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TITLE: **Address Resolution Proposal**

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ABSTRACT: This contribution proposes an address resolution method to associate addresses in the client space with those in the optical network. The proposed approach emphasizes the use of client addresses for lightpath destinations, rather than termination points in the optical network. This proposal:

- Supports the overlay network model, where the address resolution is performed by the optical network
- Supports multiple client address types (IPv4, E.164, others)
- Maintains a separate address space between the client and optical network
- Allows the client to signal a lightpath request using either the destination client address or the optical network termination point
- Proposes semantics for the addressing, and uses the notion of a logical address for termination points
- Supports address registration either inside or outside the neighbor discovery process
- Considers issues of address space uniqueness and address distribution methods within the optical network

Introduction

This contribution proposes an address resolution method to associate addresses in the client space with those in the optical network. This contribution:

- Supports the overlay network model, where the address resolution is performed by the optical network
- Supports multiple client address types (IPv4, IPv6, E.164, others)
- Maintains a separate address space between the client and optical network
- Allows the client to signal a lightpath request using either the destination client address or the optical network termination point
- Proposes semantics for the addressing, and uses the notion of a logical address for termination points
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The motivation for this work was a network vision using an overlay model between the client devices and the optical network. To the optical network, the “client” may be either a router or an interface to another administrative domain. The optical network may consist of optical cross-connects providing the routing intelligence, as well as optical add-drop multiplexers providing connectivity to client devices.

The proposed approach emphasizes the use of client addresses for lightpath destinations, rather than termination points in the optical network. This provides the following advantages:

- It conceals the optical network resource information from client devices
- It supports the overlay network model, our model of choice, while still supporting peer approaches
- It cleanly separates the client and optical network address spaces
- It simplifies the requirements of client devices and offers scalability advantages by reducing the amount of information that must be received and maintained by the clients

Address Registration and Resolution

In the proposed address resolution, the client address space and optical network address space are kept completely separated. It allows a client to directly specify a destination client address (using IPv4, E.164 or other address type) when lightpaths are established. The format defined in the section 6.1 of the User Network Interface – UNI v1.0 Proposal (reference: OIF2000.125.2) for identifying internal lightpath termination points is still used to identify source and destination addresses within the optical network. Such an address could automatically be translated within the optical network to identify the ONE termination-point for the lightpath.

Addressing scheme

The concepts used to describe the termination-point address registration mechanism are the following:

- **Logical-address**: the address associated with a logical-port.

Logical-address could be one of the following:

- IPv4 address: 32-bit field
- IPv6 address: 128-bit field
- ITU-T E.164 ATM End System Address (AESA): 160-bit field
- British Standards Institute ICD AESA: 160-bit field
- ANSI DCC AESA: 160-bit field
- Ethernet address: 48-bit field

- Default-value: 56-bit field (UNSPECIFIED: 0x0...0)

The logical-address field (maximum 21-byte field) consists of the logical-address type sub-field and the logical-address value sub-field:

- the logical-address type is a 8-bit sub-field indicating the type of the logical-address (default-value of the logical-address type is 0x00).
- the logical-address value is a variable-length field of maximum 20 bytes indicating the value of the logical-address (maximum 20-byte sub-field without justification).

The default-value (type 0x00) is a 56-bit field to optionally indicate the User-Group ID (7-byte field) within this field. Consequently, the logical-address of the Client will map a virtual identifier corresponding to the User-Group ID to which the lightpath belongs. By using this method, the Virtual Private optical Network – VPoN concept is integrated within the logical addressing scheme.

- **Logical-port ID**: identifies a logical port; concatenation of the port-ID (16-bit field), the Channel-ID (8-bit field) and the Sub-channel-ID (8- bit field), as described in Chapter 6 of OIF2000.125.2.

- **Termination-point ID**: 64-bit field resulting from the concatenation of the unique IPv4 address (32-bit field) associated with the device and the logical-port ID (32-bit field) , as described in Chapter 6 of OIF2000.125.2.

- **Termination-point address**: concatenation of the logical address and the termination-point ID.

Consequently for the Client Network Element (CNE) addressing:

<CNE termination-point address> := <logical address; termination-point ID>
<CNE termination-point ID> := <CNE IPv4 address; logical-port ID>

The termination-point ID is a 64-bit field (32-bit IP Address, 16-bit Port ID; 8-bit Channel ID, 8-bit Sub-Channel ID). By concatenating this value with the logical-address a maximum 232-bit field results.

and for the Optical Network Element (ONE) addressing:

<ONE termination-point address> := <logical address; termination-point ID>
<ONE termination-point ID> := <ONE IPv4 address; logical-port ID>

For ONEs which do not associate logical addresses with their interfaces, the ONE termination-point address corresponds to the UNSPECIFIED value concatenated with the ONE termination-point ID.

The following table summarizes the type, length and default values of the terms defined above:

Type	Length	Default Value
Logical-Address	Max. 160-bit	0x00000000000000 (56-bit)
Logical-Address Type	8-bit	0x00 (8-bit)
Logical-port ID	32-bit	0x00000000 (32-bit)
Termination-point ID	64-bit	
Termination-address	Max. 232-bit	

Address Registration - Procedure

The address registration mechanism enables the dynamic registration of the CNE logical address into the optical network. This mechanism in turn enables the mapping between the ONE Termination-Point ID and the CNE logical address corresponding to CNE Termination-Point ID to which the ONE Termination-Point is connected.

The address registration could occur either during the neighbor discovery process or during the end-point registration process (reference: OIF2000.125.2 - Chapter 9) depending on:

- If this mechanism occurred at the end of the initial neighbor discovery process then the client initiates a registration process that associates the CNE Termination-point ID with the corresponding address Logical-Address together with ONE Port ID.
- If this mechanism occurred at the end of the end-point identity registration process, then the client initiates a registration process that associates the CNE Termination-point ID with the corresponding address Logical-Address together with ONE Termination Point ID.

Consequently, we have the following potential sequences into which the address registration can be included:

- Address registration inside neighbor discovery process:

1. Setup a communication channel for neighbor discovery
2. Neighbor discovery with Address registration
3. Setup a communication session for service discovery
4. Exchange service and port (resource) capabilities
5. Setup signaling session/channel

- Address registration outside neighbor discovery process (default behavior):

1. Neighbor discovery (not based on communication channel)
2. Setup a communication channel for service discovery
3. Exchange service and port (resource) capabilities
4. Address registration
5. Setup signaling session/channel

The common address registration process occurs in two steps.

Step 1 - The first step enables the discovery between the boundary CNE and ONE of the supported level of address resolution:

- ONE termination-point ID: Type 0x0
- CNE termination-point ID resolution: Type 0x1
- CNE logical-address resolution: Type 0x2

These levels are inclusive, meaning that if the supported level of address resolution is of type 0x1 then the ONE termination-point ID address resolution is implicitly supported.

Consequently, when the default value of the logical address corresponds to the user-group identifier to which the lightpath belongs, the address resolution is based on the CNE termination-point ID. This mechanism reconciles concepts of logical addressing and VPoN by integrating the corresponding user-group identifier within the lightpath logical-address. From the functional point-of-view this built-in feature does not change the VPoN mechanism and enables the user-group identifier to appear as a super-addressing field.

Step 2 - The second step depends on the supported level of address resolution. The ONE termination-point ID mechanism (type 0x0) implies the client CNE knows the mapping between the CNE termination-point ID and the ONE termination-point ID. Since there is no resolution at all and the mappings are static, we do not further consider this mechanism in the remaining parts of this section.

In the second case, the CNE termination-point ID resolution (type 0x1) implies the boundary ONE knows the mappings between the CNE Termination-point ID and the ONE Termination-point ID. This case is considered as a particular variation of the previous case, where the CNE logical address fields are empty.

In the last case (type 0x2), the CNE registers its logical addresses within the optical network through the following exchange: over each port connecting the CNE to the ONE and for each termination-point belonging to this port, the CNE sends the following field to the ONE:

[<<CNE IPv4 address; logical-port ID>; logical address> ; <ONE IPv4 address; logical-port ID>]

Depending on the level of address resolution, the ONE fills the missing fields into the logical-port ID with the channel-ID and sub-channel ID and hence obtains the mapping between the CNE termination-point address:

- and the ONE termination-point ID when the ONE does not associate a logical address with the Termination-point ID
- and the ONE termination-point address when the ONE associates a logical address with the Termination-point ID

For instance, the following field are sent by the CNE and registered by the ONE:

[<<CNE IP Address; Log-Port ID>; Unspecified> ; <ONE IP Address, Log-Port ID>]
[<<CNE IP Address; Log-Port ID>; Unspecified> ; <ONE IP Address, Log-Port ID>]
...
[<<CNE IP Address; Log-Port ID>; E.164 AESA> ; <ONE IP Address, Log-Port ID>]
[<<CNE IP Address; Log-Port ID>; E.164 AESA> ; <ONE IP Address, Log-Port ID>]
...

[<<CNE IP Address; Log-Port ID>; Sub-interface IP Address> ; <ONE IP Address, Log-Port ID>]
[<<CNE IP Address; Log-Port ID>; Sub-interface IP Address> ; <ONE IP Address, Log-Port ID>]
...

where <CNE IP Address; Log-Port ID> := <CNE Termination-Point ID>
<ONE IP Address; Log-Port ID> := <CNE Termination-Point ID>

By receiving these mappings the ONE will attach the corresponding Termination Point-ID (more precisely, if needed the ONE will fill the missing field of the Logical-Port ID and so uniquely define the Termination-Point ID). Consequently, the ONE has the knowledge of all the mappings between the CNE logical addresses and the Termination-Point IDs.

The mappings between the CNE Logical Address and ONE Termination-Point ID could either distributed into the optical sub-network (through the use of a Topology & Resource Distribution Protocol) or sent to a centralized directory service.

Consequently, the client address space and optical network address space are kept completely separated.

Address Space Uniqueness

By default, the address space is unique within a given optical network. This means that all client addresses connected to the same optical network must be unique. However, if the optical network supports the concept of client identifier (which determines the owner of the CNEs connected to the optical network), then the address space uniqueness could be limited to logical addresses belonging to the same client ID. We do not further consider this option in the remaining part of the document.

In to order to guarantee the uniqueness of the client addressing scheme and consequently the uniqueness of the mappings, the following mechanism is provided during the client address registration process:

When the CNE sends the logical address – termination-point ID mappings to the ONE

[<<CNE IP Address; Log-Port ID>; E.164 AESA> ; <ONE IP Address, Log-Port ID>]
[<<CNE IP Address; Log-Port ID>; E.164 AESA> ; <ONE IP Address, Log-Port ID>]
...
[<<CNE IP Address; Log-Port ID>; IPv4 Address> ; <ONE IP Address, Log-Port ID>]
[<<CNE IP Address; Log-Port ID>; IPv4 Address> ; <ONE IP Address, Log-Port ID>]
...

For each registered address, the ONE responds as follows

[<<CNE IP Address; Log-Port ID>; E.164 AESA> ; <<ONE IP Address, Log-Port ID> ; <Status>>]
[<<CNE IP Address; Log-Port ID>; E.164 AESA> ; <<ONE IP Address, Log-Port ID> ; <Status>>]
...
[<<CNE IP Address; Log-Port ID>; IPv4 Address> ; <<ONE IP Address, Log-Port ID> ; <Status>>]
[<<CNE IP Address; Log-Port ID>; IPv4 Address> ; <<ONE IP Address, Log-Port ID> ; <Status>>]
...

The status-field indicates if the mapping between the logical-address and the corresponding termination-point ID has been registered or rejected.

If the mapping has been registered, then it means that this mapping is unique within the optical network; otherwise if the mapping has been rejected it means that either the logical address already exists within the optical network or the logical address-type is invalid.

When a duplicated logical address generates a mapping rejection, the rejected mapping must be the one coming from the newly non-registered address. This in order to ensure a non-disruptive service for the established lightpath already using this mapping. Additional mechanisms could be defined to enable logical address mismatch, rejection, and error tracking. These mechanisms are left for further study.

Address Resolution - Procedure

The address registration mechanism enables the following addressing option: At the UNI the lightpath create request sent by the CNE does not need to include the ONE Source and Destination Termination-Point Address (or Termination-point ID if there is no logical address associated with the corresponding Termination-point ID).

The lightpath create message sent by the CNE to the ONE includes the source CNE logical address and the destination CNE logical address. When receiving this message, the ONE either performs an address-lookup to its local mapping table or sends an address-lookup request to a centralized directory service.

When receiving the mapping between the CNE Logical Address and the ONE Termination-point ID, the ONE adds (or replaces depending on the signaling protocol) into the lightpath create message the Logical address of the corresponding Termination-Point ID.

Consequently, the optical network client only needs to know the CNE source and destination logical address in order to request a lightpath creation; any other topological information concerning the optical network termination-point is transparent for the client.

Address mappings – Distribution

In a centralized approach, the CNE logical-address to ONE termination-point ID mappings (the CNE Termination-point ID to ONE Termination-point ID) are available through an address-lookup request to centralized directory service. Within this approach, if the directory service is unavailable or unreachable the UNI-N sends a notification message to the client. Then the client may decide to use the CNE termination-point ID or the ONE termination-point ID depending on the address resolution mechanism supported.

In a distributed approach, the topology Distribution Protocol is the mechanism provided to distribute the discovered termination-point information of the boundary ONE included in an optical sub-network.

The Topology Distribution Protocol is closely related to the neighbor discovery (cf. Neighbor discovery protocol) and based on the OSPF basic concepts:
- maintaining neighbor relationship with peering ONEs

- flooding of the ONEs state and adjacencies
- flooding of the ONEs topological and resource information

The topological information flooded through the optical sub-network includes the CNE logical address to termination-point ID mappings. The other topological information flooded throughout the optical sub-network is the following:
- the termination-point identifier,
  - the termination-point resource-related information (available and reservable bandwidth and the associated framing)
- the termination-point protection level(s)
- and termination-port diversity (SRLG-related information)

Note: For further details concerning the topology distribution protocol refer to OIF2000.083; these considerations are out of scope for this contribution.

<u>Address Mappings – Updates</u>

The CNE address space and ONE address space are disjoint. Relationships between these address spaces are realized through the address mappings. Consequently, when a CNE Logical Address modification occurs only the address mapping must change; the lightpath source and destination-point identifiers remain unchanged.

In a distributed approach, address mappings updates are flooded throughout the optical network by using the topology distribution protocol. In a centralized approach, address mappings updates are directed to the centralized directory service.

<u>Rationale for Proposed Address Resolution</u>

The address resolution described in this contribution allows the client to signal a lightpath request using only the destination client address, without an internal ONE termination point identifier. This form of address resolution would be the responsibility of the optical network, not the client. This raises issues of the additional processing burden placed on the optical network, and what benefit is derived from it. The rationale for the proposed approach in light of these issues is as follows.

1. <u>Processing Demands</u> The processing demands of the ingress ONE may not be much greater under the proposed approach. Even when using internal ONE termination point ID’s for lightpath create requests, the ingress ONE needs current information on the ports of the egress ONE in order to route the lightpath, and to “validate” the request (to verify that the requested endpoint is valid and available). What the ingress ONE does not need to know in the current OIF specification is knowledge of the destination client (e.g. the IP address). This may not be a significant addition to the functionality already required of an ONE.

2. <u>Link State Updates</u> Over time, the status of individual links between ONE's and clients will change. Some links will be used by active lightpaths, some may fail, some may be added or taken out of service. A client requesting a new lightpath using internal ONE endpoint ID's would have to be aware of these changes. The optical network needs this link status whether it performs address resolution or not, to validate

and route the lightpath request. Decoupling the client from knowledge of link state of other UNI's should simplify the client requirements and reduce the information needed by the client.

3. Multiple Client Access Points A destination client may be connected to more than one egress ONE. The optical routing/traffic engineering algorithms may be able to choose a better route through the optical network to the destination than the source client, who does not know internal optical network topology.

4. Operational Benefits The motivation for relegating the address resolution to the optical network is not to benefit the optical network, but rather the clients. Using this address resolution approach the client does not need to know the ONE termination points. A client TMN can thus setup paths without regard to resource details of the optical network This should simplify the demands on clients, allowing more clients to access the optical network.

This contribution does not define a dedicated address resolution protocol but a mechanism within the functions already defined for ONE's. This would not be the case if the address mappings are located on the client. The address resolution is performed during the lightpath setup, allowing a natural integration with the Connection Admission Control.

Conclusions

This contribution described an address resolution method to associate addresses in the client space with those in the optical network. It emphasized the use of client addresses for lightpath destinations, but also supported ONE termination points for destinations, as in the current UNI specification. Methods were proposed to support multiple client address types and to maintain a separate address space between the client and optical network. In addition, it described semantics for the addressing, details of the registration and issues of uniqueness and address distribution.

A new section 5.3.2 Address Resolution was recently added to the OIF UNI specification. This section states that Address Resolution "allows a client to obtain the optical network termination point addresses of other clients, subject to user group and policy restrictions." It is recommended that the Address Resolution be considered to include resolution within the optical network to allow a client to request a lightpath using only client addresses. It is also recommended that this contribution be considered for inclusion into that section of the UNI specification.

References:

1. OIF2000.125.2, "User Network Interface (UNI) 1.0 Proposal", October, 31, 2000
2. OIF2000.083.1, "Routing Information Exchange over the UNI and the NNI", May 2, 2000