AN ENERGY EFFICIENT EVENT DETECTION CLASSIFIER IN WIRELESS SENSOR NETWORK USING SUPPORT VECTOR MACHINE

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Abstract

Wireless sensor network (WSN) comprises of nodes that are spatially distributed to monitor the environments and detect the events accordingly. Correlated Data Gathering (CDG) in wireless sensor network used Adaptive and Distributed Routing (ADR) algorithm for correlated data gathering in order to minimize the total energy consumption. Though energy consumption was reduced in the network, energy delay tradeoff occurred while securing data in sensor network was high. Energy-efficient and High-accuracy (EEHA) scheme provided a secured data aggregation technique using an aggregation tree which provided privacy but the energy consumption was high during event detection. Recoverable Concealed Data Aggregation (RCDA) for Data Integrity recovered all sensing data events even when the data were aggregated, by reducing the transmission overhead but with higher energy ratio. To develop an energy efficient Event Detection Classifier in wireless sensor network, a predetermined event weight based on Support Vector Machine (EDC-SVM) is proposed in this paper. The EDC-SVM initially identifies the weight of the events for effective classification using SVM with minimal energy consumption. EDC-SVM uses Doppler Effecting method for recovering all sensing data events with minimal energy. The task of Doppler Effecting method in EDC-SVM is to detect the periodic events of moving objects (i.e.,) sensor nodes to reduce the classification time of sensor events. With the minimal time on classification, the energy delay tradeoff is overcome in EDC-SVM. Furthermore, with the application of an event section key generation in EDC-SVM, reduces the energy consumption during the generating of section key and broadcast the notification to the sensor nodes within the section. EDC-SVM with event section key generation improves the security level on object collection. Experimental work is carried out on the factors such as classifier rate, security level, and energy consumption rate.

Keywords: Support Vector Machine Classifier; Event Detection: Sensor Network; Doppler Effecting; Key Management; Weight.

1. Introduction

Large number of sensor nodes in Wireless sensor networks (WSNs) is highly correlated due to the presence of object in different locations. Sometimes, the transmission of all the objects to the destination may increase traffic and results in congestion. Transmitting all sensor data can increase traffic in the network and congestion at the destination nodes. This in turn increases the energy consumption of the entire network. To solve the problems many researchers have presented object classification by applying data aggregation in WSNs to minimize the traffic occurring in the network.

CUSUM [15] provide an energy efficient distributed cooperative mechanism where each sensor deployed the CUSUM algorithm and the packets were transmitted by the sensors only when the CUSUM was above certain threshold value. But the time taken to measure the threshold value was large. Certain case scenarios where the sensor nodes are provided with energy constraint is highly observed in wireless sensor networks. In [16], stochastic tools were presented for the design of forwarding schemes for selecting specific messages. The selection of messages was highly dependent upon certain metrics as battery availability, the energy consumption during retransmission and so on.

In [1], multi-hop data aggregation technique was presented to reduce the energy consumption of the overall network using data aggregation times keeping in mind the energy efficiency. For this, an integrated algorithm called the adaptive and distributed routing algorithm was presented for gathering of data using a game theoretic framework. Though energy consumption was reduced to certain extent in the overall network, the energy delay tradeoff occurred while securing the data in sensor network was high.

With the increasing built-in capabilities of sensor nodes which are constrained in resources, one of the major problems to be solved in wireless sensor networks is related to communication overhead. Though, the problem can be solved using aggregation of data, but it may result in limited lifetime of the network. In EEHA, [2] an integrated scheme comprising of energy efficiency and high accuracy was provided for providing security during data aggregation. Though accuracy was achieved at a higher extent, the energy consumption was high during the detection of events. In [10], measures were taken to increase the security from a typical source node to the destination node over fading channels. Here both the legitimate nodes and eavesdroppers were all located in a random manner. Both the non-colluding and colluding eavesdroppers were taken into consideration. But the scheme was addressed for local connectivity whereas global connectivity remains unaddressed.

The applications involved in wireless sensor networks are increasing at a greater rate than ever before which includes, health, environment factor, surveillance and so on. Several data aggregation schemes have been proposed by many researchers, but aggregation functions get constrained. In [3], the problems related to constrain was solved by designing the base station in such a way that it could recover all sensing data object though they are aggregated, called as “recoverable”. Though the data was aggregated by reducing the transmission overhead, the cost of energy ratio was high.

Wireless sensor networks consist of dense sensor nodes that perform the task of collection and dissemination of the environmental data to the destined node. In [4], bandwidth allocation was studied by distributing the data slots available at an extensive rate between several users, for providing QoS. A mathematical model was also constructed to measure the delay metrics for Service Data Unit (SDU) for a multiuser environment. But the acknowledgement of effective or ineffective distribution was transmitted after substantial amount of time.

In [5], a practical scenario was investigated that achieved higher rate of connectivity and exact level of resilience with minimum amount of resources being used with the help of pair wise key distribution method. But the issues were not addressed for heterogeneous wireless sensor network. In [14], an attack method using cryptanalysis was presented against the key distribution scheme and security was provided. A new key management technique as presented in [18] is a combination of tradition encryption and group key agreement. In this method, each user maintained only single public/secret key pair. The sender broadcast only when he looks upon the public keys of the members and is chosen in an ad hoc manner for enhancing the security.

Providing efficient energy and throughput are two goals that have to be achieved in wireless sensor networks. The packet assignment method presented in [7] resulted in robustness that opened the door for coded modulation methods while maintaining efficiency in energy transmission. But providing higher throughput for multi-channel models remain an open issue. The application of Distributed Coordination Function (DCF) [6] paid emphasize on multi rate Wireless LAN which resulted in optimal throughput allocation. The results obtained highly increased the aggregated throughput of DCF, in addition to fairness between the nodes in the network, but at the cost of time.

Two different types of encoding methods called as the Quantize and Estimate (Q&E) and Compress-and-Estimate (C&E) [8] was presented in wireless sensor networks to provide solution to decentralized estimation of parameter by obtaining an optimal trade-off. Sensing spectrum is one of the key technologies for the future generation of wireless communications systems. The sensing of spectrum is highly needed for different types of cognitive radio applications that accompany dynamic spectrum access. With the application of unsupervised learning, it opens the door for cognitive radio applications to measure its classifier with the evolvement of radio environment. The paper [9] presented mechanisms to countermeasure the attacks and proves the robustness for the better classification of signals.

In this work EDC-SVM, focus is made on event detection classifier in wireless sensor networks by maintaining higher throughput level during object detection. To reduce the energy consumption, EDC-SVM identifies the weight of the events for effective classification using SVM. EDC-SVM also applies Doppler Effecting method to detect and group similar events for effective recovery of sensing data events with minimal energy. With the application of event section key management in EDC-SVM, security is enhanced. As a result, EDC-SVM concurrently broadcast the notification to the sensor nodes and also improves the security level of object collection.

This paper is organized as follows: Section 2 presents the relevant theoretical background of different types of classification of objects in wireless sensor networks. Section 3 presents a vehicle event classification using optimal hyper plane for providing an energy efficient event detection classifier. Section 4 presents an empirical evaluation of our method with the help of simulations and Section 5 discusses the issues with other state-of-art methods. Finally, the conclusions are provided in Section 6.

2. Related Works

In the research community, minimizing the energy consumption and increasing the throughput for sensor nodes in wireless sensor networks have for a longer period been treated as two separate issues to be solved. In [11], optimization of throughput was provided for single user using High Speed Downlink Packet Access (HSDPA) with the help of two types of optimization algorithms called as the offline and online optimization. To achieve higher throughput, the Channel Quality Indicator (CQI) was accordingly adjusted for proper scheduling of data transmission. Though higher throughput level was obtained, the study was limited to only SISO systems whereas MIMO systems remain unaddressed.

False data inject during data aggregation and forwarding is one of the serious issues to be solved in wireless sensor network. In [20], a hybrid method involving data aggregation and authentication protocol was designed called as the DAA. In this method, data verification was performed for small-size message and data aggregator also performed the job of effective aggregation. But network security and efficiency of the network was unaddressed.

Coverage is one of the most important issues to be solved in wireless sensor networks. In [12], the problem related to coverage was addressed from the angle of localization of target nodes for wireless sensor networks. In [19] optimization of packets using anycast forwarding schemes was presented to minimize the packet-delivery delays from the sensor nodes to the sink. On the results analyzed, a solution was provided to control the system parameters and anycast packet-forwarding to increase the network lifetime.

In wireless networks, the packet arising from a source node is relayed with the help of other sensor nodes to the destined node to increase the performance of network performance. RACE [13] also referred to as the report-based payment scheme for wireless networks was presented to regulate the flow of transmission of packets, increase node cooperation and provide fairness. Though security was provided using RACE, the selection of node on the basis of trust with low overhead remained an open issue. In [17], a scheme was presented that did not exploit per-destination information by establishing a single queue during each link and provided optimality in throughput.

3. Energy Efficient Event Detection Classifier Using Support Vector Machine In Sensor Network

In this section, we present an energy efficient even detection classifier for wireless sensor networks. Here, predetermined event weight based Support Vector Machine (EDC-SVM) is used for secure data collection system in wireless sensor network. The basic design consideration behind the proposed system is that EDC- SVM predetermines the weight of the events in the wireless sensor network to effectively classify the nodes with minimal energy consumption. The objects in EDC-SVM are detected using different group of events and also provide decision borders to classify the events on sensor network. The decision boundary in the EDC-SVM is depicted in figure 1.

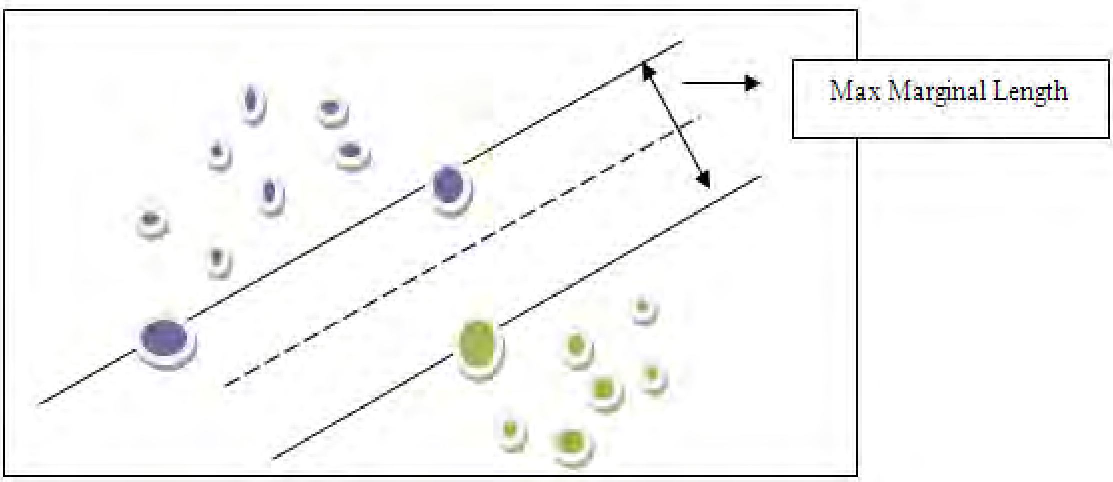


Figure 1. Identifying Hyper plane to detect Events

Optimal Hyper plane

As shown in figure 1, our work EDC-SVM detects the events in the sensor network using hyper plane maximal marginal length. The optimal hyper plane is measured and denoted in dotted lines in Figure 1. The Optimal Hyper plane computation formula is elaborated in section 3.1. For instance within the specific area, the nodes in the sensor network are distributed and the event activities of the vehicles have to be fetched. The vehicles activity in the specific area is monitored and in this similar manner, events of different users are collected and classified. The EDC-SVM classifies the vehicle events in terms of size, shape and load with the minimal energy consumption rate. With the increased vehicle movements in the network, the events in WSN also changes over time. The vehicle event classification is represented through diagram.

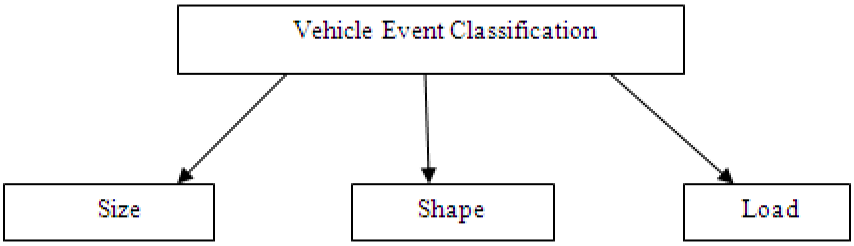


Figure 2. Vehicle Event Classification

As depicted in figure 2, the Vehicle Event Classification is performed based on the size, shape and load using the support vector machine with maximal marginal length obtained from optimal hyper plane value. Next, to detect the periodic events with varying level of frequency range, Doppler Effecting method is proposed. Doppler Effecting method is applied on the source object node to the target node for sensing the events.

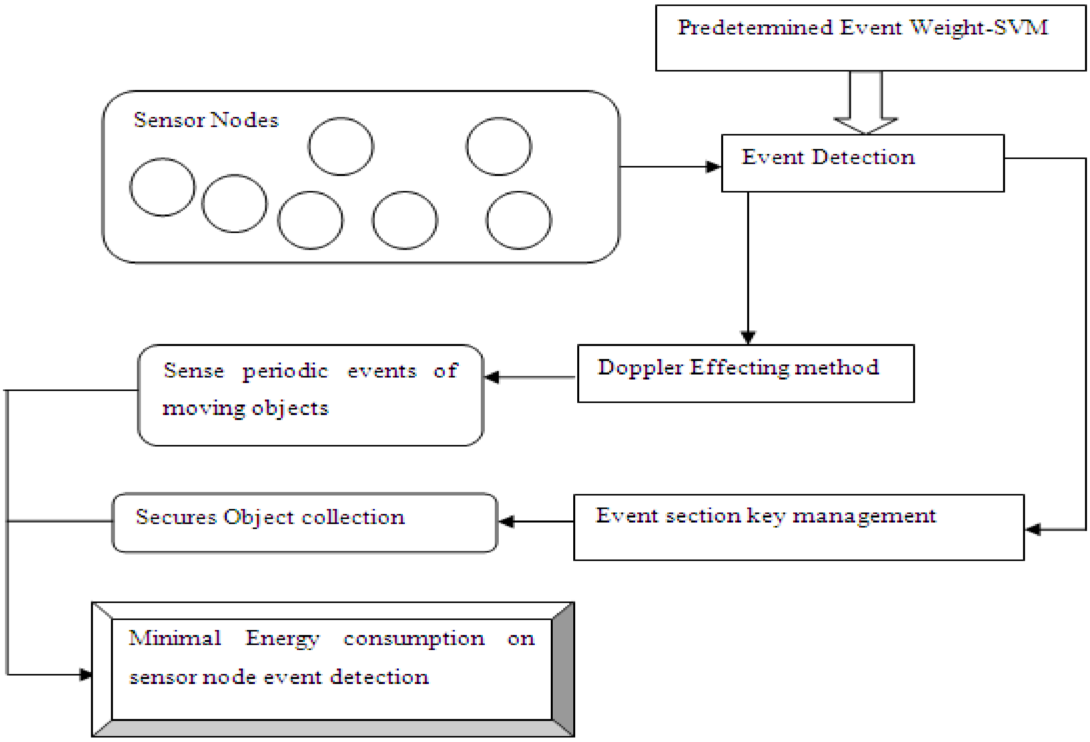


Figure 3. Architecture Diagram of EDC-SVM

The Doppler Effecting method in EDC-SVM detects all the events within the minimal processing time. The Doppler Effecting method consumes lesser processing time to detect the node though the frequency values increases when compared with previous iteration. The Doppler Effecting method detects and group similar events together, thereby reducing the energy consumption rate. In EDC-SVM, security is provided with the help of event section key management. The sensor node key is established in EDC-SVM to secure the collected objects with minimal energy consumption. The architecture diagram of EDC-SVM is depicted in Figure 3.

As illustrated in Figure 3, EDC-SVM detects the events in the sensor network. The network with varying size of sensor nodes performs SVM classifier using predetermined weight. With predetermined weight, the objects are classified in the sensor network. The sensing of periodic events is performed using Doppler Effecting method. The detected objects are then collected and grouped in a secure way using event section key management system. EDC-SVM is developed on the goal to safeguard the energy usage in the sensor network event detection. The detailed design considerations involved in EDC-SVM is presented in the following subsections.

3.1 Design of Predetermined Event Weight-SVM

Let us consider a sample object $P = \{x_i, y_i\}$ that uses support vector machine to identify the optimal hyper plane value with the help of predetermined weight vector 'w'. The 'i' value range from hyper plane in EDC-SVM is computed as

$$min(w) = \frac{1}{2}\,|w|^2 + \,E\sum_{i=1}^{n}(x_i\,, y_i) \tag{1}$$

The predetermined weight 'w' is used for range of objects 'x_i' and 'y_i respectively. 'E' denotes the energy consumption rate on the EDC-SVM. The undetermined vector in the SVM is described as,

$$y_i(w.x_i + u) \tag{2}$$

The weight 'w' is summed up with the undetermined vector points to predetermine the weight. The vector with optimal hyper plane in EDC-SVM is represented as,

$$Optimal\ Hyperplane\ (H) = \sum_{i=1}^{n}\rho_i\, x_i y_i \tag{3}$$

The ρ_i in the sensor network denotes the Lagrange multipliers used to find the optimal hyper plane value and the number of vector used to classify the objects is based on the maximal marginal length. The decision function for classifying objects in EDC-SVM is written as

$$Decision\ Function\ Classifer = Cl(\sum_{i=1}^{n}(\rho_i x_i y_i)\,, (\,x_i, u)) \tag{4}$$

The decision classifier classifies the event detection objects where 'Cl' represents the classification of the objects. The optimal hyper plane with Lagrange multipliers is used for classification and undetermined vector points are classified separately in sensor network. EDC-SVM takes the hyper plane value and sequence of incremental steps takes place with the Doppler effecting method to detect the events in the sensor network. With the application of Doppler effecting method in EDC-SVM, reduces the energy consumption rate using the varying frequency ranges in the sensor network.

3.2 Doppler Effecting method

Doppler Effecting method is applied from the source object sensor node to the target sensor node for detecting the events in EDC-SVM. The speed of the source sensor node movement with the frequency 'f' is denoted as,

$$f = (\frac{E+V_t}{E+V_s})f_0 \tag{5}$$

Where, E in (5) denotes the energy consumption for detecting the events in sensor network with V_t , and V_s the velocity of target node 't' and velocity of source node 's' to detect the events with optimal hyper plane value respectively.

The Doppler Effect method in EDC-SVM senses all the events within the minimal processing time. The source node objects detect the events in EDC-SVM if the target node is closer to the source node. The closer the sensor node action improves the frequency rate and decreases the energy consumption. The relationship between the target (current) frequency and previous frequency in EDC-SVM classifier is denoted as,

The speed velocity of $V_t$and V_s detecting the events in target (current) frequency and previous frequency are described as,

$$Current\ Frequency\ f = (1 + \frac{\Delta V_t}{E})f_0 \tag{6}$$

$$Previous\ Frequency\ f_0 = (\frac{\Delta V_t}{E}) \tag{7}$$

ΔV_t denote the overall velocity range to the target node and 'E' denote the energy consumption value. f_0 denotes the previous frequency range value used on the current value to identify the improved frequency range. To detect the periodic events with varying level of frequency range, Doppler Effecting method is applied to detect all the events within the minimal processing time. The frequency range EDC-SVM varies on the each successive iteration.

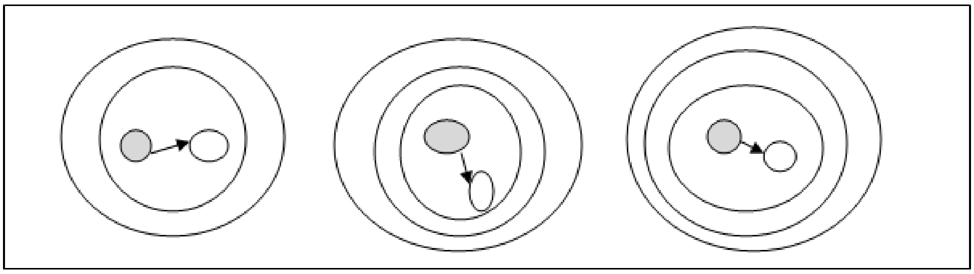
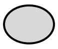
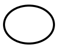


Figure 4. Doppler effecting method with Different Frequency Level

 - Source node

 - Target node

The Doppler effecting method in the EDC-SVM as depicted in Figure 4 requires lesser processing time to detect the events from the sensor node. From the figure, the space between the source node and the target node varied as the frequency range changes. The frequency level improvement on iteration effectively identifies the events on the sensor network with the least energy consumption rate using EDC-SVM.

3.3 Event section key management

Once the events are detected, security is provided to the sensor nodes in EDC-SVM using event section key management. The sensor node key is established in the EDC-SVM to secure the collected objects with minimal energy consumption. The security provided using event section key management is illustrated through algorithmic steps,

Begin

Step 1: ID random number generation on network

Step 2: Section key node establishment using node key distribution

Step 2.1: Message E_i [H, Cl, f] = Acquires Section Key

Step 3: Success Event detection message

Step 4: Session Key creation on event section

Step 4.1: $K_{(x,y)} = f(w_x, w_y)$

Step 5: Secure events detected in sensor network

End

The above algorithmic step describes the event section key management with key node establishment. The key node check the hyper plane to secure the objects, classifier performs secure SVM classification for different frequency range sensor node event detection. The user set time and section key is generated and as a result the energy consumption for maintaining the security level is reduced. Finally, the objects are collected at different frequency range with higher security level.

4. Experimental Evaluation

An efficient Event Detection Classifiers in wireless sensor network using predetermined event weight based on Support Vector Machine (EDC-SVM) performs the experimental evaluation on NS2 simulator. EDC-SVM compares the experimental work with existing Correlated Data Gathering (CDG), Energy-efficient and High-accuracy (EEHA) scheme Recoverable Concealed Data Aggregation (RCDA). In the simulations, 100 sensor nodes are constructed in sensor network environment. The sensor nodes use the AODV routing protocol to perform the experiment on randomly moving objects.

The movement of all nodes generated over a 900m x 900m sensor field is measured. The nodes moves at the random speed of 30 m/s and an average pause of 0.01s. The experimental work is carried out in the simulation platform. The experimental work is experimented on the factors such as classifier rate, mean classification time, throughput, and energy consumption rate and processing time.

Classifier rate in EDC-SVM measures the rate at which the events are classified and obtained using (3). Higher the classifier rate, lower is the energy consumption and classifier rate is measured in terms of %. Mean classification time measures the time taken to detect the periodic event based on shape, size and load for range of objects 'x_i' and 'y_i', ρ_i Lagrange multipliers to find the optimal hyper plane value with the undetermined vector points '$u' as$ given below which is measured in terms of milliseconds (ms).

$$MCT = Time\ [Cl(\sum_{i=1}^{n}(\rho_i x_i y_i)\,,(\,x_i,u))]$$

Throughput (T) defined as the number of packets sent from the source object sensor node to the target sensor node for detecting the events which is measured in Kbits/second

$$Throughput\ (T) = \frac{Number\ of\ packets\ sent\ from\ source\ node\ to\ target\ node}{Time}$$

Energy consumption rate (ECR) defines the consumption of energy for the target node, 't' and source node 's' to detect the events with optimal hyper plane value which is measured as given as

$$ECR = E(s+t)$$

The Processing time (PT) in EDC-SVM is the time taken to obtain the current frequency (f) and previous frequency (f_0) for an overall velocity range measured in terms of milliseconds (ms) given as below

$$PT = Time\ (f +\ f_0)$$

5. Result Analysis Of Edc-Svm

The result analysis of for Event Detection Classifiers in wireless sensor network using predetermined event weight based on Support Vector Machine (EDC-SVM) is compared with existing Correlated Data Gathering (CDG) [1], Energy-efficient and High-accuracy (EEHA) scheme [2] and Recoverable Concealed Data Aggregation (RCDA) [3]. The table 1 represents the classifier rate obtained using NS2 simulator and comparison is made with three other methods, namely CDG [1], EEHA [2] and RCDA [3].

Table 1.Tabulation for classifier rate

Sensor Nodes (N)	Classifier Rate (%)			
	EDC-SVM	CDG	EEHA	RCDA
15	62	58	55	52
30	65	60	57	54
45	68	64	59	56
60	72	68	63	59
75	74	71	64	61
90	78	73	68	62

Figure 5. shows the classifier rate in wireless sensor network for EDC-SVM, CDG [1], EEHA [2] and RCDA [3] versus increasing number of sensor nodes from N = 15 to N = 90. The classifier rate improvements are observed in EDC-SVM over three other methods which increase gradually as the number of sensor nodes grows. The reason is that the application of Doppler Effecting method in EDC-SVM detect the periodic events of moving objects (i.e.,) sensor nodes easily and improves the classifier rate by 4 – 7 % when compared to CDG [1] and by 11 – 13 % than EEHA [2].

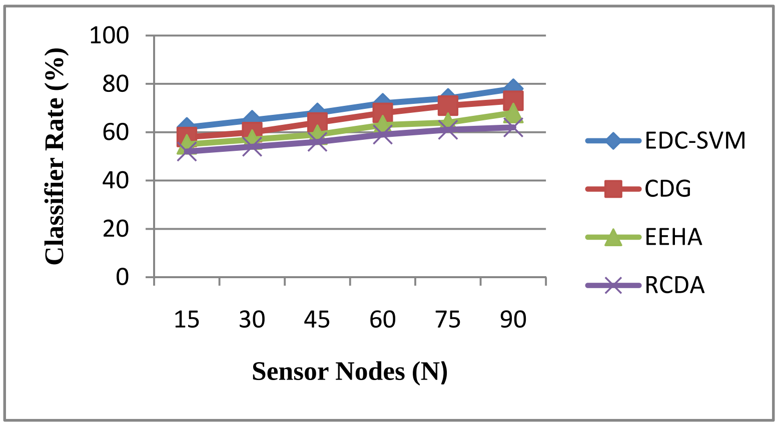


Figure 5.Sensor nodes Vs classifier rate

Further with the application of support vector machine, identify the optimal hyper plane value using the predetermined weight vector 'w' resulting in improved classification rate by 16 – 20 % when compared to RCDA[3].

Table 2. Tabulation for mean classification time

Sensor Nodes (N)	Mean Classification Time (ms)			
	EDC-SVM	CDG	EEHA	RCDA
15	43	50	53	57
30	41	48	50	55
45	40	47	47	54
60	38	46	45	51
75	36	40	43	49
90	30	38	41	47

Table 2 represents the comparison results of mean classification time and performance with 90 sensor nodes for simulation purpose.

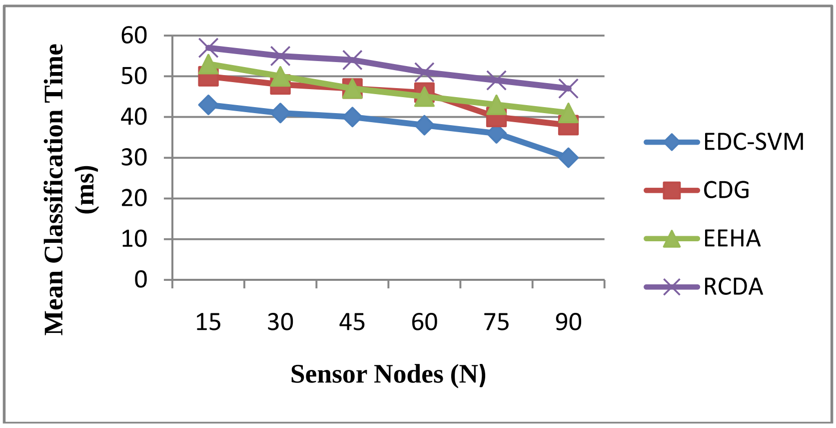


Figure 6. Sensor nodes Vs mean classification time

Figure 6 shows the mean classification time of EDC-SVM, CDG, EEHA and RCDA for 15 to 90 nodes. The performance of all the mean classification time is improved as the sensor nodes becomes larger. But comparatively, the mean classification time is reduced in the proposed EDC-SVM than when compared to other three methods. For example, for sensor node N = 30, the percentage mean classification time improvements of EDC-SVM over CDG [1] and EEHA [2] are on the order of 17.07 and 21.95, whereas, for sensor node N = 60, the percentage improvements are 21.05 and 18.42 respectively. This is because the periodic events are detected based on the shape, size and load for range of objects 'x_i' and 'y_i', $and\ \rho_i$ Lagrange multipliers to find the optimal hyper plane value resulting in minimizing the mean classification time.

Table 3. Tabulation for throughput

Number of iterations	Throughput (Kbits/sec)			
	EDC-SVM	CDG	EEHA	RCDA
2	320	312	300	295
4	330	318	315	310
6	350	325	320	315
8	370	340	329	318
10	375	342	335	325
12	395	345	340	338

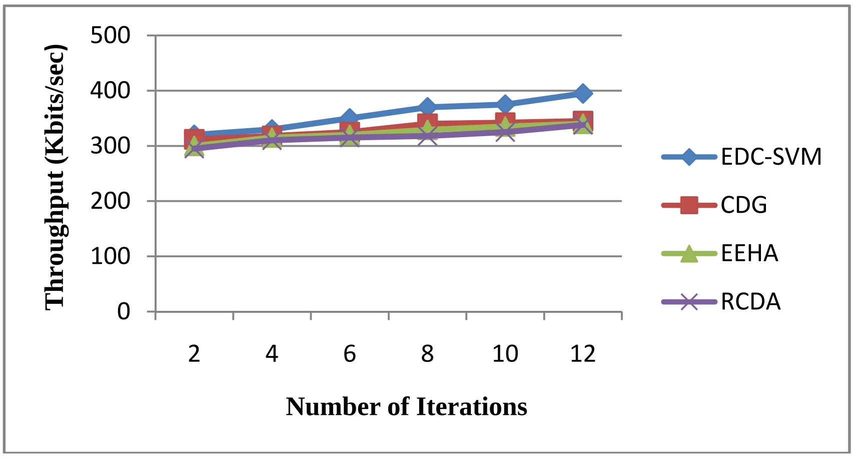


Figure 7. Number of iterations Vs throughput

Figure 7 shows the rate of throughput of EDC-SVM compared to CDG [1], EEHA [2] and RCDA [3]. From the figure it is evident that the most significant improvements occur in the first three iterations (i.e., 2, 4 and 6) and comparatively the throughput is higher in EDC-SVM than the other three methods. This is because with the application of Doppler Effecting method EDC-SVM detects the events with varying level of frequency range and therefore the throughput is increased by 2 – 12 % when compared to CDG. Further, the events are detected using optimal hyper plane value by increasing the throughput by 4 – 13 % when compared to EEHA and 6 – 14 % when compared to RCDA.

Table 4. Tabulation for energy consumption

Sensor nodes (N)	**Energy consumption (Joules)**			
	EDC-SVM	CDG	EEHA	RCDA
15	22	30	32	35
30	25	32	37	37
45	28	34	40	39
60	30	37	43	41
75	32	40	45	42
90	34	42	47	43

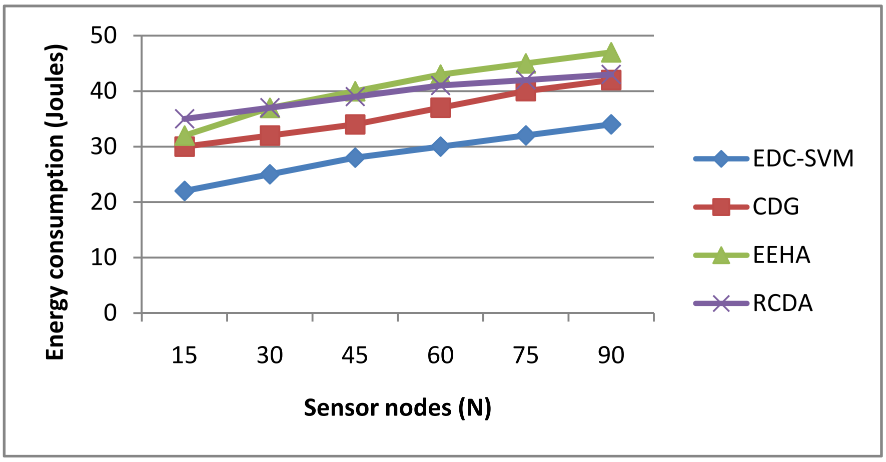


Figure 8. Sensor nodes Vs energy consumption

Table 4 and figure 8 shows the energy consumption level using the proposed EDC-SVM and comparison is made with three other methods with different number of sensor nodes. Simulation results show that the energy consumption of EDC-SVM is lower than that of CDG [1], EEHA [2] and RCDA [3]. This is because of the fact that EDC-SVM identifies the weight of the events using SVM and therefore reduces the energy consumption by 21 – 38 % when compared to CDG. Furthermore, it can be seen that the proposed EDC-SVM uses Doppler Effecting method for recovering all sensing data events reducing the energy consumption by with minimal energy by 38 – 48 % than EEHA. The proposed method also has the advantage of event section key management that secures the collected object with minimal energy consumption by 26 – 59 % when compared to RCDA.

6. Conclusion

The energy efficient event detection provides a unifying framework for the efficient detection of events in a wireless sensor network by detection and classification of periodic events. The algorithms of this approach, event section key generation apply a SVM classifier as a way to reduce energy consumption on different sensor nodes. Each sensor node is provided with a section key that broadcasts the information to the sensor nodes to improve the security level. In this paper, we developed decision function classifier for classification of objects and optimal hyper plane with Lagrange classifiers for effective classification. With the application of Doppler Effecting method, the periodic event of moving objects is detected with minimal processing time. The wireless sensor network finally obtained the theoretical model by attaining 13.25 % higher throughput by applying Doppler Effecting method. By means of simulations and executions the energy consumption provides better performance than the state-of-art methods.

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