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Soft Set Matrix Optimization Based Node Selection in Wireless Sensor Networks

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Abstract: The nodes in the wireless sensor networks can be scheduled for sleep and active states in order to prolong the life time. The various parameters from different layers are utilized for scheduling. It leads the optimization problem while implementing in real time. This research describes the optimization in decision theory for non convex problems. In this study, a novel methos presented to solving this type of optimization by soft set matrix method. The proposed Soft set Node matrix (SN) is finding the strong node based on cyclic and pivotal element selection methods. It is applicable to solving different parameters of the nodes without compromising the scalability issues. The numerical results are also provided for verifying the feasibility of the algorithm.

Key words: Node selection, optimization, soft set matrix, MAC protocol, wireless sensor networkss

INTRODUCTION

Wireless Sensor Networks (WSNs) are deployed by a group of the battery powered tiny sensing devices. Generally, the sensor nodes are self configuring in nature after deployment, it monitors the region of interest and conveys the sensed information to sink. Due to its limited resource constraints, it is necessary to focus the energy utilization of the sensing nodes (Giorgi, 2015; Suma and Purusothaman, 2014). Different kind of communication protocols and optimization techniques has been proposed to increase the life time of the WSNs (Ya *et al*., 2014). Lots of protocol designs were implemented with layers of Open Systems Interconnection (OSI) model. Most of the research researchs incorporated to develop the optimum routing and Medium Access Control (MAC) protocols to achieve the nodes with longer life time. The network layer is responsible to find the best effort routing path to transmitting the information from source to destination as well as the MAC layer is used to achieve congestion free communication, scheduling and effective channel utilization. The Cross Layer (CL) protocol model which contains the properties of different layers is designed to achieve the optimum performance of WSNs (He *et al*., 2012). The CL approach yields better performance metrics compared to the layers used alone. Different types of cross layer mechanisms have been developed for satisfying the user application requirements. Whenever, combining more than one layer parameters, it causes the optimization problems like convex and non convex. Most of the research of cross layer designs is not solved the optimization issues clearly and it implies some practical difficulties when considering for real time implementation. Hence, it is necessary to concentrate on the optimization problems of cross layer model (Liu *et al*., 2010). The proposed soft set node matrix (Vijayabalaji and Ramesh, 2013) is used for optimizing the nodes in the WSNs and provided the justification for the user requirement.

MATERIALS AND METHODS

Let U be the cluster (universal set) and E be the set of parameters and it will be defined as $E \subseteq U$. Let P(U) be the power set of universal set U. Soft set theory defines a matrix which is used for the decision making in complex applications. Finally, it constructs a min-max, max-min and max-max approach to solve the uncertainties. In this approach, let us define the soft set f as:

$$f : E \rightarrow P(U) \quad (1)$$

The nodes in the sensor networks can be categorized by various parameters. The particular node has selected for participating in the data transmission according to the

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network resource rudiments. In this research, the parameters of the nodes such as Queue state (Q), Residual energy (R) and received signal strength indicator (D) are taken into consideration. These parameters are used to justify whether the particular node actively participates in the current communication or not. The decision is one of the important criteria to fix the node stability.

Let A, B are the subsets of E and given as, A, B⊆E. Let us define the two functions (F, A) and (G, B) are the cartesian product as given in Eq. 2:

$$(H, A\times B) = (F, A)\times(G, B) \tag{2}$$

The subsets of (A, B) can be written as in Eq. 3:

$$A = (Q, R)\subseteq E \text{ and } B = (R, D)\subseteq E \tag{3}$$

The parameters associated with the function set A are written as:

$$F(Q) = \{n_1, n_2, n_4\} \tag{4}$$

The function F(Q) in Eq. 4 defines the nodes in the set which satisfies the condition of queue state of the individual nodes:

$$F(R) = \{n_2, n_3\} \tag{5}$$

The function F(R) in Eq. 5 defines the nodes in the set which satisfies the condition of residual energy of the individual nodes. The parameters associated with the function set B can be written in Eq. 6 and 7:

$$G(R) = \{n_1, n_4\} \tag{6}$$

$$G(D) = \{n_1, n_3\} \tag{7}$$

The Cartesian products of the subsets (A, B) can be written in Eq. 8:

$$A\times B = \{(Q, R), (Q, D), (R, R), (R, D)\} \tag{8}$$

Let H is a variable which is used to find the elements of the SN matrix and it is computed by Cartesian products of F and G and is written in Eq. 9 and 10:

$$H = F\times G \tag{9}$$

$$H = F\times G$$

$$H = \begin{cases} (Q, R), (n_1n_1)(n_1n_4)(n_2n_1)(n_2n_4)(n_4n_1)(n_4n_4) \\ (Q, D), (n_1n_1)(n_1n_3)(n_2n_1)(n_2n_3)(n_4n_1)(n_4n_3) \\ (R, R), (n_2n_1)(n_2n_4)(n_3n_1)(n_3n_4) \\ (R, D), (n_2n_1)(n_2n_3)(n_3n_1)(n_3n_3) \end{cases} \tag{10}$$

The rows of the matrix define the number of nodes and the column defines the product of elements of (A, B). It uses the characteristics of the soft set decision making algorithm.

Elements selection: The cyclic nodes from H are selected as row elements for matrix formulation. The row elements of the SN matrix are {(Q, R), (Q, D), (R, R), (R, D)} and the column of the matrix are $\{n_1, n_2, n_3, n_4\}$.

Let, n is the number of elements = 4 and p is product of the number of elements in A and B = 2×2 = 4, Hence, the 4×4 matrix (p×n) is computed as:

$$SN = \begin{bmatrix} n_1n_1 & n_1n_1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & n_3n_3 \\ n_4n_4 & 0 & 0 & 0 \end{bmatrix}$$

In the SN matrix, the node n_1 satisfies the parameters (Q, R) and (Q, D). The node n_3 satisfies the parameter (Q, D) hence, the cyclic codes are assigned to one. The parameter (R, R) cannot have the cyclic codes hence, it is assigned to zero. So, the above matrix can rewrite as:

$$SN = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix}$$

In SN matrix, the elements processing criteria are in the order of row and column. The selection can be made up of three cases, namely, max-min, min-max and max-max. The three cases should always provide dual solutions (minimization and maximization). In case one, the row selects the max value. It selects the node n_1 as max and it cannot be minimized. Hence, the case one is not satisfies the duality principle. In case two, the row selects the node n_2 as min value and all other elements of matrix SN is zero. Hence, it cannot provide the desirable result. In case three, the row selects the node n_1 as max value as well as the column also selects node n_1 as max. Hence, the case, three provides the desirable justification and also satisfies the duality principle. According to the max-max approach, the node n_1 is chosen as an intended node for participating in current transmission.

The same result can be obtained by using the selection of pivotal element as an intersection of rows and columns in the matrix. The pivotal element of the SN matrix is concluded as the intended node. The intersection point denotes the pivotal element (n_1) in Eq. 11. Hence, the node n_1 justified as the resultant node. Intersection point of pivotal element:

$$SN = \begin{bmatrix} 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix} \quad (11)$$

Extension: For sake of the convenience, only the three parameters of the nodes are taken for consideration. But this method can further be extended to any number of nodes (n, m as well as any number of parameters (p_n). The number of nodes in the network is $\{n_1, n_2, n_3, ... n_m\}$ and $B = \{p_1, p_2, p_3, ... p_n\}$. The generalized form of SN is given in matrix form as:

$$m \times n = \begin{vmatrix} n_1 n_1, p_1 & n_1 n_1, p_2 & \cdots & n_1 n_1, p_n \\ \vdots & \ddots & & \vdots \\ n_m n_m, p_1 & n_m n_m, p_2 & \cdots & n_m n_m, p_n \end{vmatrix}$$

RESULTS AND DISCUSSION

Numerical verification: The sample values of parameters Q, D and R to the nodes n_1, n_2, n_3, n_4 are as in Table 1. In Table 1, it is obtained the max-max value as 85. The node n_4 is the optimum one by using max-max criterion of decision theory according to R but it allows a single parameter (residual energy) only.

In the modified decision theory, the proposed algorithm allows multiple parameters to find the desirable node (Table 2).

$$n_1 n_1 \frac{(65+75)}{2} = \frac{140}{2} = 70$$

In soft matrix, it should be in [0, 1]. Hence, it can be taken in terms of percentage as 0.7 for (Q, R):

$$(n_4 n_4) = \frac{75+85}{2} = \frac{160}{2} = 80;\ 0.8 \text{for}(Q,R)$$

$$(n_1 n_1) = \frac{65+75}{2} = \frac{140}{2} = 70;\ 0.7 \text{for}(Q,D)$$

$$(n_3 n_3) = \frac{75+80}{2} = \frac{155}{2} = 73;\ 0.73 \text{for}(R,D)$$

$$(Q,R),(Q,D),(R,R),(R,D)$$

Table 1: Parameter values to nodes by decision theory

Parameters	n_1	n_2	n_3	n_4
Q	65	45	50	75
D	75	60	75	60
R	75	75	80	85
Max	75	75	80	85

Table 2: Parameter values to nodes by the proposed method

Parameters	Q	D	R
n_1	65	75	75
n_2	45	60	75
n_3	50	75	80
n_4	75	60	85

$$SN = \begin{bmatrix} 0.7 & 0.7 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.73 \\ 0.8 & 0 & 0 & 0 \end{bmatrix}$$

In the matrix SN, the row max value is 0.7, 0.7 in n_1 and the column max value is 0.7, 0.8 in n_4. Its intersection point intimates the optimum node as n_1:

$$\begin{matrix} & (Q,R),(Q,D),(R,R),(R,D) \\ \begin{matrix} n_1 \\ n_2 \\ n_3 \\ n_4 \end{matrix} & \begin{bmatrix} 0.7 & 0.7 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0.73 \\ 0.8 & 0 & 0 & 0 \end{bmatrix} \end{matrix}$$

The node n_1 is most efficient one for (Q, D), the node n_3 is most efficient for (R, D) and the node n_4 is most optimum for (Q, R). But, the node n_1 is a desirable node for the parameters (Q, R, D). Hence, the node n_1 is concluded as intended one via which the active communication is happening.

CONCLUSION

This proposed research verifies the node's parameters of the WSNs and chooses the best nodes to participate in the current transmission. The algorithm formulates the SN matrix to find the desirable node. The generalized matrix is also defined for multiple nodes and parameters analysis. In this SN matrix method, the desirable node selection can be obtained by cyclic and the pivotal element method. It is shown that the theoretical and numerical analysis is proved for justification of the results.

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