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Adaptive Majority-based Re-routing for Differentiated Delay in Wireless Sensor Networks

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Abstract

The main purpose of a sensor network is information gathering and delivery. Therefore, the quantity and quality of the data delivered to the end-user is very important. In this paper, we focus on building one aspect of service quality based routing model as delay called MRHD which can route packets towards the destination node by classifying data into differentiated classes. Moreover, MRHD employs an adaptive policy called majority based re-routing policy in order to route the packets with instantaneously change in number implying occurrence of special events via paths with lower delay.

Keywords: *Wireless Sensor Networks (WSNs); delay routing; QoS-based routing; hop by hop routing; majority-based re-routing.*

1. Introduction

Recent advancement in wireless communications, electronics, low power design and also tendency to use high performance low cost products have led to emergence of Wireless Sensor Networks (WSNs) [1].

As the main purpose of a WSN is information gathering and transmission of it to the sink node, the main problem is to deliver information correctly with minimum energy consumption.

An important issue in WSN is routing protocol; since it deals with energy consumption, delay, delivery ratio, and network lifetime. Depending on different applications, generated packets call for diverse Quality of Service (QoS) supports. The commonly accepted QoS metrics include bandwidth, delay, delay jitter (delay variation), reliability (packet loss rate), etc[2].

SWR [3] (Single path With Repair routing scheme) is a scheme in which data is forwarded along a pre-established single path. SWR consists of four phases: optimal path setup, data forwarding along the selected path, broken link detection, and path repairing. High delivery ratio is achieved by path repair whenever a break is detected.

SPEED [4] provides an guarantee end-to-end and software real time The protocol requires that each node keeps the information of its neighboring nodes to find a geographical route is used. SPEED attempts for all packets in the network to guarantee a specified speed So that each application before decisions could delay end-to-end packet transmission speed calculated by dividing the distance to the BS.

MMSPEED [5] extends the SPEED protocol through introducing multiple speed levels to guarantee timeliness packet delivery. In this protocol, data packets are assigned to the appropriate speed layer to be placed in the suitable queue according to their speed category. After that, data packets are serviced in the FCFS policy. This mechanism ensures that high-priority packets are serviced before low-priority packets. MMSPEED provides a probabilistic QoS guarantee in two different domains through combining geographic forwarding technique with a multipath routing approach.

Energy-Efficient Multipath Routing Protocol [6] exploits the path diversity provided by multipath routing approach to prolong network lifetime by distributing network traffic over multiple node-disjoint paths.

Delay-Constrained High-Throughput Protocol for Multipath Transmission (DCHT) [7] of using multipath routing approach to support high-quality video streaming in low-power wireless sensor networks. DCHT introduces a novel path reinforcement method and uses a new routing cost function, which considers the expected transmission count (ETX) [8] and delay metrics to discover high-quality paths with minimum end-to-end latency.

In this paper, we focus on building a general routing protocol called MRHD which takes into consideration of several factors that affect the routing policy. These factors are relevant to previously delays, progress to the sink node, hop count, free buffer size of sensors, distance of the node and energy level of sensors for each path. All these factors are mixed and integrated into the notion of Path Score in this protocol. As the main objectives of this protocol are the reduction of packet loss, reduce use energy, and reduce delay, we are interested in choosing the best quality path of the network for data transfer.

Actually, this protocol guarantees a longer network lifetime, less end to end delay , less packet loss , and higher delivery ratio.

The remainder of the paper is organized as follows. Section 2 explains the network model and assumption. The specifications of MRHD protocol description are presented and discussed in section 3. Section 4 describes performance analysis. Finally, Section 5 concludes our work, and discusses some future directions.

2. NETWORK MODEL AND ASSUMPTION

In the following, the network is represented by a set V of nodes. We note $dist(v_i,v_j)$as the linear distance between two nodes $v_i,v_j \in V$. Each node should be aware of its own coordinates. Sensors shipped with the GPS receivers, can readily sense their location information. Alternatively, location information can also be acquired through a distributed localization service. This position serves as the network (global) address. In addition, the node should be aware of its current battery state B(v_i) (also termed residual energy). We assume that nodes have the same and spherical transmission power range P_{range}, and that each node can control its transmission power. The set of nodes in vi's vicinity denoted by $N(v_i)$ is called vi's neighboring nodes defined by $N(v_i) = \{v_j: dist(v_i,v_j) \leq P_{range}\}$. In addition to N(vi), we define the set of neighboring nodes providing positive progress for node v_i, towards the sink, denoted by $N_{prog}(v_i)$, as the set of neighboring nodes that are closer to the sink than v_i . It is given by: $N_{prog}(v_i) = \{v_j \in N(v_i): dist(v_j, sink) \leq dist(v_i, sink)\}$. Also, MRHD uses the progressive value between two nodes v_i and v_j denoted by d_{prog} (v_i, v_j), which is the distance from one node to the other node in the direction of the vector from the source to the sink. Like all geographic routing protocols, each node needs to know about the positions of its neighboring nodes as well as the destination node (sink). A HELLO protocol is executed between neighboring nodes allowing mutual update of the neighboring nodes' list and several parameters, as in [5],[9].

3. PROTOCOL DESCRIPTION

As mentioned earlier, MRHD running on each node in a distributed manner determines next nodes of paths from a source node to the sink based on a score function for normal decision making along with a majority-based rerouting policy for special situations.

3.1 Normal Decision Making

Depending on the application, it is possible to define n differentiated classes of delay denoted by DC_k ($0 \leq k \leq n$). Each one is requested by some packets. A score function is a key means to make decision during routing. In fact, this function value determines the class every link can support. This function formally defined as:

$$Score\_total = a \times Score\_delay + b \times Score\_energy \quad (1)$$

$$Score\_delay = \alpha \times W_D + \beta \times W_P + \gamma \times W_H + \rho \times W_B \quad (2)$$

$$Score\_energy = \vartheta \times W_T + \tau \times W_E \quad (3)$$

$a, b, \alpha, \beta, \gamma, \rho, \vartheta$ and τ, are the coefficients denoting the significance of each factor. All coefficients take their absolute value in the interval [0,1]. Also, the sum of the each relationship coefficients must be equal to 1. If we set any of them to be zero, the corresponding component is no longer considered. So, MRHD can have variant configurations depending on application and one can choose a suitable configuration set to satisfy his/her specific requirements.

At the beginning, each node noticing different factors of reliability determines the delay class provided by every node in its vicinity, and then the packets will be forwarded through appropriate nodes based on the delay class they support.

To describe more exactly, a set of neighboring nodes of node v_i which can support a specific class of delay DC_k denoted by $N_{prog}^{DC_k}$, is formally defined as: $N_{prog}^{DC_k}(v_i) = \{v_j \in N_{prog}(v_i): NS_k \leq Score\_total(v_j) \leq NS_{k+1}\}$

;where NS_k and $NS_{k+1}$are two possible successive values for score function(values of NS_k and NS_{k+1} depend on the application). According to the delay class requested by a packet at node v_i, it will be forwarded to a suitable next node v_j in RCk $N_{prog}^{DC_k}(v_i)$ having the highest score function value.

Next, we will give a formal definition for each factor of Win function separately.

1) W_D

W_D indication that previously delays caused in the packet is considered. In order to reduce packet delay, among several paths from a source node to the sink, we are interested in the paths for which the previous delays are less than others. The factor W_D is calculated by:

$$W_D = \frac{Hdelay - delay(v_m, v_i)}{Hdelay} \quad (4)$$

where, '$delay(v_m, v_i)$' denotes the average previous delays of the node and $Hdelay$=max $\{delay(v_j,v_i), v_i,v_j \in V\}$. Other main advantages of using this factor are reduction of the end to end packet transmission delay.

2) W_P

W_P indication is progress to the destination node (sink). In order to reduce the packet delay of a node is the sink node is to transfer data more progress to be selected. W_P factor is calculated as follows:

$$W_P = \frac{d_{prog}(v_m, v_i)}{dist(v_m, sink)} \tag{5}$$

where, '$d_{prog}(v_m, v_i)$' denotes the progress to the sink node and $dist(v_m, v_i)$ Linear distance between the node v_m and v_i the node.. Other main advantages of using this factor are reduction of the end to end packet transmission delay.

3) W_H

Among several paths from a source node to the sink, we are interested in the paths for which the total hop count is less than others. It leads to employing the shortest paths and reducing the end to end packet transmission delay. The factor W_H is calculated by:

$$W_H = \frac{1 + H_0 - HC(v_i)}{H_0} \tag{6}$$

where, ' $HC(v_i)$' denotes the total hop count of the node to the sink and H_0=max $\{HC(v_i), v_i \in V\}$ (actually we use the network diameter for H_0) . Another advantage of using this factor is to reduce the number of intermediate nodes and wireless links on the path, and consequently an improved delay.

MRHD operates in a best-effort manner and estimates the number of required hops for routing the data to the sink. If node v_i chooses its neighbor v_j as the next node to transfer data to it, then v_i can estimate the total hop count needed to route the data to the sink as follows:

$$HC(v_i) = \left\lceil \frac{dist(v_m, sink)}{d_{prog}(v_m, v_i)} \right\rceil \tag{7}$$

4) W_B

In order to balance the network traffic load and to prevent buffer overflow in intermediate nodes, it is crucial to forward packets to the sensor nodes with less traffic load. Therefore, among several potential candidates, we are interested in those whose free buffer sizes are more than other ones. The factor W_B is calculated by:

$$W_B = \frac{FBS(v_i)}{B_0} \tag{8}$$

where, '$FBS(v_i)$' denotes the free buffer size of the node and B_0=max $\{ FBS(v_i), v_i \in V \}$. The initial value for the parameter '$FBS(v_i)$' is B_0. Other main advantages of using this factor are reduction of packet loss due to buffer overflow and reduction of the end to end packet transmission delay.

5) W_T

W_T indication is distance of the node. In order to reduce packet delay, among several paths from a source node to the sink, we are interested in choose to energy saving interests are is closest to the node. The factor W_T is calculated by:

$$W_T = 1 - \frac{dist(v_m, v_i)}{R_{range}} \tag{9}$$

where, 'R_{range}' denotes the transmission range sensor node and $dist(v_m, v_i)$ Linear distance between the node v_m and v_i the node. Other main advantages of using this factor are reduction use energy.

6) W_E

In order to increase the network lifetime and to reduce the retransmissions due to the frequent path breakdowns, it is necessary to select paths which consist of the sensor nodes with more residual energy. Therefore, among several candidates, we are interested in the nodes where residual energy relevant parameter is more than other nodes. The factor W_E is calculated by:

$$W_E = \frac{RE(v_i)}{E_0} \tag{10}$$

where, '$RE(v_i)$' denotes the residual energy of the node and E_0=max $\{ RE(v_i), v_i \in V \}$. By providing a more stable transmission environment, MRHD can reduce packet loss due to the energy depletion of intermediate nodes.

Decision to select the next node to send packets is shown in the following algorithm.

An node (v_m) receives a packet
if (residual energy < operation energy) then
  discard the receives packet
else
  for every $v_i \in N_{prog}(v_m)$
    update $delay(v_m, v_i)$, $FBS(v_i)$ and $HC(v_i)$ parameters in Neighbour table
    Calculate the "Score_delay" and "Score_energy" using node Score parameters in Neighbor table and as in equation (2) and (3).
    update$N_{prog}^{DC_1}(v_m), N_{prog}^{DC_2}(v_m), \dots, N_{prog}^{DC_n}$ for node v_m
  end for
  get packet class delay parameter DC_x (that $1 \leq x \leq n$)
  if $(N_{prog}^{DC_x}(v_m) \neq \emptyset)$ then
    for every $v_j \in N_{prog}^{DC_x}(v_m)$
      Calculate the "Score_total" using equation (1).
    end for
    select $v_k \in N_{prog}^{DC_x}(v_m)$ that is $max(Score\_total)$
  end if
  else if$\left(N_{prog}^{min(DC_{x+1}, DC_n)}(v_m) \neq \emptyset\right)$then //$N_{prog}^{DC_x}(v_m) = \emptyset$
    for every $v_j \in N_{prog}^{DC_{x+1}}(v_m)$
      Calculate the "Score_total" using equation (1).
    end for
    select $v_k \in N_{prog}^{DC_{x+1}}(v_m)$ that is $max(Score\_total)$
  end if
  .
  .
  .
  else if$(N_{prog}^{DC_n}(v_m) \neq \emptyset)$then // $N_{prog}^{DC_x}, \dots, N_{prog}^{DC_{n-1}}(v_m) = \emptyset$
    for every $v_j \in N_{prog}^{DC_n}(v_m)$
      Calculate the "Score_total" using equation (1).

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end for
select $v_k \in N_{prog}^{DC_n}(v_m)$ that is $\max(Score\_total)$
end if
else
discard the receives packet
end if
end if
Transmit the packet to v_k node
Update the $RE(v_m)$ and $FBS(v_m)$ on a label.
Add node ID to label.
Transmit the label to neighbour nodes.

3.2 Majority-Based Re-Routing Policy

Sensors detect the necessity of re-routing for particular packets by observing significant changes in the number of those types of packets. During network operation, the network nodes observe the traffic they are conveying and each of them learns the different traffic flows that it may be carrying. Normally, all the packets are routed based on the delay level they demand for; but if the number of packets reporting occurrence of special events in the whole network or some parts of it, changes instantaneously and in an explosive manner, then re-routing policy is activated and the packets will be routed according to a new delay level assigned to them.
This simple mechanism allows for an on-line classification of each successive packet from a given source. However it can also be used by intermediate nodes if they themselves wish to decide whether a packet is a routine or unusual event packet, as long as they are able to distinguish between the source destination pairs contained in the packets as well as keeping track of content values. Suppose in a time period t the number of receiving packets demanding for a specific original delay class DC_x, is denoted by $S_{DC_x}(t)$. Also, L_is $(0 \leq i \leq n)$ are the thresholds for receiving packet count variation in two successive periods. This adaptive policy is shown in the following algorithm.

for each time interval T do
Each node determines for each type of packet the value of $S_{DC_x}(t)$
Update $DS_{DC_x} = S_{DC_x}(t) - S_{DC_{x-1}}(t-1)$
$NP = sign(DS_{DC_x})$
if (NP=1) then
if $(L_0 \leq DS_{DC_x} \leq L_1)$ then
$DC_s = \min(DC_{x+1}, DC_n)$
else if $(L_1 \leq DS_{DC_x} \leq L_2)$ then
$DC_s = \min(DC_{x+2}, DC_n)$
.
.
.
else if $(L_{n-1} \leq DS_{DC_x} \leq L_n)$ then
$DC_s = \min(DC_{x+n-1}, DC_n)$
end if
else
if $(L_0 \leq DS_{DC_x} \leq L_1)$ then
$DC_s = \max(DC_{x-1}, DC_x)$
else if $(L_1 \leq DS_{DC_x} \leq L_2)$ then
$DC_s = \max(DC_{x-2}, DC_x)$
.
.
.
else if $(L_{n-1} \leq DS_{DC_x} \leq L_n)$ then
$DC_s = \max(DC_{x+n-1}, DC_x)$
end if
end if
end for

3.3 Neighbor Manager

The neighbor manager enables it to provide the Decision Making levels with the required information for routing. This runs the HELLO protocol, manages neighbor table. Neighbor table assigns an entry for each neighbor node, which includes all information related to the node such as position, residual energy, estimated hop count to sink, neighboring nodes in direction of sink, required transmission energy towards it, estimated packet reception ratio and etc. The HELLO protocol consists of periodical broadcast of HELLO packets. These packets are used to update existing entries, and delete entries when neighboring nodes break down, which can be detected in case of not receiving HELLO packets after a defined period of time (timeout). Neighbor manager is the first module that receives the packet from the higher layers. It provides the routing module with all information it needs such as the set of nodes ensuring positive progress (N_{prog}) and current values of its required parameters.

4. PERFORMANCE ANALYSIS

In this section, we evaluate the performance via simulation. We implemented a simulation OPNET. The goal of the simulation is to show that MRHD can provide a high quality transmission. Since the protocol is a new idea, to compare the performance of this protocol, we simulate a situation where is not the differentiated Services (there is not traffic flow classification) and decide to send the packet only the former path delays are and the packets are sent along with low delay DRP call it. In addition, we simulated the case as MRHD is differentiated Services, but is not the majority based re-routing NMRHD call it.

4.1 SIMULATION MODEL

The same network setup is used to compare the two routing protocols. Each node is equipped with a total amount of energy 2J at the beginning of the simulation. We applied the same radio model introduced in [10] and used by several papers. The simulation area is 100m×100m and number of nodes is 100. We used a traffic scenario, where one source node at the left side of the terrain send periodic data to the sink at the right side. Normally, source node generates data units at the rate 1000 packets/s. The coefficients α, β, γ, ρ, a, b, τ and θ are respectively set to 0.5, 0.2, 0.2, 0.1, 0.7, 0.3, 0.7 and 0.3. These values are chosen based on our several experiences run with different coefficient settings during the test.

4.2 SIMULATION RESULTS

In this section, simulation results are discussed. As shown in Fig. 1 is shown in the simulation, the MRHD proposed protocol delays have considered three classes. DC3 has the highest priority and the scheduling class to use for this class is always zero queuing delay, so end-to-end delay is less. DC1 is also the priority class than the class considered in the simulation is the end to end delay than the DC2 class. Fig. 2, 3 and 4 Average delay per class MRHD shown at the NMRHD. Since the MRHD has re routing base majority policy when the number of packets of a class change of certain level, change priority packets. For example, it makes the base lower class packets with higher priority routing That is better performance and lower class packets .The Fig. 5 Average total end-to-end delay DRP, MRHD and NMRHD shown that MRHD end-to-end delay is less. Fig. 6 Average energy DRP, MRHD and NMRHD shown that better performance is MRHD. Considering the factors affecting energy (equation 3) plays an important role in the decision to send the packet to the next node is the MRHD performance. Fig. 7 is shown MRHD packet delivery rate for different class. As can be seen DC3 class packet delivery rate are increased. Fig. 8, 9 and 10 Packet delivery rate for each class is shown at the MRHD of NMRHD. As can be seen, the packet delivery rate per class MRHD, with higher delivery rate. The fig. 11 packet delivery rate overall DRP, MRHD and NMRHD shown that the packet delivery rate is more MRHD. Fig.12 shows the throughput for different classes MRHD. Fig. 13 Average throughput DRP, MRHD and NMRHD shown that better performance is MRHD.

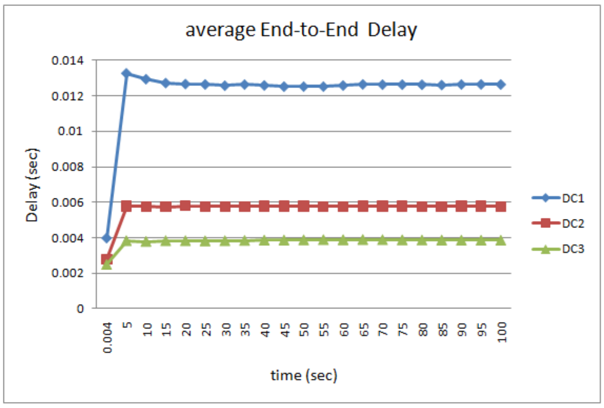

Fig. 1 Average end-to-end delay for different delay classes of MRHD protocol.

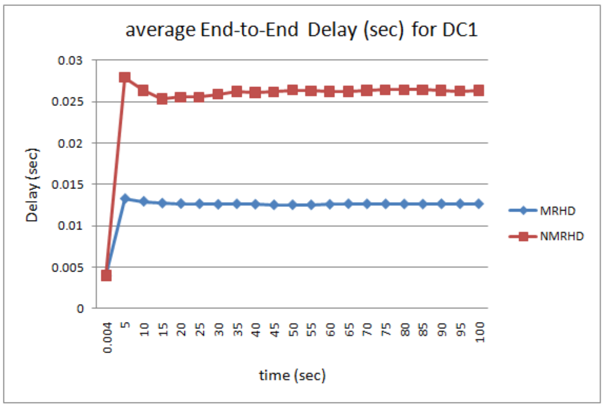

Fig. 2 Average end-to-end delay for DC1 delay class.

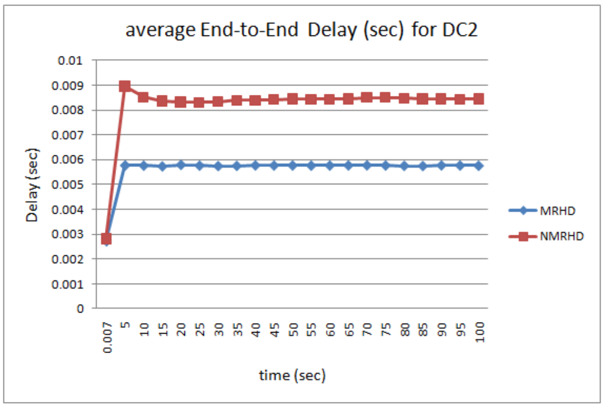

Fig. 3 Average end-to-end delay for DC2 delay class.

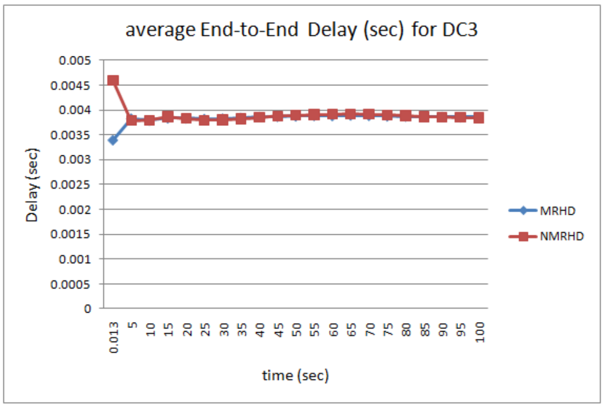

Fig. 4 Average end-to-end delay for DC3 delay class.

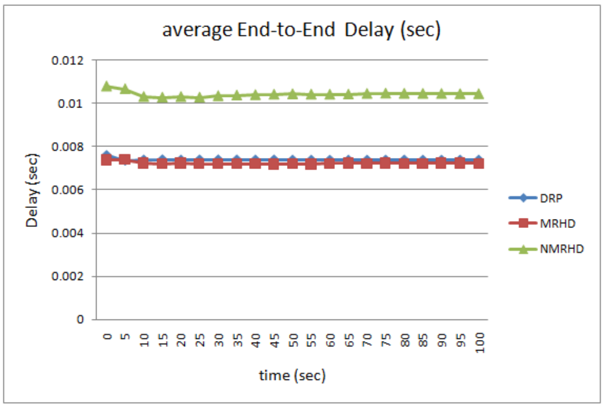

Fig. 5 Average end-to-end total delay.

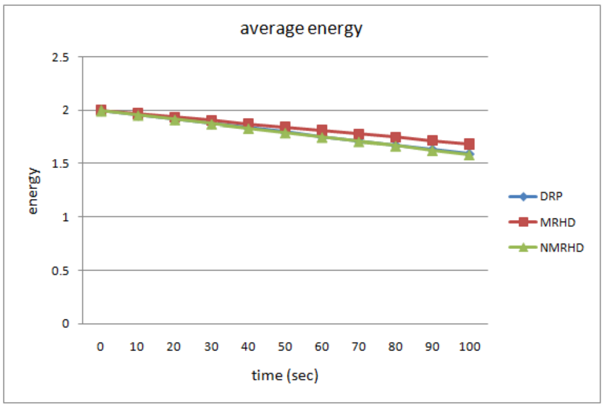

Fig. 6 Average total energy.

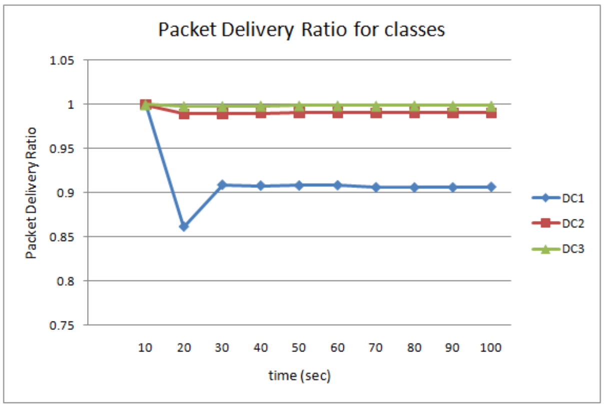

Fig. 7 Packet Delivery ratio for different classes of MRHD protocol.

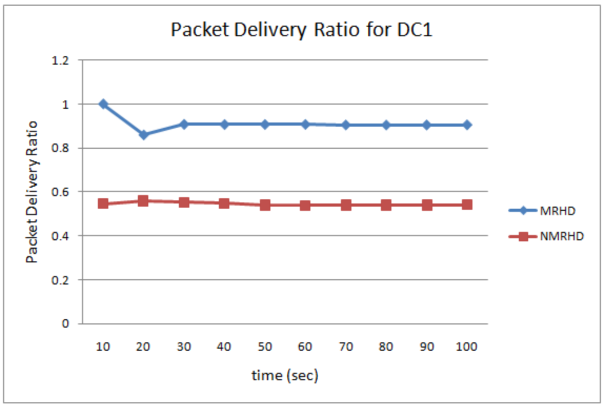

Fig. 8 Packet delivery ratio for DC1 delay class.

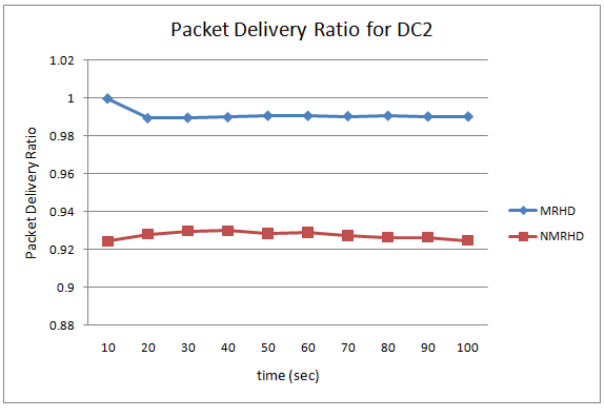

Fig. 9 Packet delivery ratio for DC2 delay class.

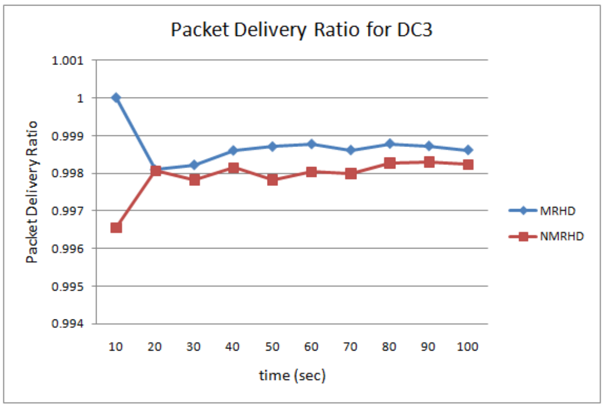

Fig. 10 Packet delivery ratio for DC3 delay class.

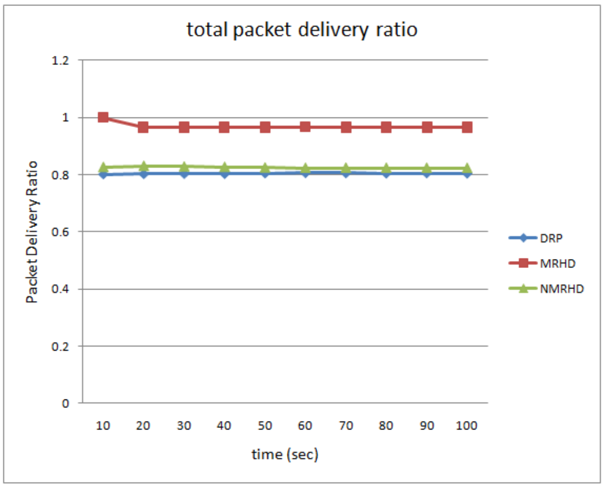

Fig. 11 Total packet delivery ratio.

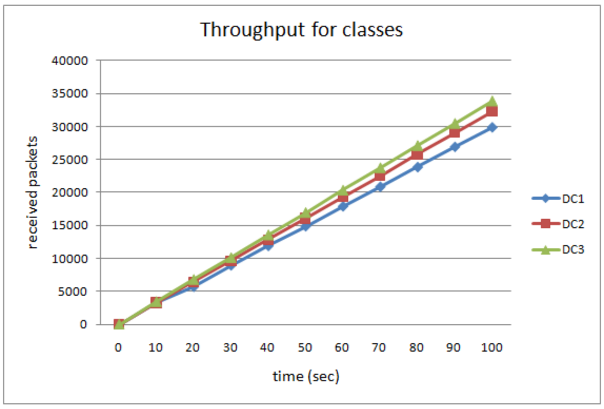

Fig. 12 Throughput for different classes of MRHD protocol.

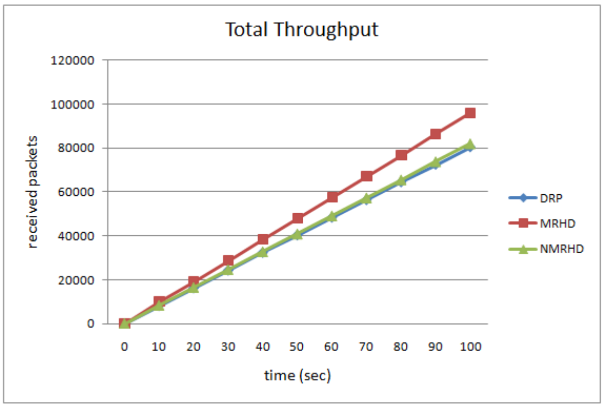

Fig. 13 Total throughput

5. CONCLUSION

In this paper, we focus on building a One aspect of service quality based routing model as delay named MRHD which can route packets towards the destination node by classifying data into differentiated classes. Also, our proposed protocol employs a majority based re-routing policy in order to route the packets with instantaneously change in number implying occurrence of special events via paths with lower delay. We evaluated the performance of MRHD protocol through simulation. We demonstrated that MRHD protocol exhibits a better performance. As a future work, we plan to improve the proposed protocol using multipath routing and fuzzy systems for better adjusting the various factors of decision making.
Also, we intend to implement our method for optimization of tree-based routing protocols.

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