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AN EVALUATION OF IMPROVED CLUSTER-BASED ROUTING PROTOCOL IN AD-HOC WIRELESS NETWORK

Adekiigbe Adebanjo[1], Awotidebe M. Lanre[1], Ekuewa J. Bamidele[1], Ayeleso C. Emmanuel[1], Onyeka N. Camilia[1], Abu Bakar Kamalrulnizam[2]

[1]Department of Computer Science
The Federal Polytechnic Ede, Nigeria
[2]Department of Computer Science
Universiti Teknologi Malaysia
adebanjoadekiigbe@gmail.com

ABSTRACT

In this paper we presents a performance comparison of Dynamic Source Routing (DSR), Ad hoc On Demand Vector (AODV), Cluster Based Routing Protocol (CBRP) and Improved Cluster Based Routing Protocol (*i*-CBRP) routing protocols which builds upon a cluster based wireless network infrastructure. This evaluation is necessary due to unique enhancement made to traditional CBRP by way of implementing congestion control scheme as part of the structure establishing *i*-CBRP. First, we introduce the network infrastructure on which the routing protocols are to send packets. We simulates Mobile Ad-Hoc Network (MANET) network infrastructure using NS2 network simulator. DSR, AODV, CBRP and *i*-CBRP routing protocols are implemented to generate various simulation results. The results shows that *i*-CBRP performs better in terms of average packet delay, throughput, volume of traffic controls and average packet delivery ratio when compared with CBRP, while DSR performs better in terms of total volume of control traffic. AODV is the overall best in terms of average packet delay.

Key words: Node Density, Evaluation, MANET, Cluster, Routing

INTRODUCTION

Wireless ad-hoc networks are network architecture that can be promptly set up in the absence of any fixed infrastructure. In recent times, there has been an amplified attention in wireless ad-hoc networking research (Alotaibi & Mukherjee, 2012; Mohsin, Bakar, Adekiigbe, & Gafoor, 2012, Ali. S. et al, 2015)**.** A typical example of wireless ad-hoc network is mobile ad-hoc network (MANET). MANET is created by connecting autonomous mobile devices through wireless links without the need for external infrastructure. Wireless ad-hoc network has invariably grown the concept of pervasive and ubiquitous computing into a standardized level. Ad-hoc networks are applied in the area of disaster recovery and military communication hardware deployment and usage. In some cases, such as universities and colleges recreations, international conferences and e-learning within campuses, this network has shown to perform adequately well even under various scenarios (Lee, Belding-Royer, & Perkins, 2003).

The success of implementing wireless ad-hoc network brings a challenge in which the implementation of this type of network poses different burdens upon the traditional wireless systems or wired networks (Frikha, 2013). On the other hand, a MANET is anticipated to be of enormous size when compared with the radio range of wireless antenna, for this reason, it requires that the traffic be routed through multihops. Unfortunately, the dynamism of MANET manifests rapid changes of network topology which invariably add more traffic data to the mandatory traffics for the data routing procedure. MANET also offers wireless transmission channel which is shared by nodes. Hence, the consequence of limited bandwidth in a large network topology is congestion. Another major challenge militating against ad-hoc network is energy constraints. Most often, ad-hoc nodes are powered by batteries. Consequently, these nodes quickly get exhausted during data traffic if no efficient power consumption techniques are adopted for these autonomous mobile nodes (Mohsin et al., 2012).

Generally, routing protocols in ad-hoc networks can be classified into Reactive (on-demand routing protocol), Proactive (table driven routing protocol) and Hybrid routing protocol. The principal objective of an ad-hoc network routing protocol is to provide correct and efficient route setup between various nodes so that messages may be delivered as at when due (Salunkhe & Sankpal, 2013). Some on-demand and table driven routing protocols are in the class of flat routing protocols, where all nodes are saddled with equal function in transferring packets from source to destination.

In table-driven protocol, each node maintains a routing table, containing routing information on reaching every other node in the network. All nodes update these tables so as to maintain a consistent and up-to-date view of the network. Whereas proactive routing protocol uses periodic broadcast to establish routes and maintain those routes. The advantage of table driven protocol is that routes to any destination are always available without the overhead of a route discovery. In on-demand routing, all up-to-date routes are not maintained at every node, instead the routes are created when required, hence minimal routing overheads when compared with table driven protocol. In case of hybrid protocols, it combines the benefits of both table driven and on-demand protocols approaches together. These protocols are scalable to network size. Various routing protocols such as Dynamic Source Routing (DSR)(Johnson, Maltz, & Broch, 2001) and Ad-Hoc On-demand Distance Vector (AODV)(Chakeres & Belding-Royer, 2004) are some of the routing protocols that were designed to work with ad-hoc networks.

Due to various challenges of on-demand and table-driven routing protocols, hierarchical routing attracted the attention of researchers in ad-hoc networks. This is because hierarchical routing protocols decreases the complexity of network topology. It also increases routing efficiency and reduces routing communication overheads (Adekiigbe & Abu Bakar, 2013; Cheng, Li, & Horng, 2013; Frikha, 2013). The cluster heads in hierarchical routing protocols are only allowed to transmit data packets on behalf of other cluster members, hence more burden and responsibility on cluster heads while other nodes remain ordinary member of the cluster.

Cluster based routing protocol (CBRP) is a routing protocol with hierarchical-based design (Jiang, 1999). The network area is divided into smaller sizes of cluster by the protocol. Due to mobility of client nodes, sometimes node with lowest ID with high mobility is selected as cluster head. In the same vein, more energy is dispensed by cluster head to actively perform its roles, therefore, the cluster head energy runs down too often. To improve on the functionality of CBRP, work presented in Adekiigbe and Abu Bakar (2013) proposed a fuzzy logic approach for the selection of cluster heads for cluster based routing protocol (*i*-CBRP), this work produces a routing protocol which shows better performance over the traditional CBRP. Though, this protocol was only implemented on wireless mesh client network, it was not bench-marked with relatively popular AODV and DSR on Ad Hoc mobile network.

We are motivated by the need to domesticate ***i***-CBRP in virtually all wireless networks since it has been successfully implemented in wireless client mesh network. Hence, the quest to do performance evaluation of ***i***-CBRP in mobile Ad-hoc network. In doing this, we aim to evaluate the performances of AODV, DSR, CBRP and *i*-CBRP, under varying network sizes using simulation approach in mobile ad hoc networks. It is expected that the performance comparison will show the weaknesses and strengths of various routing protocols under comparison, the outcome is expected to help practitioners in making decision when implementing ad-hoc networks.

The remainder of the paper is organized as follows: In section 2, a summarized review of the differences in implementation techniques of DSR, AODV, CBRP and *i*-CBRP routing protocols are given. Section 3 evaluate related works while section 4 discusses the simulation environment and the parameters for evaluation of the protocols under varying network sizes. Section 5 discusses the analysis of the simulation results while section 6 draws conclusion on the performance comparison of these routing protocols.

IMPLEMENTATION TECHNIQUES OF DSR, AODV, CBRP AND *i*-CBRP

Dynamic Source Routing protocol (Johnson et al., 2001) (DSR) is one of the flat routing protocols proposed for ad-hoc networks. It is a simple and efficient routing protocol designed specifically for use in multi-hop and ad-hoc wireless networks. DSR permits the network to be completely self-organizing and self-configuring devoid of need for any existing network infrastructure. DSR is an on-demand routing protocol which uses source routing to send packets. Source routing techniques ensure that source node must know the complete hops sequence to the destination. All nodes maintain a route cache in which all routes leading to destination are kept. Route discovery process can only be started if and only if the desired route cannot be located within the route cache. In other to reduce the number of route requests broadcast, a node processes the route request message only if it has not previously received the message and its address is not present in the route record of the message.

Ad-hoc On-Demand Distance Vector routing protocol (AODV) (Chakeres & Belding-Royer, 2004) is one of the routing protocols used in mobile ad-hoc networks in other to provide secure and reliable data transmission within the network. AODV uses broadcasting techniques to discover a route through the network. In the route discovery process, the source host initiates the route discovery by broadcasting a route request to its neighbors. The route request carries destination sequence number. Destination sequence number prevents old routing information being used as reply to the previous request, therefore safeguards the routing protocol against looping problem. During process of packets transfer from a node to a particular destination node, if the node does not have a valid route in its routing table for that destination, it therefore initiates a route discovery process. The source node broadcasts a route request (RREQ) packet to its nearest neighbors; these neighbors also transfer the request to their neighbors until its get to the destination node. All the neighboring nodes that receive the route request sends back a route reply (RREP) using unicast to source node. In the process of route reply along reverse path, intermediate nodes along this path set up forward path entries to the destination in its route table. When the RREP reaches the source node, a route from source to destination is established. Once the route is established, packets transfer can commence earnestly.

One of the common cluster based routing scheme basically designed for ad-hoc networks is CBRP (Jiang, 1999). CBRP is an on-demand routing protocol which uses source routing. CBRP is similar to DSR in that it also avoids formation of loops when routing packets. In the protocol, nodes in the network are divided into several clusters, using a clustering algorithm of lowest ID (LID) (Perkins & Royer, 1999). Event-driven approach is used in the cluster structure maintenance in CBRP, this is comparable to what is available in Least Cluster Change algorithm (Chiang, Wu, Liu, & Gerla, 1997) (LCC). Once the clusters are formed, every node creates neighbour table in which information about other neighbours nodes is kept; apart from independent neighbour table maintained by cluster heads, they also have another table called cluster heads neighbour where information about neighbouring cluster heads are kept.

In CBRP, a route discovery process begins with the source node broadcasting a route request to its neighbours, of which the cluster head is also a neighbour. Afterward, the route request is flooded to the entire neighbouring cluster heads via cluster gateway when no direct communication links exist between cluster heads. This process goes on until the route request gets to the cluster head that is hosting destination node. The destination clusterhead unicasts route request to destination node. All clusterheads that participated in route request will only be recorded and this will be made available to destination node on arrival. The real route is worked out when the destination node returned route reply. Every cluster head on the route reply path finds minimum hop-by-hop route path from earlier node to subsequent cluster head along the path. Once the route request and route reply process is completed, every other process in CBRP such as packet transfer is similar to how data packets are transferred in DSR.

Improved cluster based routing protocol (*i*-CBRP) (Adekiigbe & Abu Bakar, 2013) was proposed to annex the shortcomings of clustering algorithm used in CBRP. Unlike the LID and LCC algorithms used in both cluster formation and cluster maintenance in CBRP, fuzzy logic clustering algorithm is used in *i*-CBRP. The work presented in Adekiigbe, Abu Bakar, and Umelo (2014) gives detailed of the nodes clustering process in *i*-CBRP. Like the original concept of CBRP, the design of *i*-CBRP has two major phases, the route discovery and route maintenance respectively. Once the cluster structure construction is established, the process of route discovery and route maintenance remains the same as in CBRP.

In *i*-CBRP, some properties that enhance the chances of successful data packet delivery such as high node degree and low hop count are defined. Whenever a clusterhead is classified as weak or very weak, the clusterhead is not as much likely to be involved as part of routing path for RREQ. For the purpose of clarification, if a clusterhead has low node degree, the chances are that such clusterhead drops packet when its energy is low and the fewer available nodes cannot hold forth for the dying clusterhead. A route path cannot at all-time be made of clusterheads with strong chances of data packet delivery due to many wireless network dynamic characteristics, therefore it is expedient to find a perfect mix of metrics for the selection of routing path by using fuzzy logic controller. Once the clusters are formed, every node maintained all data structures that are needed for the purpose of route construction and maintenance. The data generated are the list that provides the mapping between clusters with their client node membership composition. In the same manner, it gives nodes the link that joins different clusters to each other.

The information in the cluster and cluster gateway lists are used to generate the routing table information that needs to be kept by each node in the network. The routing table usually has the following information to route data packets from source to destination: Destination address, Source address, Address of next hop, Hop counts and route life time.

RELATED WORKS

Ashish K. Maurya (2010) evaluated AODV, FSR and ZRP for Scalable Networks. The work performs simulations with the following two different scenarios for the performance evaluation of AODV, FSR and ZRP routing protocol. Network designed make use of random waypoint mobility model with different pause time and variable number of nodes. Performance of AODV, FSR and ZRP routing protocol is assessed by considering four performance metrics which includes average end to end delay, packet delivery ratio and throughput. The result depicts AODV as having better performance when compared with FSR and ZRP in terms of packet delivery ratio and throughput. AODV delivers well over 60% of packets sent when network is presented as a function of pause time and delivers well over 80% of all CBR packets when network is presented as a number of nodes.

In Yassein and Hijazi (2010), Vice Cluster Based Routing Protocol (VCHCBRP) was proposed to enhancing CBRP, it was specifically designed to assist self-healing of clusters. In other to enable self-healing, the concept of a vice cluster heads was introduced. In the proposal, once a cluster head and its vice are elected, the cluster head will notify every member of the cluster about its vice. In case, the cluster head dies due to power exhaustion and or moves away from the cluster, the vice cluster announces itself as the de-facto cluster head. Both SERC and VCHCBRP increases network stability and improve the clustering performance, however, selection of secondary clusterheads increase routing overhead.

Cross-CBRP proposed by Dana, Yadegari, Hajhosseini, and Mirfakhraie (2008) adopted mobility aware clustering algorithm which uses cross layer design to handle problems of cluster instability. The price to pay for the cross layer design is the increasing design complexity to be able to gather and compiling information from different layers of the network.

Jahanbakhsh and Hajhosseini (2008) proposal was intended to also use cross-layer design to optimize CBRP. They exploited parameters that are characterized and shared by Physical, MAC and Network layers and use the signal strength to determine the mobility speed of nodes that was used in selecting the cluster head node. It was noted that cluster head change rate is reduced, hence superior protocol performances with respect to original CBRP. However, it was noted that the cross layer design increases design complexity (Dana et al., 2008; Jahanbakhsh & Hajhosseini, 2008). Apart from the complexity of design, other limitations of the abovementioned algorithms are that they consider one node metric for selection of cluster heads. In a highly dynamic and scalable topology, consideration should be given to various parameters exhibited by node in order to form highly stable and reliable clusters. A cluster formed with a single parameter consideration can affect the stability and the organization of the clusters, hence poor routing performance.

i-CBRP as proposed in Adekiigbe and Abu-Bakar (2015) made some changes to the cluster head table and the data packet header of *CBRP* to validate the proposed congestion avoidance mechanism. This yielded a new improved *CBRP* that is fortified with a congestion avoidance mechanism. In the first instance, we add transmission rate information to the packet header from the transmitting cluster head to be able to notify the receiving cluster head of the present traffic rate state and also we add the present traffic rate to the cluster heads table to provide immediate access for comparison by the packet receiving cluster head.

Due to significance improvement made to CBRP in *i-CBRP*, the intention here is to benchmark *i-CBRP* with some established routing protocols.

METHODOLOGY

In this paper, performance of each of the protocol under consideration is studied using simulation techniques. It is adequate to simulate in a situation where the real test-bed is a bit costlier to bring together. We simulated a MANET network of 1000 x 1000 meters with varying number of nodes which ranges between 30 and 60 using network simulator 2 (ns-2). We examined the behavior of these protocols under varying network densification. Table I depicts the simulation environment in which the experiments were carried out.

In order to moderate the node mobility within the network, the velocity of nodes is stationed at 10m/s while the pause time was set to zero in the simulation.

Random Waypoint Mobility Model is used based on the fact that this model is most widely used as entity mobility model for researches in MANET (Zhang & Chong, 2009). In this mobility model, each member node selects a destination within the simulation area while the node speed is consistently distributed between the minimum and maximum speed. Once a member node determines and selects a speed, it then travels toward the destination based on the selected speed. When the member node arrives the destination, it pauses for a period of time before starting the process of selecting the next route.

Table I: SIMULATION ENVIRONMENT

Parameters	Value
Node Range	250m
Phy and MAC Model	802.11
Radio Propagation Model	Two-Ray
Max. Queue Capacity	50 packets
Packet Size	512 bytes
Mobility Model	Random Waypoint
Traffic Source	UDP
Simulation Time	200s
Network Area	1000m x 1000m
Traffic Type	CBR
Number of Nodes	30-60
Node Mobility Speed	10m/s

Among the various parameters evaluated are average packet delay, packet delivery ratio, traffic overhead and network throughput. The choice of parameters for evaluation are based on some related works presented in Adekiigbe and Abu-Bakar (2015), Ng, Ng, Ali, and Noordin (2013), and Salunkhe and Sankpal (2013). Average packet delay gives the average time necessary to transfer a data packet from one node to another. The packet delivery ratio compute the percentage of packets sent within the networks that are successfully delivered to the destination. The volumes of traffic generated by routing protocols are evaluated by the traffic overhead parameter. The throughput is the total volume of data packets delivered within the simulation time.

ANALYSIS OF RESULTS AND RESULT DISCUSSIONS

The parameter values are selected as highlighted in Table I. *i*-CBRP's performance is compared with DSR, AODV, and CBRP routing schemes while the various performance measures for mobile wireless ad hoc networks are evaluated.

Performance Evaluation under Varying Network Density

In this section, we used the following performance metrics under varying node densification: average packet delay (APD), packet delivery ratio (PDR), traffic overheads (TO) and average throughput (ATP) for DSR, AODV, CBRP and *i*-CBRP.

Average Packet Delay (APD): Delay refers to the time taken by packets to traverse the network from the source node to destination node. It includes delays caused by buffering and wireless transmission during route discovery, queuing at the interface queue, retransmission delays at the MAC, propagation and transfer times. The delay that is calculated from end-to-end only concerns those packets successfully delivered to their destination. Any packet loss due to route failure and any other reasons along the route path are not considered during the calculation of average packet delay parameter. Figure 1 summarizes average delay suffered by packets in each of the routing protocols under consideration based on various node densification.

In AODV routing protocol, hop-by-hop initiation helps reduce end-to-end delay. While the delay for AODV is higher at a start in case of 30 nodes but it reduces in subsequent stages until end of simulation. Since DSR uses cached routes more often, it sends traffic to out-of-date routes which causes re-transmission and leads to too much delays. Delay for CBRP is higher because of its route discovery process. It takes a lot of time to discover and to make decision on a route through which data can be transferred.

The average end to end delay increases as the density of nodes increases for all routing protocols under comparison. CBRP and *i*-CBRP behaves similarly as per the increased in end-to-end delay. This is as a result of the fact that more nodes are connected as network density increases. However, the end-to-end delay increment noticed in *i*-CBRP is lower than that of CBRP.

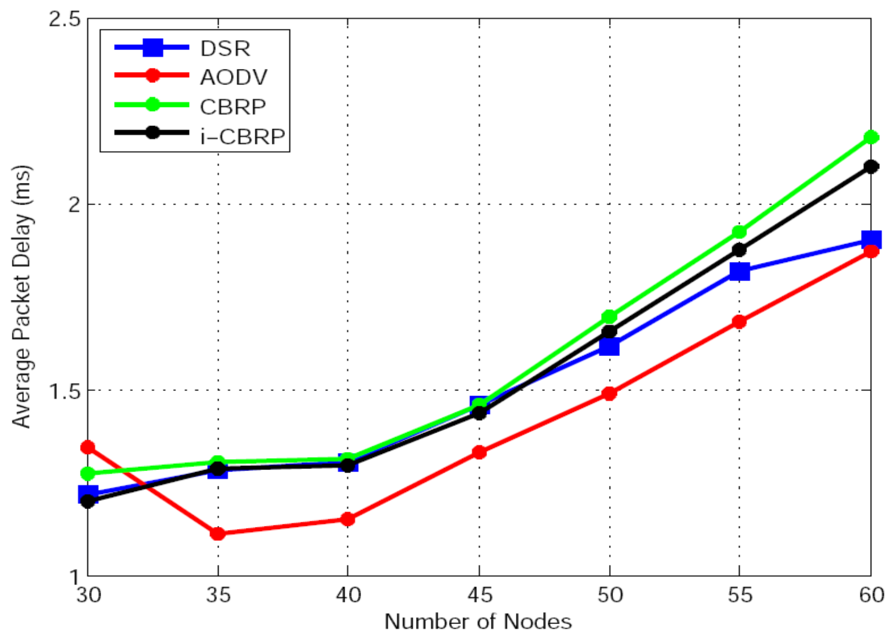

Figure 1: Average Packet Delay in Varying Node Density

Packet Delivery Ratio (PDR): PDR is the total number of data packets received by various destination nodes over the total number of data packets sent by all source nodes within the network area. Figure 2 shows the performance of DSR, AODV, CBRP and *i-CBRP* on packet delivery from source to destination under varying node densities. In all, packet delivery rate increases for all routing protocols as number of nodes increases. The noticeable increment in PDR was as a result two reasons: the pause time for nodes is set to zero and the number of nodes were not much considering the network area. The trend might show decrease in PDR if the node density is higher than what we have for the simulation. *i-CBRP* outperforms all other routing protocols due to congestion free mechanism introduced into its packet routing technique in Adekiigbe and Abu-Bakar (2015).

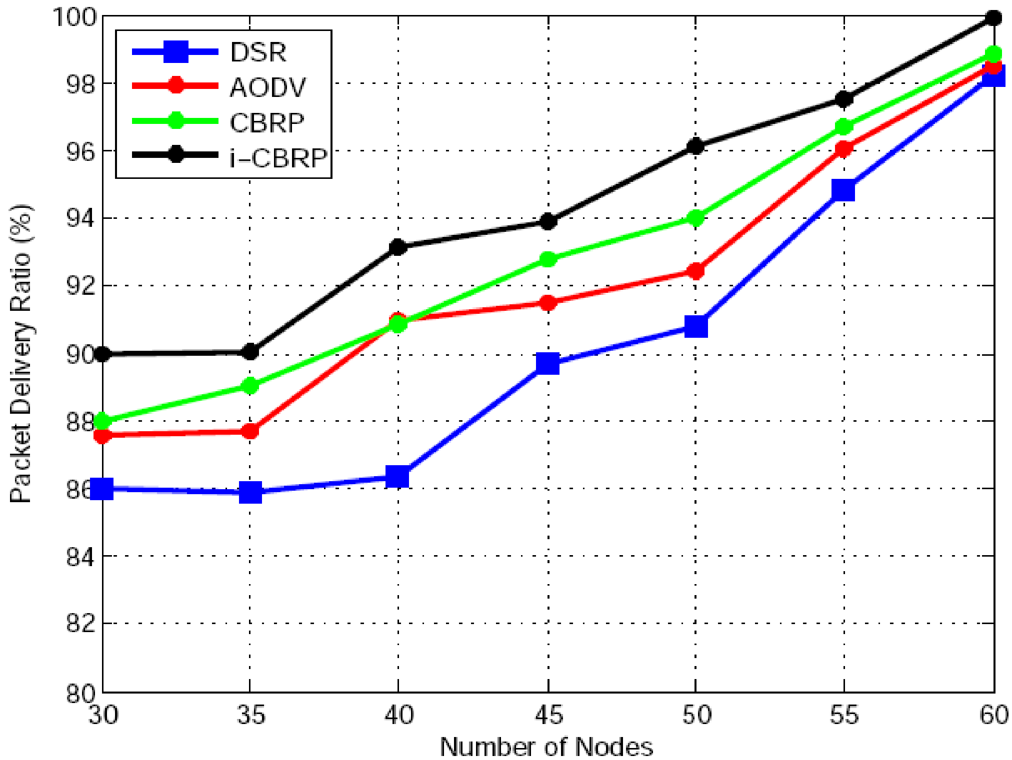

Figure 2: Packet Delivery Ratio in Varying Node Density

Traffic Overheads (TO): The quantity of routing traffic sent by DSR, AODV, CBRP and *i*-CBRP protocols were evaluated. As shown in figure 3, DSR routing protocol incurs less routing overheads, the reason being that it sends the routing traffic only when it has data to transmit. This eliminates the need to send unnecessary routing traffic. AODV incurs routing overhead slightly higher than DSR for reasons of generation of multiple route replies to a single route request. The routing overhead for CBRP and *i*-CBRP is higher than AODV and DSR because of the intermittent beaconing of HELLO packets that are usually sent to discover new route. Since CBRP and *i*-CBRP are constantly flooding the network with control and routing traffics in other to keep its routing tables updated, this resulted in higher routing overhead as compared with AODV and DSR.

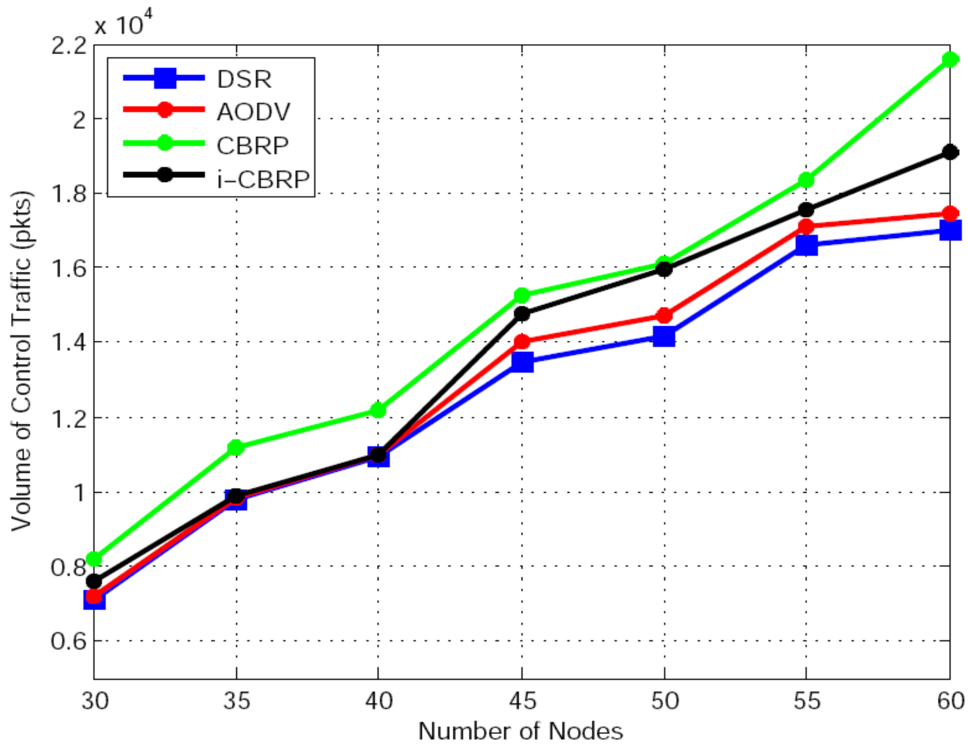

Figure 3: Traffic Overheads in Varying Node Density

Average Throughput (ATP): The total throughput in all cases is highest for i-CBRP as compared with other protocols. This is due to availability of routing paths for data to be sent from source to destination. The total throughput for i-CBRP is higher, this is as a result of the clustering algorithm adopted in i-CBRP (Adekiigbe et al., 2014). AODV performs better in network with relatively high number of traffic sources and higher mobility. The noticeable increment in ATP was due to the number of nodes that make up the network area. If the number of nodes is slightly increased, the throughput generation might reach a saturation point. The DSR throughput is very low in the network in all cases. However, i-CBRP performs better than all other protocols under comparison. This is due to low end-to-end delay enjoyed by the protocol which results in high packet delivery rate.

CONCLUSION

One principal contribution of this paper is to show case the improvement made on CBRP by *i*-CBRP routing protocol. The robustness of *i*-CBRP was depicted in all the performance parameters evaluated. We examined packet delivery rate, average packet delay, traffic overheads and network throughput. In all these parameters, *i*-CBRP performance was averagely better than other protocols under consideration. In the future, we will investigate and proffer solution to the high volume of traffic being generated by *i*-CBRP and also explore the performance of *i*-CBRP with other protocols cluster based routing protocols using varying node velocity.

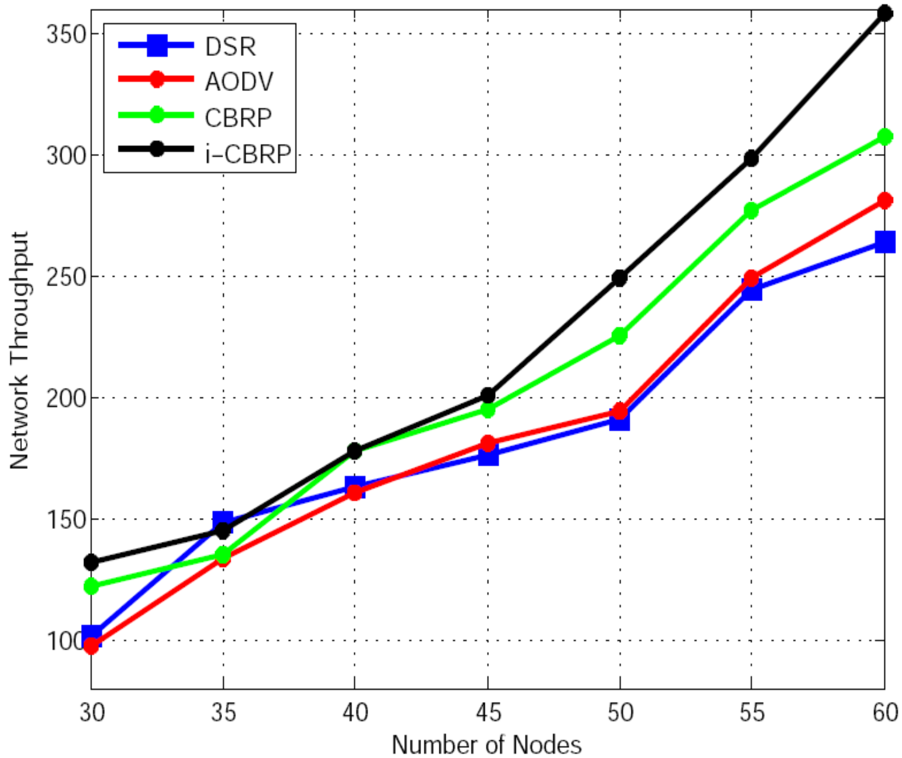

Figure 4: Throughput in Varying Node Density

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