ADAPTIVE SENSOR SENSING RANGE TO MAXIMISE LIFETIME OF WIRELESS SENSOR NETWORK

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ABSTRACT

Wireless Sensor Network (WSN) is commonly used to collect information from a remote area and one of the most important challenges associated with WSN is to monitor all targets in a given area while maximizing network lifetime. In wireless communication, energy consumption is proportional to the breadth of sensing range and path loss exponent. Hence, the energy consumption of communication can be minimized by varying the sensing range and decreasing the number of messages being sent. Sensing energy can be optimized by reducing the repeated coverage target. In this paper, an Adaptive Sensor Sensing Range (ASSR) technique is proposed to maximize the WSN Lifetime. This work considers a sensor network with an adaptive sensing range that are randomly deployed in the monitoring area. The sensor is adaptive in nature and can be modified in order to save power while achieving maximum time of monitoring to increase the lifetime of WSN network. The objective of ASSR is to find the best sensing range for each sensor to cover all targets in the network, which yields maximize the time of monitoring of all targets and eliminating double sensing for the same target. Experiments were conducted using an NS3 simulator to verify our proposed technique. Results show that ASSR is capable to improve the network lifetime by 20% as compared to other recent techniques in the case of a small network while achieving an 8% improvement for the case of a large networks.

KEYWORDS

Wireless Sensor Network, (WSN), Adaptive Sensor Sensing Range (ASSR), Deterministic Energy Efficient Protocol (DEEP), Adjustable Range Deterministic Energy Efficient Protocol (ADEEP), Distributed Lifetime Coverage Optimization protocol (Dilco), Adjustable Range Load Balancing Protocol (ALBP).

1. INTRODUCTION

Wireless Sensor Network (WSN) contains a large number of sensor nodes that are deployed in a certain coverage area to monitor some targets; this sensor is connected by wireless communication, containing transceivers, processing unit, memory, and batteries. Sensor nodes are randomly deployed which requires intelligent algorithms to control and maximize network lifetime while ensuring reliable communication between sensors and sink node. It needs to collect data from the monitoring area and send it to the base station, where end users can retrieve and process the data [1]. In this way, the sensor network provides an efficient monitoring mechanism and further provides a better understanding of the monitored area.

When compared to traditional ad hoc networks, WSN is facing some difficulties such as power and memory limitations. Sensor nodes have limited battery capacity that is not rechargeable because this process is very difficult of almost impossible, if these sensors are deployed in an ocean or dangerous area. In such a situation, all network requirements must be equipped with minimal power consumption to maximize the time of monitoring and further improve the lifetime of WSN.

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In WSN, a low number of operating sensors can kill, or terminate the network, since some targets in the monitoring area became not covered, or some data is not transmitted to the base station. One of the primary objectives of a wireless sensor network is achieve continuous target monitoring to ensure that each target in the network is monitored by at least one active sensor. Regarding to wireless a sensor network energy constraint, it is important to dynamically change the state of sensor into sleep or active state to decrease power consumption, or by modifying the sensing range of the sensor. Such dynamic configuration allows minimization of power consumption while ensuring a good quality of monitoring [2]. Large sensing range increases energy consumption because they will require additional processing methods to improve the signal-to-noise ratio and achieve the desired confidence level of transmitting data for large distances [3]. Therefore, an adaptive sensing range will allow the reduction of power consumption by minimizing power usage data transmission. In this situation, a sensor node in WSN is responsible to collect data from monitoring area, processing it, then transmit these data to the base station or the sink sensor. Note that, data transmission process requires much more power than dataprocessing [4]. In WSN, location awareness, networking, data integration, and energy management are all important techniques that require extensive exploration and investigation [5].

Generally, there are two ways to reduce power consumption and further save more power in wireless sensor networks. The first way is to schedule the sensor state to the monitoring mode. In this mode, the sensor is active and consume power, and the other sensor nodes in the network will be set into a sleep mode which is considered as a low power mode. The second way is to modify the sensor sensing to reduce power consumption which further capable to lengthen the WSN lifetime [6].

This paper is organized as follows. In the next section (i.e., Section 2), related works on the concept of sensing range will be discussed. Then in Section 3 and 4, problem definition and use case example were presented, respectively. Further, Section 5 discusses the proposed algorithm (ASSR). Section 6 discusses simulation results, where the proposed algorithm is compared with four other recent algorithms in sensing range and with fixed sensing range algorithm, while the last section presents the conclusion.

2. RELATED WORK

A heuristic algorithm for coverage problem and scheduling has been proposed in [7] to extend the lifetime of WSN by organizing the sensor coverage. In this paper, the author proposed a sensor deployment method based on discrete wavelet transform (DWT). A sensing model, called Smooth Sensing Range, was proposed in [8] which varying the sensing diameter. The author solved the problem by using an approximation algorithm and the sensing angle of many sensors is restrained. In [9], the author proposed a hybrid approach that combines a column generation method and an immune genetic algorithm to maximize the lifetime of WSN by using smooth ie varying of sensor sensing diameter. Further in [10], the author proposed an algorithm that enhances the target coverage by using limited node mobility called edge Based Centred Algorithm. This algorithm is based on a diagram that is used to split the sensing area into polygons. Recently, researchers developed integrated techniques for both coverage and connectivity problems. A barrier cover of wireless sensors is the asset of sensors located between two sides such that an object moving from top to bottom side or from bottom to topside to be detected by at least one sensor [11].

A coverage maximization was achieved when a sensor node can move to the low-density area. In other words, it divides the monitoring area into a grid, and the selected sensor node in the next round is situated in the low-density target cover [12]. The goal behind this method is to select the smallest set of nodes in identifying the target coverage and determine the positions for the deployed sensor nodes in WSN. This method is not efficient in the area coverage with large network area where the monitoring of each target is necessary. In [13], the author considers the coverage problem as the most important problem, where they address the problem with the deployment of the smallest number of sensor node to reach coverage maximization. The authors propose three optimization models to reach this goal. The first model minimizes the number of sensors deployed in the area to attain high detection. Meanwhile, second optimization model minimizes the number of nodes deployed in some locations that require low coverage and further adjust the number of nodes deployed in other locations that require higher coverage. Then, the third model is based on the determination of available sensors positions by limiting the number of sensors for perfect coverage. In [14], the author implements Genetic Algorithm (GA) to solve coverage problem. This algorithm specifies the positions and the number of sensor nodes to be deployed in the area of targets in order to achieve maximum coverage. The application of this algorithm overloads the nodes so that it always leaves the nodes in active state. Further in [15], the author proposed a heuristic approach that based on column generation scheme to maximize the set of non-disjoint area, with adjustable sensing range to improve the lifetime of the WSN. In [16], the author encountered area coverage with varying sensing range by density control model which improves the sensor's coverage. Meanwhile in [17], target coverage problem with adjustable sensing range is formulated as a non-linear integer programming problem to maximize the network lifetime. In [18], the author proposed an algorithm that uses varying sensing ranges and exploits node motion to fix emerging cap holes. The algorithm selects the appropriate nodes by measuring the degree of interference and the residual energy of each sensor near the coverage area. Further in [19], a dual-tuning duty cycle table scheme is proposed. This scheme mainly consists of two duty cycle algorithms, an asynchronous tuning algorithm for active slot nodes in the same sensing area, and a continuous tuning algorithm for two adjacent nodes on the routing path with one active slot interval.

In [20], the author proposed a CS-based algorithm for efficient data transmission in WSN. It uses Multiple Objective Genetic Algorithms to improve the transmission range and sensing area. In [21], the author proposed a barrier coverage mechanism for adaptive sensing band utilization for WSN. It applies a probabilistic sensing model to evaluate the contribution of cooperative sensing to each sensor and to identify choke points in time and space during the barrier construction process. It then adjusts the sensor diameter for the sensors with the greatest quality contribution and then tabulates them to monitor the targets.

3. PROBLEM DEFINITION

Assume that N sensors are randomly deployed to cover X targets with each sensor has an initial energy E and has the capability to varying its sensing range. Sensing range options are r1, r2…. rn, corresponding to energy consumptions of e1, e2, …, en. Assume a base station (BS) or sink node located within the communication range of each sensor. One method to compute the sensor target coverage is to consider that a sensor covers a target, if the Euclidean distance between the sensor and target is no greater than sensing range. The formal problem definition is as follows: Given M targets with known location and energy constrained, WSN with N sensors are randomly deployed in the targets area, schedule the sensor nodes activity such that all targets are covered and the network lifetime is maximized.

The approach that we used in this study is to organize the sensors in sets, where only one sensor in the set is responsible for monitoring or sensing the target, and all other sensors are in sleep mode. Besides determining the set covers, we are also concerned with setting the sensing range of each active sensor. The goal is to use a minimum sensing range to minimize the energy consumption for monitoring all targets in the network to maximize the network lifetime, NS3 simulation tools is used to test the proposed algorithm and compare it with a recent algorithm in this field.

4. USE CASE EXAMPLE

Given an area of interest, the WSN aims to achieve maximum lifetime by consuming minimal power while covering all targets in the network area. The varying sensing range aims to schedule all feasible cover activities to maximize the lifetime of WSN and forward each sensor in such a way that it will not exceed its energy capacity. The following example shows how the adaptive sensing radius can reduce power consumption to maximize the WSN lifetime. In this example, let assume that there are four target (t1,t2,t3,t4) and five sensors (s1,s2,s3,s4,s5) with three sensing radius (SR1,SR2,SR3). SR1 is the minimum sensing radius, SR2 is the medium sensing radius, while SR3 is the maximum sensing radius (SR1<SR2< SR3) as shown in Figure 1.

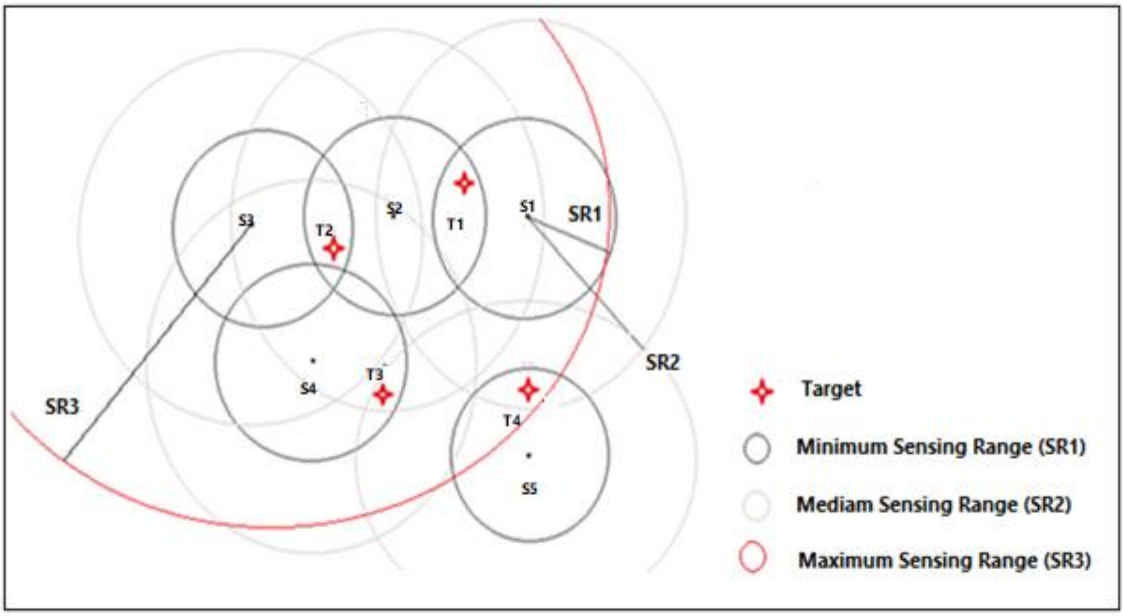

Figure 1. Sensor Network for four targets and five sensors

Assume that the initial energy at each sensor is equal to 4, and ESR1=1(energy requires for one time with sensing radius SR1), ESR2=2 (energy requires for one time with sensing radius SR2), and ESR2 = 3 (energy requires for one time with sensing radius SR2).

In this sensor network, a sensor can be part of more than one set of scenario with six different sets can be obtained using the adaption of sensing radius SR1, SR2, and SR3 as the following: C1 = {(s2, SR2), (s5, SR1}, C2 = {(s1, SR2), (s4, SR2)}, C3 = {(s2, SR1), (s5, SR2)}, C4= {(s2, SR1), (s4, SR1) (s5, SR1)}, C5 = {(s1, SR2), (s3, SR1), (s4, SR1)}, C6 = {(s4, SR2), (s1, SR1), (s5, SR1)}, as shown in Figure 2.

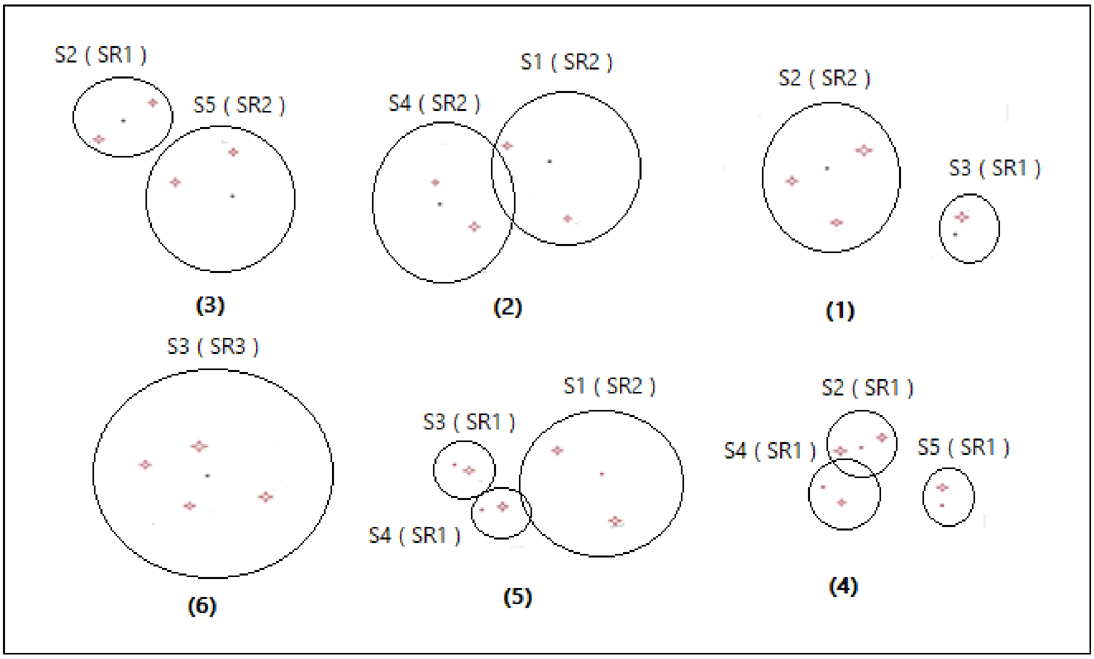

Figure 2. Target cover with different sensing radius

If the sensor nodes do not have the adjustable sensing radius, then the life time if all the sensor using SR3 is one round (3 joule for each round) , and if using SR2 is two round (2 joule for each round) and if using SR1 is four round (1 joule for each round) as mention before , but when using adaptive sensing range the life time is increasing to six round which is equal to three times enhanced than traditional sensor network, assume the power consumption for each rounds as follow , round one s2(4-2=2), s5(4-1=3), round two s1(4-2=2), s4 (4-2=2), round three s2(2-1 =2), s5 (3-2=1), round four s2(1-1=0), s4 (2-1=1) ,s5 (1-1=0), round five s1(2-2=0), s4 (1-1=0),s3(4-1=3), and finally round six s3 (3-3=0)as shown in Table 1.

Table 1. Examples of life time rounds using adaptive sensing radius.

		Power Level				
Round	**Power consumed**	Sensor 1	Sensor 2	Sensor 3	Sensor 4	Sensor 5
1	s2(4-2=2), s5 (4-1=3)	4	2	4	4	3
2	s1(4-2=2), s4 (4-2=2)	2	2	4	2	3
3	s2(2-1=2), s5 (3-2=1)	2	1	4	2	1
4	s2(1-1=0), s4 (2-1=1),s5 (1-1=0)	2	0	4	1	0
5	s1(2-2=0), s4 (1-1=0),s3 (4-1=3)	0	0	3	0	0
6	s3 (3-3=0)	0	0	0	0	0

5. ADAPTIVE SENSOR SENSING RANGE (ASSR)

The objective of this study is to maximize the monitoring time of all targets in the network area by sensors to increase the WSN lifetime because if there is any target that cannot be covered by at least one sensor, the network become useless and the goal of the network fails, and it is useless to have any sensors live after the network fails. There are two main questions that should be answered. The first question is: which condition must the sensor use it to become an active or idle state, and the second question is: what should be the sensor sensing range if it decides to become inactive state?

At any time, each sensor in the network must be in one of the following three states; 1) active state, which means that the sensor monitors the target, 2) idle state, which means that the sensor only listens to other sensors (doesn't monitor the target), and 3) deciding state, which mean that the sensor monitors target, but may change its state to active or idle state.

The procedure is as follows: Assume that each sensor can communicate with its adjacent sensors with a maximum sensing range to find the covering of target. Each sensor broadcasts its battery level and covered targets to all its adjacent sensors, and then stays deciding with its maximum sensing range. However, when a sensor is in the decision state with range R (n), then it should change its state to one of the following states:

- Active state: with sensing range R(n) if there is a target at range R that are not covered by any other active sensors.
- Decision State: if all targets at range R are covered by an active sensor, then this sensor became in deciding state and decreases its sensing range to the next range R (n-1)
- Idle state or sleep state: when the sensing ranges of the sensor becomes R (0) which means that the sensing range is 0 as shown in Figure 3.
- If a target x has a small number of sensors that covers it (for example one, two, or three sensors), we assume a small number of sensors by 1, 2, or 3 sensors because there is at least one sensor to cover the target. When the power level of this sensor is exhausted, then it has to make a choice between the other two sensors to cover the target. In other words, this is a poor target, where it has a small number of sensors that cover it. Then, the sensor with the highest energy level will then enter into active mode. In this situation, the rest will enter an idle or sleep mode state, until this sensor that cover this target exhaust its battery level below than these idle sensors. Then if that the case, one of the rest sensors is entering the active state for the rest of time.

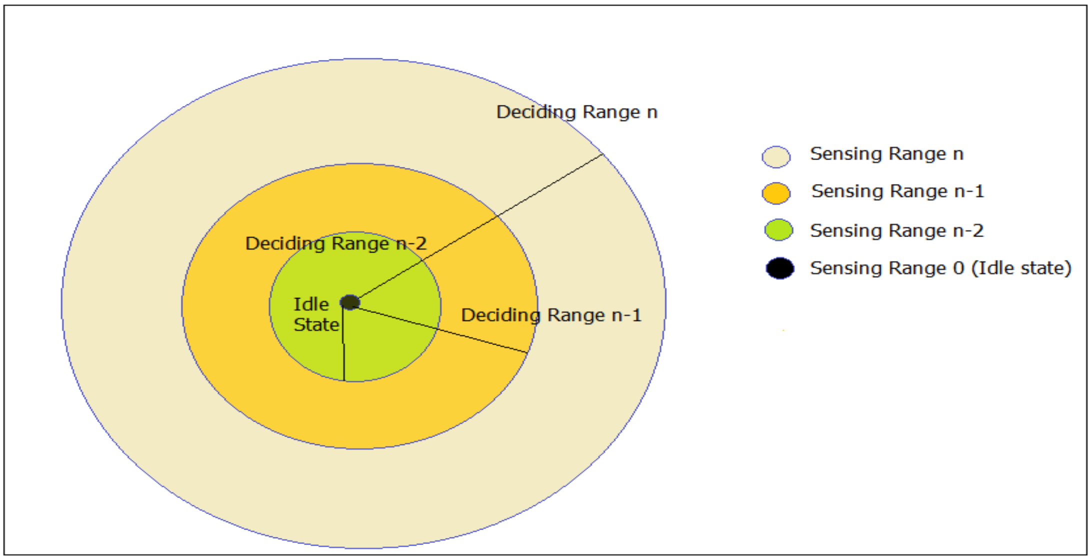

Figure 3. Diagram for deciding range and sensing range

- If a target x has a large number of sensors that cover it (for example more than three sensors) and if the number of sensors is 4 or above, then we assume that this is a large number because there are many choices available to cover this target. Therefore, regarding a sensing range and power level, (in this case, it is a rich target), then the overall sensors will cover this target. The sensor that does not cover many targets or the sensor that has a small number of targets in its sensing range (poorest target cover), will be placed an active mode state to cover this target. If there are several such sensors, then the sensor that has the largest battery level among them is put into an active state to cover this target as shown in Figure 4.

- After all sensors have decided their states whether it is an active mode or idle mode (sleep), each sensor will stay in that state some of time (the duration depends on the nature of the target that we need to sense. For example, if the target is moving then this period is small. Meanwhile, if the target is stationary or not moving then this period will be long), or until there is an active sensor exhausts its power, and its power level dropped to the level less than other sensor in the sleep mode state.

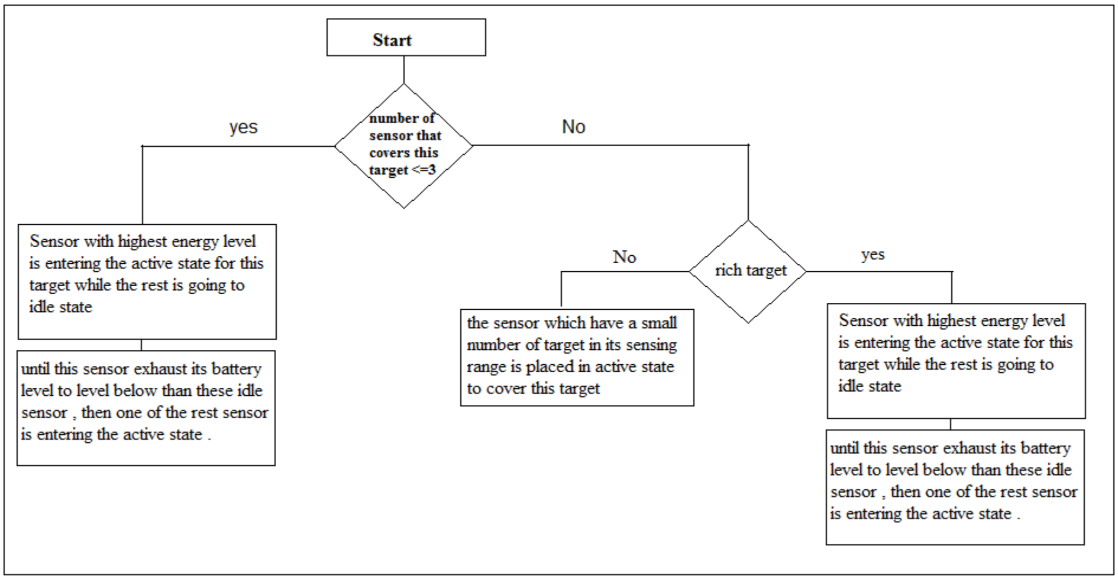

Figure 4. Flow chart for proposed technique (ASSR)

6. RESULTS AND DISCUSSIONS

In this section, we evaluate the performance of centralized and distributed algorithms and analyse the data generated from the simulations. We have simulated a fixed sensing range with varying sensing range. For the simulation environments, a static wireless network of sensors and targets which are scattered and random in 100m x 100m area is considered as in [22] which yield a small network. Menawhile, an environment with 1000m x 1000m is considered as in [23] which represents a large network in order to show the robustness of the proposed technique. We assume that the communication range for each sensor is two times the sensing range. The energy model is the linear model e = c * r, where r is the distance from sensor to target (sensing range) as describe in [24], and E = 10 is the sensor starting energy. For both energy models, the simulation results are consistent. It indicates that network lifetime increases with the number of sensors and decreases as more targets have to be monitored. All simulation parameter values are summarized and shown in Table 2. These values are considered from [25] in order for comparison purposes between proposed technique and other existing techniques.

Table 2. Simulation parameters

Parameter	Value
Number of sensor node	10 - 200
Number of Target	40-120
sensing range	5m - 60m
Monitoring Area	100m x 100m
Initial energy	5 J

Experiments were executed by varying the number of sensors and the lifetime is calculated from the beginning of the execution of monitoring target until the time that the first target is does not cover by any sensor. We also vary the maximum sensing range, and numbers of targets with various experiment scenarios. The corresponding data and graphs were presented in the following sections.

In Table 3, we use the same number of sensors i.e., between 10-200sensors.The number of targets in this simulation is 40. We simulated four different existing algorithms, namely ALBP, DEEP [26], ADEEP [27]. and Dilco [28], and compare with our proposed ASSR technique and analyse the sensing range problem. The results indicate that the network lifetime increases with the number of sensors, and the network lifetime using the proposed algorithm is better than the four previous algorithms including the fixed range scenario. As shown in all experiments, the network with fixed sensing range consumes more power than the network that using varying sensing range. Figure 5 shows the graph result obtained from fixed range, ALBP, DEEP, ADEEP, Dilco algorithms against our proposed algorithm.

Table 3. The lifetime (in second) of WSN with 40 targets for different sensing range algorithms

Sensor Number	Fixed Sensing Range	ALBP	DEEP	ADEEP	Dilco	Proposed
10	5.2	6.8	8.2	13.3	14	16
20	7.6	10.3	12.1	18.2	18.2	24.4
40	10.2	13	19.2	23.3	25	29.2
60	17.8	18.4	26.5	29.2	28.2	38.2
80	27.5	26.8	38.6	44.2	43.2	56.3
100	31.2	33.6	52.2	61.2	62.2	70.8
120	38.2	43.6	63.2	70.1	72.2	80.5
140	43.6	54.2	75.2	81.1	83.4	92.3
160	48	54.6	81.2	88.8	90.4	103.4
180	54.8	60.2	92.6	97	104.2	112.4
200	59.1	66	99.3	106.4	114.4	122.3

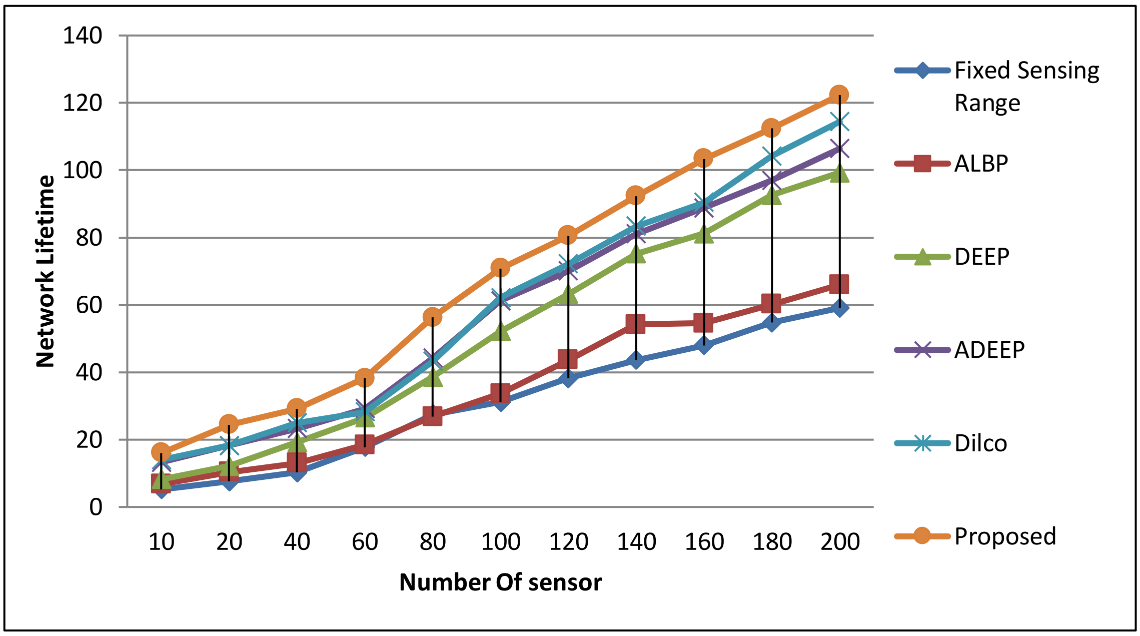

Figure 5. Network lifetime for fixed range, ALBP, DEEP, ADEEP, Dilco algorithms and our proposed technique obtained for 40 targets.

Results from second experiment is shown in Table 4. In this experiment, we use the same number of sensors i.e., between 10-200sensors, with the number of targets are 70 targets. The results obtained indicate that the network lifetime is decreased when the number of targets is increased. Further, as shown in the result, the WSN lifetime obtained from our proposed technique (i.e., ASSR) is better than the four other algorithms. As shown in Table 4, the proposed technique ASSR needs to be in a network that contain 200 sensorsfor122.3 seconds until the first target becomes uncovered. Meanwhile, Dilco algorithm needs 114.4 seconds, ADEEP needs 106.4 seconds, DEEP needs 99.3 seconds, ALBP needs 65seconds, and the fixed sensing range needs 59 seconds. These results proved that our proposed technique is far better than ALBP algorithm by100%, DEEP by 23%, ADEEP by 15.5%,and Delco by 8%.The network that is using fixed sensing range consumes more power than the network that is using varying sensing range. This is because of power consumption to monitor more than one target at the same time. Figure 6 shows the graph for comparison results for different sensing range algorithms. As expected, the results show that the proposed technique is the best technique when compared with other existing algorithms by approximately 8% due to network life time.

Table 4. The lifetime of WSN with 70 targets for different sensing range algorithm

Sensor Number	Fixed Sensing Range	ALBP	DEEP	ADEEP	Dilco	Proposed
10	3	4.2	5.2	8.2	9.2	9.4
20	5.2	7.4	8.2	12.4	12.8	16.6
40	7.2	10.4	12.4	16.2	19.4	23.2
60	10.4	13.6	16.4	20.4	24.6	28.8
80	15.6	18.2	21.4	26.6	32.4	35.8
100	20.4	24.6	30.2	33.2	40.6	44.2
120	26.2	29.8	38.6	40.4	51.8	54.8
140	31.4	35.8	44.8	48.4	60.6	65.2

160	36.8	40.6	56.4	59.2	71.4	77.4
180	41.6	48.2	65.8	72.4	85.8	90.2
200	49.6	56.2	77.2	85.6	96.6	102.4

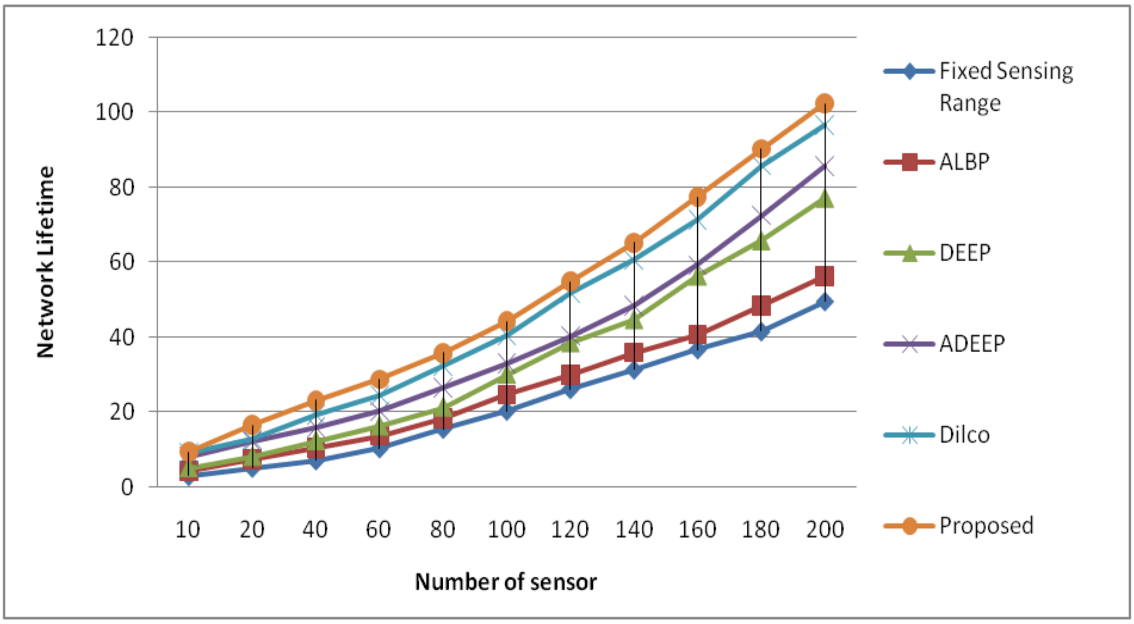

Figure 6. Network life time between fixed range, ALBP, DEEP, ADEEP, Dilco and proposed technique for 70 targets.

Results from the last experiment is shown in Table 5. In this experiment, we use different number of sensors as compared with previous experiments. We use large number of sensors to design a huge network density. Number of sensors considered in this experiment is between 300-1500 sensors and the number of targets is 120.As shown in the result, our proposed technique ASSR needs to be in a network that contain 1100 sensors for 393 seconds until the first target becomes uncovered, while Dilco needs 378 seconds, ADEEP needs 361 seconds, DEEP needs 337 seconds, ALBP needs 318 seconds, and fixed sensing range needs 302 seconds. These results proved that the ASSR is far better than ALBP by 23%, DEEP by 17%, ADEEP by 9%, and Delco by 4%. Therefore, in summary, for small and large networks, the network that using fixed sensing range, consumes more power than the network that using varying sensing range. Figure 7 shows the graph comparison result for different sensing range algorithms, and it is proved that our proposed technique is the best technique as compared to other technique in terms of network lifetime.

Table 5. The lifetime of Large WSN with 120 targets for different sensing range algorithm

Sensor Number	Fixed Sensing Range	ALBP	DEEP	ADEEP	Dilco	Proposed
300	78	81	96	101	109	112
500	119	125	142	154	170	176
700	198	203	224	238	267	274
900	262	271	298	319	347	356
1100	302	318	337	361	378	393
1300	349	365	389	423	460	472
1500	372	398	421	458	492	506

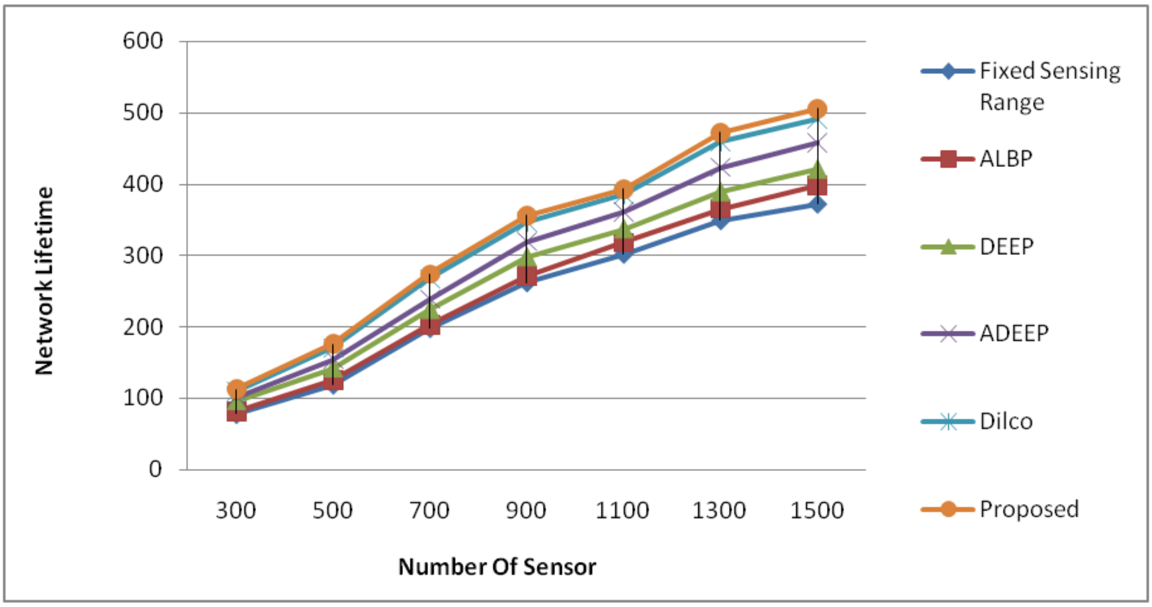

Figure 7. Network life time between fixed range, ALBP, DEEP, ADEEP, Dilco and proposed technique for 120 targets

7. CONCLUSION

In this paper, we proposed a scheduling strategy technique for the target coverage problem of WSN with varying sensing range named Adaptive Sensor Sensing Range (ASSR). The problem addressed in this study is on how to achieve maximum network lifetime by varying the sensor sensing range, while all targets in the network are covered and sensor energy resources are constrained. Our proposed technique solved the power dissipation problem as it senses the same target with many sensors and maximize the network life by decreasing the power dissipation due the sensing range. The experiment results using NS3 simulation tool showed that the proposed technique (i.e., ASSR) is capable to lengthen the network lifetime when compared with fixed sensing range technique, and other four recent techniques addressed this problem by 20% in small network, and approximately 8%.in large network. Finally, we conclude that the delay of massages that have been sent in the network from sensors to the base station is an important factor that must be taken into consideration in designing future solutions.

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