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The New Multipoint Relays Selection in OLSR using Particle Swarm Optimization

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Abstrak

Standar optimized link state routing (OLSR) memperkenalkan konsep yang menarik, multipoint relays (MPRs), untuk mengurangi beban pesan selama proses pembanjiran. Kami mengajukan algoritma baru untuk pemilihan MPRs untuk mengembangkan unjuk kerja OLSR menggunakan particle swarm optimization sigmoid increasing inertia weight (PSOSIIW). Fungsi sigmoid di peningkatan beban inersia secara signifikan meningkatkan particle swarm optimization (PSO) dalam kesederhanaan dan konvergensi cepat dalam mencari solusi yang optimal. Fungsi fitness baru dari PSOSIIW, penundaan pake tiap titik dan tingkat kemauan diperkenalkan untuk mendukung pemilihan MPRs dalam OLSR. Throughput, rugi-rugi paket dan penundaan dari ujung ke ujung pada metode yang diajukan diuji menggunakan simulator jaringan 2 (ns2). Hasil keseluruhan diperlihatkan bahwa OLSR-PSOSIIW menunjukkan unjuk kerja yang bagus dibandingkan standar OLSR dan OLSR-PSO khususnya throughput dan penundaan ujung ke ujung. Secara umum OLSR-PSOSIIW menunjukkan keuntungan menggunakan PSO untuk mengoptimisasikan jalur rute dalam algoritma pemilihan MPRs.

Kata kunci: *multipoint relays, OLSR, protokol, particle swarm optimization, routing*

Abstract

The standard optimized link state routing (OLSR) introduces an interesting concept, the multipoint relays (MPRs), to mitigate message overhead during the flooding process. This paper propose a new algorithm for MPRs selection to enhance the performance of OLSR using particle swarm optimization sigmoid increasing inertia weight (PSOSIIW). The sigmoid increasing inertia weight has significance improve the particle swarm optimization (PSO) in terms of simplicity and quick convergence towards optimum solution. The new fitness function of PSOSIIW, packet delay of each node and degree of willingness are introduced to support MPRs selection in OLSR. The throughput, packet loss and end-to-end delay of the proposed method are examined using network simulator 2 (ns2). Overall results indicate that OLSR-PSOSIIW has shown good performance compared to the standard OLSR and OLSR-PSO, particularly for the throughput and end-to-end delay. Generally the proposed OLSR-PSOSIIW shows advantage of using PSO for optimizing routing paths in the MPRs selection algorithm.

Keywords: *multipoint relays, OLSR, protocol, particle swarm optimization, routing*

1. Introduction

The development of wireless mesh networks (WMNs) have progressed significantly. With benefit is owned by wireless mesh networks, cities can connect citizens and public services over a widespread high speed wireless connection. This is possible because the infrastructure built by WMNs involves the establishment of multihop routes. This technology has appeared as an alternative to reduce last mile costs for internet access. The core functionality of WMNs is the routing capability. Routing protocols provide the availability paths through a mesh gateways and nodes in WMNs which the node able to communicate on good or optimal paths over multiple wireless hops. Due to collaboration between mesh nodes, mesh gateways and internet link allowing more efficient bandwidth usage without the need for wire line infrastructure to end user. The routing protocols have to take into account the complexity of radio environment with its frequently changing and maintaining reliable and efficient communication over the WMNs.

The stationary or have minimum mobility nodes, distance between nodes, and multichannel are challenges faced by WMNS in designing routing protocol. Hence, the reliability

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and network performances are important goals for WMNs. Since WMNs share common features with wireless ad hoc networks, the routing protocols developed for MANET's can be applied to WMNs. Among the protocols are Dynamic Source Routing (DSR) [1], Ad hoc On-demand Distance Vector (AODV) [2], Destination Sequenced Distance Vector (DSDV) [3] and Optimized Link State Routing (OLSR) [4]. However, the core concept of existing routing protocols are improved and extended to meet requirements of WMNs. Most of the existing wireless ad hoc routing protocols [1-4] optimize hop count when making a route selection. The OLSR is a well-known route discovery protocol for wireless mesh networks. OLSR optimizes the flooding of link state information through network using MPRs. Only nodes selected as MPRs have right to forward the data packet.

Finding the optimal MPRs selection has been proven to be NP-complete problem [4]. The OLSR routing protocol also known as RFC 3626 proposed a simple algorithm for MPRs selection. The MPRs selection algorithm has been further investigated in [5-9]. In [5], proposed the Qayyum heuristic for MPRs selection and analyzed [6-7, 9] with NP-complete problem. The results show the efficiency of MPRs using Qayyum heuristic [5]. The evaluation performances of MPRs for Qayyum heuristic [5] have analyzed with analytical methods for indoor (random graph) and outdoor (random Cartesian graph) environment models [8]. They [8] made comparison between MPRs OLSR with non optimized link state routing protocols. The results show that the MPRs able to provide optimal route length and minimize flooding through the WMNs. Other INRIA Technical Report written by D. Nguyen and P. Minet [10] added QoS parameters such as available bandwidth, delay, loss rate and residual energy into MPRs selection. They made comparison in MPRs selection using non Qos and QoS parameters. The results show the number of MPR nodes in QoS MPR higher than non QoS in large and dense networks.

The optimal path in MPRs selection using QoS parameters becomes interesting issue for enhancement of the OLSR. Two algorithms for MPRs selection based on QoS parameters are introduced [11]. The maximum bandwidth and minimum delay have been choose as QoS parameters in order to improve quality requirements in the MPRs selection and routing information. The proposed algorithm found the optimal MPRs with guarantee maximum bandwidth and minimum delay has better result than others in static and mobile networks simulation [12].

The development of OLSR continues and has created opportunity to apply artificial intelligence algorithm such as genetic algorithm (GA), simulated annealing (SA), tabu search (TS), greedy algorithm and neural network (NN) also contribute to the improvement of MPRs selection algorithm in OLSR. The MPRs selection using GA, SA and TS is introduced by Chizari et al. [13]. Nguyen and Minet [10] and Guo and Malakooti [14] are proposed the greedy algorithm and NN for achieving the improvement of the OLSR. These methods of MPRs selection aim to minimize node re-transmission by selecting the MPRs node and to deliver the data packet efficiently with less packet loss in WMNs. The drawback of these methods is the computation time consumed in the node when calculation the MPRs selection in WMNs.

Based on literatures, the researchers have proposed many MPRs algorithm to enhance the OLSR. The MPRs selection has been added with QoS parameters such as bandwidth, delay, probability of delivery, link stability, transmission packet delay, expected transmission, loss rate and residual energy. It is found in the literatures two types of approach applied in making decision of MPRs node in OLSR; mathematical model and artificial intelligent methods. The mathematical model has been influenced many MPRs selection algorithm. However, only few [10, 13-14] has explored the advantages of artificial intelligence method for MPRs selection enhancement.

The complexity of network has been our motivation to use the Particle Swarm Optimization that also known to be advantageous compared to other artificial intelligence algorithms. Due to its simplicity, the PSO in MPRs selection is proposed and simulated in various applications and different density of networks. The PSO has modified to meet requirement of MPRs selection with contribute better QoS performance. The simplicity and quick convergence towards optimum solution is the solution has proposed by the new PSO named as Particle Swarm Optimization Sigmoid Increasing Inertia Weight (PSO-SIIW). Thus, the PSO-SIIW has implemented in MPRs selection algorithm with less iteration to finding the MPRs nodes in WMNs.

The new fitness function as part of PSO-SIIW which is packet delay of each node and degree of willingness are proposed. The packet delay will be calculated based on the average time required to send packets from one node to another in one hop. Thus, the degree of willingness refers to the willingness of the node to give priority to other nodes in order to send data in the network.

This paper is organized as the following. In Section 2 introduce the proposed OLSR-PSOSIIW and functionalities. Simulation results and discussions are presented in Section 3. Finally, concluding of this paper in section 4 and acknowledgment ini section 5.

2. The OLSR-PSOSIIW

The key concept of OLSR is MPRs selection to minimize flooding packet through entire WMNs. The broadcast packet handled by MPRs nodes forwarding the packet to the destination nodes. Much of the algorithms for MPRs selection in WMNs have been proposed as mention in section 2. To optimize the selection of MPRs node in WMNs, a different approach in MPRs selection algorithm using PSO-SIIW is introduced. The simplicity and quick convergence towards near optimum solution are advantageous to PSO-SIIW for implementing the MPRs selection algorithm. The new approach of MPRs selection named as OLSR-PSOSIIW will be simulates and evaluates the performance compare to other OLSR.

2.1. OLSR

OLSR is a link state type, table driven and proactive routing that uses the multipoint relays (MPRs) for forwarding the network packet. OLSR has been developed at INRIA [4] and has been standardized at IETF as Experimental RFC 3626 [4]. The functions of MPRs are to minimize the overhead of routing messages, limit the flooding effect of broadcast and provide shortest path in OLSR. This technique restricts the set of nodes retransmitting a packet from all nodes, to a subset of all nodes. The size of this subset depends on the topology of the network.

In MPRs selection, every node calculates its own set of MPRs as a subset of its symmetric neighbor nodes chosen so that all 2 hop neighbors can be reached through a MPR. The mechanism shows that for every node in the network it can be reached from the local node by at least two symmetric hops and there must MPRs that has symmetric link to the node.

OLSR may optimize the reactivity to topological changes by reducing the maximum time interval for periodic control message transmission. Furthermore, as OLSR continuously maintains routes to all destinations in the network, the protocol is beneficial for traffic patterns where a large subset of nodes are communicating with another large subset of nodes, and where the (source, destination) pairs are changing over time. The protocol is particularly suited for large and dense networks, as the optimization done using MPRs works well in this context. The larger and more dense a network, the more optimization can be achieved as compared to the classical link state algorithm.

OLSR is designed to work in a completely distributed manner and does not depend on any central entity. The protocol does not require reliable transmission of control messages: each node sends control messages periodically, and can therefore sustain a reasonable loss of some such messages. Such losses occur frequently in radio networks due to collisions or other transmission problems.

The OLSR does not require sequenced delivery of messages. Each control message contains a sequence number which is incremented for each message. Thus the recipient of a control message can, if required, easily identify which information is more recent - even if messages have been re-ordered while in transmission.

2.2. The Particle Swarm Optimization Sigmoid Increasing Inertia Weight

Particle Swarm Optimization (PSO) is population based stochastic optimization technique inspired by social behavior of bird flocking and fish schooling [15]. The PSO algorithm was first introduced by Erberhart and Kennedy in 1995 [15-16]. A PSO algorithm maintains a swarm of particles, where each represents a potential solution. In analogy with evolutionary computation paradigms, a swarm is similar to a population, while a particle is similar to an individual. Each particle adjusts its trajectory towards the best its previous position attained by any member of its neighborhood or globally, the whole swarm. The particles are flown through multidimensional search space, where the position of each particle adjusted according to its own experience and that of its neighbors. The movement of each particle in search space with adaptive velocity and store the best position of the search space it has ever visited. The particles search for best position until a relatively unchanging state has been encountered or until computational limitation exceeded.

Since its introduction, PSO has seen many improvements and applications. Most modifications to the basic PSO are directed towards improving convergence of the PSO and increasing the diversity of the swarm [17]. The modification in PSO consists of three categories: extension of field searching space [18], adjustment the parameters [19], and hybrid with another technique [20]. A number of parameters modification include inertia weight, velocity clamping, velocity constriction, cognitive and social coefficient, different ways of determining the personal best (*pbest*) and global best (*gbest*) positions, and different velocity models. The modification of basic PSO was reported in [21-23] that introduced new methods of inertia weight which tuned based on trial and error. Suitable selection of the inertia weight provides a balance between global and local searching. In these concepts proposed a linearly decreasing, linearly increasing and sigmoid decreasing inertia weight to get better PSO performance. There are advantages between three methods which is sigmoid decreasing inertia has near optimum solution better than the others and linearly increasing weight has quick convergence ability better than the others. For Linear decreasing has near optimum solution better than linear increasing inertia weight (LIIW).

The efficiency of PSO is expressed as the number of iterations or generations to find optimum solution with specified accuracy. With less generation, the near optimum solution can be reach with quick convergence ability by the swarm. This paper presents alternative solution for quick convergence towards near optimum solution. The method of sigmoid increasing inertia weight (SIIW) is proposed exploiting sigmoid inertia weight function leading to fast towards the solution region. The schema attempted to increase inertia weight by means of sigmoid function.

This work has been proposed in [24]as a new PSO inertia weight modulated with sigmoid function for improving the performance of PSO. Based on the detail observation and analysis, this method has been inspired by the excellence performance show by linearly increasing and sigmoid decreasing inertia weight. The concept of an inertia weight was developed is to control exploration and exploitation. The aim of inertia weight was to be able to control the exploration and exploitation mechanism and eliminate the need for velocity clamping. The use of an inertia weight in the PSO algorithm is first published in 1998 [25]. The inertia weight has been successful in addressing the first aim but could not completely eliminate the need of velocity clamping. The inertia weight (*w*) controls the momentum of the particle by weighting the contribution of the previous velocity. Equation (1) and (2) describe the velocity and position update equations with an inertia weight included [25]. It can be seen that these equations with the addition of the inertia weight (w) as a multiplying factor of v_i^k in equation (1).

$$v_i^{k+1} = w * v_i^k + c_1 * rand() * (pbest - x_i^k) + c_2 * rand() * (gbest - x_i^k) \quad (1)$$

$$x_i^{k+1} = x_i^k + v_i^{k+1} \quad (2)$$

$$w_k = \frac{(w_{start} - w_{end})}{(1 + e^{u*(k - n*gen)})} + w_{end} \quad (3)$$

$$u = 10^{(\log(gen) - 2)} \quad (4)$$

where:
w_k is inertia weight at *k* (number of particle), w_{start} and w_{end} are inertia weights at the start and end of a given run, respectively. Furthermore, *u* is the constant to adjust sharpness of the function, *gen* is the maximum number of generations to run and *n* is the constant to set partition of sigmoid function.

In sigmoid increasing weight, a small inertia weight is maintained in the first part of PSO process to implement local search. This process facilitates the PSO to avoid being attracted only to local optima, explore the whole solution space and make out the correct direction [21]. Next, a large inertia weight is retained to facilitate global optima more efficiently. There is a gradation between small and large value for local and global search. However, such alteration improves the quick convergence ability and maximizes the solution prominently. In this work, the proposed PSO-SIIW is applied in OLSR to improve MPRs selection. Details are discussed in next section.

2.3. MPRs Selection using OLSR-PSOSIIW

OLSR performs a distributed election of a set of multipoint distribution relays (MPRs) that play the role of designated routers. In OLSR, only nodes such as MPRs are responsible for forwarding control traffic, intended for diffusion into the entire network. MPRs provide an efficient mechanism for flooding control traffic by reducing the number of transmissions required. In this experiment, OLSR makes use of "Hello" messages to find its one hop neighbors and its two hop neighbors through their responses. However, when there are more than 1-hop neighbors covering the same number of uncovered 2-hop neighbors, the one with the minimum delay and high degree of willingness to the current node is selected as MPRs node.

The OLSR uses exchange HELLO messages to get information and calculate delay. In OLSR, a node emits HELLO messages periodically. Changes in the neighborhood are detected from the information in these messages. A HELLO message contains the emitting node's own address and the list of neighbors known to the node, including status of the link to each neighbor (e.g. symmetric or asymmetric). A node thereby informs its neighbors with which neighbors, and in what direction, communication has been confirmed.

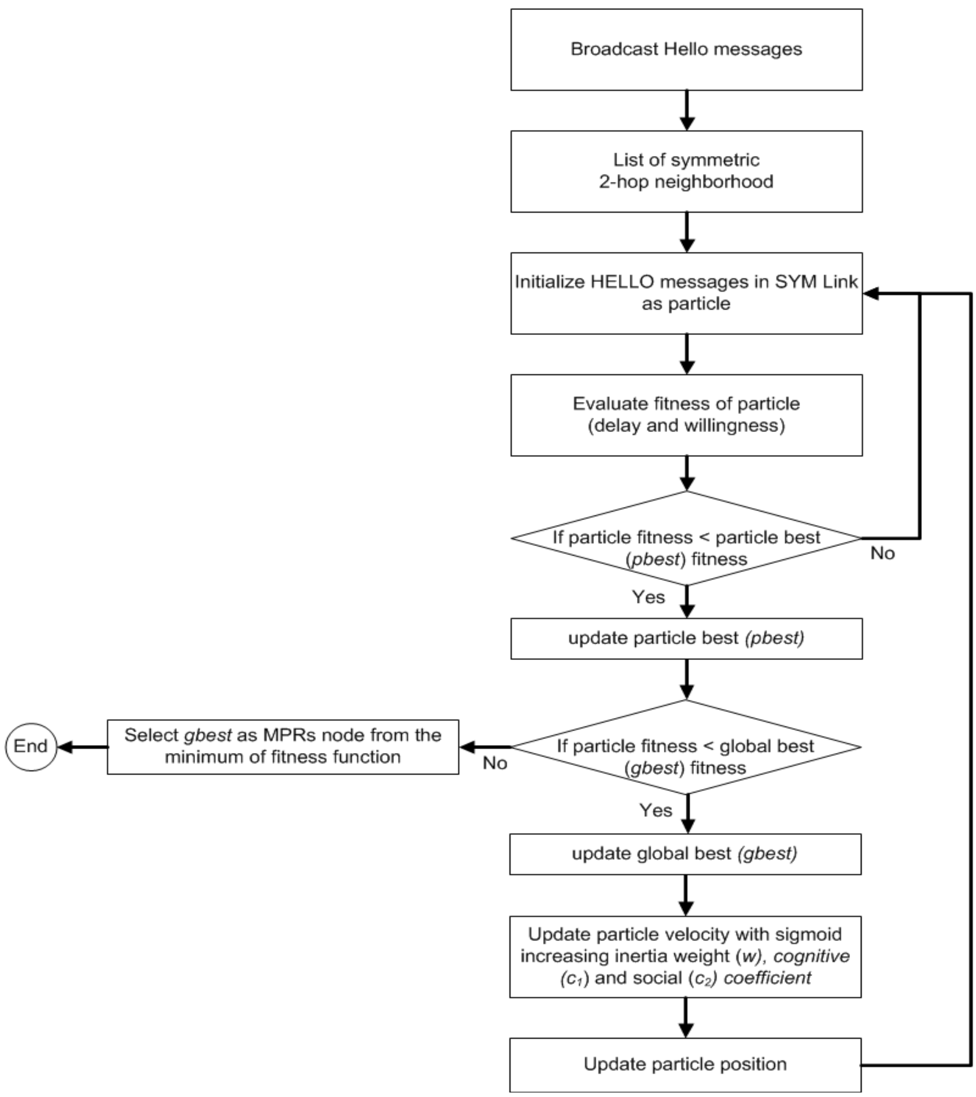


Figure 1. The flowchart of OLSR-PSOSIIW in MPRs selection algorithm

Upon receiving a HELLO message, a node can thus gather information describing its neighborhood and two-hop neighborhood, as well as detect the quality of the links in its neighborhood: the link from node *m* to neighbor *n* is symmetric if in the HELLO message from *n* the node *m* sees its own address (with any link status)-otherwise the link is asymmetric. The process of MPRs selection in OLSR-PSOSIIW is shown in Figure 1.

Each node maintains an information set, describing the neighbors and two hop neighbors. Such information is considered valid for a limited period of time. HELLO message is exchanged between neighbors only and provides a node with topological information describing its neighborhood and two hop neighborhoods. The information from the HELLO Message exchange together with its time sent and time received will be used to calculate delay between nodes which becomes one of our proposed routing metrics for OLSR-PSOSIIW. The other proposed routing metric is degree of willingness.

The degree of willingness refers to the willingness or interest of the node in wireless mesh networks to give a contribution or commitment to other nodes in order to send data in the network. In OLSR, the willingness is set based on power status of the node [26]. The willingness node is set to any integer value between 0 to 7 and it indicates how willing a node is to forward traffic on behalf of other nodes. The list of willingness values as shown in table 1 [27].

Table 1. Degree of Willingness

Degree of willingness	Value
WILL_NEVER	0
WILL_LOW	1
WILL_DEFAULT	3
WILL_HIGH	6
WILL_ALWAYS	7

By default, nodes will have willingness WILL_DEFAULT. WILL_NEVER indicates that a node always be selected to carry traffic on behalf of other nodes. If the node no longer carry the foreign traffic due to the draining of power capacity then willingness status becomes WILL_NEVER.

After calculating delay from HELLO messages exchange and setting the degree of willingness the routing metric becomes the fitness function for PSOSIIW (see equation 5). In PSOSIIW, a number of particles are placed in the search space of fitness function. Thus, the PSOSIIW evaluate each particle's objective of fitness function at its current position. Each particle represents as HELLO Messages in every node and determines its movement through the search space by combining aspect of history of its own current and best location (best fitness) with those of one or more members of the particles with some random perturbations. The next iteration takes place after all particles have been moved. The process of PSOSIIW will come to end when criterion is met (minimum fitness function) is found. The node with minimum value of fitness function will be selected as MPRs node.

$$f_{mn}(k) = d_{mn}(k) + w_{mn}(k) \quad (5)$$

where:

$f_{mn}(k)$: fitness function for transmission of packet *k* from node *m* to node *n*

$d_{mn}(k)$: time delay required by transmission of packet *k* from node *m* to node *n*

$W_{mn}(k)$: degree of willingness of packet *k* transmission from node *m* to node *n* (the value is integer).

3. Simulation Results and Discussions

To validate the proposed method, the performance of the proposed OLSR-PSOSIIW against OLSR-PSO (OLSR-Particle Swarm Optimization) and Standard OLSR (RFC 3626) is compared. The UM-OLSR v0.8.8 [28] in ns2-2.34 as the simulation tool and made some assumptions on the parameters of the system architecture. The simulation modeled a network in a 1000 m x 1000 m area with 10 to 200 nodes in grid topology. The simulation time is 200 seconds [29] with two applications (FTP and Voice). The maximum packet size for FTP and voice application is 512 and 200 bytes per packet with interval 0.25 and 0.05 seconds respectively. Transmission range is set to 200 m.

The parameters of PSO algorithm are chosen as follows: the maximum generation is set to 500 [28]. The learning rates c_1 and c_2 described in equation (1) are set to 1 [30].

To observe analyze the performance of each method, three values are measured:

a. Throughput: The amount of data that can be transferred through a network within a certain time period.
b. Packet Loss: The discarding of data packets in a network when a node is overloaded and cannot accept any incoming data at a given moment.
c. End-to-End Delay: The time taken for a packet to be transmitted across a network from source to destination.

The results obtained for both FTP and voice applications are shown in Figures 2-4.

Figures 2(a) and 2(b) describe the average throughput of standard OLSR, OLSR-PSO and OLSR-PSOSIIW in FTP and voice applications with different number of nodes used. The results show that the throughput increases as the number of nodes increases. The maximum throughputs given by OLSR-PSOSIIW in both FTP and voice applications are 5,586.37 and 1,719.34 kbps, respectively which outperform the standard OLSR and OLSR-PSO. Based on mean and standard deviation analysis, the OLSR-PSOSIIW is able to find an optimal path in multi-hop routing for MPRs selection, better than the standard OLSR and OLSR-PSO.

Figures 3(a) and 3(b) show the end-to-end delay performance of standard OLSR, OLSR-PSO and OLSR-PSOSIIW in the FTP and voice applications. It shows that the average end-to-end delay increases as the number of nodes increases. As shown in Figures 3(a) and 3(b), the minimum end-to-end delays (mean) in the FTP application are 109.07, 132.64 and 4.99 ms for standard OLSR, OLSR-PSO and OLSR-PSOSIIW respectively. On the other hand, the minimum end-to-end delays (mean) for the voice application are 6.88, 6.93 and 1.41 ms for standard OLSR, OLSR-PSO and OLSR-PSOSIIW, respectively. It is also revealed that the OLSR-PSOSIIW performs better performance than the standard OLSR and OLSR-PSO in the end-to-end delay based on mean and standard deviation results. It is observed that the proposed OLSR-PSOSIIW is able to give faster decision in selecting MPRs nodes when the node has many alternative routes in both applications and is able to forward the data packet using MPRs node. Every node in standard OLSR and OLSR-PSO has the protocol processing time longer than OLSR-PSOSIIW. Thus, the shortest path performed by the MPRs selection in OLSR-PSOSIIW produce minimum delay time compared to standard OLSR and OLSR-PSO.

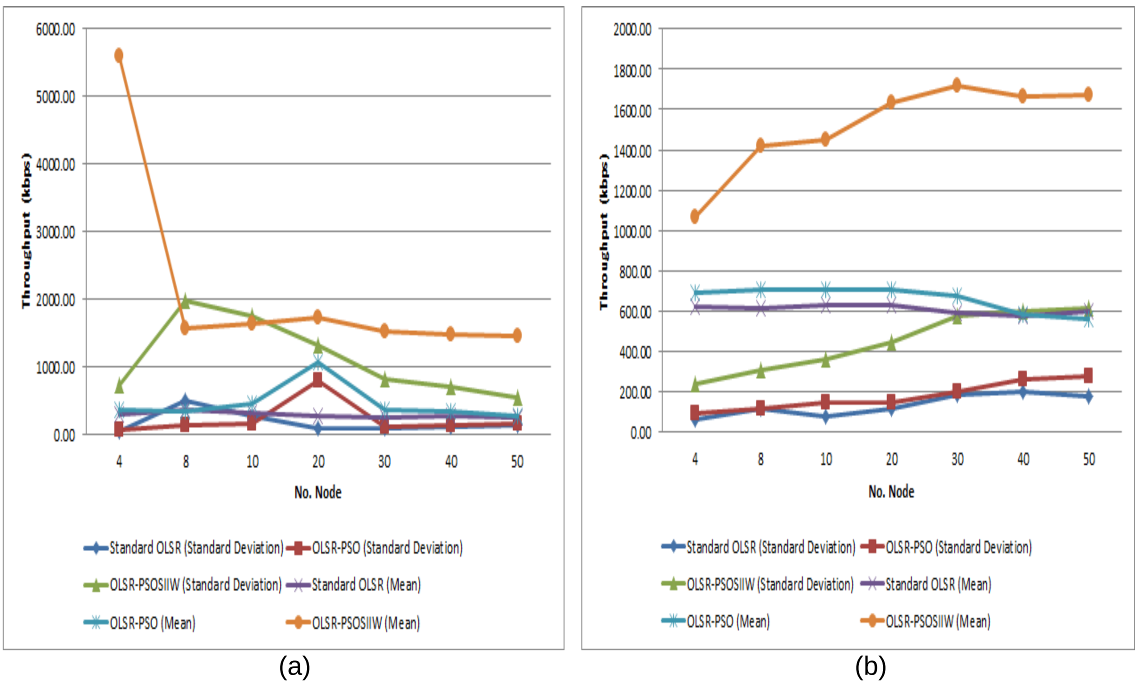
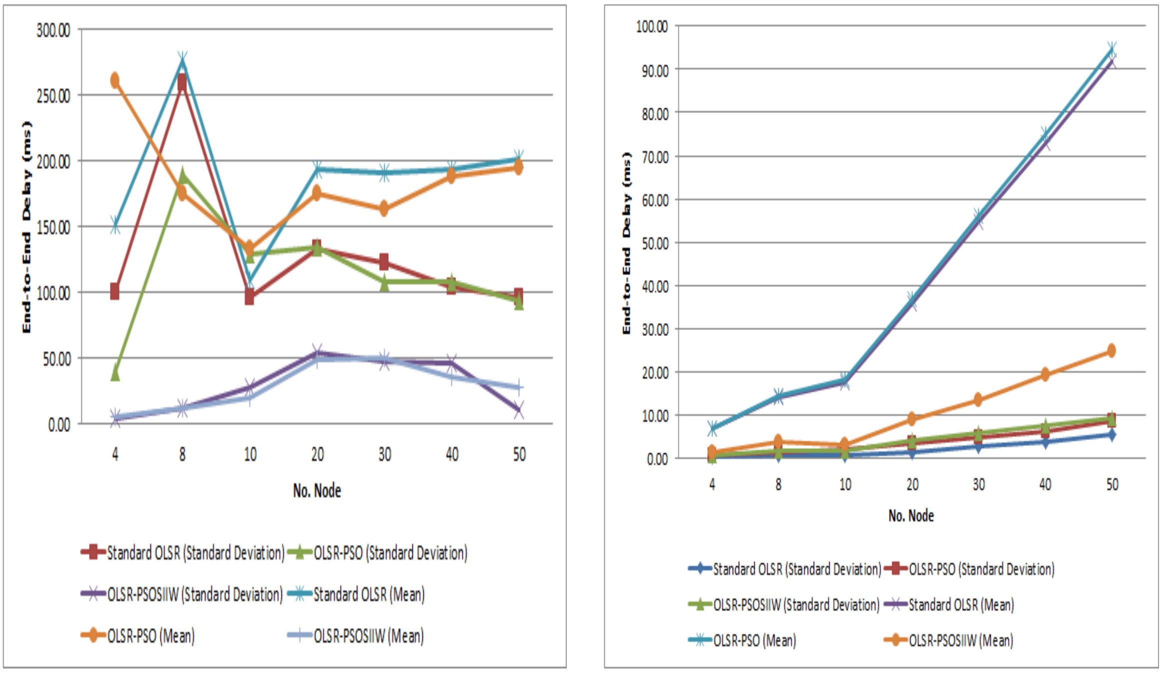
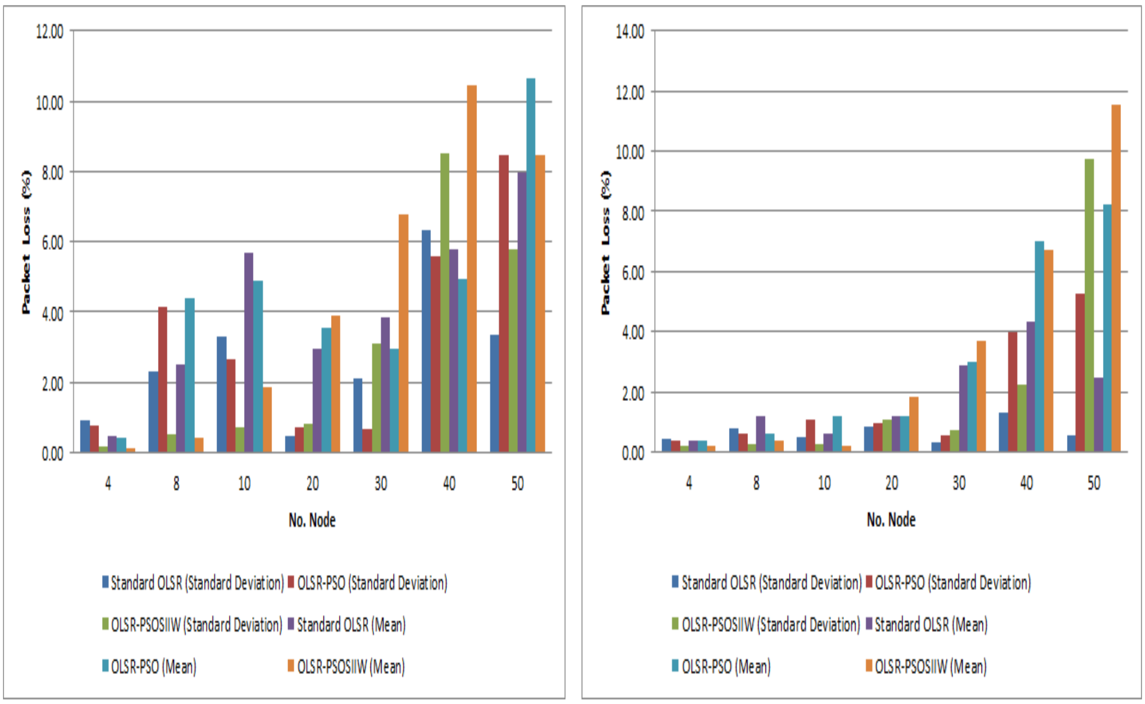


Figure 2. Comparison performances of standard OLSR, OLSR-PSO and OLSR-PSOSIIW for throughput in (a) the FTP application and (b) the voice application.



(a) (b)

Figure 3. Comparison performances of standard OLSR, OLSR-PSO and OLSR-PSOSIIW for End-to-End Delay in (a) the FTP application and (b) the voice application.



(a) (b)

Figure 4. Comparison performances of standard OLSR, OLSR-PSO and OLSR-PSOSIIW for packet loss in (a) the FTP application and (b) the voice application.

Figures 4(a) and 4(b) show the percentage of packet loss for standard OLSR, OLSR-PSO and OLSR-PSOSIIW in FTP and voice applications, for different number of nodes used. The results (mean and standard deviation) show that minimum packet loss in the FTP and voice applications are 0.13% and 0.19% at the OLSR-PSOSIIW for node 4. It is observed here that in the case of packet loss, OLSR-PSOSIIW only outperform the standard OLSR and OLSR-PSO for the nodes up to 10. The OLSR-PSOSIIW in term of packet loss performs better than OLSR-PSO in both applications in less density network (less than 40 nodes). The OLSR-PSOSIIW is more reliable in handling data packet drop in the WMNs compared to the OLSR-PSO. However, the density of network affect the packet loss performance in our propose OLSR-PSO and OLSR-PSOSIIW. The protocol processing time of PSO in OLSR-PSO is longer than the standard OLSR, causing delay and more packet drop.

4. Conclusion and Future Work

In this paper presented an enhancement of MPRs selection in OLSR routing protocol using particle swarm optimization sigmoid increasing inertia weight (OLSR-PSOSIIW) with the delay and degree of willingness are proposed as fitness function. In order to examine our proposed method, throughput, packet loss and end-to-end delay measurements are applied to two different applications; ftp and voice. In the process of MPRs selection, the PSOSIIW algorithm and proposed routing metric are added to every node of wireless mesh networks. The results show that OLSR-PSOSIIW has better performance than the standard OLSR and OLSR-PSO in terms of throughput and end-to-end delay but otherwise in packet loss. In OLSR-PSOSIIW, the FTP application with asymmetric transmission is able to achieve maximum results compared to the voice application. Contrary, OLSR-PSOSIIW has achieved significant performance in end-to-end delay in FTP and Voice applications. The finding indicates our proposed OLSR-PSOSIIW has given promising solution including shortest path in WMNs.

As future work, The OLSR-PSOSIIW development for implementation into wireless broadband router 802.11g and evaluate in experimental environment.

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