Threshold Analysis Method using Threshold based Congestion Control Protocol in Wireless Sensor Networks for Node Optimization

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Abstract - Applying real time applications in Wireless Sensor Networks (WSNs) requires certain delay and bandwidth which pose more challenges in the design of networking protocols. In this paper, we present a simulation of several current WSN motes, compared and contrasted under a number of different parameters using Threshold Adaptation Method (TAM). These parameters range from physical characteristics such as size, weight and battery life to electrical specifications for the microprocessor and radio transceiver employed in the respective mote architectures, including processing ability, expected lifetime and measurement capabilities. By using TAM we can achieve effective data transmission with minimum delay, negligent packet loss and maximum throughput.

Keywords*- WSN, QoS, Threshold Adaptation Method, Threshold based Congestion Control Protocol, SNR.*

I. INTRODUCTION

In the past 10 years, wireless sensor networks have grown from a theoretical concept to a burgeoning modren technology. Technologies are many but still there are many criteria uncovered. Wireless Sensor Networks (WSNs) have been widely considered as one of the most important technologies for the twenty – first century [1][2]. WSNs have unique characteristics such as denser level of node deployment, higher unreliability of sensor nodes, severe energy computation and storage constraints [3], which present many new challenges in the development and application of WSNs. A WSN generally consists of a base station that can communicate with a number of wireless sensors via a radio link. Data collected by the wireless sensor node is compressed and transmitted to the gateway directly or if required, use other wireless sensor nodes to forward data to the gateway. The transmitted data is then presented to the system by the gateway connection.

Efficient utilization of sensor's energy resources, maximizing the network lifetime were and still are the main design considerations of the protocols. The concepts of latency, throughput, packet loss, and jitter need to be concentrated in research work. For example, the data generated by a sensor network that monitors the temperature in a normal weather monitoring station are not required to be received by the processing center or the sink node within certain time limits. On the other hand, for a sensor network that used for fire detection in a forest, any sensed data that carries an indication of a fire should be reported to the processing center within certain time limits. Furthermore, the introduction of multimedia sensor networks along with the increasing interest in real time applications have made strict constraints on both delay and throughput in order to report the time-critical data (in such applications) to the processing center or sink within certain time limits and bandwidth requirements without any loss. These performance metrics (i.e. delay and bandwidth) are usually referred to as Quality of Service (QoS) requirements [4][5]. Thus QoS routing is an important topic in sensor networks research, and it has been under the focus of the research community of WSNs [6][7].

In these proposals, the unique properties of the WSNs have been taken into account. These routing techniques can be classified according to the protocol operation into negotiation based, query based, QoS based, and multi-path by applying threshold. The negotiation based protocols have the objective to eliminate the redundant data by include high level data descriptors in the message exchange. In query based protocols, the sink node initiates the communication by broadcasting a query for data over the network. The QoS based protocols allow sensor nodes to make a tradeoff between the energy consumption and some QoS metrics before delivering the data to the sink node [8]. Finally, multi-path routing protocols use multiple paths rather than a single path in order to improve the network performance in terms of reliability and robustness.

The Threshold Adaptation Method(TAM) helps in establishing multiple paths between the source-destination pair [9]. Mutli-path routing has focused on the use of multiple paths primarily for load balancing, fault tolerance, bandwidth aggregation, and reduced delay. We focus on supporting quality of service through multi-path routing using Threshold based Congestion Control Protocol (TCCP). In this paper, we propose TCCP protocol to achieve energy efficiency, QoS aware multi-path routing protocol for WSNs to recover from node failures, load balancing through splitting up the traffic across a set of available node-disjoint. Using this technique increases resiliency to path failures and increases the probability that an enough portion of the packet is received at the destination to recover the original data message without incurring excessive delay through invoking data retransmissions. TAM uses the residual energy, node available buffer size, Bandwidth and Signal-to-Noise Ratio (SNR) to predict the best next hop through the paths construction phase.

II. RELEATED WORK

1. Threshold-based AntNet

The main strategy of the standard AntNet algorithm[10] [11] is to search for better routes via launching ants that fetch for routes among the network nodes. A threshold values for travelling times between the nodes of a given road network, could be estimated or obtained [12].

2. RSSI Threshold

Received Signal Strength Indicator (RSSI) can also be used as a metric to measure the wireless link quality. Srinivasan et al [13][14] presents the facts about RSSI in estimating link quality. It is shown that packet reception rate is very good if average RSSI is above a certain threshold. According to their study if the RSSI value is less than the threshold, packet reception rate varied a lot. Bhaskaran etal [15] also analyzed the relation between RSSI variability and packet error rate. It is shown that the packet error rate is unpredictable if RSSI variability window overlaps with the threshold. If there is no RSSI window overlap with the threshold region the error rate is observed to be stable and low.

3. Transmission Power Control (TPC)

This technique improves the performance of the network in several aspects. First, power control techniques improve the reliability of a link. Upon detecting that link reliability is below a certain threshold, the MAC protocol increases the transmission power, improving the probability of successful data transmissions [16–18]. Second, only nodes which really must share the same space will contend to access the medium, decreasing the amount of collisions in the network. This enhances network utilization, lowers latency times and reduces the probability of hidden and exposed terminals [18]. Finally, by using a higher transmission power, the physical layer can use modulation and coding schemes with a higher bit/baud ratio [19][20], increasing the bandwidth in the presence of heavy workloads, or decreasing it to maximize energy savings. Above listed are only few thresholds implementing protocols like Threshold-based LEACH protocol [21].

III. DESCRIPTION OF TCCP WITH APPLIED TAM ALGORITHM

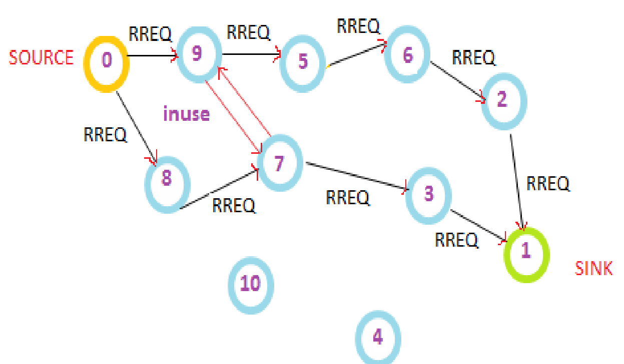


Figure 1: Example of path discovery.

TAM uses the residual energy, node available buffer size, Bandwidth and Signal-to-Noise Ratio (SNR) to predict the best next hop through the paths construction phase. By means of computer simulations, we evaluated and studied the performance of our protocol. Simulation results have shown that our protocol achieves lower average delay and higher packet delivery ratio than the other protocol. This protocols use multiple paths rather than a single path in order to improve the network performance in terms of reliability and robustness. Multi-path routing has focused on the use of multiple paths primarily for load balancing, fault tolerance, bandwidth aggregation, and reduced delay.

1. Assumption

Assuming N identical nodes are distributed randomly in the sensing filed. All nodes have the same transmission range, and have enough battery power to carry their sensing, computing, and communication activities. Each and every node in the network is assigned a unique ID and all nodes are willing to participate in communication process by forwarding data. The sensor nodes are stationery for their lifetime. At any time, we assume that each sensor node is able to compute it residual energy, and its available buffer size, bandwidth as well as record the link performance between itself and its neighboring node in terms of signal-to noise ratio (SNR). Examining recent link performance data, predications and decisions about path stability may be done.

2. Link cost function

The node uses link cost function to select the next hop during the path discovery phase. We use a cost function such as presented in [22] with some changes. Let Nx is the set of neighbors of node x. Then our cost function includes an energy factor, available buffer factor, bandwidth factor and interference factor with appropriate weights (α, β, δ and γ):

Next hop = max y ∈ Nx {αEresd, y + βBuffer, y + δBandwidth, y +γInterference, xy} (1)

Where, *Eresd, y* is the current residual energy of node *y*, where *y* ∈ *Nx*, Bbuffer, y is the available buffer size of node *y*, δBandwidth, y is the available bandwidth of node y and interference, xy is the SNR for the link between *x* and *y*.

Here total cost *(C_{total})* for a path *P* consists of a set of *K* nodes is the sum of the individual link costs *$l(xy)_i$*, i ∈ K along the path. Then we have:

$$C_{total,P} = \sum_{i=1}^{k-1} L(x,y)_i \qquad (2)$$

3. Paths Discovery Phase

With the idea of the directed diffusion [23][24], the sink node starts the multiple paths discovery phase to create a set of neighbors that able to forward data towards the sink from the source node. The constructed multi-paths are such a way that we have no common nodes except the source and the destination.

Path discovery process is done according to the following phases:

• ***Initialization phase:*** To have enough information about which of its neighbors can provide it with the highest quality

data, each sensor node maintains and updates its neighboring table during this phase. The information about the list of neighboring nodes of the sensor node will be contained in neighboring table. Figure 2 illustrates the structure of the hello message. The *link quality* field is in terms of signal-to-noise ratio (SNR) for the link between any node and its neighbor. Hop count is distance expressed in terms of hops for the message from its source.

Figure 2: Hello message structure.

• ***Primary Path discovery phase:*** After above phase each sensor node has negligible information to compute the cost function for its neighboring nodes. The sink node locally computes its preferred next hop node using the link cost function, and sends out a Route Request (RREQ) message to its most preferred next hop (figure 3 shows the structure of the RREQ message).

Through the link cost function, RREQ message sent to its next hop by the preferred next hop node of the source that locally computes its most preferred next hop in the direction of the source node, the operation continues until sink node (see figure 1).

• ***Alternative Paths discovery phase:*** The alternate path RREQ message is sent to its next most preferred neighbor for the second alternative path by the source. To avoid having recurring paths with visited node, we restrict each node to accept only one RREQ message, if received more than one RREQ message, the first RREQ message is accepted and remaining messages are rejected (see figure 1, for an example of path construction. In the example the double arrow is seen between node 9 and 7, where 9 node next preferred neighbor is it node 7. Node 9 generates RREQ message and forwards to node 7, but node 7 has been added in the primary path, then

node 7 simply responds to node 9 with an INUSE message indicating that node 7 is already added in a routing path. Then, immediately node 9 searches its neighboring table and for the next preferred neighbor, which will be node 5, and sends out RREQ message to it. The message is accepted by node 5 and the procedure is continued in the direction of the sink node).

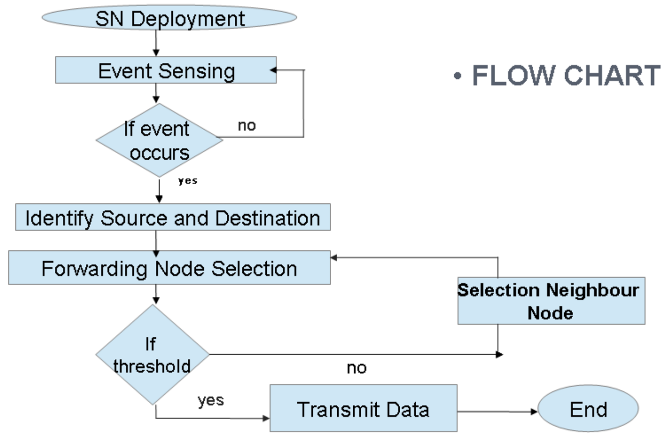
Figure 3: RREQ message structure.

Paths Selection: After the completion of paths discovery phase and the paths have been constructed, we need to select a set of paths from the N available paths to transfer the traffic from the source to the destination with a desired bound of data delivery [25]

Algorithms Phase 1 (Path selection**)**
1: Select the source node
2: Measure energy, free buffer, bandwidth, interference of each forwarded neighbor node
3: Measure the next hop using cost function using (1)
4: Find the maximum quality factor to select next neighbor**.**
5: Repeat step 2 to 4 till destination is reached.

Phase 2 (Quality of Service**)**

6: Read energy, free buffer, bandwidth, interference of each node in the path.
7: Measure the link established between every node using total cost function (2).
8: Find the quality factor greater than threshold
Qf > or < Tr
9: If node parameter is greater than threshold divert the packet to its next neighbor and repeat step 2 to 4.
10: end.



Flowchart 1: Applying TAM

IV. PERFORMNACE EVALUATION OF TCCP PROTOCOL

We discuss in this section about our simulation results for the performance study of our TCCP protocol. For our protocol we used NS-2 to implement and conduct a set of simulation experiments. Our simulation environment consists of a field of 500m x 500m containing 20 sensor nodes randomly deployed. The source node is situated at the upper right corner of the simulation field, and the sink node is situated on the left bottom corner. Table 1 shows the simulation parameters. We investigate the performance of the TCCP protocol in a multi-hop network topology and study the impact of changing throughput, packet delivery ratio, and energy consumption by changing the number of source and analyze the changes.

Table 1: Simulation parameters

Network field	500m X 500m
Number of Sensors	20
Number of Sinks/Sources	1/1
Transmission Range	25m
Packet Size (Data + Over head)	1024 bytes
Initial Battery Power	100 Joules
Sub-packet size	256 bytes
Transmit Power	15 mW
Receive Power	13 mW
Idle Power	12 mW
MAC layer	IEEE 802.11
Max Buffer Size	256 K-bytes
Buffer Threshold	1024 bytes
Simulation time	100 Seconds
Sleep mode Power	0.015 mW

It is often the case that a number of solutions exist for solving the same node optimization problem. Evaluating the performance of threshold algorithms is important for both researchers and practitioners, either when validating a new algorithm against the previous state of the art, or when choosing existing algorithms which best fit the requirements of a given WSN application. However, there is currently no agreement in the research and engineering community on the criteria and performance metrics that should be used for the evaluation and comparison of threshold algorithms.

Figure 4 shows a graph plotting the number of sensor nodes along the x- axis and throughput along the y-axis. We can observe in graph that, when the source count increases the throughput with threshold increases and that of without threshold decreases , the plotted values are as shown in the table 2 which gives the measures of throughput with and without threshold.

Table 2: Throughput measure in the network

THROUGHPUT(kbps)						
Sources(nodes)	5	10	15	20	25	30
WITHOUT-THRESHOLD	23	34	24	77	65	54
WITH-THRESHOLD	34	38	130	60	90	86

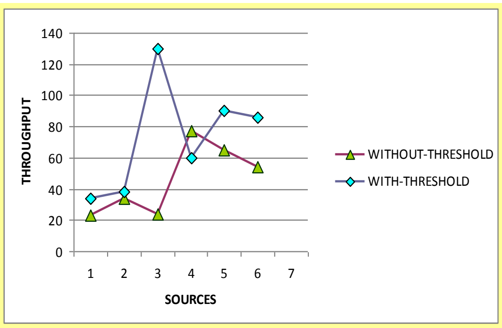


Figure 4: Throughput measure in the network

Figure 5 shows a graph plotting the number of sensor nodes along the x- axis and packet loss along the y-axis. We can observe in graph that, when the source count increases the packet loss with threshold decreases and that of without threshold increases , the plotted values are as shown in the table 3 which gives the measures of packet loss with and without threshold.

Table 3: Packet loss measure in the network

PACKET LOSS ANALYSIS (%)						
Sources(nodes)	5	10	15	20	25	30
WITHOUT-THRESHOLD	1.4	1.7	1.9	2.1	2.3	2.4
WITH-THRESHOLD	1.2	1.3	1.4	1.6	1.7	1.9

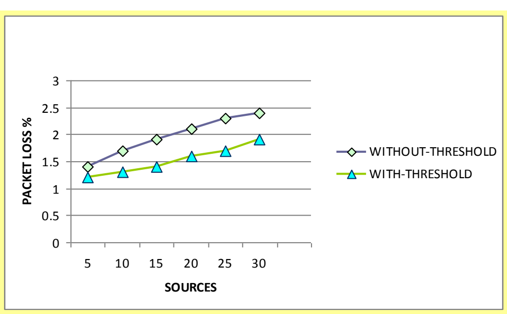


Figure 5: Packet loss measure in the network

Figure 6 shows a graph plotting the number of sensor nodes along the x- axis and average delay along the y-axis. We have observed in graph that, when the source count increases the average delay with threshold decreases and that of without threshold increases , the plotted values are as shown in the table 4 which gives the measures of average delay with and without threshold.

Table 4: Average Delay(s) measure in the network

AVERAGE DELAY(S)						
Sources(nodes)	5	10	15	20	25	30
WITH-THRESHOLD	20	40	160	110	170	120
WITHOUT-THRESHOLD	84	120	170	240	190	220

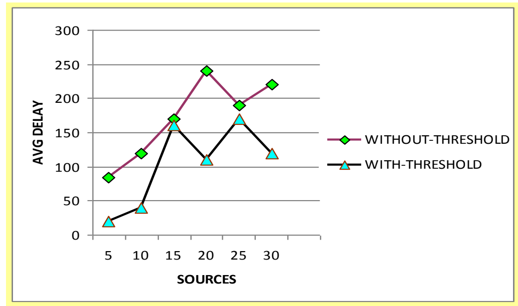


Figure 6: Average Delay(s) measure in the network

Figure 7 shows a graph plotting the number of sensor nodes along the x- axis and packet delivery ratio along the y-axis. We can observe in graph that, when the source count increases the packet delivery ratio with threshold increases and that of without threshold decreases , the plotted values are as shown in the table 5 which gives the measures of packet delivery ratio with and without threshold.

Table 5: Packet Delivery Ratio measure in the network

PACKET-DELIVERY-RATIO (%)						
Sources(nodes)	5	10	15	20	25	30
WITHOUT-THRESHOLD	94	90.7	88.6	82.7	78.8	78
WITH-THRESHOLD	100	92.7	90.6	86.7	82.4	80.5

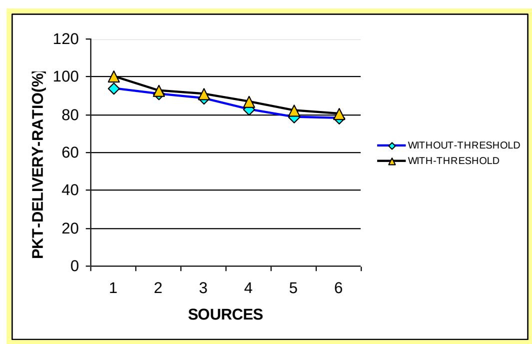


Figure 7: Packet Delivery Ratio measure in the network

Table 6: Final Result Analysis

FINAL RESULT	
Protocol	**TCCP**
Send	11294
Receive	6445
Throughput	257
Pkt-Delivery Ratio (%)	57.07
Avg-Delivery(ms)	0.221651
Dropped Data Pkt	344
Pkt Loss	3.05

Table 6 shows the number of packet sent and received along with other parameter like throughput, packet delivery ratio, average delay, dropped data packet and packet loss. By all this analysis we can realize that applying threshold will have effective data transmission with minimum delay and negligent packet loss.

In Figure 4 we have observed that, when the source count increases the throughput with threshold increases and that of without threshold decreases. The Figure 5 we have observed that, the source count increases the packet loss with threshold decrease and that of without threshold increases. The Figure 6 shows that, when the source count increases the average delay with threshold decreases and that of without threshold increases. The Figure 7 shows that, when the source count increases the packet delivery ratio with threshold increases and that of without threshold decreases.

Table 6 shows the number of packet sent is 11294 and received is 6445 along with other parameter like throughput 257, packet delivery ratio 57.07, average delay 0.221651, dropped data packet 344 and packet loss 3.05.

By all these analysis we can realize that applying threshold will have effective data transmission with minimum delay, negligent packet loss and maximum throughput.

The TAM algorithm performance has evaluated by considering Throughput, Packet Delivery Ratio, Average Delay and Packet loss as performance metrics. Simulation results are shown in table and graph declares that the performance of all these will increase with threshold.

CONCLUSION AND FUTURE ENHANCEMENT

The TAM algorithm performance has evaluated by considering Throughput, Packet Delivery Ratio, Average Delay and Packet loss as performance metrics. Simulation results are shown in table and graph helped in understanding the execution of project. The result drawn from the graph and table shows that applying threshold will have effective data transmission with minimum delay, negligent packet loss and maximum throughput.

The proposed TAM algorithm has successfully achieved the application of threshold in sensor node and thereby reducing the burden on each node and increasing the throughput which resulted in effective data transmission with minimum delay and negligent packet loss and thus avoids failure of nodes. This simulation and result analysis selects the WSN motes under different headings, highlighting the individual mote's performance and path establishment between sources to sink under each category. Hence TAM achieves effective data transmission with minimum delay, negligent packet loss and maximum throughput.

In future work, the implemented method can be verified using real sensors in mobility assisted wireless sensor networks and the security issue can be addressed. Performance comparison of the TAM algorithm with other threshold methods can be done. This simulation does not consider node utilization completely so this can be taken into consideration for further enhancement.

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