Quality of Service Provisioning by Integrated and Differentiated Services

Ashutosh Punj
Computer Science and Engineering
University of Texas at Arlington
axp6404@omega.uta.edu

ABSTRACT

The Internet protocol in its original form provides only the best effort service to its users. The best effort service attempts to provide the best possible service however it does not make any guarantee regarding the quality of service parameters such as Latency, Bandwidth, Utilization and Packet loss. The best effort service does not support the real time applications because of varying queuing delays and congestion losses associated with it. Also due to lack of provision for sharing the bandwidth, the IP is not able to provide heterogeneous services to its users. The Integrated and Differentiated Services are two architectures recommended by the IETF to remove the above-mentioned limitations of the IP network.

Index Terms: Quality of Service, Service Models, Integrated Services, Differentiated Service, RSVP.

1. Introduction:

1.1 Quality of Service: Quality of service is the management of the bandwidth available over a network such that applications can have desired bandwidth and delivery requirements. It can also be stated as a service quality, a user can expect from a given service. The user can express the desired service in terms of throughput, packet loss, jitter, latency or in terms of any other network parameters [5], [7].

A network provides guaranteed service to its users by:
- Supporting dedicated bandwidth.
- Improving loss characteristics.
- Avoiding and managing network congestion.
- Shaping network congestion.
- Setting traffic priorities across the network:

1.2 Service Models: Service models are the architectures designed by different organizations for providing end-to-end quality of service to its users. Each architecture is characterized by its signal flow, type of service which it provides, service guarantees, type of connection (connection oriented/connection-less) and similar other parameters. Examples of some of the architectures are IP network, integrated service network, differentiated service network, ATM, Frame-relay etc. In this paper I am going to concentrate on the integrated services and differentiated services architectures [11].

The rest of the paper is organized as follow: in Section 2 the background of the topic is presented, Section 3 presents the integrated service model, Section 4 gives a detailed idea about the differentiated service model, Section 5 presents integrated and differentiated service models for the wireless networks, Section 6 gives an idea about the current research in the field of integrated and differentiated service models, Section 7 presents research opportunities and Section 8 will provide discussion & conclusion of the paper.

2. Background:

2.1 Various Service Models:

All of the available service models can be categorized into one of the following categories:

1. Relative Priority Marking.
2. Service Marking.
3. Label Switching.
4. Integrated Services.
5. Differentiated Services.

This section will give a brief idea about the e first three categories while the other two are explained in the following sections.

1. Relative Priority Marking: In this category of service models, the host selects relative priority (discard priority, delay priority etc) for the packets and the network takes care to forward the packets according to the forwarding behavior associated with the chosen priority. Examples of this category are Ipv4 precedence marking, token ring priority and the default interpretation of ip traffic classes [12].

2. Service Marking: In this model each packet is marked with "type of service" tag, which may include minimized delay, maximized throughput, minimized cost or maximized reliability. Network nodes will select forwarding routes so as to satisfy the "type of service need" need of the flow. Ipv4 TOS is an example of this model [11].

3. Label Switching: In label switching, the nodes keep a track of all the received packets. When the first packet of a flow is received then the out going path on which the packet was forwarded is stored in a table. A label is associated with that flow and the sender(s) of that flow are told to attach the label with all of their packets. Now all the incoming packets are checked for that label. If some match is found out then the packet is forwarded on the pre-determined link. In this scheme, as compared to IP network, the number of comparisons required for determining the forwarding route for a packet is very less. While in the IP network the number of comparisons is equal to the number of ip addresses in the routing table, the number of comparisons in the label switching is equal to the number of flows. In this service model, resources reservation for the flows can take place at the nodes. MPLS and ATM are two examples of this scheme [13].

2.1 Motivations for Developing The Integrated and The Differentiated Service Models:

The Internet protocol in its original form provides only the best effort service to its users. In best effort service, no guarantee is provided and the network delivers the best possible quality. The best effort service does not support the real time applications because of varying queuing delays and congestion losses associated with it. As new applications are emerging with varying requirements, support for heterogeneous services over the Internet is realized. But due to lack of provision for sharing the bandwidth on a particular link among different traffic classes, the IP is not able to provide heterogeneous services to its users. For removing the above-mentioned drawbacks of the IP network, the IETF has come up with two service models: Integrated Services Model and Differentiated Service Model [1], [2], [4].

3 The Integrated Service (IntServ) Model[1]:

The IntServ model is an enhancement over the current IP network. The IntServ architecture is basically designed for multicast transmission of data packets but it can also be used for unicast transmission. While the IP network stores the flow states only in the end systems, the IntServ intends to store the flow states in the core routers as well. The main design principle of the IntServ model is that guaranteed service can only be provided if the resources are reserved in advance. By guaranteed service, the IntServ implies a bounded and a predictable service. The IntServ proposes that before actually using the resources required by a service, they have to be explicitly reserved in all the routers on the route between the two host machines. This requires the core routers to store the flow states. This in turn requires a major change in the design of the core IP routers. Current IP routers are not designed for storing flow states but they have to be designed to do so. The IntServ model has few requirements. For example assuming that the bandwidth over any link is limited, method has to be provided to ensure that a new flow is admitted into the network only if there are sufficient resources over the links. The other major requirement of the IS model is that the hosts should be able to tell its resource requirements to the network. All of these requirements and other issues related with the IS are explained in the next section.

3.1 Service Classes:

The IntServ has the following service classes:

1. Best effort service: It is characterized by absence of QoS specifications and the network provides the best possible quality.
2. Guaranteed service: This service class provides guaranteed bandwidth, firm end to end delay bounds and no queuing loss for the flows. This class has a wide range of services i.e. the users can express their service requirements in terms of network bandwidth, throughput, delay, jitter etc.
3. Controlled load service: This service class ensures that the service provided to the users will be as close as possible to the best effort service provided in a lightly loaded system.

3.2 Building blocks:

The IntServ architecture has the following four main components:

1. Packet classifier
2. Packet scheduler.
3. Admission control block.
4. Resource reservation setup protocol (RSVP).

3.2.1 Packet classifier

In the IntServ model, all the packets belonging to a flow are identified by some combination of packet headers. The combination can be source-destination IP addresses or source-destination IP addresses plus port numbers or some other similar combinations. A flow is a stream of datagrams that results from a single user activity and every flow is characterized by the quality of service parameters specified by the users. Once routers have received the packets, the packet classifier reads the packet headers to determine the class to which the packets belong. A class may correspond to a broad category of flows or a single flow. The backbone router may choose to map several flows to a single class while the peripheral routers may choose to map every flow to a unique class. This enables the core routers to limit the size of their routing tables.

3.2.2 Packet scheduler

After the classifier has classified a packet, the packet scheduler puts the packet at some appropriate slot in the output queue. The slot is decided by studying the quality of service needs of the flow corresponding to the packet.

3.2.3 Admission Control

In order to determine whether a host can be provided the requested QoS without impacting earlier promises, admission control algorithms is used. For making this decision the router/host must have information about the currently allocated resources and the complete resource bank. This information should be gathered in a dynamic manner.

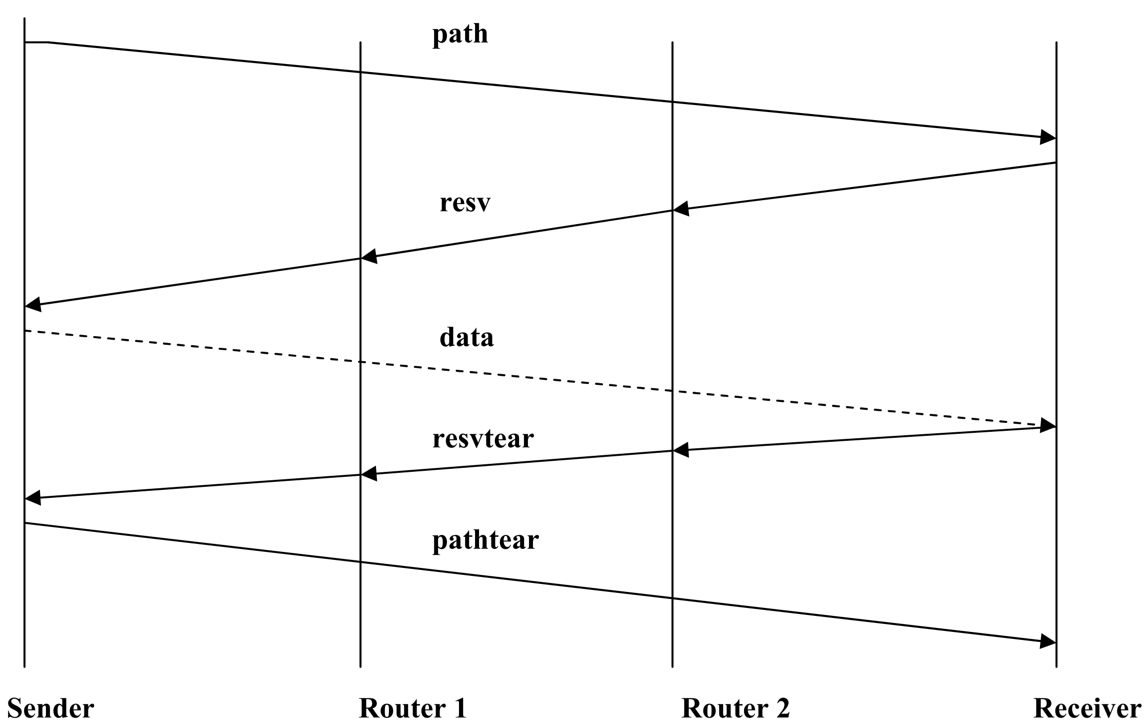
3.2.4. Resource reservation setup protocol [2]:

The RSVP is a signaling mechanism used for carrying the QoS parameters from the sender to the receiver. The QoS parameters are used to make resource reservations along the path. The RSVP is a receiver-initiated protocol.

RSVP works in the following manner:

a. The sender of an application sends PATH message containing the traffic specifications to the receiver(s) of the application that will use this reservation.
b. The receiver receives the PATH message and sends RESV message to the sender specifying its flow requirements.
c. As the RESV message flows back to the sender, reservations are made at very node along the way. If a node on the path is not able to support the requested resources then that request is blocked.
d. At every router/host along the way, path and reservation states are maintained for every application session.
e. The end hosts periodically send PATH and RESV messages to refresh the states.

The flow of messages and data in RSVP is diagrammatically represented below:



3.2.4.1 Flow specs and Filter Specs:

RSVP uses flow specs to let the users convey their resource requirements to the IS architecture. The filter spec is used by the users to specify the packets (within the same flow), which will be enjoying the reserved resources. Users can use the filter spec to prioritize the packets within the same flow. In case the flow is admitted by the admission control, the flow control is used to parameterize a resource class in the packet scheduler. The packet classifier will use the filter spec to map the packets to their corresponding flows.

3.2.4.2 Reservation Styles:

In a network, packets from different sources may be destined for the same destination. The destination can be a single IP address or an address of a multicast group. Reservation styles are used by RSVP to determine how the resources reserved for a host (which is acting as a receiver) are to be divided among different senders. A wildcard reservation style uses filter spec that is not source specific. It means that all packets destined for the same destination may use all of the reserved resources. The reservation style can choose a filter spec that is source specific and such that only the packets corresponding to specified sources will enjoy the reserved resources. The sources that will be enjoying the reserved resources can be either stated at the time of submission of the flow request or can be stated dynamically.

3.2.4.3 Receiver initiation

The IntServ is a receiver initiated service model. The reason for it being a receiver-initiated model is that in a heterogeneous network, different hosts will be having different receiving capabilities and in this situation only the receivers can tell their exact receiving capacity.

3.2.4.4 Routing issues in RSVP:

a. Adapt to a router failure: In a IS network if some route fails, then adaptive routing of the network will find an alternate route. The periodic refresh message of RSVP will automatically request a reservation along the new path. The reservation will fail in case of non-availability of resources along the new path.
b. Problem of timeliness: Due to large overhead associated with the transmission of refresh messages, the frequency of their transmission is limited. The low frequency of transmission of refresh messages may cause a significant time gap between the breaking down of a route and finding a new route. It can be improved by replacing the global refresh messages (which goes from one end host to the other end host) by local repair mechanism. The local repair mechanism uses the route table information of the routers, which are located close to the broken link.
c. Adapt to route changes (without failure): In some cases the network can change the route even in case of non-failure of some route. This may cause degradation of the quality of service in case the admission test fails on the new route. To avoid this problem, a mechanism called 'route pinning' can be used. In this mechanism the routes associated with reserved resources are pinned. The routing protocol will keep on using the pined routes until they are in a working condition.

3.3 Advantages of Integrated Service Architecture

a. Provides guaranteed quality of service: Due to its resource reservation model, the IS model is able to provide guaranteed services to its users.
b. Supports a wide range of services.

c. In the form of R.S.V.P, the I.S model gives a way to manage the bandwidth over the Internet. It provides a way to support heterogeneous services over the Internet.

3.4 Disadvantages of Integrated Service Architecture

a. The IntServ Architecture is not scalable: This is because the routers/hosts are required to store the flow states. Assuming that the routers have limited memory, the flow states they can store will be a finite number. So the IntServ architecture is not scalable.

b. The end hosts/routers need to be IntServ aware.

4. The Differentiated Service Model (DiffServ) [3], [4]:

DiffServ is a service model recommended by the *IETF.* The main objective of this model is to obtain service differentiation and network scalability. In this model the DS field of the Ipv4/Ipv6 header is used to mark the flows. DS field is the TOS octet in Ipv4 and the traffic class octet in Ipv6. Bit numbers 0 to 5 of the DS field are used as code point field (DSCP). The bit combination of the code point field is determined from the SLA (service level agreement) between the user and the network service provider. The users specify their QoS requirements using SLA. QoS requirements can be specified in quantitative or statistical terms of throughput, delay, jitter or/and packet loss or may be specified in terms of some relative priority of access to the network resources.

4.1 Terminology

Domain: A DiffServ domain is a network, which provides same service classes in all of its nodes.

Per Hop Behavior (PHB):

PHB determines the way by which data packets are to be forwarded through the core routers. Every domain may have its own set of PHBs and DS field to PHB mappings. Upon receiving a packet, the core router will perform DS field to PHB mapping to determine the traffic aggregate of the data packet. The packet will be forwarded according to assigned traffic characteristics of the traffic aggregate. The traffic aggregate can be considered as a service class. As different domains may have different DS field to PHB mapping, so the same packet may be forwarded in a different manner in each of the domain. PHBs may be specified in terms of their resource (buffer, bandwidth) priority relative to other PHB or in terms of relative traffic characteristics like delay, jitter. PHBs are implemented by means of some buffer management and packet scheduling algorithms.

Traffic Conditioning Agreement (TCA):

It is possible that two interconnected networks may be supporting different DS field to PHB mappings and different traffic aggregates. TCA is an agreement between the two network administrators for how to map the DF field from one network to the other network. Care should be taken to do a mapping, which will provide a service as close as possible to the previous one.

Packet Classifier:

Packet classifier selects the packets in a traffic stream based on the content of the packet header. The BA (behavior aggregate) classifier selects packets on the basis of the DS field only, where as the multi field classifier selects the packets on the basis of one or more header fields such as DS field, protocol id, source ip address, destination ip address, source port number, destination port number etc.

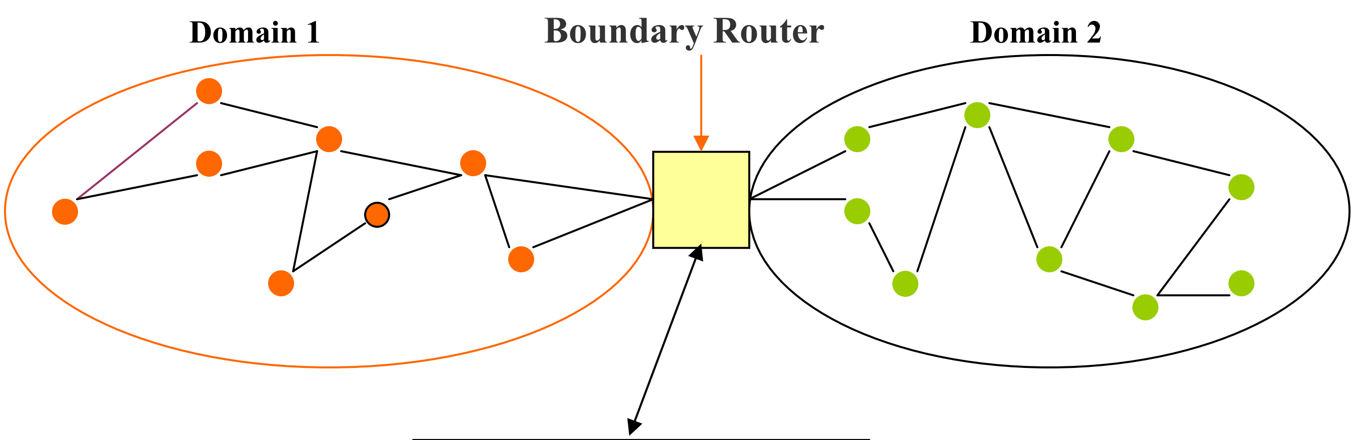
Traffic Conditioners:

Traffic conditioners are used by the DiffServ model to make sure that the traffic characteristics (delay, jitter, allocated bandwidth) of all the data packets flowing through the network are in accordance with their respective SLAs. If there is a flow which violates the terms and conditions of its SLA then the traffic conditioners try to regulate the flow by either delaying or dropping the packets. The traffic conditioners have got a finite size buffer to hold the packets that are to be delayed. The packets will be dropped in case there is not enough space to store them. The traffic conditioners are generally located in the peripheral routers. The second job of the traffic conditioners is to check whether the upstream domain has a TCA with its own domain. There will be a TCA between the two domains only if both of them do not support the same PHB set and the same DS field to PHB mapping. In case they have some TCA, then the traffic conditioner will modify the DS field of the incoming packet according to the guidelines of the TCA. If the two neighboring domains have got the same PHB set and the same DS field to PHB mapping, then there will be no need to condition the incoming packets.

In explanation of the traffic conditioner, it is assumed that DiffServ model is supported in both of the upstream and down stream domains.

4.2 Basic Operation of the Differentiated Service Model:

In the differentiated service model, the traffic entering a network is classified and possibly conditioned at the boundaries of the network and assigned to different traffic aggregates. The DS field of the packet header identifies each traffic aggregate. In the core routers, packets are forwarded according to the PHB of the DS field. The flow of data packets in a differentiated region is explained by the use of the following figure:



TCA between the two domains		
Domain 1	→	Domain 2
DS Field X	→	DS Field Y
DS Field P	→	DS Field Y
DS Field P	→	DS Field Y

Suppose that the domains 1 and 2 do not support the same PHB set and the same DS field to PHB mapping. It means both the domains should have a TCA with each other. The TCA will specify how the packets coming from other domain have to be conditioned or how the DS field has to be modified (at the boundary router) so as to map it to some service level (PHB) of the host domain. In each of the domain the data will be forwarded according to the traffic characteristics of the corresponding PHB.

4.3 Advantages of the Differentiated Service Model:

1 The Differentiated service model achieves scalability by implementing conditioning functions only at the core routers
2. Provides differentiated service classes.

4.4 Interoperability with Non-Differentiated Service Compliant Nodes:

A non-differentiated service compliant node is a node that neither interprets the DS field in a manner it should do, nor implements any/all of the standardized PHBs. The resources, which are to be provided to a flow, are decided by the PHB of the flow. Since a non-DiffServ compliant node would not be interpreting the PHBs, no resources will be explicitly provided to the packets. In a lightly loaded system this may not cause much difference but in a heavily loaded system this will prevent the network from providing a low delay & low jitter service to the traffic aggregates.

4.5 Interoperability with Non-Differentiated Service Compliant Domains:

A non-differentiated service compliant domain will not have any provision to condition the packets coming from other domains. It is possible that the domain may be containing DiffServ compliant nodes in it. But due to lack of appropriate DS field to PHB mapping DiffServ compliant nodes will not be able to provide suitable services to the packets. In such cases, before sending the packets to a Non-DiffServ compliant domain, the DiffServ compliant domain should mark the packets in a mutually agreed way. Then DiffServ compliant nodes in the Non-DiffServ compliant domain will be able to treat the packets in an appropriate way. In case the nodes of a non-DiffServ compliant domain are also non-DiffServ compliant, then before sending the packets to such domains the DiffServ compliant domain can set the DS field to zero. Now the Non-DiffServ compliant nodes will provide best effort service to all the packets. At the exit of the Non-DiffServ compliant domain arrangements should be provided to reset the DS fields to their previous values.

4.6 Multicast Considerations in the Differentiated Service Model:

For providing multicast facilities in the DiffServ model a number of service provisioning issues have to be studied. First multicast packets entering a domain may simultaneously be taking several paths. It means that the multicast packets will be consuming more resources then the unicast packets. Second since membership to a multicast group takes place in a dynamic manner, so it is difficult to predict the resource requirements of a multicast group. It implies that it is difficult to provide quantitative services to multicast groups. Also due to large resource requirements of the multicast groups, resources may have to be isolated between the unicast and the multicast traffic. The resource isolation may be obtained by explicitly reserving certain code points and PHBs for the unicast traffic.

4.7 Security Concerns of the Differentiated Service Model:

In the DiffServ model the type of service that has to be provided is totally determined by the DS field of the packet header. Now a malicious user may try to exploit this feature of the DiffServ model i.e. it may try to inject malicious packets in the network with DS fields corresponding to the higher priority flows or it may try to modify the bit pattern of the DS field of some of the packets. So steps have to be taken to protect the network from such malicious users. Since the peripheral routers of a Differentiated Service network are interface to the other networks, majority of the security controls should be implemented over there. The boundary routers can check to make sure that the DS field of a received packet corresponds to the SLA between the user and the service provider. Packets having invalid code points must be discarded or must be modified to some valid bit combination. The DS code point of the packets will be modified so as to offer them just the best effort service. Similar authentication mechanisms can also be deployed at the core routers.

5. Integrated and Differentiated Services for Mobile and Wireless Networks [8], [14], [15]:

The IntServs and DiffServ architecture were basically designed for the wired networks. During the design of these architectures, the design requirements of the wireless networks were not considered. QoS architecture for wireless networks must consider the following salient features of the wireless networks:

- High packet losses.
- Low bandwidth.
- Battery power considerations.
- Mobility.

5.1 Enhancements that can be applied to both the integrated and differentiated architectures:

1. Handling high packet losses: Due to limited bandwidth available over wireless channels and possible fading & blackout conditions that can occur when a mobile moves from one cell to other, mobile networks suffer from high packet losses. The QoS architecture for mobile networks must be design in such a way so as to select packets for dropping out. The applications can choose between bursty losses and distributed losses. For example a video application can bear distributed loss of packets because then the loss will give appearance of a flicker. An audio application may choose to have a bursty loss of packets because even after some packets are dropped the output will still be tangible.

2. Battery power considerations: Due to limited battery power of the mobiles, steps should be taken to minimize the battery power consumption in the mobile. A major fraction of the battery power (14%) is consumed by the network interface card attached to a mobile device and signal transmission & reception also consumes a lot of battery power. So the base station should avoid unnecessary transmission and reception of signals from the mobile.

3. Mobility: To avoid the blackout situations generated during hand offs, steps like advance buffering of data at the neighboring cells should be taken.

5.2 Modifications for Integrated Service Scheme:

1. Handling bandwidth constraints: In IntServ, sending refresh messages consumes a lot of bandwidth. This high bandwidth consumption by the refresh messages is not affordable in wireless network. Since in a wireless network, there is always a single hop between the base station and the mobile, so the refresh message can be avoided in wireless networks.
2. Handling mobility issues: For handling the mobility issues, the basic approach available is advance reservation of resources in the neighboring cells. But reserving the resources just before the movement of the mobile into some neighboring cell may prove fatal, as the resources may not be available and the data can be delayed/destroyed during the period it takes to setup the new reservation. To handle this approach passive reservation is used in the IntServ architecture. Passive reservations are made from the base station of the cell where the mobile currently resides to all the neighboring base stations. The mobile can move into any one of the cells and use the reserved resources. It means that resources reserved in some of

the neighboring cells may not be used. To avoid this situation, passive reservation allows for use of the reserved resources by other mobiles in the cells until the mobile in question needs to use the reservation.

5.3 Modifications for the Differentiated Services Scheme:

1. Need for signaling mechanisms: Differentiated architecture does not use end-to-end signaling scheme. But an end to end signaling is required in a wireless network because
   - Static provisioning is not sufficient since user mobility demands dynamic allocation of resources.
   - Information like the current battery power available at the mobile needs to be frequently sent to the base station.
   - Sender must know the limitations of the wireless link for better performance.
2. Classifications of packets within a flow: in differentiated service architecture, all the packets in a flow are treated equally. Provisions can be provided to give different priorities to packets belonging to the same flow. By this priority, the network can take decision as to
   - During congestion, which of the packets should be dropped
   - Which of the packets should always be delivered & which can be delayed by some amount of time.

6. Current Research [10], [5]

Though both the integrated service and the differentiated service architectures provide better service then the traditional IP model, they still have some drawbacks. While the integrated service model lacks scalability, the differentiated service model is not 'that' suitable for providing service to the real time flows and also it doesn't provide a wide range of services. Current research is going on to determine how to combine the two models so as to extract the benefits of both the schemes. The *IETF* has recommended two schemes for interoperability between the integrated and differentiated service models.

The first approach suggests running the integrated service and the differentiated service model independently of each other. While the Integrated service model will be used for attending real time traffic, the differentiated service model will be used for catering to the non-real time flows. The negative point of this approach is that it limits the use of RSVP to few flows only. It means that in future, if this approach is adopted, then even if the need arises the non-real time flows will not be able to reserve the resources.

The second scheme proposes to use the integrated service models over the peripheral networks while the differentiated model over the core network. In this model, devices installed at the interface of the two networks will maintain an information bank about the resources available in the differentiated networks. The information bank will be updated on a dynamic basis. Upon receiving a RSVP message at the interfacing device, RSVP admission control will check the integrated service flow spec to determine the resource requirements of the message. Then it will look for the available resources in the differentiated network to determine whether the requested resources can be provided or not. In case the requested resources can be provided then the interfacing device will map the resource requirements of the RSVP message to the appropriate differentiated class. In this model several integrated service flows are mapped to a single differentiated service class. Now the router at the interface between the two networks will use this mapping to choose the appropriate traffic class for the received packets.

7. Research Opportunities:

After studying the integrated services and differentiated services models, we found that these models have few drawbacks and limitations. These drawbacks and limitations provide the direction in which the future research should be carried out.

Research Opportunities in the Integrated Services [1]:

The major drawback of the IntServ model is that it is not scalable. Since this drawback of IntServ model results from the way the model works so removing this drawback, I suppose, will require modifications in the IntServ model. So that the routers can store greater number of flow states, the size of the flow identifiers should be minimized. The way in which the RSVP[2] works also provides future research opportunities. In RSVP, the sender sends the path message to the receiver. The path message goes on some path and on the return journey of the message on the same path resources are reserved. If a node is not able to provide the required resources then all the reservations on the entire route will be cancelled. Then the time spent by the message prior to reaching that node will be wasted. Future research should concentrate on how to remove this overhead and how to minimize the time required for making the resource reservations. A step in that direction can be to simultaneously explore several routes. This will in turn consume more network bandwidth, but assuming that infinite bandwidth will be available in the future, this approach should not have much overhead.

Research Opportunities in the Differentiated Services [3], [4]:

The major drawback of the DiffServ model is that this model is not suitable for real time traffic. Lack of provision of reserving the resources in the DiffServ is responsible for this drawback. The objective, guaranteed bandwidth, of resource reservation can be realized in DiffServ by using only those routes which have abundant amount of free bandwidth or the routes which are under utilized. The basic design of the DiffServ model supports differentiation in one direction only. It means that the DiffServ model is an asymmetric model. Making the DiffServ model support differentiation in both the directions is a topic of future research.

8. Discussion and Conclusion

After the detailed discussion of the IntServ[1] and DiffServ [3],[4] models we are in a position to compare the two with the other available Service categories/models. The DiffServ model can be considered alike the relative priority-marking model [12] since both of them make use of packet priority information stored in the header. But the DiffServ model is a refinement to the relative priority-marking model since it more clearly specifies the role of boundary nodes and traffic conditioners. The label-switching model [13] provides a better way to find the next hop, which in turn results in better service. Since, unlike the DiffServ and IntServ models, the label-switching model is a connection oriented model so it can provide more predictable and serialize flows. But as compared to other models, the label-switching model has got more overheads in form of additional management and configuration requirements to establish and maintain the label switched paths.

After the discussion, the results can be summarized in the following manner:

1 Due to varying delay and congestion losses associated with it, the traditional IP network is not able to serve the real time traffic.

2 The IntServ model is suitable for catering to the real time traffic but has the drawback of scalability.

3 The DiffServ model is suitable for providing heterogeneous services but is not suitable for catering to the real time traffic.

4 By using the IntServ model over the peripheral routers and the DiffServ model over the core routers, we can extract the advantages of both the models.
5. For making the DiffServ and IntServ models compatible with the requirements of the wireless networks, the control message transmission overhead should be minimized and also mobility issues should be considered.
6 The DiffServ model is a refinement over the relative priority-marking model.

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