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**NV03 Data Plane Requirements**  
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## Abstract

Several IETF drafts relate to the use of overlay networks to support large scale virtual data centers. This draft provides a list of data plane requirements for Network Virtualization over L3 (NV03) that have to be addressed in solutions documents.

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## [1. Introduction](#)

### [1.1. 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 [RFC-2119](#) [[RFC2119](#)].

In this document, these words will appear with that interpretation only when in ALL CAPS. Lower case uses of these words are not to be interpreted as carrying [RFC-2119](#) significance.

### [1.2. General terminology](#)

The terminology defined in [[NV03-framework](#)] is used throughout this document. Terminology specific to this memo is defined here and is introduced as needed in later sections.

DC: Data Center

BUM: Broadcast, Unknown Unicast, Multicast traffic

TES: Tenant End System

VAP: Virtual Access Point

VNI: Virtual Network Instance

VNID: VNI ID



Lookup tables can be populated using different techniques: data plane learning, management plane configuration, or a distributed control plane. Management and control planes are not in the scope of this document. The data plane based solution is described in this document as it has implications on the data plane processing function.

The result of this lookup yields the corresponding tunnel information needed to build the overlay encapsulation header. This information includes the destination L3 address of the egress NVE. Note that this lookup might yield a list of tunnels such as when ingress replication is used for BUM traffic.

The overlay tunnel encapsulation header MUST include a context identifier which the egress NVE will use to identify which VNI this frame belongs to.

The egress NVE checks the context identifier and removes the encapsulation header and then forwards the original frame towards the appropriate recipient, usually a local VAP.

### **3. Data Plane Requirements**

#### **3.1. Virtual Access Points (VAPs)**

The NVE forwarding plane MUST support VAP identification through the following mechanisms:

- Using the local interface on which the frames are received, where the local interface may be an internal, virtual port in a VSwitch or a physical port on the ToR
- Using the local interface and some fields in the frame header, e.g. one or multiple VLANs or the source MAC

#### **3.2. Virtual Network Instance (VNI)**

VAPs are associated with a specific VNI at service instantiation time.

A VNI identifies a per-tenant private context, i.e. per-tenant policies and a FIB table to allow overlapping address space between tenants.

There are different VNI types differentiated by the virtual network service they provide to Tenant End Systems. Network virtualization can be provided by L2 and/or L3 VNIs.





### **3.2.1. L2 VNI**

An L2 VNI MUST provide an emulated Ethernet multipoint service as if Tenant End Systems are interconnected by an 802.1Q LAN over a set of NV03 tunnels. An L2 VNI provides per tenant virtual switching instance with MAC addressing isolation and L3 tunneling. Loop avoidance capability MUST be provided.

In the absence of a management or control plane, data plane learning MUST be used to populate forwarding tables. Forwarding table entries provide mapping information between MAC addresses and L3 tunnel destination addresses. As frames arrive from VAPs or from overlay tunnels, the MAC learning procedures described in IEEE 802.1Q are used: The source MAC address is learned against the VAP or the NV03 tunnel on which the frame arrived.

Broadcast, Unknown Unicast and Multicast (BUM) traffic handling MUST be supported. To achieve this, the NVE must be able to build at least a default flooding tree per VNI. The flooding tree is equivalent with a multicast (\*,G) construct where all the NVEs where the corresponding VNI is instantiated are members.

The ability to establish or pre-provision multicast trees at the NVE SHOULD be supported.

It MUST also be possible to select whether the NVE provides optimized multicast trees inside the VNI for individual tenant multicast groups or whether the default VNI flooding tree is used. If the former option is selected the VNI MUST be able to snoop IGMP/MLD messages in order to efficiently join/prune End System from multicast trees.

### **3.2.2. L3 VNI**

L3 VNIs MUST provide virtualized IP routing and forwarding. L3 VNIs MUST support per-tenant routing instance with IP addressing isolation and L3 tunneling for interconnecting instances of the same VNI on NVEs.

In the case of L3 VNI, the inner TTL field MUST be decremented by 1 as if the NV03 egress NVE was one hop away. The TTL field in the outer IP header must be set to a value appropriate for delivery of the encapsulated frame to the tunnel exit point. Thus, the default behavior must be the TTL pipe model where the overlay network looks like one hop to the sending NVE. Configuration of the uniform TTL model where the outer tunnel TTL is set equal to the inner TTL on



ingress NVE and the inner TTL is set to the outer TTL value on egress should be supported.

L2 and L3 VNIs can be deployed in isolation or in combination to optimize traffic flows per tenant across the overlay network. For example, an L2 VNI may be configured across a number of NVEs to offer L2 multi-point service connectivity while a L3 VNI can be co-located to offer local routing capabilities and gateway functionality. In addition, integrated routing and bridging per tenant must be supported on an NVE. An instantiation of such service may be realized by interconnecting an L2 VNI as access to an L3 VNI on the NVE.

The L3 VNI does not require support for Broadcast and Unknown Unicast traffic. The L3 VNI MAY provide support for customer multicast groups. This paragraph will be expanded in a future version of the draft.

### **3.3. Overlay Module**

The overlay module performs a number of functions related to NV03 header and tunnel processing. Specifically for a L2 VNI it provides the capability to encapsulate and send Ethernet traffic over NV03 tunnels. For a L3 VNI it provides the capability to encapsulate and carry IP traffic (both IPv4 and IPv6) over NV03 tunnels.

#### **3.3.1. NV03 overlay header**

An NV03 overlay header MUST be included after the tunnel encapsulation header when forwarding tenant traffic. This section describes the fields that need to be included as part of the NV03 overlay header. In this version the focus is on the VN instance and service QoS fields. Future versions may include additional fields.

##### **3.3.1.1. Virtual Network Identifier (VNID)**

A VNID MUST be included in the overlay encapsulation header on the ingress NVE when encapsulating a tenant Ethernet frame or IP packet on the overlay tunnel. The egress NVE uses the VNID to identify the VN context in which the encapsulated frame should be processed. The VNID can be either a globally unique identifier (on a per-administrative domain) or a locally significant identifier. It MUST be easily parsed and processed by the data path and MAY be distributable by a control-plane or configured via a management plane.



The VNID MUST be large enough to scale to 100's of thousands of virtual networks.

#### **3.3.1.2. Service QoS identifier**

Traffic flows originating from different applications could rely on differentiated forwarding treatment to meet end-to-end availability and performance objectives. Such applications may span across one or more overlay networks. To enable such treatment, support for multiple Classes of Service across or between overlay networks is required.

To effectively enforce CoS across or between overlay networks, NVEs should be able to map CoS markings between networking layers, e.g., Tenant End Systems, Overlays, and/or Underlay, enabling each networking layer to independently enforce its own CoS policies. For example:

- TES (e.g. VM) CoS
  - o Tenant CoS policies MAY be defined by Tenant administrators
  - o QoS fields (e.g. IP DSCP and/or Ethernet 802.1p) in the tenant frame are used to indicate application level CoS requirements
- NVE CoS
  - o NVE MAY classify packets based on Tenant CoS markings or other mechanisms (eg. DPI) to identify the proper service CoS to be applied across the overlay network
  - o NVE service CoS levels are normalized to a common set (for example 8 levels) across multiple tenants; NVE uses per tenant policies to map Tenant CoS to the normalized service CoS fields in the NV03 header
- Underlay CoS
  - o The underlay/core network may use a different CoS set (for example 4 levels) than the NVE CoS as the core devices may have different QoS capabilities compared with NVEs.
  - o The Underlay CoS may also change as the NV03 tunnels pass between different domains.



Support for NVE Service CoS SHOULD be provided through a QoS field, inside the NV03 overlay header. Examples of service CoS provided part of the service tag are 802.1p and DE bits in the VLAN and PBB ISID tags and MPLS EXP bits in the VPN labels.

### **3.3.2. NVE Tunneling function**

This section describes NVE tunneling requirements. From an encapsulation perspective the IPv4 and IPv6 encapsulations MUST be supported, MPLS tunneling MAY be supported.

#### **3.3.2.1. LAG and ECMP**

For performance reasons, multipath over LAG and ECMP paths SHOULD be supported.

LAG (Link Aggregation Group) [IEEE 802.1AX-2008] and ECMP (Equal Cost Multi Path) are commonly used techniques to perform load-balancing of microflows over a set of a parallel links either at Layer-2 (LAG) or Layer-3 (ECMP). Existing deployed hardware implementations of LAG and ECMP uses a hash of various fields in the encapsulation (outermost) header(s) (e.g. source and destination MAC addresses for non-IP traffic, source and destination IP addresses, L4 protocol, L4 source and destination port numbers, etc). Furthermore, hardware deployed for the underlay network(s) will be most often unaware of the carried, innermost L2 frames or L3 packets transmitted by the TES. Thus, in order to perform fine-grained load-balancing over LAG and ECMP paths in the underlying network the NV03 encapsulation headers and/or tunneling methods MUST contain a "entropy field" or "entropy label" so the underlying network can perform fine-grained load-balancing of the NV03 encapsulated traffic, (e.g.: [[RFC6391](#)], [[RFC6438](#)], [[draft-kompella-mpls-entropy-label-02](#)], etc.) It is recommended this entropy label/field be applied at the ingress VNI, likely using information gleaned from the ingress VAP. If necessary, the entropy label/field will be discarded at the egress VNI.

All packets that belong to a specific flow MUST follow the same path in order to prevent packet re-ordering. This is typically achieved by ensuring that the fields used for hashing are identical for a given flow.

All paths available to the overlay network SHOULD be used efficiently. Different flows SHOULD be distributed as evenly as possible across multiple underlay network paths. This can be





achieved by ensuring that some fields used for hashing are randomly generated.

### **3.3.2.2. DiffServ and ECN marking**

When traffic is encapsulated in a tunnel header, there are numerous options as to how the Diffserv Code-Point (DSCP) and Explicit Congestion Notification (ECN) markings are set in the outer header and propagated to the inner header on decapsulation.

[RFC2983] defines two modes for mapping the DSCP markings from inner to outer headers and vice versa. The Uniform model copies the inner DSCP marking to the outer header on tunnel ingress, and copies that outer header value back to the inner header at tunnel egress. The Pipe model sets the DSCP value to some value based on local policy at ingress and does not modify the inner header on egress. Both models SHOULD be supported.

ECN marking MUST be performed according to [RFC6040] which describes the correct ECN behavior for IP tunnels.

### **3.3.2.3. Handling of BUM traffic**

NV03 data plane support for either ingress replication or point-to-multipoint tunnels is required to send traffic destined to multiple locations on a per-VNI basis (e.g. L2/L3 multicast traffic, L2 broadcast and unknown unicast traffic). It is possible that both methods be used simultaneously.

L2 NVEs MUST support ingress replication and SHOULD support point-to-multipoint tunnels. L3 VNIs MAY support either one of the two methods.

There is a bandwidth vs state trade-off between the two approaches. User-definable knobs MUST be provided to select which method(s) gets used based upon the amount of replication required (i.e. the number of hosts per group), the amount of multicast state to maintain, the duration of multicast flows and the scalability of multicast protocols.

When ingress replication is used, NVEs must track for each VNI the related tunnel endpoints to which it needs to replicate the frame.

For point-to-multipoint tunnels, the bandwidth efficiency is increased at the cost of more state in the Core nodes. The ability to auto-discover or pre-provision the mapping between VNI multicast



trees to related tunnel endpoints at the NVE and/or throughout the core SHOULD be supported.

### **3.4. External NV03 connectivity**

NV03 services MUST interoperate with current VPN and Internet services. This may happen inside one DC during a migration phase or as NV03 services are delivered to the outside world via Internet or VPN gateways.

Moreover the compute and storage services delivered by a NV03 domain may span multiple DCs requiring Inter-DC connectivity. From a DC perspective a set of gateway devices are required in all of these cases albeit with different functionalities influenced by the overlay type across the WAN, the service type and the DC network technologies used at each DC site.

A GW handling the connectivity between NV03 and external domains represents a single point of failure that may affect multiple tenant services. Redundancy between NV03 and external domains MUST be supported.

#### **3.4.1. GW Types**

##### **3.4.1.1. VPN and Internet GWs**

Tenant sites may be already interconnected using one of the existing VPN services and technologies (VPLS or IP VPN). A VPN GW is required to translate between NV03 and VPN encapsulation and forwarding procedures. Internet connected Tenants require translation from NV03 encapsulation to IP in the NV03 gateway. The translation function SHOULD NOT require provisioning touches and SHOULD NOT use intermediate hand-offs, for example VLANs.

##### **3.4.1.2. Inter-DC GW**

Inter-DC connectivity may be required to provide support for features like disaster prevention or compute load re-distribution. This may be provided through a set of gateways interconnected through a WAN. This type of connectivity may be provided either through extension of the NV03 tunneling domain or via VPN GWs.

##### **3.4.1.3. Intra-DC gateways**

Even within one DC there may be End Devices that do not support NV03 encapsulation, for example bare metal servers, hardware appliances



and storage. A gateway device, e.g. a ToR, is required to translate the NV03 to Ethernet VLAN encapsulation.

#### **3.4.2. Path optimality between NVEs and Gateways**

Within the NV03 overlay, a default assumption is that NV03 traffic will be equally load-balanced across the underlying network consisting of LAG and/or ECMP paths. This assumption is valid only as long as: a) all traffic is load-balanced equally among each of the component-links and paths; and, b) each of the component-links/paths is of identical capacity. During the course of normal operation of the underlying network, it is possible that one, or more, of the component-links/paths of a LAG may be taken out-of-service in order to be repaired, e.g.: due to hardware failure of cabling, optics, etc. In such cases, the administrator should configure the underlying network such that an entire LAG bundle in the underlying network will be reported as operationally down if there is a failure of any single component-link member of the LAG bundle, (e.g.: N = M configuration of the LAG bundle), and, thus, they know that traffic will be carried sufficiently by alternate, available (potentially ECMP) paths in the underlying network. This is a likely an adequate assumption for Intra-DC traffic where presumably the costs for additional, protection capacity along alternate paths is not cost-prohibitive. Thus, there are likely no additional requirements on NV03 solutions to accommodate this type of underlying network configuration and administration.

There is a similar case with ECMP, used Intra-DC, where failure of a single component-path of an ECMP group would result in traffic shifting onto the surviving members of the ECMP group.

Unfortunately, there are no automatic recovery methods in IP routing protocols to detect a simultaneous failure of more than one component-path in a ECMP group, operationally disable the entire ECMP group and allow traffic to shift onto alternative paths. This is problem is attributable to the underlying network and, thus, out-of-scope of any NV03 solutions.

On the other hand, for Inter-DC and DC to External Network cases that use a WAN, the costs of the underlying network and/or service (e.g.: IPVPN service) are more expensive; therefore, there is a requirement on administrators to both: a) ensure high availability (active-backup failover or active-active load-balancing); and, b) maintaining substantial utilization of the WAN transport capacity at nearly all times, particularly in the case of active-active load-balancing. With respect to the dataplane requirements of NV03 solutions, in the case of active-backup fail-over, all of the



ingress NVE's MUST dynamically learn of the failure of an active NVE GW when the backup NVE GW announces itself into the NV03 overlay immediately following a failure of the previously active NVE GW and update their forwarding tables accordingly, (e.g.: perhaps through dataplane learning and/or translation of a gratuitous ARP, IPv6 Router Advertisement, etc.) Note that active-backup fail-over could be used to accomplish a crude form of load-balancing by, for example, manually configuring each tenant to use a different NVE GW, in a round-robin fashion. On the other hand, with respect to active-active load-balancing across physically separate NVE GW's (e.g.: two, separate chassis) an NV03 solution SHOULD support forwarding tables that can simultaneously map a single egress NVE to more than one NV03 tunnels. The granularity of such mappings, in both active-backup and active-active, MUST be unique to each tenant.

#### **3.4.2.1. Triangular Routing Issues, a.k.a.: Traffic Tromboning**

L2/ELAN over NV03 service may span multiple racks distributed across different DC regions. Multiple ELANs belonging to one tenant may be interconnected or connected to the outside world through multiple Router/VRF gateways distributed throughout the DC regions. In this scenario, without aid from an NV03 or other type of solution, traffic from an ingress NVE destined to External gateways will take a non-optimal path that will result in higher latency and costs, (since it is using more expensive resources of a WAN). In the case of traffic from an IP/MPLS network destined toward the entrance to an NV03 overlay, well-known IP routing techniques may be used to optimize traffic into the NV03 overlay, (at the expense of additional routes in the IP/MPLS network). In summary, these issues are well known as triangular routing.

Procedures for gateway selection to avoid triangular routing issues SHOULD be provided. The details of such procedures are, most likely, part of the NV03 Management and/or Control Plane requirements and, thus, out of scope of this document. However, a key requirement on the dataplane of any NV03 solution to avoid triangular routing is stated above, in [Section 3.4.2](#), with respect to active-active load-balancing. More specifically, an NV03 solution SHOULD support forwarding tables that can simultaneously map a single egress NVE to more than one NV03 tunnels. The expectation is that, through the Control and/or Management Planes, this mapping information may be dynamically manipulated to, for example, provide the closest geographic and/or topological exit point (egress NVE) for each ingress NVE.





### **3.5. Path MTU**

The tunnel overlay header can cause the MTU of the path to the egress tunnel endpoint to be exceeded.

IP fragmentation should be avoided for performance reasons.

The interface MTU as seen by a Tenant End System SHOULD be adjusted such that no fragmentation is needed. This can be achieved by configuration or be discovered dynamically.

Either of the following options MUST be supported:

- o Classical ICMP-based MTU Path Discovery [[RFC1191](#)] [[RFC1981](#)] or Extended MTU Path Discovery techniques such as defined in [[RFC4821](#)]
- o Segmentation and reassembly support from the overlay layer operations without relying on the Tenant End Systems to know about the end-to-end MTU
- o The underlay network may be designed in such a way that the MTU can accommodate the extra tunnel overhead.

### **3.6. Hierarchical NVE**

It might be desirable to support the concept of hierarchical NVEs, such as spoke NVEs and hub NVEs, in order to address possible NVE performance limitations and service connectivity optimizations.

For instance, it is possible that the amount of tunneling state to handle within a single NVE be too important. This can happen with both IP based tunneling and more specifically with MPLS based tunneling.

NVEs can be either connected in an any-to-any or hub and spoke topology on a per VNI basis.

### **3.7. NVE Multi-Homing Requirements**

Multi-homing to a set of NVEs may be required in certain scenarios:

- . End Device dual-homed to two ToR switches acting as NVEs
- . Multi-homing into NVE-GWs providing connectivity between domains using different technologies
- . Hierarchical NVEs: Spoke NVE multi-homed to Hub NVEs



This section will be extended in the next revision.

### **3.8. OAM**

NVE may be able to originate/terminate OAM messages for connectivity verification, performance monitoring, statistic gathering and fault isolation. Depending on configuration, NVEs SHOULD be able to process or transparently tunnel OAM messages, as well as supporting alarm propagation capabilities.

Given the critical requirement to load-balance NV03 encapsulated packets over LAG and ECMP paths, it will be equally critical to ensure existing and/or new OAM tools allow NVE administrators to proactively and/or reactively monitor the health of various component-links that comprise both LAG and ECMP paths carrying NV03 encapsulated packets. For example, it will be important that such OAM tools allow NVE administrators to reveal the set of underlying network hops (topology) in order that the underlying network administrators can use this information to quickly perform fault isolation and restore the underlying network.

The NVE MUST provide the ability to reveal the set of ECMP and/or LAG paths used by NV03 encapsulated packets in the underlying network from an ingress NVE to egress NVE. The NVE MUST provide the ability to provide a "ping"-like functionality that may be used to determine the health (liveness) of remote NVE's or their VNI's. The NVE SHOULD provide a "ping"-like functionality to more expeditiously aid in troubleshooting performance problems, i.e.: blackholing or other types of congestion occurring in the underlying network, for NV03 encapsulated packets carried over LAG and/or ECMP paths.

### **3.9. Other considerations**

#### **3.9.1. Data Plane Optimizations**

Data plane forwarding and encapsulation choices SHOULD consider the limitation of possible NVE implementations, specifically in software based implementations (e.g. servers running VSwitches)

NVE should provide efficient processing of traffic. For instance, packet alignment, the use of offsets to minimize header parsing, padding techniques SHOULD be considered when designing NV03 encapsulation types.

Software-based NVEs SHOULD make use of hardware assist provided by NICs in order to speed up packet processing.



### **3.9.2. NVE location trade-offs**

In the case of DC traffic, traffic originated from a VM is native Ethernet traffic. This traffic can be switched by a local VM switch or ToR switch and then by a DC gateway. The NVE function can be embedded within any of these elements.

The NVE function can be supported in various DC network elements such as a VM, VM switch, ToR switch or DC GW.

The following criteria SHOULD be considered when deciding where the NVE processing boundary happens:

- o Processing and memory requirements
  - o Datapath (e.g. lookups, filtering, encapsulation/decapsulation)
  - o Control plane processing (e.g. routing, signaling, OAM)
- o FIB/RIB size
- o Multicast support
  - o Routing protocols
  - o Packet replication capability
- o Fragmentation support
- o QoS transparency
- o Resiliency

## **4. Security Considerations**

The tenant to overlay mapping function can introduce significant security risks if appropriate protocols are not used that can support authentication.

No other new security issues are introduced beyond those described already in the related L2VPN and L3VPN RFCs.

## **5. IANA Considerations**

IANA does not need to take any action for this draft.

## 6. References

### 6.1. Normative References

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