Effective QoS Routing Mechanism for Multimedia Applications in MANET

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Abstract

A Mobile Ad-Hoc Network (MANET) is a collection of wireless mobile nodes forming a temporary network without the aid of any established infrastructure or centralized administration. The emergence of real-time applications and the widespread use of wireless and mobile device have generated the need to provide the QoS support in wireless and mobile networking environment. To provide the QoS support in MANET, QoS routing plays an important role. In this paper, an efficient QoS routing scheme is proposed to find the most relevant path for a particular traffic. The traffic is classified into video, audio and message. The different parameter sets are used for a particular traffic class. The selective parameters for route discovery is hop count, end-to-end delay and bandwidth. Hop count and end-to-end delay are used for optimization purpose and bandwidth is used for constraint. All qualified paths excluding the primary path are maintained after the route discovery. To provide fault tolerance and to keep the continuity of data packet delivery, this proposed mechanism also uses the backup route when the current active route breaks. Our scheme is applied to the Ad-hoc On Demand Distance Vector (AODV) protocol. This work is intended to provide the required QoS satisfied routes for each type of traffic class and to reduce the unnecessary computation complexity. Network Simulator tool NS-2 (ver 2.34) is used to simulate the proposed QoS routing mechanism. The performance of our solution is compared with original AODV in terms of Packet Delivery Ratio (PDR) and routing overhead (RO) to show the effectiveness of the proposed mechanism.

1. Introduction

Nowadays, wireless networks are developing very quickly with the immense growth in wireless network devices like handheld computers, PDAs and cell phones. There are two kinds of wireless network. A basic service set (BSS) without an access point (AP) is called a mobile ad hoc network and a BSS with AP is called an infrastructure network.

Current wireless networks are infrastructure network that support mobile/wireless access for mobile communications devices by providing a wireless interface between the mobile devices and a fixed network of limited range base-stations (BS). On the basis of this *infrastructure* model for wireless communications, the air-interface consists of a single data-link terminating on a BS. Communication from that point is routed across a fixed network to its destination. Mobility is managed by allocating a limited set of communication frequency channels to each BS and dynamically assigning a mobile device to a local channel as it moves from the coverage are of one BS to another. While providing QoS in an infrastructure environment is difficult, supporting QoS in mobile ad hoc networks, which does not depend on a BS for communication, is more difficult. Therefore, researchers are encouraged to improve the network services and performance of MANET [1][2]. The remainder of this section provides an overview of MANET and QoS Concept.

1.1. Properties and Challenges of MANET

Ah hoc network are self organization, rapidly deployable and require no fixed infrastructure [13] [14] [15]. The wireless mobile nodes can be deployed anywhere and must cooperate to establish communication dynamically. The implementation of MANET presents a unique set of challenges. Nodes must act cooperatively to handle traffic transmission as routers. Since, network devices are free to move, network topology may change randomly and rapidly.

The wireless medium that carried out the all communication consists of a bandwidth constrained links. Moreover, the effects of multiple accesses, fading, noise, and interference conditions will also result in time-varying channel capacity, making it difficult to determine the aggregate bandwidth between two end-points. Therefore, wireless network has a significantly lower capacity than the wired network. Resources, including energy, bandwidth, processing capacity and memory, that are relatively abundant in wired environments, are strictly limited. This is a difficult task for best-effort routing without even considering QoS requirements.

Controlling overhead is another key consideration for ad hoc network. The control packets will also compete with the data for network resources such as channel and bandwidth. Since the resources are very limited in ad hoc network, they must be preserved for data traffic.

These unique characteristics of MANET distinguish this new network architecture from the traditional infrastructure wired and wireless networks and also impact on QoS provision on these networks [5]. There are a lot of research and efforts to enhance the Internet with QoS components for real-time data including multimedia. But these are not suitable for ad hoc network because current QoS routing algorithm requires accurate link state such as packet loss rate, available bandwidth, estimated delay and topology information. Therefore, QoS models for wired network are not insufficient and QoS support still remains an open problem for ad hoc networks.

1.2. Overview of QoS Concept in MANET

In today's Internet, ad hoc network are being designed to provide best-effort service in which packets are dropped regardless of their important. If the packet lost, the sender can simply retransmit the lost packet. However, this method is not efficient for real-time application, such as video-on demand, video conferencing and Internet telephony which are sensitive to packet loss and delay, and may need to have minimum bandwidth requirements. Consequently, QoS support is necessary for these multimedia applications [12].

According to [16], QoS is a set of service requirements to be met by the network while transporting a flow. A fundamental requirement of any QoS mechanism is a measurable performance metric [17]. Typical QoS metrics include bandwidth, delay, packet loss rate, jitter, hop count and path reliability.

QoS can be technically achieved in two ways: (1) over-provision and (2) traffic engineering. Overprovision simply increases the available resource (bandwidth, buffers). Traffic engineering tries to utilize the sources efficiently and to make the network QoS aware. This includes additional service classes, admission control, resource reservation and so on. This paper focus on the additional service classes the traffic engineering approach.

Providing a complete QoS solution for the ad hoc networking environment requires the interaction and cooperation of several components. These components include: (1) QoS routing protocol, (2) a resource reservation scheme and (3) a QoS capable medium access control (MAC) layer.

QoS routing is an essential part of the QoS architecture. Before any connection can be made or any resource reserved, a feasible between a source-destination pair must be established. QoS routing is a routing mechanism under which routes for traffic are determined on the basis of some knowledge of resource availability in the network as well as the QoS requirements of the flows or connections [16]. The objectives of QoS routing is: if one exists, find a feasible path between a source-destination pair (i.e. a path that has sufficient available resources capable of satisfying the QoS requirements. In other words, the QoS routing protocols tries to find a path that has a good chance of meeting the QoS requirements. To design the QoS routing algorithm for ad hoc network, it must consider the metric selection (bandwidth, delay), path computation and maintenance.

The purpose of this paper is to support the QoS satisfied route for multimedia application in MANET from the QoS routing point of view.

2. Related Works

This section provides a review of the current research concerned with the providing QoS routing in a wireless network architecture called mobile ad hoc network for each QoS component (e.g. QoS routing, resource reservation and the MAC layer).

Shakeel Ahmed, A. K Ramani [10] proposed an on-demand routing protocol for improving the Quality of Service in mobile ad hoc network with the modification of AODV protocol. It discovers the route by calculating the bandwidth requirement to find the primary route and the alternate route from the source node to destination by applying the mechanism of carrier sense in IEEE 802.11b, Listen Bandwidth Estimation. The alternative route is maintained in the ARQoS routing table. The route is rediscovered when both the primary route and the alternate route fails. The main drawback of this solution is that the accurate available bandwidth cannot be able to determine. In listen bandwidth estimation, the host can't release the bandwidth immediately when a path breaks, because it does not know how much bandwidth each node in the broken route consumes.

Mie et. al. [7] discusses a QoS routing protocol by extending the original AODV protocol. Multiple parameters are considered in making routing decision. Hop count and mobile speed are considered for routing decision. Accounting for the uncertainty of route information in ad-hoc network, fuzzy logic is used for optimizing the route. This protocol can transmit the data through the route with the lowest delay. However, the main drawback is the processing delay of route discovery because fuzzification is need at every intermediate node that takes time.

In [9], fuzzy energy based routing protocol is mentioned to support QoS in wireless ad hoc networks, but no specific algorithms were designed. The fuzzy controllers take number of hops, packet queue occupancy and remaining energy along the paths into account while picking routes. Similarly, route discovery cause a great end to end delay for route selection because fuzzification must perform at every node.

3. AODV Routing Protocol Overview

Among on-demand routing protocols, AODV is one of the most popular routing protocols for MANET [11]. AODV is a method of routing messages between mobile computers which they cannot directly communicate. In the original AODV, hop count is used as a parameter to find the shortest path for the packet transmission. Two procedures of AODV are: route establishment and route maintenance.

3.1. AODV Route Discovery Process

Whenever a node wants to make a transmission, it first checks its routing table. If there is a route, it uses that route to send the packets to the destination. If not, then the route discovery is initiated by broadcasting the RREQ (Route Request) packet in the network.

Node that receives the RREQ checks itself whether it is the destination or it has a valid route. If so, the node sends back the RREP (route Reply) packet to the source. If not, it rebroadcast the RREQ message to its neighbors until it reaches the destination or the intermediate node which has a valid route. Duplicated RREQ messages are discarded. Each time a node receive a RREQ message, it makes a reverse route entry to source and each time a node receive a RREP message, it makes a forward route entry to destination. As soon as the source receives the RREP, it can start transmission.

The diagram in the Fig. 1 shows the operation of AODV route discovery with six nodes on a wireless network. The circles illustrate the transmission range. Because of the limited range, each node can only communicate with the nodes next to it.

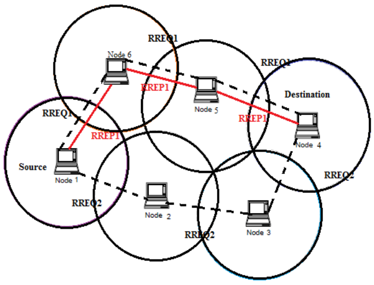

Figure 1. AODV route discovery

3.2. AODV Route Maintenance Process

When a node detects a link failure during the packet transmission, the upstream node of the broken link sends a route error packet (RERR) upwards to the source node. RRER lists all the nodes affected by the link failure. When a node receives RRER, it marks its route to the destination as an invalid. When a source node is received RRER, then, the source node will re-initiate route discovery. Link failure is detected by exchanging Hello message to neighbors periodically. This can lead to a situation, where routing overhead is extremely great with AODV. Later, local Repair method is used in which upstream node locally repairs the break without notifying the source node. If repair attempt is unsuccessful, it sends the RRER to the source. Therefore, Local Repair Procedure also leads to packet loss problem. The diagram in Fig.1 shows the operation of AODV route maintenance.

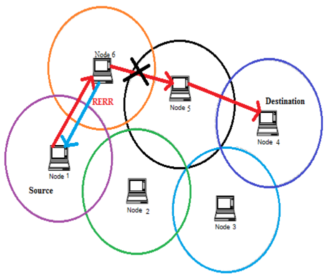

Figure 2. AODV route maintenance

4. The Proposed System

4.1. Review of Original AODV and Existing QoS over AODV

There are some drawbacks in the original AODV. The original AODV does not support the Quality of Service. Only hop count parameter is used for route selection. It chooses the route with the smallest hop count for data transmission. This kind of choosing manner is not suitable for multimedia application because smallest hop count does not mean the high bandwidth and the least delay. Multimedia applications have their own requirements. Video and audio are very delay sensitive. Video demands even the enough bandwidth. To support the demanding QoS for multimedia application, more than one parameter are selected. There are a lot of researches that use more than one parameter to support QoS. But, the disadvantage is that the more parameters are used, the higher the complexity and the slower to convergence. On the other hand, this type of QoS routing protocol is not suitable for normal data traffic for which results in the performance degrading.

Moreover, when the source node broadcasts route request message to the neighboring nodes, the intermediate node will create reply message to the source if it has a valid route. This leads to the stale RREP message. In addition to, it does not utilize the multiple paths and maintains only one path to the destination. Therefore, a new method is proposed as an efficient and comprehensive mechanism with backup scheme.

4.2. New Mechanism of QoS Support over AODV

This system defines the parameters based on traffic class. Before route discovery, QoS requirements of each traffic class are determined. Therefore, the application layer directly informs the traffic class to the network layer which determines the relevant parameters for the given traffic class. Traffic is classified into three classes here: (1) Class 1, (2) Class 2 and (3) Class 3.

Class 1 is the ordinary traffic type such as message. It does not demand QoS. So, only hop count is enough for route discovery as the original AODV. Class 2 means the delay sensitive traffic, audio. For this, hop count and end-to-end delay parameters are used for route selection. Video is defined as the Class 3. For this type of content, parameters are used for constraint as well as optimization. To gain high throughput, route should have enough bandwidth. So, bandwidth parameter is used as constraint parameter to collect the bandwidth guarantee routes. This application content is also delay sensitive application, hop count and end-to-end delay are used for choosing the optimized route among the bandwidth guarantee routes.

4.2.1. Traffic Class Information Retrieval from Traffic Source

To implement the proposed mechanism, three traffic generators are developed at the Application Layer. They are message (Class 1), audio (Class 2) and video (Class 3) traffic generators. When these traffic generators generate the packets, application layer sets the traffic class in the packet type field (*ptype*) of the packet header. Then, application layer sends the packets to the network layer which examines the packet type from the header to determine the relevant parameters for route discovery.

For the proposed system, Route discovery Procedure and Route Maintenance Procedure of AODV is slightly modified which will explain in detail in the later sections. The relationship between the traffic type and parameters are shown in Table 1.

Table 1. The relationship between the traffic types and parameters

Content	Parameters for path optimization	Link constraint
Video	End-to-end delay, hop count	Bandwidth
Audio	End-to-end delay, hop count	No
Message	Hop count	No

To provide a new QoS support over AODV, a set of QoS extension has been made for the RREQ and RREP messages. Before a node can rebroadcast a RREQ or unicast a RREP to the source, it must be capable of meeting the requested QoS constraints. The RREQ control message adds two extra fields, application content (*app_type*) and requested bandwidth (*req_bw*). Route discovery Procedure and Route Maintenance Procedure of AODV is slightly modified which will explain in detail in the later sections. The original routing table (*rtable*) is extended too. A new routing table (*bk_table*) is created for the purpose of storing backup route.

4.3. Route Discovery Phase

The main purpose of route discovery is to establish a route between the source and the destination. In this phase, Route Request (RREQ) and route reply (RREP) messages are used for route discovery.

The route establishment is initiated when a source needs a route to a destination for which it does not have a route in its routing table. Before sending the RREQ message, the source defines the application content type in RREQ. For Class 1 and Class 2, it initializes the zero value in the (*req_bw*) field, and it calculates the requested bandwidth for Class 3and then put the value in the (*req_bw*). The required bandwidth is calculated using (1). After that, RREQ message is broadcast and sent to all neighbor nodes over the wireless link.

$$\text{RBW} = \text{SVM}/\text{TML} \tag{1}$$

Where:
RBW: Required Bandwidth
SVM: Size of Data (Video)
TML: Total Time Length of Video

Every intermediate node only process the first received RREQ and discard the duplicated ones. Then it adds the route information of the source node to its route request table and checks the application content. If the application content is Class 3, then it determines that its available bandwidth is sufficient for the requested bandwidth. If the available bandwidth is less than the requested bandwidth, it will discard the RREQ message. If not, it will rebroadcast the RREQ to all neighbor nodes. For Class 1 and Class 2, the intermediate node will simply rebroadcast the RREQ.

In this proposed system, only the destination node will reply RREP messages. Whenever the destination accepts the RREQ message, the corresponding RREP is replied to the source.

At the source, as soon as it had just initiated a route discovery, it started the timer. During the timer, the multiple RREPs with the same destination are received by the source and calculate the cost of each replay and then store the route with cost in the backup route (*bk_table*). When the timer is up, the best route is chosen using the cost value of each route. The route with the smallest cost is used as main route and store in the original routing table. The backup table clears the chosen in its table. The source calculates the cost value of each route as shown in Section. 5. All the rest routes are still in the (*bk_table*) to be used as backup routes because single path is considered one of the biggest drawbacks of AODV.

4.3.1. Cost Evaluation

Routes are selected according to their cost value. The cost equation of each route can be defined to be a two-dimensional function as in (2). (*F1*) is the hop count and (*F2*) is the end-to-end delay.

$$\text{Cost\_Fun} = f(F1, F2) = \alpha F1 + \beta F2 \tag{2}$$

Where α and β are manually configured coefficients. There is no need to consider the end-to-end delay parameter for Class 1. So, β is initialized ‘0’. For Class 2 and 3, α is set to ‘0.4’ and β is ‘0.6’ because delay is more emphasized for delay sensitive application contents. (*F2*) is expressed as shown in (3).

$$F2 = link\ delay + node\ delay = \sum_{i=1}^{E} link\_delay_i + \sum_{j=1}^{N} node\_delay_j \tag{3}$$

Where:
E: the number of edges on each route
N: the number of nodes on each route

4.4. Route Maintenance and Backup Procedure

Hello message and Route Error (RERR) message are used for route maintenance. During data transmission, neighboring nodes monitor the link status of next hop in active routes by exchanging Hello messages periodically and absence of hello message indicates a link failure. When a node detects a link failure while attempting to forward a packet of the next hop, it sends a RERR packet to the source.

By the time the source receives the RERR message, it does a backup procedure as follow:

IF there remains data to send (to destination)
  Delete the route from the routing table
  IF there is backup route in the *bk_table*
    Extract the second optimal route
    Store the second optimal route in the routing table

Delete the second optimal route from the *bk_table*

Send the data using the second optimal route

ELSE

Reinitiate the Route Discovery

END IF

ELSE

Delete the route from the routing table

END IF

The source checks its (*bk_table*) if there remains data to send. If there is no backup route, it initiates a route rediscovery. Otherwise, the source extracts the second optimal route and replaces the primary route with the secondary route. Therefore, the source node immediately utilizes its backup route, without an interruption of data packet transmission. In this scheme, backup route is maximally used for two times to avoid the stale route problem.

The random and unpredictable movements of nodes in MANET occurs link break which is the major factor of performance degrading although the QoS satisfied route is already obtained. Using backup route scheme makes high strength for supporting QoS of many applications. As a result it increases more reliable and available.

4.5. Node's Action of Proposed System

The following flow chart summarizes the action of node in the proposed system when processing an incoming message. Hello message are excluded from the diagram for brevity:

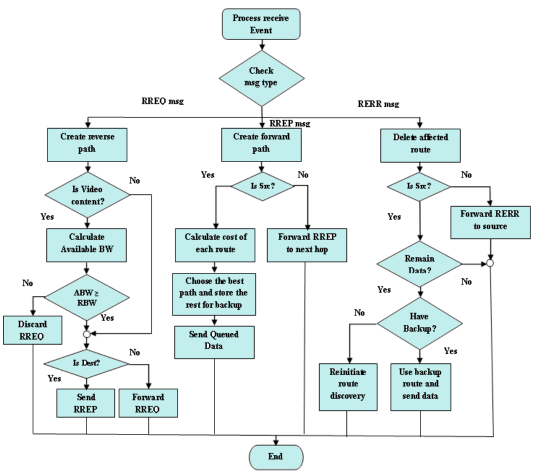

Figure 3. Action of node

4.6. Example

Fig. 4 is a simple topology to show how the proposed system is worked. The topology is composed of four hosts. Node 2 and 3 are in the transmission range of node 1 and node 4.

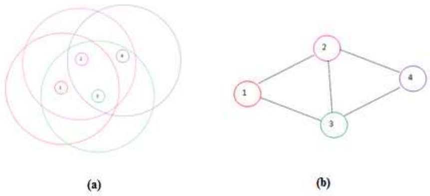

Figure 4. Simple topology

When node 1 (source) wants to send Audio traffic, it broadcasts RREQ message. Node 2 and node 3 get RREQ messages. Since they are not the destination, they rebroadcasts RREQ message. When RREQ message arrives at Node 1, 2 and 3, they discard it because they had already accepted it. Here, node 4 receives two RREQs from the path 1-2-4 and the path 1-3-4, and then it sends back the corresponding replies (RREP). Node 1 has two routes for node 4. Then, source node (node 1) computes the cost of each route. Hop count of both paths is 2 and it assumes that the delay for the path 1-2-4 is 5 and the day for the path 1-3-4 is 10. The value of each route is 3.8 and 6.8 respectively. Now, the route whose next hop is node 2 is built as an active route and the route whose next hop is node 3 is a backup route. This propagation of route discovery is illustrated in Fig. 5.

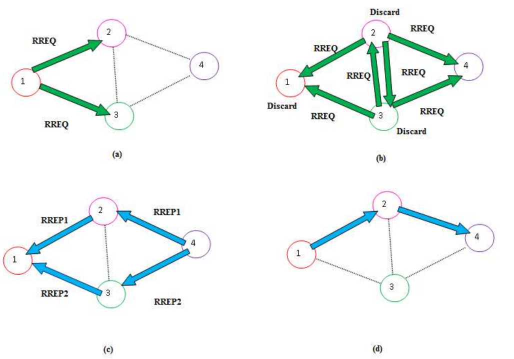

Figure 5. The propagation of route discovery

In Fig. 6(a), when node 2 detects that the link to node 4 is broken, it sends back the RERR message to the node 1. So node 1 switches to a new route, whose next node is node 3, as is shown in Fig. 6(b).

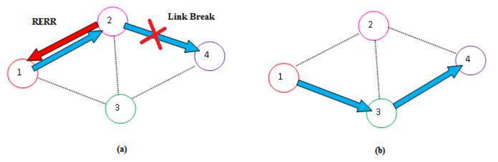

Figure 6. The process of RERR message

5. Performance Evaluation

To evaluate the impact of traffic type on QoS routing protocol in MANET, simulations with NS-2.34 [13] are carried out. For our simulation, we use the IEEE 802.11 Mac at the physical and data link layer. The channel is Wireless Channel based on Two Ray Ground radio propagation model. AODV is used at the network layer as the routing protocol. Finally, UDP is used at the transport layer. The traffic sources are Data (including Message), Audio and Video. The network is done with various pause times: 0, 10, 20, 30, 40, 50, and 60 ms. The overall simulation parameters are presented in Table 2. We have evaluated the performance of the proposed system protocol with the original AODV protocol. The simulation time is 300s. The performance is expressed in terms of packet delivery ratio and routing overhead.

Table 2. Simulation parameters

Parameter	Value
Simulator	NS-2.34
Area	750m x 750m
Routing Protocol	AODV, MYAODV
Simulation time	300s
Application Traffic	CBR, Audio, Video
Number of Nodes	30
Packet Size	512
Mac Protocol	Mac/802.11
Transmission rate	4 Packet/s
Maximum Speed	0,10,20,30,40,50,60 ms
No of Connection	5
Movement Model	Random Waypoint

A. Packet Delivery Ratio

It is the ratio between the number of CBR packets sent by the source and the number of packets received by the destination.

B. Routing Overhead

It is the ratio between the total number of routing packets received and the total number of data packet received.

We evaluated the performance of AODV and proposed AODV in the context of variation in mobility speed using three sets of experiments. The first set considers the data traffic source. The second set has the audio traffic source whereas the other has the video traffic. The PDR of proposed AODV protocol is higher than the AODV. The simulation result with respect to packet delivery ratio is shown in Fig. 7, Fig. 8 and Fig. 9. Therefore, the results obtained from the simulations show the effectiveness of proposed route discovery and route maintenance.

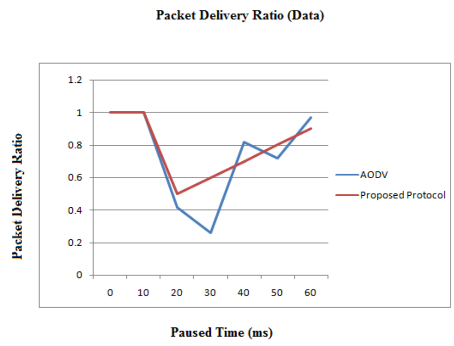

Figure 7. Packet delivery ratio and pause time for data

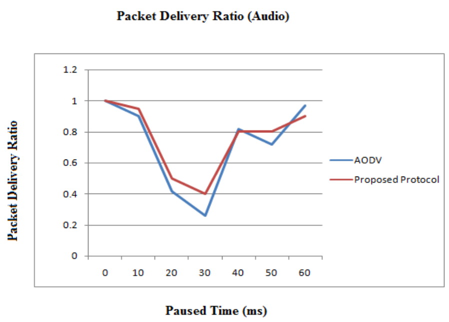

Figure 8. Packet delivery ratio and pause for audio

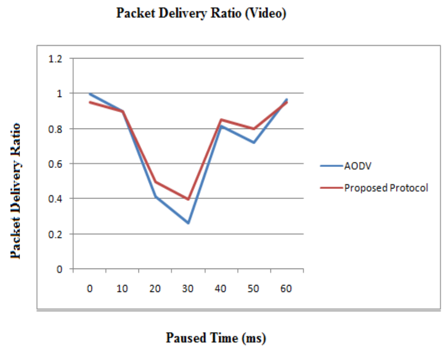

Figure 9. Packet delivery ratio and pause time for video

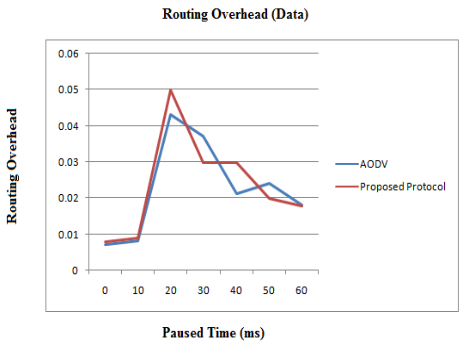

Figure 10. Routing overhead and pause time for data

The performance of AODV and proposed AODV are evaluated in terms of routing overhead in Fig. 10, Fig. 11 and Fig. 12. From the results, proposed AODV exhibits the good results. We can find that the routing overhead in proposed AODV is slightly higher than original AODV when nodes are not moving in all three experiments because the number of RREP and RREQ message in proposed is greater than AODV but they are very few because the RREPs are unicast towards source. However, the proposed protocol outperformed when node mobility occurs. Although there is no significant difference in routing overhead for data traffic type, the amount of overhead in AODV is almost doubled than the proposed system because of the frequent route re-initiate during the data transmission. Low routing overhead saves the scarce network bandwidth, thus increasing the network capacity. Therefore, the proposed system is said to be more reliable and to obtain a better overall performance compared to AODV.

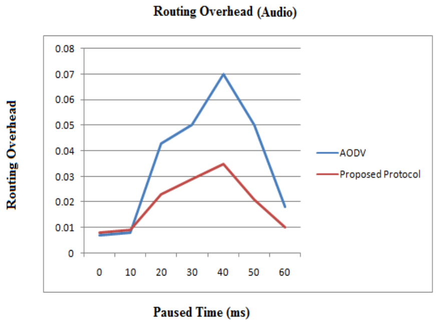

Figure 11. Routing overhead and pause time for audio

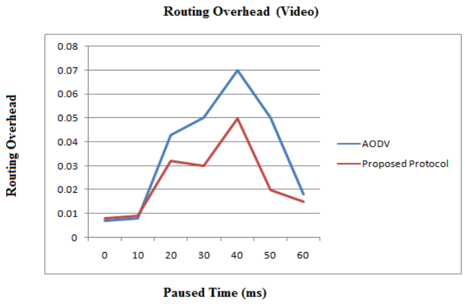

Figure 12. Routing overhead and pause time for video

6. Conclusion and Future Work

In this paper, a new QoS mechanism is presented to make more robust and efficient. The more parameters are used, the more accurate the quality of routes is. On the other hand, many parameters make the complexity of the system increases. In this system, the most appropriate treatment is given the specific content. For the traffic class for which QoS is essential, many parameters are used to have the required QoS satisfied route. In Class 3, both optimization parameters and constraint parameter are used. To provide bandwidth guarantee, bandwidth parameter is used as constraint. Among the bandwidth guarantee routes, the optimized route is chosen based on hop count and end-to-end delay. But for the application like data, if more parameters are used, then it will take more delay and increase the complexity. Moreover, the result route is not an optimized one. Therefore, for such kind of content, only hop count meets its requirement.

The performance of the proposed system is evaluated with the original AODV using NS-2 based on packet delivery ratio and routing overhead. The experimental result and performance evaluation indicate the effectiveness of this proposed mechanism. In this proposed system, only link break problem is solved by using the backup route. Detecting that the requested QoS can no longer be maintained is not considered. It is hoped that in the future, QoS lost problem will be solved. Next point is that resource reservation is another effective complement to support QoS. A more suitable approach that integrates of QoS routing and resource reservation is also the future work.

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