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Article 8. [illegible]

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- **Liang Zhou**, Nanjing University of Posts and Telecommunications

Wireless Days 2016 Technical Sessions

WiCom 1 : Wireless Communication – session 1 (Wednesday 23 11h45-12h45)

How to wake up an access point?
Dareen Shehadeh (Institut Mines Telecom / Telecom Bretagne, France) Tanguy Kerdoncuff (Institut Mines Telecom / Telecom Bretagne, France) Alberto P Blanc (Telecom Bretagne, France) Nicolas Montavont (Institut Mines Telecom / Telecom Bretagne, France)

A dynamic rate adaptation algorithm using WB E-model for voice traffic over LTE network
Duy-Huy Nguyen (Telecom SudParis, France) Hang Nguyen (Institut Mines-Telecom, Telecom SudParis, France)

A Clustering Algorithm for Distributed Service Registries in Heterogeneous Wireless Networks
Christopher Kramer (University of Kaiserslautern, Germany) Dennis Christmann (University of Kaiserslautern, Germany) Reinhard Gotzhein (University of Kaiserslautern, Germany)

WiCom 2 : Wireless Communication – session 2 (Wednesday 23 15h30-17h00)

A New Waveform based on Slepian Basis for 5G System
Xianjun Yang (Fujitsu Research & Development Center, P.R. China) Wang Xin (Fujitsu Research and Development Center, Beijing, P.R. China) Jian Zhang (Fujitsu R&D Center China, P.R. China)

Outage Probability of Full-Duplex Fixed-Gain AF Relaying in Rayleigh Fading Channels
İbrahim Altunbaş (Istanbul Technical University, Turkey) Asil Koc (Istanbul Technical University, Turkey) Abbas Yongacoglu (University of Ottawa, Canada)

Wsec : Wireless Security (Wednesday 23 14h00-15h00)

Evaluation of Sybil Attack Detection Approaches in the Internet of Things Content Dissemination
Danilo Evangelista (Federal University of Parana, Brazil) Farouk Mezghani (University of Toulouse, France) Aldri Santos (UFPR, Brazil) Michele Nogueira (Federal University of Paraná, Brazil)

Key Exchange Protocols for Secure Device-to-Device (D2D) Communication in 5G
Ravindranath Sedidi (Indian Institute of Technology Hyderabad, India) Abhinav Kumar (Indian Institute of Technology Hyderabad, India)

V&DTN : Vehicular and Delay Tolerant Networks (Wednesday 23 14h00-15h00)

Path Planning of Unmanned Aerial Vehicles With Terrestrial Wireless Network Tracking
Mustapha Bekhti (Université Paris 13, Sorbonne Paris Cité, France) Marwen Abdennebi (L2TI Laboratory, University of Paris Nord, France) Nadjib Achir (University of Paris 13 & L2TI - University of Paris 13, France) Khaled Boussetta (University of Paris 13, France)

Analysis of multi-hop broadcast in vehicular ad hoc networks: a reliability perspective
Mozhdeh Gholibeigi (University of Twente, The Netherlands) Geert Heijenk (University of Twente, The Netherlands)

AHSN 1 : Ad Hoc and Sensor Networks – session 1 (Wednesday 23 11h15-12h45)

New 802.11aa ACK leader selection scheme for multicast QoS improvement
Kaouthar Mansour (ENIT, Tunisia) Issam Jabri (Ecole Nationale d'Ingénieurs de Gabès, Tunisia) Tahar Ezzeddine (ENIT, Tunisia)

Reliability Assessment of Wireless Sensor Network Deployments
Dina Deif (The American University in Cairo, Egypt) Yasser Gadallah (The American University in Cairo, Egypt)

DecaDuino: An Open Framework for Wireless Time-of-Flight Ranging Systems
Adrien van den Bossche (Université Fédérale de Toulouse, France) Rejane Dalce (Institut de Recherche en Informatique de Toulouse UMR 5505 - CNRS, France) Fofana Nezo Ibrahim (University of Toulouse, France) Thierry Val (University of TOULOUSE - UT2J - CNRS - IRIT - IRT team, France)

AHSN 2 : Ad Hoc and Sensor Networks – session 2 (Thursday 24 10h45-12h45)

Social-aware Clustering for Wireless Ad hoc Networks
Luís Conceição (University of Coimbra, Portugal) Marilia Curado (University of Coimbra, Portugal)

Simba: Similar-evolution Based Aggregation in Wireless Sensor Networks
Jin Cui (Univ Lyon, INSA Lyon, Inria, CITI, France) Fabrice Valois (Univ Lyon, INSA Lyon, Inria, CITI, France)

Confident-based Adaptable Connected objects discovery to HArmonize smart City Applications
Riccardo Petrolo (Inria Lille - Nord Europe, France) Valeria Loscrí (Inria Lille-Nord Europe, France) Nathalie Mitton (Inria Lille - Nord Europe, France)

Collaborative Edge Mining for Predicting Heat Stress in Dairy Cattle
Kriti Bhargava (Telecommunications Software & Systems Group, Waterford Institute of Technology, Ireland) Stepan Ivanov (Waterford Insitute of Technology & TSSG, Ireland)

AHSN 3 : Ad Hoc and Sensor Networks – session 3 (Friday 25 10h45-12h45)

MCLSPM: Multi-constraints Link Stable Multicast Routing Protocol in Adhoc Networks
Gaurav Singal (Malaviya National Institute of Technology, Jaipur, India) Vijay Laxmi (Malaviya National Institute of Technology, Jaipur, India) Manoj Singh Gaur (Malaviya National Institute of Technology, India) Swati Todi (RU, Jaipur, India) Vijay Rao (DRDO, India) Akka Zemmari (University of Bordeaux, France)

Traffic-adaptive duty cycle adaptation in TR-MAC protocol for Wireless Sensor Networks
Sarwar Morshed (University of Twente, The Netherlands) Mitra Baratchi (University of Twente, The Netherlands) Geert Heijenk (University of Twente, The Netherlands)

Energy-Efficient Adaptive Forwarding Scheme for MANETs
Atif A. Alghamdi (Heriot Watt University - Edinburgh, United Kingdom) Robert Pooley (Heriot Watt University at Edinburgh UK, United Kingdom) Peter King (Heriot Watt University at Edinburgh UK, United Kingdom)

Dynamic Multi-Channel Allocation Mechanism for Wireless Multimedia Sensor Networks
Zongyi Liu (Toulouse Institute of Computer Science Research(IRIT), INSA, University of Toulouse, France) Daniela Dragomirescu (LAAS-CNRS, University of Toulouse & University of Toulouse, France) Georges Da Costa (University of Toulouse, France) Thierry Monteil (LAAS-CNRS, University of Toulouse, France)

5G : 5G (Friday 24 10h45-12h45)

Mobile Users Assignment Control Strategies For LTE Networks
Barth Dominique (University of Versailles, France) Amira Choutri (University of Versailles, France) Leila Kloul (PRiSM Laboratory, University of Versailles, France) Olivier Marce (Alcatel-Lucent Bell Labs, France)

Optimization of the predefined number of replications in a Ultra Narrow Band based IoT network
Yuqi Mo (CITI of INSA-LYON & SIGFOX, France) Minh-Tien Do (Centre of Innovation in Telecoms and Integration Service, INSA Lyon & SIGFOX, France) Claire Goursaud (INSA-Lyon, France) Jean-Marie Gorce (INSA-Lyon, France)

Deployment of UAV-Mounted Access Points According to Spatial User Locations in Two-Tier Cellular Networks
Boris Galkin (Trinity College Dublin, Ireland) Jacek Kibilda (Trinity College Dublin, Ireland) Luiz DaSilva (Trinity College & Trinity College Dublin, Ireland)

LTE-A Random Access Channel Capacity Evaluation for M2M Communications
Soukaina Cherkaoui (INSA Lyon & INRIA, France) Inès Keskes (Ecole Nationale d'Ingénieurs de Tunis, INSA Lyon, France) Herve Rivano (Inria & Université de Lyon, INRIA, INSA Lyon, CITI, France) Razvan Stanica (INSA Lyon, France)

WM&S 1 : Wireless Models and Simulations – session 1 (Wednesday 23 15h30-17h00)

Evaluation of Medium Access and a Positioning System in Wireless Underground Sensor Networks
Sergio Conceição (INESC TEC, Portugal) Cristiano Pendão (University of Minho, Portugal) Adriano Moreira (University of Minho & Algoritmi Research Centre, Portugal) Manuel Pereira Ricardo (Universidade do Porto & INESC Porto, Portugal)

Modeling, Implementation and Evaluation of IEEE 802.11ac in NS3 for Enterprise Networks
André Jönsson (Lund University, Sweden) David Åkerman (Lund University, Sweden) Emma Fitzgerald (Lund University, Sweden) Christian Nyberg (Lund University, Sweden) Basuki Endah Priyanto (Sony Mobile Communications AB, Sweden) Kåre Agardh (Sony Mobile Communications AB, Sweden)

Multi-client Emulation Platform for Performance Testing of High Density 802.11 Networks
Germán Álvarez (Plan Ceibal, Uruguay) Martín Álvarez (Plan Ceibal, Uruguay) Fernando Bagalciague (Laboratorio de Otoneurología, Uruguay) Germán Capdehourat (Universidad de la República & Centro Ceibal, Uruguay) Juan González (Plan Ceibal & Universidad de la República, Uruguay) Juan Marfia (Plan Ceibal, Uruguay) Pedro Porteiro (Plan Ceibal, Uruguay) Ana Rodríguez (Plan Ceibal, Uruguay)

WM&S 2 : Wireless Models and Simulations – session 2
MN&App : Mobile Networks Protocols and Applications (Thursday 24 10h45-12h45)

QoE Optimization of ON/OFF Video Streaming Strategy in Wireless Networks
Mohamed Bouzian (University of Nice Sophia Antipolis & Orange Labs, France) Mustapha Bouhtou (Orange Labs, France) Taoufik En-Najjary (Orange Labs, France) Lucile Sassatelli (Université Nice Sophia Antipolis, France) Guillaume Urvoy-Keller (Université de Nice Sophia-Antipolis, France)

Towards a Time-domain Traffic Model for Adaptive Industrial Communication in ISM Bands
Ahmad Saad (Fraunhofer Institute for Embedded Systems and Communication Technologies ESK, Germany) Barbara Staehle (HTWG Konstanz, Germany)

Modeling Aeronautical Data Traffic Demand
Christoph Petersen (Hamburg University of Technology, Germany) Maciej Mühleisen (Hamburg University of Technology & RWTH Aachen University, Faculty 6, Germany) Andreas Timm-Giel (Hamburg University of Technology, Germany)

A Study on MPTCP for Tolerating Packet Reordering and Path Heterogeneity in Wireless Networks
Amani Alheid (University of Bristol & Public Authority for Applied Education and Training (PAAET) - Kuwait, United Kingdom) Angela Doufexi (University of Bristol, United Kingdom) Dritan Kaleshi (University of Bristol, United Kingdom)

AHSN 4 : Ad Hoc and Sensor Networks – session 4 (Friday 25 14h00-16h00)

Finding Network Connectivity Failure in a Wireless Sensor Network
Mahmuda Naznin (Bangladesh University of Engineering and Technology (BUET), Bangladesh)

Virtual and Unified Address Assignment for Continuous Communication in Mobile Networks
Robson Gomes de Melo (Federal University of Paraná, Brazil) Farouk Mezghani (University of Toulouse, France) Michele Nogueira (Federal University of Paraná, Brazil) Aldri Santos (UFPR, Brazil)

Monitoring KPIs in Synchronized FTDMA Multi-hop Wireless Networks
Guillaume Gaillard (INSA LYON, Citi Lab & Orange Labs, France) Dominique Barthel (Orange Labs & France Telecom, France) Fabrice Theoleyre (CNRS - University of Strasbourg, France) Fabrice Valois (Univ Lyon, INSA Lyon, Inria, CITI, France)

Maximally Pair-wise Disjoint Set Covers for Directional Sensors in Visual Sensor Networks
Shahla Farzana (Bangladesh University of Engineering and Technology, Bangladesh) Khaleda Papry (Bangladesh University of Engineering and Technology, Bangladesh) Ashikur Rahman (State University of New York, USA) Raqeebir Rab (Ahsanullah University of Science and Technology, Bangladesh)

WM&S3 : Wireless Models and Simulations – session 3 (Friday 25, 14h00-16h00)

A New Approach to Polynomial Chaos Expansion for Stochastic Analysis of EM Wave Propagation in an UWB Channel
Piotr Górniak (Poznań University of Technology, Poland) Wojciech Bandurski (Poznań University of Technology, Poland)

Laboratory tests of ATSC M/H commercial receivers
Flor G. Ortíz (Universidad Nacional Autónoma de México, Mexico) Carmen López (Universidad Nacional Autónoma de México, Mexico) Mario Hernández (National Autonomuos University of Mexico, Mexico) Andrés Miranda (Universidad Nacional Autónoma de México, Mexico) José María Matías (Universidad Nacional Autónoma de México, Mexico)

Effective Deployment of Cooperative Moving Relay Nodes in a High Speed Train
Ayotunde Laiyemo (Centre for Wireless Communication, Finland) Harri Pennanen (University of Oulu, Finland) Pekka Pirinen (University of Oulu, Finland) Matti Latva-aho (UoOulu, Finland)

Wireless Days 2016 Poster Sessions

Poster session 1 — AHSN-P : Ad Hoc and Sensor Networks – Poster Session (Wednesday 23 10h30-11h15)

Multi-channel routing protocol for dynamic WSN
Bizagwira Honoré (Université Blaise Pascal & France, France) Joël Toussaint (LIMOS - CNRS, France) Michel J. Misson (Clermont Université / LIMOS CNRS, France)

QoS-aware Streaming With HCCA TXOP Negotiation in Overlapped Wi-Fi Networks
Evgeny Khorov (IITP RAS, Russia) Anton Kiryanov (IITP RAS) Andrey Lyakhov (IITP RAS, Russia)

Why is Frequency Channel Diversity so Beneficial in Wireless Sensor Networks?
Liviu-Octavian Varga (STMicroelectronics, France) Martin Heusse (Grenoble Informatics Laboratory & Grenoble INP, France) Roberto Guizzetti (STMicroelectronics, France) Andrzej Duda (Grenoble Institute of Technology, France)

Machine-to-Machine Communications over the Internet of Things: Private Wi-Fi Access Prospects
Mohamed Anis (Ain-shams University, Egypt) Yasser Gadallah (The American University in Cairo, Egypt) Hadya El-Hennawy (Ain Shams University, Egypt)

Fragment Retransmission Scheme with Enhanced Collision Avoidance for Energy-Efficient IEEE 802.11 WLANs
Prosper Mafole (University of Dar es Salaam, Tanzania) Mussa Kissaka (University of Dar es Salaam, Tanzania) Masayoshi Aritsugi (Kumamoto University, Japan)

Towards Quality of Service for Long-range IoT in Unlicensed Radio Spectrum
CongDuc Pham (University of Pau, France)

LEACH-Reformed Clusters: A Novel Cluster Formation Algorithm in LEACH protocol
Vesna Glavonjic (University of Belgrade, Serbia) Ljerka Beus-Dukic (University of Westminster, United Kingdom) Aleksandar Neskovic (University of Belgrade, School of Electrical Engineering, Serbia)

A Novel Dynamic Secure Combinatorial Key Approach for Differentiated Heterogeneous WSNs
Wael Hosny Fouad Aly (University of Quebec in Montreal, Canada)

Poster session 2 — WiCom-P : Wireless Communication – Poster Session
V&DTN-P : Vehicular and Delay Tolerant Networks – Poster Session (Thursday 24 10h00-10h45)

QoS-aware Admission Control Formalism for OFDMA-based Network
Abbes Yosra (Supcom, Tunisia) Sameh Najeh (Sup'com, Tunisia) Hichem Besbes (Ecole Superieure de Communications de Tunis, Sup'Com, University of Carthage, TUNISIA, Tunisia)

A Cooperative MAC Protocol for Lossy Forwarding Networks
Mathias Brulatout (Thales Communications & Security, France) Hicham Khalife (Thales Communications & Security, France) Vania Conan (Thales Communications & Security, France) Szymon Szott (AGH University of Science and Technology, Poland) Marek Natkaniec (AGH University of Science and Technology, Poland) Katarzyna Kosek-Szott (AGH University of Science and Technology, Poland) Lukasz Prasnal (AGH University of Science and Technology, Poland)

Real Time Haptic Data Transferring
George Kokkonis (University of Macedonia, Greece) Kostas Psannis (University of Macedonia, Greece) Manos Roumeliotis (University of Macedonia, Greece)

Enhanced CSI Feedback Scheme for Non-Orthogonal Multiple Access
Wei Xi (Fujitsu Research & Development Center Co., LTD., P.R. China) Hua Zhou (Fujitsu Research & Development Center Co., LTD, P.R. China)

Hybrid Solutions for Data Dissemination in Vehicular Networks
Lars Wischhof (Munich University of Applied Sciences & Hochschule Muenchen, Germany) Smriti Gopinath (Munich University of Applied Sciences, Germany) Christoph Ponikwar (Munich University of Applied Sciences, Germany) Hans-Joachim Hof (Munich University of Applied Sciences, Germany)

Survey of Angle-based Forwarding Methods in VANET Communications
Lisa Kristiana (University of Zürich, Switzerland) Burkhard Stiller (University of Zürich & ETH Zürich, TIK, Switzerland) Corinna Schmitt (University of Zurich, Switzerland)

Dissemination Strategies in Realistic V2V Highway Networks: the Madrid Trace Case
Alexandre Mouradian (University Paris-Sud, France) Véronique Vèque (University of Paris-Sud 11, France)

Massive M2M Deployments: LTE Attachment Prospects
Mostafa elTager (Cairo University, Egypt) Yasser Gadallah (The American University in Cairo, Egypt)

Reduced M2M Signaling Communications in 3GPP LTE and Future 5G Cellular Networks
Pilar Andres-Maldonado (University of Granada, Spain) Pablo Ameigeiras (University of Granada, Spain) Jonathan Prados (University of Granada, Spain) Juan J. Ramos-Muñoz (University of Granada, Spain) Juan M. Lopez-Soler (University of Granada, Spain)

Poster session 3 — WM&S-P : Wireless Models and Simulations – Poster Session
MN&App-P : Mobile Networks Protocols and Applications – Poster Session
5G-P : 5G – Poster Session (Friday 25 10h00-10h45)

Thresholds Selection for Censored Energy Detection based Two Witnesses Rule for Cognitive Radio Networks
Rahma Bouraoui (Engineering College of Communication of Tunis, Sup'Com & COSIM Reasearch Lab, Tunisia) Hichem Besbes (Ecole Superieure de Communications de Tunis, Sup'Com, University of Carthage, TUNISIA, Tunisia)

Assessing the WiFi offloading benefit on both service performance and EMF exposure in urban areas
Mathieu Brau (SIRADEL, France) Julien Stephan (SIRADEL, France) Luis Diez (University of Cantabria, Spain) Yoann Corre (SIRADEL, France) Yves Lostanlen (SIRADEL & University of Toronto, Canada) Ramón Agüero (University of Cantabria, Spain)

Very Tight Coupling Between LTE and WiFi: From Theory To Practice
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Survey of Angle-based Forwarding Methods in VANET Communications

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***Abstract*—The location information for a forwarding scheme for Vehicular Ad-hoc Network (VANET) communications serves several purposes based on specific network characteristics. The concept of the angle-based forwarding scheme takes into account the relative-angle calculation to support an optimal forwarding decision. This survey summarizes angle-based forwarding schemes in VANET by reviewing their characteristics, purposes, advantages, and drawbacks. Additionally, this work determines which angle-based forwarding scheme fits best VANET communications of an intermittent connectivity, environment, and frequent topology changes.**

***Index Terms*—Angle-based forwarding, classification, VANET.**

I. Introduction

Vehicular Ad-hoc Networks (VANET) define an approach for mobile communications in public transportation environments, while integrating the vehicles themselves to carry, forward, source, or sink data [5]. The routing mechanism is the process to transmit relevant control information between routers, especially to enable packets to be transmitted from a source *S* to a receiver *R*. The forwarding decision, the core task of a routing mechanism, overcomes several factors that influence VANET communications performance. These factors include the environment, network type, and mobility. The environment describes the characteristic of road topologies and is classified as a two-dimensional (2D) area (*i.e.*, the road in a city with intersections) and three-dimensional (3D) area that represents a road with different road levels, such as overpass or underpass, as indicated in the altitude level [1].

As the number of participating vehicles has an impact on communications, it is necessary to classify network types into two distinct categories: dense network and sparse network. Due to various velocities of participating vehicles, the mobility factor can be classified as high or low speed. Although it is not common in VANETs, mainly because vehicles usually move in pre-defined paths (*i.e.,* the road), both random and non-random mobility models are also considered due to multiple lanes' roads and frequent lane switches. 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.

Thus, this paper — based on [15] — is organized as follows: Section II describes angle-based forwarding schemes. While Section III classifies angle-based forwarding schemes, Section IV provides a detailed discussion of the angle-related forwarding approach and several open issues. Finally, a summary is provided in Section V, complemented with main conclusions.

II. Forwarding Scheme

A forwarding scheme calculates the path from a source *S* to its neighbors in order to obtain the best path to the receiver *R*. 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 [2], [3].

The *Most Forwarding Scheme (MFS)* selects the intermediate node (*i.e.,* node *A*), which has the closest distance to the receiver amongst forwarding nodes within the transmission range of a source node. The *Near Forwarding Scheme* (NFS) determines the opposite to MFS, because NFS selects the intermediate node (*i.e.,* node *B*) that has the closest distance to *S*. The *Angle Forwarding Scheme* (AFS) relies on an angle calculation [4]. 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, 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 this imaginary line, AFS provides an additional measurement metric, which is known as the relative angle. Figure 2 outlines the calculation of the distance from *S* to *R* by forming the imaginary line between *S* and *R*.

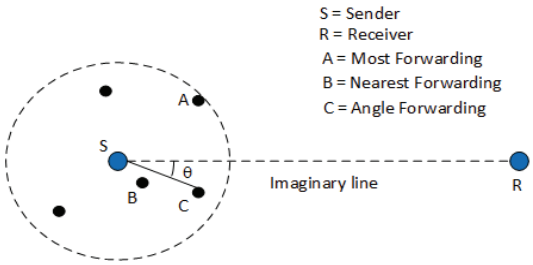

Fig. 1. Angle Forwarding Scheme

The ***imaginary line*** for 2D and 3D 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 2D area, while $S(x_S, y_S, z_S)$ and $R(x_R, y_R, z_R)$ determine those in the 3D area. Based on these location coordinates, the imaginary line can be defined generally as Equation 1.

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

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*.

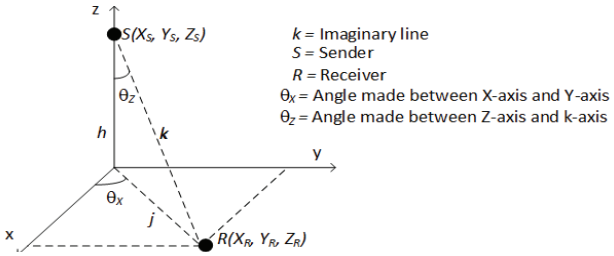

Fig. 2. Relative-angle Calculation.

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

$$\theta z = atan\left(\frac{j}{h}\right) \qquad \text{(Eqn. 2)}$$

III. Relative Angle-based Forwarding Scheme

In order to properly design the angle based forwarding scheme, the algorithm, advantages, and drawbacks of each scheme are presented [15].

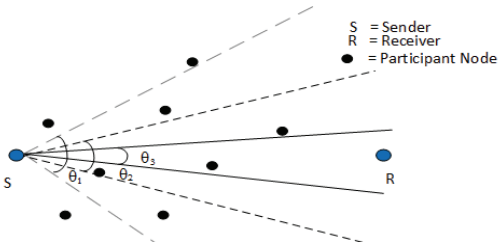

Fig. 3. Angle-based Candidate Restriction

Candidate Restriction: This method calculates the reference angle *i.e.*, θ_1,θ_2, and θ_3, as illustrated in Figure 3. The reference angle decreases the degree value, and filter out the candidates within the reference angle area [7]. Therefore, it reduces the number of hops required for communications and narrows the area of flooding mechanisms [6]. This approach is well-suited for dense networks. In case of dense networks with high speed vehicles, 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.

Area Clustering: This scheme creates imaginary zones to cluster neighbor nodes within an specific angle θ, as shown in Figure 4. The clustering mechanism is used to determine those vehicles with the same direction and transmission range, in order to manage the communications process [11]. If the particular zone is the zone, where *R* is located, *S* will only forward to nodes within a specific region. This scheme is useful for a dense network with a random mobility as an additional factor.

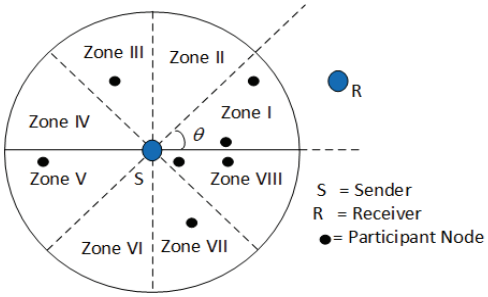

Fig. 4. Angle-based Zone Clustering.

Movement Prediction: the movement prediction schemes require the time-based relative angle calculation. This time-based property can be determined, since this type describes the current angle. Since VANETs typically show frequent topology changes [5], [13], it is necessary to obtain the current velocity information, which is used to predict the movement of intermediate nodes. 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 (cf. Figure 5). It is considerably well suited for a network, which has high mobility and random direction factors. In contrast, this approach has an insignificant impact to 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.

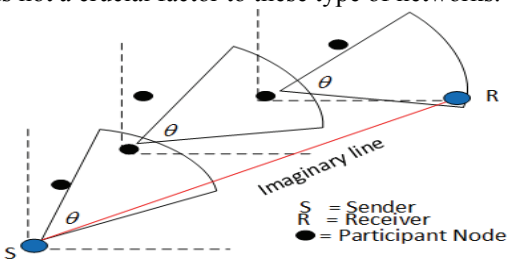

Fig. 5. Angle-based Movement Prediction

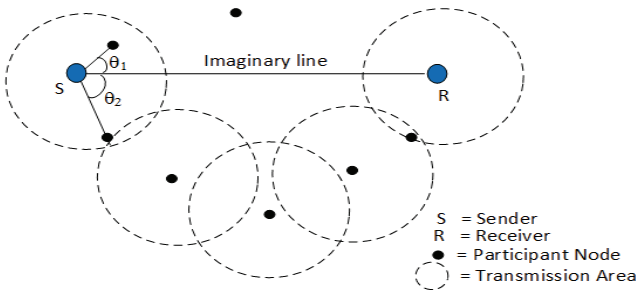

Fig. 6. Angle-based Void Avoidance

Void Avoidance: The void avoidance scheme refers the term "void" to a condition, where there is no neighboring node around the intended transmission node which is also known as local minimal problem. This scheme is an approach

to a angle forwarding issue in a sparse network [12]. This scheme targets at the increase of the angle gradually 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 6. Advantages of the void avoidance approach include the fact that they are highly suitable for a 3D area, since several simulations indicate that the vertical relative angle being included into the consideration leads to cope the local minimum issue [14]. The other approach to void avoidance is further discussed in [8]

IV. 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

V. 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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