PERFORMANCE EVALUATION OF DATA FILTERING APPROACH IN WIRELESS SENSOR NETWORKS FOR ENERGY EFFICIENCY

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ABSTRACT

Wireless Sensor Network is a field of research which is viable in every application area like security services, patient care, traffic regulations, habitat monitoring and so on. The resource limitation of small sized tiny nodes has always been an issue in wireless sensor networks. Various techniques for improving network lifetime have been proposed in the past. Now the attention has been shifted towards heterogeneous networks rather than having homogeneous sensor nodes in a network. The concept of partial mobility has also been suggested for network longevity. In all the major proposals; clustering and data aggregation in heterogeneous networks has played an integral role. This paper contributes towards a new concept of clustering and data filtering in wireless sensor networks. In this paper we have compared voronoi based ant systems with standard LEACH-C algorithm and MTWSW with TWSW algorithm. Both the techniques have been applied in heterogeneous wireless sensor networks. This approach is applicable both for critical as well as for non-critical applications in wireless sensor networks. Both the approaches presented in this paper outperform LEACH-C and TWSW in terms of energy efficiency and shows promising results for future work.

KEYWORDS

Filtering, Clustering, Aggregation, Energy consumed, delay, jitter, overhead

1. INTRODUCTION

Wireless sensor networks were initially developed for applications in severe conditions. But now they are being deployed in various application areas including patient care in hospitals, traffic management, pollution monitoring and control etc. Earlier the concern was its resource limited nature and is still the same despite of many proposed solutions. Due to its resource limitations, the focus has been shifted towards heterogeneous sensor nodes in the wireless networks. In this type of network, some homogeneous nodes are placed for sensing and better configured nodes are placed for data clustering and communication. The better configured nodes can be mobile or static depending upon the nature of the application [1].

The data communication in wireless sensor networks takes most of the energy of the sensor nodes. Hence, the focus of the research is to reduce inter-node transmissions for conserving energy at the sensor node level. Energy efficient clustering and data filtering may help to increase the network lifetime. Filtering the data at the sensor node level checks the redundant information and passes only the new entry to the cluster-head. The cluster-head also applies the same data filtering approach and sends only the required information to the base station. This whole process

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may reduce the inter-node transmissions and further increases the network lifetime. Energy efficient clustering also adds the benefit and helps in longevity of the network.

Therefore, the process is multilevel that deals with sensing, filtering and aggregating the correlated data from various sources. Along with clustering, data filtering and fusion appears to be an effective technique for the reduction of communication overhead by removing the redundant messages. Therefore, this technique happens to be very important aspect in increasing energy efficiency and lifetime of wireless sensor networks.

The rest of the paper is organized as follows: Section 2 reviews related work in the clustering and data filtering in wireless sensor networks. Section 3 represents the approach used in this paper. Section 4 describes the simulation results and discussions and Section 5 concludes the paper.

2. LITERATURE REVIEW

A. Clustering

In the recent literature, various clustering algorithms have been proposed. [2] presented the survey of various clustering algorithms in terms of convergence time, node mobility, cluster overlapping, location awareness, energy-efficiency, failure recovery, balanced clustering and cluster stability. [3-7] used voronoi diagrams for the movement of various mobile nodes in the area of observation for efficient data collection. [8-13] used ant systems and its various modifications for choosing the optimal path between source and the destination in wireless sensor networks. Voronoi diagram has been a successful technique for boundary estimation and grid formation [14]. An ant system has proved itself to be energy efficient in choosing the optimal paths. VAS [15] presented the combination of voronoi diagrams and ant systems that helps in improving network performance in terms of energy efficiency.

VAS has been compared with AODV and OSPFv2 which are routing algorithms. To prove its significance in wireless sensor networks, we intend to compare VAS with traditional LEACH-C algorithm for energy efficiency.

B. Data Filtering

The algorithms presented in [16-18] are based on hierarchical approach for data aggregation and do not implement any data fusion process to reduce data size. [19-27] used various fusion techniques. [28-30] presented data aggregation methods in resource constraint wireless sensor networks.

[31-32] used Kalman filtering and TWSW filtering for over sighting the redundant data respectively. Both the papers do not cover the criticality of an application and is majorly suitable for non-critical applications. The technique presented in [33] is a modification of TWSW filtering and hence we call it as MTWSW. This approach is suitable both for critical as well as for non critical applications in wireless sensor networks. MTWSW filtering approach filters out the data in such a way that spurious and redundant data can be ignored for non-critical applications and crucial information is disseminated for critical applications.

MTWSW has not been compared with any filtering approach in the literature. Hence we intend to compare MTWSW with the original TWSW for its significance in the field of wireless sensor networks.

3. APPROACH USED

The approach used in this paper is as follows:

1: Network Initialization, Node Initialization, Neighbour Initialization.
2: Cluster formation:
- a) Cluster-head nodes run VAS (Voronoi Ant Systems) algorithm.
- b) All sensor nodes identify their membership status through VCP (Voronoi Control Packet).
- c) Data dissemination starts from sensor nodes to sink node through respective cluster-head nodes.

3: An Ant system from VAS is used for route discovery and route maintenance in the network.
4: Comparison of VAS and LEACH-C on the basis of average end-to-end packet delay, energy consumption and data delivery ratio with varying network size and data send rate.
5: Apply MTWSW to all the sensor nodes as well as to all the cluster-head nodes, so that:
- a) Redundant packets are filtered out at sensor node level and intermediate level.
- b) Further unimportant/redundant data is filtered out at cluster-head level.

6: Comparison of MTWSW and TWSW on the basis of average end-to-end packet delay, energy consumption and data delivery ratio with varying network size and data send rate.

ABBREVIATIONS AND ACRONYMS

VAS: Voronoi Ant Systems
VCP: Voronoi Control Packet
TWSW: Two Way Sliding Window
MTWSW: Modified Two Way Sliding Window
AODV: Ad hoc On-Demand Distance Vector Routing
OSPFv2: Open Shortest Path First version 2 Routing
LEACH: Low Energy Adaptive Clustering Hierarchy

4. RESULTS & DISCUSSIONS

The area of observation is (100X100) m^2 with 100 homogeneous sensor nodes, 10 cluster-head nodes having unlimited battery, 1 sink node placed outside the side of observation. The power parameter used for the experiment are: MicaZ, ZigBee Application with 127 Bytes packet size, IEEE 802.15.4 standard at the MAC and Physical Layer, Linear Battery model (1200 mAh) for sensor nodes, two-ray signal propagation model. Simulations have been performed in QualNet version 6.1. We assume that the temperature of an agriculture land's surface is to be monitored continuously.

VAS Clustering versus LEACH-C

VAS has been compared by AODV and OSPFv2 in its previous work, but no comparison has been made with any clustering approach for wireless sensor network. In this paper, we tend to compare VAS with LEACH-C algorithm on the basis of average end-to-end packet delay, energy consumed and data delivery ratio. The varying parameters are network size and data send rate.

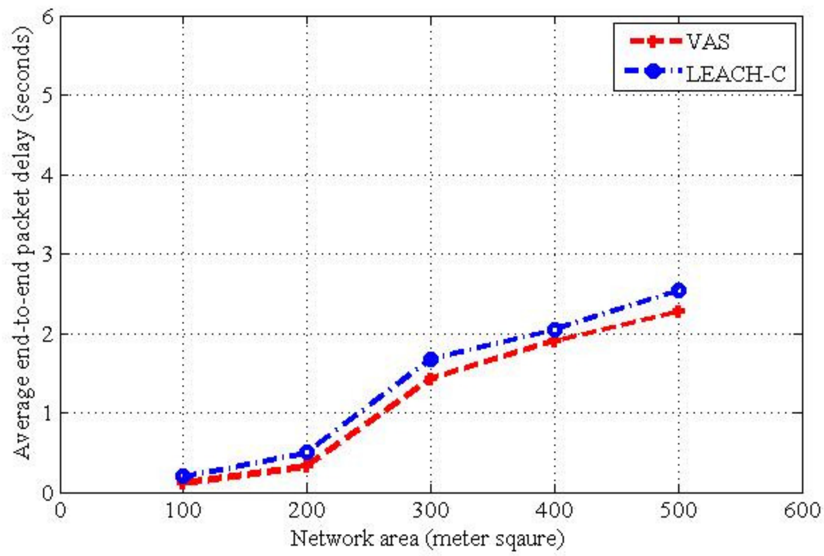

Figure 1(a) Average end-to-end packet delay with varying network area

LEACH-C uses base station to make a decision for cluster formation whereas in VAS all the cluster head nodes makes the decision of cluster formation which in turn saves time and energy.

As shown in Figure 1, with increase in network area, the communication between cluster heads and base station takes more time and hence VAS shows better results than LEACH-C in-terms of average end-to-end packet delay.

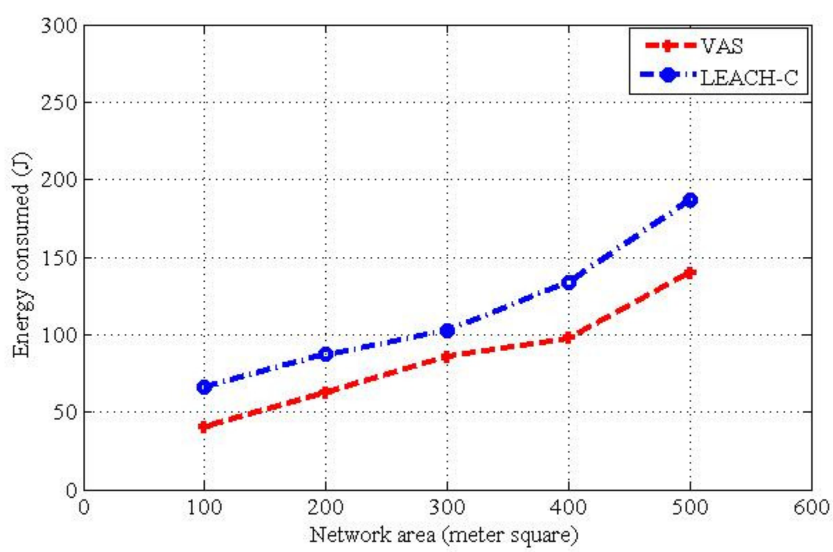

Figure 1(b) Energy consumption with varying network area

Hence overall energy consumption of VAS is less as compared to LEACH-C as shown in Figure 1(b). As shown in Figure 1(c), data delivery ratio of VAS is much better than LEACH-C because of better route planning and implementation by ant systems by VAS.

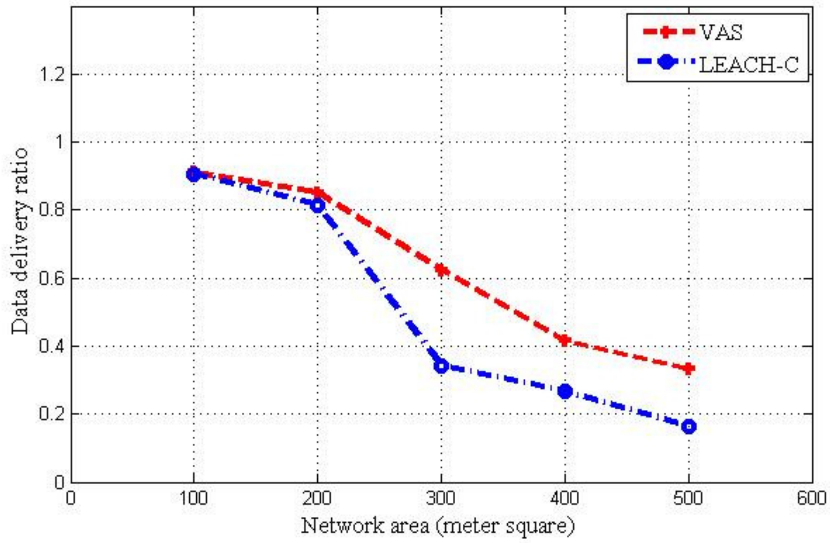

Figure 1(c) Data delivery ratio with varying network area

As the data send rate varies in Figure 2, performance of both the algorithms deteriorates. With variation in data send rate, more number of data packets is generated in the network and hence leads to congestion. VAS uses ant systems for route discovery and route maintenance. An ant system used in VAS is very useful in handling traffic congestion as shown in Figure 2(a). It handles the redundant packets very well whereas LEACH-C performs poorly in this scenario.

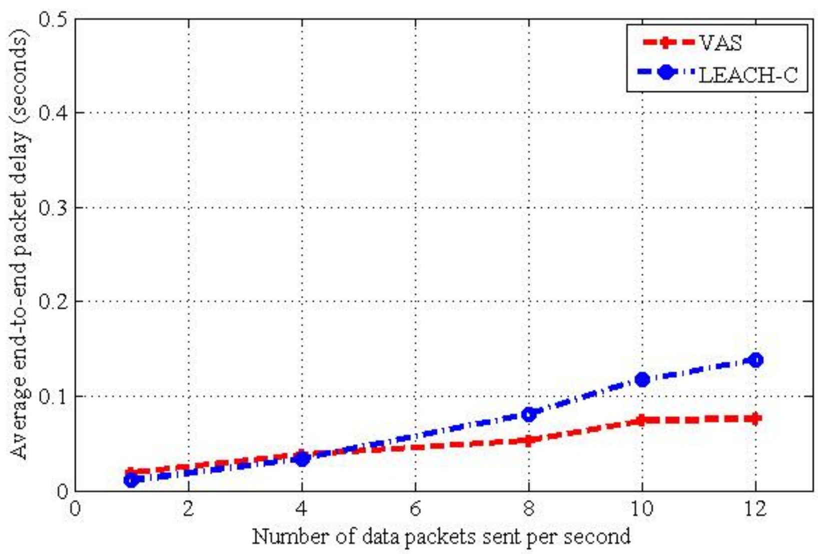

Figure 2(a) Average end-to-end packet delay with varying data send rate

Therefore, VAS is more energy efficient as compare to LEACH-C as shown in Figure 2(b)

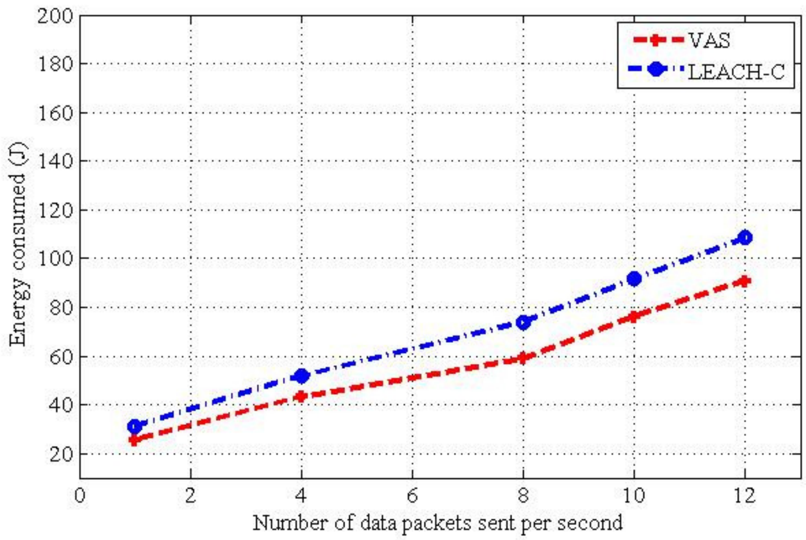

Figure 2(b) Energy consumption with varying data send rate

VAS performs well with 4 data packets per second as shown in Figure 2(c). Though it performs well as compare to LEACH-C for 10-12 data packets per second but we consider 4 is the optimum number for VAS. VAS shows good performance as compared to LEACH-C with all the parameters.

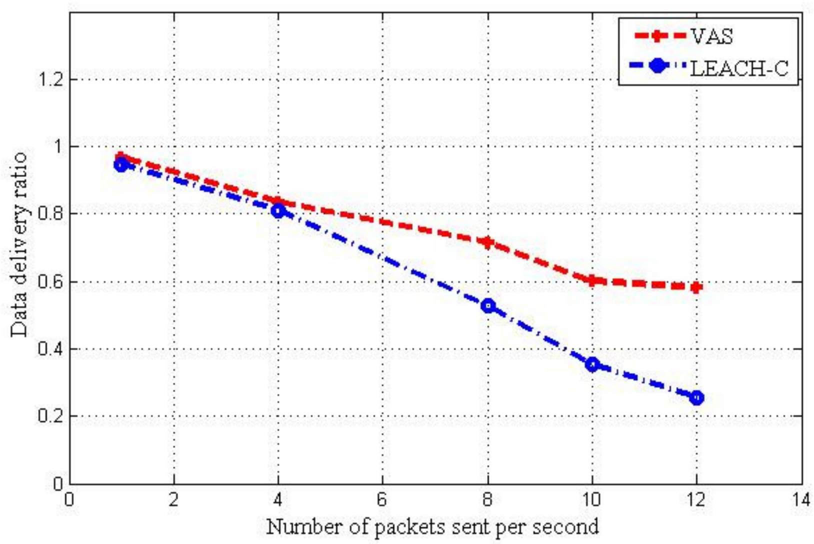

Figure 2(c) Data delivery ratio with varying data send rate

Hence VAS proves to be better than LEACH-C with varying network area and data send rate in terms of average end-to-end packet delay, energy consumption and data delivery ratio.

MTWSW versus TWSW

After analyzing VAS clustering in wireless sensor network, we implement filtering approach for improving it further. To check the significance of MTWSW with VAS in wireless sensor networks, we apply TWSW as well. Here in this section, a comparative analysis is presented between TWSW and MTWSW with varying network size and data send rate. The algorithms have been compared on the basis of average end-to-end packet delay, energy consumption and data delivery ratio.

Variation i network size has lot of impact on the network performance. Figure 3(a) and 3(b) represents average end-to-end packet delay, energy consumed respectively with varying network size.

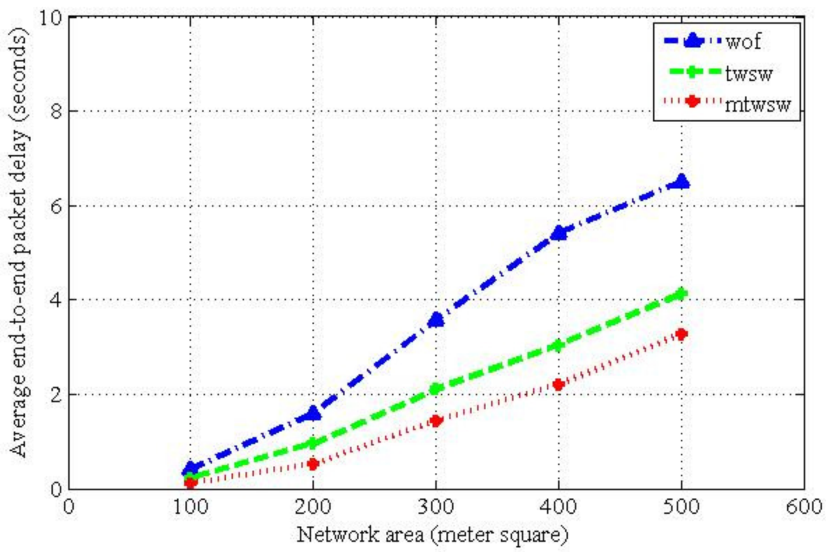

Figure 3(a) Average end-to-end packet delay with varying network area

Figure 3(a) shows that average end-to-end delay has increased because node density directly affects the network performance. The sparsely populated sensor nodes in a networks form a very difficult environment because of poor connectivity. MTWSW shows better performance in terms of average end-to-end packet delay than TWSW because the sensed data items have been filtered at the sensor/relay node level and only non redundant information is transmitted to cluster head nodes which further decreases the average delay.

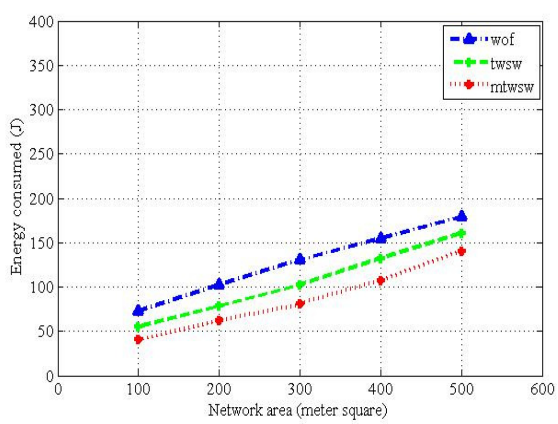

Figure 3(b) Energy consumption with varying network area

Energy consumption as shown in Figure 3(b) has increased with increasing network area because of sparse networks. But energy consumed by MTWSW is much less than TWSW as well as without filtering approach

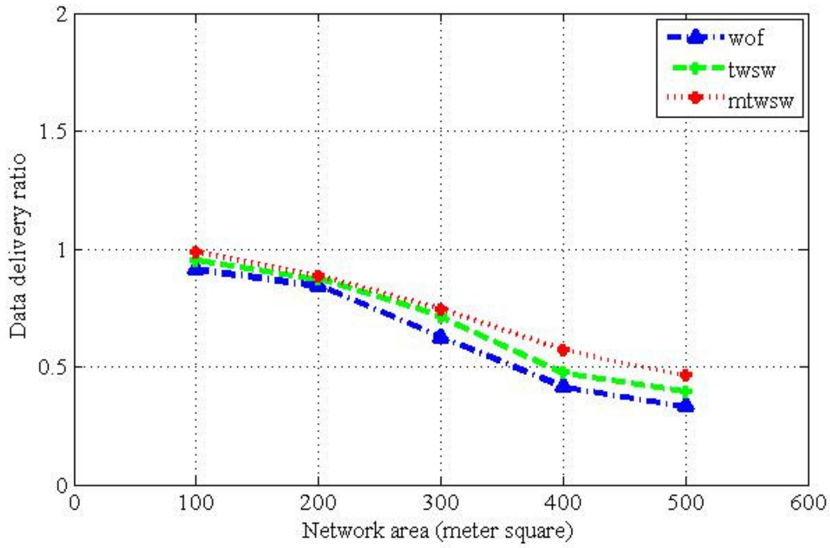

Figure 3(c) Data delivery ratio with varying network area

As shown in the Figure 3(c), the data delivery ratio is deteriorating with increasing network area because the average path length between two communicating nodes is increasing and hence increasing the chances of link failure and hampers the repair mechanism. Even in the worst case MTWSW is able to deliver approximately 48 % of the data as compare to 40 % by TWSW in the worst case

The data send rate i.e. number of packets sent per second has been varied from 1 to 12 packets per second. By varying the number of packets sent per second, increases the network load and congestion and interference becomes more likely.

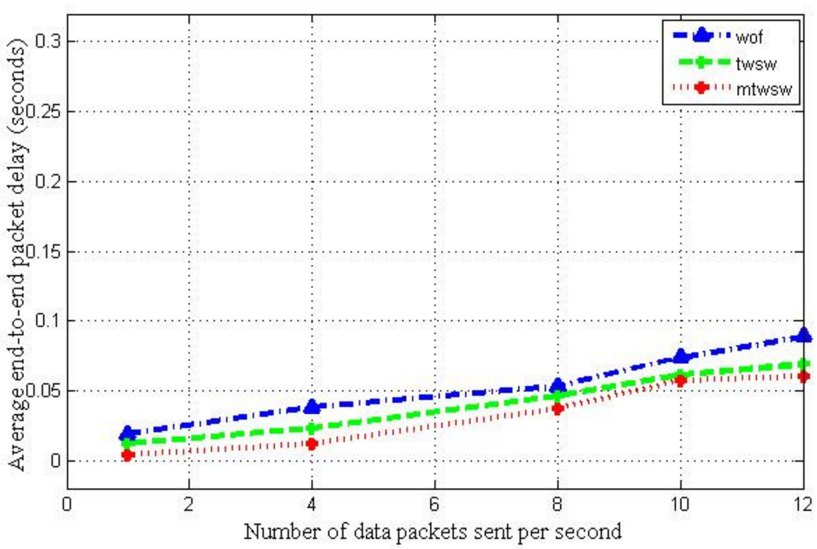

Figure 4(a) Average end-to-end packet delay with varying data send rate

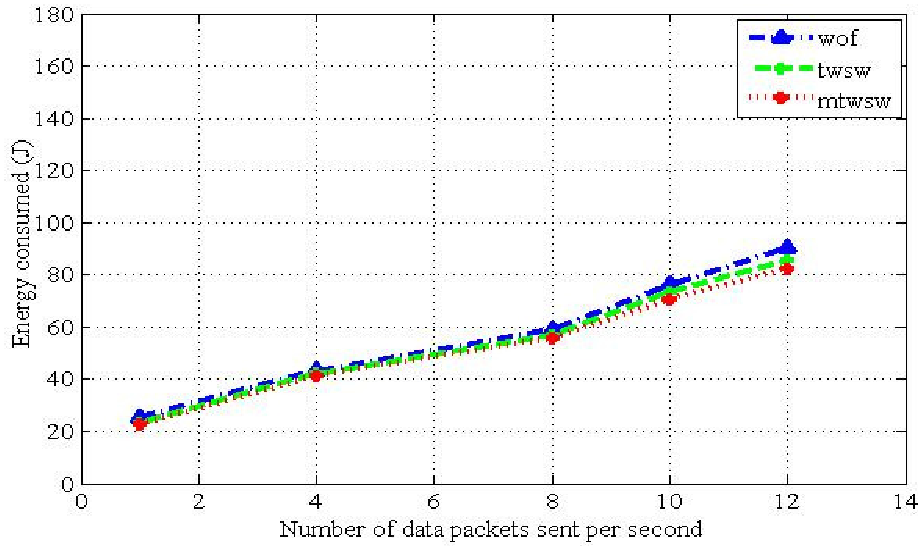

Figure 4 (b) Energy consumption with varying data send rate

Figure 4(a) and 4(b) represents average end-to-end packet delay and energy consumed respectively with varying data send rate. As shown in the figures, both the parameters suffered with increase in data send rate from four packets to eight packets per second. But in this case also MTWSW filtering approach performed better than its counterpart.

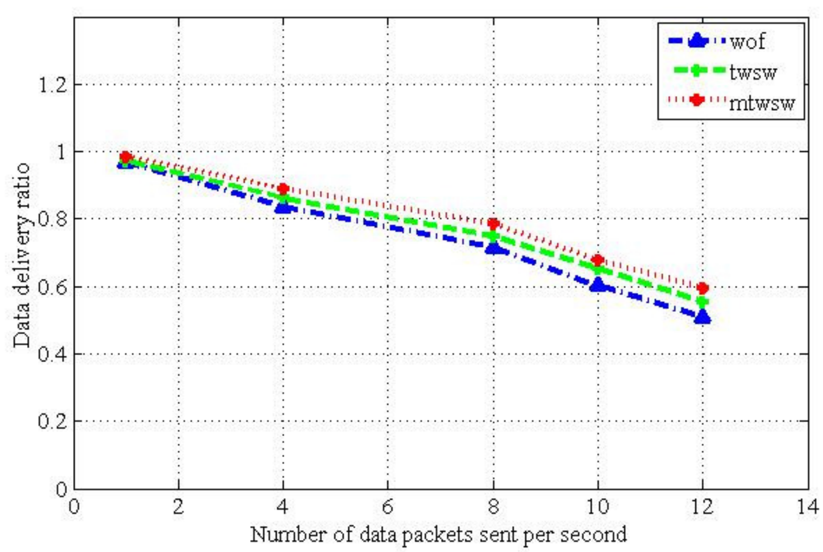

Figure 4(c) Data delivery ratio with varying data send rate

Data delivery ratio has been represented by Figure 4(c) with varying data send rate. In this case, we considered the number of data items sent from the source nodes after filtering redundant data items rather than the number of data items sensed at the source node. It has been noticed from the figure that increasing data send rate from four packets to eight packets has a great impact on data delivery ratio and energy consumption. With four data packets per second MTWSW was able to deliver approximately 89% of the data accurately whereas TWSW delivered approximately 85% of the data accurately. Hence TWSW has shown better performance than TWSW.

5. CONCLUSIONS

In this paper, we have compared VAS and TWSW with standard approaches for their validation in the field of wireless sensor networks. The paper has been divided into two continuous sections. In first section, VAS has been compared with LEACH-C and in preceding section; MTWSW has been compared with TWSW. The comparison has been made on the basis of average end-to-end packet delay, energy consumed and data delivery ratio with varying network size and number of packets sent per second. In the first section, VAS has been proved better than LEACH-C and MTWSW has been proved better than TWSW in preceding section. This papers represents the significance of clustering and filtering in resource limited wireless sensor networks. Further research in this area will offer promising results. We plan to extend this approach by implementing mobility in this type of heterogeneous network. We did not take up security aspects of wireless sensor networks in this work. Wireless sensor network security can also be taken up as future work.

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