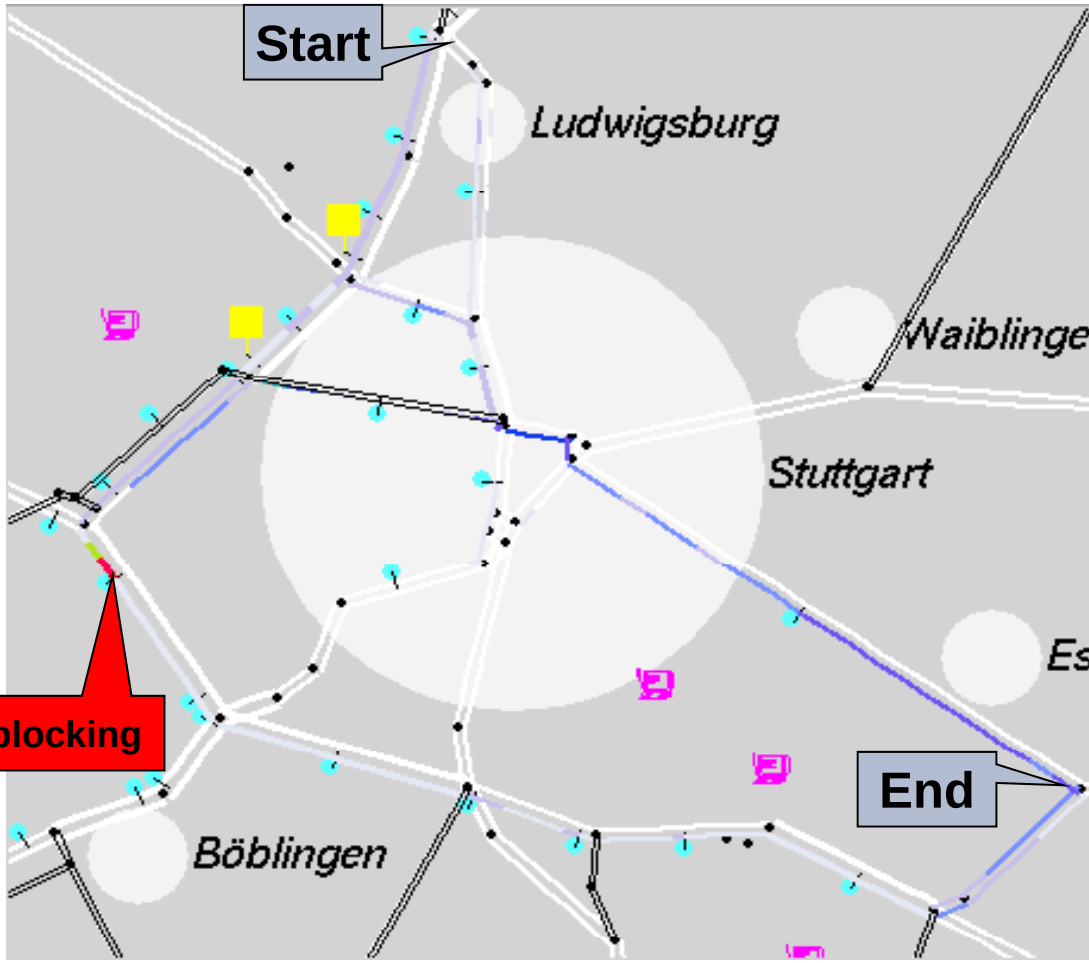

Time 08:09

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Market-Based Traffic Coordination

DAIMLERCHRYSLER

Auction Based Traffic Control

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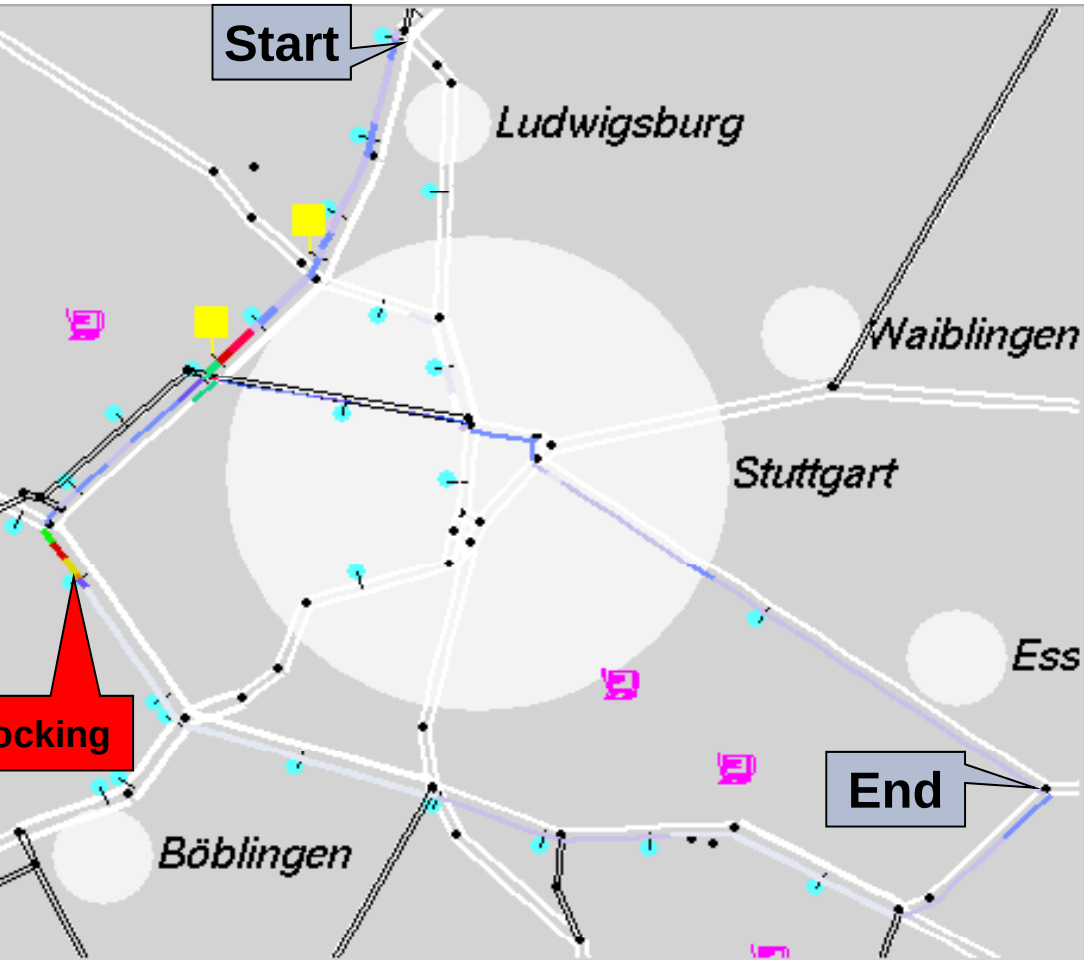

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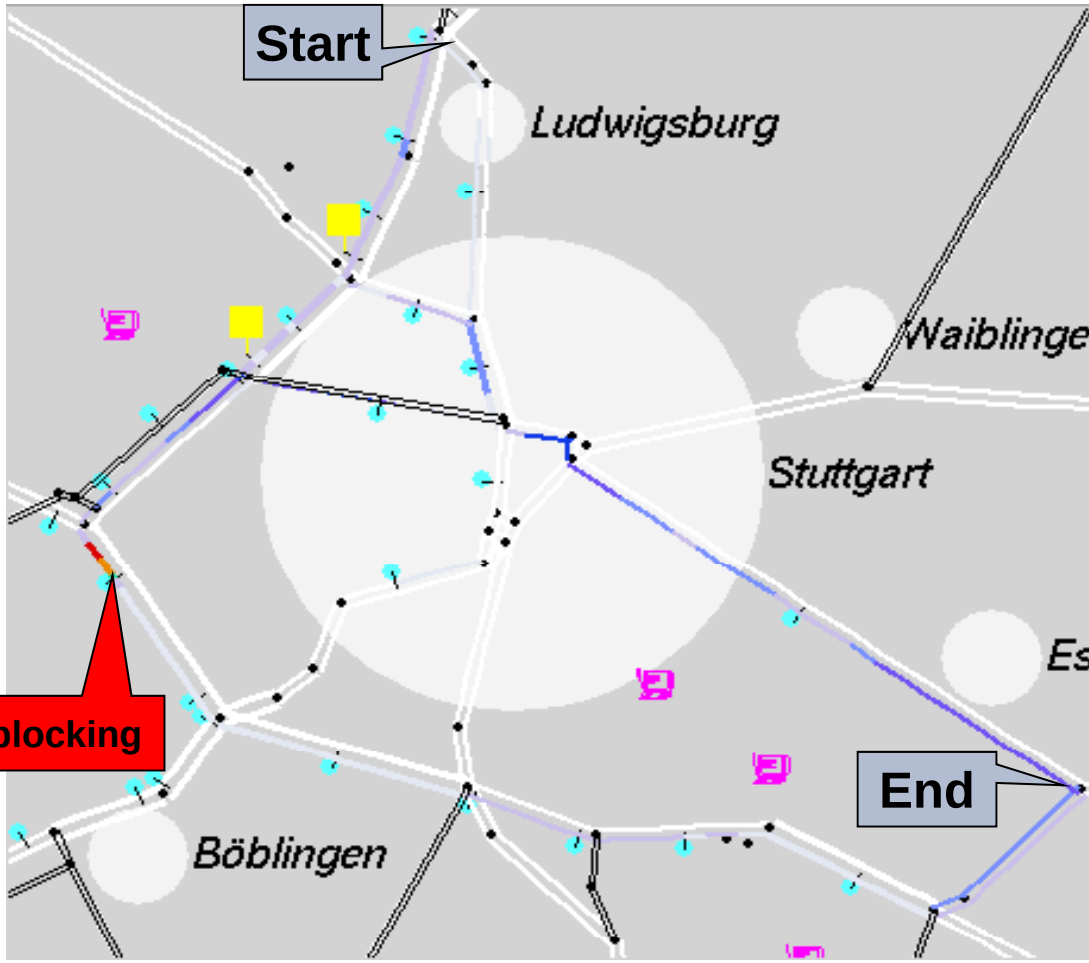

Time 08:12

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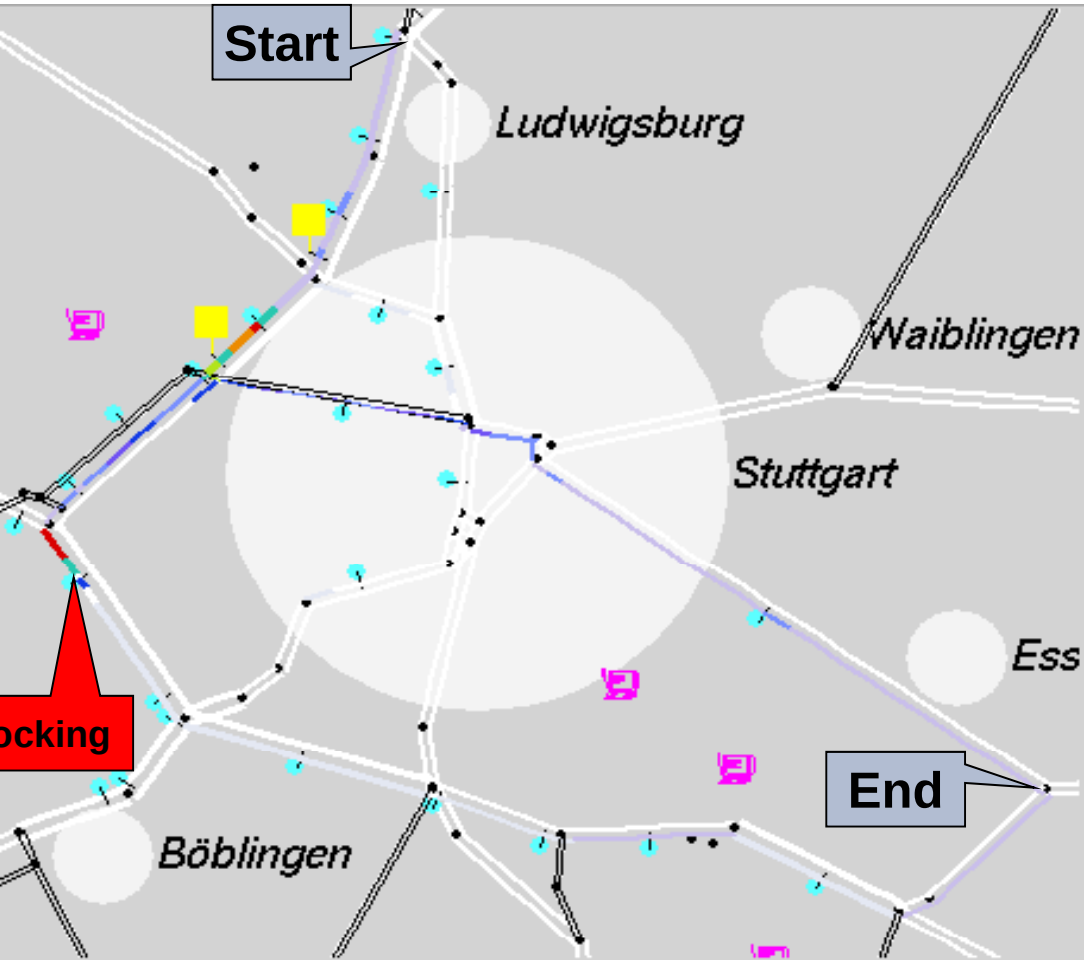
Market-Based Traffic Coordination

DAIMLERCHRYSLER

Auction Based Traffic Control

No Coordination



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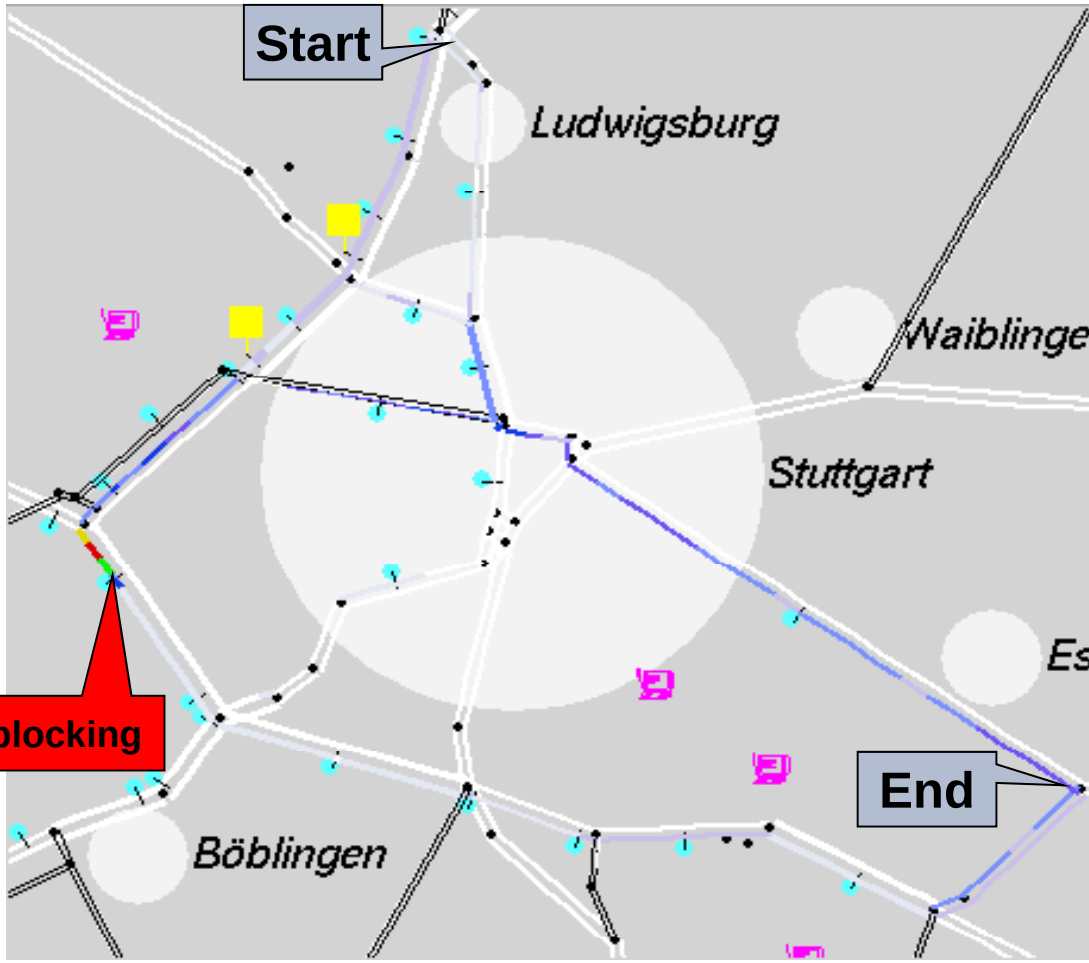

Time 08:15

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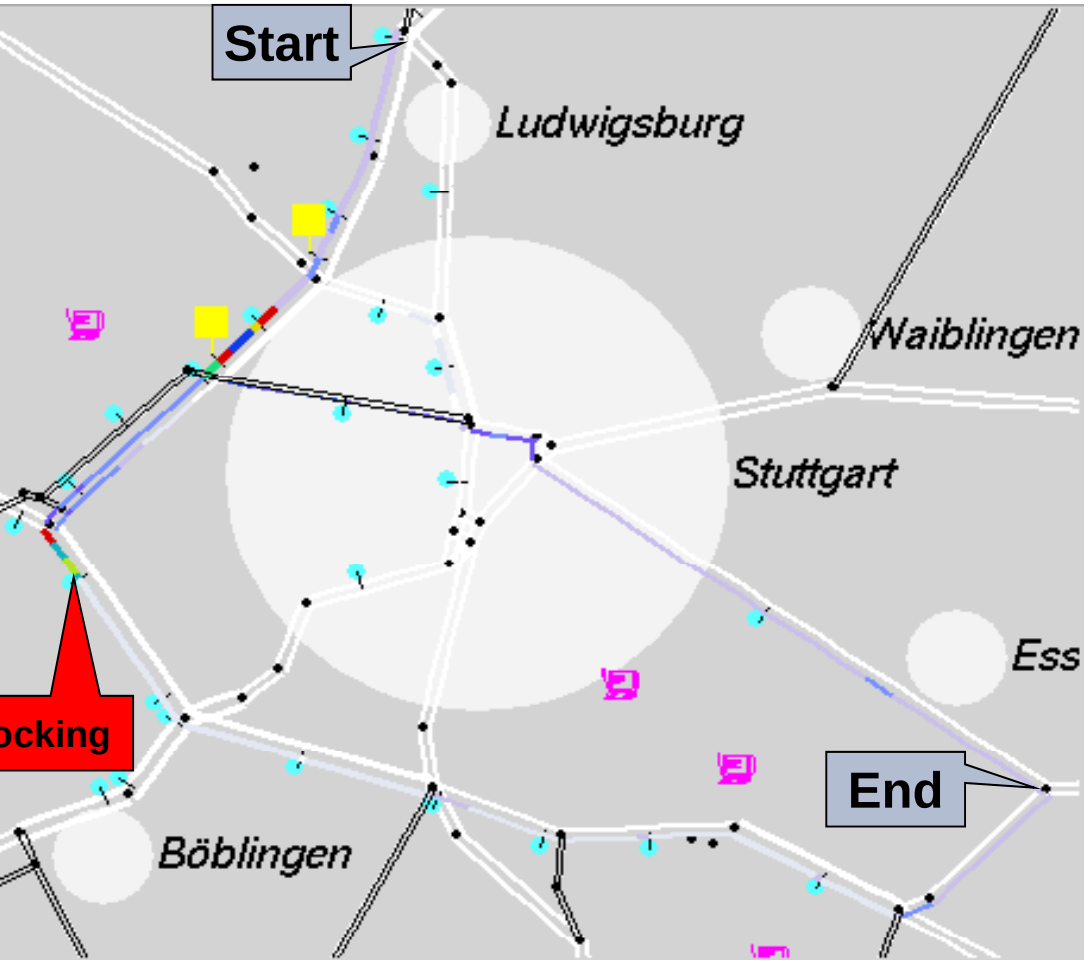
Market-Based Traffic Coordination

DAIMLERCHRYSLER

Auction Based Traffic Control

No Coordination



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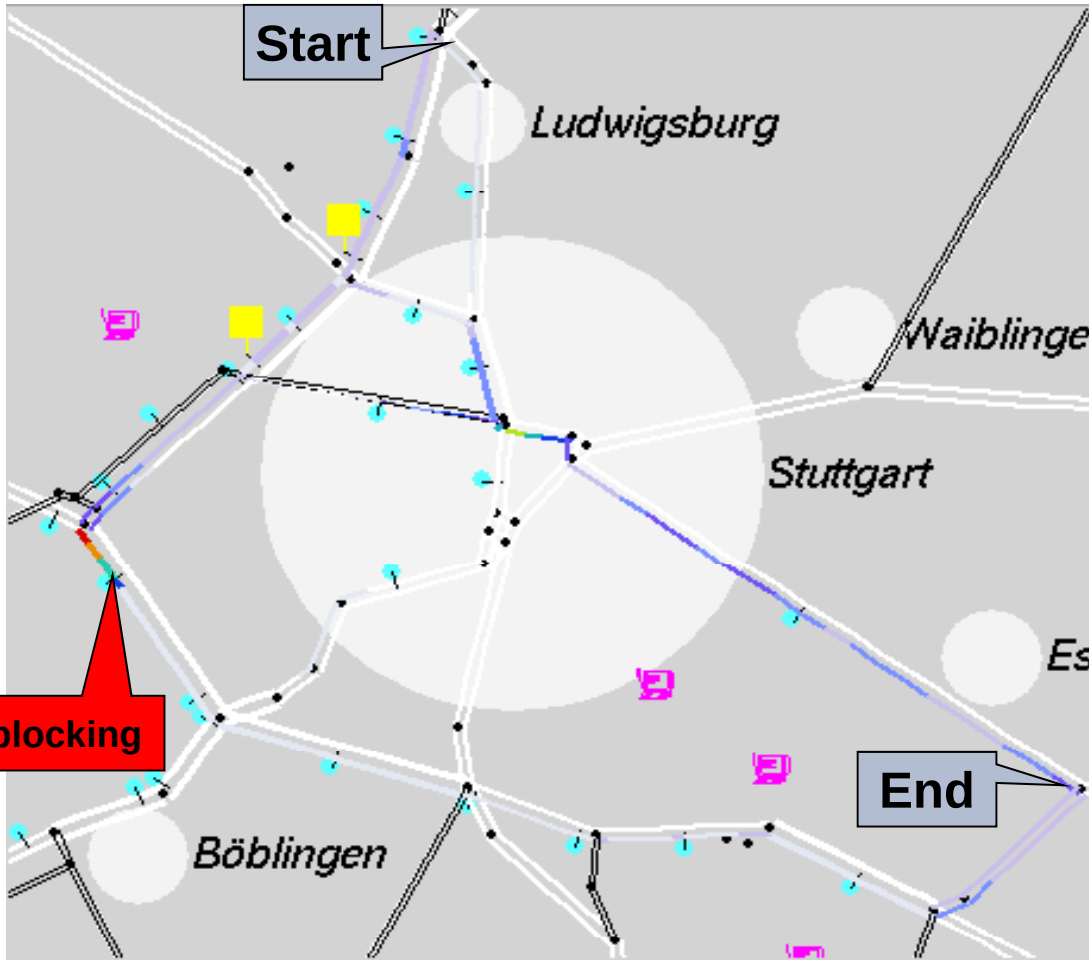

Time 08:18

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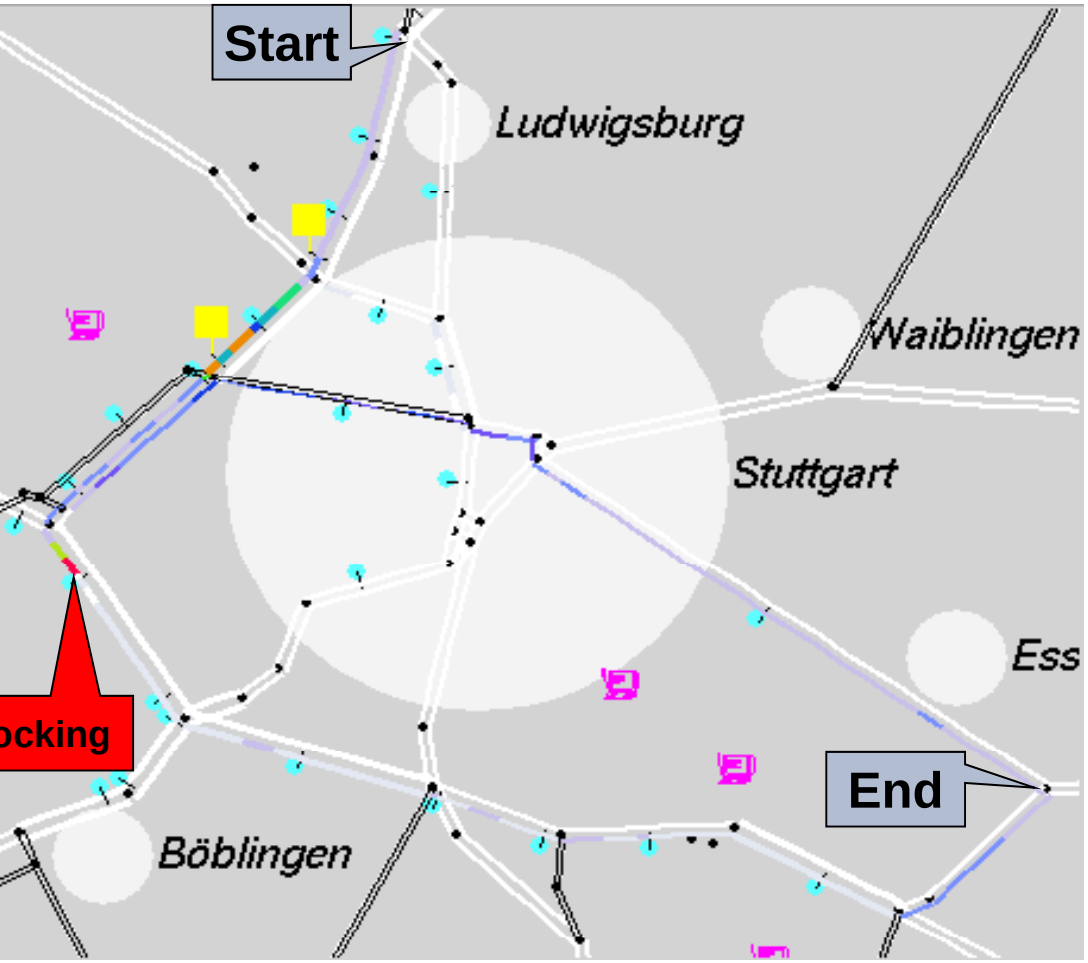
Market-Based Traffic Coordination

DAIMLERCHRYSLER

Auction Based Traffic Control

No Coordination



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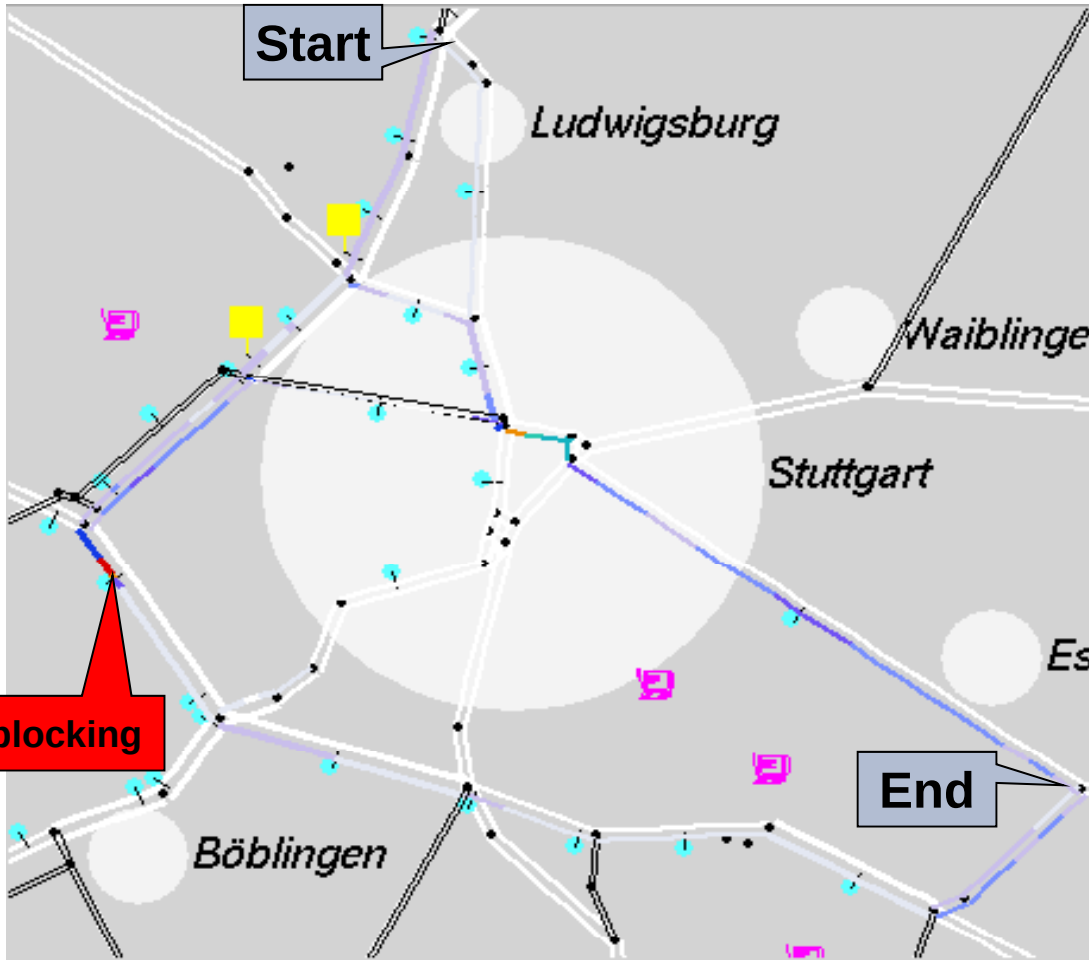

Time 08:21

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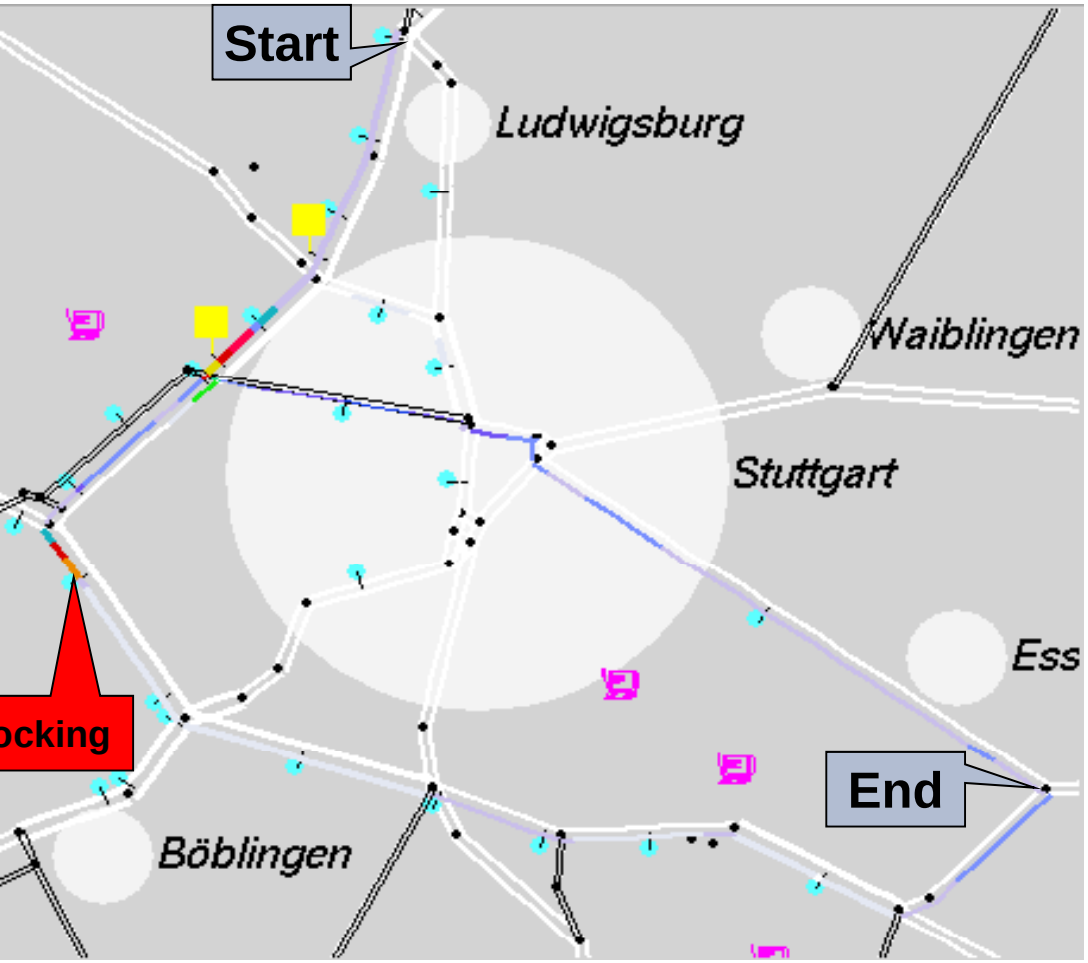
Market-Based Traffic Coordination

DAIMLERCHRYSLER

Auction Based Traffic Control

No Coordination



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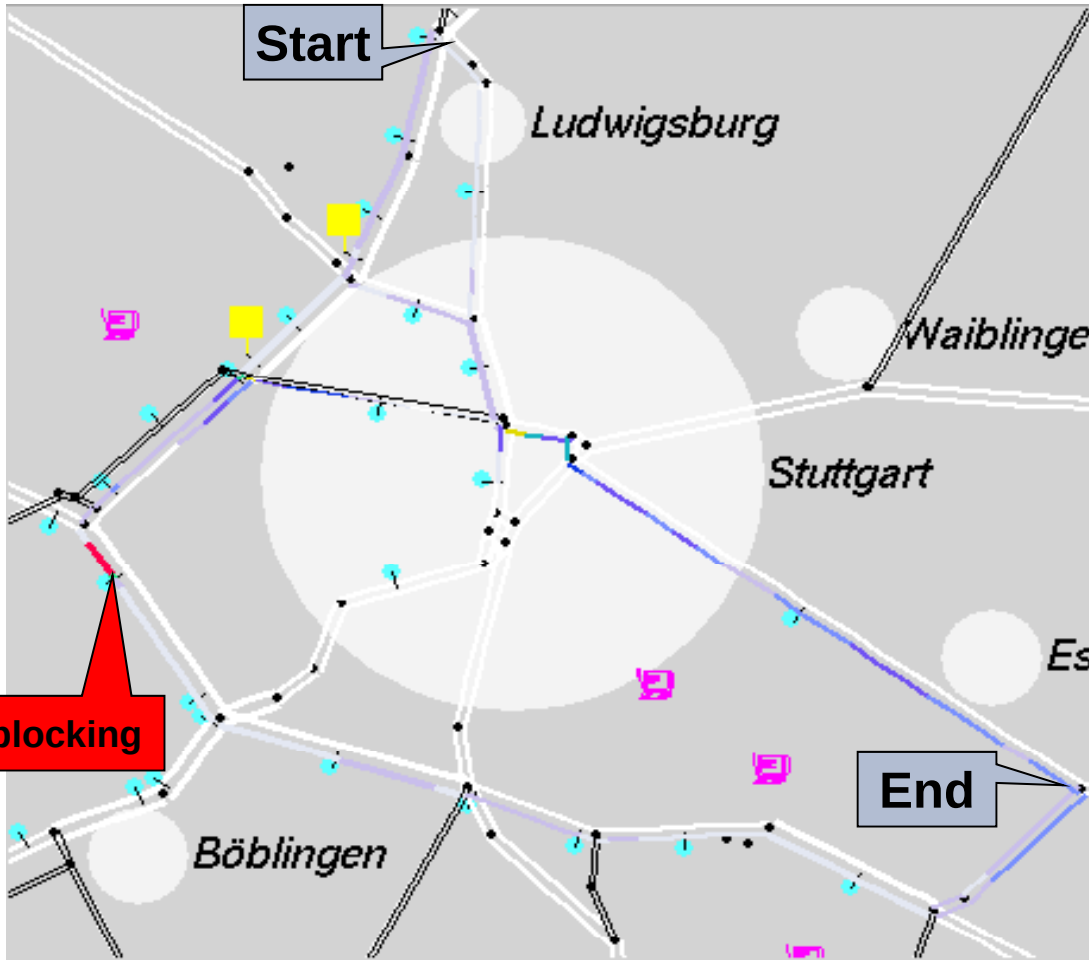

Time 08:24

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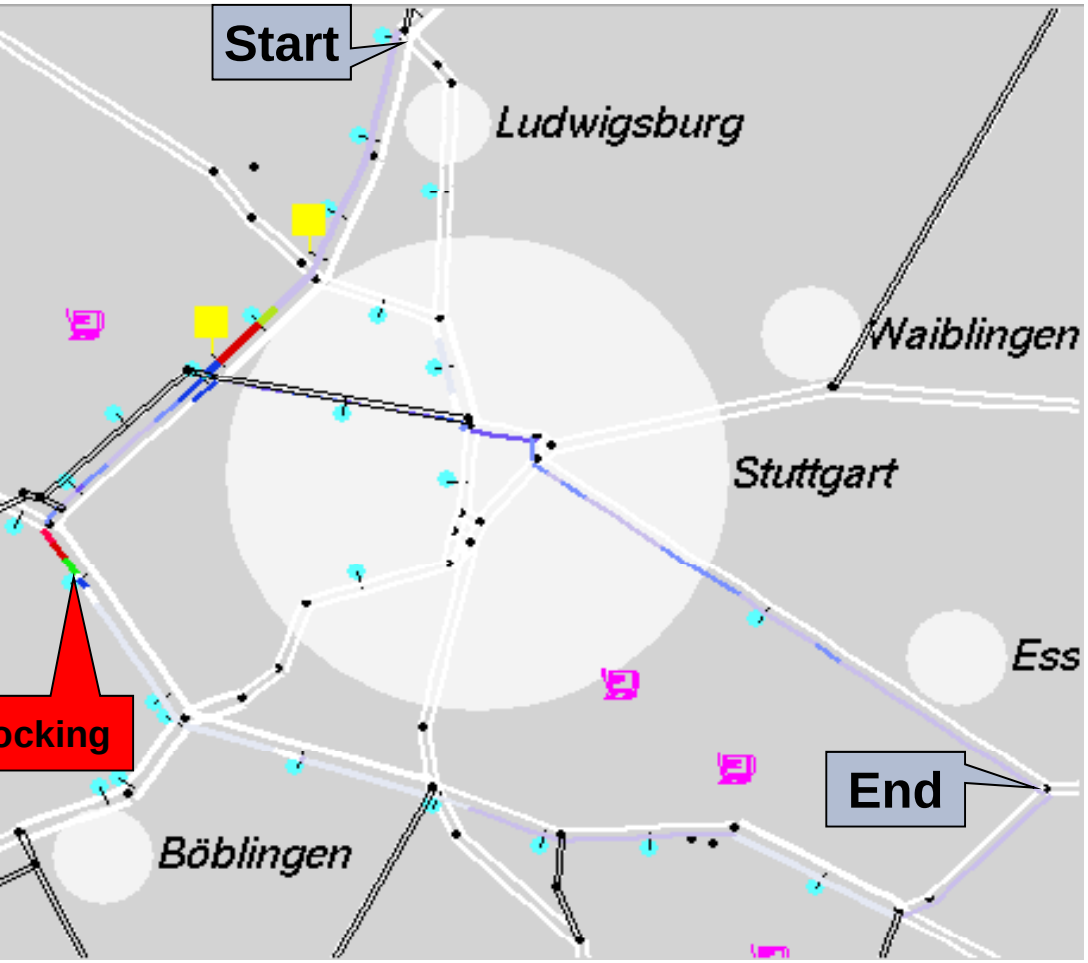
Market-Based Traffic Coordination

DAIMLERCHRYSLER

Auction Based Traffic Control

No Coordination



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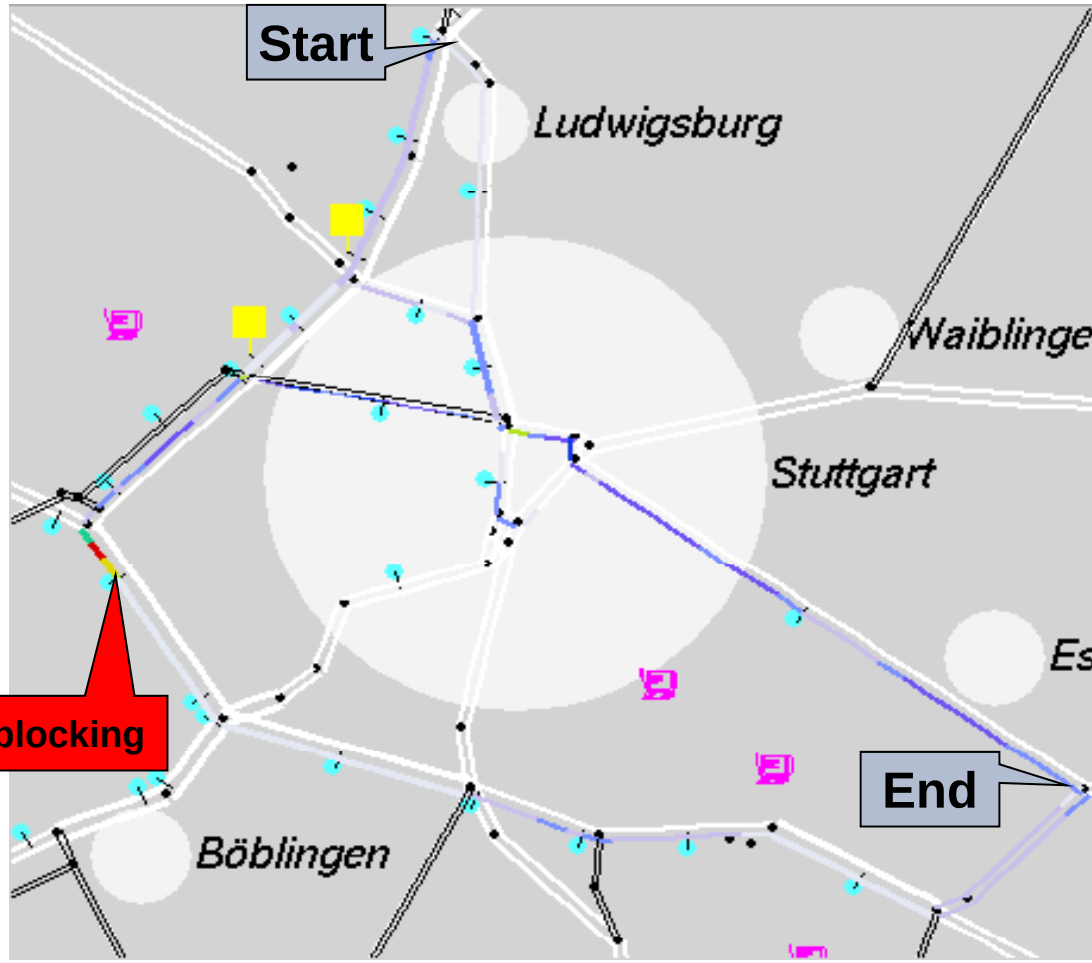

Time 08:27

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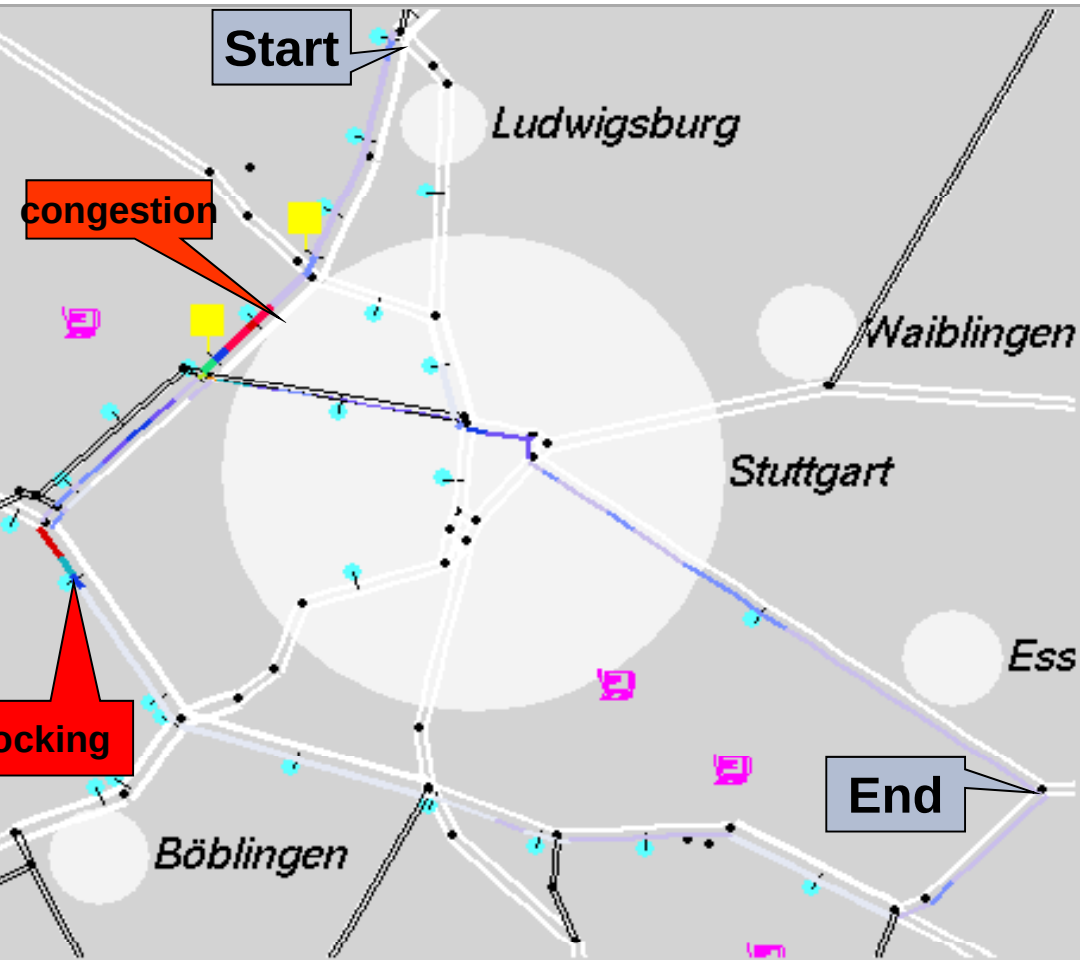
Market-Based Traffic Coordination

DAIMLERCHRYSLER

Auction Based Traffic Control

No Coordination



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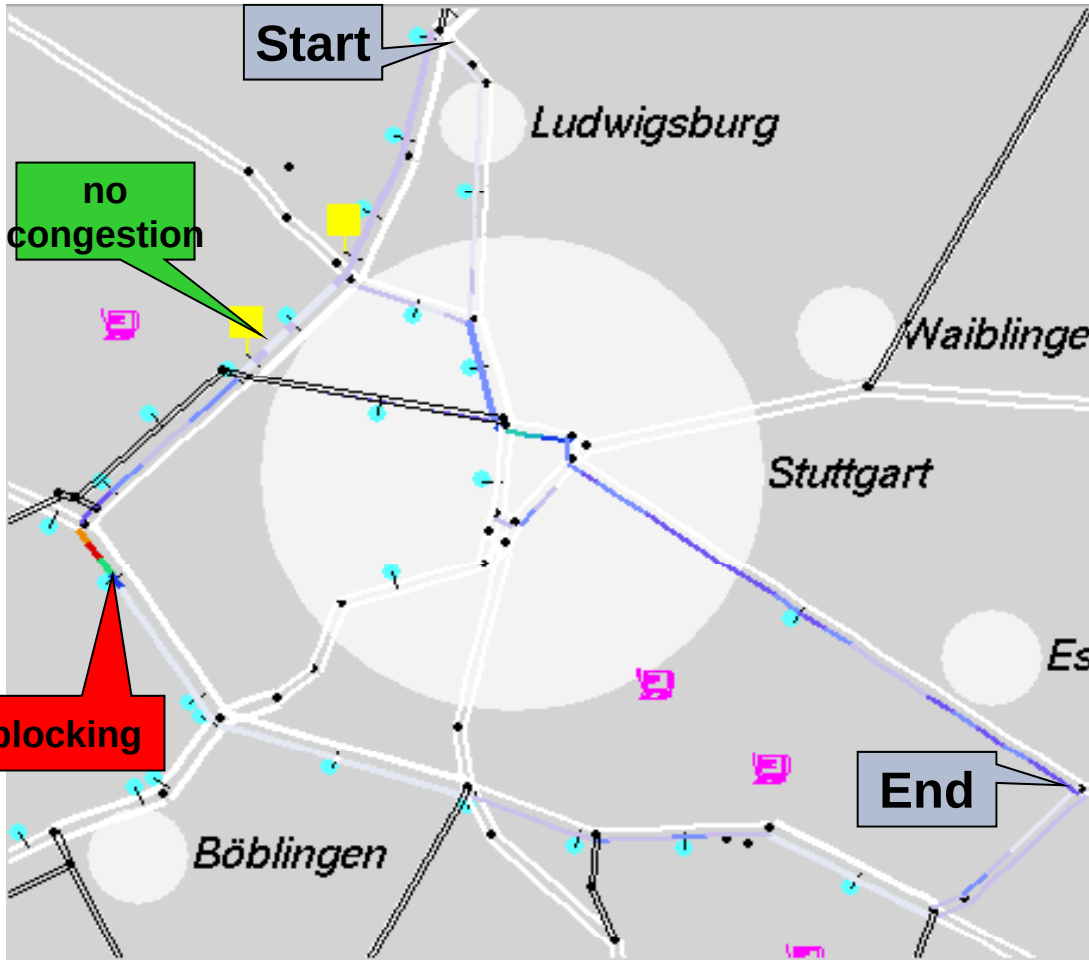


Time 08:30 **End of Simulation**

Market-Based Traffic Coordination

Prime Application

Road Pricing

Advantages of ABTC for Road Pricing:

- enables toll collection by supply and demand
- makes a better utilization of scarce road resources
- considers and enables individual needs of users
- supports new traffic concepts

Ideal Application: Toll Lanes

Market-Based Traffic Coordination

ABTC even works for toll-free roads !

Observation:

Bidding with virtual budgets = Giving priorities to the roads using a uniform scale

ABTC may be used for toll-free roads with 100 % virtual budgets

ABTC for toll roads:

charge fee in relation to bids of agents

ABTC for toll-free roads:

- assign using rights in relation to bids of agents
- do not collect fees for actual usage

Problem

Disobeying the assignments has no consequences for drivers

Market-Based Traffic Coordination

ABTC even works for toll-free roads !

How to make it attractive for drivers to follow coordination assignments ?

Basic principle of this approach

Drivers who get a more advantageous assignment have to pay to drivers who get a less advantageous assignment

- payment need not be directly from driver to driver
- payment need not involve real money

→ **ABTC for toll-free roads results in auction-based trading**

Market-Based Traffic Coordination

Coordination for toll-free roads: Trading

3 alternative trading principles:

- **Auction-Based Trading**

  most mature (already tested by simulation)

- **Exchange-Based Trading**

  theoretically most suited for application Individual Route Guidance

  enables traffic prediction on base of future intentions

- **Transactions between Predetermined Vehicles**

  theoretically most suited for application Individual Road Clearance

Market-Based Traffic Coordination

Auction-Based Trading

Solution Details

- let VDUs make bids for road segments (like in ABTC)
- assign road segments in auction (like in ABTC)
- collect fees for road segments used according to latest bids (like for toll-roads)
- at end of auction round:
  redistribute collected fees uniformly among auction participants

Problem

At time of bidding, one does not know if one will pay or get a refund

Solution

For each segment, prescribe equilibrium bound m
such that bids above m have to pay and bids below m get a refund
(VDUs are charged or refunded proportional to their biddings)

Market-Based Traffic Coordination

Exchange-Based Trading

Solution Details

- issue the goods of type „right to use road segments at a certain time“ into an exchange market with multiplicity corresponding to road segment capacity
- perform a call market for the rights to use road segments at a certain time, i.e. VDUs may buy and sell such rights at any time according to the call market rules
- assure that vehicles entering a road segment own the corresponding right
  => If they do not own it before, they buy it automatically for current market price
  If no right is available, they must buy surplus rights for a surplus rate

Note that up to now using up rights would cost money !

- redistribute the money collected by the rights used up by travelling in periodic intervals among the exchange participants

Market-Based Traffic Coordination

Transactions between Predetermined Vehicles

Auction-based trading: No direct transactions between vehicles

Exchange-based trading:
Only direct transactions between vehicles after price is determined
For determination of price no direct negotiations

Solution Details

3rd technique:
Determine seller and buyer first
Determine price thereafter

Prime application: Road clearan

Several techniques possible following the principles:

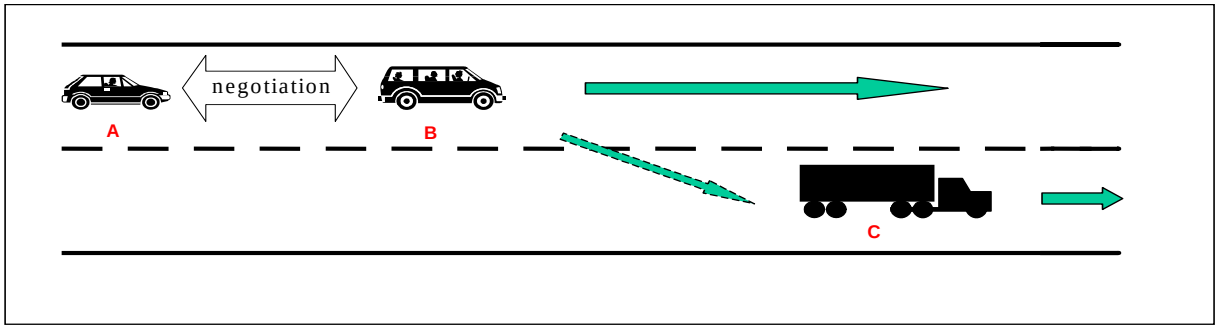
- Drivers have to obey legal rules (no prevention of passing !)
- If A passes B such that B is not inconvenienced this costs less than in case that B has to reduce speed

Transactions between Predetermined Vehicles

Different techniques:

- **Bilateral trading**

Solution Details



- **Continuous payment for passing**

Use a degressive scale !
i.e.: the more a vehicle is passed, the cheaper is the cost for the pass

Coordination for toll-free roads: Trading

Questions:

- How to make it attractive to participate in the coordination system ?
- How to prevent non-participators to obtain the same benefits ?

Answers:

- provide new traffic-specific information exclusively for participants

  E.g.: Use quotations in the exchange-based method for traffic predictions

- Include third-party offers into subscription system

  E.g.: gas stations, shops, local advertisement

Concept Summary

Purpose of existing dynamic navigation systems

Guide driver on most convenient route to his destination considering the current traffic conditions

Problem

When dynamic navigation systems enter mass market
=> congestions shift from one road to another
because all drivers try to escape the same way

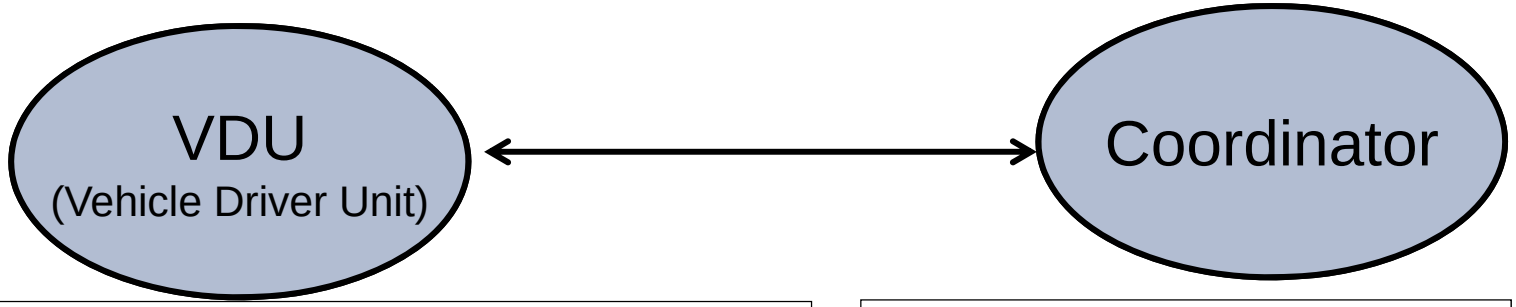
Conclusion

! **The penetration of any traffic advising system into mass market requires a coordination of users** !

Concept Summary

Software architecture

- for each vehicle:
- at a central platform:

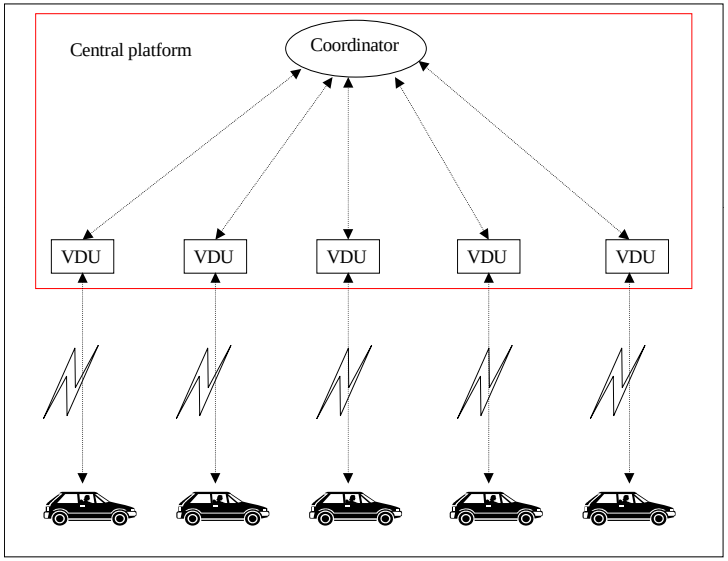


- knows individual strategies of driver
- communicates automatically with Coordinator
- may get new instructions from driver at any time

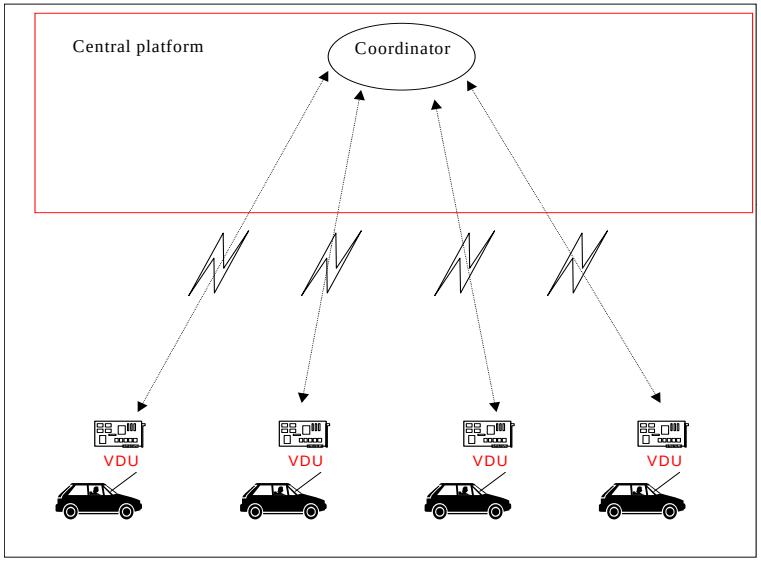
- accepts queries from VDUs
- distributes using rights to VDUs
- knows current traffic situation

Market-Based Traffic Coordination

Distribution of software on the existing hardware



Alternative 1:
VDUs on a central server

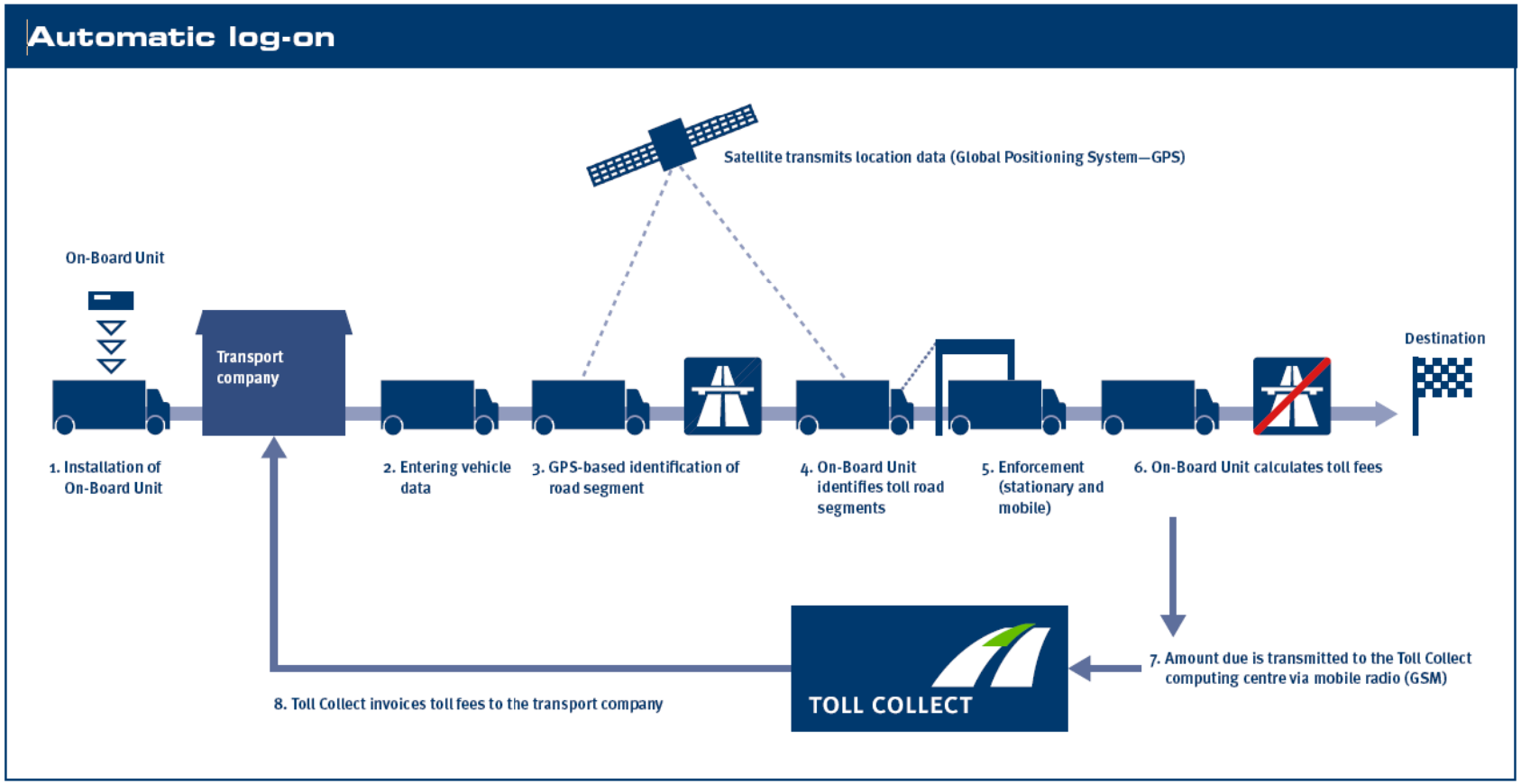


Alternative 2:
VDUs in the vehicles

In any case:
User interface for VDU in the vehicles

Market-Based Traffic Coordination

Possible platform for implementation in real life:



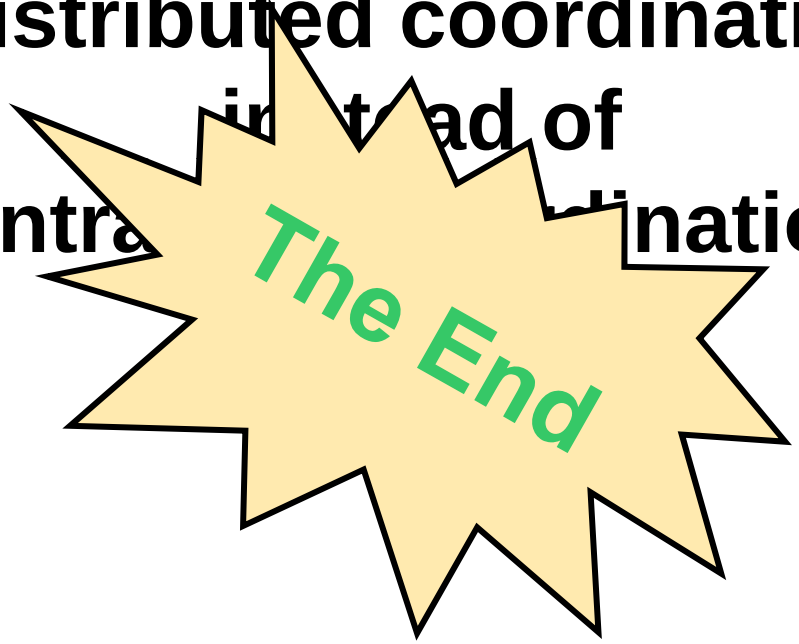
Toll collect 15 mts. demo video available at www.toll-collect.de
(can be shown here)

Conclusion

Distributed coordination

ir[illegible]t[illegible]ad of

centra[illegible]dination !



Thank you for your attention !