THE FULLY NETWORKED CAR

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Dynamic Vehicle Group Architecture for Efficient V2V and V2R Networking

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o Need to minimize traffic casualty and injuries
  - US---43,000 (casualty) and ~5 million (injuries)

o Need to reduce congestion/travel time/pollution/ fuel use
  - US---cost of congestion $12.5B -> $63B ('82 to '03; 80%)
  - About 3B gallons of fuel wasted on congestion per year
  - Highway congestion accounts for ~50% of CO_2 emissions

o Vehicle communications to help prevent crashes or reduce congestion
  - Many injuries caused by roadway departures and intersection incidents, which may be reduced by communications
  - Currently vehicles have no wireless communications with other vehicles running nearby (V2V) or with roadside infrastructure (V2R)
  - Safety and mobility may be improved by sharing information about nearby drivers or road situations

Vehicle Group Communications Background
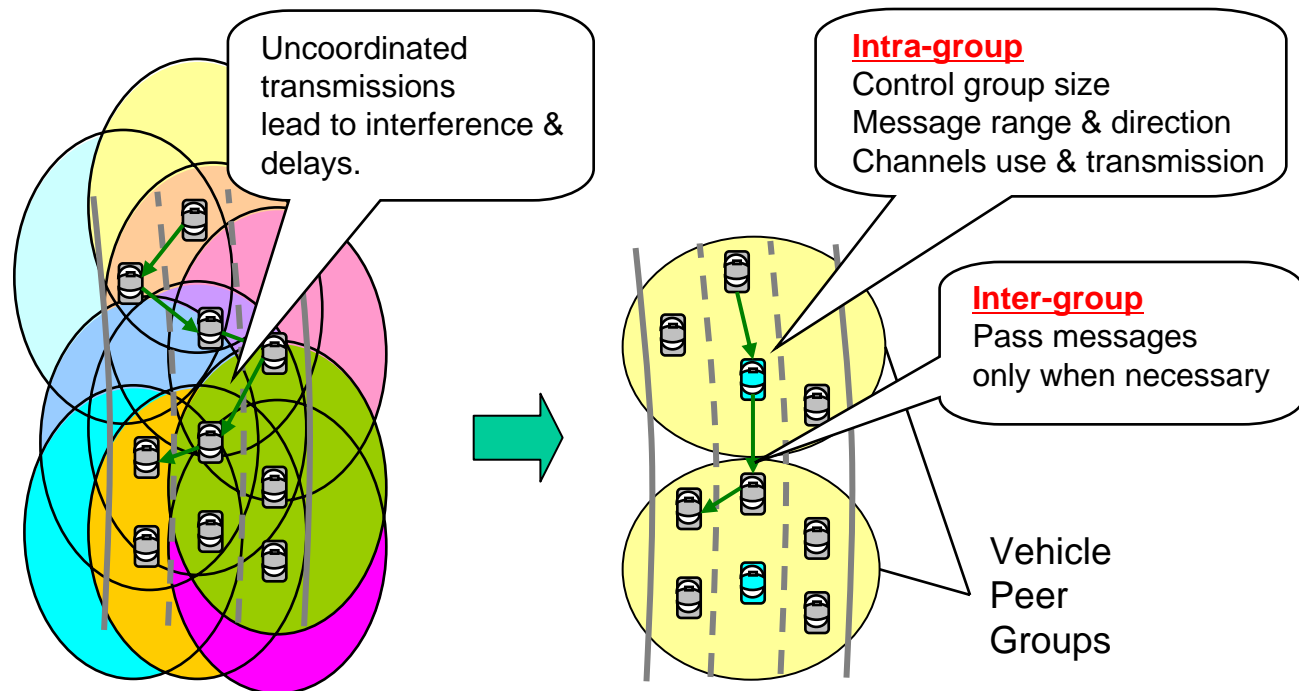## Proposal of Vehicle Peer Group for Ad Hoc Communication

o Challenges of ad hoc communications:
- Scalability
- Fast & reliable communication
- Secure

o Vehicle Peer Group as manageable unit for vehicle ad hoc communications:
- Partitioned ad hoc network
- Control of partition (size, range) & message direction, coordination on transmissions, routing & multicast

Uncoordinated transmissions lead to interference & delays.

Intra-group
Control group size
Message range & direction
Channels use & transmission

Inter-group
Pass messages only when necessary

Vehicle Peer Groups

o Emergency information distribution (support active safety)
- Messages can be delivered beyond the one-hop radio reach
- Dissemination routes are maintained at all times to enable immediate transmission use

Traffic Direction

Sudden Entry

Emergency Brake
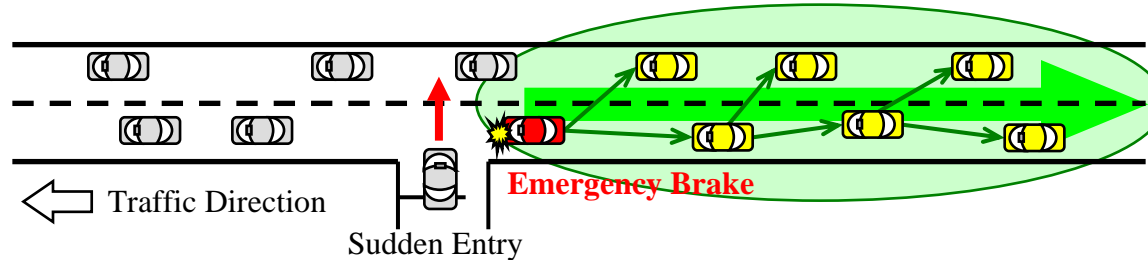
o Information download (information update applications)
- Enable each group member to download a segment, during short communication with roadside unit, to be shared with other members afterwards to obtain larger data message / file
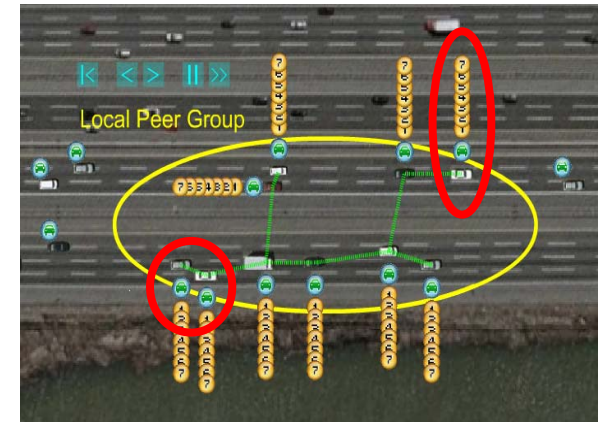
LPG Collaborative Download Concept

Packets Sent

LPG

RSU Communication Range

Traffic Info

Map Data

MAP
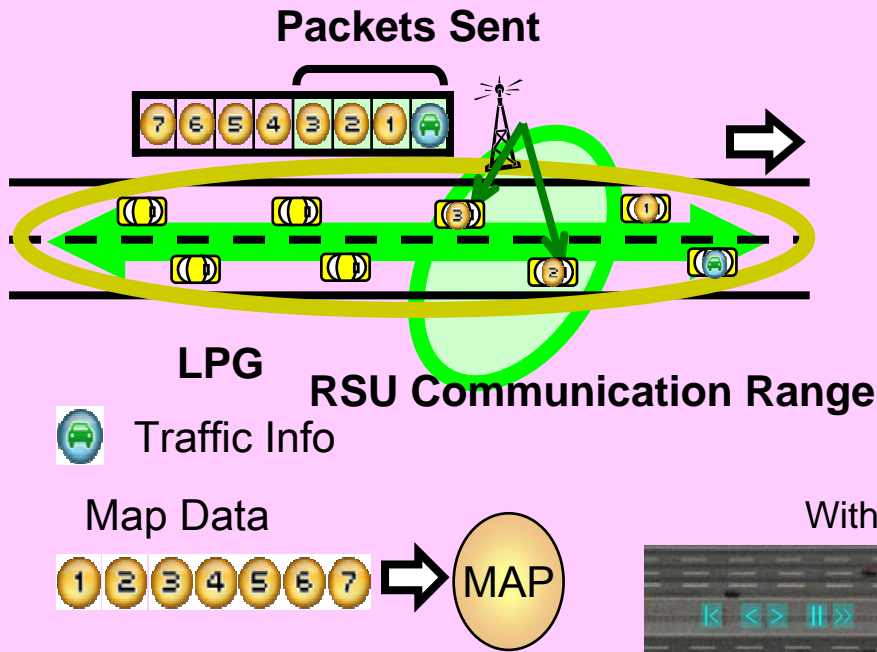
Without LPG

Each vehicle receives a small amount of data from RSU (some vehicles receive nothing due to shadowing, etc)
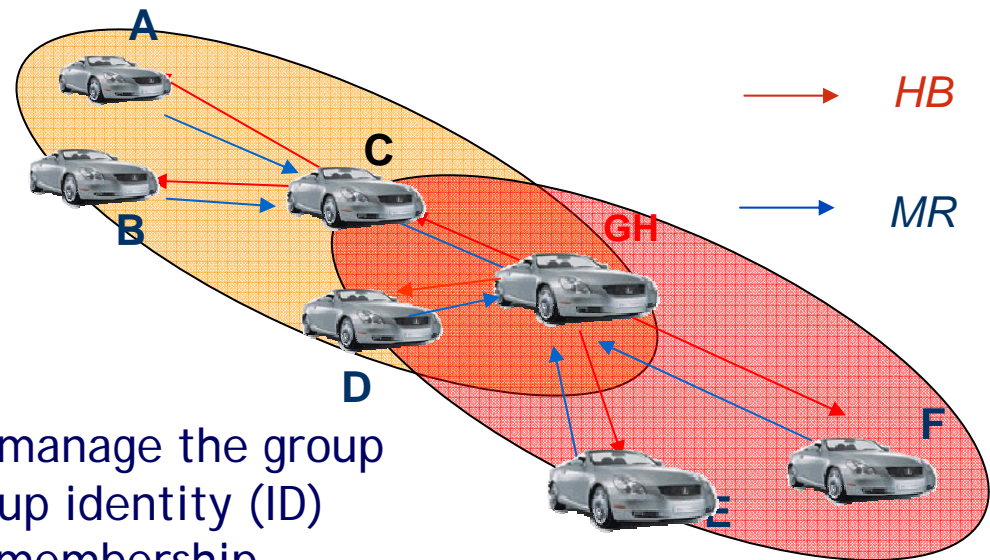
With LPG: Collaborative download

Local Peer Group

Vehicles receive and later collaborate to exchange missing segments to combine to a much larger dataset

Dynamic Vehicle Group Organization

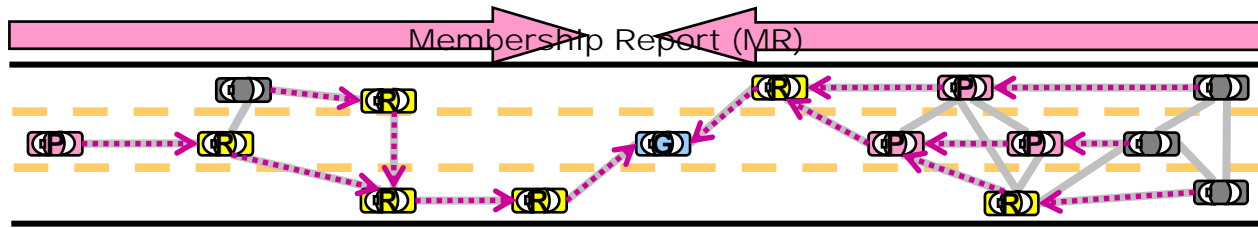o **Group Header (GH)**
  - A special node elected to manage the group
  - Creates and maintains group identity (ID)
  - Handles changes in group membership
  - Periodically broadcasts HeartBeat (HB) with group ID, GH info and member list

o **Group Node (GN)**
  - Node in group which is not a group header
  - Responds to the HB with a Membership Report (MR) to maintain membership in group
  - Can become a GH if current GH disappears (GH timeouts)

Vehicle Group Multicasting Operation
Tree formation

o HB/MR messages for mesh formation and maintenance and use of Light Suppression to control multicast forwarding

**Multicast participants join the multicast mesh through their MR messages.**

Membership Report (MR)

MR takes the reverse paths of HB toward the GH. Accordingly the multicast mesh is formed.

(G) GH Node	(P) Multicast Participant Node
(R) MR Relay Node	(F) Multicast Forwarding Node
···▸ MR Route	— Multicast Route Path (Tree)
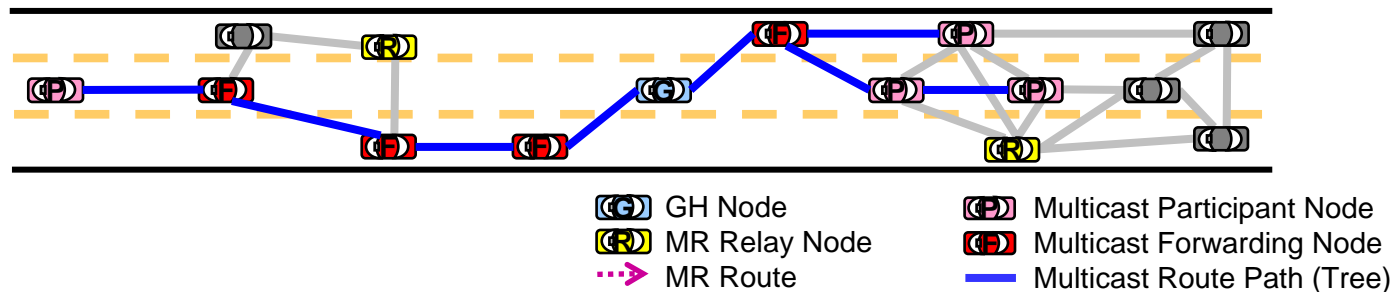
Multicasting Simulation Comparisons
Delivery Ratio & Average Delay

Delivery Ratio
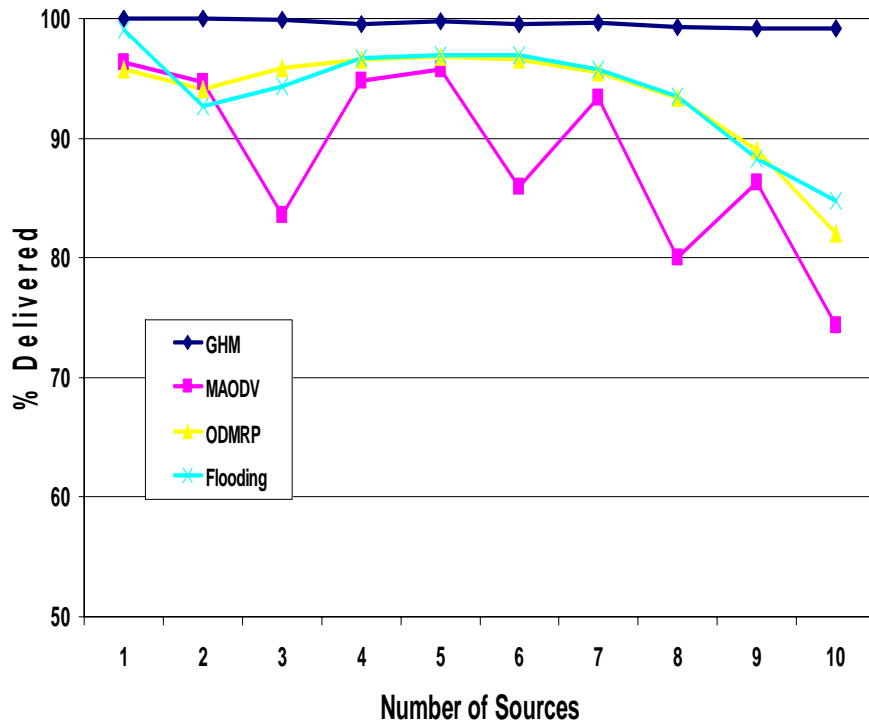
Average Delay
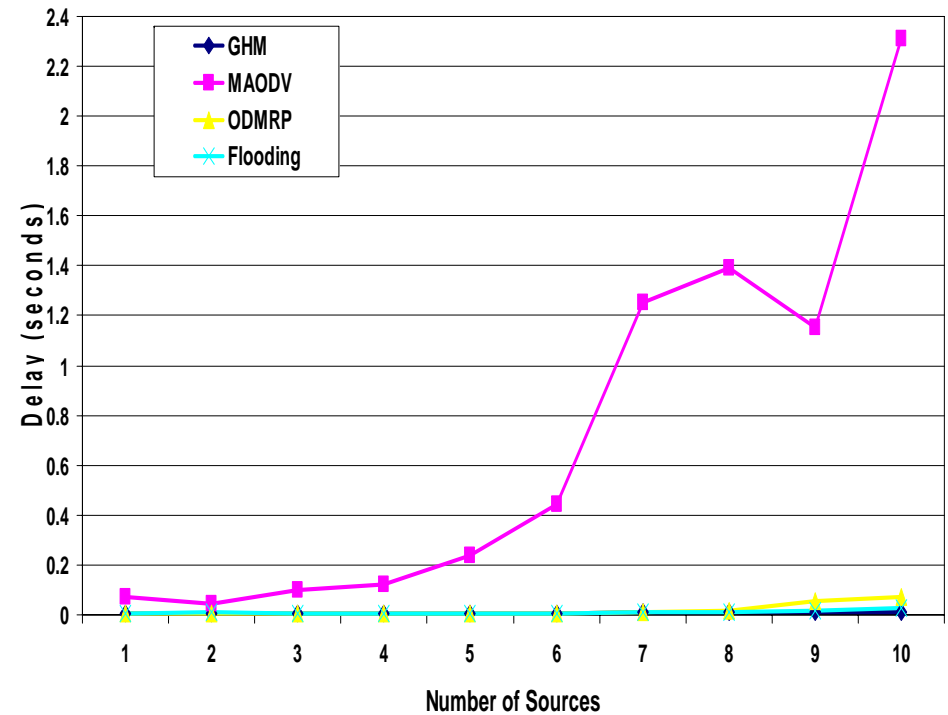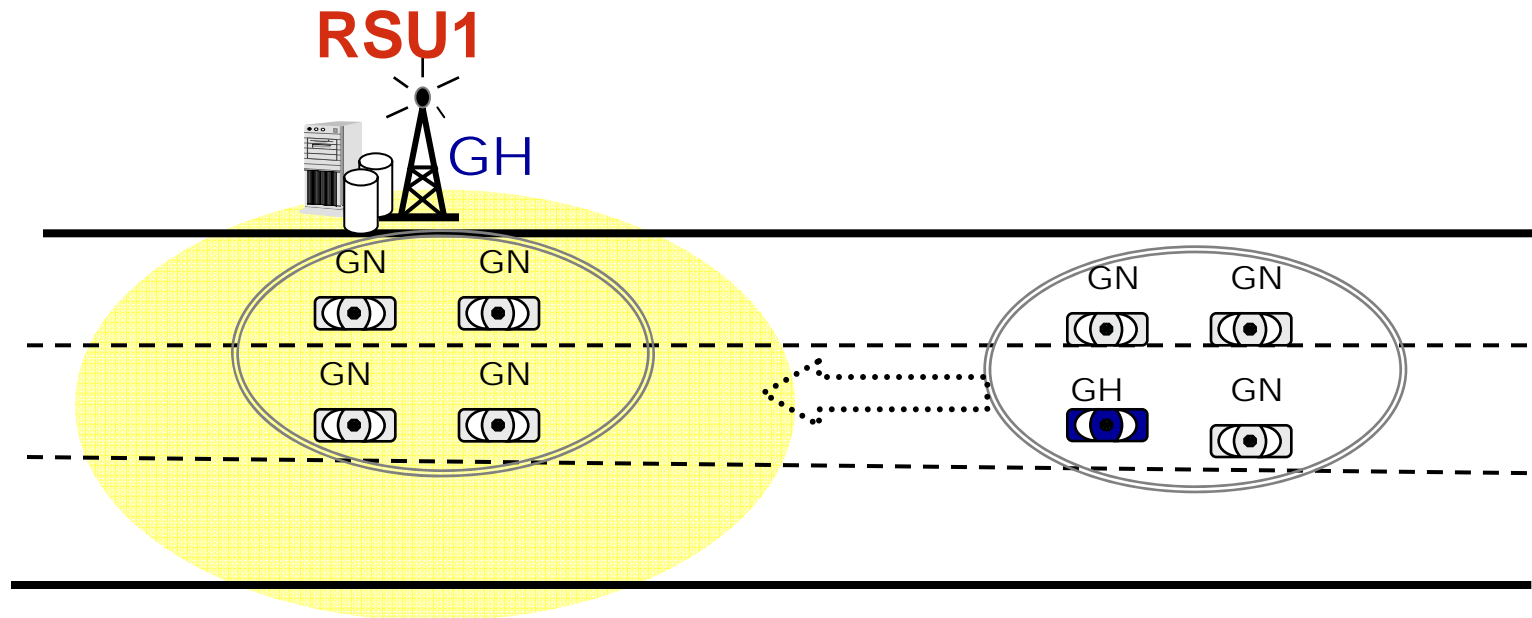
Networked RSUs
Dense RSUs Environment
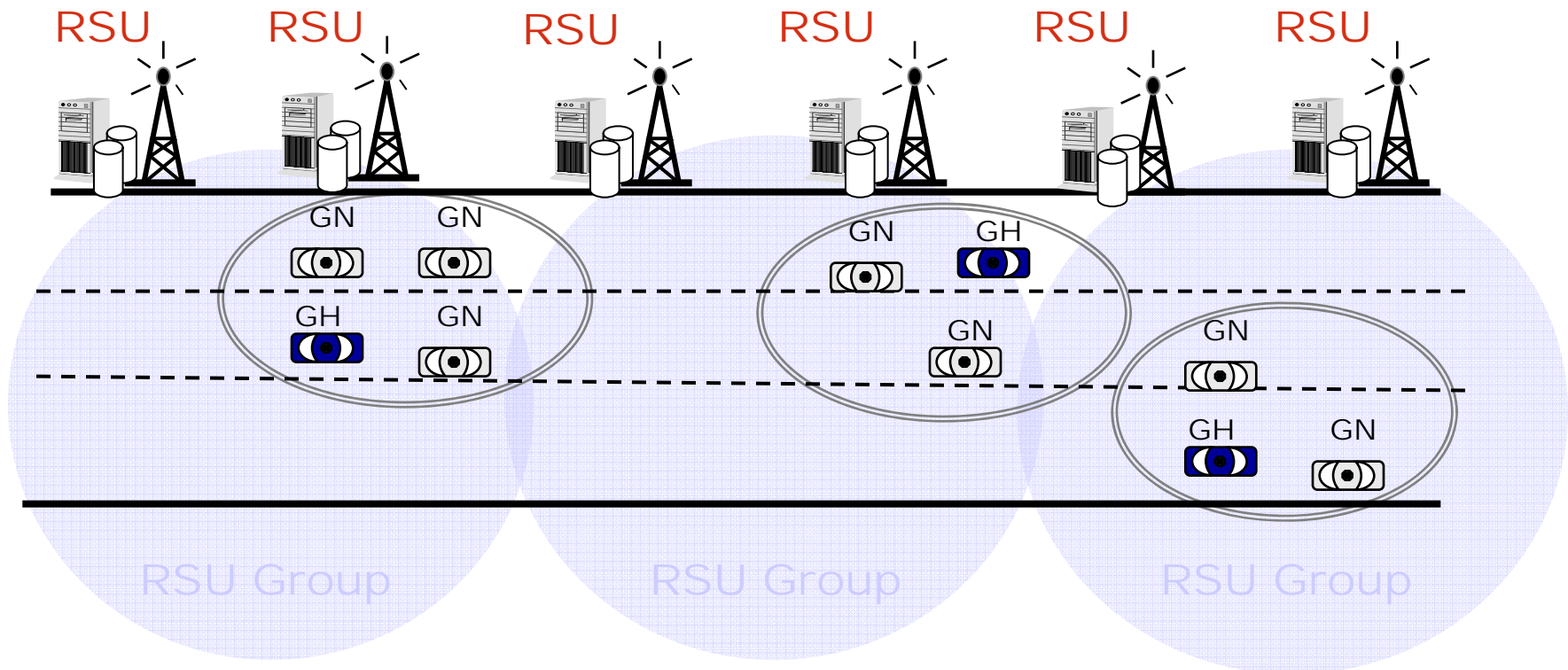
Use of RSU groups to reduce frequency of RSU handoff by LPGs

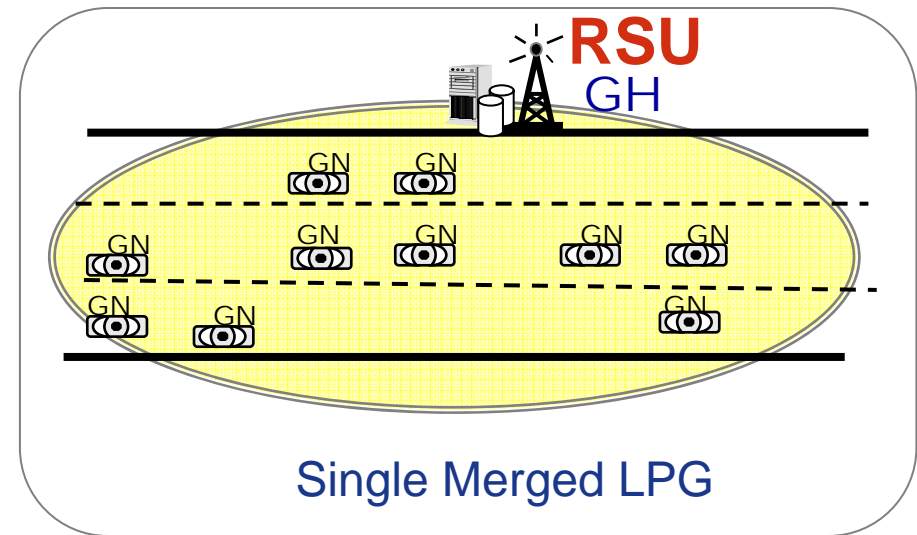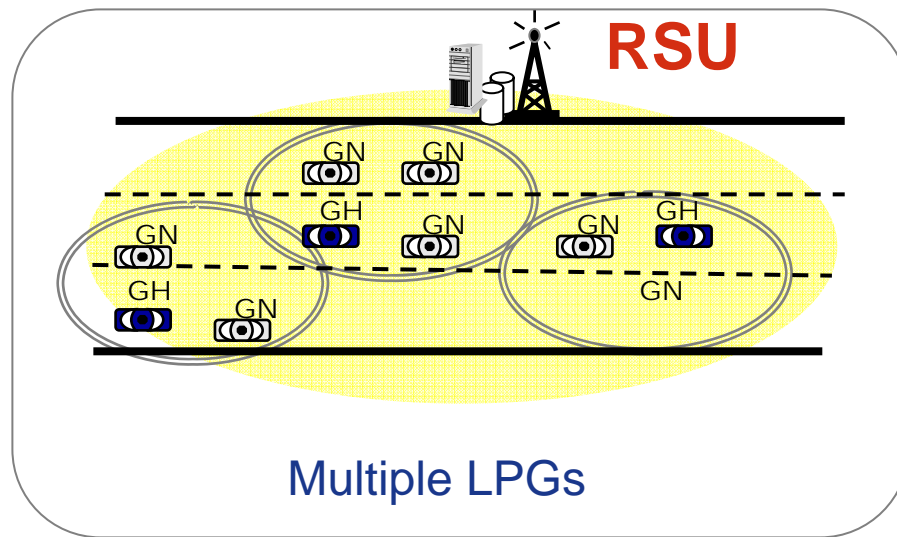# Vehicle Group Interaction with RSU
Isolated RSUs Environment

o Outside the RSU range, LPG maintained by a vehicle GH

o RSU may become new GH for LPG within RSU coverage area

- May pre-configure RSU to win header resolution

Merging of Vehicle Groups in RSU Area

Multiple LPGs

Single Merged LPG

o   Routes created based on the propagation of HBs and MRs

- •   Multiple LPGs within the RSU range may be merged into a single group

o   RSU may become common relay node by which vehicles route to each other

- •   Reduce the number of hops in intra-LPG communication
- •   V-V interface may go unused
- •   Modify routing to load-balance between V-V and V-R

o   Goal: Keep LPGs stable to limit re-organization and route updating