Swarm Optimized Multicasting For Wireless Network

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Abstract: Multicast routing in wireless networking is the latest technology for network groups. Multicast routing is part of point-to-point/multipoint-to-multipoint communications. Multicast routing ensures efficient, reliable and secure for wireless networks than unicast routing due to protocols and techniques speed which are combined on multicast routing for wireless technology. Due to redundancy lack in multipath/multicast structures, multicast routing protocols are vulnerable to the ad hoc networks component failure. Some techniques to overcome this are optimizing routing which increases packet delivery minimizing overhead. Particle swarm optimization (PSO) is a network optimizing tool. This paper proposes new PSO based Multicast Ad-hoc On-demand Distance Vector (MAODV) Protocol for MANETs to improve link break prediction accuracy and congestion occurrence. The proposed technique improves routing packages packet delivery ratio. PSO based MAODV allows each network node to forward multicast data packets which are broadcast when propagated along a multicast group tree.

[C. Rajan, N. Shanthi. **Swarm Optimized Multicasting For Wireless Network.** *Life Sci J* 2013;10(4s):511-516] (ISSN: 1097-8135). http://www.lifesciencesite.com. 78

Keywords: Wireless Networks, Multicasting, Multicast Ad-hoc On-Demand Distance Vector Routing (MAODV), Particle swarm optimization (PSO)

1. Introduction

Wireless applications, like emergency searches, rescues and military battlefields where information sharing is mandatory, need rapidly deployable and quickly reconfigurable routing protocols. This leads to the need for multicast routing protocols. Multicasting is crucial in MANETs to support such applications involving datagram transmission to a group of zero or more hosts identified by a single destination address. It is projected for group oriented computing. All the host group destination members receive a multicast datagram with the same "best effort" reliability as unicast IP datagrams. The datagram is not guaranteed to arrive intact at group member destinations or in the same order with regard to other datagrams [1]. Multicasting in MANETs has many benefits including reducing communication cost improving wireless channel efficiency when sending multiple copies of same data by exploiting wireless transmission's inherent broadcasting properties. Multicasting minimizes channel capacity consumption instead of sending data via multiple unicasts, preserves sender and router processing, energy consumption, and delivery delay, which are important MANET factors. Also, multicasting provides simple and robust communication method through which a receiver's individual address remains unknown to the transmitter or is transparently changeable by the transmitter [2, 3].

Wireless networks have two types of multicast routing protocols and they include tree-based multicast routing protocol. This can be unstable in multicast ad-hoc routing protocols due to needing regular re-configuration in dynamic networks. An example is Multicast extension for Ad-Hoc On-Demand Distance Vector (MAODV) [4] and Adaptive Demand- Driven Multicast Routing protocol (ADMR) [5].

Multiple characteristics/challenges should be considered when multicast routing protocols are developed including, network topology dynamics, energy constraints, network scalability limitations and differing characteristics between wireless and wired links like limited bandwidth and poor security [6, 7, 8]. A multicast routing protocol should have robustness, efficiency, control overhead, energy consumption, service quality, unicast routing protocol efficiency and resource management [9].

MANET Multicasting is more complicated than in wired networks with many challenges. Movement of multicast group members precludes the use of fixed infrastructure multicast topology. Wireless channel characteristics vary over time with restrictions on node energy and capacity [10]. Multicast protocols suggested for wired networks can only be indirectly ported to MANETs due to the lack of mechanisms to handle frequent link breakages and route changes, or due to differing networks characteristics. Chiang et al. proposed mechanisms to adapt wired multicast protocols to MANETs [11-12]. Simulation results revealed increased control packet overhead and a lowering in throughput with more node mobility. Additionally simulation results revealed the need to explore alternative multicast strategies.

Several MANET multicast routing protocols, based on different design principles and with different operational features were proposed and evaluated [13-15]. The protocols available in the literature are based on different design principles having different operational features when they are applied to the multicast problem. The properties preferred depend on the protocol.

This paper proposes a new Particle Swarm Optimization based Multicast Ad-hoc On-demand Distance Vector Protocol for MANETs, to improve routing messages packet delivery ratio. PSO based MAODV allows each network node to send multicast data packets, which are broadcast when propagating on a multicast group tree.

2. Related Works

Shen, et al [16] applied swarm intelligence to MANET's multicast routing problems. The proposed protocol adapts a core-based approach to create multicast connectivity among members through a specified node (core). The first multicast connection can be rapidly setup when the core floods the network with announcements that reverse path nodes are requested by group members to serve as forwarding nodes. Additionally, every member who is not a core periodically deploys a small packet behaving like an ant to explore various paths to the core. This helps the protocol to locate new forwarding nodes yielding lower total forwarding costs, where abstract cost represents any metric suiting applications. Simulations demonstrated the proposed approach's performance comparing it with some current multicast protocols.

Xu et al [17] proposed a reliable ODMRP (R-ODMRP) for preferable throughput suited for high-speed MANET including packet acknowledgement, lost packet recovery, secure authentication and QoS based packet delivery. With active network exploration R-ODMRP constructs multicast routing based on a cluster, establishes a distributed acknowledgment/recovery of packet delivery mechanism. With cluster key distributed in one cluster, this protocol authenticates multicast source and receivers consistency based on local security strategy. Specific mesh links are adaptively chosen by descriptive QoS vectors and forwarding nodes flexibly schedule different multicast packets depending on multicast application types. The proposed scheme's performance is evaluated based on the network simulator achieving significant improvement.

Hu, et al [18] proposed a novel algorithm titled distance complete ant colony system (DCACS), which solves multicast routing problems using ants to search for best routes to send data packets from the source node to a destinations group. The algorithm is based on an ant colony system (ACS) framework adopting Prim's algorithm for probabilistic tree construction. Both pheromone and heuristics influence the node selection. Multicast network destination nodes are selected by heuristics first and a reinforcement proportion to destination nodes is studied in case experiments. Three heuristics are tested, with results showing a modest heuristic reinforcement to destination nodes accelerates algorithm convergence achieving better results.

Shirodkar et al [19] proposed multicasting with multiple cores through swarm intelligence adoption. Multiple cores are selected through Swarm intelligence. These connect to group members. Proposed work supports group communication applications requiring much coordination showing dynamic group membership changes. This work is simulated using C language to test operation effectiveness with regard to performance parameters like Packet delivery ratio, Latency and route discovery time.

3. Methodology

3.1 Multicast Ad-hoc On demand Distance Vector Protocol (MAODV)

Multicast Ad-hoc On demand Distance Vector Protocol (MAODV) [20-23] is an integral part of Ad-hoc On demand Distance Vector Protocol (AODV) performing unicasting, broadcasting and multicasting. MAODV is an on-demand tree based protocol where nodes are not group members but their position is critical to forwarding multicast information.

When a node plans to send a message, it locates a route for this purpose. When a node wants to join a multicast group/send a message having no prior route to a group, then it sends a Route Request (RREQ) message. Similarly, if a member node wants to terminate group membership it seeks termination from the group after which membership is terminated.

All multicast groups have an unique address and group sequence number. A group member who first constructs the tree becomes that tree's group leader and has to maintain it by periodical broadcasting of Group Hello (GRPH) messages.

Each node has three tables: Unicast Route Table, Multicast Route Table and Group Leader Table. Unicast Route Table has the net hop's address to which the message is forwarded. Multicast Route Table has next hops addresses for each multicast group's tree structure. Group Leader Table records current multicast group addresses with group leader and the next hop addresses and that the group leader receives a periodic GRPH message.

Tree structure nodes are described as downstream or upstream nodes. When a node leaves a multicast group, tree structure requires pruning. A downstream node is required to repair breakage when a link breaks. It is also responsible for sending GPH-U to all downstream nodes to indicate a new leader and update group information into Multicast Route Table.

MAODV protocol's increased mobility causes frequent link breakages and data packet drops with link outages generating repair messages and increasing control overheads. Packet drops are minimized by using an intelligent technique, Particle swarm optimization (PSO) to existing MAODV.

3.2 Particle swarm optimization

Particle swarm optimization (PSO) is a computational intelligence optimization approach based in the behaviour of swarming/flocking animals like birds/fishes. In PSO, an individual moves from a given point to a new weighted combination of the individual's best position found, and of the group's best position. PSO algorithm is simple involving adjusting few parameters. It is applicable, with some modification, to a range of applications and PSO have received growing interest from various field researchers due to this.

PSO selects the algorithm which repairs broken links in this work assuming that each node (particle) executes its individual PSO algorithm. A swarm includes all nodes on a primary route. AODV-BR [24] outperforms AODV-LR (Local repair) when the intermediate node moves fast or is far from the destination. This work assumes that the following equation based on AODV-LR and AODV-BR simulation results is valid,

$$BR(t) = x_1 \left(v(t)\right)^{x_2} * \left(h(t)\right)^{x_3}$$

where the inputs $v(t)$ and $h(t)$ denote node speed and remaining hop counts, respectively, and output BR(t) is compared to a predetermined threshold to decide which approach constructs alternate path if there is a link break. The parameters x1, x2 and x3 are determined by PSO technique. The PSO's fitness function is packet delivery ratio for multimedia packets at intermediate nodes, as high packet delivery ratio goal achievement is the aim of this work. Again, packet delivery ratio achieved by each service route's best particle is passed by HELLO message during fixed time intervals.

This work allows each node to execute its individual PSO algorithm to adapt to MANET's volatile environment. Motivation to use PSO congestion detection module is to ensure learning and adapting capability. Similar to AODV approach, an acknowledgment (ACK) packet is reverted to the source node when destination node gets a data packet to certify successful packet delivery to destinations. When a source node fails to receive an ACK packet shortly, due to either data packet or returning ACK packet being damaged, the source node then rediscovers a path.

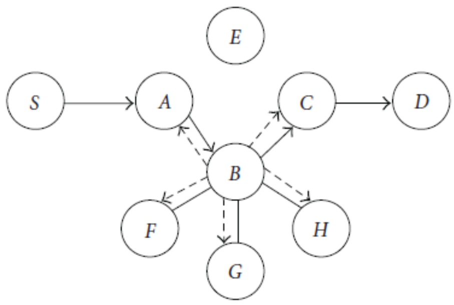

Figure 1: Congestion/Link break message.

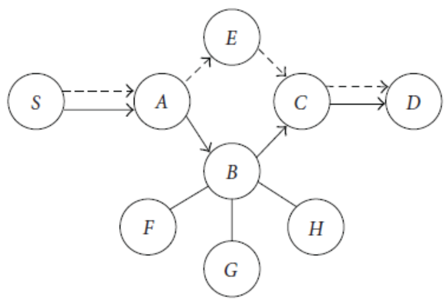

Figure 2: Alternate path construction.

Transmission path nodes can compute packet delivery ratio through counting data and ACK packets that pass through it. This is used as a performance metric for PSO algorithm. A standard PSO algorithm has a swarm of particles representing potential solutions to on hand issues. These particles fly through hyperspace having two essential reasoning capabilities including memory of their own best positions and knowledge of global or neighbourhood's best ones. Swarm members communicate good positions to each other adjusting their positions and velocities based on their positions.

The PSO algorithm employed in this work can be summarized by the following.

(1) Initialize swarm particles so that the position $\vec{x}_{ij}(t=0)$ of each particle is random in hyperspace.

(2) Compare each particle's fitness function, $F\left(\vec{x}_{ij}(t)\right)$, which is the packet delivery ratio

of individuals during current time period, to its best performance till then,

$pbest_{ij}$: if $F(\vec{x}_{ij}(t)) < pbest_{ij}$, then

$$pbest_{ij} = F(\vec{x}_{ij}(t)),$$

$$\vec{x}_{pbest_{ij}} = \vec{x}_{ij}(t)$$

(3) Compare $F(\vec{x}_{ij}(t))$ to the global best particle,

$gbest_j$: if $F(\vec{x}_{ij}(t)) < gbest_j$, then

$$gbest_j = F(\vec{x}_{ij}(t)),$$

$$\vec{x}_{gbest_j} = \vec{x}_{ij}(t)$$

(4) Revise the velocity for each particle:

$$\vec{v}_{ij}(t) = \vec{v}_{ij}(t-1) + c_1.r_1.(\vec{x}_{pbest_{ij}}(t) - \vec{x}_{ij}(t)) + c_2.r_2.(\vec{x}_{gbest_j}(t) - \vec{x}_{ij}(t))$$

where r_1 and r_2 are random numbers between 0 and 1, and c_1 and c_2 are positive acceleration constants.

(5) Move each particle to a new position:

$$\vec{x}_{ij}(t) = \vec{x}_{ij}(t-1) + \vec{v}_{ij}(t)$$

$$t = t+1$$

Repeat steps (2) through (5) until convergence.

4. Results and Discussion

The simulation parameters used are shown in Table 1. The investigations were carried out using MAODV and the proposed PSO based MAODV. OPNET was used for the experimental setup. OPNET - a versatile simulation tool to model devices in the network, protocols and architecture - was used for experiments. OPNET can simulate designed network performance. Simulations were done with 80 nodes over a 6 sqkm area. Wireless nodes are mobile and investigated for 15, 30, 45 and 60 kmph mobility speed. MANET's performance is studied with regard to Packet Delivery Ratio (PDR), End to End delay and Jitter.

Table 1: Simulation Parameters

Parameter	Value
Number of Wireless nodes	80
Area	6000 sqm
Type of Traffic	Constant Bit Rate
Transmission Power	0.05w
Bandwidth	2 Mbps
Node mobility speed	15, 30, 45 and 60 kmph

Table 2 tabulates the simulation results for Packet Delivery Ratio (PDR), End to End delay and Jitter of the network when the mobility speed of the nodes is 15 Kmph.

Table 2: Performance of the Network when mobility speed of nodes is 15 Kmph

	Number of Senders	Avg PDR x100%	Avg. End to End delay in	Avg. Jitter in second
MAODV	1	0.9241	0.0217	0.000632
	10	0.9124	0.0298	0.000602
	20	0.8973	0.0327	0.000642
	30	0.8745	0.0394	0.000928
	40	0.8321	0.0425	0.001274
PSO-MAODV	1	0.9432	0.0207	0.000612
	10	0.9246	0.0237	0.000598
	20	0.912	0.0284	0.000612
	30	0.9017	0.0318	0.000746
	40	0.8832	0.0376	0.000832

Figure 3 to 5 show the graphs of the Packet Delivery Ratio (PDR), End to End delay and Jitter of the network when the mobility speed of the nodes is 15 Kmph.

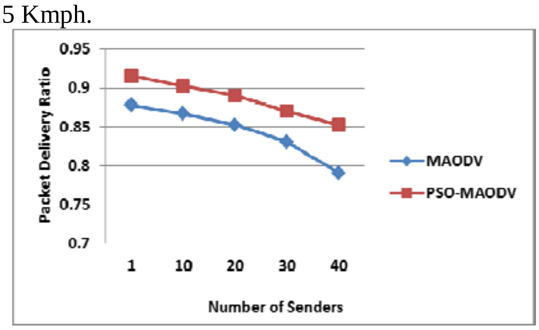

Figure 3: Average Packet Delivery Ratio when mobility is 15 Kmph

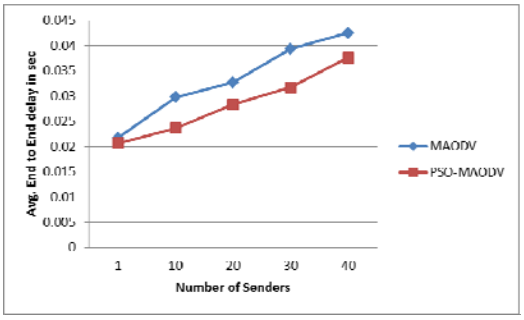

Figure 4: End to End Delay when mobility is 15 Kmph

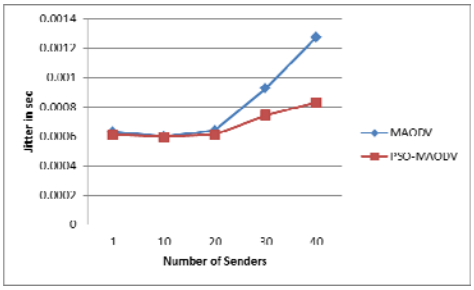

Figure 5: Jitter when mobility is 15 Kmph

Table 3 tabulates the simulation results for Packet Delivery Ratio (PDR), End to End delay and Jitter of the network when the mobility speed of the nodes is 30 Kmph.

Table 3: Performance of the Network when mobility speed of nodes is 30 Kmph

	Number of Senders	Avg PDR x100%	Avg. End to End delay in second	Avg. Jitter in second
MAODV	1	0.877895	0.020615	0.0006004
	10	0.86678	0.02831	0.0005719
	20	0.852435	0.031065	0.0006099
	30	0.830775	0.03743	0.0008816
	40	0.790495	0.040375	0.0012103
PSO-MAODV	1	0.915188	0.0169755	0.00059058
	10	0.902239	0.0228705	0.00057707
	20	0.89008	0.027406	0.00059058
	30	0.8701405	0.028687	0.00071989
	40	0.852288	0.032284	0.00080288

Figure 6 to 8 show the graphs of the Packet Delivery Ratio (PDR), End to End delay and Jitter of the network when the mobility speed of the nodes is 30 Kmph.

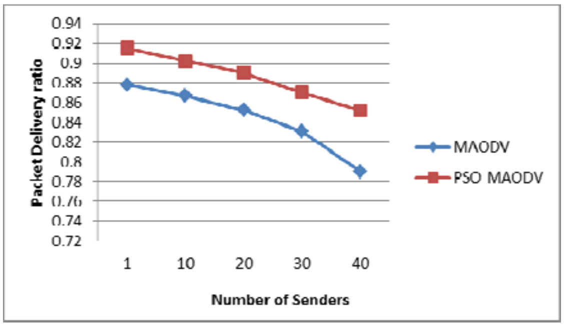

Figure 6: Average Packet Delivery Ratio when mobility is 30 Kmph

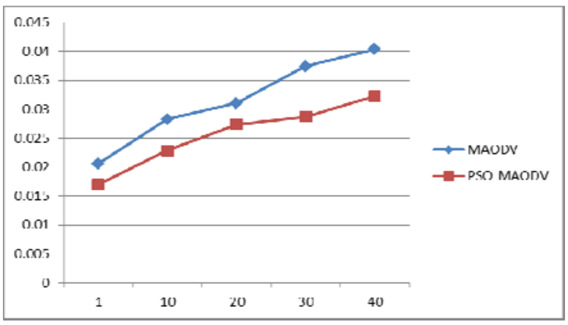

Figure 7: End to End Delay when mobility is 30 Kmph

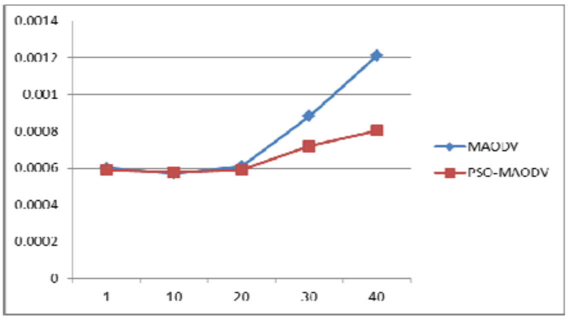

Figure 8: Jitter when mobility is 30 Kmph

It is observed from the tables and figures that the wireless network performs considerably better with PSO-MAODV than MAODV when the mobility is less. PDR improves considerably with the proposed PSO-MAODV. It can be seen that the end to end delay for and jitter also reduces, thus the Quality of service is improved.

5. Conclusion

In this paper, a link enhancement mechanism for MANETs is proposed. Alternate route construction and congestion avoidance mechanisms based on mobility pattern are presented to prevent link failures. This paper proposes new PSO based Multicast Ad-hoc On-demand Distance Vector (MAODV) Protocol for MANETs, to enhance the accuracy of prediction of link break and congestion occurrence. The proposed technique improved routing messages packet delivery ratio. PSO based MAODV allows each network node to send multicast data packets which are broadcast when propagated along a multicast group tree.

Simulations reveal that the proposed PSO based MAODV improved packet delivery ratio and reduced end to end delay and jitter.

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