A RELAY SELECTION ALGORITHM FOR NODE COMMUNICATION IN VEHICLE-TO-VEHICLE NETWORKS USING MULTI-METRIC LOCALIZATION PARAMETERS

BY

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DEDICATION

I Dedicate this Thesis to God Almighty.

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ABSTRACT

Relay selection is one of the major challenges that affect Vehicle-to-Vehicle (V2V) communication. The inability to select the most important Relay nodes during transmission has been a problem for several years. This has resulted to increased number of relay involvement, increased number of simulation runs and high cost of implementation, delay and data loss. This research proposed an intelligent algorithm called Multi-Metric Consensus algorithm. This algorithm considered position of the vehicles in the V2V network, distance and displacement angle of vehicles within the source node's communication range. The relay nodes (vehicles) are selected based on the degree distribution and the Multi-Metric consensus-based algorithm, considering the position, angle and distance of the destination from the source node. This algorithm involves some processes like, distance matrix computation, Adjacent matrix computation and the routing table computation. Based on the information of the nodes in the routing table, the relay node is selected. The simulation results of Multi-Metric Consensus algorithm were compared with the conventional consensus algorithm. Multi-Metric Consensus algorithm performed better by about 20% and 40% for number of algorithm runs and number of relay nodes involved respectively. The centralised method, consensus based algorithm and multi-metric consensus algorithm were compared in terms of cost of implementation, the multi-metric consensus was cheaper by 90% and 85% for centralized and conventional consensus respectively, when considered for a period of five years. The performance analysis of this research shows that, Multi-Metric Localization algorithm performs best when compared with conventional algorithm and centralized method.

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LIST OF ABBREVIATIONS

Abbreviations	Meaning
5G	Fifth Generations
CACC	Cooperative Adaptive Cruise Control
CALM	Communication Access for Land Mobiles
CAV	Connected and Automated Vehicles
DSRC	Dedicated Short Range Communication
IEEE	Institute of Electrical Electronics Engineering
InVANET	Intelligent VANET
IoT	Internet of Thing
IP	Internet Protocol
ISM	Industrial Scientific and Medical
LTE-A	Long Term Evolution- Advanced
LTE-V2V	Long Term Evolution- Vehicle-to-Vehicle
MANET	Mobile Adhoc Network
MATLAB	Matrix Laboratory
OBU	OnBoard Unit

RFID	Radio-Frequency Identification
UWB	Ultra Wide Band
V2I	Vehicle-to-Infrastructure
V2N	Vehicle-to-Network
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Everything
VANET	Vehicular Adhoc Network
WANET	Wireless Adhoc Network
WAVE	Wireless Access in Vehicular Environment
Wi-fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WMN	Wireless Mesh Network
WSN	Wireless Sensor Network

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Internet of Vehicles (IoV) consists of Vehicle-to-Infrastructure (V2I), Vehicle-to-Everything (V2X), Vehicle-to-Vehicle (V2V). V2V Network consists of wireless data transmission between motor vehicles. Vehicular communication and accident prevention are the main aims behind this V2V technology (Mohamed *et al.*, 2020). Vehicles are used as communication devices as they communicate information like lane changes, hazard information and traffic conditions (Neil, 2020). Huge Spatial-temporal data (big data) / vehicular cloud/ low latency, traffic management, safety and reduced collision probabilities are the aims of V2V communication (Jurgen, 2012). Road safety report globally, shows that there are about 1.2 million people die every year by road accidents globally. 50% of these victims are mainly Vulnerable Road Users (VRU). With the aid of creativity and innovations in V2V communication, there will be reduction in mortality rate of VRU (WHO, 2020).

OBUs and roadside units (RSUs) make up the traditional V2V communication. The management and unification configuration of resources is handled by the RSUs. In some regions, they serve as centralised nodes. Poor scalability and low bandwidth utilization are defects of centralised structure. It suffers from single failures. The main information publisher would be paralyzed, if the central control in a region goes down. Besides, the implementation cost is extremely expensive with the centralised V2V system, as it needs a lot of base stations costing about ₦120,000,000 for each (Liuqing Y. & Huiyun L., 2019).

The efficiency of information dissemination in V2V communication is related to the relay selection criteria. Inadequate selection of relay vehicles to retransmit important information could degrade the Intelligent Transport System (ITS) performance in terms of latency, overhead and reception rate. This can result to devastating consequences of road users (Alotaibi, 2017).

A P2P system has the features of self-organizing system of equal and autonomous entities (peers) which aims to share distributed resources without the involvement of centralized services. P2P vehicular communication has grouped routing protocol into three categories: broadcast, unicast and Geocast approaches (Evjola, 2013).

Unicast protocols provide communication between two nodes. It is straightforward way to implement. Large delay of packet transmission and low packet delivery ratio are some disadvantages of unicast (Zhao *et al.,* 2008; Bi *et al.,* 2009). A broadcast is effective for cooperative driving in VANET. Message redundancy and link unreliability are some disadvantages of broadcast (Durresi *et al.,* 2005; Tonguz *et al.,* 2007). Geocast helps in broadcasting the information from a source vehicle node to all nodes within a network, provided their geographical locations are known. The transition area is reduced in Geocasting, thereby reducing congestion. However, untrusted environment is not considered (Kihl *et al.,* 2008).

This work will be using a Geocasting algorithm that helps in obtaining a more efficient way of selecting relay nodes, considering positions of vehicles, angle of vehicles, relay selection, allocation of source nodes at every stage of transmission and many other factors.

1.2 Statement of the Research Problem

To maximize the full potentials that V2V communication has to offer, several challenges such as Message redundancy, Relay Selection, Link unreliability, Vehicle discovery, Mode selection, needs to be studied and carefully regulated**.**

One of the major challenges in V2V communication has been Relay selection. (Liuqing Y. & Huiyun L. 2019) proposed Consensus-based algorithm for relay selection, in P2P network topology for V2V communication. The results were compared with the traditional methods and it performed better. In this research, an algorithm was developed, that improved on Liuqing Y. & Huiyun L. 's work, thereby it further reduced the number of algorithm runs, reduce the number of relays and also reduce the cost involved during implementation.

1.3 Aim and Objectives of the Study

The aim of this research is to develop an improved relay selection algorithm for node communication in vehicle-to-vehicle networks using multi-metric localization parameters. This aim will be achieved through the following objectives.

i. Develop an algorithm for Relay selection in V2V network using multi-metric localization parameters.

ii. Evaluate the performance of the developed algorithm

iii. Compare the performance metrics of the developed algorithm with Consensus algorithm.

1.4 Justification for the Study

V2V relay selections have been widely researched on and several algorithms and modifications accompanying relay selections have been done in order to reduce the number of relays involved in the transmission. In this study, a Multi-Metric localization parameters algorithm is considered and compared with consensus algorithm in terms of number of runs, number of relay nodes needed to transmit information from the source to destination and the cost of implementation.

1.5 Scope of the Study

V2V communication consists of a lot of models, innovations and technologies that drive Vehicular networks. In this research, an improved algorithm-based P2P communication for V2V network is adopted in Relays (Vehicle-nodes) selection. This P2P communication will be based on an improved algorithm that considers Position, distance and angle, and it will eliminate centralised nodes. This will be compared with the Consensus-based algorithm for relay selection in order to evaluate performance.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

This section describes some related works and their limitations that have been reviewed in relation to this thesis. The description of Vehicular Adhoc Network (VANet), Dedicated Short Range Communication (DSRC), overview of vehicular communication, Peer-to-peer communication in V2V network, Relay selection, Flowcharts and Algorithm related works that is necessary for the analysis of this work will be discussed in this section.

2.2 **Vehicular Adhoc Network (VANet)**

VANET enables V2V communication to exchange non-safety and exchange safety information. Dedicated Short Range Communication (DSRC) spectrum was allocated to V2V communication by Federal Communication Commission (FCC) to enhance service in ITS. MANet is an infrastructureless network where there is exchange of data in a defined topology of mobile nodes. High speed conditions among vehicles can be handled by VANet (Singh *et al*., 2018; Ajaltount *et al*., 2017). Vehicular Network is one of the realistic applications of MANet which is also a subclass WANet (Archade *et al*., 2017). Figure 2.1 is a hierarchical illustration of classification of Adhoc networks.

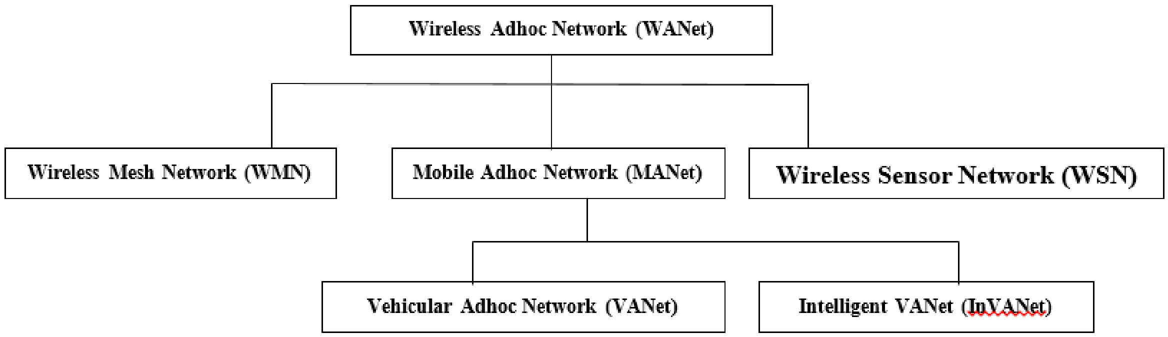

Figure 2.1: Classification of Adhoc networks (Archade *et al*., 2017)

Vehicular Adhoc Network (VANet) based on IEEE 802.11p standard are increasingly receiving attention for provision of road safety. VANets is faced with the challenge of hidden terminal. The IEEE Network uses Request to send/ Clear to send mechanism (RTS/CTS) to alleviate the challenge of hidden terminal (Kumar *et al*., 2019). Vehicular communication has three methods; they are vehicles to vehicle (V2V), Vehicle to Infrastructure (V2I) and Vehicle to Everything (V2X) communication. V2V, V2I and V2X technologies by vehicles at different situations (either in motion or parked position) for communication (Archade *et al*., 2017). The aim of the next generation 5G wireless communication is to provide high data rates (typically of Gbps order), extremely low latency QoS. In this work we can up with a proposed relay selection algorithm, which helps to properly select relay nodes considering the different positions of vehicles on the road, method of relay selection, allocation of source nodes at every stage of transmission and many other factors.

2.3 Vehicular Communication

2.3.1 V2V Standard communication model

DSRC is the most reliable communication technology for V2V. A comparison of different existing communication in V2V technologies includes;

a. DRSC

DSRC is a mutual way wireless communication. V2I and V2V programmes are make use of DSRC which reduces car crashes, through the communication of nearby cars and communications gadgets (Jeff, 2010). DSRC offers:

i **Privacy and Security**

Privacy and authentication are supplied by DSRC for safety messages. This is really important to avoid sending information to unauthorized vehicles.

ii **Prioritization of Safety Programmes**

Important safety programmes are also in a highly prioritized rank. This happens by a process called beaconing. The term beaconing indicates the process of periodically broadcasting a short message, with important information, to neighboring vehicles in the same transmission range. Accordingly, a beacon means the short message that required to be transmitted with some regularity. An example is the Basic Safety Message (BSM) that contains information on the state of vehicle, which is periodically broadcast to surrounding vehicles iii **High Accuracy**

Under serious working conditions like climate condition and high speed vehicles, DSRC provides efficient accuracy.

iv **High Acquisition of Network**

An instant mode for safety programmes should be established for all connections (new and existent).

v **Particular certified bandwidth**

Secured and reliable communications are provided by bandwidth reserved for safety programmes as it relates to vehicular communications.

vi **Flexibility**

In the same network, DSRC has the capacity to combine network methodologies like V2V and V2I for safety programmes.

b. IEEE 802.11p

DSRC can be used for safety services and connections among vehicles and RSUs (Kenney, 2011). Table 2.1 describes IEEE802.11 protocol evolution (Kenney, 2011).

c. LTE-V2V

The is a product of the cellular uplink technology that maintains similitude with the present LTE systems: frame structure, clock accuracy requirements, sub-carrier spacing and the concept of a resource block. LTE-V2V is an authentic substitute and offers a better environment for entertainment usage.

Table 2.1: Communication Technologies in V2V (Archade, 2017)

Communication Technologies	**Communication Protocols**	**Range**	Characteristics
DSRC	IEEE 802.11p	1000m	High Data Transfer Rate. Reliable for large network.
Infrared	IEEE 802.11	10m	Reliable, mature and easy to master.
Bluetooth	IEEE 802.15.1	10m	Low Power. Good communication Security.
Wi-Fi	IEEE 802.11a/b/g	76-305 m	High Data Transfer Rate.
UWB	IEEE 802.15.3a	10m	Strong anti-interference ability.
Zigbee	IEEE 802.15.4	100m	Low cost. Low Power.
MmWave	IEEE 802.11ad/IEEE 802.15.3c	10m	High Transmission Quality.

There are standards for WAVE. IEEE 802.11p is an upgraded version of IEEE 802.11 standard. The physical (PHY) and Media Access Control (MAC) layers of vehicular communication are standardized by IEEE 802.11p (Archade, 2017). Figure 2.2 shows IEEE 802.11p standardization.

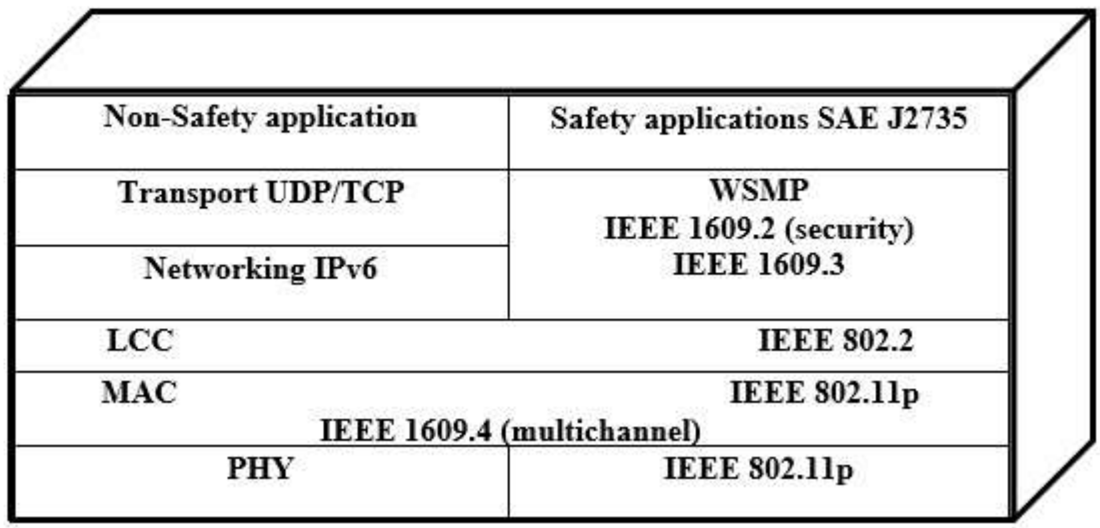

Figure 2.2: Wireless Ad-hoc Vehicular Environment protocol stack (Archade, 2017)

DSRC is allocated a spectrum of one controller and six services with 10MHz each and 70MHz band of seven channels as shown in Figure 2.3 experiences challenges as the number of vehicles increase. The unused spectrum of Primary Users can be shared with secondary users in order for VANet to benefit (Archade, 2017).

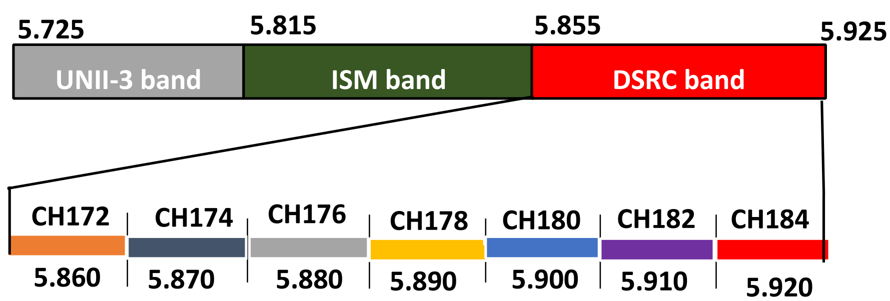

Figure 2.3: DSRC band for V2V (frequencies in GHZ) (Archade, 2017)

All participating vehicle in a mobile network is a wireless router or node, allowing vehicles within 100 to 300m to connect, resulting in a wide range. A *cluster* is formed by strongly connected vehicles to start a group communication (Archade, 2017). Another way to make the system reliable is to communicate through the fixed improved algorithms.

2.3.2 Wireless communication technologies used for V2V

Blue-tooth, Ultra Wide Band and ZigBee are three Personal Area Network (PAN) standards vehicle communication. Wi-Fi is WLAN for inter-connected vehicles (Vaishali, D.K. & Pradhan, S.N., 2017).

a. **Bluetooth (IEEE 802.15.1)**

Products that implement the Bluetooth specification can facilitate automatic establishment of a connection between the car’s hands-free system (typically part of its audio system) and a mobile phone (Vaishali, D.K. & Pradhan, S.N., 2017).

b. **ZigBee (IEEE 802.15.4)**

It is a new low-cost, low-power wireless PAN standard, intended to meet the needs of sensors and control devices (Vaishali, D.K. & Pradhan, S.N., 2017).

c. **UWB (IEEE 802.15.3a), or Ultra Wide Band**

UWB uses very low-powered, short-pulse radio signals to transfer data over a wide spectrum of frequencies that makes it tolerant to all type of disturbances (Vaishali, D.K. & Pradhan, S.N., 2017).

d. **Wi-Fi (wireless fidelity)**

This is the general term for any type of IEEE 802.11 network. Examples of 802.11 networks are the 802.11a (up to 54 Mbps), 802.11b (up to 11 Mbps), and 802.11g (up to 54 Mbps). These networks are used as WLANs (Vaishali, D.K. & Pradhan, S.N., 2017).

2.3.3 Onboard unit (OBU)

OBU is a DSRC transceiver device in a vehicle used to transmit and collect data for various applications (Hafeez, 2022). More specifically, an OBU (on-board unit) is an electronic device installed in a vehicle that records traffic and driving data and can connect to roadside and satellite navigation systems. They are generally used for the automated billing and recording of tolls, referred to as electronic toll collection (ETC), but can also be utilised for additional services. For instance, OBUs can be used for diagnostic and emergency data storage, route planning, and navigation. Additionally, they are capable of handling vehicle-to-infrastructure (V2I), vehicle-to-vehicle (V2V) and vehicle-to-roadside (V2R) communication (Hafeez, 2022).

In their typical use in tolling, OBUs employ various methods to communicate with tolling system and assess the distance traveled, and subsequently, the toll amount due. The two most common methods used are with radio and mobile radio technologies and satellite navigation.

2.3.3.1 *Methods of OBU communication*

i. Mobile Radio technology

In the case of radio technology, a radio beacon transmits a signal which is received by the OBU. That signal is then modulated by the OBU and the data sent back to the beacon. The stationary position of the beacon allows it to determine the distance traveled (Hafeez, 2022).

ii. Satellite Navigation

When using satellite navigation in tolling, the OBUs have a GPS receiver which receives the navigation signal. The data is then sent by SMS from the OBU via a GSM modem to the toll centre. The toll is then calculated using this navigation data, often also taking into account other vehicle specific data such as the exhaust gas class and number of axles (Hafeez, 2022). When being used for emergency data, an OBU can act as an interface for Intelligence Transportation System (ITS) services, such as warnings and travel information, to be delivered to the driver. In this case, OBUs continuously transmit information to other vehicles, roadside units (RSUs), and other devices in the form of Basic Safety Messages (BSMs) (Hafeez, 2022).

2.3.4 Methods of vehicular communication

Figure 2.4 shows different methods of vehicular communications:

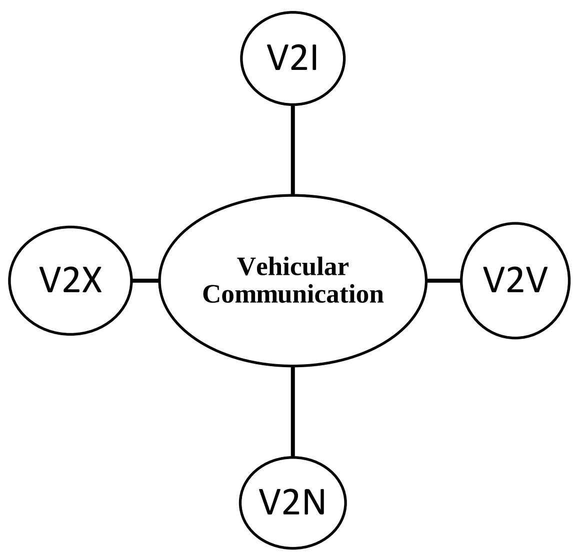

Figure 2.4: Types of vehicular communication (Wu *et al.,* 2018)

i. Vehicle-to-Vehicle (V2V)

This consists of wireless information transmission between vehicles. Accident prevention is the main aim behind this V2V communication. Vehicles transfer data of their location and speed within an ad-hoc mesh network. The partially or fully connected mesh is used (Wu *et al*., 2018). In the past, it used to be wired connection but with the help of wireless Personal

Area Network (WPAN), it is easier and cheaper to have these vehicles connected (Wu *et al*., 2018).

ii. Vehicle -to- Infrastructure (V2I)

This enables transmission between vehicles and road systems (these include traffic light, Radio-Frequency Identification (RFID) readers, lane markers, cameras, street lamps, parking meters and signage) (Jurgen, 2012). V2I are bidirectional wireless communication, that make use of use DSRC transceiver frequencies to transfer data. The information is sent via ad hoc network from the vehicle to the infrastructure or vice versa. The V2I sensors gets infrastructural information and provide vehicle drivers with sending information on road conditions, real-time advice, traffic congestions, auto crashes or fire accidents on the roadway and construction sites in order to achieve furl savings, traffic flow and avoid accidents (Wu *et al*., 2018).

iii. Vehicle -to - Everything (V2X)

V2X model completes the V2I and V2V communication models. Vehicle to Everything is the transfer of data from a vehicle source node to anything that can communicate with it, or vice versa, and also incorporate. Other communication types like Vehicle to Roadside (V2R), Vehicle-to-Pedestrian (V2P), Vehicle-to-Grid (V2G) and Vehicle-to-Device (V2D) (Wu *et al*., 2018).

2.4 V2V Network Operation Types

When discussing Peer-to-Peer technology, the term "decentralised network" often comes up and what advantage these network systems have over centralised networks. Each network architecture has its pros and cons (Cryptopedia, 2021).

i. Centralised Network

Centralised networks are built around a single, centralised server/master node like RSU or Base station. Data processing, data storage and user information can be accessed by other users. Some advantages. Some of advantages of centralised network are simple deployment, consistency, affordable maintenance. Some disadvantages are; high cost of implementation, limited scalability and high security risk (Cryptopedia, 2021).

ii. Decentralised Network

A decentralised network system distributes information-processing workloads across several devices instead of depending on a single central client. As a result, the system is not affected by the failure of any node in the network, because the entire network will continue to operate with no disruption (Cryptopedia, 2021). Recent technological advancements have made centralised networks possible, that have equipped computers that can be synced up and leveraged for distributed processing. Some of advantages of decentralised network are increased scalability and enhanced privacy. Major challenge in decentralization is coordination issues (Cryptopedia, 2021).

2.5 Relay Selection in V2V Communication

Relays in V2V communication are vehicles that transmits information to another vehicle in a vehicular network. In a V2V network, there are a lot of Relays. In the array of candidate relays, some relays maybe selected based on algorithm, protocol or standards. This process is known as Relay Selection in V2V communications (Alotaibi, 2017). Relay selection is required to eliminate message redundancy. This is achieved by suppressing unnecessary transmission, but at the same time ensuring high reception of a message by all vehicles within the required distance. In dense environment, where there is high competition for wireless medium, there is need for relay selection (Alotaibi, 2017).

High speed and mobility of vehicles is another challenge to Relay selection protocol. This means communication period between these vehicles can only last for a short time. Improper timing may cause information to be outdated or delay. Many vehicles' safety applications scenarios require having latency of the range of 100ms. In order to avoid accident and safe lives, high latency must be avoided (Alotaibi, 2017). Non-uniformity in vehicle density is also a challenge in Relay selection in V2V Networks. Where the density is highly variable regarding time and space. It varies throughout the day. For instance, the density reaches high level during the rush hours. This can lead to interception, because a lot of vehicles wants to send information at the same time. While at low level, network will suffer from low packet due to intermittent connectivity. Other challenges in relay selection include, selection of relay node based on network topology from neighbors table (Alotaibi, 2017).

2.6 P2P Network

P2P network works without centralised control, consisting of all peers participating as network nodes. It is designed as a distributed system (Castro *et al.,* 2006). Good communication quality and high security are guaranteed in P2P network. Single point failure, and challenges in guaranteeing the signal quality of hot spots are disadvantages of centralised systems (Degui *et al.,* 2014). P2P as a decentralised network has a lot advantages over centralised structures. Good robustness, other peers can automatically adjust the entire topology, stabilised network links, service is shared among the nodes and information transmission are features of P2P network (Yufeng, 2017).

Disagreement among nodes and self-organization of nodes are some problems solved by P2P network. The Challenge of trusted communication in an untrusted network environment is solved by distributed consensus algorithms in blockchain technology. Single point failures occurrence is avoided and it has high flexibility and reliability. The nodes present in this network may serve as relays, therefore, increasing reliability and flexibility. There are different P2P file sharing architecture. Below is a brief explanation of the different architectures.

2.6.1 Types of P2P File sharing Architecture

i Unstructured P2P Network message sharing Architecture

In unstructured, query is sent to all the nodes in the network, in order to receive the relevant information matching the query. The advantage of such system, is that they accommodate highly transient node population. The disadvantage is, it is difficult to find files without distributing queries widely. This makes it unscalable (Stephanos, 2002).

ii Structured P2P Network message sharing Architecture

This emerged in order to address the issues that are not scalable in unstructured P2P Network. In structured P2P Network, files are placed at specific locations and the network is tightly controlled. This system provides mapping between files identifiers and locations in form distributed routing tables, so that the requests can be directed to the nodes with the desired message efficiently. It offers scalable solutions for exact matching of queries. The downsides of structured P2P network is, it is hard to maintain (Ratnasamy *et al*., 2002).

iii Loosely Structured P2P Network

They are purely decentralised and they are also self-organizing. Loosely structured P2P performs more of message storage than message sharing services. Messages are pushed to other nodes for replication, persistence and storage (Stephanos, 2002).

2.7 Consensus Algorithm

Some few important challenges P2P network has to care of self-organisation and disagreement among vehicles in a vehicular network. There is huge similarity between blockchain and vehicle networks. This blockchain technology exploits consensus algorithm. This is because it solves the problems of trusted communication in an untrusted environment. Self-maintenance is a reality with consensus algorithm (Khan *et al.*, 2021). Figure 2.5 shows Consensus algorithm state transition among nodes.

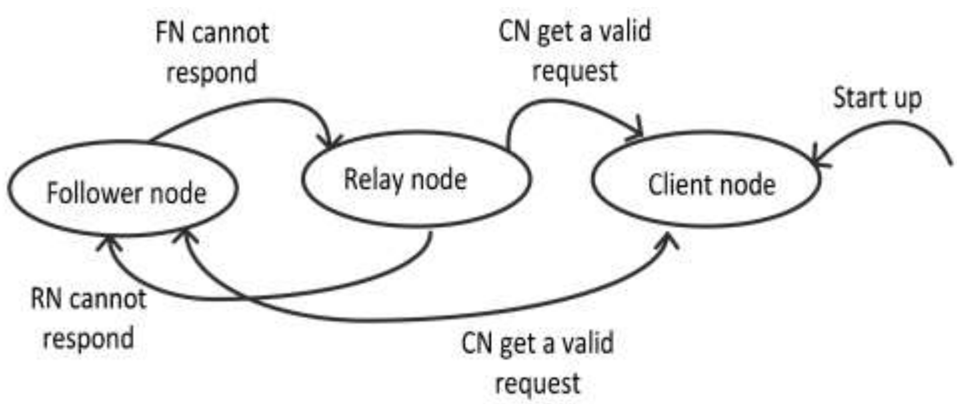

Figure 2.5: Consensus algorithm State transition among nodes
(Liuqing & Huiyun, 2019)

From Figure 2.5, the client sends a request to the vehicles in its routing table. The vehicles (follower nodes) receive the request and responds by sending back their destination to the source. If any of the follower nodes carry useful information, it sends it to the client node.

Else if the vehicles do not have any useful information to relay to the client, the client picks the node whose destination is closest to its own and the highest K_v valve to be the node for relay.

Some consensus algorithms in the realm of blockchain includes Delegated POS (DPOS) Proof of Work (POW) and Proof of Stake (POS). The major downsides are, they demand high computing time and power. They also do not allow constant changes in vehicle networks. Paxos and Raft are examples of traditional consensus algorithms (Lamport, 2001; Ongario *et al.,* 2014). The Raft consensus algorithm achieves self-maintenance in vehicular network.

2.7.1 Consensus-based vehicle network scenario

The consensus algorithm in a vehicular network, handles trusted nodes in an untrusted environment. There are several steps involved. These includes adjacent matrix, distance matrix, angle and distance equations of the vehicular network. Equation 2.1 shows the adjacent matrix, in the vertex set, v adjacency matrix D_{con} defines the adjacency list, where the element $a_{i,j}$ represents the communication states between node i^{th} and j^{th}. Equation 2.1 shows the adjacent matrix with all diagonal element having zero.

$$D_{con} = \begin{bmatrix} 0 & a_{12} & \cdots & a_{1j} \\ a_{21} & 0 & & \\ \vdots & & \ddots & \vdots \\ a_{i1} & a_{i2} & \cdots & 0 \end{bmatrix} \quad (2.1)$$

The reason for the zero, is the elements like a_{11}, a_{22}, a_{33}, a_{44}…………a_{jj} all have zero communication links. The P2P vehicle network uses the adjacency table P, for routing table in practice as shown in the matrix below. Considering the first column of D_{con}, it represents the link between the first vehicle and the other *ith* vehicles nodes. Equation (2.2) shows the routing table. The routing table is developed by constant exchange of vital information (like position, angle and distance) between vehicles.

$$P = [0 \quad a_{2,1} \quad a_{3,1} \quad \cdots \quad a_{i1}]^T \tag{2.2}$$

In practice, the adjacency matrix is the transpose matrix of every column of the adjacent matrix. The distance matrix is used to obtain the matrix below to obtain the adjacent matrix. Equation 2.3 shows the distance matrix.

$$M_{dist} = \begin{bmatrix} d_{1,1} & d_{1,2} & \cdots & d_{1,t} \\ d_{2,1} & d_{2,2} & & d_{2,t} \\ \vdots & & \ddots & \vdots \\ d_{t,1} & d_{t,2} & \cdots & d_{tXt} \end{bmatrix} \tag{2.3}$$

Each element *d* is obtained using GPS data of vehicles. With the use of Differential GPS positioning technology, accurate position (coordinates) of the vehicles can be obtained. This is summarized in the flowchart below.

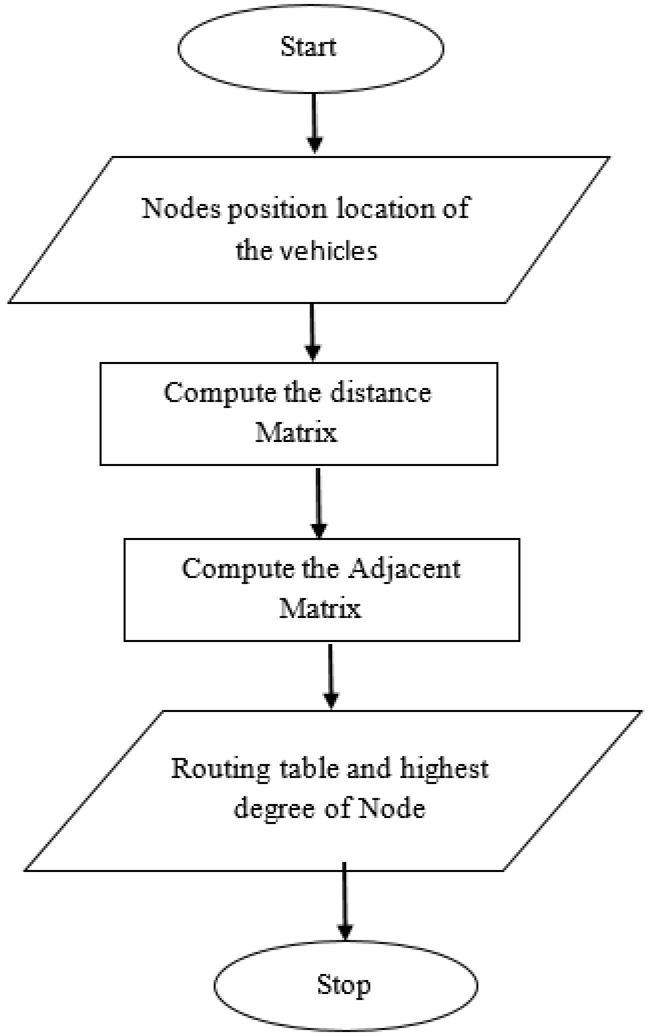

Figure 2.6: Flowchart showing steps in selecting Relay and matrices involved

Considering Figure 2.7, the V2V communication scenario of vehicles connected together in a peer-to-peer network. Each vehicle is assumed to Onboard Unit or on-board diagnosis system installed, which enables radio communication and consists of several sensors which provides with GPS information, and BSM information. Figure 2.7 shows the V2V communication scenario among several vehicles in a P2P network on a straight road.

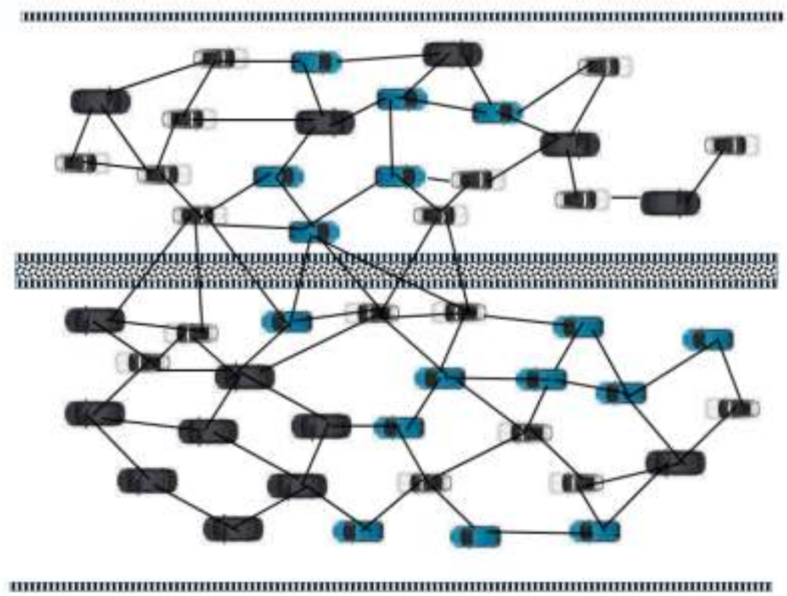

Figure 2.7: P2P network with V2V users on a straight road.

The OBU aids the transmission or reception of Basic Safety Messages (BSMs) among peers within the communication range. All the vehicle nodes in the network are trusted. Vehicles that needs the information, in other to make decision on which route to follow or other BSM, there may need to introduce relays. which serve as transceivers to those vehicles. These vehicles will communicate via consensus-based P2P vehicle network.

From the P2PV2V based network, the source node receives information and it wants to pass information (maybe accident) to the destination node. It first checks the its communication range (distance threshold) to know if the destination node is within. If it is within and the source send directly to the destination node. If the destination node is not within the communication range, then it requires a relay selection.

From Figure 2.7, the source node wants to send information to the destination node, which is not within the communication threshold of the source node. Consensus algorithm selects the array by looking at the degree of node array. The degree of node is available to the to all vehicles and it captures the distances between the vehicles and compares it with the thresholds. It gives a value of 0, when a particular distance is less than or equal to the threshold. Therefore, communication can be done without a relay. It gives a value of 1 if the particular distance is above the distance threshold. The vehicle has an idea of the degree of node of all the vehicles in the network, based on distance information alone and it makes a decision on which becomes the relay.

The information moves from the original source node to a new relay. The new relay becomes the new source and now performs the same operation. It goes to consults the degree of node, looks at the candidate relay around it, see if the destination is within the threshold, if yes, the destination node receives the information, else it repeats the same process for relay selection. It is consensus because, each vehicle knows the information about other vehicles in the network and decides based on the degree of node information. The consensus algorithm only considers the distance in selecting relay. Considering distance alone for relay selection is not sufficient. This is because, a relay can be selected based on the closeness to the source node, but it is moving further away from the direction of the destination node. It is important to add displacement angle threshold as a parameter to be considered when selecting a relay.

2.8 Review of Related Works

For proper understanding of this work, review of past works on V2V communication network that majored on relay selection was done. This section focuses on different areas of Vehicular communication where consensus algorithm has been used.

(Wei, 2006) proposed a longitudinal motion control in real-time for automated vehicles that are connected using consensus-based algorithm. Thereby, focusing on authenticating the performance in term of real constraints (like safety constraints, efficiency constraints and comfort constraints). This is because, non-identical initial states like longitudinal speed, position have high influence on the consensus algorithm performance. This paper built lookup tables to store the ideal control gains. When the consensus algorithm is run in real time, based on the condition, from the table, it can search ideal control gains.

Ziran *et al.* (2017) suggested that, the challenges of sustainability, safety and mobility issues in the current intelligent transportation system has a promising solution and that is, the CAV technology. Consensus algorithm was proposed in this paper to curb the motion of CAVs in real-time. Consensus algorithm was adopted to build lookup-tables, searching in real-time, with respect to non-identical initial conditions of CAVs, the ideal control gains. Simulations show that, the consensus algorithm lookup table performs better than Van Aram's linear feedback-based longitudinal motion control Algorithm. The CACC systems adopted decentralised consensus algorithm and protocol for merging maneuvers, platoon formation and splitting maneuvers. This paper took into consideration, the position of the GPS antenna on vehicles and performance braking system for different vehicles.

Huiye *et al.*(2019) aims at securing important information that is shared among nearby vehicle nodes for safety purposes and traffic efficiency via consensus-based algorithm. This paper used Byzantine –tolerant distributed consensus to address security at the application layer. Vehicles that are within the communication range of the source was established using "Proof of Eligibility" consensus. With the availability of compromised (Byzantine faulty) participants' number, their algorithm provides correct consensus among healthy vehicles in real-time. It also shows that it can disseminate traffic information quicker when compared to previous information dissemination approaches.

Chen, (2021) Researched on data loss and counterfeit avoidance, and monitoring in the data exchange in Vehicular communication. This paper aims to improve security of identity authentication of IoV, and relies on the framework of Hyper Ledger Fabric and divides it according to the characteristics of its modular components. Consensus algorithm combined with traditional authentication technology based on cryptography was used to propose a solution for the IoV identity authentication. This proposed solution will improve the security of identity authentication while considering the needs of other aspect of dependability.

Hong *et al.* (2020) proposed a simple design to cooperatively improve the vehicular localization accuracy in vehicular communication network. This was achieved in a consensus manner by exchanging local data and getting updates. In order for vehicles to update their own estimates, vehicles exchange information based on measured distance and angle relationship. This design consists of two stages and they are, the consensus-based updates and the compensation stage. The consensus-based updates stage, explains the exchange of localization estimates in a consensus-based and iterative manner. Every vehicle in the network first performs self-localization before initialization of the location estimate update. The collated measurements, calculation of new estimated distance and angle in relation to corresponding partner are all handled at this stage. The compensation stage was designed to filter out the accumulated errors by taken advantage of the update similarities.

Khaleel *et al.* (2021) proposed a framework that consists of private block chain model to secure the transactions initiated by cars. The model made use of Proof of Accumulated Trust (PoAT). PoAT is a consensus-based algorithm for securing the Internet of Vehicles. PoAT mechanism selects specific RSUs based on their accumulated trust. In addition, each car and RSU transmits information and RSU sends a transaction to many destinations, this is to steer clear any form of harm of the IoV nodes. Experiments were conducted and compared with two recent IoV blockchain-based security frameworks, simulation result shows the superiority of the system over others in terms of attack detection rate, block generation time, and network traffic overhead.

Liuqing Y., & Huiyun, L., (2019) Proposed a P2P network. This paper used consensus algorithm and graph theory to achieve stability of the network system and also to increase network fault tolerance. P2P network topology for V2V communication was explained to a large extent. This work also proposed the DSRC transceiver installation in all the vehicles that will participate in the network to enable V2V communication topology. A Centralised (traditional) network and P2P network were compared with each other, in terms of efficiency, real-time capability and cost effectiveness. Simulation result shows, the Consensus-Based Algorithm P2P performs better. Figure 2.8 shows the P2P node distribution in their experiment.

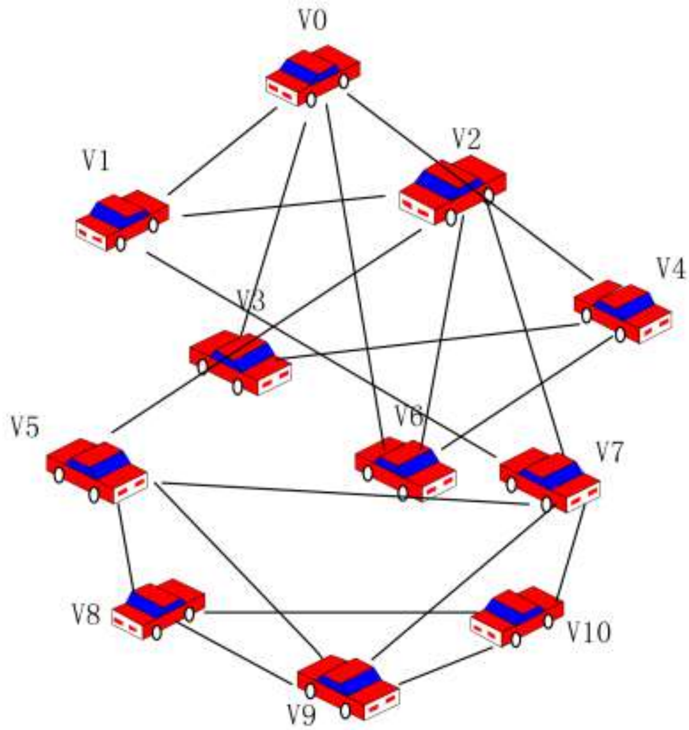

Figure 2.8: P2P node distribution in their experiment (Liuqing & Huiyun, 2019).

Table 2.2: Related Works

Paper	Communication system	methodology	Evaluation Parameters	Relay Selection	Contribution	Merit	*Demerit*
(Ziran *et al.*, 2017) Developing a Distributed Consensus-Based Cooperative Adaptive Cruise Control System for Heterogeneous Vehicles with Predecessor Following Topology	DSRC	Used consensus algorithm with given online initial condition of vehicles to control real-time longitudinal motion of connected and automated vehicles.	Speed (ms^{-1}) Time (s) Distance (m)	Consensus (Decentralization)	Propose a novel CACC system, where distributed consensus algorithm and protocol are designed for platoon formation, merging maneuvers, and splitting maneuvers	noted time-varying communication delay, length, GPS antenna's location, and braking ability of different vehicles	*Should have considered more P2P-based algorithms to compare performance.*
(Huiye *et al.*, 2019) A Byzantine-Tolerant Distributed Consensus Algorithm for Connected Vehicles Using Proof-of-Eligibility	DSRC	Used PoF consensus algorithm to identify compromised (Byzantine faulty) participants.	Decision time (m). Consensus time. Vehicle Density. Simulation time	Consensus (Decentralization)	With the presence of limited number of compromised (Byzantine faulty) participants, their algorithm provided correct consensus among healthy vehicles in real-time	Compared other approaches. Consensus algorithm approach gave a better performance.	*There was no much information on the vehicles network illustrations.*
(Chen, 2021) Design of Internet of Vehicles Authentication Scheme Based on Blockchain.	DSRC	Combined consensus and traditional authentication technology to improve security of identity authentication of IoV.		Consensus (Decentralization)	improved in the efficiency of encryption and decryption, greatly reduces the safety maintenance cost and disaster tolerance of the Internet of Vehicles system	Improved the security of identity authentication of IoV.	*There is no mathematical equations to defend the findings.*
(Hong *et al.*, 2020) Vehicular Localization Enhancement via Consensus	LTE	Used consensus-based updates to obtain the exacts location of vehicles in vehicles in a vehicular network	Distance (m) Localization error. Improvement Factor. Node Failure Probability.	Consensus (Decentralization)	Proposed a strategy to improve the accuracy of the localization estimate in V2X networks in a consensus-based manner.	Improved the accuracy of vehicular localization.	*Complex mathematics.*

Paper	Communication system	methodology	Evaluation Parameters	Relay Selection	Contribution	Merit	Demerit
(Khaleel *et al.*, 2021) Proof of accumulated trust: A new consensus protocol for the security of the IoV	DSRC	Used PoAT consensus algorithm to select specific Road side unit (RSU) based on their accumulated trust. Thereby improving security in vehicular network	Detection Rate (DR). Block Generation Time (BGT). Transaction Latency (TL). Avarage Network Traffic (ANT).	Consensus (Decentralization)	Used consensus algorithm that examined attack detection rate, block generation time, and network traffic overhead.	Compared model with two similar systems and the simulation result shows the superiority of the system over others	**Complex Mathematics and Should have considered more P2P-based algorithms to compare performance.**
(Liuqing Y., & Huiyun, L. *et al.*, 2019) Vehicle-to-Vehicle communication based on peer-to-peer network with graph theory and consensus algorithm.	DSRC	Used consensus based P2P to evaluate performance of V2V in terms real-time capabilities, efficiency and cost effectiveness.	Distance (m). Path length (m). Cost ($).	Consensus (Decentralization)	Proposed a network model based on P2P to increase network fault tolerance and to improve stability in V2V network systems.	Gave detailed Comparison analysis on Cost implementation between Centralised and Decentralised networks.	**Should have considered more P2P-based algorithms to compare performance.**
(Wei, 2006) Consensus Based Formation Control Strategies for Multi-Vehicle Systems.	Wi-fi	Used consensus algorithm to select best control gains for motion control in connected and automated vehicles.	Time (m). Distance (m). Time varying reference state.	Consensus (Decentralization)	Introduced a consensus algorithm for V2V systems, modeled by second-order dynamics, by appropriately choosing the information states on which	Built lookup tables to store the ideal control gains. When the consensus algorithm is run in real time, it can simply search for the ideal	**Complex Mathematics and Should have considered more algorithms to compare.**

2.9 Research Gap

There are several challenges involved in V2V communication, such as message redundancy, mode selection, Link unreliability, vehicle discovery and Relay selection. V2V Relay selection have been widely researched on. Although, many studies have examined challenges in relay selection in V2V communication. Several algorithms and modifications accompanying relay selection have been done, however, there is a lack of research on how to reduce the number of Relay nodes involvements, number of algorithm runs and cost of implementation during the Relay selection.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

A P2P-based algorithm in V2V network architecture is proposed. Details of the P2P topology will be discussed in this chapter and how a Multi-Metric Localization algorithm was used to help handle the relay selection and self-organization. P2P vehicle network topology, Flowcharts, Algorithms, Decentralized Consensus, adjacent matrix, Routing table and distance matrix will be discussed in this Chapter.

3.1 P2P Vehicular Network Model

The P2P vehicle nodes acts the role of a client. Vehicles can join the P2P network and exits at will, not causing any harm to the entire network. Figure 3.1 shows that if node B leaves the network, node A and C can quickly reconnect. The reliability of the system is achieved via the distribution and balanced load feature. P2P network has high security and good robustness avoiding single point failure. In the P2P vehicular network, every vehicle is seen as a node. Every vehicle in the network has the same peer, each vehicle has OBU installed. The OBU is a DSRC transceiver which aids

a. b.

Figure 3.1: P2P vehicle network showing how Node B joins and exits P2P vehicle network, without affecting the system reliability

communication among the peers. Parameters like distance, position, BSM can be communicated among these peers. Nodes in the network can exit and join as shown in Figure 3.1. However, the entire network performance is not affected. Figure 3.2 shows how vehicles in a V2V network communicate based on P2P.

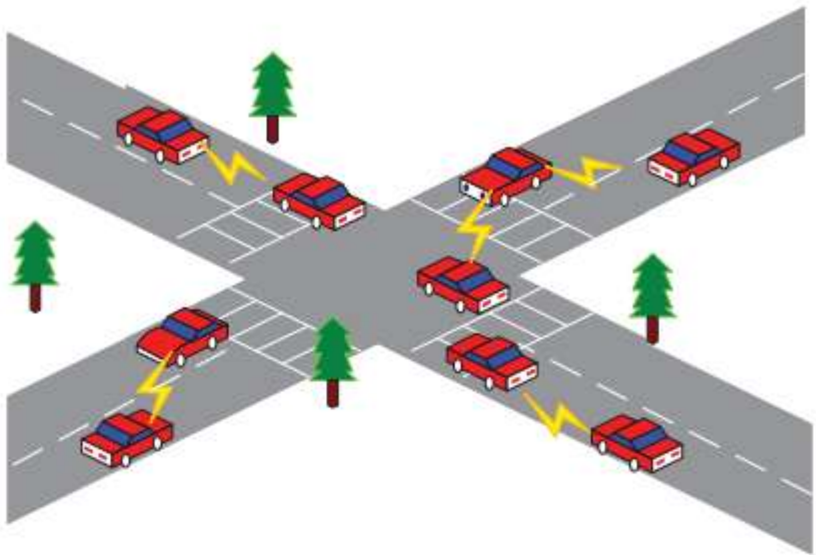

Figure 3.2: Vehicle network based on P2P (Liuqing & Huiyun, 2019)

An undirected graph G= (Ve, Ed) representing the connected graph is used to model the vehicle network as shown in Figure 3.1. V represents that number of vertex (vehicles) and E represents the edges (V2V communication) in the undirected graph The edge and vertex in the undirected graph models each vehicle and V2V communication path respectively.

3.1.1 Multi-metric consensus-based vehicle network scenario

Figure 3.3 shows the V2V source to destination transmission considering position, distance and angle.

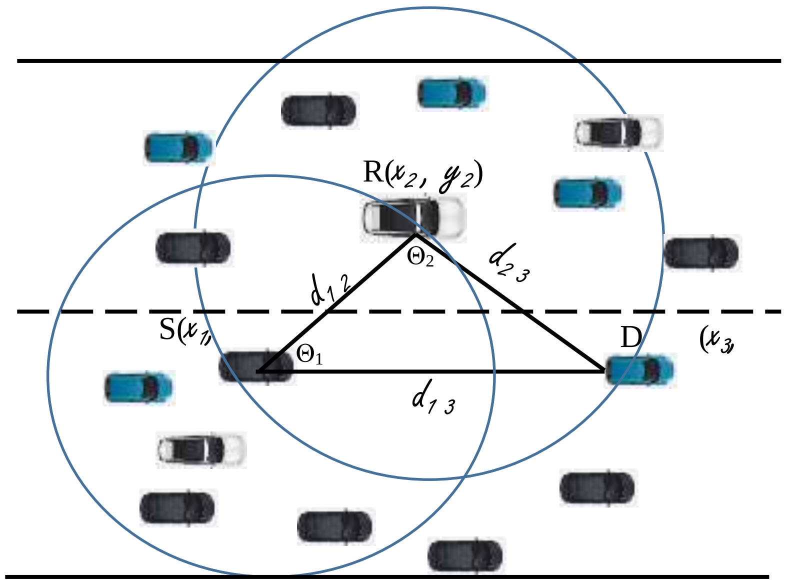

Figure 3.3: V2V source to destination transmission considering Angle, distance and position

From Figure 3.3, the source node wants to send information to the destination node, which is not within the communication threshold of the source node. Multi-Metric consensus algorithm will first compute distance threshold, displacement angle thresholds and the position of other vehicles. The algorithm checks if the destination is within the distance threshold, if it is, the source sends information directly to the destination. If the destination node is not within the distance threshold, it requires a relay node to get the information to the destination.

The source node checks for relay that is within the distance threshold and displacement threshold, when it wants to send information to a destination node that is not within the source communication range as shown in Figure 3.3. Once a new relay is selected, it becomes the new source node. It checks if the destination node is within the communication range, if yes, the information is sent directly to destination node, else the new source node repeats same procedure for selecting new relay node.

The algorithm gives a value of 0, when a particular distance is less than or equal to the threshold and also when displacement angle is less than or equal to the displacement threshold. Therefore, communication can be done without a relay. It gives a value of 1 if the particular distance is above the distance threshold and the displacement angle is greater than the displacement threshold. The source node vehicle has an idea of the degree of node of all the vehicles in the network, based on distance information alone and it makes a decision on which becomes the relay and adds it to the relay list. From Figure 3.3, the following was deduced;

$$d_{1,2} = \text{abs}(x_1\text{+1i x y1-}(x_2\text{+1i*}y_2)) \tag{3.4}$$

$$d_{1,3} = \text{abs}(x_1\text{+1i*}y_1\text{-}(x_3\text{+1i*}y_3)) \tag{3.5}$$

$$d_{2,3} = \text{abs}(x_2\text{+1i*}y_2\text{-}(x_3\text{+1i*}y_3)) \tag{3.6}$$

$$\text{dispAngle} = \cos^{-1}((d_{1,2}^2 + d_{1,3}^2 - d_{2,3}^2)/(2d_{1,2} \text{ x } d_{1,3})) \tag{3.7}$$

Where

(x, y) are coordinates positions of vehicles in the network.

$d_{1,2}$ is the distance between node 1 and node 2.

$d_{1,3}$ is distance between node 1 and 3.

$d_{2,3}$ is distance between node 2 and 3.

According to the equation above, the distance dispAngle is represented as 1, if the angle of displacement between the two angle is less than 40 then, it is allotted one else, it is zero.

3.2 Flowchart and Algorithm

In this section the Algorithm for consensus algorithm to select relays to send a message from a vehicle source node to all other destination nodes one after the other, consensus algorithm was used to select relays to send a message from a vehicle source to destination nodes one after the other and proposed algorithm to select relays based on Multi-Metric (distance and angle) parameters have been carefully noted.

3.2.1 Consensus Algorithm for V2V Relay Selection

The complete procedure is for a vehicle to receive a response after a request has been sent. Algorithm 1 in Table 3.1 explains the steps involved. Client Node = 1, if a client gets an authentic response else, Client Node = 0. If in the following node, the vehicle responds to the request, it is assumed that Follower Node = 1, else, Follower Node = 0. If the vehicle node is chosen as a relay node, RN = 1, else RN = 0. After each process, the count of relay messages is increased by 1.

The vehicle source sends requests to all the vehicle nodes within its within it threshold. When these nodes receive the request, the surrounding vehicle nodes transmit to the corresponding rolls. The routing table helps to process this efficiently, by constant exchange of vital information (like position and distance from the source) between vehicles. If a surrounding vehicle has important information, then FN_useful_message = 1. At this time, the surrounding vehicles can directly reply to the client node without relaying. If FN_useful_message = 0, the following node need replies their destination to the client node, the client picks the node whose destination is closest to its own and the highest K_v valve to be the node for relay.

In summary, the relay nodes should have the similar destination as the requesting node. This indicates that the relay node at any instant is within the threshold distance of the source node at that instance. Thereby ending the relay process. This helps improve the efficiency of information transmission in the P2P network. Figure A1 shows the flowchart of consensus Algorithm to select relays to send a message from a vehicle source node to other destination nodes one after the other.

Table 3.1: Algorithm 1: Consensus Algorithm for Relay selection from a source to destination nodes, one after the other (Liuqing Y. & Huiyun L., 2019).

Consensus Algorithm to **SELECT RELAYS** to send a message from a Vehicle Source node to other destination nodes one after the other

Input: Request from vehicles who needed to transfer information
Output: The vehicle receives useful information by relaying;
Initialize: CN, FN, RN, view=0;

```
    While (CN=0) do:
    The client makes a request to the vehicle in its routing table P.
    Receives the Request, the surrounding vehicles are transformed into following
    nodes;
        If (Surrounding vehicles carries useful information)
        FN=1;
        Client's useful information is acquired, CN=1;
        Else if
        FN=0;
        The following node replies their destination to the client node;
        The client node selects the node whose destination is similar to itself and
        has higher Kv value as the relay node. And the Relay node RN=1;
        END if
        View++

    End
```

3.3.2 Proposed multi-metric consensus algorithm for relay selection based on distance and angle parameters.

Algorithm 3 explains proposed algorithm to select relays based on Multi-Metric (distance and angle) parameters. All the coordinates of the vehicles (nodes) in the network are obtained, a threshold distance (**d_thresh)** and threshold angle of displacement threshold, (**di_thresh)** is set. The source node is identified. The distance matrix, adjacency matrix, degree of node and transmission length of the V2V network are computed. The sorted distance matrix is computed in ascending order. The source node is identified and set as current relay, since it is the one with the original message. If the CR is the destination node, then it means it has received message, noted the time of receipt of message and algorithm ends. Else find the displacement angle (**da_1**) between the original source node and destination node. Create an array list of sorted Distances (**SD**) of all nodes from destination. If node has not been a relay, find displacement angle (**da_2**) between node and destination. Find the distance array of the CR from the distance matrix. If the displacement angle is less than the displacement angle threshold and the distance is less than the distance threshold, then node is added to the list of Relay Candidates. Then Algorithm ends.

The source node position is the current node that holds the information to be transmitted to the next relay node that passes the threshold. The relay count helps to keep track of how many relay nodes were encountered before getting to the destination node. Relay angle track keep track of displacement angles of selected relays. This relay angle happens in order of proximity (SortedArrayIndex). Figure A2 shows the flowchart for the proposed algorithm to select relays based on multi-metric (distance and angle) parameters.

Table 3.2: Algorithm 2: Proposed Algorithm for Relay Selection based on Multi-Metric (distance and angle) parameters.

Proposed Algorithm to **SELECT RELAYS** based on Multi-Metric (Distance and Angle) Parameters

Step 1:

- Obtain all node coordinate locations
- Set a threshold distance for node communication, **d_thresh** and set a threshold angle of displacement threshold, **di_thresh**

Step 2:

- Compute the **distance matrix, adjacency matrix, degree of node** and **transmission length**
- Compute the **sorted distance matrix** (in ascending order)

Step 3: Identify the source node (original node with the message) and set it as current relay (**CR**)

Step 4:

- **START FOR LOOP** (Iterate through all destination nodes)
    - **START FOR LOOP**
        - IF **CR =** destination node THEN
            - Note THE TIME RECEIVED and **GO TO ALGORITHM END**
        - ELSE
            - Find the *displacement angle* **da_1** between **original source node** and **destination node**
            - Create an array list of the sorted distances **(SD)** of nodes from the **destination node**
            - **START FOR LOOP** (Iterate through **SD**)
                - IF node has not been a relay, find the *displacement angle* **da_2** between node and **destination node**
                - Find the distance array of **CR** from the **distance matrix**
                - IF **abs(da_1 – da_2) < di_thresh** and distance < **d_thresh** THEN node is added to list of relay candidates **(RC)**
                - **BREAK** from current **FOR LOOP**
            - **END LOOP**
        - END IF
    - **END FOR LOOP**

Step 5: **ALGORITHM END**

3.3 Cost of Implementation

Compared to the centralised network, the cost of the Consensus-based P2P vehicle network is cheaper. Also compared to the Consensus-based P2P vehicle network, the cost of this proposed algorithm-based P2P is lower, because it will involve fewer vehicles. The number of cars (N_{cars}) in a city like Minna, Niger State is about 300,000. Within city limits, it is assumed that a base station could accommodate two hundred and fifty vehicles $A_{capacity}$ simultaneously.

$$n_{eNB} = \frac{n_c}{a_{cap}} \qquad (3.8)$$

Where n_{eNB} is number of base stations

n_c is number of cars

a_{cap} is capacity of base stations

Each base station (m_{eNB}) costs ₦120,000,000 and an annual repair cost (m_{repair}) of ₦12,000,000 (Linqing *et al.*, 2019). y_{eNB} refers to the time (years) the base stations are in good working condition. The base station cost C_{eNB} is calculated using Equation (3.9)

$$C_{eNB} = n_{eNB} \left(m_{eNB} + m_{repair} y_{eNB}\right) \qquad (3.9)$$

Considering each vehicle with OBU installed. The cost sum of base station and OBU is the cost of traditional network as expressed in Equation (3.10). But the cost of the consensus-based P2P only needs the cost of OBU multiplied by the number of vehicles involved as in Equation (3.11).

$$C_{trad} = C_{eNB} + C_{OBU} m_{OBU} \tag{3.10}$$

$$c_{P2P} = C_{OBU} m_{OBU} \tag{3.11}$$

Where C_{trad} is number of base stations

C_{eNB} is cost of base station

c_{P2P} is cost of the consensus-based P2P

C_{OBU} is number of vehicles involved

m_{OBU} is cost of OBU

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

In this Chapter, results are presented showing the performance of the proposed Multi-Metric algorithm that reduces the problem of relay selection in V2V communication. For each of the algorithms, simulations were run. MatLAB R2015b was used for the simulation process. A flowchart detailing all procedures followed during the simulation is also presented. Eventually, the results of the simulations are presented as plots for Number of relay nodes and distance between source and destination nodes. These results are discussed here in details.

4.1 Simulation Scenario with Respect to Vehicular Coordinates

Sixty vehicles with different vehicular coordinates were considered during the simulation. These vehicles have On-Board Unit (OBU) installed on each, which aids communication among them. Table 4.1 Below are several vehicles with their unique positions.

Table 4.1: Traffic Parameters

Parameters	value
Number of Vehicles	60
Road area	$300x300m^2$
Radius of OBU	250m
displacement angle threshold	70^0
distance threshold	100m, 125m, 150m, 250m.

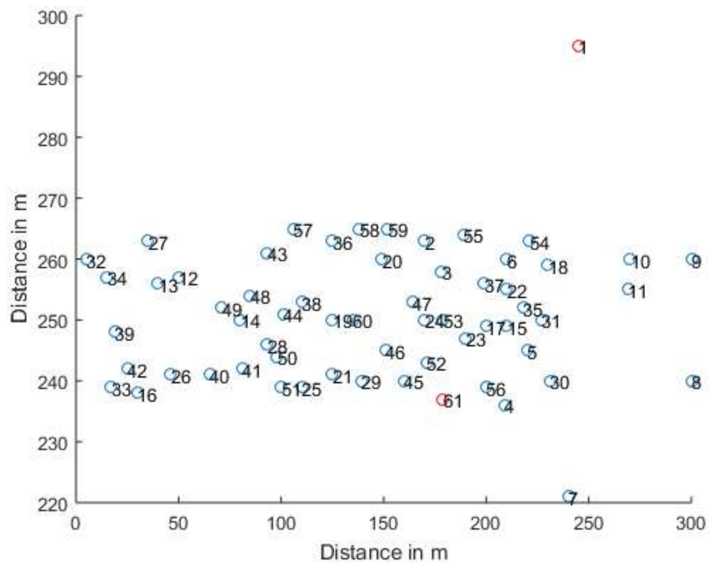

Figure 4.1: Simulation Scenario: P2P vehicle network

4.3 Adjacent matrix Result

Equation 4.1 shows the adjacent matrix of a vehicle network. In the vertex set, V_e the set of the adjacency list is defined as adjacency matrix D_{con} , where $a_{i,j}$ represents the connection states between i^{th} node and j^{th} node. Equation 4.1 shows the adjacent matrix with all diagonal element to be zero.

$$D_{con} = \begin{pmatrix} 0 & 81.54 & \dots & 87.86 \\ 81.54 & 0 & \dots & 27.57 \\ \vdots & \vdots & \ddots & \vdots \\ 87.86 & 27.51 & \dots & 0 \end{pmatrix} \qquad (4.1)$$

4.4 Graphical Results

4.4.1 Number of algorithm runs

The number of Algorithm runs is presented in Figure. 4.2 to 4.8. The number of runs the algorithms underwent to successfully transmit message from source to destination was observed. Figure 4.2 shows the result for the running the simulation for number of runs, using consensus algorithm using a distance threshold of 75m. This is a plot of Number of runs against number of destination nodes during transmission of information. Between 0 to 10 destination nodes, the number of runs started growing with an average of 5 number of algorithm runs. Between 10 to 20 destianation nodes, the next leel of growth of the number of algorithm runs went up to to an average of 18 algorithm runs. The growth continued and suddenly drops between 28 and 35 destiantion nodes. It rose between 35 to 45 destination nodes giving a n average above 50 number of algorithm runs.

Figure 4.3 shows the result for running the simulation for number of runs, using proposed algorithm at a threshold distance of 75m. Between 0 to 10 destination nodes, the number of runs started growing with an average of 1.5 number of algorithm runs. Between 10 to 20 destianation nodes, the next level of growth of the number of algorithm runs went up to to an average of 2.5 algorithm runs. It was still constant 28 and 35 destiantion nodes running at an average numbers of algotrithms between 2.5 and 3. It drops between 35 to 55 destination nodes giving a n average between 2 and 2.5 number of algorithm runs. This also brings informs that it is stable.

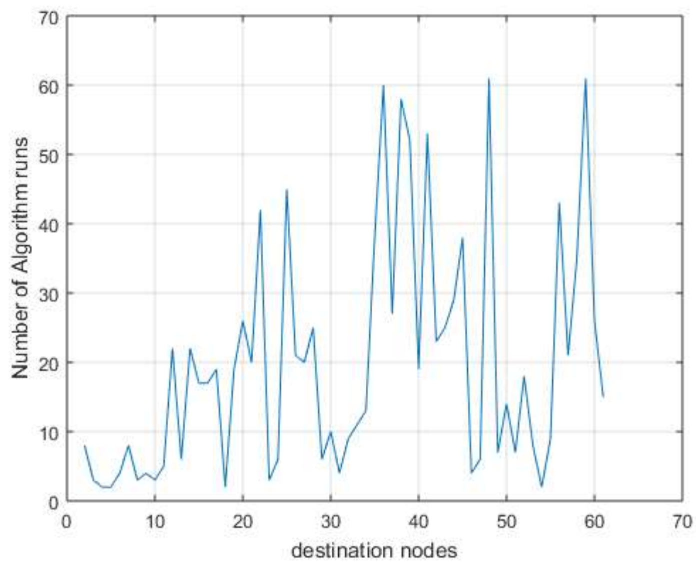

Figure 4.2: Number of Algorithm runs at distance threshold of 75m using Consensus Algorithm

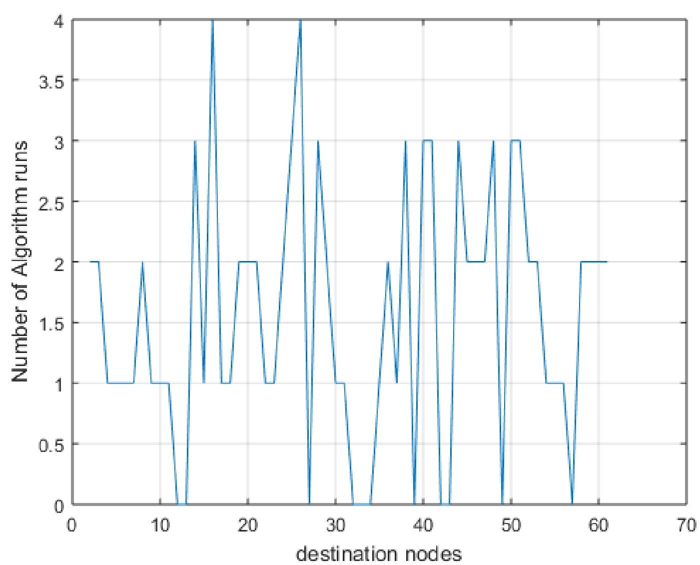

Figure 4.3: Number of Algorithm runs at distance threshold of 75m using Multi-Metric Algorithm

The simulation resuts for the number of Algorithm runs for consensus algorithm and the proposed (Multi-Metric) algorithm was compared at different distance thresholds. Figures

4.4, 4.6, 4.7 and 4.8 shows the simulation comparison at distance thresholds of 75m, 100m, 125m, 150m and 175m. Table 4.1 shows a comparison in behavior of the several distance thresholds.

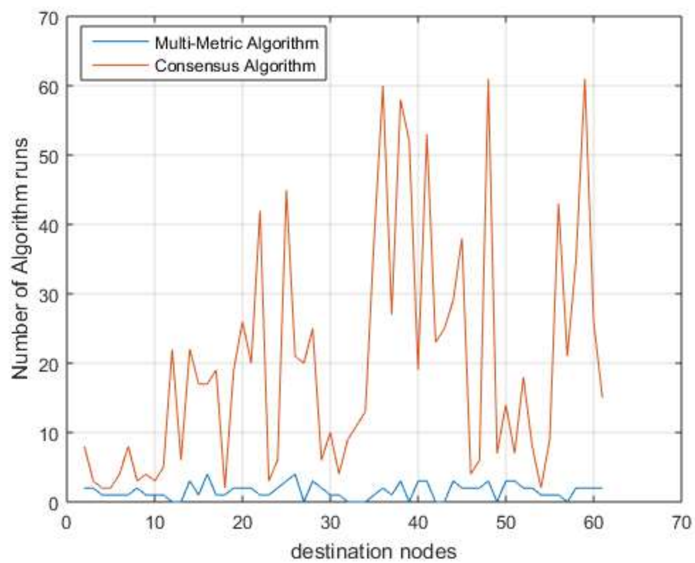

Figure 4.4: Number of Algorithm runs at distance threshold of 75m

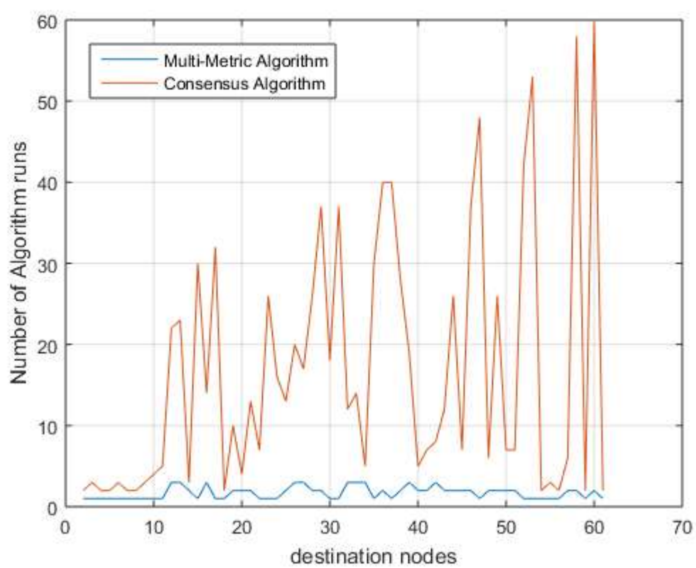

Figure 4.5: Number of Algorithm runs at distance threshold of 100m

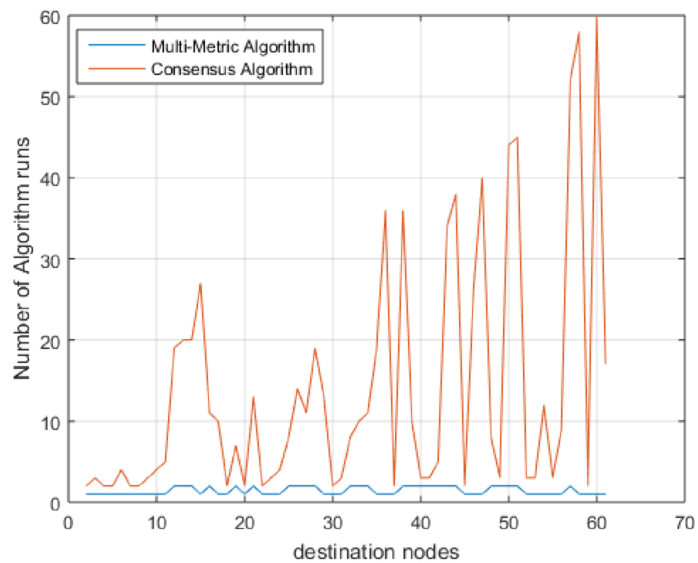

Figure 4.6: Number of Algorithm runs at distance threshold of 125m

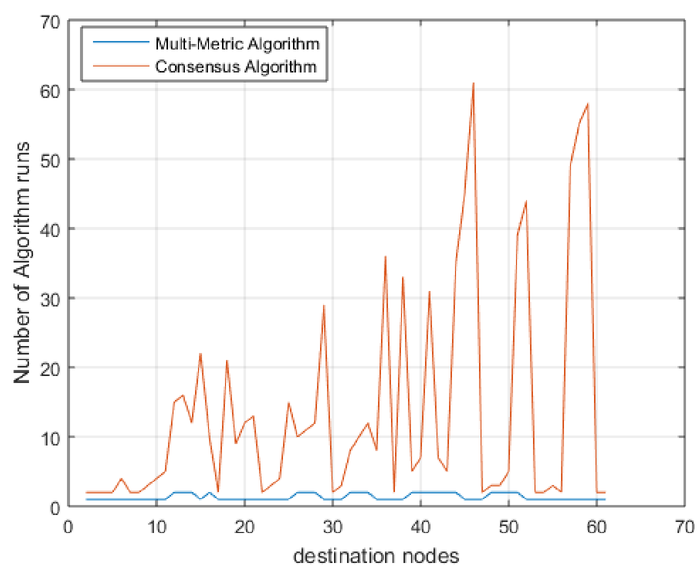

Figure 4.7: Number of Algorithm runs at distance threshold of 150m

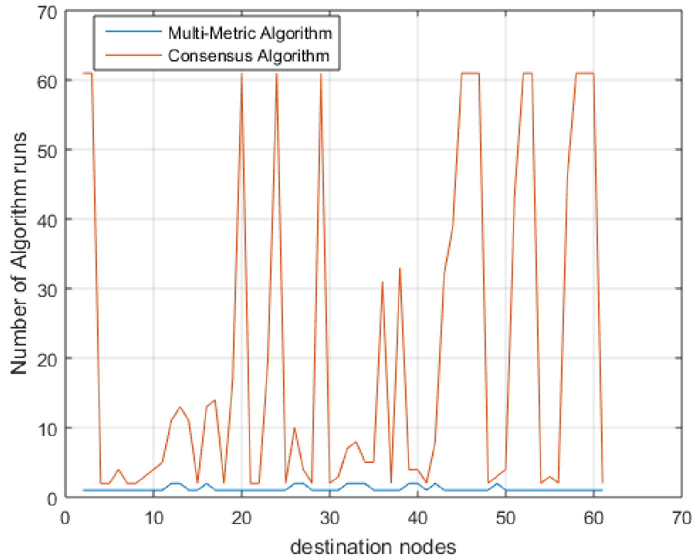

Figure 4.8: Number of Algorithm runs at distance threshold of 175m

From the comparison of Consensus algorithm and propose algorithm as shown from Figure 4.4 to Figure 4.8, Table 4.1 shows the summary of the performance at different thresholds.

Table 4.2: Consensus Vs. Proposed Algorithm Simulation summary for Number of Algorithm runs

Number of destination nodes	Thresholds =70m		Thresholds =100m		Thresholds =125m		Thresholds =150m		Thresholds =175m	
	CA	PA	CA	PA	CA	PA	CA	PA	CA	PA
20	26	2	4	2	2	1	11	2	2	2
40	19	3	6	3	2	1	7	3	4	2
50	14	3	8	2	44	1	6	3.5	4	1

From Table 4.2, it was observed that, the number of algorithms runs fluctuates within a certain limit. The number of Algorithm runs for the consensus algorithm tends to change in the upper and lower limits as the distance threshold changes. At distance threshold of 70m from Figure 4.4, the simulation result started with about 8 algorithm runs at about 2 destinations nodes, it drops down to 3 algorithm runs at 5 destination nodes and rises again to 8 algorithm runs and the fluctuation begins as shown in Figure 4.4. From Figure 4.5, the system begins to perform better, because the there is an increase of the distance threshold to 100m, thereby resulting in reduction in the number of algorithm runs. From destination nodes between 0 to 35 from Figure 4.4, 4.5 through 4.7. There is a noticeable reduction in the algorithm runs. This also tends towards achieving stability of the system. From Figure 4.8 there is very few high algorithm runs, indicating an overall reduction in the algorithm runs when compared with the consensus simulation result in Figure 4.4.

The number of Algorithm runs for the proposed algorithm tends to change in the upper and lower limit as the distance threshold changes. At distance threshold of 75m, the upper limit and lower limit of the algorithm runs for system under the proposed algorithm was 4 and 0 respectively as observed in Figure 4.4. When the distance threshold increased to 100m, the upper and lower limit was 3 and 1 respectively. When the distance threshold was expanded to 125m, the upper and lower limit of the algorithm runs became 2 and 0 respectively as shown in Figure 4.5. When the distance threshold became 150m, the upper and lower limit of algorithm remain the same, the only difference was that, the system was more stable compared to that of Figure 4.4. The distance threshold increased to 175m, and most of the algorithm runs was one, this indicated that, with one algorithm run, information is transmitted. This also deduced that the system performs better when the distance threshold is increased.

From the simulation results, it was observed that the number of runs for the Multi-Metric localization algorithm outperforms, that of consensus-based algorithm. Therefore, it was deduced that Multi-Metric Localization algorithm will reduce delay better than consesusbased algorithm because it will require fewer algorithm runs compared to the consensus-based algorithm. The Multi-Metric Localization algorithm will enhance faster transmission of message from source source to destination node.

4.4.2 Number of relay nodes

The number of Relay nodes is presented in Figure. 4.9 to 4.15. Several nodes are involved as relay nodes in transmission of messages from source to destination node. The number of nodes involved in transmission is unique for specific distances. This was checked for both Consensus-based algorithm and Multi-Metric Localization-Based algorithm.

Figure 4.9 shows the result for the running the simulation for number of relays involved at specific distances between the source and destination vehicle nodes, using consensus algorithm using a distance threshold of 75m. This is a plot of Number of relays against maximum distances between the source and destination nodes, during transmission of information. At 0m distance between the source and destination node, for transimission of information to occur, about 4 relay vehicles will have to be involved. At 50m distance, about 16 relay vehicles will be involved, 100m distance will require about 30 vehicles and for a distance of about 200m, about 19 relay vehicles will be involved.

Figure 4.10 shows the result for running the simulation for number of relays involved at specific distances between the source and destination vehicle nodes, using proposed algorithm at a threshold distance of 75m. At 0m distance between the source and destination node, for transimission of information to occur, only 1 relay vehicle will have to be involved. At 50m distance, about 1.4 relay vehicles will be involved, 100m distance will require about 2 vehicles and for a distance of about 200m, 1 relay vehicle will be involved.

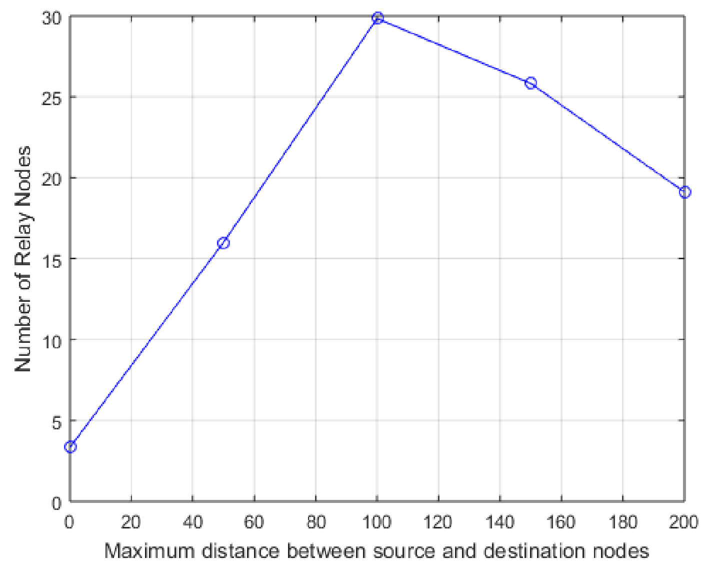

Figure 4.9: Relay nodes required for transmission at distance threshold of 75m using Consensus Algorithm

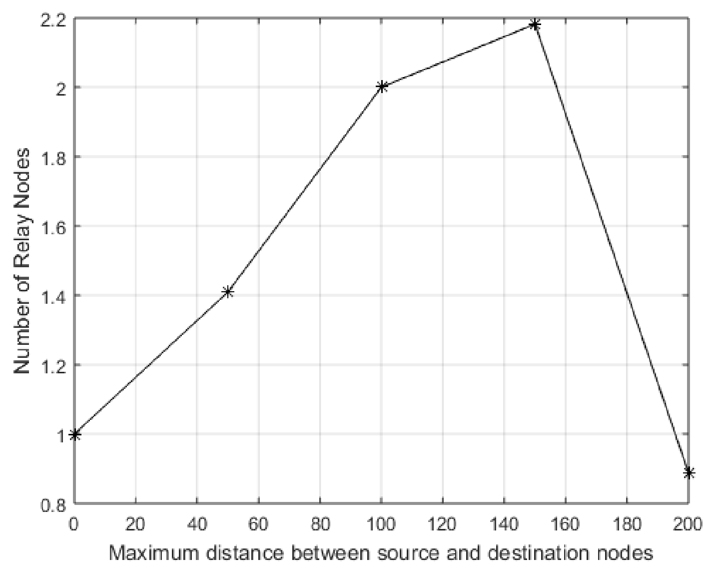

Figure 4.10: Relay nodes required for transmission at distance threshold of 75m using Multi-Metric Algorithm

The simulation resuts for the number of Relay nodes needed for specific distances between source and destination vehicles nodes, for consensus algorithm and the proposed (Multi-Metric) algorithm were compared at different distance thresholds. Figures 4.11, 4.12, 4.13, 4.14 and 4.15 shows the simulation result comparison at distance thresholds of 75m, 100m, 125m, 150m and 175m. Table 4.2 shows a performance of the system at several distance thresholds. The number of relay values are normalised simulation values.

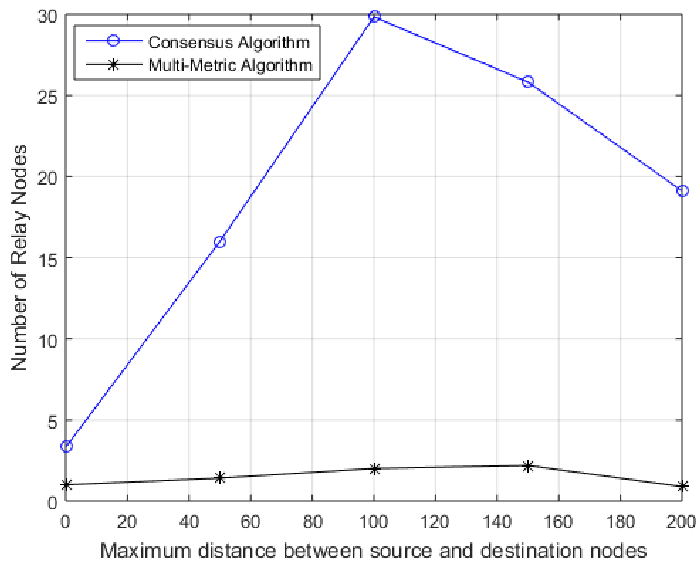

Figure 4.11: Relay nodes required for transmission at distance threshold of 75m

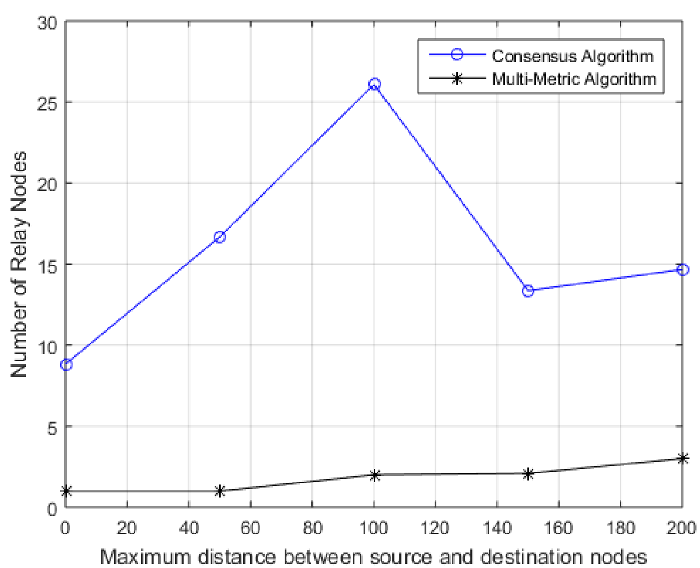

Figure 4.12: Relay nodes required for transmission at distance threshold of 100m

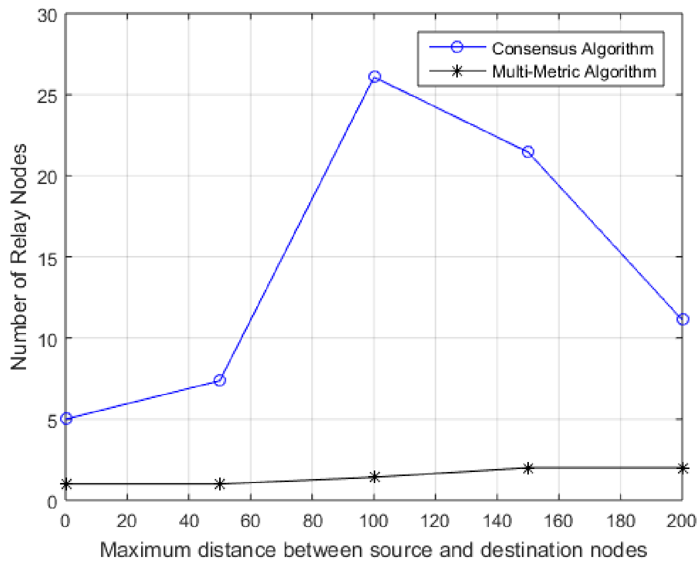

Figure 4.13: Relay nodes required for transmission at distance threshold of 125m

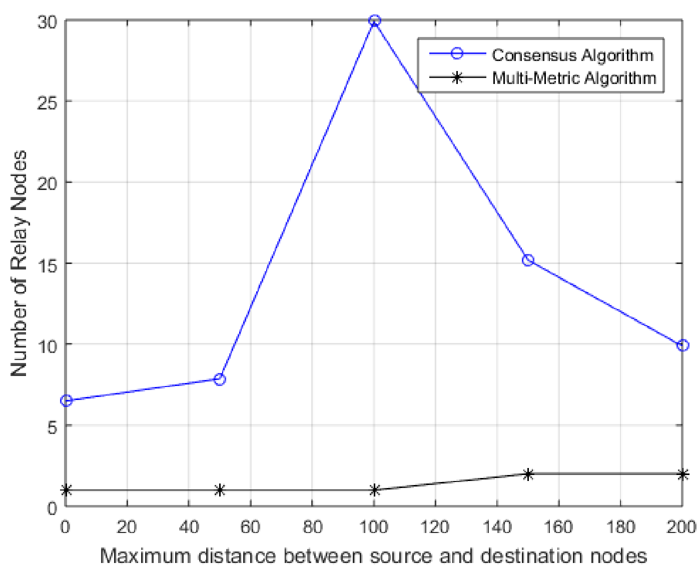

Figure 4.14: Relay nodes required for transmission at distance threshold of 150m

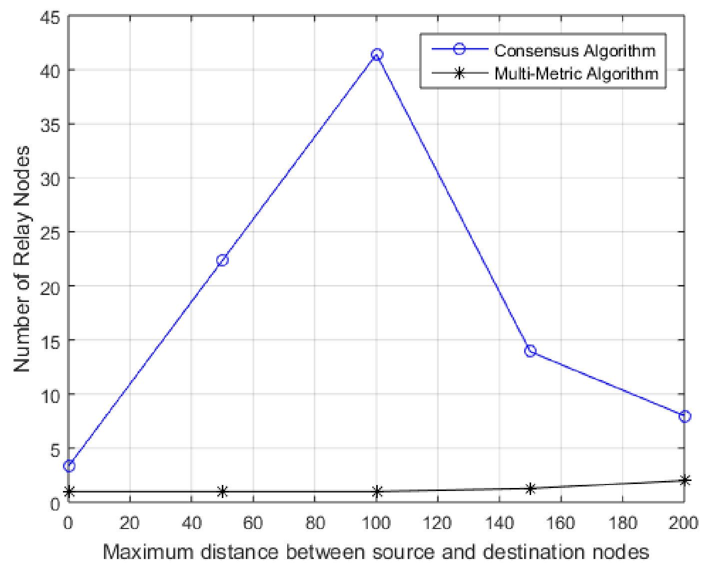

Figure 4.15: Relay nodes required for transmission at distance threshold of 175m

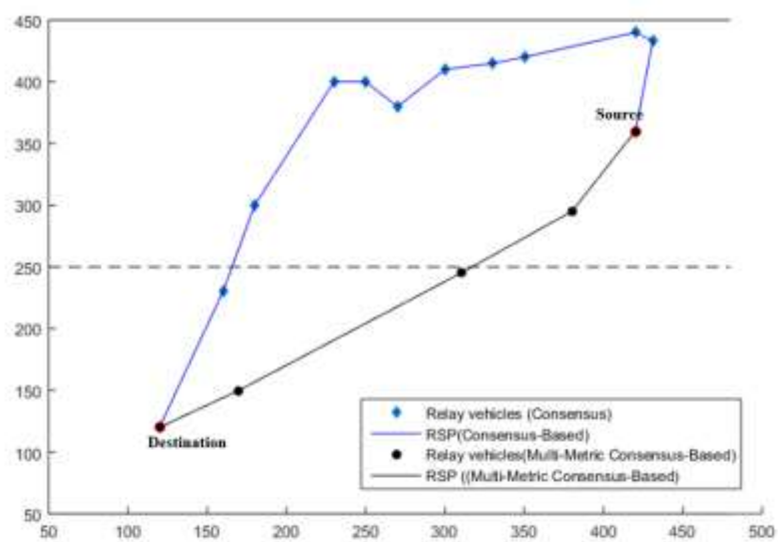

Figure 4.16: Number of Relay involved during transmission of information from Source to destination

Table 4.3: Consensus Vs. Proposed Algorithm simulation summary for Number of Relay nodes

Max Dist. Between source and Destination	Thresholds =75m		Thresholds =100m		Thresholds =125m		Thresholds =150m		Thresholds =175m	
	CA	PA	CA	PA	CA	PA	CA	PA	CA	PA
0	3.5	1	8	1	5	1	6	1	3	1
50	16	1.4	17	1	8	1	7	1	23	1
100	30	2	13	2	26	1	30	1	42	1
150	26	2.2	26	2.1	22	2	15	2	14	1
200	19	1	15	3	11	2	10	2	8	2

From Table 4.3, it was observed that as the maximum distance between source and destination, increases, for Consensus-based algorithm relay selection, the number of relay nodes required, rises and begins to drop as the distance between source and destination begins to go above 100m. For the Proposed algorithm, it starts rising and also drops negligibly as the distance between the source and destination begins to go above 150m.

Also, as the distance thresholds for transmission begin to increase, there is significant drop in the number of required Relay nodes involved in the communication transmission, especially for the proposed algorithm. Considering the maximum distance of 150m, for distance threshold of 70m, about 26 relays nodes are required for transmission using consensus algorithm, whereas, only 2 relay nodes are required using the proposed algorithm. For distance threshold of 175m, about 14 relays nodes are required for transmission using consensus algorithm, whereas, only 1 relay node is required using the proposed algorithm.

During the running of the simulation, it was observed that when the maximum distance threshold was set for 75m, 100m, 125m, 150m and 175m, it was observed that Multi-Metric

Location algorithm performed better than the consensus based algorithm. Therefore, the number of relay nodes, involved for transmission from a specific source node to the destination node, is fewer than that of consensus-based algorithm. It was also deduced that, the Multi-Metric Localization will reduce delay and cost, since it is involved fewer Relay nodes. Figures 4.11, 4.12, 4.13, 4.14, 4.15 and 4.16 confirms that Multi-Metric Localization algorithm performs better than the consensus-based algorithm.

4.5 Cost of Implementation

The results show that the Multi-Metric Localization algorithm performs better than the consensus-based algorithm. Having observed the coordinates, distance matrix and Adjacent Matrix. The number of runs using different distance threshold.

Figure 4.17 shows the cost of traditional methods, consensus-based and Multi-Metric Consensus P2P vehicle networks in five years for vehicles ranging from one thousand to three hundred thousand. Cost implementation of the decentralised network is cheaper than that of the traditional vehicle network. Let us consider a city containing 200,000 vehicles, such as in Minna, Niger State, the Multi-Metric Localization-based P2P vehicle network will save ₦693 Billion for the V2V network implementation.

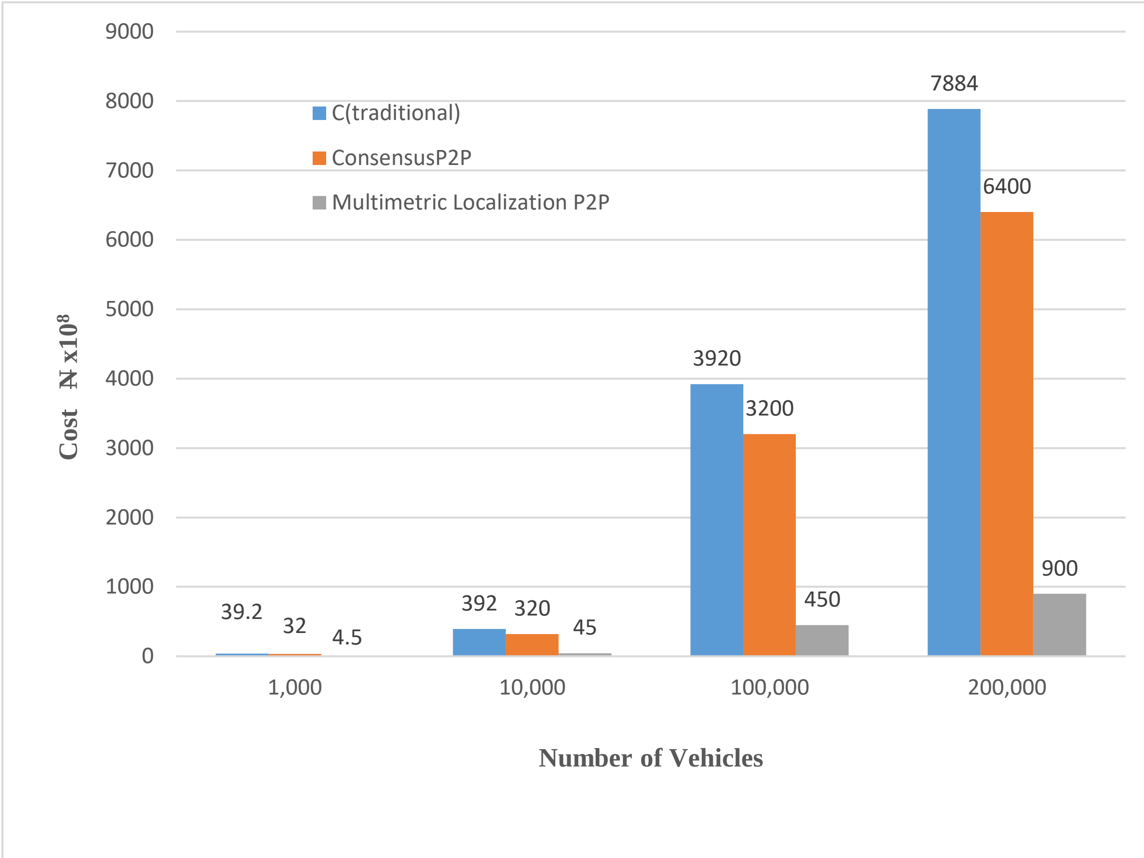

Figure 4.17: Traditional, consensus-based P2P and Multi-Metric Consensus-based networks

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

A new algorithm for relay selection in V2V was achieved. This Multi-Metric localization algorithm, has been tested using simulation, it was observed to have better performance in selection of relay, thereby reducing the delay.

The coordinates of vehicles were realized, the distance matrix for these coordinates was achieved using MATLab simulation tool. The performance of the relay selection in V2V using Consensus algorithm and Multi-Metric Localization was carried out and analyzed using MaTLab simulation Environment. The Multi-Metric Consensus algorithm performed better by about 20% and 40% for number of algorithm runs and number of relay nodes involved respectively. The centralised method, consensus based algorithm and multi-metric consensus algorithm were compared in terms of cost of implementation, the multi-metric consensus was cheaper by 90% and 85% for centralized and conventional consensus respectively, when considered for a period of five years.

5.2 Recommendation

This research shows the multi-metric localization algorithm for V2V relay selection has better performance in cost of implementation, number of relay and number of algorithm runs. This was achieved by considering distance between vehicles, position of the vehicles, communication range and angle of displacement within the V2V network. However, other parameters like speed, instantaneous velocity can be explored using this algorithm. The performance of other algorithms can be examined and compared to multi-metric localization algorithm.

5.3 Contributions to Knowledge

One of the major contribution is the development of an algorithm to implement V2V communication network based on multi-metric localization parameters. Results show that the multi-metric algorithm gives better performance than the consensus-based algorithm. The Multi-Metric Consensus algorithm performed better by about 20% and 40% for number of algorithm runs and number of relay nodes involved respectively. The cost of implementation of this algorithm when compared with consensus-based and traditional methods, it is cheapest. The multi-metric consensus was cheaper by 90% and 85% for centralized and conventional consensus respectively, when considered for a period of five years. Based on this research findings, implementation of relay selections in V2V networks that make use of Multi-Metric localization parameters will safe more money compared to Relay selections that are based on consensus-based algorithm and traditional methods.

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APPENDICES

Appendix A

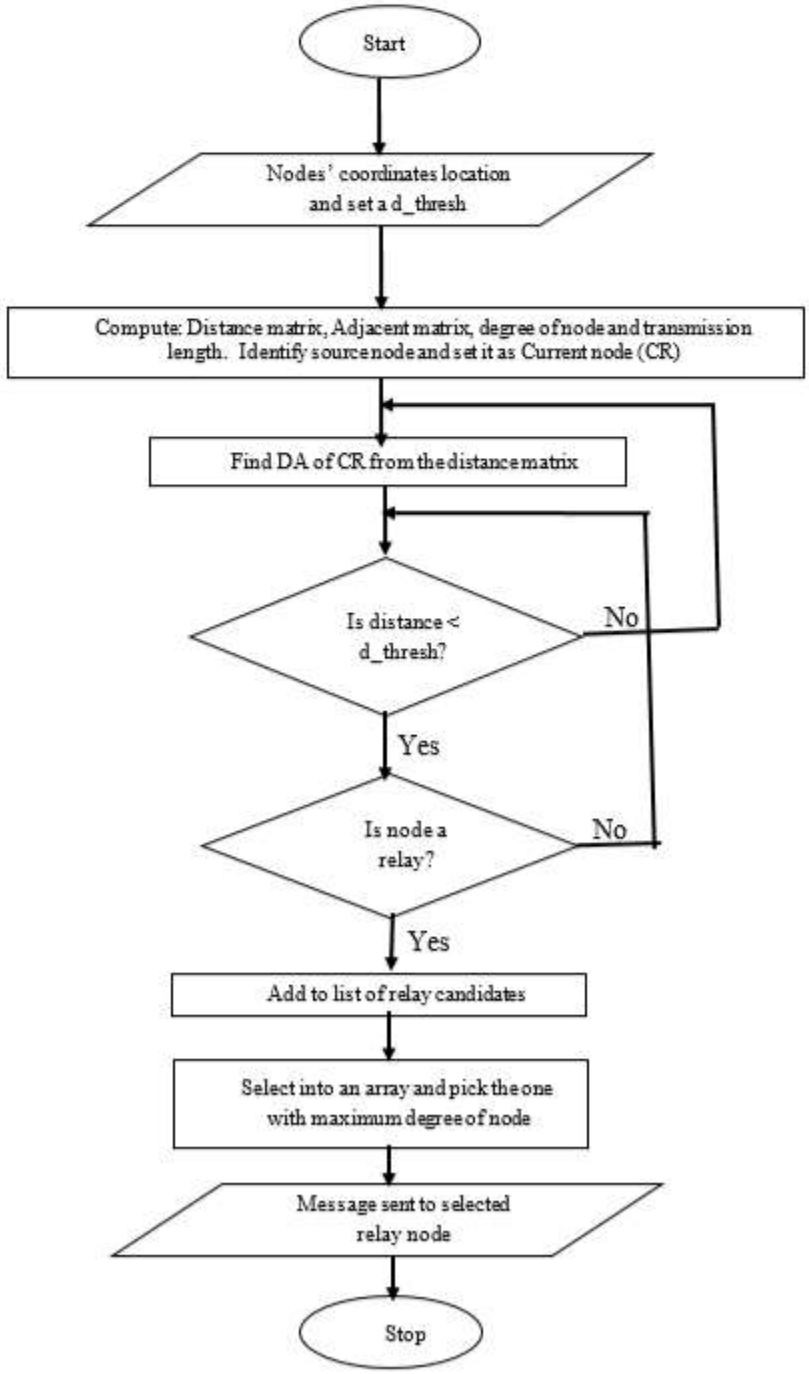
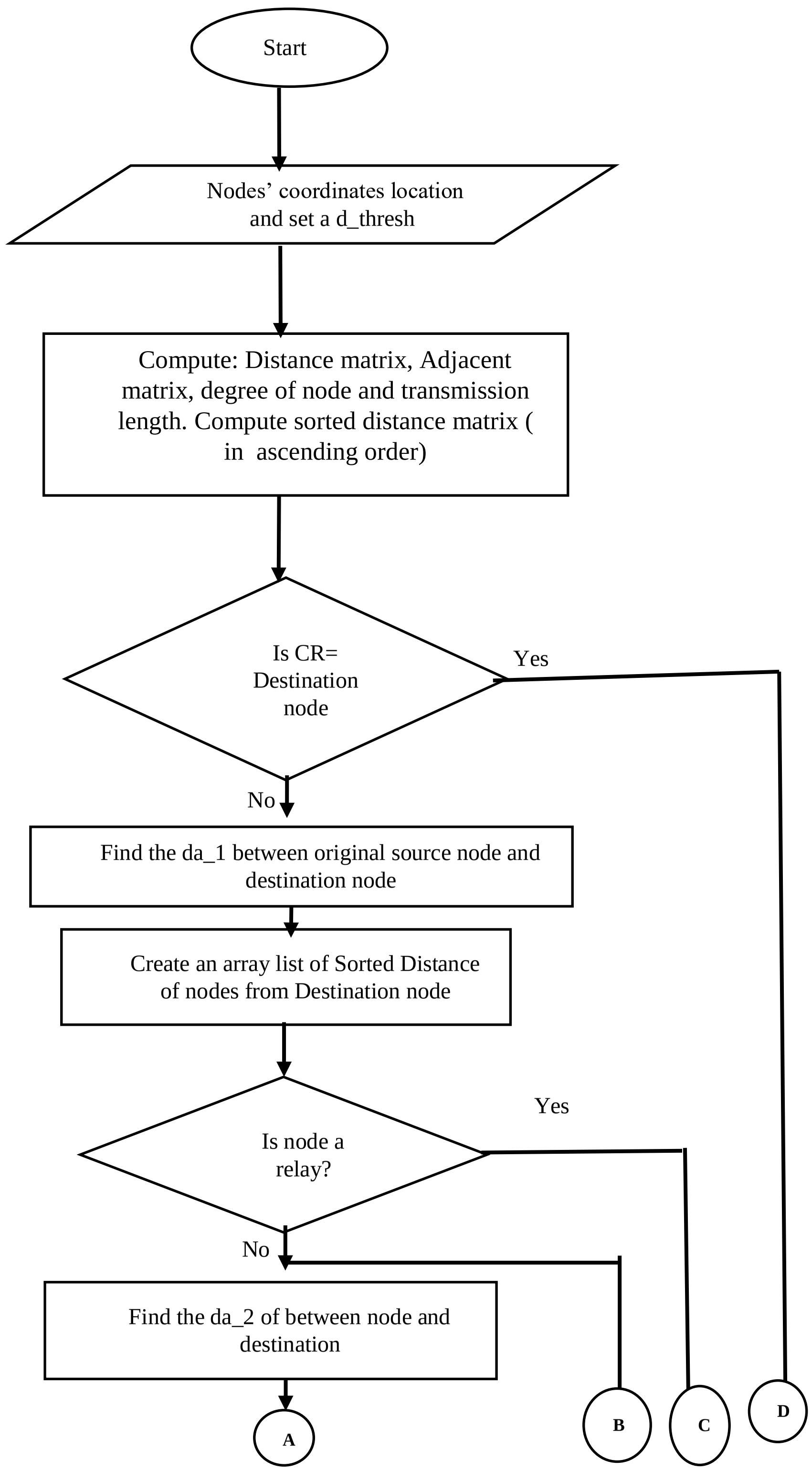


Figure A1: Flowchart showing Consensus Algorithm to **SELECT RELAYS** to send a message from a Vehicle Source node to other destination nodes one after the other



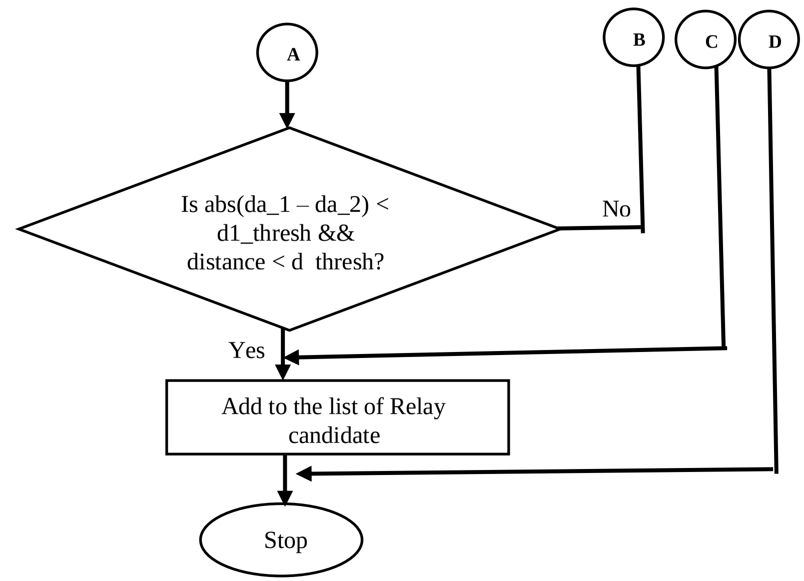


Figure A2: Flowchart showing Proposed Algorithm to SELECT RELAYS based on Multi-metric (Distance and Angle) Parameters

Appendix B

Table B1: Coordinates of 60 vehicles distribution within 300x300m^2

Label for veh.	x (m)	y(m)	Label for veh.	x(m)	y(m)	Label for veh.	x(m)	y(m)
1.	245	295	**21.**	125	241	**41.**	81	242
2.	170	263	**22.**	210	255	**42.**	25	242
3.	178	258	**23.**	190	247	**43.**	93	261
4.	209	236	**24.**	170	250	**44.**	101	251
5.	220	245	**25.**	110	239	**45.**	160	240
6.	210	260	**26.**	46	241	**46.**	151	245
7.	240	221	**27.**	35	263	**47.**	164	253
8.	300	240	**28.**	93	246	**48.**	85	254
9.	300	260	**29.**	139	240	**49.**	71	252
10.	270	260	**30.**	231	240	**50.**	98	244
11.	269	255	**31.**	227	250	**51.**	100	239
12.	50	257	**32.**	5	260	**52.**	171	243
13.	40	256	**33.**	17	239	**53.**	179	250
14.	80	250	**34.**	15	257	**54.**	221	263
15.	210	249	**35.**	218	252	**55.**	189	264
16.	30	238	**36.**	125	263	**56.**	200	239
17.	200	249	**37.**	199	256	**57.**	106	265
18.	230	259	**38.**	110	253	**58.**	138	265
19.	125	250	**39.**	19	248	**59.**	152	265
20.	149	260	**40.**	65	241	**60.**	135	250

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