Middleware Design of Bandwidth Constrained QoS Model for Multi Hop Ad Hoc Networks

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Abstract: Middleware is actually a resource manager that guarantees the implementation of all policies, contracts to be satisfied, and it ensures that contracts do not go beyond the limits of network capacity. It also authentication, so that only the legitimate users could avail the network resources according to the agreed format. The middleware is supposed to be the backbone for QoS assurance and the system behavior depends on it. This paper proposes design of a middleware based on a bandwidth constrained QoS model for multi hop ad hoc networks. Our model is designed not only on the basis of conceptualization but we have considered the basic functionalities available in networking equipments like routers etc. The elements of QoS aware middleware are admission control, resource reservation, policy control and a feedback module. Finally we discuss our future work to find the primary and alternative route to the destinations by keeping the bandwidth constraints in mind.

Key-words: Multi hop, Ad hoc Networks, Packet Classifier, Resource Reservation, Quality of Service, Real Time Applications

1. Introduction

From the two architectural designs given in [1], ad hoc networks are 2nd approach that does not rely on stationary infrastructure. Ad hoc networks are formed in situations where mobile computing devices require networking applications while a fixed network infrastructure is not available or not preferred to be used. In these situations mobile devices could setup possibly short-lived network for the communication needs of the moment, in other words ad hoc network. Fig.No.1 gives conceptually the idea of Fixed and Multi hop ad hoc network. Multi hop ad hoc network are formed by a group of mobile users or mobile devices spread over a

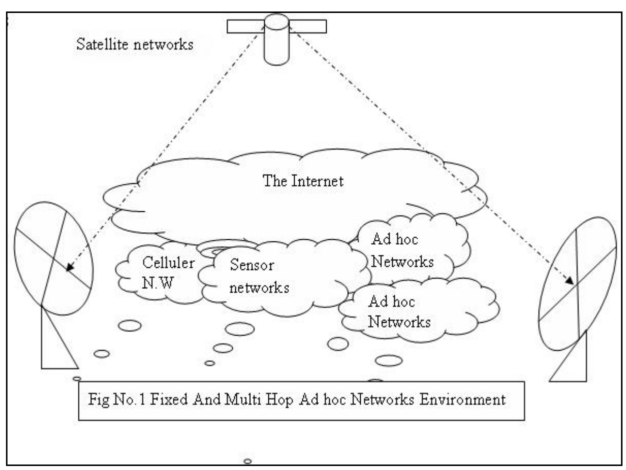

Fig No.1: Fixed and Multi hop ad hoc network certain geographical area. We call the users or devices forming network as nodes. The services area of ad hoc network is whole geographical area where nodes are distributed [2]. Each node is equipped with a radio transmitter and receiver, which allow it to communicate with other nodes [3]. As different nodes crates a multi hop ad hoc network among themselves without using any administrative support [4]. Ad hoc wireless networks are self-organized, self-creating and self administrating. They come into being solely by interactions among their constituent wireless mobile nodes, and it is only such interactions that are used to provide the necessary control and administration functions supporting such networks. Each node of ad hoc network can generate data for any other node in network [5]. A mobile ad hoc network may be connected through dedicated gateways or nodes functioning as gateways, to other fixed networks or the Internet. In this case the mobile ad hoc network expends the access to fixed network services [6].

Therefore, all nodes can function, if needed, as relay station for data packets, to be routed to their destinations. Thus a node in ad hoc network operates both as host and router.

Now days Military environments as army navy and air force, emergency environment as search and rescue, policing, fire fighting, hospitals, telemedicine and earthquakes and civilian environment as transmission of news, road conditions, meetings, shopping malls, entertainment and games are the major application areas of mobile ad hoc networks. Especially these networks are getting their importance in commercial applications that cause to generate big revenue.

All above applications need a guaranteed QoS. QoS is provision to provide service according to certain attributes satisfying the transmission of information and now a days QoS means minimum bandwidth, minimum delay guarantee enforced by some constraints to agreement for providing the service. As the medium in ad hoc networks is shared by all neighbors, therefore support to QoS can not be done by host itself but by cooperation of all neighbors that require a middleware to support the communication between neighbors to provide QoS.

2. Problems and Issues

The absence of fixed infrastructure makes the nodes to communicate directly with one another in peer-to-peer fashion. The mobility of these nodes imposes limitations on their power capacity and on their transmission range [7]. As the nodes move in out of range with respect to other nodes, resulting that topology becomes dynamically changeable. In accommodating the communication needs of user applications, the limited bandwidth of wireless channels and their generally hostile transmission characteristics impose additional constraints with respect that how much administrative and control information may be exchanged and how often [8]. Effective routing is one of the great challenges of multi hop ad hoc network [9].

The frequent path breaks due to the mobility, difficulty of time synchronization that consumes bandwidth, bandwidth reservation that requires complex medium access protocol and cost of an elegant mobile host are major problems with multi hop ad hoc networks [10]. Where medium access schemes, routing, multicasting, transport layer protocol, pricing schemes, self organization, security, energy management, addressing, service discovery, scalability, deployment consideration and above all Quality of Services (QoS) are major solvable issues to mobile ad hoc networks [11].

3. Motivation

Rapid adoption of wireless technology continues; coupled with the explosive growth of the Internet, it is clear that there will be increasing demand for wireless data services.

A user node in a multi hop network has to transmit both relayed and its own traffic. Also it has to maintain the routing information of the network. Fig.No.2 shows a simple multi hop ad hoc network. In this network, node A is the source node (VoD Server) and node B is destination node (VoD Client/Player). If node A transmits data to node B, it has to get help of various intermediate nodes. So data has to move from multiple hops before reaching to destination and there can be congestion at any intermediate node. The topology is very much dynamic in such multi hop networks as any mobile node can vanish due to any reason and we have to ensure continuous connectivity for a mobile unit.

4. Related Research Work

When we talk about QoS and its model to provide QoS it include the three components as: QoS aware medium access control, QoS oriented routing plus resource reservation and signaling process. QoS

MAC resolve the problem of medium access, support reliable communication and provide

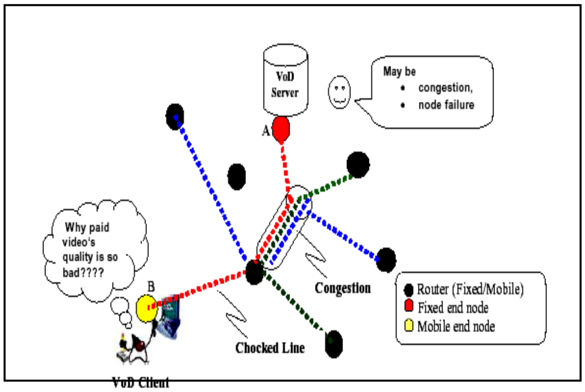

Fig.No.2: Multi hop Ad hoc Network

resource reservation for different categories of traffic. QoS routing provide route discovery and maintenance of routes those satisfy QoS objectives under specific constraints. QoS signaling provide a perfect admission control and information of QoS resource reservation.

To satisfy these requirements a lot of work has been performed by researchers and at best of our knowledge ten major QoS models are presented in last decay. All of those models posses some qualities and few drawbacks or deficiencies. Here we are giving the overview of those models with all their functions, purposes and deficiencies.

Xiao presents FQMM [12] that was the first QoS model to provide the services on traffic class basis and use three types of nodes as ingress node that sends data, an interior node which forward data and an egress node that is destination. This model uses per flow property of IntServ and service differentiation of DiffServ. The low priority traffic is given differentiation of DiffServ, therefore it applies hybrid provisioning and both IntServ and DiffServ facilities. This model do not specify that how much flow sessions are possible, how intermediate node determine packet information and how scheduling will be performed at intermediate nodes. LQoS [13] was given by Christian Bonnet with the idea of separating the network layers with respect to their functionalities and responsibilities, specially separating the network layer and application layer metrics. In this model layers perform different functions according to QoS requirements. The authors present the idea that on network side this model maximizes the network life by distribution of traffic according to different categories, on other side this model helps to select a path to meet he QoS requirements. LQoS does not describe the specific protocol, it only express the architecture and methodology to provide specific type of service. SWAN [14] by G. Ahn suppose many things as assumptions before providing mechanisms for QoS, as it suppose that routing protocol has found the best valid path to route the traffic. The best quality of this model is that it supposes that topology changes do not affect the traffic. It uses feedback based control mechanism and the admission control at source node. It is actually the distributed model that assumes the best effort mechanism. S. B. Lee introduces INSIGNIA [15] for providing signaling. It was specifically designed for resource reservation. It is used for adaptive QoS requirements. It gives minimum qualitative QoS guarantee called Base-QoS. It is used to support real time traffic. It supports in band signaling by adding a new option in IP header to carry signaling control information .It provide per flow and if the required resources are unavailable , the flow will be degraded to best effort service. QoS reports are sent to the source node periodically to report network topology changes as well as QoS statistics as loss rate, delay and throughput. INORA [16] was also given by S. B. Lee and was extension of INSIGNIA. In this QoS Resource reservation signaling mechanism interacts with the routing protocol to deliver QoS guarantee. INORA was classified in to two schemes as: coarse feedback scheme in which when a node fails to admit QoS flow it send a failure control message to upstream to change the route and class based fine feedback scheme in which minimum and maximum bandwidth flow is divided into N classes. The drawback of this scheme is that it does not reserve resources before the actual flow therefore not suitable for QoS guaranteed services. PRTMAC [17] of T. Sandeep is a cross layer QoS model that is the best solution for the traffic that requires bandwidth reservation and availability estimation services. It is developed to support real time traffic and service differentiations to highly mobile networks. But this model is suitable in scenarios where power resources are not a major concern as military networks, high speed vehicles, fleets of ships etc. Lie Chen also presents cross layer based QoS [18] model to support real time data transmission. This model contains QoS transport layer, QoS routing queue management and priority MAC. The simulation results that it reduces delay and greatly improves the quality of real time video streams, but it lacks to provide support to multiple different priority traffic streams.

5. Middleware Design

After the extensive study of the work done related to design of framework or model to support QoS given in previous section, we have reached at a conclusion that although it is a prestigious work but every model lacks with reference to certain priorities, conditions and have different deficiencies that we have explained after the description of each model in last section. Our motive is to design a complete model that have all the required facilities to meet the challenges of QoS in all traffic conditions, with fulfillment of all constraints and with full availability of QoS requirements in all scenarios of practical implementation and deployment of ad hoc networks.

5.1 Basic Framework

Different applications have different requirements regarding QoS and their associated parameters are also different. Here we have concentrated upon one of those parameters, i.e., bandwidth reservation. But in [19] it is observed that to recognize the guarantee of bandwidth is not sufficient in QoS promising applications, they need assurance of delay and delay bounds (jitter). To provide QoS guarantee for delay and jitter the management with respect to reservation, allocation and policing of delay is necessary and performance oriented application may demand guarantee of one or all of bandwidth, delay and jitter. Middleware is actually a resource manager that guarantees for the implementation of all the policies, contracts and agreements required to be satisfied and it ensures that contract do not go beyond the limits of network capacity. To perform this entire network must be divided in to manageable domains and each domain is responsible to manage the policies strictly. It can be performed by an Admission Control with respect to bandwidth reservation and delay. Here we have given the conceptual design of middleware which perform the different functionalities for the implication of traffic contract and make the validation confirm through enforcement policy. While the designing, this thought was kept to be mandatory that during implementation it must be compatible with the latest routing devices. Fig.No.3 shows the design of our proposed middleware/resource manager. The details of its modules and their proposed functionalities in QoS required environment are explained in next section.

5.2 Issues

Following we are highlighting few factors that must be kept in mind, while designing Middleware for QoS model:

i. The model must be capable to manage the delay and jitter to an acceptable level.

ii. The model must be capable to reserve the resources for future utilization according to the agreement.

iii. The model must analyze the traffic for the satisfactory performance of the network, so that applications can adjust their rate of transmission depending on current traffic load and actual traffic.

iv. The model can manage the capabilities of heterogeneous routers and support different routers designed by different vendors.

5.3 Basic Architectural Model

Different applications have different requirements regarding QoS and their associated parameters are also different. Here we have concentrated upon one of those parameters, i.e., bandwidth reservation. Middleware is actually a resource manager that guarantees for the implementation of all the policies, contracts and agreements required to be satisfied and it ensures that contract do not go beyond the limits of network capacity. Here we have given the conceptual design of middleware which perform the different functionalities for the implication of traffic contract and make the validation confirm through enforcement policy. While the designing, this thought was kept to be mandatory that during implementation it must be compatible with the latest routing devices. Fig.No.3 shows the design of our proposed middleware/resource manager. The details of its modules and their proposed functionalities in QoS required environment are explained in next section.

6. Proposed QoS Model

As stated earlier, our objective is to enable an ad hoc network to provide assurances on Quality of Service (QoS). There could be many solutions to this problem. However, here we have proposed an architectural model that is on the basis of bandwidth reservation. The model design actually implements functions of middleware with respect to protocol stacks. The model is organized in two parts. First part handles the matters pertaining to the reservation of bandwidth and second part specifies the policy to achieve the results of first part by applying certain constraints.

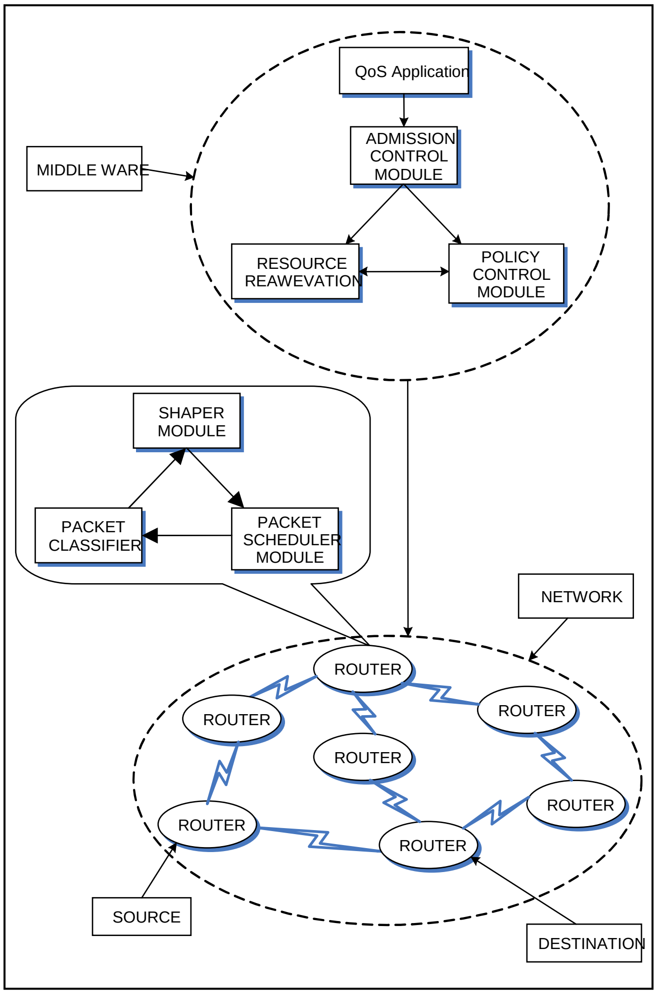

Fig.No.3: Architectural Model of the Middleware

6.1 Traffic Contract (Reserve Bandwidth)

Our idea is to discriminate traffic on the basis of their priority. The high priority traffic (paid accordingly) would have a contract with the network. This contract may consists of various parameters including but not limited to the amount of bandwidth to be used and the duration of time for which it is to be used. These contracts would enable the network to determine the needs of the users and the available network capacity. The network resource manager (a middle that we have designed), would ensure that the contract do not go beyond the network capacity. In Fig.No.4 the proposed design of model is given, which contains the QoS Application Module, Admission Control Module, Resource Reservation Module and Policy Control Module. We expect that the modules of design will perform the following functionalities:

i) QoS application: There can be many applications that demand for QoS from military, emergency and civilian environments. This can be a real time application including Audio, Video or Voice.

ii) Admission Control Module: This module is responsible for accepting or rejecting a new QoS request or application. If the required resources are available, the request is accepted otherwise the request will be rejected. To do all this, the tracking of resources availability is necessary functionality of admission control module.

iii) Resource Reservation Module: This module is responsible for reservation of resource for the high priority applications and other applications according to certain predefined criteria. Once resources reserved, these resources will be used by that application only. On the unavailability of that category of application due to any reason, rather than vesting the resources they will be allotted to other priority rank applications.

iv) Policy Control Module: This module will be responsible for forcing the over all policy of the QoS architecture. This module includes the rules and regulations for resource reservation and other related issues. Two types of policies are used in this regard:

i. Fixed Policy in which changes occurs in long time durations as in hours. This policy is modified infrequently.
ii. Stationary Policy in which changes occurs in short time as in minutes. This policy is modified very frequently.

6.2 Contract Enforcement (Policing, Shaping, Etc)

In order to ensure the assurances for the QoS of the network to the users, it is also necessary that the users give honor to their contract. However, one can not leave contract enforcement on the will of users, because it is likely that some of the users would not be able to fulfill their contract intentionally or unintentionally. If some users do not fulfill their contract and uses network resource more than allocated to them, the network would not be able to fulfill its guarantees to other users as well. Therefore, we need to make sure that all users behave according to their agreement made with the network. For implementing this behavior we have designed “**Contract Enforcer**” and we intend to implement this “**Contract Enforcer**” on the routers**.** This contract enforcer would enforce user contracts by "***policing***" (dropping packets which are not within the scope of the contract) and "***shaping***" (smoothing if out of the format of the traffic so as to make it compliant with the contract).Our proposed design contain three modules for implementation of this contract enforcement as Shaper Module, Packet Classifier Module and Packet Scheduler Module. The functionalities of the modules are expected as follows:

i) Shaper Module: The shaper module is responsible for making the packet into its agreed upon format. If the sender is violating the size and frequency of the packet, it re-shapes the packet accordingly.

ii) Packet Classifier Module: This module is responsible for classifying the incoming packets according to the agreement. After classification, the packets are put into the appropriate queue.

iii) Packet Scheduler Module: This component is responsible for sending the packets to the outgoing interface depending upon its priority. The high priority packets are sent to the outgoing interface before the low priority packets, this providing service differentiation.

iv) Feedback Module: This module is responsible to acquire data from the lower layer devices (routers etc), analyze that data to verify compliance of the contract for a particular communication. If that particular communication is found to be non-compliant, report it to the middleware for an appropriate decision. Feedback module may also verify if the allocated resources have, indeed been provided to that particular communication.

6.3 Analysis

For implementation**,** we have started with the design of algorithm for one of the traffic categories that have priority to transmit data to other types of traffic and it can start communication. Fig No.5 explains the algorithm and Fig.No.6, 7 highlights the activity and collaborative diagrams for the middleware oriented QoS model. These both designs help in our next step of work, i.e. to design and develop a resource manager for this middleware. These designs explain the transmission of information for better analysis to the flow of traffic from different modules of model and their interaction with each other for the smooth transfer of communication. In future while designing the resource manager for the allocation of resources these behaviors will help in better understanding of the system transitions.

7. Evaluation and Discussion

Ad hoc networks are different than the traditional networks in the sense that the routes are very dynamic and may change frequently for an application/session. A route can be determined which fulfils the QoS requirements of an application for the sake of a particular communication over a period of time. However, it is likely that in ad hoc networks this route becomes unavailable in the middle of communication. This is a very critical issue which we think can be addressed through the following two approaches.

Approach #1: For the sake of understanding, the route selected for communication on the basis of QoS requirements is termed as the "***primary route***". Now our first approach is to find an alternative route which fulfils the original QoS requirements as and when the primary route becomes unavailable. Let us call this alternative route as the "***alternate route***" for the sake of discussion. However, there is a risk of not finding an alternate route in the middle of communication. This risk may be unacceptable for certain mission critical applications like telemedicine and missile defense. This approach can be tuned further by negotiating with the application (beforehand) a less stringent set of QoS parameters when the primary route becomes unavailable. The risk seems less critical and can be hedged against by the application.

Approach #2: A second approach could be to identify the primary route and the alternate route before the communication begins. However, there is a disadvantage of this approach, i.e., potential wastage of the bandwidth. If two routes are reserved for one communication, it is not possible to assign the alternate to other QoS related traffic. It may be used for the best effort traffic but not for the QoS related traffic.

We need to do an evaluation both of these approaches in terms of efficiency of switching time, re-routing of traffic and optimized use of the bandwidth. Currently we are in the process of doing simulations to evaluate these two approaches. Based on the analysis of the obtained results, it is also possible that a combination of the two may be more feasible.

8. Future Work

Routes in ad hoc networks are very dynamic and may change frequently for an application during the session. Therefore another route is required to be determined. We intend to handle this issue for our future work in a way that:

i) Normally found route for the transmission of QoS requiring application is **Primary Route,** now we wish to find an **Alternative Route** as the primary route becomes unavailable due to the dynamical topology change.

ii) Second approach is to find **Primary** and **Alternative Routes** before the communication begins so that the delay can be controlled which takes time to find an alternative route.

Currently we are in the process of doing simulations to evaluate these two approaches. Based on the analysis of the obtained results, it is also possible that a combination of the two may be more feasible.

9. Summary and Conclusion

In this paper, we propose a model for providing Quality of Service (QoS) on multi hop ad hoc networks using bandwidth reservation. This architecture provides assurance of a particular service level to the users of the network by:

1. Allocating and reserving the required bandwidth, and,
2. Making sure that no user uses more bandwidth than its due share (reserved) by using policing, shaping and dropping.

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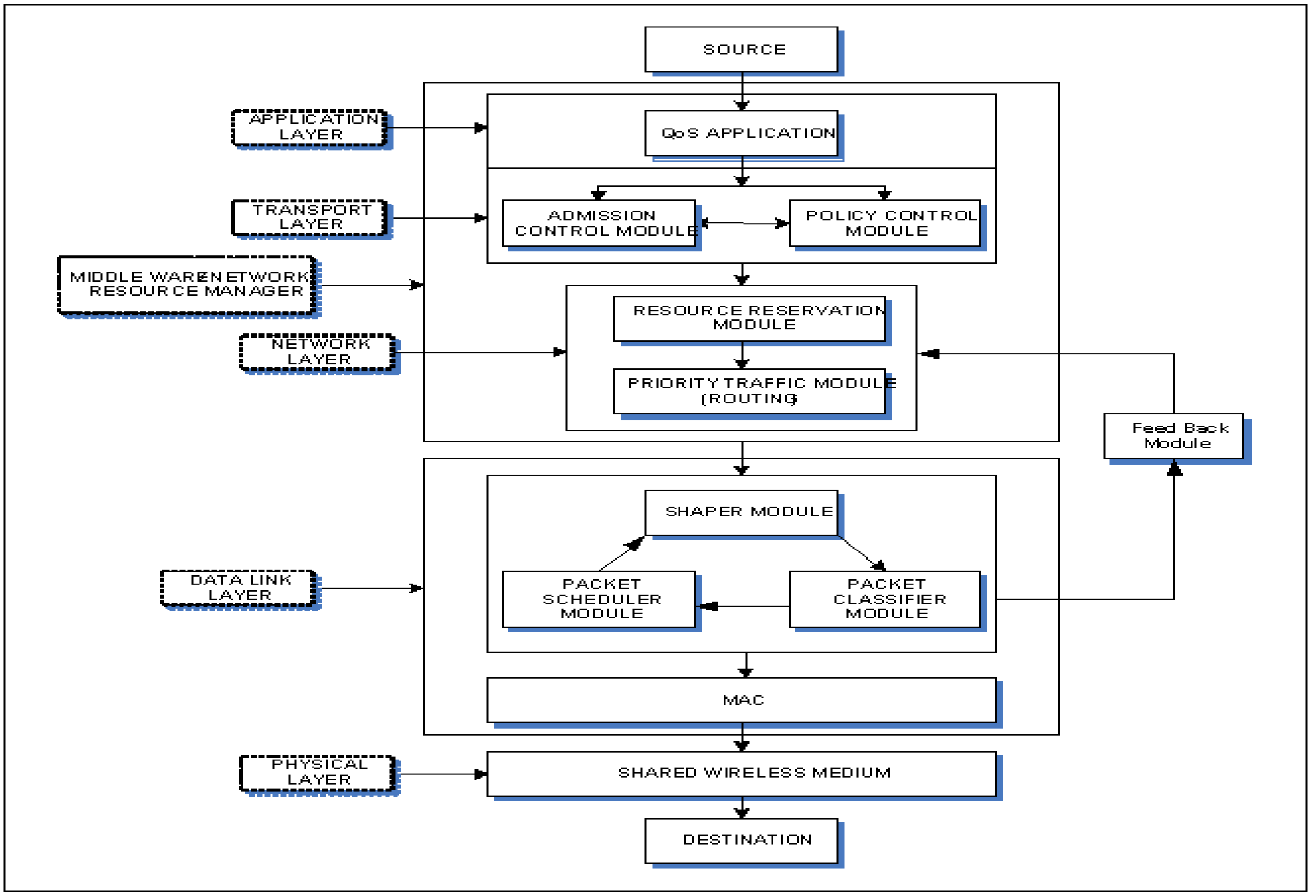

Fig. No. 3: QoS Model

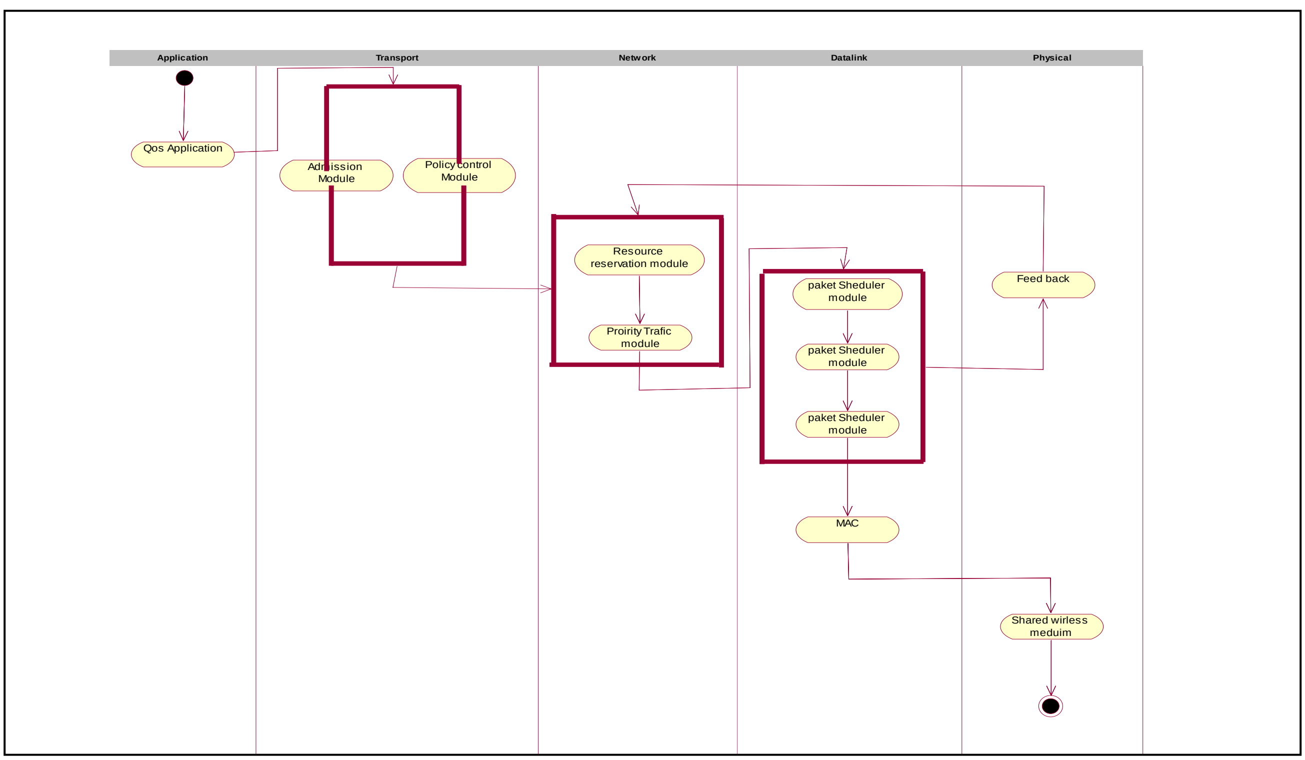

Fig.No.4: Activity Diagram for QoS Model Functions

1. ***receive*** request from the source,
2. ***check*** it by applying admission control criteria,
    if the required resources are available then
        accept request and enforce over all policy constraints for QoS
    else
        wait until resources become available,
        (request may also be rejected),
3. ***allocate/release***, resources according to the priority,
    set priorities as:
        High priority if traffic is Real Time
            (i.e., video, video conference)
        // ***Medium Priority*** if traffic is Non Real Time
            (i.e., web, audio, file transfer)
        // ***Low Priority*** if traffic is Best Effort
            (i.e., email, chat, remote access)
4. ***select*** the data packets according pre-agreed format and conditions of priority,
    if the packets are not according to the policy ***then***
        functionalities of shaper, classifier and scheduler modules will be performed automatically by the design up to an extent,
    else
        reject the packets and return back to the network middleware through feedback module,
5. functionalities of **MAC**
6. functionalities of **shared medium**

Fig.No.5: Algorithm for Real Time Traffic Flow in QoS Model

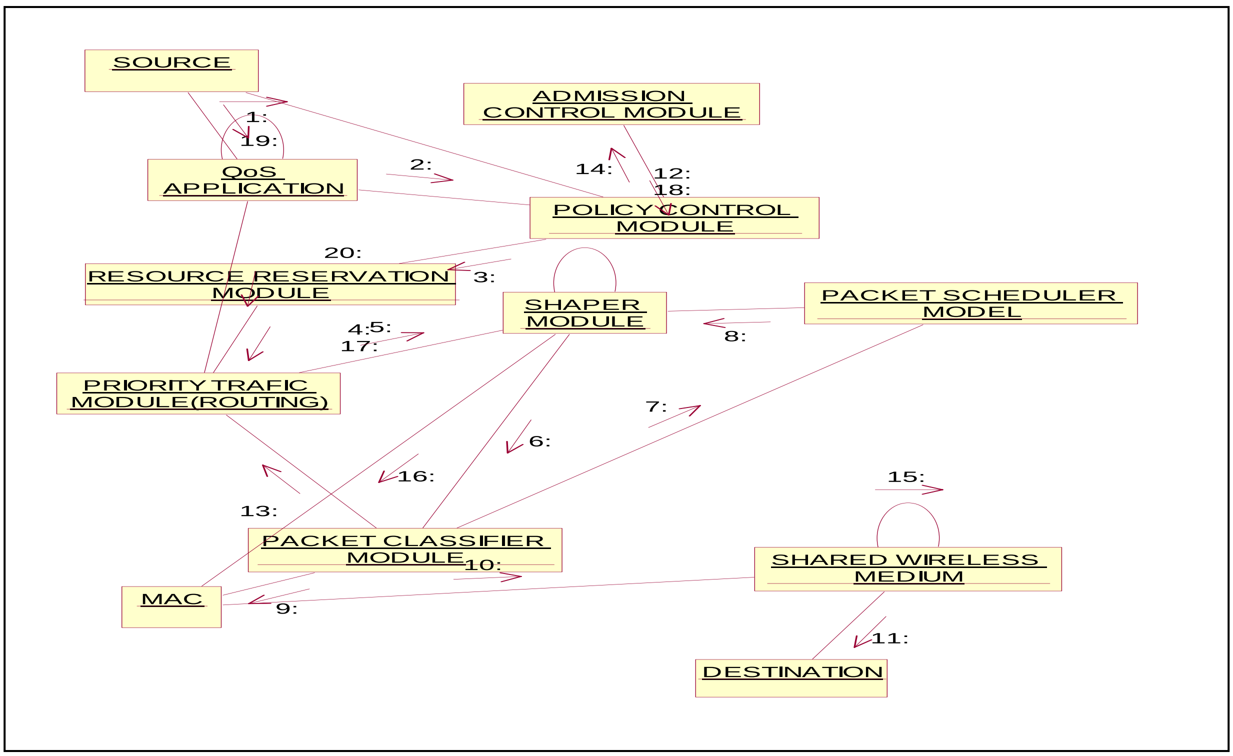

Fig.No.6: Collaborative Diagram for QoS Based Middleware Design

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