A SURVEY ON VEHICULAR SOCIAL NETWORKS

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ABSTRACT

In this presentation, we delve into the topic of vehicular social networks. Approximately 1.35 million people die from road crashes every year, which amounts to around 3,700 people daily. In addition, 20 to 50 million people suffer from long term and short-term disabilities due to vehicular transportation accidents. Due to this, it is of prime importance that we apply existing technology in communication networks, autonomous vehicles, and social media phenomena to create a comprehensive protocol or framework to ensure better safety as well as better entertainment applications for passengers. This will help create an automotive experience with better traffic flow and safety. Researchers are trying to merge the social aspects into vehicular ad hoc networks to provide novel methods for message exchange in dynamic environments resulting in vehicular social networks. Human factors play a role in vehicular ad hoc networks to enhance safety and entertainment. We present the main features of vehicular social networks, as well as their challenges and applications. Through this survey, we hope to examine different concepts that would make this new generation of vehicular transportation a reality, one where driverless cars have wireless capabilities connected to the cloud, thus making traffic lights obsolete.

Topics Covered

VEHICULAR AD HOC NETWORKS – OPPORTUNISTIC AND AD HOC NETWORKS

NEXT GENERATION VEHICLES AND ITS FEATURES

MERGING SOCIAL NETWORKING TO VEHICULAR AD HOC NETWORKS- VEHICULAR SOCIAL NETWORKS

APPLICATIONS OF VEHICULAR SOCIAL NETWORKS

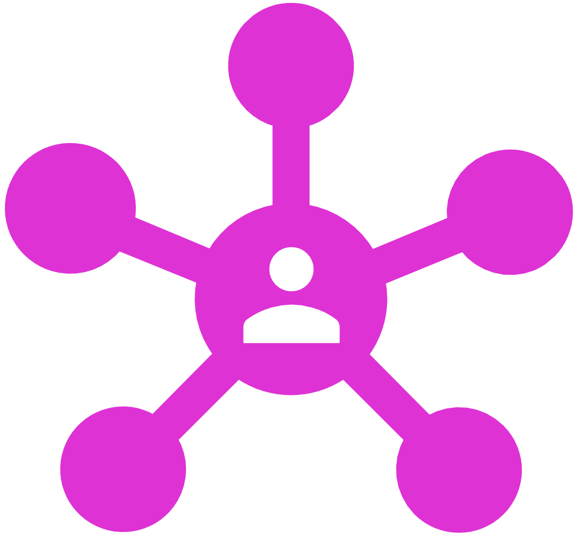
Opportunistic and Ad Hoc Networks

Opportunistic networks

- Networks which use store-carry-forward methodology,
- Nodes here store a message and carry it until a link is available upon which the message is forwarded.
- Communication can take place without the availability of end-to end message routing paths.

Ad Hoc Networks

- Networks that are dynamically created between nodes when they are in proximity.
- Decentralized network.
- Lacks complex infrastructure – networks created on the fly



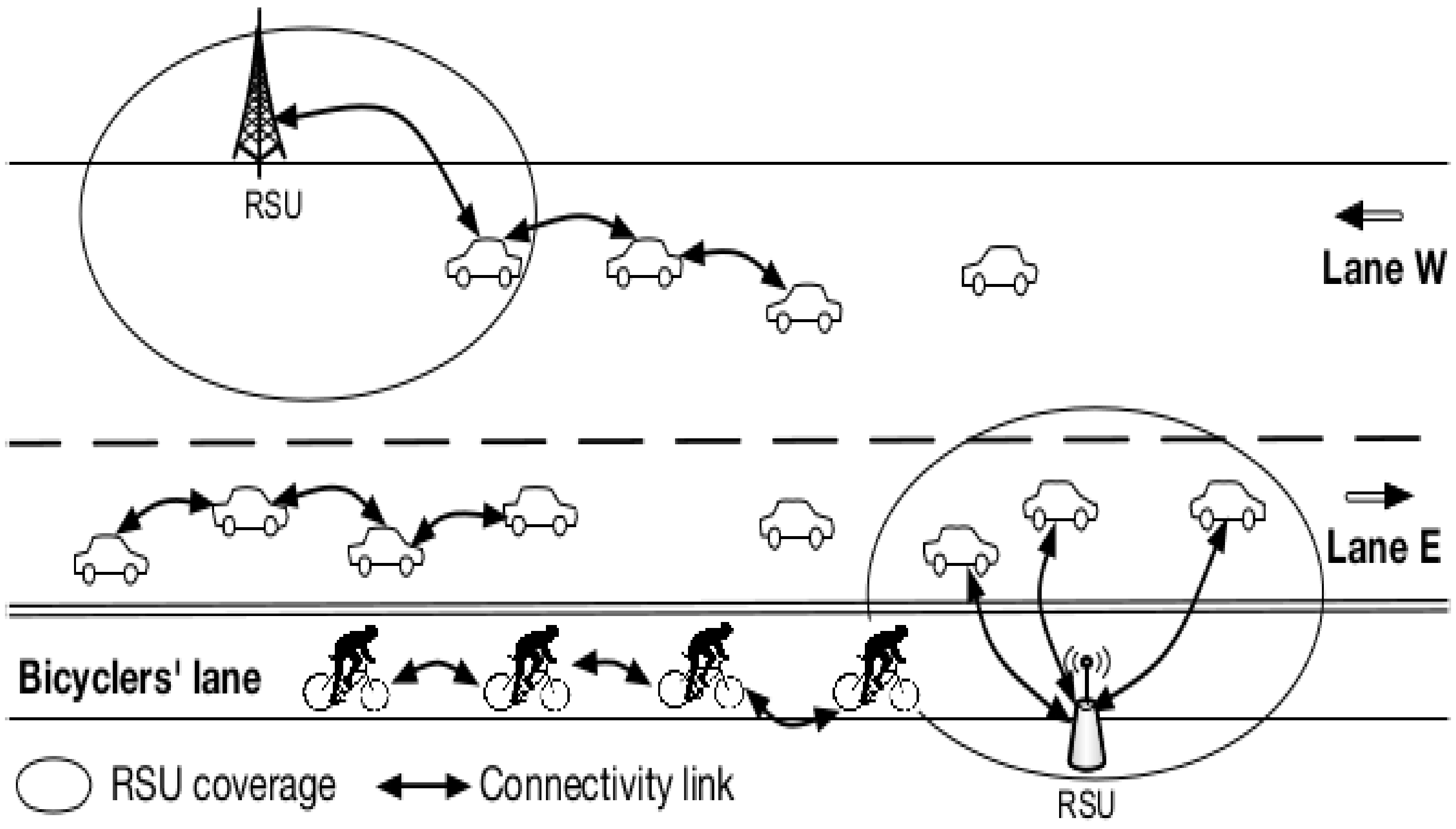
Vehicular Ad Hoc Networks (VANET)

- Class of Mobile Ad Hoc Networks (MANETs), with constraints of high vehicle velocity, hostile propagation environment, and quickly changing network topologies
- Added element of opportunistic networks to improve the ability to transmit information amongst vehicles
- Two types of links in vehicular opportunistic ad hoc networks
  - **Vehicle to vehicle (V2V)**, built dynamically, where any vehicle becomes the next hop for end-to-end communication
  - **Vehicle to infrastructure (V2I)**, created between vehicles and roadside infrastructure with wireless capabilities

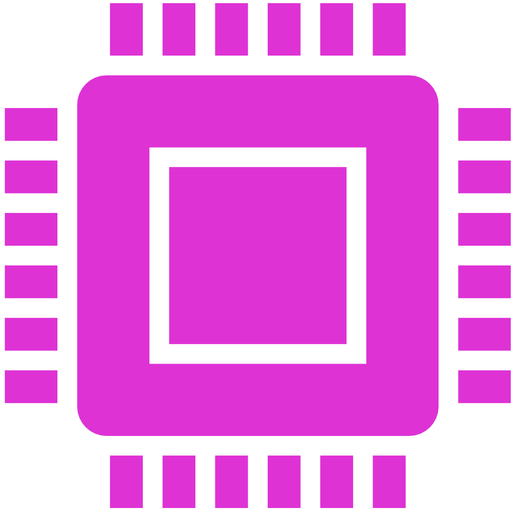
  For example, V2V links can be used to transfer information amongst vehicles about the destination, V2I link can be used to receive traffic information from roadside units on potential traffic issues further along the route.

VANET- a schematic

- The figure demonstrates the schematic of a VANET with its companion wireless network infrastructure.
- The V2V links can be used amongst bicyclers to check the status of an ongoing race, the prevalent weather conditions, and the available paths.
- The V2I links could be used to check on the existing traffic by cars travelling on the road,



Next Generation Vehicles (NGV)



- VANETs are the foundational concept for the future of NGV's.
- Further enhanced by Global Navigation Satellite Systems (GNSS) for tracking and positioning of vehicles, WAN interface cards like LTE, and IEEE 802.11 technology.
- Use of better sensors and better ways of communicating information can help create a new vision for the car of the future.
- Features for NGVs:

1. **Safety driving** using better collision detection systems through warnings via V2V and V2I links.

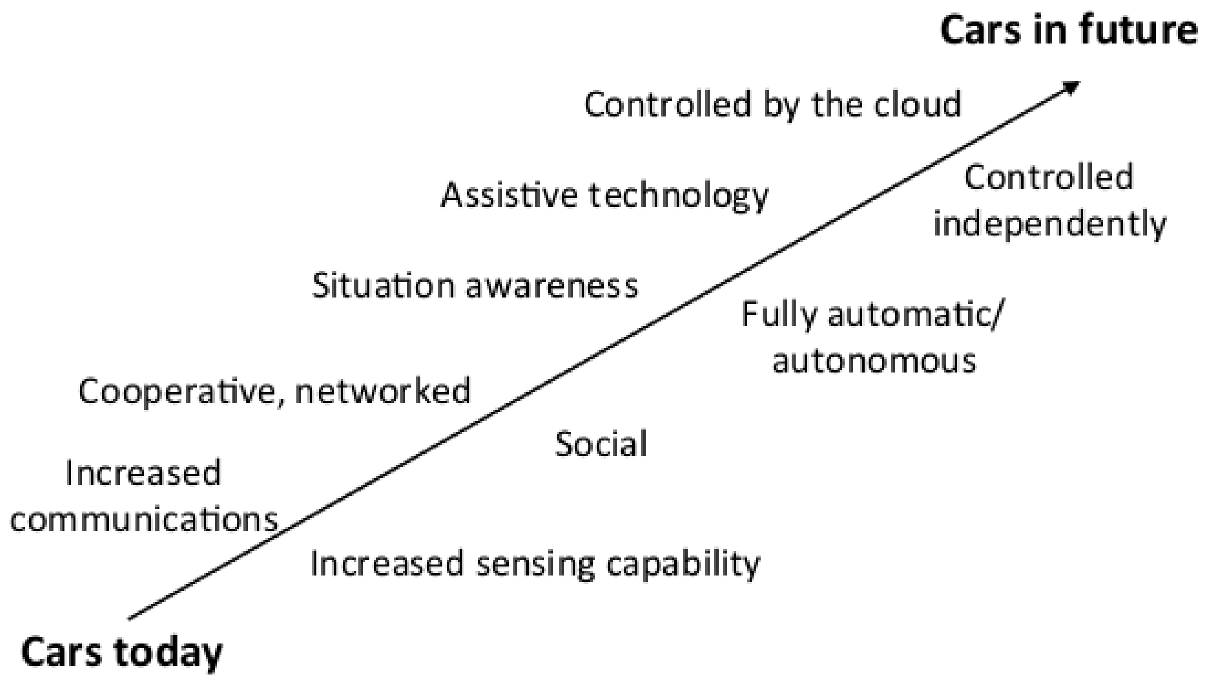
2. **Autonomous driving** through cars communicating over the cloud, supporting each other with better information

3. Social driving, social networks formed on the fly between vehicles.

4. **Mobile applications,** with drivers and passengers connected to each other through internet browsing, online gaming , and other entertainment applications.

5. **Electric vehicles**, with emission free driving and less harmful effect on the environment.

- The use of human-computer interaction can increase security in NGV's.
- Many accidents are caused by reduced reaction times of drivers when they have a scattered attention within the car. The solution to this are In-Car-Communication-Systems(ICCS), which allow drivers to access their smartphones without losing focus on the road.
- The Multimodal Interface for Mobile Info-communication (MIMI) is a prototypal multimodal ICCS and adds speech control to this.
- Current systems include Cadillac Cue-a navigation and entertainment system which allow interfacing of the smartphone, OnStar's Remote link-which allows control of the car through the phone.
- A similar system has been developed by Robotics Research Centre, IIIT Hyderabad, called "Talk to the Car", which generates waypoints based on conversational directions given to its self-driving car



A summary of NGVs, its challenges and capabilities

Packet exchange in NGV

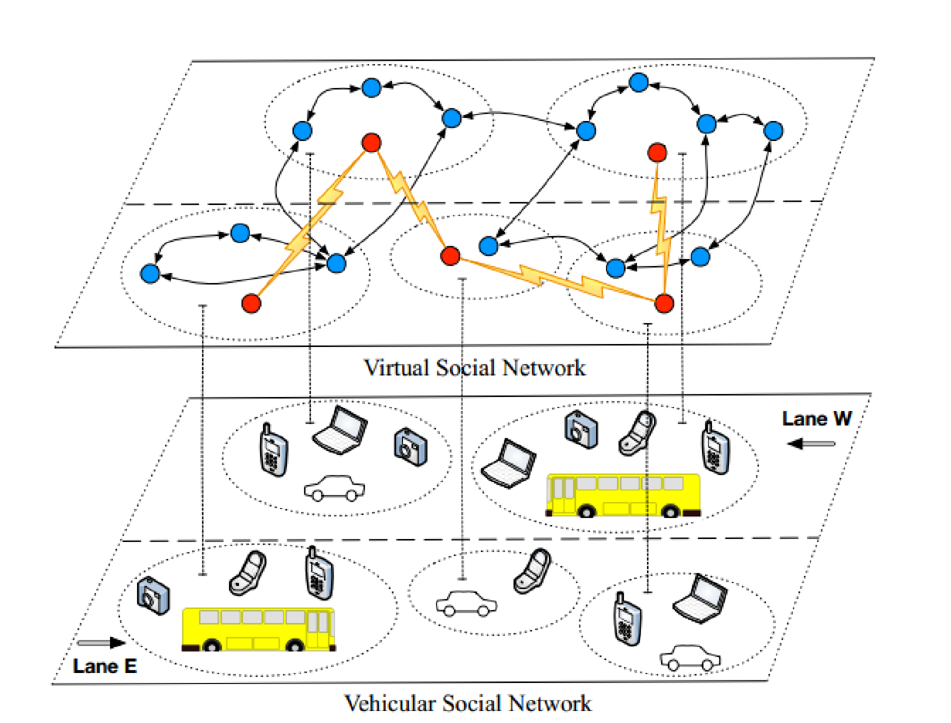
- Packet exchange in NGV done depending on a social similarity score. High similarity score shows that both nodes have common interests and characteristics.
- Drawback-the forwarding process has a low efficiency of data delivery.
- To address this, the forwarding algorithm incorporates situational-based scores along with similarity scores.
- Issues with NGV to forward packets:
  - Lack of integration of sensors with multiple protocols
  - Security and privacy related issues

  Packets forwarded between nodes may contain corrupted data and be fake. There is a need to establish trust between vehicles. Abbani et al formulated a model based on trust models of VSN security:

  - Formulation of social groups: a node becomes part of a group only if it is like the rest of the group
  - Trust evaluation: a node's behavior and participation in a group determines its trust
  - Decentralized architecture: nodes exchange group updates and manage automatically

  Protection if user's location data is of paramount importance. Protocols like Social-based PRivacy-preserving packet forwardING (SPRING), Social-Tier-Assisted Packet (STAP), Social spot-based Packet Forwarding (SPF) are deployed so that RSUs can disable the packets from tracing back to their source.

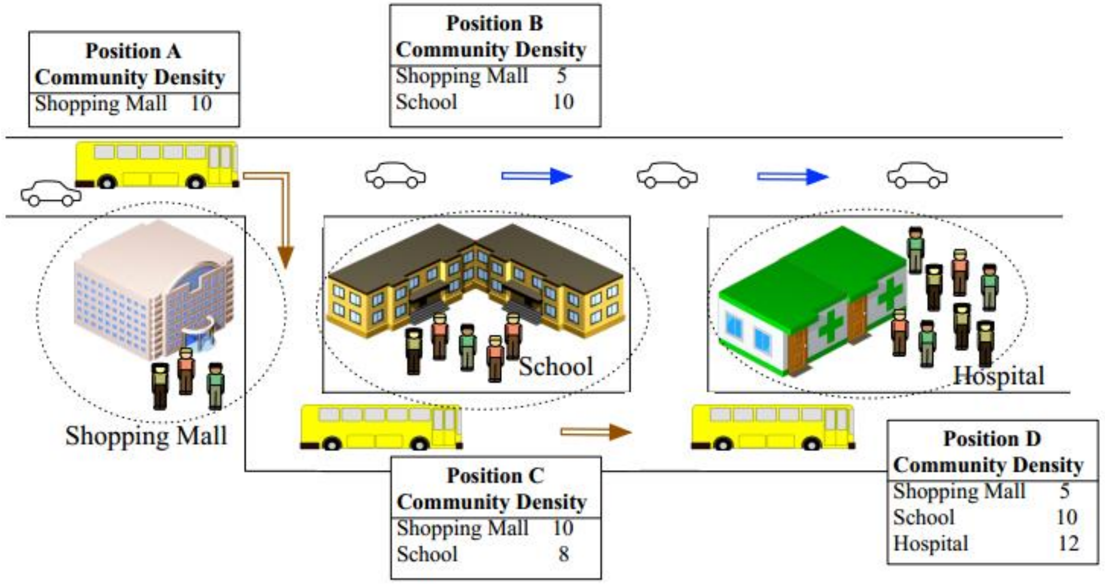
Merging Social Networking to Vehicular Ad hoc networks- Vehicular Social Networks



- Opportunistic networks can be related to social networking, and can be applied to human factors like mobility, user preferences, data and location sharing for VANETs.
- This is called Socially aware Networking, which combines social relationships in MANETs and the existing VANETs to form Vehicular Social Networks (VSN).
- VSN can be a group of individuals who have common interests and preferences in the temporal and spatial presence of vehicles on a road.
- Data can be shared amongst vehicles, like location and common destinations of interest, traffic information, and road conditions.
- Social-aware networking conceptualizes the following:
  - Social relationships are stable
  - Transmission links are temporary and vary more frequently

  The two social levels: Vehicular social networks and virtual social networks are shown. Vehicles in red circles make social ties based on mobility and common interests,. Mobile devices in blue circles form an electric social network when they are close to each other and are formed due to inherent social ties.

BEEINFO



The BEEINFO (Artificial BEE Colony inspired INterest-based FOrwarding) system describes a routing mechanism that classifies communities into different categories on the criteria of interests. This is done by recording information of vehicular densities of passing communities through mobile nodes. The densities recorded shows the number of nodes belonging to a community and can serve to select next-hop forwarders in a better manner. We can now examine the example of a VSN along with the BEEINFO system in an urban scenario.

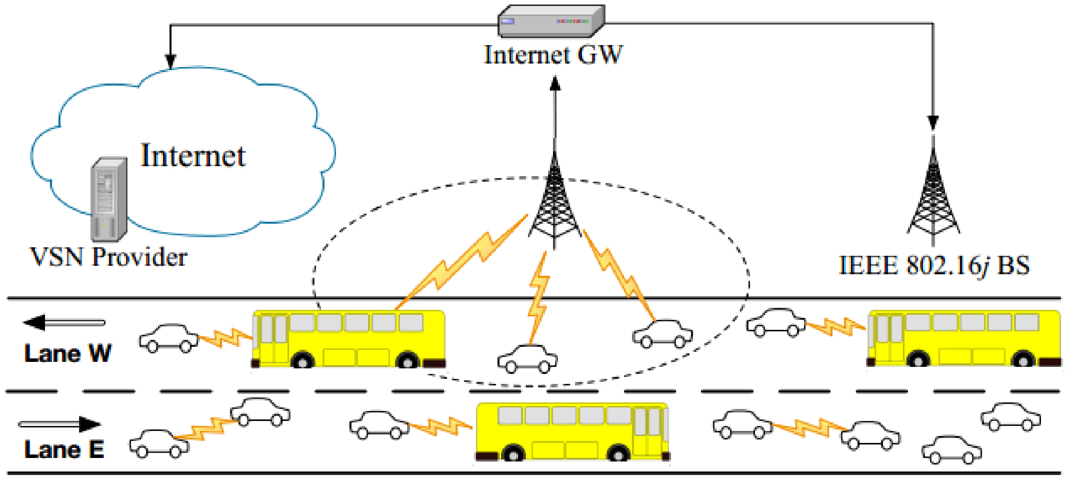
In this figure, we consider three different communities in relation to a shopping mall, a school, and a hospital. The bus follows the brown arrows through the hospital and school, while the car follows the blue arrows through the other three spots. Both the car and bus pass the shopping mall in B and C, but the bus approximates a higher density value than car in the shopping community (10 > 5), but lower in the school community (8 < 10). Hence, for message dissemination, the bus will forward information better to the shopping mall community while the car will forward information better to the school community. This is the same process used in selecting a person to forward information in a community, the more two people meet, the better their social tie is, which is demonstrated in this example.

VSN in an urban scenario

A VSN comprises of two layers:

- A physical layer provided by the ad hoc network
- A social networking framework running on top

A VSN requires cooperation between the two layers. In the figure, we have a VSN in an urban environment with vehicles moving in opposite directions in the two lanes. The vehicles are relay stations (RSs) carrying multiple users which provide connectivity to the white vehicles in its coverage, which are the subscriber stations (SSs). The roadside base stations (BSs) are connected to the internet through internet gateways and serve many moving RSs. Apart from this, the VSN provider is also connected to the internet, and enables users to register and employ the use of a web-based portal for accessing social networking services.



VSNs as a graph

- VANETs are constantly evolving, and we must examine how to build opportunistic links as vehicles move dynamically.
- **Social Network Analysis (SNA)** is a tool employed here. This can be visualized as a graph G(V,N) where V is the set of nodes and N is the set of edges. Metrics can be defined to assign how important a node is.

1. Degree centrality

This describes how many direct connections a node v has to its neighbours, and is given by:

$$d(v) = \sum_{j \in V, j \neq v} l_{vj},$$

Here, lvj is the link from the node v to its neighbours j. This metric defines how popular a node is, which is dependent on how many neighbours it has. A node with high degree centrality would possibly be chosen as a next-hop forwarder since it has a higher chance of being in contact with other nodes

2. **Betweenness centrality**

This describes the number of shortest paths passing through a node *v*, and is given by:

$$BC(v) = \sum_{\substack{s \neq v \neq t \\ s,v,t \in V}} \frac{\rho_{st}(v)}{\rho_{st}},$$

Here, ρ_{st} is the number of shortest paths from node *s* to *t*, and $\rho_{st}(v)$ is the number of shortest paths from s to to t passing through node v. This metric defines how important a node is by using the proportion of the number of shortest paths passing through it to the number of shortest paths. The node with a higher betweenness centrality has a higher number of shortest paths amongst the node pairs passing through *v.*

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3. Closeness centrality

This describes the inverse of the distance of node v to every other node j in the network ($d_{v,j}$), which implies that the node v has the shortest paths to the other nodes in the graph. It is given as:

$$CC(v) = \left[\sum_{j \in V, j \neq v} d_{v,j} \right]^{-1}.$$

Hence, this metric describes how central a node is in terms of its proximity to the other nodes. The decision to use a more central node described by this metric in a VANET ensures the wider delivery of a message within it.

4. BRidging Centrality

This describes whether a node v is located in between highly connected regions. It is the product of BC(v) and the bridging coefficient b(v), where b(v) describes how well a node v is located between high degree nodes.

$$BRC(v) = BC(v) \cdot b(v),$$

$$b(v) = \frac{d^{-1}(v)}{\sum_{i \in N(v)} d^{-1}(i)},$$

Here, N(v) is the set of neighbours of node v.

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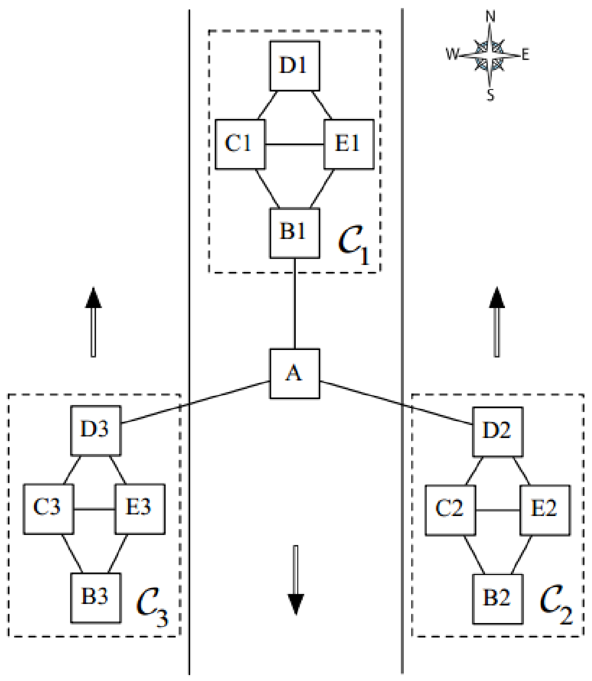


$$d(A) = 3$$

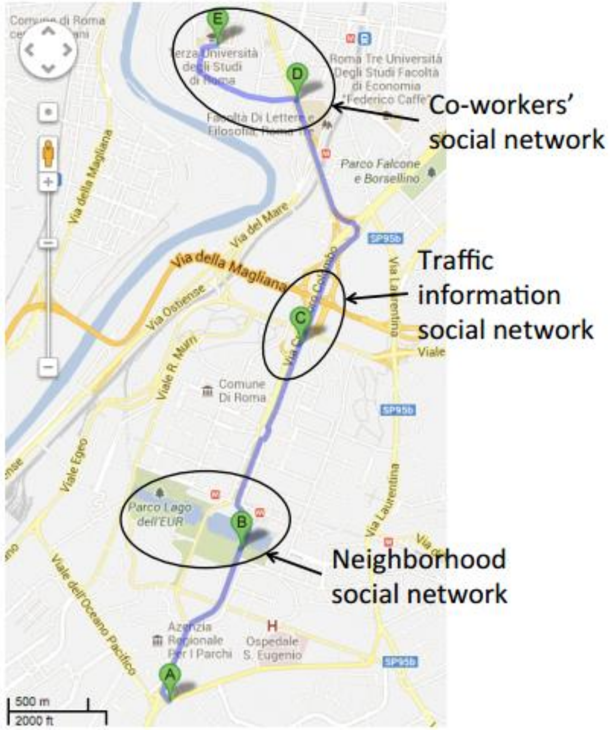
$$BC(A) = \frac{48}{66} = 0.727$$

$$CC(A) = 0.5$$

$$BRC(A) = BC(A) * b(A) = 0.73 \cdot 0.333 = 0.243$$

Social features in VSN

Flooding traffic situations can create clusters of vehicles to share data. One issue in a cluster with a lot of vehicles results in broadcast storming due to redundant links. Broadcast storm is repetition of a broadcast package even though all the nodes have already received the packet. This redundant broadcast of messages stalls the network and results in over utilization of a node's resources. Due to rapidly changing network topology there is a need to reduce broadcast storms. As a solution to this researchers develop a Sociological Pattern Clustering algorithm that exploits their tendency to share similar routes. Human mobility, preferences, and selfish status affect the VSN network.

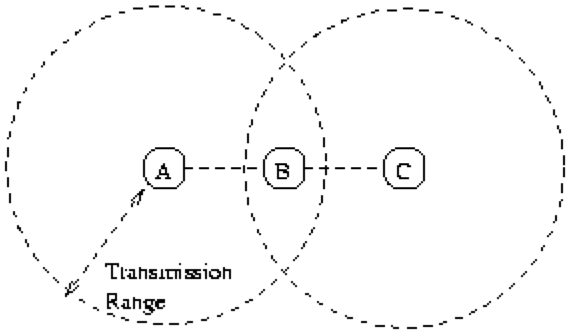


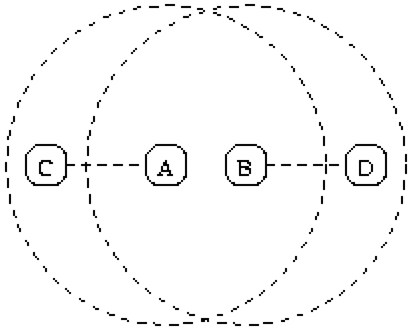
Networking in Vehicular Social Networks

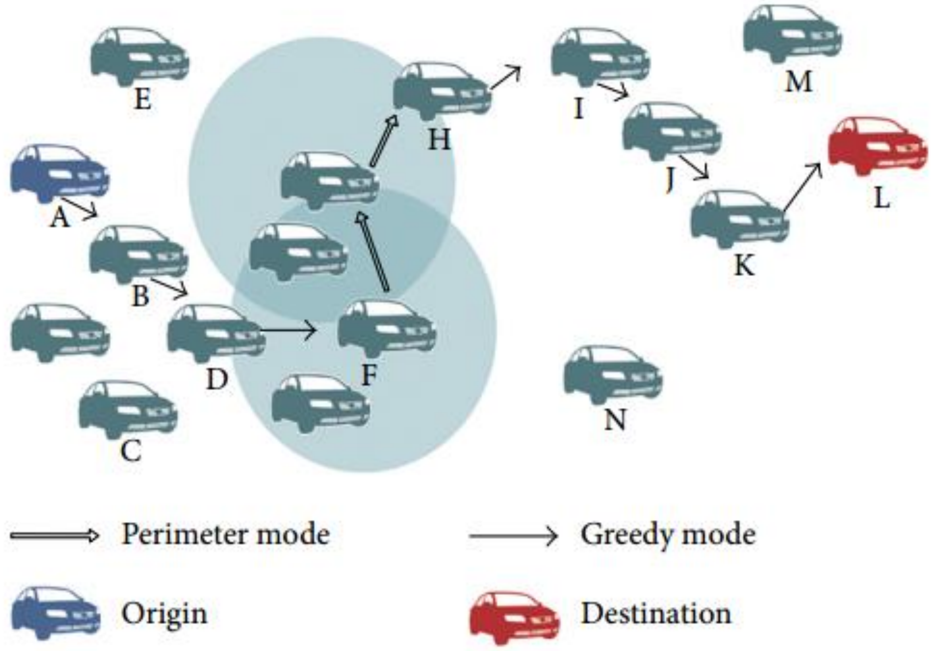
Hidden terminals are nodes that are not visible to the sender that is in proximity to the receiver. In the given figure, node C is hidden to node A. If both nodes A and C need to transmit a packet to B, they encounter a packet collision that results in data corruption. **Exposed terminals** are nodes that are in the sender's proximity restricting it to transmit data to avoid a collision. For instance, in the given figure, if A is transmitting data to C, then node B must wait till the transmission is over, else a collision occurs as B is in A's proximity.

Ad hoc networks are built dynamically which makes it difficult to deliver packets without any collisions. In this section, we describe the networking issues involved in VSNs and some protocols that solve them. In ad hoc, the concept of hidden and exposed terminals becomes very crucial and it becomes challenging to design protocols to avoid collisions.

VSN protocols use **request-to-send (RTS)** and **clear-to-send (CTS)** processes to deal with these issues. In this process, a source node sends a request-to-send (RTS) packet to the destination node and awaits a clear-to-send (CTS) response. The **Urban Multihop Broadcast (UMB)** is one such protocol that is used to disseminate messages to RSUs that are out of reach from the source. It operates in two modes, the intersection mode, and the directional diffusion mode. During the directional **diffusion mode**, the node finds the farthest node from its position to transfer the packet to diffuse (rebroadcast) it further. The **intersection mode** aims to build repeaters at node intersections for the broadcasting of important packets. When a packet encounters an intersection, the intersection broadcasts this packet in all directions as it has the best line view of road segments (eg., in the presence of high buildings.). UMB avoids collision by using different channels for control (eg., RTS, and CTS) and data signals.



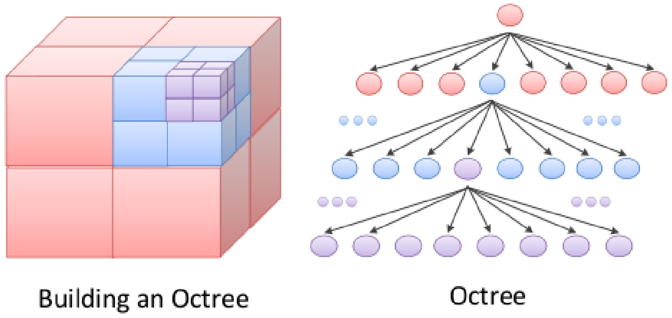




Routing in VSNs

Another issue that VSNs must deal with is routing a packet from source to destination in a dynamic environment. The **Greedy Perimeter Stateless Routing (GPSR)** protocol chooses nodes that are closest to the destination node for transmitting packets. In this protocol, each node contains information about its geographic location. During the route discovery process, **beacons** (messages) are sent to nodes at a distance of one hop from the source. Beacons provide identification and location of neighboring nodes. In GPSR, forwarding is achieved using greedy-based and perimeter-based algorithms. In the greedy approach, packets are forwarded to nodes closest to the destination node in its vicinity. In the scenario where this node is not able to forward the packet, the perimeter-based routing algorithm forwards the packet to nodes away from the destination.

Applications of VSNs



CarSpeak is an example of a communication system for autonomous driving. The system adopts an approach of mapping the regions along the road using 3-D point cloud scans from a LiDAR sensor. These scans are shared amongst other cars in the vicinity using an octree data structure, which allows regions to be stored along with its point cloud data efficiently at different resolutions so that the data can be zoomed in and out for seeing small objects in a scene. Each node in the tree is called a cube, as shown in the figure, and each cube can be accessed quickly and efficiently for accessing a particular part of the scene.

Carspeak takes a content-centric approach for sharing information, i.e. it adopts a content centric MAC based protocol for sending data, and objects in a scene compete for medium access instead of different senders competing for access like conventional protocols like 802.11 and 802.11+Naming. The content-centric MAC handles both internal and external requests to add to a region in the octree. When the MAC receives a request from its own car, it performs a broadcast to the other vehicles over a wireless medium, and when the packets with the regions arrive, the system vets the data, checks if the request has timed out or not, and adds it to the octree. The MAC also actively listens to track external requests for data in the regions of the car’s octree, and to identify what regions are observed by the vehicles in the network created. Furthermore, the octrees are compressed to allow for better transmission across the vehicles to increase the speed of the real-time system. This system provides better safety, since the autonomous vehicles now have data they didn’t have previously, and can see across corners as well as see vehicles and pedestrians that are otherwise occluded by other objects.

Applications of VSNs

VSNs also enable decentralizing computation tasks among different nodes. This represents the crowdsourcing concept that allows multiple nodes to compute smaller tasks to solve a larger complex problem together. This increases resource efficiency and reduces time spent by cruising vehicles. For instance, while finding a vacant parking spot crowdsourced data from different vehicles along with the navigation system allows users to find a parking spot quickly without wasting fuel. Another instance of this is **MobiliNet**, which combines cellular infrastructure like smartphones and tablets with mobile internet access in order to perform interlinking between people and vehicles alike. The system supports planning and forms social groups among people driving on routes, and forms a service referred to as the “Internet of Mobility”. The system allows for connecting users together through which carpools can be made for future trips and provides for estimating a traffic situation based on the historical data. This system is a precursor to the current implementation of Google Maps, which crowdsources data from all the phones using its service on the roads and provides real-time route planning based on the traffic present on a particular intersection. This system is of great use and helps in conserving unnecessary travel time for passengers.

Vehicular Social Networks also allows tagging that alerts users when a friend is along the way. About 30% of traffic in busy areas is due to the lack of a vacant parking slot. Searching for vacant parking lots adds to the traffic congestion that increases the global carbon emissions. Carbon-Recorder mobile social application allows users to track daily carbon emissions. **Carbon-Recorder** raises awareness among drivers of the increasing carbon emissions and encourages them in reducing it. It also helps researchers collect data for vehicle traffic management, carbon emissions, and user behavior analysis.

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