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Enhanced Open Shortest Path First (Ospf) Protocol Using Parallel Tabu Search In Wireless Mesh Network

[1]Bilal Abdulhaq, [2]Makhfudzah Binti Mokhtar, [3]Aduwati Sali

[1,2,3]Department of Computer & Communication Systems Engineering,Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

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ABSTRACT

Wireless mesh networks (WMNs) considered as self – organized, self – configured networks, and easily deployed ad hoc networks. Many ad hoc routing protocols were applied to WMNs and several studies were conducted to analyse the functionality of such networks. Many studies have been done on ad hoc routing protocols in WIMAX environment especially OSPF due to its widely available in the real network implementation. However, there was no comparison been made between OSPF and other ad hoc routing protocols such as DSDV, and OLSR in WIMAX environment using mesh mode specifically in terms of throughput, end to end delay, delivery ratio, and packet drop. As the technology of WIMAX using mesh mode is quite immature, this study is aimed to investigate and compare the capability of OSPF with other ad hoc protocols in such technology environment. This study is also intended to contribute to OSPF protocol enhancement dedicated for WIMAX using mesh mode by adjusting the weight setting and applying Parallel Tabu Search PTS – Ring technique. In this study, a performance analyses has been made among Optimized Link State Routing (OLSR) protocol, Destination-Sequenced Distance Vector (DSDV) routing protocol, and an intra-domain link-state of Open Shortest Path First (OSPF). The analysis has been made under WIMAX environment using mesh mode. In our simulation, 10 to 50 mesh nodes were arranged in a mesh topology, with a working area of 500 meter x 500 meter. The transmission range of each node is 250 meters. From simulation results, it was found that the conventional OLSR has the worst performance when it is compared to OSPF and DSDV in term of end-to end delay, delivery ratio and packet drop ratio. The results showed the proposed extension of OSPF has better results than the conventional OSPF in terms of all the above parameters including the throughput.

INTRODUCTION

WMNs can be defined as the packet switched networks that have static wireless routers connected directly to the wired infrastructure where some of these routers are gateways (Yigal Bejerano, Seung-Jae Han and Amit Kumar, 2007). WMNs are low-cost access networks (Miguel Elias, M., 2008), self-organized, self-optimized and have fault tolerant aspects. It means that WMNs have wireless nodes and a wireless backbone interconnects these nodes. WMNs are low-cost access networks (Miguel Elias, M., 2008).

Generally, stationary and/or mobile clients are interconnected in wireless mesh network, and the access is provided optionally to the Internet. The essential feature of a WMN is that data to and from the clients is forwarded using a multi hop strategy by the nodes which are in the core network and hence a Mobile Ad Hoc Network (MANET) is formulated (Mihail, L., Sichitiu, 2005).

From the view of network topology (Kaabi1, F.S., Ghannay2, and F. Filali, 2010), WMNs, Ad Hoc Networks and Wireless Sensor Networks are similar. They are distributed systems and they are created by the wireless communications tools without any central node needed within the network. The communication is done in the network nodes by wireless multi-hop approach by the help of other nodes' relay. However, there are some significant variations between the WMN and the above two networks (Huaiyu Wen, 2012).

First of all, nodes are fixed in WMN; hence topology changes are irregular, and they may occur only because of irregular failures of the node, disabling the node to maintain it, or when new nodes are added. Secondly, the aggregation of traffic characteristics for high traffic flows does not change very often, and network enhancing is allowed by measuring traffic profiles. Thirdly, the traffic distribution in a WMN is twisted, because most of the user traffic is flowed through in or out a wired network. It is happened (Ian, F., *et al*., 2005), due to the need for accessing resources on the Internet. In the end, for an effective backbone provision *proactive* discovery of paths is needed by a WMN and hence decreases packet delays. Quite the

Corresponding Author: Makhfudzah Binti Mokhtar, Department of Computer & Communication Systems Engineering,Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia
E-mail: fudzah@upm.edu.my

reverse, in most mobile ad hoc networks, because of on-demand route discovery acceptance reactive routing approaches are a common as additional packet latency.

On the other hand The IEEE 802.16 standard known as WIMAX was published in 2002 and it is described as the air interface for fixed point-to-multipoint broadband wireless access networks (Michel Barbeau, 2005). It is a rising "broadband wireless access system where the last mile is bridged, replacing costly wire line and also providing high speed multimedia services" (Yan Zhang and Masayuki Fujise, 2006). It offers multi-hop mesh and used as a high speed wide-area wireless network. On top of that, it provides low cost, easy deployment and a solution of scalability for fiber-optic backbone. Larger wireless coverage of about 5 miles, with LOS (line of sight) transmission within bandwidth of up to 70 Mbps, can be provided by WiMax base stations (Hung-Yu Wei, *et al*., 2005).

IEEE 802.16 contains two modes namely point-to-multipoint (P2MP) and mesh mode, and these modes share the wireless medium. First IEEE 802.16 P2MP mode, allows the wireless links to work together with a Base Station (BS) nodes and a set of Subscriber Stations (SSs). The BS operates as transmitter which works only on the downlink that is from Base Station to Subscriber Station; therefore, it works without having any coordination with other stations. The uplink is shared by the subscriber stations to the BS on a demand basis.

Second is the mesh mode where every single node is structured in an ad hoc manner, and the traffic can be transmitted by each node to others. Quality of Service (QoS) is provided on a packet-by-packet concept. A framework having a direct route to backhaul outside the WMN is named as the Mesh BS. Remaining nodes of a WMN are named as the Mesh SSs. Uplinks are the directions to Mesh BS and downlinks are the directions from Mesh BS. Mesh is varied from P2MP mode, since in the mesh mode, the traffic could take place directly between the Mesh SSs, and it is routed by other Mesh SSs.

Unlike point to multi point mode where each of the client nodes has to communicate with the base station before sending information to other client nodes and they should be located within the transmission range of the base stations, mesh mode provided the ability of routing among the clients nodes without the need of base station, and the base station nodes can behave as gateways of that network to the internet and other networks (Bo Han, Weijia Jia and Lidong Lin, 2007).

WIMAX standard using mesh mode has given the IEEE 802.16 the advantages in which the client nodes can perform routing among each other, without the need of base station nodes, as well as providing the network capability of being self-organized, self-configured, and easy maintenance.

Many studies have been done on ad hoc routing protocols in WIMAX environment especially OSPF (Bo Han, Weijia Jia and Lidong Lin, 2007; Xiaowen Zhang and Hao Zhu, 2007) due to its widely available in the real network implementation. However, there was no comparison been made between OSPF and other ad hoc routing protocols such as DSDV, and OLSR in WIMAX environment using mesh mode specifically in term of throughput, end to end delay, delivery ratio, and packet drop. As the technology of WIMAX using mesh mode is quite immature, this study is aimed to investigate and compare the capability of OSPF with other ad hoc protocols in such technology environment. This study is also intended to contribute for OSPF protocol enhancement dedicated for WIMAX using mesh mode.

In this paper, we attempt to achieve the following: First to investigate the performance of OSPF, DSDV, and OLSR in WIMAX environment using mesh mode in term of four parameters i.e. throughput, end to end delay, packet delivery ratio, and packet drop. Second objective in this study is to investigate the performance of the same environment using hybrid OSPF and OLSR protocols in order to enhance the performance of the network routing. Third is to enhance the performance of OSPF by proposing new cost function which depends on bandwidth and delay as well as applying parallel Tabu search technique.

Tabu Search is an iterative method where optimization problems are solved. This technique is capable of using memory structures in an explicit manner to guide a hill-descending heuristic for continuous exploration consistently. For that reason, In our proposed work we implement this technique in WIMAX Mesh environment. Many studies were done in the area of parallelization of iterative heuristics generally and Parallel Tabu Search (PTS) (Bortfeldt, A., H. Gehring, and D. Mack, 2003; Yoshihro Ogita Hiroyuki Mori, 2002; Pierpaolo Caricato, *et al*., 2033; Michel Toulouse, *et al*., 1998) specifically to solve a range of combinatorial optimization problems. Different implementation techniques and approaches were presented in the literature including, using dynamic Tabu Search parameters (Nair, S. and A. Freville, 1997)at different processors, using a cluster in some hierarchical architecture (Ahmad Al-Yamani, *et al*., 2002; Michel Toulouse, *et al*., 1999) to enhance the search, integration of different parallelization strategies (Ahmad Al-Yamani, *et al*., 2002), etc. A detailed survey of various parallelization strategies and their application to one or more classical or specific optimization problems can also be found in the literature (Teodor Gabriel Crainic and Michel Toulouse, 2002; Talbi, E.G., *et al*., 1997; Crainic, T.G., *et al*., 1997).

Based on (Sadiq, M., *et al*., 2009), which is a study that made a comparison among different PTS approaches, the results obtained proved that PTS-Ring has achieved better cost than any other PTS approach including PTS-Star and that is because PTS-Ring induces the diversification into the search. So it was decided to implement the new proposed cost function using PTS-Ring on OSPF and apply the enhanced OSPF in WIMAX Mesh environment.

METHODS AND MATERIALS

Destination Sequenced Distance Vector (DSDV):

DSDV (Vijayalakshmi, M., *et al*., 2010) is based on the traditional Routing Information Protocol (RIP). In DSDV, a new attribute, sequence number is inserted. By this newly inserted sequence number, the mobile nodes can differentiate the information of decayed route and new route. Hence, they will avoid the formation of routing loops.

The main goal of DSDV is maintaining the updated routing data between every single source and destination nodes in the network. More than one table may be used by each node to keep the desired routing information, therefore The number of routing tables and the update method being used are important elements in DSDV (Bo Han, Weijia Jia and Lidong Lin, 2007), as These tables are revised based on the network topology changes by propagating update information through the network. The numbers assigned by the destination node considered as an indication of entries in the table. These numbers act as status indicators of the nodes which therefore, decreases routing loops.

For maintaining table consistency, routing update packets will be transmitted throughout the network. The indication of accessibility of each node to other node and the monitoring of required number of hops to reach the destination nodes applying distance-vector algorithms is done by using routing update packets. These update packets could lead to a high level of traffic in the network. Two types of update packets are presented in DSDV based networks. The first type is transmitted in an infrequent manner known as full dump. Available routing information are carried out by this type of packet. The second type, which is known as incremental packet, is used to send the routing data which is replaced by the last full dump. Both update packets contains fixed size Network Protocol Data Unit (NPDU).

Optimised Link State routing Protocol (OLSR):

OLSR protocol (Sunil Kumar, 2010) is a table driven link-state routing protocol. It is able to establish and maintain efficient paths among the nodes. In OLSR, an optimised flooding procedure is applied for the distribution of information to ensure that the same vision of the network topology is shared by every node in the network. Furthermore, OLSR support the usage of loadable plugins, that can be utilized to grasp and produce costume packet types (Miray Kasa, *et al*., 2011).

The OLSR is an enhancement of the classic link state protocol, adopted for MANETs. In OLSR, the stability of the pure link state algorithm is inherited, and the routes can be obtained immediately when they required. This protocol is one of the examples of a controlled-flooding protocol. Controlled-flooding protocols are designed for control overhead reduction. Flooding the network with routing updates might cause many issues in scalability, specifically if any changes in the working space conditions are happened in a frequent manner. The localized on-demand link state (LOLS) presents a long-term cost and a short-term cost to links. The first one will represent the usual cost and the second one will represent the current cost of a link. For the control overhead reduction, short-term costs are transmitted to neighbours in frequent fashion. But, the long-term costs will be transmitted with longer periods (Rehan Rasheed, M., *et al*., 2010).

OLSR was mainly designed for mobile wireless networks. OLSRv1 was designed at INRIA and standardized by IETF (RFC 3626, 2003). OLSR based OSPF is considered as an optimized classic link state protocol. In standard link state protocols, the overhead is quite high when it comes to the transmission of broadcast packets. By using multi-point relay (MPR) nodes, OLSR can reduce the overall messaging overhead significantly (Venkat Mohan., S and N. Dr. Kasiviswanath, 2011).

Open Shortest First (OSPF):

OSPF (Er. Monika Gupta, 2010) is considered as the most popular intra-domain routing protocol. The routers configured with OSPF should exchange routing data with every router within the Autonomous System (AS). The topology information of entire network is required to establish the routes, since the full topology has been stored in each router which can calculate all required shortest paths. OSPF is also a dynamic protocol, and it has the ability to detect the changes in network topology within the AS quickly and calculate new loop-free routes within short convergence time. The process of routes calculation done by OSPF is as follows.

A dimensionless metric such as cost or weight is assumed by each link. The integer of cost metric ranges from 1 to 65535 (= 2^{16} -1), and it is stored in the link-state database. The cost of a route from source to destination node is represented as the sum of the link costs. Using Dijkstra's algorithm, OSPF directs every router for finding the shortest path from that router to each and every destination node within the network in AS. The destination router in the first hop is dragged into the IP routing table. When the multiple shortest paths are applied in OSPF, the load balancing can be used and the traffic flow will be distributed on various shortest paths.

OSPF is a link state routing protocol in which a full map of the network topology is maintained by each router in that network. For that reason, a router has the ability of computing routes to each and every destination within the network at any time, based on the router knowledge about the network. The routers within the network will transmit routing messages declaring their link states, and each router is guaranteed that it has consistent view of the network. OSPF (Mohammed, H., *et al*., 2006) is organized as an Interior Gateway Protocol (IGP), and the information is routed in AS referred as a routing domain. To achieve scalability, areas have been defined and grouped as an AS. Theoretically, an area is a generalization of an IP subnetwork, grouping networks together in the same manner as one group's routers together to structure a network. To reduce the routing traffic in the AS, the area topology is screened from the routers out of that area.

In general, OSPF has Better convergence time than distance vector, Larger networks is supported by OSPF, and Less susceptible to bad routing Information

The basis of OSPF overheads are recognized to the three sub-protocols and five different types of OSPF packets. The hello protocol is responsible of generating hello packets periodically. Database description (DBDesc), link state request (LSR), link state update (LSU), and link state acknowledgement (LSAck) packets are used by the synchronization protocol. The flooding protocols also use the LSU packets to propagate link state advertisements (LSAs).

For achieving overhead efficiency of OSPF, several extensions were presented. One of the most known extensions was the reduction of router numbers participating in the flooding process. Both the MANET Designated Routers (MDR) (Yan Zhang and Masayuki Fujise, 2006) and the Multi-Point Relays (Hung-Yu Wei, *et al*., 2005) extensions choose a CDS (Connected Dominating Set) in which flooding will be done by the nodes in the resulting CDS. Many algorithms for reducing network topology such as MDR (source-independent) and MPR (source-dependent) have been used to build a flooding backbone. The simulation study on the two approaches showed that both approaches decreased a considerable amount of overhead lacking the compromising of the routing/forwarding performance.

In addition of reduction the number of flooding nodes, minimizing the size of every single hello packet and construction of adjacencies are also presented. In differential hellos scheme, the size of the hello packet can be reduced by containing only new data (i.e., newly added or lost neighbours) in the periodic sending of hello packets. In Smart Peering algorithm, the reachability information, which is available in the SPT, can be employed to decrease the number of adjacencies without compromising reachability and routing paths redundancy.

Contrary to the approaches decreasing the overhead by using flooding backbone or selective peering, overhead reduction scheme explores the notion of *distance effect*. In the distance effect scheme, whether to relay (or reflood) a link state update (LSU) at every single node is determined by the hop-count distance the LSU travelled from the source node. Accordingly, re-flooding frequency can be reduced when the LSU is moving from the origination (Er. Monika Gupta, 2010).

Enhanced OSPF Operation:

OSPF is a link state routing protocol, capable of computing the shortest paths using weights given to the links. Routing on the Internet defines the traffic flow over the chosen paths. Traffic engineering try to provide the required QoS to the users, therefore, the available resources should be utilized in an efficient way and all traffic flow should be managed efficiently.

Link weights are used by OSPF as its routing metric. The basic concept of assigning the link weights is that they inversely proportional to the capacity of link.

Proposed cost function:

The weight setting (OSPFWS) (Sadiq, M., *et al*., 2009) problem of OSPF could be presented as follows: Given a directed network of nodes and links $G = (N,A)$, a demand matrix D, and capacity C_a for each link $a \in A$, a weight parameter could be assigned as $\omega_a \in [1, \omega_{max}]$ for each link $a \in A$ such that the cost function Φ should be at minimum. When OSPF is applied to a network as a routing protocol, the shortest paths are determined by the assigned link weights at every way possible, and hence the traffic flows, the partial loads on each link for a given destination are calculated. This is performed for all destination nodes. The total load l_a on a given link is given by the partial loads which are aggregated for all destinations on that particular link. The cost of traffic being sent through this link is given by $\Phi_a(l_a)$. The cost value is dependent on the utilization of the link and is given by the linear function found by Fortz and Thoroup (Bernard Fortz and Mikkel Thorup, 2000).

$$\Phi_a^{'} = \begin{cases} 1 & for\ 0 \leq \frac{l}{C_a} < \frac{1}{3}, \\ 3 & for\ \frac{1}{3} \leq \frac{l}{C_a} < \frac{2}{3}, \\ 10 & for \frac{2}{3} \leq \frac{l}{C_a} < \frac{9}{10}, \\ 70 & for \frac{9}{10} \leq \frac{l}{C_a} < 1 \\ 500 & for\ 1 \leq \frac{l}{C_a} < \frac{10}{11}, \\ 5000 & for \frac{10}{11} \leq \frac{l}{C_a} < infinity \end{cases} \quad (1)$$

The Fortz cost function is given in equation (2).

$$\Phi = \sum_{a \in A} \Phi_a(l_a) \quad (2\ )$$

The objective is to minimize Φ, subject to these constraints:

In constraint (3), for traffic between a source and a destination pair *(s,t)*, $f_a(s,t)$ indicates the number of traffic flow that goes over arc a. The methodical steps

$$l_a = \sum_{(s,t) \in NXN} f_a^{(s,t)} \quad a \in A \quad (3)$$

$$f_a^{(s,t)} \leq 0 \quad (4)$$

Displaying the formulation of this cost function can be discovered in references (Bernard Fortz and Mikkel Thorup, 2000) and (Mohammed, H., *et al*., 2006).

Existing versions of OSPF uses the bandwidth as the link cost metrics. Hoeever link delay is another important QoS parameter that affects routing. Hence the traditional OSPF must be enhanced by combining the bandwidth and delay as a new cost metric.

- The delay metric measured on link is represented by its mantissa (four highest bits of Delay field) and by its exponent (four lowest bits of Delay field). In other words:

Delay = α *(1+x/16)* 2^y [in milliseconds]

where “x” is the integer representing the four highest bits of the field and “y” the integer representing the four lowest bits of the field. Notice, that for the previous proposed value of α, (1/16 seconds), the values, in seconds, expressed by the formula above can be stored, without loss of precision, in binary fixed point or floating point numbers with at least 8 bits of fractional part. This corresponds with NTP time-stamps and single precision IEEE Standard 754 floating point numbers. Given one of the above holding times, a way of computing the mantissa/exponent representation of a number T (of seconds) is the following: -

find the largest integer 'y' such that: T/α >= 2^y - compute the expression 16*(T/(α *(2^b))-1), which may not be a integer, and round it up. This results in the value for 'x' - if 'x' is equal to 16: increment 'y' by one, and set 'x' to 0

now, 'x' and 'y' should be integers between 0 and 15, and the field will be a byte holding the value x*16+y For instance, for values of 2 milliseconds, 6 milliseconds, 15 milliseconds, and 30 milliseconds respectively, x and y would be: (x=0,y=5), (x=8,y=6), (x=14,y=7) and (x=14,y=8) respectively.

The new cost function is given as below,

$$\Phi_{new} = \alpha\ Delay + \frac{\sum_{a \in setCA} (l_a - c_a)}{E} \quad (5)$$

This proposed equation or function contains two parts. The first part determines the delay created by the network, and the second part representing the extra load on the link. The extra load is defined as the load of the link when it excess the network divided by the number of edges presented in the network for normalizing the entire cost function. α is represented as delay constant. The number of edges present in the network is represented by *E*. To solve the OSPFWS problem, the Parallelized Tabu Search (PTS) is used by applying this new cost function.

Parallelized Tabu Search:

Tabu Search (Haroldo, G., *et al*., 2005), is an iterative method where optimization problems are solved. This technique is capable of using memory structures in an explicit manner to guide a hill-descending heuristic for continuous exploration consistently.

Local search procedures almost became stuck in areas where the solutions are at the minimum level or in areas where scores plateau. For avoiding these unwanted conditions and exploring unexplored regions of the neighbourhood, Tabu search is proposed. This method carefully explores the neighborhood of every single solution as the search continues.

Parallel Tabu Search mechanism (Sadiq, M., *et al*., 2009) could be explained as follows, an initial solution will be generated and its cost will be computed separately by each and every processor including the master processor. For a certain number of iterations, each processor search for the best solution in its part of the neighborhood, then this best solution will be sent by each processor to the master. The job of the master is to select the best solution among the solutions retrieved from each slave. The selection process is subjected by Tabu rules. The master then broadcast the best move or solution to all slaves unless the stopping criteria is met, then the search will stop.

The implemented strategy selects the best move or solution, and which of the slave processors this move will be broadcasted to. Each slave processor will continue the search and exploring the neighborhood using the solution received from the master. The Tabu list for master processor which contains the chosen solution will be broadcasted, and the Tabu list for each slave processor will be updated.

PTS-Ring:

Improving the way of finding the best solution was the sole purpose of using PTS-Ring strategy. This is done by exploring various regions of the network. PTS-Ring makes different sets of processors exploring different parts of the search space. To induce the diversification, PTS-Ring explores new regions of the network especially when the search fails to find the new best solution in a given region.

In PTS-Ring (Sadiq, M., *et al*., 2009) the network consisted of *(n+1)* processors which refer to n of slave processors and one master. The structure of PTS-Ring is built for each slave processor or node *n* an index i define this nod as a node S_i that can exchange information about the best solution between its neighbors (S_{i-1}, S_{i+1}). The neighbors for the last node are (S_{n-1}, S_1), and the neighbors of the first node are (S_n, S_2). In this, case the formation of the network set of nodes is a ring with the last node followed by the first node. The mechanism of how PTS-ring strategy is explained as follow:

Each and every slave node or processor generates an initial solution based on the random number generation for each entity, and start the search for a number of iterations at the end of the iteration. Each slave will send its best solution to the master processor. The master will choose the best solution for the slave processor from the solutions of the neighbors set (S_{j-1}, S_{j+1}). The slave will receive the solution and set it as its current solution and then it starts its Tabu search until the stopping criteria is met.

The benefit of this strategy is that each time the solution is exchanged, different set of processors begin the Tabu search with different solutions as their starting point. This is better than PTS-Star which starts the Tabu search with the same solutions at every solution exchange. Hence, by using this enhancement technique in OSPF we can minimize the number of congested links used in the routing.

The PTS-Ring algorithm is as follows:

Simulation and Results:

Simulation and network:

In our simulation, the network built as a ring of varied number of nodes from 10 to 50 of size 500 x 500 meter region. The transmission range of the node is set to 250 meters. A total of 3 traffic flows (two VoIP and one VoD) are used. NS2 was used as our simulator. Network Simulator (NS-2) (http://www.isi.edu/nsnam/ns) can be defined as an object-oriented network simulator, developed at UC Berkely. This simulator was developed based on two languages, C++ and OTcl. NS is basically designed to simulate local and wide area networks.

NS is considered as an event driven network simulator designed to simulate different types of IP networks. Many network protocols for example TCP, traffic source behaviour like FTP, and VBR, router queue mechanism like Drop Tail, and CBQ, routing algorithms such as bellman ford and more are implemented using NS. Furthermore NS has its share in the implementation of multicast mechanism. Recently the NS simulator is nursed by the VINT project. Various tools are used for network topologies conversion, built by known network generators to NS formats are developed by VINT project. Currently, NS (version 2) is developed at the MIT.

Our simulation settings and parameters are summarized in Table 3.1.

Table 3.1: Simulation Settings

No. of Nodes	10,20,30,40 and 50
Area Size	500 X 500
Mac	802.16e
Radio Range	250m
Simulation Time	100 sec
Traffic Source	VoIP and VoD
VoD Packet Size	65536
VoD Rate	150Kb
VoIP Codec	GSM.AMR
No. of VoIP frames per packet	2
Topology Type	Mesh
OFDM Bandwidth	10 MHz

The performance of the simulated network was measured according to the following metrics.

- **Average end-to-end delay:** It is the time taken by the packet to travel for source to destination, and it could be calculated by putting a time stamp on a packet and when it reaches its destination. The delay time is represented by subtracting the time the packet reached its destination from the time it started to be forwarded from the source.

The average end to end delay could be calculated using NS2 simulator by assigning a time stamp to the packet when it is transmitted from the source till it reach its destination, and then by subtracting the value of the time stamp at the sender from the time stamp at the receiver.

- **Packet Drop**: It is the total number of packets dropped or lost or never received by the destination.

Packet dropped = Number of packet send – Number of packet received in a specific time

The performance of the protocol is being at it best when the value of packet loss is kept to minimum. **Average Packet Delivery Ratio:** It is the ratio of successful delivered data packet to the destination and the total number of packet sent, defined by:

$\sum$ Number of packet receive / $\sum$ Number of packet send

- **Throughput:** It is the number of packets received successfully from source to destination in a given time.

RESULTS AND DISCUSSION

Comparison of DSDV, OLSR and OSPF:

In the first scenario, the 3 three protocols (i.e. DSDV, OLSR and OSPF) are compared and the above performance metrics (i.e. Throughput, End to end delay, Delivery Ratio and Packet loss) are evaluated. The number of nodes is varied from 10 to 50 in all the protocols.

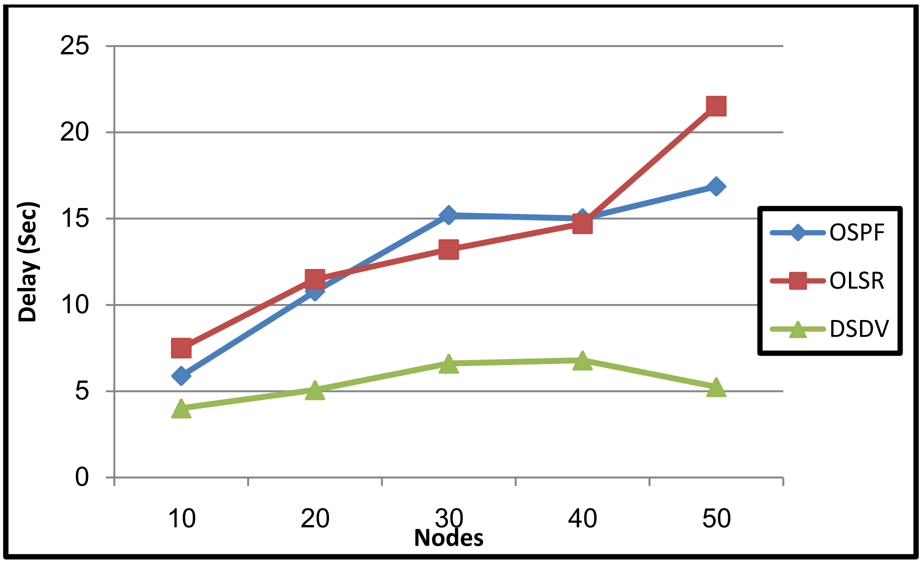

Fig. 3.1: Nodes vs. Delay for DSDV, OLSR and OSPF

Figure 3.1 presents the end-to-end delay for the protocols when the nodes are increased. From the figure, we can see that DSDV has the least and OLSR has the highest delay among all the protocols. The reason of high delay in OLSR is that, protocol has no scalability in WMNs and large amount of bandwidth and CPU power is needed when using OLSR to find the best routes. The delay of OSPF is almost similar to that of OLSR up to 40 nodes. Beyond that, the delay in OSPF reduces and equals to that of DSDV due to its to work with Resource Reservation Protocol (RSVP) which is capable of working with OSPF traffic engineering to provide 50 msec fail-over time for route path changes. This makes OSPF perform better and decrease the delay whenever the network is getting larger.

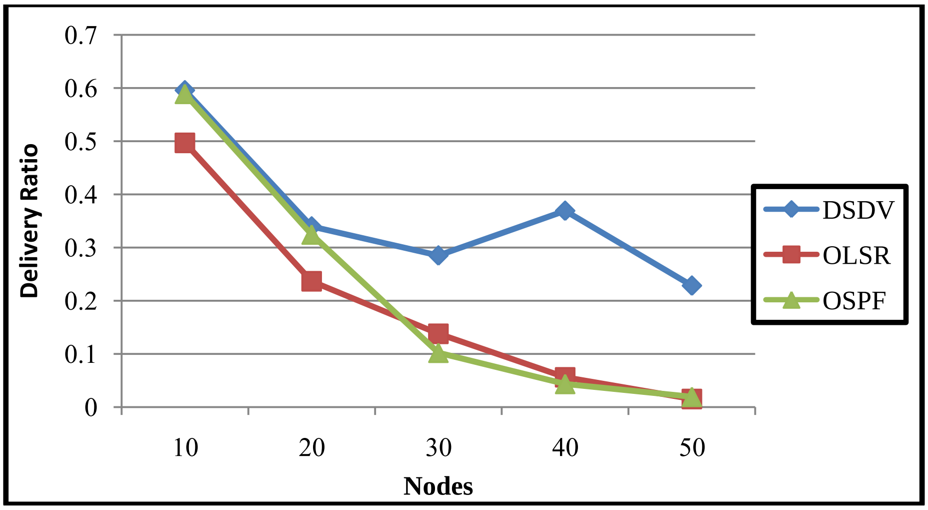

Fig. 3.2: Nodes vs. Packet Delivery Ratio for DSDV, OLSR and OSPF

Figure 3.2 gives the packet delivery ratio for the three protocols when the nodes are increased. From the figure, we can see that DSDV has the highest delivery ratio among all the protocols. The delivery ratio of OSPF is higher than OLSR up to 20 nodes and beyond that, it reduces and it equals to that of OLSR.

From the figure, we can also notice the sudden increase in the delivery ratio of DSDV when the number of nodes equal to 40. In fact, it occurs due to unpredicted behaviour of the nodes and the characteristics of the routing protocols. In the case of DSDV, each node can support multiple paths to destinations which guarantee the delivery of the packet especially when the number of nodes is increased.

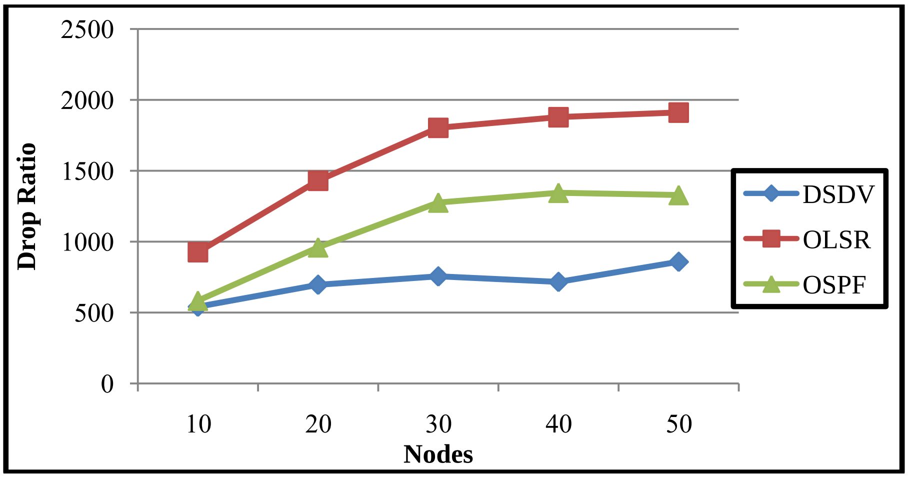

Fig. 3.3: Nodes vs. Packet Drop for DSDV, OLSR and OSPF

Figure 3.3 shows the packet drop for the three protocols when the nodes are increased. From the figure, we can see that DSDV has the least number of packet drops among all the protocols, followed by OSPF and OLSR. The OSPF has similar packet drop of that in DSDV when the number of nodes equals to10. When the number of nodes become 20 and above the packet drop in OSPF become larger than the packet drop of DSDV.

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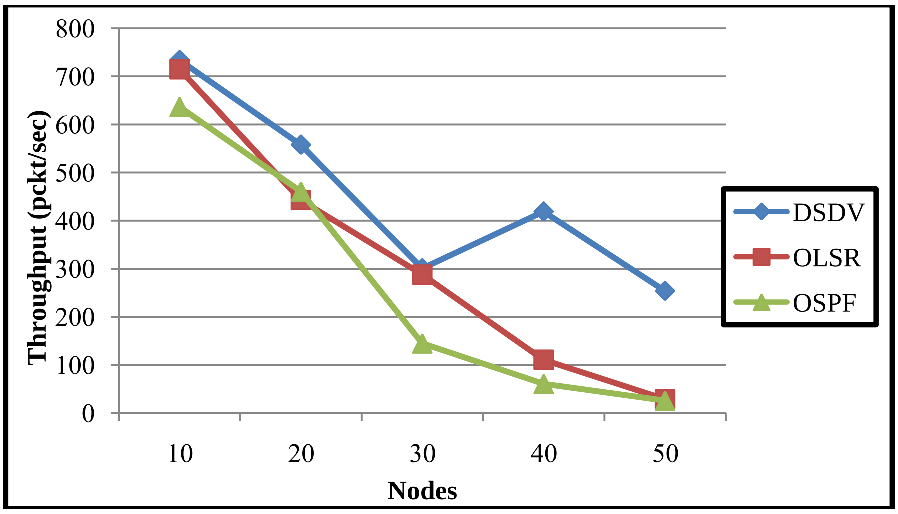

Fig. 3.4: Nodes vs. Throughput for DSDV, OLSR and OSPF

Figure 3.4 shows that the throughput for the three protocols is decreased when the nodes are increased. From the figure, we can see that DSDV has the highest throughput among all the protocols, followed by OLSR and OSPF.

Note that, the sudden increase in the throughput of DSDV can be noticed when the number of nodes equal to 40. This happens due to unpredicted behaviour of the nodes and also on the characteristics of the routing protocols. In the case of DSDV, each node can support multiple paths to destinations which guarantee the delivery of the packet especially when the number of nodes is increased.

From the figure, we can see that OLSR has higher throughput than OSPF. The reason is that, OLSR protocol is designed to deal with ad hoc networks and perform better specially when there is no mobility in that network due its property of using MPRs that ensures the delivery of packets to the destination.

Enhancement Scenario - Implementation of OSPF and EOSPF:

In the second scenario, we use the enhancement scenario in which existing OSPF and the proposed EOSPF routing protocols are implemented and compared. The number of nodes is varied from 10 to 50.

The results showed, for all the four testing parameters, the proposed extension of OSPF has proven it is much better in performance than the traditional OSPF, when it applied in WIMAX environment with mesh mode In other words, it shows better results in delay, throughput, drop ratio, and delivery ratio compared to OSPF, OLSR, and OSPF-OLSR.

Our findings showed that the proposed extension of OSPF enhanced the delay by 25% better than the delay with the traditional OSPF. It also shows that the throughput is increased by 28%, with decreasing in the drop ratio by 39.1%. On top of that, the delivery ratio was increased by 37.6%. Therefore, it is proven that say the proposed extension of OSPF came up with satisfying results.

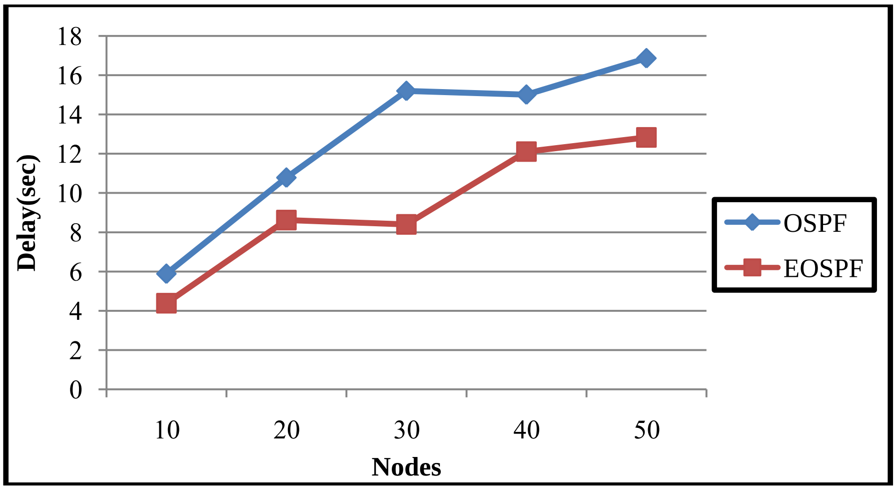

Fig. 3.9: Nodes vs. Delay EOSPF

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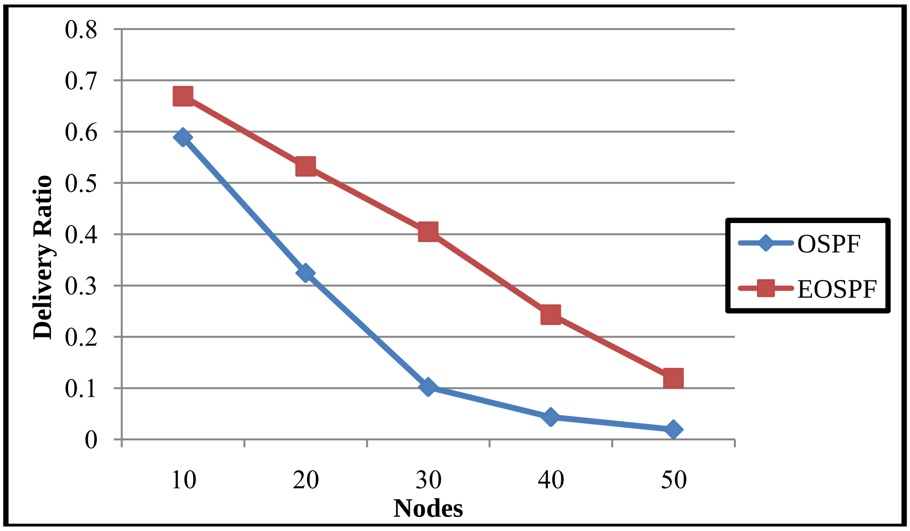

Fig. 3.10: Nodes vs. Delivery Ratio for EOSPF

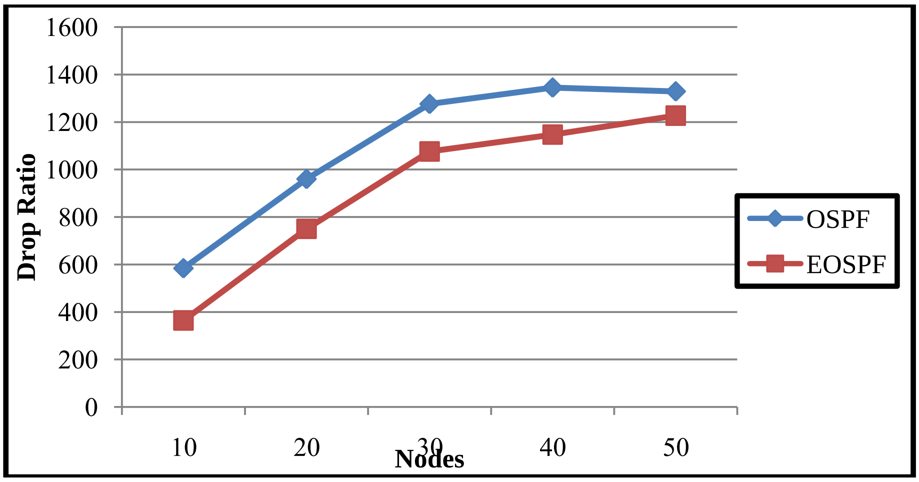

Fig. 3.11: Nodes vs. Packet Drop for EOSPF

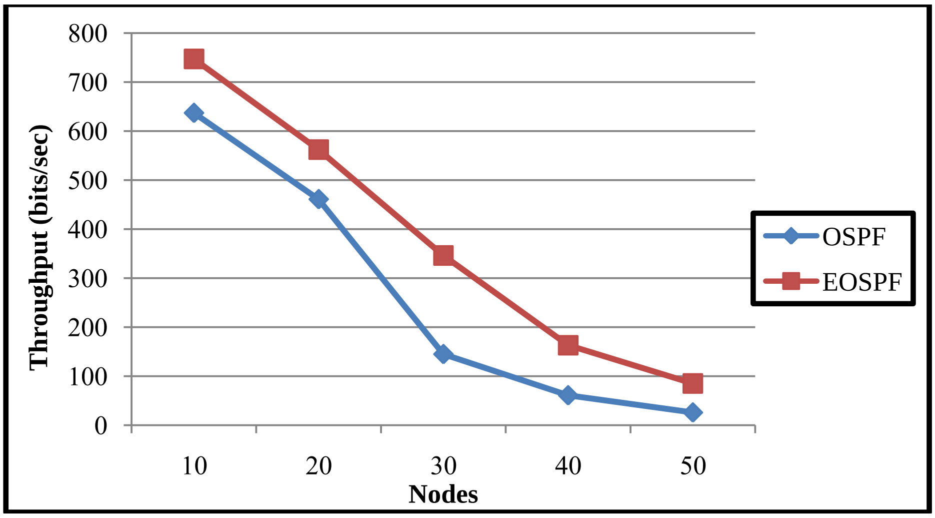

Fig. 3.12: Nodes vs. Throughput for EOSPF

Conclusion:

Wireless mesh network has grown with a lot attention in the recent years, as it can provide reliable, low cost connections. WMNs considered as self-Organized organized and self-configured networks, also WMNs and grants the network high scalability and reliability. Meanwhile, in the other hand, WIMAX provide the network with the last mile connection enabling long distance communications, also and WIMAX designed for high speed broadband wireless networks. M, most of network applications implemented in WIMAX using PMP mode. In, in this work, a performance analysis of different routing protocols regarding QOS has been done in WIMAX environment using Mesh mode, which enables the clients nodes not to communicate with just the base nodes, but also with the other clients node. The analysis has been done to DSDV, OLSR, and OSPF. An enhancement technique in OSPF for Wimesh networks was proposed to improve the weight setting of OSPF by applying new cost function that depends not only on bandwidth but also on the delay.

The performance analysis based on Throughput, End to End delay, Packet drop, and Delivery ratio showed that DSDV has the best performance in Wimesh networks followed by OSPF, and the worse performance was OLSR in term of these parameters except for the throughput. As for the enhanced extension of OSPF, the results showed that it improved the performance of OSPF in a significant way in terms of all the parameters used for the performance analysis.

In order to extend this work in future, concentration on fault management in OSPF can be done. Many methods are proposed for fault management such as protection management systems and they have the ability for fast recovery from any failure happened in the network. However they demand high cost resources and they are expensive to build. As there are restoration management systems, these systems are less costly in a significant way but generate longer service disruption. Another advantage of fault management is that, the failures can be detected and recovered. Therefore, backup paths need to be computed for rerouting, and to ensure the delivery of the packets, multiple copies of the original packet will be sent through the backup paths. This will decrease the delay time and increase the throughput at the same time. All in all, these pros and cons of fault management system in OSPF give a room for this work to be discovered and expended in future.

REFERENCES

Ahmad Al-Yamani, Sadiq M. Sait, Habib Youssef, and Hassan Barada, 2002. Parallelizing tabu search on a cluster of heterogenous workstations. Journal of Metaheuristics, 8: 277-304.

Bernard Fortz and Mikkel Thorup, 2000. “Internet Traffic Engineering by Optimizing OSPF Weights”, INFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies, 2: 519-528.

Bo Han, Weijia Jia and Lidong Lin, 2007. “Performance evaluation of scheduling in IEEE 802.16 based wireless mesh networks”, Computer Communications, 30(4): 782-792.

Bo Han, Weijia Jia and Lidong Lin, 2007. “Performance evaluation of scheduling in IEEE 802.16 based wireless mesh networks”, Elsevier, Computer Communications, 30: 782-792.

Bortfeldt, A., H. Gehring, and D. Mack, 2003. A parallel tabu search algorithm for solving the container loading problem. Parallel Computing, 29: 641-662.

Crainic, T.G., M. Toulouse, and M. Gendreau, 1997. Towards a taxonomy of parallel tabu search heuristics. INFORMS Journal of Computing, 9(1):61-72.

Er. Monika Gupta, 2010. “Open Shortest Path First Simulator By Using Java RMI”, International Journal of Engineering Science and Technology, 2(6): 2155-2163.

Haroldo, G., Santos, Luiz S. Ochi, and Marcone J.F. Souza, 2005.“ A Tabu Search Heuristic with Efficient Diversification Strategies for Class/Teacher TimeTabling Problem” ACM Journal of Experimental Algorithmic (JEA), 10: 1-16.

Huaiyu Wen, 2012. Guangchun Luo “Environmental Cognition Based Wireless Mesh Network Cross-layer Routing Protocol”, Journal of Information & Computational Science, 2(9): 473-487.

Hung-Yu Wei, Samrat Ganguly, Rauf Izmailov and Zygmunt J. Haas, 2005. “Interference-Aware IEEE 802.16 WiMax Mesh Networks”, in Proc. of the 61st IEEE Vehicular Technology Conference (VTC Spring 2005), 5: 3102- 3106.

Hung-Yu Wei, Samrat Ganguly, Rauf Izmailov and Zygmunt J. Haas, 2005. “Interference-Aware IEEE 802.16 WiMax Mesh Networks”, in Proc. of the 61st IEEE Vehicular Technology Conference (VTC Spring 2005), 5: 3102-3106.

Ian, F., Akyildiz, Xudong Wang and Weilin Wang, 2005. “Wireless mesh networks: a survey”, 47(4): 445-487.

Kaabi1, F.S., Ghannay2, and F. Filali, 2010. “Channel Allocation and Routing in Wireless Mesh Networks: A survey and qualitative comparison between schemes”, International Journal of Wireless and Mobile Networks (IJWMN), 2: 1.

Michel Barbeau, 2005. "WiMax/802.16 Threat Analysis", In 1st ACM Workshop on QoS and Security for Wireless and Mobile Networks (Q2SWinet), pp: 8-15.

Michel Toulouse, K. Tulsiraman, and Fred Glover, 1999. Multi-level cooperative search: A new paradigm for combinatorial optimization and application to graph partitioning. European Conference on Parallel Processing.

Michel Toulouse, Teodor Gabriel Crainic, Brunilde Sans, and K. Thulasiraman, 1998. Selforganization in cooperative tabu search algorithms. IEEE International Conference on systems.

Miguel Elias, M., 2008. Campista, Pedro Miguel Esposito, Igor M. Moraes, Luís Henrique M. K. Costa and Otto Carlos M. B. Duarte, "Routing Metrics and Protocols for Wireless Mesh Networks", IEEE Network.

Mihail, L., Sichitiu, 2005. "Wireless Mesh Networks: Opportunities and Challenges", The tenth IEEE symposium on computers and communications, Spain.

Miray Kas a, Ibrahim Korpeoglu b, Ezhan Karasan, 2011."OLSR-aware channel access scheduling in wireless mesh networks", Journal of Parallel and Distributed Computing, 71(9): 1225-1235.

Mohammed, H., Sqalli, Sadiq M. Sait, and Mohammed Aijaz Mohiuddin, 2006. "An Enhanced Estimator to Multi-objective OSPF Weight Setting Problem", 10th IEEE/IFIP Network Operations & Management Symposium, pp: 240-247.

Nair, S. and A. Freville, 1997. A parallel tabu search algorithm for the 0-1 multidimentional knapsack problem. 11th International Parallel Processing Symposium.

Network simulator, NS manual online, http://www.isi.edu/nsnam/ns, " Accessed February 2012".

Pierpaolo Caricato, Gianpaolo Ghiani, Antonio Grieco, and Emanuela Guerriero, 2003. Parallel tabu search for a pickup and delivery problem under track contention. Parallel Computing, 29: 631-639.

Rehan Rasheed, M., M. Kamran Khan, M. Naseem, Aisha Ajmal and M. Ibrahim, 2010. Hussain Performance of Routing Protocols in WiMAX Networks IACSIT International Journal of Engineering and Technology, 2: 5.

Sadiq, M., Sait, Mohhamed H. Sqalli, and Syed Asadullah, 2009." Parallel Tabu Search for optimizing the OSPF weight setting problem",WSEAS Transactions on communications, 8(3): 311-320.

Sunil Kumar, 2010."Reactive and Proactive Routing Protocols for Wireless Mesh Network using Multimedia Streaming", International Conference on Recent Advances and Future Trends in Information Technology (iRAFIT2012) Proceedings published in International Journal of Computer Applications® (IJCA).

Talbi, E.G., Z. hafizi, and J-M. Geib, 1997. Parallel adaptive tabu search for large optimization problems. 2nd Metaheuristics International Conference.

Teodor Gabriel Crainic and Michel Toulouse, 2002. Parallel strategies for meta heuristics.

Venkat Mohan., S and N. Dr. Kasiviswanath, 2011."Routing Protocols for Wireless Mesh Networks", International Journal of Scientific & Engineering Research, 2(8).

Vijayalakshmi, M., Avinash Patel and Linganagouda Kulkarni, 2010."QoS Parameter Analysis On AODV And DSDV Protocols In A Wireless Network", Indian Journal of Computer Science and Engineering, 1(4): 283-294.

Xiaowen Zhang and Hao Zhu, 2007. "Two-Tier Load Balancing in OSPF Wireless Back-Hauls",26th IEEE International Conference on Computer Communications IEEE, pp: 2341-2345.

Yan Zhang and Masayuki Fujise, 2006. "Energy Management in the IEEE 802.16e MAC", IEEE Communications Letters, 10(4): 311-313.

Yan Zhang and Masayuki Fujise, 2006. "Energy Management in the IEEE 802.16e MAC", IEEE Communications Letters, 10(4): 311-313.

Yigal Bejerano, Seung-Jae Han and Amit Kumar, 2007. "Efficient load-balancing routing for wireless mesh networks", Elsevier, Computer Networks, 51(10): 2450-2466.

Yoshihro Ogita Hiroyuki Mori, 2002. A parallel tabu search based approach to optimal network reconfigurations for service restoration in distribution systems. Proceedings of the IEEE International Conference on Control Applications.