Application-based solutions for networking vehicles

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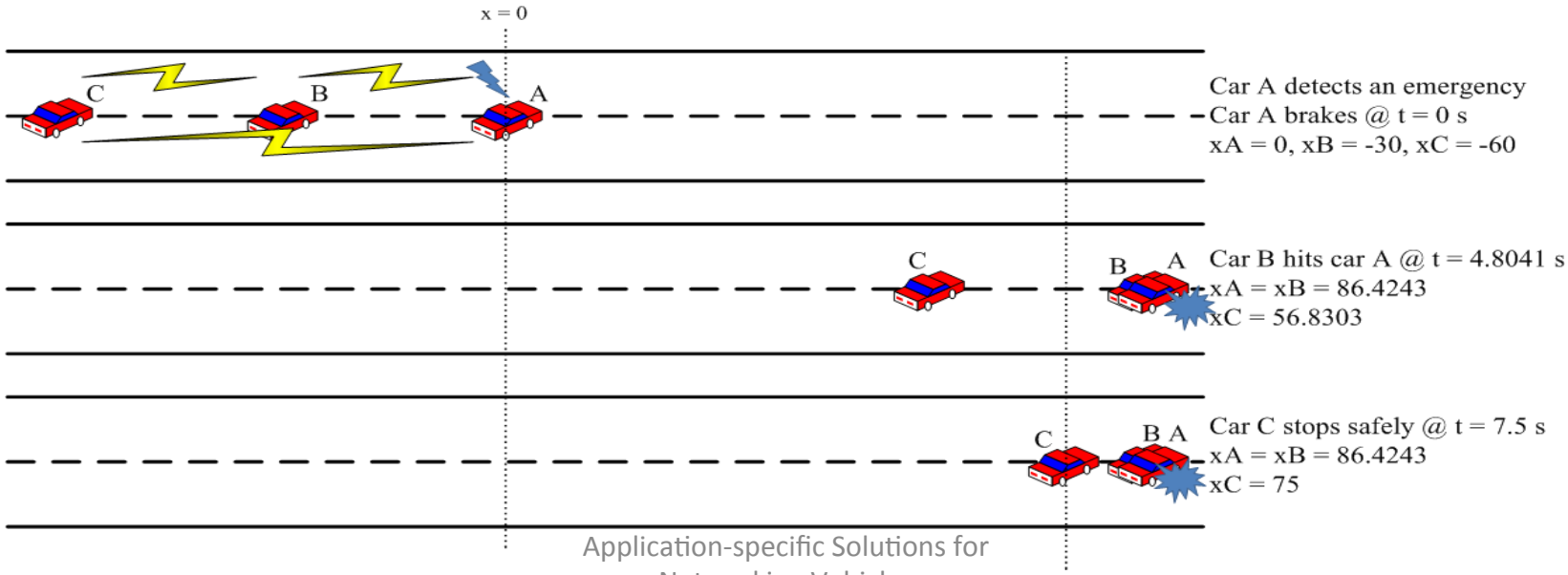
Introduction

- ***Routing solutions*** should be developed to enable wireless networking over vehicles
- We recognized the most efficient design approach for routing solutions in vehicular networks is the ***application-based*** approach
  - with respect to specific challenges, considerations, QoS requirements of each application
- Vehicular applications categorized as ***safety*** and ***non-safety***

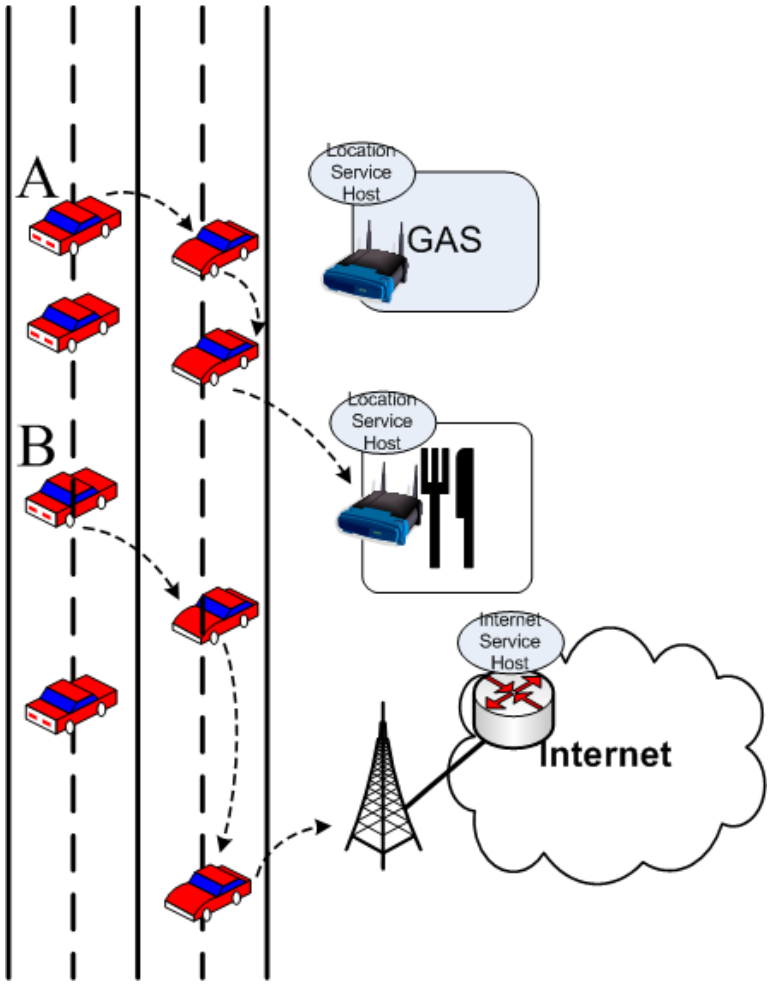
Safety applications

- Safety applications, e.g., collision warning to alert drivers, active collision avoidance
- Main need: notification of emergency, e.g., impending collisions, airbag deployment, ABS activation, should be sent to every vehicle present in the neighborhood
- This type of routing solutions called ***data dissemination***



Non-safety applications

- Non-safety applications, e.g., IP-based applications (require access to global Internet), location-based applications
- Main need: vehicular end-users need to establish a route to a Road-side Unit (RSU)
- This type of routing solutions called routing protocols



Outline

- EIDD (Enhanced Intersection-mode Data Dissemination)
  - Fully ad hoc data dissemination mechanism for safety applications
- CMGR (Connectivity-aware Minimum-delay Geographic Routing
  - Routing protocol for homogeneous networks for non-safety applications
- HMTR (Hybrid Multi-Technology Routing protocol)
  - Routing protocol for heterogeneous networks for non-safety applications

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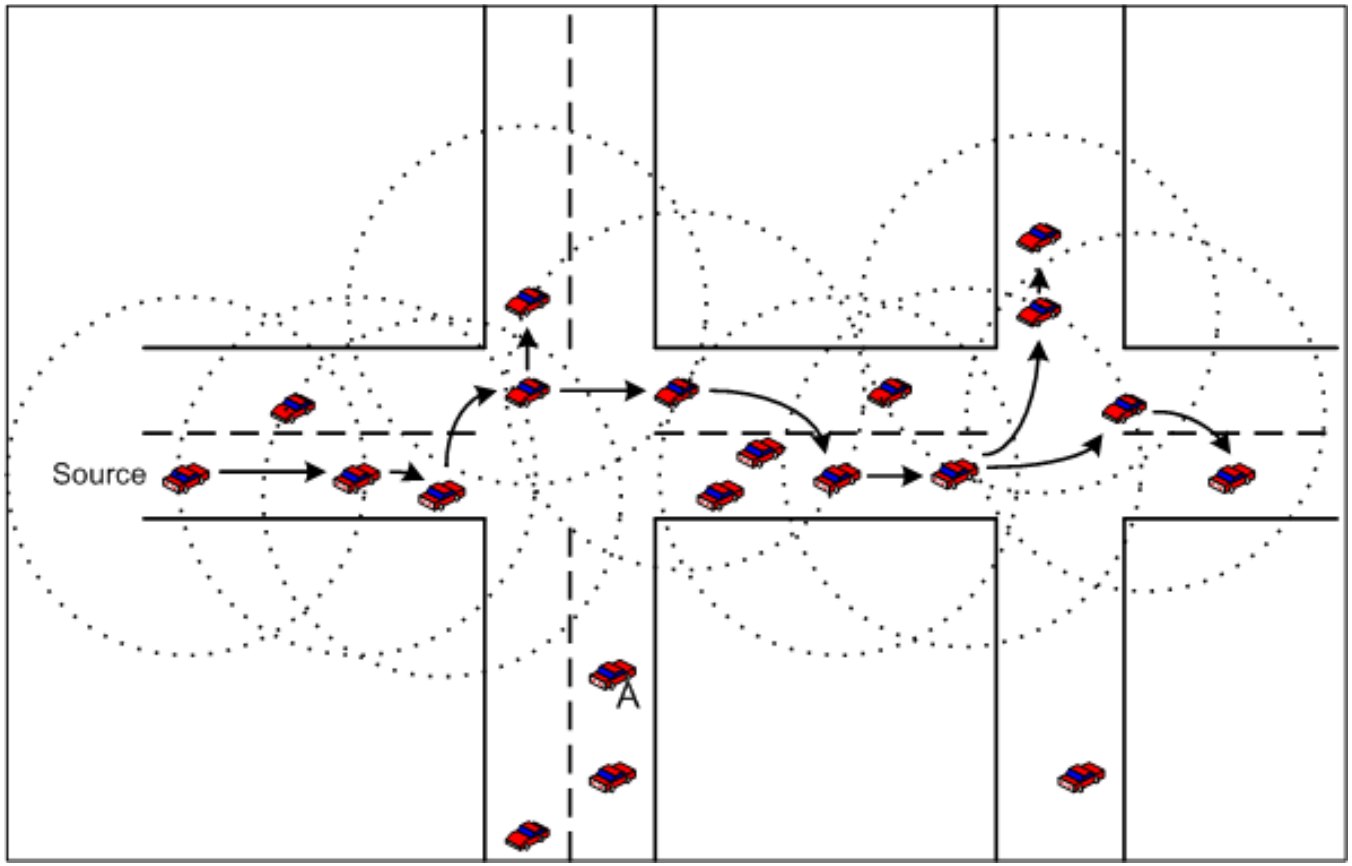
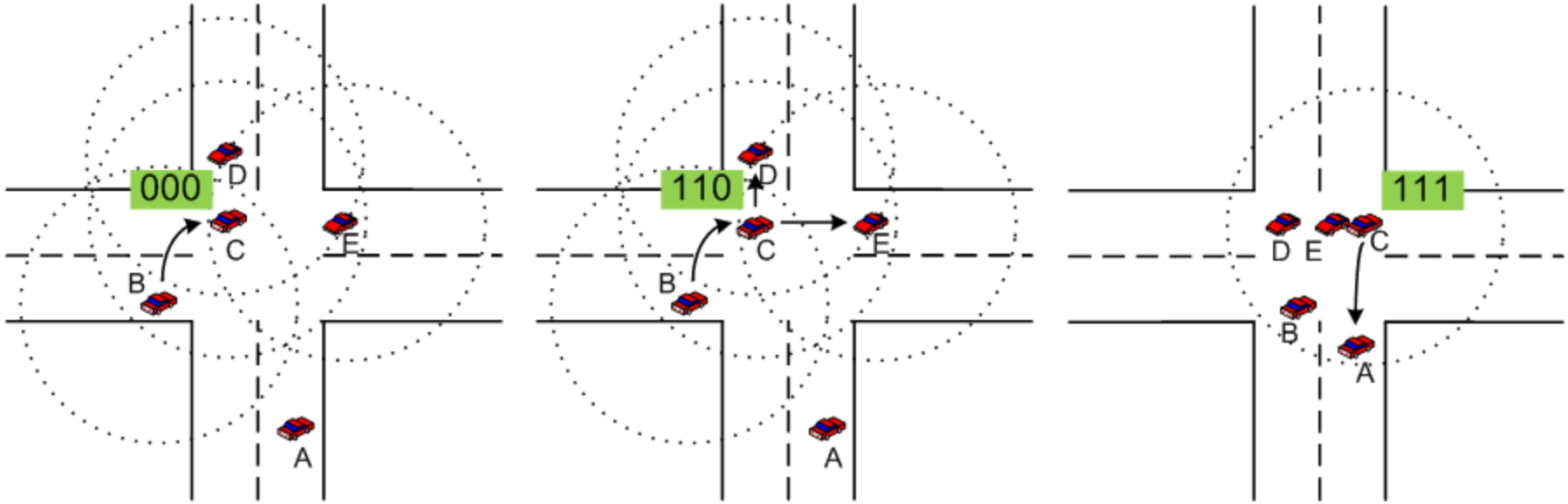
Data dissemination mechanisms for safety applications - challenges



- Challenge 1: Fully ad hoc
  - Most previous works rely on infrastructure
- Challenge 2: Failure scenarios when forwarding across intersections
  - Previous work does not guarantee message delivery at intersections

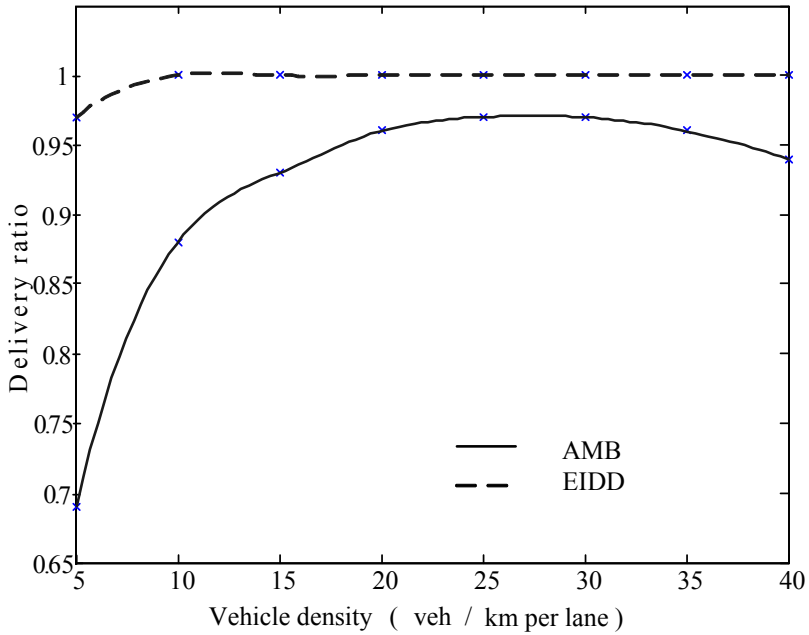
EIDD - Enhanced Intersection-mode Data Dissemination

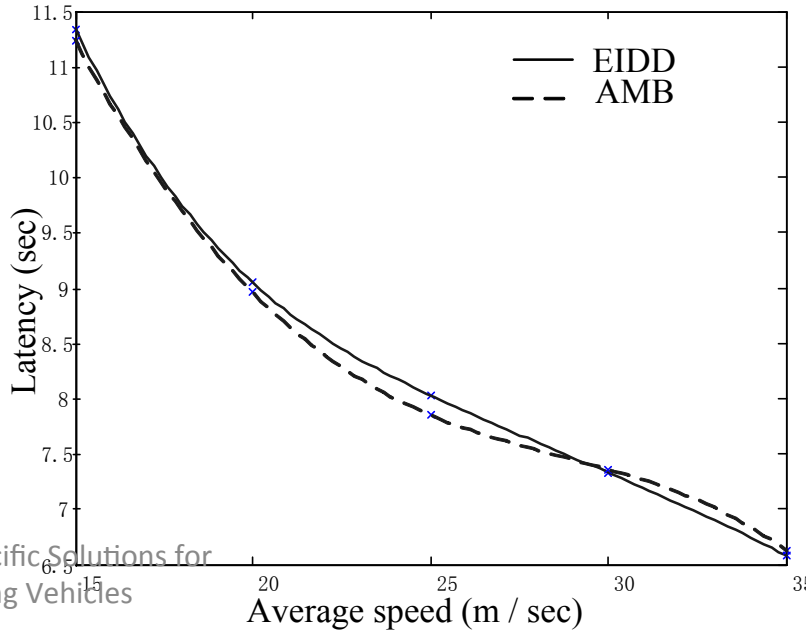


- Main feature: keep messages in the intersection long enough to make sure it has been disseminated to all outgoing roads

Performance evaluations

- Performance compared with ad hoc mechanism AMB
- Delivery Ratio of EIDD is close to 100% for almost all vehicle densities
- EIDD shows the highest improvement in lower vehicle densities where disconnections at intersections are more likely





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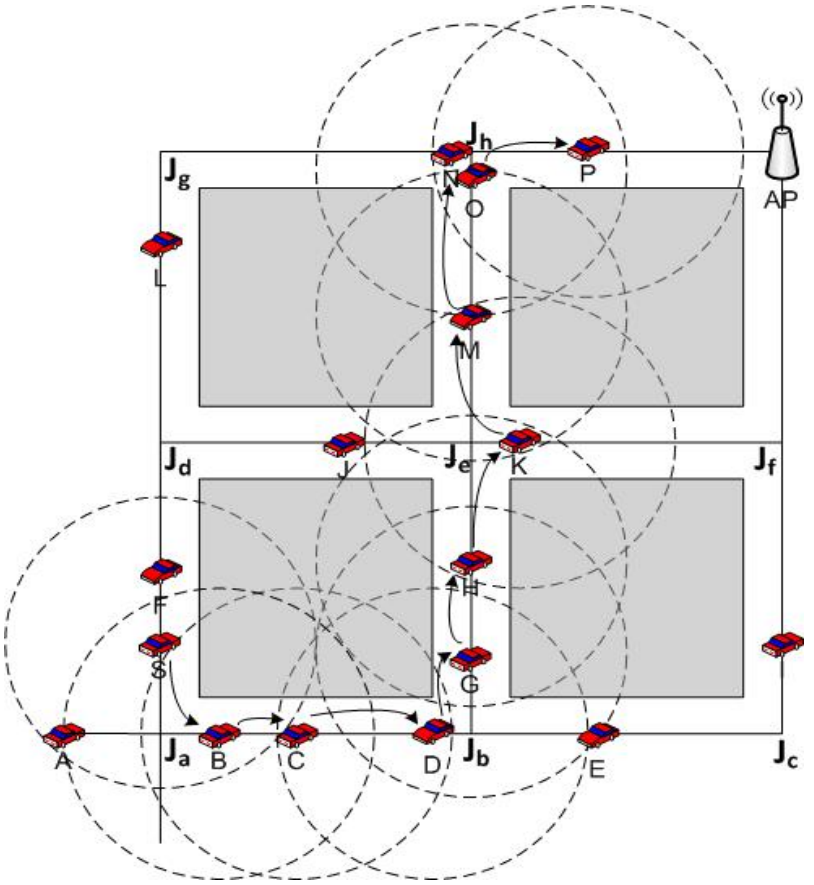
Routing protocols for homogeneous networks for non-safety - challenges

- Challenge 1: adaptable to both sparse and dense situations
  - Previous work designed to only deal with sparse situations-causing congestions in dense situations
- Challenge 2: metrics to assess connectivity should be real-time
  - Metrics used in previous work based on average values in offline databases
- Challenge 3: situation where source vehicle has turned a corner



CMGR - Connectivity-aware Minimum-delay Geographic Routing

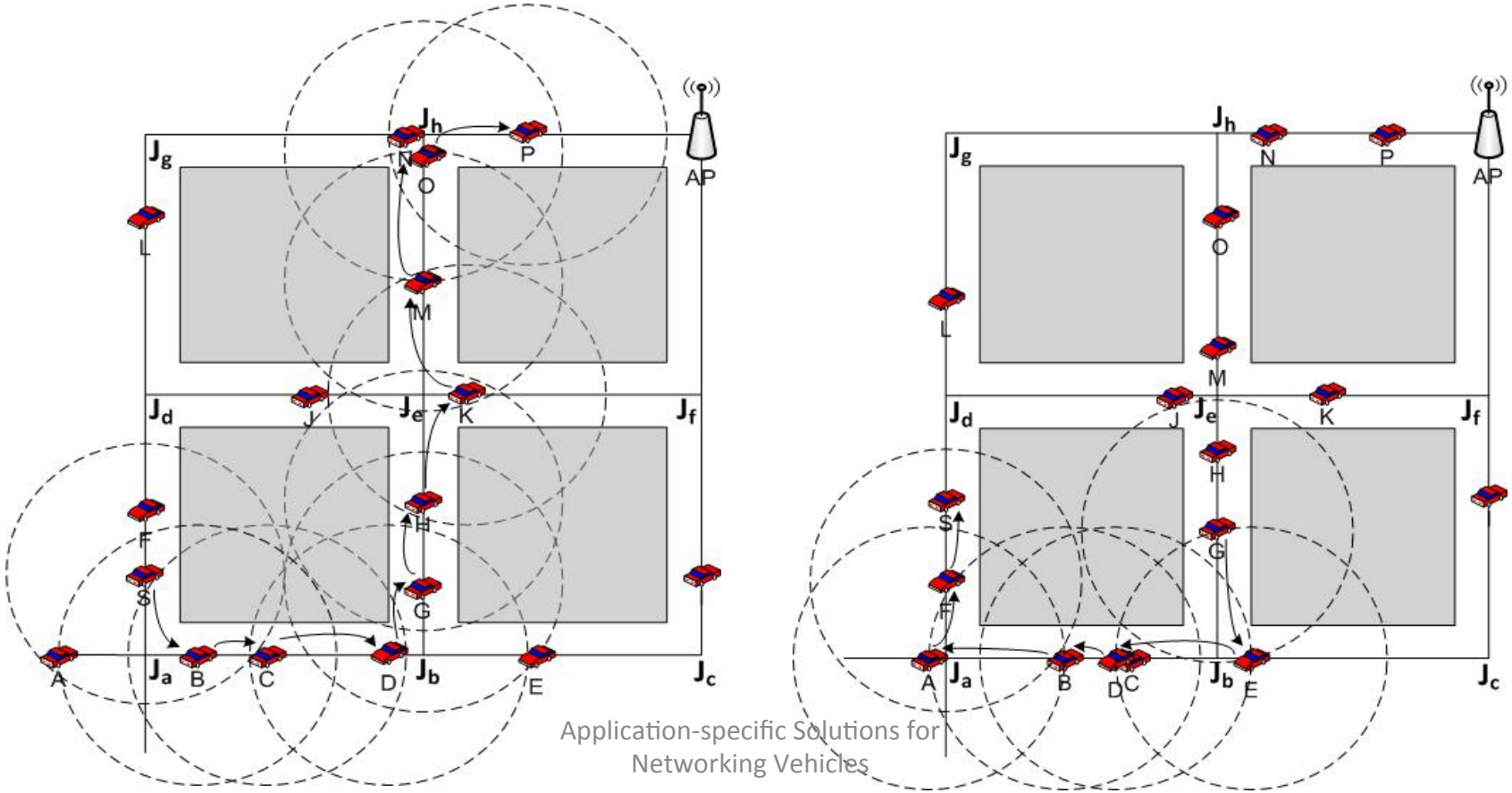
- Feature 1: adapting to vehicles densities - both sparse and dense situations
  - Connectivity-aware route selection in sparse situations and QoS-aware route selection, e.g., maximum available bandwidth in dense situations

$$\text{route } k = \begin{cases} \underset{\text{route } j \in V}{\arg\max}(RBW_j) & \exists \text{route } j:\ 1/C_j < R \\ \underset{\text{route } j \in U}{\arg\max}(C_j) & \text{otherwise} \end{cases}$$

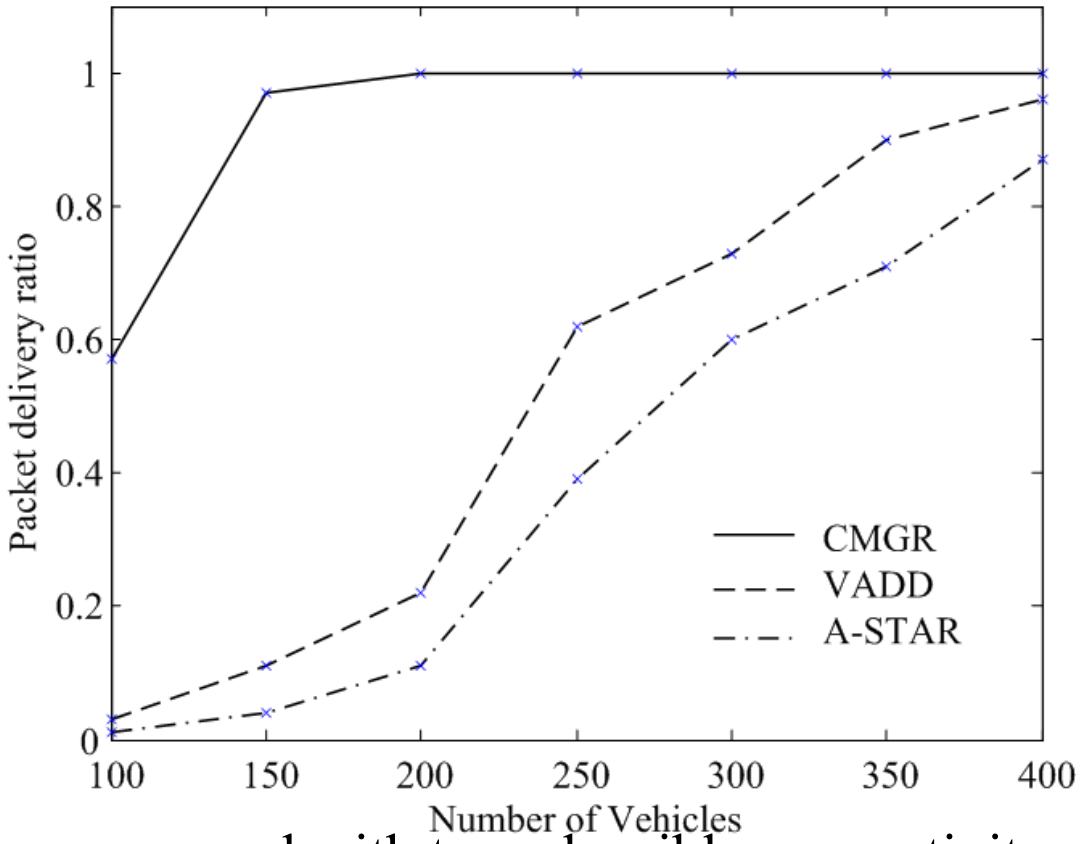
- Feature 2: real-time connectivity information calculated on-the-fly upon route discovery phase

CMGR - Connectivity-aware Minimum-delay Geographic Routing (cont.)

- Feature 3: vehicle tracking mechanism
  - Keep velocity vector of source in intersection until route reply comes



Performance evaluation



- Performance compared with two plausible connectivity-aware routing protocols, A-STAR and VADD
- 25% better delivery ratio at higher densities, 900% better delivery ratio at lower densities attributed to vehicle tracking mechanism

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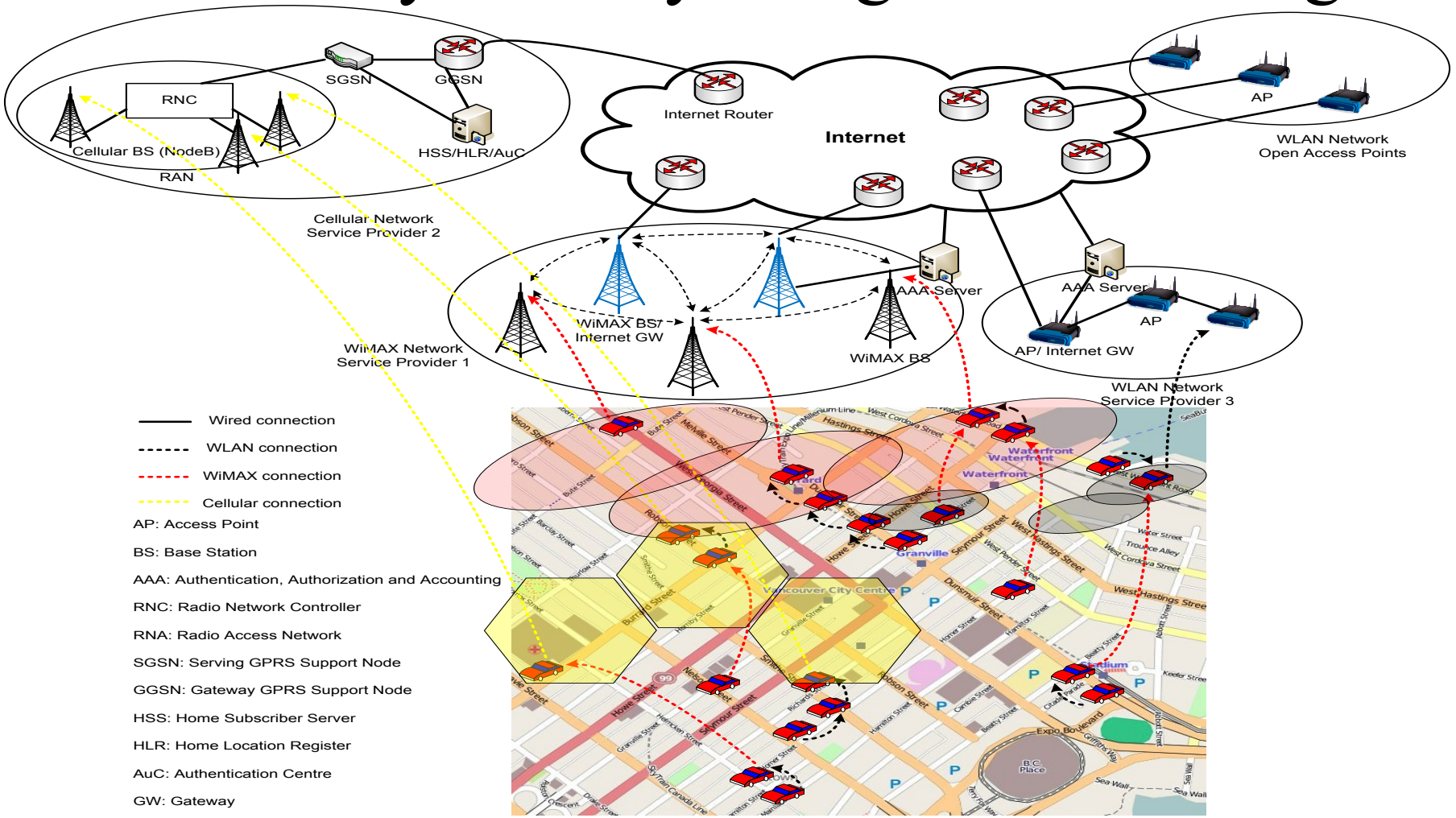
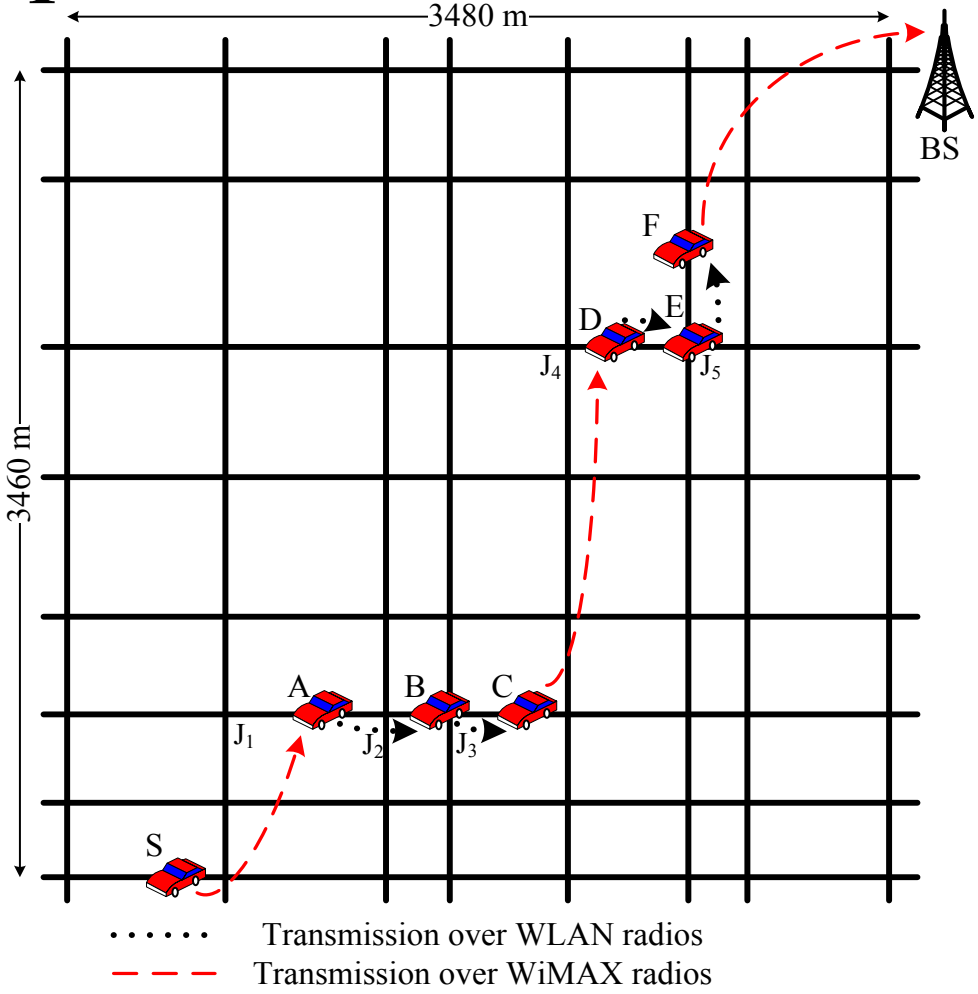
Routing protocols for heterogeneous networks for non-safety – newly recognized challenges



- Opportunity: long-range technologies that are more likely to be *stable* hops used as fixed parts of the route to improve reliability and robustness

HMTR - Hybrid Multi-Technology Routing protocol

- Feature 1: stability of hops evaluated, stable hops kept as fixed parts of routes
  - WiMAX radios more stable due to longer transmission ranges
  - Instead of classic trend (including locations only), for those using WiMAX their IDs included in the route to make them fixed parts of the route, i.e., (ID_S, L_A, L_B, ID_C, L_D, L_E, ID_F)



HMTR - Hybrid Multi-Technology Routing protocol (cont.)

- Feature 2: use of comprehensive set of decision-making metrics
  - ***Subscriber*** preferences in terms of travel time, data rate and price
  - ***Operator*** preferences in terms of residual bandwidth
  - Including connectivity-awareness in sparse situations

Operator perspective:

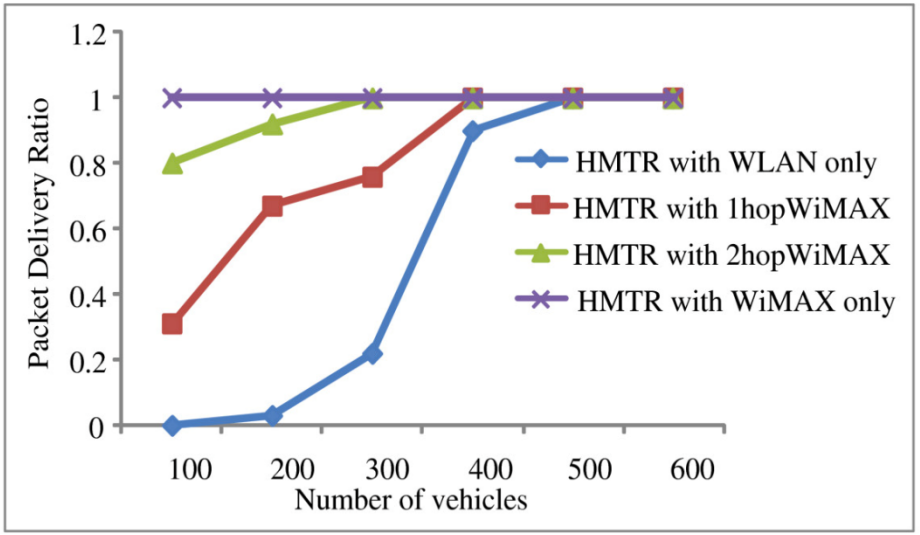
$$route\,k = \begin{cases} \arg\max_{route\ j \in V}(BW_j - BW_{req}) & \exists \text{route j: } 1/\rho_{\text{jmin}} < \text{R} \\ \arg\max_{route\ j \in U}(C_j) & Otherwise \end{cases}$$

Subscriber perspective:

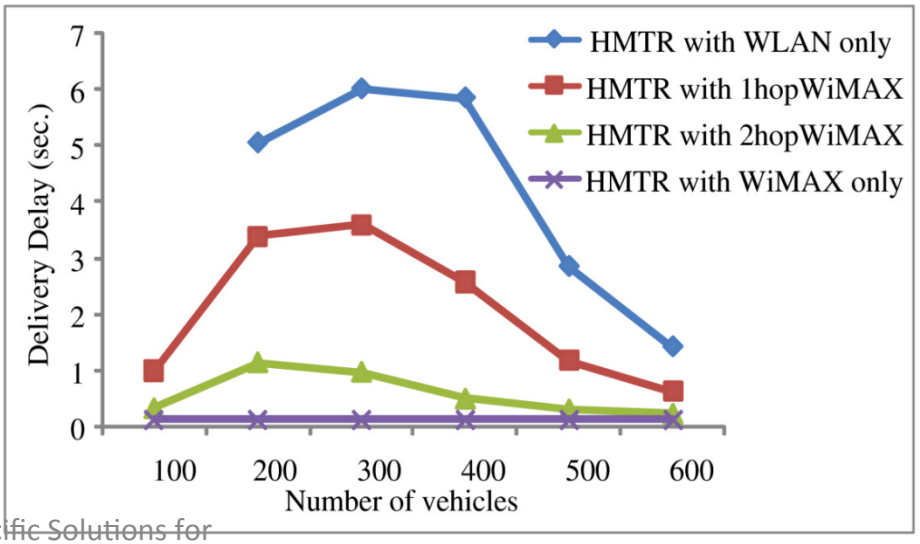
$$route\,k' = \begin{cases} \arg\max_{route\ j \in V'}(P_j) & \exists \text{route j: } 1/\rho_{\text{jmin}} < \text{R} \\ \arg\max_{route\ j \in U'}(C_j) & Otherwise \end{cases}$$

Performance evaluation

- Vehicles equipped with both WLAN and WiMAX
- WiMAX higher data rate, longer transmission ranges, higher costs
- More WiMAX forwarding yields better performance but higher costs
- Feature 3: best possible performance for a given budget
  - In previous works sacrificing performance or budget is inevitable



(a)



(b)

HMTR with 1hopWiMAX	12,600 Units/s
HMTR with 2hopWiMAX	21,656 Units/s
HMTR with WiMAX only	24,216 Units/s

Concluding remarks

- Aspect 1: performance improvement
  - Under specific conditions, EIDD shows delivery ratio of 100% for almost all densities
  - Under specific conditions, CMGR performs 25% and 900% better than its peers at high and low vehicle densities in terms of delivery ratio

Concluding remarks (cont.)

- Aspect 2: newly proposed challenges
  - Adapting routing protocols to sparse and dense situations
  - Using real-time measures of connectivity
  - Dealing with source vehicle turning a corner
- Aspect 3: proposed protocols adaptable to a wide range of needs and conditions required by vehicles
  - HMTR achieves best performance for any given budget, whereas in previous work sacrificing performance or budget was inevitable

Thank you!