Information Management in Emergent Vehicular Ad Hoc Networks

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ABSTRACT: *Information Exchange and communication among vehicles has become a very practical, interesting and challenging problem in Vehicular Networks. Since vehicles are in ad-hoc and rapidly mobile mode, there is no way for fixed network topologies. This necessitates the need for novel mechanisms for efficient data management in Vehicular Networks. Caching and Replication are two common approaches taken to ensure efficient data access. Though replicated items provide faster data access, identification of the location of a replica, placing the replica in the appropriate location and retrieving the needed data from replicas, becomes a big challenge in Vehicular Ad-hoc Networks. We will discuss our preliminary framework for information management issues in emergent vehicular networks in this article.*

1. OVERVIEW

Information Management among participating vehicles in a Vehicular Ad Hoc Network (VANET) is an emerging area of interest to the research community. Applications include file exchanges, commercial dissemination, emergency warning, automatic cruise control etc. A host of research works have appeared in this including information retrieval [1], incentive management [2], data aggregation [3] etc.

In the realm of VANETs, there are several issues that make information management saliently different from that in typical Mobile Ad Hoc Networks (MANETs) and Wireless Sensor Networks (WSNs). Unlike WSNs, nodes in VANETs are mobile, however, such mobility is clearly different from mobility of nodes in typical MANETs. In VANETs, node mobility follows critical constraints like road speed, number of lanes, well defined directionality etc., while in MANETs, node mobility is always assumed to be random in some form or the other. Within this avenue also, many works are recently appearing focusing on mobility models and simulators for VANETs [4, 5].

Interestingly, from the perspective of networking, mobility of nodes in VANETs turns out to be a double edged sword. On the one hand, challenges include handling rapid speeds, unexpected network dynamics (due to time of day, congestion etc.), and human in the loop. On the other hand, there are also opportunities to exploit like predictable mobility (due to constraints like road topology, speed limits etc.), possibility of using infrastructures like traffic lights which are already in place, high processing power at nodes (which are vehicles with relatively less size and energy limitations). Clearly, any application in the emerging VANETs must be designed such that mobility management can exploit opportunities provided and minimize the corresponding challenges. In this article, we present our preliminary ideas to address the application of information management in VANETs.

2. PROPOSED APPROACH

The goal of our problem is to design an efficient holistic framework for information sharing in VANETs. Considering the dynamic nature of nodes in VANETs, information request, discovery and retrieval on the fly is not practical. In our proposed approach, we introduce a term called '*Hot Spot*'. The term Hot Spot refers to those geographical areas in a network where node availability is relatively high and node mobility is highly predictable/ less dynamic/ even static. Note that as a function of the traffic density, more than one Hot Spot may also be present in the design. An instance of such a Hot Spot could be a busy parking lot in a city. Our proposed approach is to ensure that information to be shared in VANETs is appropriately replicated at these Hot Spots. Subsequently, information to be requested or retrieved is also done by appropriately contacting the Hot Spots in the network. Once we have identified Hot Spots, there are five key issues to resolve – Information Delivery to the Hot Spot, Information Storage in the Hot Spot, Query delivery from requesting node to the Hot Spot, Content Retrieval, and Information delivery from Hot Spot to requester. We will present preliminary ideas on the first issue in this article.

Information Delivery to Hot Spots

Consider a simple road topology as shown in Figure 1, where the white dots are vehicles, and the red circles (with 'H') are Hot Spots. The numbered circles are the intersections in the road network. This road network is converted into a graph structure as in Figure 2.

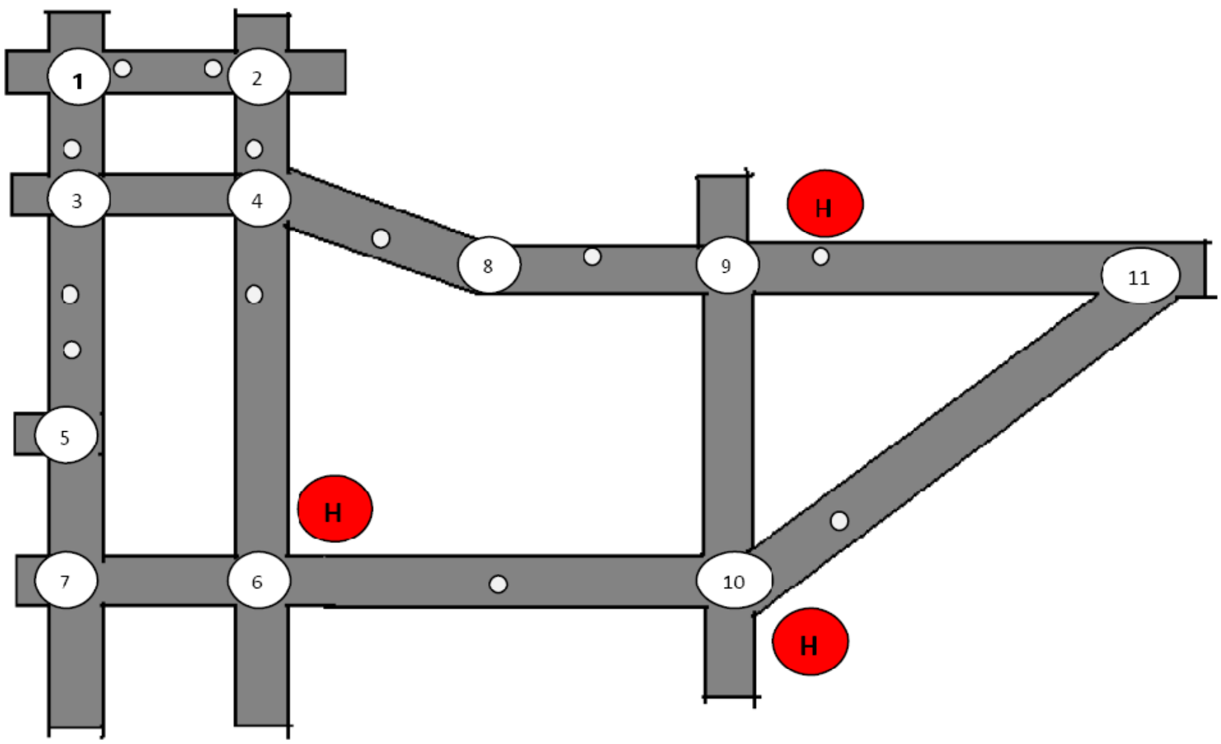

Figure 1: A simple road topology with intersections, vehicles and Hot Spots

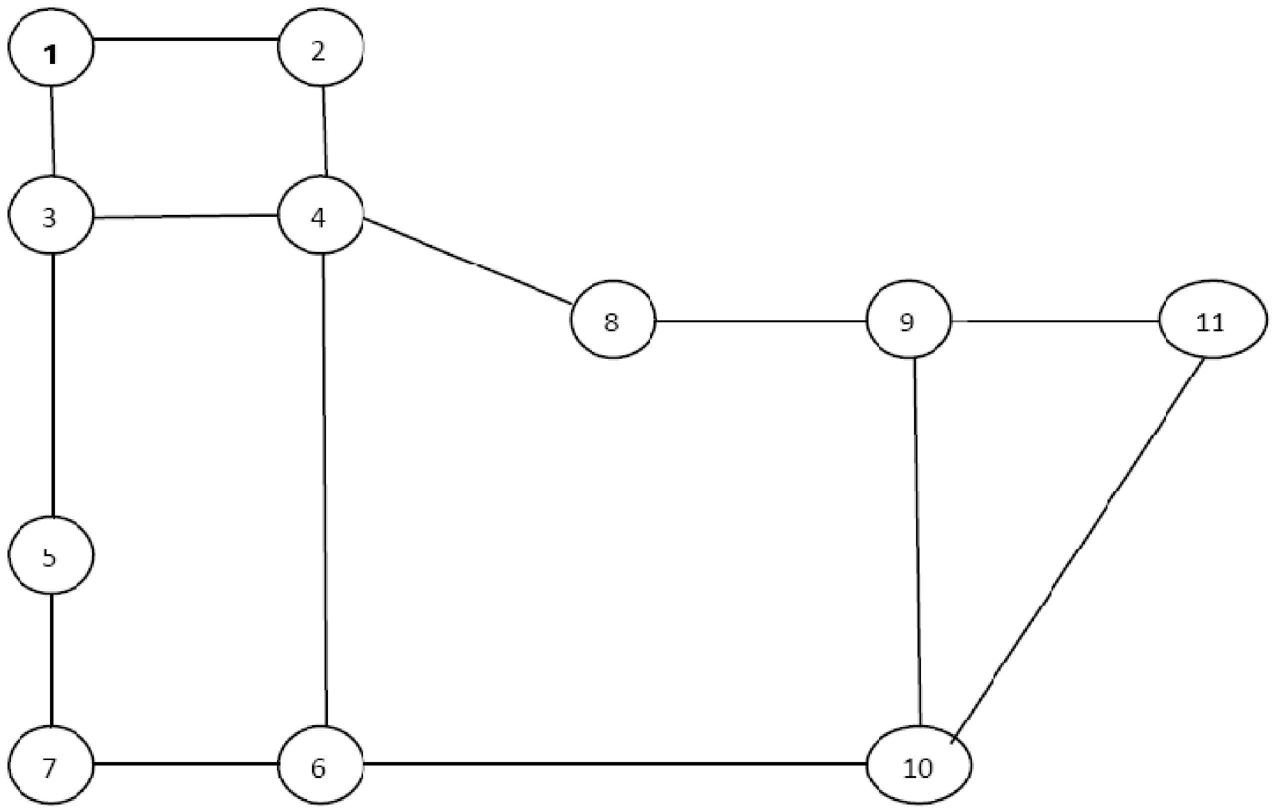

Figure 2: The graph representing the Road Topology in Figure 1

Each node in the VANET can construct such a graph based on available toad topology (which is quite feasible to get). In our approach, the next step is the construction of a topology for information delivery from any node in the VANET to the Hot Spots. The information is basically whatever content the node wishes to share. We present a simple Tree based construction mechanism below for information delivery in VANET

In the proposed approach we have two parts.

1. Tree Construction Algorithm (Construction of tree based on road topology).
2. Replicating Files and Information based on Constructed Tree.

Tree Construction Algorithm

The road topology is converted to graph structure (like in Figures 1 and 2) based on the construction algorithm presented below.

Master node ←Intersection where the inform message originates.

1. *The root node is the master node and children of the root nodes are the neighbors of the root node.*
2. *While (true)*
3. *If nodes have not occurred in previous level, expand it such that, it's one hop neighbors are its children. Mark the node as visited.*
4. ***@expand**: If a neighbor is already a child of another node at the same level ,don't add it as a child node.*
5. *Else If (All nodes in current level is visited) break;*
6. *level ++;*
7. *End*

Algorithm 1: Our Tree Construction Algorithm

As an example, the formation of tree based on the topology shown in Figure 1 is presented below in Figure 3 assuming inform message originated at node 1. The red nodes are the Hot Spots.

Replicating Files and Information based on Constructed Tree

Once the tree has been constructed, the next step is forwarding of the content to the Hot Spots based on the constructed tree. The following are the steps involved.

1) The originating node will construct the tree based on the algorithm, and identifies the hot spot under it.

2) If there are various hot spots under it, it duplicates the File/Information with respect to the number of children having hotspots and handles it to neighboring cars reaching the subsequent intersection.

3) The packet handled to the neighboring car contains the virtual tree and duplicated file/information.

4) The subsequent cars at intersections getting this duplicated packet, has the virtual tree and hence repeats the above process and performs duplication if needed and handles the packets to cars moving towards intersections below it.

5) This form of duplication and handling of packets to vehicles takes place until all the hotspots at leaves are reached.

The explanation of this replication scheme with respect to the above Figure 3 is discussed below. The file or information originating at the boundary intersection 1 has to be replicated to all the hotspots 6, 9, 10.

Intersection "1" is at the boundary as per the road topology, it receives a inform message from an external zone vehicle to store its current zone ID for file X. A car at Intersection "1" constructs the above virtual tree and finds both its children 2 & 3 have hotspot under them, hence it duplicates two copies of the inform message and gives one to vehicle going to Intersection 2 or 4 and other to vehicle going to Intersection 3. The packet will be delivered to hotspot 6 under sub tree rooted at 3. Let us see how the packets get delivered to hotspot 9 & 10. The car when moving to the Intersection 4 finds, two of its children 6 & 8 are having hot spots under them, hence duplicates two packets one to 6 & other to 8. The car reaching 6 broadcasts the packet since 6 is a hotspot and finds another hotspot 10 lying below it and handles the packet to car moving towards Intersection 10. Similarly the car reaching 8 finds a hotspot 9 under it, hence handles the packet to a car moving towards intersection 9. This repeats until all hotspots at leaves are reached.

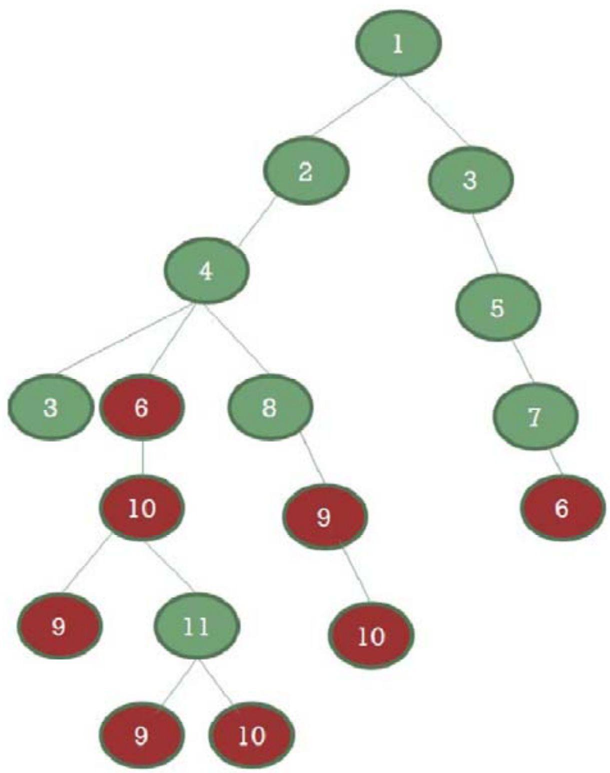

Figure 3: The Tree constructed by Algorithm 1 for the Road Topology in Figure 1

Features of the Proposed Technique

In the proposed approach, multiple replications occur, with increase in no of hot spots under a specific sub tree. In the above example we have 2 replications at 6 and 3 replications at 9, 10. How to reduce these is one challenge. Secondly, the worst case complexity of construction of tree or parsing the tree is $O(log(n))$ for n intersections in the topology. At the worst case all the n intersections might be required to route the message to hotspot. Hence the worst case routing complexity is $O(nlgn)$. Efficient usage of shortest path to destination nodes must be exploited based on road topology and nature of wireless communication.

3. OPEN ISSUES

The proposed work is only preliminary. Our current work focuses on Dijkstra based implementation for the Information Delivery to minimize the weaknesses of our current Tree based construction algorithm. Other issues to be addressed in the future are networking semantics in inter vehicular communications, context aware clustering of similar data sets, efficient techniques for popularity and incentive data management, mobility management exploiting benign properties of node mobility in VANETs, effective information storage within Hot Spots, security and privacy.

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