Research Article

Improving The Performance Of Wireless Sensor Network With Multi Factor Strategies

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Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 16 April 2021

Abstract : In the design of wireless sensor network (WSN), packet delivery ratio(PDR) is an import parameter to be maximized. PDR plays an important role for improving the performance of WSN. With the existing schemes, a secure zone-based routing protocol was implemented for life time improvement in WSNs. In multi - hop communication, a new routing criterion was formulated for packet transmission. Security against message tampering, dropping and flooding attacks were incorporated in the routing metric. The approach skipped risky zones as a whole from routing and choose alternative path to route a packet in secured manner with less energy consumption. Though energy conservation and attack resilience are achieved, congestion in WSN is increased and because of it packet delivery ratio is diminished. To address this problem, we propose a solution to improve the packet delivery ratio with a multi factor strategy involving routing, differentiation of flows, flow-based congestion control with retransmission and redundant packet coding. Detailed analysis and simulations are undertaken to evaluate the efficiency of the contemplated work compared to the existing solutions.

Keywords: multi factor strategies, novel routing metric, packet coding, packet delivery ratio.

1. Introduction

Wireless sensor network is the group of sensor nodes that has the capability of wireless data dissemination. Sensor nodes sense the environment variables depending on application requirements and send them to sink either directly or through multi hop transmission. WSN is being increasingly used in many applications like precision farming, industrial safety, smart home etc. The sensor networks are designed with the consideration of many requirements like packet delivery ratio, latency, life time and security. In earlier works [1], a zone-based sensor network is designed with consideration for life time and security. The sensor network is secured against message tampering, dropping and flooding attacks WSN Life time is increased by optimizing the power usage and packet routing. The network is split to zones and each zone is assigned a score. This score is calculated depending on past security lapses and present residual energy in that zone. A zone with higher score is preferred for routing. Though the network life span and attack resilient capability improved, congestion increased which leads to packet loss in WSN. The solution in the existing work minimizes the packet delivery ratio owing to a significant raise in total numbers hops and node overhead in the network.

Multi factored Secure Routing approach is proposed to improve packet delivery ratio in WSN by addressing the draw backs related to energy efficient attack resilient routing. The Multi factored approach involves flow level management through differentiation and flow control, reducing the retransmission through packet coding and selection of routing paths with increased delivery ratio. Through differentiation of flows and control of flows, low priority packets are buffered and high priority packets routed in an adaptive manner. The necessity for retransmission is reduced by adding sufficient redundancy in the packets so that sinks can reconstruct the lost packets using the redundancy information in the packets. Packet delivery ratio is increased by introducing a weighted routing metric with the consideration of various factors. The goal is to increase the packet delivery ratio applying multiple factors like flow management, retransmission control and weighted routing metric to zone based sensor network.

In the following, Section II presents the related review for proposed solution. Section III elaborates the proposed Multi Factored Strategy, Section IV presents salient features in proposed solution, Results of proposed work are given in Section V. Lastly, the paper concludes in Section VI.

2. Related Work

Authors in [2] proposed a distributed multi path algorithm with the goal of higher packet reliability. The path selection is adapted to network changes and failures. With the availability of multiple base stations and routing on multiple paths to these stations, fidelity of packet is improved in this work. Nevertheless, the major limitations are increased network overhead and reduced throughput. An opportunistic routing scheme is presented in [3] to increase the packet delivery ratio in WSN. Relay nodes are selected based on minimization of retransmission. Due to the reduction of retransmission, the overall throughput of the network is increased and thereby reducing the packet loss. An opportunistic routing scheme similar to [3] is proposed in [4] with the aim of increasing the reliability and reducing the latency. The best relay satisfying the QoS criteria is selected based on reliability and time guarantee. Compressive sensing is used to reduce the packet overhead in [18]. Compressive sensing improves the network utilization and packet delivery ratio. Compressive sensing also minimizes the power usage in WSN. Packet reliability is increased using energy aware Quality of service (QoS) transmission protocol depending on various parameters in [6]. Similar to it, an optimal energy efficient routing protocol is formulated in [7]. A stateless position-dependent packet forwarding scheme is modelled in [19]. Stateless routing was realized using greedy perimeter routing. Geographic routing along with greedy data transmission is able to increase the packet delivery time. Detection of malicious nodes in sensor network is explored in [9, 10,25]. Network life time is increased by enhanced energy efficient clustering of sensor network in [11,27]. LEACH algorithm is improved to select the best cluster head to enhance the lifespan of the network. Ant colony-based routing algorithm is proposed in [12] with the goal of higher packet delivery ratio. The ant colony algorithm uses the fitness function optimized based on communication distance, transmission direction and current residual energy. Packet delivery ratio is increased using opportunistic multipath routing in [13]. Similar to it, in [14] A multi path routing algorithm is formulated to increase packet reliability by forwarding on multiple paths. The solution also uses aggregation to diminish the number of efficient transmissions in WSN. Packet prioritization and optimized back-off MAC protocol is proposed in [15,26]. Due to reduction of collision in the optimized back-off MAC protocol, packet reliability is improved. The optimized back off MAC works by assigning back off time depending on the packet priorities. A virtual node concept is introduced in [16] to enhance the QoS in WSN based on clustering technique. The scheduling is realized using TDMA in this network. High priority is assigned to certain designated nodes. During higher traffic load, the packets from these designed nodes are given more importance in routing so that latency for those packets is reduced. The stateless opportunistic packet transmission scheme is defined in [17] with the objective of enhancing the packet reliability. Forwarding area for packet is adapted dynamically depending on the consistency of the sensor nodes so that reliability is increased. Energy consumption is reduced by optimal positioning of nodes in [20,21]. Clustering based energy minimization strategies are explored in [23, 28]. Attack resilient routing in wireless sensor network is discussed in [22, 24]. Bandwidth and energy aware routing protocol for increased packet delivery ratio in Adhoc network is proposed in [29]. The routing protocol is able to adapt to dynamic network topology involving selective multipath routing based on QoS. A multipath routing protocol with goal of QoS optimization is proposed in [30]. Cluster head is selected by applying a modified particle swarm optimization. Path selection is done using round robin rule with consideration for QoS metrics.

3. Proposed Multi Factored Strategy

The architecture of the proposed multi factored strategy is given in figure 1. It involves four important concepts

- Selection of energy efficient routing path
- Redundancy and Retransmission management
- Differentiation of flows in the network
- Flow based congestion control

A. Packet Routing

The Whole area of WSN is split into zones of $N \times N$ size. In one hop routing, any node in the zone will connect to any other node. Node close to centre of zone which can observe all the packet transmission is selected as zone head. The information of nodes within each zone is present in the sink. Three distinct scores, security score, energy score and reliability score are attained in each zone. The value of score varies from 0 to 10. The zone with high score is recommended for routing when compared with zone of lower score. The zone scores are calculated based on fuzzy function using the following input variables.

- Packet traversing count (PTC)
- Packet traversing failure count (PTFC)
- Tampered incidence count (TIC)

- No tampered count (NTC)

These scores are detailed in [1], but the counters are kept at zone head in this work deviating from [1] where the counters are kept at sink. The fuzzy function for calculating the security score is given as

$$SS_p = \mu_1 * Q(PTC) + \mu_2 * Q(PTFC) + \mu_3 * Q(TIC) + \mu_4 * Q(NTC)$$

Where
$Q(x)$: the fuzzification kernel of input x.
The de-fuzzification score is measured by using center of gravity formula

$$Score = \frac{\int \mu_{Dr}^{-}(x).xdx}{\int \mu_{Dr}^{-}(x).dx}$$

Where x = {PTC, PTFC, TIC, NTC}.
The energy score of a zone is measured as below

$$ES = \frac{10 * (E - TPC * E_c)}{E}$$

Where TPC is the total packets transmitted.
Rather than the revised AODV based routing addressed in [1], the packets are transmitted using a geographical routing through preference score-dependent path selection. Past packet forward statistics are used to calculate the reliability score for the zone. Packet forward success message is sent by each node with successful forward for packet to next hop. Whenever this message is reached, packet forward success counter is incremented. Periodically, the reliability score is measured as

$$R_t = \alpha \times R_{t-1} + (1 - \alpha)\frac{PFS}{TPC}$$

With $R_0 = 0$
The packet is first sent from the node to head of the zone. The head of Zone sends a packet containing hello message to other neighbouring heads. The heads of zones receiving 'HELLO' message calculate the preference score (PS) and send a 'HELLO_RES' as response to 'HELLO'. The PS is measured as sum of weighted values of security score, energy score and reliability score.

$$PS = w_1 * SS_p + w_2 * ES_p + w_3 * R_t$$

With $w_1 + w_2 + w_3 = 1$ and $w_3 > w_2 > w_1$

The zone accepting 'HELLO_RES' , selects the zone head with highest PS score as relay hop and route the DATA packet to that zone head.

After the reception of HELLO_RES by zone head, the K nearest neighbour heads are sorted depending on the distance from sink node. Among K neighbouring head nodes, the node whose PS value above threshold T_1 is selected to send data packet. Data packet is forwarded to all K neighbour nodes, if none of the neighbour has PS values above T_1 . This process is repeated at every hop until data packet received by the sink node.

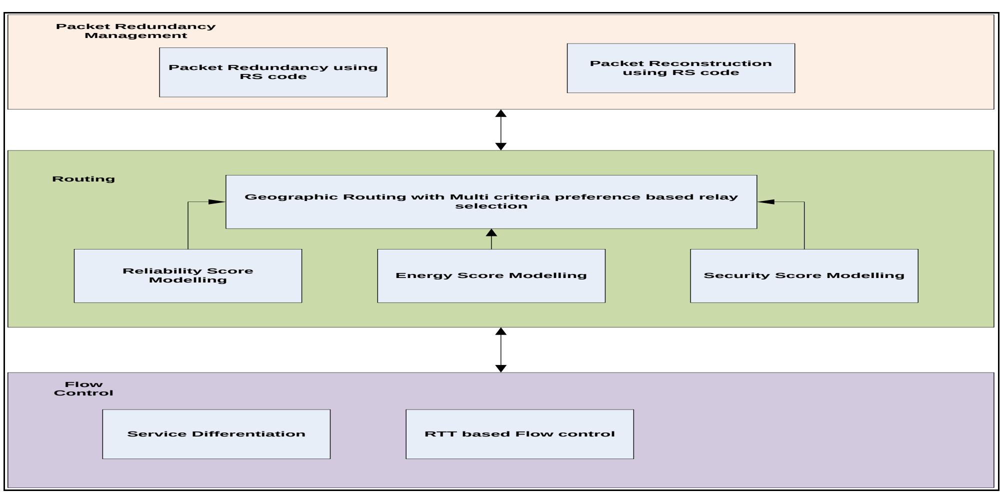

Figure 1:Architecture of secure routing based on of Multi factored approach

Before applying fuzzy function on the input variants NTC,TIC,PTC, PTFC ,these variables must converted from numerical to categorical values of Low (L), Medium (M) and High (H) applying following transformation functions as given in figures 2,3,4,5.

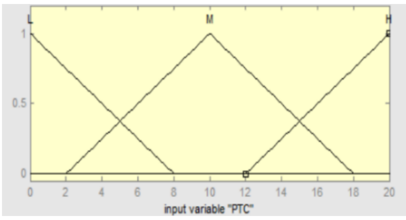

Figure 2 PTC transformation function

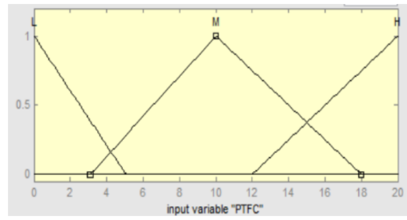

Figure 3 PTFC transformation function

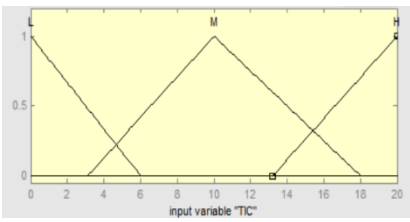

Figure 4 TIC transformation function

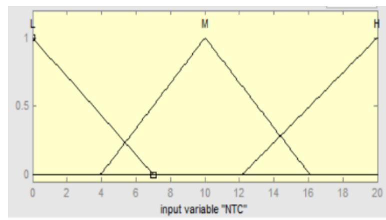

Figure 5 NTC transformation function

The output variable of preference score is converted from numerical to categorical value using the transfer function given in Figure 6.

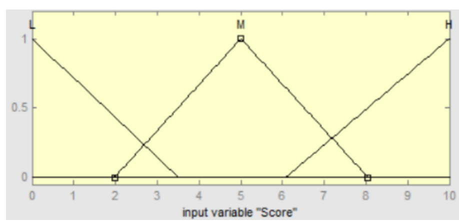

Figure 6 Preference score transformation function

The input variables PTC, PTFC, TIC and NTC are mapped with output variable of preference score using fuzzy rule base.

B. Flow differentiation and congestion control

Packet flow is split to two categories of high and low priority in the network. At each routing hop, the flow of packets is controlled differently for the packets based on high and low priorities. Packets with high priority are transmitted and low priority packets are buffered during network congestion period. Due to buffering of low priority packets, network congestion reduces. This allows for reliable transmission of packets. Round trip time (RTT) is measured at hop node on reception of packet forward success message. Based on probability delay, RTT is, measured as below

$$RTT = \begin{cases} \sum_{i=0}^{\infty} f_i(a).f_i(b) \ , x = 0 \\ \sum_{i=0}^{\infty} f_i(a).f_{2x+i}(b) + \sum_{i=0}^{\infty} f_i(b).f_{2x+i}(a), x > 0 \end{cases}$$

In the above equation, a is forward path and b is the backward path. F is the probability mass function. Adaptive flow control for the packets is shown in figure 7.

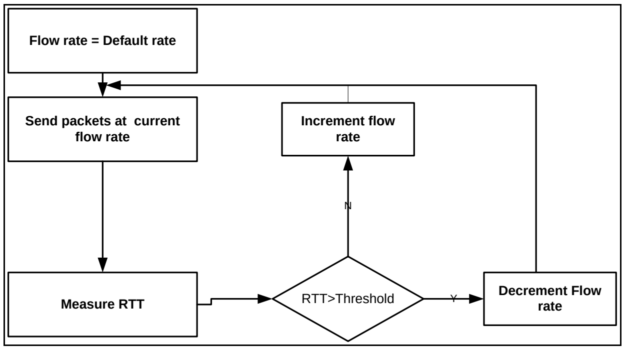

Figure 7: Flow of packets

Initially, data flow rate is initialized to default value and data flow control starts from this value at every node. Depending on the acquisition of packet forward success message, RTT delay is measured. Data Flow rate is decreased when RTT is above configured threshold and increased when RTT is below configured threshold.

C. Redundant Packet Coding

The packets sent from source is divided into n packets using erasure coding (n,k) and only k packets are sufficient for reconstruction. The source node sends n packets and if k out of n packets are received at sink, packet can be reconstructed without any necessity for retransmission. This work uses Reed Solomon erasure coding. Use of Reed Solomon code has following advantages.

1. The reed Solomon transformed contents are encrypted and secure.
2. Retransmission can be avoided with lower value for k.

4. Salient Features in Proposed Solution

The proposed multi factor strategy has following salient features:

1. Risky areas in the network are quantified using scores and routing is adapted to skip those risky areas
2. Packet flow is differentiated and flow is managed to reduce the congestion is the network. Flow management is dynamic to congestion in the network.
3. Retransmission is avoided in the network due to erasure coding.
4. Proactive routing in secure path results is attack resiliency.

5. Results

The proposed multi factored strategy is simulated in NS2 platform. The simulation parameters used for testing the proposed solution is given in Figure 8

Parameters	Values
Number of Nodes	50 to 250
Communication range (m)	100
Area of simulation (m*m)	1000*1000
Priority distribution	Uniform distribution with 20% distribution for each priority
Node Deployment Topology	Random
Simulation time (in minutes)	30
Interface Queue Length	50
MAC	802.11

Figure 8: Simulation parameters

The proposed work performance is simulated and evaluated by comparing with the following solutions

1. Secure energy efficient routing is contemplated in [1]
2. Optimal Energy efficient routing formulated in [5]
3. Secure localized routing is defined and implemented in [8]

Performance evaluation parameters considered for comparison are: packet delivery ratio, packet delay, overhead, WSN Longevity and throughput.

Packet delivery ratio measures the ratio of successfully acquired packets at sink to the total number of packets sent by the sources. It is calculated as

$$PDR = \frac{number\ of\ packets\ recived\ at\ sink}{total\ number\ of\ packets\ sent}$$

The results of packet delivery ratio against number of nodes is given in Table 1 & Figure 9

No of Nodes	Proposed	[1]	[5]	[8]
50	93	87	82	81
100	92	86	81.5	79.5
150	91	85.2	79.1	78
200	90	84	78	76.9
250	89	83.2	76.8	75.1

Table 1: comparison of packet delivery ratio

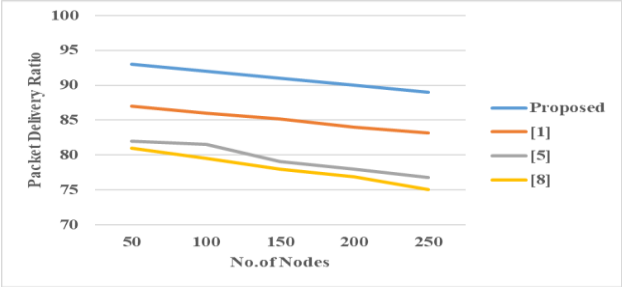

Figure9: Packet delivery ratio

Compared to [1], the packet delivery ratio is 6.95% more in the proposed solution, 14.6% more compared to [5] and 16.51% more compared to [8].

The results of average delay against number of nodes is given in Table 2 & Figure 10

No of Nodes	Proposed	[1]	[5]	[8]
50	15	18	21	24
100	14	16	18	22
150	13	15	17	21
200	12	15	16	20
250	12	14	15	18

Table 2: comparison of delay

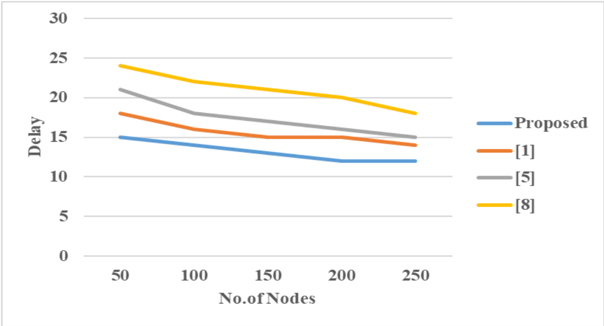

Figure10:Delay comparison

Compared to [1] , average delay is lower by 15.38% in the proposed solution , 24.13% lower compared to [5] , 37.14% lower compared to [8]. The delay is lower in the proposed solution due to reduction in number of hops in the geographic routing strategy adopted in the proposed work.

The result of network overhead against number of nodes is shown in Table 3 & Figure 11.

No of Nodes	Proposed	[1]	[5]	[8]
50	72	80	82	85
100	85	92	93	97
150	89	97	100	106
200	94	104	108	116
250	97	116	118	127

Table 3: Analysis of overhead

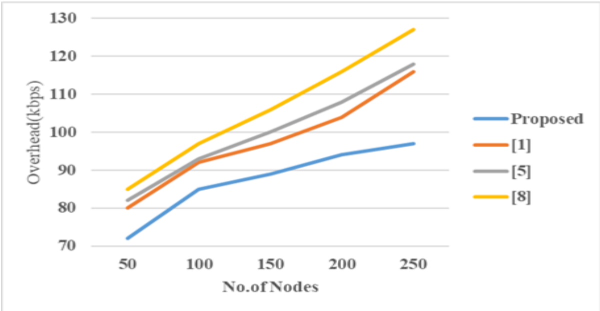

Figure 11: Analysis of overhead

Compared to [1], overhead is lower by 10.63% in proposed solution, 12.77% lower than [5] and 17.7% lower than [8]. Adaptive multi path propagation and geographic routing has reduced the network overhead in proposed solution.

The result of life time against number of nodes is given in Table 4 & Figure 12.

No of Nodes	Proposed	[1]	[5]	[8]
50	28	24	19	15
100	33	27	21	17
150	38	32	22	19
200	43	36	23	21
250	48	40	25	22

Table 4: Life time comparison

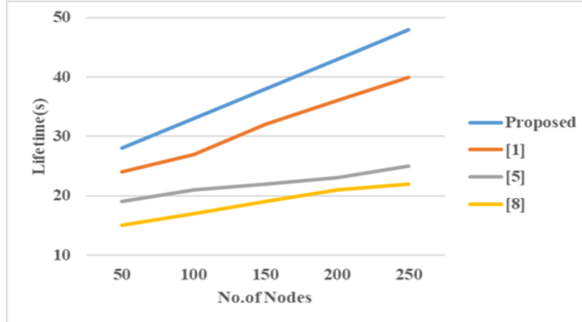

Figure 12: Life time comparison

Compared to [1], life time is higher by 19.4% in the proposed solution, 72.7% more compared to [5] and 102.1% more compared to [8]. Due to the minimization of number of hops and retransmissions, energy consumption is reduced and this has increased the life span in the proposed work.

The results of network throughput for different rate of packet generation are given in Table 5 & Figure 13.

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Total Sending rate (kbps)	Proposed	[1]	[5]	[8]
100	92	84	83	81
150	140	136	129	125
200	181	173	167	160
250	224	208	201	195
300	267	251	242	238

Table 5: Throughput comparison

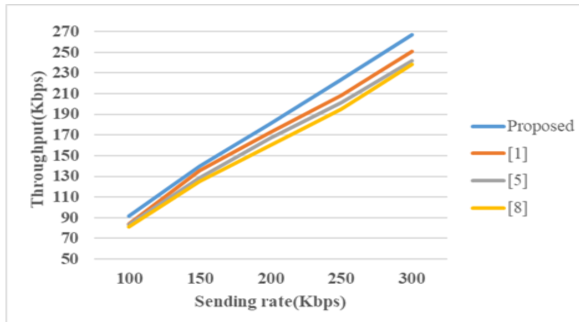

Figure 13: Throughput comparison

The proposed solution has higher throughout in terms of 6.1% more than [1], 9.97% more than [5] and 13.14% more than [8].

The split ratio between high and low priority packet is set to 70:30 and throughput is measured for varied packets rate from source. The comparison is given in Table 6 & Figure 14

Total Sending rate (kbps)	Proposed	[1]	[5]	[8]
100	65	52	50	47
150	100	83	82	79
200	130	100	96	90
250	160	120	117	110
300	195	160	157	147

Table 6: comparison of throughput on 70:30 split

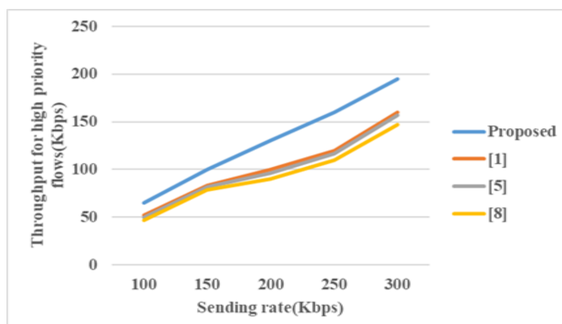

Figure 14: Throughput comparison on 70:30 split

The proposed solution has higher throughput in terms of 9.97% greater than [1], 29.48% greater compared to [5] and 47.42% greater compared to [8]

6. Conclusions and Future scope

A multi factored strategy with the objective of providing improved packet delivery ratio in zone-based sensor network is proposed in this work. Geographic routing is adapted with relay selection based on a preference score, adaptive multi path propagation, flow differentiation and congestion control, redundancy coding are the multi factored strategies proposed in this work. Redundancy coding has reduced the number of retransmissions in the network. Flow differentiation and control has reduced the congestion in the network. Preference score is calculated based on energy availability, security and reliability of the nodes and use of it in routing has increased the packet reliability. Due to multi factored strategy, the packet delivery ratio improved by 6.95% in the proposed work, life time improved by 19.4% and delay reduced by 15.38% compared to existing works. In the further enhancement, the proposed solution can be improved to reduce the average energy consumption of nodes within the zone in order to improve packet delivery ratio.

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