# Energy Efficient Routing Algorithm in Wireless Sensor Networks

Maryam El azhari[1*] Ahmed Toumanari[2*]Rachid Latif[3]

ESSI, National School of applied Sciences, Ibnou zohr university, Agadir Morocco

* E-mail of the corresponding author: maryam.ensa@gmail.com

**Abstract**

This Wireless sensor network (WSN) is widely considered as one of the most important technologies for the twenty-first century, it provides the availability of small and low-cost sensor nodes with the ability of sensing different types of physical and environmental conditions, data processing, and wireless communication. Sensor nodes have a limited transmission range, and their processing and storage capabilities as well as their energy resources are also limited. Thus, optimized routing algorithms for wireless sensor networks should be utilized in order to maintain the routes in the network and to ensure reliable multi-hop communication under these conditions.

**Keywords:** Wireless Sensor Networks, Energy Efficiency, Routing Protocols, Solar Sensors, Mobile Agents

## 1. Introduction

In the last years, wireless sensor networks (WSNs) have gained increasing attention from both research community and actual users. Since sensor nodes are battery-powered devices, the main problematic to resolve is to minimize the energy consumption of nodes so that the network lifetime can be extended to reasonable periods of time (Brussel et *al.*1998). Several algorithms were proposed to meet strict energy saving requirements which may be divided into: Location; Data-centric; Mobility; Multipath; Heterogeneity; Qos; and other specific criterions (Chiara Buratti et *al.*2009). However, those protocols based on the client-server concept don't actually consider the fact that a sensor node has to afford various capabilities for multiple applications. That's why researches introduced the mobile agent (MA) approach. The Mobile Agent saves a great amount of energy but still presents much more latency compared with the client –server approach. Looking for alternative energy source seems efficient for prolonging the network lifetime moreover, solar energy has become more attractive recently because of its environmental benefits and because the efficiency of photovoltaic cells has increased significantly in the past few years, that's why, in this work, we tried to find a trade-off balance between the energy consumption and task latency using both solar powered nodes and mobile agents and we presented afterwards the SMA algorithm (solar aware routing with the mobile agent concept ) which is a new routing algorithm for energy efficiency based on solar powered sensors as alternative energy source**.** The remainder of this paper is organized as follows: in Section 2 and 3 we highlighted the advantages of using the mobile agent and solar power nodes. In Section 4 we present the proposed algorithm for energy efficiency in WSNs and finish up with perspectives of our work.

## 2. Mobile Agent

The application-specific nature of tasking a wireless sensor network (WSN) requires that sensor nodes have various capabilities for multiple applications. It would be impractical to store in the local memory of embedded sensors the entire program needed to run every possible application, due to the tight memory constraints. A mobile agent (MA) is a special kind of software that migrates among network nodes to carry out task(s) autonomously and intelligently in response to changing conditions in the network environment, in order to achieve the objectives of the agent dispatcher (Min Chen et *al.*2006). There are seven good reasons for using Mobile agents: Secure Brokering distributed information retrieval, parallel processing information dissemination, monitoring and notification, workflow applications and groupware, telecommunication networks services (Corke et *al.*2010). The use of MAs to dynamically deploy new applications in WSNs has been proven to be an effective method to address this challenge. Recently there has been a growing interest on the design, development, and deployment of MA systems for high-level inference and surveillance in WSNs. The agent design in WSNs is decomposed into four components, i.e., architecture, itinerary planning, middleware system design and agent cooperation. Among the four components, itinerary planning determines the order of source nodes to be visited during agent migration, which has a significant impact on energy performance of the MA system. It has been shown that finding an optimal itinerary is NP-hard. Therefore, heuristic algorithms are generally used to compute competitive itineraries with a sub-optimal performance.

## 3. Using Solar Powered Nodes for Power Efficiency

Solar energy has become more attractive recently because of its environmental benefits and because the efficiency of photovoltaic cells has increased significantly in the past few years. Solar energy is derived from Nature's greatest renewable resource and it is non-toxic in nature (Xiaoping Fan et *al*.2007). Solar cells can be utilized to power the sensor as well as to charge the batteries for WSNs, where their design goal is to provide autonomy lifetime (for wireless sensor nodes), making WSNs more valuable in terms of versatility and longevity. Solar cells are well-developed technology compared to other energy harvesting techniques (Jean Bulking et *al*.2008), they are fairly compact, capable of efficiently generating multiple potentials, and compatible with other processors. Two generations of solar cells are distingued:

### *3.1 Belk solar cells*

Figure 1 shows the Bulk solar cells, they are better suited to high light conditions and the outdoors spectrum, with efficiency ~ 15% - 20%; the poly-crystalline Si is cheaper, but less efficient than single-crystalline silicon.

### *3.2 Thin-film solar cell*

Figure 2 shows thin-film solar cells. The spectral response is more closely matches that of artificial indoor light; amorphous Si presents conversion efficiencies are ~5-10%; CdTe cells with good PV potential that give rise to environmental concern

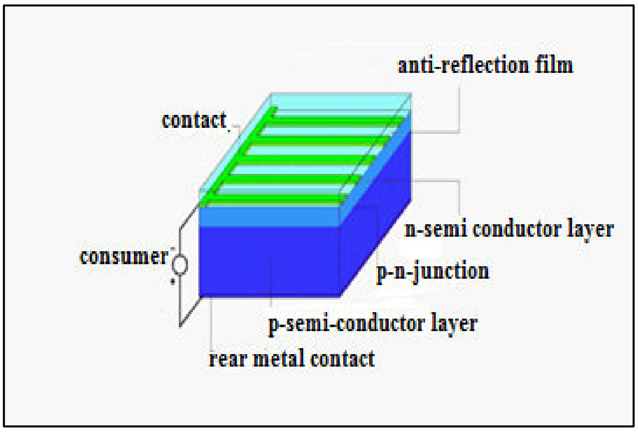


Figure 1. Bulk solar cells structure

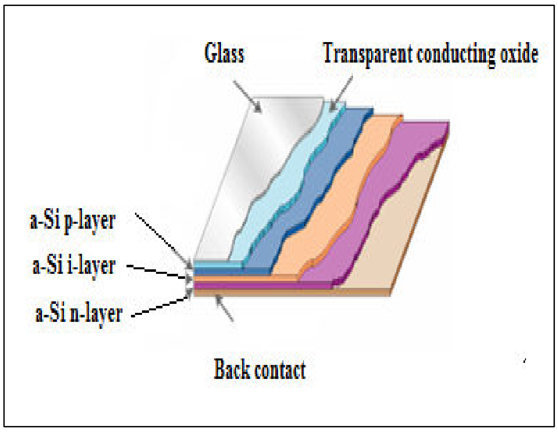


Figure 2. Thin-film solar cells component

Freie Universität Berlin laboratory team has highlighted the pros of solar powered nodes by using sensor board hardware (Wei cai et *al.*2011.), it consists of a Texas Instruments MSP430 controller as core and a set of associated sensor hardware. These sensors are:

- A light sensor for the detection of visible light
- A passive infrared sensor for detection of movement
- A temperature sensor
- A gravitation sensor for the detection of movement of the sensor board
- A microphone for determination of the ambient noise level

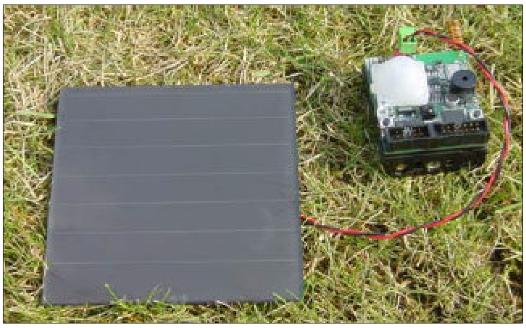

Figure 3. Sensor board with attached solar cells

## 4. The Proposed Algorithm

In this section, we present a routing algorithm for energy efficiency in WSNs christened SMA algorithm which consists of two phases: set-up phase and the steady phase. Our algorithm assumes that the sink node knows the geographic information of all source nodes and that the primary itineraries planning are executed at the sink Node with unlimited energy resources.

### *4.1 The Set-Up Phase*

The main purpose of the set-up phase is to find the nearest auxiliary sink (Solar Node) to sensor nodes, which consist of calculating the matrix of minimal distances A:

$$A = [d_{i,j}]$$
$$d_{i,j} = min(dist(Sensor\ Node,\ SinkNode_k))$$

*Where:*

$$j \in \{1.....n\};\ k,i \in \{1....m\};\ m=\sum Sink\ Nodes\ ; \quad (1)$$
$$n= max\ (Size(A_i))$$

After calculating the minimal distance matrix, the sink node will then solve the shortest path of each entry of the matrix from the sink nodes to the source nodes using Dijkstra's algorithm (indicate the source of Dijkstra algorithm) and then send the corresponding paths to the auxiliary nodes as show in Figure 4.

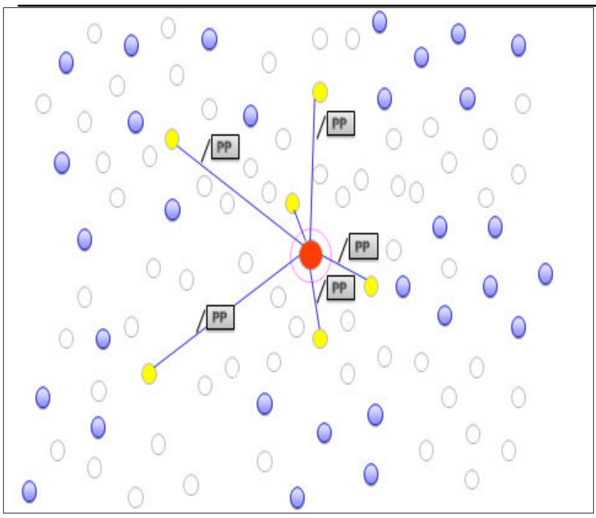


Figure 4. Setup phase of SMA algorithm

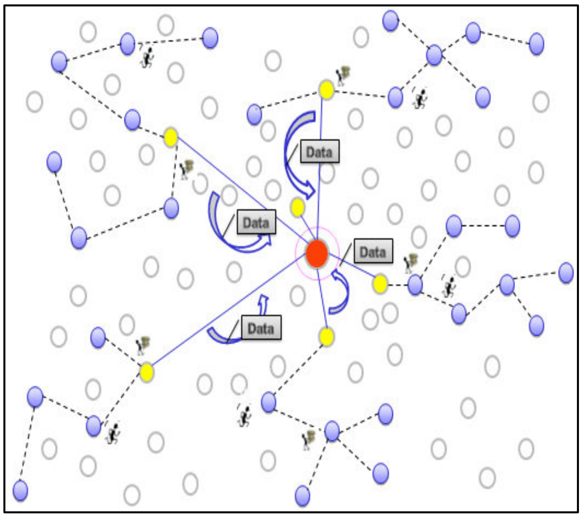


Figure 5. Steady phase of SMA algorithm

*4.2 The Steady State*

After receiving the short paths, each solar node (i.e sink node) will generate a mobile agent that will circulate the itinerary e.g. the minimum path in order to gather data and send it back to the sink node as shown in Figure 5.The solar nodes will then communicate the gathered data directly to the sink node, therefore a great amount of energy is saved, the end-to-end delay is reduced, and EPD converges considerably to smaller values.

*4.3 SMA Execution Steps*

SMA algorithm starts with the set-up phase ad mentioned in Figure 6, followed by the steady phase. If the location of a sensor is changed or its battery is running out of energy, the setup phase is taking place again in order to recalculate the new paths otherwise the same old paths are used.

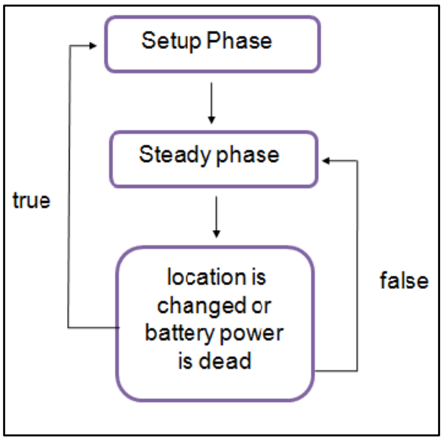


Figure 6. SMA algorithm execution steps

*4.4 Simulation Steps*

We implemented the basic of SMA algorithm in NetTopo environment and we compared it with both

CSWSN and MAWSN presented in (Min Chen et *al*.2006) based on the following metrics: energy consumption, average end-to-end delay and cost of communication (energy *delay) .We determined afterwards the main criteria under which the SMA is more efficient than CSWSN and MAWSN. A set of parameters was considered to highlight the tendency of the metrics such as: target source number ($n_{source}$), reduction ratio(r), size of sensed data at each sensor ($S_{data}$) and the basic parameters configuration are presented in Table 1, it has been observed that the performance of SMA algorithm the minimum number of sensor nodes that it has to be deployed.

Table 1. Table of parameters

| **Network Scale and Source Specification** | |
|---|---|
| Network Size | 300 m * 300 m |
| Maximum Transmission Range | 15 m |
| Topology Configuration | Randomized |
| Total Sensor Node Number | 600 |
| Number of Target Sources ( $n_{source}$ ) | Default : 4 |
| Data Rate at MAC layer | Default : 7 |
| **Sensed Traffic Specification** | |
| Size of Sensed Data ($S_{data}$ ) | Default: 4Kbytes |
| Sensed Data Interval | 1 s |
| Task Duration ($T\ task$ ) | Default: 100 minutes |
| **MA Specification** | |
| Fusion Factor ( $\rho$ ) | 1 |
| Reduction Ratio (r ) | Default: 10% |
| Local Processing Time at Target Source ($T\ proc$ ) | Default: 50ms |
| Size of Processing Code ( S *proc* ) | Default: 0.4Kbytes |

*4.4.1 Effect of the Number of Target Sources*

In these experiments, we change the number of sources from 1 to 14 and keep all the other parameters in Table 1 unchanged. As shown in Figure 7, SMA algorithm consume less energy compared with MAWSN and CSWSN algorithms, with maximum energy consumption equals to 1, 14 compared with 3,5 for MAWSN and 7,95 for CSWSN .In Fig. 8, the average $t_{es}$ increases relatively to $n_{sources}$, however even though the performance of SMA algorithm overcomes both CSWSN and MAWSN, the end to end delay introduces much more latency when the number of source nodes becomes higher than 11 source nodes, and this is due to the additional time required by the mobile agent to process data locally but it depends also on the maximum time that would take a mobile agent to circulate all the source nodes in order to collect data. However in Figure 9, it can be observed clearly that the cost (energy * delay) is the lowest compared with the other algorithms.

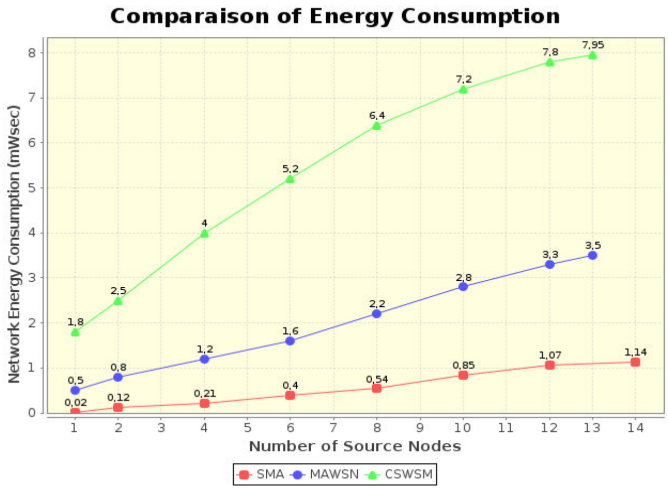


Figure 7. Comparison of total energy consumption

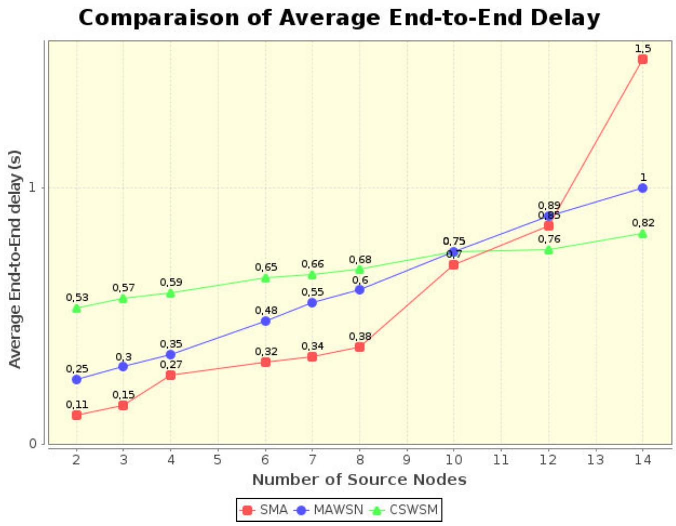


Figure 8. Comparison of the Average End-to-End delay

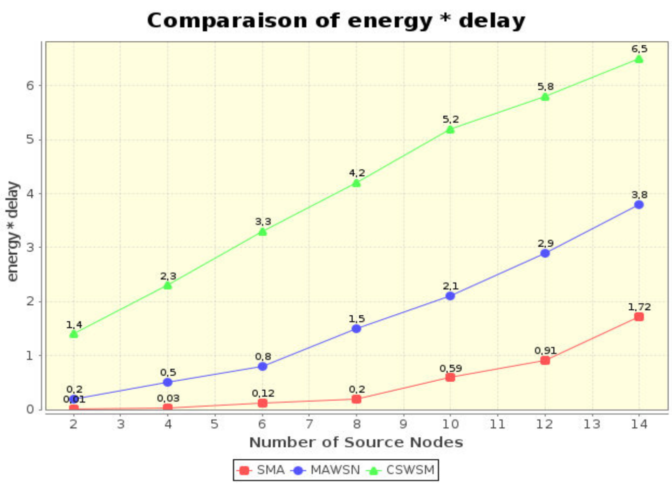


Figure 9. Comparison of the energy * delay

 

*4.4.2 Effect of Size of Sensed Data*

In these experiments, we change the size of the sensed data at each sensor (S data) from 0.5 KB to 4 KB in 0.5 KB interval. Figure10 shows that the energy consumption of SMA is always lower than that of MAWSN and CSWSN when the size of data packet varied with maximum consumption of 0.24 (mWsec) for SMA algorithm, 1.2 (mWsec) for MAWSN and 4.1 (mWsec) for CSWSN. Figure 11 shows that SMA algorithm always outperforms CSWSN and MAWSN algorithm in terms of energy delay with preference given to CSWSM in the first 0.5 KB interval, so the larger the data size is, the more efficient is the SMA algorithm and once again in Figure 12, the cost (energy*delay) of SMA algorithm is much better compared with MAWSN and CSWSN

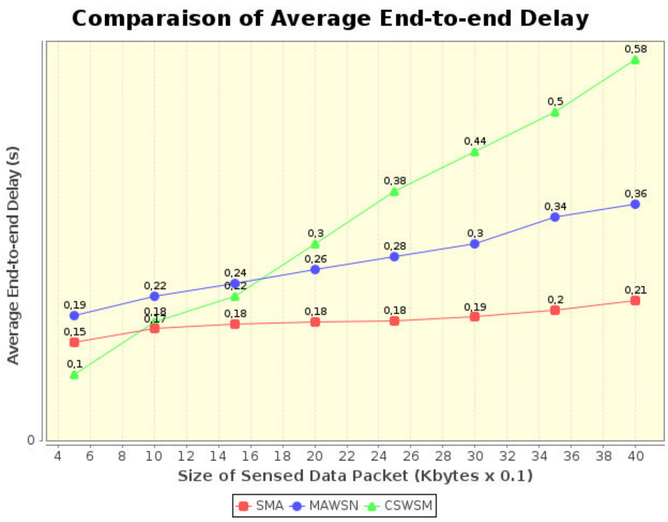


Figure 10. Comparison of the Average End-to-End delay

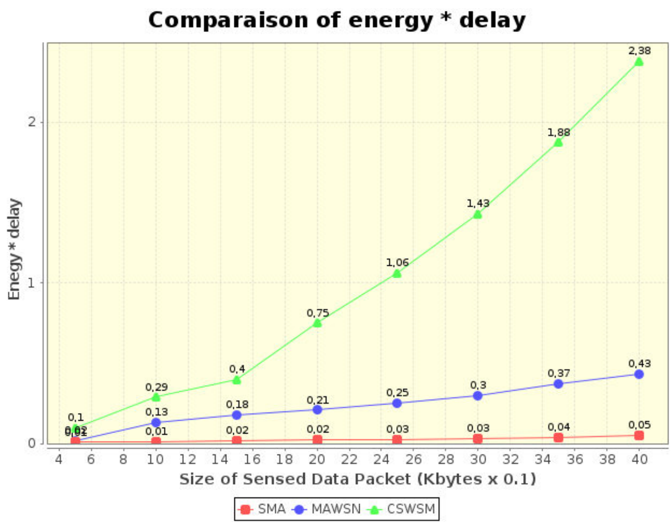


Figure 11. Comparison of the energy * delay

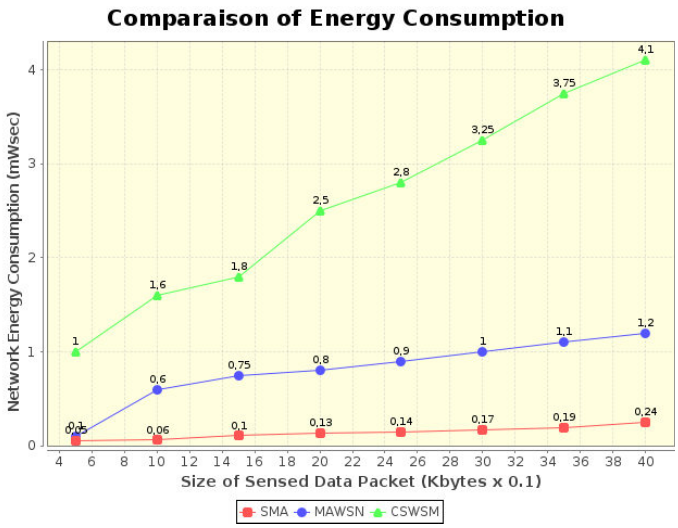


Figure 12. Comparison of energy consumption

*4.4.3 Effect of Reduction Ration*

In the experiments, we change the reduction ration r from 0.1 to 0.4 and keep the other parameters in Table 1 unchanged. As observed in Figure 13, the energy consumed by SMA is much lower than CSWSN and MAWSN and the same behavior is noted in Figure 14 where the end-to-end delay presents the minimum values compared with the other algorithms Figure 15 we can clearly observe that when the Reduction Ratio is taking different values, the performance of the SMA algorithm in terms of the cost(energy * delay) is still the best.

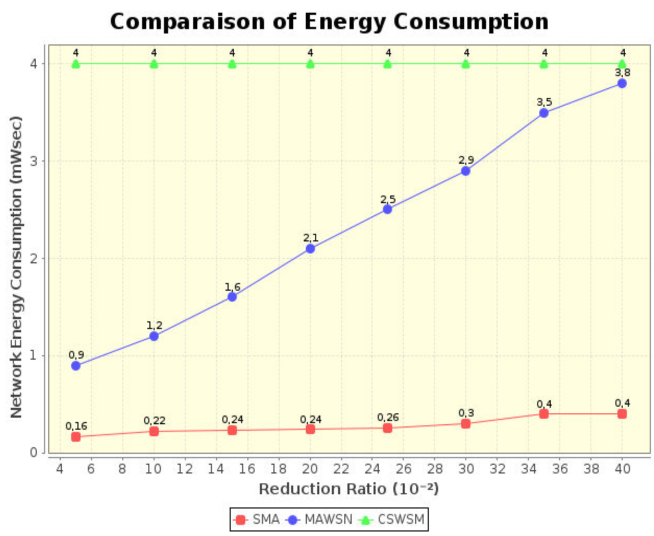


Figure13 comparison of energy consumption

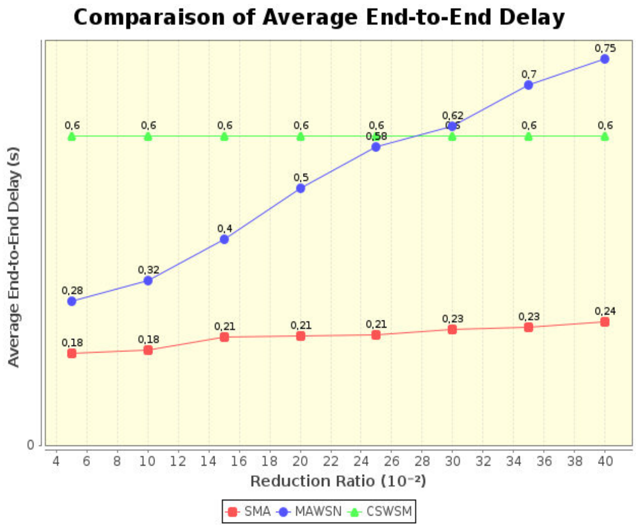


Figure 14 comparison of the Average End-to-End delay

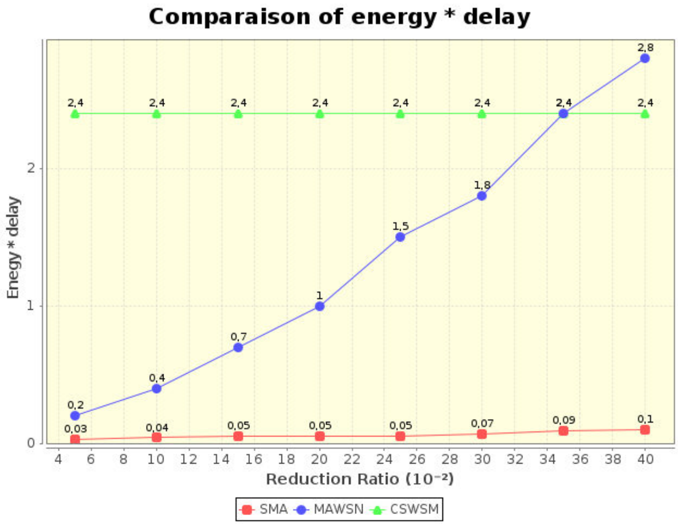


Figure 15 comparison of energy * delay

## 5. Conclusion and Perspectives

Sensor Networks are emerging as a great aid in improving the way of accessing to data. The previous studies show that solar energy is an efficient alternate energy source for WSNs. The solar energy based routing concepts increase the performance and life of WSNs compared with other conventional routing algorithms. In this paper, we present the SMA routing algorithm for WSNs based on solar powered nodes, and as a future work, we would be working on resolving the issue where the location of a sensor is changed or its battery is running out of energy. SMA new tendency can be described as follows: every time the location of a sensor is changed, the sink Node would send a beacon packet to alert the solar nodes. As soon as received, the solar nodes will drop the paths and stop generating mobile agents to collect data until the new paths are received. In cases where a sensor node's battery power is dead, solar nodes will wait for the mobile agent until the timeout T is expired. T corresponds the delay taken by a mobile agent to circulate the longest path towards the destination (solar node or sink node) .Thus, when T is expired, solar node will send a beacon packet to the Sink Node in order to recalculate the new paths. The development of this new methodology is still in progress.

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