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A Survey on Void Handling Techniques for Geographic Routing in VANET Network

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Abstract

Geographic routing exerts geographic information to select the next-hop along the route to the destination. Greedy forwarding is a geographic routing mechanism that uses geographical location information of nodes and the distance of each node to the destination, to select next-hop node that achieve the most positive movement to the destination. Where greedy forwarding is not possible, it can be said a void occurred. In this case, if there is no an alternative mechanism, packets are easily removed. Hence a void-handling technique is need to continue routing and recovery greedy forwarding. There is a possibility of void in all types of wireless networks including vehicular ad hoc network (VANET). In this article we introduce void problem and present a survey on varied void-handling techniques which are suitable for VANET networks. At the end, we provide a comparative survey of these techniques based on some important features that are effective on the network performance.

Keywords: *Geographic routing, ad-hoc, VANET, void, greedy forwarding*

1. Introduction

Today, a VANET network, owing to its characteristics such as self-configuration, multi-hop routing and lack of centralized management, has gained considerable attention. Due to the mobility of nodes, unreliable wireless environment and time-sensitive applications in VANET, a routing protocol with minimum delay and higher packet delivery ratio always been need [1-5]. Traditional routing protocols such as AODV, DSR, etc., are based on the network topology [6] and therefore not consistent with rapid changes of network topology in VANET [7, 8]. Hence, another type of routing is introduced which does not require knowledge of the network topology and use geographical information. This type of routing is known as geographic routing [8].

Geographic Routing, which in some references is also called "Position-Based Routing" [4, 7], is known as one of the best routing methods to use in vehicular ad hoc networks due to its high scalability [4, 10]. This routing algorithm, unlike topology based routing, instead of using path information it uses the geographically position information of nodes to route packets to reach the destination. Hence it’s not necessary to create and maintain a path from source to destination. As a result, nodes do not have to store and update any routing table. In addition, the network bandwidth is not occupied for exchange routing packets [10].

Basic and common method in geographic routing is “greedy forwarding”, through which the packet is forwarded to one of the neighboring nodes that compared to the other nodes have a shorter distance to the destination. Sometimes it is not possible to use the greedy forwarding, because none of the neighboring nodes are closer to the destination

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than the current node. For example, in Figure 1 exist two valid path from S to D, $S->X->Y->D$ and $S->U->V->W->D$. As regards S is closer to the destination D than any of its neighboring nodes, so, it cannot continue moving the packet toward D using greedy forwarding. This situation called a "communication void" [11], is sometimes also known as a local minimum [10] or local maximum [12]. The high density of nodes reduces the probability of occurrence of void, but it may be some packages meet voids, due to lack of constant density over time, presence of obstacles and unreliable nodes. In this case, these packets are easily removed, because the greedy routing cannot be used to forward them. To prevent this, an effective recovery mechanism is needed as an alternative mechanism [9, 11].

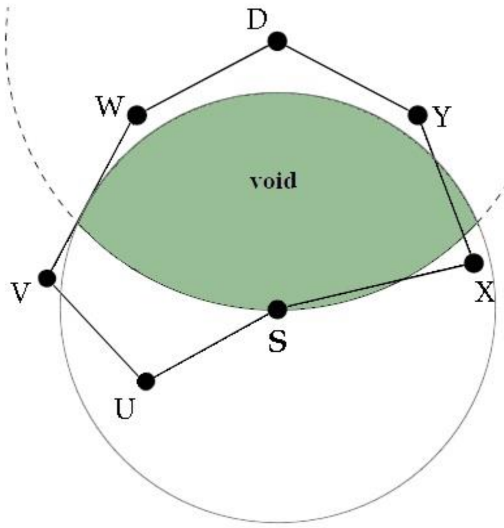


Figure 1. A Void Occurred at Node S

So many void-handling techniques have been proposed which may be appropriate either for mobile networks or static networks according to the method used in them. In this paper a review on techniques that are suitable for VANET networks provided. For this purpose, first concepts of geographic routing and void problem described. Then surveys of various techniques have been used to address the void introduced. And finally a brief comparison between these techniques base on their important features presented.

2. Basic Concepts and Description of Problem

Geographic routing [10] is composed of two basic elements: a positioning service and a geographic based routing algorithm. The main task of positioning services is determining the location of the destination, in response to a request from the source node. Then position obtained added to the packet header by the source node.

Operation of Geographic forwarding algorithm runs in two modes: greedy mode and recovery mode [11]. In greedy mode data packet is forwarded to one of the neighboring nodes that provide the greatest positive progress towards the destination. This selection process is performing by considering geographic location of current node, neighboring nodes and the destination node. Each node is aware of its own position using GPS receiver. Also, the positions of the other nodes are obtained through exchange periodic beacon packages. Thus, intermediate nodes can easily route packets according to geographic location of its own, neighboring nodes and the destination node. When the packet encountered a void, recovery mode is invoked. In this situation, the packet gets stuck at a node that called "void node". In recovery mode, the void node tries to forward the stuck packet surrounding the void since it is probability that there is a topologically valid route from the source to the destination node. The basic difference between various recovery techniques is their criterion to select the next hop.

Without using an appropriate technique when dealing with voids, some of the packets in the network are likely to be discarded, and furthermore, much of the network resources are wasted. Hence, one of the major challenges for geographic routing protocols is the existence of communications voids problem and effectively and efficiently handling this problem. The most plain void-handling technique is flooding in which stuck packet is broadcasted to all neighbors by void node and every node that receives stuck packet at the first time. Through this technique, the packet will certainly reach its destination. So this technique has a good effectiveness, but on the other hand, this is not efficient method. Because large amounts of network resources, including network traffic capacity allocated to a single packet. In addition, may be a large number of unnecessary duplicate packets received by the destination node [10]. When the stuck packet reaches at a node that is closer to the destination than the void node, routing mode returns to greedy forwarding. Note that should be in the attention is that a void-handling technique is invoked only when encountering a packet with voids.

3. Void handling Techniques

In following section, existing void handling techniques suitable for VANET network are classified into six distinct categories [9, 11] and function and characteristics of each are described briefly.

3.1. Planar-graph-based Techniques

Planar graph is a graph in which the edges of the network do not intersect. With creating planar graph of the network, a planar graph traversal algorithm, which operates on the right hand rule, can be used to forward packets to the destination. Base on the right hand rule it can be traverse an obstacle such as a wall in a maze by keeping one's right hand against the wall while walking forward [11]. In wireless networks, around each node, there is a circular area with a radius r which indicates the node's radio range. Each node is a vertex of the network and two nodes form a network edge if they are within wireless range of each other. Converting the network graph into a planar graph and using a planar graph based forwarding algorithm, guarantees that packets will be reach to its destination via traverse the planar graph.

Performance of planar graph based techniques, in addition to being dependent on performance of planar graph traversal algorithm, also depends on performance of planarization algorithm. The most well-known planar graph based void-handling technique is perimeter routing that used in Greedy Perimeter Stateless Routing (GPSR) protocol [13] and two other of these techniques are Request-Response algorithm (RR) in Beacon-Less Routing (BLR) [14] and 2-Hop Forwarding in SPEED-vb protocol [15]. In the following these techniques are explained.

3.1.1 Perimeter Routing: The void-handling technique that is used in GPSR protocol [13], like the other techniques in this category is consists of two distinct algorithms, one for planarization the network graph and another to traverse planar graph. In GPSR protocol planarization operation is done in a pre-processing phase, which creates a planar graph of network graph using either RNG planarization algorithm or GG planarization algorithm. When a packet encounters a void, forwarding mode is changed to perimeter routing. In this case void node puts its own ID and position into data packet header as the location of the void, before forwarding it to one of the neighboring nodes according to the right-hand rule. While the graph is traverse by a packet, other information such as the position of intersection of current face and pervious face, and the first edge traversed on the current face, are inserted to the packet header. After each hop to forward packet, the algorithm using information that has been added to the packet header checks whether the current node or any of the neighboring nodes is closer to the destination than the void node, if yes retrieves the greedy forwarding. Note here is that the traversal path using the perimeter routing for forwarding stuck packet to the destination not necessarily the optimal path. An example of a planar graph traversal by perimeter routing algorithm is shown in Figure 2 from [11].

3.1.2. Request-Response: In this technique, which is one of two techniques presented in the BLR protocol [14], like perimeter routing forwarding packets to the destination is done via a planar graph traversal algorithm, however in RR technique a partial planar graph is constructed only in the area around the void on demand (*e.g.*, only when a data packet encounters a void). Since the BLR protocol does not exchange periodically beacon packets to update position of the nodes, before forwarding the data packet, a request sent by the source node to all neighboring nodes and through it their current position is obtained. If one of the neighboring nodes has a shorter distance to the destination than the source node, is selected as the next hop. Otherwise, the source node runs planarization algorithm and then begins traversing the planar graph. Upon reaching the data packet to a point that is closer to the destination than the void node, greedy forwarding begins again. The main disadvantage of this technique is the high network latency, due to continuous requests to get the current position of the nodes [14].

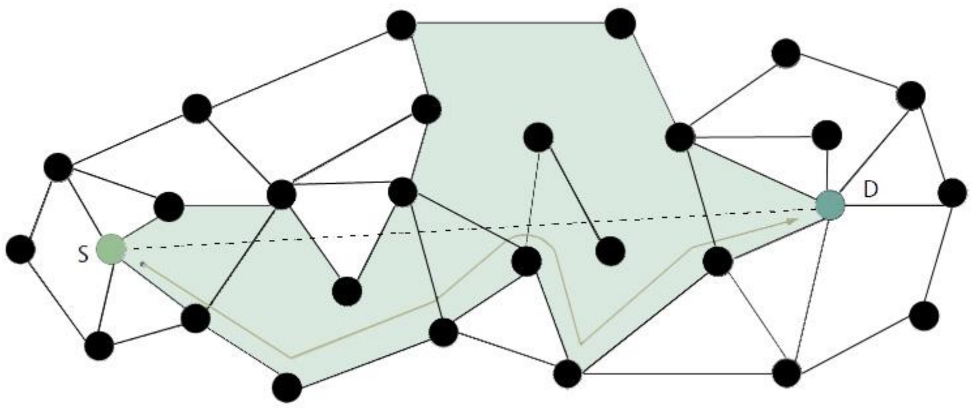


Figure 2. Planar Traversal using Perimeter Routing

3.1.3. 2-Hop Forwarding: This technique, that has been proposed to improve the protocol SPEED [16], provides a 2-hop forwarding approach [15] to address the problem of void in the networks. In this technique, which uses four Separate and complementary algorithms to forward a data packet, voids in the network are divided into two categories: open voids and closed voids. Closed voids means voids that are surrounded by network nodes and open voids located on the border of the network. Depending on whether the packet is stuck in the area of a closed void or open void, invoked a different algorithm. Two algorithms VBM and VBD are implemented respectively in order to recognize closed voids and updated them, and two algorithms NBM and NBD are used to recognize and update open voids. When a node S needs to send a packet, via this technique 3 case are possible: 1- Sender s has no information about voids: In this case, if none of the s's neighbors are not in the forward candidate neighbors set (FS), the sender s runs the VBD algorithm to identify the void region, otherwise forward the packet to one of the nodes in FS set. 2- Sender s is on the network boundary: Sender s uses the OVA-nb mechanism, which is described in [17], to direct packets to the destination by using a 2-hop forwarding mode on the network boundary. 3- Sender s is on boundary of a closed void:

Sender s invokes the OVA-vb routine based on a 2-hop forwarding mode on the void boundary. Thus, If there is no neighbor of s in the forwarding area as shown in Figure 3-a from [15], sender s sends the packet to its 2-hop upstream node identified by the VBD algorithm, but if the this area is not empty (*i.e.*, there is at least one non-boundary node in FS as shown in Figure 3-b), sender s forwards the packet to a neighbor n selected from its reduced FS.

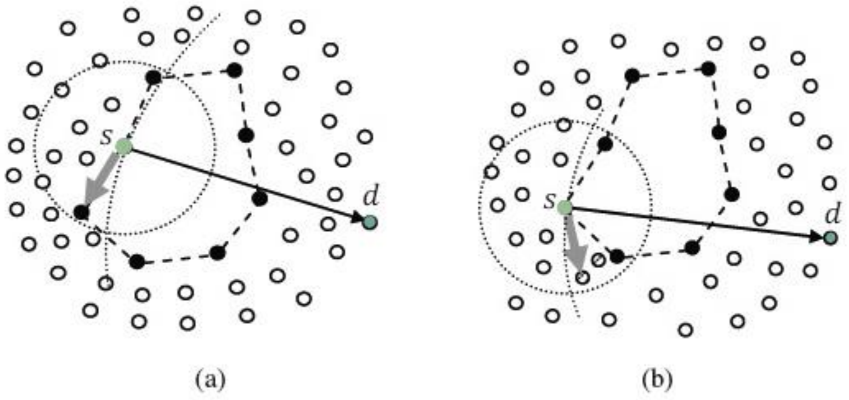


Figure 3. Sender s is on the Boundary of a Closed Void

2.2. Geometric Techniques

The basic idea of these techniques is the use of the geometric characteristics to identify void regions. By implementing a distributed detection algorithm, checked that a node is located at the border of a void or not. Then details of the boundary of the void are stored in the void nodes. According to the requirement of the applications, this algorithm can be implemented in a pre-processing phase or on demand. BOUNDHOLE technique [14] is the best known and most effective technique in this group.

2.2.1. BOUNDHOLE: By the TENT rule [12], which is implemented in a distributed manner, void region detection operation is done. Through this rule neighboring nodes of node p are numbered according to the order of their position, then for each pair of adjacent nodes (p, x) and (p, y) perpendicular bisectors of the lines (p, x) and (p, y) is assumed. Intersection of these two bisectors, for example O point, considered as criterion to identify voids. If this point is within radio range of node p, as shown in Figure 4 from [12], node p is a non-void node; otherwise, the node p is located at the boundary of a void.

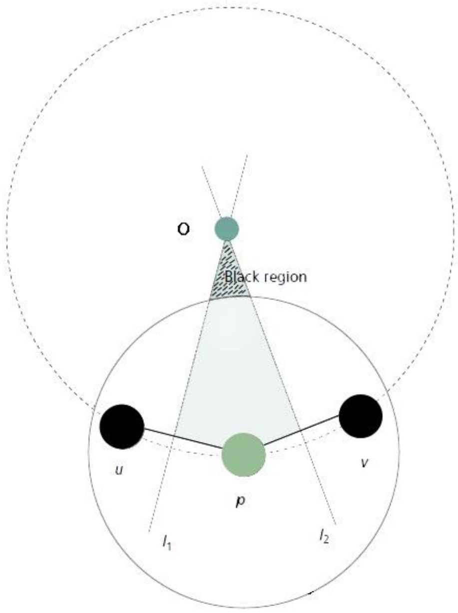


Figure 4. The TENT Rule to Detect Void Nodes

In the latter case node p runs BOUNDHOLE algorithm to identify whole boundary of the void region. The algorithm starts by sending specific packet from node p to neighboring nodes. Each void node that receives the packet, stores IDs of previous boundary nodes and sends packet contained these IDs to its neighbors. This process continues until the packet entered again at node p. Once all void regions of the network were identified through BOUNDHOLE algorithm and using TENT rule, upon arrival the first data packet at node p and get stops data packet at this node, stuck packet is forwarded on the boundary of void using IDs of boundary nodes are stored in the node p. Upon reaching data packet to a node that has less distance to destination than the distance between node p and destination, greedy forwarding algorithms back. The process of the algorithm is shown in Figure 5 from [12].

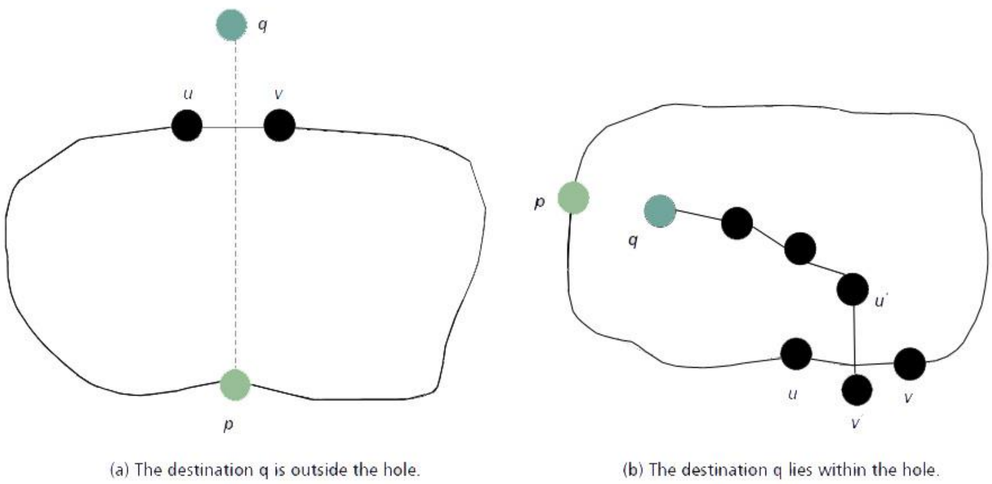
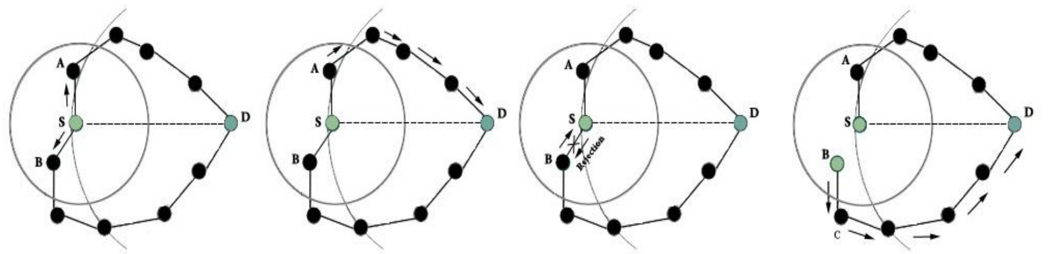


Figure 5. An Example to Show BOUNDHOLE Technique

2.3. Flooding based Techniques

Void-handling techniques in this category can guarantee packet delivery to the destination using flooding packets in a network. Through the simplest type of flooding which known as original flooding or full flooding [18], every node in the network is supposed to get a copy of stuck packets. Although this method is very effective and simple but it has extremely low efficiency, because a data packet is only useful for a specific destination, and the other nodes are not interested to receive unimportant Packets. Another reason that makes the method inefficient is large number of duplicate packets received at the destination. In short it can be said a large amount of network resources consumed to transmit a single packet. So in order to reduce the cost of flooding and keep its simplicity and effectiveness in flooding-based void-handling techniques, attempts have been made to control the range of flooding and the frequency of occurrence of flooding at void nodes to an intended extent. These flooding mechanism are called restricted flooding or partial flooding [19]. Among the techniques in this group there are the one hop Flooding [20] and Partial Source Routing which second algorithm is provided in OGF protocol [21].

2.3.1 One-hop Flooding: A kind of partial flooding mechanisms that is initiated by the void node through which the void node broadcasts stuck packet to only nodes in its immediate neighborhood. Upon receiving the packet, each neighbor resumes forwarding packet using greedy forwarding algorithm individually. If the void node be selected again as the next hop by one of the neighboring nodes to forward the stuck packet, void node discards the packet and sends a warning message to forwarder neighbor that means another node must be selected. If this neighbor node does not found another appropriate node to forward packet through it, this neighbor node has become into a void node. This algorithm can be extended to n-hop flooding technique. Function of this algorithm to handle a void is shown in Figure 6 from [21].



(a) One-hop flooding is executed at the void node S. Nodes A and B receive the stuck packet.

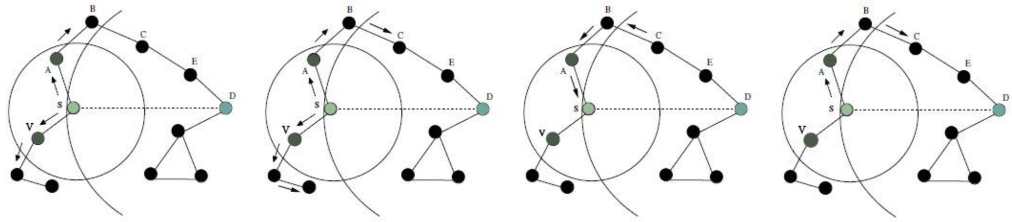
(b) The copy of the stuck packet at node A is delivered back to the destination D by greedy forwarding.

(c) Using greedy forwarding, node B has to send its copy of the stuck packet back to Node S, which then rejects the packet by acknowledging node B with a rejection packet. Node B cannot locate another appropriate node and becomes a new void node.

(d) One-hop flooding is executed at the void node B and greedy forwarding is reactivated again at node C to deliver the copy of the stuck packet back to the destination D.

Figure 6. An Example to Demonstrate How One-hop Flooding Handles a Void

2.3.2 Partial Source Routing: This technique includes an ON-Demand algorithm that consists of two phases: partial route discovery and source packet forwarding [23]. The aim of the algorithm in route discovery phase is finding a route through which the void node is directly connected to the destination node or to a node closer to the destination node than the void node. The route discovery phase begins at void node by sending a discovery packet to all its two-neighboring nodes. If a path discovered, this phase ends up otherwise the range of sending the discovery packet expanded to three-hop that is one more hop than the previous search, and then the discovery packet is re-broadcasted. This process continues until the desired node is found or the number of algorithm running is reaches the threshold defined in the protocol, which at the latter case the stuck packet will be discarded. At the forwarding phase the void node inserts to the stuck packet header the path that is learned and begins the packet forwarding in that path. Note here is that the path has been found is stored only in the void node. In Figure 7 from [21], a simple example of how to handle a void using the partial source routing is shown.



(a) A partial path request packet is initiated at the node S with Time to Live (TTL) is equal to 2, this discovery fails.

(b) Another partial path request packet is initiated with TTL is equal to 3.

(c) A partial path reply packet is sent back from node C, which is closer to data sink D.

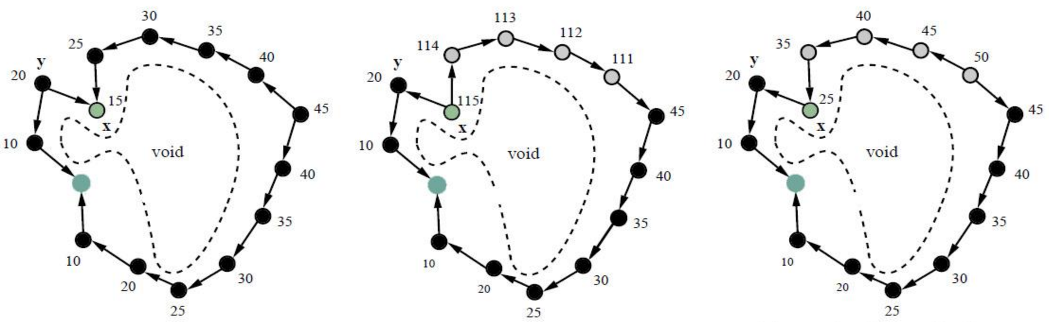
(d) The stuck data packet is then forwarded to node C by source packet forwarding and a void is resolved. Greedy forwarding is reactivated for the packet at this time.

Figure 7. An Example to Demonstrate How PSR Handles a Void

2.4 .Cost-based Techniques

These techniques handle a void through a cost based idea. One technique into this category is Distance Upgrading Algorithm (DUA) [22]. Main operation of these techniques is forwarding packets from a node has a higher cost towards a node has a lower cost. Proportional to the using context cost parameter can be defined differently. Once the using a cost based technique, according to the cost parameter defined in the protocol, a cost value will be assigned to all nodes in the network. Then the technique is activated after encountering any package with void.

2.4.1. Distance Upgrading Algorithm: The DUA algorithm, main idea is similar to the idea of cost-based forwarding in the PAGER-M protocol, describes two problems in cost-based algorithms and offers a solution for each. First problem is that there is a possible to generate inefficient routing paths, due to too high cost value that is upgraded at each node. In this algorithm, a method is provided for reducing the distance cost to an appropriate level. Figure 8.b and 8.c from [22] show respectively the mentioned problem and the presented solution in this algorithm. Second problem is incompatibility of these techniques with changes of the network topology. Hence, the algorithm proposed and applied a cost recovery process.



(a) The original cost (Euclidian distance to the destination) distribution.

(b) The cost distribution after distance upgrading.

(c) The cost distribution after distance downgrading.

Figure 8. An Example to Demonstrate How Distance Downgrade Produces Efficient Routing Paths

2.5. Heuristic Techniques

These techniques are based on several intuitive ideas and thus there is no a strict theoretical analysis on their effectiveness and performance. The basis of such techniques is exploiting some additional resources or using the natural properties of the network topology and geographical properties of the void area. Some of these techniques are avoidance, such as Anchored Geodesic Packet Forwarding (AGPF) [23] and Timer Based DFS recovery (TBD-LAROD) [24]. The other of these techniques includes alternate network [20] and intermediate node forwarding (INF) [25].

2.5.1. Alternate Networks: In this technique, each network node to handle the void and forward data packet around void area should be equipped with an alternative wireless network (*e.g.,* satellite). Although this method is effective but its cost is very high.

2.5.2. Intermediate Node Forwarding: The algorithm uses a probabilistic approach to forward packets that are stuck at a void node. When a packet encounters a void, the void node discards the stuck packet and sends a warning message to the source node. Once the source node receives such a message, assumes a line between themselves and the destination node and considers the middle point of the line as center of circle O. Afterwards the source node selects a random point inside the circle O and resend the data packet. If the packet enters at a node that random point is within the communication range, the node sends the packet to a neighbor node that is close to the destination than the other. If the packet re-stopped in a void node and discarded again, source node increases the radius of circle O and chooses another random point. This process repeated until either the packet reaches the destination, or the number of repetition reach to threshold value and the source node suppose that the destination is unreachable. Operation of the algorithm is shown in figure 8 from [25]. Node A is sending a data packet to the destination G. The data packet forward to node C via node B and gets stuck at node C. In this case, C discards the stuck packet and notifies to A via a warning message. Upon receiving the message at node A, it forms circle with radius r1 and selects random point l1 inside the circle. For the second time the data packet forwarded to node C and discarded by node C. Once receiving the second warning, the source node A increases radius r1 to r2 and considers another random point. Thus data packet delivered via route $C->D->E->F$ to destination G.

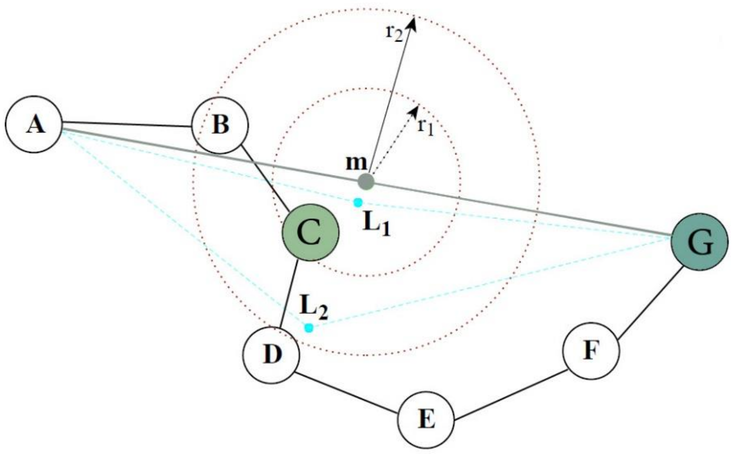


Figure 9. An INF Example

2.5.3. Anchored Geodesic Packet Forwarding: Unlike a lot of void-handling techniques, AGPF in terminode routing [23] is a preventive technique, which tries to prevent a packet from encountering. In this technique, the source node attaches a list of temporary destinations which are called anchors, in the packet header before sending that. Once reaching the data packet to a node that has the first anchor in its radio range, ID of that removed from the list and forwarded to the second anchor. This process continues until all IDs of anchors removed from the list then deliver to the original destination. The data packet is forwarded greedily between anchors. If the anchors are properly chosen, there is high possibility to deliver the data packet to the destination. Note that the sender needs to acquire the position information of anchors and maintain it periodically. Note that the sender needs to maintain and update the current position of anchors.

2.5.4. TBD-LAROD Technique: In this technique, that is presented to improve the performance of the LAROD-LoDiS protocol, when a node i is required to forward a stuck packet it broadcasts a ReTF message to find the next best node among the neighboring nodes. As soon as receiving the ReTF message, each neighbor node calculates a timer based on the node's positive progress towards the destination node and void flag value. VF flag is maintained locally via each node Flag indicates the state of the node with respect to a specific destination. When the timer expires, each node responds with an RsTF (Response-To-Forward) message to notify its willingness to be the next hop. Other nodes cancle sending your response when node I receives the first RsTF message. An example of how to deliver data packets from a source to a destination using TBD algorithm is shown in Figure 9 from [24]. Gray nodes show the nodes that are involved in the process of sending and receiving RsTF and ReTF messages, an arrow between two nodes indicates the direction of sending messages, dotted lines represent movements by nodes when packet could not be transmitted and the numbers besides nodes are the void flag [24]. Node x is recognized as a void node. Also in this figure can realize the locally maintaining VF values.

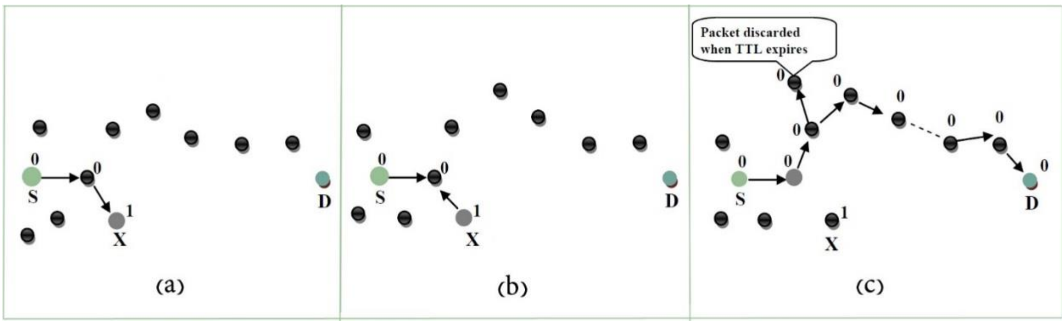


Figure 10. Example of Packet Forwarding by TBD-LAROD Technique

2.6. Virtual Destination based Technique

Exploit of Virtual destinations in void-handling Techniques is a new approach has been introduced in [26]. According to this proposed algorithm advantages of greedy forwarding can be exploited to direct data packets even in dealing with voids by specifying one or more temporary destination, whereas during the other void handling techniques the advantage of greedy forwarding cannot be achieved. POR algorithm [27] is an effective and efficient technique in this group.

2.6.1. POR: A POR algorithm's feature that is different from another geographic routing protocol is node that changes the routing mode. In most geographic routing protocols after encountering with a void, the forwarding mode changes at the void node, whereas the POR algorithm shows a situation (Figure 10 from [26]) where choosing the void node to change the packet forwarding mode, here node 5 in Figure 10, causes a non-optimal routing path. Hence the algorithm provides a solution in which void node sends a warning message to its previous node. Upon receiving the void warning message, that is just the data packet with some extra flags included in its header, the previous node (referred as trigger node) obliged to switch routing mode from greedy to void handling and forward the stuck packet. Greedy forwarding mode can be return when the stuck packet receives at a node that is closer to the destination than the trigger node. If the number of hops passed by the stuck packet exceeded the threshold a disrupt message sent to the trigger node, then the trigger node stops the routing in this path. It's clear that if the void happens at the source node, this node will be selected as trigger node and so source node will set forwarding mode as void handling without any other choice.

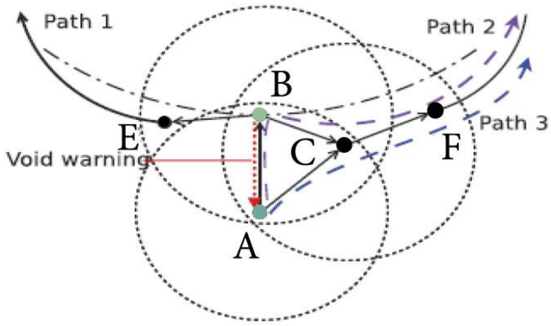


Figure 11. Example of Packet Forwarding by Position based Opportunistic Routing Technique

4. Brief Comparison

In this section these explained void handling techniques compared based on some important features to determine the most appropriate technique to use in the VANET. Table 1 shows the comparison of explained techniques.

Table 1. Characteristics of Void Handling Techniques

	Optimal Path	Overhead	Complexity	Scalability	Guarantee Delivery
Perimeter routing	No	Medium	Medium	Yes	Yes
Request-Response	No	Medium	Medium	Yes	Yes
2-hop forwarding	Yes	Medium	High	Yes	Yes
BOUNDHOLE	No	Medium	High	Yes	sometimes
One hop flooding	No	High	Low	Yes	Yes
PSR	Yes	High	High	No	Yes
DUA	Yes	Medium	Medium	Yes	Yes
Alternate network	No	Medium	High	Yes	Yes
INF	No	High	Medium	No	No
AGPF	No	Medium	High	Yes	No
TBD-LAROD	Yes	Medium	Medium	Yes	Yes
POR	Yes	Medium	Low	Yes	Yes

From table can be found that although planar graph based techniques, flooding based techniques and cost based techniques guarantee delivery data packets, however, only in distance upgrading algorithm, 2-hop forwarding and partial source routing the path through which the packet reaches the destination first is the optimal path. Instead, in the POR algorithm, a Virtual Destination based void handling method can provide high reliability in packet delivery through optimal path. BOUNDHOLE algorithm can guarantee the delivery of data packets to the destination only when the destination is outside the void region; however it's not necessarily the optimal path. Also, in alternate network technique, when it's available, is no attempt to find the optimal path but can ensure the delivery of packet. The TBD-LAROD algorithm with using a prioritization function can guarantee the delivery of packet and finds the optimal path.

The complexity of an algorithm is the degree of difficulty and cost in implementing the algorithm. Alternate network technique has a lot of complexity because of using of additional resources during implementation. Besides, the BOUNDHOLE algorithm, the PSR, 2-hop forwarding and AGPF techniques have a large complexity when implementing because of the difficulty of the protocol is used. The one hop flooding-based void-handling technique minimizes the flooding cost leads to no scalability.

About overhead can be found that likewise the flooding based techniques that have a large overhead because the nature of this type of publication, the INF algorithm impose excessive overhead to the network.

5. Conclusions

In this paper, a variety of void handling techniques to address voids in the vehicular ad-hoc network were examined. Process of each of these techniques and their features were explained. After that these void handling techniques were compared in term of several important features in order to study their impact on vehicular ad-hoc network performance.

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