ISTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

WEIGHTED VOTING GAME BASED RELAY NODE MANAGEMENT IN VANETS

M.Sc. THESIS

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Department of Computer Engineering

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

ARAÇ GEÇİCİ AĞLAR İÇİNDE AĞIRLIKLI OYLAMA YÖNTEMİYLE RÖLE DÜĞÜM SEÇİMİ

YÜKSEK LİSANS TEZİ

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Elham Dehghan Biyar, a M.Sc. student of ITU Graduate School of Science Engineering and Technology 504131514 successfully defended the thesis entitled "WEIGHTED VOTING GAME BASED RELAY NODE MANAGEMENT IN VANETS", which he/she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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To my parents,

FOREWORD

I would like to thank my advisor, Berk Canberk for guiding and supporting me, for his scientific care and invaluable help during the thesis. I would specially like to thank my parents for their constant encouragement, love and supports.
I dedicate this thesis to my father and mother. I couldn't finalize this piece of work without their support. I also dedicate this thesis in the memory of my grandmother.

June 2016 Elham Dehghan Biyar

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ABBREVIATIONS

AU	: Application Unit
BPI	: Banzhaf power index
CTS	: Clear To Send
DIFS	: Distributed Inter-Frame Space
GPS	: Global Positioning System
ICT	: Information and Communications Technology
IP	: Internet Protocol
MAC	: Media Access Control
MANET	: Mobile Ad Hoc Network
NE	: Nash Equilibrium
OBU	: On-Board Unit
PDA	: Personal Digital Assistant
RSU	: Road Side Unit
RTS	: Ready To Send
SISF	: Short Interframe Space
SSPI	: Shapley–shubik Power Index
VANET	: Vehicular Ad Hoc Network
WVG	: Weighted Voting Game

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WEIGHTED VOTING GAME BASED RELAY NODE MANAGEMENT IN VANETS

SUMMARY

In traditional Vehicular Ad Hoc Networks (VANETs) deployments, permanent and robust connection establishment to road side units (RSU) has arisen as a crucial problem. Here it is a known fact that, this challenge has been triggered by high mobility pattern of vehicles. To handle this problem, optimal relay vehicle selection can be seen as an efficient solution. To this end, in this work, we propose a novel optimal and fair relay vehicle selection algorithm based on weighted voting game. In our game theoretic approach, relay vehicle selections have been performed by various cooperative coalitions. Note that game theory is a perfect tool while designing such an algorithm as it is a formal applied mathematical tool to analyze and model complicated situations of interactive decision making.

Our proposed weighted voting game algorithm can achieve fair and optimal results as well as increasing throughput and decreasing message transmission delay during packet dissemination as a result of using Banzhaf power measure. Performance evaluation results showed that compared to non-cooperative methods, throughput increases approximately by 24% and message dissemination delay decreases by 18%. This algorithm is repeated for various speed ranges.

A general introduction and explanation of relay node management was presented in chapter 1. With recent advances in Information and communications technology VANET has become an important concept in order to provide an efficient and convenient road trips for drivers by obtaining required information along the road. Due to the mobile nature of vehicles that results in dynamic topological changes, establishing permanent and robust connection with road side units for maintaining connectivity has arisen as a challenging issue. To overcome these problems and for efficient management of optimal connectivity, it is essential to use some of the vehicles as a relay for compensation and reinforcement of connection. Providing a satisfying method for this selection is required and it is a challenging issue due to dynamic environment of roads. In literature survey part different methods of relay node selection is considered. In contribution section a brief introduction of proposed framework and algorithm has been given.

In chapter 2, a detailed description of vehicular ad hoc networks is given. In this chapter the main purpose of using (VANET), and also their system components are discussed. Furthermore, a brief explanation of VANETs application is mentioned. The application of VANET varies from safety applications to traffic efficiency and infotainment applications. In addition, characteristic of VANETs which is an important factor of challenge recognition is considered. Different methods of communication pattern that is an inseparable part of every VANET is illustrated. Various type of routing protocols are also discussed.

Game theory is a perfect tool while resolving some problematic situations. It is a formal applied mathematical tool to analyze and model complicated situations of interactive decision making. In chapter 3, the reason of game theory usage in this work is discussed. A general classification of games is shown. Voting game permits participants to come up with a common decision to choose the most eligible and suitable candidate. This method is used in this work for relay node selection and categorized. One type of voting game is called weighted voting game. Each player's weight doesn't represent the amount of power that player holds. For achieving fair results, there exist couple of power indices measures that are illustrated and explained in details.

Banzhaf power measure is one of power indexes. It is defined by the probability of changing an outcome of a vote where voting rights are not equally divided among the voters. Players are free to enter and leave the coalitions. Therefore, because of mobile nature of vehicles we use this power index method. If one of the players changes its strategy and other players remain constant, the specific player can't acquire more benefits from that change in its strategy, this is called Nash equilibrium point. A brief definition of Nash Equilibrium that is the fundamental of each game is also given.

Network architecture and system model is discussed and detailed in Chapter 4. The abstract network is shown. Anchor and Relay vehicle phrases are introduced. Moreover, an explanation of our proposed algorithm is given. A mapping between VANET elements for relay node selection and game theory is happened. Network topology examples and also proposed system model schema are shown. System model is consist of scanning, connection attempt, forming coalition, voting, optimal relay selection, and packet dissemination. Pay-off functions for both anchor and relay vehicles are calculated regarding to transmission probability of links between relay vehicle and RSU, available bandwidth of RSU, bandwidth characteristic of vehicle, and the cost of the service.

Chapter 5, provided experimental results and performance evaluation. The performance of proposed cooperative weighted voting game algorithm is evaluated and compared with non-cooperative approach by using Matlab. Vehicles with 2 different speed ranges are examined by using this algorithm. Performance evaluation results showed that compared to the non-cooperative method increment in throughput results and decrement in message dissemination delay are achieved.

In addition, a Realistic VANET Simulations is considered. A real world data is needed for realistic VANET simulations. Accumulating realistic data is required for this simulation. These information is processed using traffic generators. Realistic traffic generators are important to enhance the quality of VANET simulations. Usage of simple mobility models leads to optimistic communications. At the end, the conclusion part explains all the steps and methods. In this section a brief explanation of all the used methods are given.

ARAÇ GEÇİCİ AĞLAR İÇİNDE AĞIRLIKLI OYLAMA YÖNTEMİYLE RÖLE DÜĞÜM SEÇİMİ

ÖZET

Geleneksel VANET (Araç Geçici Ağı) açılımında yol kenarı birimleri (RSU) ile kesintisiz ve güçlü bağlantı kurulumlarında ciddi problemler ortaya çıkmaktadır. Bilinen bir gerçek olarak bu sorun araçların yüksek hareketliliği ile tetiklenmesinden doğmaktadır. Bu sorunu gidermek için en uygun çözümün, röle görevi gören en optimum aracın seçilmesi ile mümkün olabilir.

Bunun bir sonucu olarak bu çalışmada en uygun ve optimum röle aracının ağırlıklı oylama yöntemi kullanılarak algoritmik seçiminin yapılması ile ilgili öneri getirilmiştir. Oyun teorisi yaklaşımımızda röle aracı seçimleri çeşitli yardımlaşma koalisyonları ile gerçekleştirilmiştir. Belirtilmelidir ki, oyun teorisi interaktif karar verme gibi karmaşık durumlarda matematiksel analiz ve modelleme yapabilen uygulamalı matematik algorittması ile dizayn edilen mükemmel bir araçtır.

Sunduğumuz ağırlıklı oylama yöntemi algoritması Banzhaf güç ölçüsünün kullanılarak paket dağıtımları esnasında, artan throughput lar ve azaltılan mesaj iletişim gecikmeleri gibi adil ve optimal sonuçlar ortaya çıkmasını sağlar. Performans değerlendirme sonuçları, kendisini düşünen bağımsız düğümler içeren beraber çalışmayan metodlarla karşılaştırıldığında ağırlıklı oylama oyun teorimiz throughput larda yaklaşık 24% artış ve mesaj iletim gecikmelerinde 18% azalış göstermektedir. Bu algoritma farklı hız menzillerinde tekrarlanmaktadır.

Genel bir giriş ve tanımlama olarak röle düğüm yönetimi 1.kısmında sunulmaktadır. VANET (Araç Geçiçi Ağı) bilgi ve iletişimdeki son ilerlemelerle birlikte sürücülerin rahat ve verimli seyahatleri için yol boyunca gerekli bilgileri sağlayarak sürücülere yardımcı olan önemli bir konsept olmuştur. Araçların daimi hareketi topolojinin dinamik olarak değişimine neden olduğu için dinamik olarak yol kenarı iletişim noktalarıyla sürekli ve güçlü bir bağlantının kurulması ve sürdürülebilirliği için zordur.

Bu problemlerin üstesinden gelmek ve verimli optimal bir bağlantıyı yönetmek için bazı araçları röle olarak bağlantıyı güçlendirmek ve takviye etmek amaçlı kullanılması gerekmektedir. Tatmin edici bir metod sağlamak bu seçim için gerekmektedir. Araçları yollarda sürekli bir şekilde hareket yapmalari ve topoloji değişimleri nedeniyle zor bir durumdur.

Literatür araştırması kısmında farklı röle bağı seçim metodları değerlendirilmiştir. Contribution kısmında önerilen çalışmanın çerçevesi ve algoritması ile ilgili özet bir bilgilendirme yapılmıştır.

2.Bölümde, Araç geçici ağı hakkında ayrıntılı açıklama yapılmıştır. Bu bölümde VANET'in ana kullanım amacı ve ayrıca sistem bileşenleri anlatılmaktadır. Ayrıca, VANET uygulaması ile ilgili özet açıklamada yapılmıştır. VANET uygulaması, güvenlikten trafik verimliliğine ve eğlence uygulamalarına kadar çeşitlilik içerir.

Ek olarak, VANET karakteristiği zorluk tanımlamalarının önemli bir faktörü olarak bahsedilmiştir. İletişim modellerinin farklı metdoları VANET'in ayrılmaz kısımları olarak gösterilmiştir. Çeşitli yönlendirme protokollerinde bu bölüm içerisinde bahsedilmiştir.

Oyun teorisi problemli olan bazı durumların çözümlenmesi için mükemmel bir araçtır. Bu aracın matematiksel analiz ve modelleme yapabilen uygulamalı matematik algoritması ile dizayn edilir. 3.Bölümde oyun teorisinin kullanım nedeni bu çalışma içinde bahsedilmiştir. Oyunların genel sınıflandırılması gösterilmiştir. Oylama oyunu katılımcıların en makul ve uygun olan adayın seçiminde ortak bir sonuç belirlemesine izin vermektedir. Oylama oyununun çeşitleride yine bu bölümde anlatılmaktadır.

Bu çeşitlerden bir tanesi ağırlıklı oylama yöntemi olarak adlandırılır.Her oyuncunun ağırlığı o oyuncunun sahip olduğu gücün miktarını temsil etmez. Adil sonuçlara ulaşmak için, detaylı bir şekilde gösterilmiş ve açıklanmış bazı çeşitli güç endeks ölçüleri vardır. Banzhaf güç ölçüsü bu güç indekslerinden biridir.

Bu indeks, oylama sonuçlarının oy verenler arasında eşit dağıtılmadığı bir oy sonucunun değişim oranını ifade eder. Oyunlar kendi aralarında koalisyona girme ya da koalisyondan çıkmak haklarına sahiptir. Bu nedenle, araçların hareketli olması dolayısıyla Banzhaf güç ölçüsü kullanılmaktadır. Eğer bir oyuncu stratejisini değiştirir ve diğerleri sabit kaldığında, stratejisini değiştiren oyuncu strateji değişiminden çok fazla bir fayda kazanç elde edemeyebilir. Bu Nash dengesi olarak adlandırılı. Nash dengesinin kısa bir özeti her oyunun temeli olarak verilmiştir.

Bölüm 4 te Ağ mimarisi ve sistem modeli anlatılmış ve detaylandırılmıştır. Ağ özeti gösterilmiştir. Anchor ve Relay araç ifadeleri tanıtılmıştır. Dahası, çalışmamızda sunduğumuz algoritmanın bir açıklaması yapılmıştır. VANET elementleri arasında röle düğümü seçimi ve oyun teorisinin oluşumunda bir haritalama yapılmıştır.

Ağ topoloji örnekleri ve sunulan sistem model şemaları gösterilmiştir. Önerdiğimiz sistem modelimiz tarama, bağlanma girişimi, koalisyon şekillendirmesi, oylama, optimal röle seçimi, paket dağıtımını içerir. Pay-off fonksiyonu hem anchor hem röle araçları için hesaplanmıştır. Bu hesaplama röle aracı ile RSU arasındaki linkin transmisyon olasılığına dayanarak ve ayrıca kullanılabilir bant genişliğine,bant genişliği özelliğine ve hizmetin bedeline göre hesaplanmıştır.

5.Bölümde deneysel sonuçlar ve performans değerlendirmesi sağlanmıştır. Sunulan kooperatif ağırlıklı oy oyun algoritmasının performans değerlendirilmiş ve Matlab kullanılarak kooperatif olmayan yaklaşım karşılaştırılmıştır. 2 farklı hız menziline sahip araçlar bu algoritma kullanılarak incelenmiştir. Performans değerlendirme sonuçları göstermektedir ki, bizim sunduğumuz algoritma kooperatif olmayan metodla karşılaştırıldığında throughput sonuçlarındaki artışlar ve mesaj dağıtımları hakkkında ki gecikme azaltılmıştır.

Ek olarak, gerçekçi VANET simülasyonu dikkate alınmış. Bu simülasyon için gerçek dünya verileri kullanımı gerekmektedir. Bu bilgiler haritalar, istatistiksel veriler, trafik sayaçları, gerçek izleri, GPS tabanlı veri elde edilebilir. Bu bilgiler trafik jeneratörleri kullanılarak işlenir.

Gerçekçi trafik jeneratörler VANET simülasyonları kalitesini artırmak için önemlidir. Basit hareketlilik modellerinin kullanımı iyimser iletişim için yol açar. Sonunda, sonuç bölümü tüm adımları ve yöntemleri açıklamaktadır. Bu bölümde tüm kullanılan yöntemlerin kısa bir açıklaması verilmektedir.

1. INTRODUCTION

Daily use of vehicles are increasing each day and by this increment alike many technology obstacles and problems arise. Vehicular ad hoc networks are established by applying the principle of mobile ad hoc networks (MANETs) and it is a particular form of manets. VANETS use dedicated short range communication among mobile vehicles to provide wireless communication.

With the recent advances in Information and Communications Technology (ICT), VANET has become an important concept in order to provide efficient and convenient road trips for drivers by obtaining required information along the road. Vehicles that exist in a specific area are all need to deal with similar and relevant types of information. This information can vary from infotainment to traffic efficiency, safety applications, on demand application management and updating information [1] [2].

Examples of this information usage can be driver's traffic assistance, entertainment application and traffic coordination. For obtaining all the mentioned information, packet dissemination all along the road is important. The aim of packets dissemination among vehicles is hazard prevention or facility improvement for drivers [3].

Toward this end, two methods of packet dissemination have been proposed. In a dynamic environment of roads , each vehicle starts to communicate with its nearest neighbor via vehicle to vehicle (V2V) or vehicle to road side unit (V2R) communication [4]. These two methods are helpful for better data dissemination and informative network creation.

1.1 Purpose of Thesis

Due to the mobile nature of vehicles that results in dynamic topological changes, establishing permanent and robust connection with road side units for maintaining connectivity has arisen as a challenging issue. Furthermore, transmission failure of actual amount of packets during data transfer can happen because of Doppler effect, loss of signal, dissimilar speed of send and receive, and bandwidth limitation of

RSU [5]. To overcome these problems and for efficient management of optimal connectivity, it is essential to use some vehicles as a relay for compensation and reinforcement of connection. While selecting the optimal relay vehicle, we need to take into account several factors such as quality of service (QoS) [6], system performance, cost-efficiency role of chosen node and fairness [7].

Providing a satisfying method for this selection is required and it is a challenging issue due to dynamic environment of roads. Toward this end, for selecting optimal relay an algorithm and framework based on game theory has been proposed. Game theory has become a handy tool for modeling different kind of networks. Recent works on different challenges of computer networks is a witness of the intersection between networks and game theory. Furthermore, in this work by applying some game theoretic methodologies optimizations in throughput and delay results are analyzed.

1.2 Literature Review

There are works which have dealt with relay node selection. In [8] source nodes try to find the most appropriate relay node based on self optimizing algorithm. Considering enviornmental feedbacks, these source nodes select their relay nodes by using "Decentralized learning based relay assignment".In [9], decode and forward (DF) relaying has been proposed, when there is no direct link exists, forwarding signal from a source vehicle to a destination vehicle is done by selecting the most appropriate relay. In [10] an algorithm based on AODV for next-hop selection by focusing on path life time is proposed. Stopping theory for efficiency assurance is applied.

In [11] distributed relay node selection provides responsibility of rebroadcasting of alert messages to further distances. They have used bidirectional stable communication algorithm for selecting set of qualified relay nodes. The author has focused on quality of relay nodes and has not considered other metrics and optimization methods while selecting the optimal relay among multiple options. Besides, none of them did a work using Game Theory.
In [12], the problem of message transmission interruption and secrecy rate reduction is solved by using a game theoretic based relay selection method. This method has improved the average secrecy percentage. In [5] coalitional game theory approach for

solving cost-efficient content downloading has been proposed. In this work, vehicles can cooperate to download contents from their neighbors instead of road side units.

In [13], their proposed cooperative algorithm is based on *Shapley value*, where it selects best relay node, as well as, choosing optimal power resource allocation. In [14] relay vehicle selection based on game theory is proposed, pay-off functions are designed with respect to some metrics, and an optimal matching problem has been solved using Kuhn-Munkres algorithm. Although game theory has been used to optimal relay vehicle selection, defining Nash equilibrium point for cooperation is missing. Moreover, fairness has not been considered.

In this work, an algorithm based on Weighted Voting Game will be introduced that we believe is more efficient for optimization and fairness. All aforementioned works, have mainly focused on quality of chosen relay node, but few works are focused on choosing a relay among multiple number of eligible relays. Moreover, in these proposed methods fair relay node selection have not been considered.

One of the notable issues in network management is fairness [7]. In this work, fairness is defined as an impartial relay assignment in a way that it also optimizes pay-off functions for various individual anchor users. In addition, we believe that Game Theory should be used in relay vehicle selection because it is a formal applied mathematical tool to analyze and model complicated situations of interactive decision making [15]. There are several decision makers with various intentions, which decision of each one effects the overall result of decision making process [15].

In this work, Weighted Voting Game is proposed, which is a popular model of interactive decision making in cooperative games. This model has recently been used in a wide range of research areas such as economy, science, and management [16] [17]. Besides, Banzhaf power measure to designate both fairness and optimization parameters for relay vehicle selection has been introduced. Moreover, in each game with bounded number of players there exist at least one Nash equilibrium point [18] [19], so that existence of Nash equilibrium point is demonstrated through using this algorithm.

1.3 Contributions

In this work, a relay selection algorithm based on WVG is proposed for a VANET. A game theory based cooperative schema designed to choose fair and optimal relay vehicle for anchors. The existence of Nash Equilibrium point has been proved. In each game there exist pay-off functions that is introduced as a mathematical function as a reward of each player's participation in a game.

We introduced some metrics to formulate pay-off functions for both anchor and relay vehicles to use in our weighted voting game algorithm to get better results for throughput and delay parameters. Overall the main contributions of this work, are summerized as :

- An algorithm based on Weighted Voting Game to choose fair and optimal relay vehicle for anchor vehicles is proposed.
- It is shown that after using Weighted Voting Game (WVG) algorithm, obtained solution is a Nash Equilibrium (NE) point.
- Pay off functions for both anchor and relay vehicles are calculated.
- A method for choosing a fair relay node to acquire fairness is introduced.
- Cooperative WVG algorithm's throughput and delay results with non-cooperative approach are compared.

2. VEHICULAR AD HOC NETWORKS

2.1 Purpose

Daily use of vehicles are increasing each day. By this increment alike every technology obstacles and problems arise. Vehicular ad hoc networks are established by applying the principle of mobile ad hoc networks (MANETs). Vehicles communicate through using dedicated short range communications (DSRC) that is a type of two-way wireless communications and it is capable of very high data transmission.

In VANETs each vehicle communicate with other vehicles or RSUs that may never face again or hasn't faced previously. However, these connections are temporary and connection among vehicles are highly ephemeral, therefore establishing robust connection has become a very tough challenging issue.

2.2 VANETs System Components

There are three main system components in VANETs. On-board units (OB) , Application Units (AU) and RoadSide Units (RSU) [20].

2.2.1 On-Board units

Every vehicle has an on board unit as an equipment that is assembled on each vehicle. This device is used for exchanging information with other onboard units on various vehicles or road side units. It contains a memory to information storage and retrieval, user interface, an interface to obtain connection with other OBUs and a network device for wireless communication.

The primary functions of OBU are IP mobility, reliable message transfer, adhoc and geographical routing and congestion control. Set of elements that are required for OBUs are as follows:

- Memory: is a storage space that records all the information

- GPS: wireless communication is required for each vehicle to be able to communicate with other vehicles or infrastructures.
- Easy hand-off: OBUs manage handovers with network adapter.
- Sensors: can be used to collect driver's physical parameters or other piece of information. These information can be collected and for later process and usage.

2.2.2 Roadside unit

In VANETs, vehicles are all moving in a pre-defined and specific path. The vehicles that use VANET applications reduce hazards for drivers. Moreover, packet dissemination all along the road will become more confident, available and accurate. The vehicles identify the RSU by sending hello packets and getting confirmation. RSUs are used to extend the communication range. Store and forward methods can be done in RSUs that is a multipurpose object. Sometimes this object function as an access point, buffer or even a router. In addition, it can be used to provide internet connection for various type of applications that are used in vehicles.

2.2.3 Application unit

Application units can function as a Personal Digital Assistant (PDA) or a dedicated safety application device. This units can be connected to internet through OBU.

2.3 Applications of VANETs

VANETs usage can be classified into three major category [21]

- Safety applications
- Traffic efficiency applications
- Infotainment and business

2.3.1 Safety applications

Nowadays safety applications plays an important rule in saving lives and avoiding accidents. The propose of cooperative collision avoidance (CCA) is to avoid chained and head-on collisions. However, this application has real-time demands on communication reliability and its latency. Usage of emergency warning messages, results in hazard alert dissemination among drivers in the specific area.

2.3.2 Traffic efficiency applications

Road traffic efficiency applications focus on traffic flow improvements and traveling time reduction. The main difference between traffic efficiency applications and safety applications is the real-time factor that distinguishes these applications. In safety applications delays are not acceptable due to sensibility of network. In the condition that delay happens serious collisions may happen.

2.3.3 Infotainment and business

Main focus of this application is providing entertaining results such as multimedia, news, music etc. for business purposes local advertising messages for restaurants, fuel stations, hotels with the information about their discounts, menu, and events can be a good example of this application.

2.4 Characteristics of VANETs

In spite of the fact that, there are similarities between some features of VANETs and mobile ad hoc networks (MANET), VANETs possess specific characteristics that are classified as [4] [22]:

- Dynamic topology
- Infinite power
- Lack of robust connection
- Various type of communication ambience
- Critical delay constraints
- Communication with on-board sensors
- Location estimation

A detailed explanation of all these characteristics are as follows:

2.4.1 Dynamic topology

Due to the high speed of vehicles, topology changes occur most frequently. Variety of density cause short-lived connection in vehicle to vehicle (V2V) and vehicle to road side units (V2R) communications. Moreover, mobility causes channel fading and impairments that results in tough packet losses.

2.4.2 Infinite power

Vehicles doesn't have power limitations for processing and data storage.

2.4.3 Lack of robust connection

As mentioned before, considering high mobility of vehicles establishing permanent and robust connection due to intermittent disconnection along the road with both vehicles and RSUs is a challenging issue.

2.4.4 Various type of communication ambience

Unlike other network environments, vehicles travel in various location such as cities, highways. This places can be crowded or quiet places. In the condition that vehicles are sparsely distributed, connection disruption may happen. On the other hand in rush hours, in multi-lane highways or the locations that has high density, vehicles may suffer bandwidth limitation. In addition, severe channel contention may happen because of high amount of data transmission.

2.4.5 Critical delay constraints

Some of the notifications such as hazard have to be disseminated without any delay. Heterogeneity of some applications cause different delay tolerances, as an example safety messages need high priority, lower delay and also higher reliability.

2.4.6 Communication with on-board sensors

Sensors that are assembled on vehicles collects data such as velocity, directions etc. These data will be used for further processes.

2.4.7 Location estimation

Predefined roadmaps and routing graphs plays a key role on location estimation due to high mobility and dynamic topological changes of vehicles.

2.5 Communication Patterns

In this section appropriate communication patterns in VANET that are likely to be implemented and designed are explained below [23]. These patterns are explained using the following template that is consist of objective, proposed mechanism, motivations, message coordination, data configuration and quality of service.

2.5.1 Beaconing

Objective- in the neighboring area all the nodes need continues up-to-date information.
Proposed mechanism- all the packets are sent as link layer distributes to neighbors. Note that packet forwarding doesn't happen in this method.
Motivation– in this pattern message dissemination happens periodically.
Message coordination- packets are moving in a single direction.
Data configuration- the origin of the packets are usually is the senders.
Quality of services- is the requirement of communication pattern for measuring the quality. Some of related services and metrics are considered such as throughput, packet dissemination and delay. In beaconing middle range latency is required.

2.5.2 Geobroadcast

Objective- in this pattern prompt message dissemination in a large region happens.
Proposed mechanism- the message destination region is predefined from the sender of the packet. The message is using link-layer for broadcasting to all neighbors. The recipient of the message forwards that without alerting the message via broadcasting method.
Motivation- when an unpredictable event happens geobroadcast messages are sent, note that these messages aren't sent frequently. Although messages with the same context may be repeated time to time.
Message coordination- these messages have single direction.

Data configuration- in the situation that an accident happens sender sends message as a warning.

Quality of services- as mentioned before these messages form while an incident happens, so messages with high priority have to be forwarded rapidly. Because of this event based nature, packets dissemination requires very low delay.

2.5.3 Unicast

Objective- in order to send data to a certain destination this communication pattern is used. The aim of this method as in it is obvious from its name is to unicast the messages.

Proposed mechanism- this pattern may include single or multi hop routing schema.

Motivation – internal incidents cause to send packets via this communication pattern.

Message coordination- in this pattern, packet dissemination can be uni- or bidirectional.

Data configuration- optional data can be sent.

Quality of service- the priority of data that are sent with this pattern is normally lower than other patterns. Even there exist a priority hierarchy among all packets.

2.5.4 Information aggregation

Objective- in this pattern, nodes process data rather than just forwarding. This method also alleviate the probability of collision and number of dropped packets that results in more available bandwidth. In some cases this method improves the quality of disseminated information.

Proposed mechanism- new pieces of information is shared among vehicles. The messages are accumulation of data collected from different vehicles.

Motivation- is sharing information periodically.

Data configuration- data is consist of collected information from different sources.

Quality of service- rather than delay or other parameters quality of the information is an important fact in this kind of message dissemination pattern. Usage of time-sensitive messages is not suitable in this method.

2.6 Routing Protocols in VANET

Due to the mobile nature of vehicles, establishing a permanent connection and a stable routing is very challenging.

As shown in fig 2.1, routing protocols are classified into 5 categories [24]:

1. Topology based
2. Position based
3. Cluster based
4. Geo-cast
5. Broadcast routing protocol

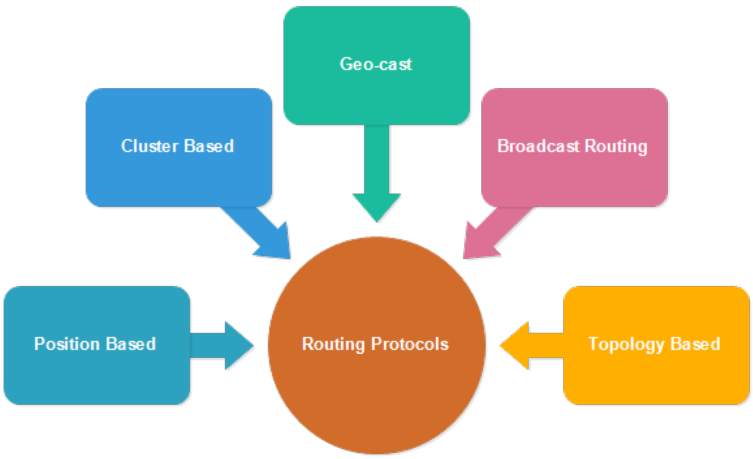

Figure 2.1 : Routing protocols.

2.6.1 Topology based routing

This routing is divided into proactive and reactive routing. In proactive routing every node preserves the entire topology of the existing network. In order to have an up-to-date routing information, tables are updating their neighboring data frequently. On the other hand, reactive routing protocol doesn't memorize the information. As a result, in comparison to proactive protocols it has higher latency and lower overhead.

2.6.2 Position based routing

In this method geographic positioning for choosing next hop is used. There is no need to memorize any routing map. Toward this end, packets are sent to the nearest neighbor. This routing protocol is divided into two types: position based greedy V2V protocols and delay tolerant protocols. In cluster based routing method a group of nodes have become as a part of cluster. Each node has its own header. Furthermore, designated header node broadcasts the packet to other clusters. In each cluster nodes communicate by using direct links.

2.6.3 Broadcast routing

This method is mostly used for sharing traffic reports, weather, emergency messages, advertisement, etc.

2.6.4 Geo cast routing

This kind of routing is a location based multicast routing. The aim of this method is packet delivery from a source node to adjacent nodes that are in zone of relevance (ZOR). Furthermore, geo cast is considered as a multicast service in a specific geographical region. Direct flooding is mostly used in geo cast routing method. Toward this end, this method tries to reduce message overhead and network congestion.

3. GAME THEORY

3.1 Why Do We Need Game Theory In VANETs

There exist various reasons for adapting game theory in networks and VANETs. Nodes in VANETs are making all decisions independently and only for their own interest. Furthermore, game theory is an efficient tool to analyze behavior and action of each node. Considering the fact that game theory deals with distributed optimization, local information is often needed. Therefore game theory helps us to design these kind of optimizations.
Pay-off function of each player depends on other players. Game theory can be used to modeling nodes in different layers of computer networks such as physical layer, link layer and network layer. The standard behavior of nodes degrade in the presence of selfish nodes. A selfish behavior increases the profit for that individual node. A selfish vehicle may drop all incoming packets which it receives for forwarding. This action is called packet dropper that is one of denial of service threats. A question of interest is how to acquire motivation to refuse selfish behavior. Selfish behavior of nodes is harmful all over the network.

An example of selfishness can be the individual nodes ignorance for forwarding packets to its neighbors.In every coalition, selfish nodes try to refuse packet dissemination. Our proposed algorithm encourages each node to collaborate in a coalition. Encouraging each node for collaboration in coalition happens by calculating pay-off function for every node. Table 3.1 shows typical mapping between game theory and relay node selection.

3.2 Purpose

Game theory is a perfect tool while designing some problematic situations. It is a formal applied mathematical tool to analyze and model complicated situations of interactive decision making. In game theoretic models all entities make rational choices that are beneficial, considering each players description of profits [25]. Each game involves players, pay-off functions and strategies where, a decision making agent in each game is called player, Reward of each participant in game is mathematically calculated as pay-off function, one of the probable actions of players show strategy of the game respectively.

Table 3.1 : Typical mapping between game theory and relay node selection.

Components of game	Elements of VANETs
Players	Vehicles
Strategy	Cooperation or defection in a coalition,Find fair and optimal relay
Pay-off	Performance metrics(e.g, transmission probability, bandwidth availibilty)

3.3 Game Classification

According to properties of games, considering their focus and usage, games can be classified into different categories

- Cooperative Games
- Non-cooperative Games

In cooperative games, joint action of groups are analyzed where in non-cooperative games action of each individual player has to be considered. In non-cooperative games, each player decides on its own chosen strategy to maximize its pay-off function.

3.4 Coalitional Games

Entities that have goals as a group not as an individual forms coalitions. There are winning and losing groups in coalition game, so it is necessary to take part in a successful group to acquire satisfying results. Coalitional game mostly considers on group of achievements rather than individual player's attains. Solutions of coalitional games are determined by pay-off assignment to diverse coalitions.

This pay-off assignment can occur in two phases. When the total amount of pay-off function divided among groups and these amounts can't be distinguished between members. This kind of assignment is referred as transferable pay-off. The alternative method is called non-transferable pay-off coalitional game. In this method each player has a different amount of pay-off based on its own benefits of belonging to a coalition. Non-transferable pay-off can't be shared among other entities.

3.5 Voting Game

We present *Voting Game*, that is one of the popular coalitional game models in scientific areas. In our work Voting Game is used to model relay node selection in VANETs. As the name illustrates, selecting a best candidate among eligible members is a dilemma. As shown in fig 3.1 there exist 5 various type of voting models. In the next paragraphs these models are described. Voting game permits participants to come up with a common decision to choose the most eligible and suitable candidate.

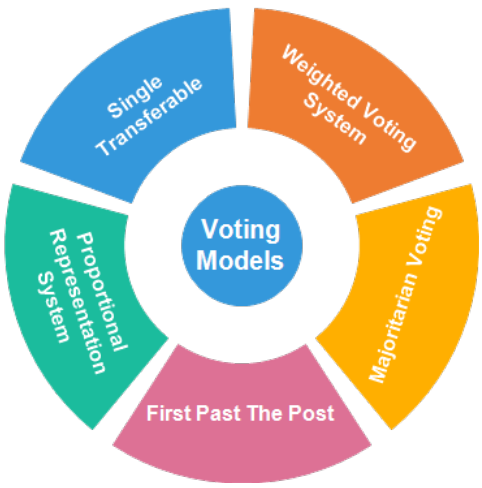

Figure 3.1 : Voting models.

First past the post: Candidates with the highest number of votes win the voting game. There isn't any constraint in the number of votes so the elected candidate receives more votes than other ones.

Majoritarian Voting: An old and simple electoral system. Absolute amount of votes are needed for each candidate to be elected. This amount is specified as 50% plus one vote.

Proportional Representation System: Each group of candidates are elected according to the proportional of votes.

Single transferable vote system: In this method voting is based on a preferences of the voters so each candidate is selected based on preferences and priority of voters. While counting the number of votes if the number of votes pass the quorum candidate will be selected otherwise surplus or wasted votes are all transferred according to stated preferences.

Weighted voting System: Voters are all unequal in the number of votes they control. A voters weight is very essential to his vote. Each weighted voting game is consist of players, quota and weights. On a more practical note, players are referred to voters of the weighted voting game. We will denote players as $\{P_1, P_2, ..., P_N\}$. Every individual player controls specific number of votes that is called weights and represented as w. All these weights are positive integers. In each game quota will be defined as the minimum number of votes that are required to pass the motion. quota is depicted by q. The Weighted voting game is depicted as

$$[q : w_1, w_2, ..., w_N] \tag{3.1}$$

In order to design our proposed algorithm, we have used weighted voting game as a theoretical perspective for achieving a suitable solution for relay vehicle selection, we will consider additional details for this algorithm implementation. We have used this method because this voting game specifies weights that are necessary in our assumptions to gain better results.

3.6 Fairness

Fairness can be considered at some levels. First, fairness in acquiring the channel in competing environment. This is addressed by the MAC protocol. Second, fairness is about how fairly a node can disseminate its intermittent packets successfully without encountering any collision [26].

In our game theoretic approach fairness is defined in a way that it also optimizes pay-off functions and causes to come up with a Nash equilibrium point. Fairness in choosing relay is important for obtaining the channel among the vehicles in competing environment of relay selection.

3.7 Power Index

Each player's weight doesn't represent the amount of power that player holds. For instance, consider a player with the plenty number of votes may have no power. In contrast, a player with little amount of votes may hold a lot of power or another situation is when players have an equal number of votes but one of the players have more power in comparison to others.

To clarify this situation, assume a game $A = [50 : 25, 25, 24]$, in this case although third player holds as many votes as others, this players vote won't effect the consequence the voting. On the other hand, assume $B = [15 : 7, 6, 1]$ the motion can't be passed unless all the players participate in coalition. To be more specific, third player holds the same power as other two participants.

Power index measures the influence of each individual player on the formation coalition and the result of game. In this situations a mathematical method called power index is jointly used to measure the effect and influence of each player on the establishment of coalitions and also results of the game consequently. As depicted in fig power indexes are categorized as follows:

- Shapley–Shubik power index
- Holler-Packel Value
- Banzhaf power index

3.7.1 Holler-Packel value

The Holler-Packel Power index is total value of minimal crucial coalitions in the game. This method is mainly focus on the number of coalitions that is satisfying for the coalition [25].

$$HPI_i(N,v) = \sum_{S \in M(N,v)} (v(S) - v(S \setminus \{i\}) = \mid \{S \in M(N,v) : i \in S\} \mid \tag{3.2}$$

Where $M(N,v)$ is the set of minimal coalitions for $i = 1, 2, \ldots, N$.

3.7.2 Shapley–Shubik power index

In a sequential coalition, the players are listed in the order that they have entered the coalition. In this kind of power index order of players is important. Therefore, some players are function as a pivotal player. In every Shapley–Shubik power index (SSPI), there exist one pivotal player for every coalition.

A pivotal player is the player in a sequential coalition who alerts the coalition from a losing coalition into a winning one. There are $N!$ sequential coalitions which are constituting of all N players. These steps are listed as follows:

1. Making a list of all sequential coalitions containing all the players.
2. Defining and determining the pivotal player of each coalition.
3. $\dfrac{\text{The number of times the player is pivotal}}{N!}$

3.7.3 Banzhaf power index

Banzhaf power index (BPI) is defined by the probability of changing an outcome of a vote where voting rights are not equally divided among the voters. Players are free to enter and leave the coalitions. Therefore, because of mobile nature of vehicles we use this power index method. A grand coalition is a coalition which consists of all the participants of coalition. Coalition is the subset of players that all vote in the same way. The number of all possible coalitions are; $2^N - 1$ [27].

Critical player is the player that eliminating it's weight from the whole votes cause the coalition turns into loosing one and the number of remaining votes fail to pass the quota. Some voters are more powerful [27].

$$W - w < q \tag{3.3}$$

Where W indicates weight of the coalition, w is the weight of the player and q is quota. This equation shows how a critical player can be distingushed. Each Player's power should be measured by counting the number of times that every player act as a critical player. A list of complete power indexes of players show Banzhaf Power distribution. First we will start by listing all achievable winning coalitions, next specifying critical players. Then, after these steps counting down the number of times each player is critical. After that, by repeating this process, we can find Banzhaf Power index distribution list. Finally, let T shows the sum of critical player counts the division of $\frac{B_i}{T}$ illustrates Banzhaf Power index. This index can be expressed either as a fraction or percentage.

In WVG, BPI and SSPI methods are more accurate in comparison to other methods. In our case, BPI is better for measuring power because considering dynamic topological characteristic of VANETs players can freely join or leave the coalition, where in the SSPI, players are obligated to stay at the coalition. In our proposed algorithm, BPI is used for fair and optimal resource allocation. On the other hand, considering unbalanced weight distribution this power index helps to pick up the most appropriate vehicle as a relay for packet dissemination.

3.8 Nash Equilibrium Point

A fundamental concept in game theory is Nash Equilibrium. Nash Equilibrium is widely used in predicting the consequence of a strategic interactions. Pure strategy NE is an action profile, in such a way that single players can't acquire a higher pay-off by deviating from its profile. In some cases, players may choose probability distributions instead of simply choosing an action. This randomization over set of actions is called mixed strategies. NE sometimes corresponds to the consequences that are inadequate. Actually, there may exist an alternative results that are practical and preferable by all players.

On a more practical note, inadequate information leads to dramatic results in the NE concept. Hence, while applying NE in practical situations, we need to take into account all the information that each individual has about preferences and rationality when they are interacting with other players. In the normal-form game that has n-player G=$\{S_1,...,S_n\}$, if player S_i changes its strategy and other players remain constant, player S_i can't acquire more benefits from that change in its strategy, this is called Nash equilibrium point. NE point will tell us how many of players are cooperating in the coalition [28].

$$u_i(s_1^*,...,s_{i-1}^*,s_i^*,s_{i+1}^*,s_n^*) \geq u_i(s_1^*,...,s_{i-1}^*,s_i,s_{i+1}^*,s_n^*) \tag{3.4}$$

Two steps are required to find Nash equilibrium point in each game. First, dealing with each players optimal strategy consecutively, while encountering other player's action. Second, a Nash Equilibrium point is defined when whole players concurrently are doing their optimal approach [19]. In other words if all players, play their best response to each other's strategy.

4. NETWORK ARCHITECTURE AND SYSTEM MODEL

4.1 Proposed Network Architecture

The abstract network is shown in fig 4.1 that consists of RSU, N anchor vehicle and M relay vehicle.

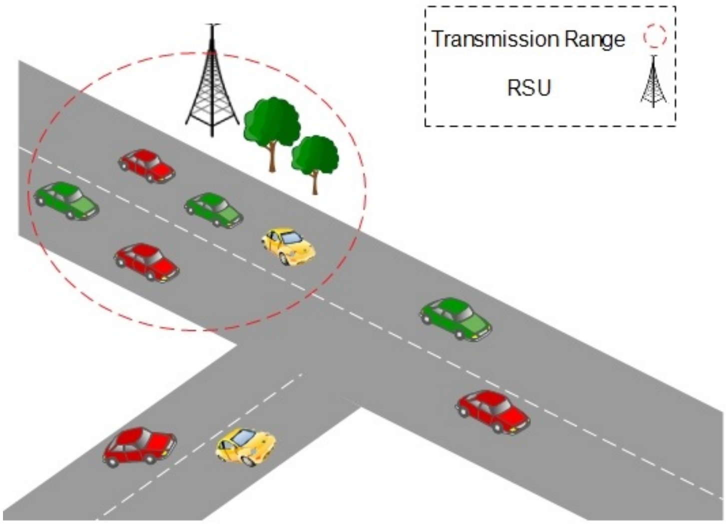

Figure 4.1 : Network topology.

Anchor Vehicle: In this work, anchor vehicle is defined as a node that fails to establish connection with roadside unit or due to high mobility characteristic of vehicles, connection loss happens between node and RSUs or even other adjacent vehicles. This unlucky node that fails to get its desired packet is called Anchor.

Relay Vehicle: Is defined as an assistant node for anchors to compensate and reinforcement of packet dissemination.

After these definitions, these steps will occur respectively:

1. We have a message to give from RSU to vehicles. This message can be Safety applications, traffic efficiency applications, infotainment and business.

2. If the vehicle is in the coverage area, it will try to get that message directly from RSU. In the case of failure for direct connection, it will try to use relay nodes.

3. For the vehicles which are not in the coverage area of RSU, it is not possible to get this message unless they enter that area.

4. With the proposed algorithm vehicles disseminate the RSU message among all other vehicles, even if they are not in the coverage area. After all we propose an algorithm to select the best relay node that is optimal and fair to get the message and it will be based on weighted voting game algorithm.

4.2 System Model

As shown in fig 4.2, we have 2 number of anchor vehicles (D, E) and 3 number of relay vehicles (A, B, C). Anchor vehicles are the vehicles that fail to establish connection directly to road side units so they try to find optimal relay node for packet dissemination. In our scenario relay nodes are the nodes that help anchors to preserve connectivity. While (D, E) enter coverage area of RSU, they try to connect to RSU in the case of connection setup failure, as shown in fig 4.2 (b) they use one of (A, B, C) nodes as a relay to establish connection. One of these optimal nodes will be chosen by our proposed algorithm.

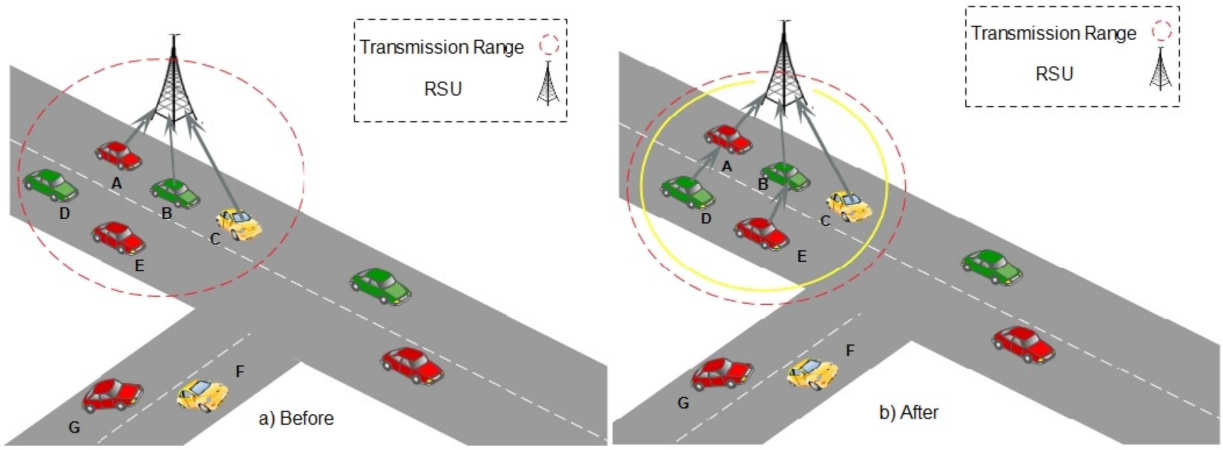

Figure 4.2 : Network topology example.

Another scenario is depicted in fig 4.3 where vehicles(F,G) from other lane join to the main lane and want to access to RSU's information. In this phase (F,G) can form coalition with (A,B,C) which have RSU header as their origin [29]. By our proposed algorithm one of (A,B,C) nodes can be choosen as an optimal relay for the anchors.

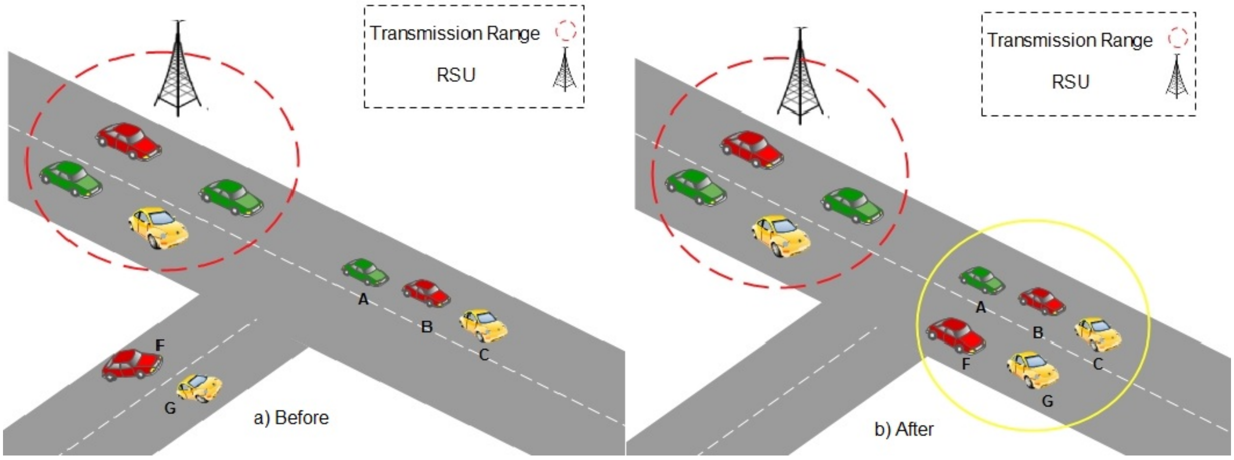

Figure 4.3 : Network topology example.

Each game consists of players, action profiles, preferences and pay-off functions. In this work, multiple anchor vehicles and multiple relay vehicles are the players of the weighted voting game and will be denoted by M and N respectively. Overall we need to consider two kind of relays:

1. Local relay node : In the presence of RSU, a relay can be selected, when vehicles fail to connect directly to RSU.
2. Mobile relay nodes : After exiting from RSU coverage area, relay node can be selected for connection maintenance. Furthermore, relays with appended RSU header [29] can act as a small RSU for other vehicles.

In our algorithm, Players, Actions and preferences are defined as follows :

1. Players: Number of vehicles in coalition.
2. Actions: A= { Cooperate, Defect }.
3. Preferences: at least k node should participate in a way that maximize the total utility.

There are number of vehicles that their cooperation in a game cause to acquire benefits. We are looking for an action profile that each player does one of two actions, whether to cooperate or defect in a coalition. Each player has two phases and in total we have $S = M + N$ players. Therefore, number of action profiles are 2^S.

As shown in fig 4.4, this algorithm is proposed to investigate optimality of each player in every coalition. Detecting data origin by appending small header for received packet will help to identify whether the data origin is RSU or relay node. The nodes with RSU header appendix have priority in voting game [29].

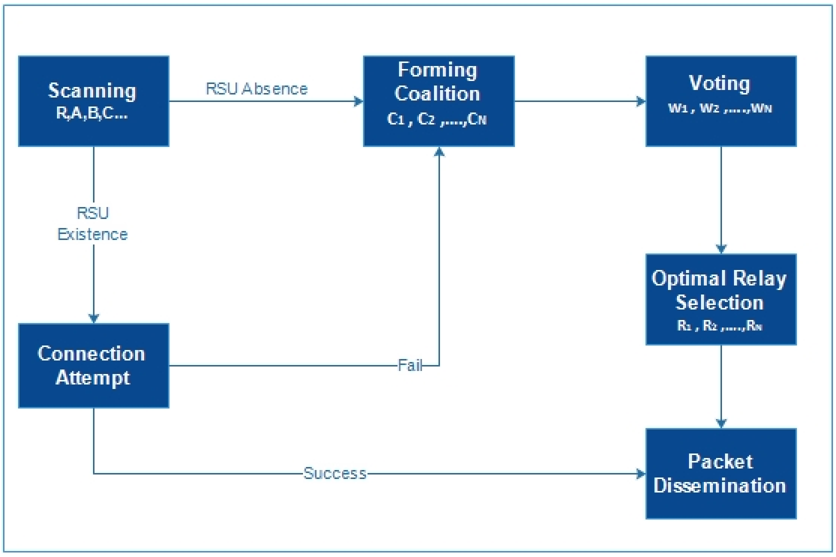

Figure 4.4 : The proposed system model.

4.2.1 Scanning

While a vehicle enters an area tries to detect its neighbors. Neighbor identification can be done by broadcasting hello packets [30]. In order to find neighbors for packet dissemination, utility functions for each present node must be calculated to decide whether to setup direct connection with RSU or looking for relay node. Defection in coalition for direct connection with RSU must be evaluated at first. Regarding to the amount of pay-off function, as represented as U in equation (4.1) defection may cause connection establishment or failure with RSU [28].

$$U = R - C \tag{4.1}$$

Where R represents revenue of relay using RSU or anchor vehicle through using relays and C shows data forwarding expenses. In this step, the amount of R^r for relay vehicle can be expressed as:

$$R^r = P_{jRSU} B_j F_{ij} \tag{4.2}$$

Where P is successful transmission probability of links between jth relay vehicle and RSU, B is availible bandwidth of RSU and F is bandwidth characteristic of relay vehicle [14]. If the available bandwidth of RSU is smaller than minimum required bandwidth, in this case, quality of service can't be guaranteed so the amount of F_{ij} will set to 0. On the other hand, if the available bandwidth is larger than maximum required bandwidth the F_{ij} is set to be 1. In the condition that, the available bandwidth is in the range of minimum and maximum bandwidth requirement, the amount of F_{ij} is represented as the subtraction of maximum and minimum bandwidth. After connection establishment with roadside unit these connected nodes can act as relay nodes. Afterward setting data origin to RSU should happen [29]. In the case of connection establishment failure with the RSU, Packet dissemination through RSU will fail.

4.2.2 Connection attempt

In this step, as depicted in fig 4.4, some of vehicles start packet dissemination successfully. Otherwise, other steps are taking place.

4.2.3 Forming coalition

Definition 2: Coalition is the subset of players that all vote in the same way. The number of all possible coalitions are ; $2^N - 1$ [27]. By neighbor detection, anchor nodes can form coalition with local relay node or mobile relay node candidates, which are calculated and identified in previous steps.

4.2.4 Voting

Definition 3: Weighted voting game voters are unequal in the number of votes they control, it is depicted as :

$$[q : w_1, w_2, ..., w_n]$$

where q is quota and w is weight [27] .

Definition 4: Winning coalitions are the coalitions that have enough number of votes to win. Voters are unequal in the number of votes they control [27] .

In voting step, pay-off function computation for every neighbor that holds RSU header, is required. For this aim amount of R^a can be expressed as :

$$R^a = \frac{P_{ij} B_i A D}{T} \tag{4.3}$$

where P is successful transmission probability of links between ith Relay Vehicle and jth anchor node, B is availible bandwidth of ith relay, T is data transmission time, which is depicted as:

$$T_{ij} = 2T_{OH} + \frac{S_{PL} + S_{MAC}}{R_{SR}} + T_{SIFS} + T_{BO} \tag{4.4}$$

where

$$T_{OH} = T_{DIFS} + 3T_{SIFS} + T_{RTS} + T_{CTS} + T_{ACK} + 2T_{PLCP}$$

Distributed inter-frame space (T_{DIFS}): Before data transmission, a station should sense the situation of the wireless medium to determine whether the channel is idle or busy in DIFS intervals. Meanwhile, if continuously the channel is found busy data transmission will be postponed.

Short inter-frame space (T_{SIFS}): It is the amount of time required for processing and sending response in wireless interfaces. T_{RTS}, T_{CTS} Request to send (RTS) and Clear to send (CTS) show the amount of time that is required for reducing frame collisions. T_{ACK} shows packet reception admission duration and T_{BO} shows average back off time. D is distance between relay and anchor node, A is attainable rate of the link between ith relay and jth anchor [14]. Expressing attainable rates between relay vehicles and anchors is by using Shannon formula [31]:

$$A_{ij} = B \log_2(1 + \delta)$$

δ represents signal to noise division and B depicts bandwidth of channel.

The cost of service by each relay and RSU or anchor, can be modeled as a function of unit price denoted by α and consumed bandwidth resource [14]:

$$C = \alpha_i F_{ij} \tag{4.5}$$

After calculating pay-off functions, one of anchor nodes and whole relays will be chosen to decide upon the optimal relay for specific anchor. In addition, utility functions have been assigned as weights of relays. In each winning coalition the range of the quota is defined as [27]:

$$\frac{w_1 + w_2 + \ldots + w_n}{2} \leq q \leq w_1 + w_2 + \ldots + w_n \tag{4.6}$$

4.2.5 Optimal relay selection

In this step after calculating pay-off functions for anchor vehicles :

$$U^a = R^a - C \tag{4.7}$$

And assigning this pay-off function as a weight of our voting game

$$w = U^a \tag{4.8}$$

quota will be set to

$$q = \frac{w_1 + w_2 + \ldots + w_n}{2} \tag{4.9}$$

In our algorithm the amount of q is :

$$q = \frac{u_1^a + u_2^a + \ldots + u_n^a}{2} \tag{4.10}$$

Furthermore to acquire fairness while applying weights, Banzhaf power measure has been introduced.

Definition 5: Critical player is the player that eliminating it's weight from the whole votes cause the coalition turns into losing one and the number of remaining votes fail to pass the quota. Some voters are more powerful [27].

Required steps for Banzhaf power measure calculation are listed as follows [32] [27]:

1. Listing all achievable wining coalitions.

2. Determining critical players.
3. In succession check the number of times players are critical, this amount is shown with B_i notation.
4. Calculate total number of times that players are critical $\sum_{i=1}^{N} B_i$.
5. The proportion of $\beta = \frac{B_i}{\sum_{i=1}^{N} B_i}$ gives Banzhaf power index.

The most powerful node with higher β is set to be the relay of coalition. These steps will be repeated for all other anchors. For choosing relay node in the absence of RSUs or direct connection failure with RSU, last two steps which are voting and optimal relay selection will be repeated. After these procedures each node is doing its own best strategy. After all, it is proved that the outcome of the offered algorithm is a Nash equilibrium point.

4.2.6 Packet dissemination

In packet dissemination, after passing all previous steps and choosing fair and optimal relay, packet dissemination among all vehicles will start. Choosing optimal relay vehicle is important, consequently anchor vehicle's pay-off function is related to throughput function. Considering revenue function of anchor vehicle which is calculated in equation (4.3).

Throughput is the rate of received packets at the destination over communication channel [33]. Our objective is to maximize throughput and minimizing message transmission delay respectively. As shown below, throughput and delay are both function of our proposed pay-off function:

$$D(u^a), T(u^a) = \frac{P_{ij} B_i A D}{T} - \alpha_i F_{ij} \tag{4.11}$$

Where T is throughput and D depicts delay respectively.

5. PERFORMANCE RESULTS

5.1 Performance Evaluation

The performance of our proposed cooperative weighted voting game algorithm will be evaluated and compared with non-cooperative approach by using Matlab. In our simulation a road of 5 km that has allocated road side units and number of vehicles that varies from 20 to 90 with randomly distributed velocities has been considered. The simulation parameters are all shown in table 5.1.

Table 5.1 : Parameters for simulation.

Number of vehicles	$[20,90]$
Road length	$5km$
Number of lanes	2
RSU coverage area diameter	$60 \sim 350m$
Max speed	$25m/s$
Min speed	$45m/s$
Pricing factor α	100
SNR of transmitter	$10dB$
Number of simulation iteration	100

The aim of this algorithm is choosing a fair and efficient relay for anchor vehicles. The simulation results have validated our analysis and demonstrate better throughput and transmission delay outcomes. Our proposed algorithm can achieve 24.4% of increment in throughput as well as 18% reduction in transmission delay compared to non-cooperative approach.

In this work, the number of participant selfish nodes percentage in every non-cooperative and cooperative methods vary between 30%-50% in each iteration. Fig 5.1 and 5.2, represent the throughput and delay results for the speed range of 25 m/s.

Fig 5.3 and 5.4, illustrate both throughput and delay outcomes for the speed range of

45 m/s. On a more practical note, for higher speeds, the amount of throughput in comparison to lower speeds is lesser. In addition, delay is a bit higher due to speed increment.

Fig 5.1 and 5.3, demonstrate total throughput of all vehicles versus number of vehicles. It can be observed that during relay vehicle selection, by using Banzhaf power measure, pay-off function increases. Fair relay will be chosen considering equation 4.11. Pay-off function increment results in better throughput. To be more specific using weighted voting game algorithm causes optimal relay vehicle selection, which also has maximum available bandwidth B and successful transmission probability P.

Fig 5.2 and 5.4, display average transmission delay versus number of vehicles. According to equation 4.11, it is noted that by increasing number of vehicles, more coalition will occur, besides probability of successful reception is the other parameters that has been considered within our proposed algorithm which causes to consume more time in our voting game algorithm to find optimal relay. In more practical note, this work has focused on the transmission collision and back-off delay.
Consequently, when the number of vehicles grow, transmission delay increases. This changes happen as a result of increment in probability of collision and back-off delay.However, as depicted, this incremental results are less than non-cooperative approach.
As shown in fig 5.5 and 5.6 , it is depicted that the true and known values of the population mean stands on the illustrated intervals with 95% confidence. In addition, For every specific sample of vehicles this interval differs for throughput and delay metrics.

5.2 Realistic VANET Simulations

A realistic VANET simulations are contain 4 steps. The first step is accumulating realistic data that have an influence on traffic maps, statistical data, traffic counters and real traces. These accumulated information is processed using traffic generators that models traffic demand and generates synthetic traces. In every time slap, a network simulator updates its own node's position.

Traffic simulator can modify each vehicles rout by using VANET applications. In addition, these simulators use information about current traffic density, traveling time of each driver, so that these information effects drivers decision and adjusting activity schedule of each individual driver. A real world data is needed for realistic VANET simulations.

These information can be obtained from maps, statistical data, traffic counters, real traces, GPS based data. While using maps as a real world data, in addition to the shape of roads, a real topology of street, speed limitation, traffic lights location have to be considered and gathered for microsimulation. Moreover, for determining travel stops, all the buildings in a particular area that differs from residential to commercial have to be specified.

Realistic traffic generators is important to enhance the quality of VANET simulations. Different types of motion changes simulation results. In the realistic traces, networks are less stable. Usage of simple mobility models leads to optimistic communications. Nowadays traffic traces are collected by GPS tracking services [34].

5.3 Conclusion

A game theory based relay vehicle selection algorithm, based on weighted voting game, by applying Banzhaf power measure has been introduced. The proposed algorithm selects optimal and fair relay vehicle for packet dissemination by using pay-off functions that are derived for both anchor and relay vehicles. Our proposed algorithm, as shown in fig 4.4, is consists of scanning, connection attempt, forming coalition, voting , optimal relay selection and packet dissemination modules. Moreover, our proposed weighted voting game algorithm can achieve fair and optimal results, as well as, increasing throughput and decreasing message transmission delay during packet dissemination as a result of using Banzhaf power measure. Performance evaluation results illustrated that compared to non-cooperative methods, throughput increases by 24.4 % and message dissemination delay decreases by 18%.

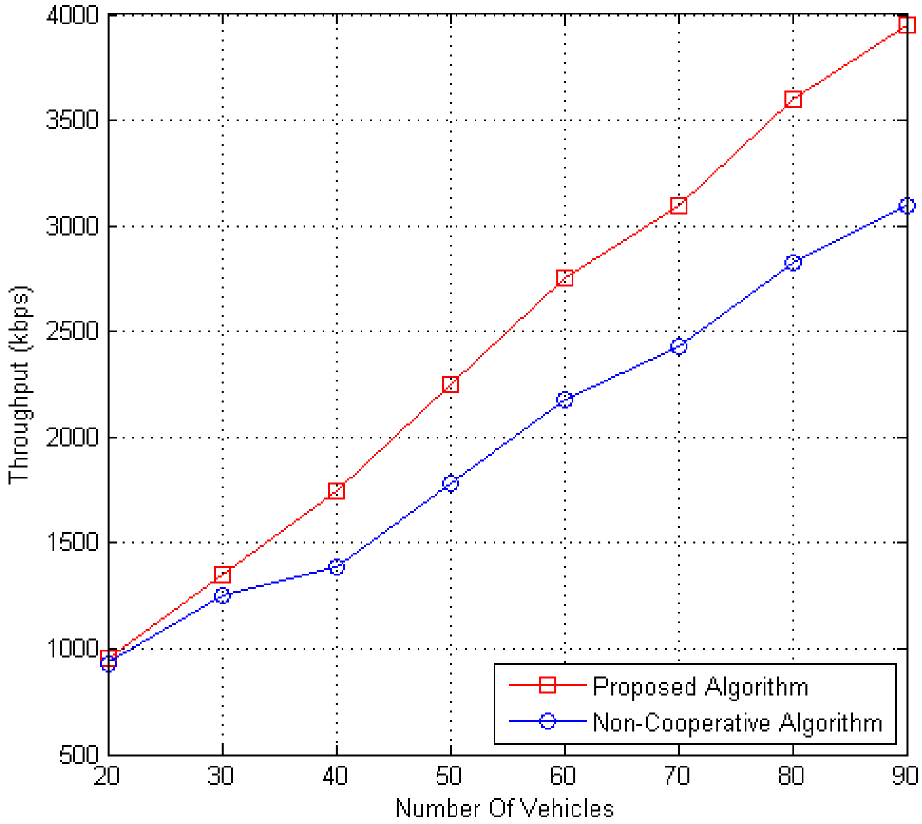

Figure 5.1 : Total throughput for min speed.

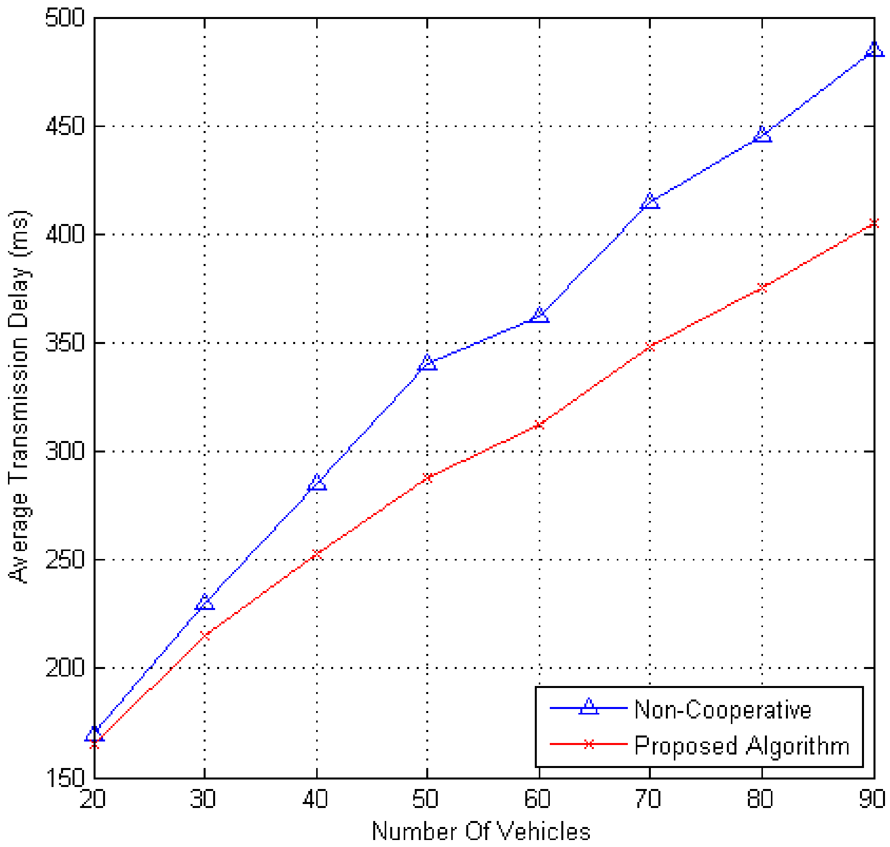

Figure 5.2 : Average transmission delay for min speed.

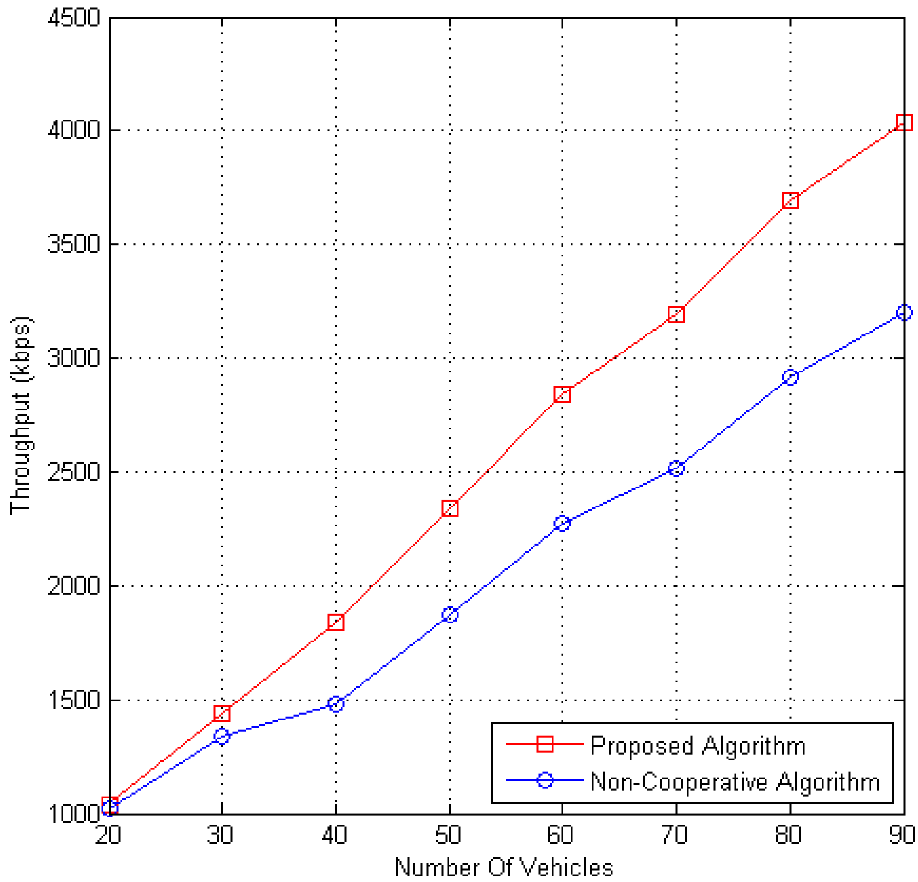

Figure 5.3 : Total throughput for max speed.

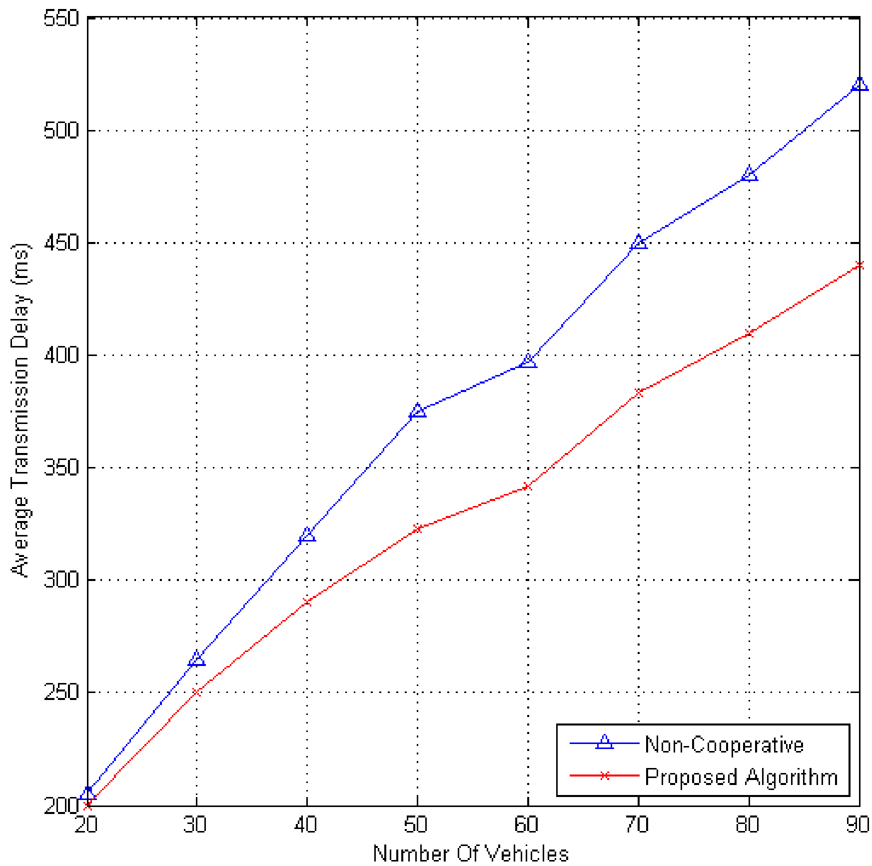

Figure 5.4 : Average transmission delay for max speed.

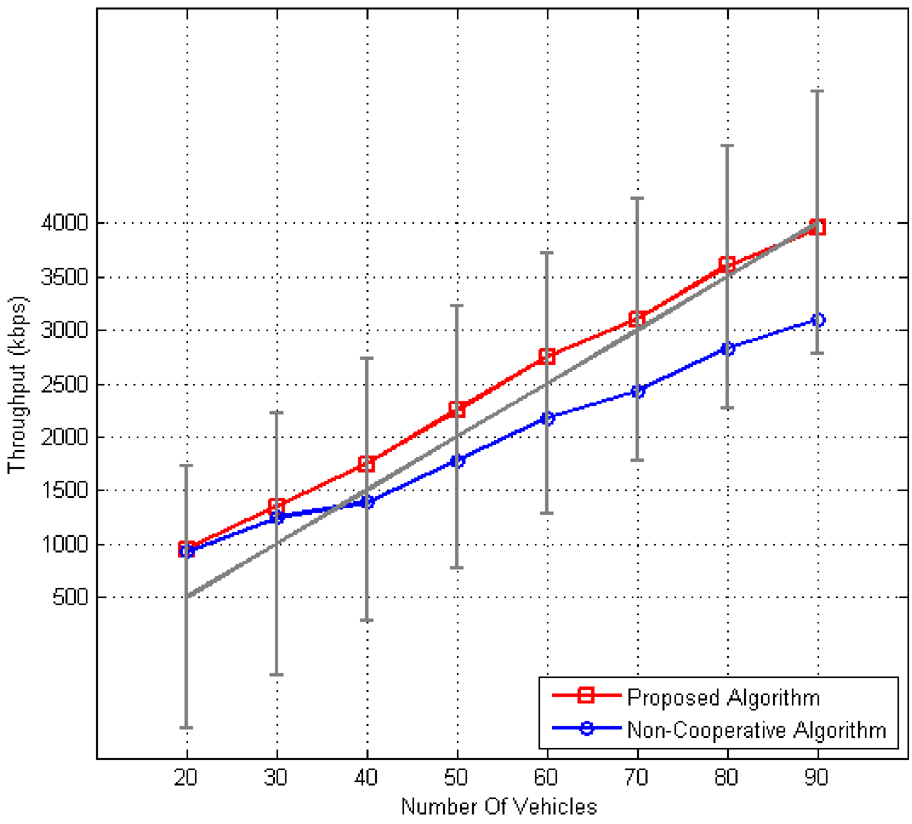

Figure 5.5 : Confidence interval for total throughput.

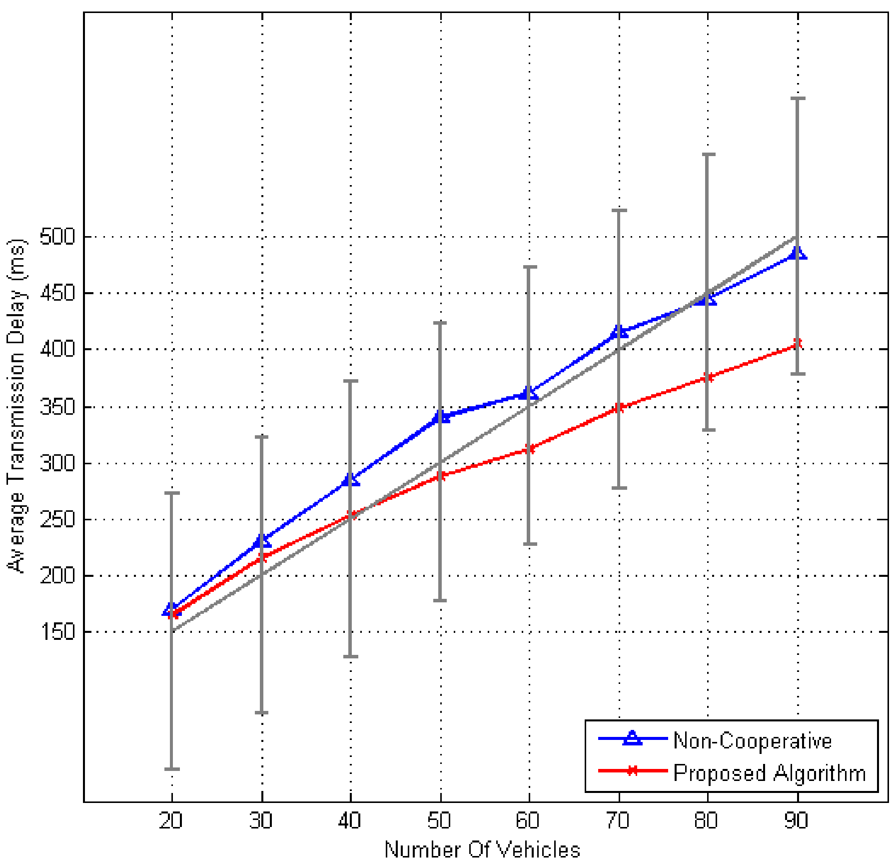

Figure 5.6 : Confidence interval for average transmission delay.

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