Quality of Service improvement by optimizing network using multichannel aggregation based routing protocol

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Abstract

Improvement in Quality of Service (QoS) of wireless networks has always been a study subject for wireless network designers worldwide. Optimization of end to end communication delay, reduction in energy consumption, improvement in network throughput and reduction in end to end communication delay jitter are some of the parameter optimizations which are used to improve the QoS of the wireless networks. In this paper, we propose a QoS aware routing protocol which uses a combination of delay & energy aware routing with data aggregation & multichannel communication in order to reduce the energy consumption, reduce the end to end delay and improve the network throughput. The simulation results show that there is a more than 20% improvement in network communication speed, and atleast 15% improvement in the network lifetime after using the proposed QoS aware routing protocol.

Keywords: QoS, delay, throughput, aggregation, multichannel, energy aware.

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1 Introduction

QoS optimization in wireless networks has been a topic of study for more than a decade now. While researchers have claimed to improve the QoS by using various optimization techniques like route optimization, selected node optimization, multichannel usage, and several others, but the study is still ongoing, and is a NP hard problem to solve. Thus, researchers can only provide a finite number of solutions to the problem, but the best solution is solely dependent on the technology in place, and will always keep on changing based on the advances in network optimizations.

One such solution is proposed in this paper, which uses a QoS aware routing algorithm, a layer of compression and data aggregation & multichannel routing with the help of distance and energy measures. QoS aware routing usually refers to the field of routing where the routing protocol is developed in such a manner that the QoS parameters like end to end communication delay, throughput, energy & others are optimized. This is done by incorporating these parameters while selecting the route for communication. For example, if we need to optimize the delay and energy while routing, then the node selection process uses a metric like distance/energy, and then minimizes it for each of the selected node. Thus, the nodes with minimum distance to energy ratio are selected for routing, this ensures that the nodes selected are having lowest distance of communication, and have the highest energy of communication, thus if a node has high energy for communication, then it will have higher lifetime when compared to a node with lower energy, thereby improving the delay and the energy consumption of the network, thus optimizing the overall QoS of the network, and such a protocol is called as a QoS aware routing protocol.

1.1 Overview

In this paper, we have designed a novel protocol for QoS optimizing in terms of end to end communication delay, network throughput, network lifetime and network jitter, which is a measure of the delay consistency in the network. This is achieved by using a QoS aware protocol, and combining it with a multichannel distance to

energy based data aggregation routing protocol. The details about this proposed protocol is described in section 3 of this paper. The next section describes some of the standard protocols which are used while QoS optimizations in wireless networks, followed by the proposed protocol, which is followed by a result analysis and comparison section, where we have performed an in-depth analysis of the proposed protocol and compared it's performance with the existing protocols in order to evaluate the superiority of our proposed protocol over other standard techniques. Finally we have laid out some finer points which describe how the work can be taken further by other researchers in order to further optimize the QoS of the overall wireless network.

2 Literature review

Researchers have worked rigorously on improving the overall network performance of wireless networks using different optimization techniques. In the research done by Ming Zhao [2] and team on low power and lossy networks, they have used a region based AODV routing protocol which is based on the P2P protocol of communication. The node discovery is restricted to a particular region based on the selected source and destination, thereby saving energy which is needed for node discovery in networks. They have obtained an improvement in both network delay and network lifetime by using the region based protocol. In contrast to this research, the work done by Marc Barcelo [3] and their team focuses on addressing the mobility in AODV by using position assisted metrics, wherein they apply the kalman filter for finding the nodes which will be used for routing. The paper introduces Kalman position based AODV protocol, which reduces the network load and thereby reduces the network cost and increases the overall network lifetime.

Another interesting protocol MoMoRo [4] is proposed by Jeong Gil Ko and Marcus Chang. In this protocol, the researchers have provided mobility assistance to low power wireless devices. Basically it is a separate layer in the communication stack which collects network data, and converts it into fuzzy decision values in order to estimate the quality of link for the routing. This allows the protocol to be both flexible and highly run time reconfigurable. The MoMoRo technique uses the widely accepted AODV protocol for routing and achieves a high packet delivery ratio of 96%.

Some researchers have also proposed how computational intelligence can be applied to wireless sensor networks. A detailed description of this is given by Raghavendra V. Kulkarni and his team [5], wherein they have compared various algorithms for computational intelligence like neural networks, fuzzy logic, evolutionary algorithms like genetic algorithm, swarm intelligence techniques like particle swarm optimization, Artificial Immune Systems and Reinforcement Learning. Using this research, we evaluated that reinforcement learning which a part of machine learning is one of the best choices for routing in wireless networks, and can be exploited further for increased network performance. Clique, Q-Routing, DRQ-Routing,Q-RC,RL-Flooding,TPOT-RL,SAMPLE,AdaR,Q-PR,Q-Fusion,RLGR are some of the examples of algorithms which are developed by various researchers over the globe to demonstrate how reinforcement learning can be used to optimize the network performance.

Another example of reinforcement learning is given by Anna Forster and Amy L. Murphy [6] in their paper on FORMS, wherein they are using reinforcement learning to optimize multiple sinks in the WSN networks. They have used Q-Routing technique to the multiple sink problem and obtained a low network overhead while maintaining an acceptable network QOS in practical WSNs. Their algorithm natively supports node failure, sink mobility and reduces the routing cost. Our work is inspired by these algorithms, and we thus developed a novel technique which is based on machine learning, for routing the data in the given wireless network environment. The next section describes our algorithm in details.

3 QoS optimization with multichannel data aggregation

Our routing algorithm can be described as follows:

1. Deploy a network of N nodes placed randomly in an area of X x Y sq. meters.
2. Select any source (S) and destination (D) from the network for routing process
3. Let the euclidean distance between node S and D be dref

4. Select all nodes from the network, where the following conditions are satisfied,

a. dsn + dnd > dref
b. dsn < dref
c. dnd < dref

where, dsn = Distance between source to selected node

dnd = Distance between selected node to destination

5. This filters in only those nodes which are in the routing path, and removes all other nodes
6. For each node in the path, evaluate the following metric,

   Metric = di/Ei

   where, di = Distance between the nodes

   Ei = Energy of the source node
7. Start the node selection from the source till the destination node is reached.
8. Once reached, send the data on the selected path
9. Before sending the data, apply data aggregation at the source node Split the aggregated data into k parts, where k is the number of channels available for routing.
10. Send the data on all the k channels from the source node to the destination.
11. Repeat this process for all communications

The above algorithm makes sure that the data is sent from the source to destination with minimum delay, and minimum energy due to data aggregation, multichannel communication and incorporation of d/E factor in the routing process. The throughput is optimized as well due to improvement in delay and reduced packet loss due to multichannel communication. This makes sure that the packet is transmitted in the almost same timing interval as the previous packets, thereby reducing the jitter of the network. The detailed result analysis is mentioned in the next section.

4 Results and Analysis

We simulated our routing protocol in the network simulator version 2.34 environment, under the following network conditions, the configuration for network is as follows:

Network parameter	Value
Network type	Wireless
Number of nodes	30 to 100
Network area	300m x 300m
Routing protocols	QoS aware
Packet size	1000 bits @ 0.001 packets per second
Number of communications	2 to 20
Initial node energies	Randomized, with maximum energy of 1000 mJ per node
Energy model	2 mJ per transmission 1 mJ per reception 0.1 mJ idle energy

For comparison purpose we compared our proposed protocol with the AODV routing for the wireless network, and the following parameters were obtained,

Nodes	Comms.	Delay AODV (ms)	Delay Proposed (ms)	% Improv.

20	2	0.31	0.24	21.74
20	3	0.35	0.27	22.78
20	4	0.38	0.26	31.10
20	5	0.41	0.33	18.45
20	6	0.44	0.32	27.39
20	7	0.45	0.35	22.17
20	8	0.48	0.36	24.85
20	9	0.49	0.33	31.65
20	10	0.56	0.45	19.47
50	5	0.37	0.32	12.49
50	6	0.39	0.28	27.31
50	8	0.52	0.41	20.32
50	12	0.63	0.49	23.00
50	15	0.65	0.50	22.83
50	20	0.73	0.52	28.61
75	5	0.66	0.46	30.32
75	10	0.69	0.54	22.64
75	15	0.72	0.53	26.16
75	20	0.79	0.55	29.92
100	5	0.46	0.32	30.39
100	10	0.70	0.47	32.43
100	15	0.79	0.59	26.18
100	20	0.82	0.60	27.20
Mean Improvement		**0.556**	**0.412**	**26 %**

Similar comparisons were made for energy, packet delivery ratio, throughput and jitter. The following table shows the performance comparison for all the 5 parameters,

Parameter	**AODV**	**Proposed**	**% Improvement**
Avg. Delay (ms)	0.556	0.412	26 %
Avg. Energy (mJ)	3.126	2.198	29 %
Avg. PDR (%)	99.5	98.6	0 %
Avg. Throughput (kbps)	137.8	134.9	-0.5 %
Avg. Jitter (ms)	0.0062	0.0058	7 %

From the above table we can observe that the network delay has been minimized, the energy consumption has been reduced by maintaining a constant average packet delivery ratio and average throughput. The overall packet

delivery jitter has also been slightly improved using the machine learning approach. The delay is reduced due to selection of minimum distance nodes for routing, while energy is reduced because of it's inclusion in the routing metric as an inversely proportional parameter. Due to reduction in delay, the jitter is also reduced and thus it makes the network more reliable and consistent in terms of packet delivery times at the receiver. The PDR and throughput of AODV is already optimized, and thus there in minimal scope of improvement in that area. We recommend researchers to further evaluate this machine learning routing technique in order to check it's viability for the applications for which they would be designing the communication network.

5 Conclusion

The proposed approach when applied to the wireless network gives a significant improvement in network performance, when compared with the recent de-facto AODV routing algorithm. The performance improvement to network lifetime is more than 25%, while the delay minimization is more than 20% for a wide variety of network simulation parameters. This causes the network throughput to reduce by an infinitesimal percentage which is admissible by the wireless networks, due to the fact that our algorithm increases the energy consumption efficiency for the network, that can be used effectively by low power devices.

6 Future work

As a future work, we plan to realize the protocol using hardware implementation in a real time wireless based network, due to the low cost nature of Arduino based wireless nodes, the hardware realization can be done in a closed lab environment. We also intend to research more into the QOS improvement of the wireless networks by incorporating more parameters into our machine learning protocol, and also adding Q-Learning and deep nets into the routing algorithm, which can adapt to the network patterns and select the most optimum route intelligently and in real time, with minimum on-the-fly complexity.

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