High Speed Datagram Delivery over Internet using ATM Technology

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abstract

Framework of high throughput with small latent IP packet delivery using ATM technology in large scale heterogeneous internets keeping the current communication paradigm is studied.

This paper discusses how to carry TCP/IP over ATM, or, in general, how to carry connectionless and/or connection oriented network layer protocol over connection oriented QoS-ed datalink layer. Low latency property of ATM is fully extracted both for connectionless and connection oriented communication over TCP/IP without changing the current architecture of TCP/IP network.

Regarding connection oriented IP packet forwarding, source host, having the mapping functionality between flow-ID (e.g. in the SIPP16 header) and VCI/VPI value, forwards connection oriented IP packets cell-by-cell.

Connectionless IP packets can be also transferred cell-by-cell through the re-directed (concatenated) VCCs which bypass IP processing in the intermediate routers, when the cache for re-directed VCCs is hit. Otherwise, they will be forwarded to the adjacent router (hop-by-hop IP forwarding). Also, the active connectionless IP packet flow can use a dedicated VCC as a IP forwarding cache. Connectionless IP packets are forwarded cell-by-cell, instead of packet-by-packet, as long as the connectionless IP packet flow is in active state.

1 Introduction

ATM is recognized as one of the platforms to provide high speed datalink layer service with certain QoS (Quality of Service). Here, the QoS datalink layer service can be end-to-end, rather than link-by-link, in ATM networks. But, it should be still recognized as a data-link layer service, rather than a network layer service. ATM network provides both connection oriented (RSVP's resource reserved path [RSVP]) and connectionless network layer service (e.g. current IP forwarding using connectionless service functions) topping on connection oriented VCCs, which could have a certain QoS.

Physical or logical data-link network segments, including an ATM network, will be interconnected through router (network layer entity), even when the ATM becomes major data-link platform.

This draft proposes high speed and small latent IP packet delivery architecture over the Internet, using ATM technology. Regarding connectionless service, we can provide the small latent IP packet delivery using ATM bypass route, not only for IPv6 network but also for IPv4 network. And, connectionless IP packet can be forwarded cell-by-cell using the dedicated ATM-VCC, as long as the connectionless IP packet flow is in active state.

Regarding connection oriented (network layer) service, we can provide high throughput small latency IP packet delivery using end-station's mapping functionality between flow-ID in the IP packet header and VCI/VPI value. Also, when router has a mapping capability between the network layer QoS parameter (flow-spec) and the ATM's QoS parameter, end-to-end network layer QoS will be provided.

The proposed architecture can be applied to all of ATM network architecture discussed in IETF and in ATM Forum [CLIP][NBMA] [NHRP]. The proposed architecture can improve the performance of IP forwarding beyond IP subnet and can include short cut routing discussed in [NHRP].

Here, though this draft only discusses ATM technology, the technique discussed in this draft can be generally applied to other communication platforms that are based on connection oriented technology (e.g. Frame Relay).

2 Internet Architecture including ATM-LANs

2.1 Network Architecture in ATM Forum and IETF

Models developed at LE-WG (LAN Emulation Working Group) of ATM Forum and at ATM-WG and ROLC(Routing Over Large Cloud)-WG of IETF are discussed [CLIP][NBMA].

Basically following three architecture models are discussed. They are referred to as CLIP-model (Classical IP model), NBMA-model and COIP-model (Conventional IP model), in this draft. We did not discuss LAN Emulation Model of ATM Forum, because the essential issue addressed here in LAN Emulation Model of ATM Forum is the same as the issue in CLIP-model.

2.1.1 IP-model

To operate a network with a lot of hosts and some redundant paths, the network should be divided into several data-link network segments, which are interconnected by routers. It would be recommended that each data-link network segment accommodates only one IP subnet (network layer segment). This is the current network architecture in the Internet. And, both from the distributed application's point of view and from the network management's point of view, the data-link network segment (including ATM-LAN) should have broadcast capability. This is because broadcast is the only way to communicate with other end-stations (or routers) without prior knowledge of their addresses.

2.1.2 CLIP-model [CLIP]

Generally, (logical) IP subnets will overlay on a single ATM network segment, which may be large scale network. This means that several end-stations which generally belongs to different IP subnets will exist on a single (ATM-ed) data-link segment.

IP subnets are interconnected by routers, which are the same as the current router. The router in [CLIP] has only IP forwarding capability, but it does not have cell relaying capability. This means that ATM-VCC shall be always terminated at the router. Therefore, it is impossible to provide end-to-end Qo-ed virtual connection using CLIP-model, without some protocols, [RSVP]. Here, even when RSVP is applied in CLIP model, datagram transferring is still performed with an IP packet level and it causes both delay and HOL (Head Of Line) blocking at router. Also, since the IP packet must be always reassembled at the router (i.e. packet-by-packet forwarding), every IP packet experiences IP packet reassembling delay.

2.1.3 NBMA-model [NBMA][NHRP]

Logical IP subnets will overlay on a single ATM data-link segment. NBMA-subnet is defined as that network domain where end-to-end ATM-VCC can be established.

Within the NBMA-subnet, each end-station can establish (seamless) ATM-VCC toward any end-station that is located at other IP subnet, without passing through a router, i.e. short-cut routing. However, when IP packets should be transferred to out-side the NBMA-subnet, IP packet will be transferred to the boarder router between two NBMA-subnet's. This means that, even if the neighbor NBMA-subnet is also an ATM network, it is impossible to establish end-to-end ATM-VCC using IP address. Then, we can not obtain high performance IP packet forwarding beyond NBMA subnet.

Here, the segmentation of the large scaled network into multiple NBMA subnets may be realized due to security concern. Therefore, the routers locating at the edge of NBMA subnets may perform security functionalities, e.g. fire-wall function.

2.1.4 COIP-model [Ohta]

COIP-model is just same as IP-model for all the connectionless and most of the connection oriented IP flows. But, some connection oriented traffic may be mapped to multiple datalink layer ATM VCCs. On routers, ATM-VCCs are conceptually terminated at router but actually relayed cell-by-cell.

As the model allows moderately small datalink layer without losing direct connectivity of ATM, it is possible to introduce subnet-wide broadcast capability.

2.2 Internet Architecture including ATM Platforms

Network segments (autonomous systems) based on ATM technology will increase in the future. However, ATM-LANs will be interconnected to each other, as well as to other network platforms (e.g.high speed Ethernet, FFOL or Fibre Channel). And, the old network platform must be smoothly replaced by ATM technology or by the other high speed platforms. Also, from the network operation point of view, the each network segment would be rationally small, and be operated independently.

Since transmission of cells (or packet) over WAN may be costly, outgoing (or incoming) cell VCCs would be aggregated into fewer VCCs. In a WAN environment, the user may want to open very few VCs and cell flows from a lot of end-stations would be connected to few VCCs to cross the WAN. Also, the signaling protocol would be different between the WAN environment and LAN environment, e.g. actually, signaling specification defined by ITU-T is slightly different from the specification defined by ATM Forum [ATM Forum].

ATM-LAN is composed of switch nodes, and the interface to the adjacent network segment is either UNI or NNI. Data-link segment may be identical to IP subnet, or multiple IP subnets may overlay over large cloud data-link network. But, IP subnets are interconnected by routers. Data-link network segment may have multiple switching nodes (cell-relaying entities), or may have only a single switching node in it. In the latter case, every switching node has both cell-relaying functionality and IP forwarding functionality, while each switching node has its own IP subnet.

The key functionalities of the proposed router, that interconnects ATM networks (represented as ATM router) are as follows.

1. Cell Relaying
   Cells are relayed as ATM layer's function. Since the assignment of VCI/VPI value is performed independently at each individual ATM-LAN, router has the VCI/VPI translation functionality so as to concatenate distinct ATM-VCCs, which are provided by individual ATM-LANs. Here, within each ATM-LAN segment, each IP packet flow, that can be transferred by the concatenated ATM-VCCs, uses an individual ATM-VCCs. Since IP processing can be bypassed by ATM layer cell relaying at the router, the transmission latency to pass through the router can be sufficiently small, which is the same as an ATM switch node. Here, bypassing of IP processing by cell relaying is applied both to connection oriented IP flow, discussed in section 4, and to connectionless IP flow, discussed in section 5.

2. End-to-end connection oriented data transfer channel set-up
   During a set-up procedure of end-to-end connection oriented (sometimes called resource reservation oriented) data transfer channel, e.g. using path and reserve messages in RSVP, routers co-operate with the connection (ATM-VCC as data-link connection) control entities in the ATM-LANs. And, also, we can achieve higher throughput than the conventional hop-by-hop IP forwarding done by the router. For example, the VCI/VPI translation table will be established during a set-up procedure.

3. VCC multiplexing/de-multiplexing
   When communication cost over the WAN is costly, cell flows crossing WAN would be aggregated at the router. And, aggregated packet flows into few ATM-VCCs would be demultiplexed at the router.

4. Security Functionality (if necessary)
   Since every cell (or packet) passes through the router, the segmentation of subnet can be fulfilled as well as the current Internet architecture. For instance, the proposed router can equip security functionalities, e.g. packet filtering in fire-wall function. The proposed router can equip security functionalities, that is, unauthorized packets are filered just as usual firewall and unauthorized reservation request packets for cell relaying are rejected.

Routers are network entities which interconnect several IP subnets. Routers exchange routing information and maintain routing information tables to forward the received packet. Logically, each packet is relayed to the optimal interface by looking up the routing tables. But, actually, routers don't have to consult routing table everytime they receive a packet. Implementations are free to have internal cache or bypass to minimize the packet routing delay of complex table looking up. Likewise, the proposed routers don't have to consult with a routing table everytime they receive a cell. Implementations are free to have internal bypass to remove the packet reassembling delay and packet routing delay of complex table looking up.

3 Network Reference Model

The following four are the network reference models discussed in this draft. In the following referenced models, every router in each model is the router proposed in this draft.

3.1 CLIP model

Large cloud network accommodates multiple logical IP subnets (LISs). In the figure, two sets of routers and end-hosts belonging to the different LIS is shown. IP packet from host *A.1* toward host *B.1* passes through Router *A.0* and Router *B.0*. Direct ATM-VCCs are used for IP packets transfer from host *A.1* to Router *A.0*, from Router *A.0* to Router *B.0*, and from Router *B.0* to host *B.1*.

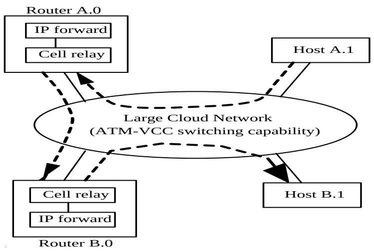

Figure 1: Classical IP Model

When an IP packet flow from host *A.1* to host *B.1* is either an active flow or connection oriented IP transport flow, the IP packet will be forwarded without IP forwarding process in these router.

3.2 NBMA model

NBMA subnet accommodates multiple logical IP subnets (LISs). In the figure, two end-hosts belonging to different LISs, but belonging same NBMA subnet are shown. In order to transfer IP packet (both connection oriented IP packet and connectionless IP packet) from host *A.x.1* to host *A.y.1*, host *A.x.1* resolve the ATM address of host A.y.1 or the ATM address of some other entity (e.g. router similar to the CLIP model) which relays IP packets to host *A.y.1* using NHRP server. Then, IP packet from host *A.x.1* to host *A.y.1* could pass through so called a short-cut route. Short-cut route may bypass the intermediate router(s), physically.

IP packet from host *A.x.1* toward host *B.z.1* passes through Router, which is located at the edge point of NBMA subnets. When the IP packet flow from host *A.x.1* to host *B.z.1* is either active flow or connection oriented IP transport flow, the IP packet will be forwarded without IP forwarding process in the router, as well as in the NBMA subnet.

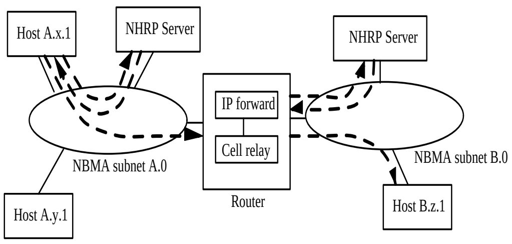

Figure 2: NBMA Model (Overlay Model)

3.3 COIP model

Data-link network segment is identical to IP subnet. Therefore, IP packet beyond IP subnet must always pass through the router which is located at the edge of data-link network segments. In order to transfer the IP packet (both connection oriented IP packet and connectionless IP packet) from host *A.1* to host *B.1*, host *A.1* may resolve the ATM address of Router. Router relays the received IP packet toward host *B.1*. When the IP packet flow from host *A.1* to host *B.1* is either active flow or connection oriented IP transport flow, the IP packet will be forwarded without IP forwarding process in the router.

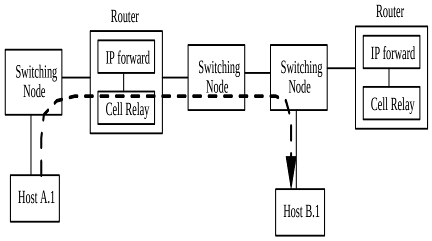

Figure 3: Conventional IP Model

3.4 Router Interconnection model

Data-link network segment is identical to a single switching node and also is identical to IP subnet. Therefore, IP packet beyond an IP subnet must always pass router (i.e. switching node). In order to transfer the IP packet (both connection oriented IP packet and connectionless IP packet) from host *A.1* to host *C.1*, host *A.1* transfer IP packet to the router (i.e. switching node) whose subnet ID is *A.0*. Routers (*A.0*, *B.0* and *C.0*) relay the received IP packet toward host *C.1*. When the IP packet flow from host *A.1* to host *C.1* is either active flow or connection oriented IP transport flow, the IP packet will be forwarded without IP forwarding process in the router.

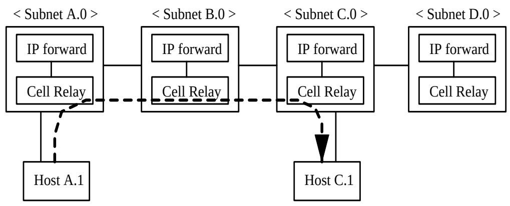

Figure 4: Router Interconnection Model

4 Connection Oriented Service Architecture

Currently, the connection oriented IP transport flow (i.e. network layer connection oriented service or sometime said as resource reservation oriented service) has been discussed in IETF, e.g. [RSVP][SIPP1]. The goal of connection oriented communications is to provide end-to-end IP transport. Such a transport flow can have a certain QoS. In such IP transport flow, there is an admission policy at network layer level, that is similar concept to CAC (Connection Admission Control) in ATM network. When the IP transport flow set up request is admitted, the resource for the transport flow is reserved at corresponding routers. Here, in order to find out the next network (or can be said router) that the IP transport flow should be routed, some kind of routing protocol (e.g. similar to OSPF) is executed among routers.

The architecture proposed in this section assumes QoS-ed communication over not only ATM but also other types of platform, using the concept of connection oriented IP transport. The connection oriented IP transport is mapped into data-link layer connection (ATM-VCC) provided by the ATM networks.

Connection oriented data-link layer networks (e.g. ATM) can provide QoS-ed connection between any data-link SAPs (Service Access Point) within the data-link network segment through connection set up procedure. Communication beyond data-link network segment is performed by QoS-ed IP transport flow to the router. When the data-link network segment is connection oriented, router or source end-station establishes QoS-ed data-link connection (e.g. ATM-VCC) toward the router. Other routers perform the same procedure, until the IP transport flow set-up message arrives at the destination end-station.

After the IP transport flow is established, IP packets are forwarded through the QoS-ed pipe. A unique identifier, called flow-ID, could be used along the IP transport flow [SIPP1][RSVP]. Within the ATM data-link network, VCI/VPI can be used instead of flow-ID defined in the IP layer.

The IP packet forwarding procedure is as follows.

1. Packet arrives at router.
2. Flow-ID and IP address (source/destination) are checked and next hop router is determined.
3. TTL (Time To Live) is decremented.
4. Unless the router is destination end-station, packet is forwarded.

This procedure is not ATM specific and it is applicable to all other platform. Packet handling procedures in the proposed router in the following three cases are shown below.

4.1 ATM-LAN → ATM-LAN

End-to-end IP packet transmission path will be established via some resource reservation protocol messages (e.g. using path message and reserve message in RSVP) in network layer level [RSVP]. Router has mapping table between ingress VCI/VPI and egress VCI/VPI for each cell flow according to the appropriate IP transport flow. Then, it is unnecessary to examine the flow-ID and IP address in step 2 : "Re-direction" (concatenation) of ingress and egress data-link connection. Here, mapping table is established during connection set up procedure.

1. Cell arrives at router
2. VCI/VPI of ingress cell is examined and the next hop VCI/VPI of egress cell is determined (maybe by hardware)
3. TTL in IP header may not be decremented
4. Unless the router is destination end-station, cell is forwarded.

4.2 ATM-LAN → Other-LAN

Router will just reassemble IP packet to forward it to the appropriate router or end-station.

1. Cell arrives at router
2. IP packet is reassembled (e.g. AAL5)
3. Flow-ID and IP address (source/destination) is examined and the next hop router is determined.
4. TTL in IP header is decremented
5. Unless the router is destination end-station, packet is forwarded.

4.3 Other-LAN → ATM-LAN

Router has a mapping table between ingress flow-ID/IP-address and egress VCI/VPI for each IP transport flow. Here, again, the mapping table is established during IP connection set-up procedure. Here, the TTL decrement value in step 3 may not be one. This is because, within the ATM-LANs, the TTL of IP packet header is not dealt with at the bypassed router, even when the IP packet passes through the router.

1. Packet arrives at router
2. Flow-ID and IP address (source/destination) is examined and the next hop VCI/VPI of egress cell is determined.
3. TTL in IP header is decremented (may not be one)

When ATM end-stations communicates purely over ATM-LANs, a seamless end-to-end cell-relaying virtual channel can be established between them. It should be noted that, even though many ATM-VCCs (data-link connection) are used at data-link layer, the seamless connection over ATM-LANs is a network layer connection (not data-link layer connection).

5 Connectionless Service Architecture

5.1 Connectionless Service over ATM Networks

Connection oriented service must perform IP level connection set-up procedure, before transferring the information. It is said that connection set-up latency for a large scale ATM network would be small [Schmt]. On the contrary, connectionless service does not require IP level connection set-up procedure. ATM-VCC (data-link connection), in order to provide connectionless service, would be established in advance. Here, ATM-VCCs to provide connectionless (conventional IP forwarding) service would be SPVC (Semi-Permanent VC) or SVC (Switched VC), rather than PVC (Permanent VC). Once the VC(s) for connectionless service is(are) established, there will be no connection set-up latency to transfer connectionless IP packet. Therefore, even when ATM networks and other networks provide end-to-end connection oriented data transmission service, connectionless service will be still important. And, from the view point of co-existence with the data-link network that is not connection oriented (e.g. FFOL), connectionless data transmission service (i.e. conventional IP forwarding) must be provided by the ATM networks.

5.2 Connectionless Services in Conventional Data Networks

In IP networks, IP processing will be generally performed, whenever the IP packet is transferred to other data-link network segment [Comer]. This means that, in a large scale network, the IP packet will experience many IP processing points between source and destination end-stations. Therefore, in the large scale network, large delay for IP packet delivery is expected, due to a large number of IP processing points. This is similar to CLS (ConnectionLess Server) approach defined by ITU-T [I.364].

Each router can directly recognize the destination subnet (i.e.Net-ID) of the received IP packet, as the address view of routing domain. However, the network layer protocol (e.g. IP) is performed at every router to terminate data-link layer (i.e. MAC). As a result, even the distance associated with the address management view is small, the distance associated with the data-link layer's view is not small.

5.3 Proposed Connectionless Service Architecture

Connectionless IP packet transmission in the proposed architecture is fundamentally no different from that of existing IP forwarding. Within the data-link network segment, end-stations and routers exchange IP packets using data-link connections (e.g. ATM-VCC). IP packet beyond the data-link segment is sent to an appropriate router from the source end-station. If a router has some knowledge on local topology (e.g. topology information in routing domain) that it can determine not only the next but also the second or third next hops, it is possible to bypass IP layer processing on the intermediate routers, by having direct ATM connection between distant routers.

Routers exchange routing information and forward IP packets to the appropriate router. Following discussion is regarding the network that has only ATM-LANs. Toward other types of platform from ATM network, ATM-VCC shall be always terminated at the router to execute conventional IP forwarding process. On the contrary, regarding toward ATM network from the other types of platform, you can see the router as the end-station in the following discussion.

The proposed ATM router has both cell relaying and IP forwarding capabilities. IP packet toward out-side the ATM-LAN where the source end-station belongs to is sent to an appropriate router from the source end-station. Routers exchange routing information and forward packets to the appropriate router. Regarding the current routing protocol (e.g. OSPF), every router does know all of subnet IDs (Net-IDs) within the domain where the routing protocol is applied.

5.3.1 Hop-by-hop ATM-VCC Cacheing for Active IP Flow

When the first (of session or of after idle period) IP packet arrives at router (attaching to ATM), the next router is decided using IP header, i.e. route decision will be done based on IP address (and flow-ID in IPv6). After certain next router is decided, a dedicated ATM-VCC is picked up for the IP packet flow. When the packet comes from ATM (or connection-oriented platform, e.g. Frame Relay), router maps between incoming VCI/VPI (or some flow-ID in data-link layer)and (picked up) outgoing VCI/VPI. When the packet is coming from the conventional platform (e.g. Ethernet/FDDI), router always examine IP header in the case of IPv4 (in IPv6, flow-ID could be mapped with outgoing VCI/VPI). And, when IP packet is come from ATM, the successive IP packet is forwarded based on incoming VCI/VPI value, without any usual IP processing.

If the activity of IP packet flow is/becomes low, the mapping information (i.e. cached information) is pushed out. That means that the pushed out IP packet flow from cache must be examined via usual IP processing (looking at IP header) at the router. As a result, high activity IP packet flow can bypass a usual IP processing at the router.

Above procedure is performed at every router (e.g. intermediate router that interconnects ATM networks). Then, intermediate router can deal with high activity IP packet flow with very small latency. This is because IP packet forwarding is done by cell relaying, which will be done by hardware. The job of router is maintaining VCI/VPI mapping table in the cell switch, or is maintaining mapping table between flow-ID and VCI/VPI, as a cache (bypass) processing path for usual IP forwarding process.

When every data-link segment is ATM, small latent IP packet forwarding will be provided, even for connectionless IP packet. This is because IP packet is relayed by cell-by-cell at every routers, regarding active IP packet flow.

5.3.2 Bypassed ATM-VCC for Active Transaction

When routers knows that it will have or is having a lot of communication with a certain router (or subnet), it may create bypass (concatenated) ATM-VCC (called as bypassing cell-relay pipe below) which is seamlessly connects the two routers. This bypassing cell-relay pipe cuts through the IP processing at the intermediate routers along to the cell transmission route between the two routers. On the other hand, when router does not use the bypassing cell-relay pipe for IP packet forwarding, the IP packet will be forwarded hop-by-hop way, that is completely same approach as the current IP forwarding.

When router can establish a seamless bypassing cell-relay pipe the intermediate router's network layer protocol processing along the routing path to the destination end-station, we can reduce the end-to-end IP packet delivery latency due to the reducing the number of network layer protocol processing points at the intermediate routers. Here, it is unnecessary to propagate the information of such bypassing cell-relay pipe for every routers. The information of bypassing cell-relay pipe shall be maintained by the source and destination routers associated with the bypassing cell-relay pipe. This means that the routing protocol and routing information exchanged by routers is nothing different from the existing routing protocol.

The information and path regarding bypassing the intermediate router(s) could be seen as a cache image associated with the information and path for hop-by-hop route (i.e. conventional IP forwarding route). When the cache is missed (i.e. when there is no bypass route), the hop-by-hop information is referenced and the IP packet is forwarded to the adjacent router. On the contrary, when the cache is hit (i.e. when a bypass route exists associated with the destination subnet), the cache information is referenced and the IP packet is forwarded using the bypass route.

The establishment of bypass route will be issued by the following two cases. Here, source router and destination router used in this subsection can be intermediate router, from the view point of end-stations. This means that source (or destination) router may not be directly connected to the source (or destination) end-station through a single ATM-VCC. In other words, in order to reach source router from source end-station (or to reach destination end-station from destination router), intermediate router(s) may be required.

1. Source router
   Source router has activity information regarding the destination subnet's. When the IP forwarding activity toward the certain destination subnet is high, the source router tries to establish the bypass ATM-VCC toward the destination subnet's router. When the activity becomes low, the established bypassing cell-relay pipe will be teared down (i.e. cache information is pushed out). Bypassing cell-relay pipe from the source router toward the destination router can be established without activity information.
   This means that bypassing cell-relay pipe can be established both dynamically and statistically based on network's configurational information.

   * Here, NBMA net's short-cut routing can be realized when we assume that the creating bypass route is performed at ATM-VCC

establishment phase (i.e. signaling phase) for connection oriented IP service or when we assume that the creating bypass route is performed during address resolution procedure for connectionless IP service. These procedure can be analogous to "re-direction" procedure in RFC1620, or can be analogous to ARP procedure in NHRP [RFC1620][NHRP].

2. Intermediate router (cell-relay re-direction) When the intermediate router becomes high load, the intermediate router can create bypass routes that is bypassing itself. The intermediate router establishes the bypassing cell-relay pipe for active source and destination router pair. After the establishment of two bypassing cell-relay pipes, that are (a) from source router to intermediate router and (b) from intermediate router to destination router, these two cell-relay pipes are coupled at the intermediate router. This procedure could be seen as re-direction of cell-relaying : i.e. the cell-relaying coming from the source router to IP forwarding entity in the intermediate router is "re-directed" to the cell-relaying entity toward the destination router.

The ideal and optimal case is full meshed cell-relay pipes are established among all of routers that are exists in the routing entry of routing information.

Obviously, the every host can act as same as the router discussed above (i.e. you can see the router as a end-station). Then, the seamless cell transmission channel will be established, i.e. (a) from source end-station to router, (b) from source end-station to destination end-station, and (c) from router to destination end-station.

6 Conclusion

High throughput small latent datagram (IP packet) delivery architecture using ATM technology is proposed in this contribution. Using the ATM's cell relaying capability at router, we can provide high throughput small latent end-to-end IP packet delivery. The proposed architecture can be generally applied to all of network reference model discussed in IETF and ATM Forum.

Regarding connection oriented IP packet transmission, since the router can map between flow-ID (and IP address) in the IP packet header and VCI/VPI, we can reduce the IP processing latency at the routes within the ATM network.

Regarding connectionless IP packet transmission, we can also reduce the IP processing latency at the routers within the ATM networks, through the re-direction (bypassing) technique at the routers. When the proposed architecture is applied, we can reduce the processing load of each router, as well as reducing end-to-end packet delivery delay. This is because, due to the bypassing IP processing by redirect technique, the amount of IP processing for intermediate IP packets can be reduced.

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References

[I.150] ITU-T Rec.I.150 : "BISDN Asynchronous Transfer Mode", 1990

[I.364] ITU-T Rec.I.364 : "Support of Broadband Connectionless Data Service on BISDN", June, 1992

[ATM Forum] ATM Forum : "ATM UNI Specification 3.0", Aug.1993

[Schmit] A.Schmidt, R.Campbell : "Internet Protocol Traffic Analysis with Applications for ATM Switch Design", Computer Communications Review, vol.23, No.2, pp.39-52, April, 1993

[CLIP] M.Laubach ;"Classical IP and ARP over ATM", RFC1577, Jan., 1994

[NBMA] J.Heinanen ;"NBMA Address Resolution Protocol", RFC1735, Dec., 1994.

[NHRP] D.Katz, D.Piscitello ;"NBMA Next Hop Resolution Protocol (NHRP)", (Internet-Draft), draft-ietf-rolc-nhrp-03.txt, Dec., 1994

[RFC1620] B.Braden, J.Postel, Y.Rekhter, "Internet Architecture Extensions for Shared Media", RFC 1620, May, 1994

[SIPP1] S.Deering : "Simple Internet Protocol Plus (SIPP) Specification (128-bit address version)", (Internet-Draft), draft-ietf-sipp-spec-01.txt, July, 1994

[SIPP2] P.Francis, S.Deering, R.Hinden, R.Govindan : "Simple Internet Protocol Plus (SIPP) : Addressing Architecture", (Internet-Draft), draft-ietf-sipp-routing-addr-02.txt, July, 1994

[IPng] F.Kastenholz, C.Partridge : "Technical Criteria for Choosing IP:The Next Generation (IPng)" (Internet-Draft), draft-kastenholz-ipng-criteria-02.txt, May, 1994

[RSVP] L.Zhang ;"Resource ReSerVation Protocol (RSVP)", (Internet-Draft), draft-ietf-rsvp-spec-02.ps, May, 1994

[Ohta] M.Ohta, H.Esaki, K.Nagami ;"Conventional IP over ATM", (Internet-Draft) draft-ohta-ip-over-atm-01.txt, July, 1994

[Comer] D.E.Comer;"*Internetworking_with_TCP/IP*", Prentice Hall, 1991

[Esaki1] H.Esaki, Y.Tsuda, T.Saito, S.Natsubori : "Class D Service Architecture in ATM-Internet", ICC'94, May, 1994.

[Esaki2] H.Esaki, Y.Tsuda, T.Saito, S.Natsubori : "Datagram Delivery in an ATM-Internet", IEICE Trans. on Communications, Special Issues for Future Private Networks, March, 1994