Prolonging the Lifetime of Visual Sensor Network using Coverage Preserving Algorithm

Gaurang S Patkar
Assistant Professor
Computer Engineering Department
Don Bosco College of Engineering, Goa, India

Michelle Araujo e Viegas
Assistant Professor
Electronics and Telecommunication Department
Don Bosco College of Engineering, Goa, India

ABSTRACT
Visual sensor networks (VSNs) have been attracting more and more research attention nowadays. There are applications where the spatial density of sensors is a constraint. Assuming that with the current technology the cost of a sensor is tens of times greater than the cost of embedded batteries, it will be valuable to examine whether the lifetime of the network could be increased by simply distributing extra energy to some existing nodes without introducing new nodes. In this paper an improvement to LEACH protocol is done to increase the lifetime of network. CPA is heterogeneous-aware, in the sense that election probabilities are weighted by the initial energy of a node relative to that of other nodes in the network. This prolongs the time interval before the death of the first node (stability period), which is crucial for many applications where the feedback from the sensor network must be reliable.

Keywords
LEACH, CPA, VSN

1. INTRODUCTION
Visual sensor networks are networks of wireless camera-nodes, where the camera-node consists of the imager circuitry, a processor, and a wireless transceiver. In the near future visual sensor networks will provide more suitable solutions, compared with existing networks of high-power and high-resolution cameras, for many image-based applications that assume no infrastructure on site or no time for planning of the camera's placement [1][2][3]. In visual sensor networks, the camera-nodes can be simply stuck on walls or objects prior to use without the need for preplanning of the cameras' placement, thereby obtaining arbitrary positions/directions. Furthermore, camera-nodes are powered by batteries, and therefore, they do not require a constant power supply. This makes visual sensor networks suitable for use in applications where temporary monitoring is needed and in applications that require fast deployment and removal of the camera network[4][5][6].
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2. MOTIVATION
Some multimedia sensors, in particular video sensors, have larger sensing radii and are sensitive to direction of acquisition (directivity). Furthermore, video sensors can capture images only when there is unobstructed line of sight between the event and the sensor [9]. More the lifetime more is the coverage. Hence, coverage models developed for traditional wireless sensor networks are not sufficient for pre-deployment planning of a multimedia sensor network. New protocols need to be designed for multimedia coverage problem. We are motivated by the fact that there are a lot of applications that would highly benefit from understanding the impact of such heterogeneity. One of these applications could be the re-energization of sensor networks. As the lifetime of sensor networks is limited there is a need to re-energize the sensor network by adding more nodes. These nodes will be equipped with more energy than the nodes that are already in use, which creates heterogeneity in terms of node energy.
There are also applications where the spatial density of sensors is a constraint. Assuming that with the current technology the cost of a sensor is tens of times greater than the cost of embedded batteries, it will be valuable to examine whether the lifetime of the network could be increased by simply distributing extra energy to some existing nodes without introducing new nodes.

3. COVERAGE PRESERVING ALGORITHM (CPA)
In this section we describe CPA, which improves the stable region of the clustering hierarchy process using the characteristic parameters of heterogeneity, namely the fraction of advanced nodes (m) and the additional energy factor between advanced and normal nodes (α). In order to prolong the stable region, CPA attempts to maintain the constraint of well balanced energy consumption. Intuitively, advanced nodes have to become cluster heads more often than the normal nodes, which is equivalent to a fairness constraint on energy consumption. Suppose that Eo is the initial energy of each normal sensor. The energy of each advanced node is then Eo $(1+\alpha)$. The total (initial) energy of the new heterogeneous setting is equal to:
$n. (1-m). Eo + n. m. Eo. (1 + \alpha) = n. Eo. (1 + \alpha . m)$
So, the total energy of the system is increased by a factor of $1+ \alpha. m$. The first improvement to the existing LEACH is to increase the phase of the sensor network in proportion to the energy increment. In order to optimize the stable region of the system, the new phase must become equal to $1/popt . (1+ \alpha . m)$ because the system has $\alpha . m$ times more energy and virtually $\alpha . m$ more nodes (with the same energy as the normal nodes.) We can now increase the stable region of the sensor network by $1+\alpha.m$ times, if (i) each normal node becomes a cluster head once every $1/popt(1+ \alpha.m)$ rounds per phase; (ii) each advanced node becomes a cluster head exactly $1 + \alpha$ times every $1/popt(1+ \alpha.m)$ rounds per phase; and (iii) the average number of cluster heads per round per phase is equal to n * popt (since the spatial density does not change.) Constraint (ii) is very strict—If at the end of each phase the number of times that an advanced sensor has become a cluster head is not equal to $1+ \alpha$ then the energy is not well distributed and the average number of cluster heads per round per phase will be less than n * popt.

3.1 Guaranteed well distributed energy consumption

In this section we propose a solution; we call CPA (Coverage Preserving Algorithm), which is based on the initial energy of the nodes. This solution is more applicable compared to any solution which assumes that each node knows the total energy of the network and then adapts its election probability to become a cluster head according to its remaining energy [10][11][12].

Our approach is to assign a weight to the optimal probability popt. This weight must be equal to the initial energy of each node divided by the initial energy of the normal node. Let us define as Pn the weighted election probability for normal nodes, and Px the weighted election probability for the advanced nodes.

Virtually there are n * (1+ m) nodes with energy equal to the initial energy of a normal node. In order to maintain the minimum energy consumption in each round within an phase, the average number of cluster heads per round per phase must be constant and equal to n*popt. In the heterogeneous scenario the average number of cluster heads per round per phase is equal to n. (1+ α.m)*Pn (because each virtual node has the initial energy of a normal node.)

The weighed probabilities for normal and advanced nodes are, respectively

Pn = Po/ (1+ a*m)

Px = Po / (1+ a.m) * (1+ a.m)

We define as T(sn) the threshold for normal nodes, and T(sx) the threshold for advanced nodes. Thus, for normal nodes, we have:

T(sn)= Pn/ 1- Pn.(r.mod. 1/Pn) if sn Є G'

0 Otherwise

where r is the current round, G' is the set of normal nodes that have not become cluster heads within the last 1 /Pn rounds of the phase, and T(sn) is the threshold applied to a population of n . (1 - m) (normal) nodes. This guarantees that each normal node will become a cluster head exactly once every 1/popt (1+α . m) rounds per phase, and that the average number of cluster heads that are normal nodes per round per phase is equal to n . (1 - m) * Pn. Similarly, for advanced nodes, we have:

T(sx)= Px/ 1 – Px . (r . mod 1/ Px) if sx ЄG''

0 otherwise

where G'' is the set of advanced nodes that have not become cluster heads within the last 1/Px rounds of the phase, and T(sx) is the threshold applied to a population of n . m (advanced) nodes. These guarantees that each advanced node will become a cluster head exactly once every [1/popt. (1+α.m/1+α)] rounds.

Let us define this period as sub-phase. It is clear that each phase (let us refer to this phase as ―heterogeneous phase‖ in our heterogeneous setting) has 1 + α sub-phases and as a result, each advanced node becomes a cluster head exactly 1+α times within a heterogeneous phase. The average number of cluster heads that are advanced nodes per round per heterogeneous phase (and sub-phase) is equal to n.m.Px. Thus the average total number of cluster heads per round per heterogeneous phase is equal to:

n . (1 – m) * Pn + n .m * Px= n * popt

which is the desired number of cluster heads per round per phase. We next discuss the implementation of our CPA protocol and two methods namely static and dynamic of surveillance system.

3.2 Solved example

Assume that n=5, m=0.2, a=3, P=1/5, using equations we get Pn=1/8 and Px=4/8.

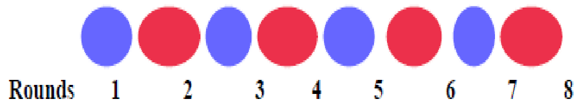

Figure 1.a numerical example for n=5, m=0.2, a=3 and p=1/5

If we consider a homogeneous scenario where each node has initial energy equal to the energy of a normal node, then the phase would be equal to 1/Popt =5 rounds. In the heterogeneous case, the extended heterogeneous phase is equal to rounds, 1/Pn= 8 rounds.

4. SIMULATION OF CPA

Let us assume a heterogeneous sensor network in a 100mx100m sensor field, as shown in Figure 2. We denote with (o) a normal node, with (+) an advanced node, with (.) a dead node, with (*) a cluster head, and with (x) the sink. As long as all the nodes are alive, the nodes that are included in the same Voronoi cell will report to the cluster head of this cell. Let m be the fraction of the total number of nodes n, which are equipped with α times more energy than the others. We refer to these powerful nodes as advanced nodes. The initial energy of a normal node is set to E0=0.5 Joules, Transmitter/Receiver Electronics (Eelec) = 50nJ/bit, Transmit Amplifier (Єfs) = 10pJ/bit/m2. The size of the message that nodes send to their cluster heads as well as the size of the (aggregate) message that a cluster head sends to the sink is set to 4000 bits.

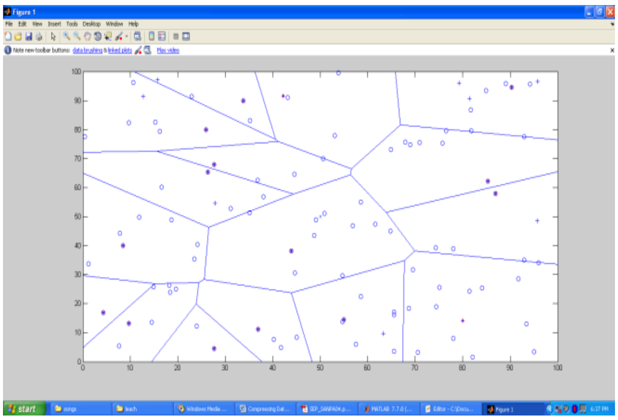

Figure 2.A wireless sensor network when all nodes are alive

Supplying a times more energy to the network will create two categories of nodes, one with normal energy and other with more energy. Figure 3 shows snapshot of sensor network after execution of some rounds.

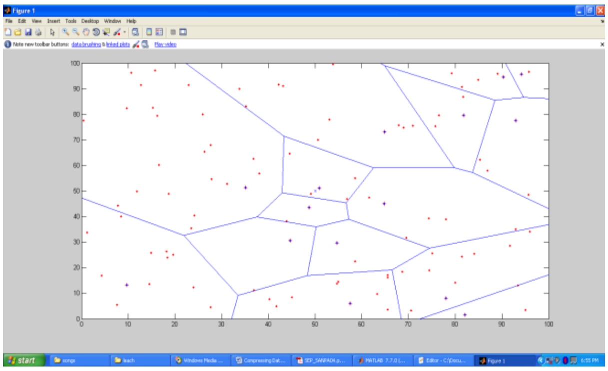

Figure 3. A snapshot of network when some nodes are dead

4.1 Simulation parameter setting

(1) Sensor nodes contain two kinds of nodes: sink nodes (no energy restriction) and common nodes (with energy restriction);

(2) 100 Nodes are randomly distributed in a area within 100m×100m;

(3) Suppose that every node knows its position, channels between sensor nodes are ideal, sending energy consumption is the same as receiving energy consumption, initial energy of each node is 0.5J;

(4) Probability of being cluster head equals 0.1; this means that on average, 10 nodes must become cluster heads per round;

(5) The po for this setting is approximately equal to 0.104325, using equation po =ko/n

(6) Radio characteristics used in simulation are as follows:

Transmitter/Receiver Electronics- Eelec = 50nJ/bit, Data Aggregation (EDA) = 5nJ/bit/report, Transmit Amplifier(if dtoBS <d0) - Єfs = 10pJ/bit/m2, Transmit Amplifier (if dtoBS >d0) - Єmp = 0.0013pJ/bit/m4.

(7) The size of the message that nodes send to their cluster heads as well as the size of the (aggregate) message that a cluster head sends to the sink is set to 4000 bits.

5. EXPERIMENTAL RESULTS

In this subsection the results of CPA is shown. Figure 4 is a graph of number of dead nodes versus rounds. At round number 1330 the first node dies and till the end of 5000 rounds one node is alive and that node is advanced node. The graph of number of cluster heads per round is given in figure 5. From figure 6 it is clear that the death of first normal node is at 1330th round and death of last normal node is at 1864th round. The death of first advanced node happens at 1359th round and death of last advanced node happens after 5000 rounds. This is shown in figure 7. The graph of number of packets send to cluster head per round is given in figure 8. Packets to Base station graph of Sensor nodes versus number of rounds is shown in figure 9. The performance of our CPA protocol to LEACH is compared where the extra initial energy of advanced nodes is uniformly distributed over all nodes in the sensor field. Figure 10 shows results for the case of m = 0.2 and a= 3. It is obvious that the stable region of CPA is extended compared to that of LEACH (by 10%), even though the gain is not very large. Figure 11 shows results for the case of m = 0.2 and with different values of a. It is observed that as the value of a increases the network lifetime increases.

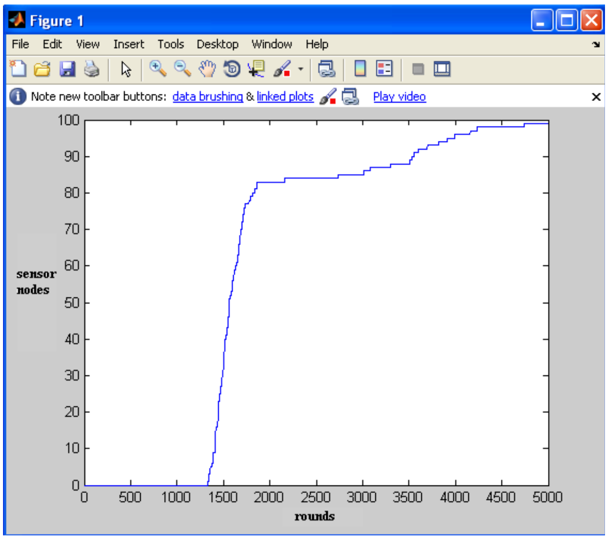

Figure 4. Graph of number of dead nodes per round

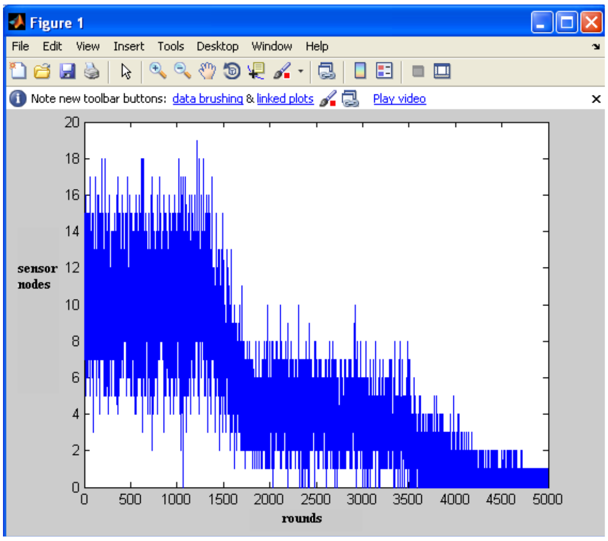

Figure 5. Graph of number of Cluster heads per round

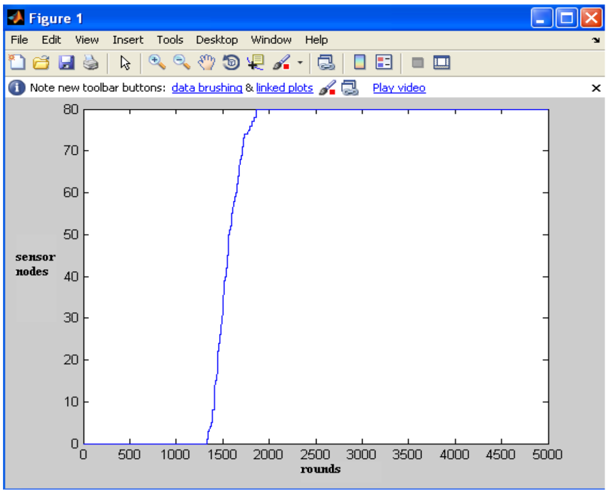

Figure 6. Graph of Dead normal nodes per round

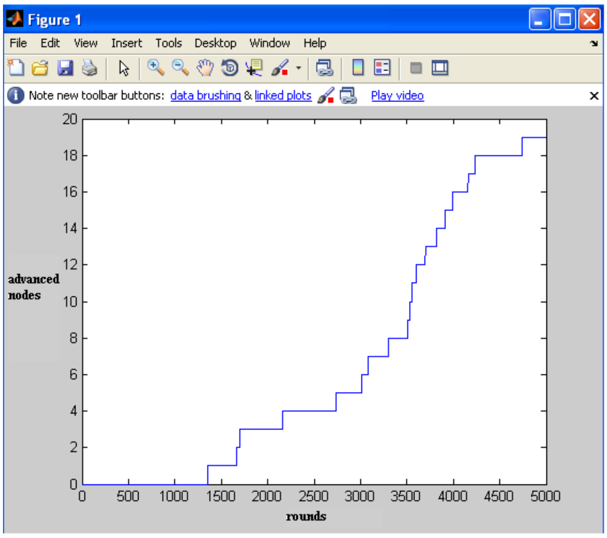

Figure 7. Graph of Dead advanced nodes per round

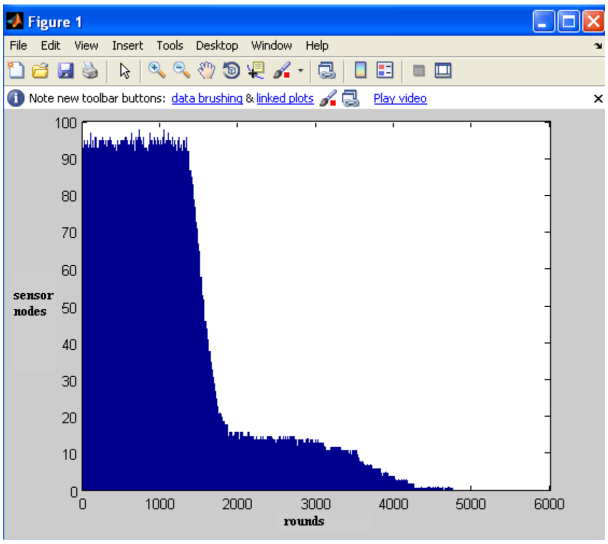

Figure 8. Graph of Packets to cluster head per round

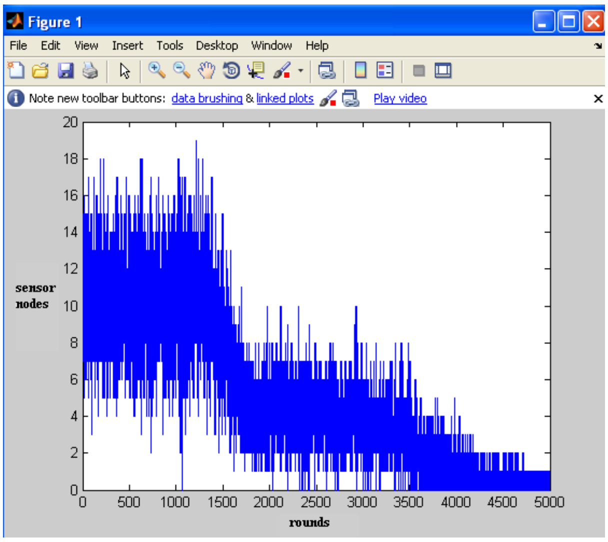

Figure 9. Graph of Packets to Base station per round

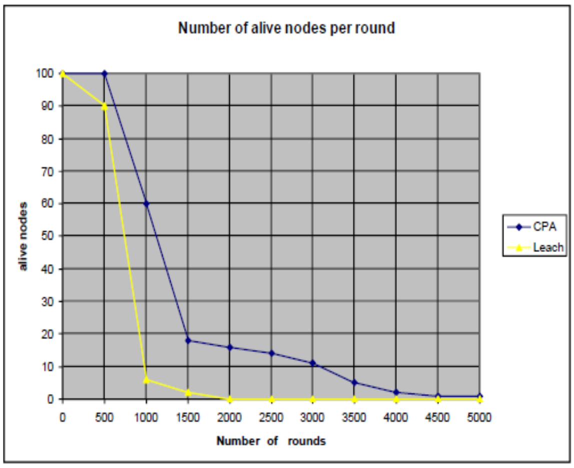

Figure 10. Comparison between LEACH and CPA in the presence of heterogeneity: m = 0.2 and a = 3

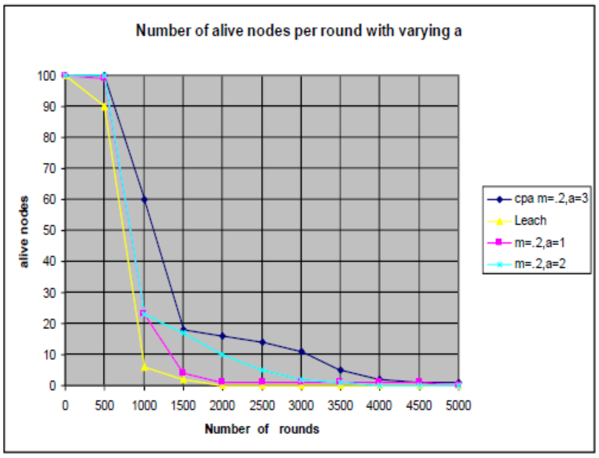

Figure 11. Comparison between LEACH and CPA in the presence of heterogeneity: m = 0.2 and varying a

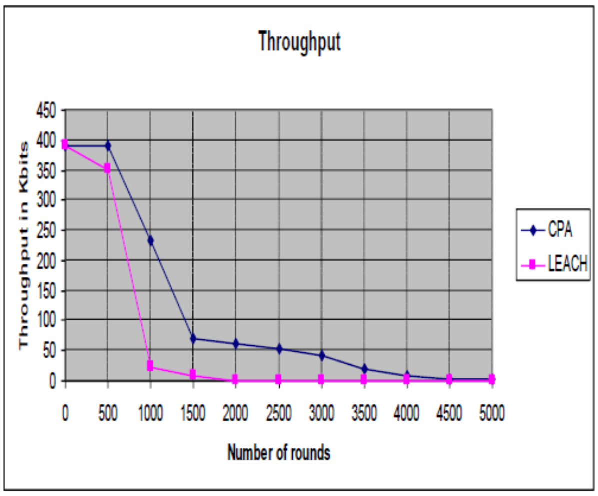

Figure 12. Throughput comparison between LEACH and CPA in the presence of heterogeneity: m = 0.2 and a = 3

In order to prolong the stable region, CPA attempts to maintain the constraint of well-balanced energy consumption. Intuitively, advanced nodes have to become cluster heads more often than the normal nodes, which is equivalent to a fairness constraint on energy consumption.

6. CONCLUSION

Coverage Preserving Algorithm (CPA) is implemented with initial assumption of heterogeneity to increase the lifetime of the visual sensor network. The proposed algorithm is compared with LEACH algorithm in the presence of heterogeneity. The behavior of both protocols in terms of the performance measures is evaluated and analyzed. It can be observed from figures 10 that the stability period of network is increased by 10%. Also the sensitivity of CPA to the degree of heterogeneity in the network is examined in terms of network lifetime and throughput. We found that CPA yields longer stability region and throughput for higher values of extra energy brought by more powerful nodes.

7. REFERENCES

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