Quality of Service for Differentiated Traffic using Multipath in Wireless Sensor Networks

Prabha R, Shivaraj Karki, Manjula S. H, K. R. Venugopal, L. M. Patnaik

Abstract- Providing Quality of Service in wireless sensor networks refers to a set of service requirements to be satisfied when transmitting a packet from source to destination. The main challenge involved in quality of service based data transmission is to select the efficient path from source to destination. Quality of service in wireless sensor networks is an important factor. The two most important parameters that hinder the goal of guaranteed event perception are time-sensitive and reliable delivery of gathered information, while minimum energy consumption is desired. In this paper, a multi-traffic, multi-path and energy aware data transmission mechanism is proposed for improving Quality of Service in Wireless Sensor Networks. The simulation results demonstrate that, the algorithms efficiently improve quality of reception ratio, satisfying the required quality of service metrics.

Index terms- Differentiated Traffic, End-to-End Delay, Energy, Reliability, Wireless Sensor Networks.

I. INTRODUCTION

The Wireless Sensor Networks (WSN) is a kind of self-organizing wireless network consisting of a group of randomly distributed embedded sensor node. These nodes integrate sensor, data processing unit and communication module. WSN serves a large number of applications that are critical to the extent of saving human life. Serving reliable and timely information is utmost important to any WSN. Quality of Service (QoS) in WSN enables techniques and requirements to provide reliable and trusted service. QoS is a set of service parameters to be fulfilled when transmitting a stream of packets from source to destination. Reliability, timeliness, energy, robustness, availability, security, throughput, end-to-end delay, jitter and packet loss rate are the most fundamental parameters of QoS in WSN. Certain applications of wireless sensor networks like biomedical and vehicular have different QoS requirements. In wireless sensor network the data traffic type is classified into (i) Regular traffic which does not require any data related QoS requirement. (ii) Reliable traffic which requires data delivery without any loss, can withstand a certain amount of delay. (iii) Delay sensitive traffic which requires data delivery within certain deadline. (iv) Critical data which is delivered within the deadline time [1].

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Motivation: Quality of Service based data forwarding in wireless sensor network has major challenges and constraints. Localized Multi-Objective Routing LOCALMOR [1] implements a localized QoS routing protocol based on different traffic types and routing decision is based on latency, packet reception ratio, packet delivery time and energy criteria. LOCALMOR [1] considers CBR traffic type, uses multisink and single path hence priority queue is required.

Contribution: The main contribution of this work is of QoS based data forwarding techniques in wireless sensor networks for differentiated traffic. The proposed algorithms handle different traffic categories namely, Constant Bit Rate (CBR) traffic for regular traffic, Variable Bit Rate (VBR) for delay sensitive traffic. The packet is forwarded from source to destination considering QoS metrics namely, delay, reliability, residual energy and link quality.

Organization: Section II discusses the Related Work, Section III presents the Network Model and Assumptions, Section IV gives the Problem Definition, Section V Explains the Algorithms for the various data traffic types. Section VI deals with Performance Analysis and simulation study followed by Conclusions and References.

II. RELATED WORK

Localized routing protocols makes use of localization information in order to select the next forwarding node among the neighbors. Djamel and Ilangko proposed a multi-objective Quality of Service (QoS) protocol for wireless sensor networks (WSN). The protocol takes into account the traffic diversity typical for many applications. It ensures several QoS metrics for different traffic categories, and attempts for each packet to fulfill the required metrics in a power- aware and localized way [1]. Lim and Mohan [2] addressed three energy aware geographical data forwarding schemes. The proposed three energy aware forwarding schemes are namely, Energy Aware Geographical Forwarding Scheme (EAGFS), Highest Energy Forwarding Scheme (HEFS) and Above Average Energy Forwarding Scheme (AAEFS), this schemes Considers residual energy in their decision of the next hop. The aim is to delay the death of the first node in the sensor network so as to achieve a longer network lifetime thus enhancing the QOS in the network. Navid and Turgay [3] discussed the reasons behind failure in packet reception ratio. Analyzed the concept of multiple receiver radios in mobile sinks. Actual experiments were conducted to gain performance using multi-radio sinks. Multiple sinks significantly improved packet reception ratio with less number of retransmission. Minimizing number of retransmissions improves QoS performance metrics delay, efficient use of energy and network lifetime. Energy efficiency, network

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communication traffic and failure tolerance are important QoS factors related with performance of WSN. He *et al.*, [4] forwards packets by selecting routes that ensures a given speed. Exponential Weighted Moving Average for link latency estimation is used. The aim of this protocol is to reduce QoS metric delay. It probabilistically chooses the node among the ones that fulfill the required speed, which is energy efficient and balances the network load.

Jain *et al.*, [5] came up with centralized and distributed solution for QoS topology control, by employing opportunistic transmission to catch the best transmission opportunities on transitional links. A unique contribution of this work is consideration of link quality and applies opportunistic communication in topology control for wireless sensor networks.

Muhammad *et al.*, [6] addressed an energy-aware, multi-constrained and multi-path QoS provisioning mechanism for WSN based on optimization approach. Detailed analytical analysis of reliability, delay and energy consumption is presented to formulate the optimization problem in an analytical way. A greedy algorithm is proposed to achieve the desired QoS guarantee while keeping the energy consumption minimum. A simple but efficient retransmission mechanism is employed to enhance the reliability further, while keeping the delay within delay bound.

Felemban *et al.*, [7] presented a novel packet delivery mechanism called Multi-Path and Multi-SPEED Routing Protocol (MMSPEED) for probabilistic QoS guarantee in wireless sensor networks. The QoS provisioning is performed in two quality domains namely, timeliness and reliability. Multiple QoS levels are provided in the timeliness domain by guaranteeing multiple packet delivery speed options. In the reliability domain, various reliability requirements are supported by probabilistic multipath forwarding. These mechanisms for QoS provisioning are realized in a localized way without global network information by employing localized geographic packet forwarding augmented with dynamic compensation, which compensates for local decision inaccuracies as a packet travels towards its destination.

Applications like target tracking require some QoS guarantees. Some factors limit the ability of multi- hop sensor networks to achieve desired goals such as the delay caused by network congestion, limited energy and computation of sensor nodes, packet loss due to interferences and mobility. Shanghong *et al.,* [8] designed an adaptive QoS and energy-aware approach using an improved ant colony algorithm for WSNs. Belghachi *et al.*, [9] focused on an idea to ensure QoS, by detecting paths which meet QoS requirements based on Ant Colony Optimization through a routing process, which can detect path based on ant colony optimization.

Jeya [10] analyzed energy-aware QoS protocol for adhoc wireless networks. The performance metrics considered were average lifetime of the node, average delay per packet and network throughput. The parameters considered are end-to-end delay, real time data generation or capture rates, packet drop probability and buffer size. Mirela *et al.*, [11] focused on QoS based protocol for wireless sensor networks application. Packet forwarding was done based on geographic routing mechanism with QoS support. Forwarding node selection is based on high residual energy at the nodes, high link quality and low load. Congestion control was incorporated using ring or barrier mechanism combined with QoS support is used to forward packets in the network.

Adel et al., [12] designed a data forwarding protocol for WSN which aimed at extending the network lifetime. Position information and remaining energy of nodes are parameters for forwarding packets from source to destination. The protocol is an efficient and energy conservative technique for wireless sensor networks.

III. NETWORK MODEL AND ASSUMPTIONS

Nodes are aware of their positions, through an internal Global Positioning System (GPS) device. Each node is aware of its battery state E_{vi}, all nodes have same initial energy and spherical transmission power range E_{range}. The set of nodes in n_i vicinity represented by S_{ni} consists of n_i's neighboring nodes which are within the power range and within one hop distance, S_{ni}= { n_j: Ln_i, n_j <= E_{range} and one hop distance } *i.e*, forward set for node n_i towards destination which provide positive advance towards the destination Regular Sink (*RS*), Normal Sink (*NS*).

$$E = 2\ Eelec\ +\beta d\alpha \qquad (1)$$

The energy consumed for transmitting one bit from source to destination is as given in equation (1) [1]. Where *Eelec* is the energy utilized by transceiver electronic, which is independent of the distance. $\beta d\alpha$ is the power utilized in transmitting one bit over destination d. Where α is the path loss ($2 \le \alpha \le 5$) and β is a constant given in Joules/bit × m^{α} . Equation (1) is for unicast packets. For broadcasting messages energy consumed is given by equation (2).

$$E = ((\ \|N(vi)\| + 1\ ) E_{elec}\ ) +\ \beta\ d^{\alpha} \qquad (2)$$

Like other geographical routing protocols nodes determine their neighboring nodes other related parameters via the execution of Hello Protocol.

IV. PROBLEM DEFINITION

The objective of proposed algorithms is to ensure required quality of service for differentiated traffic types namely CBR and VBR traffic types. The QoS metrics considered are reliability, timeliness and residual energy of the node. Multiple sinks and multi path are employed for improving packet reception ratio and reliability.

V. ALGORITHMS

This section presents the various algorithms designed for providing QoS for different traffic types in WSN. The algorithm for obtaining Neighbor information is given in Table I. The algorithm extracts up to date network information viz., node location, packet reception ratio, velocity or speed with which packet can be forwarded to destination and residual energy of the nodes. Updates the number of neighbor nodes available for given node and their respective QoS metrics. These QoS metrics are periodically updated by Hello protocol. Each Hello packet carries the location of sending node, node id, node residual energy, hello packet sequence number, global synchronous clock, time stamp. At every node on reception of hello packets, nodes calculate packet reception

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ratio using Weighted Mean Exponential Weighted Moving Average (WMEWMA) [1].

A. Neighbor Management Algorithm:

Table I : Algorithm for Neighbor Management

Begin

Input HelloPacket

1. Neighbour set of node$_i$: S_{ni} where Sn_i = { n : $Dist_{i,}$, *node* < P_{range} }

2. Set of nodes that belong to Sn_i which are closer to destination FW_i^d (*Dest*) = $nSn_i : L - L_{next} \geq o$

3. Becon message or hello message is sent at regular Time Interval

4. A Counter/Timer is set to Hello Period and is Decremented Timer = Hello Period

5. If Timer Expires

6. Hello Protocol Broadcast Packets to all Neighbor nodes.

7. At Nodes receiving Hello pkt Initial *NLP* = 0

8. Update Neighbor Link Profile

9. Update Delay

10. Update *PRR*

using Weighted Mean Exponential Weighted Moving Average (WMEWMA) [1].

B. Algorithm for Delay Updating

Algorithm for updating delay process is given in Table II. Updating delay process involves following procedure. Initially delay of all nodes are set to zero in line 1, after receiving each Hello packet delay is calculated by taking difference between sent time and current time, size(ack)/bw (considers time of receiving entire packet). For successive reception of Hello packet from same node Exponential Weighted Moving Average (EWMA) is used in calculating Delay.

Table II: Algorithm for Updating Delay

Begin
1. Initialize delay = 0
2. for each Hello packet received for first time
3. $delay_{curr}$= *Sent Time* – ((*RevdTime* - *Size(ack)*) / *BW* at regular Time Interval
4. *Delay* = α $delay_{curr}$ + (1 - α) $delay_{prev}$
end

Table III: Algorithm for Updating PRR

Begin
1. *MP* (Missed Packet) = 0; *SQL* (Sequence no of last Packet) = 0; *CW*(Current Window) = 0; *Pr* (no of packets received) = 0;

2. for each Hello packet received

do
{
CW = CW+1; Pr = Pr+1; MP =P + Pck.sq - (SQL+1);
SQL=Pck.sq;
}

3. *Prr = Pr* / (*Pr + Mp*)

4. If (*CW == W*)

{ $Prr_{ni,nj}$= α $Prr_{ni,nj}$ + (1 - α_);

r=(r + f);

MP = CW = Pr = 0 **}**

End

C. Algorithm for Updating Packet Reception Ratio

The algorithm for calculating the Packet Reception Ratio (PRR) is given in Table III. Updating PRR involves calculating packet reception ratio. WMEWMA is used in calculating PRR, initially number of missed packets, sequence no of last packet received, window size is set and number of packets received is set to zero in line 1. For each Hello packet received current window, packet received count are incremented. Number of missed packets is calculated using *SQL* and received packet sequence number. *Prr* is calculated in line 3, when current window reaches window size *Prr* is calculated using α = 0.6. In line 4 window size is set to 30.

VI. PERFORMANCE EVALUATION

The performance of the QoS based algorithms are validated through simulations. This section describes the simulation set up and result analysis.

A. Simulation Setup

The QoS parameters considered in the proposed work is implemented in the network. Implementation of these QoS based packet forwarding techniques is carried out in network simulator2 (ns2). ns2 uses OTCL and C++ languages. The proposed QoS algorithms are implemented in ns2 are rigorously executed to measure various QoS metrics viz., latency, reliability, energy and throughput. The network scenario is tested for various time duration considering different environment and congestion settings. Comparison of our work is extensively carried out with LOCALMOR [1], considering the QoS metrics End-to-End delay, packet reception ratio and on time packet delivery. The major criteria considered for forwarding the packets depending on type is time constraint and energy. The simulation configuration consists of 200 nodes with 500 * 500 simulation area and 1000s of simulation time. This high number of nodes permits to investigate scalability.

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The nodes are distributed in Poisson point process manner with node density 0.005 nodes/meter square, distributed in a grid topology, with approximately 50m of power range, resulting in an average density of 8 (each node has seven neighboring nodes, on average). Constant Bit Rate (CBR) traffic is used to generate regular packets with1kb/s.

Variable Bit Rate (VBR) is used to generate reliable packets. Hello protocol is executed more frequently for 1 sec, thus the overall traffic of the network, i.e., traffic overload is more as compared to LOCALMAR [1]. Table IV summarizes the simulation parameters used in the simulation. Packet delivery time is foremost important QoS metric, in this work packet delivery time is considered as packet deadline time. Unlike the previous work LOCALMOR each traffic type is assigned different deadline time i,e., 160 ms for critical and delay sensitive packets. 200 ms for regular and reliable packets. Thus critical and delay sensitive packets have 80% lesser deadline time than other traffic type.

B. Performance Analysis

Implementation is carried out in network simulator 2 (ns2) which uses OTcl and C++ codes to implement the given scenario. Performance metrics considered here are End-to-End delay, packet reception ratio and on time packet delivery. Starting with end to end packet reception ratio, critical packet rate is varied keeping VBR and CBR unaffected. Time taken by packets to reach sink is calculated by destination (sink) node using 'sent time' field information in received packet (network uses global synchronized time). End-to-End delay is measured in milliseconds.

Fig 1 shows the comparison of critical packet End-to-End delay versus critical packet rate. Critical packet rate is varied keeping VBR and CBR unaffected. Time taken to reach sink node is measured, and tabulated in milliseconds. At lower critical packet rate, critical packet End-to-End delay is lower and increases for next consecutive packet rates, and remains almost constant for higher packet rates, this increase is due to increase in overall traffic in the network. End-to-End delay varies from 40ms to 69.9ms where as in LOCALMOR End-to-End delay ranges around 155ms.

Table IV: Simulation parameter values for simulation scenarios

Parameter	Value
Number of Nodes	200
Simulation Area	500 × 500
Traffic Regular	1 Kb / s
Critical Packet Rate	From 0.1 to 1 kb/s
Deadline for Critical Packet	0.2 sec
Hello period	1 sec
EWMA Smoothing Parameter α	0.6
EWMA Window	30
Total required PRR	100
MAC Layer	802.11
Bandwidth	200 Kb/s
Propagation Model	TwoRayGround

Thus our work outperforms LOCALMOR giving 45 % lesser End-to-End delay as depicted by the curve MTD. This comparison effectively justify that availability of minimum number of nodes during end to end transmission of packets is been enhanced by EAGFS technique

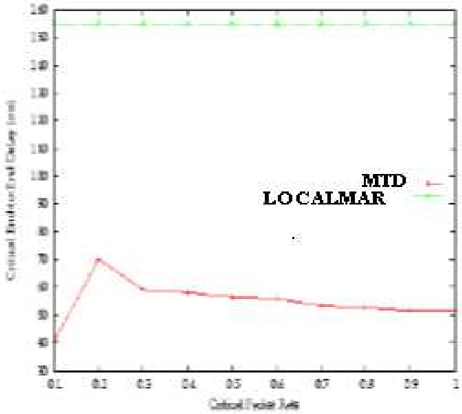

Figure 1: Critical Packet Rate v/s Critical End-to-End Delay

Fig 2 shows the comparison of critical packet reception ratio versus critical packet rate. Our work performs on-par with LOCALMOR. Critical Packet Reception Ratio (PRR) is maximum for lower rate and it decreases and remains constant at higher critical packet rate. Decrease in PRR for higher packet rate is due to overall increase in traffic rate in network reception.

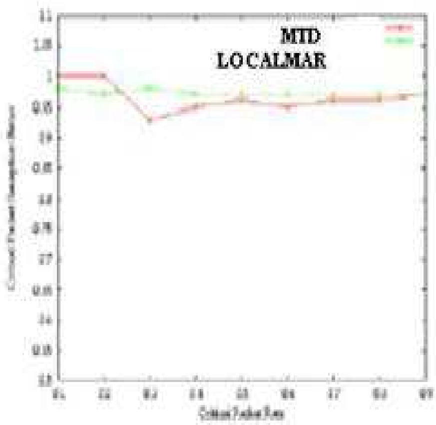

Figure 2: Critical Packet Rate versus Packet Reception Ratio for Critical Packets

Fig 3 shows comparison of End-to-End delay of regular and reliable packets, considering End –to-End delay of regular and reliable traffic which constitute CBR and VBR traffic against critical packet rate. As critical packet rate increases End-to-End delay increases from 114.6ms to 128.08ms, this gradual increase along critical packet rate is due to overall increase in the network traffic, whereas in LOCOALMOR regular packet End-to-End delay decreases from 280ms to 160ms. Fig 4 shows regular packet reception ratio against critical packet rate. Packet reception ratio of regular and reliable packet is maximum for lower rate and slightly decreases as critical packet rate increases. Packet reception ratio of regular packet is

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compared with LOCOLMAR our work outperforms LOCOMAR protocol.

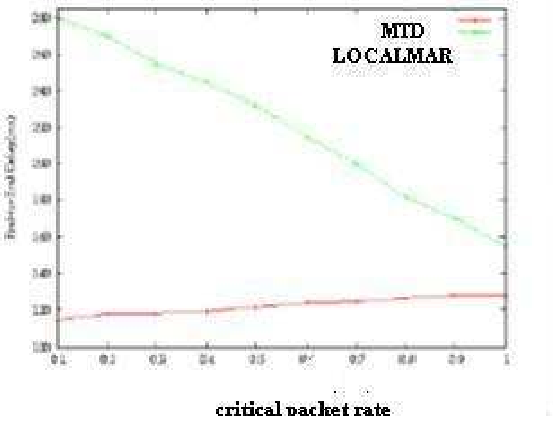

Figure 3: Critical Packet Rate versus End-to-End delay

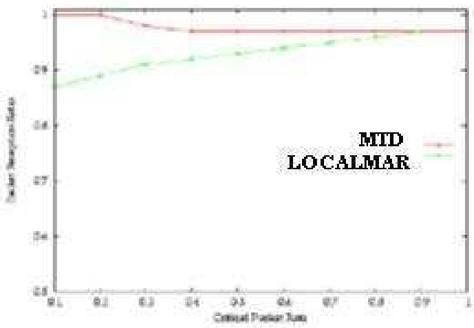

Figure 4: Critical Packet Rate versus Packet Reception Ratio

VII. CONCLUSIONS

Proposed protocol considers the different traffic types VBR, CBR and burst traffic which are used for different application. The protocol provides differentiated QoS based data forwarding considering different QoS metrics for each packet type. Protocol ensures required QoS metrics for each packet type with which it can be routed. QoS metric considered are energy, reliability, latency and speed. Congestion is introduced to get realistic readings. Energy efficiency is considered for all packets and achieved by selecting the most power efficient candidate among those offering the required data related QoS (delay and reliability). Future enhancements, the protocol can be implemented with real-time devices. Though congestion is not an issue in our implementation increasing further traffic type and traffic rate may impose congestion problem.

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