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Performance Comparative Study of DSDV, E-DSDV, I-DSDV and O-DSDV MANET Routing Protocols

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Abstract—A Mobile Ad-hoc Network (MANET) is a dynamic single or multi-hop wireless network where nodes are connected wirelessly, and the network is self-configured. Due to the high mobility of nodes, network topology changes more frequently and thus, routing becomes a challenging task. Several routing protocols have been proposed by the researchers for MANETs like the well-known Destination Sequenced Distance Vector (DSDV) and its variants. It is a table-driven routing protocol that was mainly proposed to solve routing loop problems and it performs very well in sparse and low mobility environments. However, it suffers from several performance issues when implemented on high and dense MANETs. A number of modifications of DSDV have been proposed to make it more adaptive and suitable for different environments. In this paper, the performance of DSDV, E-DSDV, I-DSDV, and O-DSDV routing protocols is compared. The performance metrics that were considered in this analysis are packet delivery ratio, throughput, End-to-End delay, and routing overhead. Several simulation scenarios were carried out using the Network Simulator tool (NS3) by varying the number of nodes, pause time and velocity. The simulation results have shown that I-DSDV outperforms the others in low mobility scenarios, whereas O-DSDV has the best performance in high velocity environments.

Keywords-MANET; DSDV; I-DSDV; E-DSDV; O-DSDV Simulation; Network Performance; NS3.

I. Introduction

Mobile Ad-hoc Networks (MANETs) are a special type of networks where the nodes (computers, laptops, mobile phones, etc.) are connected without a fixed infrastructure, this means that there is no need to use dedicated routers or access points to connect any two nodes. Not only does a normal node in this kind of network initiate connection requests to other nodes, but also they act as routers to serve other nodes. The nodes in this type of network can forward the connection requests from one node to another. All operations are distributed among all the nodes, therefore, there is no centralized management for security or for routing. Most nodes have a small size of memory and low power battery. Links between nodes are wireless making them subject to path disconnections and packet losses. The mobility nature of the nodes makes it difficult to build routing information in a coherent way.

MANET has many applications. For example, in the military arena MANETs can be used to exchange information among the vehicles, soldiers and military headquarters. On a more personal level, MANETs can simplify the interconnection between lightweight devices such as laptops, smartphones, and tablets. They can also be helpful in disaster situations when the commutation infrastructure is damaged like in fires, floods and earthquakes.

Current MANET-applications face several challenges such as: transmission range is very limited; security issues due to the wireless environments; and, the power resources are very battery-operated and limited. The mobility nature of a MANET makes its topology highly dynamic which leads to an increase in the packet loss and route changes.

Several networking protocols were proposed to deal with these challenges, specially Routing Protocols. These are special algorithms used by wireless devices to find the best path (route) for forwarding data between two (or more) nodes. Many of them were proposed in the literature, and enhanced versions continue to appear. Good routing protocols usually try to optimize performance metrics such as: control overhead (minimize), bandwidth consumption (minimize), throughput (maximize), end-to-end delay (minimize), security (maximize), fault tolerance (maximize) and energy efficiency (maximize). Numerous routing protocols focus on some of these performance aspects and ignore the others depending on the field where they are designed to work in. There are different classifications for routing protocols; one of them classifies them into three types: (1) proactive (table-driven) routing protocols, (2) reactive (on-demand) routing protocols, and (3) hybrid protocols which combine the proactive and the reactive methods. In the proactive category, every node maintains one or more routing tables, these tables contain routing information about all the nodes within the network. These protocols update the table(s) periodically which leads to increased network overhead, bandwidth and power consumptions, but it minimizes the End-to-End delay and keeps the routing information up to date. Examples of such category of protocols are: OLSR (Optimized Link State Routing Protocol) [16], DSDV (Destination Sequenced Distance Vector) [3], and WRP (Wireless Routing Protocol) [18]. In the reactive routing protocols, the node routing information will not be maintained frequently or periodically. If a node needs to communicate with another node, it will first send a request (broadcast) to the whole network. Every node will pass the request until it reaches the destination node. The destination node will reply using the same path used for the request message. In this case, the sender node will not have the routing information until it receives the reply message. This process increases the End-to-End delay, but it saves the bandwidth and power consumption. These advantages will not be clear in high-density wireless networks. Examples of this category are: AODV (Ad Hoc On-demand Distance Vector) [4] and DSR (Dynamic Source Routing) [6], among others.

Finally, the hybrid routing protocols were built to use both techniques and attempt to get the best out of the two worlds; These protocols will maintain a routing table for nodes within some range and will send a routing request for the nodes outside this range. Examples of hybrid routing protocols are: ZRP (Zone Routing Protocol) [28] and TORA (Order One Routing Protocol) [25], among others.

In this paper, we made a comprehensive performance comparative study among several routing protocols. We mainly focused on the DSDV and some of its variants. The aim of this study is to analyze the strengths and weaknesses of these protocols and their respective environments. The protocols in this paper are modified versions of the DSDV routing protocol. We will analyze the performance effects of these modifications and analyze them in different conditions like node density, velocity, discontinuous mobility. As previously mentioned, this protocol is a proactive routing protocol, and many extended versions have been proposed by the research community in past few years. Some studies focused on improving nodes' power consumptions, others focused on enhancing the fault tolerance metric, while others handled network overhead and bandwidth issues. In this research we study and analyze in more detail five routing protocols – these are: The original DSDV protocol; the Improved DSDV (I-DSDV), the Efficient DSDV (E-DSDV) and the last one is the Optimized DSDV (O-DSDV) which was mainly proposed for VANET applications.

II. Overview of Routing Protocols

In this section, a brief description of each of the DSDV, I-DSDV, E-DSDV and the Optimized DSDV routing protocols will be presented.

A. *Destination Sequenced Distance Vector DSDV*

DSDV [3] is an Ad-Hoc network proactive loop free distance routing protocol. In this protocol, the nodes periodically broadcast packets with routing information about themselves, these packets contain fields such as: destination, hop count, and sequence number. The neighbors receive these messages and update their routing tables accordingly. In this case, the updates will be added to the routing table in certain situations, e.g., when there is no routing information about the destination in the routing table, the updated message has a higher sequence number, or the updated message has the same sequence number but with a shorter path (smaller hop count). Any new updates in the routing table will be immediately broadcasted after increasing the metric parameter in the records by one, and at the same time, the routing information in the routing table will periodically be rebroadcasted. Fig. 1 illustrates the mechanism of broadcasting routing information in this protocol.

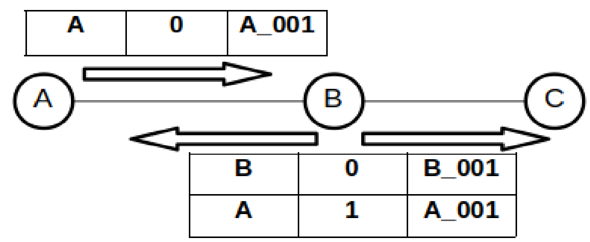


Figure 1. An example of routing message exchange in DSDV routing protocol

DSDV routing table mainly contains the following fields:

- Next hop: represents the first node to be visited to reach the destination.
- Metric: represents the number of nodes which the data packet will visit before reaching the destination.
- Sequence number: sequential number to distinguish old updates from new ones.
- Settling time: the time that a node will wait before broadcasting the incoming updates (any update for the record will reset the timer).
- Hold down time: the time that a node will wait before considering the record as expired (i.e., broken connection).

B. *Efficient DSDV Routing Protocol E-DSDV*

E-DSDV [10] was presented as an extension to the DSDV. The main purpose of this protocol is to reduce network congestion. DSDV routing protocol is designed to choose the shorts' path to reach any node within the network. But this principle does not apply to the E-DSDV protocol. The purpose of this protocol is to deliver routing data updates as quickly as possible, even if this is done by choosing longer paths. The purpose of this mechanism is to avoid network bottlenecks. E-DSDV Eliminate settling time that was used in DSDV protocol to reduce oscillation and replace it by a new mechanism.

The nodes in this protocol always consider the updates only when they have higher sequence numbers. In case a node receives a route advertisement message with higher sequence number, it will advertise the message immediately. The node will discard the new route advertisement messages having the same sequence number even if it has a smaller hop-count.

C. Improved DSDV Routing Protocol (I-DSDV)

I-DSDV [21] improves the packets' delivery ratio of the DSDV in high mobility scenarios. A new field was added to DSDV routing message. In some cases, routing tables contain broken links and these links are usually fixed when the router updated data arrives from the source. This process takes time to reuse the path. This protocol proposes a new approach to repair broken links without having to wait for the source. The new message has four fields: destination, type, hop-count and sequence number. Nodes with stale routes will send a routing message and will set the message type as INVALID. The neighbors of the sender will deal with this message as a route request. If these neighbors have a VALID route information with a better or an equal sequence number and smaller or equal hops count, they will broadcast the VALID routing information. On the other hand, if the neighbors do not have a valid routing information, they will rebroadcast the received INVALID routing message in case they need this route. Otherwise, they will remove the route from there table only.

D. Optimized DSDV Routing Protocol (O-DSDV)

This protocol [27] presents an approach to reduce the End-to-End delay, increase throughput, and maximize packets delivery ratio in VANETS applications. The developers of this protocol analyzed the performance of DSDV and noticed that its performance is low, especially in high-traffic environments, so they made a number of modifications to suit these conditions. The O-DSDV suggests two modes, high velocity mode and low velocity mode. While the protocol will act like the original DSDV in low velocity mode, it reduces its update interval and sets its settling time equals to zero for the incoming updates in high velocity scenarios. When the speed of the node exceeds 25 m/s, the protocol gradually reduces the update period until the speed reaches 40 m/s. The update period is settled at a predefined low value. For settling time, it has two values one for high speeds and the other for low speeds. In this way, the received updates will be sent immediately and the interval between the node's updates will be shorter in high mobility environments.

III. PERFORMANCE EVALUATION

This section contains a brief description of several quantitative metrics that can be used for evaluating the performance of MANET routing protocols. We have used the following metrics for evaluating the performance of the four routing protocols in this study (DSDV, I-DSDV, E-DSDV, and O-DSDV)

- Packet delivery ratio: It is defined as the ratio of data packets delivered to the destinations to those generated by the constant bit rate sources CBR.
- Throughput: It is the total number of bits that are successfully delivered to the destination in a given time period.
- End-to-End delay: It is defined as the average time delay for data packets to reach from the source node to destination node, this includes all possible delay that was caused by buffering, interface queuing and data retransmission.
- Normalized routing overhead: It is defined as the total number/size of routing packets transmitted per data packets.

We have evaluated the protocols in our study based on the simulation using the NS3 simulator. NS3 is an open source software and a discrete-event network simulator. NS3 is NS2 replacement. It is implemented using C++ and its scripts also can be implemented using C++. It has also a better performance and enhanced memory management when compared to NS2. The simulator also includes many tracing models which makes it easy to measure the protocols' performance.

IV. OVERVIEW OF ROUTING PROTOCOLS

We built three different scenarios to measure the performance of the four routing protocols considered in this study. The first scenario was built to measure the performance in variant load environments. We repeated the experiment twelve times using different number of nodes. The second scenario was built to measure the performance in variant mobility environments where every node in the scenario has a different speed. The scenario was repeated multiple times with different pause time. The last scenario was set to compare the performance between the routing protocols based on different speed environments. All the nodes in this scenario have the same speed. The experiment was repeated several times with a new speed for all nodes in each iteration. The simulation area size in the three scenarios is fixed to 750m x 750m. The transmission range in each node is set to 250m. The duration of each scenario is fixed to 100s. Nodes mobility was based on random waypoint model in all scenarios.

Existing research studies on data routing protocols in MANETs have shown that the UDP protocol is the preferred transport control protocol compared to the TCP. This is due to several technical reasons such as: (i) Unlike the TCP protocol which was mainly designed for wired networks, the UDP protocol is extensively used in wireless and Ad-Hoc networks because it's a lightweight, simple and mainly relies on little control packets, which reduces its impact on the network performance; (ii) The main characteristics of wireless networks such as frequent link changes, interference between signals of neighboring nodes, and contention with TCP-ACK packets and routing protocols makes the implementation of the TCP protocol useless; (iii) In our study, we focused on evaluating the performance of several routing protocols considered in this study in isolation from other factors triggered by the TCP control overhead. Based on these technical reasons, we decided to use the UDP protocol.

Table1 summarizes the common parameters of the simulated testbed.

TABLE I. SIMULATION PARAMETERS AND THEIR GIVEN VALUES.

Parameter	Value
Area	750mx750m
Transmission range	250m
Duration	100s
Traffic sources	CBR (512 bytes)
Mobility Model	Random waypoint
Transport protocol	UDP

The results of our study were divided according to the three scenarios as follows:

A. *Dense vs. Sparse Mobile Ad-Hoc Networks.*

In this scenario, the number of nodes varied from 10 to 60 with an increment of 10 nodes each time the experiment runs. Other simulation parameters are fixed. The pause time is initially set to zero for all nodes. All the nodes are moving in a fixed speed (30 m/s). The rest of the parameters are described in Table 1. After applying this scenario using NS3 simulator we reached the results shown in Figure 2, where Part (A) illustrates the effect of increasing the number of nodes on the Packet Delivery Ratio; Part (B) shows the effect of increasing the number of nodes on the network Throughput; Part (C) displays the relationship between increasing number of nodes and the average End-to-End delay; And finally, Part (D) presents the relationships between increasing the number of nodes and the routing Overhead.

In terms of Packet Delivery Ratio all the considered protocols in this study have the same behavior in case of increasing the number of nodes. The Packet Delivery Ratio decreases in dense network. This behavior can be clearly explained considering the network congestion overhead. However, the E-DSDV has the lowest Packet Delivery Ratio among the others. The network Throughput also increases as the number of nodes increased as well. When the number of nodes reaches 30 nodes the network Throughput almost has a stable value. After that the E-DSDV has the lowest network Throughput in this scenario. There is no significant difference between them except that when the number of nodes reaches 60 nodes the O-DSDV outperforms the others for the Throughput value. The average End to End delay is also increased. Again, there is no significant differences in the average delay except that the E-DSDV has the highest End to End delay. In terms of routing overhead, the E-DSDV has the lowest routing overhead in all cases. The O-DSDV has the highest routing overhead when the number of nodes is small (10-20 nodes - spare network), and the I-DSDV has the highest routing overhead when the number of nodes is high (50-60 node - dense network).

B. *Discontinuous mobility Mobile Ad-Hoc Networks*

In this scenario the pause time is varied from 0 to 100 with an increment of 20 seconds. All the nodes are moving in a fixed speed (30 m/s). The nodes stop moving at several random locations for the specified pause time. When the pause time is set to zero, the nodes will move without stopping. Our scenario duration is 100 secs which means when the pause time is set to 100 secs the nodes will stay in a fixed place. The rest of the parameters are described in the Table 1. After applying this scenario, we got the results shown in the Figure 3. Part(A) illustrate the effect of increasing the pause time on the Packet Delivery Ratio, Part (B) shows the effect of increasing pause time on the network Throughput, Part (C) displays the relation between increasing pause time and the average End-to-End delay. Finally, Part (D) presents the relation between increasing the pause and the routing Overhead.

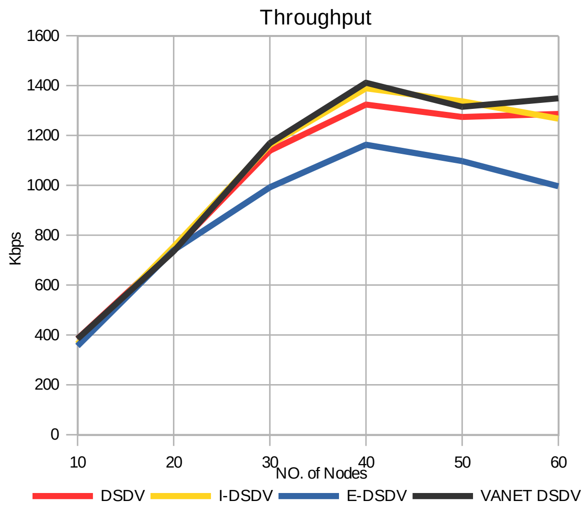
In terms of Packet Delivery Ratio and network throughput, O-DSDV has the best Packet Delivery Ratio and throughput when we have a short pause time (< 50s). This can be considered a logical result as this protocol is designed for high mobility environments. I-DSDV has the best Packet Delivery Ratio and throughput when we have a long pause time interval whereas is a great possibility of fixing broken links. E-DSDV has the lowest Packet Delivery Ratio and network throughput. Other routing protocols have identical behavior in all situations. The average End-to-End delay increases dramatically in E-DSDV when the pause time is set between (0 – 80s) whereas this protocol is designed to avoid network cognition not to select the shortest path which lead to increase in the average delay. Other routing protocols have similar average delay. Trying to recover broken connection makes I-DSDV with the highest routing overhead specially in the short pause time situation where the nodes in high

speed most of the time. E-DSDV has the least routing overhead. When the pause time is greater than 40s, all remaining protocols have identical routing overhead.

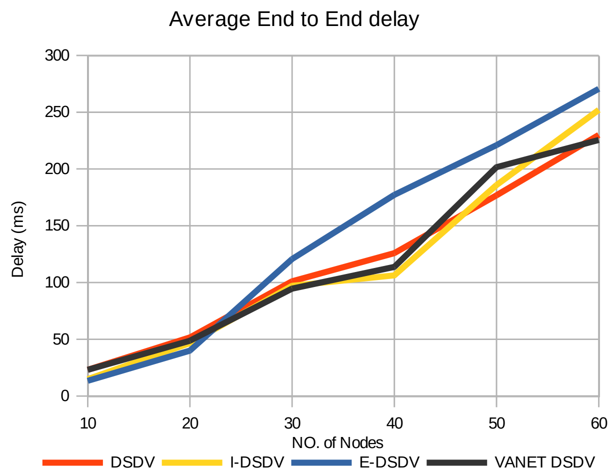
C. *Discontinuous mobility Mobile Ad-Hoc Networks*

In this scenario the speed of the nodes is varied from 5 to 30 m/s with an increment of 5 m/s. The scenario has 30 nodes in all cases. The pause time is set to zero for all nodes. The rest of the parameters are described in the Table 1. After applying this scenario, we got the results shown in the Figure 4. Part(A) illustrates the effect of increasing nodes' mobility on the Packet Delivery Ratio, Part (B) shows the effect of increasing nodes' mobility on the network Throughput. Part (C) displays the relationship between increasing nodes' mobility and the average End-to-End delay. Finally, Part (D) presents the relationship between increasing nodes' mobility and the routing Overhead.

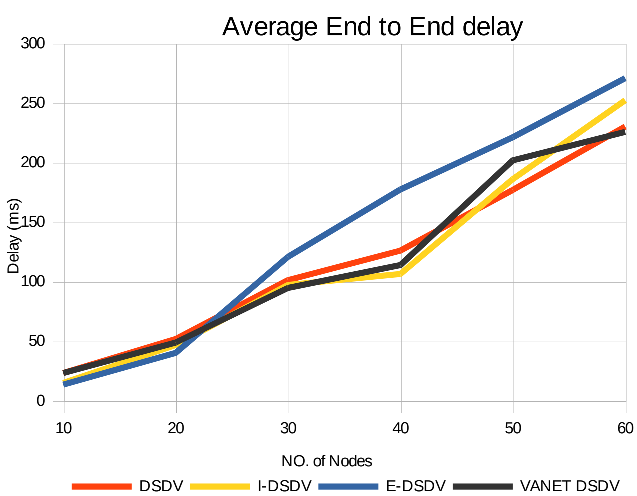
In terms of Packet Delivery Ratio and network throughput all the considered protocols in this study have the same behavior in case of increasing nodes' mobility. Although E-DSDV performance is lower than that of other protocols, it has the same behavior. O-DSDV was designed for high speed mobility specially for the nodes of speed over 25 m/s, therefore it showed a sudden improvement when the speed exceeded 25 m/s. The average End-to-End delay almost has a stable value for the variable speed for all protocols, which means that the nodes' speed has no significant effect on the End-to-End delay. In terms of routing overhead as always E-DSDV has the lowest routing overhead in all cases. DSDV and O-DSDV have identical slope whenever the nodes' velocity is slower than 25 m/s. The speed of nodes has a high negative effect on I-DSDV as we noticed from previous scenarios as well.



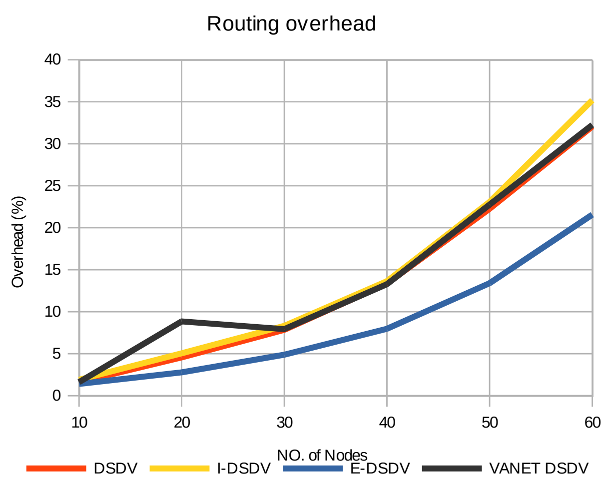
Part (A)



Part (B)

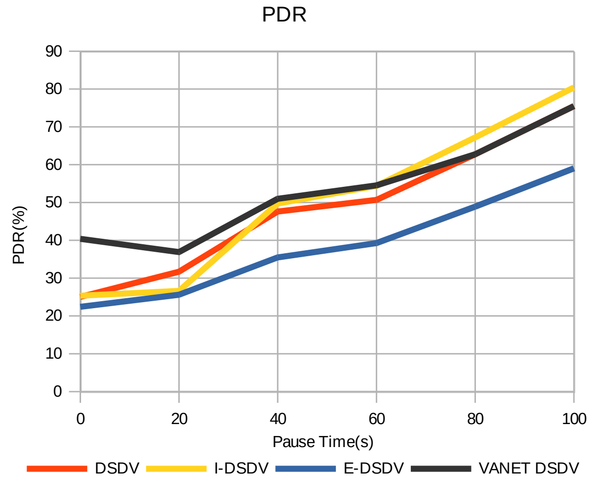


Part (C)

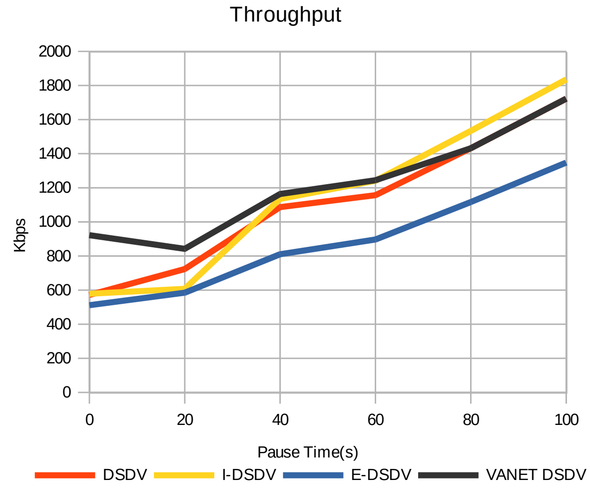


Part (D)

Figure 2. Performance comparative charts, Part (A) Packet delivery ratio vs. number of nodes, Part (B) Throughput vs. number of nodes, Part (C) End to end delay vs. number of nodes, and Part (D) Routing overhead vs. number of nodes.



Part (A)



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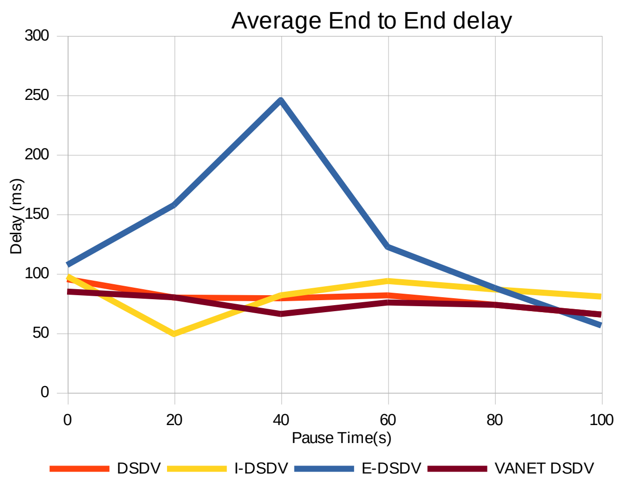
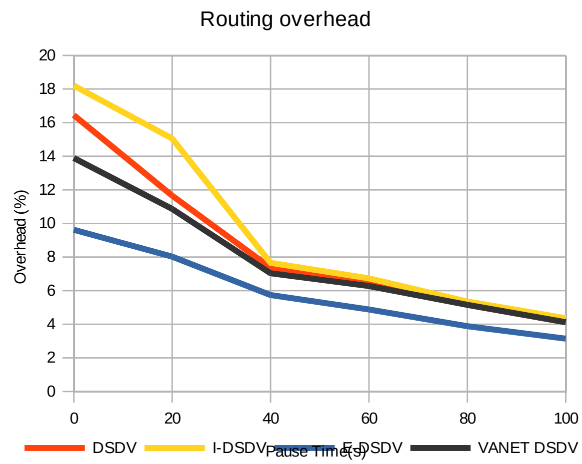


Part (C)



Part (D)

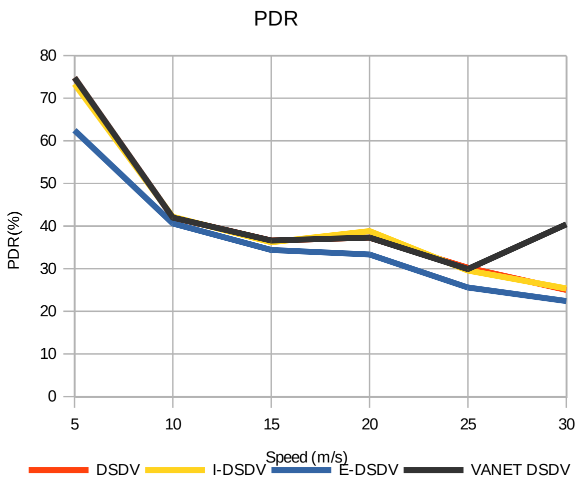
Figure 3. Performance comparative charts, Part (A) Packet delivery ratio vs. pause time, Part (B) Throughput vs. pause time, Part (C) End to end delay vs. pause time, and Part (D) Routing overhead vs. pause time.

V. CONCLUSIONS AND FUTURE WORK

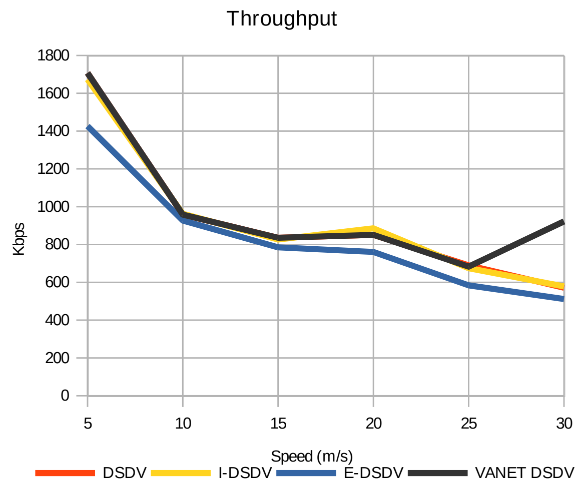
Routing protocols performance evaluation is necessary for analyzing the existing approaches and this is often the first step to propose modifications and improvements on these protocols. In this paper, we have carried out a detailed comparative simulation study of the performance characteristics of DSDV and other extensions/variations of it. The study was conducted on three different scenarios by changing patterns of motion, number of nodes, and velocity.

The simulation results have indicated that in low mobility environments, I-DSDV outperforms the other protocols in terms of packet delivery ratio and network throughput, but this has led to a noticeable increase in routing overhead. In other scenarios the protocol performance was very similar to the DSDV performance.

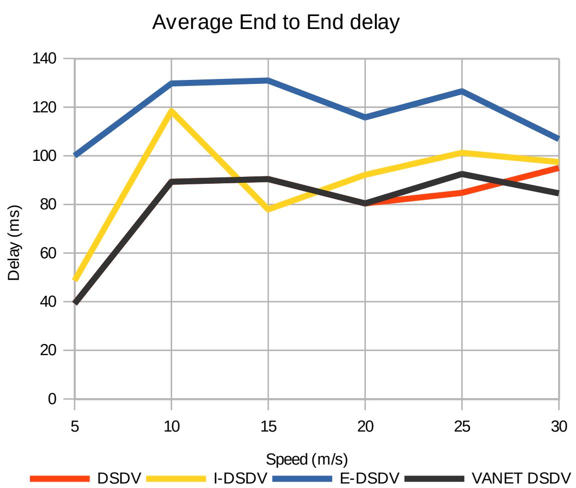
When compared to DSDV, O-DSDV does not show a performance improvement at low mobility environments and at slow speeds, but it gave the best performance at high mobility and high speed (especially speeds over 25 m/s). This is due to the fact that this protocol is adapted to fit highly-dense networks. Also, the results have shown that the E-DSDV had the least routing overhead in all scenarios and the highest end to end delay. This can be understood because E-DSDV canceled settling time concept and was not designing to select the shortest path. In terms of high-density environment there is no significant differences between the studied protocols.



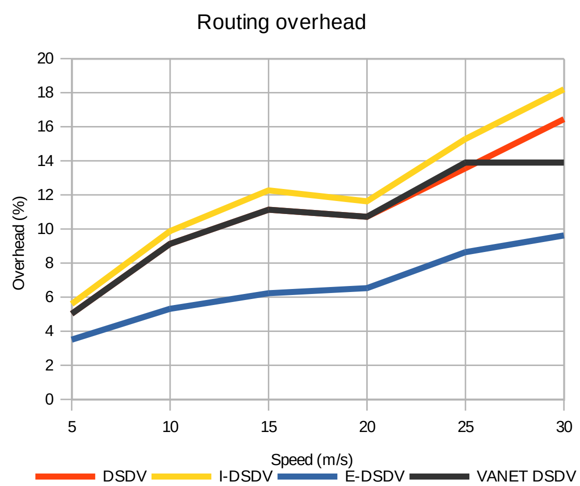
Part (A)



Part (B)



Part (C)



Part (D)

Figure 4. Performance comparative charts, Part (A) Packet delivery ratio vs. speed, Part (B) Throughput vs. speed, Part(C) End to end delay vs. speed, Part (D) Routing overhead vs. speed.

In future work and based on these results we will identify the strengths and weaknesses in each protocol, then we will propose a new extension to the DSDV protocol to improve its performance, especially in environments with different velocity or environments of variant velocity.

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