OPTIMIZED TASK ALLOCATION IN SENSOR NETWORKS

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ABSTRACT

In this paper we propose an approach for optimization of energy consumption in sensor networks. Compared to existing approaches the proposed approach takes into account the energy for data communication between nodes in task allocation. In the proposed approach firstly the tasks are allocated to sensor nodes by DPSO Algorithm, while the cost function including network constraint is optimum. Performed simulation result that the proposed approach causes reduction in energy consumption, as well as increasing sensor network lifetime.

KEYWORDS

Cost function, Energy consumption, Sensor networks, task allocation.

1. INTRODUCTION

Although wireless sensor nodes have existed for decades and used for applications as diverse as earthquake measurements to warfare, the modern development of small sensor nodes dates back to the 1998 Smartdust project [1] and the NASA Sensor Webs Project [2] One of the objectives of the Smartdust project was to create autonomous sensing and communication within a cubic millimeter of space. Though this project ended early on, it led to many more research projects. They include major research centres in Berkeley NEST [3] and CENS. [4]

Sensor networks are new type of data collection systems that consist of a lot of small sensor [5]. Each sensor node really is Microprocessor and small network that supplied by a battery. In general, each node combines three components: sensing unit, data processor and communication unit. This is an integrated system with low power consumption. The main idea of sensor networks is collecting high quality information in specified areas such as inaccessible areas, dangerous areas for human such as place of dangerous residual materials, military areas and generally where information collecting is impossible with existing technologies.

Each sensor node measures necessary parameters from around area and communicate it's with radio sender through electrical signal. Processing of this signal extracts specification such as object placement or around events. Sensor networks application commonly stereotyping into military and unmilitary. Military such as enemy taking, etc and unmilitary such as critical management, traffic control, etc.

Important problem in sensor networks is low capacity of its battery that reduces with computations and communications. A method for reducing power consumption is optimized task allocation.

This paper consists of: structure of sensor node (section 2.1), related work (section 2.2), proposed approach (section 3), simulation (section 4), results and conclusion.

1.1. Structure of sensor node

Figure 1 shows modular structure of each multi sensing sensor node. Each sensor node consists of: multi sensing interface and A/D (for sensing corresponding analog area such as pressure, temperature …), memory, CPU, RF and controller.

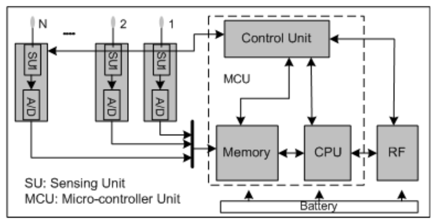

Figure 1. Sensor node structure with multiple sensing units

Each component of sensor node can work in different states. If each node consists of N components with M_i states it can has $\Pi_i^n (M_i)$ states but in practice all of these states not used. Eight states of these states are used in scheduling algorithm that they are shown in table I [6]. These states are arranged as decreasing by power consumption.

Table 1. Eight valid states of a sensor node arranged in the decreasing order of power consumption

State	Sensor	RF	CPU	Memory
S_1	On	Tr-Rx	Active	On
S_2	On	Rx	Idle	Off
S_3	On	Rx	Sleep	Off
S_4	On	Off	Sleep	Off
S_5	Off	Tr-Rx	Active	Off
S_6	Off	Rx	Idle	Off
S_7	Off	Rx	Sleep	Off
S_8	Off	Off	Sleep	Off

2. Related work

In [7] Tasks are allocated to gateways a way that maximizes the life of these cluster-heads and eventually the whole network. This work didn't consider all nodes except gateway of clusters. In [8] energy-balanced allocation of a real-time application onto a single-hop cluster of homogeneous sensor nodes connected with multiple wireless channels was proposed.

3. Proposed approach

3.1. Task allocation

There are many tasks, should be assign to sensor nodes in network, that executing of these tasks consume energy of networks as follow minimum network lifetime. Consumption energy is specified by a cost function. Cost function is defined as user application tends.

3.2. Sensor networks presentation

$$\text{Cost function} = \sum_{\forall i} E_{comp}(i) + \sum_{\forall (u,v)} E_{comm}(u,v) + penalty$$

Each sensor networks is presented as a weighted graph, for example Figure 2 In this graph each node is a sensor node an each edge is a path between to sensor nodes.

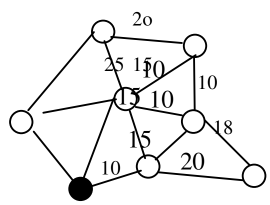

Figure 2. Sensor network Graph

3.3 Cost Function

$E_{comp}(i)$: consumption energy for executing task i.
n: sensor node n.
$E_{com}(u,v)$: consumption energy for transfer data from node u to node v.
that is depends on distance between u and v, and this depends to network, MAC protocols and hardware constraints.
Penalty: if violation (i.e. assigned many tasks to a node) is occurred it's valued to ∞ to protects from violation.

3.4. Task allocation algorithm

Task allocation algorithm centrally runs and should minimum above cost function. Propose an algorithm that assigns the task to nodes in a sensor network (represented as a graph) while satisfy above cost function has very large search space; on the other hands the task allocation is a NP-Complete problem. We have used a particle swarm optimization for task allocation in sensor networks. The goal of allocation is to minimize the cost function as result increasing network lifetime. Task allocation model is an integer program with an equation that includes cost function with integer coefficients (Equation 1).

Min Cost function = $\sum_{i=1}^{n}\sum_{j=1}^{m} ec_{ij}a_{ij} + \sum_{i=1}^{n-1}\sum_{k=i+1}^{m} cc_{ik}a_{ij}(1-\sum_{j=1}^{m} a_{ij}a_{kj})$ (Equation 1)

$\sum_{j=1}^{t} a_{ij} = 1,2,3,\ldots,n$ (Equation 2)

a_{ij} (0,1) (Equation 3)

Equation 2 states that each task should be allocated to exactly one sensor node. Equation 3 states that a_{ij} is binary variable.

Now, we want to design particle to present a sequence of tasks in sensor networks that is represented by a weighted graph. In my approach solutions are encoded as n × m matrixes, called position matrix, in which m is the number of available sensor nodes at the time of allocation and n is the number of tasks. The position matrix of each particle has the two following properties:

1) All the elements of the matrices have either the value of 0 or 1. In other words, if X_{id} is the position matrix of i-th particles in a d-dimensional space, then:
X_{id} (0,1)
2) In each row of these matrices only one element is 1 and others are 0.

In position matrix each row represents a task allocation and each column represents allocated tasks in a processor. Velocity V_{id} of each particle is considered as a n×m matrix whose elements are in range$[-V_{max}, V_{max}]$. Also Pbest and nbest are n×m matrices and their elements are 0 or 1 as position matrices. P_{id} represents the best position that i-th particle has visited since the first time step and P_{gd} represents the best position that i-th particle and its neighbors have visited from the beginning of the algorithm. In this paper we used star neighborhood topology for P_{gd} . In each time step P_{id} and P_{gd} should be updated:

$$V_{id}^{new} = weight \times V_{id}^{old} + C_1 \times rand_1 \times (P_{id} - X_{id}) + C_2 \times rand_2 \times (P_{gd} - X_{id})$$ (Equation 4)

$$X_{id}^{new}(n,m) = \begin{cases} 1 & if\ V_{id}^{new}(n,m) = max\{V_{id}^{new}(n,m)\} \\ 0 & otherwise \end{cases}$$ (Equation 5)

In (4) $V_{id}^{new}(n,m)$ is the element in n-th row and m-th column of the i-th velocity matrix in the updated time step of the algorithm and $X_{id}^{new}(n,m)$ denotes the element in n-th row and m-th column of the i-th position matrix in the updated time step. C_1 and C_2 are positive acceleration constants which control the influence of P_{id} and P_{gd} on the search process. Also $rand_1$ and $rand_2$ are random values in range [0, 1] sampled from a uniform distribution. weight which is called inertia weight was introduced by Shi and Eberhart [9] as a mechanism to control the exploration and exploitation abilities of the swarm. Usually w starts with large values (e.g. 0.9) which decreases over time to smaller values so that in the last iteration it ends to a small value (e.g. 0.1). Equation (5) means that in each row of position matrix value 1 is assigned to the element whose corresponding element in velocity matrix has the max value in its corresponding row. If in a row of velocity matrix there is more than one element with max value, then one of these elements is selected randomly and 1 assigned to its corresponding element in the position matrix.

The pseudo code of the proposed DPSO algorithm is stated as follows:

Create and initialize a n×m -dimensional swarm with P particles

```
do{
      for (each particle i=1 to P) do
      {
        if  f(X_id) > f(P_id)
            P_id = X_id
        if  f(P_id) > f(P_gd)
            P_gd = P_id
      }
      for (each particle i=1 to P) do
    {
       update  the velocity matrix using Equation (4)
       update  the position matrix using Equation (5)
     }
  } While (stopping condition is false)
```

In commutative and associative tasks such as Min(), Max(), Sum() and Avg() at each task allocation to a node states of its neighbor nodes is given to it. Thus tis nod after finishing executing its task wait to receive data from its neighbors. Then send total result as a message. For example in Figure 3 node P3 sends its data and P1,P3 data as a message to P4 instead of sending three message. This action cause less communication in sensor networks that implies less energy consumption.

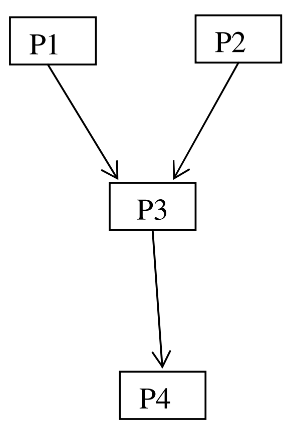

Figure 3. Data collecting from neighbour

4.Simulation

Simulation is done for a sensor network with 128 nodes in SWANS [10]. Remaining average of energy in various loads of tasks computed. This simulation consists of running:

1) Optimization of task allocation in cluster based sensor networks, 2) Proposed approach. Results curves shown in Figure 4.

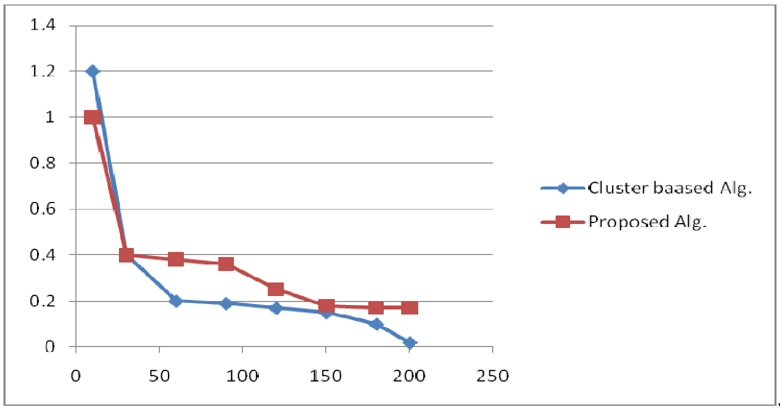

Figure 4. Remaining average of energy in various loads

5.Conclusion

With regard to Figure 4 clearly that in low loads approach 1 has lowest consumption energy but in height load proposed approach has lowest consumption energy because in proposed approach at high load a lot of nodes send one message for its data and their neighbour data instead of sending multiple message. By this technique we avoiding communication and preserve network energy.

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