Applied Mathematics & Information Sciences
An International Journal

http://dx.doi.org/10.18576/amis/120109

Effective Scheduling Strategy in Wireless Multimedia Sensor Networks for Critical Surveillance Applications

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Received: 18 Jul. 2017, Revised: 25 Oct. 2017, Accepted: 3 Nov. 2017
Published online: 1 Jan. 2018

Abstract: A wireless multimedia sensor network (WMSN) consists of a set of interconnected, battery-powered miniature video cameras, each packaged with a low-power wireless transceiver that is capable of processing, sending, and receiving data. A WMSN can operate in an Ad-hoc manner and hence does not require a network infrastructure which adding a much higher level of flexibility and allowing a wider range of applications such as video surveillance, health care, industrial process control, and traffic management. In this paper, we propose a new dynamically efficient strategy to schedule the activities of sensor nodes in mission-critical surveillance applications according to the node's redundancy level. Simulation results show that our strategy outperforms the existing work in terms of average capture rate, network lifetime, and percentage of active, sleep, and dead nodes.

Keywords: Wireless Multimedia Sensor Network, Cover set, Bezier curves, Field of View, Network lifetime.

1 Introduction

WMSNs deploy a large number of scalar sensors (i.e., motion, temperature, light, etc.) in conjunction with a certain number of image and video sensors to collect and process multimedia data[1,2]. WMSNs have been received a lot of attention very recently due to their potential to be deployed flexibly in various applications with lower costs [3]. WMSNs not only boost typical applications of WSNs but also trigger new ones [3]. Such network is particularly suitable for applications to include multimedia surveillance (such as agriculture, water, forest, fire detection), intrusion detection, habitat monitoring, and health care delivery (such as elderly people, home monitoring), military (battlefields, border surveillance), disaster relief [4,5,6].

Wireless multimedia communication is obstructed by restrictive factors in WMSNs such as high bandwidth demand, application specific QoS requirements, and severe energy constraints [7,8]. Subsequently, for multimedia applications, an efficient sensor network deployment should take these factors into consideration. It is critical to reduce data redundancy as much as possible because of the high cost of communicating and processing the multimedia data in WMSNs. In WMSNs, unlike scalar sensors, multimedia sensors cannot sense, collect, and transmit multimedia data all the time this will quickly exhaust their battery power. Redundancy leads to overlaps among the sensing areas. Therefore, determining a subset of the deployed nodes to be active while the other nodes can sleep is the common approach to extract redundancy. The result is an activity scheduling of the sensor nodes in such a way that guarantees the required area coverage as well as the network connectivity.

In WSN, two scalar nodes are probably redundant if the nodes are close to each other. In WMSNs, multimedia nodes have a limited sensing coverage area (sector coverage) determined by the camera constraints and its field of view (FoV), i.e., the designed protocols for scalar sensor networks may not be suitable for WMSNs. In this paper, we propose a new strategy for efficient scheduling of nodes activities in mission-critical surveillance applications.

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1.1 Problem Description

In WMSN, as the capture rate of the multimedia node increases, the target or events could be better detected and identified [9]. However, even in the case of very critical applications, in active mode, it is not opportunistic to consider that multimedia nodes should always capture at their maximum capture rate. The low criticality applications don't require a high frame capture rate while the high criticality applications do. Before the deployment, the criticality level's value (r^0) could be initialized into all sensors nodes [10]. The value of r^0 can be taken between 0 and 1 to define the minimum and the maximum criticality level. Multiple levels of activity are critical in some surveillance applications like intrusion detection system because such systems have to be able to work on for along time on the basis that no one knows when such intrusions could occur. Also, some surveillance applications may require a barrier coverage rather than a blanket coverage. In this matter, boundary sensor nodes of the area of interest should be more active while interior nodes can decrease their activity.

In this paper, we solve the problem of efficiently extracting the cover sets of the multimedia sensors, where the sensing area is represented by a sector area FoV and not by a circle. We present a new distributed algorithm that enables each node to extract its cover sets by organizing its neighbors into non-disjoint subsets, each of which overlaps its FoV. For autonomous sensors, the process of determining whether the nodes' neighbors completely cover the node's FoV or not is a time wasting task which is usually too resource exhausting. Thus, without compromising the coverage of its own FoV, a node decides to be in active or in sleep mode according to its neighbor's activity. For that purpose, we have used a model based on behavior functions [9,10] to adjust the capture rate according to the node cover set cardinality and the application's criticality level. The node's activity is scheduled according to its cover sets cardinality, the nodes with large cardinality are likely to put in sleep mode. We have used the scheduling model presented in [10] to schedule the node's activity in order to guarantee a high percentage of coverage of the area of interest and an adjustable frame capture rate while reducing the energy consumption.

The rest of the paper is organized as follows: In Section 2 we discuss the related research. Section 3 presents our coverage model and our cover set construction strategy. Section proposes a model that uses behavior functions modeled by modified Bezier curves. Section 4 presents the adaptive scheduling model. Simulation results are presented in Section 5. Conclusions are given in Section 6.

2 Related work

Determining what parts of the node's FoV is covered by its neighbors or determining whether a sensor's FoV is completely covered by a subset of its neighbor sensors is a complex task which affects badly on the time consumption and usually is too resource consuming for autonomous sensors. Otherwise, in the case of an omnidirectional sensing, determining what parts of the node's coverage disc is covered by its neighbor sensors can simply be done by a node [11].

The most commonly used approach to ensure a high level of coverage of the monitored area while at the same time minimizing energy consumption and extending network lifetime is to select a subset of nodes to be active and keeping the remaining nodes (redundant nodes) in sleep mode. The notion of the cover set has therefore, been introduced to define the redundancy level of a sensor [12]. The work in [12] addressed the connected set covers problem to determine the maximum network lifetime when all targets are covered. In [13], the authors proposed a model to find subsets of nodes that cover the FoV area of a given node in video sensor network (WVSN) and discussed the performance of various cover set construction strategies. The performance of the various cover set construction strategies is evaluated through simulations to enable an efficient scheduling of nodes in mission-critical surveillance applications. In [14], the authors proposed two new approaches for cover sets construction by using the specific points of triangle's vertices of the node's FoV and the midpoints of its sides.

Designing a distributed and localized protocols for organizing the sensor nodes in sets for the area coverage process in WMSN is an urgent method for extending the network lifetime. The network activity is changed in rounds, with sensors in the active mode guaranteeing the area coverage, while all the remaining sensors are in the sleep mode. The problem requirements the percentage of area monitoring, connectivity, energy efficiency definition of the set formation. Many different approaches have been presented in the literature [15,16,17,18] for determining the eligibility rule, that is, to select which sensors will be active in the next round. The work in [10] used a behavior function modeled by modified Bezier curves to define multiple activity levels model that perform the application classes and allow for adaptive scheduling. Besides providing a model for translating a subjective criticality level into a quantitative parameter of the surveillance system, the approach can also optimize the resource usage for video sensor nodes by dynamically adjusting the provided service level.

Based on a coverage model of [10], the authors of [9] addressed the problem of critical surveillance applications of scheduling randomly deployed video sensor nodes. The result is that node with a large cover set will capture faster because it can be easily replaced if it dies. [19] proposed an algorithm based on Greedy Perimeter Stateless Routing protocol, which is launched by the sink node at the beginning of simulation in order to discover network boundary. Boundary nodes are assigned high criticality (high capture rate) while low criticality is assigned to interior nodes. In this paper, we present a new approach for constructing a node's cover set, where each node constructs its cover set by taking into consideration the correlation among its FoV and its neighbors and the correlation between the neighbors of FoVs themselves.

In [9] a cover set construction technique using the center of gravity point creates strong constraints on neighbor selection leading to a high mean percentage of coverage per cover set at the expense of the number of sensor nodes with cover sets which are very small. When nodes do have cover sets, the number of cover sets is also very small. Therefore, very few sensors could be in sleep mode. On the other hand, our approach creates a lighter constraint in the neighbor selection by making use of the intersection constraint, by this way, the number of sensor nodes with cover sets and the number of cover sets per sensor (cardinality) are increased this leading to more sensors will be in sleep mode. The simulation results show that the mean percentage of coverage per cover set are also high. We take into account the application criticality and apply a model that dynamically defines multiple levels of activity corresponding to capture rate (how many samples (images) are captured per unit of time).

3 Relevant Definitions and Notations

Here, we give the definitions and the notations that will be used in the proposed algorithm.

3.1 Coverage Model and Cover Set

A multimedia sensor node v is defined by the FoV of its camera. The term FoV refers to a directional sensing area of multimedia sensor node, which is approximately hypothesized as an isosceles triangle in two-dimensional space. The 2D model of a multimedia sensor node v is denoted by a 4-tuple v (P, R_s, θ, α), where P is a random or static position of node v, R_s is sensing range of v, α is the orientation angle of the camera's FoV which determines the sensing direction, and θ is the vertex angle of FoV as shown in Figure 2.

The coordinates of vertices (p, b, c) of v's FoV can be calculated using the following equations:

$$c.x = p.x + R_s * \cos\alpha. \quad (1)$$

$$c.y = p.y + R_s * \sin\alpha. \quad (2)$$

$$b.x = p.x + R_s * \cos((\alpha+\theta) mod\ 2\pi). \quad (3)$$

$$b.y = p.y + R_s * \sin((\alpha+\theta) mod\ 2\pi). \quad (4)$$

Definition 1: The cover of a multimedia node v ($Co_i(v)$) is a subset of multimedia nodes such that: $\bigcup_{v' \in Co_i(v)}$ (v''s FoV) covers the area of v's FoV.

Definition 2: The set $Co(v)$ of a node v is defined as $Co(v) = \{Co_1(v), Co_2(v), \ldots, Co_i(v), \ldots, Co_n(v)\}$, where $Co_i(v), (i = 1, \ldots, n)$ is the cover set number i of v and n is the total number of cover sets of v.

Definition 3: The cardinality of a set $Co(v)$, ($|Co(v)|$) is the number of cover sets in the set $Co(v)$.

3.2 Bezier Curves

The Bezier curve representation is one that is most frequently utilized in computer graphics and geometric modeling. A Bezier curve is defined by a set of control points P_0 through P_n, where n is the order (n =1 for linear, 2 for quadratic, ... etc).

The Bezier curve begins at P_0 and ends at P_n. The Bezier curve only approximates the control points. However, the intermediate control points (if any) generally do not lie on the curve. A curve can be split at any point into two or more sub-curves, each of which is also a Bezier curve.

Definition 4: Quadratic Bezier curve is the path traced by the function B(t), it is determined by three control points P_0, P_1, and P_2:

$$B(t) = (1-t)^2 P_0 + 2(1-t)tP_1 + t^2 P_2, t \in [0,1]. \quad (5)$$

The tangents to the curve at P_0 and P_2 intersect at P_1. As t increases from 0 to 1, the curve departs from P_0 in the direction of P_1, then bends to arrive at P_2 in the direction from P_1.

3.3 Behavior Function

Definition 5: The Behavior Function (BV) is the cartesian form of quadratic Beizer curve, thus, BV function is able to draw smooth curves which are achieved using three points P_0, P_1, and P_2, starting at P_0 going towards P_1 and terminating at P_2 (see Figure 1 and [9,10]).

– $P_0(0, 0)$ is the origin point.
– $P_1(B_x, B_y)$ ($0 \le B_x \le Tx$ and $0 \le B_y \le T_y$) is the behavior point. The coordinates of this point are guided by the application risk level $r^0 \in [0,1]$ through the diagonal of the rectangle that is defined by P_0 and P_2. Level r^0 is represented by the position of point P_1. If r^0=0, P_1 will have the coordinate(T_x,0). If r^0 = 1, P_1 will have the coordinate (0,T_y).
– $P_2(T_x, T_y)$ is the threshold point ($T_x > 0$ and $T_y > 0$) represent respectively the cover set cardinality and the frame capture rate thresholds.

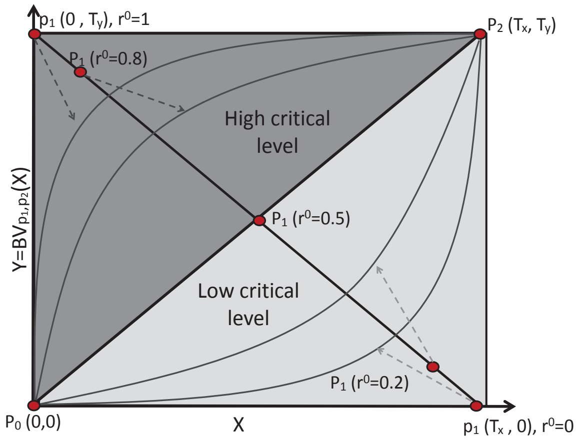

Fig. 1: The Behavior curve functions.

As illustrated in Figure 1, the curvature of the curve can be adjusted by moving the behavior point P_1 through the diagonal of the rectangle that is determined by the points P_0 and P_2. The BV function takes as input the node's cover cardinality $|Co|$ on the x-axis (X) and computes as output the corresponding frame capture speed on the y-axis (Y). To obtain the BV function with the Bezier curve, instead of taking a temporal variable t, the Bezier curve is modified to obtain the output (Y) as a function of (X). The cartesian function BV of the form $Y = f(X)$ is defined by the following equation:

$$BV : [0, T_x] \to [0, T_y], \ \ X \to Y$$

$$BV_{P1,P2}(X) = \begin{cases} \frac{(T_y - 2B_y)}{4B_x^2} X^2 + \frac{B_y}{B_x} X \ \ if (T_x - 2B_x) = 0 \\ (T_y - 2B_y)(\omega(X))^2 + 2B_y \omega(X) \ \ otherwise \end{cases}$$

where,

$$\begin{cases} \omega(X) = \frac{-B_x + \sqrt{B_x^2 - 2B_x X + T_x X}}{T_x - 2B_x} \\ T_x > 0 \\ 0 \le B_x \le T_x \\ 0 \le X \le T_x \end{cases} \tag{6}$$

The positions of the behavior point $P_1(B_x, B_y)$ are updated as the value of r^0 changes between 0 and 1. The following equations define the values of B_x and B_y:

$$\begin{cases} B_x = (1 - r^0) T_x \\ B_y = r^0 T_y \end{cases} \tag{7}$$

The capture rate of the multimedia node is computed in rounds. At each round, the node computes its capture rate according to the number of its valid cover set not the number of cover sets extracted at the beginning of the cover sets construction procedure. The nodes that have a high capture rate are those nodes that will exhaust their batteries early. Once the node dies, the cover sets that include it will not be a valid cover set any more for the other nodes.

4 Scheduling Strategy Description for WMSN

In this section, we outline our proposed strategy algorithm to schedule the multimedia nodes activities in WMSW. First, we determine the cover sets for every node v, then we model the Behavior Functions using Bezier Curves and then we provide a step by step description of our scheduling algorithm.

4.1 Determining Cover Sets

In our model for determining cover sets, we use three distinctive points p, c, and b to represent the vertices of the FoV triangle of v as shown in Figure 2. The FoV of node v is covered by a set $Co_i(v) \in Co(v)$ if the following conditions are satisfied:

1. $\forall v' \in Co_i(v)$, v' covers at least one of the v's FoV vertices p, c, b.
2. The nodes p, c, and b are all covered by the elements in $Co_i(v)$.
3. All the elements in $Co_i(v)$ that covers the vertices p,c, d are intersected with each other i.e., their FoVs overlap with each other.

To find the cover sets of node v, first we find the sets C_p, C_c, C_b of neighbor nodes that cover the points p, c, and b respectively. Then, test the intersection between the elements of these sets by examining the line intersection of each side of each triangle with all other sides i.e., the perimeter of the other triangles. The equations of the sides of FoV triangle can be defined using the coordinates of the vertices of each triangle as:

$$\overline{bc} : \frac{y - b.y}{x - b.x} = \frac{b.y - c.y}{b.x - c.x}. \tag{8}$$

$$\overline{pc} : \frac{y - p.y}{x - p.x} = \tan(\alpha). \tag{9}$$

$$\overline{pb} : \frac{y - p.y}{x - p.x} = \tan(\alpha + \theta) mod\ 2\pi. \tag{10}$$

For clarification consider the example in Figure 3, the cover sets of v are $C_p = \{v_2, v_4\}$, $C_c = \{v_3, v_5\}$, and $C_b = \{v_1\}$.

The possible cover sets for v will be $Co(v)$={$\{v\}$,{v_1, v_4,v_3}, { v_1 , v_2 , v_3 },{ v_5, v_2, v_1 }} and the cover set cardinality $|Co(v)| = 5$, the singleton $\{v\}$ is considered as a cover set. There are other sets like $\{v_2, v_3, v_5\}$, $\{v_2, v_1, v_5\}$ besides v not fully covered by $\{v_5, v_4\}$ and $\{v_5, v_2\}$.

.35

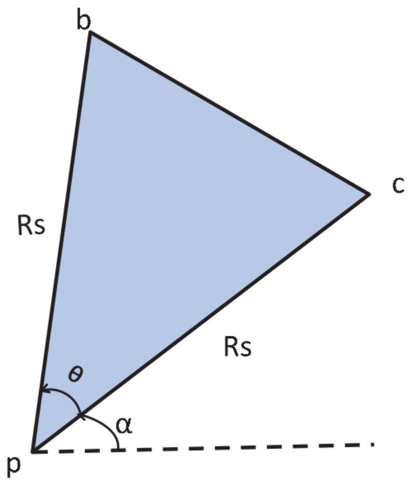

Fig. 2: FoV Coverage Model

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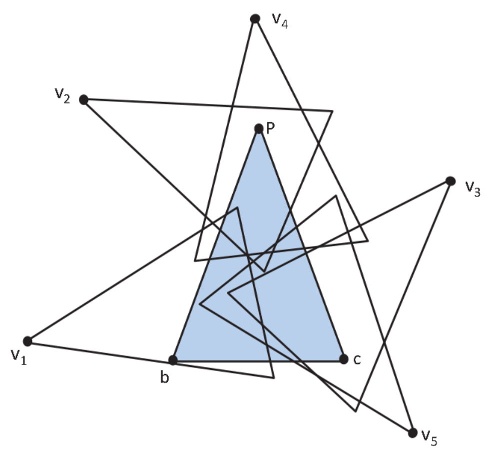

Fig. 3: Cover Sets construction Example

The coverage simulations are implemented using the method in [20]. It is accurate method to test whether a point is inside the *pbc* triangle or not.

4.2 Modeling Behavior Functions using Bezier Curves

Here, we use BV functions which expressed by a Cartesian form of the quadratic Bezier curve. The node is enabled by this function to join the observed events (i.e. risk level r^0) and the network deployment (i.e. cover set cardinality $|Co|$) to its frame capture speed. In critical surveillance applications, the BV function is used to guarantee the following:

– Nodes that can be easily replaced, i.e., nodes with a large cover set cardinality can have a high capture rate. On the other hand, nodes that can be hardly replaced, i.e., nodes with a small cover set cardinality should preserve its energy and consequently should have a low capture rate.
– In critical surveillance applications, even for nodes with small number of cover sets, the capture speed must be increased by increasing the risk level.

4.3 Scheduling algorithm

The scheduling algorithm will be executed in rounds and the algorithm operates after the nodes construct their cover sets. The status for every multimedia node is tested in rounds. At each round, every node decides to be active or not according to the activity messages received from its neighbors. At the beginning, the node arranges ascending its cover sets according to their cardinalities (the cover set with minimum cardinality has a largest priority). After that, the node changes arrangement of its cover sets according to collectable remaining energy for each one.

Each node v receives the activity messages from its neighbors, it checks if the active nodes belongs to its cover sets $Co(v)$. The node v will go to sleep mode if it can find at least one active cover set $Co_i(v) \in Co(v)$ and all its nods are active. In this case, the node will send its decision to its neighbors. Otherwise (no active cover set) $Co_i(v)$, the node v will decide to remain in active mode. In this algorithm, the nodes that have no cover sets will be active all the time until the expiration of their batteries.

The singleton $\{v\}$ is a cover set of a node v, and it is given the lowest priority in both metrics (cardinality and remaining energy). The reason behind this is we want to benefit from the active cover nodes. So the node $\{v\}$ will be active only if it has no active cover set. As shown in the following algorithm. The node v starts by sorting its cover set $Co(v)$ then it testing the activity of the first cover set $Co_1(v)$ (the cover with highest priority). If there exists one sleep node v' in $Co_i(v)$, it means this cover set cannot be selected and the node v tests the next cover set $Co_{i+1}(v)$ and so on until it finds one active cover set to go to sleep mode or it reaches to singleton$\{v\}$, in this case, it will decide to be active. This process will be repeated every round.

Algorithm 1 Scheduling algorithm

This Algorithm will be executed by each multimedia node in each round.

v is active.
v sorts its cover set $Co(v) = \{Co_1(v), Co_2(v), \ldots, Co_i(v), \ldots Co_n(v)\}$,
n=$|Co(v)|$.
Active $\_Co_i(v) \leftarrow 1$ { as v is active cover set}
while i $\leq |Co(v)|$ **do**
  if $\forall v' \in Co_i(v)$,v' is in active mode **then**
    v will decide to sleep and send its decision to its neighbors.
    Active$_Co_i(v) \leftarrow$ Active$_Co_i(v)$+1.
    break
  else
    $\{\exists v' \in Co_i(v)$ in sleep mode$\}$
    i$\leftarrow$i+1
  end if
end while
if Active$_Co_i(v)$=1 **then**
  {v is the only active cover set}
  v remains active and sends its decision to its neighbors.
end if

5 Simulation results

To evaluate our new technique, we conducted a series of simulations and run each simulation 16 times using different simulation seeds to reduce the impact of randomness. Sensor nodes are randomly deployed in 75 m $\times$ 75 m square region. Nodes have equal communication and sensing ranges of 30 m and 25 m respectively, an AoV of $\theta = 60°$, a battery life of 100 units, random position P, and random orientation angle α (direction). At the beginning of the simulation, each node discovers its neighbors and in each round each node will decide to be active or not.

We evaluate our technique COV$intersect1$ where all the nodes of the cover set are intersected with each other against the following approaches:

1. COV$intersect2$ where for every node v in the cover set there is a node u and v and u are intersect,
2. COVwG where there is a point g represents the triangles center of gravity is taken into account when determining eligible neighbors to be included in a sensors cover sets ([9]).

5.1 Percentage of coverage and cover set size

The obtained results from iterations with various node populations 80, 100, 125, 150, and 175. For each sensor v with cover sets, we compute the percentage of coverage of each cover set Co$_i(v)$ by sampling a large number of random points (50000 in our simulation) in v's FoV and determining whether this point is covered by one of the sensor in Co$_i(v)$. The first note that can be drawn from the histograms depicted in Figures 4, 5, 6, 7, 8, and 9 is that the performances of all techniques increase significantly when the number of nodes increases. Figures 4, 6, and 8 show that the percentage of coverage of the v's FoV in the COV$intersect1$, COV$intersect2$, and COVwG approaches are 90%, 65%, and 95% respectively. The coverage percentage of COVwG is the largest one this is because the the point g must be covered by the nodes covering v's FoV nodes. The coverage percentage of COV$intersect1$ is more than COV$intersect2$ because in each cover set in COV$intersect1$ all nodes intersect with each other while in each cover set in COV$intersect2$ only each two nodes intersect. The coverage percentage of COVwG as shown in Figure 8 increases at the expense of the percentage of nodes in cover sets, in some deployments this percentage is null. Figures 5, 7, and 9 show that the cover set cardinality is very small in COVwG compared to the other approaches. It is clear that, as adding more constraints in getting the cover set, the coverage percentage increases and the percentage of nodes in cover and the cover set cardinality both decrease. Therefore, the COV$intersect1$ is a practical technique that gives a high level of coverage and acceptable percentage of nodes in cover and cover set cardinality.

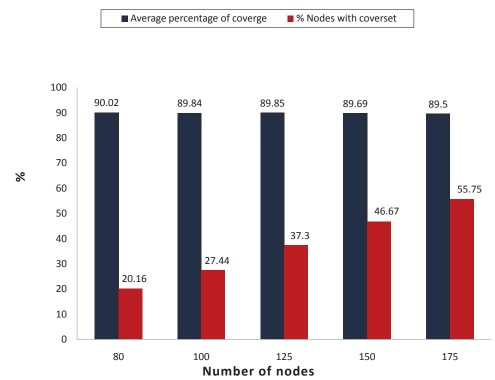

Fig. 4: COVintersect1: Average Percentage of Coverage and Percentage Nodes of Cover Sets.

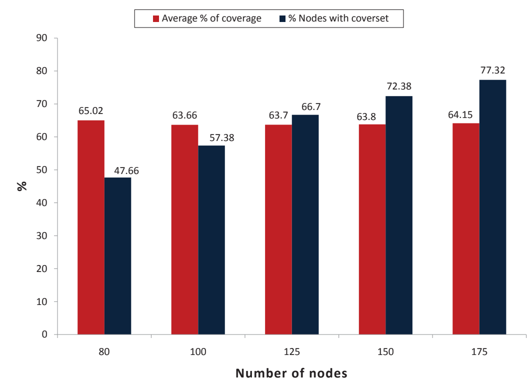

Fig. 6: COV*intersect*2: Average Percentage of Coverage and Percentage Nodes with Cover Sets.

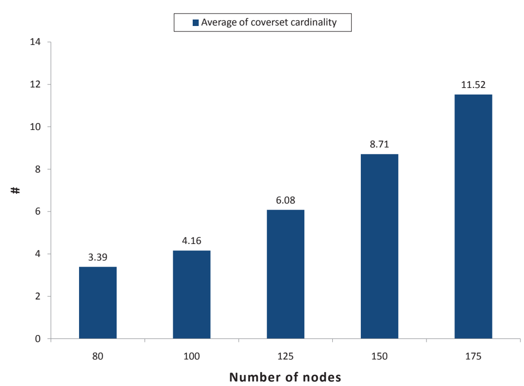

Fig. 5: COV*intersect*1: Average of Cover Set Cardinality

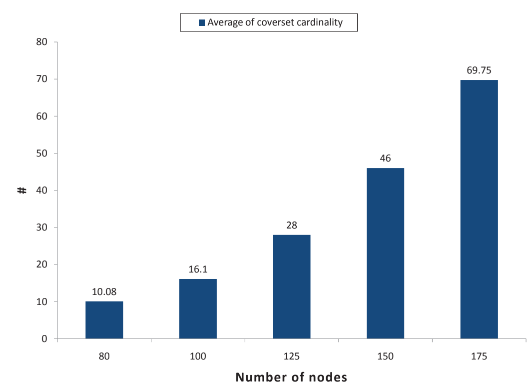

Fig. 7: COVintersect2: Average of Cover Set Cardinality.

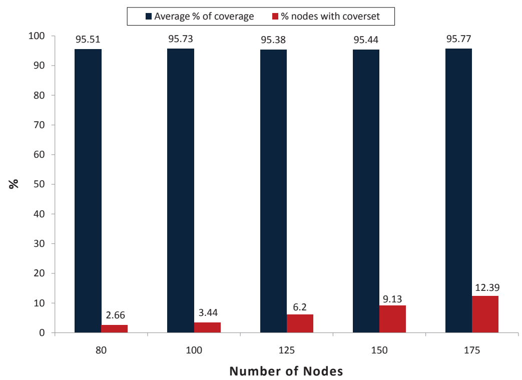

Fig. 8: COVwG: Average Percentage of Coverage and Percentage Nodes in Cover Sets.

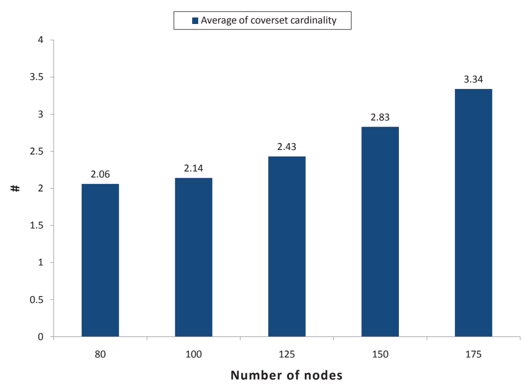

Fig. 9: COVwG: Average of Cover Set Cardinality.

5.2 Lifetime and average capture rate

To evaluate our technique in terms of lifetime and average capture rates, we deployed 100 nodes randomly in 75×75 square region. Each sensor node captures with a given number of fps (between 0.01 and 3 fps) and the battery capacity decreases accordingly by 1 unit per captured frame (initial capacity is 100 units). Nodes with 12 or more cover sets will capture at the maximum speed. Simulation ends when there are no more live nodes. The capture rates corresponding to 3 levels of criticality (r° = 0.2, 0.5, and 0.9) and for each cardinality (between 1 and 12) are shown in Table 1. Tables 2 and 3 present the network lifetime and the average capture rate of COV$intersect1$ and COVwG. We can note that the two techniques have same lifetime because the existence of last sleep node in COVwG leads to same life time. Even though the two techniques have the same lifetime, the COV$intersect1$ gives average capture rate larger than COVwG because as mentioned in the previous section, COV$intersect1$ provides larger average of cover set cardinality, therefore, the COV$intersect1$ produces higher surveillance quality than COVwG.

Table 1: The capture rate in fps (maximum capture rate=3 and maximum cardinality= 12)

r^0	0.2	0.5	0.9
1	0.07	0.25	1.08
2	0.15	0.5	1.59
3	0.25	0.75	1.94
4	0.37	1	2.2
5	0.5	1.25	2.39
6	0.67	1.5	2.55
7	0.87	1.75	2.68
8	1.1	2	2.78
9	1.39	2.25	2.86
10	1.76	2.5	2.92
11	2.25	2.75	2.97
12	3	3	3

Table 2: COV$intersect1$ Performance

Risk level	Average capture rate (fps)	Lifetime
0.2	0.24	2907
0.5	0.53	801
0.9	1.38	187

Table 3: COVwG Performance

Risk level	Average capture rate (fps)	Lifetime
0.2	0.076	2907
0.5	0.27	801
0.9	1.1	187

5.3 Percentage of active, sleep and dead nodes

In this section, we present the comparison results of our approach COV$intersect1$ and COVwG in terms of the percentage of the active, sleep, and dead nodes with the time for three different critical levels (r°= 0.2, 0.5, and 0.9). Figure 10 (the x-axis is in logarithmic scale) shows the percentage of the active nodes. We can note that the number of active nodes in COV$intersect1$ is lower than in COVwG this is because the percentage of nodes in cover is more in COV$intersect1$ than in COVwG which leads to increment in the number of sleep nodes. Figure 11 shows the percentage of the sleep nodes. It is clear that the number of sleep nodes is larger in our approach than in COV*wG* this is due to the increasing of percentage of nodes in cover set and the cover set cardinality. Figure 12 shows that the percentage of dead nodes in our approach is higher in some rounds than COV*wG* this is due to the higher of average capture rate in our approach. However, in the majority of rounds, the number of dead nodes in our approach is lower than COV*wG* because a higher number of sleep nodes.

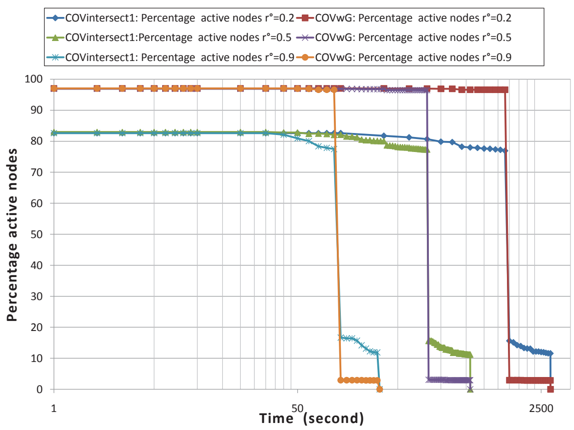

Fig. 10: Percentage of active nodes

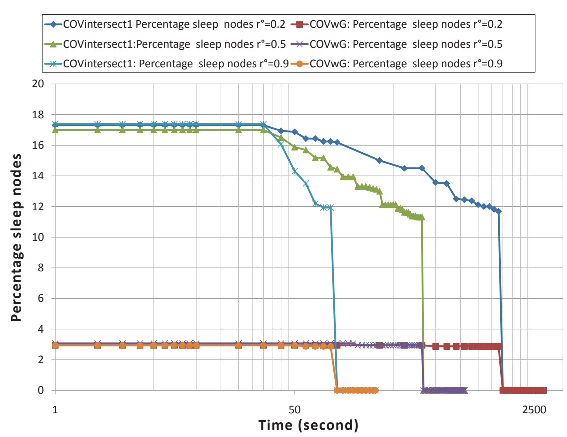

Fig. 11: Percentage of sleep nodes

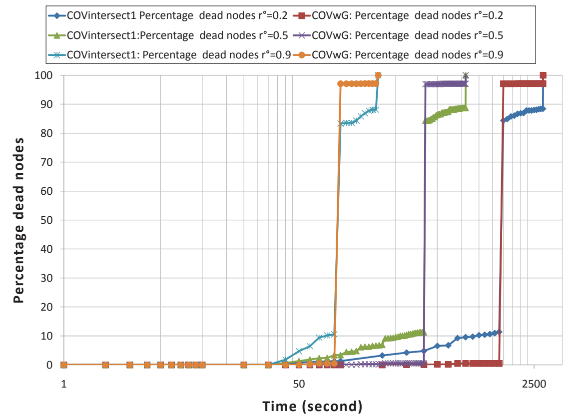

Fig. 12: Percentage of dead nodes

6 Conclusion

Defining the redundancy level to determine cover sets is of prime importance for scheduling and increasing the network lifetime for mission-critical sensor networks. In this paper, we have proposed a new approach for finding subsets of nodes that cover the FoV area of a given node. The new approach is based on two models, the first model uses behavior functions modeled by modified Bezier curves that links the frame capture speed to the cover sets cardinality and the area criticality levels. The second model is adaptive scheduling algorithm for multimedia sensor nodes for optimizing the resource usage by adjusting the provided service level dynamically. Simulation results in terms of number of nodes in cover set, percentage of coverage, and the size of the cover set (cardinality) show that the performance of our approach exceeds the existing approaches where our approach produces high surveillance quality by providing a high average capture rate and increase the number of sleep nodes which influences on the network lifetime and the number of active and dead nodes.

References

[1] M. Rahimi, R. Baer, O.I. Iroezi, J.C. Garcia, J. Warrior, D. Estrin, M. Srivastava, Cyclops: in situ image sensing and interpretation in wireless sensor networks, in: ACM Conference on Embedded Networked Sensor Systems (SenSys), San Diego, CA, (2006).

[2] S. Hengstler, D. Prashanth, S. Fong, H. Aghajan, Mesheye: a hybridresolution smart camera mote for applications in distributed intelligent surveillance, in: Information Processing in Sensor Networks (IPSN-SPOTS), Cambridge, MA, (2007).

[3] I.F. Akyildiz, T. Melodia, K.R. Chowdhury, A survey on wireless multimedia sensor networks, Computer Networks 51 (4), 921-960 (2007).
[4] R. Holman, J. Stanley, T. Ozkan-Haller, Applying video sensor networks to nearshore environment monitoring, IEEE Perv. Comput. 2 (4), 14-21 (2003).
[5] F. Hu, S. Kumar, Multimedia query with QoS considerations for wireless sensor networks in telemedicine, in: Proc. of Society of Photo-Optical Instrumentation Engineers 17 Intl. Conf. on Internet Multimedia.
[6] J. Campbell, P.B. Gibbons, S. Nath, P. Pillai, S. Seshan, R. Sukthankar, IrisNet: an Internet-scale architecture for multimedia sensors, in: Proc. of the ACM Multimedia Conference, (2005).
[7] E. Gurses, O.B. Akan, Multimedia communication in wireless sensor networks, Annals of Telecommunications 60 (7-8), 799-827 (2005).
[8] S. Misra, M. Reisslein, G. Xue, A survey on multimedia streaming in wireless sensor networks, IEEE Communications Surveys and Tutorials 10 (4), 18-39 (2008).
[9] C. Pham, A. Makhoul and R. Saadi, A risk adaptative scheduling in randomly deployed video sensor networks for critical surveillance application, Journal of Networks and Computer Applications (JNCA), 34 , DOI information: 10.1016/j.jnca.2010.10.002, 783-795 (2011).
[10] A. Makhoul, R. Saadi, and C. Pham, Risk management in intrusion detection applications with wireless video sensor networks, in IEEE WCNC, (2010).
[11] D. Tian and N. D. Georganas, A coverage-preserving node scheduling scheme for large wireless sensor networks, 1st ACM WSNA, (2002).
[12] M. Cardei, M. T. Thai, Y. Li, and W. Wu, Energy-efficient target coverage in wireless sensor networks, IEEE INFOCOM, (2005).
[13] C. Pham, A. Makhoul, Performance study of multiple cover-set strategies for mission-critical video surveillance with wireless video sensors, Proceedings of the IEEE WiMoB 2010, canada, (2010).
[14] A. Benzerbadj, B. Kechar and M. Senouci, New approaches for calculating cover sets in wireless video sensor networks for surveillance critical applications, First International Conference on Distributed Systems and Decision (ICDSD1712), Oran, Algeria, (2012).
[15] J. Carle and D. Simplot, Energy Efficient Area Monitoring by Sensor Networks17, IEEE Computer, 37(2), 40-46 (2004).
[16] D. Tian, and N. D. Georganas, Coverage Preserving Node Scheduling Scheme for Large Wireless Sensor Networks17, ACM Workshop on Wireless Sensor Networks and Applications, (2002).
[17] X. Wang, G. Xing, Y. Zhang, C. Lu, R. Pless, and C. D. Gill, Integrated Coverage and Connectivity Configuration in Wireless Sensor Networks17, First ACM Conference on Embedded Networked Sensor Systems, (2003).
[18] H. Zhang, and J. C. Hou, Maintaining Sensing Coverage and Connectivity in Large Sensor Networks17, NSF International Workshop on Theoretical and Algorithmic Aspects of Sensor, Ad Hoc Wireless and Peer-to-Peer Networks, (2004).
[19] A. Benzerbadja, B. Kecharb, Redundancy and criticality based scheduling in Wireless Video Sensor Networks for monitoring critical areas, The 4th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN-2013).
[20] C. Moreno, 17 https://www.mochima.com/articles/cuj geometry article/cuj geometry rticle.html", (2015).

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