A NEW METRIC FOR ADAPTIVE ROUTING IN MOBILE AD HOC NETWORKS

HAREKETLİ TASARSIZ AĞLARDA ADAPTİF YÖNLENDİRME İÇİN YENİ BİR METRİK

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- all cited studies have been fully referenced
- I did not do any distortion in the data set
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ABSTRACT

A NEW METRIC FOR ADAPTIVE ROUTING IN MOBILE AD HOC NETWORKS

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Mobile Ad-Hoc networks (MANETs) have become very popular for military applications, disaster recovery operations in which the fixed network infrastructure might not be available due to wars, natural disasters, and the like. One of the main research challenges in mobile ad hoc networks is designing adaptive, scalable and low-cost routing protocols for these highly dynamic environments. In this thesis, we propose a new metric called *hop change metric* in order to represent the changes in the network topology due to mobility. *Hop change metric* represents the changes in the number of hops in the routing table. It is believed that the change in the hop count is a good representative of the mobility. The high number of change in the hop count can be a sign of high mobility. This metric is implemented in two popular and main routing protocols. *Hop change metric* is firstly employed to the most popular reactive protocol AODV (Ad hoc On-Demand Distance Vector Routing). This approach called LA-AODV (Lightweight Adaptive AODV). The the main goal of LA-AODV is selecting a route with a low degree of mobility. LA-AODV uses the *hop change metric* for selecting better routes among valid route reply packets. Due to reflecting the change in the network, *hop change metric* helps to select a stable route to the destination. The results show that, LA-AODV enhanced performance in all performance metrics. There are significant improvement on original AODV from the point of packet delivery ratio, end-to-end delay, network overhead and dropping rate. Secondly, we focus on the proactive protocols, especially DSDV (Destination-Sequenced Distance Vector Routing) protocol and aim to adapt periodic update time in this protocol. We determine a threshold value based on this metric in order to decide the full update time dynamically and cost effectively. The proposed approach called LA-DSDV (Lightweight Adaptive DSDV) is compared with the original DSDV and ns-DSDV. Simulation results show that our threshold-based approach improves the packet delivery ratio and the packet drop rate significantly with a reasonable increase in the end-to-end delay. *Hop change metric* represents a clear potential in order to represent changes in both proactive and reactive routing protocols.

Keywords: AODV, DSDV, adaptive routing protocols, mobile ad hoc networks (MANETs), reactive routing protocols, proactive routing protocols, mobility metric, hop change metric, update time.

ÖZET

HAREKETLİ TASARSIZ AĞLARDA ADAPTİF YÖNLENDİRME İÇİN YENİ BİR METRİK

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Tasarsız ağlar kendinden yapılı, hareketli düğümler ile telsiz bağlantıların bir araya gelmesi ile oluşan ağlardır. Bu ağlar önceden kurulmuş, sabit bir alt yapıya sahip değillerdir. Bu özellikleri, onları birçok uygulama için çekici kılmıştır. Askeri uygulamalar, sabit yapının kurulmasının olanaksız olduğu afet (sel, deprem, vb.) kurtarma operasyonları ilk akla gelen örneklerdir. Bu ağlarda en önemli problemlerden biri, bu ağların dinamik yapısına uygun adaptif, düşük maliyetli ve ölçeklendirilebilir yönlendirme protokollerinin tasarlandırmasıdır. Bu tezde, haraketlilikten kaynaklı değişiklikleri yansıtmak için "*hop change metric*" isimli yeni bir metrik önerilmiştir. Bu metrik, yönlendirme tablosundaki hedef dügümlere olan uzaklıklardaki değişimi göstermektedir. Bu metrik, iki popüler yönlendirme protokolü üzerinde test edilmiştir. Bu protokollerden birisi, en çok kullanılan reaktif yönlendirme protokolü AODV'dir (Ad hoc On-Demand Distance Vector Routing). AODV "*hop change metric*" kullanarak, en sabit ve kararlı yolu seçmeyi amaçlamaktadır. Bu yaklaşım LA-AODV (Lightweight Adaptive AODV) olarak adlanmıştır. Benzetim sonuçlarına göre, LA-AODV yaklaşımı orijinal AODV protokolünden daha iyi bir performans sergilemektedir. İkinci aşamada, bahsedilen metrik bir proaktif yönlendirme protokolü (DSDV) üzerine uygulanmıştır. Bu yaklaşımda tanıtılan metriğe dayalı bir eşik değeri tanımlanarak, bu yaklaşım, periyodik

güncellemenin zamanı belirlenmektedir. Bu yaklaşım LA-DSDV (Lightweight Adaptive DSDV) olarak adlanmıştır, değişim ve haraketlilik çok olduğu anda periyodik güncelleme işlemini tetikleyerek ağın performansını yükseltmektedir. Benzetimde LA-DSDV yaklaşımı, orijinal DSDV (Destination-Sequenced Distance Vector Routing) protokolü ve ns-DSDV protokolü ile karşılaştırılmıştır. Sonuçlar, LA-DSDV'nin paket teslim oranı ve paket düşme oranını, uçtan uca gecikmeyi arttırarak geliştirdiğini göstermektedir. Önerilen metriğin, ağdaki değişikleri belirlemede bir potansiyeli olduğu ve hem proaktif, hem de reaktif yönlendirme protokollerine uygunluğu gösterilmiştir.

Anahtar Kelimeler: AODV, DSDV, hareketli tasarsız ağlar, adaptif yönlendirme protokolleri, proaktif yönlendirme protokolleri, reaktif yönlendirme protokolleri, hareketlilik metriği, hop değişim metriği, güncelleme oranı

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CONTENTS

Page

ABSTRACT i
ÖZET iii
ACKNOWLEDGEMENTS v
CONTENTS vi
FIGURES ix
TABLES xi
ABBREVIATIONS xi
1. INTRODUCTION 1
1.1. Motivation 1
1.2. Major Contributions of the Thesis 3
1.3. Organization of the Thesis 4
2. RELATED WORKS 5
2.1. Metrics for Handling Mobility and Network Density 6
2.2. AODV improvements 10
2.3. DSDV improvements 11
3. ROUTING PROTOCOLS IN MOBILE AD HOC NETWORKS 14
3.1. AODV protocol 14
3.2. DSDV protocol 19
4. A NEW METRIC FOR ADAPTING ROUTING PROTOCOLS IN MANETS 25
4.1. Introduction 25
4.2. Hop Change Metric 26
4.3. LA-AODV (Lightweight Adaptive AODV) 27
4.4. LA-DSDV (Lightweight Adaptive DSDV) 29
5. PERFORMANCE EVALUATION OF HOP CHANGE METRIC IN ROUTING PROTOCOLS 32
5.1. Performance Metrics 32
5.2. Simulation Environment 33

5.3. The Performance of AODV 34
5.4. The Performance of LA-AODV 35
5.5. The Performance of DSDV 40
5.6. The Performance of LA-DSDV 41
6. CONCLUSION 46
6.1. Discussion and Future Work 47
A - Additional results - LA-AODV 48
B - Additional results - LA-DSDV 54
REFERENCES 60

FIGURES

Page

2.1. Encounters of node A. 8
2.2. An example of PER value calculations over a path. 9
2.3. An example of different routing decisions using HOP, AER, and PER metrics. 10

3.1. Broadcasting of route request packets 15
3.2. An example of a reverse path 16
3.3. Establishing a reverse path 16
3.4. Establishing a forward path to sending data 17
3.5. An example of an ad hoc network 21
3.6. Updating process in a routing table 22
3.7. Broken link process in a routing table 23

4.1. Calculating hop change metric in LA-AODV periodically 28
4.2. Route selection procces in LA-AODV 29
4.3. Periodic update in LA-DSDV 31

5.1. The performance of AODV protocol 35
5.2. Packet delivery ratio of LA-AODV and AODV on networks with varying mobility patterns 36
5.3. End-to-end delay of LA-AODV and AODV protocols on networks with varying mobility patterns 37
5.4. Overhead of LA-AODV and AODV protocols on networks with varying mobility patterns 38
5.5. Dropping rate of LA-AODV and AODV protocols on networks with varying mobility patterns 39
5.6. Performance of DSDV protocol 40
5.7. Packet delivery ratio at different thresholds 42
5.8. Packet delivery ratio of DSDV, ns-DSDV and LA-DSDV 42

5.9. End-to-end delay of DSDV, ns-DSDV and LA-DSDV 43
5.10. Overhead of DSDV, ns-DSDV and LA-DSDV 44
5.11. Dropping rate of DSDV, ns-DSDV and LA-DSDV 45

TABLES

3.1. The fields of a RREP packet. 17

5.1. Simulation parameters 34
5.2. Packet delivery ratio of LA-AODV and AODV on networks with varying mobility patterns 36
5.3. End-to-end delay of LA-AODV and AODV protocols on networks with varying mobility patterns 37
5.4. Overhead of LA-AODV and AODV protocols on networks with varying mobility patterns 38
5.5. Dropping rate of LA-AODV and AODV protocols on networks with varying mobility patterns 39
5.6. The performance of LA-DSDV at different threshold values 41
5.7. Packet delivery ratio of DSDV, ns-DSDV and LA-DSDV 43
5.8. End-to-end delay of DSDV, ns-DSDV and LA-DSDV 44
5.9. Overhead of DSDV, ns-DSDV and LA-DSDV 44
5.10. Dropping rate of different protocols in varying of pause times 45

1.1. Results of La-AODV and AODV for Pause time = 0 48
1.2. Results of La-AODV and AODV for Pause time = 5 49
1.3. Results of La-AODV and AODV for Pause time = 10 50
1.4. Results of La-AODV and AODV for Pause time = 15 51
1.5. Results of La-AODV and AODV for Pause time = 20 52
1.6. Results of La-AODV and AODV for Pause time = 25 53

2.1. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 0 54
2.2. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 5 55
2.3. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 10 56
2.4. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 15 57
2.5. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 20 58

2.6. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 25 59

ABBREVIATIONS

Symbols

Abbreviations

MANETs	Mobile Ad hoc Networks
AODV	Ad hoc On-Demand Distance Vector Routing
DSDV	Destination-Sequenced Distance Vector Routing
LA-AODV	Lightweight Adaptive AODV
LA-DSDV	Lightweight Adaptive DSDV
ns	Network Simulator
PDF	Packet Delivery Ratio
E2E	End-to-End Delay
OVR	Overhead
DRP	Drop rate

1. INTRODUCTION

1.1. Motivation

A mobile ad hoc network (MANET) is an infrastructureless network that has been used for various applications. The main characteristics of this kind of networks is being mobile and routing without any infrastructure. There is an extensive diversity of applications of MANETs. For instance these networks are very popular in military, disaster recovery operations in which the fixed network infrastructure might not be available due to wars, natural disasters, and the like. Some MANETs are limited to local of wireless devices, however others would be connected to the Internet such as Vehicular Ad Hoc Network (VANETs). VANETs consist of vehicles which communicate with each other and road side units. Roadside equipment are connected to the Internet and receive useful information about roads and, distribute this data among nodes or vehicles.

The high level of node mobility is essence of MANETs. In this networks, nodes can communicate directly with other nodes which are in transmission range. And if they are out of the range, source node can use intermediate nodes as router in order to transfer its message to the destination node. In MANETs networks, there are some routing protocols use for finding and updating the routes, and selection appropriate protocol depends on network elements and parameters.

The communication between nodes is determined by routing protocols. The manner of construction and maintain routing table is different from one protocol to other. There are two main classes of routing protocols employed in packet switching networks: link state and distance vector routing protocols.

In link state method every node has a view of network topology with a weight for each link and is updated periodically these information. All nodes know about the paths reachable by all other nodes in the network. Nevertheless some of weight for links can be incorrect, it is due to long propagation delay, partitioning networks and etc. [1]

Distance vector method involves with distance or metric of destination and vector, or direction to destination node. Every node knows about its neighbors and use a hop count to determine the optimize path through the network. It is means that the hop count is a measurement of distance. Table updating is necessary for routing and nodes update periodically their routing table. First classical distance vector algorithm is Distributed Bellman Ford [1].

There are three kinds of routing protocols on MANETs: proactive, reactive and hybrid protocols [2] [3].

Proactive Protocols:

Proactive routing protocols use periodic exchange of control messages between nodes to build up a routing table. In proactive routing protocols, routes are ready before they are needed. So, two nodes who want to communicate with each other can start communication immediately by using the route available in their routing table. However, there is a considerable overhead due to the high number of control messages in order to keep routing table up-to-date. The routing protocols DSDV [4] and OLSR (Optimized Link State Routing Protocol) [5] are among the popular proactive protocols proposed.

Reactive protocols:

Reactive protocols start route discovery when a route is needed. In the other means, routing protocol establish a route when a node request a path for communicate with other node. There are some advantages for this kind of networks. For instance, the node in network does not need to discover and maintain information about other nodes, it is due to on demand characteristic of reactive protocols. Another significant characteristic of this protocols is low amount of network overhead in compared with proactive protocol. Nevertheless the biggest disadvantage of these protocols is the latency caused by the route discovery process which is need to be carried out before the communication between the end nodes starts. The most popular reactive protocols are AODV [6] and DSR (Dynamic Source Routing) [7].

Hybrid Protocols:

There are also some hybrid protocols which combine proactive and reactive routing protocols and take advantage of both. For instance, Zone Routing Protocol (ZRP) [8] is a hybrid protocol that takes advantage of proactive protocol in local neighborhood and using a reactive protocol between neighborhoods. ZRP divides the topology of the network into zones and uses both of proactive and reactive protocols within and between the zones. ZRP is quit flexible that means it can be used with different proactive and reactive protocols within zones but generally ZRP uses DSDV protocol for local neighborhood or inter-zone communication and AODV protocol for intra-zone communication.

Although there are many routing protocols are proposed for MANETs [9]. Different deployments exhibit various constraints, such as energy limitations, opportunities, such as the knowledge of the physical location of the nodes in certain scenarios, and requirements, such as real-time or multi-cast communication.

1.2. Major Contributions of the Thesis

One of the main research challenges in mobile ad hoc networks is designing adaptive, scalable and low-cost routing protocols for these highly dynamic environments. This thesis focuses on a metric that leads to the selecting stable route with low level of mobility in AODV protocol and handles the periodic update time on DSDV protocol. Proactive routing protocols mainly use static update period time for keeping routes up-to-date, which is against the dynamic nature of MANETs. This might cause low packet delivery ratio and high packet drop rate under high mobility. Updating routing table adaptively is the main focus here.

In this research, we aim to improve packet delivery ratio, packet drop rate, overhead and end-to-end delay by selecting stable route on AODV protocol and changing the update period time dynamically instead of using the static update period time as in the original DSDV. We introduce a new metric called hop change metric in order to achieve that. We proposed two approaches for mentioned protocols that are called LA-AODV and LA-DSDV.

The proposed approach is low cost in terms of computation and communication. In the first step, nodes select the route which is low level of mobility and establish the stable route on AODV protocol. Simulation results indicate a significant improvement from point of throughput, end to end delay, overhead and dropping rate. In the second step, there is no message exchanging between nodes in order to decide the update period time. Every node decides upon updating locally. The simulation results show that the proposed approach (LA-DSDV) improves the packet delivery ratio, the packet dropping rate and the overhead with a reasonable increase in the end-to-end delay. Moreover, the hop change metric could reflect different mobility patterns dynamically and cost effectively in proactive routing protocols.

1.3. Organization of the Thesis

In Chapter 2, we review some previous works on adapting routing protocols from the point of handling mobility. In Chapter 3, we review AODV and DSDV protocols. In Chapter 4, we introduce *hop change metric* and our adaptive routing approaches based on this metric. In Chapter 5, we present the performance of adaptive routing protocols, LA-AODV and LA-DSDV on networks. Finally, in Chapter 6 we conclude the thesis with a brief summary of our work and possible future research directions.

2. RELATED WORKS

Even though, there are many routing protocols proposed in the literature, only the approaches adapting themselves according to the changes in the network is considered due to their relevance in this chapter.

There are some approaches to address issues in routing protocols caused by the dynamic topology of MANETs. One of the solutions is using hybrid routing protocols which combines the best properties of both proactive and reactive protocols by changing the routing protocols adaptively. This change depends on the current configuration of the network and the behavior of the nodes. ZRP [8], ZHLS [10] and HARP [11] are some examples of hybrid protocols. ZRP reduces the control overhead of proactive routing protocols and decreases the latency of routing discovery in reactive routing protocols. While ZHLS reduces the communication overhead, HARP reduces delays happening during early path maintenance. Another approach is to change some parameters of routing protocols dynamically based on some criteria such as mobility, power, and traffic.

Topology is changing unpredictably due to the movement of mobile nodes in MANETs. A study in [12] represented that the high mobility of nodes cause the decreasing of throughput. Another factor that decreases throughput is network density [13].

As mentioned, routing in MANETS is typically classified into reactive and proactive protocols [2] [3]. They can be classifed into several more types such as hybrid, location-aware, power-aware, multi-path routing protocols, and so on based on their underlying architectural framework [9]. Most of the protocols use a metric to indicate the path length. This chapter focuses on the metrics that help protocols to select optimal routes.

It is generally the most common metric used for routing in MANETs is $\mathbf{hop\_count}$ [9] [14]. This metric represents the length of the end-to-end path in hop. Theretofore, it has been used as a good metric for routing performance in wired and wireless networks [3] [15]. As regards, level of mobility and network density are not concerned in this metric; so the selected route might not be the stable and good one to sending data. In other words, the hop metric is not an optimal solution for routing in mobile ad hoc networks.

2.1. Metrics for Handling Mobility and Network Density

Many studies have tried to recommend alternative metrics to adapt to the mobility and the density changes of MANETs. Adya et al. [16] introduced a new metric relied on per-hop round trip time (RTT) concerning the duration of sending and receiving a probe packet from a sender to 1-hop neighbours. The sender should update the estimated weighted average RTTs which are stored the routing table to its neighbours. Routing procces looks up a minimum RTT path. Anyway, the periodic propagation of probe packets and probe anyway packets for getting the RTT value may expand more bandwidth and cause more network contention. So applying this metric is not efficient in MANETs [15].

In another approach, Khelil et al. [17] introduced a metric called contact-based mobility metric relied on the concept of $\mathbf{encounter}$. Two nodes encounter to each other when the distance between them becomes smaller than the communication range R. The simulation results in [17] indicate that the number of new encounters have direct relation with the mobility and density of the networks. In the other words, a node could predict its relative velocity to other nodes around with the number of encounter [18]. In the another approach, Boleng et al. [19] offered a mobility metric named $\mathbf{link\_duration}$ defined as the time that two nodes are within the transmission range of one another.

De Couto et al. in [20] presented a well-known metric, called $\mathbf{ETX}$, which helps protocols in MANETs to find the highest throughput path to forward packets. The $\mathbf{ETX}$ of a link is the expected number of data transmissions required to send a packet over that link, including retransmissions in MAC layer. Mathematically, $\mathbf{ETX}$ of a link can be defined as:

$$ETX = \frac{1}{d_f d_r} \tag{1}$$

In the Equation 1, d_f is the forward delivery ratio which represents the probability of successful packets arrived at receiver; d_r is the reverse delivery ratio which represents the probability of successful ACK packets received. $\mathbf{ETX}$ indicates throughput of communication links. In this approach, a protocol chooses the highest throughput link with the minimum $\mathbf{ETX}$ to forward data packets. The simulation results of this approach represents the improvement of packet delivery ratio up to 40% compared to the hop metric. To calculate the d_f and d_r in Equation 1, it is vital to collaborate with the link layer to periodically broadcast the fixed size messages to its 1-hop neighbors. This process causes the additional bandwidth and more network contention.

Based on the $\mathbf{ETX}$ metric, Draves et al. [21] defined the $\mathbf{ETT}$ metric to overcome the $\mathbf{ETX}$ issues by handling the broadcast process in different rates and packet sizes rather than remaining in basic rate and fixed packet size. The results showed that the throughput under $\mathbf{ETT}$ metric enhanced by 16% compared with the $\mathbf{ETX}$.

Another approach [22] introduces a new time-based metric for routing in MANETs based on the route packet forwarding metric μ and the rate that packets enter the router input queue λ_q. This metric shows the expected time required for a packet to pass through a router. This time includes the expected time to complete a unicast and the expected routing overhead. The performance of this metric in simulation results represents that packet delivery ratio is enhanced around 20-25%.

A modified version of the $\mathbf{ETX}$ is the $\mathbf{IBETX}$ [23] which applied a cross-layer solution to take into account the interference occurring in MAC layer. This metric works on Destination-Sequenced Distance Vector (DSDV) routing protocol. The simulation results show this metric enhances the packet delivery ratio up to 19% in compared with $\mathbf{ETX}$.

Another development of the $\mathbf{ETX}$ is the $\mathbf{ECTX}$ [24]. This approach operates this metric in two mode: non- cooperative mode and cooperative mode. Non-cooperative mode is actually the IEEE 802.11 MAC. The other, cooperative mode employed the cooperative retransmission mechanism in MAC-layer. This mechanism aims to diminish the expected total number of transmissions that required by $\mathbf{ETX}$ on the same path. Simulation results show the packet delivery ratio of $\mathbf{ECTX}$ 30% higher than the $\mathbf{ETX}$. However, $\mathbf{ECTX}$ has a big problem that it requires a change to MAC layer which seems to be infeasible for real network devices.

$\mathbf{ETX}$ and $\mathbf{ECTX}$ were extreamly evaluated, they only have good results in static or low mobility levels of MANETs [20] [21]. For high mobility, some approaches used a metric named Mobility Factor ($\mathbf{MF}$) [25] [26] to consider the link stability before forwarding a packet. This factor based on the symmetric difference of neighbours of a node between two consecutive HELLO messages. This factor is calculated as follows:

$$MF = \sqrt{1 - \frac{|n_i(t) \Delta n_i(t - T_{HELLO})|}{|n_i(t) \cup n_i(t - T_{HELLO}|}} \tag{2}$$

where $n_i(t)$ is the set of neighbors of node i at time t; T_{HELLO} is the interval that node i sends HELLO messages to its neighbors in order to check if links are still available or not; Δ is the symmetric different operation. The $\mathbf{MF}$ aims protocol to choose the stable path for transmitting data packets. Simulation results of the protocol which used MF metric, represent that throughput has been improved in compared with the original AODV. Meanwhile, to calculate the MF value, each node is required to maintain a table to record the historical neighbor list $n_i(t - T_{HELLO})$ besides the current neighbor list $n_i(t)$ and this caused to different problems such as resource usage and computational complexity at a node when the scale of MANETs grows up.

Recently, another metric introduced [27] for routing in MANETs, is called Path Encounter Rate ($\mathbf{PER}$) metric based on the concept of *encounter* stated in [13], which has the ability to deal with the changes of MANETs in mobility situations. This metric has better routing performance compared to other routing metrics. In this approach, every node has a average encounter rate that is calculated as follow:

$$AER = \frac{|E_A|}{T} \tag{3}$$

where E_A is the set of new encounters (see Equation 1) that node A experienced within observation time T from t_i to t_{i+1}.

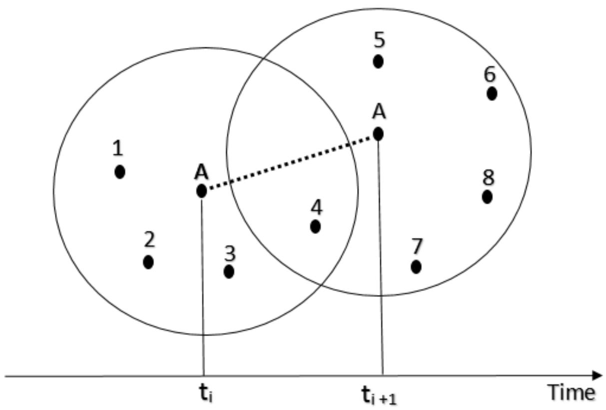

Figure 2.1. Encounters of node A.

Figure 2.1. examines encounters of node A moving in duration T [t_i , t_{i+1}]. Node A has four encounters, namely 1,2,3,4 at t_i, and the numbers of encounters are increased up to five

(4,5,6,7,8) at t_{i+1}. Hence, The number of new encounters of node A in the duration T is equal to four ($|E_A|$ = 4).

The Path Encounter Rate (**PER**) is defined for a path or a route as a sum of square root of Average Encounter Rate values of all nodes along to that route. **PER** is calculated as follows:

$$PER = \sum_{i=1}^{m} AER_i^2 \tag{4}$$

Where m is the number of nodes along the path including source and destination nodes, Figure 2.2. shows an example of PER value obtained over a 3-hop path.

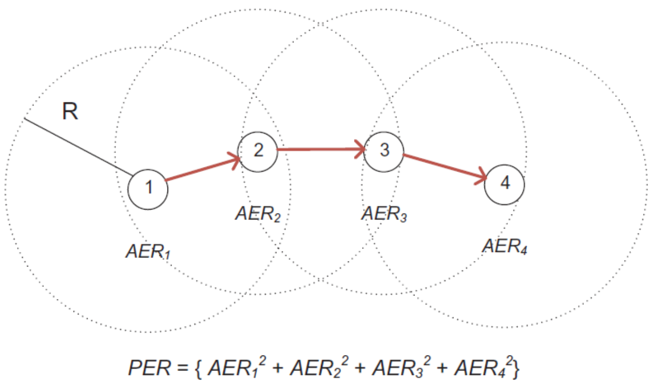

Figure 2.2. An example of PER value calculations over a path [27].

In principle, the goal of a protocol is to select a path which has the lowest cost to forward data packets. In the proposed approach, the cost of each path is considered as its corresponding **PER**. Routing protocol selects the path which has the lowest **PER** value among the available paths to the destination.

In order to assign the **AER** value, each node sends periodically the probe packets to neighbors within its communication range R to detect a new encounter, and then calculates the **AER** in a duration T.

Figure 2.3. represents routing decisions between node a and b based on three different routing metrics: **HOP**, **AER** and **PER**. Even though Route 2 is actually the shortest path, it has the highest **PER** value. It means that the node pass through is highly mobile or highly dense

area. In this example, the route 1 is selected for routing with the lowest $\mathbf{PER}$ value. It is due to the level of mobility or network density.

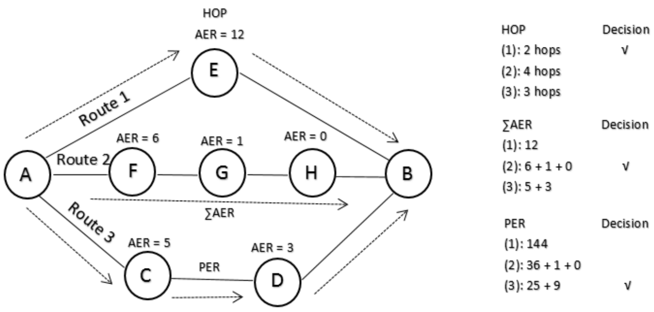

Figure 2.3. An example of different routing decisions using HOP, AER, and PER metrics.

The simulation results indicate the increment of routing performance under $\mathbf{PER}$ metric compared to the hop-count and other metrics such as $\mathbf{ETX}$ in various mobility and density scenarios. The packet delivery ratio of the network improved, especially in high mobility and high density scenarios.

2.2. AODV improvements

There are many adaptive improvements on AODV protocol by using different factors such as mobility, power consumption and etc. Only improvements on AODV that aims to address issues caused by dynamic nature of MANETs is summarized on this section.

One of these approaches is AODV-BR introduced in [28]. Most of the protocols use single route and do not utilize multiple alternate paths. In this approach, the authors introduced a scheme to improve existing on-demand routing protocols by creating a mesh and providing multiple alternate routes. This algorithm establishes the mesh and multipaths without transmitting any extra control message and does not require any modification to the AODV's RREQ (route request) propagation process. When a node that is not part of the route overhears a RREP packet not directed to itself transmitted by a neighbor, it records that neighbor as the next hop to the destination in its alternate route table. When the source node receives a RREP packet, it also has an alternative route table. The primary route and alternate routes together establish a mesh structure. Simulation results represents that AODV-BR technique provides robustness to mobility and increases protocol performance but does not perform well under heavy traffic.

Some approaches focus on the mobility for routing better and select the stable route from the point of mobility. In [29], a mobility-based method was proposed for improving the performance of the AODV protocol. Mobility metric was introduced and used in the route discovery step. In route discovery, the original AODV hop-count metric replaced with a combination of two mobility parameters: average and mean of the calculated mobility along the path between any source node and destination. This affects the network overhead and also reduces the use of RRER packets.

AODV Hello packets were used to increase mobility awareness in AODV [30]. When a node receives a Hello packet with the Global Positioning System (GPS), coordinates of the source node. When a node receives a RREQ packet and has to send a RREP, it will use the mobility awareness to choose the stable neighbor which is not moving frequently. A path with the maximum number of low mobile nodes is established between source and destination. Based on that value, when mobility is high, the rate at which neighbors change is also high, so the suitable reaction is reducing the *HELLO_INTERVAL* and vice versa. Adaptively controlling the broadcast of Hello Messages could be reducing the number of unnecessary hello packets. Then, network traffic is reduced. This approach leads AODV protocol to have lower network overhead.

Another approach that is focus on the mobility aware introduced in [31].The proposed approaches consider the degree of node's mobility in order to assist in making a proper routing decision. The decision is either made by the destination to send a reply back through the stable route. This approach decreases the control packets and increases packet delivery ratio.

2.3. DSDV improvements

Several improvements have been proposed for DSDV in the literature. One of these approaches is ARM-DSDV introduced in [32]. ARM-DSDV is a control mechanism which dynamically adapts the routing protocol with the following two metrics: mobility metric and route demand metric. The mobility metric indicates the changes in the number of neighbors; the route demand metric indicates which destinations are currently involved in data forwarding. ARM-DSDV dynamically adjusts the update period time and the content of the control messages based on these metrics. It is believed that updates should be more frequent under high mobility. That is why the mobility metric is calculated by considering the changes in the number of neighbors (one hop away nodes). Each node evaluates the mobility metric and sends it to his neighbor nodes in order to obtain aggregate mobility metric which is the average mobility metric in the neighborhood. This might cause high communication overhead. Different nodes can send their control messages at different times in this technique. This is a different approach than the original DSDV sending all updates together. The update period control and the update content control are carried out locally in each node with some overhead. This approach can be applied to any proactive protocol as stated in [32].

One of the most important problems in the original DSDV is the diagnosis of invalid routes. This is called the stale route problem and many improvements on DSDV focus on this problem. The stale route problem occurs when a route is broken. Since there is no alternative route maintained in the routing table, the next periodic update has to be waited for re-building the route. One of the approaches work on this issue is Imp-DSDV [33]. In the original DSDV, a node who has observed a broken link assigns infinity to the hop metric for this link in his routing table and waits for the next update period. However the nodes maintain an alternative route in their routing tables in Imp-DSDV. In other words, when a link is broken, the alternative route is used for communication immediately. They introduce a new field called *type* which holds the validity of the route in the routing table.

Another improvement on DSDV protocol is Eff-DSDV [34] which aims to use an alternative route again when a broken link is detected. In the original DSDV, when there is a high number of broken links, the stale route problem causes low packet delivery ratio [35] [36] [37]. In Eff-DSDV, when a node detects a broken link, the node uses a temporary link from his neighbors which have a valid route to destination. An alternative link is created by sending two one-hop messages; ROUTE-REQUEST and ROUTE-ACK. An additional field for route update time to the routing table is introduced. The update time is embedded into ROUTE-ACK message and it is used for selecting a temporary route. If a node receives multiple ROUTE-ACK messages from different neighbors, it will choose the route which is updated recently.

Another approach proposed to solve the stale route problem is I-DSDV [38]. This algorithm has improved the packet delivery ratio without any message exchange and any overhead. This approach also reduces the end-to-end delay and the number of dropped data packets. It shows a better performance than both the original DSDV and Imp-DSDV. In I-DSDV, each node keeps two routing tables. They are called the main routing table and the secondary routing table respectively. As a result of these two routing tables, every node has two routes for each destination. The routes in the secondary routing table can be valid or invalid. The valid routes in this table should have the same hop metric and the same destination sequence number as in the main routing table. However the next hop to the destination is different. At the beginning, all routes in the secondary routing table are invalid. When a node receives a route update with the same metric and the same sequence number as in his main routing table, but with the different next hop, the secondary route is updated. When a route in the main routing table is broken, it is replaced with the respective route in the secondary routing table.

Another approach proposed for DSDV is the optimization in ns-2 [39]. ns-2 is a simulation tool developed at the University of California, Berkeley. In this optimization, a metric which represents the number of changes in the routing table is introduced. When the change multiplied by 3 is bigger than the routing table size, a full update by all nodes has started. The algorithm increases the packet delivery ratio considerably. However it also increases the end-to-end delay and the overhead of control messages. The algorithm sends a lot of full updates under high mobility. It forces the nodes to send the full update almost every second (where the periodic update time in the original DSDV is 15 seconds) under high mobility. As far as we know, there are a few number of improvements proposed for DSDV in the literature. In this section, we summarize all these improvements on DSDV.

3. ROUTING PROTOCOLS IN MOBILE AD HOC NETWORKS

As mentioned in previous chapters, mobile ad hoc protocols are mainly divided into two groups, proactive and reactive protocols. This chapter represents the details of two routing protocols. One of them is a reactive protocol, AODV and the other one is a proactive protocol, DSDV. Analyzing of these protocols and evaluating them on varying networks mobility and traffic patterns is very essential for this thesis, since proposed *hop change metric* is employed on these two routing protocols and assessed.

3.1. AODV protocol

This chapter explains the most popular reactive protocols in mobile ad hoc networks. Most of the studies on MANETs use AODV as an exemplar routing protocol. In AODV routes are obtained as needed with no periodic advertisements. AODV protocol is flexible and does not need a specially aspect of physical medium. AODV is designed for networks consisting of tens to thousand of mobile nodes [40]. It is claimed to handle low, moderate mobility as well as a variety of data traffic levels [40].

Nodes in AODV protocol do not need to discover and maintain route to another node until both nodes need to communicate. Every node could detect its neighbors with one-hop hello messages or other ways such as passive acknowledgment. Routing table in AODV protocol maintains information about neighborhood for optimize response time to local movements.

3.1.1. Path Discovery

AODV protocol uses broadcast messages to discover a route. This process is initiated when a source node wants to communicate with another one that there is no information about the destination node in its routing table. Every node maintains a *sequence_number* and a *broadcast_id*. The source node starts route discovery by broadcasting a route request (RREQ) packet to its neighbors. *Broadcast_id* is created uniquely and is incremented when a source node issues a RREQ packet. Each neighbor receives RREQ packets and sends back RREP packet if it has information about the destination node in its routing table or broadcasts the RREQ packet to own neighbors. A node may receive multiple copies of the same RREQ packets from various neighbors. However, it only processes the first arrived RREP packets, others are dropped.

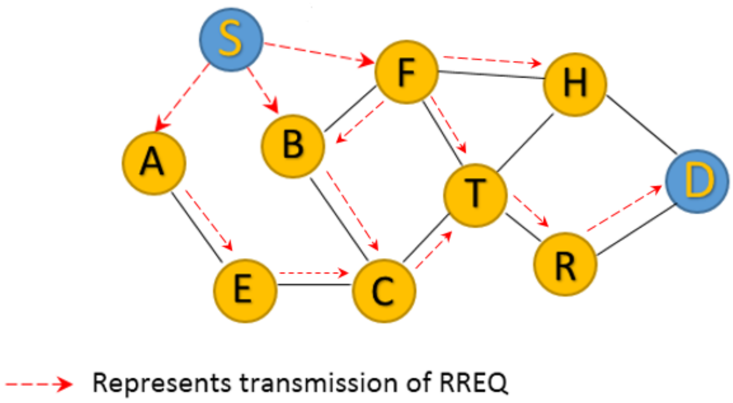

Figure 3.1. Broadcasting of route request packets.

As illustrated in Figure 3.1., node S wants to communicate with node D so it issues the RREQ packet and broadcasts the packet over the networks, as mentioned this message rebroadcasts until to reach to the destination D or a node who has a valid route to the destination D. The RREQ packet passes on the intermediate nodes to the destination that is indicated with arrow in the Figure 3.1..

3.1.2. Reverse Path Setup

As mentioned before, RREQ packet travel from nodes to various destinations. AODV protocol sets up the reverse path from the destination node to the source node. As represented in Figure3.2., a node records address of neighbors which it received first copy of RREQ packet and, sets up the route reverse path. Reserve path has a timeout, it will be deleted with protocol when expired.

As represented in Figure 3.3., the source node S records all neighbors that they receive the first RREQ packet. As represented, the blue arrow shows the reverse path that it recorded over rebroadcasting.

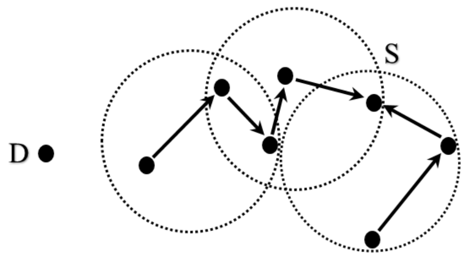

Figure 3.2. An example of a reverse path.

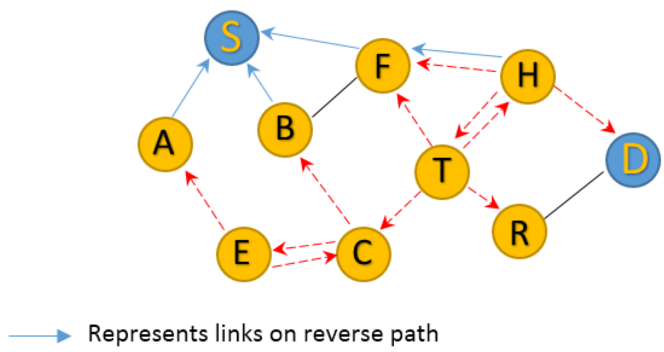

Figure 3.3. Establishing a reverse path.

3.1.3. Forward Path Setup

As referred to earlier, RREQ packets broadcasts over the network to find the destination node. When a intermediate node receives a RREQ and it has no information about the destination node, it rebroadcasts the RREQ packet. If the node has information about the destination node, issues RREP packet and sends back to the source node. If an intermediate node has a route to the destination node so it checks the sequence number of the REEQ packet and the route in its own routing table, if the sequence number of the RREQ packet received is greater than the route in the routing table, the intermediate route does not use its recorded route to respond to the RREQ packet with a RREP packet. As an alternative, it rebroadcasts the RREQ packet. The destination node or an intermediate node who has a valid route to the destination, use unicast to sends back RREP packet to the source node.

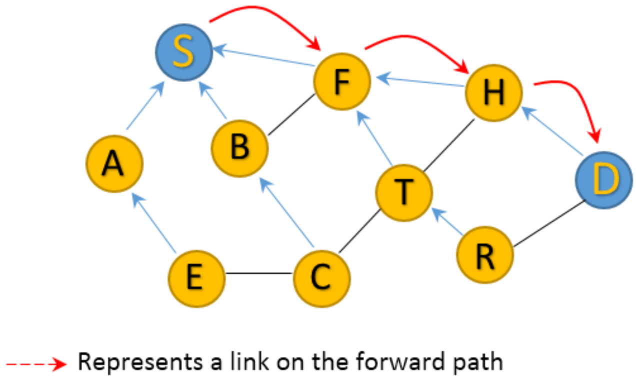

Figure 3.4. Establishing a forward path to sending data.

As represented in 3.4., when the source node D receives the first RREQ packet, it sends a RREP packet to the source node. The source node S has the reverse path from the destination to itself so it constructs the forward path to start communicating and sending data to the destination D.

A RREP contains the following fields:

source_addr	Source Address
des_addr	Destination Address
des_sequence_number	Destination Sequence Number
hop_cnt	The number of hops between source and destination
lifetime	Time to Live

Table 3.1. The fields of a RREP packet.

When the source node receives a RREP packet, it must update its own routing table with new information received. Then, the source node could begin to send data packets to the destination as soon as the first RREP packet is received.

3.1.4. Route Table Management

Routing table in AODV has more useful information about routes in addition to source and destination node's sequence numbers.

One of the important field in routing table is *route_request_expiration_timer*. The intent of this timer is to prevent useless and old RREQ. The value of this timer is completely depend on the size of ad hoc network. Another significant parameter that has an important role in routing table is *route_caching_timeout*. This parameter represents which route is valid and when the route is going to be invalid in the routing table. This parameter helps nodes to have update and valid information for respond quickly. Every node maintains information about the destination nodes that they want to communicate with.

Each entry in routing table constructed by the following fields:

- Destination: The destination node

- Next Hop: The next node towards the destination node

- Number of Hops (Metric): The number of hops from the source node to the destination node

- Sequence number: The sequence number of the destination node

- Expiration time: The expiration time for the route table entry

If a node receives a routing control message, the node compares sequence numbers which belong to its routing table and routing control message and selects greater one. If the sequence numbers of new offered route and the sequence number of route in its routing table are the same, it will select the smaller metric (fewer number of hops) between them.

3.1.5. Path Maintenance

Links could be broken, due to the movement characteristic of mobile ad hoc networks. If the next hop is unreachable, the node propagates the RREP packet with a fresh sequence number and changes hop metric to infinite symbol. This message propagated to its valid and active nodes. Upon the source node relieves a notification about the broken link, it can restart the discovery process if they want to pursue communication with the destination node.

3.1.6. Local Connectivity Management

Despite of the on-demanding characteristic of AODV protocol every node should know about its neighbors for quick routing that there are two ways to nodes to learn about its neighbors. The first way is that when a node receives a broadcast from a neighbor. If the receiving routing message is valid and fresh, it updates own routing table with new information and manage local connectivity.

In the second way, every node sends hello message to its neighbors periodically. In the other words, every node sends a hello message (a special RREQ packet) to its neighbors within a time interval that is called *hello_interval*. Hello messages do not propagate in the whole network because they have a time to live (TTL) value of 1 that prevent them to be rebroadcasting.

There is a metric for detecting broken links in hello messages that is called *allowed_hello_loss*. The optimum value for *allowed_hello_loss* is two in AODV protocol. Every node sends hello messages to its neighbors and receives acknowledgment from them. If a node sends twice hello message to a neighbor and receive no acknowledgment message for it, the node starts the broken link process as described in the section 3.1.5.

3.2. DSDV protocol

This section focus on proactive protocols, especially DSDV protocol. DSDV protocol is one of the most popular protocols proposed for mobile ad hoc networks. The main reason to design this algorithm is that each client can perform both client and router tasks and advertise its view of the interconnection topology with other clients or mobile host within a network periodically. DSDV is a modification of the basic Bellman Ford routing mechanisms, as specified by IRIP [4] [41].

The main issue of routing protocols is the finding of shortest path between others with minimum amount of network overhead and calculation. Every routing protocol for tackles this issue, should construct a routing table and maintains which refer to it when a sending packet flow is processing. DSDV protocol is not exceptional about this fact. It also constructs and maintains a table for routing operation.

3.2.7. Route Discovery

Routing table in DSDV protocol lists all available destination and number of hops to any other nodes or mobile hosts. In the other words for each node there is a route that is tagged with a particular sequence number which is originated by the destination. There are some changes over time for any routing table due to mobility. Nodes sending packets properly need to have an up-to-date routing table although for this purpose nodes advertise update information about their routing table to other nodes periodically. In another point of view, every node receives periodically update information about other nodes over time. There are two kinds of advertisements for keeping up-to-date information for tables. The first one is called *Periodic Update* that broadcasts whole routing table periodically over the time between nodes and the other advertise information is occurred when a significant information available. Each node must be active at all the time. Even if there is no change in the network topology, the periodic update occurs. Hence these updates result in high traffic overhead in DSDV. Every node has the same information about whole network. This is due to the fact that DSDV protocol is a distance vector protocol and there is a route for each destination node.

3.2.8. Table Management

The main reason of existence sequence number in routing table for each route is that sequence number prevents infinite circles or loops in routes. Furthermore nodes drops some packet that they have not new sequence number. During the route selection process, route updates are carried out when the destination sequence number in a control message is bigger than the sequence number in the routing table. It guaranties the use of newest information from the destination. If the sequence numbers are equal, the shortest route will be selected.

Figure 3.5. illustrates an example of the ad hoc network that nodes are mobile. Every node has a routing table that includes sequence number field for each route. As it is illustrated in the figure, there are eight nodes that constructs a network that some nodes have movements over time.

Figure 3.6. represents updating process in the routing table for a node that receives new update message. In this example node H5 advertises update packet to its neighbors. When H3 receives the update packet, it will start to check all routes that exist in both own routing

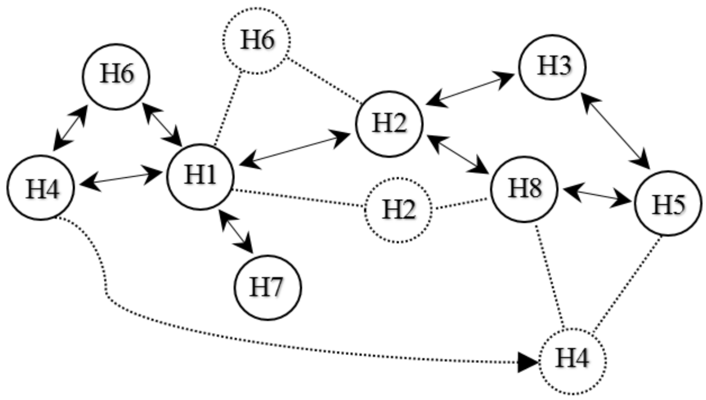

Figure 3.5. An example of an ad hoc network.

table and update packet. The entries with higher sequence numbers process and update routing table. For example, the entry H1 has newer sequence number. This sequence number is entered into the updated routing table. In the other step H3 node checks route to H2 in the update message and finds out the sequence number in the update message is bigger than the existing entry in the own routing table, therefore updates it routing table with the new information by received the update message. In the last step, H3 node checks other routes in the update message and compares the entries in its routing table. For example it checks H4 and H6 routes and it knows that the sequence numbers are small in the update message received and it would not update information.

3.2.9. Route Maintenance

Advertising in DSDV protocol is broadcast, also routing information cover easily as soon as possible in whole of network. The links could be broken due to the mobility. There are some reasons for broken links. For example, the broken link may be detected by the communication hardware or maybe broken links detect from a neighbor that it does not receive any routing packet from a particular neighbor over a certain period of time. Nodes might detect broken link from Acknowledge messages that they receive from own neighbors. Nodes might detect broken links when they send routing messages and they would not receiving any ACK messages. On the other hand sometimes broken links are detected by link layer.

Destination	Next Hop	Metric	Sequence Number
H5	H5	0	S124_H5
H1	H8	3	S242_H1
H2	H3	2	S218_H2
H3	H3	1	S324_H3
H4	H8	4	S214_H4
H6	H8	4	S522_H6
H7	H3	4	S632_H7
H8	H8	1	S368_H8

The routing table of H5 (the update packet)

Destination	Next Hop	Metric	Sequence Number
H1	H2	2	S212_H1
H2	H2	1	S242_H2
H3	H3	0	S516_H3
H4	H5	2	S324_H4
H5	H5	1	S214_H5
H6	H2	2	S548_H6
H7	H2	3	S632_H7
H8	H5	2	S372_H8

The routing table of H3 (before the update)

Destination	Next Hop	Metric	Sequence Number
H1	H5	4	S242_H1
H2	H3	3	S242_H1
H3	H3	0	S516_H2
H4	H3	2	S324_H3
H5	H5	1	S214_H4
H6	H2	2	S548_H6
H7	H2	3	S632_H7
H8	H5	2	S372_H8

The routing table of H3 (after the update)

Figure 3.6. Updating process in a routing table.

Broken links are identified as infinite metric. When a link for a next hop is broken, any routes through that node, signed the link with infinite metric and increases sequence number that it will help to other nodes to know about that broken link.

Figure 3.7. represents a broken link processes in a routing table. H5 detects a broken link with H8. In the first step, it changes the metric which belongs to H8 to infinite. In the second step, it increases the sequence number by one and advertises this routing information to its own neighbors. After that H3 receives this routing message from H8 and checks the sequence

Destination	Next Hop	Metric	Sequence Number
H5	H5	0	S124_H5
H1	H8	3	S242_H1
H2	H3	2	S218_H2
H3	H3	1	S324_H3
H4	H8	4	S214_H4
H6	H8	4	S522_H6
H7	H3	4	S632_H7
H8	H8	∞	S373_H8

The routing table of H5 (the update packet)

Destination	Next Hop	Metric	Sequence Number
H1	H2	2	S212_H1
H2	H2	1	S242_H2
H3	H3	0	S516_H3
H4	H5	2	S324_H4
H5	H5	1	S214_H5
H6	H2	2	S548_H6
H7	H2	3	S632_H7
H8	H5	2	S372_H8

The routing table of H3 (before the update)

Destination	Next Hop	Metric	Sequence Number
H1	H5	4	S242_H1
H2	H3	3	S242_H1
H3	H3	0	S516_H2
H4	H3	2	S324_H3
H5	H5	1	S214_H4
H6	H2	2	S548_H6
H7	H2	3	S632_H7
H8	H5	∞	S373_H8

The routing table of H3 (after the update)

Figure 3.7. Broken link process in a routing table.

numbers so detects broken link and update own table.

There are two types of response to topology change in DSDV: full and incremental update. Immediate advertisement broadcasts information when a new route is added, or when a link is broken, and the like. In these situations, necessary update messages are propagated immediately to the neighbor nodes. Where all routing information is sent in the full update, only entries that have changed are sent to other nodes in the incremental node.

There is an extra field in routing table that reduces the update operations that is called *setting time*. Sometimes there are two different paths from a node to destination and source node receive routing packets in two different route with small interval. Also this situation causes an extra update operation. For prevention of this problem, DSDV uses a setting time. It means every node before updating its routing table, should wait as much as the setting time.

3.2.10. Problems of DSDV

There are some challenges about DSDV protocol. The main problem of DSDV protocol is the high amount of network overhead resulting from the packet storming and periodically updates. DSDV protocol forces to update whole network periodically and it causes more routing messages and more updates so network overhead is high in compare with other types of routing protocols.

General implementation of DSDV assumes all links are bidirectional. Nevertheless some nodes are unidirectional in real situations. Another significant issue is energy conservative, every node should be in active mood all the time and this causes to waste unnecessarily energy.

4. A NEW METRIC FOR ADAPTING ROUTING PROTOCOLS IN MANETS

4.1. Introduction

One of the main research challenges in mobile ad hoc networks (MANETs) is designing adaptive, scalable and low-cost routing protocols for these highly dynamic environments. Therefore, the main aim is adapting routing protocol based on the mobility level of network in this thesis. Well representing the changes in MANETs based on mobility helps to protocols to improve their throughput and to find optimum value of significant parameters that lead protocols to works properly.

The main characteristic of mobility aware metric is to find the proper and stable route especially in reactive protocols. Establishing a stable route could help protocols to increase throughput of the networks. On the other hand, reflecting hop changes in the network helps protocols to handle updating process in the whole network especially in proactive routing protocols. Due to the movements of nodes and mobility, routing update messages play a significant role in protocols and should be sent on time. Some of the movements are not significant so that protocol forces to broadcast routing update messages for every movements. It is the main reason of the network overhead. If the protocol predicts about mobility of nodes by observing hop changes, it could handle sending of routing update messages on time. Hence, packet delivery ratio increases, since this leads protocols to selects more stable route to the destination. Therefore sending messages from an area that has a lowest mobility is better than others.

This thesis focus on a metric that reflects changes in MANET networks. A new metric called *hop change metric* is introduced in order to represent the changes in the network topology due to mobility. This metric is implemented in two popular routing protocols.

This thesis focuses on the two main category of routing protocols in MANETs. One is a proactive routing protocol (DSDV) and the other one is reactive routing protocol (AODV).In the first step, this thesis focus on a popular reactive protocol and proposes a new improvement on AODV protocol. This approach selects the best route to the destination based on the *hop change metric*. While AODV chooses the node with the mimimum number of hops, our approach aims to choose the route which is less mobile. The proposed approach (LA-AODV) tries to select best route between valid routes based on the *hop change metric*. LA-AODV is compared with the original AODV. In the second step, this thesis proposes a new improvement on DSDV, which is one of the most popular proactive routing protocols in MANETs. It determines a threshold value based on this metric in order to decide the full update time dynamically and cost effectively. The proposed approach (LA-DSDV) is compared with the original DSDV and ns-DSDV which is employed in the ns-2 simulator.

4.2. Hop Change Metric

We introduce a new metric called *hop change metric* which represents the changes in the number of hops in the routing table. We define the Equation 5 to calculate this metric. In the Equation 1, $HopCount_{New}$ is the new hop count between the current node and the node i. $HopCount_{Previous}$ is the previous hop count at the previous update. $t_{NewUpdate}$ and $t_{PreviousUpdate}$ are the last and the previous update period times respectively. Number_of_nodes represents the number of nodes in the routing table of the node calculating the *hop change metric*. In DSDV, each node includes routes to all nodes in its routing table. Therefore, Number_of_nodes is equal to the number of all nodes in the network in DSDV. On the other hand, only nodes communicated with or overheard are added into the routing table in AODV.

It is believed that the change in the hop count is a good representative of the mobility. The high number of change in the hop count can be a sign of high mobility. However this approach is not useful in group mobility patterns. Mobility models represent the movement of mobile user, and how their speed and location change over time. Group mobility pattern defines certain movement among the nodes such on a road. This mobility pattern is used in some special situations where nodes move in a determined area such as models wireless nodes on vehicles crossing each other at a highway interchange.

$$hop\ change\ metric = \frac{\sum_{i=0}^{i=Number\_of\_nodes} \frac{|HopCount_{new} - HopCount_{previous}|}{t_{NewUpdate} - t_{PreviousUpdate}}}{Number\_of\_Nodes} \tag{5}$$

This is a simple and low cost approach in terms of computation and communication. In the AODV step, the metric defines a trifle communication cost to determine stable route but it causes the significant improvements. In the DSDV step, it does not introduce any communication cost to determine the update time as in the mobility metric given in [32]. The mobility metric called *link change rate* is well accepted and shown to be a more accurate measurement than the mobile speed [42]. The *hop change metric* defined here is more cost effective than the *link change rate* [42]. Because in the approach [42] a node collects neighbor change metrics from its neighbors periodically. Furthermore, the *hop change metric* is believed to give a broader view of mobility than the neighborhood change, which might differ considerably from one node to another, in routing protocols.

4.3. LA-AODV (Lightweight Adaptive AODV)

This section focus on the most popular reactive protocol AODV. It is believed that the *hop change metric* could be used in the other type of protocols. The main goal of LA-AODV is selecting a best route with a low degree of mobility. LA-AODV uses the *hop change metric* for selecting better routes among valid route reply packets. Due to the mobility prediction *hop change metric* helps to select more stable node to destination.

4.3.1. Mobility Prediction

LA-AODV protocol uses a periodic process to calculate mobility. Every node calculates *hop change metric* periodically that represents the mobility of the area of its neighbors. It means that every nodes know about the mobility of its area. The frequent of calculating mobility is found empirically and fixed to 10 seconds. For this propose LA-AODV adds a new field to the routing table that called *hop change metric*. As illustrated in 4.1. *hop change metric* is calculated every 10 seconds with the equation 5 for each node in the network.

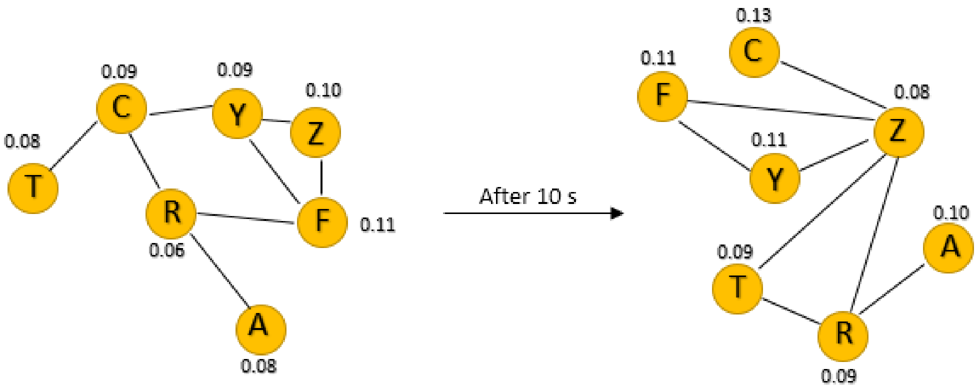

Figure 4.1. Calculating hop change metric in LA-AODV periodically.

4.3.2. Route Selection

LA-AODV carries out the same steps as in the original AODV in the route discovery mechanism but LA-ADOV have some changes in the route selection mechanism while establishing a forward path among route reply packets. As mentioned, the original AODV finds route on demand by broadcasting a route request packet to the network. Source node tries to establish a forward path for communicating with the destination node as soon as it receives the first route reply packet. It is believed that this way is not the perfect way for all situations. Evaluating the first route reply packet could be useless in some situation due to mobility. LA-DSDV tries to evaluate legitimacy route reply packets that is received from destination node. For this purpose, we add a new field to route reply packets that called *Total_Hop_Changes* that represents the *hop change metric* of the route. This metric adds *hop change metric* of intermediate nodes between the source node and the destination node. It means that every route reply packet has a metric that represents the stability of the route.

Source nodes in LA-AODV wait a certain period of time to receive route reply packets. LA-DSDV compares the first two route reply packets received with the *Total_Hop_Changes* that inspired from *hop change metric*. LA-AODV selects the route reply packet which has more stable. It means this approach tries to establish a forward path which is the best route from point of mobility.

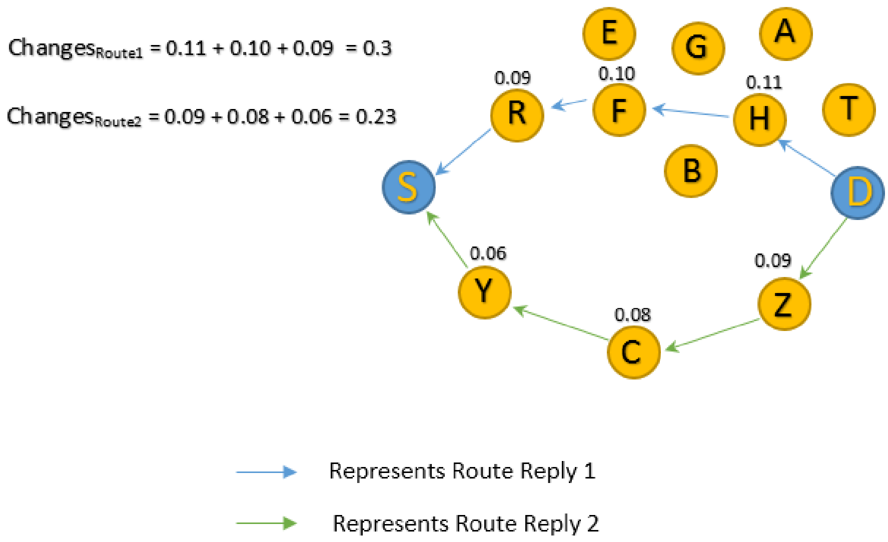

Figure 4.2. Route selection procces in LA-AODV.

As illustrated in 4.2., route selection process is described in LA-AODV. The source node selects the route with low level of mobility. As represented, the source node S receives two route reply packets from the destination node D. Every node has a *hop change metric* that is updated periodically. The source node S adds *hop change metric* of intermediate nodes and obtains the *Total_Hop_Changes* of the routes. The source node compares *Total_Hop_Changes* of routes and selects the small one that represents more stable route or less mobile.

4.4. LA-DSDV (Lightweight Adaptive DSDV)

This section proposes a new improvement on DSDV protocol. LA-DSDV is a lightweight threshold based on *hop change metric*. This thesis aims to determine changes in the topology and use this information for handling periodic update in DSDV protocol. In the original DSDV, there are some trifle movements that periodic update is not needed. Nevertheless in some situations that mobility is high, periodic update needs to be more frequent. These situations lead to decreasing the performance of the protocols. Therefore the main aim of the LA-DSDV protocol is determining a threshold for mobility to handle periodic update time.

As mentioned, the full dumps of the nodes can be transmitted relatively infrequently when little movement of mobile nodes is occurring [4]. On the other hand, the periodic update needs to be more frequent under high mobility due to the high number of changes in the network topology.

It is believed that the change in the hop count is a good representative of the mobility. The high number of change in the hop count can be a sign of high mobility. Furthermore, this change affects every node in the same way. Hence we could determine a periodic update time without exchanging any information between nodes. The proposed metric is used to adjust DSDV protocol.

The proposed approach (LA-DSDV) is compared with the original DSDV and ns-DSDV. This approach shows a similarity with the optimization done in ns-2. While we only consider changes in the number of hops, ns-DSDV takes into account any change to the routing table such as adding a new node, updating sequence number/hop count. Some of these changes such as updating sequence number do not have a direct relation with the topology change due to mobility. Furthermore, the threshold value for the *hop change metric* is defined empirically. Our purpose updates routes more frequently when needed under high mobility. As it is seen in the simulation results, our method outperforms ns-DSDV.

In this approach, we determine a threshold value for the *hop change metric* empirically. First of all, we determine the range of the *hop change metric* between 00.00 - 0.8 that represent the minimum and maximum amount of changes. We evaluate the packet delivery ratio, end-to-end delay, network overhead and drop rate at different values in this range.

Packet delivery ratio represents the proportion of the receiving data packets to sending packets that called throughput of the network. Drop rate shows the ratio of dropping packets in the network. Overhead indicates the propotion of routing packets to data packets and end-to-end delay is the average time taken by a data packet to arrive in the destination.

A threshold is selected based on these performance metrics. As mentioned before, we calculate the *hop change metric* when an triggered update packet is received. If the calculated *hop change metric* is bigger than the defined threshold, a full update is carried out. This approach works on full update routing packets. It means, LA-DSDV aims to handle periodic update or full update.

We define the threshold by using a network under medium mobility (pause time = 10ms). We evaluate the performance of our method by using networks with varying mobility levels from low to high. Lastly, we compare our protocol (LA-DSDV) with the original DSDV protocol and the ns-DSDV. The following performance metrics are used in the comparison: the packet delivery ratio (PDF), the overhead, the end-to-end delay and the packet drop rate.

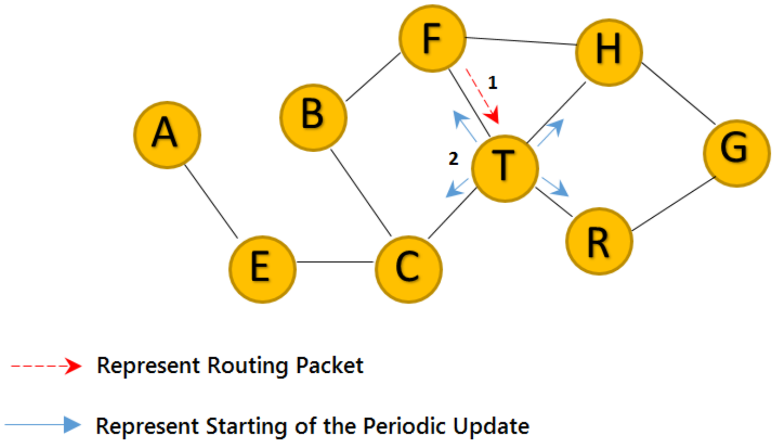

Figure 4.3. Periodic update in LA-DSDV.

After determining a threshold for high mobility, LA-DSDV could decide the periodic update time. Every node should calculate *hop change metric* when they receive a routing message. As illustrated in 4.3. there are eight nodes that constitute a network. Node T receives a routing message that it is shown with red arrow at t_i (1). Hence node T calculates the *hop change metric* as soon as possible it receives a routing control packet and compares the result with the threshold. If it is greater than the defined threshold, a full update will be triggered at t_{i+1} (2). A larger value of defined *hop change metric* represents high mobility situation in the network.

It is believed that the *hop change metric* represents the topology changes due to mobility well and it can be used for determining the full update time adaptively. Moreover, it does not introduce any communication cost to determine the update time as in the mobility metric based on the neighborhood change given in [32]. In proactive routing protocols, the *hop change metric* is also believed to give a broader view of mobility than the neighborhood change which might differ considerably from one node to another.

5. PERFORMANCE EVALUATION OF HOP CHANGE METRIC IN ROUTING PROTOCOLS

This chapter focuses on the simulation results and analysis the output data of the mentioned protocols. All experiments have been simulated in ns-2.35 simulation. Ns is a name for series of discrete event network simulators, specifically ns-1, ns-2 and ns-3. Ns-2 was initiated by Steve McConne in 1996-97. The core of ns-2 is written in C++ and simulation scripts are written in the OTcl language, an extension of the Tcl scripting language. We use BonnMotion software [43] to create mobility traffic files and use AWK scripts to analysis output data from ns2. ns-2 runs in Linux operating system. It takes two files as input: a tcl file and a traffic scenario file which generated with BonnMation software. ns-2 produces an output file showing the network communication accrued during the simulation.

5.1. Performance Metrics

We analysis data from the point of four parameters: packet delivery ratio, network overhead, drop rate and end to end delay. Routing protocols mainly use these parameters in order to evaluate their performance.

5.1.1. Packet Delivery Ratio (PDR)

Packet delivery ratio represents the ratio of the number of delivered data packets to the destination node to number of packets sent from the source node. This indicates the level of delivered data to the destination. It is calculated as below:

$$Packet\ Delivery\ Ratio = \frac{\sum Number\ of\ Packets\ Received\ by\ Destination\ Node}{\sum Number\ of\ Packets\ Sent\ by\ Source\ Node} \quad (6)$$

5.1.2. Network Overhead (OVR)

Network overhead is a rate between data packets and routing control packets that the node receives. Overhead represents the quotient of division data packet to control packets. Hence this rate represent the overhead of the network.

$$Network\ Overhead = \frac{\sum Number\ of\ Data\ Packets}{\sum Number\ of\ Routing\ Control\ Packets} \tag{7}$$

5.1.3. End-to-end Delay (E2E)

End-to-End delay is the average time taken by a data packet in order to the destination. It also consists the delay caused by the route discovery process and the queue in data packet transmission. It is calculated as below:

$$End{-}to{-}End\ Delay = \frac{Arrive\ Time\ of\ Data\ Packets - Send\ Time\ of\ Data\ Packets}{Number\ of\ Connections} \tag{8}$$

5.1.4. Drop rate (DRP)

Drop rate is the rate of packets dropped during the simulation. The major causes of packet losses on MANETs are wireless link transmission errors, mobility and congestion. There are other causes as well such as buffer overflow due to the high amount of traffic in the network. It is shown that more than 60% packet losses on AODV results from mobility [44].

$$Drop\ Rate = \frac{\sum Number\ of\ Dropping\ Packets}{\sum Number\ of\ Sent\ Packets} \tag{9}$$

5.2. Simulation Environment

Ns-2 is used for simulating networks with varying mobility levels. The simulation parameters of ns-2 used is given in table 5.1.. The parameters not given here are the default parameters of the simulator. Network mobility is either represented by different node speeds or different pause time. In this thesis, the approach using different pause time for representing different mobility level is employed. Pause time 0 indicates a network that constantly moving. When the pause time increases, the changes in the topology decreases. We evaluated mentioned approaches and original protocols in different pause times. We use Random Waypoint Mobility Model for mobility pattern that is a random model for the movement of mobile users, and how their location, velocity and acceleration change over time. The movement of nodes is governed in the following manner: Each node begins by pausing for a fixed number of seconds. The node then selects a random destination in the simulation area and a random speed between 0 and the maximum speed determined. The node moves to this destination and again pauses for a fixed period before selecting another random location and speed. This behaviour is repeated for the length of the simulation [45].

Parameter	Value
Network Dimensions	1000*1000
Number of Nodes	100
Packet Traffic	CBR with 60 connections
Speed	0-20 m/s
Pause Time	0, 5, 10, 15, 20, 25 ms
Transmission Range	250 m
Simulation Time	500 s
Mobility Model	Random waypoint

Table 5.1. The simulation parameters.

5.3. The Performance of AODV

We simulate the original AODV by using different mobility levels. Figure 5.1. demonstrates the performance of the AODV routing protocol from the point of packet delivery ratio, network overhead, end to end delay and dropping rate. Here, the pause time = 0 indicates the network under the highest level of mobility and pause time = 25 represents the network under the lowest level of mobility. These results are the average of fifty different network runs as shown in Appendix A. As it is seen in the figure 5.1. (A), packet delivery ratio has some trifle fluctuating over the mobility (different pause times); however it has a trend to increase

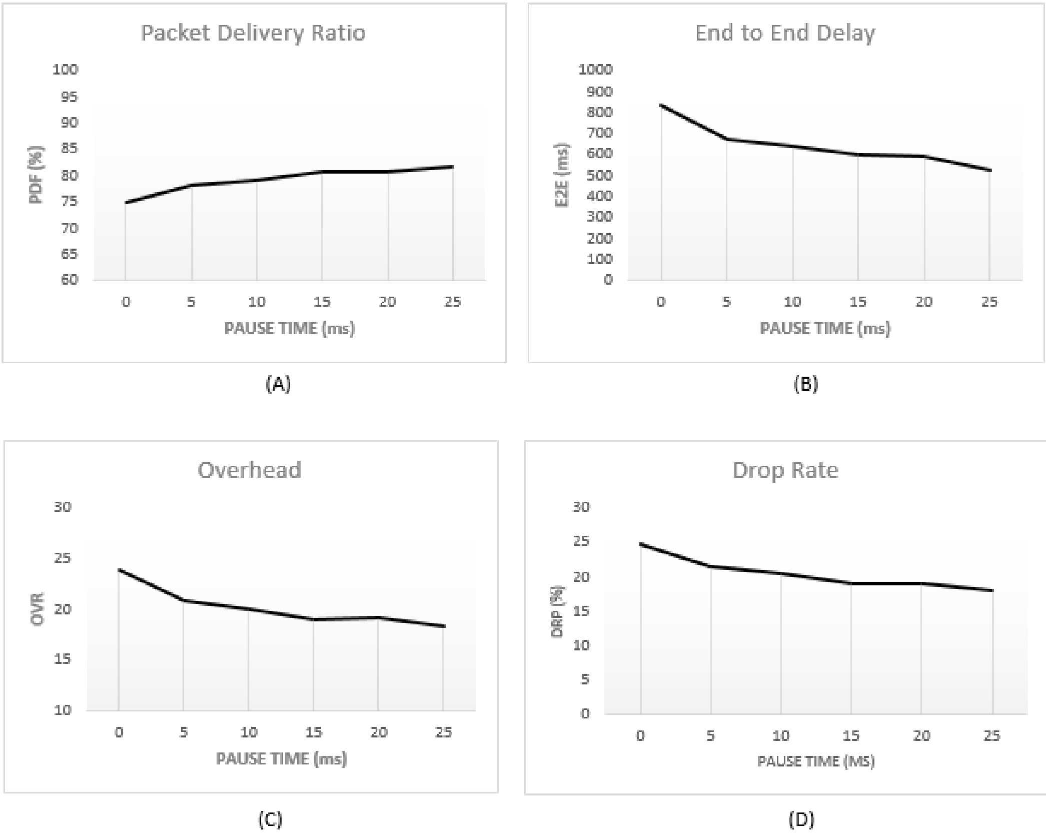

Figure 5.1. The performance of AODV protocol.

over the pause time likewise that property is reflected in end-to-end delay 5.1. (B), hence it means end to end delay decreases over the mobility.

AODV protocol has some trifle fluctuating in medium mobility from point of network overhead 5.1. (C) but in general network overhead in low mobilities is less than high mobilities. As illustrated in the Figure 5.1. (D), dropping rate is linear but it has a subtractive trend over the pause time.

5.4. The Performance of LA-AODV

Figure 5.2. illustrated the packet delivery ratio in varying pause times on ADOV and on the proposed approach LA-AODV. Firstly, it can be seen in the figure that LA-AODV is extremely better than original AODV protocol. Detailed information in Table 5.2. emphasizes

the fact that LA-AODV improves almost 5% of the throughput of AODV protocol. As shown in the figure, increasing the packet delivery ratio over the pause times is completely obvious.

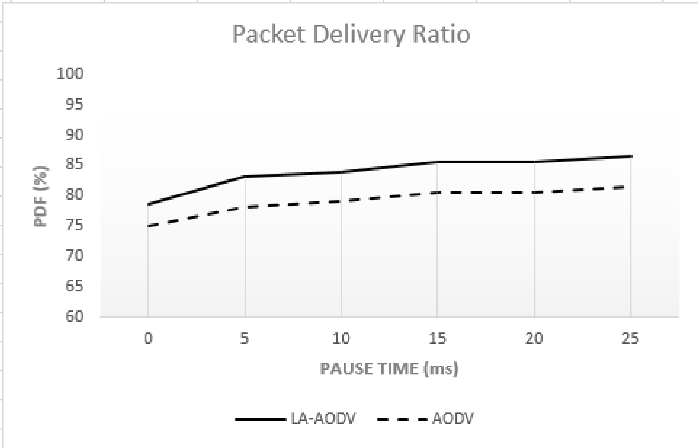

Figure 5.2. Packet delivery ratio of LA-AODV and AODV on networks with varying mobility patterns.

Pause Time	AODV	LA-AODV
0	0.749	0.785
5	0.780	0.832
10	0.790	0.839
15	0.805	0.855
20	0.806	0.856
25	0.815	0.865

Table 5.2. Packet delivery ratio of LA-AODV and AODV on networks with varying mobility patterns.

Figure 5.3. and table 5.3. demonstrates the end-to-end delay in networks with varying mobility patterns on the original AODV and LA-AODV. It can be seen in the fist step, LA-AODV has extremely better performance than the original AODV. The reason is that LA-AODV selects more stable routes by using the *hop change metric* . It is given in the second step, the delay is decreased over the pause time in both protocols.

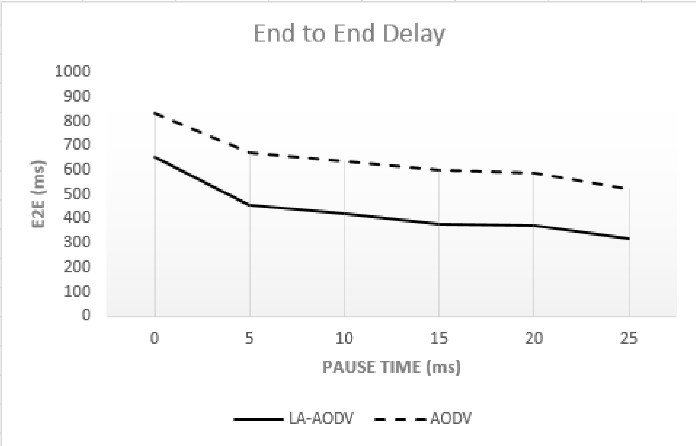

Figure 5.3. End-to-end delay of LA-AODV and AODV protocols on networks with varying mobility patterns.

Pause Time	AODV	LA-AODV
0	832.01	655.12
5	671.60	454.61
10	637.29	418.73
15	600.73	377.72
20	586.91	371.45
25	523.60	320.31

Table 5.3. End-to-end delay of LA-AODV and AODV protocols on networks with varying mobility patterns.

Network overhead is shown in Figure 5.4.. LA-AODV has less overhead than the original AODV protocol. Selecting more stable nodes decrease the routing control packets (RREQ, RRER, RREP) in the network. Table 5.4. gives network overheads in two protocols. As mentioned, network overhead caused by the routing control packets and due to the selecting routes with low mobility, LA-AODV has less routing control packets than AODV protocol.

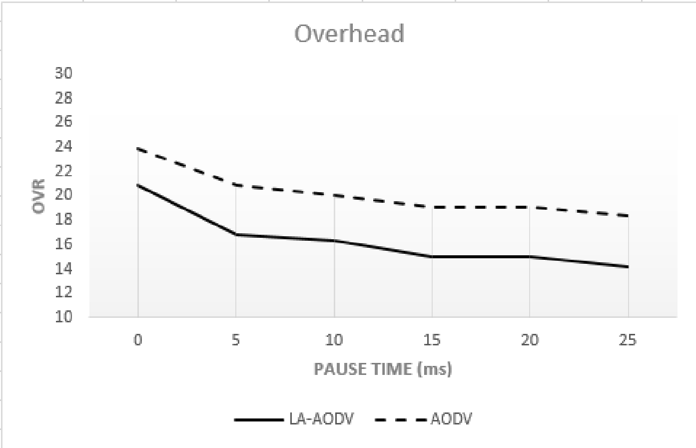

Figure 5.4. Overhead of LA-AODV and AODV protocols on networks with varying mobility patterns.

Pause Time	AODV	LA-AODV
0	23.89	20.92
5	20.89	16.78
10	20.09	16.36
15	19.03	15.01
20	19.13	14.99
25	18.34	14.18

Table 5.4. Overhead of LA-AODV and AODV protocols on networks with varying mobility patterns.

Packet loss occurs when one or more packets of data traveling across a computer network fail to reach their destination. As mentioned before, packet dropping occurs in different situations such as wireless link transmission errors, mobility and congestion. The mobility is not the only reason for dropping data packets. The packet dropping rate is illustrated in Figure 5.5. and Table 5.5. LA-AODV protocol has less packet dropping rate than the original AODV protocol.

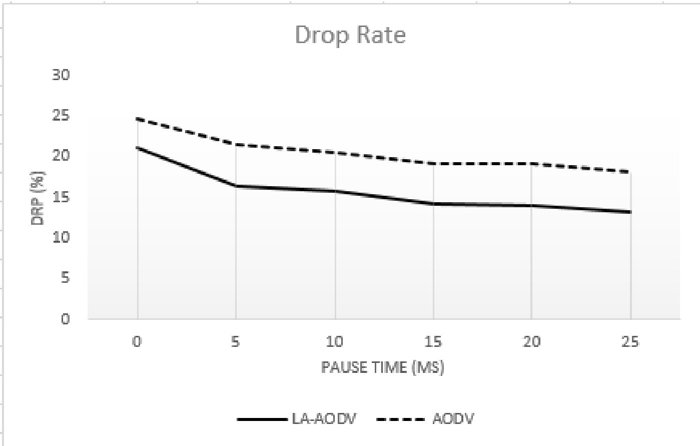

Figure 5.5. Dropping rate of LA-AODV and AODV protocols on networks with varying mobility patterns.

Pause Time	AODV	LA-AODV
0	0.246	0.210
5	0.214	0.164
10	0.205	0.158
15	0.190	0.142
20	0.190	0.140
25	0.181	0.132

Table 5.5. Dropping rate of LA-AODV and AODV protocols on networks with varying mobility patterns.

Table 5.5. explains the detail of the dropping rate over the pause time. It can be seen there are significant improvement from the point of mobility. The main reason of this improvement could be the following two reasons. The first reason is that packet dropping due to the mobility is decreased and the second reason is selecting more stable routes leads to decrease the dropping packets.

5.5. The Performance of DSDV

This study, compares simulation results on DSDV on networks with varying mobility patterns. This results are the average of fifty different network runs as shown in Appendix B.

Figure 5.6. Performance of DSDV protocol.

As shown in the Figure 5.6. (A) showing the packet delivery ratio, throughput has some fluctuating over the pause time and it is seen in the graph the range of the changes in completely close over the mobilities. This is due to the fact that, that mobility does not much affect on the packet delivery ratio. This property is also reflected in the dropping rate. As it seen in the Figure 5.6. (D) Dropping rate is almost in the same ranges over the mobility. The major causes of packet losses on MANETs are congestion, mobility and wireless link transmission errors. In PDR graph, 25ms pause time has high PDR rate in compare with other. It might be that mobility is in low level than others.

The network overhead with varying pause time is shown in Figure 5.6. (C). Overhead depends on the various situation and different reasons. In general, DSDV protocol has high amount of overhead that it is due to updating periodically. Average network overhead approximately decreases in the low mobility. Every node in DSDV protocol maintain information of any other nodes in the network and update periodically all of this information. The chief reason why overhead increases with mobility is transferring high amount of routing packets through the network.

Figure 5.6. (B) represent end-to-end delay in varying of pause times. Packet delay has a slight increase and decrease over the pause times but approximately has the same amount of delay in different pause times. Simulation results illustrate DSDV is not suitable for high mobility networks. It means that DSDV cannot coverage network in low pause times.

5.6. The Performance of LA-DSDV

We analyze the hop change metric and define different threshold values. Table 5.6. shows the performance of our method at different threshold values. We use fifty networks under medium mobility (pause time=10) for training and, determining a threshold value for the hop change metric. The figure below illustrates parameters that average of fifty networks in pause time = 10.

Threshold	0.08	0.09	0.10	0.11	0.12	0.25
Packet Delivery ratio	0.7028	0.7016	0.7046	0.7046	0.6975	0.6964
Drop Rate	0.29087	0.2921	0.2921	0.2918	0.2995	0.301
End to End Delay	656.28	557.46	498.49	399.29	362.042	332.747
Network Overhead	3.319	3.198	3.044	2.8036	2.728	2.7089

Table 5.6. The performance of LA-DSDV at different threshold values.

According to the results given in the Table 5.6., the threshold value is set to 0.11 in this study. Even this value does not show the best result, it shows a good result in each performance metric. Figure 5.7. shows the packet delivery ratio at different threshold values. In terms of PDF, it performs the best at 0.11.

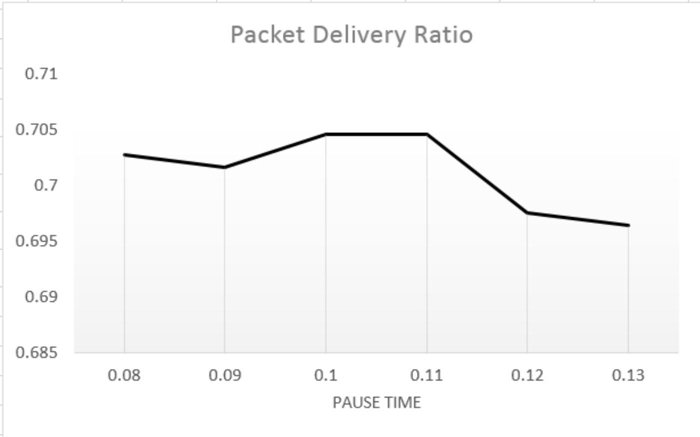

Figure 5.7. Packet delivery ratio at different thresholds.

For testing, various networks are created by running simulations at different pause times (0, 5, 15, 20, and 25 seconds). We run DSDV, ns-DSDV and our approach on these networks with varying mobility patterns and compare their performance metrics (packet delivery ratio, network overhead, end-to-end delay and packet drop rate). For this purpose fifty different networks are generated for each mobility level and evaluated all routing protocols (LA-DSDV, DSDV and ns-DSDV) on these networks.

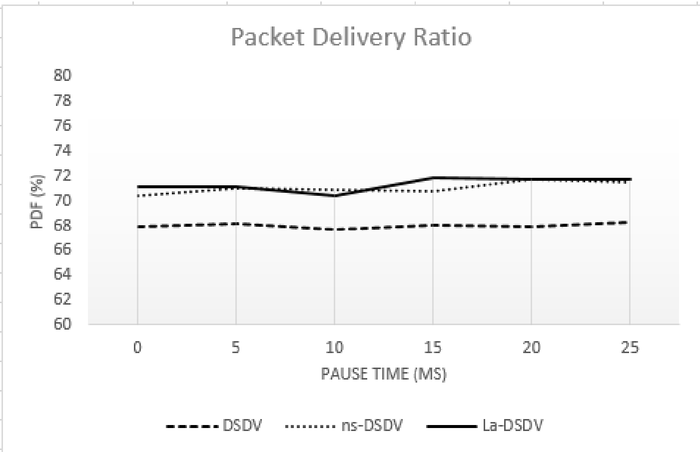

Figure 5.8. Packet delivery ratio of DSDV, ns-DSDV and LA-DSDV.

Pause Time	DSDV	ns-DSDV	LA-DSDV
0	0.679	0.704	0.7111
5	0.6819	0.7102	0.714
10	0.677	0.7093	0.7046
15	0.6801	0.708	0.7186
20	0.679	0.7179	0.7171
25	0.6826	0.7154	0.7173

Table 5.7. Packet delivery ratio of DSDV, ns-DSDV and LA-DSDV.

Figure 5.8. demonstrates the average of fifty different networks of packet delivery ratio for LA-DSDV, DSDV and ns-DSDV protocols on various networks as shown in Appendix B. The Table 5.7. shows that LA-DSDV achieves better results in low, medium and high mobility than the original DSDV. It can be concluded that LA-DSDV is preferable than the original DSDV from the packet delivery ratio point of view. It outperforms ns-DSDV considerably under some pause times. The results could be improved by determining different thresholds for different networks with varying mobility patterns.

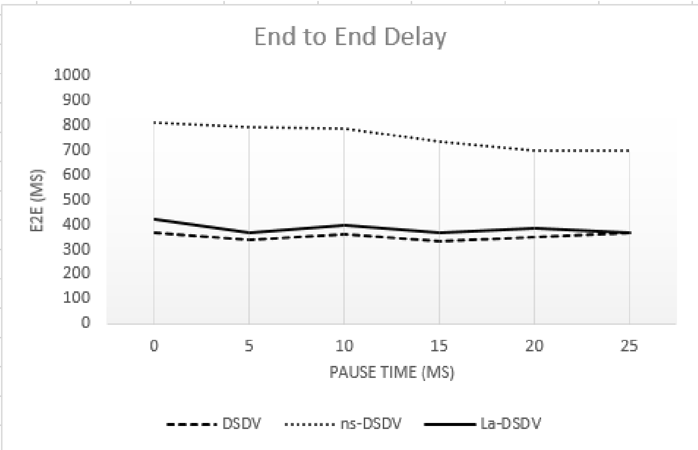

Figure 5.9. End-to-end delay of DSDV, ns-DSDV and LA-DSDV.

Pause Time	DSDV	ns-DSDV	LA-DSDV
0	370.72	815.06	419.95
5	336.443	792.57	371.1
10	363.86	786.91	399.29
15	331.99	733.28	371.29
20	349.08	699.97	383.409
25	369.11	697.51	365.776

Table 5.8. End-to-end delay of DSDV, ns-DSDV and LA-DSDV.

Figure 5.9. and Table 5.8. depict the end-to-end delay for networks with varying mobility patterns. As it is seen, LA-DSDV has a lower end-to-end delay than ns-DSDV. The update time which is decreased down to one second in ns-DSDV might cause this delay. Our approach also does not increase the delay much when compared with the original DSDV.

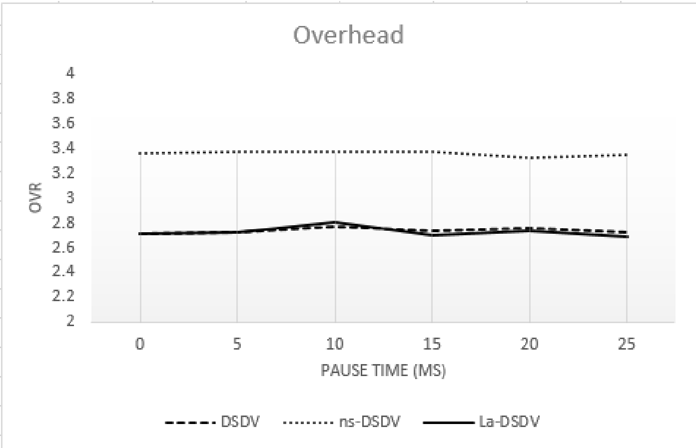

Figure 5.10. Overhead of DSDV, ns-DSDV and LA-DSDV.

Pause Time	DSDV	ns-DSDV	LA-DSDV
0	2.713	3.363	2.71
5	2.73	3.381	2.723
10	2.77	3.374	2.803
15	2.74	3.38	2.7
20	2.76	3.33	2.74
25	2.72	3.35	2.69

Table 5.9. Overhead of DSDV, ns-DSDV and LA-DSDV.

Figure 5.10. and Table 5.9. demonstrates the overhead caused by the routing control packets in each protocol. LA-DSDV protocol approximately has the same amount of overhead in compared with original DSDV; however it improves other performance metrics such as the packet delivery ratio and the packet drop rate.The LA-DSDV protocol has much lower overhead than the ns-DSDV protocol.

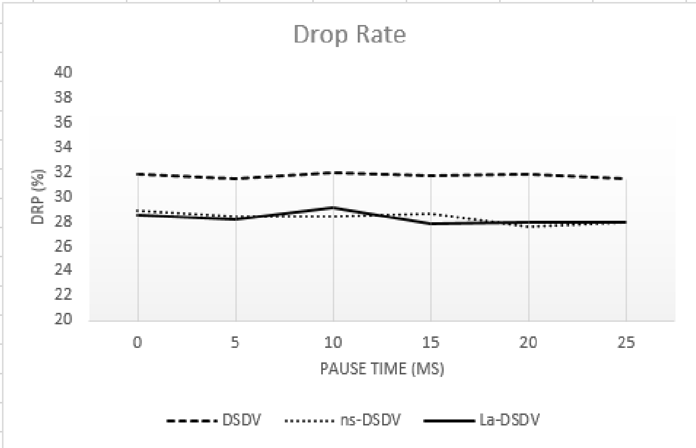

Figure 5.11. Dropping rate of DSDV, ns-DSDV and LA-DSDV.

Pause Time	DSDV	ns-DSDV	LA-DSDV
0	0.319	0.2894	0.285
5	0.315	0.284	0.282
10	0.3204	0.2849	0.2919
15	0.3173	0.2869	0.278
20	0.3184	0.2766	0.2793
25	0.3148	0.2794	0.2795

Table 5.10. Dropping rate of different protocols in varying of pause times.

Finally, the packet dropping rate is demonstrated in Figure 5.11.. LA-DSDV protocol has less packet drop rate than the original DSDV protocol. The details of the simulation results are presented in Table 5.10.. Even though mobility is one of the biggest factors on the results, other factors such as network topology, traffic patterns also play a part.

6. CONCLUSION

This thesis introduced a new mobility aware metric called *hop change metric*. This metric aims to find a stable routes and to handle updating process. This metric is adapted in two main kind of protocols, reactive and proactive. The results indicate that this metric enhances the performance of protocols. *hop change metric* represents the changes in the number of hops in the routing table. It is believed that the change in the hop count is a good representative of the mobility. Well representing the changes in MANETs based on mobility helps to protocols to improve throughput and to find optimum value of significant parameters that lead protocols to works properly. The high number of change in the hop count can be a sign of high mobility. This thesis focuses on the two main category of routing on protocols in MANETs. One is a proactive routing protocol (DSDV) and the other one is reactive routing protocol (AODV).

In the first step, we use *hop change metric* in AODV protocol and introduced a new protocol that called LA-AODV. LA-AODV has a small modification in routing selection between RREP packets. The main goal of LA-AODV is selecting a best route from the point of mobility with a low degree of mobility. Every node calculates hop change metric periodically that represents the mobility of the area of its neighbors. It means that every nodes know about the mobility of its area. LA-AODV tries to evaluate legitimacy route reply packets that is received from destination node. LA-AODV selects the stable route which has the smaller change metric. Every RREP packets has the change rate that is come from the summation of *hop change metric* of intermediate nodes. As mentioned in results section, LA-AODV enhanced performance in all performance metric. There are significant improvement on original AODV from point of packet delivery ratio, end to end delay, network overhead and dropping rate. The change rage between ADOV and LA-AODV from point of network throughput is almost 5%. It is obvious that LA-AODV is superior and preferable than original AODV protocol.

In the second step, we focus on the proactive protocols specially DSDV protocol and aim to adapt periodic update time in this kind of protocols. In this step aims to determine changes in the topology and use this information for handling periodic update in DSDV protocol. The periodic update needs to be more frequent under high mobility due to the high number of changes in the network topology. The main aim of the LA-DSDV protocol is determining a threshold for mobility to handle periodic update time. For this propose, a new lightweight threshold-based scheme is proposed in order to improve the low packet delivery ratio of the original DSDV under high mobility. We use *hop change metric* to determine threshold for handling periodic update. Our approach could start the full update with determined threshold. The threshold value for the hop change metric is defined empirically. If the calculated *hop change metric* is bigger than the defined threshold, a full update is carried out. It is believed that the hop change metric represents the topology changes due to mobility well and it can be used for determining the full update time adaptively. The results support this belief and show that our approach based on *hop change metric* improves the packet delivery ratio and the packet drop rate with a reasonable increase in the overhead and the end-to-end delay.

The computational costs for *hop change metric* is so trifle on the protocols. In the AODV protocol, proposed metric has a little increasing of the computational cost due to the adding new fields in routing tables and RREP packets for calculating *hop change metric*. In the DSDV protocol there are no additional cost for calculating *hop change metric* because LA-DSDV protocol use the current information and routing packets and *hop change metric* calculates dynamically.

6.1. Discussion and Future Work

This is a simple method which decides upon the update time without communicating with other nodes in the network. Since the communication between nodes is the main cause of battery depletion, it is an important attribute for the nodes that usually run on battery power in MANETs. This new metric can be used in various applications on MANETs. In the future, we would like to work on an adaptive system which changes the periodic update time dynamically by taking into account other criteria such as traffic, power as well. Moreover, the metric which represents the mobility, the changes in the topology the best is aimed to be explored. In the future, we would like to adapt this metric for other mobility patterns. This metric could be compared with other change metric such as **PER** [27] and **ARM** [32] in the future.

A - Additional results - LA-AODV

AODV

	E2E	PDF	DRP	OVR
1	159.16	0.907	0.094	11.98
2	492.58	0.801	0.191	17.84
3	213.07	0.884	0.117	13.75
4	835.82	0.731	0.269	22.69
5	209.84	0.892	0.108	12.5
6	1029.54	0.7	0.295	28.78
7	524.36	0.792	0.208	18.1
8	124.77	0.92	0.081	10.06
9	127.48	0.919	0.081	10.25
10	90.5	0.931	0.07	8.9
11	646.42	0.777	0.224	18.75
12	143.91	0.912	0.089	10.49
13	204.3	0.904	0.097	10.81
14	179.43	0.907	0.094	11.62
15	1011.1	0.704	0.296	24.41
16	1321.03	0.636	0.355	31.7
17	1829.2	0.554	0.44	41.91
18	413.61	0.832	0.165	15.91
19	511	0.811	0.188	17.87
20	816.78	0.731	0.269	25.28
21	851.39	0.714	0.286	26.73
22	751.88	0.757	0.237	21.23
23	389.32	0.851	0.149	14.9
24	1401.92	0.656	0.341	30.63
25	2002.34	0.522	0.468	45.88
26	1427.09	0.651	0.348	29.99
27	202.33	0.892	0.109	12.82
28	1138.26	0.664	0.321	30.87
29	2077.26	0.465	0.519	54.6
30	221.76	0.876	0.124	14.55
31	702.58	0.806	0.194	16.8
32	414.13	0.85	0.151	15.66
33	123.25	0.911	0.09	10.58
34	739.6	0.775	0.226	20.29
35	1257.06	0.694	0.302	26.33
36	215.81	0.892	0.109	13.26
37	1770.71	0.51	0.481	47.8
38	1940.1	0.538	0.448	44.71
39	1466.8	0.556	0.435	41.71
40	140.96	0.914	0.086	10.63
41	1661.31	0.629	0.364	35.26
42	1112.95	0.679	0.316	30.7
43	431.71	0.833	0.167	16.71
44	1644.72	0.542	0.447	42.51
45	1809.58	0.532	0.458	46.26
46	1298.67	0.625	0.367	33.4
47	728.74	0.769	0.232	21.31
48	425.8	0.84	0.159	14.54
49	1351.81	0.615	0.373	34.2
50	1017.17	0.688	0.311	26.55

La-AODV

	E2E	PDF	DRP	OVR
1	145.03	0.905	0.096	12.42
2	363.7	0.826	0.166	16.75
3	216.06	0.891	0.11	12.66
4	788.23	0.758	0.242	20.9
5	262.92	0.868	0.123	14.13
6	247.31	0.864	0.128	14.85
7	639.76	0.786	0.214	17.71
8	106.73	0.921	0.081	9.28
9	129.68	0.919	0.081	9.86
10	87.1	0.936	0.065	8.2
11	289.31	0.883	0.118	12.5
12	108.13	0.923	0.078	9.39
13	148.56	0.913	0.088	10.3
14	126.4	0.913	0.088	10.89
15	681.49	0.766	0.234	20.21
16	1374.05	0.594	0.396	37.31
17	1461.04	0.597	0.394	35.31
18	332.8	0.839	0.147	14.72
19	399.6	0.86	0.141	15.06
20	897.3	0.755	0.243	22.87
21	565.6	0.799	0.202	20.36
22	256.68	0.891	0.109	12.18
23	537.2	0.797	0.203	18.37
24	746.7	0.781	0.22	19.35
25	728.55	0.736	0.262	24.09
26	248.2	0.886	0.111	12.17
27	162.96	0.904	0.097	11.98
28	1371.53	0.612	0.375	35.4
29	1729.44	0.495	0.495	51.05
30	1143.43	0.708	0.292	25.1
31	156.02	0.905	0.095	11.27
32	360.75	0.866	0.134	14.42
33	123.85	0.906	0.095	10.92
34	294.23	0.88	0.12	13.49
35	669.43	0.792	0.207	19.69
36	142.24	0.91	0.091	10.95
37	1998.08	0.531	0.459	45.68
38	1493.07	0.622	0.369	35.08
39	1285.61	0.603	0.394	37.37
40	123.43	0.925	0.075	9.73
41	1404.83	0.656	0.333	32.49
42	1070.45	0.695	0.298	29.03
43	194.02	0.895	0.105	13.02
44	1691.46	0.511	0.477	45.84
45	1286.69	0.648	0.351	33.33
46	1784.77	0.516	0.473	46.39
47	832.74	0.719	0.281	24.43
48	87.33	0.935	0.066	8.03
49	1181.55	0.69	0.299	28.53
50	780.59	0.764	0.237	21.45

Table 1.1. Results of La-AODV and AODV for Pause time = 0

AODV

	E2E	PDF	DRP	OVR
1	1729.98	0.521	0.47	44.12
2	120.98	0.918	0.083	9.74
3	627.34	0.774	0.226	20.01
4	832.8	0.659	0.33	27.69
5	118.57	0.912	0.088	10.79
6	226.07	0.9	0.101	11.5
7	1474.96	0.602	0.384	34.84
8	960.94	0.682	0.311	26.89
9	1308.49	0.659	0.334	29.87
10	1312.18	0.6	0.39	35.44
11	160.32	0.906	0.094	11.75
12	1417.17	0.631	0.362	31.01
13	115.03	0.918	0.083	10
14	807.66	0.761	0.239	23.71
15	976.8	0.689	0.303	26.82
16	1859.32	0.568	0.422	39.1
17	1315.91	0.588	0.403	38.5
18	178.08	0.892	0.108	11.98
19	1837.5	0.589	0.411	39.26
20	148.83	0.907	0.094	11.62
21	479.94	0.8	0.201	18.22
22	1180.74	0.654	0.332	29.6
23	164.01	0.903	0.098	12.1
24	376.41	0.856	0.144	15.18
25	627.02	0.816	0.184	17.94
26	1200.95	0.594	0.395	35.67
27	205.5	0.888	0.113	13.41
28	704.96	0.771	0.23	21.73
29	112.43	0.923	0.078	9.51
30	572.27	0.827	0.173	15.86
31	1655.47	0.611	0.379	38.53
32	1776.3	0.567	0.43	39.02
33	801.08	0.691	0.298	26.19
34	710.27	0.784	0.216	18.65
35	107.79	0.92	0.08	10.12
36	1743.91	0.518	0.468	46.7
37	176.19	0.904	0.096	12.09
38	183.67	0.905	0.096	11.44
39	238.83	0.864	0.127	12.35
40	115.02	0.925	0.076	10.17
41	165.3	0.907	0.094	11.8
42	1057.82	0.635	0.355	30.55
43	407.03	0.834	0.166	15.27
44	165.4	0.908	0.091	10.75
45	84.07	0.946	0.055	7.25
46	133.78	0.925	0.075	9.83
47	338.9	0.821	0.171	15.21
48	140.43	0.907	0.093	11.4
49	154.41	0.911	0.09	10.64
50	271.57	0.882	0.119	13.31

La-AODV

	E2E	PDF	DRP	OVR
1	1160.65	0.658	0.327	29.08
2	115.77	0.922	0.079	9.49
3	799.98	0.78	0.22	20.58
4	821.39	0.722	0.273	24.26
5	159.26	0.908	0.089	10.79
6	136.26	0.923	0.077	9.14
7	1457.67	0.629	0.36	31.56
8	998.22	0.66	0.334	27.74
9	1109.23	0.665	0.322	29.55
10	1051.25	0.669	0.319	27.5
11	176.99	0.901	0.099	12.51
12	809.31	0.706	0.287	24.88
13	117.82	0.927	0.074	9.21
14	418.78	0.853	0.148	16.84
15	264.95	0.884	0.115	13.44
16	1033.27	0.745	0.254	23
17	1254.71	0.572	0.418	39.06
18	147.46	0.904	0.097	11.41
19	739.64	0.761	0.239	22.32
20	209.36	0.903	0.098	12.34
21	270.22	0.876	0.124	13.05
22	223.11	0.882	0.119	13.6
23	342.41	0.862	0.139	14.99
24	193.29	0.887	0.11	12.79
25	825.85	0.744	0.25	21.76
26	1175.45	0.634	0.356	32.74
27	208.11	0.904	0.097	11.71
28	1162.9	0.7	0.3	28.44
29	139.85	0.917	0.084	10.35
30	140.02	0.918	0.082	10.23
31	859.87	0.768	0.232	24.48
32	199.68	0.884	0.116	13.64
33	530.32	0.754	0.235	22.2
34	285.19	0.875	0.125	13.1
35	146.9	0.906	0.094	11.34
36	975.1	0.668	0.331	28.35
37	125.1	0.913	0.087	10.99
38	192.36	0.895	0.105	12.01
39	128.83	0.915	0.086	10.58
40	137.24	0.913	0.088	11.23
41	128.95	0.908	0.093	11.6
42	180.42	0.898	0.099	12
43	179	0.898	0.103	12.02
44	180.53	0.914	0.086	10.35
45	80.28	0.947	0.054	7.02
46	96.5	0.931	0.07	9.34
47	136.02	0.924	0.077	9.43
48	148.41	0.905	0.096	11.54
49	168.55	0.915	0.086	10.4
50	188.75	0.901	0.1	12.6

Table 1.2. Results of La-AODV and AODV for Pause time = 5

AODV

	E2E	PDF	DRP	OVR
1	1064.27	0.702	0.297	26.85
2	133	0.911	0.08	11.24
3	179.48	0.905	0.094	11.19
4	331.19	0.859	0.141	16.14
5	632.72	0.81	0.184	18.89
6	118.05	0.921	0.07	9.97
7	613.69	0.79	0.207	19.63
8	419.67	0.782	0.207	18.98
9	1000.65	0.634	0.359	33.11
10	1546.24	0.629	0.37	33.81
11	648.95	0.771	0.229	20.3
12	119.77	0.924	0.075	10.02
13	156.28	0.906	0.094	11.72
14	264.49	0.864	0.13	14.04
15	141.05	0.903	0.101	11.72
16	118.99	0.924	0.078	10.03
17	323.64	0.863	0.137	15.08
18	352.35	0.858	0.142	15.31
19	1877.06	0.574	0.412	38.13
20	1159.12	0.674	0.327	29.38
21	202.83	0.903	0.097	11.23
22	1023.22	0.68	0.318	28.14
23	513.69	0.814	0.178	17.26
24	673.43	0.754	0.245	23.36
25	235	0.877	0.12	14.1
26	857.84	0.729	0.266	24.56
27	787.88	0.777	0.222	20.1
28	105.34	0.928	0.073	9.25
29	169.81	0.894	0.106	12.83
30	1297.6	0.641	0.355	31.36
31	677.2	0.716	0.274	23.46
32	994.56	0.711	0.288	25.67
33	1544.7	0.583	0.415	36.75
34	95.36	0.931	0.07	8.95
35	127.31	0.913	0.087	11.13
36	1547.52	0.587	0.406	35.45
37	138.26	0.917	0.08	9.89
38	926.34	0.701	0.286	27.17
39	144.43	0.909	0.091	11.32
40	301.42	0.867	0.134	14.47
41	1316.38	0.622	0.376	34.27
42	698.81	0.748	0.242	22.43
43	386.98	0.86	0.139	14.47
44	731.3	0.77	0.23	20.34
45	1038.08	0.646	0.343	30.98
46	550.62	0.823	0.178	18.46
47	950.15	0.72	0.276	27.22
48	1341.69	0.676	0.323	29.69
49	115.78	0.922	0.078	10.02
50	1170.98	0.727	0.273	24.93

La-AODV

	E2E	PDF	DRP	OVR
1	227.09	0.885	0.115	14.09
2	107.34	0.926	0.074	9.61
3	147.73	0.913	0.087	10.78
4	364.46	0.844	0.141	16.42
5	455.25	0.839	0.157	17.16
6	282.14	0.893	0.118	12.82
7	438.15	0.813	0.184	18.72
8	460.45	0.776	0.214	19.53
9	936.82	0.708	0.293	26.94
10	115.69	0.923	0.076	9.6
11	790.49	0.773	0.226	20.86
12	112.11	0.929	0.072	9.32
13	217.16	0.896	0.103	11.85
14	256	0.859	0.133	15.04
15	143.64	0.909	0.092	11.49
16	106.83	0.931	0.069	9.14
17	198.79	0.886	0.114	13.62
18	148.73	0.914	0.087	11.15
19	1092.06	0.725	0.27	26.64
20	1242	0.673	0.328	30.68
21	130.52	0.917	0.083	9.68
22	783.5	0.726	0.273	25.27
23	494.97	0.808	0.183	18.06
24	511.26	0.789	0.202	21.09
25	184.4	0.893	0.108	12.59
26	334.52	0.831	0.161	16.82
27	198.6	0.889	0.111	12.88
28	150.44	0.917	0.084	10.56
29	147.38	0.894	0.106	12.86
30	445.2	0.821	0.18	17.46
31	632.5	0.764	0.229	20.28
32	764.61	0.728	0.273	23.28
33	1242.88	0.613	0.385	34.5
34	91.46	0.94	0.06	7.68
35	115.54	0.907	0.093	11.06
36	1466.83	0.637	0.352	30.34
37	110.12	0.915	0.085	9.92
38	206.86	0.887	0.112	13.07
39	197.85	0.905	0.095	11.88
40	195.95	0.892	0.108	12.36
41	1141.27	0.691	0.31	28.18
42	369.85	0.863	0.138	15.25
43	128.27	0.913	0.087	9.98
44	654.79	0.782	0.211	19.72
45	614.86	0.77	0.221	21.86
46	133.66	0.9	0.101	11.81
47	273.33	0.879	0.12	14.5
48	914.89	0.701	0.292	25.87
49	122.67	0.918	0.083	10.26
50	335.2	0.872	0.129	13.74

Table 1.3. Results of La-AODV and AODV for Pause time = 10

AODV

	E2E	PDF	DRP	OVR
1	1173.03	0.713	0.287	26.89
2	314.64	0.879	0.121	13.57
3	1273.56	0.662	0.33	30.42
4	306.27	0.866	0.13	14.53
5	100.38	0.94	0.06	8.2
6	733.6	0.802	0.197	19.93
7	97.53	0.929	0.071	9.22
8	495.12	0.821	0.18	17.66
9	204.93	0.893	0.108	12.32
10	103.45	0.93	0.071	8.9
11	531.03	0.803	0.19	20.02
12	422.79	0.834	0.167	17.3
13	1366.72	0.598	0.393	36.41
14	119.81	0.925	0.076	9.07
15	560.18	0.806	0.187	18.92
16	129.21	0.912	0.087	10.53
17	132.38	0.912	0.088	10.62
18	717.28	0.789	0.211	20.33
19	929.31	0.705	0.295	26.35
20	893.12	0.772	0.229	20.9
21	79.59	0.939	0.062	7.75
22	1612.52	0.625	0.368	35.55
23	425.72	0.828	0.172	16.7
24	431.24	0.84	0.16	15.9
25	156.05	0.915	0.083	10.37
26	136.35	0.903	0.098	12
27	189.04	0.902	0.099	11.51
28	2015.56	0.527	0.462	44.98
29	920.83	0.748	0.251	22.94
30	753.72	0.809	0.191	16.75
31	470.81	0.807	0.187	16.66
32	654.09	0.788	0.21	19.1
33	1684.51	0.585	0.405	37.83
34	1097.12	0.634	0.354	30.93
35	172.19	0.906	0.093	11.4
36	196.27	0.906	0.094	11.27
37	1656.44	0.548	0.437	41.82
38	400.14	0.83	0.164	16.21
39	144.61	0.907	0.094	11.28
40	1175.35	0.656	0.338	31.03
41	2037.28	0.528	0.464	44.67
42	811.72	0.733	0.268	22.58
43	102.67	0.927	0.074	9.25
44	170.3	0.904	0.097	12.43
45	348.72	0.863	0.129	14.36
46	539.85	0.782	0.218	18.31
47	123.04	0.907	0.094	11.52
48	407.42	0.81	0.183	19.06
49	142.55	0.908	0.092	11.21
50	376.9	0.858	0.142	14.61

La-AODV

	E2E	PDF	DRP	OVR
1	624.94	0.827	0.173	16.87
2	133.55	0.912	0.088	10.75
3	373.1	0.833	0.158	16.17
4	129.01	0.907	0.093	11.43
5	103.52	0.936	0.065	8.54
6	539.16	0.813	0.181	17.14
7	109.45	0.928	0.073	9.34
8	183.19	0.899	0.102	12.06
9	130.31	0.91	0.091	11
10	106.22	0.929	0.071	8.8
11	704.83	0.774	0.225	21.33
12	422.87	0.852	0.149	16.19
13	1187.98	0.647	0.347	31.57
14	106.89	0.924	0.077	9.53
15	313.12	0.877	0.123	14.5
16	117.27	0.922	0.079	9.32
17	222.03	0.896	0.105	12.88
18	151.43	0.906	0.096	11.83
19	294.63	0.865	0.136	15.15
20	822.67	0.776	0.225	20.53
21	84.39	0.937	0.064	7.9
22	1142.12	0.684	0.308	29.34
23	378.51	0.848	0.149	16.35
24	185.02	0.897	0.103	12.58
25	191.98	0.916	0.085	10.64
26	549.04	0.805	0.187	18.18
27	209.42	0.9	0.101	12.13
28	663.1	0.819	0.182	19.49
29	719.03	0.777	0.223	20.17
30	110.87	0.924	0.077	9.15
31	364.28	0.82	0.172	16.27
32	320.65	0.877	0.122	14.47
33	1342.54	0.652	0.347	31.15
34	684.95	0.734	0.255	22.5
35	120.37	0.916	0.084	10.06
36	168.06	0.903	0.098	11.58
37	1182.64	0.638	0.348	30.25
38	137.32	0.906	0.095	11.71
39	167.53	0.899	0.102	11.98
40	804.59	0.781	0.22	21.6
41	655.63	0.807	0.193	19.45
42	216.6	0.903	0.098	11.29
43	120.97	0.929	0.072	8.96
44	217.43	0.897	0.102	12.34
45	243.29	0.881	0.112	12.59
46	447.34	0.839	0.161	15.63
47	118.9	0.914	0.087	10.64
48	284.98	0.841	0.15	16.23
49	119.93	0.912	0.089	10.77
50	158.85	0.914	0.087	10.7

Table 1.4. Results of La-AODV and AODV for Pause time = 15

AODV

	E2E	PDF	DRP	OVR
1	731.03	0.73	0.258	23.41
2	841.79	0.703	0.289	27.15
3	157.45	0.909	0.092	11.31
4	136.36	0.91	0.091	11.35
5	156.97	0.903	0.097	11.44
6	157.12	0.904	0.096	12.23
7	613.95	0.796	0.194	20.12
8	134.74	0.919	0.081	10.55
9	162.44	0.912	0.089	10.97
10	129.49	0.916	0.085	9.84
11	185.67	0.893	0.107	13.28
12	1740.47	0.576	0.422	42.64
13	192.96	0.909	0.092	10.57
14	1492.82	0.579	0.412	40.22
15	609.35	0.804	0.197	18.45
16	220.6	0.9	0.1	12.04
17	160.28	0.913	0.088	11.12
18	416.34	0.849	0.151	16.04
19	944.95	0.714	0.276	26.24
20	135.41	0.92	0.081	10.09
21	131.49	0.917	0.084	10.15
22	1508.3	0.544	0.442	43.47
23	437.84	0.831	0.168	15.9
24	1752.48	0.58	0.417	37.2
25	1900.51	0.537	0.462	42.85
26	1872.72	0.586	0.405	38.41
27	1225.69	0.607	0.393	35.65
28	140.33	0.924	0.076	10
29	158.69	0.909	0.092	10.91
30	136.01	0.925	0.076	9.72
31	1457.82	0.636	0.364	32.63
32	164.94	0.906	0.095	11.46
33	134.84	0.913	0.087	10.73
34	1177.86	0.651	0.339	28.62
35	596.63	0.75	0.25	19.69
36	1134.47	0.676	0.316	29.21
37	140.37	0.931	0.069	8.65
38	114.11	0.914	0.087	10.81
39	165.31	0.915	0.086	11.06
40	601.77	0.762	0.229	18.73
41	532.55	0.832	0.167	16.47
42	113.64	0.93	0.071	9.64
43	685.33	0.753	0.239	22.33
44	962.24	0.705	0.294	24.68
45	412.79	0.85	0.15	16.57
46	235.55	0.892	0.107	11.75
47	86.87	0.931	0.07	8.42
48	1419.85	0.637	0.351	33.38
49	93.69	0.938	0.063	8.13
50	531.07	0.791	0.204	20.6

La-AODV

	E2E	PDF	DRP	OVR
1	735.24	0.745	0.246	23.15
2	310.95	0.861	0.138	16.01
3	216.94	0.894	0.106	12.19
4	140.3	0.916	0.084	10.47
5	208.91	0.905	0.096	11.51
6	318.92	0.88	0.121	14.08
7	348.58	0.837	0.15	14.92
8	178.78	0.925	0.076	10.31
9	118.75	0.919	0.081	10.25
10	160.34	0.915	0.086	9.83
11	148.73	0.901	0.097	11.81
12	1295.33	0.67	0.33	31.9
13	133.56	0.922	0.079	10.04
14	698.35	0.722	0.268	25.04
15	290	0.886	0.115	13.6
16	162.65	0.902	0.099	11.87
17	186.77	0.91	0.091	11.88
18	148.77	0.907	0.094	11.65
19	1047.15	0.69	0.302	27.77
20	433.95	0.868	0.132	13.98
21	133.05	0.92	0.081	9.91
22	1119.47	0.637	0.352	32.57
23	136.15	0.912	0.086	10.52
24	135.77	0.912	0.089	10.81
25	695.42	0.779	0.22	20.94
26	1007.34	0.69	0.302	27.32
27	709.24	0.759	0.241	20.89
28	171.15	0.911	0.09	10.9
29	184.65	0.905	0.096	11.31
30	204.8	0.891	0.102	11.62
31	208.02	0.885	0.115	14.12
32	208.63	0.891	0.109	12.39
33	147.42	0.918	0.082	10.19
34	985.89	0.711	0.278	23.22
35	198	0.89	0.111	12.86
36	607.91	0.783	0.215	20.68
37	103.75	0.93	0.071	8.8
38	133.81	0.912	0.089	10.99
39	146.51	0.919	0.082	10.6
40	105.06	0.934	0.067	8.65
41	469.11	0.848	0.15	15.33
42	106.4	0.932	0.069	9.11
43	192.44	0.898	0.103	12.61
44	962.19	0.763	0.237	21.4
45	333.79	0.859	0.133	15.13
46	307.42	0.886	0.113	12.2
47	128.99	0.925	0.076	9.08
48	1133.47	0.683	0.308	29.4
49	101.41	0.929	0.071	8.93
50	212.53	0.874	0.127	15.42

Table 1.5. Results of La-AODV and AODV for Pause time = 20

AODV

	E2E	PDF	DRP	OVR
1	419.56	0.826	0.166	16.2
2	646.46	0.776	0.215	21.42
3	462.17	0.809	0.181	17.45
4	954.2	0.741	0.254	23.77
5	137.82	0.917	0.083	10.23
6	1334.92	0.678	0.321	28.91
7	1475.84	0.627	0.371	32.82
8	1407.6	0.595	0.405	36
9	125.8	0.918	0.082	10.09
10	366.02	0.836	0.158	17.05
11	121.36	0.927	0.074	9.36
12	198.27	0.903	0.098	11.99
13	310.55	0.882	0.119	13.31
14	418.14	0.802	0.191	19.08
15	133.22	0.918	0.083	10.62
16	996.33	0.724	0.271	25.35
17	1495.09	0.552	0.438	40.29
18	154.21	0.906	0.095	11.1
19	84.57	0.936	0.064	7.82
20	283.33	0.871	0.121	14.08
21	119.64	0.918	0.083	10.22
22	330.76	0.877	0.123	12.58
23	575.14	0.822	0.178	17.25
24	119.82	0.925	0.076	9.4
25	294.7	0.879	0.121	14.39
26	873.55	0.74	0.258	24.12
27	153.79	0.915	0.086	10.3
28	1372.56	0.511	0.475	46.86
29	1926.37	0.55	0.442	43.26
30	176.62	0.894	0.105	13.2
31	752.33	0.715	0.275	24.89
32	289.84	0.863	0.138	15.15
33	1542.53	0.527	0.461	43.6
34	744.67	0.745	0.256	21.37
35	140.51	0.9	0.1	11.92
36	734.58	0.715	0.275	25.05
37	93.77	0.924	0.077	9.24
38	407.37	0.846	0.152	15.82
39	140.9	0.906	0.095	11.42
40	574.4	0.784	0.215	19.89
41	199.32	0.896	0.105	12.48
42	645.8	0.805	0.193	20.7
43	115.85	0.922	0.079	9.82
44	145.45	0.916	0.085	10.92
45	365.44	0.85	0.149	16.07
46	595.68	0.829	0.172	16.12
47	97.15	0.93	0.071	8.81
48	829.6	0.734	0.266	22.77
49	142.25	0.908	0.092	11.54
50	154.69	0.909	0.092	11.35

La-AODV

	E2E	PDF	DRP	OVR
1	117.3	0.913	0.088	10.46
2	160.91	0.896	0.105	12.72
3	388.94	0.807	0.182	17.33
4	700.02	0.771	0.228	20.45
5	155.33	0.918	0.083	9.99
6	357.22	0.862	0.139	15.6
7	415.62	0.864	0.135	14.26
8	884.25	0.679	0.322	28.26
9	242.74	0.89	0.111	12.37
10	312.81	0.867	0.134	15.61
11	70.53	0.942	0.059	7.4
12	155.74	0.909	0.092	11.06
13	204.06	0.894	0.107	11.82
14	309.08	0.857	0.143	15.83
15	125.68	0.926	0.075	9.48
16	556.11	0.812	0.189	17.75
17	1009.12	0.681	0.311	28.9
18	114.65	0.924	0.077	9.29
19	122.05	0.936	0.064	8.09
20	187.9	0.889	0.11	12.93
21	163.25	0.914	0.086	10.52
22	116.75	0.921	0.079	9.66
23	273.29	0.882	0.119	13.52
24	128.17	0.923	0.078	9.67
25	285.16	0.882	0.119	13.6
26	127.26	0.917	0.083	10.68
27	228.65	0.902	0.099	11.9
28	1275.07	0.616	0.374	33.97
29	880.05	0.73	0.264	24.59
30	170.89	0.902	0.094	12.09
31	512.02	0.816	0.179	18.88
32	293.38	0.873	0.127	14.24
33	547.43	0.818	0.182	17.98
34	654.98	0.769	0.23	18.96
35	192.58	0.901	0.1	12.2
36	658.59	0.755	0.237	23.18
37	120.3	0.924	0.078	9.59
38	187.77	0.895	0.105	12.43
39	296.36	0.862	0.135	13.43
40	539.6	0.836	0.164	16.04
41	164.2	0.912	0.084	10.69
42	342.79	0.852	0.14	15.45
43	145.26	0.916	0.084	10.3
44	110.93	0.919	0.081	9.98
45	186.47	0.895	0.106	12.68
46	194.32	0.906	0.095	11.57
47	98	0.937	0.063	8.31
48	213.24	0.897	0.104	12.27
49	107.13	0.917	0.085	10.22
50	211.9	0.9	0.1	11.44

Table 1.6. Results of La-AODV and AODV for Pause time = 25

B - Additional results - LA-DSDV

DSDV

	E2E	PDF	DRP	OVR
1	374.71	0.69	0.309	2.65
2	487.34	0.726	0.272	2.24
3	217.1	0.65	0.349	2.79
4	382.38	0.654	0.343	2.92
5	347.51	0.638	0.359	2.94
6	536.33	0.668	0.331	2.64
7	390.6	0.656	0.342	2.86
8	339.83	0.705	0.293	2.46
9	387.79	0.65	0.348	2.82
10	412.74	0.687	0.311	2.66
11	583.67	0.659	0.339	2.93
12	373.68	0.69	0.308	2.7
13	263.09	0.685	0.313	2.65
14	476.82	0.664	0.333	2.98
15	462.42	0.638	0.36	2.9
16	343.91	0.665	0.333	2.92
17	406.26	0.654	0.344	2.95
18	453.78	0.694	0.304	2.58
19	341.4	0.684	0.314	2.7
20	360.33	0.677	0.321	2.74
21	351.54	0.678	0.32	2.62
22	374.31	0.685	0.313	2.72
23	248.43	0.691	0.308	2.75
24	357.76	0.678	0.32	2.75
25	565.6	0.654	0.344	2.86
26	212.49	0.687	0.311	2.72
27	272.52	0.648	0.35	3.06
28	360.18	0.64	0.357	3.12
29	411.8	0.681	0.317	2.77
30	249.9	0.717	0.282	2.56
31	275.45	0.675	0.323	2.65
32	336.81	0.639	0.359	2.95
33	213.69	0.69	0.309	2.58
34	344.55	0.688	0.311	2.68
35	337.28	0.694	0.304	2.51
36	454.8	0.681	0.318	2.68
37	278.65	0.711	0.287	2.39
38	379.04	0.705	0.294	2.47
39	177.33	0.718	0.28	2.38
40	408.08	0.656	0.341	2.93
41	450.03	0.689	0.31	2.61
42	370.87	0.639	0.359	3.06
43	438.5	0.702	0.296	2.55
44	429.53	0.686	0.312	2.7
45	268.44	0.71	0.288	2.59
46	463.69	0.67	0.327	2.87
47	347.68	0.687	0.311	2.65
48	413.98	0.683	0.316	2.72
49	522.78	0.678	0.32	2.69
50	278.96	0.759	0.24	2.23

ns-DSDV

	E2E	PDF	DRP	OVR
1	2192.76	0.693	0.296	3.3
2	1220.78	0.711	0.281	3.42
3	943.74	0.721	0.274	3.25
4	739.93	0.685	0.308	3.34
5	652.46	0.692	0.306	3.46
6	647.23	0.701	0.295	3.43
7	629.76	0.689	0.307	3.48
8	1191	0.681	0.307	3.48
9	760.18	0.666	0.327	3.6
10	601.36	0.695	0.302	3.41
11	994.63	0.67	0.323	3.59
12	563.84	0.73	0.267	3.34
13	520.94	0.703	0.293	3.37
14	629.38	0.748	0.249	3.23
15	947.06	0.696	0.299	3.36
16	604.42	0.687	0.311	3.51
17	567.74	0.729	0.268	3.23
18	663.56	0.71	0.286	3.33
19	1105.93	0.744	0.252	3.09
20	497.58	0.759	0.239	3.13
21	1041.28	0.678	0.318	3.5
22	722.03	0.711	0.286	3.26
23	599.45	0.73	0.267	3.25
24	962.51	0.684	0.308	3.33
25	1107.58	0.68	0.308	3.53
26	486.92	0.719	0.278	3.33
27	755.24	0.721	0.276	3.43
28	933.41	0.716	0.279	3.26
29	842.18	0.722	0.275	3.33
30	643.24	0.742	0.254	3.05
31	679.47	0.715	0.28	3.28
32	793.41	0.695	0.298	3.37
33	840.71	0.65	0.34	3.66
34	619.17	0.687	0.308	3.42
35	911.91	0.724	0.27	3.29
36	579.85	0.699	0.298	3.4
37	1119.39	0.702	0.292	3.25
38	528.76	0.721	0.274	3.21
39	919.39	0.729	0.267	3.15
40	725.73	0.71	0.285	3.4
41	893.6	0.685	0.31	3.43
42	648.03	0.7	0.298	3.59
43	1303.67	0.678	0.31	3.46
44	539.25	0.743	0.254	3.21
45	1346.04	0.708	0.281	3.4
46	430.31	0.716	0.281	3.36
47	916.94	0.674	0.322	3.5
48	915.46	0.698	0.295	3.44
49	774.78	0.693	0.303	3.49
50	499.31	0.709	0.289	3.44

La-DSDV

	E2E	PDF	DRP	OVR
1	519.75	0.722	0.272	2.74
2	596.97	0.7	0.291	2.93
3	622.07	0.706	0.289	2.85
4	441.77	0.731	0.267	2.28
5	388	0.756	0.237	2.5
6	398.29	0.717	0.279	2.7
7	176.88	0.739	0.259	2.57
8	500.75	0.7	0.297	2.86
9	654.29	0.692	0.306	2.99
10	469.22	0.701	0.297	2.78
11	432.41	0.7	0.296	2.71
12	395.47	0.71	0.288	3.08
13	460.59	0.665	0.33	3.02
14	424.24	0.699	0.298	2.89
15	784.37	0.695	0.303	2.91
16	345.38	0.718	0.279	2.64
17	521.15	0.701	0.295	2.95
18	332.94	0.759	0.239	2.32
19	434.36	0.699	0.3	2.74
20	486.84	0.692	0.305	2.84
21	150.29	0.734	0.264	2.37
22	370.77	0.7	0.297	2.94
23	503.74	0.704	0.292	3.01
24	314.63	0.732	0.265	2.48
25	385.24	0.706	0.291	2.76
26	381.62	0.744	0.252	2.7
27	301.63	0.733	0.266	2.34
28	472.51	0.719	0.278	2.75
29	255.91	0.748	0.251	2.36
30	351.22	0.724	0.275	2.6
31	233.71	0.709	0.289	2.58
32	417.21	0.681	0.315	3.09
33	236.39	0.752	0.246	2.31
34	552.99	0.713	0.283	2.85
35	588.68	0.699	0.296	2.96
36	441.49	0.648	0.35	2.93
37	363.77	0.713	0.283	2.62
38	367	0.743	0.255	2.44
39	518.91	0.696	0.301	2.96
40	267.43	0.725	0.273	2.48
41	168.38	0.693	0.304	2.75
42	373.63	0.722	0.277	2.4
43	279.02	0.73	0.269	2.48
44	387.97	0.726	0.274	2.47
45	653.64	0.672	0.324	3.2
46	460.69	0.709	0.289	2.61
47	472.08	0.657	0.34	3.09
48	339.22	0.715	0.284	2.56
49	500.1	0.703	0.294	2.86
50	501.92	0.729	0.267	2.84

Table 2.1. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 0

DSDV

	E2E	PDF	DRP	OVR
1	455.76	0.674	0.324	2.86
2	441.48	0.667	0.331	2.87
3	270.12	0.69	0.307	2.63
4	467.19	0.656	0.341	2.81
5	309.25	0.691	0.307	2.48
6	292.86	0.695	0.303	2.64
7	246.07	0.693	0.306	2.57
8	404.58	0.645	0.353	2.9
9	235.41	0.712	0.285	2.44
10	447.85	0.671	0.327	2.78
11	147.69	0.734	0.265	2.52
12	339.78	0.675	0.324	2.75
13	355.85	0.698	0.301	2.7
14	360.89	0.637	0.361	2.97
15	493.2	0.692	0.306	2.81
16	386.26	0.699	0.3	2.62
17	426.64	0.665	0.333	3.02
18	305.08	0.676	0.323	2.75
19	596.63	0.68	0.318	2.85
20	233.44	0.681	0.318	2.68
21	375.9	0.692	0.307	2.61
22	381.23	0.679	0.319	2.67
23	269.3	0.714	0.284	2.58
24	280.48	0.67	0.329	2.74
25	393.2	0.687	0.311	2.76
26	298.22	0.726	0.272	2.45
27	293.17	0.69	0.308	2.63
28	483.61	0.668	0.33	2.89
29	516.19	0.616	0.381	3.25
30	399.24	0.673	0.325	2.8
31	380.07	0.719	0.278	2.57
32	543.43	0.609	0.388	3.28
33	388.27	0.715	0.284	2.45
34	370.02	0.693	0.305	2.72
35	344.94	0.645	0.353	2.92
36	407.5	0.75	0.249	2.3
37	209.57	0.734	0.265	2.35
38	228.6	0.698	0.301	2.51
39	339.51	0.66	0.338	2.86
40	421.87	0.681	0.317	2.76
41	418.73	0.685	0.314	2.63
42	535.37	0.674	0.324	2.78
43	451.74	0.647	0.351	2.94
44	342.39	0.659	0.339	2.92
45	282.87	0.7	0.299	2.66
46	442.72	0.681	0.317	2.85
47	496.07	0.668	0.33	2.9
48	236.7	0.731	0.267	2.39
49	356.54	0.653	0.344	3
50	218.94	0.666	0.332	2.89

ns-DSDV

	E2E	PDF	DRP	OVR
1	596.6	0.715	0.282	3.41
2	753.55	0.717	0.278	3.38
3	932.7	0.674	0.322	3.63
4	1050.68	0.697	0.297	3.39
5	552.07	0.716	0.28	3.35
6	571.48	0.717	0.279	3.38
7	599.11	0.718	0.279	3.4
8	1234.87	0.688	0.304	3.38
9	1122.05	0.686	0.309	3.46
10	412.75	0.742	0.254	3.25
11	633.28	0.712	0.285	3.38
12	815.09	0.711	0.284	3.4
13	1512.68	0.705	0.288	3.34
14	956.18	0.664	0.33	3.64
15	1390.37	0.71	0.28	3.3
16	975.82	0.716	0.28	3.37
17	525.46	0.73	0.267	3.28
18	509.11	0.715	0.28	3.41
19	723.66	0.736	0.258	3.17
20	1605.3	0.684	0.309	3.52
21	613.28	0.727	0.27	3.35
22	822.83	0.669	0.328	3.61
23	537.65	0.731	0.266	3.27
24	1017.68	0.704	0.291	3.38
25	794.45	0.697	0.296	3.41
26	725.81	0.713	0.282	3.41
27	397.15	0.76	0.237	3.12
28	596.78	0.717	0.281	3.45
29	654.3	0.699	0.297	3.5
30	619.5	0.708	0.288	3.39
31	720.38	0.678	0.317	3.63
32	553.2	0.726	0.271	3.28
33	1859.94	0.644	0.35	3.77
34	913.23	0.71	0.284	3.39
35	843.27	0.736	0.26	3.18
36	736.38	0.716	0.279	3.31
37	635.2	0.716	0.281	3.33
38	987.7	0.711	0.281	3.38
39	659.88	0.704	0.293	3.41
40	961.04	0.659	0.335	3.73
41	635.47	0.707	0.29	3.44
42	554.48	0.742	0.255	3.27
43	716.87	0.738	0.258	3.29
44	766.55	0.729	0.267	3.36
45	566.03	0.749	0.247	3.11
46	793.81	0.727	0.268	3.21
47	626.43	0.728	0.27	3.37
48	746.35	0.707	0.285	3.41
49	649.7	0.711	0.286	3.35
50	450.39	0.719	0.278	3.31

La-DSDV

	E2E	PDF	DRP	OVR
1	601.8	0.693	0.305	3.03
2	395.8	0.695	0.301	2.97
3	457.85	0.704	0.292	2.79
4	339.69	0.707	0.291	2.46
5	309.29	0.728	0.27	2.6
6	327.16	0.71	0.289	2.62
7	297.22	0.722	0.276	2.69
8	227.59	0.743	0.255	2.63
9	425.35	0.722	0.275	2.69
10	243.73	0.708	0.291	2.46
11	400.21	0.695	0.303	2.8
12	352.37	0.737	0.262	2.57
13	294.56	0.703	0.293	2.86
14	362.56	0.702	0.296	2.78
15	497.22	0.721	0.274	2.9
16	438.83	0.737	0.26	2.61
17	441.98	0.714	0.283	2.58
18	672.82	0.706	0.288	2.82
19	229.51	0.741	0.257	2.57
20	338.78	0.738	0.259	2.67
21	454.59	0.692	0.303	2.99
22	350.44	0.699	0.3	2.71
23	524.49	0.679	0.317	3.26
24	336.94	0.748	0.249	2.57
25	265.54	0.708	0.29	2.79
26	533.97	0.706	0.292	2.87
27	185.76	0.697	0.301	2.71
28	286.41	0.693	0.304	2.75
29	268.84	0.769	0.23	2.21
30	403.51	0.737	0.262	2.51
31	378.85	0.737	0.26	2.62
32	469.15	0.682	0.311	3.01
33	483.34	0.707	0.29	2.99
34	384.05	0.726	0.273	2.55
35	368.87	0.714	0.283	2.8
36	336.58	0.682	0.316	2.9
37	317.21	0.735	0.263	2.65
38	370.22	0.727	0.272	2.52
39	416.55	0.702	0.295	2.81
40	259.68	0.756	0.243	2.4
41	333.11	0.734	0.265	2.4
42	221.51	0.726	0.272	2.56
43	334.39	0.686	0.31	2.96
44	364.82	0.704	0.295	2.67
45	434.34	0.692	0.306	3.01
46	337.1	0.702	0.296	2.73
47	406.3	0.714	0.282	3.09
48	239.73	0.724	0.274	2.45
49	320.58	0.748	0.249	2.6
50	512.03	0.687	0.31	3.17

Table 2.2. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 5

DSDV

	E2E	PDF	DRP	OVR
1	461.69	0.687	0.312	2.73
2	402.14	0.661	0.336	2.82
3	464.39	0.626	0.372	3.16
4	516.69	0.695	0.304	2.5
5	549.76	0.643	0.355	2.96
6	318.91	0.658	0.341	2.89
7	408.3	0.701	0.297	2.7
8	341.07	0.661	0.338	2.85
9	299.51	0.701	0.298	2.36
10	321.56	0.735	0.263	2.48
11	453.64	0.694	0.305	2.76
12	386.35	0.7	0.299	2.62
13	510.43	0.62	0.378	3.11
14	296.73	0.689	0.309	2.67
15	327.37	0.674	0.325	2.9
16	319.51	0.702	0.297	2.54
17	325.26	0.639	0.359	3.24
18	175.16	0.759	0.24	2.32
19	423.83	0.659	0.339	2.98
20	312.09	0.678	0.321	2.66
21	115.02	0.74	0.259	2.5
22	423.27	0.646	0.353	3.03
23	570.94	0.664	0.334	2.9
24	320.66	0.706	0.292	2.6
25	431.79	0.618	0.38	3.19
26	360.09	0.652	0.346	3.03
27	453.86	0.678	0.32	2.77
28	288.22	0.701	0.298	2.71
29	187.8	0.704	0.294	2.65
30	494.02	0.614	0.384	3.27
31	182.36	0.737	0.263	2.22
32	398.43	0.681	0.317	2.79
33	384.81	0.681	0.317	2.72
34	463.74	0.691	0.308	2.64
35	443.95	0.618	0.38	3.1
36	369.4	0.686	0.312	2.59
37	319.68	0.697	0.301	2.65
38	314.14	0.66	0.339	2.85
39	454.55	0.691	0.307	2.65
40	272.06	0.643	0.355	3
41	408.85	0.692	0.306	2.69
42	352.51	0.677	0.322	2.79
43	339.22	0.613	0.385	3.37
44	242.51	0.682	0.316	2.74
45	210.3	0.754	0.245	2.17
46	432.68	0.639	0.359	3.05
47	205.8	0.695	0.303	2.7
48	412.88	0.639	0.359	3.12
49	347.39	0.7	0.298	2.5
50	378	0.694	0.304	2.73

ns-DSDV

	E2E	PDF	DRP	OVR
1	697.96	0.717	0.279	3.38
2	746.9	0.71	0.285	3.38
3	604.68	0.689	0.306	3.53
4	834.57	0.703	0.293	3.37
5	779.85	0.665	0.33	3.65
6	1207.39	0.652	0.342	3.72
7	788.73	0.7	0.296	3.43
8	1220.22	0.687	0.307	3.49
9	917.98	0.745	0.248	3
10	725.48	0.689	0.304	3.34
11	870.75	0.735	0.259	3.29
12	694.77	0.744	0.253	3.25
13	637.92	0.708	0.289	3.39
14	496.51	0.713	0.285	3.34
15	760.4	0.711	0.283	3.32
16	976.04	0.698	0.296	3.46
17	1551.78	0.686	0.307	3.47
18	678.71	0.708	0.288	3.42
19	726.62	0.719	0.278	3.36
20	673.67	0.718	0.27	3.33
21	618.18	0.692	0.305	3.61
22	883.92	0.744	0.25	3.11
23	631.17	0.729	0.267	3.33
24	535.39	0.718	0.278	3.42
25	708.59	0.704	0.291	3.3
26	636.23	0.753	0.244	3.15
27	804.14	0.685	0.31	3.53
28	460.18	0.715	0.283	3.41
29	1168.9	0.775	0.221	2.88
30	571.97	0.724	0.272	3.24
31	490.35	0.758	0.238	3.15
32	817.05	0.721	0.276	3.34
33	732.75	0.695	0.302	3.47
34	720.31	0.705	0.29	3.52
35	564.75	0.717	0.279	3.39
36	483.51	0.736	0.261	3.28
37	678.9	0.728	0.269	3.28
38	697.61	0.691	0.306	3.54
39	1428.37	0.665	0.322	3.45
40	723.14	0.741	0.255	3.28
41	1138.16	0.708	0.282	3.33
42	743.54	0.68	0.315	3.6
43	522.1	0.723	0.274	3.3
44	1250.13	0.642	0.354	3.71
45	1029.72	0.7	0.294	3.43
46	583.66	0.726	0.27	3.32
47	669.66	0.711	0.283	3.34
48	778.15	0.7	0.296	3.45
49	785.6	0.7	0.296	3.5
50	898.48	0.709	0.288	3.35

La-DSDV

	E2E	PDF	DRP	OVR
1	355.24	0.704	0.292	2.87
2	436.68	0.678	0.32	2.83
3	616.94	0.647	0.349	3.36
4	273.68	0.712	0.287	2.49
5	680.76	0.643	0.352	3.33
6	470.19	0.663	0.333	2.98
7	451.73	0.682	0.315	3.01
8	236.45	0.749	0.25	2.52
9	410.44	0.71	0.286	2.84
10	650.37	0.679	0.316	3.04
11	329.96	0.738	0.259	2.44
12	408.61	0.721	0.278	2.36
13	577.4	0.74	0.255	2.72
14	387.81	0.712	0.287	2.82
15	370.38	0.711	0.287	2.85
16	311.18	0.718	0.279	2.68
17	210.54	0.72	0.277	2.71
18	384.59	0.701	0.296	2.89
19	418.27	0.739	0.26	2.52
20	371.05	0.727	0.272	2.46
21	486.45	0.664	0.332	3.15
22	357.37	0.695	0.304	2.75
23	285.31	0.768	0.23	2.57
24	491.33	0.696	0.302	2.89
25	476.28	0.687	0.31	3.07
26	234.54	0.719	0.28	2.59
27	570.01	0.661	0.336	3.46
28	198	0.768	0.231	2.36
29	339.92	0.703	0.295	2.91
30	368.94	0.68	0.316	3.06
31	436.48	0.697	0.301	2.7
32	253.75	0.732	0.267	2.55
33	346.87	0.762	0.237	2.53
34	784.31	0.652	0.344	3.27
35	244.21	0.67	0.329	3
36	258.21	0.768	0.231	2.27
37	462.47	0.697	0.299	2.91
38	227.99	0.762	0.237	2.43
39	350.43	0.705	0.293	2.67
40	600.08	0.654	0.343	3.31
41	389.77	0.678	0.319	3.03
42	400.26	0.684	0.312	2.96
43	320.98	0.719	0.279	2.81
44	253.92	0.728	0.271	2.66
45	624.63	0.642	0.353	3.51
46	263.77	0.744	0.255	2.25
47	530.47	0.698	0.3	3.08
48	293.01	0.72	0.279	2.5
49	377.2	0.7	0.299	2.77
50	385.55	0.711	0.288	2.68

Table 2.3. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 10

DSDV

	E2E	PDF	DRP	OVR
1	334.51	0.722	0.277	2.52
2	344.67	0.655	0.343	2.93
3	355.39	0.705	0.294	2.58
4	389.65	0.662	0.337	2.74
5	313.46	0.672	0.326	2.75
6	336.11	0.671	0.327	2.86
7	363.34	0.684	0.315	2.65
8	244.32	0.692	0.307	2.64
9	329.94	0.703	0.295	2.64
10	335.07	0.66	0.338	2.71
11	285.87	0.706	0.292	2.55
12	139.23	0.696	0.302	2.67
13	448.88	0.635	0.364	3.1
14	324.14	0.674	0.325	2.69
15	349.08	0.632	0.368	3.04
16	304.11	0.697	0.301	2.65
17	302.75	0.7	0.298	2.74
18	264.13	0.733	0.265	2.41
19	392.71	0.676	0.323	2.9
20	351.79	0.693	0.306	2.69
21	356.88	0.641	0.357	3.01
22	321.49	0.706	0.293	2.56
23	346.26	0.698	0.301	2.64
24	241.93	0.696	0.302	2.7
25	343.83	0.655	0.343	2.91
26	339.21	0.663	0.335	2.74
27	638.76	0.658	0.341	2.84
28	399.17	0.635	0.363	3.1
29	187.08	0.782	0.217	2.11
30	282.14	0.694	0.304	2.68
31	440.58	0.683	0.315	2.76
32	336.36	0.676	0.322	2.76
33	276.03	0.702	0.296	2.69
34	226.46	0.651	0.347	2.97
35	265.51	0.662	0.336	2.91
36	379.68	0.677	0.322	2.82
37	326.15	0.704	0.295	2.5
38	212.94	0.705	0.294	2.51
39	438.57	0.677	0.322	2.8
40	461.68	0.697	0.302	2.64
41	420.48	0.653	0.345	2.97
42	346.97	0.637	0.362	2.94
43	213.82	0.672	0.326	2.82
44	193.76	0.671	0.327	3.01
45	218.54	0.692	0.307	2.73
46	431.34	0.674	0.325	2.69
47	388.18	0.682	0.316	2.71
48	448.03	0.656	0.343	2.89
49	293.84	0.697	0.301	2.68
50	315.31	0.672	0.326	2.91

ns-DSDV

	E2E	PDF	DRP	OVR
1	789.82	0.719	0.276	3.28
2	550.59	0.691	0.305	3.52
3	712.53	0.713	0.283	3.36
4	1137.6	0.697	0.298	3.35
5	677.96	0.693	0.303	3.48
6	823.72	0.671	0.325	3.66
7	694.68	0.709	0.289	3.38
8	591.86	0.694	0.303	3.43
9	550.46	0.75	0.247	3.25
10	777.46	0.672	0.324	3.63
11	705.85	0.719	0.274	3.27
12	648.19	0.698	0.298	3.49
13	765.42	0.701	0.295	3.4
14	766.47	0.705	0.291	3.39
15	614.14	0.713	0.283	3.33
16	534.87	0.731	0.264	3.13
17	529.13	0.711	0.286	3.37
18	639.35	0.726	0.27	3.33
19	708.95	0.679	0.317	3.59
20	737.46	0.726	0.271	3.32
21	1194.93	0.71	0.285	3.41
22	489.72	0.735	0.261	3.22
23	530.14	0.706	0.29	3.5
24	678.99	0.681	0.316	3.54
25	1072.84	0.725	0.268	3.24
26	1675.64	0.654	0.337	3.68
27	974.34	0.697	0.299	3.51
28	390.53	0.731	0.266	3.26
29	557.6	0.721	0.275	3.29
30	666.34	0.717	0.279	3.35
31	642.84	0.747	0.248	3.24
32	570.53	0.708	0.289	3.42
33	655.48	0.721	0.274	3.33
34	634.52	0.747	0.25	3.15
35	994.9	0.691	0.303	3.52
36	526.41	0.744	0.253	3.12
37	625.72	0.709	0.288	3.32
38	889.17	0.661	0.335	3.68
39	567.32	0.741	0.256	3.14
40	945.72	0.694	0.3	3.45
41	702	0.704	0.291	3.45
42	798.22	0.728	0.269	3.22
43	730.48	0.677	0.319	3.57
44	435.56	0.738	0.259	3.22
45	1153.6	0.675	0.322	3.55
46	559.59	0.729	0.268	3.2
47	829.09	0.662	0.334	3.63
48	621.61	0.736	0.259	3.2
49	458.47	0.72	0.277	3.36
50	1135.77	0.697	0.297	3.5

La-DSDV

	E2E	PDF	DRP	OVR
1	236.15	0.722	0.278	2.57
2	449.14	0.713	0.284	2.71
3	436.5	0.681	0.317	2.78
4	365.14	0.7	0.297	2.78
5	287.26	0.733	0.264	2.85
6	277.99	0.727	0.271	2.6
7	358.4	0.688	0.309	3.01
8	486.47	0.732	0.266	2.71
9	452.01	0.717	0.276	2.71
10	458.15	0.731	0.266	2.77
11	523.9	0.685	0.311	3.18
12	246.7	0.703	0.295	2.85
13	371.84	0.716	0.282	2.63
14	508.64	0.694	0.303	3.04
15	351.63	0.738	0.262	2.41
16	268.05	0.717	0.28	2.7
17	442.86	0.718	0.278	2.86
18	339.77	0.75	0.249	2.44
19	463.46	0.711	0.288	2.89
20	423.13	0.703	0.294	2.82
21	433.39	0.718	0.28	2.63
22	427.57	0.706	0.291	2.81
23	250.75	0.712	0.285	2.73
24	270.44	0.738	0.261	2.45
25	129.14	0.782	0.217	2.15
26	383.23	0.702	0.297	2.74
27	409.62	0.721	0.277	2.79
28	239.56	0.737	0.262	2.51
29	366.22	0.689	0.308	2.86
30	415.25	0.726	0.271	2.81
31	355.86	0.72	0.277	2.91
32	377.31	0.741	0.257	2.63
33	382.02	0.696	0.303	2.85
34	328.27	0.724	0.274	2.56
35	348.64	0.714	0.285	2.51
36	235.34	0.751	0.248	2.34
37	352.86	0.699	0.299	2.66
38	341.23	0.698	0.298	2.9
39	310.24	0.754	0.243	2.49
40	237.45	0.712	0.285	2.81
41	331.97	0.712	0.285	2.75
42	450.62	0.722	0.271	2.89
43	328.86	0.739	0.26	2.49
44	579.87	0.686	0.311	3.14
45	617.99	0.726	0.271	2.93
46	274.5	0.757	0.241	2.34
47	355.48	0.707	0.29	2.74
48	452.33	0.72	0.277	2.77
49	372.49	0.747	0.252	2.46
50	459.03	0.718	0.281	2.64

Table 2.4. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 15

DSDV

	E2E	PDF	DRP	OVR
1	367.81	0.699	0.3	2.62
2	459.39	0.674	0.324	2.85
3	388.72	0.648	0.349	2.89
4	425.69	0.709	0.29	2.51
5	448.42	0.654	0.344	2.84
6	378.63	0.657	0.342	2.95
7	361.5	0.728	0.27	2.37
8	192.43	0.703	0.295	2.67
9	253.15	0.703	0.296	2.6
10	366.45	0.629	0.369	3.11
11	421.63	0.652	0.346	2.9
12	522.51	0.637	0.361	3.12
13	302.11	0.613	0.386	3.17
14	355.09	0.678	0.321	2.8
15	220.9	0.709	0.29	2.57
16	299.32	0.74	0.259	2.35
17	468.74	0.637	0.362	3.08
18	252.92	0.686	0.312	2.58
19	195.86	0.728	0.271	2.5
20	273.48	0.737	0.262	2.46
21	460.27	0.646	0.352	3.07
22	296.15	0.672	0.326	2.67
23	364.2	0.664	0.335	2.86
24	289.49	0.662	0.337	2.92
25	441.92	0.701	0.298	2.66
26	288.3	0.674	0.324	2.75
27	436.75	0.666	0.333	2.86
28	400.45	0.627	0.372	3.09
29	304.8	0.745	0.253	2.29
30	512.67	0.667	0.33	2.95
31	154.84	0.718	0.281	2.52
32	329.81	0.65	0.348	3.18
33	382.39	0.677	0.321	2.76
34	498.31	0.691	0.308	2.68
35	211.8	0.734	0.266	2.42
36	233.92	0.638	0.36	2.95
37	278.89	0.688	0.31	2.73
38	255.6	0.674	0.324	2.72
39	266.61	0.674	0.325	2.79
40	281.19	0.673	0.325	2.7
41	372.86	0.661	0.338	3.08
42	480.86	0.67	0.327	2.79
43	370.68	0.698	0.3	2.64
44	161.9	0.739	0.26	2.43
45	598.5	0.672	0.326	2.86
46	304.02	0.707	0.292	2.45
47	325.65	0.665	0.334	2.99
48	213.51	0.679	0.319	2.94
49	498.46	0.668	0.33	2.75
50	485.16	0.656	0.341	2.88

ns-DSDV

	E2E	PDF	DRP	OVR
1	732.6	0.716	0.277	3.31
2	527.04	0.73	0.268	3.3
3	760.43	0.673	0.323	3.58
4	863.55	0.706	0.288	3.36
5	859.07	0.685	0.311	3.58
6	713.91	0.716	0.279	3.33
7	1208.98	0.723	0.269	3.25
8	617.7	0.725	0.271	3.31
9	641.11	0.697	0.301	3.41
10	974.59	0.711	0.281	3.41
11	765.51	0.689	0.307	3.56
12	396.99	0.741	0.255	3.26
13	685.21	0.721	0.276	3.26
14	1066.82	0.739	0.256	3.21
15	590.98	0.713	0.283	3.36
16	792.86	0.716	0.28	3.31
17	595.07	0.713	0.283	3.45
18	1051.72	0.679	0.316	3.52
19	603.77	0.698	0.298	3.48
20	499.42	0.722	0.275	3.35
21	829.07	0.688	0.307	3.48
22	1048.38	0.722	0.272	3.28
23	586.24	0.743	0.254	3.19
24	598.32	0.688	0.305	3.48
25	468.36	0.758	0.237	3.11
26	573.49	0.714	0.282	3.37
27	542.85	0.744	0.251	3.25
28	655.92	0.733	0.263	3.28
29	737.18	0.719	0.278	3.47
30	506.45	0.712	0.285	3.37
31	756.48	0.716	0.28	3.35
32	464.89	0.754	0.244	3.14
33	682.55	0.708	0.287	3.35
34	581.05	0.716	0.278	3.37
35	1007.56	0.678	0.315	3.47
36	528.17	0.732	0.264	3.32
37	591.11	0.735	0.26	3.15
38	666.9	0.696	0.298	3.48
39	789.48	0.7	0.294	3.46
40	643.44	0.743	0.253	3.16
41	633.09	0.731	0.266	3.23
42	657.96	0.712	0.284	3.38
43	626.52	0.764	0.231	3.08
44	807.83	0.717	0.28	3.38
45	391.64	0.722	0.274	3.22
46	440.04	0.749	0.248	3.29
47	505.4	0.75	0.246	3.17
48	544.26	0.75	0.247	3.2
49	1378.37	0.69	0.307	3.51
50	808.69	0.725	0.269	3.32

La-DSDV

	E2E	PDF	DRP	OVR
1	664.42	0.697	0.3	3.04
2	440.45	0.703	0.294	2.94
3	566.62	0.707	0.286	2.77
4	529.41	0.684	0.312	3.07
5	343.55	0.727	0.271	2.39
6	437.27	0.724	0.273	2.72
7	519.64	0.716	0.283	2.81
8	680.02	0.671	0.326	3.28
9	264.45	0.722	0.277	2.58
10	200.93	0.782	0.217	2.14
11	448.51	0.728	0.27	2.78
12	454.96	0.711	0.286	2.78
13	455.05	0.706	0.289	2.94
14	172.83	0.719	0.28	2.64
15	382.89	0.747	0.249	2.59
16	300.61	0.711	0.286	2.63
17	392.71	0.744	0.251	2.66
18	148.83	0.752	0.247	2.49
19	589.23	0.689	0.308	3.11
20	287.27	0.728	0.272	2.44
21	436.65	0.685	0.312	2.94
22	287.95	0.721	0.276	2.72
23	463.79	0.685	0.313	3.04
24	210.39	0.725	0.274	2.56
25	310.92	0.758	0.24	2.43
26	348.29	0.718	0.279	2.92
27	264.82	0.757	0.242	2.32
28	381.32	0.689	0.308	3.11
29	344.31	0.721	0.276	2.71
30	254.35	0.712	0.286	2.63
31	193.85	0.747	0.251	2.56
32	568.88	0.674	0.324	3.3
33	451.35	0.714	0.282	2.86
34	291.54	0.712	0.286	2.72
35	271.65	0.737	0.261	2.51
36	464.64	0.709	0.286	2.91
37	323.34	0.673	0.326	2.78
38	431.99	0.703	0.294	2.84
39	302.45	0.762	0.237	2.27
40	289.42	0.708	0.29	2.73
41	493.62	0.682	0.315	3.19
42	631.88	0.718	0.278	2.78
43	247.16	0.729	0.267	2.75
44	406.83	0.707	0.292	2.65
45	213.02	0.749	0.25	2.49
46	694.67	0.713	0.283	3.04
47	293.26	0.723	0.275	2.49
48	433.21	0.723	0.274	3
49	251.13	0.746	0.253	2.63
50	334.38	0.713	0.285	2.76

Table 2.5. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 20

DSDV

	E2E	PDF	DRP	OVR
1	474.06	0.672	0.326	2.86
2	163.98	0.691	0.308	2.64
3	556.87	0.657	0.342	2.89
4	362.05	0.687	0.311	2.55
5	397.53	0.688	0.311	2.67
6	409.46	0.664	0.335	2.74
7	475.52	0.697	0.301	2.67
8	432.79	0.67	0.329	2.87
9	383.52	0.671	0.328	2.72
10	248.15	0.684	0.316	2.65
11	292.71	0.733	0.267	2.49
12	438.05	0.68	0.318	2.7
13	445.85	0.665	0.334	2.83
14	372.28	0.703	0.296	2.5
15	331.07	0.716	0.283	2.54
16	250.1	0.749	0.249	2.47
17	426.71	0.695	0.304	2.64
18	273.7	0.691	0.308	2.63
19	249.87	0.672	0.327	2.65
20	390.14	0.661	0.338	2.95
21	293.88	0.648	0.35	3.01
22	476.04	0.645	0.353	3.04
23	273.26	0.686	0.312	2.68
24	497.29	0.657	0.341	3.06
25	386.61	0.721	0.277	2.45
26	514.18	0.643	0.356	3.04
27	206.13	0.684	0.314	2.66
28	330.61	0.697	0.302	2.57
29	475.83	0.674	0.325	2.85
30	274.97	0.7	0.299	2.7
31	383.25	0.658	0.34	2.89
32	282.69	0.732	0.267	2.5
33	408.89	0.673	0.325	2.77
34	304.21	0.683	0.315	2.75
35	495	0.647	0.35	2.84
36	277.31	0.76	0.239	2.24
37	175.76	0.692	0.306	2.63
38	333.13	0.663	0.336	2.82
39	341.49	0.681	0.317	2.64
40	528.39	0.689	0.309	2.67
41	308.05	0.713	0.286	2.53
42	605.79	0.664	0.334	2.89
43	438.31	0.671	0.328	2.82
44	474.88	0.634	0.364	3.16
45	246.53	0.687	0.311	2.72
46	328.74	0.704	0.294	2.63
47	385.48	0.687	0.312	2.72
48	473.25	0.652	0.346	2.95
49	344.55	0.685	0.314	2.74
50	216.88	0.682	0.316	2.77

ns-DSDV

	E2E	PDF	DRP	OVR
1	730.07	0.707	0.29	3.44
2	602.81	0.698	0.296	3.51
3	1136.03	0.682	0.301	3.56
4	895.55	0.693	0.302	3.46
5	582.31	0.726	0.27	3.36
6	870.38	0.678	0.317	3.52
7	645.77	0.717	0.279	3.37
8	658.48	0.725	0.272	3.35
9	640.21	0.683	0.314	3.52
10	642.41	0.717	0.28	3.33
11	1528.95	0.675	0.318	3.51
12	484.37	0.771	0.226	3.06
13	510.16	0.722	0.275	3.33
14	760.98	0.714	0.284	3.36
15	1277.95	0.71	0.283	3.29
16	535.75	0.737	0.26	3.3
17	787.73	0.728	0.269	3.29
18	572.75	0.735	0.261	3.23
19	799.4	0.673	0.321	3.44
20	434.85	0.759	0.239	3.22
21	796.94	0.715	0.281	3.3
22	510.54	0.744	0.253	3.26
23	703.34	0.724	0.273	3.36
24	602.47	0.725	0.271	3.31
25	476.08	0.739	0.258	3.35
26	529.77	0.723	0.274	3.38
27	476.05	0.738	0.26	3.27
28	719.66	0.69	0.305	3.55
29	612.13	0.71	0.288	3.36
30	668.08	0.73	0.267	3.3
31	794.84	0.705	0.292	3.41
32	711.17	0.725	0.271	3.25
33	766.66	0.709	0.284	3.41
34	596.84	0.697	0.3	3.42
35	630.4	0.733	0.262	3.24
36	729.18	0.693	0.303	3.51
37	663.13	0.725	0.271	3.25
38	555.74	0.715	0.28	3.31
39	854.64	0.705	0.291	3.49
40	626.95	0.72	0.277	3.37
41	625.89	0.707	0.291	3.53
42	840.46	0.728	0.269	3.26
43	687.1	0.726	0.269	3.18
44	835.89	0.712	0.284	3.36
45	562.76	0.739	0.257	3.26
46	877.07	0.716	0.277	3.37
47	508.2	0.73	0.267	3.23
48	568.27	0.71	0.286	3.41
49	580.84	0.705	0.291	3.43
50	667.84	0.709	0.287	3.35

La-DSDV

	E2E	PDF	DRP	OVR
1	378.41	0.702	0.296	2.69
2	427.15	0.694	0.304	2.93
3	528.64	0.707	0.291	2.58
4	316.83	0.701	0.297	2.73
5	367.63	0.729	0.267	2.77
6	451.68	0.699	0.298	3.04
7	121.88	0.75	0.249	2.38
8	352.59	0.725	0.273	2.82
9	343.8	0.733	0.264	2.67
10	382.38	0.696	0.303	2.73
11	244.39	0.692	0.306	2.67
12	272.39	0.742	0.256	2.54
13	413.18	0.699	0.298	2.8
14	412.32	0.745	0.252	2.66
15	284.79	0.727	0.272	2.69
16	240.85	0.72	0.278	2.63
17	383.97	0.685	0.312	2.9
18	244.84	0.714	0.285	2.48
19	305.23	0.717	0.281	2.6
20	222.13	0.749	0.25	2.54
21	387.28	0.714	0.285	2.64
22	251.28	0.711	0.287	2.58
23	373.05	0.716	0.281	2.92
24	421.22	0.734	0.265	2.42
25	360.57	0.693	0.304	2.94
26	421	0.706	0.293	2.83
27	680.95	0.7	0.297	3.14
28	492.17	0.719	0.279	2.62
29	191.71	0.744	0.254	2.4
30	429.59	0.741	0.257	2.63
31	401.61	0.723	0.276	2.69
32	330.54	0.716	0.283	2.6
33	479.29	0.715	0.282	2.9
34	591.18	0.708	0.289	2.92
35	314.06	0.739	0.261	2.54
36	382.41	0.691	0.306	2.86
37	343.38	0.782	0.216	2.24
38	343.33	0.711	0.287	2.62
39	254.56	0.732	0.266	2.63
40	424.43	0.726	0.272	2.8
41	542.06	0.709	0.288	2.71
42	289.15	0.706	0.293	2.69
43	211.01	0.722	0.276	2.57
44	295.41	0.704	0.294	2.8
45	446.39	0.71	0.287	2.76
46	644.53	0.714	0.282	2.91
47	355.84	0.714	0.284	2.65
48	209.46	0.732	0.266	2.63
49	429.94	0.706	0.29	2.84
50	296.55	0.728	0.27	2.74

Table 2.6. Results of DSDV, ns-DSDV and La-DSDV for Pause time = 25

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Oral and Poster Presentations