Network Working Group
Request for Comments: 4392
Category: Informational

V. Kashyap
IBM

April 2006

IP over InfiniBand (IPoIB) Architecture

Status of This Memo

Copyright Notice

Abstract

InfiniBand is a high-speed, channel-based interconnect between systems and devices.

This document presents an overview of the InfiniBand architecture. It further describes the requirements and guidelines for the transmission of IP over InfiniBand. Discussions in this document are applicable to both IPv4 and IPv6 unless explicitly specified. The encapsulation of IP over InfiniBand and the mechanism for IP address resolution on IB fabrics are covered in other documents.

Table of Contents

1. Introduction to InfiniBand

The InfiniBand Trade Association (IBTA) was formed to develop an I/O specification to deliver a channel based, switched fabric technology. The InfiniBand standard is aimed at meeting the requirements of scalability, reliability, availability, and performance of servers in data centers.

1.1. InfiniBand Architecture Specification

The InfiniBand Trade Association specification is available for download from http://www.infinibandta.org.

1.2. Overview of InfiniBand Architecture

For a more complete overview, the reader is referred to chapter 3 of the InfiniBand specification.

InfiniBand Architecture (IBA) defines a System Area Network (SAN) for connecting multiple independent processor platforms, I/O platforms, and I/O devices. The IBA SAN is a communications and management infrastructure supporting both I/O and inter-processor communications for one or more computer systems.

An IBA SAN consists of processor nodes and I/O units connected through an IBA fabric made up of cascaded switches and IB routers (connecting IB subnets). I/O units can range in complexity from a single Application-specific Integrated Circuit (ASIC) IBA-attached device (such as a LAN adapter) to a large, memory-rich Redundant Array of Independent Disks (RAID) subsystem.

An IBA network may be subdivided into subnets interconnected by routers. These are IB routers and IB subnets and not IP routers or IP subnets. This document will refer to InfiniBand routers and subnets as 'IB routers' and 'IB subnets' respectively. The IP routers and IP subnets will be referred to as 'routers' and 'subnets', respectively.

Each IB node or switch may attach to a single or multiple switches or directly with each other. Each IB unit interfaces with the link by way of channel adapters (CAs). The architecture supports multiple CAs per unit with each CA providing one or more ports that connect to the fabric. Each CA appears as a node to the fabric.

The ports are the endpoints to which the data is sent. However, each of the ports may include multiple QPs (Queue Pairs) that may be directly addressed from a remote peer. From the point of view of data transfer the QP number (QPN) is part of the address.

IBA supports both connection-oriented and datagram service between the ports. The peers are identified by QPN and the port identifier. There are a two exceptions. QPNs are not used when packets are multicast. QPNs are also not used in the Raw Datagram mode.

A port, in a data packet, is identified by a Local Identifier (LID) and optionally a Global Identifier (GID). The GID in the packet is needed only when communicating across an IB subnet, though it may always be included.

The GID is 128 bits long and is formed by the concatenation of a 64-bit IB subnet prefix and a 64-bit EUI-64-compliant portion. The EUI-64 portion of a GID is referred to as the Global Unique Identifier (GUID; EUI stands for Extended Unique Identifier). The LID is a 16-bit value that is assigned when the port becomes active. The GUID is the only persistent identifier of a port. However, it cannot be used as an address in a packet. If the prefix is modified, then the GID may change. The subnet manager may attempt to keep the LID values constant across reboots, but that is not a requirement.

The assignment of the GID and the LID is done by the subnet manager. Every IB subnet has at least one subnet manager component that controls the fabric. It assigns the LIDs and GIDs. The subnet

manager also programs the switches so that they route packets between destinations. The subnet manager (SM) and a related component, the subnet administrator (SA), are the central repository of all information that is required to set-up and bring up the fabric.

IB routers are components that route packets between IB subnets based on the GIDs. Thus, within an IB subnet a packet may or may not include a GID but when going across an IB subnet the GID must be included. A LID is always needed in a packet since the destination within a subnet is determined by it.

A CA and a switch may have multiple ports. Each CA port is assigned its own LID or a range of LIDs. The ports of a switch are not addressable by LIDs/GIDs or, in other words, are transparent to other end nodes. Each port has its own set of buffers. The buffering is channeled through virtual lanes (VL) where each VL has its own flow control. There may be up to 16 VLs.

VLs provide a mechanism for creating multiple virtual links within a single physical link. All ports must support VL15 which is reserved exclusively for subnet management datagrams and hence does not concern the IP over Infiniband (IPoIB) discussions. The actual VL that a packet uses is configured by the SM in the switch/channel adapter tables and is determined based on the Service Level (SL) specified in every packet. There are 16 possible SLs.

In addition to the features described above viz. QPs, SLs, and addressing (GID/LID), IBA also defines the following:

Partitioning:

Every packet, but for the raw datagrams, carries the partition key (P_Key). These values are used for isolation in the fabric. A switch (this is an optional feature) may be programmed by the SM to drop packets not having a certain key. The CA ports always check for the P_Keys. A CA port may belong to multiple partitions. P_Key checking is optional at IB routers.

A P_Key may be described as having 'limited membership' or 'full membership'. For a packet to be accepted, at least one of the P_Keys (i.e., the P_Key in the packet or the P_Key in the port) must be 'full membership' P_Keys.

Q_Keys:

Q_Keys are used to enforce access rights for reliable and unreliable IB datagram services. Raw datagram services do not use Q_Keys. At communication establishment, the endpoints exchange

the Q_Keys and must always use the relevant Q_Keys when communicating with one another. Multicast packets use the Q_Key associated with the multicast group.

Q_Keys with the most significant bit set are considered controlled Q_Keys (such as the General Service Interface (GSI) Q_Key [IB_ARCH]) and a Host Channel Adapter (HCA) does not allow a consumer to arbitrarily specify a controlled Q_Key. An attempt to send a controlled Q_Key results in using the Q_Key in the QP context. Thus, the Operating System maintains control since it can configure the QP context for the controlled Q_Key for privileged consumers. It must be noted that though the notion of a 'controlled Q_Key' is suggested by IB specification, it does not require its use or implementation.

Multicast support:

A switch may support multicasting, that is, replication of packets across multiple output ports. This is an optional feature. Similarly, support for sending/receiving multicast packets is optional in CAs. A multicast group is identified by a GID. The GID format is as defined in RFC 2373 on IPv6 addressing [IB_ARCH]. Thus, from an IPv6-over-InfiniBand point of view, the data link multicast address looks like the network address. An IB port must explicitly join a multicast group by sending a request to the SM to receive multicast packets. A port may send packets to any multicast group. In both cases, the multicast LID to be used in the packets is received from the SM.

There are six methods for data transfer in IB architecture:

1. Unreliable Datagram (unacknowledged - connectionless)

   The Unreliable Datagram (UD) service is connectionless and unacknowledged. It allows the QP to communicate with any unreliable datagram QP on any node.

   The switches and hence each link can support only a certain MTU. The MTU ranges are 256 octets, 512 octets, 1024 octets, 2048 octets, and 4096 octets. A UD packet cannot be larger than the link MTU between the two peers.

2. Reliable Datagram (acknowledged - multiplexed)

   The Reliable Datagram (RD) service is multiplexed over connections between nodes called End-to-End Contexts (EEC), which allows each RD QP to communicate with any RD QP on any node with an established EEC. Multiple QPs can use the same

EEC and a single QP can use multiple EECs (one for each remote node per reliable datagram domain).

3. Reliable Connected (acknowledged - connection oriented)

   The Reliable Connected (RC) service associates a local QP with one and only one remote QP. The message sizes maybe as large as 2^31 octets in length. The CA implementation takes care of segmentation and assembly.

4. Unreliable Connected (unacknowledged - connection oriented)

   The Unreliable Connected (UC) service associates one local QP with one and only one remote QP. There is no acknowledgement and hence no resend of lost or corrupted packets. Such packets are therefore simply dropped. It is similar to RC otherwise.

5. Raw Ethertype (unacknowledged - connectionless)

   The Ethertype raw datagram packet contains a generic transport header that is not interpreted by the CA but it specifies the protocol type. The values for ethertype are the same as defined by Internet Assigned Numbers Authority (IANA) [IANA] for ethertype.

6. Raw IPv6 (unacknowledged - connectionless)

   Using IPv6 raw datagram service, the IBA CA can support standard protocol layers atop IPv6 (such as TCP/UDP). Thus, native IPv6 packets can be bridged into the IBA SAN and delivered directly to a port and to its IPv6 raw datagram QP.

The first four types are referred to as IB transports. The latter two are classified as raw datagrams. There is no indication of the QP number in the raw datagram packets. The raw datagram packets are limited by the link MTU in size.

The two connected modes and the Reliable Datagram mode may also support Automatic Path Migration (APM). This is an optional facility that provides for a hardware based path fail over. An alternate path is associated with the QP when the connection/EE context is first created. If unrecoverable errors are encountered, the connection switches to using the alternative path.

1.2.1. InfiniBand Addresses

The InfiniBand architecture borrows heavily from the IPv6 architecture in terms of the InfiniBand subnet structure and GIDs.

The InfiniBand architecture defines the GID associated with a port as a 128-bit unicast or multicast identifier. IBA derives the GID address format, as defined in RFC 2373 [IB_ARCH], with some additional properties/restrictions defined to facilitate efficient discovery, communication, and routing.

Note: The IBA explicitly refers to RFC 2373, which is obsolete [RFC3513]. It must be noted that IBA is therefore unaffected by any further changes that are introduced in IPv6 addressing architecture.

IBA defines two types of GIDs: unicast and multicast.

1.2.1.1. Unicast GIDs

The unicast GIDs are defined, as in IPv6, with three scopes. The IB specification states the following:

a. link local: FE80/10.

   The IB routers will not forward packets with a link-local address in source or destination beyond the IB subnet.

b. site local: FEC0/10

   A unicast GID used within a collection of subnets that is unique within that collection (e.g., a data center or campus) but is not necessarily globally unique. IB routers must not forward any packets with either a site-local Source GID or a site-local Destination GID outside of the site.

c. global:

   A unicast GID with a global prefix; an IB router may use this GID to route packets throughout an enterprise or internet.

1.2.1.2. Multicast GIDs

The multicast GIDs also parallel the IPv6 multicast addresses. The IB specification defines the multicast GIDs as follows:

   FFxy:<112 bits>

   Flag bits:

The nibble, denoted by x above, are the 4 flag bits: 000T.

The first 3 bits are reserved and are set to zero. The last bit is defined as follows:

T=0: denotes a permanently assigned, that is, well-known GID
T=1: denotes a transient group

Scope bits:

The 4 bits, denoted by y in the GID above, are the scope bits. These scope values are described in Table 1.

scope value	Address value
0	Reserved
1	Unassigned
2	Link-local
3	Unassigned
4	Unassigned
5	Site-local
6	Unassigned
7	Unassigned
8	Organization-local
9	Unassigned
0xA	Unassigned
0xB	Unassigned
0xC	Unassigned
0xD	Unassigned
0xE	Global
0xF	Reserved

Table 1

The IB specification further refers to RFC 2373 and RFC 2375 while defining the well-known multicast addresses. However, it then states that the well-known addresses apply to IB raw IPv6 datagrams only. It must be noted though that a multicast group can be associated with only a single Multicast Global Identifier (MGID). Thus the same MGID cannot be associated with the UD mode and the Raw Datagram mode.

1.3. InfiniBand Multicast Group Management

IB multicast groups, identified by MGIDs, are managed by the SM. The SM explicitly programs the IB switches in the fabric to ensure that the packets are received by all the members of the multicast group that request the reception of packets. The SM also needs to program the switches such that packets transmitted to the group by any group member reach all receivers in the multicast group.

IBA distinguishes between multicast senders and receivers. Though all members of a multicast group can transmit to the group (and expect their packets to be correctly forwarded), not all members of the group are receivers. A port needs to explicitly request that multicast packets addressed to the group be forwarded to it.

A multicast group is created by sending a join request to the SM. As will be explained later, IBA defines multiple modes for joining a multicast group. The subnet manager records the group's multicast GID and the associated characteristics. The group characteristics are defined by the group path MTU, whether the group will be used for raw datagrams or unreliable datagrams, the service level, the partition key associated with the group, the Local Identifier (LID) associated with the group, and so on. These characteristics are defined at the time of the group creation. The interested reader may look up the 'MCMemberRecord' attribute in the IB architecture specification [IB_ARCH] for the complete list of characteristics that define a group.

A LID is associated with the multicast group by the SM at the time of the multicast group creation. The SM determines the multicast tree based on all the group members and programs the relevant switches. The Multicast LID (MLID) is used by the switches to route the packets.

Any member IB port wanting to participate in the multicast group must join the group. As part of the join operation, the node receives the group characteristics from the SM. At the same time, the subnet manager ensures that the requester can indeed participate in the group by verifying that it can support the group MTU and its accessibility to the rest of the group members. Other group characteristics may need verification too.

The SM, for groups that span IB subnet boundaries, must interact with IB routers to determine the presence of this group in other IB subnets. If present, the MTU must match across the IB subnets.

P_Key is another characteristic that must match across IB subnets since the P_Key inserted into a packet is not modified by the IB switches or IB routers. Thus, if the P_Keys did not match the IB router(s) itself might drop the packets or destinations on other subnets might drop the packets.

A join operation may cause the SM to reprogram the fabric so that the new member can participate in the multicast group. By the same token, a leave may cause the SM to reprogram the fabric to stop forwarding the packets to the requester.

1.3.1. Multicast Member Record

The multicast group is maintained by the SM with each of the group members represented by an MCMemberRecord [IB_ARCH]. Some of its components are the following:

```
MGID      - Multicast GID for this multicast group
PortGID   - Valid GID of the port joining this multicast group
Q_Key     - Q_Key to be used by this multicast group
MLID      - Multicast LID for this multicast group
MTU       - MTU for this multicast group
P_Key     - Partition key for this multicast group
SL        - Service level for this multicast group
Scope     - Same as MGID address scope
JoinState - Join/Leave status requested by the port:
            bit 0: FullMember
            bit 1: NonMember
            bit 2: SendOnlyNonMember
```

1.3.1.1. JoinState

The JoinState indicates the membership qualities a port wishes to add while joining/creating a group or delete when leaving a group. The meaning of the JoinState bits are as follows:

FullMember:
Messages destined for the group are routed to and from the port. A group may be deleted by the SM if there are no FullMembers in the group.

NonMember:
Messages destined for the group are routed to and from the port. The port is not considered a member for purposes of group creation/deletion.

SendOnlyNonMember:
Group messages are only routed from the port but not to the port. The port is not considered a member for purposes of group creation/deletion.

A port may have multiple bits set in its record. In such a case, the membership qualities are a union of the JoinStates. A port may leave the multicast group for each of the JoinStates individually or in any combination of JoinState bits [IB_ARCH].

1.3.2. Join and Leave Operations

An IB port joins a multicast group by sending a join request (SubnAdmSet() method) and leaves a multicast group by sending a leave message (SubnAdmDelete() method) to the SM. The IBA specification [IB_ARCH] describes the methods and attributes to be used when sending these messages.

1.3.2.1. Creating a Multicast Group

There is no 'create' command to form a new multicast group. The FullMember bit in the JoinState must be set to create a multicast group. In other words, the first FullMember join request will cause the group to be created as a side effect of the join request. Subsequent join or leave requests may contain any combination of the JoinState bits.

The creator of the group specifies the Q_Key, MTU, P_Key, SL, FlowLabel, TClass, and the Scope value. A creator may request that a suitable MGID be created for it. Alternatively, the request can specify the desired MGID. In both cases, the MLID is assigned by the SM.

Thus, a group will be created with the specified values when the requester sets the FullMember bit and no such group already exists in the subnet.

1.3.2.2. Deleting a Multicast Group

When the last FullMember leaves the multicast group the SM may delete the multicast group releasing all resources, including those that might exist in the fabric itself, associated with the group.

Note that a special 'delete' message does not exist. It is a side effect of the last FullMember 'leave' operation.

1.3.2.3. Multicast Group Create/Delete Traps

The SA may be requested by the ports to generate a report whenever a multicast group is created or deleted. The port can specify the multicast group(s) it is interested in by using its MGID or by submitting a wild card request. The SA will report these events using traps 66 (for creates) and 67 (for deletes)[IB_ARCH].

Therefore, a port wishing to join a group but not create it by itself may request a create notification or a port might even request a notification for all groups that are created (a wild card request). The SA will diligently inform them of the creation utilizing the aforementioned traps. The requester can then join the multicast group indicated. Similarly, a SendOnlyNonMember or a NonMember might request the SA to inform it of group deletions. The endnode, on receiving a delete report, can safely release the resources associated with the group. The associated MLID is no longer valid for the group and may be reassigned to a new multicast group by the SM.

2. Management of InfiniBand Subnet

To aid in the monitoring and configuration of InfiniBand subnet components, a set of MIB modules needs to be defined. MIB modules are needed for the channel adapters, InfiniBand interfaces, InfiniBand subnet manager, and InfiniBand subnet management agents and to allow the management of specific device properties. It must be noted that the management objects addressed in the IPoIB documents are for all of the IB subnet components and are not limited to IP (over IB). The relevant MIB modules are described in separate documents and are not covered here.

3. IP over IB

As described in section 1.0, the InfiniBand architecture provides a broad set of capabilities to choose from when implementing IP over InfiniBand networks.

The IPoIB specification must not, and does not, require changes in IP and higher-layer protocols. Nor does it mandate requirements on IP stacks to implement special user-level programs. It is an aim of IPoIB specification that the IPoIB changes be amenable to modularization and incorporation into existing implementations at the same level as other media types.

3.1. InfiniBand as Datalink

InfiniBand architecture provides multiple methods of data exchange between two endpoints as was noted above. These are the following:

```
Reliable Connected (RC)
Reliable Datagram  (RD)
Unreliable Connected (UC)
Unreliable Datagram (UD)
Raw Datagram : Raw IPv6 (R6)
             : Raw Ethertype (RE)
```

IPoIB can be implemented over any, multiple, or all of these services. A case can be made for support on any of the transport methods depending on the desired features.

The IB specification requires Unreliable Datagram mode to be supported by all the IB nodes. The host channel adapters (HCAs) are specifically required to support Reliable connected (RC) and Unreliable connected (UC) modes but the same is not the case with target channel adapters (TCAs). Support for the two Raw Datagram modes is entirely optional. The Raw Datagram mode supports a 16-bit Cyclic Redundancy Check (CRC) as compared to the better protection provided by the use of a 32-bit CRC in other modes.

For the sake of simplicity, ease of implementation and integration with existing stacks, it is desirable that the fabric support multicasting. This is possible only in Unreliable datagram (UD) and IB's Raw datagram modes.

Thus, it is only the UD mode that is universal, supports multicast, and supports a robust CRC. Given these conditions it is the obvious choice for IP over InfiniBand [RFC4391].

Future documents might consider the connected modes. In contrast to the limited link MTU offered by UD mode, the connected modes can offer significant benefit in terms of performance by utilizing a larger MTU. Reliability is also enhanced if the underlying feature of automatic path migration of connected modes is utilized.

3.2. Multicast Support

InfiniBand specification makes support of multicasting in the switches optional. Multicast however, is a basic requirement in IP networks. Therefore, IPoIB requires that multicast-capable InfiniBand fabrics be used to implement IPoIB subnets.

3.2.1. Mapping IP Multicast to IB Multicast

Well-known IP multicast groups are defined for both IPv4 and IPv6 [IANA, RFC3513]. Multicast groups may also be dynamically created at any time. To avoid creating unnecessary duplicates of multicast packets in the fabric, and to avoid unnecessary handling of such packets at the hosts, each of the IP multicast groups needs to be associated with a different IB multicast group as far as possible. A process is defined in [RFC4391] for mapping the IP multicast addresses to unique IB multicast addresses.

3.2.2. Transient Flag in IB MGIDs

The IB specification describes the flag bits as discussed in section 1.2. The IB specification also defines some well-known IB MGIDs. The MGIDs are reserved for the IB's Raw Datagram mode which is incompatible with the other transports of IB. Any mapping that is defined from IP multicast addresses therefore must not fall into IB's definition of a well-known address.

Therefore all IPoIB related multicast GIDs always set the transient bit.

3.3. IP Subnets Across IB Subnets

Some implementations may wish to support multiple clusters of machines in their own IB subnets but otherwise be part of a common IP subnet. For such a solution, the IB specification needs multiple upgrades. Some of the required enhancements are as follows:

1) A method for creating IB multicast GIDs that span multiple IB subnets. The partition keys and other parameters need to be consistent across IB subnets.

2) Develop IB routing protocol to determine the IB topology across IB subnets.

3) Define the process and protocols needed between IB nodes and IB routers.

Until the above conditions are met, it is not possible to implement IPoIB subnets that span IB subnets. The IPoIB standards have however, been defined with this possibility in mind.

4. IP Subnets in InfiniBand Fabrics

The IPoIB subnet is overlaid over the IB subnet. The IPoIB subnet is brought up in the following steps:

Note: the join/leave operation at the IP level will be referred to as IP_join/IP_leave and the join/leave operations at the IB level will be referred to as IB_join in this document.

1. The all-IPoIB nodes IB multicast group is created

The fabric administrator creates an IB multicast group (henceforth called 'broadcast group') when the IP subnet is set up. The 'broadcast group' is defined in [RFC4391]. The method by which the broadcast group is setup is not defined by IPoIB. The group may be setup at the SM by the administrator or by the first IB_join.

As noted earlier, at the time of creating an IB multicast group, multiple values such as the P_Key, Q_Key, Service Level, Hop Limit, Flow ID, TClass, MTU, etc. have to be specified. These values should be such that all potential members of the IB multicast group are able to communicate with one another when using them. In the future, as the IB specification associates more meaning with the various parameters and defines IB Quality of Service (QoS), different values for IP multicast traffic may be possible. All unicast packets also need to use the P_Key and Q_Key specified in the broadcast group [RFC4391]. It is obvious that a thought out configuration is required for a successful setup of the IPoIB subnet.

2. All IPoIB interfaces IB_join the broadcast group

The broadcast group defines the span and the members of the IPoIB link. This link gets built up as IPoIB nodes IB_join the broadcast group.

The IB_join to the broadcast group has the additional benefit of distributing the above mentioned multicast group parameters to all the members of the subnet.

Note that this IB_join to the broadcast group is a FullMember join. If any of the ports or the switches linking the port to the rest of the IPoIB subnet cannot support the parameters (e.g., path MTU or P_Key) associated with the broadcast group, then the IB_join request will fail and the requesting port will not become part of the IPoIB subnet.

3. Configuration Parameters

As noted above, parameters such as Q_Key and Path MTU, which are needed for all IPoIB communication, are returned to the IPoIB node on IB_joining the 'broadcast group'. [RFC4391] also notes that

the parameters used in the broadcast group are used when creating other multicast groups.

However, the P_Key must still be known to the IPoIB endnode before it can join the broadcast group. The P_Key is included in the mapping of the broadcast group [RFC4391]. Another parameter, the scope of the broadcast group, also needs to be known to the endnode before it can join the broadcast group. It is an implementation choice on how the P_Key and the scope bits related to the IPoIB subnet are determined by the implementation. These could be configuration parameters initialized by some means by the administrator.

The methods employed by an implementation to determine the P_Key and scope bits are not specified by IPoIB.

4.1. IPoIB VLANs

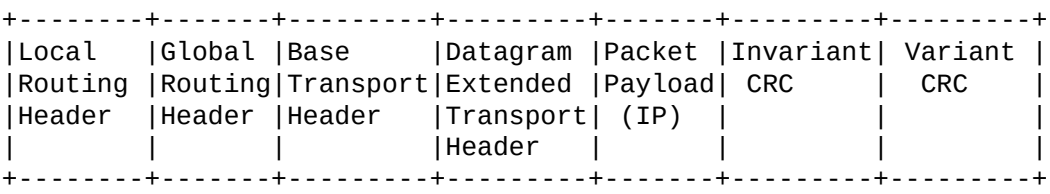
The endpoints in an IB subnet must have compatible P_Keys to communicate with one another. Thus, the administrator when setting up an IP subnet over an IB subnet must ensure that all the members have compatible P_Keys. An IP subnet can have only one P_Key associated with it to ensure that all IP nodes in it can talk to one another. An endpoint may, however, have multiple P_Keys.

The IB architecture specifies that there can be only one MGID associated with a multicast group in the IB subnet. The P_Key is included in the MGID mappings from the IP multicast addresses [RFC4391]. Since the P_Key is unique in the IB subnet, the inclusion of the P_Key in the IB MGIDs ensures that unique MGID mappings are created. Every unique broadcast group MGID so formed creates a separate abstract IPoIB link and hence an IPoIB VLAN.

4.2. Multicast in IPoIB subnets

IP multicast on InfiniBand subnets follows the same concepts and rules as on any other media. However, unlike most other media multicast over InfiniBand requires interaction with another entity, the IB subnet manager. This section describes the outline of the process and suggests some guidelines.

IB architecture specifies the following format for IB multicast packets when used over Unreliable Datagram (UD) mode:



For details about the various headers please refer to InfiniBand Architecture Specification [IB_ARCH].

The Global Routing Header (GRH) includes the IB multicast group GID. The Local Routing Header (LRH) includes the Local Identifier (LID). The IB switches in the fabric route the packet based on the LID.

The GID is made available to the receiving IB user (the IPoIB interface driver for example). The driver can therefore determine the IB group the packet belongs to.

IPv4 defines three levels of multicast conformance [RFC1112].

Level 0: No support for IP multicasting

Level 1: Support for sending but not receiving multicasts

Level 2: Full support for IP multicasting

In IPv6, there is no such distinction. Full multicast support is mandatory. In addition, all IPv4 subnets support broadcast (255.255.255.255). IPv4 broadcast can always be sent/received by all IPv4 interfaces.

Every IPoIB subnet requires the broadcast GID to be defined. Thus, a packet can always be broadcast.

4.2.1. Sending IP Multicast Datagrams

An IP host may send a multicast packet at any time to any multicast address.

The IP layer conveys the multicast packet to the IPoIB interface driver/module. This module attempts to IB_join the relevant IB multicast group. This is required since otherwise InfiniBand architecture does not guarantee that the packet will reach its destinations.

A pure sender may choose to join the multicast group as a FullMember. In such a case, the sender will receive all the multicast packets transmitted to the IB group. In addition, the IB group will not be deleted until the sender leaves the group.

Alternatively, a sender might IB_join as a SendOnlyNonMember. In such a case, the packets are not routed to the sender though packets transmitted by it can reach the other group members. In addition, the group can be deleted when all FullMembers have left the group. The sender can further request delete updates from the SM.

If the sender does not find the group in existence, it is recommended in [RFC4391] that the packets be sent to the MGID corresponding to the all-IP routers address. A sender could also send the packets to the broadcast group. The sender might also choose to request 'creation' reports from the SM.

4.2.2. Receiving Multicast Packets

The IP host must join the IB multicast group corresponding to the IP address. This follows from the IBA requirement that the receiver must join the relevant IB multicast group. The group is automatically created if it does not exist [IB_ARCH].

The IP receivers must IB_leave the IB group when the IP layer stops listening of the corresponding IP address. The SM can then choose to delete the group.

4.2.3. Router Considerations for IPoIB

IP routers know of the new IP groups created in the subnet by the use of protocols such as Internet Group Management Protocol (IGMPv3) / Multicast Listener Discovery (MLD) [RFC3376, RFC2710]. However, this is not enough for IPoIB since the router needs to IB_join the relevant IB groups to be able to receive and transmit the packets. There is no promiscuous mode for listening to all packets.

The IPoIB routers therefore need to request the SM to report all creations of IB groups in the fabric. The IPoIB router can then IB_join the reported group. It is not desirable that the router's IB_joining of a multicast group be considered the same as the IB_join from a receiver -- the router's IB_join should not disallow the group's deletion when all receivers leave. To overcome just this type of situation, IBA provides the NonMember IB_join mode.

The NonMember IB_join mode can be used by IP routers when they join in response to the create reports. A router should ideally request the delete reports too so that it can release all the resources

associated with the group. The MLID associated with a deleted MGID can be reassigned by the SM, and therefore there is a possibility of erroneous transmissions if the MLID is cached. A router that does not request delete reports will still work correctly since it will receive the correct MLID , and purge any old cached value, when it IB_joins the IB group in response to a create report.

It is reasonable for a router to IB_join as a FullMember if it is joining the IB group in response to an application/routing daemon request. In such a case, the router might end up controlling the existence of the IB group (since it is a FullMember of the group).

4.2.4. Impact of InfiniBand Architecture Limits

An HCA or TCA may have a limit on the number of MGIDs it can support. Thus, even though the groups may not be limited at the subnet manager and in the subnet as such, they may be limited at a particular interface. It is advisable to choose an adequately provisioned HCA/TCA when setting up an IPoIB subnet.

4.2.5. Leaving/Deleting a Multicast Group

An IPv4 sender (level 1 compliance) IB_joins the IB multicast group only because that is the only way to guarantee reception of the packets by all the group recipients. The sender must, however, IB_leave the group at some time. A sender could, when not a receiver on the group, start a timer per multicast group sent to. The sender leaves the IB group when the timer goes off. It restarts the timer if another message is sent.

This suggestion does not apply to the IB broadcast group. It also does not apply to the IB group corresponding to the all-hosts multicast group. An IPv4 host must always remain a member of the broadcast group.

An IP multicast receiver IB_leaves the corresponding IB multicast group when it IP_leaves the IP multicast group. In the case of IPv4 implementation, the receiver may choose to continue to be a sender (level 1 compliance), in which case it may choose not to IB_leave the IB group but start a timer as explained above.

As noted elsewhere, the SM can choose to free up the resources (e.g., routing entries in the switches) associated with the IB group when the last FullMember IB_leaves the group. The MLID therefore becomes invalid for the group. The MLID can be reassigned when a new group is created.

SendOnlyNonMember/NonMember ports caching the MLID need to avoid this possibility. The way out is for them to request group delete reports. An IP router requesting reports for all groups need not request the delete report since an IB_join in response to a create report will return the new MLID association to it.

A router might prefer to IB_leave the IB multicast group when there are no members of the IP multicast address in the subnet and it has no explicit knowledge of any need to forward such packets.

4.3. Transmission of IPoIB Packets

The encapsulation of IP packets in InfiniBand is described in [RFC4391].

It specifies the use of an 'Ethertype' value [IANA] in all IPoIB communication packets. The link-layer address is comprised of the GID and the Queue Pair Number (QPN) [RFC4391].

To enable IPoIB subnets to span across multiple IB-subnets, the specification utilizes the GID as part of the link-layer address. Since all packets in IB have to use the Local Identifier (LID), the address resolution process has the additional step of resolving the destination GID, returned in response to Address Resolution Protocol (ARP) / Neighbor Discover (ND) request, to the LID [RFC4391]. This phase of address resolution might also be used to determine other essential parameters (e.g., the SL, path rate, etc.) for successful IB communication between two peers.

As noted earlier, all communication in the IPoIB subnet derives the Q_Key to use from the Q_Key specified in the broadcast group.

4.4. Reverse Address Resolution Protocol (RARP) and Static ARP Entries

RARP entries or static ARP entries are based on invariant link addresses. In the case of IPoIB, the link address includes the QPN, which might not be constant across reboots or even across network interface resets. Therefore, static ARP entries or RARP server entries will only work if the implementation(s) using these options can ensure that the QPN associated with an interface is invariant across reboots/network resets [RFC4391].

4.5. DHCPv4 and IPoIB

DHCPv4 [RFC2131] utilizes a 'client identifier' field (expected to hold the link-layer address) of 16 octets. The address in the case of IPoIB is 20 octets. To get around this problem, IPoIB specifies [RFC4390] that the 'broadcast flag' be used by the client when requesting an IP address.

5. QoS and Related Issues

The IB specification suggests the use of service levels for load balancing, QoS, and deadlock avoidance within an IB subnet. But the IB specification leaves the usage and mode of determination of the SL for the application to decide. The SL and list of SLs are available in the SA, but it is up to the endnode's application to choose the 'right' value.

Every IPoIB implementation will determine the relevant SL value based on its own policy. No method or process for choosing the SL has been defined by the IPoIB standards.

6. Security Considerations

This document describes the IB architecture as relevant to IPoIB. It further restates issues specified in other documents. It does not itself specify any requirements. There are no security issues introduces by this document. IPoIB-related security issues are described in [RFC4391] and [RFC4390].

7. Acknowledgements

This document has benefited from the comments and suggestions of the members of the IPoIB working group and the members of the InfiniBand(SM) Trade Association.

8. References

8.1. Normative References

[IB_ARCH] InfiniBand Architecture Specification, Volume 1, Release 1.2, October, 2004.

[RFC4391] Chu, J. and V. Kashyap, "Transmission of IP over InfiniBand (IPoIB)", RFC 4391, April 2006.

[RFC4390] Kashyap, V., "Dynamic Host Configuration Protocol (DHCP) over InfiniBand", RFC 4390, April 2006.

[RFC2131] Droms, R., "Dynamic Host Configuration Protocol", RFC 2131, March 1997.

8.2. Informative References

[RFC3513] Hinden, R. and S. Deering, "Internet Protocol Version 6 (IPv6) Addressing Architecture", RFC 3513, April 2003.

[RFC2375] Hinden, R. and S. Deering, "IPv6 Multicast Address Assignments", RFC 2375, July 1998.

[IANA] Internet Assigned Numbers Authority, URL http://www.iana.org

[RFC1112] Deering, S., "Host extensions for IP multicasting", STD 5, RFC 1112, August 1989.

[RFC3376] Cain, B., Deering, S., Kouvelas, I., Fenner, B., and A. Thyagarajan, "Internet Group Management Protocol, Version 3", RFC 3376, October 2002.

[RFC2710] Deering, S., Fenner, W., and B. Haberman, "Multicast Listener Discovery (MLD) for IPv6", RFC 2710, October 1999.

Author's Address

Vivek Kashyap
IBM
15450, SW Koll Parkway
Beaverton, OR 97006

Phone: +1 503 578 3422
EMail: vivk@us.ibm.com

Full Copyright Statement

Intellectual Property

Acknowledgement

Funding for the RFC Editor function is provided by the IETF Administrative Support Activity (IASA).