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LOAD BALANCING METRIC BASED ENERGY CONSUMPTION IN WIRELESS MESH NETWORKS

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ABSTRACT

Load balancing and energy consumption have become important criterions for evaluating a Wireless Mesh Networks performance. The progress of technology and smart devices has been put up in a rapid way recently. Despite its advantages, it has some drawbacks, for example increase of energy consumption in the worldwide. In our paper, we propose a load balancing routing metric based energy consumption. The aim of our metric is to minimize the energy consumption and balance the node's traffic in the network, by comparing the traffic load and energy value of each node with a standard threshold value. For that, we evaluate the traffic load and energy value of each node and all its neighbors. We evaluate the performance of our routing metric, comparing it with others existing routing metrics, using simulator tool NS2. We find that our new routing metric achieves the minimum energy consumption.

Keywords: *WMNs; Energy Consumption; Load Balancing; Performance.*

1. INTRODUCTION

The important challenge in Wireless Mesh Networks (WMNs), resides in energy consumption. Therefore many researches [1] [2] [3] have started exploring aspects of reducing energy consumption in Wireless Mesh Networks.

A WMN with high performance should satisfy the following characteristics: low cost, easy network connectivity, communication with high quality such as: High bandwidth, minimum jitter, latency, and error rate, as well as load balancing. A WMN which satisfies all the characteristics mentioned above with minimum energy consumption and minimum CO2 volume produced by the ICT (Information and Communication Technology) [4], is named Green Wireless Mesh Networks [5].

According to the previous statements, energy consumption has become a major factor that characterizes ICT, industries, and communication performance of Wireless Mesh Networks.

In the paper [6] we have proposed a new routing metric called "LAmETX" , which captures the inter-flow interferences in the path, high throughput, lower packets delivery ratio, load balancing. This metric is incorporated into the routing protocol OLSR, to minimize the energy consumption in Wireless Mesh Networks, compared with the routing metric ETX and Um-OLSR.

The newest research prove that the devices of WMNs consume 80% of telecommunication network energy consumption, and are active (consume the energy) during both busy and Idle periods which cause the waste of energy. That means that the devices in WMNs consume the energy during congestion state which necessitates conserving the energy during the busy time.

Regarding this problematic energy consumption, recent research is taking into account this problematic, and for our side, our work is focused to save the energy consumption during the congestion state of devices (nodes).

The problem is how to controlling and saving the energy consumption in each node in the congestion state, using the OLSR protocol?

The rest of this paper is organized as follows: We discuss the major techniques for minimizing energy consumption in Wireless Mesh Networks, section III, reviews the literature which tacks into account the problematic of energy consumption; We present a traffic models, we give a detail for conditioning for sleeping in WMNs, and we presents a different approaches used in a tree layer

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of network. Section IV presents our proposed routing metric and the evaluation of results with simulation in section V. Finally, we present conclusion and future work of our paper.

2. RELATED WORKS

Due to existence of various factors that affect WMN's performance, such as inter and intra-flow interferences, easy network connectivity, low cost, load balancing, energy consumption is an important factor in Wireless Mesh Networks. As mentioned above, minimum energy consumption could be reached through routing metric, routing protocol and clusters. To improve minimum energy consumption in WMNs, many researchers suggested new strategies and novel techniques [7] [8] [9] .

In [2], the authors consider that the packet transmission causes the totality of energy consumption and they proposed the routing metric , for prolonging network energy lifetime.

Following the same trend as [2],the authors in [10], are proposing a new technique for improving the transmission energy and delay, based on the receiving of Hello message. The authors proposed to calculate both the energy and delay in each node in the network. Other technique is proposed for reducing the energy consumption, based in keep asleep the network's components such as gateways, routers, and network interfaces during a fixed time [11]. In the same paper the authors proposed new scheme which is: Adding the newest links inter router, can help to aggregate more traffic and reduce more energy consumption. An algorithm for clustering inactive nodes in the network, among high energy consumption, is proposed with alleviate the traffic among these gateways [12].

Another technique for conserving energy consumption, OEEMD Optimal Energy Efficiency Management Design),using a MILP (Mixed Integer Linear Program) model, is discussed in [13].

For balancing routing metric (BL), proposed by Moad , and Hansen [14], is designed for diversity link in determined radio. It minimizes a WMN's energy consumption, by calculating energy in different radios, and using the transmission and reception cost for each radio. BL routing metric can be defined as the following:

$$BL(i,j) = WETX(i,j) / RE_j \qquad (1)$$

Where :

WETX : Weighted ETX;
$i,j \leq N$, RE_j is the remaining energy of the node n_j,
$n_i \in Ne_j$, and $n_i \in Ne_j$.

We conclude that Clustering technique is more suitable for ad-hoc networks, which nodes have a minimum mobility; Furthermore, in Wireless Mesh Networks, the routing metric is more suitable for addressing load congestion and dissipation energy consumption.

3. OVERVIEW OF ENERGY CONSUMPTION.

Energy consumption has latterly attracts a lot of attention, due to its increase and its WMNs performance's effects. An overview of the various configurations related to: Energy consumption types, Traffic models, Conditioning for sleeping and Energy conservation in Wireless Mesh Networks is detailed in this section.

2.1 Energy consumption types:

We can classify the energy consumption types depending on state of MRs, in three categories [15]: Active, Idle and Off. When the energy consumption reaches a maximum level, we can say that is Active; Idle, is a state when the energy consumption consumes ¾ of totality, and Off, when the energy consumption value is null, as shown in figure 1 bellow:

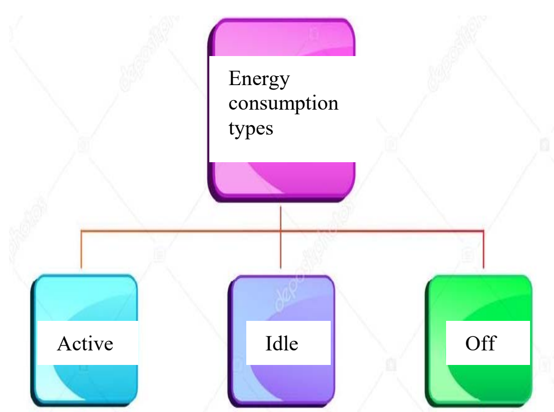

Figure 1: Energy consumption types

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2.2 Traffic models:

Traffic in WMNs can be classified in two main models: Standard and busy; Standard, when the traffic value is between 1 and 8 Mbps; And Busy, when the traffic value is between 8 and 10 Mbps.

2.3 Conditioning for sleeping:

In this section, we first present the types of energy consumption, and traffic models in WMNs. Next, we detail the conditioning for remain asleep the network's components, in order to reduce energy consumption, we will present the advantages acquires after using this technique. Finally, we present a various protocols, which reduce energy consumption in network layer, Data link layer, and Physical layer.

2.3.1 Sleeping or Idle mode:

In WMNs, remain asleep or clocking slower some or all networks components in order to minimize energy consumption is necessary.

2.3.2 Rate Switch:

It function is to limit the data rate through a specific areas of the network.

2.3.3 Which components remain asleep?

Depending on WMN's architecture, some components have priority to remain asleep as other components [13] : Gateways and routers which route traffic from end users, some routers in the backbone architecture, and routers located in the frontier of the network.

2.2.4 The appropriates time for sleeping:

We can classify the WMN's time sleeping in two categories: Uncoordinated and Coordinated [11]; At Uncoordinated category, the gateway can sleep as 95% of its operational time; At 11:30 am, and approximately the half time at 11:30 pm, but during coordinated sleeping, some gateways/Routers can remain asleep or power Off at night, and forward all traffic through other gateway located in the same network, with aggregating the traffic.

2.2.5 Advantages of sleeping:

Using a strategy of putting some of the network's components in sleeping mode, we can economize [16] the energy up to 50% during the day time and 98% at night, minimizing electricity consumption and cost of communication .

2.2.6 Energy conservation in WMNs:

In this section, we will cite a different approaches used in the tree layers of WMNs; Network layer, Data Link layer, and Physical layer as shown in figure 2.

2.2.6.1 In Network Layer:

The self-configuration is assured in Network Layer. In Following, we cite a totality of the energy conservation approaches, in WMNs:

The author in SPAN [17] , has proposed a new protocol SPAN , for minimizing the consumption of energy, he used a new grouping of nodes, where each node in the network belongs a set, or its neighbor. Each node gives informations (Status, neighbors……) for deciding, when the node should remain in sleeping mode.

The authors of the GAF [18], have proposed a new technique "GAF: Geographic Area Fixed",based on geographic positions of nodes. Selecting a minimum path using a new EMM-DSR protocol, [19] , [20]. Other routing algorithm "Power-Aware Routing "is proposed by Lin and Shroff [21] , based on adding the cost on energy reception and transmission. In [22], the authors, have proposed a new technique based on Pulse protocol destined to source of pulse.

Other algorithm called" The green-clustering", based on location, deployment of router is proposed by Jardosh [23] . Yang and Yin in [24] , have proposed a clustering (CADET) for minimizing the energy consumption.

Energy Aware Routing (EAR) [25] , taking into account the energy consumption as a criterion of performance such as Qos. In [26], the authors proposes a new throughput –aware routing (ETR), based on switching the node nonfunctional in the network in order to minimizing the energy consumption for each node in the Wireless Mesh Network. The use of a green framework and Ant colony green routing are proposed by Amokrane and Langar in [26] .

CBRP (Clustering Based Routing Protocol), [27] , is a new protocol based on clustering the nodes with high-energy consumption into various clusters and balance the traffic through these clusters.

In other side, Cardei and Cheng [28], have proposed a new scheme, has the same idea as [17].

On the light of those various techniques, we can conclude that, the algorithm is the most important for minimizing the energy consumption in network layer.

2.2.6.2 In Data Link Layer:

In this section, we will show the approaches in IEEE 802.11, which minimize the energy in Data link Layer.

PSM (Power Saving Mode) [29], is a new technique invented, based on "Active/Sleep" technique. The mesh client can put in "ON" only at time, when it receives/sends information , and it put in "Off" or on sleep the rest of time. The authors in [30], have proposed a new technique APSD (Automatic Power Save Delivery), which has the same idea (Active/Sleep) of PSM. In [31] , a new procedure is proposed to minimize the energy consumption, also based on Active/Sleep method, but ,its function is based on putting (non-AP) on slumber when other APs are on work using the channel. Founded on the same principle as PSMP, Zhang and Al [32] , have proposed NAV (Network Allocation Vector), however this technique does not keep the (non-AP) on sleep mode, but it blocks it when the channel is occupying with AP.

Utilizing a radio , the authors of [33] , have proposed a new scheme called PAMAS (Power – aware Multi Access Protocol with Signaling), which puts on sleep a node's radio, when it is no working .The author of [34] , has proposed a new technique called "SOFA", based on remaining a sleep the PSM client. PRCW (Physical Rate and Contention Window based admission control) [35], is a new technique using an admission control algorithm. In Leach (Low –Energy Adaptive clustering Hierarchy) [36] , the authors, use MAC protocol, and dividing the network in clusters for reducing energy consumption.

Ye and Estrin [37], have proposed S-MAC, an efficient energy MAC protocol, which is based on repeating listening and sleep technique.

Virtualization of NICs [38] , is the only technique using virtualization for minimizing the energy consumption in Data link Layer.

Chih and Chang [39] , have used the power control and saving technique for inventing PEM: a power efficient MAC protocol. Finally, MT-MAC (Multi-hop TDMA Energy-Efficient Sleeping MAC Protocol) [40] , is a new protocol based on partitioning the frame component the Data onto various slots. According to our studies, cited above, we can conclude that the best techniques are "S-MAC" and "PAMAS", because they are simple and efficient to obtain minimum energy consumption.

2.2.6.3 In Physical Layer:

The authors of LM-SPT (Local Minimum Shortest Path-Tree) [41] , have proposed a new algorithm based on the graph topology of WMNs.

CNN (Critical Number of Neighbors) [42] , is a new method , invented by Santi, founded on selecting a minimum number of node's neighbors which must be interfaced to each other. Aron and al [43] , have worked on a hybrid WMN's topology, and propose a new method called " Localized distributed topology ", based on calculating the minimum transmission power. Plain TC [44] , is invented by Mudalin and al, have proposed a new scheme called "PlainTC " , works with a proactive routing protocol, using the critical transmission range (CTR), or Critical Neighbors Number, to maintain network connectivity. Besides, the virtualization is utilized by Coskum and al [45],which proposes a new scheme, for assuring the utilization of number of node, large coverage, and maximum capacity. The first set, is reserved to assure a full coverage, the second, is secondary, because, we use it only when we need an additional capacity. Nedevschi and al [46] , have presented two shemes to minimize the energy consumption; The first, is a new algorithm which consists of putting in sleep mode , all the components of network, when they are nonfunctional. The second scheme, consist of the use of adaptability of each links. In the other side, Mudali and al [44] ,have proposed a new technique based on the Critical Number of Nodes. Remain on sleep the components of networks, is also proposed by Gupta and Singh [11], and they provide a new algorithm called "Greening of the Internet".

In [47] , the authors have proposed a new scheme, named" Power Control and Rate Adaptation " founded on 3 steeps: In the first step, they setted the power and rate; In the second step, they fixed the rate with varying the power, and in the third step, the authors, vary rate and power.

Capore and Sonso [28] , have proposed a new approach called " Energy Saving in WMN, in a time-variable Context", that realized a novel framework, with mathematical programming, which administrates the energy consumption of the Wireless Mesh Networks .

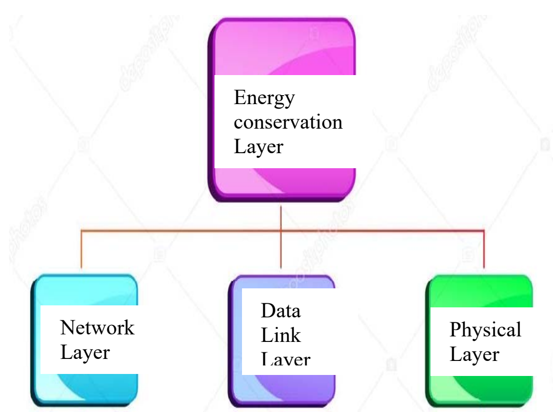

Figure 2: Energy conservation Layers

4. THE PROPOSED ROUTING METRIC

The global problem, which we are discussing is controlling and managing the energy consumption, in each components of the network.

In our scheme, we developed and added various ameliorations in our latest new routing metric[6] (precisely, OLSR routing protocol); We compare the traffic value of each node with a standard threshold value. Based on this result, we can decide to use the path or avoid it, when it is overloaded and hence energy consumed.

We can describe the functionalities of our new routing metric by:

- ✓ It enforces on each router the load balancing with a totality of aware routing.
- ✓ Calculates its traffic load value and compare it with a given threshold value.
- ✓ By dividing the queue length with the transmission rate, we can obtain the actual time required for transmission at each node as shown by the equation (2)

Time Required Transmission = Queue length Value / Transmission rate value (i) (2

Where i is a node.

LAmETX is our new routing metric with load balancing proposed in our last paper [6]; LAmETX is defined as:

$$LAmETX = exp\ [(ETX + \mu/2)/1000] + nb\ L(P) \quad (3)$$

Where ,

ETX: Expected Transmission Count metric.
μ: Estimated average packet loss ratio of a link.
nb L(P): is the number of traffic load.

5. THE ANALYSIS AND DISCUSSION OF SIMULATION RESULTS:

5.1 Simulation environments:

Our proposed metric is evaluated by Network Simulator NS2[48] , using 2,35 version. We have integrated a standard version of OLSR (UM-OLSR) [49] , in this NS2 version.

In our simulation, we will evaluate the performance of our new metric, comparing it with OLSR standard (Um-OLSR), and OLSR-ETX, in which, we will be focusing only on the energy consumption effects.

5.2 Simulation Setups:

To carry out our simulation, we use the parameters cited in the following:

The number of a node are varied in the interval of (50, 60 and 70); Where each node moves through an RWP (Random Waypoint) mobility model [50], through an area of 1000x1000 m2; With 250 m in radio Scope. Pause Time is fixed to 0 second ; Maximal Speed ε [5,30], with the step of 5. CBR traffic (Constant Bite Rate), is varied and we have fixed it at a value equal to 512 bytes. The User Datagram Protocol (UDP) attains 1024 bytes, this value is used by each node to send the packets every 2.5 seconds.

Those parameters are summarized in the following table 1:

Table 1: parameters of simulations

Environments of simulation	Parameter value
Flat size	1000mx1000m
Radio scope	250m
Number of nodes	50, 60, 70 nodes.
Mac layer	IEEE 802.11 peer mode.
Transport Layer	User Datagram Protocol (UDP)
Traffic model used	CBR
Package size	1024 bytes
Rate	0.4
The number of connection	1/5 of the number of nodes.
Mobility model	RWP (Random Waypoint)
Pause time	0 second
Maximum speed of nodes	5,10,15,20,25,30
Maximum CBR traffic of nodes	5,10,15,20
Simulation time	250 sec.

In all scenarios, we will compare the energy consumption of our new routing metric LAmETX incorporated in OLSR routing protocol, with UM-OLSR and the basic metric ETX, which was implemented in OLSR routing protocol. All results will be presented by curves with an accuracy of 100%.

✓ **Scenario 1: Number of nodes varies.**

In the first scenario, we will be interested in results with a number of nodes varied between 50, 60, 70 nodes. And we will vary the maximum speed between 5 and 30 m/s, and the CBR traffic will be taken the values between 5 and 20.

According to the results in fig 3,4,5,6 we can conclude that, the energy consumed by our LAmETX, is the minimal energy compared with other energy consumed by ETX, and UM-OLSR , due to characteristics of LAmETX, which takes into account the interferences (inter and intra), and the load balancing .

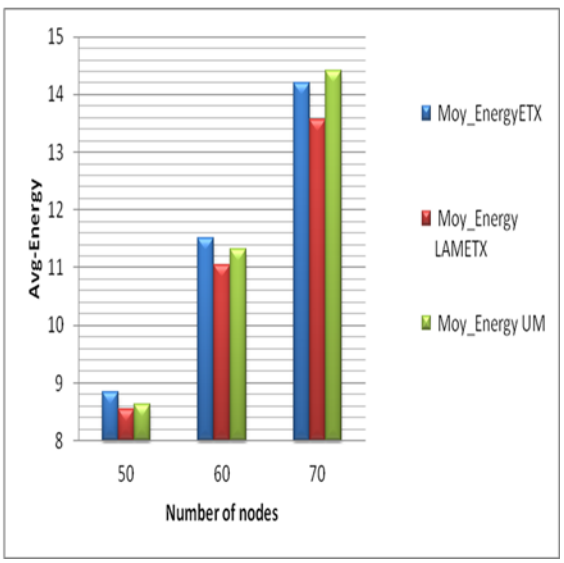

Fig 3: Avg-Energy Speed =5 CBR= 5

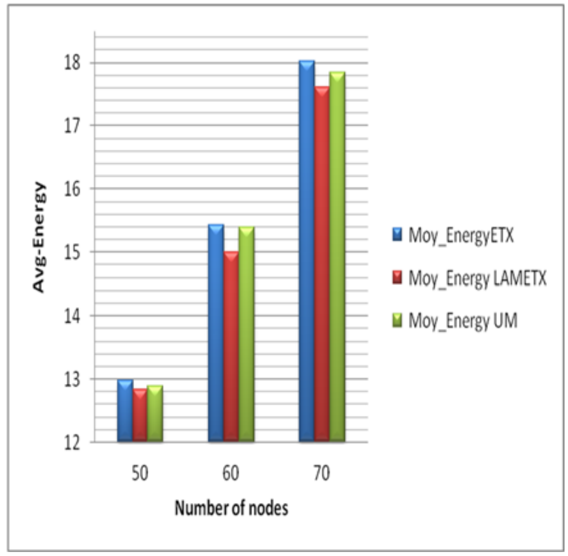

Fig4: Avg-Energy Speed =5 CBR=20

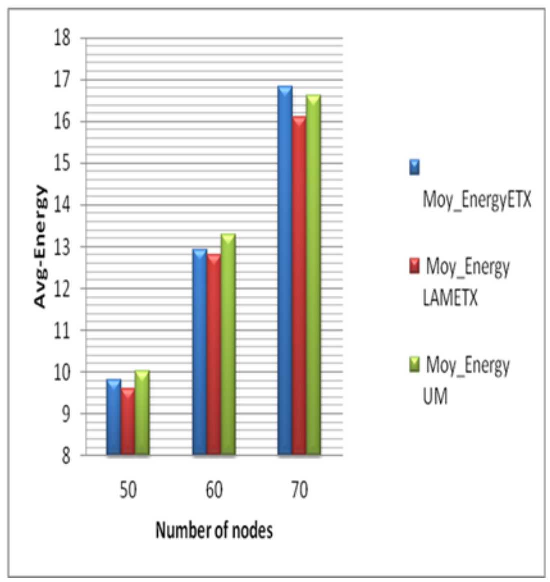

Fig 5: Avg-Energy Speed = 30 CBR=5

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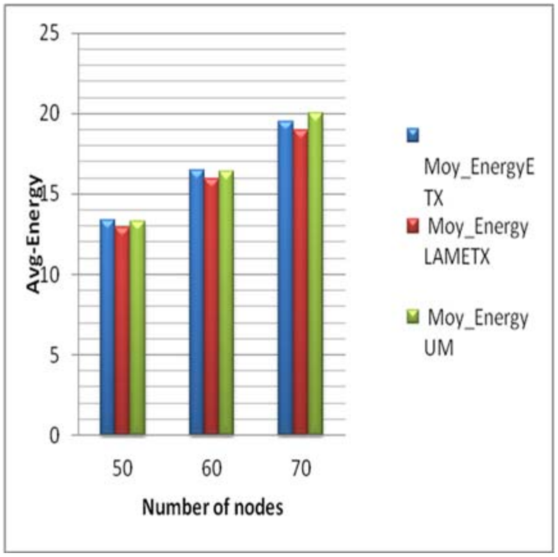

Fig 6 : Avg-Energy Speed =30 CBR=20

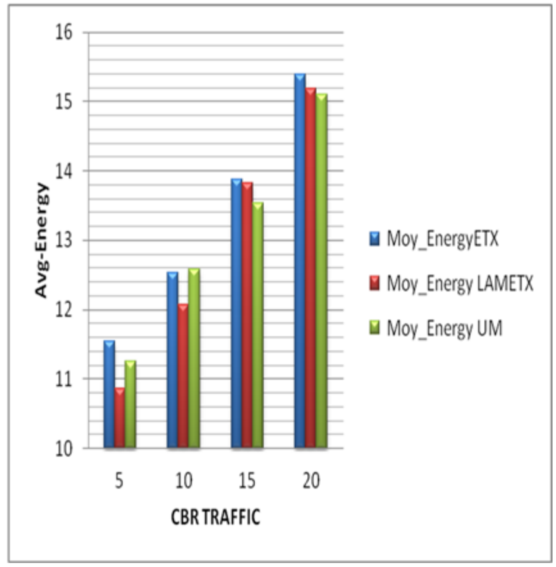

Fig 7: Avg-Energy Speed=5 CBR varied

✓ **Scenario 2: Number fixe of node.**

In this scenario , we will vary the CBR value between 4 and 20 packets/second, with step of 5, while maintaining the number of nodes at 60 in the Wireless Mesh Network.

As shown in figure 7, we can conclude that LAmETX energy consumption, is minimal compared with ETX-OLSR and UM-OLSR when CBR traffic varies from 5 to 10 packets / second, but between 15 and 20 CBR traffic value, we have:

UM-OLSR Energy Consumption < LAmETX Energy Consumption <ETX Energy Consumption

Figure 8, show that the LAmETX energy consumption, is relatively small compared with ETX-OLSR and UM-OLSR energy consumption.

This is because, the routing metrics ETX and UM-OLSR, don't balance the load in the network.

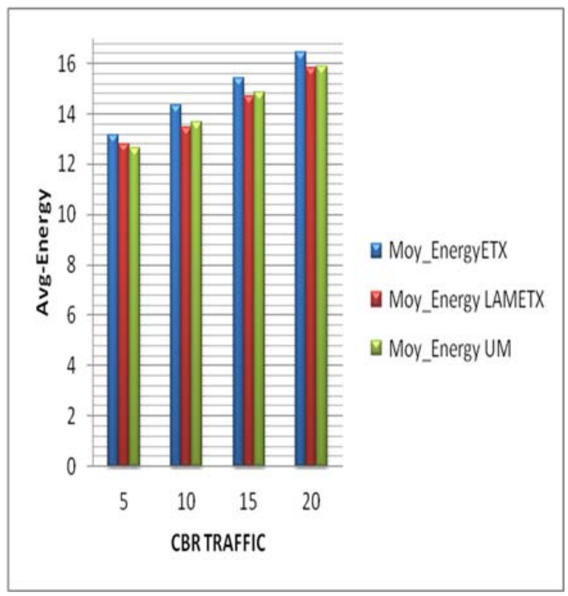

Fig 8 : Avg-Energy Speed =30 CBR varied

To summarize the simulations results, we find clearly, that LamETX has the best performance with between 5 and 30 CBR traffic flows, compared to other routing metrics, which LamETX ranks the lowest average energy consumption, and OLSR-STD achieves the second place, in the same time, OLSR-ETX suffers high energy waste (Figures 3,4,5 and 6).

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In other side, OLSR-STD has the best performance when between 15 and 20 CBR traffic flows with speed fixed to 5m/s, while LamETX scores the first place when between 5 and 10 CBR traffic flows (Figures 5).

Hence, LamETX still provide a better network performance (Energy consumption and Load Balancing), compared to other routing metrics, OLSR-ETX and OLSR-STD.

6. CONCLUSION AND FUTURE WORKS

In this paper, we addressed the energy consumption constraint. For realizing this proposed, we have proposed a new routing metric, called" LAmETX", which provides good results in energy consumption in Wireless Mesh Network. The simulation results using NS2 simulator tool , shows that proposed routing metric exhibits good results in energy consumption compared with others existing routing metric.

Future work, we will try to deploy our new routing metric in multi-radios, multi-channel. In addition, to study the QoS of our routing metric, by modifying LAmETX, in order to achieve the QoS of Wireless Mesh Networks.

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