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**DetNet Service Model**  
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Abstract

This document describes the service model for scenarios requiring deterministic / time sensitive networking.

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**[1.](#) Introduction**

Deterministic Networking service provides a capability to carry specified data flow, whether unicast or multicast, for an application with constrained requirements towards network performance, e.g. low packet loss rate and/or latency. During the discussion of detnet use-cases, detnet architecture and various related networking scenarios several confusions have been arrised due to different service model interpretations. This document defines service reference points, service components and proposes naming for service scenarios to achieve common understanding of the detnet service model.



## **2. Conventions Used in This Document**

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 [[RFC2119](#)].

The lowercase forms with an initial capital "Must", "Must Not", "Shall", "Shall Not", "Should", "Should Not", "May", and "Optional" in this document are to be interpreted in the sense defined in [[RFC2119](#)], but are used where the normative behavior is defined in documents published by SDOs other than the IETF.

## **3. Terminology and Definitions**

Additional terms to [[draft-data-plane](#)] and [[draft-arch](#)] used/ described in this draft .

App-flow: Data flow between the applications requiring deterministic transport.

DetLink: Direct link between two entities (node/end-system) used for deterministic transport.

DetNet AC: Attachment Circuit of a DetNet transport service for a DetNet-flow.

DetNet-flow: Data flow requiring deterministic transport between two DetNet-UNIs.

DetNet-UNI: UNI of an Edge/Relay node to provide deterministic service for a connected node/end-system.

DetNetwork: Transport network between DetNet-UNIs.

Native AC: Attachment Circuit of a DetNet transport service for an App-flow.

## **4. End-systems connected to DetNet**

Deterministic transport is required by time/loss sensitive application(s) running on an End-system during communication with its peer(s). Such a data exchange has various requirements on delay and/ or loss parameters. The native data flow between the source/sink End-Systems is called as application-flow (app-flow) as shown in Figure 1. The traffic characteristics of an app-flow can be CBR or VBR and can have L1 or L2 or L3 format (e.g., TDM, Ethernet, IP).



[Note: Interworking function for L1 application-flows is out-of-scope in this document and therefore not depicted on figures.]

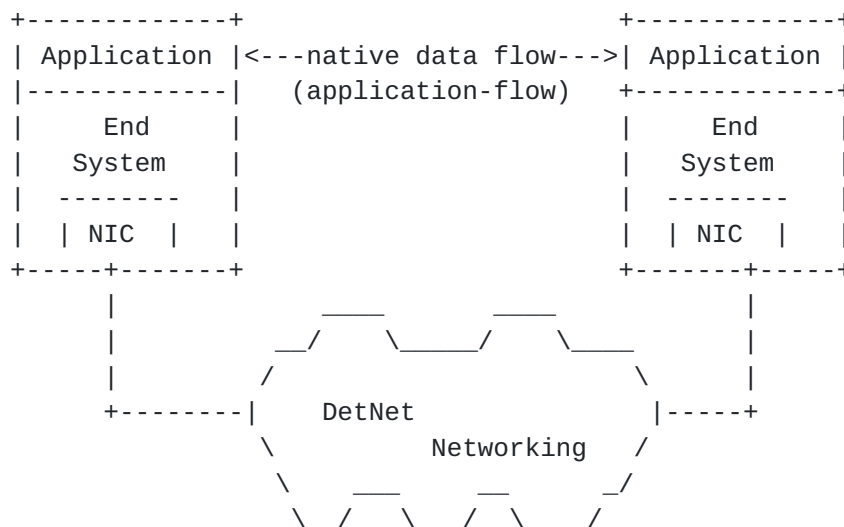


Figure 1: End-systems connected to DetNet

End-system(s) may or may not be directly connected to the DetNet transport network. End-systems may or may not contain DetNet specific functionalities and are referred as "DetNet aware End-system" or "DetNet unaware End-system" respectively [[draft-data-plane](#)]. (Note: [[draft-data-plane](#)] refers to "DetNet unaware end-systems" as "TSN End-system")

- o "DetNet aware End-system" has the same forwarding paradigm as the DetNet transport network and it creates the DetNet-flow from the app-flow. DetNet aware End-system is connected via "DetNet AC" to the DetNet transport network.
- o "DetNet unaware End-system" originates a native data flow (app-flow) from which an Edge node creates a DetNet-flow (with proper Flow-ID and Seq-num attributes) by encapsulating native data flow according to the forwarding paradigm of the transport network. DetNet unaware End-system is connected via "Native AC" to the DetNet transport network.

These end-systems are shown in Figure 2



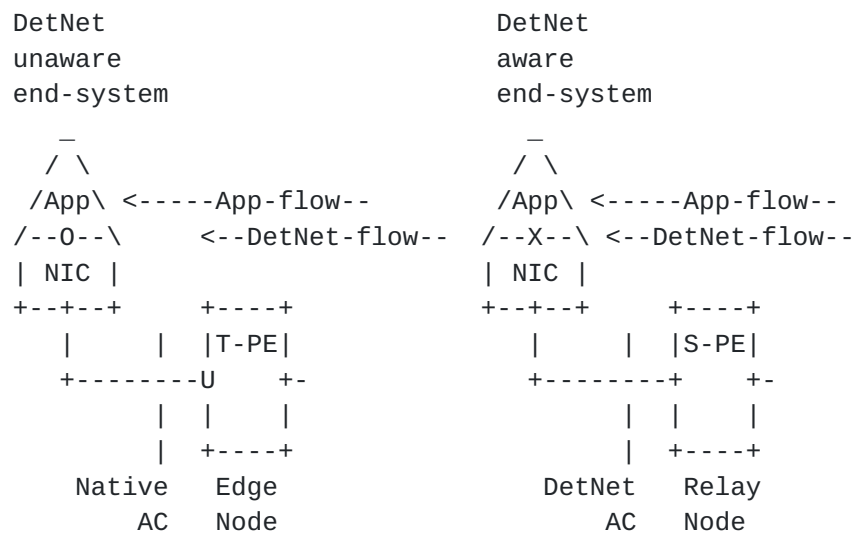


Figure 2: DetNet aware/unaware End-systems

## 5. DetNet service model

### 5.1. Service parameters

The DetNet service can be defined as a service, that provides a capability to carry specified data flow, whether unicast or multicast, for an application with constrained requirements towards network performance, e.g. low packet loss rate and/or latency.

Delay and loss parameters are somewhat correlated as too late arrival of a packet can be treated as lost. However not all applications require hard limits on both parameters (delay and loss). For example, some real-time applications allow graceful degradation if loss happens (e.g., samples based processing, media distribution). Some others may require high bandwidth connections that makes the usage of techniques like flow duplication economically challenging or even impossible. Some applications may not tolerate loss, but are not delay sensitive (e.g., bufferless sensors).

Primary transport service attributes for DetNet transport are:

- o Bandwidth parameter(s),
- o Delay parameter(s),
- o Loss parameter(s).





Time/Loss sensitive applications may have somewhat special requirements especially for loss (e.g. no loss in two consecutive communication cycles; very low outage time, etc.).

### **5.2. Service overview**

The figure below shows the DetNet service related reference points and components (Figure 3).

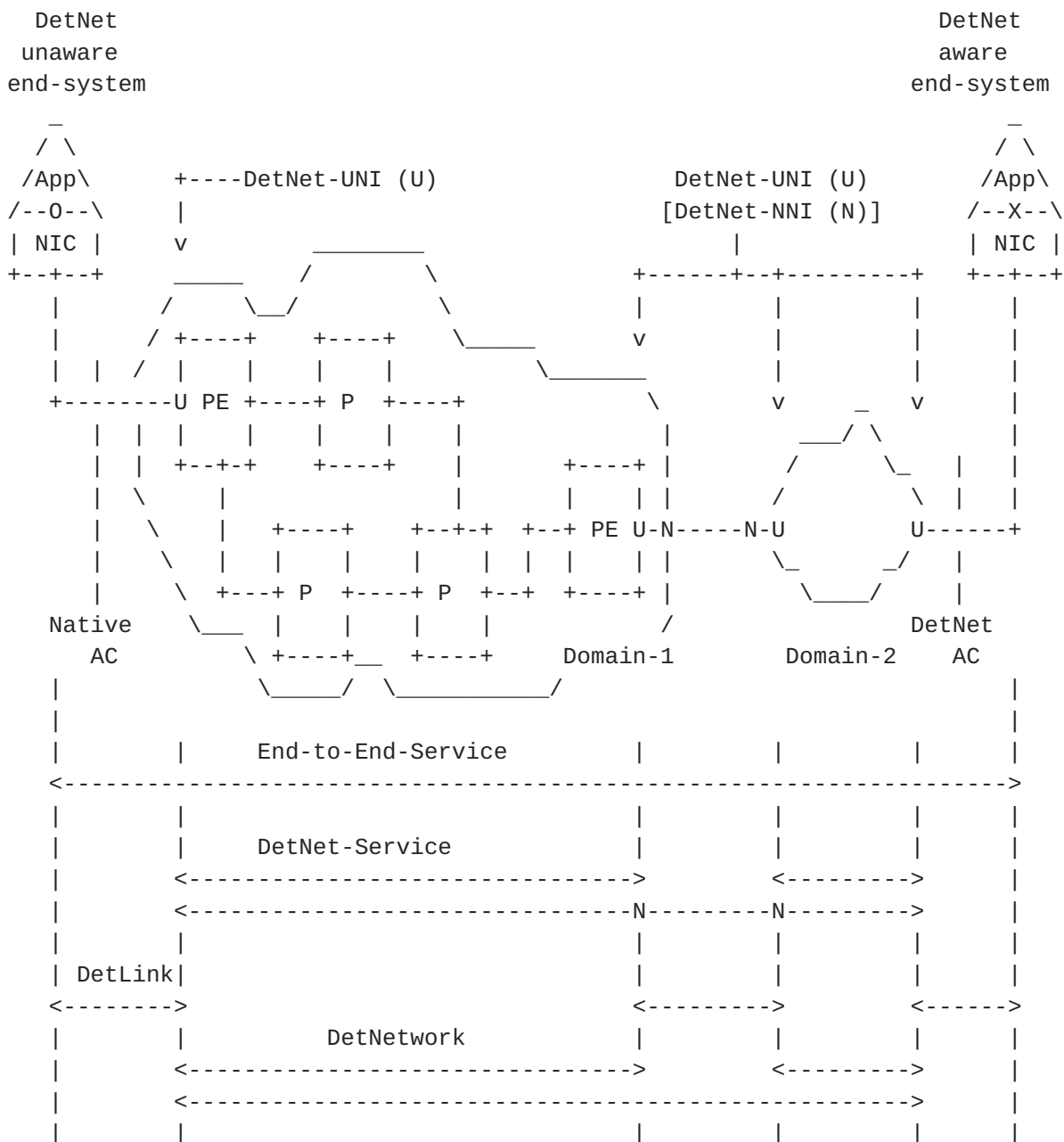


Figure 3: DetNet Service Reference Model

### 5.3. Reference Points

From service model design perspective a fundamental question is the location of the service endpoints, i.e., where the service starts or ends. Two reference points can be distinguished for all DetNet use-cases:

- o App-flow endpoints: end-system's internal reference point.



- o DetNet-UNI: edge node UNI interface of a domain.

App-flow endpoints (depicted as "O" and "X" on Figure 3) is a more challenging point from control perspective as it is an internal reference point. It is providing access to deterministic transport for the native data flow (app-flow).

A DetNet-UNI (depicted as "U" on Figure 3) is assumed in this document to be a packet based reference point and provides connectivity over the packet network. A DetNet-UNI may add networking technology specific encapsulation to the app-flow and transport it as a DetNet-Flow over the network. There are many similarities regarding the functions of an app-flow endpoint ("X") of an DetNet aware endsystem and DetNet-UNI but there may be some differences. For example in-order delivery is expected over the app-flow endpoints ("O/X"), whereas it is considered as optional over the DetNet-UNI.

#### **5.4. Service scenarios**

Using the above defined reference points two major service scenarios can be created:

- o End-to-End-Service: the service reaches out to final source/sink nodes, so it is an e2e service between application hosting devices (end-systems).
- o DetNet-Service: the service connects networking islands, so it is a service between the borders of network domain(s).

End-to-End-Service is defined between app-flow endpoints, whereas DetNet-Service between DetNet-UNIs. That allows peering of same layers/functions.

#### **5.5. Data flows**

For unambiguous references two detnet data flows are distinguished:

- o App-flow: data flow requiring deterministic transport between two app-flow endpoints, data format is application specific (e.g., bit stream, directly mapped in Ethernet frames, etc.).
- o DetNet-flow: data flow requiring deterministic transport between two DetNet-UNIs. Data format may be changed at the DetNet-UNI to allow simple flow recognition/transport/etc. during forwarding between DetNet-UNIs (e.g., on Edge Nodes by adding further encapsulation to the App-flow including new domain specific Flow-ID and Seq-num attributes) .



[Note: In some network scenarios App-flow and DetNet-flow format might be identical e.g., if the end-system provides an encapsulation, that contains all information needed by detnet functionalities (e.g., RTP based App-flow transported over a native IP network). In other scenarios their encapsulation format might differ significantly e.g., CPRI IQ data mapped directly to Ethernet frames which have to be transported over an MPLS based PSN.]

## **5.6. Service components/segments**

As a reference to service components/segments the following building blocks are used:

- o DetLink: direct link between two entities (node/end-system) used for deterministic transport.
- o DetNetwork: network between DetNet-UNIs

Using DetLink and DetNetwork component/segments any detnet service scenario can be described. For example the service between the App-flow endpoints on Figure 3 can be composed as a DetLink-1 (between end-system on the left and the edge node of domain-1) + DetNetwork-1 (of domain-1) + DetLink-2 (between domain-1 and domain-2) + DetNetwork-2 (of domain-2) + DetLink-3 (between edge node of domain-2 and end-system on the right).

## **6. DetNet service instances**

### **6.1. Local attributes used by DetNet functions**

The three DetNet functions (Bandwidth reservation and enforcement, Explicit routes, Packet loss protection) require two data flow related attributes to work properly:

- o Flow-ID and
- o Sequence number (Seq-Num).

These attributes are local to DetNet nodes and are extracted from the ingress packets of the node [[draft-arch](#)]. Flow-ID is used by all the three DetNet functions, but sequence number is used only by the duplicate elimination functionality.

Flow-ID must be unique per network domain. Its encoding format is specific to the forwarding paradigm of the domain and to the capabilities of intermediate nodes to identify data flows. For example in case of "PW over MPLS" one option is to construct the Flow-ID by the PW label and the LSP label (denoted as [PW-label;LSP-





label]). In such a case intermediate P nodes have to check all labels to identify a DetNet-flow. An other possible option is to use a dedicated LSP per data flow so the LSP label itself can be used as a Flow-ID (denoted as [LSP-label]). In such a case the intermediate P nodes do not have to check the whole label stack to recognize a data flow (DetNet-flow).

## 6.2. Service instance for DetNet data flows

The DetNet network reference model is shown in Figure 4 for a DetNet-Service scenario (i.e. between two DetNet-UNIs). In this figure the end-systems ("A" and "B") are connected directly to the edge nodes of the PSN ("PE1" and "PE2"). The data flow specific attachment circuits ("AC-A" and "AC-B") are terminated in the flow specific service instance ("SI-1" and "SI-2"). A PSN tunnel is used to provide connectivity between the service instances. The encapsulations used over the PSN tunnel are described in [[draft-data-plane](#)].

This PSN tunnel is used to transport exclusively the DetNet data flow packets between "SI-1" and "SI-2". The service instances are configured to implement a flow specific routing or bridging function depending on what connectivity (L2 or L3) the participating end-systems require. The service instance and the PSN tunnel may or may not be shared by multiple DetNet data flows. Sharing the service instance by multiple DetNet-flows requires properly populated forwarding tables of the service instance.

Serving regular traffic and DetNet data flows by the same service instance is out-of-scope in this draft, but some related thoughts are described in the annex.

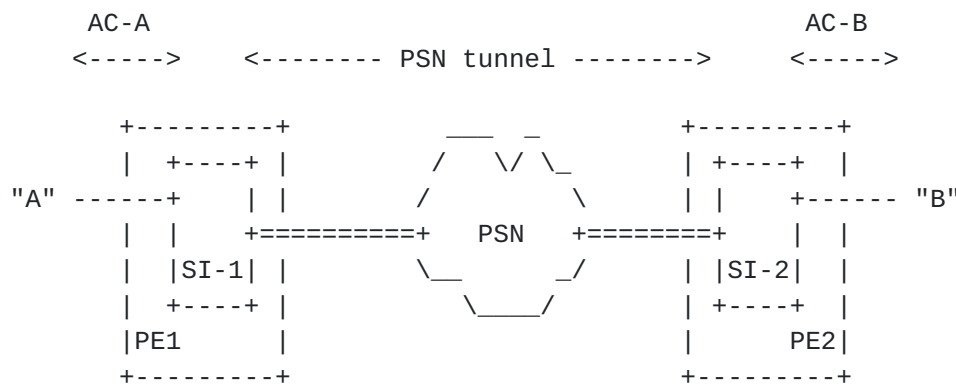


Figure 4: DetNet network reference model



[Note: There are differences in the usage of a "packet PW" for DetNet traffic compared to the network model described in [[rfc6658](#)]. In the DetNet scenario the packet PW is used exclusively by the DetNet data flows, whereas [RFC6658](#) states: "The packet PW appears as a single point-to-point link to the client layer. Network-layer adjacency formation and maintenance between the client equipments will follow the normal practice needed to support the required relationship in the client layer ... This packet pseudowire is used to transport all of the required layer 2 and layer 3 protocols between LSR1 and LSR2".]

## **[7.](#) DetNet data flows over multiple technology domains**

### **[7.1.](#) Flow attribute mappings between layers**

Transport of DetNet data flows over multiple technology domains may require that e.g., lower layers are aware of specific flows at higher layers. Such an "exporting of flow identification" [see [draft-arch section 4.7](#)] is needed each time when the forwarding paradigm is changed on the transport path (e.g., two LSRs are interconnected by a L2 bridged domain, etc.). The three main forwarding methods considered for deterministic networking are:

- o IP routing
- o MPLS label switching
- o Ethernet bridging

The simplest solution for generalized flow identification could be to define a unique Flow-ID triplet per DetNet data flow (e.g., [IP: "IPv6-flow-label"+"IPv6-address"; MPLS: "PW-label"+"LSP-label"; Ethernet: "VLAN-ID"+"MAC-address"]). This triplet can be used by the DetNet encoding function of technology border nodes (where forwarding paradigm changes) to adapt to capabilities of the next hop node. They push a further (forwarding paradigm specific) Flow-ID to packets ensuring that flows can be easily recognized by domain internal nodes. This additional Flow-ID might be removed when the packet leaves a given technology domain.

[Note: Seq-num attribute may require a similar functionality at technology border nodes.]

The additional (domain specific) Flow-ID can be

- o created by a domain specific function or
- o derived from the original Flow-ID of the app-flow



so, that it must be unique inside the given domain. Please note, that the original Flow-ID of the app-flow is still present in the packet, but transport nodes may lack the function to recognize it, that's why the additional Flow-ID is added (pushed).

## 7.2. Flow-ID mappings examples

IP nodes and MPLS nodes are assumed to be configured to push such an additional (domain specific) Flow-ID when sending traffic to an Ethernet switch (as shown in the examples below).

Figure 5 below shows a scenario where an IP end-system ("IP-A") is connected via two Ethernet switches ("ETH-n") to an IP router ("IP-1").

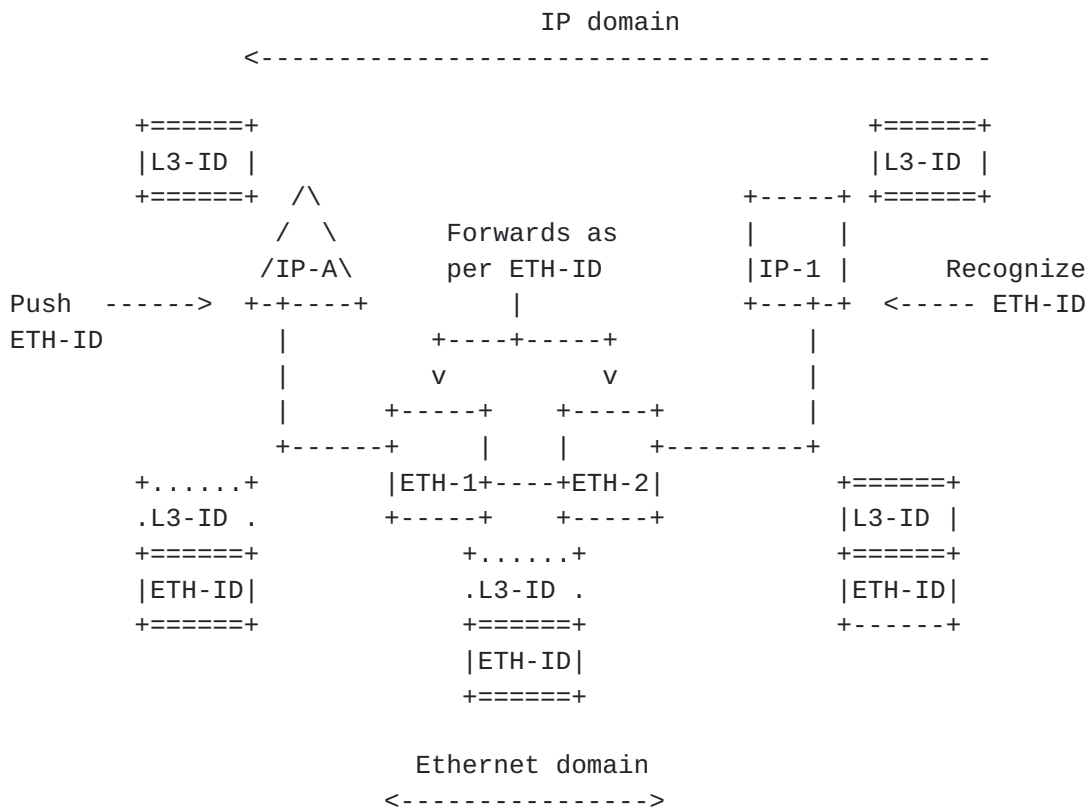


Figure 5: IP nodes interconnected by an Ethernet domain

"IP-A" uses the original App-flow specific ID ("L3-ID"), but as it is connected to an Ethernet domain it has to push also an Ethernet-domain specific flow-ID ("VLAN+multicast-MAC", referred as "ETH-ID") before sending the packet to "ETH-1". The ethernet switch "ETH-1" can recognize the data flow based on the "ETH-ID" and it does forwarding towards "ETH-2". "ETH-2" switches the packet towards the



IP router. "IP-1" must be configured to receive the Ethernet Flow-ID specific multicast stream, but (as it is an L3 node) it decodes the data flow ID based on the "L3-ID" fields of the received packet.

Figure 6 below shows a scenario where an MPLS domain nodes ("PE-n" and "P-m") are connected via two Ethernet switches ("ETH-n").

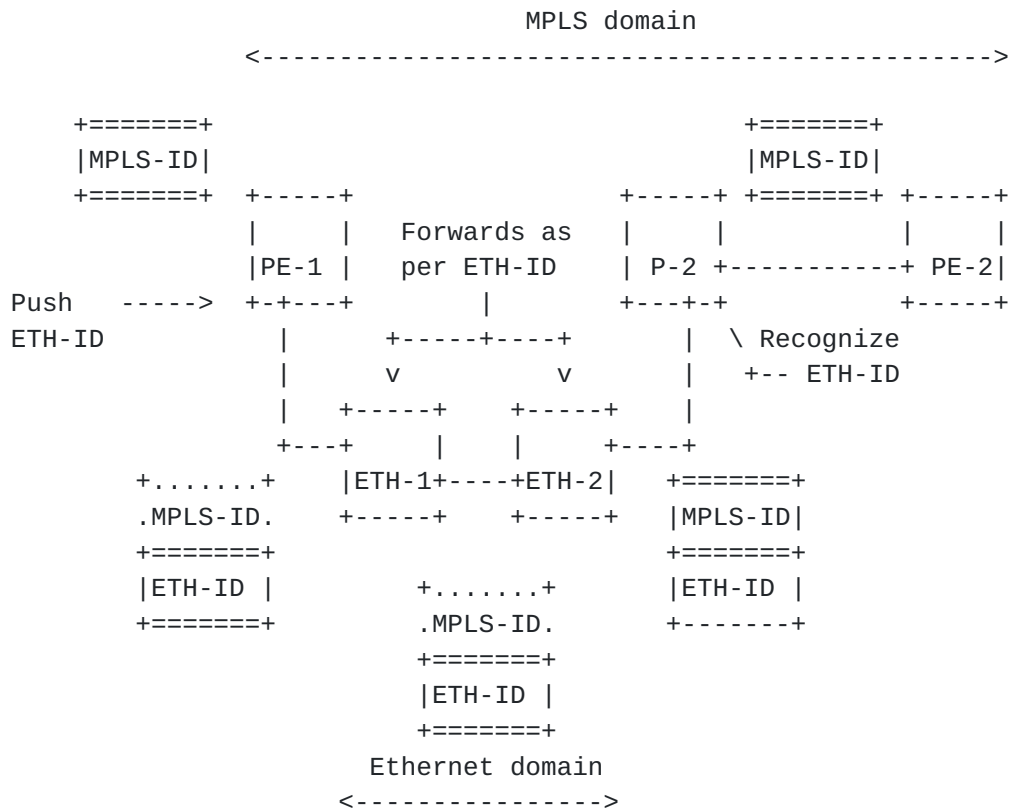


Figure 6: MPLS nodes interconnected by an Ethernet domain

"PE-1" uses the MPLS specific ID ("MPLS-ID"), but as it is connected to an Ethernet domain it has to push also an Ethernet-domain specific flow-ID ("VLAN+multicast-MAC", referred as "ETH-ID") before sending the packet to "ETH-1". The ethernet switch "ETH-1" can recognize the data flow based on the "ETH-ID" and it does forwarding towards "ETH-2". "ETH-2" switches the packet towards the MPLS node ("P-2"). "P-2" must be configured to receive the Ethernet Flow-ID specific multicast stream, but (as it is an MPLS node) it decodes the data flow ID based on the "MPLS-ID" fields of the received packet.





## **8. Summary**

This document specifies a DetNet service model via related SAPs, Components/Segments and Terminology .

## **9. IANA Considerations**

N/A.

## **10. Security Considerations**

N/A.

## **11. Acknowledgements**

The authors wish to thank Lou Berger, Norman Finn, Jouni Korhonen and the members of the data plane design team for their various contributions, comments and suggestions regarding this work.

## **12. Annex**

This Annex contains some thoughts about scenarios where the service instance is shared by DetNet and regular traffic.

### **12.1. L2 service instance shared by regular and DetNet traffic**

In case of a L2 VPN transport the service instance implements bridging. In MPLS based PSN there is a full mesh of PWs between service instances of PE nodes. Adding DetNet data flows to the network results in a somewhat modified PW structure, as a DetNet data flow requires its unique Flow-ID to be encoded in the packet.



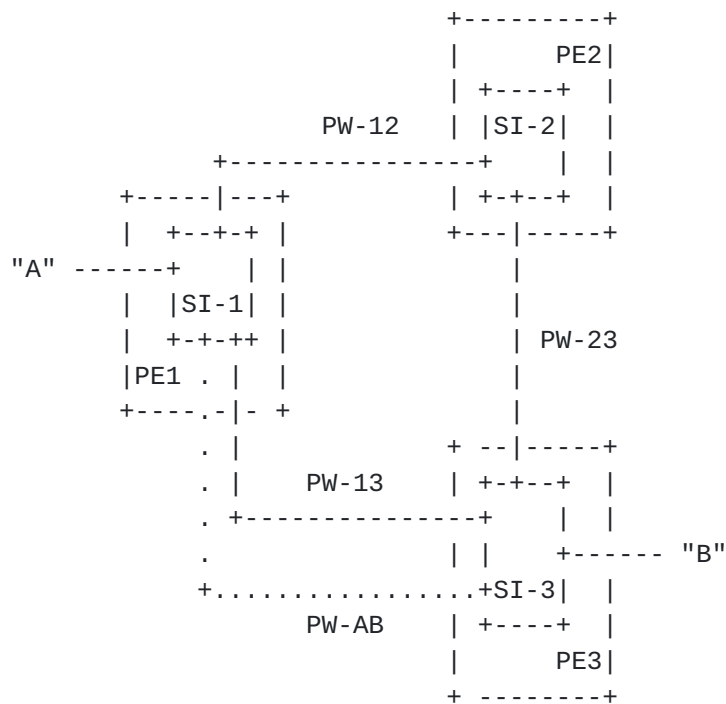


Figure 7: DetNet L2 VPN Service

Figure 7 shows a scenario where there is a DetNet data flow between the end-systems ("A" and "B"). "SI-n" denotes the L2 VPN service instance of "PEn". Regular traffic of the L2 VPN instance use "PW-12", "PW-13" and "PW-23". However for transport of DetNet traffic between "A" and "B" a separate PW ("PW-AB") have to be used. "PW-AB" is a somewhat special PW (called here "virtual PW") and it is treated differently than PWs used by regular traffic (i.e. PW-13, PW-12 and PW-23). Namely, "PW-AB" is used exclusively by the DetNet data flow between "A" and "B". "PW-AB" does not participate in flooding and no MAC addresses are associated with it (not considered for the MAC learning process). "PW-AB" may use the same LSP as "PW-13" or a dedicated one.

Regular traffic between "A" and "B" has an encapsulation [PW-13\_label ; LSP\_label], whereas DetNet data flow has [PW-AB\_label ; LSP\_label].

## 12.2. L3 service instance shared by regular and DetNet traffic

In case of a L3 DetNet service the service instance implements routing. In MPLS based PSN such a "routing service" can be provided by IP VPNs ([rfc4364](#)). However the IP VPN service add only a single label (VPN label) during forwarding, therefore the label stack does not contain a "control word" (i.e., there is no field to encode a



sequence number). So, transport of DetNet data flows requires the combination of IP VPN and PW technologies.

Adding DetNet data flows to the network results in a somewhat modified label stack structure, as a DetNet data flow requires its packet PW encapsulation ([rfc6658](#)).

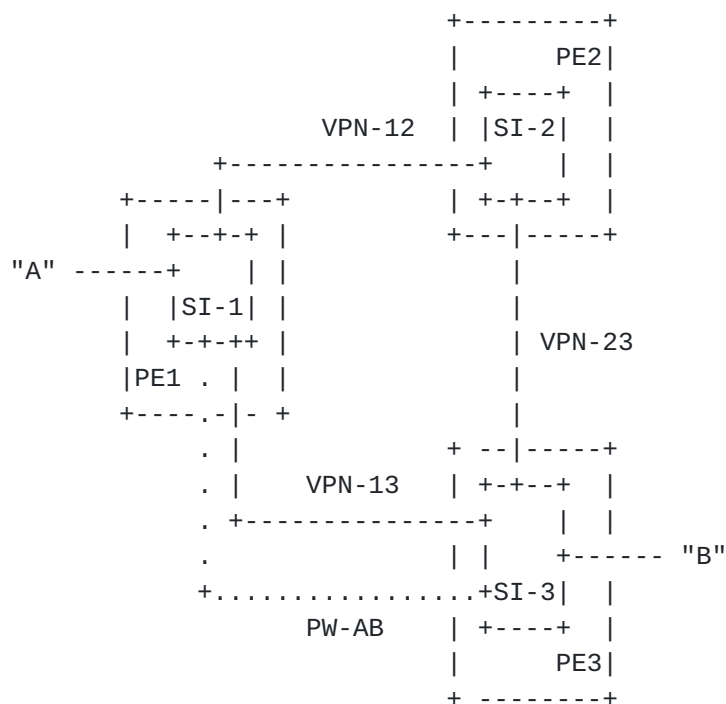


Figure 8: DetNet L3 VPN Service

Figure 8 shows a scenario where there is a DetNet data flow between the end-systems ("A" and "B"). "SI-n" denotes the L3 VPN service instance of "PEn". Regular traffic of the L3 VPN instance use as service label "VPN-12", "VPN-13" and "VPN-23". However for transport of DetNet traffic between "A" and "B" a PW ("PW-AB") have to be used, what ensures that DetNet data flow can be recognized by intermediate P nodes and a control world can be also present. "PW-AB" is used exclusively by the DetNet data flow between "A" and "B". "PW-AB" may use the same LSP as regular traffic (labeled by "VPN-13") or a dedicated one.

Regular traffic between "A" and "B" has an encapsulation [VPN-13\_label ; LSP\_label], whereas DetNet data flow has [PW-AB\_label ; LSP\_label].



## **13. References**

### **13.1. Normative References**

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