An Ontology-Based Model for Vehicular Ad-hoc Networks

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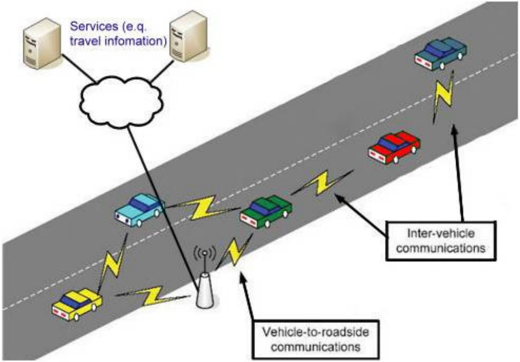
Outline

Vehicle-2-X communication

Vehicular communication standard: Wireless Access in Vehicular Environments (WAVE) or IEEE 802.11p

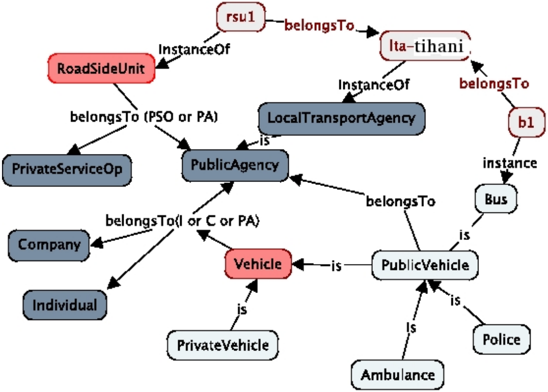


Geocast ad hoc routing protocol

- beaconing
- forwarding

Aim: integration of agent technology in the emerging field of vehicular networks.

Modeling VANETs terminology in DL



(in-tbox Vanet)
(define-primitive-role belongsTo :domain Vehicle
:range (or Individual Company PublicAgency))
(implies (or PrivateVehicle PublicVehicle) Vehicle)
(implies (or Bus Police) PublicVehicle)
(implies PublicVehicle (all belongsTo PublicAgency))
(implies LocalTransportAgengy PublicAgency)

(in-abox vanet-tihani Vanet)
(instance b1 Bus)
(instance lta-tihani
LocalTransportAgengy)
(instance rsu1 RoadSideUnit)
(related b1 lta-tihani belongsTo)
(related rsu1 lta-tihani
belongsTo)

Outline

Defining Competency Questions

Define the limits of the domain to be modeled and identify the main concepts and roles.

No	*Competency question*
CQ_1	Which are the vehicles on the same lane within a specific area?
CQ_2	Which data is available about the closest vehicle in front/behind?
CQ_3	Which is the closest vehicle approaching from opposite direction?
CQ_4	Which is the average speed for the next 5km?
CQ_5	Is it safe to change lane?
CQ_6	Is it safe to overtake the vehicle in front?
CQ_7	Which vehicles in the VANET can perform multi-hop routing?
CQ_8	Are there any emergency vehicles in the nearby?

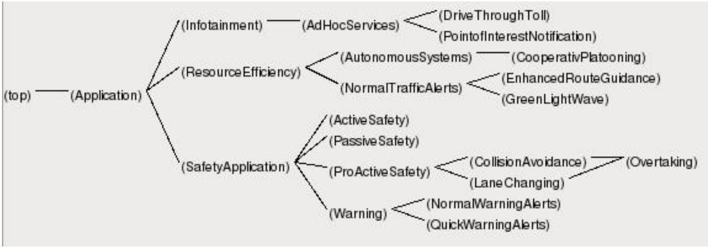
Reusing other ontologies

- Domain dependent
  - vehicular networks security: classifies the vulnerabilities based on the impact of the intrusion and functionality affected in routing protocols
  - ontology for autonomy layer of an automated vehicle: self-assessment of the perception system to monitor co-driving: environment conditions, moving obstacles, driver state
  - CAOVA (Car Accident lightweight Ontology for VANETs): structures information from two sources: i) collected from vehicle sensors when an accident occurs, or ii) imported from the General Estimates System accidents database.
- General - spatial (OSM), temporal, situation awareness.

Defining main concepts and roles

Organised on modules: communication, vehicular, traffic hazards, etc

(in-tbox Communication) (implies (or SafetyApplication Infotainment ResourceEfficiency) Application)
(implies (or Warning PassiveSafety ActiveSafety ProActiveSafety) SafetyApplication)
(implies (or QuickWarningAlerts NormalWarningAlerts) Warning)
(implies (or CollisionAvoidance LaneChanging ProActiveSafety)
(implies Overtaking (and LaneChanging CollisionAvoidance))
(implies (or NormalTrafficAlerts AutonomousSystems) ResourceEfficiency)
(implies(or GreenLightWave EnhancedRouteGuidance) NormalTrafficAlerts)
(implies CooperativPlatooning AutonomousSystems)
(implies AdHocServices Infotainment)



Communication Module

```
(implies CommunicationRegimes (or Bidirectional PositionBased))
(implies Bidirectional (and (=1 hasTarget (or Vehicle RoadSideUnit))
                  (some hasPhase Discovery)
                  (some hasPhase Connection)
                  (some hasPhase Data)
                  (some hasPhase Ending)))
(implies PositionBased (and OneWay (some hasTarget VehicleGroup)
                  (some hasPhase Discovery)
                  (some hasPhase Flooding)
                  (some hasAcknowledgement bottom)))
(equiv VehicleGroup (and (> 2 hasVehicle Vehicle) (all hasArea GeoRegion)))
(implies FastBidirectional (and Bidirectional (some hasControlChannel bottom)))
(implies SingleHop PositionBased)
(implies MultiHop PositionBased)
```

Messages module

(implies (or Alert Beacons Normal) MessageType)
(implies Beacons (some hasCommunicationRegime PermanentBased))
(equiv Priority (one-of 0 1 2 3 4))
(implies SafetyApplication ($>$ PDR 0.95))
(implies (or TTL RT) TimeCritical)
(implies LaneChanging ($<$ Latency 100))
(implies (or V2V V2I) TransmissionType)
(disjoint V2V V2I)
(implies (or T2V D2V V2B) V2V)
(implies V2RSU V2I)

Classifying warning alerts in vanets

```
(equiv NormalWarningAlerts (and Alert
                    (some hasCommunicationRegime MultiHopPositionBased)
                    (some hasApplicationType Warning)
                    (some hasTransmissionType (or V2V V2RSU))))
(implies RailCollisionWarning NormalWarningAllerts)
(implies SlowVehicleWarning NormalWarningAllerts)
(implies LimitedAccessWarning NormalWarningAllerts)
(implies WorkingAreaWarning NormalWarningAllerts)
(implies PostCrashWarning NormalWarningAllerts)
(implies HazardousLocationNotification NormalWarningAllerts)
(implies TrafficJamAheadWarning NormalWarningAllerts)
(implies (or Pit SlipperyRoadWay WaterOnLane OilOnLane) Hazard)
```

Primitive Data and Data Frames

Specified by Society of Automative Engineers (SAE)

(*implies Latitude PrimitiveDataElement*)

(*implies Longitude PrimitiveDataElement*)

(*implies Velocity PrimitiveDataElement*)

(*implies VehicleLength PrimitiveDataElement*)

(*implies Latitude* (*and*(*some hasValue Real*)
(*all measures UnitOfMeasure*)
(*some hasAcc Real*)))

(*implies DataFrame* (*and* (*some hasID ID*)
(*some hasDescription String*)
(*some hasContent PrimitiveDataElement*)))

(implies PositionDataFrame (and DataFrame (equal hasID 21)
(some hasLat Latitude) (some hasLong Longitude)))
(implies SenderDataFrame (and DataFrame (equal hasID 15)
(some hasLength Real) (some hasWidth Real) (some hasModel
Vehicle)))

Abox for data elements

```
(instance lat1 (and Latitude (= hasValue 40.6393)
               (= hasAcc .9)))
(instance long1(and Longitude (= hasValue 22.9446)
               (= hasAcc .9)))

(instance p1    (and PositionDataFrame
                (= hasLatitude lat1) (= hasLongitude long1)))
(instance       daciaLogan Vehicle)
(instance s1    (and SenderDataFrame
                (= hasLength 4.288) (= hasWidth 1.989)))
                (equals hasModel daciaLogan)))
```

Types of Messages

```
51. (implies Message (and (some hasComm CommunicationType)
52.             (some hasTransmission TransmissionMode)
53.             (some hasContent Data)
54.             (some hasRange Integer)))
57. (equiv CommunicationType (or V2V V2I))
58. (disjoint V2V V2I)
59. (equiv TransmissionMode (or Periodic EventDriven))
60. (disjoint Periodic EventDriven)
61. (implies PeriodicMessage (and Message
62.             (some hasTransmission Periodic)
63.             (some hasfrequency Time)))
64. (implies EventDrivenMessage (and Message
65.             (some hasTransmission Event-Driven)
66.             (some isTriggeredby Event)))
67. (implies Accident Event)
68. (implies TrafficJam Event)
69. (implies Overtaking Event)
70. (ShortRangeMessage (and Message (< hasRange 1000)))
```

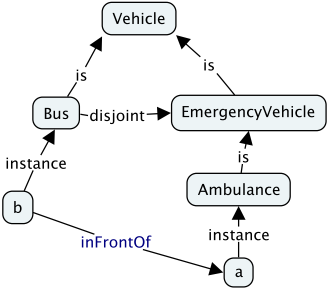
Lane Changing Warning Message

```
LaneChangeWarningMessage = ⟨ V2V, EventDriven
 Data[
   DataFrames [SenderDataFrame, PositionDataFrame],
   PrimitiveDataElements[Velocity, Acceleration,
                               TurnSignalStatus]
     ], 400⟩
```

Outline

Domain knowledge

- Vehicular ontologies



- Open Street Maps to Allegro Graph Server

Geospatial continuous reasoning

1. based on location service and beaconed data
2. Allegro GeoSpatial Reasoning:
   - get the cars inside a polygon that defines the street
   - get the cars on the same street ordered by their distance to the current car:

SELECT ?car ?p {?car ex:location ?p.
?car onStreet ex:way1.}

$$ORDER \quad BY < http://franz.com/ns/allegrograph/3.0/geospatial/fn/ \\ haversineKilometers > (?o, POINT(22.939007, 40.640392))$$

Temporal predicates in vehicular streams

Temporal predicate	Informal semantics
((move ?o) t_{start} t_{end})	object $?o$ is known to be moving between time t_{start} and time t_{end}
((approach ?o1 ?o2) t_{start} t_{end})	$?o1$ is approaching object $?o2$ during the time interval $[t_{start}, t_{end}]$
((behind ?o1 ?o2) t_{start} t_{end})	$?o1$ is behind object $?o2$ during the time interval $[t_{start}, t_{end}]$
((beside ?o1 ?o2) t_{start} t_{end})	$?o1$ is beside object $?o2$ during the time interval $[t_{start}, t_{end}]$
((in-front-of ?o1 ?o2) t_{start} t_{end})	$?o1$ is in front of object $?o2$ during the time interval $[t_{start}, t_{end}]$

Assertions of Primitive Events

11. (define-event-assertion ((move a1) 5 60))
12. (define-event-assertion ((move b1) 1 50))
13. (define-event-assertion ((approach a1 b1) 10 20))
14. (define-event-assertion ((behind a1 b1) 10 20))
15. (define-event-assertion ((beside a1 b1) 20 30))
16. (define-event-assertion ((in-front-of a1 b1) 30 60))

Complex Events Recognition: Racer Reasoning

121. (define-event-rule ((overtake ?i ?j) ?t1 ?t2)
122. ((?i vehicle) ?t0 ?tn)
123. ((?i ?j on-same-line) ?t0 ?tn)
124. ((move ?i) ?t0 ?t2)
125. ((move ?j) ?t1 ?t2)
126. ((approach ?i ?j) ?t1 ?t3)
127. ((behind ?i ?j) ?t1 ?t3)
128. ((beside ?i ?j) ?t3 ?t4)
129. ((in-front-of ?i ?j) ?t4 ?t2)
130. ((on-same-line ?i ?j) ?t4 ?t2))

Our system makes use of:

- the AllegroGraph system for geospatial reasoning
- RacerPro server for semantic and temporal reasoning.

Overtaking scenario

Before overtaking, `c1` should check that:

1. it is allowed to overtake;
2. `c2` does not signal left;
3. there is sufficient distance to return to the same lane without endangering vehicle `c3` coming from the opposite direction or breaching the norms (i.e. continuous line);
4. no other vehicle is overtaking `c1`, by checking the road behind;
5. signal intention to overtake for long enough to warn all other road users.

`(timenet-retrieve ((overtake c1 c2) ?t1 ?t2))` - to check if the vehicle `c1` successfully overtook `c2`

Outline

1. Vehicular Ad-Hoc Networks
2. Engineering the Vehicular Network Ontology
3. Car Overtaking Scenario
   - Domain knowledge
   - Geospatial reasoning
   - Temporal reasoning
4. **Conclusions**

Conclusions

- We developed a modular ontology for the vehicular networks domain.
- The standard reasoning services of DL (subsumption reasoning, satisfiability, consistency, instance retrieval) are complemented with geospatial and temporal reasoning,
- A step towards the integration of multi-agent technology in the vehicular networks domain

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Thank you!