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A Joint Congestion Control Mechanism Through Dynamic Alternate Route Selection Algorithm in IoT Based Wireless Sensor Network

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Abstract. Internet of Things (IoT) based Wireless Sensor Networks (WSN) comprises several miniaturized sensor nodes limited in terms of transmission range, available battery power and data rate. These nodes work collaboratively to monitor physical/environmental conditions and provide appropriate control action. Congestion has become one of the key issues in WSN because of the increase in multimedia traffic and IoT proliferation in WSN. The higher traffic load can easily lead to link-level or node-level congestion in the network. A joint layer 4/layer 3 driven congestion control distributed algorithm is proposed to detect congestion and thereby avoid congestion through alternate routing. In this work, congestion detection and avoidance method are presented which uses Random Early Discard (RED) scheme, instead of the Droptail Queue. This scheme computes a threshold to avoid further congestion and uses Location Aided Energy Efficient Routing protocol (LAEER) to find the alternate path for routing data packets. As a result, this approach achieves load balancing as it spreads traffic throughout the network. Also, simulation results infer that LAEER shows better results in terms of Quality of Service (QoS) metrics such as PDR in comparison with AODV as it has avoided further packet drops proactively through alternate forwarding neighbor selection.

Keywords. Congestion, Load Balancing, Queuing mechanism, Routing, Random Early Discard (RED), Location, IoT, Energy, Packet Delivery

1. Introduction

IoT based WSN consists of various resource constrained sensor nodes and at-least one sink (Gateway) that collaboratively work together to accomplish the mission. The sensor network topology can dynamically change due to failure or movement of nodes or intermittent link quality. Also, the deployment of sensor nodes can be dense or sparse depending on the application requirement. Hence, the protocol designers focus is to achieve high QoS metrics such as Packet Delivery Ratio, Throughput, minimum latency (End to End Average delay) and Network Lifetime as limited battery [1-2].TCP

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have sub-optimal performance and high energy consumption in WSN as it results in excess signalling overhead via handshakes for end-to-end data delivery [3-5].

2. Related Work

Congestion occurs if several sensor nodes simultaneously attempt to transmit packetized data to the sink.TCP variants such Tahoe, New Reno, Vegas, SACK Westwood etc can't solve congestion issues in WSN and throughput/data-rate is limited to only 250kbps for IEEE 802.15.4 [6-7]. The sensor nodes nearby sink are prone to link level congestion due to the intense upstream activity. Traffic control (i.e., limiting the offered load) and Resource Control (via increasing network capacity) are the methods to reduce congestion [8-11]. Dynamic Alternate Path Selection (DAlPaS) algorithm uses the resource control technique through alternate path selection [10], but it incurs high signalling overhead [12]. Thequeuing mechanism impacts the congestion control, because the order of buffering capacity impacts the performance. Droptail is a passive method where router drops the tail of the data packets as queue overflows, thereby it reduces the throughput. The Random Early Detection (RED) queue mechanism does not wait until the buffer is filled up to detect congestion or by removing data packets, but start to detect congestion before the buffer is nearing overflow [13-14]. A review of reliable transport protocols in WSN is carried out in [15]. [16] Proposes Active Queue Management (AQM) model to estimate and mitigate congestion using RED but doesn't optimize via the joint cross layer design. The proactive, reactive and hybrid routing protocols has its pros and cons with trade off in QoS metrics such as throughput, delay and energy consumption [17-19] surveys the energy efficient routing protocols for IoT based WSN.

3. Design Architecture

3.1. Architecture- Protocol Stack

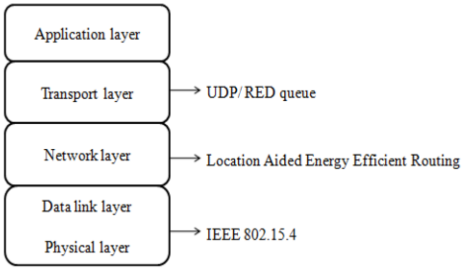

Figure 1. Protocol stack of sensor node

Fig 1 shows the proposed protocol stack, as an alternate to ZigBee stack with a new layer 3 routing protocol that uses node's location for routing decision. UDP, an overhead-less protocol that incorporates the RED mechanism in joint operation with Layer 3 helps in alternate routing path to avoid congestion.

3.2. Random Early Discard (RED)

The RED mechanism starts to signal congestion detection before the buffer starts to overflow via marking of packets without the need to drop them. The packet dropping is based on the minimum threshold (MinThres) and maximum threshold (MaxThres). The average queue size (Avg) value is monitored if it lies between MinThres and MaxThres. The incoming packet is marked with probability P=p(Avg) and is an incremental function of the average queue size. When the average queue length is more than the MinThres, the packets will be dropped randomly or will be marked in terms of Explicit Congestion Notification (ECN) bit. If average queue size is more than the MaxThres, all the packets arrived will be dropped [13-14]. The Avg parameter is initialized to zero and is monitored. The new value is assigned the value as (1-k)*Avg + k*q with each arriving packet, where k is constant and q is actual queue size.

3.3. Location Aided Energy Efficient Routing (LAEER)

LAEER routing protocol is are active on-demand algorithm that uses the geographical position and remaining battery energy of neighbour sensor nodes for route determination via forwarding neighbour selection. The modules are shown in Fig 2.

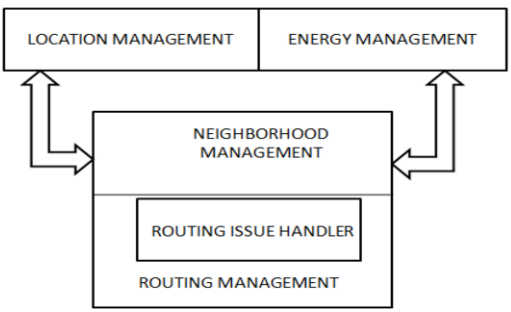

Figure 2. Node level architecture

During routing, only the neighbouring nodes that makes progress towards reaching the destination participate in forwarding packets, whereas the non-forwarding list of active nodes are switched to sleep state. The LAEER protocol chooses the best optimal forwarding neighbour that is closer to sink in terms of minimizing distance with desirable link quality. The location management module computes the position of the node via cost effective localization algorithm that uses Received Signal Strength (RSS) instead of GPS [20]. The neighbourhood management consists of neighbour discovery module and the source node requests route request and waits for reply from neighbouring nodes. In the routing management, the best progress neighbouring node is selected by the forwarding node. The best choice among forwarding nodes is selected using the metric equation given in equation 1.

$$\max\left(\alpha \times \frac{\text{Distance between Neighbor and sink}}{\text{Maximum Deployement Coverage Distance}} + \beta \times \frac{\text{Residual Energy of Neighbor}}{\text{Maximum Available Energy of Sensor Node}}\right) \quad (1)$$

Where α and β are the weighted constants and$\alpha + \beta = 1$. Energy management module is used to reduce the overall energy consumption of the network by switching to sleep state if in non-forwarding list [15].

4. Results

4.1. Performance Evaluation Metrics

The simulation has been done using Network Simulator NS2, a discrete event simulator with support of IEEE 802.15.4 MAC/PHY libraries. The joint LAEER protocol with UDP is analysed using the RED and droptail queue mechanisms under different scenarios. The metrics such as Total Energy Consumption (TEC) in the network, Normalized Energy Consumption (NEC) per packet, PDR, Average End to End Delay are evaluated.

4.2. Simulation Results

The simulation is carried in the grid topology of scalable network size of 9, 49, 64, 100 and 121 nodes that are equidistant with10metersinter-separation between nodes and all are stationary. The source and sink are both placed at the diagonal ends. The simulation was repeated for ZigBee's mesh AODV routing and results are presented.

4.3. Evaluation of metrics: PDR, Average delay, TEC, NEC using LAEER protocol

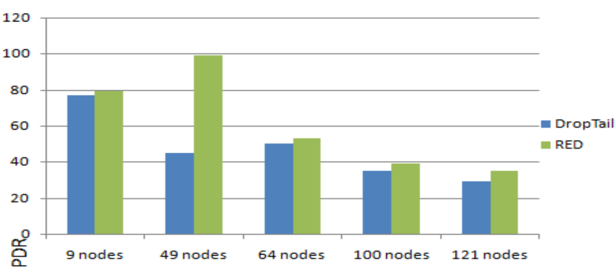

Figure 3. Queue mechanism on PDR (%) vs Network Size via LAEER

Fig 3 shows the PDR analysis using the Droptail and RED queue mechanisms and is reported high for RED since it doesn't wait till the buffer to overflow unlike droptail.

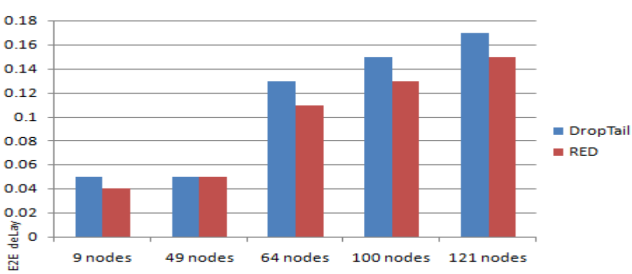

Figure 4. Impact of queue mechanism on Average end to end delay (ms) with respect to different network size via LAEER

It is evident from Fig 4, that the average packet delay is low when RED is used instead of jointly using droptail with LAEER routing strategy. Fig 5 shows TEC is more when droptail is used and is effectively reduced through LAEER alternate routing via RED. Fig 6, shows RED consumes relatively less NEC compared to Droptail via LAEER.

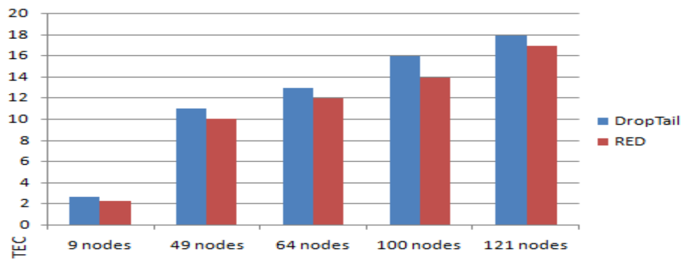

Figure 5. Impact of queue on TEC (J) with respect to different network size

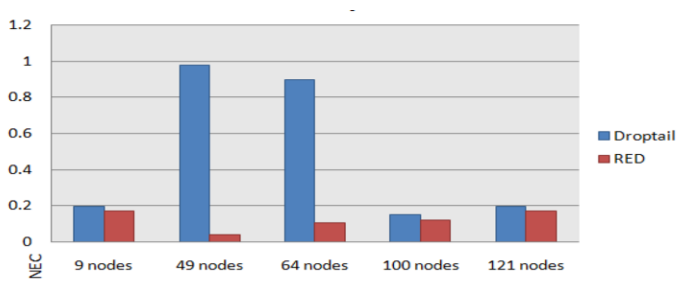

Figure 6. Impact of queue on NEC (J/packet) with respect to different network size

4.4. Evaluation of PDR using AODV protocol

RED performs well with AODV as shown in Fig 7. However, LAEER outperforms AODV due to alternate forwarder node selection instead of n/w flooding of RREQ/REP.

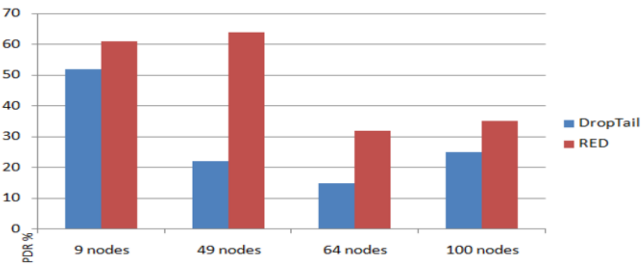

Figure 7. Performance of AODV protocol with different network sizes

5. Conclusion

The cause for data packets loss due to link level congestion and node level congestion are simulated and analysed. The QoS metrics is reported high when RED queue mechanism is used instead of conventional Droptail. Location Aided Energy Efficient protocol is proposed as the dynamic alternate path routing algorithm in this work that uses the geographical position information of forwarding nodes and residual energy as the routing metrics. Hence, the overhead and overall energy consumption is reduced in the network due to stateless, one-hop neighbourhood tracking alone. When UDP/RED mechanism jointly works in conjunction with LAEER protocol, metrics such as PDR, average E-E delay are reportedly high. It is inferred from simulation results that LAEER protocol performs better than AODV in IoT based wireless sensor network.

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