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IP over InfiniBand: Connected Mode

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Abstract

This document specifies transmission of IPv4/IPv6 packets and address resolution over the connected modes of InfiniBand.

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1.0 Introduction

The InfiniBand specification [IB_ARCH] can be found at www.infinibandta.org. The document [IPoIB_ARCH] provides a short overview of InfiniBand architecture along with consideration for specifying IP over InfiniBand networks.

The InfiniBand architecture (IBA) defines multiple modes of transports. Of these the unreliable datagram (UD) transport method best matches the needs of IP. IP over InfiniBand (IPoIB) over UD is described in [IPoIB_UD]. This document describes IP transmission over the connected modes of IBA.

IBA defines two connected modes:

1. Reliable Connected (RC)
2. Unreliable Connected (UC)

As is evident from the nomenclature, the two modes differ mainly in providing reliability of data delivery across the connection. This document applies equally to both the connected modes. IPoIB over these two modes is referred to as IPoIB-CM (connected

mode) in this document. For clarity, IPoIB over the unreliable datagram mode as described in [IPoIB_UD], is referred to as IPoIB-UD.

IBA requires that all Host Channel Adapters (HCAs) support the reliable and unreliable connected modes [IB_ARCH]. It is optional for Target Channel Adapters (TCAs) to support the connected modes.

The connected modes offer link MTUs of up to 2^31 octets in length. Thus, the use of connected modes can offer significant benefits by supporting reasonably large MTUs. The datagram modes of InfiniBand Architecture (IBA) are limited to 4096 octets.

Reliability is also enhanced if the underlying feature of "automatic path migration" supported by the connected modes is utilized.

The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD", "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be interpreted as described in RFC 2119 [RFC2119].

2.0 IPoIB-connected mode

IPoIB over connected mode is an OPTIONAL extension to IPoIB-UD. Every IPoIB implementation MUST support [IPoIB-UD] and MAY support the extensions described in this document.

Therefore, IP encapsulation, default MTU, link layer address format and the IPv6 stateless autoconfiguration mechanism apply to IPoIB-CM exactly as described in [IPoIB_UD].

2.1 Multicasting

The connected modes of IBA define a non-broadcast, multiple access network. The connected modes of IBA do not support multicasting though every node can communicate with every other node if desired.

This requires that multicasting be emulated in some form by the network. However, in the case of an InfiniBand network, instead of an emulation, an unreliable datagram (UD) queue pair (QP) can be used to support multicasting while the connected mode QP is used for unicast traffic. Since every IPoIB implementation is required to support the UD mode, every implementation supporting IPoIB-CM will be able to utilize the pre-existing IPoIB-UD QP for all broadcast/multicast communications.

Multicast mapping, transmission and reception of multicast packets and multicast routing MUST use the UD QP associated with the IPoIB interface.

2.2 Outline of Address Resolution

Every IPoIB-CM interface MUST have two sets of QPs associated with it:

1) One unreliable datagram QP
2) One or more connected mode QPs

[IPoIB_UD] describes the address resolution method to determine the link address of the peer. This response is received on the UD QP associated with the IPoIB interface.

2.3 Outline of Connection setup

Once the link address of the remote node is known, an IB connection must be setup between the nodes before any IP communication may occur.

To make a connection, the sender must know the service-ID to use in the request to make a connection [IB_ARCH]. It must also supply the "connection mode" queue pair to the remote node. The peer replies with its queue pair. Each IB connection is peer to peer and uses one connected mode QP at each end.

Though the address resolution occurs at an individual IP address level, the connection between the nodes is at the IB layer. Therefore, every individual address resolution does not imply a new connection between the peers.

3.0 Address Resolution

Address resolution queries are sent out on the "broadcast-GID" over the UD QP associated with the IPoIB interface. A unicast reply is received on the UD QP.

3.1 Link-layer Address

IPoIB encapsulation [IPoIB_UD] describes the link-layer address as follows:

<1 octet reserved>:QP: GID

This document extends the link-layer address as follows:

<Flags>:QPN:GID

Flags:

This is a single octet field. The bits indicate the connected modes supported by the interface.

Bit 0 specifies the support for the "reliable connected" (RC) mode. Bit 1 indicates the support for the "unreliable connected" (UC) mode. All other bits in the octet are reserved and MUST be set to 0 on transmits and ignored on receives. The format of the flags is:

```
+--+--+--+--+--+--+--+--+
|RC|UC| 0| 0| 0| 0| 0| 0|
+--+--+--+--+--+--+--+--+
```

Both the RC and UC MAY be set at the same time if the interface supports both the modes. Since the IPoIB-UD mode is always supported there are no flags to indicate IPoIB-UD support.

If IPoIB-CM is not supported i.e. if the implementation only supports IPoIB-UD, then the implementation MUST ignore the <Flags> on reception. It MUST set the <Flags> octet to all zeroes on transmission as specified in [IPoIB_UD].

QPN:

The queue-pair number (QPN) on which the unicast address resolution reply will be received [IPoIB_UD]. An IPoIB interface has only one UD QP associated with it whether it supports this extension or not.

The QPN also serves another purpose. It is used to form the Service-ID that is used to setup the IB connection.

On receiving the multicast/broadcast address resolution request, the receiver replies with its own link-address, including the associated UD QPN and the appropriate flags.

The receiver's reply is unicast back to the sender after the receiver has, as in the case of IPoIB-UD, resolved the GID to the LID, and determined other required parameters [IPoIB_UD].

Once the address resolution is completed the underlying IB connection on the supported connection modes can be set up. An implementation is NOT REQUIRED to setup a connection merely because the peer indicates the capability. The decision to make such a connection is left to the implementation.

3.2 IB Connection Setup

Once the address resolution is complete the IB connection can be setup by either of the peers. To setup a connection IB Management Datagrams (MADs) are directed to the peer's communication manager (CM). The connection request always contains a Service-ID for the peer to associate the request with the appropriate service. If the request is accepted, the peer returns the relevant connected mode QPN in the response MAD. The format of the CM connection messages and the IB connection setup process is described in [IB_ARCH]. The overall handshake is of the form:

```
REQ ---->
     <---- REP [or REJ(reject)]
RTA ---->
[or REJ(reject)]
```

The CM messages include, among other parameters, the Service-ID, Local connection-mode QPN, and the payload size to use over the connection.

Note:

The IB connection is setup using the Service-ID as defined in section 3.5 below. The node MUST keep a record of IB connections it is participating in. The node MAY attempt another connection to the remote peer using the same Service-ID as used for an existing IB connection. Similarly, the receiver of such a connection MAY drop the request with a suitable error indication in the CM response. The decision to accept or initiate multiple connections from or to an IPoIB interface is left to the implementation.

The node that initiated the connection is aware of the target node's IP address as described above. The node receiving the IB connection request, however cannot determine the initiating node's link address. To enable this determination, every CM message exchanged in setting up the IB connection, MUST include the sender's IPoIB-UD QPN in the "private data" [IB_ARCH] field. The IPoIB-UD QPN MUST be included in all "REJ" [IB_ARCH] messages too.

3.3 Simultaneous IB Connections

To ensure that two IB connections are not setup between the peers due to REQ crossing, the following rules MUST be followed:

The receiver forms the remote node's link-layer address using the UD QPN received in the "private data" field of the "REQ" message and the GID of the sender included in the "REQ" message. The link-layer address is used to determine if there is already an outstanding connection request "REQ" sent by the local interface to the given received link-layer address. If such an outstanding request is determined, then the two link-layer addresses (local and remote) are numerically compared. If the local link-layer address is numerically smaller, then the connection is accepted, otherwise rejected. The error code in "REJ" MAD is set to "Consumer Reject" [IB_ARCH].

Note:

The link-layer addresses formed for comparison zero out the connection mode flags specified in section 3.1. The comparison is performed from the most significant octet to the least significant octet of the link-layer address.

The above holds even if the receiver supports multiple IB connections from the same peer. This is to ensure that only one more connection is setup when the "REQ" messages cross.

3.4 IPoIB-CM IB Connection Teardown

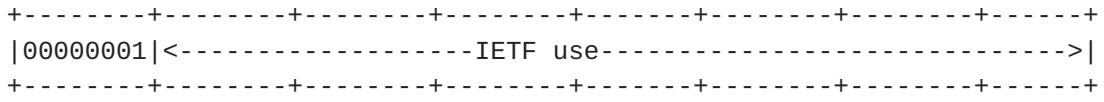
IB connections created through IPoIB-CM are considered part of an IPoIB interface. As such, they SHOULD be torn down when the IPoIB interfaces they are associated with is torn down.

Furthermore, the IB connection between two peers MAY be torn down by either peer whenever the address resolution entry expires. An implementation is free to implement alternative policies for tearing down of IB connections between peers.

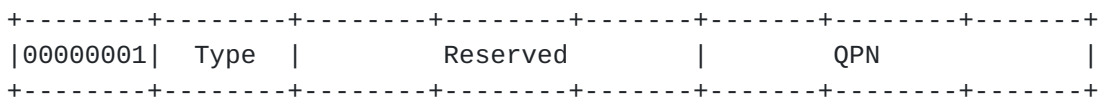
3.5 Service-ID

The InfiniBand specification defines a block of service IDs for IETF use. The InfiniBand specification has left the definition

and management of this block to the IETF [IB_ARCH]. The 64-bit block is:



The Service-IDs used by IPoIB will be in the format:



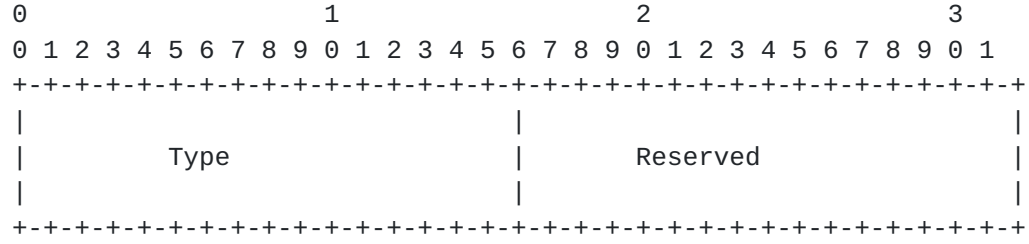
The "Type" field MUST be set to 0.

The "Reserved" field MUST be set to zeroes.

The QPN MUST be the UD QP exchanged during address resolution.

4.0 Frame Format

All IP datagrams transported over InfiniBand are prefixed by a 4-octet encapsulation header as described in [IPoIB_UD].



The type field SHALL indicate the encapsulated protocol as per the following table.

Type	Protocol
0x800	IPv4
0x86DD	IPv6

These values are taken from the "ETHER TYPE" numbers assigned by Internet Assigned Numbers Authority (IANA). Other network protocols, identified by different values of "ETHER TYPE", may use the encapsulation format defined herein, but such use is outside of the scope of this document.

5.0 Maximum Transmission Unit

The IB connection setup might be used for both IPv4 and IPv6 or it could be used for only one of them while a different connection is used for the other. The link MTU MUST be able to support the minimum MTU required by the protocols.

The default MTU of the IPoIB-CM interface is 2044 octets i.e. 2048 octet IPoIB-link MTU minus the 4 octet encapsulation header.

However, connected modes of InfiniBand allow message sizes up to 2^31 octets. Therefore, IPoIB-CM can use a much larger MTU for unicast communication between any two endpoints. The maximum and/or optimal payload that can be received or sent over an InfiniBand connection is dependent on the implementation, HCA and the resources configured.

An implementation MAY utilise the following mechanism to exchange the optimal message size across the IB connection.

5.1 Per-Connection MTU

Every IB connection setup message includes a "private data" field [IB_ARCH]. The "private data" field in the connection setup message (CM REQ) MUST include the "Receive MTU". This indicates the maximum packet size the requester can accept. The requester MUST be able to accept smaller MTU sizes as well.

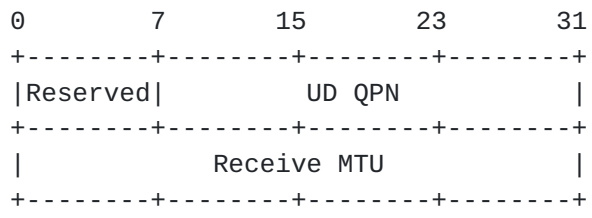
It is up to the implementation to utilize this mechanism for setting the per IB connection MTU. To calculate the resultant IPoIB MTU over the connection the smaller of the two IB "Receive MTU" values is used by both the peers. The IPoIB interface must also account for the 4-octet encapsulation header and so the IPoIB MTU over the connection will be further reduced by that amount.

6.0 Private-Data Format

The "private data" field in every CM message for connection establishment must include the following values:

1. UD QPN of the sender
2. Receive MTU supported by the sender

The format of "private data" field MUST be:



The Reserved value MUST be set to zero on transmit and ignored on receive.

7.0 IPoIB-CM Considerations

Every IPoIB interface supports IPoIB-UD. It may additionally support one or both of IPoIB-CM modes. Therefore, there can be multiple methods of communicating between any two peers. This implies that an interface MAY transmit/receive a packet over any of the RC, UC or UD modes depending on the modes supported between it and the peer. It further follows that every IPoIB implementation compliant with this document MUST accept all IP unicast transmissions over any of the IPoIB modes it supports. Multicast and broadcast packets by their nature will always be transmitted and received over the IPoIB-UD QP. Additionally, all address resolution responses (ARP or Neighbor Discovery) MUST always be encapsulated in a UD mode packet.

7.1 A Cautionary Note on IPoIB-RC

The RC mode of InfiniBand guarantees in-order delivery of packets. Every message transmitted over the RC connection is broken into physical MTU sized packets by the RC connection. If any packet is lost, it is retransmitted until the complete message is exchanged. Therefore, there is a possibility of an upper transport layer experiencing a timeout, while the RC layer is still in the process of transferring the complete message. TCP will view the timeout as an indicator of congestion and enter slow-start thereby affecting throughput drastically [RFC2581]. Other upper layer protocols might insert retransmissions into the fabric adding to the already existing congestion.

The applicability of Infiniband reliability is on a fabric with short latencies (not wide area). Therefore, the RC timer values should be short compared with the starting minimum time values used by the upper end-to-end transports. In addition, because the RC mode does not have measurement based reliable

transmission, its use over fabrics with long latency or very dynamic latency may be a concern for congestion- aware traffic traversing those fabrics.

7.2 IPoIB-CM Per-Destination MTU

As described above, interfaces on the same subnet may support different link MTUs based on the negotiated value or due to the link type (UD or connected mode). Therefore, an implementation might choose to define a large IP MTU which is reduced based on the MTU to the destination. The relevant MTU may be stored in a suitable per-destination object, such as a route cache or a neighbour cache. The per-destination MTU is known to the IPoIB-CM interface as described in section 5.0.

Implementations might choose not to support differing MTU values and always support an MTU equal to the IPoIB-UD MTU determined from the broadcast GID.

8.0 Security Considerations

A node may be returned a false set of flags by an impostor. This may cause unnecessary attempts and some delay/disruption in IPoIB communication. The same is the case if wrong/spurious QPN values are provided during address resolution broadcast/multicast.

9.0 IANA Considerations

Future uses of the reserved bits and octets in the link-layer address (section 3.1), Service-ID (section 3.5), and "Private-Data Format" (section 6.0), MUST be published as RFCs. This document requires that the reserved bits be set to zero on sends.

10.0 Acknowledgements

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11.0 References

Normative

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