A Distributed Resource Admission Control Mechanism Supporting Multicast and Heterogeneous Receivers for MANETs

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Abstract. Resource admission control is widely introduced to control the network resources, schedule the resources and admit new services. Resource reservation protocol (RSVP) is a transport layer protocol designed to reserve resource across a network for an integrated services internet. RSVP makes an appointment for each flow and the information of status grows fast with the increase of flow number, it isn't suitable for Ad Hoc networks because the cost of connection maintenance is more expensive than establishment. In this paper, we introduce a distributed resource admission control mechanism for Ad Hoc networks (DRACM), which can adapt to dynamic changes in mobile Ad Hoc network by close to call or packet transmission time granularity. DRACM responses rapidly to re-routing, can re-build a resource reservation in minimal service degradation or least service interruption. Meanwhile, we adopt client-oriented control mechanism, can also support multicast and meet the heterogeneity of receivers.

Keywords: MANETs, resource admission control, multicast, heterogeneity.

1 Introduction

With the wide use of Internet technology, mobile communication technology and multimedia technology, mobile Ad Hoc network has great development recent years, and the requirements to transmit different types of services are increasing. Different types of services ranging from real-time multimedia services to data-transfer service to a fixed or mobile user are expected to be supported. For real-time applications, qualities of which are sensitive, it may cause instability while transmitting in mobile situation, one common idea to solve this problem is to use QoS guarantee mechanism.

Quality of service is the ability to provide different priorities to different applications, users, or data flows, or to guarantee a certain level of performance to a data flow. Quality of service guarantees are important if the network capacity is insufficient, especially for real-time streaming multimedia applications because they

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often require fixed bit rate and are delay sensitive. QoS guarantees are important in MANETs because the limitation of resource and dynamic changes of network topology.

Lajos Hanzo II. and Rahim Tafazolli propose that One of the most crucial components of a system for providing QoS assurances is admission control [1]. The purpose of admission control mechanism is to estimate the state of the network's resources and thereby to decide which application data sessions can be admitted without promising more resources than are available and thus violating previously made guarantees.

Mahmoud Pirhadi describes a resource and admission control architecture and QoS signaling scenarios in Next Generation Networks, he divided the QoS resource control process into three logical states [2]:

- Authorization: The QoS resource should be authorized for the new services first based on some rules.
- Reservation: The QoS resource should be reserved based on the authorized resource and resource availability.
- Commitment: The QoS resource is committed for the requested media flows when the admit decision is made.

Mobile Ad Hoc network has its own characteristics such as dynamic network topology, mobility and limited resource. So resource admission control for Ad Hoc networks should consider these factors, which can adapt to the network features.

In this paper, we proposed an INSIGNIA [3] protocol-based distributed resource admission control mechanism for Ad Hoc networks. INSIGNIA is an in-band signaling system for supporting quality of service in Ad Hoc networks. DRACM is based on INSIGNIA to send the resource admission control message in data packet header. We adopt the DiffServ approach to mark different types of services; only real-time services need resource reservation while best effort services don't. Meantime, we distribute the QoS calculation and resource control across multiple destination nodes; intermediate nodes only need simple operation and adjustments, so it can improve the efficiency of resource admission and not introduce too much cost in Ad Hoc networks.

The rest of this paper is organized as follows. Section 2 states related works about resource admission control recent years. Section 3 covers the design and trades off for our mechanism. Section 4 describes detail steps and multicast scenario of DRACM. Section 5 shows the analysis and discussion about DRACM. Section 6 shows the simulation results. And Finally, Section 7 concludes the whole paper as well as future work.

2 Related Works

The issue of QoS guarantee in MANETs has received a lot of attention lately due to its significance in terms of enabling the delivery of real-time services over these networks [4]. And various types of resource admission control mechanisms are proposed to achieve the issue.

Admission control mechanism is divided into stateless schemes and stateful ones. As a stateless scheme, SWAN [5] uses a probe packet to test a pre-discovered route when a new data session requires admission. P. A. Chaparro and J. Alcober [6] proposed a QoS framework supporting scalable video streaming in MANETs. They use a periodic probing process to measure the available bandwidth and the end-to-end delay on the path. The lack of state information storage at intermediate nodes means that they save memory and their operation can be less complex, but the lack of reservations at intermediate nodes reduces capabilities due to the lack of state information [1].

Stateful schemes mean intermediate nodes should store state information. INIGSIA [3] introduce a flexible in-band signaling system that supports fast reservation, restoration and adaptation. PDAC [7] builds upon the flow-state extensions of the latest version of DSR and each node only forwards the admission request if it has sufficient available capacity. Stateful schemes can store session state-related information in intermediate nodes so they can make admission decision which can improve the network response efficiency. But they may bring extra cost and methods of storing and refreshing service and nodes state.

In MANETs, the network topology and nodes state changes time to time, so we should trade off the resource admission control efficiency and network cost, as well as in multicast situation.

3 Design and Trades Off

3.1 Dynamic Resource Management in Ad Hoc Networks

The purpose of resource management is trying to improve resource utilization, and to the greatest degree of QoS to meet user expectations. In MANETs, it's better to adopt dynamic resource management mechanism to ensure efficient allocation of resource than static mechanism. The goal of dynamic resource allocation is to accept more services and ensure the traffic flow smoothly adapt to resource changes.

We allow resource reservation request to specify a range instead of a fixed value to deal with the problem that dynamic network characteristics cause. This QoS range is beneficial to the separation of routing and QoS maintenance, if the network needs to calculate a new routing due to the changes in network topology, the use of QoS range can increase the probability of routes maintenance within the scope of request rather than a fixed value. Dynamic resource management can only provide soft QoS guarantees that if route fails, re-routing is needed and QoSmin~QoSmax can dynamically adjusts to changes in network resources. A principle based on dynamic adaptive QoS management process is showed in Fig. 1.

When a new request for resource arrives, the network should consult whether it has enough resource to ensure the QoS that service requirements. If so, nodes reserve and allocate proper resource for the service; otherwise, the service would wait until there is enough available resource. After that, the service begins to transmit data in an appropriate flow rate. The whole network needs some schemes to monitor available resource to improve the efficiency of resource management.

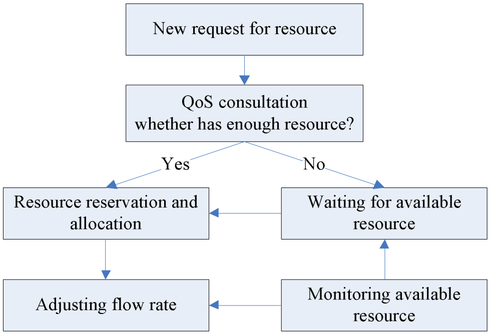

Fig. 1. Dynamic Adaptive QoS Management Based on Resource Admission Control

3.2 Distributed Resource Admission Control in DRACM

There are various QoS mechanisms so far to ensure service quality in networks. Early work used the "IntServ" philosophy of reserving network resource in which applications use the Resource Reservation Protocol (RSVP) to request and reserve resource through a network. But in this model, core routers would be required to accept, maintain, and tear down thousands or more reservations, so this approach would not scale with the growth of the Internet and the cost of network is huge.

The second and currently accepted approach is "DiffServ" or differentiated services. In this model, packets are marked according to the type of service they need. In response to these markings, routers and switches use various queuing strategies to tailor performance to requirements. The biggest advantage of DiffServ is scalability.

In order to distribute resource admission control cost in Ad Hoc networks, we adopt DiffServ approach. We distribute the QoS calculation and resource control across multiple destination nodes; intermediate nodes only need simple operation, so it can improve the efficiency of resource admission and not introduce too much cost in Ad Hoc networks.

3.3 Soft-State Adapting to Network Topology Changes

Another important factor is whether to choose soft-state or hard-state in our mechanism. Connection-oriented hard state isn't feasible in Ad Hoc network because it cannot adapt to dynamic changes of topology and resources. So we choose soft-state mechanism to adapt to the instability of wireless links, the random mobility of nodes and dynamic time that each session lasts. Specially, we compare soft-state and hard-state as follows:

- Soft-state needs a timer while hard-state needn't;
- Soft-states can be automatically removed while hard-state can only be removed explicitly;
- When there is error or missing packets in the network, soft-state can adopt proper recovery action, while hard-state may stay in an unexpected state;
- Soft-state can adapt to the requirements of mobile networks but may introduce overhead because of periodic refreshment.

Soft-state in INSIGNIA in-band signaling mechanism have these characteristics, it refreshes only when creating new data packets and adapts to network topology changes at a low cost. In our design, we change the frequency of state refresh and resource request based on network situation which will be discussed in Section 5.

3.4 DRACM Architecture

The architecture of DRACM is showed in Fig. 2. Reference to [2], we divide DRACM architecture into three main parts:

- SCF (Service Control Functions) is used for service registration. When a new service arrives, it should register to the SCF first with its basic info, such as the needed bandwidth and other QoS requirements;
- RACF (Resource and Admission Control Functions) is the main function in this architecture. It consists of decision unit, QoS calculation unit, database and timer. Admission control decision unit is used to make decision that whether to admit the new service. QoS calculation unit is different between intermediate nodes and destination nodes, intermediate nodes only need to calculate bandwidth, but destination nodes need to calculate end-to-end QoS and compare them with user requirements. Database is used to store bandwidth information. Timer is important to calculate delay and control admission control status.
- TF (Transmit Function) is used to transmit data packets. Source node uses adaptive traffic controller to change data transition parameter as required. If route fails during transition, QoS routing unit would re-route immediately to adapt to dynamic changes in the network.

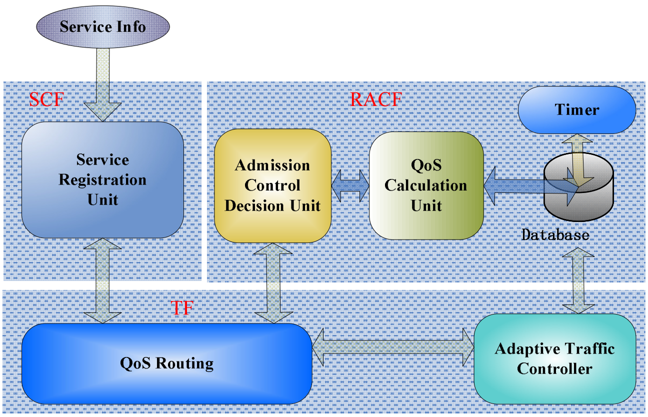

Fig. 2. DRACM Architecture

4 Resource Admission Control Mechanism and Scenarios

DRACM puts signaling message in the optional segment of IP header as an option. Table 1 shows the message format:

Table 1. DRACM Message Format

REQ/ RES	TOS	Max/ Min	Maxband	Minband	Metric		
					/	/	/

The REQ/RES segment indicates whether the message is a resource reservation request(REQ) message sent by the source node or a resource reservation response(RES) message sent by the destination node; TOS segment indicates the type of current service, BE(Best Effort) means the service doesn't need bandwidth authoritarian or reservation, RT(Real-Time) indicates that bandwidth calculation, authoritarian and reservation are required; Maxband and Minband are used to represent the bandwidth range that traffic flow needs, as we mentioned in Section III (A), we use a QoS range to adapt to dynamic resource changes inMANETs; Metric is used to record the ID of traffic and route information, such as bottleneck bandwidth, bottleneck node information and destination node information. Metric is an important segment for admission control along the whole multicast tree.

4.1 Source Node Sends a REQ Message

When a new service arrives, it should register to SCF of source node with its basic info, and then the source node will send a reservation request message along the multicast tree. For example, the reservation request message for a video service which requires a range of 50M~100M bandwidth is showed in Table 2, 1 presents the ID of video service, 12:00 presents the new service arrives at 12:00.

Table 2. Resource Reservation Request Message

REQ	RT	Max	100	50	Metric		
					1 12:00	/	/

4.2 Intermediate Node Receives the REQ Message

Intermediate node parses the first segment of REQ message as soon as receives it, REQ means it's a REQ message from the source node, RT means it's a real-time service so the node should calculate its bandwidth according to (1):

$$B_a = B_t - \sum_{i=1}^{n} B_{u_i} \tag{1}$$

B_t is the total bandwidth of the link, B_{u_i} represents the bandwidth that has been authorized or reserved, or has been occupied for data transmitting. All the bandwidth information should be stored in each node's database as Table 3 lists.

Table 3. Bandwidth Information Stored in Database

ID	Bandwidth	State	Info
2	20	Reserved	10.1.1.3
2	10	Reserved	10.1.1.5
3	10	Authorized	10.1.1.7
3	10	Authorized	10.1.1.9
4	30	Transmit	10.1.1.6

After calculating the available bandwidth, the intermediate node will do the following judgments:

If B_a > 100M, it will forward the message along the multicast tree without any change, then authorize 100M bandwidth to the appropriate service(service ID is 1) and insert a record in the database. Within a specified time (eg 10s), other service cannot occupy or reserve this part of bandwidth;

If B_a < 50M, which means the node cannot meet the minimum requirements of the service, so the node will prune and send a refuse message to the source, the refuse message should contain the node's info;

If 50M< B_a < 100M, such as 80M, the node will check the "Min/Max" segment of REQ message. If the segment is "Max" which means it is the first bottleneck node, the node would replace "Max" by "Min", and add the node's information in the Point Info segment; Otherwise, the node would check the Metric segment of REQ message and compare its bandwidth with bottleneck bandwidth stored, it would update the REQ message by the smaller value and then authorize appropriate bandwidth to the service and insert a record in the database.

4.3 Destination Node Receives the REQ Message and Sends a RES Message

The REQ message information is continuously updated along the multicast tree until the destination node receives it. The whole link can meet the minimum require of the service if the destination node could receive the packet.

The destination node parses the REQ message to get the whole information of the route, including the bottleneck node, and the bottleneck bandwidth. The destination node calculates the end-to-end QoS(delay, jitter, packet loss rate etc), then compares it with user's requirements, decides whether to accept or refuse the service. If accept, the destination node would send a RES message to notify the source node to accept the service and inform the intermediate nodes to reserve proper bandwidth for the service. Otherwise, the destination node would prune and send a refuse message to the source with its information. A RES message is showed in Table 4. Both REQ and RES message obey the same format, but the destination node should add its node info in the Metric segment, which would be used for intermediate node in multicast situation.

Table 4. Resource Reservation Response Message

					Metric		
RES	RT	Min	100	50	1 12:00	80	DES: 10.1.1.1 Node: 10.1.1.5

4.4 Intermediate Node Receives the RES Message

Intermediate node parses the message and understands this is a RES message from destination node 10.1.1.1, and then the node resolves the Metric segment in the message, knows it should reserve 80M bandwidth for service 1. Next, the node queries the service ID 1 in its database and checks if the service has been authorized. If so, the node changes the status "Authorized" to "Reserved", sets the Bandwidth value to 80; otherwise, the node inserts a new record of reserving 80M bandwidth for flow 1.

4.5 Source Node Receives the RES Message

The RES message is forwarded from destination node to the source node along the multicast tree. Each node along the route reserves proper bandwidth for the service. When the source node receives the message, it will use the funnel and bucket mechanism to send the data along the multicast tree according to the bottleneck bandwidth, which is showed in Fig. 2 as Adaptive Traffic Controller.

4.6 DRACM Mechanism for Multicast Situation

As in multicast situation, an intermediate node may accept a REQ message but should forward to several nodes, or receive several RES messages from different destinations. In this case, the intermediate node should insert several records in the database as Table 3 shows for service 2 and 3. If the node forward a REQ message to two nodes, it should divide its bandwidth by two and insert two authorized records in database.

But for the source node, it should wait until receiving all messages from the destinations except those that have been pruned. if it receives several RES message from different destinations, it gives judgments that it should send the data along the multicast tree according to the smallest bandwidth and notice all the nodes along the multi tree then they can update the bandwidth info in the database.

5 Analysis and Discussion

5.1 Admission Control Adapting to Network Changes

All the REQ and RES messages are formatted in a certain format, and the frequency of REQ message should adapt to network changes based on the RES message source node receives, that means, if the source node receives a lot of RES messages, which indicates there is little pruning behavior and the status of network is stable so the frequency of RES message can be low, otherwise, if there is a lot of pruning behavior and little RES message is received which means the network is very unstable, the source should speed up the frequency of sending RES messages.

5.2 The States Transition Diagram of Nodes

Totally, each intermediate node has four states as shown in Fig. 3:

- Idle. If there is no traffic flow going through the node, we mark it as idle.
- Authorization. If the node receives an REQ message and can meet the minimum bandwidth of the service requirements, it will authorize proper bandwidth to the service and start the timer, the bandwidth authorized cannot be occupied by other service until timeout;
- Reservation. If the node receives a RES message and parses the bottleneck bandwidth along the route, it will change to reservation state; the band reserved cannot be occupied by other services unless being released by the service or timeout.
- Transition. This state indicates that a new service is accepted and new connection is built, the network begins to transmit data. When data transition is finished, the node returns to idle state.

5.3 DRACM Used for Heterogeneous Receivers

In our mechanism, the destination node receives RES message and makes decision for admission control according to the routing QoS calculated and its own demands. In multicast situation, different destinations have different requirements, so this client-oriented control mechanism can support multicast and meet the heterogeneity of receivers.

DRACM distributes the QoS calculation and resource control across multiple destination nodes; intermediate nodes only need simple operation and adjustments, so it can improve the efficiency of resource admission and would not introduce too much cost in Ad Hoc networks.

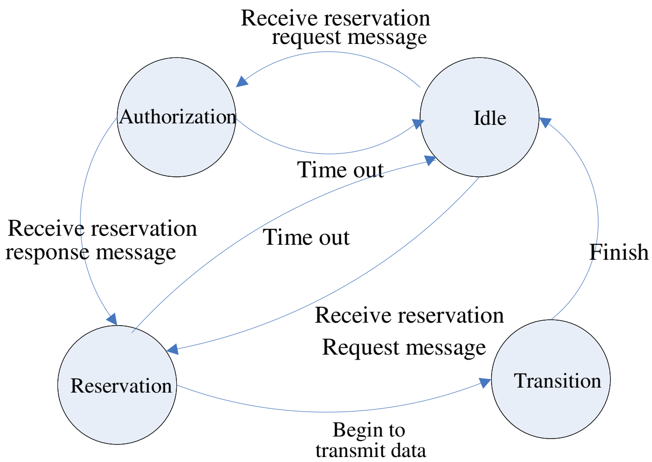

Fig. 3. States Transition Diagram of Intermediate Nodes

6 Simulation Results

We simulated DRACM on OPNET and the simulation parameters are showed in Table 5. We totally deployed 60 nodes in an area of 1000m * 1000m, where the source nodes and destination nodes are selected randomly. We both simulated none admission control scenario and DRACM scenario, collected four kinds of static including packets sent, packets received, end-to-end delay and jitter, and then calculated the results as Table 6 shows.

From the results, we can draw the conclusion that DRACM has brought good effects in network condition. As some of the services are refused by DRACM, the network can offer good QoS for the accepted services and stay in a good condition. As Table 6 shows, packet delay, jitter and packet drop ratio are reduced by 21.52%, 51.76% and 24.15%, and the network resources are utilized reasonably.

Table 5. Simulation Parameters

Simulation scenario	1000m * 1000m	**Packets interval**	0.1 s
Nodes number	60	**Packets length**	1000 bits
Type of service	Video Conference	**Simulation time**	200 s
Node speed	5m/s	**Transport layer protocol**	UDP

Table 6. Simulation Results

/	No Admission Control	DRACM	Reduction
Delay	0.0610332	0.0478973	21.52%
Jitter	0.0923473	0.0445499	51.76%
Packet Drop Ratio	10.4322%	7.9128%	24.15%

7 Conclusion

Resource admission control is widely used for resource utilization and can maintain good QoS for services as user expected. In this paper, we introduce DRACM, a distributed resource admission control, which can adapt efficiently to topology changes in MANETs. The mechanism distributes the QoS calculation and resource control across multiple destination nodes as well as the control decision. Meantime, intermediate nodes only need to do some simple actions with message and bandwidth management. As the first stage of our research, DRACM is a mechanism to support multicast and destination heterogeneity, the frequency of RES messages can adapt to the stability of network. It's also applicable in other types of wireless networks.

Our simulation results show that DRACM can bring great effects in network condition. In future, we will search for optimal methods to estimate and calculate bandwidth more accurately, to support DRACM.

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