AN INCENTIVE BASED SCORING MECHANISM FOR SELFISH NODE MANAGEMENT IN WIRELESS SENSOR NETWORKS

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Abstract - Selfish nodes in a Wireless Sensor Network (WSN) can greatly degrade the performance of all nodes by blocking routes and unbalancing data forwarding load on network nodes. The nodes' selfishness in a wireless network can be addressed by reputation based or credit-incentive based mechanisms. The credit-incentive based mechanisms are said to be more effective as such are used for stimulation of nodes rather than blockage of targeted nodes. In this paper a new scoring technique is introduced to develop an incentive based mechanism. Various features of network nodes are considered while defining a scoring technique which is further used for data transfer among multi-hops in the network. The primary concern of incentive based mechanism is to stimulated the network nodes for cooperation with one another. Initial analysis show that the mechanism is effective and can be incorporated in any WSN for handling selfish nodes in the network.

Index Terms - WSN, Routing, Incentive based, Selfish nodes, Wireless Sensor Networks, Node Stimulation.

I. INTRODUCTION

Recent development in electronics technologies and ad hoc wireless communication have enabled the adoption of low-cost, small and low-powered wirelessly interconnected sensing devices. These devices are referred as sensor nodes. A Wireless Sensor Network (WSN) is a network of many sensor nodes. In WSNs nodes sense data from the environment and then transmit it to a central station called BS. The nodes in WSNs cooperate with one another during the data transmission. This is done by giving relaying services for data transmission to source node towards BS. This technique is called multi-hop communication [1].

The sensor nodes typically operate on a limited set of configurations. Such nodes use small and restricted amount of battery power and processing and communication capabilities. Most of the researches focus on the extension of network life in term of reducing the energy consumption level of nodes [2]. It is always desired to develop energy-efficient, low-sot and easy to implement algorithms in such networks. The management, placement and density of nodes depend upon the application of WSN for which it is deployed. During communication usually nodes consume more on data forwarding services than sensing and initiating own data for transmission [3].

In WSNs, the nodes coordinate and cooperate in such networks to achieve their fundamental objectives. Nodes while cooperating with others, consume their own considerable power. They can preserve their energies if they do not offer any relaying service to others. Such act can be considered as very beneficial for an individual node but in return this can greatly affect the overall performance of the entire network [4]. Such nodes are called non-cooperative or selfish nodes. These nodes don't care about then network and try to extend their lives up to a peak. The selfishness of nodes in a network can greatly degrade its performance by reducing the number of alternate routes, replicating transfer attempts and taking relying services from few nodes only. Moreover, the placement of such nodes also has intensive impact. For example, selfish node laying near with the BS will have higher impact than those which are placed at the network borders.

The probability of packet dropping can be mapped with the existence of selfish nodes. A selfish node can take this ratio to the peak i.e. 100 %. However, this packet dropping ratio decreases with the rise in number of network nodes in a specific area in the network. It is also possible that some nodes rationally change their selfishness level according to their energy consumption rate per time [5]. Such nodes make a tradeoff between their own energies and the network relaying requirements. Various techniques can be used for selfish node management in WSNs. The most popular technique is to stimulate all the network node by offering some incentives. The incentives can be some scores or virtual currency. The foremost theme of such technique is to incorporate a buy and sell or a bargaining sort of mechanism for data forwarding service in a network. This type of technique is assumed more effective by may researches [6].

The main objective of this work is to introduce an incentive based mechanism for nodes' stimulation in a WSN. The nodes can be rewarded with some amount of values referred as scores by the BS upon getting data. Each node maintains and needs to transfer some scores to the relaying nodes for their services. While the relaying nodes also gain scores by involving themselves in a data forwarding session. The scoring mechanism can be defined by considering some key features of nodes. Each node can set its own demanding score according its features and selfishness level. This scheme also enhances the energy consumption by load balancing and adaptive data communication among the

nodes. Nodes having higher selfishness levels will always give higher demands for relaying service and in return will not be able to gain any score from other networks. Nodes having less or no score will not be able to transfer their own data. For this purpose, they will reduce their selfishness levels, so that they may adjust addressable demanding scores for other nodes.

The rest of the article is prepared as follows: in section 2 related work is given. In section 3 the proposed mechanism is given. This section is further divided into some subsections. Section 4 explains the simulation results. The conclusion along with future work are given in the last section.

II. RELATED WORK

A considerable work has been done for handling non-cooperative nodes in a wireless network. Two types of techniques can be used for this purpose. The first type of technique is repudiation based. In such techniques the network nodes are monitored and treated accordingly. The selfish nodes are punished by blacklisting them in the entire network [7]. The second type is to implement a credit-based incentive scheme for all the network nodes. The nodes use some values usually referred as virtual currency during the data transmission towards the BS [8].

The authors in [6] introduce an incentive based mechanism for a dense WSN for stimulation of nodes for packet forwarding. The forwarders are rationally chosen in this technique. For each forwarding operation nodes get credit points as incentives. The credit points are used to get relaying services for data transmission. Another article, [9] proposes a pricing mechanism for optimal route selection in WSNs. A game theoretic approach is used to enhance network performance by enhancing load distribution and path selection process. H. Zhou [10] in his work devised some models for bandwidth allocation in WSNs. An auction theory has been proposed to handle selfishness in the networks. The selfish nodes follow an algorithm and report their information correctly. Auctions are developed for bandwidth allocation. These auctions are addressed with payments by network nodes.

In an article [11] a utility function is presented to punish and stimulate selfish nodes. Initially a Nash equilibrium is given to a set of two nodes. Which is later extended to a scenario of multiple nodes. With this function each node is evaluated by considering it cooperation level. Game theory is also incorporated in this work to formalize the whole mechanism.

Some authors also addressed selfish node management in Mobile Ad hoc Networks (MANETs) like Samal et.al [12]. In this work protection against Sybil attack is considered while detecting selfish nodes and blocking them during the data transmission in the network. The authors claim that the selfishness can be decreased and the network performance can be enhanced by using their scheme in MANETs.

Some authors [13] proposed a technique based on game theory along with an incentive based mechanism. Incentives are given to the forwarding nodes for their cooperative effort in the network. The work also focuses on the rise in the reliability in network nodes. This scheme is mainly proposed for delay tolerant and vehicular networks.

III. THE PROPOSED MECHANISM

The main objective of this proposed work is to design a scoring mechanism in which all the nodes earn and then exchange scores for data communication in the network. Initially, the scores are generated as token scores by the BS for each data transfer from a source node. Each initiating node is assigned a calculated amount of token score. The token score is calculated by considering the source nodes' features. A source node maintains his score and pays the forwarding node with an amount of score. It is not necessary that the token score received must be same or greater than the score required for forwarding nodes. For this purpose, the source node tries to earn scores by providing relaying services to other nodes too. Using this scoring mechanism selfish nodes are stimulated to cooperate in the data communication in a network.

This section is further divided into features formalization, information sharing mechanism, token scoring, nodes' demanding scores, routes' demanding scores, adjustment facility from the BS, and relay selection technique.

A. Features Formation

It is assumed that all nodes try to transmit their own data on priority bases. Each node can be denoted by a unique number i. The nodes will also be able to store and process additional scoring values along fundamental routing information. In this work, the key features of each node i are considered: i.e. energy, routes' importance, nodes' hop-level, individual importance and selfishness level.

The energy if a node i can be denoted as E(i). This value can be used to determine the remaining energy amount of a node.

The route adoption is based on the scoring technique in this work. However, this feature is preliminary used for formation of scores. Optimal routes can be calculated by taking the following:

$$OpR(i) = max\left[\frac{\sum_{j=1}^{l} E(j)}{\sum_{j=1}^{l} HopLevel\,(j)}\right] \qquad (1)$$

In Eq.1 the optimal route for a node i is calculated by considering the energies of all the involved nodes along with their hop levels in the routes. In a single route, we may have a set the nodes $j = \{1,2,3, \ldots l\}$. According to the equation the energies and hop-levels of all these nodes are considered.

The network is divided into hierarchical levels referred as hop-levels. Each node is given a hop-level according

to its placement in the network. The immediate nodes with BS are given hop-levels equal to 1. While at maximum possible hop-level for a node can be equal to the total number of all nodes.

$$1 \leq Hop(i) \leq n \quad (2)$$

All the nodes in our work are self-regulating so that then may optimally utilize their resources. For this purpose, they are given authority to rationally operate on their own selfishness levels. $Sel(i)$ is used to denote the selfishness level of node i. The greater value of selfishness takes to likelihood of having intention to not participate in the forwarding operation by demanding a higher value of score. Nodes keep their energy preserved by setting this value at higher peak but in return they gain less score and cannot transmit their own data towards the BS.

B. Information Sharing Mechanism

The work is influenced by Two base protocols, DSR and OLSR. These protocols are used for fundamental routing and information exchange purposes. Since in DSR protocol, the routing information is made by taking a list of all the involved nodes with each route. Therefore, it would be much feasible for a BS to have an audit of a data transmission session. Additionally, the scoring mechanism can be easily implemented by using OLSR control packet messaging mechanism.

C. Token Scores

The BS gives a token score to each source node on reception of sensed data. This token is then added to the maintained scores of a source node. This score is calculated by considering node i's energy, hop-level and optimal route. A ratio of the number of upper-hop to the number of lower hop level node (UL) is also used in the equation.

$$Token(i) = \frac{Hop(i) \times OpR(i)}{E(i)} \times UL(i) \quad (3)$$

D. Nodes' Demanding Scores

Each node demands some score for offering its relaying services to a source node. This score can be set by taking the energy, hop-level, and nodes' selfishness level. Additionally, the number of closed neighbors, cn, is also used to put the impact of competing nodes at a certain location in the network. The equation for nodes' demanding scores is given below:

$$Dem(i) = \frac{Hop(i) \times Sel(i)}{cn \times E(i)} \quad (4)$$

E. Routes' Demanding Scores

A single route from the source to BS may have a finite number of nodes. To calculate a route's demanding score we consider the sum of Dem values of all involved nodes in the route. This demanding score can be calculated by using eq. 5 as below:

$$RoD(i) = Dem(j) + \omega(j) \quad (5)$$

It is obvious that each relay node depends on other up level forwarding nodes. $\omega(j)$ is used to show the sum of each possible involved forwarder node in the route. The node selection is made by taking the smallest vale of bargaining score in a similar level. $\omega(j)$ can be explained with the help of eq. 6.

$$\omega(j) = MIN\,[Dem\,(j-1) + \omega(j-1)] \quad (6)$$

ω is a recurrent term and at each setup the minimum value of ω is taken. In each iteration the value of upper level is considered until the most immediate nodes to the BS is reached.

F. Scoring Adjustment Facility

It is possible that some nodes enjoy a direct connection with the BS. Such nodes, hop-level one nodes, usually don't need any forwarder for their data transmission. So it is obvious that such nodes will not try to increase their scores by offering others the relaying services. To overcome this issue, the BS adaptively apply a base demand on some nodes. This demand score can be directly deducted by the BS. We can modify the equation of route demanding score by add a new term for base demand.

$$RoD(i) = BaseDem + Dem(j) + \omega(j) \quad (7)$$

The value of $BaseDem$ not fixed for all nodes. It is rationally set according to the network type, placement and hop-levels of nodes. Usually this value is kept zero for nodes having hop-level greater than one.

It is also possible that some nodes keep a vital role in the network. Some routes may keep fewer or only one node at a hop-level. Presence of such nodes are considered very important in the network.

Individual importance of node i can be obtained by taking the level of nodes' density with their energies at the location where it is placed. A set of closed neighbors is calculated for this purpose. This set can be calculated by using a simple distance formula.

$$D(i,j) = \sqrt{(x(i) - x(j))^2 - (y(i) - y(j))^2} \quad (8)$$

The distance between two nodes i and j can be taken by using eq. 8 in which the coordinates x and y of both nodes are used. After getting the distances, we can compare these with a predefined threshold distance to get a set of closed neighbors as shown in eq. 9

$$CN(i) = \{j : D(i,j) \leq D(tr)\} \quad (9)$$

Importance of each node i is further obtained by taking its energy and the sum of energies of its closed neighbors multiplied with their number cn as shown in eq. 10.

$$Imp(i) = \frac{E(i)}{cn \sum_{j=1}^{m} CN.E(j)} \quad (10)$$

The BS adjusts the load on such nodes by monitoring their gained scores and traffic.

G. Relay Selection Technique

As stated, the BS primarily assigns a $Token$ for to the data initiating node. The nodes add the earned $Token$ scores with their existing scores. For transmission, the initiator node broadcasts a route request (RREQ) packet to its upper hop neighbors. The neighbors upon receiving RREQ, generate a route reply (RREP) piggybacked with their own Dem to the source node. Then requesting node chooses a relaying node having

the least Dem. If a node is not able to pay any of the forwarders, then it repeats the same procedure by contacting it siblings in the same hop level. Nodes having smaller scores usually can't select any forwarder. For this purpose, such nodes decline their selfishness level. Once the selfishness value is reduced then such nodes can easily gain scores by making a deal for forwarding data.

IV. SIMULATION ANALYSIS

The proposed work has been simulated in MATLAB 2012 under MS Windows. A test run is made by deploying a set of hundred nodes in an area of 500x500 meters. The transmission range is set to 50 meters for each node. While the distance for closed neighbors' calculation is made 30 meters. Primarily, all the nodes are given some random values of selfishness. Finally, a test run is performed by taking a random number of data transmission for each node. The following values are extracted from the execution.

I	*E*	*c*	*Sel*	*UL*	*H*	*OpR*	*Token*	
1	39.08	1	66.238	2/3	4	35.397	2.415	3.397
2	87.19	7	53.566	2/9	3	58.836	0.449	0.230
3	61.60	0	69.474	4/1	9	13.131	3.837	5.075
4	0	5	28.579	2/2	3	14.292	0	0
5	8.75	4	10.592	6/4	2	90.273	30.92	0.483
6	70.03	2	76.389	2/3	4	27.348	1.041	1.454

The simulation results show that the token values are influenced by values of E, Hop, OpR and UL. Nodes having higher energy, e.g. ID=2, is given relatively lower $Token$ by the BS. Node 5 is given then maximum value of $Token$ due to its least energy level. It is because the BS wants to facilitate node having very low energy levels. Energy of node 3 greater than node 1. But the assigned $Token$ to node 3 is greater. It is because of the hop level consideration. Similarly, the demand score Dem is adjusted according to the nodes' Hop, Sel, cn, and E. According to results, the nodes having higher values of selfishness and hop-level are demanding more. Moreover, the energy level and number of closed neighbors of a node have inverse relationship with its demanding score.

This simulation can be further expanded by comparing our proposed work with some other incentive based mechanisms.

CONCLUSION

Various incentive based techniques for handling selfish nodes in wireless networks have been introduced. In our work we proposed a new scoring mechanism which is based on consideration of nodes' prevailing features. Additionally, a scores adjustment technique is also added to address the exceptional cases in this technique. Nodes are treated adoptively by considering their features along with their individual importance in the network. For calculating each node's importance, the density of its closed neighbors at predefined range in the network are considered. The initial analysis showed that the work could perform well and could be implemented properly. Further work can be done by enhancing the usage of nodes features and the work can be well simulated by comparing it with other research protocols

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