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A QOS AWARE MULTICAST ROUTING PROTOCOL FOR CONSTRUCTING AN OPTIMAL PATH FOR MULTIMEDIA TRAFFIC IN WIRELESS SENSOR NETWORKS

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Abstract: Wireless Sensor Networks (WSNs) are communication networks having tiny sensors with sensing and transmitting capabilities .These systems adopting traditional routing protocols to organize communication, have design issues, and quality of service is still a challenging research factor. The key idea of this research is to discover the most efficient routing protocols based on the design of a reliable and efficient routing protocol to determine quality of services in a WSN. In this paper we propose a reliable and efficient path selection strategy by designing a Quality of Service Aware multicast routing protocol.This protocol discusses the multicast routing problem of WSN with multiple QoS constraints, by discovering a minimum resource consumption path while satisfying multiple constraints optimization conditions. Simulation results show that the fair link selection strategy can yield to a good solution for this traditionally NP complex problem, as compared to the best multicast algorithms known.

Keywords: WSN, multicast routing,Steiner tree**,** QoS-aware routing

1. INTRODUCTION

Wireless sensor network is a self-organized network system with low amount of resources and constitutes of tiny sensors. Nowadays, WSN is widely used as an effective communication interface medium to interact with physical world to exchange global information. In addition WSN consist of spatially distributed autonomous sensors to cooperatively monitor physical or environmental conditions. Broadcasting across autonomous sensors produces more communication issues due to the lack of resources such as energy, bandwidth, and memory etc.

From past few years, an intensive research was conducted to address the problems during data gathering and processing among group of sensors and to address the potential of collaboration among sensors. However, sensor nodes are constrained nodes and organizing large amount communication services is a problem due to the lack of energy resources and bandwidth.

Routing in WSNs is very challenging factor due to the inherent characteristics that distinguish these networks from other wireless networks like cellular networks and mobile adhoc networks[1] . Due to the large number of sensor nodes it is difficult to form a global addressing scheme to deploy sensor nodes with different IDs and addressing the nodes produces overhead to maintain individual IDs . So the traditional IP-based routing protocols may not be advisable or WSNs. Furthermore, sensor nodes are deployed in an ad hoc manner .

Multimedia applications typically require high bandwidth and reliable routing paths to achieve higher Quality of Service (QoS). In general, WSN is a large collection of autonomous sensors and the autonomous nature of each node needs cooperative communication with other nodes. Interaction between nodes in such kind of infrastructure may cause network delay.

High bandwidth and low delay requirements are the most QOS required Multimedia applications of WSNs .Hence routing protocols which realise these QOS parameters need to be designed.[2] Many of the QOS aware routing protocols [3] in literature, focus on optimizing network resource utilization, avoiding traffic congestion, and balancing network traffic. These protocols calculate the optimal path from source to destination under best network conditions. They unfortunately do not consider the QOS requirements for these applications.

A multimedia application has different data flows for audio, video, text etc.[2] with differing QOS requirement .and these requirements should be considered for path decisions.

An optimal path decision can be made for each of these different flows take into consideration, the QOS and network conditions. This path decision should guarantee the required QOS and at the same time aim for effective network resource optimization. In such a scenario, multicast service is an efficient model. It can optimize the network resources and adapt to the bandwidth of wireless sensor network.

Message overhead is large for packets of long routing paths due to the lack of resources and infrastructure. In general attaching a packet to an entire routing path is usually not adesirable approach. In this paper we propose a novel routing path to reconstruct a routing path at route optimization node to reduce a rerouting process.

2. BACKGROUND STUDY

2.1.Steiner treeNetwork Model

A network $W = \{N_w, E_w\}$is represents as set of nodes N_w and set of edges $E_w$where$E_w \subset N_w \times N_w$. The average number of edges are derived based on the set of nodes which is referred as out degree. From among these set of edges we derive the following delay and path cost functions,

Delay: $E_w \rightarrow P^+\{0\}$and path cost $E_w \rightarrow \{1\}$. The delay and path cost are defined as the sum of delay of all the edges of the paths.

In addition to this, the multicast group represent a set of multicast receivers and is defined as $M_R \rightarrow N_w$. According to [3][4], computing the Steiner tree is an NP-Complete problem. To compute a network tree to determine an optimal path by considering original probabilistic link descriptor

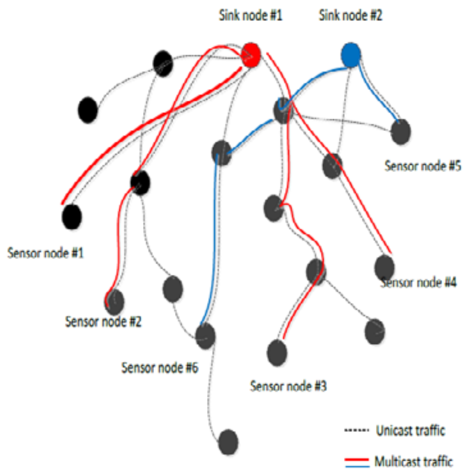

Fig 1: Multi-rate multicast wireless sensor network

3. QUALITY OF SERVICE AWARE MULTICAST ROUTING PROTOCOL (QOSMRP)

In this paper, we addressed the problem in Steiner tree network while constructing multicast routing ,duly considering Quality-of-Service requirements for each host and retaining fairness between links. To address this link fairness, we adopted two different techniques the Lagrangian Relaxation Method [5] and the Subgradient Method. These techniques determine the link capacity and improve link fairness.

By introducing Lagrangian Relaxation method [6] , Multiplier Vectors, primitive routing constraints, delay constraints and traffic constraints problem can be resolved .In multicast routing assignment, a set of routing decision variable $\{xp\}$'s corresponding multipliers can be used as each link's arc weight. With the estimation of link's arc weight, the highly loaded links can be avoided by considering the capacity allocation output from the last iteration's dual problem. The routing modelling can be summarized as follows:

Link state of edge e_n indicated by vector$\{c, d, r\}$, where $c$is the link capacity, d is the link delay and r is routing transmission rate. For a set of source and destination pairs$\{S_i, D_i\}$, the available list of paths according to the Lagrangian Relaxation are determined by considering adaptive delay and capacity. The adaptive delay and capacity of path $P(d) and P(c)$ is measured in following equations

$$P(d_p) = \sum_{i=1}^{n} d_{e\_i}\, where e is a set of nodes (1)$$

$$P(c_p) = \min_{e\_i \in p} c_{e\_i} (2)$$

The link utilization rate is estimated based on the above two equations

$$U_{e\_i} = \frac{b_{u\_i}}{c_{e\_i}} (3)$$

The available bandwidth rate can be derived for all paths as

$$B_{e\_i} = \min_{1 \le i \le n} (c_{e_{\_i}} - b_{u\_i}) (4)$$

Based on the derived routing mechanism we can not only compute the link capacity it can also derives the link delay on different paths with respective to capacity. The bandwidth rate equation is derived from the minimum available resource rate, and the optimal path represents the minimum bandwidth cost presented by sum function of each link cost

$$O_b = \sum_{i=1}^{n} \varphi(b_{u_{\_i}} + b_{req}, c_{e\_i}) (5)$$

According to the routing algorithms, to determine a feasible path to achieve the QoS requirements we need to consider the optimal path cost,and to achieve better QoS results, a feasible path selection is the one to satisfy all the QoS requirements in Steiner tree. In order to derive an efficient solution, this protocol organizes the routing process in two different steps, the first step is to determine the feasible paths which can assure link flow's QoSrequirements and second step is to discover a best-effort path when feasible path doesn't exist . If a feasible path exists, one of the best feasible paths is chosen for transmission flow. The section below presents the multicast transmission packet model.

3.1 Multicast Routing Packet Transmission Model

We modelled the Steiner tree Network Model as $G(\{E\}, \{V\}, \{\alpha_{(ab)}\}, (a, b) \in E))$, where $\{E\}$ denotes the set of edges, $\{V\}$ is the set of vertices, $\{\alpha_{(ab)}\}$ is the set of descriptor links, $(a, b) \in E$ can be a represented as bandwidth rate. The information source is a base station B where $B \in V$, set of multicast nodes as $M = \{M_1, M_2, M_3 \dots \dots M_{i-1}\} \subset V$. Let us assume that the minimum transmission power needed for each node is

$$E_{ab}^{TX} = g, \forall (a, b) \in V \qquad (6)$$

The minimum probability of power required to receive successful packet is computed as

$$E_{ab}^{RX} = exp(\frac{\theta d_{ab} \gamma}{g}) \qquad (7)$$

Where θ represent hardware related threshold, d_{ab} represents distance from node a to node b. $\gamma$is a path loss exponent.

Let assume the communication between node a to node b uses packet acknowledgment ACK, to ensure the packet delivery over a particular link. In order to identify the packet confirmation we represent flags as 0 or 1. If the packet successfully reaches the receiver the ACK flag changes to 1 and if it fails it is changed to 0. The complete cycle of communication ends when both sender and receivers ACK flags are 1.

The successful and unsuccessful packet distribution can be expressed as

$P(\sigma_{ab}) = (1 - P_{vu})^m . P_{vu}$

$where P(\sigma_{ab})$ represents the unsuccessful packet distribution where as $P(\varsigma_{ab})$ defines the successful packet distribution

$$P(\varsigma_{ab}) = P_{uv} . (1 - P_{uv})^n . P_{uv}$$

The distribution delay δ_{ab} n over the link (a, b) is

$P(\delta_{ab}) = P(\sigma_{ab})$.g+$P(\varsigma_{ab}).2g$

The overall packet transmission model represents six different fields and the packet structure is representedby six different parts, (1) packet head, (2) packet type ,(3) Source node ID, (4) unsuccessful packet distribution rate, (5) Successful packet distribution rate ,(6) Packet ID

Phead	Ptype	SID	σ	ς	PID

With the {*src*, *dst*} pair, available paths from sourceto destination are ranked dependingon bandwidth, delay, and utilization rate of the path.A feasible QOS aware path may or may not exist depending on the application's data flow. An optimal path is constructed based on whether a feasible path exists or not.

*3.1.1 Discovering a feasible path satisfying QoS requirements of the multimedia data: D*elay, capacity and bandwidth are the main QOS constraint to be satisfied while constructing a feasible path.[2] The optimal path cost equation calculates each path's bandwidth cost . The path that has the lowest cost and satisfies the bandwidth and delay requirements of the multimedia application is chosen as the optimal path.

The algorithm for finding the feasible path is given below.

Discovering Feasible path Algorithm :

Input : Number of nodes n, links e, number of paths e_p, minimum required bandwidth b_{min} , minimum required delay d_{min}

Output : bandwidth path cost, delay path cost at that particular path

1. set of nodes $N = \{n\}$, set of paths $e_p = \{\}$

2 .For each node n: 1 toN

If $node n_i discovers n_j nodes$

Add $e_p \leftarrow \{e\} \forall node n_o$

End if

Add the set of links to source and destination pairs as

$$\{S_i, D_i\} \leftarrow e_p$$

End for

3. for a given set of source and destination pairs $\{S_i, D_i\}$ $where$ $1 \geq i \leq n$

for i:1 to n

if ($b_{min} \leq b_{pi}$&&$d_{min} \geq d_{pi}$)

if($cost_{b_{pi}} > cost_{b_{pi}} + 1$)

$P = P_{i+1}$

Add feasible paths as $P = P_{i+1}$

End if

End if

End for

If the above feasible path algorithm doesn't meet the QoS requirements, and if there is no set of feasible paths among the set of source and destination pairs when there is a link instability or obstacles, the following assumptions will be considered to achieve the QoS requirements.

Assumption 1: routing algorithm for bandwidth-constraint flows

Assumption 2: routing algorithm for delay-constraint flows

Assumption 3: routing algorithm for OBSTRUCTED Links

Choosing of an appropriate bandwidth with respect to load on an over selected path is a key approach and for bandwidth sensitive flows , priority of bandwidth is muchhigher than latency.[2]The path with the lowest delay cost amongst the paths with unsatisfactory delay but satisfactory bandwidth requirement is selected as the optimal path.[7].

Hop count is defined as the metric for calculating delay cost in equations (8) and (9) and the path that has the minimum hop count is selected from the bandwidth satisfied paths . And the path with largest available bandwidth will be selected from among the paths which do not satisfy the bandwidth requirement.

The following two equations calculate the delay cost with hop count as the metric:

$$\begin{cases} cost_{d_{e\_i}} = 1, (e_i \in P) \\ cost_{d_e} = 0,\ in other case \end{cases} \quad (8)$$

$$cost_{dp} = \sum_{i=1}^{n} cost_{d_{e\_i}} \quad (9)$$

Procedure -1: Discovery of a path for ***bandwidth-constraint flows***

Let the set of nodes $N = \{n\}$, set of paths $e_p = \{\}$

If $\left(b_{req} \leq b_{pi} \&\& d_{req} \leq d_{pi}\right)$

If $\left(cost_{d_{pi}} > cost_{d_{pi+1}}\right)$

$p = p_{i+1}$

Else if $\left(b_{req} \geq b_{pi}\right)$

$p = p_{i+1}$

End else

End if

End loop

For multimedia data like video and audio , link delay has more impact on the QOS than bandwidth requirement .The path with lowest bandwidth cost is chosen as the optimal path from amongst the paths which satisfy delay requirement but unsatisfactory bandwidth requirements.[9]

In case there are no paths which satisfy the delay requirements, the path with lowest delay willbe chosen as an optimal path .

Procedure -2: Discovery of a path for delay- constraint flows

Let the set of nodes $N = \{n\}$, set of paths $e_p = \{\}$
If $\left(d_{req} \leq d_{pi} \&\& b_{req} \geq b_{pi}\right)$

If $\left(cost_{b_{pi}} > cost_{b_{pi+1}}\right)$
$p = p_{i+1}$
Else if $\left(d_{req} \geq d_{pi}\right)$
$p = p_{i+1}$
End else
End if
End loop

MULTICAST ROUTINGALGORITHM ON OBSTRUCTED LINKS

Because of an inappropriate link information, the link state chooses distribution delay metric δ_{ab} and deploys random variable to determine the random delay.[8] Based on the random delay information, we transfer data over random links to organize random search heuristic process. To determine efficient search process we introduce two different types of multicast tree routing process such as end-to-end routing process and bottle neck routing process.

We determine the bottleneck Steiner tree problem as

$$\max_{(a,b)\in T} E_{ab} < \alpha, T \in T$$

Where T contains a set of trees , E_{ab} represents the maximum power required during transmission and $\alpha$is the power limit.

1)Algorithm to get obstructed distance between (p1, p2, B)

Input: Locations, p1 and p2, of two vehicles and a predetermined binary search partition (BSP), B, of obstacles.

Output: The total obstructed distance: mo, the number of obstacle edge intersections: n.

1. mo ← 0; n ← 0
2. Initialize a maximum range, r, the distance from either point p1 or p2 to an obstacle center-point, that is used to filter the set of obstacles to the subset which are sufficiently nearby for calculation purposes (i.e., for optimization, exclude far-away obstacles).
3. Create a bounding box, b, for p1 and p2 and extend in all directions by r.
4. Get the set of potential obstacles, O. ~~O~~ the range search of b within B.
5. For every obstacle o ∈O, *do:*
6. If the distance from p1 or p2 to the obstacle centre is within range, r, then
7. *for each* edge s ∈o,
8. If s intersects a ray from p1 to p2
9. n ←n + 1 (i.e., found an obstructing wall)
10. Save the min. and max. distances from {p1, p2} to the intersection pt. (i.e., to find spanning interior distance among the edges of o)
11. mo←mo + distance between min., max. Values in step 10 (i.e., spanning interior obstructed distance)
12. Return mo and n

4. EXPERIMENTS AND PERFORMANCE EVALUATION

In this experiment we use Network Simulator Version-2 (NS2) [9] to simulate the proposed routing protocol QoSMRP. In this experiment we designed multi-hop WSN by configuring a routing protocol to evaluate the performance of proposed QoS-aware routing mechanism. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. It has the functionality to notify the network layer about link breakage.

In our simulation, we consider network area as a 1000 meter x 1000 meter region and we set a 10 seconds simulation time. All nodes have the same transmission range of 250 meters. The simulated traffic is Constant Bit Rate (CBR). Our simulation settings and parameters are summarized in table 1

Table I: Simulation Settings

Number of sensor nodes	50,100,200,300
Network Area	1000 X 1000
MAC model	802.11
Communication Range	250m
Total Simulation Time	10 sec
Traffic Source	CBR
Packet Size	512
Receiving Power	0.395
Sending power	0.660
Idle Power	0.035
Initial Energy	10.3 J
Transmission Rate	40 Kbps

5.1 Evaluation Results

We evaluate the performance of proposed QoS routing protocol by considering following metrics. We compare this protocol with Dynamic Quality of Service Stability based multicast routing protocol DQSMRP protocol by varying the number of nodes and by varying the bandwidth rate.

*1)Average Packet Delivery Ratio***:** It is the ratio of the number .of packets received successfully and the total number of packets transmitted.
2)Average Packet Drop: It is the average number of packets dropped by the misbehaving nodes.
3)Delay: It is the time taken by the packets to reach the receiver.
4)Energy Consumption: It is the amount of energy consumed by the nodes for the data transmission.

1) Based on Nodes: In our first experiment we vary the number of nodes as 50,100,200 and 300 number of nodes. First de designed a network with 50 nodes, with the network area of 1km radius; we simulate the proposed routing protocol to estimate the PDR, end-to-end delay, throughput and energy consumption. According to the simulation results, in the QoSMRP, the end-to-end delay reduced and throughput and packet delivery ration increased.

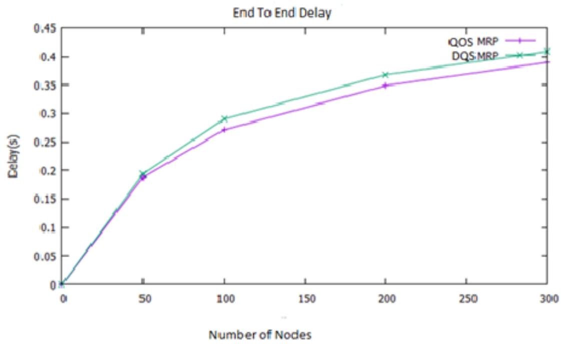

Fig 2: EndtoEnddelay : Number of nodes vs Delay (S)

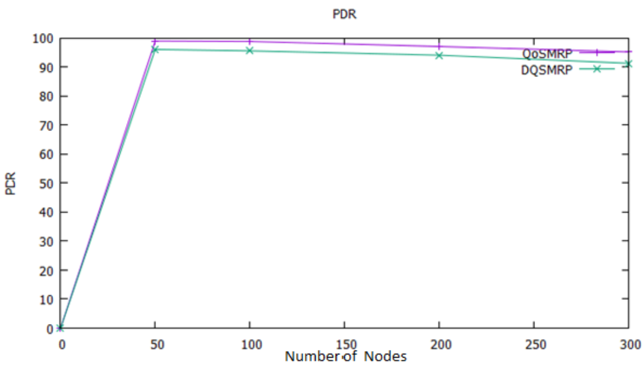

Fig 3: PDR : Number of nodes vs PDR

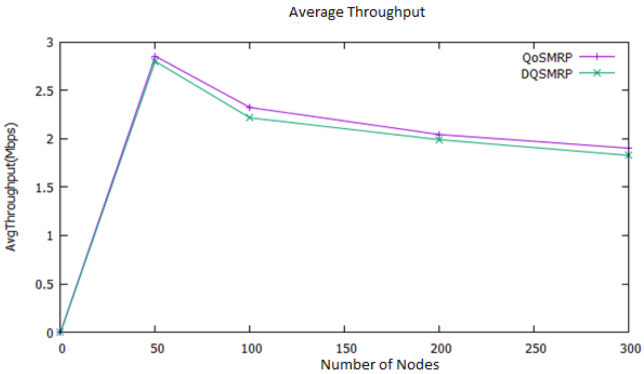

Fig 4: Average Throughput: Number of nodes vs Throughput

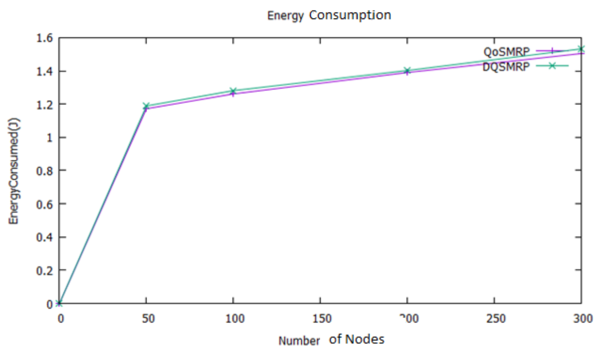

Fig 5: Energy Consumption: Number of nodes vs Energy

*2) Based on Bandwidth :*In this scenario we varied various bandwidth rates to determine the QoSMRP efficiency by comparing with existing DQSMRP protocol. According to the simulation results, the bandwidth rate improves the QoS constrains, based on the simuation results, the end-to-end delay reduced and throughput and packet delivery ration increased.

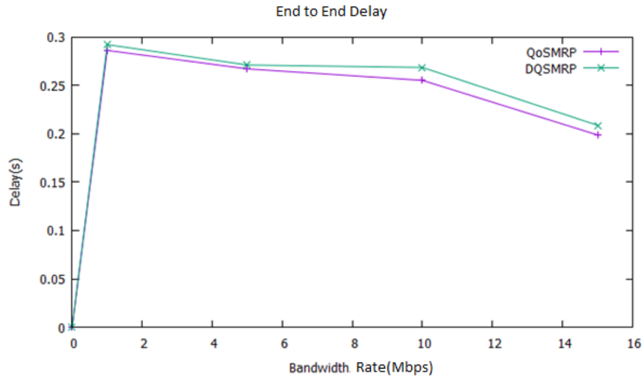

Fig 6: End to End Delay: Bandwidth Rate vs Delay

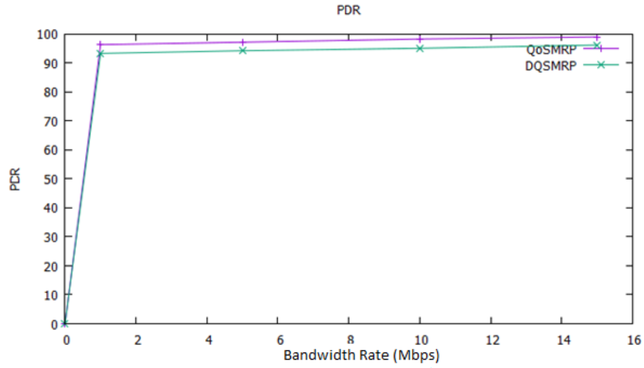

Fig 7: PDR: Bandwidth Rate vs PDR

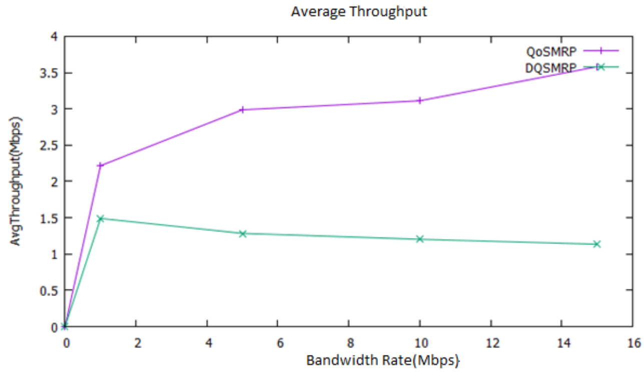

Fig 8: Average Throughput: Bandwidth Rate vs Throughput

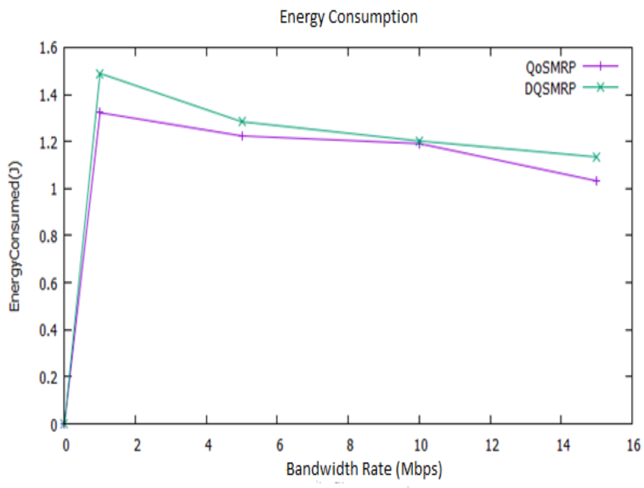

Fig 9: Energy Consumption: Bandwidth Rate vs Energy

5. CONCLUSION

In this paper we discussed the Quality of Service constrains in WSN by identifying various quality constraints by analyzing various earlier contributed multicast routing algorithms and protocols. In order to minimize the link cost utilization we designed a novel Quality of service multicast routing protocol, which adopts Steiner tree model to minimize the utilization rate to discovery feasible path. Based on the fairness rate calculation rate results the optimal route selection strategy discovered a feasible path , which minimized the rate utilization which are derived using Lagrangian Relaxation Method. The simulation results clearly show the performance improvement on different scenarios

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