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Adaptive Data Traffic Control with Wireless Sensor Networks

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***Abstract*- With the growing demand in wireless sensor network (WSN), adversary attack on sensor node becomes major issue in current WSN deployment. The replica nodes which are generated by attackers time transmits inappropriate message to the sink in the sensor networks. Existing works presented Sequential Probability Ratio Test (SPRT) which reduces the overhead of sensor node transmission on the adversary conditions. Our first work extends replica detection scheme of probability ratio test with Finite Range Query (FRQ) technique to effectively identify the mobile replica nodes and eliminate the varying query ranges of mobile sensor nodes. But it is necessary to validate the query to improve the detection of mobile replica nodes. Our second work focused on validating the functionality of the query scheme at the time of the operation, thus reducing the risk of untimely failures. Numerous source nodes require accounting data to a sink node, producing the funneling consequence where the traffic load enhances since the distance to the sink node reduces. A significance of the funneling outcome is network jamming where packet lines spread out since packets appear at nodes faster than what the nodes can broadcast. Distinctive packet traffic in a sensor network exposes distinct models that permit an adversary examining packet traffic to realize the position of a base station. To manage the packet creation rate at the sources and transitional nodes, in this work we present an adaptive traffic data control scheme. To evade over-utilizing the system in terms of the node packet shields and wireless channels, the proposed adaptive traffic data control scheme control the data flow rate at the sink based on the original nodes presence in the wireless sensor networks. An experimental evaluation is conducted to estimate the performance of the proposed adaptive traffic data control scheme in WSN [ATDCS] in terms of delay, traffic control rate, reliability.**

Keywords- WSN, replica nodes, Finite range query, query validation, adaptive traffic control scheme

I. INTRODUCTION

Wireless sensor networks might be observed as a huge compilation of small sensor nodes that can categorize themselves in an ad-hoc system. It can be accomplished of intellection ecological conditions inside their variety and have sequence activated restricted energy. After the intelligence phase, sensor nodes require to broadcast the information to the sink node or base station, wherever an appliance will practice the data. Nevertheless, a wireless sensor network generally requires communications and sensor nodes must systematize themselves so as to generate method that guide to a sink. Consequently, WSNs achieve multi hop data proliferation so as to communicate data to a fixed sink.

Apart from malevolent intention; there can be further reasons of packet dipping like crashes, buffer spread out, jamming, etc. It is significant to discover solutions that obtain these issues into account, for instance, to thwart fake alarms. Packet loss happens when one or more packets of data roaming diagonally a network not succeed to get to their destination. Packet loss is illustrious as one of the three major error kinds met in digital connections; the other two being fragment error and false packets based owing to noise. Packet loss can be processed by a amount of factors, counting signal deprivation in excess of the network standard owing to multi-path fading, packet dive as of channel jamming, dishonored packets discarded in-transit, defective system hardware, defective network drivers or standard steering routines. In count to this, packet defeat possibility is also exaggerated by Signal to noise ratio and detachment among the source and receiver. The packet failure is examined with regard to number of packet sent.

Transmission organize protocols are a solution allowing knowledge in numerous of today's sensor system requests. Applications for instance of locale supervising, structural strength supervising, and image sensing are greatly rely on overcrowding organization techniques of any communication control protocol. Well considered jamming control approaches permit efficient communication of significant degrees of data from a huge number of nodes beside one or more ways towards the data dealing out centers (generally termed as ‘sink’ in antenna network expressions). In these high data-rate requests, frequently mass data is produced in count to the continually sensed data. For instance, in structural health supervising, a place of sensors is organized in a social organization for instance a building. Each sensor trials structural atmosphere incessantly and broadcasts the data to the sink at a definite rate. When the sensors sense a significant irregularity, they produce and throw out volumes of data at a much superior rate. With no jamming power, beneath such traffic uniqueness, network disintegrate owing to jamming is predictable.

Congestion also contains harmful things on energy deficiency. As the accessible traffic weight annoyed a definite point of jamming, the number of bits that might be derived with the similar quantity of energy reduces. The network tops up killing energy by broadcasting packets from nodes upstream in the system towards the descend, merely to be crashed.

In this work we present an adaptive traffic data control scheme to avoid over-utilizing the network in terms of the node packet buffers and wireless channels. The proposed adaptive traffic data control scheme control the data flow rate at the sink based on the original nodes presence in the wireless sensor networks.

II. LITERATURE REVIEW

Communication protocols are a main technology in today’s sensor system applications. Applications for instance of locale monitoring, structural fitness tracing, and image noticing are high data-rate requests that greatly rely on jamming control techniques which are an essential element of any communication control procedure. A dispersed jamming control algorithm [1] is employed for tree based connections in wireless sensor networks that try to locate to adaptively allocate a fair and well-organized communication rate to each node.

WSNs have a broad series of possible applications connected to technical, ecological, built-up, and military monitoring. These are presently little instances of how WSNs can be utilized to assemble significant data and assist considerable services in genuine life [2]. To assemble the wireless sensor networks professionally, the author presented an algorithm [3] to build a minimal size wireless sensor networks to cover entirely the size of the grid. To enhance the energy of the wireless sensor networks, localization of the nodes in WSN is processed and efficient EM algorithm is presented [4].

Besides, enhancing fairness between flows is also extremely enviable. Nevertheless, the concept of fairness is tough to view in sensor networks as the application necessities pursue no widespread trait. Furthermore, such a plan would also be advantageous for sensor networks which can sustain numerous simultaneous applications and also systems with several users [5], where there is a necessitate to care for flows from diverse applications or users in an unbalanced manner. The authors in [6] suggest a cross-layer optimization system for jamming control in multi-hop wireless networks. They realize a discrepancy backlog based MAC preparation and router-assisted backpressure jamming power scheme.

In [7], the authors focus on fair bandwidth giving out among end-to- end flows, whereas sustaining a proficient largely throughput in the network. They recommend a active rate allotment solution that is based on a easy radio giving out model. The authors in [10] proposes a jamming control method, in which, the barrier in both node is used consistent with the transmitting downstream nodes so as to reduce packet drop; the algorithm mechanically regulates a node’s on warding rate to evade packet drops owing to jamming. The algorithm determines the equality crisis by assigning identical bandwidth to the sources. The authors in [8] suggest a rate-based fairness aware jamming organization (FACC) protocol [9], which reins jamming and attains roughly fair bandwidth portion for diverse flows.

Abundant replica node recognition approaches have been considered in the literature to conserve next to such attacks in rigid sensor networks. In [11], we suggest a fast and well-organized mobile replica node detection scheme using the Sequential Probability Ratio Test. We consider the location assessment in a mobile ad-hoc network (MANET), where every node wants to persist its situation information. It widens a stochastic chronological decision structure [12] to appraise position update resolution trouble. In this work, we plan to present an adaptive traffic control scheme to control the data traffic at the sink and provide an efficient communication.

III. PROPOSED ADAPTIVE TRAFFIC DATA CONTROL WITH WIRELESS SENSOR NETWORKS

The proposed work is efficiently designed for controlling the data traffic rate occurred while eliminating the replica nodes in the wireless sensor networks. The proposed adaptive traffic data control scheme is processed under three different phases. The first phase describes the process of identifying the mobile replica nodes (acting as adversary) and eliminates the varying query ranges of mobile sensor nodes. The second phase illustrates the process of validating the range queries in the wireless sensor networks. The third phase describes the process of controlling the traffic rate of WSN occurred while removing and validating the finite range query presents in the wireless sensor networks.

The third process describes the process of controlling the traffic data in WSN to enhance the data transmission between the sink and the base station. Numerous source nodes require accounting data to a sink node, producing the funneling consequence where the traffic load enhances since the distance to the sink node reduces. To control the packet generation rate at the sinks and intermediary nodes, we present an adaptive traffic data control scheme. The traffic data occurring at the sink is controlled based on the flow of the original nodes presence.

Consider N sensor nodes. Each node contains a definite quantity of data to be processed to a distinct base station. The nodes can create data traffic, in addition to route traffic created by other nodes. Therefore, every node can perform together as a source, and a router. The nodes model the surroundings at interrupted period, instruct the information into data packets, and drive them away to a middle base station or sink. The flow initiating from Node i be f_i , and ri be the rate at which flow f_i is introduced into the system. Assign the rate r_i to flow f_i that is both fair and efficient. Note that, ri is the rate at which node i introduces flow f_i into the system, and does not contain the rate at which node i ahead traffic.

The first process is to remove the replica nodes present in the wireless sensor networks. The replica detection scheme of probability ratio test with Finite Range Query (FRQ) is to detect replica node attacks in mobile sensor networks. If nodes are moving around in network, a benevolent mobile node will be treated as a replica because of its incessant change in location.

The second process describes the query validation process in continuation with an existing identification of mobile replica nodes in finite range query scheme. By validating the query in wireless sensor networks, the mobile replica nodes are removed entirely and it reduces the loss of data occurred while make a transaction between the nodes in the network environment.

3.1 Eliminating replica nodes in WSN

The Finite Range Query Scheme is used in the previous work made to endeavoring the mobile duplication detection problem whereas we construct an arbitrary pace with two restrictions in such a way that each pace is dogged by the research rapidity of a mobile node. The lesser and higher limits will be configured to be associated with speeds below and in burden of V_{max}, likewise. Every time a mobile sensor node schedules to a new location, each one of its neighbors desires for a obvious state having its position and time information and decides possibility of whether to promote the received state to the base station. The base station evaluates the speed from all two consecutive states of a mobile node and accomplishes the Energy Efficient Finite Range Query Scheme by permitting for speed as a practical model. Once the base station makes a decision that a mobile node has been replicated, it eliminates the replica nodes from the network.

3.2 Validating the range query of nodes in WSN

The validation of query is processed at three stages of communication in wireless sensor network environment. The first stage of query processing is made with the identification of original node in the network environment. Even the finite range queries are used for the removal of mobile replica nodes, there is a great extent of nodes to be extracted or discarded by the attacker. At this sense, it is necessary to validate the query by identifying the node authorized id given by the certified authority. The node identification query is processed based on node id, key value pairs. After verifying with the nodes present in the wireless sensor network, the valid nodes are available. The node communication is done based on sending and receiving the query and outcome with the free nodes for passing the message from source to destination. For sending the message, the sending query must contain a valid node id which is given by the authorized entity and the key value pairs for sharing the message with the destination. Before delivering the message, it is necessary to check the destination node id by the query validation scheme. The query validation scheme openly communicates with every node to authenticate the packet transmission and link feature by inspecting the node id, key value pairs provided by the authorized entity. It establishes the action of every node based on its contribution in the communications. Now the network is designed with the original nodes in the network to process.

3.3 Adaptive traffic data control scheme

Numerous source nodes require accounting data to a sink node, producing the funneling consequence where the traffic load enhances since the distance to the sink node reduces. A significance of the funneling outcome is network jamming where packet lines spread out since packets appear at nodes faster than what the nodes can broadcast. Distinctive packet traffic in a sensor network exposes distinct models that permit an adversary examining packet traffic to realize the position of a base station. To manage the packet creation rate at the sinks and transitional nodes, in this work we present an adaptive traffic data control scheme. To evade over-utilizing the system, the proposed adaptive traffic data control scheme control the data flow rate at the sink based on the original nodes presence in the wireless sensor networks.

3.3.1 Overview

In section 3.3, we build up an easy adaptive algorithm for jamming control in sensor networks. To control the traffic rate at the sink, here we used two main parameters. One is feedback and another is control interval. Feedback delay of a data flow is defined as the time interval, calculated initially from the time node i starts broadcasting flow f_i at a rate r_a to the time the control signal appears and alters the rate to r_b. Control interval is the time period over which a node obtains a choice of raise or fall in the communication rates of the flows initiated by itself and of the flows being routed during it.

Each node i, initiates flow f_i, sustain and drives the present rate r_i at which the flow is being introduced into the system. An estimation of the feedback delay of the flow is done by attaching a congestion header to each packet being departed in the flow. This permits the intermediary nodes to be conscious of the communication rates of the flows transient throughout it, and their feedback delays. In our proposed ATDCS mechanism, the nodes observe the data traffic rate. Based on the dissimilarity among the input traffic rate, the nodes calculate the preferred raise or fall in the rate of initiation of the flows distributing the link.

When a node (say j) transmits a packet fit in to flow f_i, the minimum bandwidths can be allocated to f_i by itself and by the nodes downstream (nearer to the sink) to node j. Finally, the congestion signal that achieves the source node is, so, the minimum bandwidth allocated to the flow based on the bandwidths of the nodes along the path of the transmission.

3.3.2 Adaptive data traffic control algorithm

The adaptive traffic data control algorithm can be described by the following steps carried out at each node every control interval. Before describing the algorithm, it is necessary to find out the some terms to achieve the data traffic control scheme.

i) Average Output rate of packets (AOR)

Let t_{out} seconds be the time needed to broadcast a packet, considered initiating from the time the packet was sent by the system. Then, we remind that the efficient rate r_{out} packets per second is contrary to the time interval t_{out} seconds, i.e., $r_{out} = \frac{1}{t_{out}}$. The value of t_{out} in packet transmission is instance of the average time required to broadcast a packet.

$$AOR = (\alpha_{out}) \bullet T_{out} + (1-\alpha_{out}) * \bar{t}_{out}^{\,i=1} \tag{1}$$

Where α_{out} the capacity of the sink and T_{out} is the present value of the variable t_{out}.

ii) Average Input rate of packets (AIR)

Let t_{in} seconds be the time needed to broadcast a packet, considered initiating from the time the packet was sent by the system. Then, we remind that the efficient rate r_{in} packets per second is contrary to the time interval t_{in} seconds, i.e., $r_{in} = \frac{1}{t_{in}}$. The value of t_{in} in packet transmission is instance of the average time required to broadcast a packet.

$$AIR = (\alpha_{in}) \bullet T_{in} + (1-\alpha_{in}) * \bar{t}_{in}^{\,i=1} \tag{2}$$

Where α_{in} the capacity of the sink T_{in} is the present value of the variable t_{in}.

iii) Controlling traffic data efficiency

The efficiency of traffic data controller calculates the vital transmission rate of the traffic (TR) in terms of packets per second. This is computed as [1]:

$$TR = \alpha \times (r_{out} - r_{in}) - \beta \times (\frac{Q}{t_{CI}}) \quad (3)$$

Where, t_{CI} is the control period of the node, α and β are steady parameters and Q is the constant queue size. Q is measured as the smallest number of packets to be sent in a certain interval. The value of (r_{out} - r_{in}), can be negative, positive or zero. When (r_{out} - r_{in}) is positive, positive feedback desires to enhance the communication rates of the transmissions. When (r_{out} - r_{in}) is negative, negative feedback is vital to reduce the communication rates. If (r_{out} - r_{in}) is equal to zero, i.e., the input capacity matches the sink capacity.

The below figure (fig 1) describes the entire process of ATDCS. Based on the values obtained from AOR, AIR, TR, the data flow rate at the sink is controlled. The sink would allow the packet data to enter only if the capacity is met with the incoming data packet. Finally, the traffic data rate is controlled in a reliable manner. The next section describes the experimental evaluation of the proposed ATDCS.

Input: Set of packets P, time T, nodes N
Step 1: For each packet P and node N
Step 2: Identify the out time taken to transmit the packet among the nodes N (t_{out})
Step 3: Identify the rate of packets to be sent at a second (r_{out})
Step 4: Compute AOR (equation 1)
Step 5: Identify in time taken to transmit the packet among the nodes N (t_{in})
Step 6: Identify the rate of packets to be sent at a second (r_{in})
Step 7: Compute AIR (equation 2)
Step 8: End for
Step 9: Compute α
Step 10: Based on the value of α (equation 3)
Step 11: Allocate the packet data to the sink
Step 12: If sink capacity is full,
Step 13: Transmit the packets to the Base station
Step 14: Else
Step 15: Allow the packets to enter
Step 16: End If
Step 17: End

Fig 1 Process of the proposed ATDCS

IV. Experimental Evaluation

We simulated the proposed adaptive traffic data control scheme in a wireless sensor network by using the ns2 network simulator. In the simulations, we set up n nodes consistently at arbitrary surrounded by a 900 × 900 square, with n changeable among 100 and 1000. We determine the mobile sensor node movement patterns. In particular, to exactly estimate the presentation of the system, we use the RWM model in which each node progress to an arbitrarily selected position with an arbitrarily chosen speed among a predefined minimum and maximum speed.

We guess the standard unit disc bidirectional communication representation and we change the message range, so that every node will include roughly 40 neighbors on average. The moving mobile sensor networks stays there for a predefined pause time. After the pause time, it then randomly chooses and moves to another location. This arbitrary progression is constant during the simulation period. All simulations were performed for 1,000 simulation seconds. We fixed a pause time of 25 simulation seconds and a minimum moving speed of 1.2 m/s of each node. Each node uses IEEE 802.11 as the medium access control protocol in which the transmission range is 60 m. To emulate the speed errors caused by the inaccuracy of time synchronization and localization protocols, we modify the measured speeds with maximum speed error rate. The performance of the proposed adaptive traffic data control scheme in WSN is measured in terms of Energy utilization, traffic control rate, Delay, Reliability.

V. Results and Discussion

In this work, we have seen how the data traffic could be controlled when all the replica nodes in the wireless sensor networks has been removed. The data traffic at the sink has been efficiently removed by using an adaptive mechanism based on the data flow rate at the sink. Once the sink is filled with data, it automatically allowed all the data to be transmitted into the base station. After sink gets empty, it allows the data to enter into it. The adaptive mechanism is done with the process based on the data control flow rate. The below table and graph describes the performance of the proposed adaptive traffic data control scheme in WSN.

Table 1 Finite range query vs. Energy utilization

Finite range query	Energy utilization (J)			
	Proposed ATDCS	DQV-FRQ	FRQ	Existing SPRT
5	11	12.1	12.9	14
10	9	11.2	11.5	13.7
15	8.2	10	10.5	12.6
20	7.3	8.7	9.3	11.5
25	6.4	7.9	7.3	10.3
30	5.2	6.8	6.5	8.2

The above table (Table 1) describes the utilization of energy needed to perform the data packet transmission in the wireless sensor networks. The utilization of energy consumed by the proposed adaptive traffic data control scheme in WSN is compared with the previous works DQV-FRQ (deployment of query validation for finite range query scheme in WSN), FRQ (Finite Range Query) and existing SPRT (Sequential Probability Ratio Test).

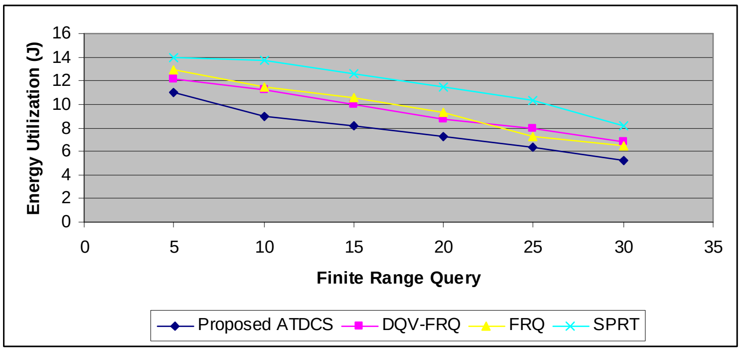

Fig 2 Finite range query vs. Energy utilization

Figure 2 describes the utilization of energy needed to perform the data packet transmission in the wireless sensor networks. The number of Finite query varies from 5 to 30. The increase of Finite Query Range under leads to decrease the energy utilization in all the schemes. In the proposed ATDCS, the finite range query are organized and processed under query validation. The proposed work controlled the data flow rate based on the removal of replica nodes in the wireless sensor networks. The utilization of energy is measured in terms of joules. Compared to the other works (FRQ, DQV-FRQ, SPRT), the proposed ATDCS consumes less energy and process the given queries.

Table 2 No. of nodes vs. traffic control rate

No. of nodes	Traffic control rate (%)			
	Proposed ATDCS	DQV-FRQ	FRQ	Existing SPRT
10	42	35	30	21
20	54	48	42	32
30	63	52	50	40
40	78	66	65	49
50	84	75	70	52

The above table (Table 2) describes the traffic data control rate to perform an efficient data packet transmission in the wireless sensor networks. The traffic control rate of the proposed adaptive traffic data control scheme in WSN is compared with the previous works DQV-FRQ (deployment of query validation for finite range query scheme in WSN), FRQ (Finite Range Query) and existing SPRT (Sequential Probability Ratio Test).

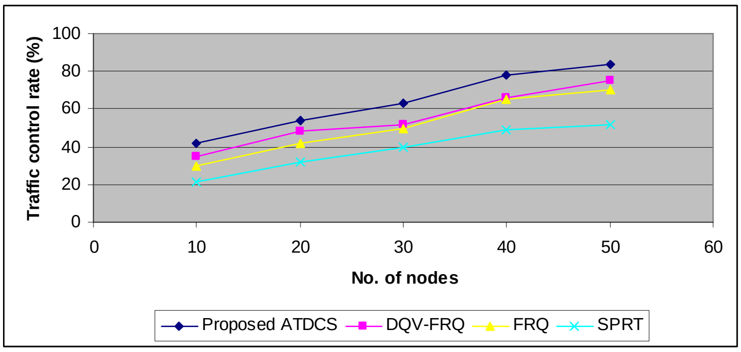

Fig 3 No. of nodes vs. traffic control rate

Fig 3 describes the traffic data control rate to perform an efficient data packet transmission in the wireless sensor networks. In the proposed ATDCS, the traffic data at the sink are efficiently controlled by the adaptive mechanism. The traffic occurring at the sink is controlled based on the capacity of the sink to have the packet data. Once the sink is filled with the data, it allowed all the packet data to the base station. After that, it allows other packet to enter into it. By the way, it controls traffic reliably. Compared to an existing SPRT and other works such as DQV-FRQ, FRQ, the proposed adaptive traffic data control scheme in WSN efficiently controlled the traffic data at the wireless sensor networks.

Table 3 No. of packets vs. Delay

No. of packets	delay (secs)			
	Proposed ATDCS	DQV-FRQ	FRQ	Existing SPRT
10	2.2	3.5	4.1	7.2
20	3.5	4.8	4.9	9.2
30	4.6	5.6	5.2	10.5
40	5.7	7.1	7.5	11.8
50	6.3	8.2	8.9	13.4

The above table (Table 3) describes the delay occurred when more number of data increases in the wireless sensor network environment. The reliability of the proposed adaptive traffic data control scheme in WSN is compared with the previous works DQV-FRQ (deployment of query validation for finite range query scheme in WSN), FRQ (Finite Range Query) and existing SPRT (Sequential Probability Ratio Test).

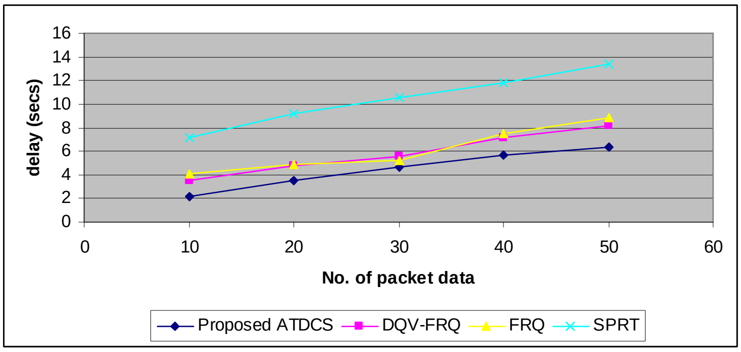

Fig 4 No. of packets vs. Delay

Fig 4 describes the occurrence of delay raised over the data which are ready to pass onto the network. The proposed adaptive traffic data control scheme in WSN performed the traffic data control scheme efficiently in terms of capacity of the sink at the sensor networks. Since the traffic control scheme is carried over with the wireless sensor network, the delay in transmission is less. The delay is measured in terms of seconds (secs) meant that a bit of data that can be transmitted over the network in a less interval of time. Compared to an existing SPRT and Finite Range Query scheme which process and transmits the network by enhancing the query, in this, there is a great extent of delay if more number of queries is waiting in the queue for transmission.

But in the proposed ATDCS, the traffic control scheme is taken place to control the data traffic at the sink. The delay is low in the proposed adaptive traffic data control scheme in WSN.

Table 4 No. of packets vs. reliability

No. of packets	Reliability (%)			
	Proposed ATDCS	DQV-FRQ	FRQ	Existing SPRT
10	54	48	40	32
20	68	56	52	43
30	73	64	58	50
40	84	75	64	57
50	90	82	72	63

The above table (Table 4) describes the reliability of the traffic data control for an efficient data packet transmission in the wireless sensor networks. The reliability of the proposed adaptive traffic data control scheme in WSN is compared with the previous works DQV-FRQ (deployment of query validation for finite range query scheme in WSN), FRQ (Finite Range Query) and existing SPRT (Sequential Probability Ratio Test).

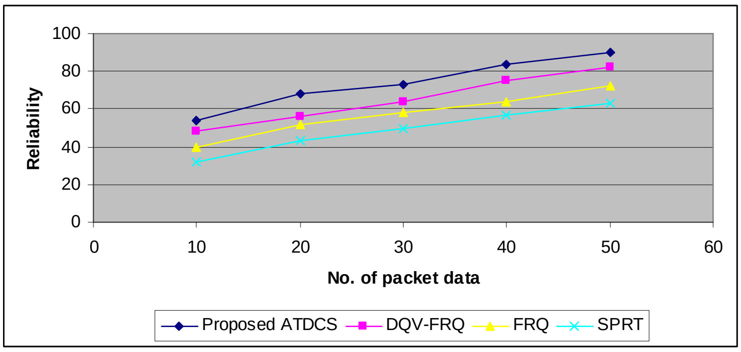

Fig 5 No. of packets vs. reliability

Fig 5 describes the reliability of the traffic data control for an efficient data packet transmission in the wireless sensor networks. Since the proposed ATDCS used adaptive mechanism for data traffic control, the reliability of the network is improved. The proposed ATDCS efficiently eradicate the replica nodes and validate the query. The reliability of the network is measured in terms of how efficient the nodes in the network are involved in communication. Compared to an existing SPRT and other works such as DQV-FRQ, FRQ, the proposed adaptive traffic data control scheme in WSN efficiently controlled the traffic data at the wireless sensor networks with high reliability.

Finally, it is being observed that the proposed adaptive traffic data control scheme in WSN efficiently solved the crisis of data traffic rate raised at the sink. Even numerous source nodes require accounting data to a sink node, the proposed adaptive mechanism controlled based on the sequence of the packet data arrives. Compared to an existing SPRT, the proposed ATDCS efficiently controlled the traffic data rate.

VI. Conclusion

The paper has presented an adaptive traffic data control scheme for traffic data control in wireless sensor networks that seeks to consign a fair and efficient rate to every node. The proposed ATDCS needs all node to observe their traffic rate, based on the dissimilarity of which every node chooses to raise or fall of the communication rates of itself and its upstream nodes. The traffic data control is invoked at every node flows transmitting through the gateway node, which we termed as the control period. We performed simulations of the proposed adaptive traffic data control scheme under an arbitrary association attack strategy in which it process the packet transmission range of the network. The results indicate that the proposed data traffic control mechanism can accomplish gradually high good put, is capable to achieve fairness for all nodes in the wireless sensor networks to obtain the finest communication rates rapidly.

References

[1] Swastik Brahma a, Mainak Chatterjee et. Al., “Traffic management in wireless sensor networks: Decoupling congestion control and fairness”, Computer Communications 35 (2012) 670–681

[2] Anya Apavatjrut ,Claire Goursaud, Katia Jaffrès-Runser, Cristina Comaniciu, and Jean-Marie Gorce, “Toward Increasing Packet Diversity for Relaying LT Fountain Codes in Wireless Sensor Networks”, IEEE COMMUNICATIONS LETTERS, VOL. 15, NO. 1, JANUARY 2011, pp 52-54.

[3] Wei-Chieh Ke, Bing-Hong Liu, and Ming-Jer Tsai, “Efficient Algorithm for Constructing Minimum Size Wireless Sensor Networks to Fully Cover Critical Square Grids”, IEEE 2009 TRANSACTIONS ON WIRELESS COMMUNICATIONS, pp 1-11.

[4] Wei Meng, Wendong Xiao, Senior Member, IEEE, and Lihua Xie, Fellow, IEEE, “An Efficient EM Algorithm for Energy-Based Multisource Localization in Wireless Sensor Networks”, IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, VOL. 60, NO. 3, MARCH 2009, pp 1017-1027.

[5] Waleed Alsalih, Hossam Hassanein, Selim Akl., “Placement of multiple mobile data collectors in wireless sensor networks” , Ad Hoc Networks (2010) Volume: 8, Issue: 4, Publisher: Elsevier B.V., Pages: 378- 390.

[6] J. Paek, R. Govindan, RCRT: rate-controlled reliable transport for wireless sensor networks, in: Sensys 2007.

[7] A. Warrier, S. Janakiraman, S. Ha, I. Rhee, DiffQ: Practical differential backlog congestion control for wireless networks, in: INFOCOM 2009, pp. 262–270.

[8] R. Vannier, I. Gurin Lassous, Towards a practical and fair rate allocation for multihop wireless networks based on a simple node model, in: 11th ACM/IEEE International Conference on Modeling, Analysis and Simulation of Wireless and Mobile Systems (MSWiM), Vancouver, Canada, October 2008.

[9] X. Yin, X. Zhou, R. Huang, Y. Fang, S. Li, A fairness – aware congestion control scheme in wireless sensor networks, IEEE Transactions on Vehicular Technology 58 (9) (2009) 5225–5234.

[10] M. Zawodniok, S. Jagannathan, Predictive congestion control protocol for wireless sensor networks, IEEE Transactions on Wireless Communications 6 (11) (2007) 3955–3963.

[11] J. Ho, M. Wright, and S. K. Das, “Fast Detection of Mobile Replica Node Attacks in Wireless Sensor Networks Using Sequential Hypothesis Testing”, IEEE TRANSACTIONS ON MOBILE COMPUTING, VOL. 10, NO. 6, JUNE 2011.

[12] Zhenzhen Ye and Alhussein A. Abouzeid , “Optimal Stochastic Location Updates in Mobile Ad Hoc Networks”, IEEE TRANSACTIONS ON MOBILE COMPUTING, VOL. 10, NO. 5, MAY 2011