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Greedy – based Heuristic for OSC problems in Wireless Sensor Networks

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Abstract*: This paper contains optimize set coverage problem in wireless sensor networks with adaptable sensing range. Communication and sensing consume energy, so efficient power management can extended the network lifetime. In this paper we consider a enormous number of sensors with adaptable sensing range that are randomly positioned to monitor a number of targets. Every single target may be redundantly covered by various sensors. For preserving energy resources we organize sensors in sets stimulated successively. In this paper we introduce the Optimize Set Coverage (OSC) problem that has in unbiased finding with an extreme number of set covers in which every sensor node to be activated is connected to the base station. A sensor can be participated in various sensor sets, but the overall energy consumed in all groups is forced by the primary energy reserves. We show that the OSC problem is NP-complete and we propose the solutions: an integer programming for OSC problem, a linear programming for OSC problem with greedy approach, and a distributed and localized heuristic. Simulation results are presented and validated to our approaches.*

I. Introduction

A Wireless Sensor Networks (WSNs) are composed of low cost sensor nodes, which can be used for a wide range of applications. WSNs are consisting of a large number of low cost devices to gather information from various kinds of remote sensing applications. WSNs enabling technology for various applications it involve long-term and low-cost monitoring, such as battlefield reconnaissance, building inspection, security surveillance, etc. A goal in most WSN applications is to reconstruct the underlying physical phenomenon, e.g., temperature, based on sensor measurements. The networks may be composed by hundreds or thousands independent devices, therefore is called sensor node.

The sensor nodes in a WSN have typically short battery life. Most WSN applications are however expected to run autonomously for months or years. An important issue in sensor networks is power scarcity it's driven in part by battery size and weight limitations. Between the functional components of a sensor node the radio consumes a major portion of the energy. The several techniques are been proposed to minimize its energy consumption. Here we ponder the network lifetime optimization issues in the WSN, the energy saving techniques can normally be classified in two types, scheduling the sensor nodes to alternate between active and sleep mode, and adjusting the transmission or sensing range of the wireless nodes.

In this paper we give a lecture for aim to coverage problem. The goal is to maximize the network lifetime to an energy consuming of WSNs for monitoring the coverage area. We have to consider a large number of sensor nodes are randomly circulated and send information by central processing node. Then the all sensing data from each node are not necessary to users, and data redundancy can be expected in a densely distributed sensor network. The way used to extend the network's lifetime is to organize the sensors into a number of sets, such that all the targets are monitored continuously. Also the energy constraints for each sensor and BS connectivity of each sensor set must be satisfied. Besides reducing the energy consumed, this method lowers the density of active nodes is less, then reducing contention of MAC layer. The contributions of this paper are:

1. Introduce the Optimize Set Coverage (OSC) problem and prove its NP- completeness.
2. The model of OSC problem using Integer Programming.
3. The model of OSC problem using linear Programming.
4. Greedy-based heuristic for OSC.
5. Design a distributed and localized heuristic for the OSC.
6. Analyze the performance of these algorithms through simulations.

7.

II. Related Work

In this paper we address the sensor coverage problem. As pointed out in, the coverage concept is a measure of the quality of service of the sensing function and is subject to a wide range of interpretations due to a large variety of sensors and applications. The goal is to have each location in the physical space of interest within the sensing range of at least one sensor.

III. Optimization Of Network Lifetime

We consider a number of sensor nodes that circulate continuously and target with known locators. We also consider a central data collector node; it will be referring to the base station (BS). The sensing data are been process by the sensors in the BS.

We assuming the number of sensors deployed are larger than to needed to process the task. The sensing nodes are been alternate between the active states and sleep states. The sensing node contains the sleep mode at the time sensing tasks.

a) Aim to coverage the lifetime problem

We consider the sensors for the energy consume WSN will randomly circulate and the location, the sensing nodes are observed continuously for network lifetime optimized.

1. The sensing node is accomplished as follows:
2. The BS collects the location information of the sensing nodes.
3. The BS executes the sensor scheduling algorithm and broadcast it when the node is in active.
4. The sensing node take breaks by own for active are to sleep.

In this paper we consider the designing the scheduling mechanisms of node and do not address the problem by selecting which protocol is used for data gathering or node synchronization.

b) Energy consuming in transmitting data

The energy is delivering from a node to another node as one bit message within transmission range in one hop communication is combined with the transmission energy to transmit a bit at the sending node and the energy needed to receive a bit at the receiving node.

A small sensor nodes are contains the limitations for battery storage is containing only the small transmission ranges and may not be able to communicate directly with the sink nodes; hence the concept of multi-hop communication is needed.

In the multi-hop communication model, it is assumed that considerable energy savings can be achieved by the use of multiple short range transmissions as opposed to one large hop transmission. The distance from the source to the destination is communicates, and the transmission range for the multi-hop communication, the required consumption energy.

IV. Optimize Set Coverage Problem

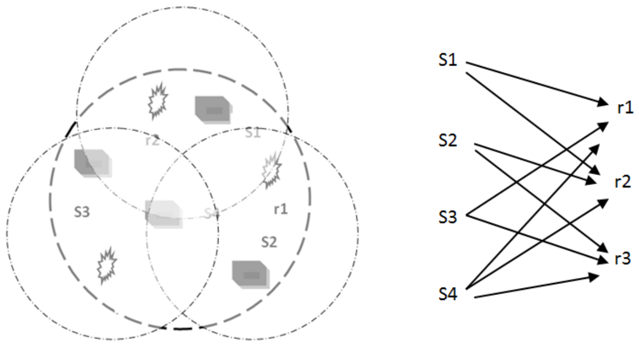
In this section we optimize the covered problem and prove it completely

a) Definition of optimize set coverage

Here we assume the given area to be covered by WSN, each of which will collect data periodically. Then, lifetime optimization of the wireless sensor network is assigning the different transmission power of nodes to balance their battery usage to avoid energy wastage at the time network coverage. The main goal of this paper is to decide the communication between the each node.

We assume that the sensor s1, s2….sn and the randomly circulate and covers the aimed location range r1, r2…rn. The base station has the coordinates of the sensor nodes and the aimed location. It is able to compute the each sensor node which is covers the locations.

The method is to assume that the sensors are covers the aimed locations, if the distance between the sensor and the location is small or same with the predefined sensing range.



(a) (b)

Figure: Example with four sensor nodes (s1, s2, s3, s4) and three location range (r1, r2, r3)

Above figure shows an example with four sensor nodes s1, s2, s3, s4 and three location range r1, r2, r3. In this example we assume that the each sensor can be active for a unit time of 1. That is, if all sensors are stored continuously, then the network lifetime is 1.

In this brief, we are improving the scheduling scheme by allowing every sensor to be part of more than one set, at by allowing the sets to be operational for different time intervals.

b) Optimize set coverage problem solution

In this section we first define the decision of optimize problem and then prove the problem.
A decision problem contains the collection of subsets of a finite sets and a number does it exist a family of set covers s1,……sn and the range r1,……rn and for each subset of collection and a is appear in s1,…..sn and the weight at most l, where l is the lifetime of each sensor.

c) Lifetime of network

The work of the WSN is collecting the data in the sensing applications. The wireless sensor network lifetime is generally determined by the last active node.

d) Sensing node

In the WSN the sensor nodes must maintain the coverage area and network connection. They determine the quality of service in the sensor network. The problem in data collecting from sensor network is how they monitored the coverage area and notice the each and every action from the wireless sensor network. It senses the coverage area to a wide-ranging of analyses in line for a large variety of sensors and applications. The goal is every location in the physical space of interest surrounded by the sensing range of at least on sensor.

The interrupts occurs at connectivity are robustness and reachable throughput of the communication link in a wireless sensor network. The wireless sensor network must also provide connectivity satisfaction; therefore every node is used for data collecting.

e) Energy model

Assume sensor nodes can adjust their transmission power to control the transmission range. The energy consumed by sensor to reliably transmit a b-bit message to sensor j.

$$e(b) = c \cdot b \cdot d_{i,j}^{\alpha}$$

Where is a system constant denoting the energy required by a transmitter amplifier to transmit 1-bit one meter, is the path loss exponent depending on the medium properties, and di,j is the distance between sensor i and sensor j.

V. Solution For Optimize Set Coverage

In this section we present the two heuristics for OSC problem. First we process the problem in integer programming. Second we process the linear programming. Then we process the greed based for OSC and finally we process the distributed and localized for OSC are given for computing the set covers.

The consolidated heuristics are implemented at the BS. When the sensors are placed, they send their synchronization to the BS. The BS calculates and broadcasts back the sensor lists. In the distributed and limited algorithm, each sensor node regulates its schedule created on communication with one-hop neighbors.

a) Integer programming for OSC problem
In this section we formulate the OSC problem using the integer programming

Given:
- Set N sensor nodes s1,s2,….sN
- Set L location range r1,r2,….rL
- The coefficient showing the relationship between the sensor nodes and ranges, therefore each sensor node is covers the aimed location. This is modeled as having each element in s is represented as a subset of the finite set r.
- Set E for initialize energy

Let us define sN = i|sensor si covers range rk

Variables:
- xij, Boolean variable, for i=1…n and j=1…p; xij=1 if sensor si is in the set cover sj,otherwise wij=0.
- tj € R, 0≤ tj ≤ 1, for j=1…p, represents the time allocated for the set cover Sj.

Maximize t1 + … +tp

Subject to
$\sum_{j=1}^{p} x_{ij} t_j \leq 1$ for all $s_i \in C$

$\sum_{i \in C_k} x_{ij} \geq 1$ for all $r_k \in R, j = 1, .., p$

Where
$x_{ij} = 0, 1$ ($x_{ij} = 1$ if and only if $s_i \in S_j$)

Remarks:
The first constraint, $\sum_{j=1}^{p} x_{ij} t_j \leq 1$ for all si € N guarantees that the time allocated for each sensor s1,across all set covers, is not larger than 1,which is the life time of each sensor.
The second constraint, $\sum_{i \in C_k} x_{ij} \geq 1$ for all rk € L, j=1…p, and Nk= i|si covers range rk, guarantees that each target rk is covered by at least one sensor si in each set cover sj.
We notice that the term xijtj is not linear. Therefore we set yij = xijtj, and reformulate the problem as:

Maximize t1 + … +tp

Subject to
$\sum_{j=1}^{p} y_{ij} \leq 1$ for all $s_i \in C$

$\sum_{i \in C_k} y_{ij} \geq t_j$ for all $r_k \in R, j = 1, .., p$

Where
$y_{ij} = 0$ *or* t_j and $y_{ij} \leq 1$

b) Linear programming for OSC problem
In this section we formulate the problem using linear programming, before that we have apply the relax technique.

Maximize t1 + … +tp

Subject to
$\sum_{j=1}^{p} y_{ij} \leq 1$ for all $s_i \in C$

$\sum_{i \in C_k} y_{ij} \geq t_j$ for all $r_k \in R, j = 1, .., p$

Where
$0 \leq y_{ij} \leq t_j \leq 1$

Linear programming based heuristic:

1. Solve the LP and get the optimal solution *xikp* and *ck*
2. Set x'ikp = 0 and c'k = 0 for all i=1…N,k=1…K,p=1…P
3. Sort ck in non-increasing order c1,c2,…ck
4. for all variable *ck* taken from the list in non-increasing order do
5. if ck > 0 then
6. sort xikp, *i* = 1..*N*, *p* = 1..*P* in non-increasing order
7. for all *xikp* do
8. if *xikp* covers new targets and sensor *i* has at least
9. *ep* energy at the beginning of setting up the cover
10. *ck* then
11. set up the range of sensor i to *rp*, *xikp* = 1
12. else
13. *xikp* = 0
14. else if
15. else for
16. if all targets are covered by *xikp* having value 1 then
17. /∗ we formed a valid set cover ∗/
18. set *c_k* = 1
19. update residual energy of any sensor *i* with range
20. *rp* in *ck*: *Ei* = *Ei* – *ep*
21. set ck = 0 and reset xikp = 0 for any i = 1..N and p = 1..*P*
22. end if
23. end if
24. end for

The heuristic begins in line 1 by solving the relaxed LP that outputs the optimal solution *xikp* and *ck*. We round this solution in order to get a feasible solution *xikp* and *ck* for the IP. We use a greedy approach, by giving priority to the set covers with a larger *ck*. When adding sensors to a cover *ck*, priority is given to the sensors with larger *xikp*. We sort values *ck* in the non-increasing order.

We add sensors to the current set cover *k*, by adding first the sensors with higher *xikp* values. If, later, the same sensor with a larger range is encountered, the new range setting is used if new targets are covered and if the sensor has sufficient energy resources for this setting. If all the targets are covered by the selected sensors in this set cover, then we set *ck* = 1. Otherwise, forming the current set cover was unsuccessful, *ck* = 0, and all of set *k*'s members are removed (*xikp* = 0 for any *i* = 1..*N* and *p* = 1..*P*).

The complication of this procedure is controlled by the linear programming solver, where *n* is the number of variables. In our case *n* = *K* (1 + *NP*), where *P* usually a small number.

c) Greedy-based heuristic for OSC

The Greedy-based heuristic for OSC is executed by the base station. When the sensors are arranged, they send their coordinates to the BS, it computes the connected set-covers and broadcasts back to the scheduling sensors.

Greed based OSC:

1.Set residual energy of each sensor u to E′u ← E
2: SENSORS ← {(s1,E′1), . . . , (sN,E′N)}
3: h ← 0
4: while the sensors in SENSORS are connected and cover all the targets do
5: /* a new set Ch will be formed */
6: h ← h + 1; Sh ← _; Rh ← _
7: TARGETS ← {r1, r2, . . . , rM}
8: while TARGETS 6= 0 do
9: /* more targets have to be covered */
10: find a critical target rcritical ∈ TARGETS
11: select a sensor su ∈ SENSORS with greatest contribution that covers r critical and has Eu ≥ E1 + E2
12: Sh ← Sh ∪ {su}
13: for all targets rj ∈ TARGETS do
14: if rj is covered by su then
15: TARGETS ← TARGETS − rj

```
16: end if
17: end for
18: end while
19: apply Breadth-First Search (BFS) algorithm starting from the BS
20: the BFS tree such that to sustain paths from the BS to each sensor in Sh
21: for all sensors su in the resulted BFS subtree with su /∈ Sh do
22: Rh ← Rh ∪ {su}
23: end for
24: for all sensors su ∈ Sh ∪ Rh do
25: if su ∈ Sh then
26: E′u ← E′u − (E1 + E2)
27: end if
28: if su ∈ Rh then
29: E′u ← E′u − E2
30: end if
31: if E′u < E2 then
32: SENSORS ← SENSORS − su
33: end if
34: end for
35: end while
36: return h-number of connected set covers and the connected set-covers (S1,R1), (S2,R2), . . . , (Sh,Rh).
```

The set covers build by the heuristic recursive, in lines 4 to 34. The enduring energy of every single sensor is set initially to E. Everyone connected set cover relates to a round that will be active for and thus an active sensing sensor consumes E1 + E2 energy, although a relay sensor consumes E2 energy per round. The set SENSORS maintain the set of sensors that must be at least E2 energy left, and can therefore contribute in additional set covers.

As like with OSC, we note with Sh (Rh) the set containing the sensing sensors in the current set-cover h. We first build the sensing sensor set Sh, in lines 8 to 18 and then the relay sensor set Rh in lines 19 to 23. The set TARGETS contain the targets that still have to be covered by the current set h. At all step, a critical target is selected, in line 10, to be covered.

This is an example for the target most densely covered, both in terms of number of sensors as well as with regard to the enduring energy of those sensors. The sensors considered for sensing have to be in the set SENSORS and to have at least E1+E2 residual energy. Once the critical target has been selected, the heuristic selects the sensor with the maximum contribution that covers the critical target. Various sensor contribution functions can be defined. For example we can consider a sensor to have greater contribution if it covers a larger number of uncovered targets and if it has more residual energy available. Once a sensor has been selected, it is added to the current set cover in line 12, and all additionally covered targets are removed from the TARGETS set. After all the targets have been covered, we need to guarantee BS connectivity.

d) Distributed and localized heuristic for OSC

In this section we process the distributed and localized for OSC, we discuss to a resolution process at each node that makes use of only data for a neighborhood within a constant number of hops. A distributed and localized algorithm is desirable in wireless sensor networks since it adapts better to dynamic and large topologies. The distributed greedy algorithm goes in rounds. Every round initiates with an initialization phase, in which sensors checks whether they will be in an active or sleep mode throughout the current round. The initialization phases proceeds *W* time, where *W* is far less than the duration of a round.

Every sensor sustains a waiting time, after that it decides its status (sleep or active) and its sensing range, and then it broadcasts the list of targets it covers to its one-hop neighbors. The waiting time of each sensor *si* depends on *si*'s contribution, and is set up initially to $Wi = (1 - BiP/B\max) \times W$ where $B\max$ is the largest possible contribution, defined as $Bmax = M/e1$, where *M* is the number of targets. The waiting time can change during the initialization phase, when broadcast messages are received from neighbors.

If a sensor *si* gets a broadcast message from one of its neighbors, at that time *si* updates the set of uncovered targets *TiP* and sets up its sensing range to the smallest value *ru* needed to cover this set of targets. The sensor contribution value is also updated to *Biu*. If all *si*'s targets are already covered by its neighbors, then *si* sets up its sensing range to $r0 = 0$. The waiting time *Wi* of the sensor *si* is as well updated to $(1 - Biu/B\max) \times W$. At the end of its waiting time, a sensor broadcasts its status (active or sleep) as well as the list of targets it covers.

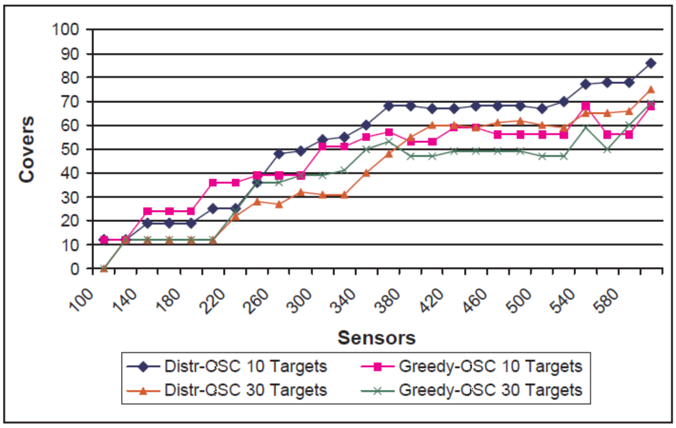
If a sensing range is $r0$ then this sensor node will be in the sleep mode, otherwise it will be active during this round. As unlike sensors have dissimilar waiting times, this serializes the sensors broadcasts in their local neighborhood and contributes priority to the sensors with advanced contribution. These sensors decide their status and broadcast their target coverage information first. In this algorithm we use a distinct time window, where the length of the time slot is d. Therefore, the time window W has $W\ d$ time units. The waiting timing of the two sensor si and sj are too close, i.e. $|Wi - Wj| < d$, then the sensors neighbors to both si and sj cannot tell from whom the message was received, thus they will not update their uncovered target set. We assume sensor nodes are synchronized and the protocol starts by having the base station (BS) broadcast a start message. If, after the initialization phase, a sensor si cannot cover one of the targets in the set TiP and its waiting time reached the value zero, then si sends this failure information to BS. In our algorithm, we measure the network lifetime as the time until BS detects the first failure. Next we present the Distributed Initialization, that is run by each sensor si, $i = 1...N$ during the initialization phase

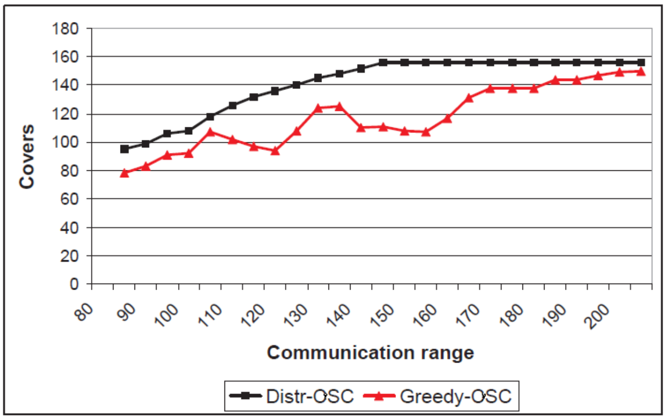
Distributed Initialization:

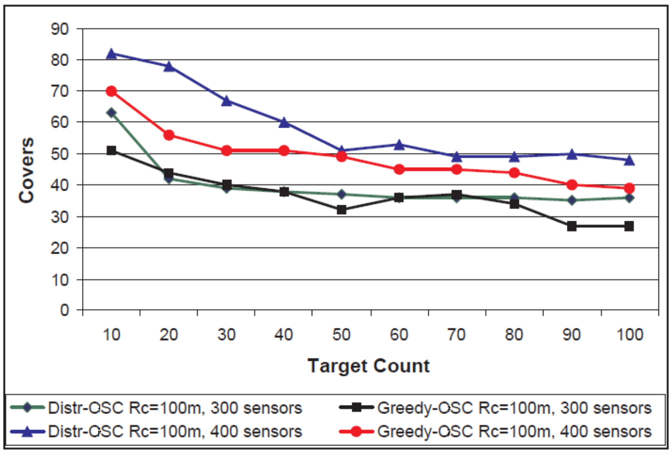
compute the waiting time Wi and start timer t
while $t \le Wi$ and TiP _= $\emptyset$ do
if message from neighbor sensor is received then
update TiP and set-up the sensing range to the smallest value ru needed to cover TiP
if $TiP == 0$ then
set si's sensing range to $r0$
break
end if
update si's contribution to Biu
update the waiting time Wi to $(1 – Biu/B\max) \times W$
end if
end while
/* assume si's sensing range was set up to ru */
if $ru == r0$ then
si broadcasts its sleep state decision
return
end if
if $Ei < eu$ then
si reports failure to BS, indicating the targets it cannot cover due to the energy constraints
end if
si broadcasts information about the set of targets Tiu it will monitor during this round
return

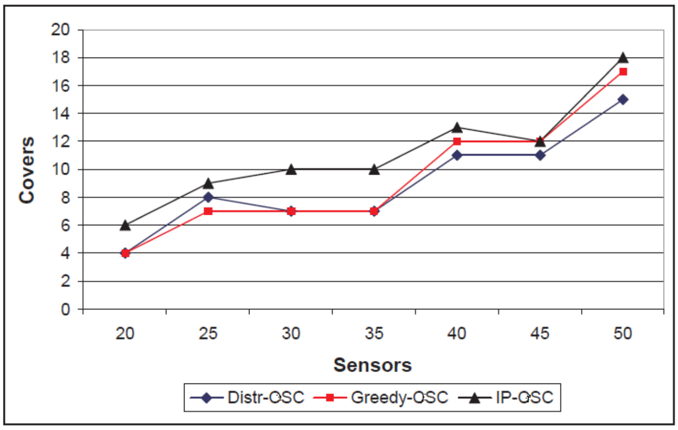
The complexity of the Distributed Initialization procedure is $O\ (Wd/\ NMP)$. This corresponds to the case when si receives messages from N neighbors, each d time. The updates for each message take $O(MP)$.

VI. Simulation Results









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