Survey of Angle-based Forwarding Methods in VANET Communications

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***Abstract*—Vehicular Network (VANET) communications determine a promising mobile communication. Under the assumption that participating vehicles are equipped with the Global Positioning System (GPS), location coordinates of each vehicle can be obtained and vehicle location coordinates support a data forwarding scheme in order to optimize packet transmissions in VANETs. One of the existing forwarding schemes is the angle-based forwarding approach. It serves several purposes based on the specific network characteristics, such as network density, mobility, and road environment. The concept of the angle-based forwarding scheme has to take into account the relative-angle calculation and how it can support an optimal forwarding decision. Thus, this survey identifies important angle-based forwarding schemes in VANETs by reviewing their characteristics, purposes, advantages, and drawbacks. Additionally, this work determines which angle-based forwarding scheme fits best those several issues in VANET communications such as intermittent connectivity, environment, and frequent change topology.**

***Index Terms*—Angle-based forwarding method, classifications, VANET.**

I. Introduction

Vehicular Networks (VANET) define an approach to provide mobile communications in public transportation environments, while integrating the vehicles themselves to carry, forward, source, or sink data [1]. One type of VANETs is the Vehicular-to-Vehicular (V2V) network, where vehicles are participants, which exchange information such as alert message or position coordinates [10]. The application of V2V networks today, which is also known as an "inter-vehicle network", includes safety and non-safety applications. Safety applications span from crash prevention to car error detection messaging, and non-safety applications include personal activities, which can be performed during transportation (*i.e.* Web surfing and social network access), if the person communicating is not the driver [1].

With the Global Positioning System (GPS) [18] today, in the future with the European Galileo System [19], the location information of vehicles can be obtained. GPS provides information coordinates for certain vehicles in terms of altitude, longitude, and altitude.

The successful transmission of a message is the main goal of a suitable routing mechanism deployed on higher communication layers, especially on top of VANETs. Thus, the transmission process has several options for (a) quality assurance and (b) trade-offs in terms of alternative path selections. Several options of quality assurance in the transmission process include amongst others high throughput and stable data rates. Moreover, the following trade-off of successful transmission means the number of message overload will increase in order to speed up the searching process *i.e.* flooding mechanism.

In order to reach a successful and reliable transmission of data and messages in VANETs, several forwarding schemes have been proposed due to the challenging VANETs environment and conditions in terms of mobility, speed, and signal fading [2],[4]. The mobility and speed refer to velocity of vehicles which leads to frequent change topology. While the signal fading refers to the propagation loss and antenna type which leads to intermittent connectivity since it can be out of transmission range or caused by obstacles. The forwarding decision, typically the basic and core task of a routing mechanism for the data delivery itself, has several characteristics. Therefore, they need to be classified. Thus, this paper identifies existing forwarding schemes and categorizes them into three distinct classes. The first class is based on the environment which is determined as the road level topology and the existing obstacles such as buildings, trees, and vehicles. The second one is based on the network behavior, which is determined as the network mobility and density. The last class is based on the method to support the forwarding decision. Specifically, this forwarding scheme classification focuses on angle-based forwarding scheme only since relevant classifications had not been found in the literature but will have a clearly defined impact on the forwarding decision itself [17].

The reminder of this paper is organized as follows: Section II describes the key understanding of forwarding schemes. While Section III classifies specifically angle-based forwarding schemes, Section IV provides a detailed discussion of the angle-related forwarding approach. Finally, the summary is provided in Section V, complemented with conclusions.

II. Forwarding Schemes

The routing mechanism is a process to transmit relevant control information between routers, especially to enable the packet to be transmitted from a source S to a receiver R. A source is an origin node, which transmits a packet, while a receiver is a node which accepts a packet. A receiver can be the final destination or the next intermediate node. The initial process of searching the intermediate nodes which are located between S to R, is also known as *searching process*. This process uses the *flooding mechanism* that sends request packet to entire network. As the further process of deciding on the transmission of a packet, means have to exist to decide upon the "best" path in order to obtain an efficient and optimum transmitting process. This routing process requires the proper calculation of weights for each path foreseen. As the weight can be a numerical value, a hop count, a link quality, a delay constraint, a geographical distance, or a signal strength, appropriate calculations for end-to-end paths [8] are needed and respective protocols to transfer these control information in a decentralized manner are required. The decision of this process is handed over to the forwarding scheme, which simply utilizes local port information of a router to forward the packet [3].

A forwarding scheme has various methods that rely on positions, specifically addressed by this paper. The initial assumption holds that all nodes are equipped with GPS, therefore, all nodes know their current position and the position of their neighbors within their communication range (*i.e.*, transmission range, where the communication process is assumed to be successful). As there exists 3 types of forwarding schemes based on such a position information, each of them is presented below.

A. Most Forwarding Scheme (MFS)

This forwarding scheme calculates the path from a source *S* to its neighbors in order to obtain the best path to the receiver *R*. The way this forwarding scheme calculates the distance from *S* to *R* by forming the imaginary line between *S* and *R*, as illustrated in Figure 1. The MFS selects the intermediate node (*I*), which has the closest distance to the receiver amongst the forwarding nodes within the transmission range of a source node. Therefore, *A* is selected by *S* and *A* becomes the intermediate node because *A* fulfills aforementioned requirement [8].

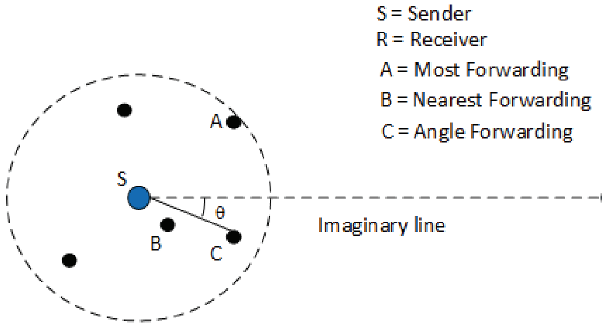

Fig. 1. Forwarding Scheme

MFS shows the key characteristic of minimizing the number of hops by maximizing the distance of transmission. Thus, in this scheme all nodes have the same transmission range without any concern about the signal strength, which means that the signal strength is considered as an evenly distributed pattern.

B. Near Forwarding Scheme (NFS)

Basically, this scheme is the opposite to MFS since NFS selects the intermediate node that has the closest distance to *S*. Therefore, the intermediate node is indicated as node B in Figure 1.

This scheme is suitable for participating nodes with different signal strengths. In order to obtain a good energy-efficient consumption of nodes, it is necessary such that they adjust the transmission power to reach their neighbors [8].

C. Angle Forwarding Scheme (AFS)

This forwarding scheme relies on an angle calculation. An angle θ is a shape formed by two straight lines, *S* to *R* and *S* to *C*, that have a vertex as illustrated in Figure 1. In order to obtain an exact angle calculation, it is necessary to discuss how this angle is measured. The initial phase of an angle calculation determines the imaginary line, which is similar to MFS and NFS. The imaginary line is the guidance line using node *S* and *R* as the reference point. Based on the imaginary line, AFS provides an additional measurement metric which is known as the relative angle. Both imaginary line and relative angle calculation are presented.

The dimensions of a transmission area can either form a 2-dimensional area or a 3-dimensional area. In a 2-dimensional area, the dimension covers a road layout, while in the 3-dimensional area, such as for underwater or aerospace situations, even for a landscape with tunnels and overpass, different contour lines define the 3-dimensional area [2]. In case of roads with a 3-dimensional property, the location information includes latitude, longitude, and altitude, which can be represented as an *x, y,* and *z*-axis in the cartesian representation.

The ***imaginary line*** for 2- and 3-dimensional areas, which is formed by line *S* and *R*, represents the dashed line *k* as shown in Figure 2. The *j* line is also an imaginary line formed between *S* (*i.e.,* in case of *S* has zero value in both *x* and *y*-axis) and *R* based on the *x* and *y*-axis, while *k* line is formed between *S* and *R* based on the *z, y* and *x*-axis. Therefore, the location coordinate of *S* and *R* are $S(x_S, y_S)$ and $R(x_R, y_R)$ in the 2-dimensional area, while $S(x_S, y_S, z_S)$ and $R(x_R, y_R, z_R)$ determine those in the 3-dimensional area. Based on these location coordinates, the imaginary line can be defined generally as Equation 1 and 2.

$$\Delta j = \sqrt{(x_R - x_S)^2 + (y_R - y_S)^2} \qquad \text{(Eqn. 1)}$$

$$\Delta k = \sqrt{(x_R - x_S)^2 + (y_R - y_S)^2 + (z_R - z_S)^2} \qquad \text{(Eqn. 2)}$$

Since various dimensions of an area are considered, ***relative angles*** in degrees are measured in two ways: First, they are measured between the positive *x*-axis and positive *y*-axis, which results in the angle θ_x, second, they are measured between the positive *z*-axis and the imaginary line, which results in the angle θ_z. In order to differ the terms of relative angle, the angle θ_x is rephrased as *horizontal relative angle* and the angle θ_z is rephrased as *vertical relative angle*.

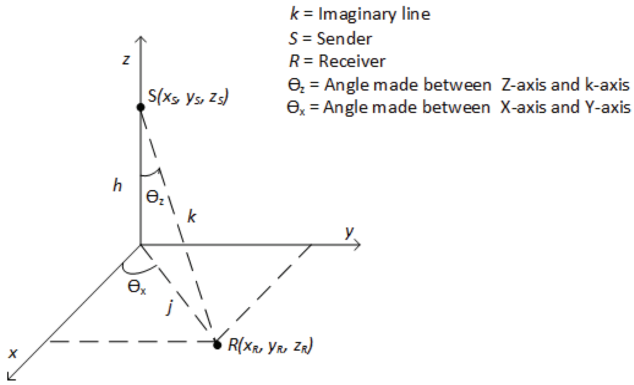

Fig. 2. Relative-angle Calculation.

Given *h, j,* and *k* as shown in Figure 2, the angles θ_z is calculated by Equation 3. The same approach can be used to calculate θ_x.

$$\theta z = atan\left(\frac{j}{h}\right) \qquad \text{(Eqn. 3)}$$

Thus, the term relative angle is defined as an angle measured between the imaginary line and the current node. By obtaining the relative angle, various angle-based forwarding schemes can be designed with respect to the potentially different network characteristics. The relative angle can be combined with a weight value to create an efficient forwarding scheme *i.e.,* the relative angle is combined with the speed of a particular node to predict the next movement of this particular node.

III. ANGLE-BASED FORWARDING

In order to decide upon an existing appropriate scheme, it is necessary to consider the various factors that influences a VANET communication. Those factors are the environment, network type, and mobility as shown in Figure 3.

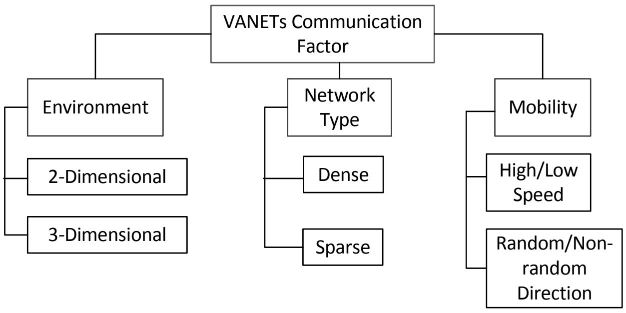

Fig. 3. VANETs Communication Factor

The first factor describes the characteristic of road topologies. This environment factor is classified as a 2-dimensional area and 3-dimensional area. The 2-dimensional area can either be the highway road or regular road in a city with intersections. The 3-dimensional area represents a road with different road levels, such as overpass or underpass, as indicated in the altitude level. However, these two environment factors can be combined since in the real road topology, a highway can have an overpass on it. Thus, this road topology is considered as a 3-dimensional area.

The second factor is the network type, which is divided into a dense network and a sparse network. A dense network involves many vehicles as participating nodes. Thus, the strategy in order to minimize the number of hops to be crossed for a communication, those participant nodes which potentially fit as the forwarder nodes, have to be reduced. For a sparse network such optimizations require a different strategy.

The third factor is the mobility, which can be classified as participant nodes with high or low speed and with random or non-random direction. Although it is not common in VANETs, mainly because vehicles usually move in predefined paths (*i.e.,* the road), both random and non-random mobility models are also considered due to multiple lanes' roads and frequent lane switches. Participant nodes with high speed and random direction show a high possibility to result in frequent topology changes. These frequent topology changes initiate an appropriate strategy in order to obtain location information in real time.

Since all of these factors influence VANET communications, it is important to cover various strategies of forwarding schemes based on the relative angle calculation as an additional weight value.

Those aforementioned factors lead to several angle-based forwarding schemes. The first angle forwarding scheme is used in routing protocol algorithms, which are designed to cope with the issue of a dense network. A candidate restriction filters out those participant nodes, which potentially become the intermediate candidate nodes. The intermediate candidates' nodes are those neighbor nodes, which can have the requirement to be the next intermediate node. This angle forwarding method calculates the reference angle *i.e.*, θ_1,θ_2, and θ_3, as illustrated in Figure 4. The reference angle decreases the degree value, therefore, the candidates within the reference angle area refer to the next intermediate nodes. This scheme is useful to be implemented in a dense network, since many neighbor nodes potentially become the intermediate node. This scheme of filtering out reduces the number of hops required for communications and narrows the area of flooding mechanisms.

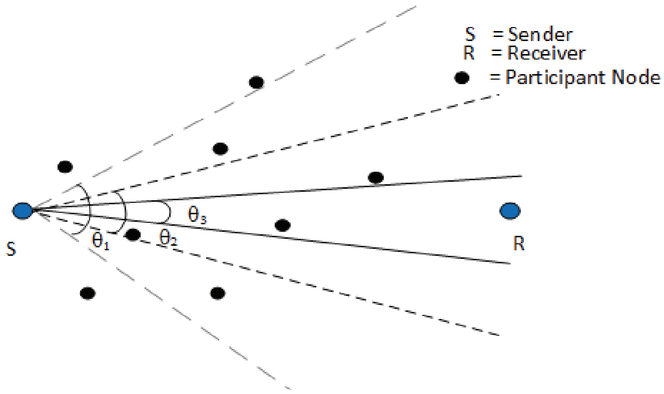

Fig. 4. Angle-based Candidate Restriction

The second angle-based forwarding scheme creates many imaginary zones. These zones aim to cluster neighbor nodes. The transmission area of *S* is divided into several zones within an specific angle *θ*. *S* is determined as the reference node to calculate the angle, as shown in Figure 5. This approach specifies those nodes, which have the same zone. If the particular zone is the zone, where *R* is located, *S* will only forward to nodes within a specific region. This angle-based zone cluster is useful for a dense network with a random mobility as an additional factor.

The third angle-based forwarding scheme predicts the movement of intermediate nodes. Since VANETs typically show frequent topology changes [7], it is necessary to obtain the current movement. The current movement of intermediate node covers velocity information, which determines a significant factor to predict the next movement. In addition, angle calculation in this forwarding scheme defines the direction of intermediate nodes.

The void avoidance scheme refers the term void to a condition, where there is no neighboring node around the intended transmission node. This scheme is an approach to a angle forwarding issue in a sparse network *i.e.*, there is no intermediate node available in that certain area [20]. The scheme of void avoidance targets at the increase of the angle

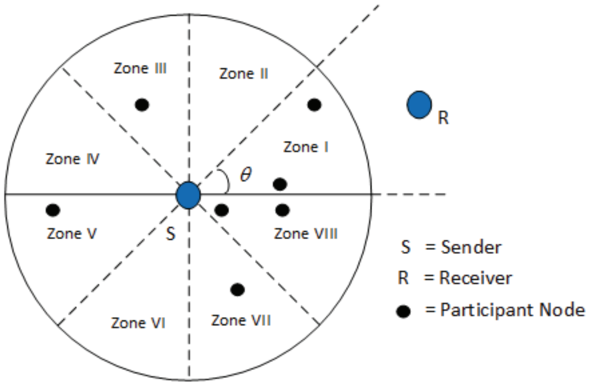

Fig. 5. Angle-based Zone Clustering.

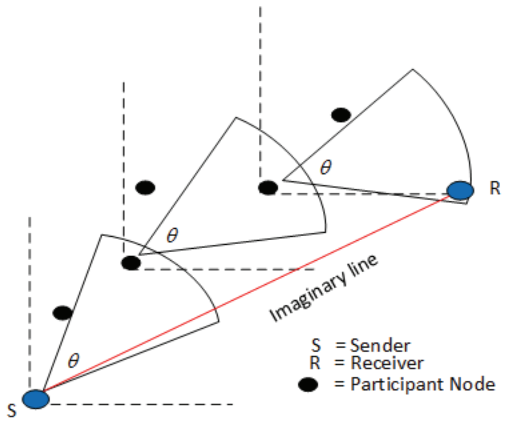

Fig. 6. Angle-based Movement Prediction

gradually in order to reach the next intermediate node in a wider area (*i.e.,* within the angle of θ_2) than the current one (θ_1) as illustrated in Figure 7.

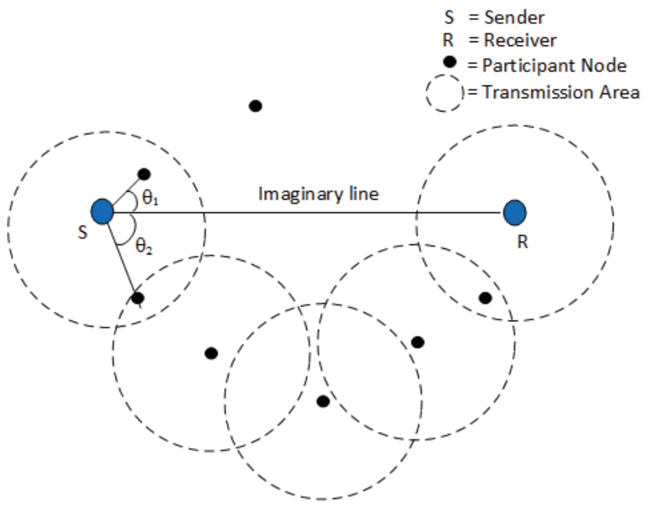

Fig. 7. Angle-based Void Avoidance

The set of angle-based forwarding schemes result in the classification as defined within Table I. Each angle based forwarding scheme works or supports either totally, partially, or not at all a selected factor, *e.g.,* dimensional area, mobility, or direction. Thus, it is necessary to combine those schemes with additional weight values, which are being adapted driven by the particular network factor. Moreover, in the following a brief analysis of each scheme with respect to the classification dimensions is done.

Candidate Restriction: This approach is well-suited for networks, which have a high dense property. Dense networks require more complex forwarding decision schemes. The number of participating nodes influences the network behavior. In case of dense networks with high speed vehicles in motion (at least on average), the forwarding decision has to look at another factor (*e.g.*, mobility behavior). In contrast, this approach has insignificant impact to a sparse network because of less participant nodes. However, this scheme can be combined with others, because most of the VANETs communication scenarios known are viable in large city environments.

Area Clustering: This is suitable for a 2-dimensional area, since it does not need to address the z-axis. The clustering mechanism is used to determine those vehicles with the same direction and transmission range, in order to manage the communications process. In addition, this approach fits to a network with the random direction factor. To the best of the author's knowledge, this type has not been designed for, prototyped, or evaluated in a 3-dimensional area, therefore, it is considered as an open problem for research.

Movement Prediction: The vector calculation does influence the mobility. Usually movement prediction schemes require the time-based relative angle calculation. This time-based property can be determined, since this type describes the current angle. It is considerably well suited within a network, which has high mobility and random direction factors. In contrast, this approach has the insignificant impact to the networks with sparse, low mobility, and non-random direction factors, since the time-based property is not a crucial factor to these type of networks.

Void Avoidance: Void issues also known as local minimal problem which occurs when there is no intermediate node which is closer to the destination than the source node it self. Advantages of the void avoidance approach include the fact that they are highly suitable for a 3-dimensional area, since several simulations indicate that the vertical relative angle being included into the consideration leads to cope the local minimum issue [23].

In several cases for sparse networks, it is difficult to find intermediate nodes which are located in the propagation area. As a result, a high delay is assumed to occur, since the search mechanism has to wait until finally a neighbor node is found. In contrast, the 3-dimensional area network shows the opposite behavior since this network type includes more participating nodes than in the 2-dimensional area [2].

IV. Angle-based Routing Protocol

This section provides a more detailed information on the key angle-related forwarding schemes that have been studied and are implemented in a few routing protocols being simulated for various VANET scenarios.

Compass Routing is the basic scheme of the relative angle forwarding method as mentioned in Section II.C. It is not a loop-free algorithm, since the smaller angle will more likely lead to a location closer to the destination. The compass method has a very high delivery rate for dense networks, but low delivery rate for sparse networks. Compass II (face routing) improves the basic mechanism with the additional feature of selecting intermediate nodes. This feature avoids the looping by reducing the spatial distance of packet transmissions [8].

Cone-Based Topology Control (CBCT) [5] takes an angle as a parameter to form a cone area. The cone area defines an expected transmission area with a defined particular degree. According to the CBCT algorithm the defined degree of $\alpha = 5\pi/6$ and $\alpha = 2\pi/3$ show the necessary and sufficient connectivity. Although there is a trade-off in using those two degrees, the relative angle has the significant impact on preserving connectivity and reducing the transmission radius.

A ***Cluster Establishment*** is performed in [6], which involves the relative angle to obtain the position between the current node and the neighbor. The relative angle is measured between the direction in which the current node is moving and the position of the closest neighbor.

This position also shows whether the current node has the neighbor or not by gathering relative angle information and distance. This position information is required to establish a cluster.

In the ***Link Quality Velocity Vector*** (LQ-VV-GPSR) approach [7] the angle-relative measurement is combined with the distance of the current node and receiver nodes, which provide their velocity information. The velocity information is, therefore, useful to predict the movement trend of participant nodes. If the measured angle is equal to or larger than 90°, the intermediate node moves in the reverse direction to the destination. If the measured angle is less than 90°, it moves the same direction with a destination or it is assumed as relatively static.

The ***Angle-based Dynamic Routing Scheme*** (ADRS) [10] determines the relative angle θ as the inclination angle, ϕ. Theoretically, they show an identical definition, since the angle is measured between the current node to its neighbor node and the current node to its destination. In ADRS, however, the predefined angle θ is set to 90°. Therefore, the inclination angle ϕ is expected not to exceed a given value $\theta/2$. In case of a small inclination angle, ADRS is suitable for a dense network. However, in case of a large inclination angle, the number of hops to be crossed is increased.

In the ***Distance Routing Effect Algorithm for Mobility*** (DREAM) [11] the relative angle is measured between *S* to *R* and *S* to *x*-axis at t_0. After a certain time, when *S* wants to send a packet to *R*, this relative angle is re-measured at t_1. Note that in this algorithm there is another relative angle *i.e.,* α, which depends on *R*'s speed. Thus, the relative angle becomes $(\theta - \alpha, \theta + \alpha)$. In addition, the relative angle is influenced by the distance of *I*. If the distance in *x* position*,* where *I* can travel at t_1 is greater than the distance between *S* and *I*, the angle α is set to π.

The ***Dynamic Angle Selection*** [12] has the purpose of reducing packet flooding. The relative angle increases 5° every time *S* cannot find *I.* If *I* has a relative angle that equals or is bigger than 90°, the packet is dropped. The initial value of the relative angle is set equal to 65°. In case of searching only one single path, the region within the angle θ is doubled. The selection of the angle is also dynamic in the sense that angles can vary, if *S* cannot find any nodes.

The ***Directional Flooding-based Routing*** (DFR) [13] determines the *base_angle* as the angle formed by *S* to *D* and *S* to *R*. The algorithm compare the *base_angle* to *current_angle*. The *current_angle* is measured by *S* to *D* and *S* to *R* at the next step. If the *current_angle is* smaller than the *base_angle*, *R* is selected as the next intermediate node. The DFR algorithm continues until *R* is the destination.

Similar to DFR, the ***Angle-based Dynamic Source Routing*** (ADSR) offers the concept of a threshold angle [21]. The threshold angle θ adjusts to the network density and to the vehicle's speed. This threshold angle will be smaller in a denser network and applied for a high speed node.

In the ***Vector-based Forwarding*** protocol (VBF) [22] a factor to measure the "suitableness" of a node to forward packets is introduced. This factor includes the measured angle between the destination node and forwarder node, which has an impact on forwarding decision.

The ***Heading direction Angles*** (HDA) [15][14] scheme divides the transmission locations to 8 zones with a separation of 45° each. The purpose of this scheme is to define which nodes belong to which zone. Thus, HDA limits the area of flooding. A similar scheme as HDA can be found in [16], which also divides locations to several zones in order to determine which intersection the vehicles are moving to.

The ***Hybrid Distributed Topology Control*** (HDTC) [17] provides an effective topology management. It uses the cone-based scheme with the additional weight value *i.e.*, time slot, to indicate the current and future position of a particular node. The cone is measured based on the relative angle with maximal angle changes.

In ***GeoAODV*** [18] a position is defined by the *x, y, z* vector and at the time *t*. However, *z* is always 0, because all nodes are located on the surface of the earth. Two angles are measured in GeoAODV algorithm, *i.e.,* angle α and angle θ. Angle α spans between 0 to 180° that indicates the search area of intermediate nodes. Angle θ is formed between *S-D* and *S-I.* Therefore, the angle θ has to be smaller than angle α in order to limit the searching area. This algorithm improve the searching process by reducing the number request packet.

The ***Angular Routing Protocol*** (ARP) [20] uses the angle-forwarding scheme with a weight value *i.e.*, time stamp, to cope with the void issues. When there is no intermediate node which is closer to the destination node than the source node itself, the ARP algorithm selects the node with the smallest angle towards the destination.

V. Discussion

The main property of the relative angle calculation is the definition of the imaginary line between the source *S* and the destination *D*. In addition, the relative angle calculation can be combined with other weight values, such as link quality, distance, signal strength, and time difference.

The set of angle-based forwarding schemes result in the classification as defined within Table I. Each angle based forwarding scheme works or supports either totally, partially, or not at all a selected factor, *e.g.,* dimensional area, mobility, or direction. Thus, the relative angle can be combined with a weight value to create an efficient forwarding scheme, *i.e.,* the relative angle is combined with the speed of a particular node to predict the next movement of this particular node.

The main parameter, both in 2D and 3D areas, is the location coordinate, which determines the distance to each participating node. The challenge of measuring the relative angle due to frequent topology changes is the determination of the latest position of the current node under investigation. Thus, a time-based weight value determines an appropriate approach, because the location coordinate update is required. Therefore, the advantage of this scheme is promising, since a real-time application may be required and foreseen.

Due to the investigation of existing implementations and simulations the use of metrics in vertical angles seems to be not fully exploited. Thus, to prevent erroneous conclusions, a more detailed exploration is required. The vertical relative angle scheme as discussed has an insignificant impact on forwarding decisions, even in the 3D area, since the transmission coverage is assumed to be evenly distributed. However, it is considerable to calculate the vertical relative angle, since it addresses the propagation loss and antenna type, which still determines open research.

To the best of the author's knowledge, those schemes are implemented in a 2D area only, since they do not address the z-axis, thus, have not been designed for, prototyped, or evaluated in a 3D area. Therefore, this is considered as open research, too.

TABLE I. ANGLE-BASED FORWARDING SCHEME CLASSIFICATION

Factor	**Angle-based Forwarding Scheme**			
	Candidates Restriction	**Area Clustering**	**Movement Prediction**	**Void Avoidance**
Sparse Network	No	No	No	Yes
Dense Network	Yes	Partially	Partially	No
2-D Area	Partially	Yes	Partially	Partially
3-D Area	Partially	No	Partially	Partially
High Mobility	No	No	Yes	Partially
Low Mobility	No	No	No	Yes
Random Direction	Partially	Yes	Yes	Partially
Non-random Direction.	Partially	Partially	No	No

VI. SUMMARY AND CONCLUSIONS

This paper classified angle-based forwarding schemes for VANETs based on the key VANET communication factors and provided the strategy to cope with network characteristics. While the angle-based forwarding requires the location coordinate as the main information in classification, such a coordinate provides a guidance to select a suitable forwarding scheme for a given set of requirements as a trade-off decision, when they shall be deployed and implemented for particular VANETs.

Concluding, the relative angle improves the performance of a routing protocol. Most of those schemes require factors that fit into VANETs' behavior. By adding weight values to angle-based forwarding schemes, the forwarding decision increases the effectiveness of locating the intermediate node, which subsequently minimizes the number of hops to be communicated across, reduces the message overhead, and decreases overall delays.

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