Common Control and Measurment Plane I. Hussain

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 GMPLS Routing and Signaling Framework for Flexible Ethernet (FlexE)

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Abstract

 This document specifies the GMPLS control plane requirements,

 framework, and architecture for the FlexE technology. The document

 also discusses interoperation between the GMPLS control plane for

 FlexE and the control plane of any networking layer using the FlexE

 technology as a server layer.

 As different from earlier Ethernet data planes FlexE allows for

 decoupling of the Ethernet Physical layer (PHY) and Media Access

 Control layer (MAC) rates.

 Study Group 15 (SG15) of the ITU-T has endorsed the FlexE

 Implementation Agreement from Optical Internetworking Forum (OIF) and

 included it, by reference, in some of their Recommendations.

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1. Introduction

 This document specifies the GMPLS control plane requirements,

 framework, and architecture for the FlexE technology. The FlexE

 control plane requirements are found in an appendix.

 Prior to FlexE Ethernet MAC rates were until constrained to match the

 rates of the Ethernet PHY(s). FlexE, specified by the OIF, allows

 MAC rates to be different from PHY rates. An OIF implementation

 agreement [OIFFLEXE1] allows for complete decoupling of the MAC and

 PHY rates. This has been further extended in [OIFFLEXE2].

 SG15 in ITU-T has endorsed the OIF FlexE data plane and parts of

 [G.872], [G.709], [G.798] and [G.8021]. The Recommendations depends

 on or are based on the FlexE data plane.

 The FlexE implementation agreement includes support for:

 a. MAC rates which are greater than the rate of a single PHY;

 multiple PHYs are bonded to achieve this

 b. MAC rates which are less than the rate of a PHY (sub-rate)

 c. support for channelization within a single PHY, or over a group

 of bonded PHYs.

 The capabilities supported by the FlexE data plane are:

 a. Support a large rate Ethernet MAC over bonded Ethernet PHYs, e.g.

 supporting a 200G MAC over 2 bonded 100GBASE-R PHY(s)

 b. Support a sub-rate Ethernet MAC over a single Ethernet PHY, e.g.

 supporting a 50G MAC over a 100GBASE-R PHY

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 c. Support a collection of flexible Ethernet clients over a single

 Ethernet PHY, e.g. supporting two MACs with the rates 25Gbps, and

 one with rate 50G over a single 100GBASE-R PHY

 d. Support a sub-rate Ethernet MAC over bonded PHYs, e.g. supporting

 a 150G Ethernet client over 2 bonded 100GBASE-R PHY(s)

 e. Support a collection of Ethernet MAC clients over bonded Ethernet

 PHYs, e.g. supporting a 50G and 150G MAC over 2 bonded 100GBASE-R

 PHY(s)

 FlexE networks feature FlexE Ethernet interfaces, for more details

 see Section 4.1.

 From a control plane perspective, the FlexE Groups may be viewed as

 logical links and FlexE Clients as logical sub-interfaces (or

 channelized interfaces).

 These logical point-to-point links may be realized in at least two

 different ways:

 a. direct point-to-point links with no intervening transport

 network.

 b. direct point-to-point links across a transport network transport

 network.

 c. Ethernet PHY(s) may be transparently transported via an Optical

 Transport Network (OTN), as defined by ITU-T in [G.709] and

 [G.798].

 The OTN set of client mappings has been extended to support the

 use cases identified in the OIF FlexE implementation agreement.

 This document is a framework for the network control plane signaling

 and routing extensions required to establish FlexE links (FlexE

 Groups (PHY) and FlexE Clients (MAC)). FlexE Links may interconnect

 customer edge devices (CE to CE), CE to provider edge devices (PE),

 PE to PE, or devices at the edge to devices in the core (PE to P) or

 devices in the core (P to P).

 Any pair of neighbouring L2 and L3 device that support FlexE

 interfaces may be interconnected P2P using a FlexE link (PHY and

 MAC). Further a device that terminates a FlexE link MUST be able to

 extract either the L2 or L3 payload and switch on the appropriate

 level, i.e. Ethernet, MPLS or IP. It should be noted that any type

 of switching is out of scope for the FlexE specification.

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 FlexE CE devices may typically be L3 routers or other devices that

 use FlexE at layers 1 and 2 to provide point-to-point connectivity

 between each other.

 Thus this draft considers the cases in which the two peer FlexE

 devices are:

 o interconnecting two parts of a customer network (CE to CE).

 o at the edge of the customer network (CE) and the close edge of the

 provider network (PE to CE).

 o opposite edges of the FlexE capable network (PE tom PE).

 o at the edge of the FlexE network PE interconnected to a provider

 device (PE to P).

 o interconnecting two provider devices (P to P).

 This list of deployment cases will help identify the GMPLS control

 plane (i.e. routing and signaling) extensions that may be required

 to support establishment of FlexE services.

1.1. Requirements Language

 The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT",

 "SHOULD", "SHOULD NOT", "RECOMMENDED", "NOT RECOMMENDED", "MAY", and

 "OPTIONAL" in this document are to be interpreted as described in BCP

 14 [RFC2119] [RFC8174] when, and only when, they appear in all

 capitals, as shown here.

1.2. Updates in the version

 This section will be removed before posting.

 1. Following a suggestion from Daniele the FlexE Control Plane

 Requirements has been moved to an appendix.

 2. There are still some of the comments from Daniele that might need

 to be addressed, but we have had a pretty large overlap in

 comments, so the intention is that all should be addressed.

 3. The terms Ethernet Interface and Ethernet sub-Interface has been

 re-introduced in relation to FlexE Group and FlexE Client

 respectively.

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 4. Except for some spelling corrections Section 5 to Section 7 are

 virtually untouched, though it is likely that some of the changes

 in the earlier parts of the document will have to be reflected

 into those sections also.

2. Terminology

 a. CE (Customer Edge): the group of functions that support the

 termination/origination of data received from or sent to the

 network. Sometimes the term CE device is used.

 b. controller: a joint term for any entity that may set up a LSP,

 FlexE Group or FlexE Client, e.g. a control plane, centralized

 controller, YANG model or management system.

 c. crunch: the term crunch in the context of OTN networks and FlexE

 links is used when e.g. unavailable calendar slots are not

 transported across the OTN network, but are removed at the

 ingress and recreated at the egress.

 d. Ethernet PHY: an entity representing Physical Coding Sublayer

 (PCS), Physical Media Attachment (PMA), and Physical Media

 Dependent (PMD) layers.

 e. FlexE Calendar: The total capacity of a FlexE Group is

 represented as a collection of slots which have a granularity of

 5Gbps. The calendar for a FlexE Group composed of n 100G PHYs is

 represented as an array of 20n slots (each representing 5Gbps of

 bandwidth). This calendar is partitioned into sub-calendars,

 with 20 slots per 100G PHY. Each FlexE Client is mapped into one

 or more calendar slots (based on the bandwidth the FlexE Client

 flow will need).

 f. FlexE Channelized sub-Interface, the channelized Ethernet sub-

 interface realized by the FlexE Client.

 g. FlexE Client: An Ethernet flow based on a MAC data rate that may

 or may not correspond to any Ethernet PHY rate.

 h. FlexE Group: A FlexE Group is composed of from 1 to n Ethernet

 PHYs. In the first version of FlexE each PHY is identified by a

 number in the range {1-254}.

 i. FlexE Interface, the Ethernet interface realized the FlexE Group

 j. FlexE Shim: the layer that maps or demaps the FlexE Client flows

 carried over a FlexE Group.

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 k. LMP: Link Management Protocol

 l. LSP: Label Switched Path

 m. OIF: Optical Internetworking Forum

 n. OTN: Optical Transport Network

 o. PE: Provider Edge (device) the term is used for the functions

 needed at the edge of a provider network or the device to which

 these functions are allocated.

 p. P: Provider (device), the term is used for the functions needed

 in the core of a provider network or the device to which these

 functions are allocated.

 q. SG15: ITU-T Study Group 15 (Transport, Access and Home).

 r. TE: Traffic Engineering

 s. TED: Traffic Engineering Database

3. FlexE Reference Model

 The figure below gives a simplified FlexE reference model.

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 +-----+

 | P |

 ...........+-+-+-+.............

 n x PHY . n x | | m x .

 . crunched | | crunched .

 +----+ +-----+ PHYs | | PHYs +-----+ +----+

 | CE +------+ PE1 +------------+ +--------------+ PE2 +----+ CE |

 +----+ +-----+ +-----+ +----+

 . .

 +----+ p x PHY . . +----+

 | CE +-----------------------------------------------------+ CE |

 +----+ . . +----+

 . OTN Network .

 . .

 ...............................

 +----+ q x PHY +----+

 | CE +-----------------------------------------------------+ CE |

 +----+ +----+

 Legend: m, n, p and q indicate how many PHYs

 there are in a FlexE Group

 Figure 1: FlexE Reference Model

 The services offered by Flexible Ethernet are essentially the same as

 for traditional Ethernet, connectionless Ethernet transport. In

 essence the FlexE interfaces and links may be viewed as any other

 Ethernet interfaces or links. However, it is possible to capture

 additional TE information in the Traffic Engineering Data Base

 showing unique characteristics of FlexE channelized interfaces and

 links. This makes it possible for the control plane to strategically

 use FlexE networks to support advanced TE.

4. GMPLS Controlled FlexE

 The high level goals for using a GMPLS control plane for FlexE can be

 summarized as:

 o Set up a FlexE Group

 o Set up a FlexE Client

 o Advertise the TE information of FlexE Groups and FlexE Clients

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 o Set up of a higher layer LSPs that require to be (or would have

 significant benefits to) be run over a FlexE network infrastructure.

 o Decoupling PHY and MAC bandwidth opens up some interesting

 features for networks that features FlexE links. By establishing

 several FlexE Clients with bandwidth that are part of the

 bandwidth of the FlexE Group, it is possible to create channels

 between two nodes.

 o By controlling the mapping a user packets (or frames) to these

 channels it is possible to create bandwidth that are dedicated for

 special purposes, and that can't be infringed on by packets (or

 frames) that does not satisfy this mapping.

4.1. Interfaces in a FlexE network

 FlexE Ethernet interfaces are realized by the means of a basic

 building block. The same building block is used for a single PHY and

 when the PHYs are bonded. The building block consists of two FlexE

 Shim functions (see Section 5.2.2.2) and a logical point to point

 link. The FlexE Shim functions are located at each end of the

 logical point to point link. This link carries the Ethernet PHY

 signals between the two FlexE Shim Functions.

4.2. Mapping of traffic in the data plane

 An example of which data plane mappings takes palace when an upper

 layer, e.g. IP or MPLS, send packets over a FlexE interface is

 shown in Figure 2.

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 IP packet IP Layer

 ||

 \/

 MPLS encapsulation MPLS

 ||

 \/

 FlexE Client ID FlexE

 ||

 \/

 calendar mapping FlexE

 ||

 \/

 FlexE Group FlexE

 Figure 2: Traffic Mapping

 In the mapping steps indicated in Figure 2 only one step in the

 mapping is visible by each layer.

 o the MPLS layer knows from the IP address, which MPLS label stack

 to encapsulate the IP packet in

 o the MPLS layer also know which MPLS label(s) that maps to which

 FlexE Client

 o the FlexE layer also knows from the FlexE Client Identifier, which

 calendar slots the packet will be transferred over

 o the FlexE layer knows which FlexE Group a certain set of calendar

 slots belongs too

4.3. The GMPLS Control Plane and the FlexE identifiers

 This section lists some of the procedures and actions on FlexE

 Interface Identifiers that a GMPLS Control plane need to perform.

 Also, a centralized controller, YANG model or a management system

 that are used to establish interfaces and links need to perform the

 same actions.

 The FlexE Group Identifier and the FlexE Client Identifier, included

 in the overhead of each frame sent over a FlexE Interface or sub-

 Interface, indicates a particular Group or Client.

 When the Control Plane, a centralized controller, a YANG model or a

 management system sets up a FlexE Interface at least the bandwidth

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 has to be included in the setup message. The FlexE system wherein the interface belongs return the

 FlexE Group Identifier in the response message.

 When a channelized sub-interface is set up, the party initiates

 the setup includes the Interface (FlexE Group) Identifier over which

 the sub-Interface will be established, and the bandwidth requested

 for the sub-interface. The FlexE system wherein the sub-interface belongs returns the FlexE Client

 Identifier.

 The identifiers received by the party that initiate a setup of an

 FlexE Interfaces are used, by a controller, to set up FlexE sub-

 interfaces.

 The identifiers received by the party that initiate a setup of an

 FlexE sub-Interfaces are used, e.g. to map an MPLS label to the

 correct FlexE sub-interfaces.

4.4. Operational concerns

 When operating a link in a FlexE network it is likely that an

 operator would like to split the FlexE Interface into some sub-Interfaces

 used for best effort traffic and some sub-Interfaces dedicated for

 special purposes. An example would be when there is a 100 Gbit/s

 FlexE are split in to five 10 Gbit/s sub-interfaces and one 50 Gbit/s

 sub-interface. The 50 Gbit/s sub-interface could be used best effort

 traffic, the five 10 Gbit/s could be used for dedicated traffic.

 In such cases it is conceivable that packets/frames that have a

 matching key will be put on a specific sub-Interface, while traffic

 that do not have a matching key will be put on the best effort sub-

 interface.

4.5. Pre-configured vs. Control Plane established LSPs in a FlexE

 capable network

 The FlexE infrastructure may be established in three different ways

 o The FlexE Groups and FlexE Client may be pre-configured

 o Only the FlexE Groups may be pre-configured, while the setup of

 the FlexE Client is triggered by the request to setup a MPLS LSP.

 o The setup of both FlexE Group and FlexE Client may be triggered by

 the request to setup an MPLS LSP.

 In the case the FlexE Groups and FlexE Clients are preconfigured the

 FlexE capable nodes need to have the ability to announce the

 preconfigured FlexE Client and/or FlexE Groups as if they were LSPs.

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4.6. Signaling Channel

 In the type of equipment for which FlexE was first specified an out

 of band signaling channel is not commonly available. If that is the

 case, and the GMPLS FlexE control plane will be used, the FlexE Group

 will have to setup by e.g. a management system and a FlexE Client on

 that FlexE Group (also configured) will have to allocated as a

 signaling channel.

 Further details of the setup of the FlexE Groups, FlexE Clients and

 MPLS LSPs over a FlexE infrastructure will be found in Section 6.2.

4.7. MPLS LSP over the FlexE Data Plane

 FlexE is a true link layer technology, i.e. it is not switched, this

 means that the FlexE Groups and FlexE Clients are terminated on the

 next-hop node, and that the switching needs to take place on a higher

 layer.

 The FlexE technology can be used to establish link layer connectivity

 with high and deterministic bandwidth. However, there is no way

 described in the FlexE specification to, in a deterministic way,

 allocate certain traffic to a specific FlexE Client. Control of the

 FlexE link layer by a GMPLS control plane can achieve this.

 A GMPLS controlled FlexE capable node may be thought of using the

 traditional model of a node with a separation between control and

 data plane.

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 +------------------+

 | +------------+ |

 | | GMPLS | |

 | | Control | |

 | | Plane | |

 | +------------+ |

 | ^ |

 | | |

 | v |

 | +------------+ |

 | | FlexE | |

 | | Data | | ^

 | | Plane | |

 | +------------+ |

 +------------------+

 Figure 3: GMPLS controlled FlexE Node

 The GMPLS control plane will speak extended standard GMPLS protocols

 with its neighbours and peers.

 Node A Node B Node Z

 +--CP

 +-|-----------+ |------------------+ ~ +---------+

 | | | | | | |

 | | +------+ | | +--------------+ | | +-----+ |

 LSP | +->| v | | | | ....x..... | | | | ^ | |

 | | | . | | | | . . | | | | . | |

 | | +--.---+ | | +--.--------.--+ | | +--.--+ |

 FlexE | +->| o | | | | o | | o | | | | o | |

 Client | | | o | | | | o | | o | | | | o | |

 | | +--o---| | | +--o--+ +--o--+ | | +--o--| |

 FlexE | +->| U | | | | U | | U | | | | U | |

 Group | | U | | | | U | | U | | | | U | |

 | +--U---| | | +--U--+ +--U--+ | | +--U--+ |

 |-------U-----+ +----U--------U----+ +----U----+

 U U U U

 UUUUUUUUUUUUUUUUUUUUU UUUUUUU ~ UUUUUUUU

 Legend ... = LSP

 ooo = FlexE Client

 UUU = FlexE Group

 Figure 4: GMPLS controlled network with FlexE infrastructure

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 Figure 4 describes how an MPLS LSP is mapped over a FlexE Client and

 FlexE Group.

4.8. Configuring the data plane in FlexE capable nodes

 In Figure 4 we show an LSP, a FlexE Client and a FlexE Group, the LSP

 is there because while the FlexE Channel and Group are not switched,

 switching in our example takes place on the LSP level. This section

 will discuss establishment of FlexE Clients and Groups, and mapping

 of the LSP onto a FlexE Client.

 The establishment of a LSP over a FlexE system is very similar to how

 this is done in any other system. Building on information gathered

 through the routing system and using the GMPLS signaling to establish

 the LSP.

4.8.1. Configure/Establish a FlexE Group/Link

 Consider the setup of a FlexE Group between node A and B,

 corresponding to the row of U's from node A to B in Figure 4. The

 FlexE Group is considered to consist of n PHYs, but does not have any

 FlexE Clients defined from start.

 When this is done by the GMPLS control plane, two conditions need to

 be fulfilled (1) there need to be a data channel defined between node

 A and B; and (2) a FlexE capable IGP-TE protocol needs to be running

 in the network.

 Node A will send an RSVP-TE message to node be with the information

 describing the FlexE Group to be setup. This information might be

 thought of as the "FlexE Group Label" (or part of the FlexE label).

 It will contain at least the following information:

 o A FlexE Group Identifier (FGid).

 o The number of active FlexE Channels (numFC), where 0 indicates

 that zero clients are active.

 o Number of PHYs that the FlexE Group is composed of, for each PHY

 \* PHY identifier

 \* PHY bandwidth

 \* slot granularity/number of slots

 \* available and unavailable slots

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 When node B receives the RSVP-TE message it checks that it can setup

 the requested FlexE Group. If the check turns positive, node send an

 acknowledgment to node A and the FlexE Group is setup.

 A more detailed description of how to setup a FlexE Group, will be

 included in the draft dealing with signaling in detail.

4.8.2. Configure/Establish a FlexE Client

 Consider the situation where a FlexE Group is already established (as

 described in Section 4.8.1) and an m G FlexE Client is needed.

 Similar to the establishment of the FlexE Group, node A will send a

 RSV-TE message to node B.

 This RSVP-TE message include at least the following information:

 o FlexE Group Identifier

 o FlexE Client Identifier

 o from which PHYs the slots will allocated, i.e. slots might come

 from more than one PHY.

 o Information per PHY

 \* PHY bandwidth

 \* slot granularity

 \* available/unavailable slots

 \* allocated slots

 A more detailed description of how to setup a FlexE Channel, will be

 included in the draft dealing with signaling in detail.

4.8.3. Advertise FlexE Groups and FlexE Clients

 Once the FlexE Group and FlexE Clients are configured they can be

 advertised into the routing system as normal routing adjacencies,

 including the FlexE specific TE information.

5. Framework and Architecture

 This section discusses FlexE framework and architecture. Framework

 is taken to mean how FlexE interoperates with other parts of the data

 communication system. Architecture is taken to mean how functional

 groups and elements within FlexE work together to deliver the

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 expected FlexE services. Framework is taken to mean how FlexE

 interacts with it environment.

5.1. FlexE Framework

 The service offered by Flexible Ethernet is a transport service very

 similar (or even identical) to the service offered by Ethernet.

 There are two major additions supported by FlexE:

 o FlexE is intended to support high bandwidth and FlexE can offer

 granular bandwidth from 5Gbits/s and a bandwidth as high as the

 FlexE Group allows.

 o As FlexE Groups and clients are setup as a configuration activity,

 by a centralized controller or by a GMPLS control plane the

 service is connection oriented.

5.2. FlexE Architecture

5.2.1. Architecture Components

 This section discusses the different parts of FlexE signaling and

 routing and how these parts interoperate.

 The FlexE routing mechanism is used to provide resource available

 information for setup of higher layer LSPs, like Ethernet PHYs'

 information, partial-rate support information. Based on the resource

 available information advertised by routing protocol, an end-to-end

 FlexE connection is computed, and then the signaling protocol is used

 to set up the end-to-end connection.

 FlexE signaling mechanism is used to setup LSPs.

 MPLS forwarding over a FlexE infrastructure is different from

 forwarding over other infrastructures. When MPLS runs over a FlexE

 infrastructure it is possible that there are more than FlexE Client

 that meet the next-hop requirements, often it is possible to use any

 suitable FlexE Clientfor a hop between two nodes. If the mapping

 between a MPLS encapsulated packet and the FlexE Client, this mapping

 need to be explicit when the LSP is set up, and the MPLS label will

 be used to find the correct FlexE Client.

5.2.2. FlexE Layer Model

 The FLexE layer model is similar Ethernet model, the Ethernet PHY

 layer corresponds to the "FlexE Group", and the MAC layer corresponds

 to the "FlexE Client".

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 As different from earlier Ethernet the combination of Flexe Group and

 Client allows for a huge freedom when it comes to define the

 bandwidth of an Ethernet connectivity.

5.2.2.1. FlexE Group structure

 The FlexE Group might be supported by virtually any transport

 network, including the Ethernet PHY. While the Ethernet PHY offers a

 fixed bandwidth the FlexE Group has been structured into 5 Gbit/s

 slots. This means that the FlexE Group can support FlexE Clients of

 a variety of bandwidths.

 The first version is defined for 20 slots of 5 Git/s over a 100 Gbit/

 s PHY. The 100 Gbit/s PHYs can be bonded to give higher bandwidth.

5.2.2.2. FlexE Client mapping

 A FlexE Client is an Ethernet flow based on a MAC data rate that may

 or may not correspond to any Ethernet PHY rate. The FlexE Shim is

 the layer that maps or demaps the FlexE Client flows carried over a

 FlexE Group. As defined in [OIFFLEXE1], MAC rates of 10, 40, and any

 multiple of 25 Gbit/s are supported. This means that if there is a

 100 Gbit/s FlexE Group between A and B, a FlexE Client of 10, 25, 40,

 50, 75 and 100 Gbit/s can be created.

 However, by bonding, for example 5 PHYs of 100 Git/s to a single

 FlexE Group, FlexE Clients of 500 Gbit/s can be supported.

6. Control Plane

 This section discusses the procedures and extensions needed to the

 GMPLS Control Plane to establish FlexE LSPs.

 There are several ways to establish FlexE Groups, allocate slots for

 FlexE Clients, and setup higher layer LSPs. A configuration tool, a

 centralized controller or the GMPLS control plane can all be used.

 To create the FlexE GMPLS control plane Groups, FlexE Clients and

 higher layer LSPs, extensions to the following protocols may be

 needed:

 o "RSVP-TE: Extensions to RSVP for LSP Tunnels" (RSVP-TE) [RFC3209]

 o "Link Management Protocol" (LMP) [RFC4204]

 o "Path Computation Element (PCE) Communication Protocol" (PCEP)

 [RFC5440]

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 o IS-IS Extensions for Traffic Engineering (ISIS-TE) [RFC5305]

 o "OSPF Extensions in Support of Generalized Multi-Protocol Label

 Switching (GMPLS)" (OSPF-TE) [RFC4203]

 o "North-Bound Distribution of Link-State and Traffic Engineering

 (TE) Information Using BGP" (BGP-LS) [RFC7752]

 A FlexE control plane YANG model will also be needed.

 Section 6.2 and Section 6.1 discusses the role of the GMPLS control

 plane when primarily setting up LSPs.

 When discussing the signaling and routing procedures we assume that

 the FlexE Group has been established prior to executing the

 procedures needed to establish an LSP. Technically it is possible to

 establish FlexE Group, allocate FlexE Client slots and LSP with a

 single exchange of GMPLS signaling messages.

6.1. GMPLS Routing

 To establish an LSP the Traffic Engineering (TE) information is the

 most critical information, e.g. resource utilization on interfaces

 and link, including the availability of slots on the FlexE Groups.

 The GPMPLS routing protocols needs to be extended to handle this

 information. The Traffic Engineering Database (TED) will keep an

 updated version of this information.

 The FlexE capable nodes will be identified by IP-addresses, and the

 routing and traffic engineering information will be flooded to all

 nodes within the routing domain using TCP/IP.

 When an LSP over the FlexE infrastructure is about to be setup, e.g.

 R1 - R4 - R5 in Figure 5 the information in the TED is used verify

 that resources are available. When it is conformed that the LSP is

 established the TED is updated, marking the resources used for the

 new LSP as used. Similarly, when a LSP is taken down the resources

 are marked as free.

6.2. GMPLS Signaling

 As described in Section 4 the state of the FlexE infrastructure may

 effect the actions needed to setup an LSP in a FlexE capable network.

 The FlexE infrastructure maybe be:

 1. fully pre-configured

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 2. partially pre-configured, i.e. the FlexE Group may be pre-

 configured, but not the FlexE Clients

 3. not pre-configured, i.e. the setup of FlexE Group and FlexE

 Client will be triggered because of the request to setup an LSP.

 Figure 5 will be used to illustrate the different cases.

 +----+

 | R1 +---------------------+

 +----+ |

 |

 +----+ +--+--+ +----+

 | R2 +------------------+ R4 +-------------------------+ R5 |

 +----+ +--+--+ +----+

 |

 +----+ |

 | R3 +---------------------+ PHY R1 to R4 100 Gbit(s

 +----+ PHY R2 to R4 100 Gbit(s

 PHY R3 to R4 100 Gbit(s

 PHY R4 to R5 200 Gbit(s

 Figure 5: FlexE LSP Example

 The text in Section 6.2 is not a specification of the GMPLS signaling

 extensions for FlexE capable network, it is a description to

 illustrate the expected features of such a protocol. Nor do we

 discuss failure scenarios.

6.2.1. LSP setup with pre-configured FlexE infrastructure

 In this first example, referencing Figure 5, one 100 Gbit/s FlexE

 Group is configured between R1 and R4, between R2 and R4, and between

 R3 and R4. Between R4 and R5 there is a 200 Gbit/s FlexE Group.

 Over each 100 Gbit/s FlexE Group there are four 5 Gbit/s, two 20

 Gbit/s and one 40 Gbit/s FlexE Clients configured. Over the 200 Git/

 s FlexE Group there are eight 5 Gbit/s, four 20 Gbit/s and two 40

 Gbit/s FlexE Clients configured.

 One of the 5 Gbit/s FlexE Clients on each FlexE Groups are used as

 signaling channel.

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 To establish the for example a 200 Mbit/s MPLS LSP the normal GMPLS

 request/response procedures are followed. R1 sends the request to

 R4, R4 allocate resources on one of the FlexE Clients, forward the

 request to R5. R5 responds to R4 indicating the label and the FlexE

 Client the traffic should be sent over, R4 does the same for R1.

 The only difference between the standard signaling and what happens

 here is that there the assigned label will be used to find the right

 FlexE Client.

6.2.2. LSP setup with partially configured FlexE infrastructure

 In the second example, also referencing Figure 5, the FlexE Groups

 are setup in the same way as in the first example, however only one 5

 Gbit/s FlexE Client per FlexE Group are established by configuration.

 This FlexE Client will be used for signaling.

 When preparing to send the request that a 5 Gbit/s MPLS LSP shall be

 set up R1 discovers that there are no feasible FlexE Client between

 R1 aand R4. R1 therefore sends the request to establish such a FlexE

 Client, when receiving the request R4 allocates resources for the

 FlexE Client on the FlexE Group. There may be different strategies

 for allocating the bandwidth for this FlexE Client. Such strategies

 are out of scope for this document. R1 then sends the information

 about the FlexE Client to R1, and both ends establish the FlexE

 Client.

 When the FlexE Client between R1 and R4 is established, R1 proceeds

 to send the request for an MPLS LSP to R4. R4 will discover that a

 feasible FlexE Client is missing between R4 and R5. The same

 procedure s for setting up the FlexE Client between R1 and R4 is

 repeated for R4 and R5. When there is a feasible FlexE Client

 available the signaling to set up the MPLS LSP continues as normal.

 The label allocated for the MPLS LSP will be used to find the correct

 FlexE Client.

 When a FlexE Clients is set up in this way they can be announced into

 the routing system in two different ways. First, they can be made

 generally available, i.e. it will be free to use for anyone that want

 to set up LSPs over the FlexE Group between R1 and R4 and between R4

 and R5. Second, the use of the FlexE Clients may be restricted to

 the application that initially did set up the FlexE Client.

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6.2.3. LSP setup with non-configured FlexE infrastructure

 This example also refers to Figure 5 as different from the earlier

 example no FlexE Group or FlexE Client configuration is done prior to

 the first request for an MPLS LSP over the FlexE infrastructure.

 To make the set up of LSPs in a FlexE network where no FlexE Groups

 or FlexE Clients have been configured two conditions need to be

 fulfilled. First an out of band signaling channel must be available.

 Second the FlexE Capabilities must be announced in to the IGP and/or

 centralized controller.

 If these two conditions are fulfilled, the set up of an MPLS LSP

 progress pretty much as in the partially configured network. The

 difference is that the set up of both the FlexE Group and FlexE

 Client are triggered by the request to set up an MPLS LSP.

 As in the partially configured case FlexE Clients can be announced

 into the routing system in two different modes, either they are

 generally available. It or they are reserved for the applications

 that first established them.

6.2.4. Packet Label Switching Data Plane

 This section discusses how the FlexE LSP data plane works. In

 general it can be said that the interface offered by the FlexE Shim

 and the FlexE Client is equivalent to the interface offered by the

 Ethernet MAC.

 Figure 6 below illustrates the FlexE packet switching data plane

 procedures.

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 R1 R3 R4

 ............. ...................... ...........

 . +-------+ . . +----------------+ . . +-----+ .

 . | LSP | . . | LSP \ / LSP | . . | LSP | .

 . | a | . . | a \/ b | . . | b | .

 . +-------+ . . +----------------+ . . +-----+ .

 . | ETH | . . | ETH | | ETH | . . | ETH | .

 . | i/f | . . | i/f | | i/f | . . | i/f | .

 . +-------+ . . +-----+ +-----+ . . +-----+ .

 . | FlexE | . . |FlexE| |FlexE| . . |FlexE| .

 . | trsp | . . |trsp | |trsp | . . |trsp | .

 . +---+---+ . . +--+--+ +--+--+ . . +--+--+ .

 ......|...... .....^..........|..... .....^.....

 | | | |

 +--------------------+ +--------------------+

 Figure 6: LSP over FlexE Data Plane

 The data plane processes packets like this:

 o The LSP encapsulating and forwarding function in node R1 receives

 a packet that needs to be encapsulated as an MPLS packet with the

 label "a". The label "a" is used to figure out which FlexE

 emulated Ethernet interfaces the label encapsulated packet need to

 be forwarded over.

 o The Ethernet interfaces, by means of FlexE transport, forwards the

 packet to node R3. Node R3 swaps the label "a" to label "b" and

 uses "b" to decide over which interface to send the packet.

 o Node R3 forwards the packet to node R, which terminates the LSP.

 Sending MPLS encapsulated packets over a FlexE Client is similar to

 send them over an Ethernet 802.1 interface. The critical differences

 are:

 o FlexE channelized sub-interfaces guarantee a deterministic

 bandwidth for an LSP.

 o When a application that originally establish a FlexE Client

 reserve it for use by that application only, it is possible to

 create uninfringeable bandwidth end-to-end for an MPLS LSP.

 o FlexE infrastructure allows for creating very large end to end

 bandwidth

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7. Operations, Administration, and Maintenance (OAM)

 To be added in a later version.

8. Acknowledgements

9. IANA Considerations

 This memo includes no request to IANA.

 Note to the RFC Editor: This section should be removed before

 publishing.

10. Security Considerations

 To be added in a later version.

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Appendix A. Requirements

 This section summarizes the signaling and routing requirements for a

 FlexE control plane, with respect to establishing FlexE Groups, FlexE

 Clients and MPLS LSPs that require support from an FlexE

 infrastructure.

 Req-1 The FlexE control plane SHALL support the creation of FlexE

 Groups.

 \* A FlexE Groups consist one or more 100GE Ethernet PHY(s).

 In the first version of FlexE the number of PHYs are in the

 range of 1 to 254.

 \* This requirement can be met by several methods, e.g.

 routing and signaling protocols, a centralized controller

 or a management system.

 Any such method need to have network access to the FlexE

 shims at each of the Ethernet PHY(s) termination points.

 Req-2 The FlexE control plane SHALL have the ability to delete a

 FlexE Group.

 Req-3 The FlexE control plane SHALL have the ability to initiate an

 administratively lock or unlock of a FlexE Group.

 \* This ability is needed e.g. for executing the next

 requirement.

 Req-4 When a FlexE Group has been administratively looked is SHALL

 be possible to add PHYs to an operational FlexE Group.

 Req-5 When a FlexE Group has been administratively looked is SHALL

 be possible to remove PHYs from an operational FlexE Group.

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 Req-6 The FlexE control plane SHALL support the ability to collect,

 advertise and discover information about FlexE capable nodes,

 including the TE information the FlexE Groups and FlexE

 Clients the nodes support.

 Note: In essence correct, but something is backward. Need to

 think.

 Req-7 The FlexE control plane SHALL allow the addition (or removal)

 of one or more FlexE clients to a FlexE Group. The addition

 (or removal) of a FlexE Client flow SHALL NOT affect the

 services of the other FlexE Client signals.

 Req-8 The FlexE control plane SHALL, though this MAY not be possible

 in all network scenarios, support FlexE Client flow resizing

 without affecting any existing FlexE Clients within the same

 FlexE Group.

 Req-9 The FlexE control plane SHALL support establishment of MPLS

 LSPs that requires the support of a FlexE infrastructure.

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