VITP: An Information Transfer Protocol for Vehicular Computing

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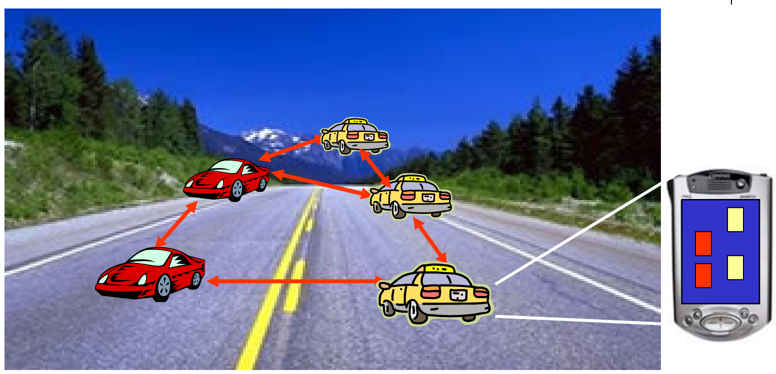
VANETs

- What are the issues in ad-hoc routing in a diverse, highly dynamic and highly mobile environment?
- Background
  - Internet on the Road
  - Configuration
    - Mobile and stationary ad-hoc nodes
  - Advantages
    1. Minimal delay in delivery
    2. Cost
    3. Relative routing decision making
  - Consortium of multiple participants

Previous work: TrafficView



- Enable drivers to view traffic in front of their cars, farther than they can see
- Based exclusively on vehicle-to-vehicle communication

VANETs - Applications

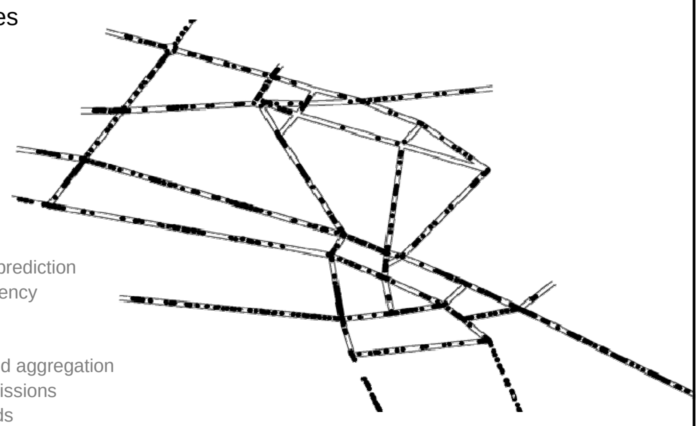
- Cooperative Driver Assistance
  - Dangerous situation warnings
  - Optimal driving environment
- Considerations
  - Position awareness
  - Low transmission latency
  - High reliability
  - High availability
- Decentralized Floating Car Data
  - Avoiding traffic congestion
  - Route weather conditions
- Considerations
  - Data coordination and aggregation
  - Periodic data transmissions
- Entertainment and Marketing
- Considerations
  - High bandwidth needs

MANETs and VANETs

- Similarities
  - Transmission range
  - Bandwidth
  - Antennae
  - Data capacity
- Differences
  - Energy

VANETs - Considerations

- Single dimensionality
- Variable densities
- Highly dynamic
- High speeds



- Position awareness/prediction
- Low transmission latency
- High reliability
- High availability
- Data coordination and aggregation
- Periodic data transmissions
- High bandwidth needs

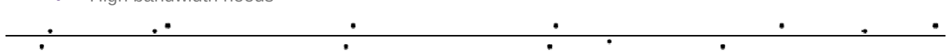
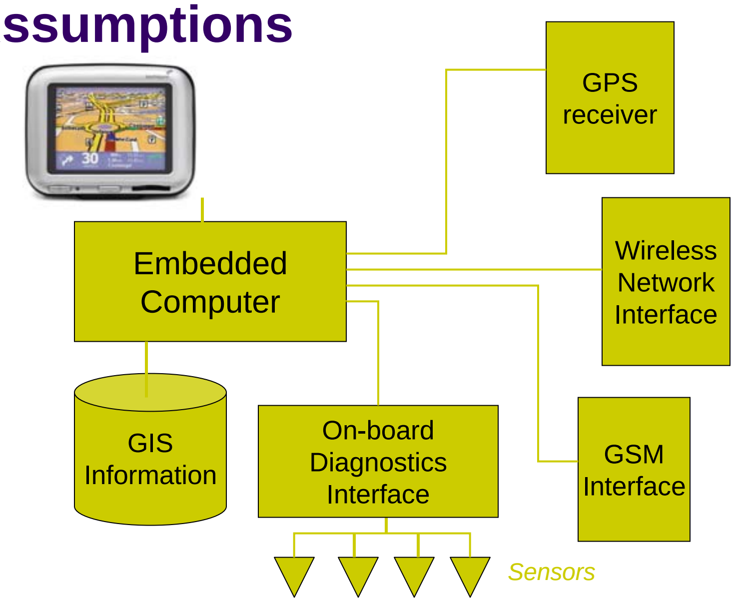


image taken from C. Lochert, et al. A Routing Strategy for Vehicular Ad Hoc Networks in City Environments.
image taken from H. Füßler, et al. A Comparison of Routing Strategies for Vehicular Networks.

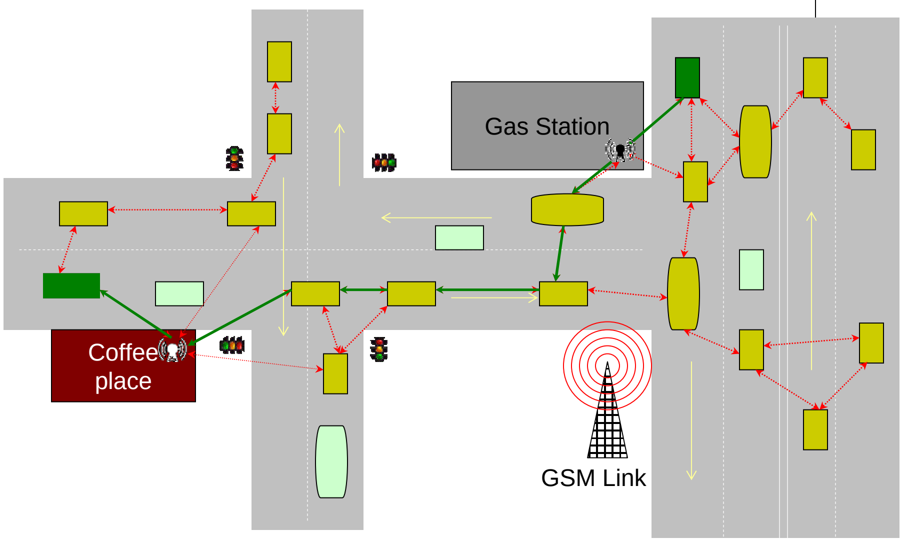
VANETs - Technology Assumptions



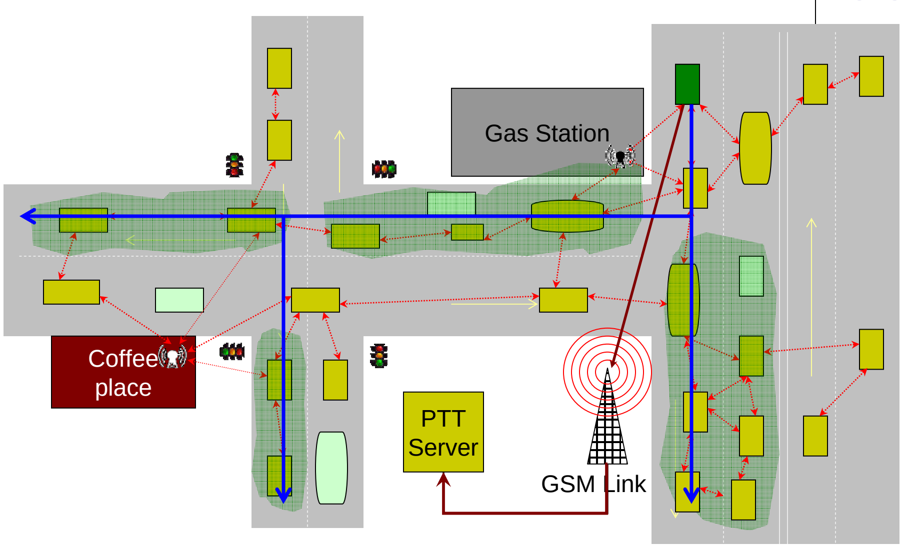
VANET Platform

- Consists of on-board sensors collecting information about its geographic location, operational conditions and environment.
- Fusing sensor data with geographic information.
- Operating as a node of a wireless ad-hoc network.
- Alternatively accessible through a cellular GSM/GPRS network.

VANETs Infrastructure Scenario



Motivation for VITP



Motivation and Contribution

- Location-oriented service provision to vehicles, taking advantage of the VANET infrastructure.
- On-demand distribution of information about:
  - Traffic conditions
  - Alerts
  - Roadside services
- Proposed solution:
  - Vehicular service provision based on extended client-server computing model established over the VANET.
  - Service interactions carried through the Vehicular Information Transfer Protocol (VITP).

Building blocks

- Information Transfer Protocol
- Nodes/Peers.
- A location encoding scheme.
- Others- performance optimizations (caching), quality assurance (termination conditions), privacy protection.

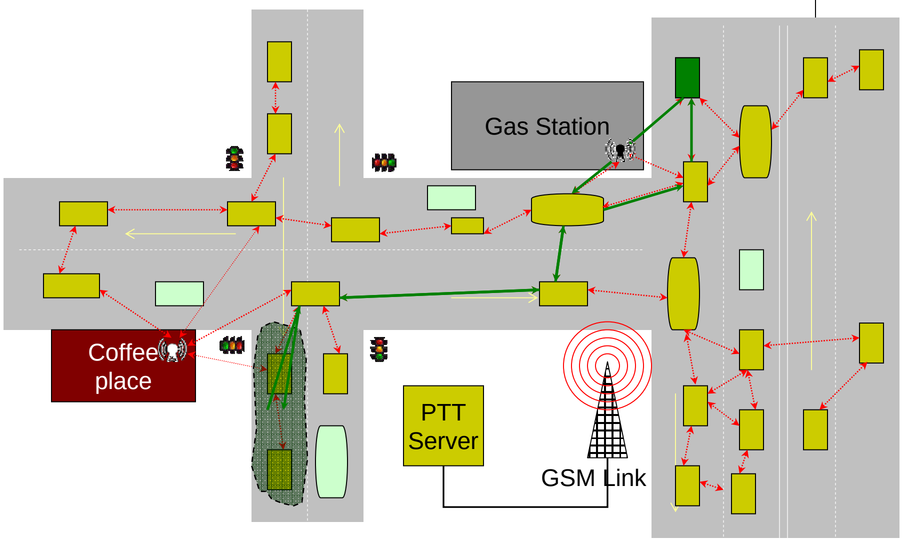
VITP

- Application-layer, stateless protocol.
- Supports the deployment of vehicular services on-top of VANET infrastructures.
- Specifies the syntax and semantics of VITP messages.
- VITP messages carry location-oriented requests and replies between VITP peers of a VANET.
- Is agnostic to underlying protocols (for routing and/or MAC-layer).

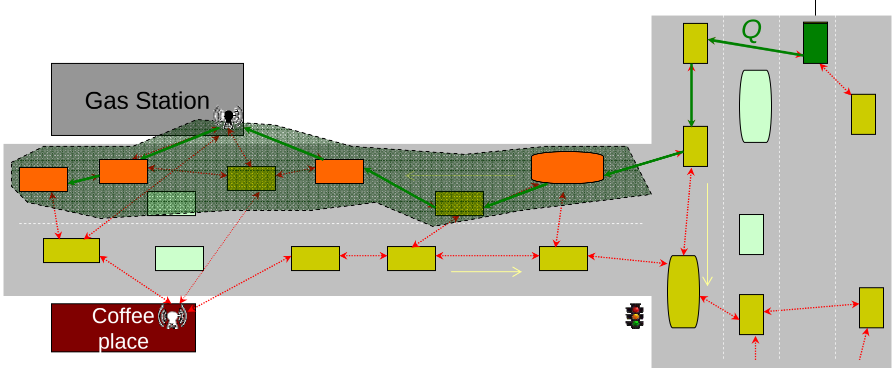
Design considerations

- Location-aware requests
- Virtual Ad-hoc Servers (VAHS)
- VITP transactions
- Return Conditions
- Protocol Layering

Location-oriented requests



Virtual Ad-Hoc Servers (VAHS)

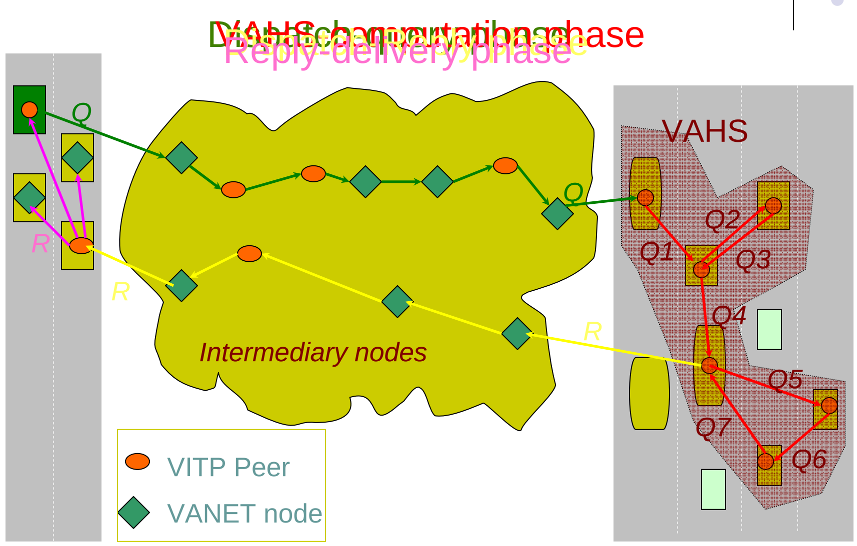


- The server that computes the reply is a dynamic collection of VITP peers that:
  - Run on vehicles moving inside the target-location area of Q.
  - Are willing and able to participate in Q's resolution.

Virtual Ad-Hoc Servers (VAHS)

- Established on the fly in an ad-hoc manner.
- Identified with a query and its target-location area.
- Follow a best-effort approach in serving queries.
- VAHS members maintain no information about other members of the VAHS.
- Maintain no explicit knowledge (state) about its constituent VITP peers.

VITP Transactions



Return Conditions

- Determine at which point in time the resolution of a VITP request can be considered done
- RC decision depends upon:
  - Query semantics
  - Timeout condition

VITP-message format

METHOD <uri> VITP/*<version_num>*
Target:: [*rd_id_dest,seg_id_dest*]
From: [*rd_id_src,seg_id_src*] with *<speed>*
Time: <current_time>
Expires: <expiration_time>
Cache-Control: <directive>
TTL: <time_to_live>
msgID: <unique_key>
Content-Length: <number_of_bytes>
CRLF
<message body>

VITP <uri> format

/<type>/<tag>?[<rc_expr>&…]&<param_expr>&…

- *type:* possible physical-world entities involved
- *tag*: actual information sought/disseminated
- Example VITP requests:

GET /vehicle/traffic?[cnt=10&tout=2000ms]&tframe=3min
GET /service/gas?[cnt=4&tout=1800ms]&price<2USD
POST /vehicle/alert?[cnt=*&tout=*]&type=slippery-road

Simulation setup

- Custom traffic-generator tool, modeling:
  - Highway traffic.
  - Highway with entries and exits every 1km.
  - Vehicles evenly distributed on the road, can change their speed and lane independently.
- Parameters: road length, number of lanes, average speed, average gap, number of service nodes, number of VITP peers.
  - A 3-lane, 25km-long highway.
  - Average vehicle speed of 20m/s.

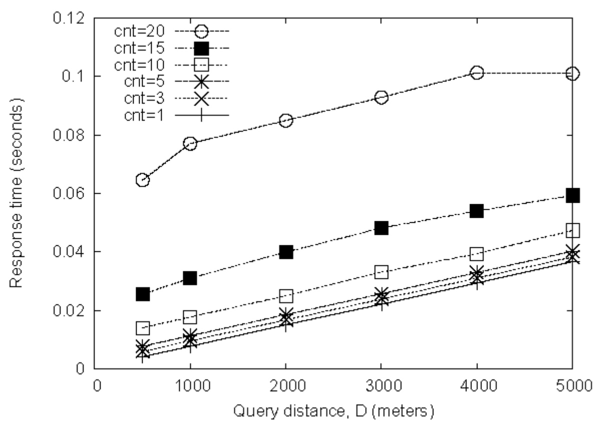
Simulation setup

- Ns-2 simulator, modeling:
  - An 802.11-compliant network.
  - 11 Mbps.
  - 250m transmission range.
  - Messages forwarded with geographic routing toward their destination

Metrics

- Response time: average (elapsed) time of successful VITP transactions.
- Dropping rate: percentage of unsuccessful queries for which vehicles time-out before receiving reply.
- Accuracy of VITP reply.
- Efficiency: percentage of messages actually employed in calculating a result.

Response time vs. Query distance



Target Segment length: 800 meters

Segment vehicle density: roughly 30 vehicles

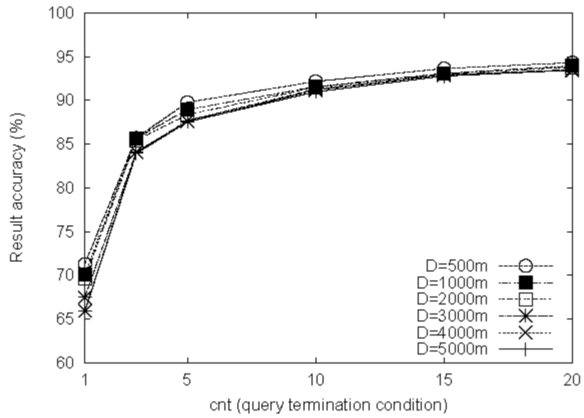
Response time increases with density gap increase

Dropping rates vs. Query distance

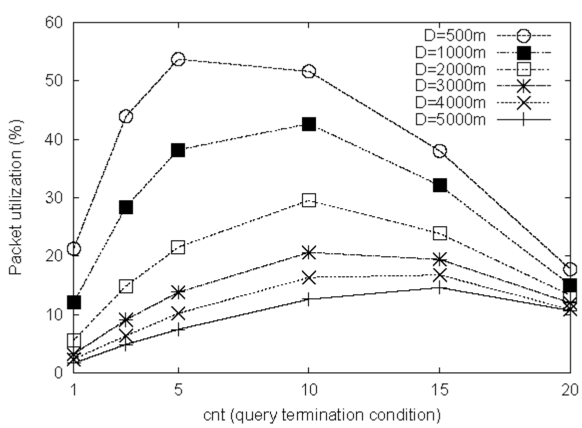
Query distance (D)	Forward dropping rate (%)	Backward dropping rate(%)
500	11.84	0.47
1000	18.41	0.64
2000	36.06	1.52
3000	50.70	2.72
4000	60.69	3.65
5000	65.95	4.24

- Forward dropping rate= query-dispatch failures/total # of queries
- Backward dropping rate=reply-delivery failures/total # of queries
- Increasing density gap increases dropping rate
- Increasing request rate increases dropping rate

Accuracy vs. Sampling size (cnt)



Efficiency vs. Sampling size



Increased gap density drastically decreases efficiency

Simulation Conclusions

- The choice and tuning of Return Conditions affect the accuracy of VITP results, the dropping rate of VITP transactions, and response time.
- There is a sampling-size value (*cnt*) that results to optimal efficiency with adequate accuracy: the choice of *cnt* should be done with care in realistic scenarios.

Strengths

- VITP has simple semantics
- VITP is lightweight, stateless
- VITP offers the ability to find optimal cnt values

Weaknesses

- Only pull-based solutions are explored
- No algorithm is given for predicting location of moving source on reply
- Piggybacking makes average determination difficult
- Return Condition value doesn't indicate timeout or count success in determining reply
- All simulation tests (except Accuracy) are dependent on the routing protocol used rather than VITP

Extensions

- The dropping rates in the query-dispatch phase can be prohibitively high. Need to investigate mechanisms to cope with this (caching, alternative networks)
- Finding the optimal routing protocol to work with VITP