A Modeling Approach to achieve optimal Quality of Service for streaming media services over MANET

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Abstract - Mobile Ad hoc (MANET) wireless communication is a powerful technology which allows self organizing connectivity and network services with no preexisting infrastructure [4], [5]. It is very difficult to provide the required QoS in Ad hoc networks as they don’t follow any fixed topology. In this paper an analytical model for the mobile Ad hoc networks using Markov Decision Process (MDP) [4] is developed. MDP [3][4] model selects an optimal policy which is suitable for the current network conditions so as to provide the appropriate QoS to the service calls. The starting of a call session decides on the service quality.

This work focuses on identifying optimal Quality of Service alone which can be developed to provide the prioritized services and effective QoS to the streaming service calls. This research work aims at identifying an optimal route which provides minimal delay, minimal jitter and hence better reliability. Different cases studies have been discussed based on MDP architecture.

Index Terms : QoS on-demand, streaming services, service priority, Markov Decision Process

1 Introduction

QoS provisioning to streaming media applications in the presence of “bursty” wireless channel is the most challenging issue for the researchers in the design of wireless systems. The distributed nature of the Ad Hoc networks makes them more robust to systemic failures, easier to deploy and more flexible to reconfigure than infrastructure based networks. The motivation behind this work is to model a mathematical model which can be used as a tool for providing effective QoS to the user. The aim of this research work is (a) To frame a mathematical model for determining effective and optimal QoS using Markov Decision Process (MDP), (b) To design an agent based architectural model for MANET in improving QoS for Media Streaming applications, (c) To focus on real time case studies using MDP to achieve Optimal QoS.

The objective of this work is to provide prioritized and customized services to the “bursty” media applications. In this paper, using Markov Decision Process (MDP) model the required optimal QoS can be identified for differing media applications and network capacity. The function of MDP is to determine the optimal policy that will satisfy the current QoS of media applications. The Markovian property [4] states that the occurrence of a future state in a Markov process depends on the preceding state and mostly on the immediately preceding state. MDP helps in determining the optimal QoS for varying networks and applications. Hence based on the varying QoS parameters of MANET, optimal QoS service is provided to media applications.

2 Related Works

A MANET is an autonomous collection of mobile nodes that communicate over relatively differing bandwidth constrained wireless links. Since the nodes are mobile the network topology may change rapidly and unpredictably over time. MANETs often experience poor network services, since nodes move frequently and network is sparse, hence routing play an important role in providing Quality services.
2.1 Need for QoS
Adaptation of streaming communication applications in wireless and wired networks require consistent bandwidth for providing the guaranteed Quality of service (QoS). QoS refer to the capability of a network to provide better or optimal service to selected network traffic over various network technologies such as FR, ATM, IP or SONET which may use any or all of these underlying technologies. QoS algorithms should focus on effective use existing resources and applying the required level of service without reactively expanding or over provisioning their networks.

Network parameters such as required bandwidth, latency, packet loss, jitter, throughput support QoS in MANET, which is challenging than in a fixed and wireless access networks. It is difficult to support diverse applications with appropriate QoS in MANET because it has highly dynamic network in varying topology and traffic load conditions, less communication bandwidth and smaller processing power capacity than fixed networks [8]. Factors such as varying wireless link capacity, propagation path loss, fading multi-user interference, power expended and topological changes become very important issues in mobile ad-hoc networks. MANET requires efficient distributed algorithms to determine the network organization, link scheduling and routing.

2.2 MANET QoS models
The end applications requiring optimal QoS has to deal with complexity of directly dealing with underlying QoS provisioning services, environment to demand and manage the service qualities [6]. There are two types of QoS models proposed by IETF: [5] Integrated Service (IntServ) [10] and Differentiated Services (DiffServ) [10]. The IntServ model integrates resource reservation and traffic control mechanisms to support special handling of individual traffic flows. The DiffServ model uses traffic control to support special handling of aggregated traffic flows. In DiffServ, priority based treatment without reserving the resources will be done. [2] uses DiffServ model for providing necessary QoS for the end users.

In mobile ad-hoc networks QoS violation can happen due to excess delays during the handovers, packet losses or total denial of a service [1]. The requirement to transfer real time multimedia traffic along with voice and data traffic with varying properties of transmission over wireless Ad Hoc networks led to the need for the optimal QoS for applications [10].

2.3 Existing QoS architectures in MANET
To guarantee optimal QoS in MANET is very difficult than in most other type of networks because the wireless band width is shared among adjacent nodes and the network topology changes as the node moves. Link state routing approach makes available detailed information about the connectivity and topology of the network. It increases the chances that the node will generate a route that meets a specified set of constraints. OLSR is an optimization over the classical LSR protocol for the mobile Ad Hoc networks. It performs hop by hop routing i.e. each node uses it’s most recent information to route a packet. Routing protocol QOLS [3] considers multiple metrics of QoS such as bandwidth and delay and impact on the path computations has been observed. It restricts on delay time of packets, hence packet losses due to multiple interference of nodes is reduced. Its performance is better compared with OLSR.

QoSME (Quality of Service Management Environment) provides a common solution of end application management and guaranteed service [8]. The main system components of this architecture are QoSockets, QoS MIBs (Management Information Bases), SNMP (Simple Network Management Protocol) agents and APIs (Application Programming Interfaces). This architecture offers open solution for delivering QoS over network systems. The interfaces applications with appropriate QoS provisioning services and applications request their QoS in terms of QoS characterization. QoSME enables the applications to monitor real-time network performances, using SNMP agents. Actually QoSME builds a middleware between applications and the underlying resource providers, which employs current internet technologies of network transmission mechanisms, services and management. When an application assigns its QoS requirements, QoSME uses RAVP or ATM to reserve the resources for that application. When the resource reservation fails, QoSME returns a message to the application QUAL (Quality of Service Assurance Language).using this message and QoSMIB the application can know the current status of the available network resources and then adopt its QoS requirements and make a new request. In this QoSME, the main discussion is about its potentiality in providing the services for Internet applications.

A single server queuing system with a finite buffer and heterogeneous arrival streams has been considered [10]. The arrival process is a Poisson or Markov Modulated Poisson Process (MMPP) while service times are with general distributions. In this classical problem of queuing theory, the probability of buffer overflow and packet dropping probability are computed. It also considers multiple transmission rates depending upon the channel conditions, distance and transmitting power. Each mobile station transmits data at an appropriate transmission rate using a particular modulation scheme based on the perceived signal to noise ratio. The service provisioning is dynamically varied by selecting links that can use higher bandwidth modulation schemes. The main focus of this paper is integrated wireless channel modeling and data queuing analysis at the packet level to study the effect of physical layer link speed on high layer
network performance. Assured forwarding (AF) in DiffServ is used to provide differentiation service between traffic classes where the low priority class experiences higher loss rates and delays than the high priority class. Arrivals are modeled as a general batch Markov arrival process in which thresholds and packet dropping probabilities are selected so that real time and non real time traffic observe different QoS performance while considering the impact of varying the physical layer link speed in a realistic MANET environment.

In wireless Adhoc networks the maximum number of simultaneous transmissions supported by the network is also a function of the network density and of the radio range of the each node in the network. In [5], an analytical model has been developed for provisioning QoS in Ad Hoc networks. Transmission blocking probability is defined as the probability that a node is blocked from transmitting a packet. It has been derived as a function of the number of nodes and network density. The assumptions made are the network does not employ power control and each nodes transmission range is normalized to 1km. to verify their model they used two computer simulations. The first simulation used Monte Carlo simulation technique to confirm that the incremental number of blocked nodes in the state is a linear function of the state. The second simulation is carried out with OPNET to verify the Transmission Blocking Probability equation. The use of directional antennas for increasing average number of transmissions is also demonstrated.

3 Proposed Architecture

More multimedia data are being transmitted through wireless media. These applications may require diverse QoS. One of the major challenges in MANET is deployment of end-to-end quality of service mechanisms. In this paper, MDP based architecture (Fig-2) has been proposed which incorporates various metrics to identify the optimal route for transfer. Since the research work focuses on identifying optimal QoS using MDP, implementation work has not been focused. The complete implementation and test-bed analysis has been discussed in our earlier work [2].

Its focus is on identifying an integrated route discovery, bandwidth provisioning, resource identification, reservation and negotiation on required bandwidth. Fig-1 shows the basic stack architecture using MDP which can deliver optimal QoS. For providing optimal QoS, integrates (a) on-demand route discovery between the source and the destination, (b) signaling functions for resource reservation and maintenance and (c) identification of optimal QoS routing path. Due to the dynamic nature of the Ad Hoc network, the connection maintenance overhead (which includes violation detection, recovery and connection tear down of the old path) RSVP protocol [9] cannot be used.

3.1 MDP model approach

An N-state threshold based queuing system is considered. The traffic intensity level will be governed by the forward threshold vector \( F = (K_{t1}, K_{t2}, \ldots) \) and a reverse threshold vector \( R = (K_{r1}, K_{r2}, \ldots) \). The behavior of this system is as follows: if the packets arriving in the empty system at the rate of \( \lambda \) can serviced at the rate of \( \mu \) at first traffic intensity level. If the packets arriving in a system cross the threshold value \( K_t \) then it will enter into the next traffic intensity level. If the packets have been serviced and falls below \( K_r \), then the system will be forced to move into the earlier predicted traffic intensity level. Fig-3 shows the state transition diagram. N state queuing system is considered and M is the corresponding Markov process with state space \( M \).

\[ M = \{K, S, I\} \]

where \( K \) is the number of packets

\( S \) is the network condition or channel state

\( I \) is the level of traffic intensity

The channel state \( S \) will be having different parameters like number of active nodes, number of groups, routes available, and session time. Using these parameters we can estimate the available bandwidth in that state. By knowing traffic intensity level one can decide how many
applications can be run in that particular state at that instant. Formally the transition diagram of the above Markov model with \( N \) state spaces can be defined as follows:

\[
egin{align*}
(0,0) & \rightarrow (K_1,1,1) \text{ with rate } \lambda \\
(i,i) & \rightarrow (i+1,j,i+1) \text{ with rate } \lambda i \{ (i = K_i \text{ or } K) \land (i = 1) \\
(i,j) & \rightarrow (i+1,j,i+1) \text{ with rate } \lambda i \{ (i \neq K_i \text{ or } K) \lor (i \neq 1) \\
(i,i) & \rightarrow (i+1,j,i+1) \text{ with rate } |i-j|\mu | (|i-j| > 0) \\
(i,j) & \rightarrow (i-1,j,i-1) \text{ with rate } j,\mu i \\
(i,j) & \rightarrow (i-1,j,i+1) \text{ with rate } i,\mu j \\
(i,i) & \rightarrow (0,0,0) \text{ with rate } \mu 
\end{align*}
\]

Here \( \mu \) is the rate at which the traffic will be increasing. \( 1 \{ x \} \) is the indicator function i.e. its value is equal to 1 if the condition is true and its value is zero otherwise. Fig.3 shows the aggregated state transition diagram of the above Markov model.

Let \( P_{ij}^{(m)} \) be the \( m \) – step transition probability.

Let \( P_{ij}^{(m)} = \sum_k P_{ik}^{(m-k)} P_{kj}^{(k)} \)

Let \( \Pi_i^{(m)} \) be the unconditional probability of state \( j \) at the \( n \)th trial.

Let \( \Pi_i^{(m)} = \text{Pr} \{ X_n = j \} \) \( P_{im} = P_{im}^{(m)} \)

Let \( k = m-1; P_{im}^{(m)} = P_{i(m-1)} P_{jm}^{(m-1)} \)

Similarly, if we go on submitting \( m = m-2, m-3 \ldots \), we get \( P_{im}^{(m)} = P_{i(m-1)} P_{j(m-1)} \ldots P_{jm}^{(m-1)} \Pi_{jm}^{(m-1)} = \Pi_{jm}^{(m-1)} \ldots P_{jm}^{(1)} \Pi_{jm}^{(1)} \ldots P_{jm}^{(1)} \)

Where \( \Pi_{jm}^{(1)} \) is the initial state vector.

Let \( Q = P - I \) then, \( P_{im}^{(m)} = \Pi_{jm}^{(m)} = \Pi_{jm}^{(m-1)} = Q \), where \( P \) is always a stochastic matrix and \( Q \) has rows that sum to zero.

Let \( N \) be the number of states and let \( P_{ij}^{(m)} \) be the probability transition matrix.

Let \( D_{ij}^{(m)} \) be the delay matrix which determines the delay in each state, while let \( f(i) \) be the optimal expected delay of the system in a particular state \( i \).

Let \( M = \{ S_1, S_2, \ldots \} \) be the set of states and \( A = \{ a_1, a_2, \ldots \} \) be the set of actions. Also let \( k \) be the available policies i.e. each policy will generate a different action that changes the state of the system. The backward recursive equation relating \( f_n \) and \( f_{n+1} \) is

\[
f_n(i) = \min_j \{ \sum_{m=1}^{N} P_{ij}^{(m)} [D_{ij}^{(m)} + f_{n+1}(j)] \}, \quad n=1, 2, \ldots, N
\]

Let \( V_i^{(k)} = \sum_{j=1}^{N} P_{ij}^{(k)} D_{ij}^{(k)} \)

We have already mentioned that \( \dot{\alpha} \) \((<1) \) is the rate of increase in traffic intensity. Also \( f_{n+1}(i) = \min_j \{ V_i^{(k)} \} \) \( f_n(i) = \min_j \{ V_i^{(k)} + \dot{\alpha} \sum_{m=1}^{N} P_{ij}^{(k)} f_{n+1}(j) \} \), where \( n = 1, 2, \ldots, N-1 \). By using the above equations we can find the optimum policy that can provide an optimum QoS to the application at that instant.

### 3.2 Performance Analysis

To analyze the performance of QoS over MANET, various case studies have been considered. Conditions for policy manager can be assumed. Consider there are some applications which have to be serviced to provide the required level of QoS. Let the available bandwidth be 500Mbps, the threshold limit of bandwidth will be 480Mbps. The policies may be

<table>
<thead>
<tr>
<th>Policy</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Allocate all required resources</td>
</tr>
<tr>
<td>2</td>
<td>Allocate sufficient resources</td>
</tr>
<tr>
<td>3</td>
<td>Allocate insufficient resources</td>
</tr>
<tr>
<td>4</td>
<td>Do not allocate any resources</td>
</tr>
<tr>
<td>5</td>
<td>Reserve in hold resources</td>
</tr>
<tr>
<td>6</td>
<td>Release all resources and Exit</td>
</tr>
</tbody>
</table>

**Table-1: Policy-Action table**

**Case 1:** When there is application whose required bandwidth is 30Mbps and it is the first application. As there is available bandwidth is 500Mbps which is more than required enough, immediately policy 1 can be chosen and the application will be provided with total required bandwidth. This scenario is a normal scenario where there is minimal necessity of the agents.

**Case 2:** If there comes three more applications which is video conferencing calls in to the system, each requires a bandwidth of 120Mbps, already a call with 30Mbps is in way and remaining bandwidth will be 470Mbps. The required bandwidth for the three applications together is 360Mbps. So the applications may be serviced to the best level.

**Case 3:** If one more video conferencing application enters into the system with the requirement of 120Mbps, then required bandwidth for all the applications will cross the threshold limit. As video conferencing is very important and cannot be stopped, it should be given the highest priority and should be treated first. So all the video
conferencing calls will be given required bandwidth, which will be equal to 480Mbps (equal to threshold). The 30Mbps call can be put in to hold.

**Case 4:** When an application with requirement of 50Mbps enters into the system, then the total requirement for all the applications will cross maximum limit. Till now the video conferencing applications have given high priority. Now the new application is also having the same priority. Now the policy manager has to decide which policy to be implemented. The policy allocate degraded bandwidth can be implemented for all the equal priority applications and now the hold on call may be provided the service.

**Case 5:** If three more applications voice call, SMS, e-mail which requires bandwidth of 30, 20, 10 enters into the system then what should be the action to be taken? Already the system is running under degraded service. Now the SMS, e-mails calls will be accepted and they can be serviced after by store and forward mechanism. But the voice call will be completely rejected as the system cannot provide the service. This will be decided by the policy manager.

### 4 Summary

In this paper, agent based QoS architecture has been developed which provides optimal QoS to the stohastic network applications such as Video / Audio Conference, Audio/ Video Call, Streaming Video transfer, Message transfer, Mail. Policy manager is trained using MDP. MDP selects the optimal policy which is suitable to the current environment. The different scenarios presented will clearly show the working of in the MANET networks. The work will be extended to frame different agent modules and their functionality in the real time environment.

#### 4.1 Future Work

This agent based model should be implemented in the real time environment using tools such as Aglets, JADE. Real time simulation test bed requires multiple WiFi enabled mobile nodes termed as MANET to communicate and inter cooperate with agents to provide an optimal QoS.

### 5 References


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