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Evaluation and Analysis of Mobility Scenarios with Varying Pause Time for Hierarchical Protocols in Wireless Sensor Networks

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Abstract: *In wireless sensor networks, mobility and pause time have a major impact that directly influences the energy consumption and the lifetime of the network. This paper analyzes the performances of three hierarchicals protocols LEACH, LEACH-C and PEGASIS with respect to different mobility models under various pauses time for wireless sensor networks. In fact, the evaluation is based on metric performance such as packet delivery ratio (PDR), average throughput, consumption and lifetime network in a simulation environment NS2. Simulation results show that PEGASIS for mobility Random Waypoint model (RWP), Manhattan model (MANHT) and Gauss Markov model (GMM) under different pause time outperforms existing protocols LEACH and LEACH-C in terms of saving energy and the overall lifetime of the mobile network. As we analyzed in all mobility models and different pause time, PEGASIS performs well for average end to end delay compared to LEACH-C and LEACH respectably, also LEACH-C shows improved average throughput than LEACH and PEGASIS. In the same way, PEGASIS works better in terms of PDR in RWP and MANHT, while LEACH-C has the best PDR in GMM.*

Keywords: *LEACH, PEGASIS, LEACH-C, Random Waypoint, Manhattan Grid, Gauss Markov, Performance Metrics, Wireless Sensor Networks*

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I. Introduction

The mobility in wireless sensor networks imposes the major challenges for researchers in the conception of routing protocols. In the same network of sensors, some applications demand environments composed of static and mobile nodes, while others request complete mobile environment[1][2]. Therefore, mobile WSNs require effective mechanisms to resolve limited resources of sensor node in term of storage, power and radio capabilities due to his small size. In order to improve the energy consumption and increase the lifetime of dynamic wireless sensor networks, many hierarchical-based routing protocols like LEACH-Mobile protocol, LEACH-Mobile Enhanced (LEACH-ME) protocol and CBR-Mobile protocol are developed to support and manage the frequent mobility in term of packets loss by adapting TDMA time [3] [4] [5] [24]. In addition, The authors of [25] treated the comportment of W-LEACH Decentralized based on a number of neighbors to reorganize node density after that it selects active nodes and those which remain asleep in a decentralized manner. To optimize clustering protocols in order to determine the moving pattern of the mobile node, various mobility patterns and different metrics should be considered in the conception [6] [7]. In this research paper, the study of the performance of the LEACH, LEACH-C and PEGASIS routing protocols according to the mobility model: Random Waypoint (RWP), Manhattan (MANHT) and Gauss Markov (GMM) will be investigated as a function of various pause time. Then, the performance of these protocols is evaluated through the following parameters : packet delivery ratio, throughput, average end to end delay, network lifetime and energy consumption. The paper is structured as mentioned bellow: Section 2 covers the study of the literature on various hierarchical routing protocols (LEACH, LEACH-C and PEGASIS). Section 3 describes the mobility models and their scenario's creation that are based on with the definition of associated metrics. Finally, we conclude our contribution in section 4.

II. Hierarchical Routing Protocols In Wireless Sensor Networks

This section highlights briefly the features of LEACH, LEACH-C, PEGASIS routing protocols :

2.1. LEACH

In [8], Heinzelman et al. proposed the original routing protocol used in wireless sensor networks called LEACH(Low-Energy Adaptive Clustering Hierarchy). To achieve energy-efficient, this hierarchical network routing divides the network into clusters, chooses the cluster head (CH) for each round in the setup phase, aggregates and sent data to the base station (BS) in steady phase [9] [10]. In classical hierarchical-based routing protocols, the cluster head is selected only as a function of a random value generated when it is below a certain threshold. Due to the random selection, different types of traffic occur at each CH. As a result, CHs will spend their energy and network performance either affected. However, LEACH protocol suffers from the problem of no uniform distribution of the CH nodes and cannot guarantee the data reception at each CH by moving.

2.2. LEACH-C

LEACH-C is a centralized version of LEACH protocol [11] [12]. In setup phase, each node transmits their location information and level energy to the base station (BS). The BS calculates the average energy and the node that has higher energy than average, it becomes a cluster head by using the Simulated Annealing algorithm (SA). The steady phase is similar to that of LEACH protocol. In addition, LEACH-C protocol is used to improve the LEACH protocol because the number of the cluster heads 'CHs' in each round is equal to a predetermined optimal value, but in LEACH protocol the number of the cluster heads 'CHs' varies from round to another which is due to lack of global coordination between different nodes in the network.

2.3. PEGASIS

To enhance LEACH protocol, PEGASIS (Power-efficient Gathering in Sensor Information System) [13] is used as a near optimal chain-based protocol to which it forms a chain among the sensor nodes. Each node transmits data through the close neighbors and takes turns being the leader in transmission to the base station. The operation of PEGASIS protocol can be done in two phases: chain construction and gathering data. So, PEGASIS protocol is affected by some problems:

- The energy level of CH selected is not taken into consideration
- Far location of BS from the selected CH.
- Excessive delays and consumption energy caused by the communication of distant nodes.

III. Mobilitys Scenario's Creation

After evaluating the performance of the tree hierarchical protocols LEACH, LEACH-C and PEGASIS in a static environment [10], we are trying in this study for various mobility models such as Random Way Point Model, Manhattan Grid Model and Gauss Markov Model to measure the performance of these hierarchical routing protocols under varying pause time, according to the following metric parameters: Packet Delivery Ratio (PDR), Average Throughput, Average End-to-End Delay, Number of Alive Nodes and Energy Consumption [20]. The following mobility scenarios are created by means of the BonnMotion Tool [15] [14].

3.1. Random Waypoint Mobility Model (RWP*)*

The Random Waypoint Mobility Model [16][17] [13] [18] [19] is a random model which the nodes move to the destination on every time with velocity chosen uniformly randomly from [0,vmax], where vmax is the maximum allowable velocity for every mobile element. When each node reaches the destination, it takes a pause time and after chooses a new direction randomly. Then, the process being repetitive until the simulation ends. As similar in [20], the following command is used to generate a Random Waypoint scenario (RWP) with 100 nodes randomly moving for 3600 seconds where initial phase of 3600 seconds is cut off on an area 100*100 meters :

./bm -f rwp RandomWaypoint -x 100 -y 100 -i 3600 -n 100 -d 3600

The results that follows are created :

rwp.movements.gz : contains the mobility scenario data in the internal BonnMotion format.

rwp.params: contains mobility parameter for the scenario.

To convert the BonnMotion movements file to a NS2 readable file, the following syntax will be used:

./bm NSFile -f rwp. The files rwp.ns_params and rwp.ns_movements were produced for Random Waypoint scenario.

3.2. Manhattan Grid Mobility Model (MANHT)

The reference [21] introduced the Manhattan Grid model which indicates that the paths that are already predefined. This movement is based on horizontal and vertical streets allowed along a grid topology.

The corresponding mobility model was created by :

./bm -f manht Manhattan Grid -n 100 -d 3600 -i 3600 –x 100 –y 100 –u 2 –v 3 when -u, -v : Number of block between the paths.

The results created were converted using the same previous commands and the corresponding files to this scenario manht.ns_params and manht.ns_movements were generated.

3.3. Gauss Markov Mobility Model (GMM)

Gauss-Markov Mobility Model (GMM) [22] [23] applies the tuning parameter, alpha α, to adapt different levels random. Each mobile node is assigned to an initial speed and direction. At limited interval of time, a new value of speed and direction are calculated for each mobile node based on the previously calculated value. This process is repeated at the time of simulation and it's described by the following equation.

$V_n = \alpha V_{n-1} + (1-\alpha)\mu + \sqrt{(1-\alpha)^2} x_{n-1}$ (1)

α : tuning parameter for randomness variance.

μ : constant that represents the average value of speed and direction respectively.

x_{n-1}: random variable from the Gaussian distribution.

Based on the previous parameters, the Gauss-Markov mobility model was generated by:
./bm -f gmm GaussMarkov -n 100 -d 3600 -i 3600 –x 100 –y 100
These files of this Gauss-Markov mobility model are : gmm.ns_params and gmm.ns_movements.

IV. Simulation Results

In this section, using NS2 and mobility models Random Waypoint Mobility Model (RWP), Manhattan Grid Mobility Model (MANHT) and Gauss Markov Mobility Model (GMM), we compare the performances of LEACH, LEACH-C and PEGASIS protocols under different pause time. The tool BonMotion-2.0 [15][14], with random speed choosing from the range [5m/s , 20m/s] is used to generate the various mobility scenarios. The resulting trace files are converted to ns2 format and are analyzed by using awk scripts. For performance comparison, we take into account the simulation parameters in the following Table 1.

PARAMETER	VALUE
Number of Nodes	100
Simulation Time	3600 s
Routing Protocol	LEACH, LEACH-C, PEGASIS
Base Station	(50,175)
Mobility Models	Random WayPoint, Manhattan Grid, Gauss Markov
Pause Time (s)	20,40, 60, 80, 100
Link Layer Type	LL
Packet Size	512 MB
Queue Length	50 Packets

Table 1. Simulation parameters

The simulation was carried out for homogeneous nodes distributed randomly in the area of 100 m × 100 m with an initial energy of 2 Joules. The energy model used is given by:

$$E_{TX(L,d)} = \begin{cases} L * E_{elec} + \epsilon_{fs} * d^2 , d < d_0 \\ L * E_{elec} + \epsilon_{mp} * d^4 , d \geq d_0 \end{cases} \quad (2)$$

$E_{TX(L,d)}$: Energy expended to transmit an L bit message over a distance d.

E_{elec} : Energy electric of transmitter or receiver

ϵ_{fs}, ϵ_{mp} : Energy spent in amplifier over distance d_0, which $d_0 = \sqrt{\epsilon_{fs}/\epsilon_{mp}}$

The energy expanded in receiving L bit message is given by: $E_{RX(L,d)}$ = L x E_{elec} (3)

4.1. Packet Delivery Ratio (PDR)

This metric represents the percentage of the number of packets delivered by the number of packets sent. The high value of this parameter indicates that the corresponding protocol is better. Consequently, the network becomes less congested. Figures 1(a), 1(b) and 1(c) below show the results of various simulation experiments to measure packet delivery ratio at different pauses time for LEACH, LEACH-C and PEGASIS protocols under three types of mobility (RWP, MANHT and GMM).

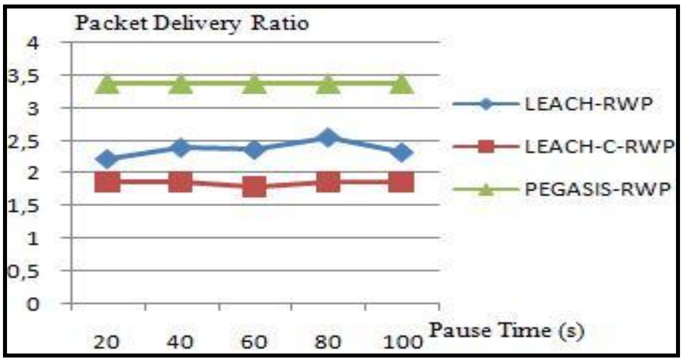

Figure 1(a): Packet Delivery Ratio vs Pause Time for RWP

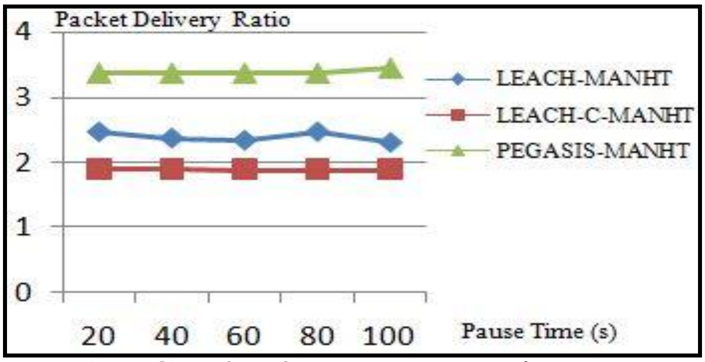

Figure 1(b): Packet Delivery Ratio vs Pause Time for MANHT

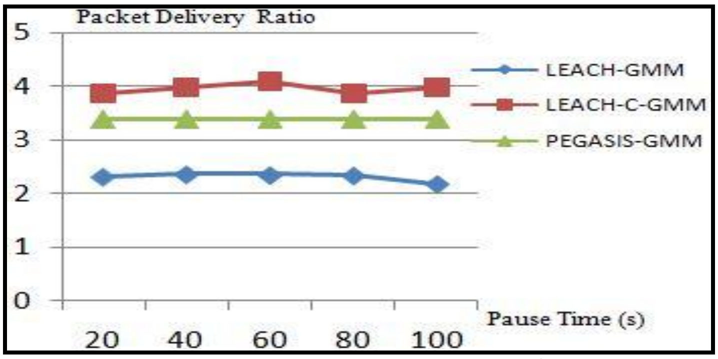

Figure 1(c): Packet Delivery Ratio vs Pause Time for GMM

As the pause time increases, the packet delivery rate slowly decreases for any mobility in the LEACH and LEACH-C protocols. In PEGASIS protocol, the PDR remains constant and unchangeable in all mobility. In the RWP model, the minimum packet delivery ratio occurred under high mobility at 20s pause time at which the ratio is 2,22 for LEACH, 1,86 for LEACH-C and 3,38 for PEGASIS, while the maximum PDR occurred at 80s pause time at which the ratio is 2.55 for LEACH, 1.86 for LEACH-C and 3,38 for PEGASIS. In the MANHT model, the minimum packet delivery ratio occurred at 100s pause time at which the ratio is 2.3 for LEACH, 1.88 for LEACH-C and 3.38 for PEGASIS, while the maximum PDR occurred at 80s pause time at which the ratio is 2.47 for LEACH, 1.88 for LEACH-C and 3,38 for PEGASIS. In addition, PEGASIS is the best protocol because it maintains a high packet delivery rate compared to the LEACH and LEACH-C protocols for the RWP and MANHT models. In the GMM model, the minimum packet delivery rate occurred at a pause time of 100 s, at which the ratio is 2.1 for LEACH, 3.99 for LEACH-C and 3.38 for PEGASIS, in mean time the maximum PDR occurred at 60s pause time at which the ratio is 2.35 for LEACH, 4.1 for LEACH-C and 3,38 for PEGASIS. Therefore, LEACH-C outperforms PEGASIS and LEACH respectively in terms of PDR by maintaining its high values for all scenarios of pause time especially for this model.

4.2. Average Throughput

Throughput measures the rate at which data packets are sent through the network until reached the destination in a unit of time. As shown in figure 2(a) below, LEACH-C shows an improvement of 0.92% to 1.23% average throughput than LEACH and from 4.89 % to 5.12% than PEGASIS in Random Waypoint model. For Manhattan model, LEACH-C shows an improvement of 0.8% to 0.92% average throughput than LEACH and from 5.1% to 5.23% than PEGASIS as indicated in figure 2(b). For Gauss-Markov model, the figure 2(c) shows that LEACH-C has an improvement of 1.86% to 2.23% average throughput than LEACH and from 8.84% to 9.6% than PEGASIS. In all scenarios, PEGASIS has the lowest average throughput than that of others and still sustainable an a one value. Then, the results show that LEACH-C protocol has been outperformed LEACH and PEGASIS protocols with various pause time and different mobilities. So, we can see that LEACH-C protocol produces best capacity of network to lead data packets successfully.

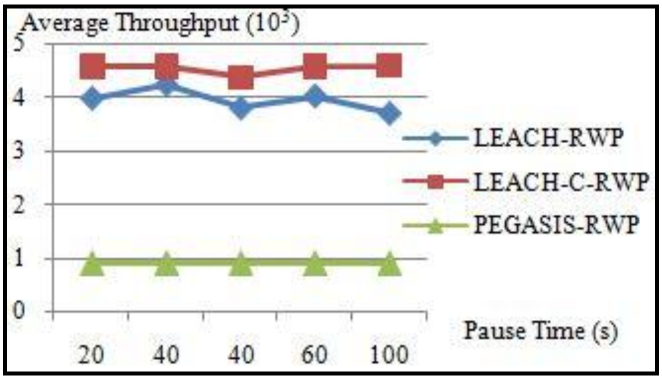

Figure 2(a): Average Throughput vs Pause Time for RWP

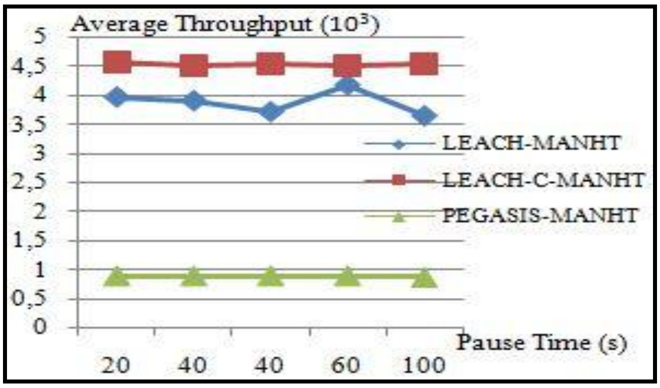

Figure 2(b): Average Throughput vs Pause Time for MANHT

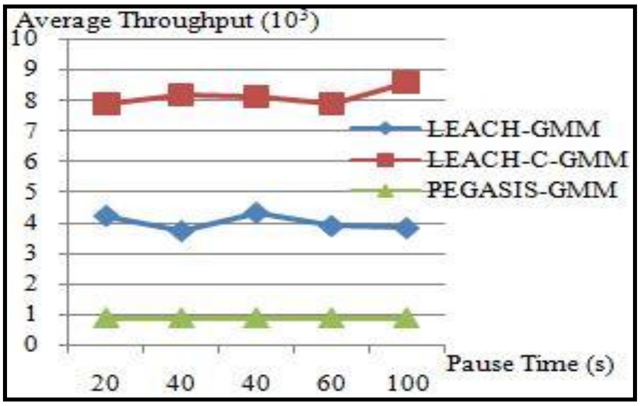

Figure 2(c): Average Throughput vs Pause Time for GMM

4.3. Average End-to-End Delay

This average represents the time related to the transmission of the data packets from source to destination. It includes total time caused by retransmission, propagation, buffering and queuing, etc.

From the Fig.3, we observe: In RWP model, LEACH shows an improvement of 0.76% to 1.23% average end to end delay than LEACH-C and from 4.07 % to 4.13 % than PEGASIS. In Manhattan model, LEACH shows an improvement of 0.76% to 1.46% average end to end delay than LEACH-C and from 4.05 % to 4.51 % than PEGASIS. In Gauss-Markov model, LEACH shows an improvement of 0.76% to 1.31% average end to end delay than LEACH-C and from 4.09% to 4.13% than PEGASIS. Concern all mobility models, we note that the average end-to-end delay remains stable when the pause time increases and has the lowest value for PEGASIS protocol. As it can be seen, PEGASIS protocol in the mobility environment can be used to have better application performance and better communication speed.

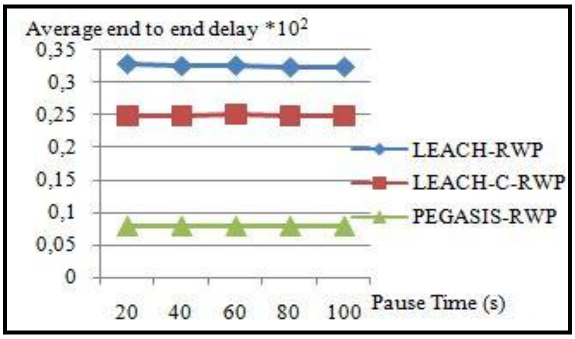

Figure 3(a): Average End to End Delay vs Pause Time for RWP

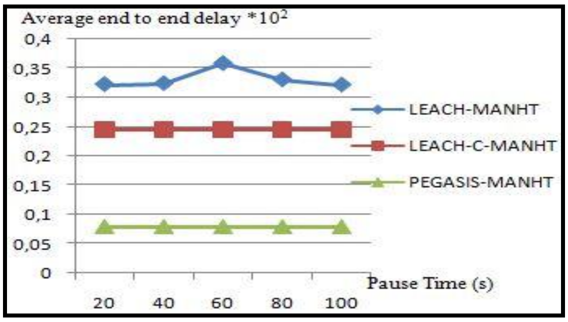

Figure 3(b): Average End to End Delay vs Pause Time for MANHT

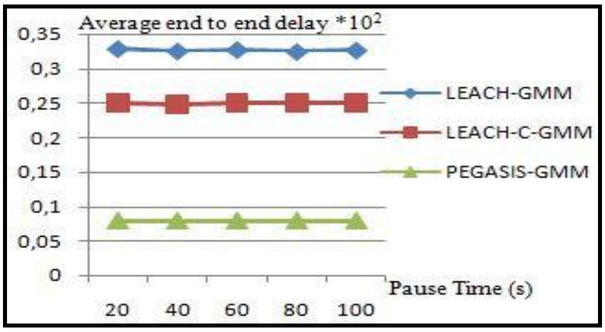

Figure 3(c): Average End to End Delay vs Pause Time for GMM

4.4. Number of Alive Nodes

The figures 4(a,b,c) show the results of different simulations experiments to measure the number of alive nodes at various pause time (100s, 60s, 20s)for LEACH, LEACH-C and PEGASIS protocols in each round and under mobility environment. From 0s to 475s of simulation time, the number of alive nodes died quickly in the LEACH and LEACH-C routing protocols. On the other hand, the number of live nodes remains stable in this period for PEGASIS protocol, then it begins to decrease which the simulation time changes from 475 to 1600 s.
For higher values of pause time (100s), PEGASIS in MANHT mobility has a high number of alive nodes compared to LEACH and LEACH-C in RWP and GMM mobilities. For average and lower values of pauses time (20s and 60s), the three protocols presents the same evaluation of number of alive nodes in each round.

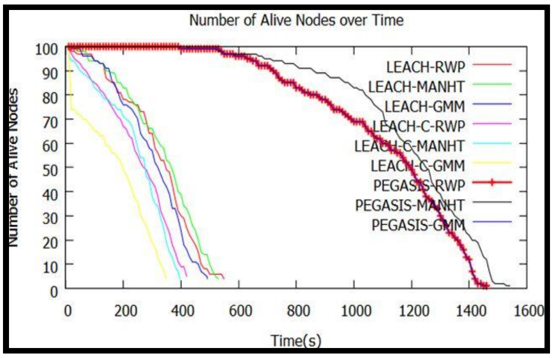

Figure 4(a): Number of Alive Nodes vs Time for 100s Pause Time

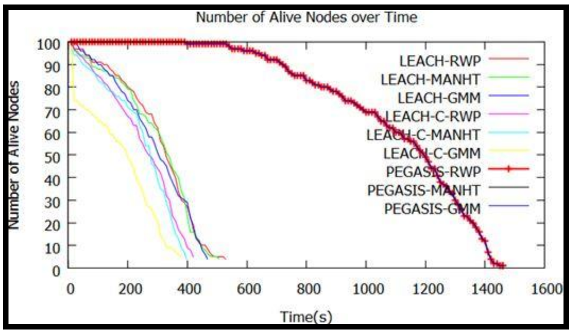

Figure 4(b): Number of Alive Nodes vs Time for 60s Pause Time

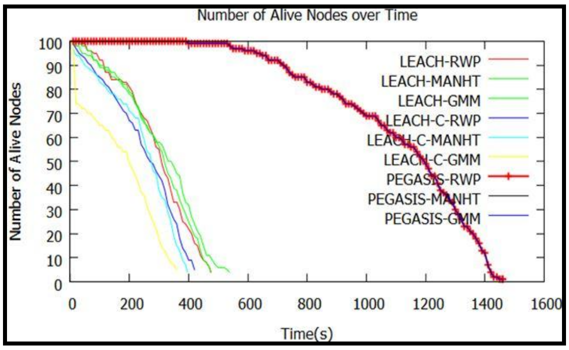

Figure 4(c): Number of Alive Nodes vs Time for 20s Pause Time

4.5. Energy Consumption

The figures 5(a,b,c) plot, in each round, the energy consumed (in joules) of three routing protocols LEACH, LEACH-C and PEGASIS for various pause time (20s, 60s and 100s) under different mobility models. For all mobility models, energy consumption is increasing as the pause time increasing. It is totally consumed in time 450s for LEACH and LEACH-C protocols and in time 1500s for PEGASIS protocol. For PEGASIS, energy consumed is less in mean time compared to LEACH and LEACH-C protocols for each round in the mobile environment and at various pause time.

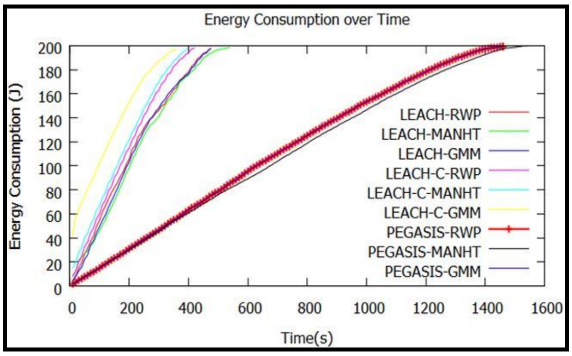

Figure 5(a): Energy Consumption vs Time for 20s Pause Time

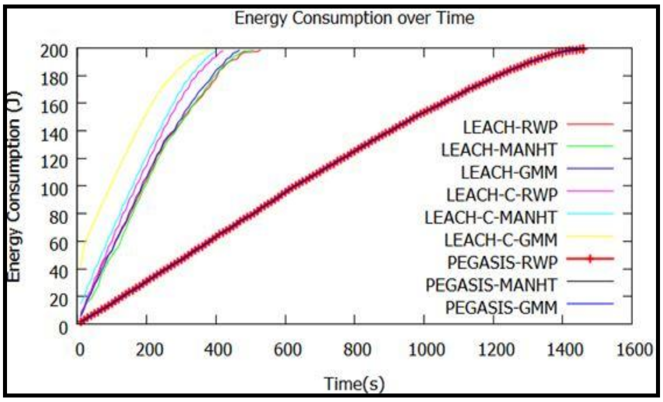

Figure 5(b): Energy Consumption vs Time for 60s Pause Time

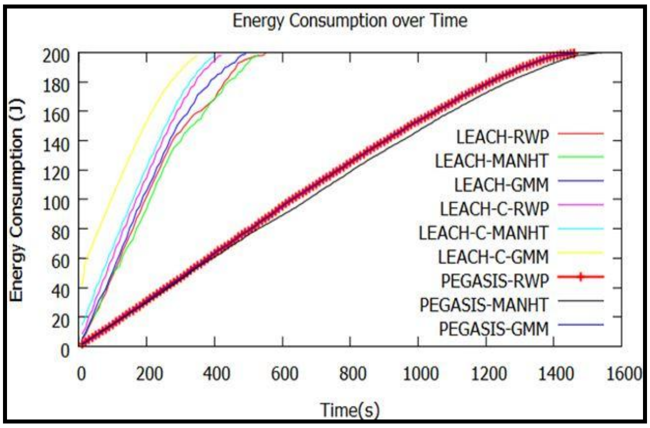

Figure 5(c): Energy Consumption vs Time for 100s Pause Time

V. Conclusion

To illustrate the performance of the three protocols LEACH, LEACH-C and PEGASIS for wireless sensor network under three mobility models with various pause time, it is demonstrated obviously that LEACH-C protocol has a good throughput compared to LEACH and PEGASIS. Also, it is shown that LEACH-C maintained high value of PDR in GMM, but it had a lower value in RWP and MANHT. And for mobility models Random Waypoint and Gauss Markov within various pause time, simulation results show that PEGASIS outperforms existed protocols LEACH and LEACH-C in terms of energy consumed and it gives well average end to end delay. At Manhattan mobility, it is obtained that PEGASIS has especially a good network lifetime of the mobile. We can also conclude that PEGASIS is the better protocol for the environment of mobility RWP and GMM.

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