Abstract
This white paper explains design considerations of the Dell EMC™ Isilon™
external network to ensure maximum performance and an optimal user
experience.

August 2019
Revisions

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<td>Initial rough draft</td>
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Executive summary

This document provides design considerations for understanding, configuring, and troubleshooting Isilon Scale-Out NAS external networking. In a Scale-Out NAS environment, the overall network architecture must be configured to maximize the user experience. Many factors contribute to overall network performance. This document examines network architecture design and best practices including factors such as Latency, Flow Control, ICMP, MTU, jumbo frames, congestion, TCP/IP parameters, and IPv6.

Note to readers

It is important to understand that the network design considerations stated in this document are based on general network design and are provided as guidance to Isilon administrators. As these are considerations, all of these may not apply to each workload. It is important to understand each consideration and confirm if it pertains to a specific environment.

Each network is unique, not only from a design perspective but also from a requirements and workloads perspective. Before making any changes based on the guidance in this document, it is important to discuss modifications with the Network Engineering team. Additionally, as a customary requirement for any major IT implementation, changes should first be tested in a lab environment that closely mimics the workloads of the live network.
Network architecture design

The architecture design is the core foundation of a reliable and highly available network, considering capacity and bandwidth. Layered on top of the basic foundation are the many applications running on a campus network with each requiring specific features and considerations.

For the following sections, it is important to understand the differences between Distribution and Access switches. Typically, distribution switches perform L2/L3 connectivity while Access switches are strictly L2. Figure 1 provides the representation for each.

![Distribution and Access Switches](image)

Figure 1  Distribution and Access Switches

1.1 General network architecture considerations

Designing a network is unique to the requirements of each enterprise data center. There is certainly not a “one size fits all” design and not a single “good network design.” When approaching network design, it is important to use principles as a leading factor, coupled with the enterprise requirements. The requirements must include current and future application consumption, providing the guiding factor in major decisions.

Network design is based on many concepts; the following are considerations and principles to guide the process:

- **Single Points of Failure**: Ensure the network design has layers of redundancy. Dependence on a single device or link relates to a loss of resources or outages. The enterprise requirements consider risk and budget, guiding the level of redundancy. Redundancy should be implemented through backup paths and load sharing. If a primary link fails, traffic uses a backup path. Load sharing creates two or more paths to the same endpoint and shares the network load. When designing access to Isilon nodes, it is important to assume links and hardware will fail, ensuring access to the nodes survives those failures.

- **Application and Protocol Traffic**: Understanding the application data flow from clients to the Isilon cluster across the network allows for resources to be allocated accordingly while minimizing latency and hops along this flow.

- **Available Bandwidth**: As traffic traverses the different layers of the network, the available bandwidth should not be significantly different. Compare this available bandwidth with the workflow requirements.

- **Minimizing Latency**: Ensuring latency is minimal from the client endpoints to the Isilon nodes maximizes performance and efficiency. Several steps can be taken to minimize latency, but latency should be considered throughout network design.

- **Prune VLANs**: It is important to limit VLANs to areas where they are applicable. Pruning unneeded VLANs is also good practice. If unneeded VLANs are trunked further down the network, this imposes additional strain on endpoints and switches. Broadcasts are propagated across the VLAN and impact clients.
VLAN Hopping: VLAN hopping has two methods, switch spoofing and double tagging. Switch spoofing is when a host imitates the behavior of a trunking switch, allowing access to other VLANs. Double tagging is a method where each packet contains two VLAN tags, with the assigned or correct VLAN tag empty and the second as the VLAN where access is not permitted. It is recommended to assign the native VLAN to an ID that is not in use. Otherwise, tag the native VLAN to avoid VLAN hopping, allowing a device to access a VLAN it normally would not have access. Additionally, only allow trunk ports between trusted devices and assign access VLANs on ports that are different from the default VLAN.

1.2 Triangle looped topology
This section provides best practices for Layer 2 Access network design. Although many network architectures may meet enterprise requirements, this document takes a closer look at what is commonly referred to as the Triangle Looped Access Topology, which is the most widely implemented architecture in enterprise data centers.

The Looped Design Model extends VLANs between the aggregation switches, thus creating the looped topology. To prevent actual loops, Spanning Tree is implemented, using Rapid PVST+ or MST. For each path, a redundant path also exists, which is blocking until the primary path is not available. Access layer uplinks may be used to load balance VLANs. A key point to consider with the Looped Access Topology is the utilization of the inter-switch link between the Distribution switches. The utilization must be monitored closely as this is used to reach active services.

The Looped Triangle Access Topology supports VLAN extension and L2 adjacency across the Access layer. Through the use of STP and dual homing, the Looped Triangle is extremely resilient. Stateful services are supported at the aggregation layer and quick convergence with 802.1W/S.

Utilizing the Triangle Looped Topology allows for multiple Access Switches to interface with the external network of the Isilon Scale-Out NAS environment. Each Isilon node within a cluster is part of a distributed architecture which allows each node to have similar properties regarding data availability and management.
1.3 Link aggregation

In the context of the IEEE 802.1AX standard, link aggregation provides methods to combine multiple Ethernet interfaces, forming a single link layer interface, specific to a switch or server. Therefore, link aggregation is implemented between a single switch and an Isilon node, not across Isilon nodes.

Implementing link aggregation is neither mandatory nor is it necessary, rather it is based on workload requirements and is recommended if a transparent failover or switch port redundancy is required.

Link aggregation assumes all links are full duplex, point to point, and at the same data rate, providing graceful recovery from link failures. If a link fails, traffic is automatically sent to the next available link without disruption.

It is imperative to understand that link aggregation is not a substitute for a higher bandwidth link. Although link aggregation combines multiple interfaces, applying it to multiply bandwidth by the number of interfaces for a single session is incorrect. Link aggregation distributes traffic across links. However, a single session only utilizes a single physical link to ensure packets are delivered in order without duplication of frames.

As part of the IEEE 802.1AX standard, the Frame Distributor does not specify a distribution algorithm across aggregated links but enforces that frames must be sent in order without duplication. Frame order is maintained by ensuring that all frames of a given session are transmitted on a single link in the order that they are generated by the client. The mandate does not allow for additions or modifications to the MAC frame, buffering, or processing to re-order frames by the Frame Distributor or Collector.

Thus, the bandwidth for a single client is not increased, but the aggregate bandwidth of all clients increases in an active/active configuration. The aggregate bandwidth is realized when carrying multiple simultaneous sessions and may not provide a linear multiple of each link’s data rate, as each individual session utilizes a single link.

Another factor to consider is depending on the workload, certain protocols may or may not benefit from link aggregation. Stateful protocols, such as NFSv4 and SMBv2 benefit from link aggregation as a failover mechanism. On the contrary, SMBv3 Multichannel automatically detects multiple links, utilizing each for maximum throughput and link resilience.

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1.3.1 Multi-chassis link aggregation

As discussed in the previous section, the IEEE 802.1AX standard does not define Link Aggregation between multiple switches and an Isilon node. However, many vendors provide this functionality through proprietary features. Multiple switches are connected with an Inter-Switch link or other proprietary cable and communicate via a proprietary protocol forming a virtual switch. A virtual switch is perceived as a single
switch to an Isilon node, with links terminating on a single switch. The ability to have link aggregation split with multiple chassis provides network redundancy if a single chassis were to fail.

Each vendor has a proprietary implementation of Multi-Chassis Link Aggregation, but externally the virtual switch created is compliant with the IEEE 802.1AX standard.

It is important to recognize that regarding bandwidth, the concepts discussed for single switch Link Aggregation still apply to Multi-Chassis Link Aggregation. Additionally, as the multiple switches form a single virtual switch, it is important to understand what happens if the switch hosting the control plane fails. Those effects vary by the vendor’s implementation but will impact the network redundancy gained through Multi-Chassis Link Aggregation.
Latency, bandwidth, and throughput

Maximizing overall network performance is dependent on several factors. However, the three biggest factors contributing to end-to-end performance are latency, throughput, and bandwidth. This section focuses on these factors to maximize the Isilon user experience.

2.1 Latency

Latency in a packet-switched network is defined as the time from when a source endpoint sends a packet to when it is received by the destination endpoint. Round trip latency, sometimes referred to as round-trip delay, is the amount of time for a packet to be sent from the source endpoint to the destination endpoint and returned from the destination to the source endpoint.

Minimal latency in any transaction is imperative for several reasons. IP endpoints, switches, and routers operate optimally without network delays. Minimal latency between clients and an Isilon node ensures performance is not impacted. As latency increases between two endpoints, this may lead to several issues that degrade performance heavily, depending on the application.

In order to minimize latency, it is important to measure it accurately between the endpoints. For assessing Isilon nodes, this is measured from the clients to a specified node. The measurement could use the IP of a specific node or the SmartConnect hostname. After configuration changes are applied that impact latency, it is important to confirm the latency has indeed decreased. When attempting to minimize latency, consider the following points:

- Hops: Minimizing hops required between endpoints decreases latency. The implication is not to drag cables across a campus, but the goal is to confirm if any unnecessary hops could be avoided. Minimizing hops applies at the physical level with the number of switches between the endpoints but also applies logically to network protocols and algorithms.
- ASICs: When thinking about network hops it also important to consider the ASICs within a switch. If a packet enters through one ASIC and exits through the other, latency could increase. If at all possible, it is recommended to keep traffic as part of the same ASIC to minimize latency.
- Network Congestion: NFS v3, NFSv4 and SMB employ the TCP protocol. For reliability and throughput, TCP uses windowing to adapt to varying network congestion. At peak traffic, congestion control is triggered, dropping packets, and leading TCP to utilize smaller windows. In turn, throughput could decrease, and overall latency may increase. Minimizing network congestion ensures it does not impact latency. It is important to architect networks that are resilient to congestion.
- Routing: Packets that pass through a router may induce additional latency. Depending on the router configuration, packets are checked for a match against defined rules, in some cases requiring packet header modification.
- MTU Mismatch: Depending on the MTU size configuration of each hop between two endpoints, an MTU mismatch may exist. Therefore, packets must be split to conform to upstream links, creating additional CPU overhead on routers and NICs, creating higher processing times, and leading to additional latency.
- Firewalls: Firewalls provide protection by filtering through packets against set rules for additional steps. The filtering process consumes time and could create further latency. Processing times are heavily dependent upon the number of rules in place. It is good measure to ensure outdated rules are removed to minimize processing times.
2.2  Bandwidth and throughput
Understanding the difference between throughput and bandwidth are important for network troubleshooting. Although these terms are conflated at times, they are actually both unique. Bandwidth is the theoretical maximum speed a specific medium can deliver if all factors are perfect without any form of interference. Throughput is the actual speed realized in a real-world scenario, given interference and other environmental factors such as configuration, contention, and congestion.

The difference between these terms is important when troubleshooting. If an Isilon node supports 40 GbE, it does not necessarily mean the throughput is 40 Gb/s. The actual throughput between a client and an Isilon node is dependent on all of the factors between the two endpoints and may be measured with a variety of tools.

During the design phase of a data center network, it is important to ensure bandwidth is available throughout the hierarchy, eliminating bottlenecks and ensuring consistent bandwidth. The bandwidth from the Access Switches to the Isilon nodes should be a ratio of what is available back to the distribution and core switches. For example, if an Isilon cluster of 12 nodes has all 40 GbE connectivity to access switches, the link from the core to distribution to access should be able to handle the throughput from the access switches. Ideally, the link from the core to distribution to access should support roughly a bandwidth of 480 Gb (12 nodes * 40 GbE).

2.2.1  Bandwidth delay product
Bandwidth Delay Product (BDP) is calculated to find the amount of data a network link is capable of, in bytes, which can be transmitted on a network link at a given time. The keyword is transmitted, meaning the data is not yet acknowledged. BDP takes into consideration the bandwidth of the data link and the latency on that link, in terms of a round-trip delay.

The amount of data that can be transmitted across a link is vital to understanding Transmission Control Protocol (TCP) performance. Achieving maximum TCP throughput requires that data must be sent in quantities large enough before waiting for a confirmation message from the receiver, which acknowledges the successful receipt of data. The successful receipt of the data is part of the TCP connection flow. The diagram below explains the steps of a TCP connection and where BDP is applicable:
Transmission Control Protocol Message Flow

In the diagram above, four states are highlighted during a TCP connection. The following summarizes each state:

1. TCP Handshake – Establishes the TCP connection through an SYN, SYN/ACK, ACK
2. Data transmitted to the server. **BDP is the maximum amount of data that can be sent at this step.**
3. Data acknowledged by Server
4. TCP Connection Close Sequence – Socket closure is initiated by either side

Once the BDP rate is calculated, the TCP stack is tuned for the maximum throughput, which is discussed in the next section. The BDP is calculated by multiplying the bandwidth of the network link (bits/second) by the round-trip time (seconds).

For example, a link with a bandwidth of 1 Gigabit per second and a 1 millisecond round trip time, would be calculated as:

\[
\text{Bandwidth} \times \text{RTT} = 1 \text{ Gigabit per second} \times 1 \text{ millisecond} = 1,000,000,000 \text{ bits per second} \times 0.001 \text{ seconds} = 1,000,000 \text{ bits} = 0.125 \text{ MB}
\]

Thus, 0.125 MB may be sent per TCP message to the server.

2.3 **Isilon network stack tuning**

Once the BDP is calculated and understood, these findings can be applied to modifying the TCP stack on the Isilon cluster. All Isilon clusters do not require TCP stack tuning. Only alter the TCP stack for a needed workflow improvement. The majority of Isilon environments do not need TCP tuning. Before applying any TCP changes, ensure the network is clean and reliable by performing basic checks for excessive retransmits, duplicate or fragmented packets, and broken pipes.
Latency, bandwidth, and throughput

Isilon OneFS is built on FreeBSD. An Isilon cluster is composed of nodes with a distributed architecture, and each node provides external network connectivity. Adapting the TCP stack to bandwidth, latency, and MTU requires tuning to ensure the cluster provides optimal throughput.

In the previous section, BDP was explained in depth and how it is the amount of data that can be sent across a single TCP message flow. Although the link supports the BDP that is calculated, the OneFS system buffer must be able to hold the full BDP. Otherwise, TCP transmission failures may occur. If the buffer does not accept all of the data of a single BDP, the acknowledgment is not sent, creating a delay, and the workload performance is degraded.

The OneFS network stack must be tuned to ensure on inbound, the full BDP is accepted, and on outbound, it must be retained for a possible retransmission. Prior to modifying the TCP stack, it is important to measure the current I/O performance and then again after implementing changes. As discussed earlier in this document, the tuning below is only guidance and should be tested in a lab environment before modifying a production network.

The spreadsheet below provides the necessary TCP stack changes based on the bandwidth, latency, and MTU. The changes below must be implemented in the order below and all together on all nodes. Modifying only some variables could lead to unknown results. After making changes, it is important to measure performance again.

**Note:** The snippet below is only for representation. It is imperative to input the calculated bandwidth, latency, and MTU specific to each environment.

![Isilon TCP network stack tuning](http://www.emc.com/collateral/tool/h164888-isilon-onefs-network-stack-tuning.xlsm)

**Figure 4** Isilon TCP network stack tuning

Download the Isilon Network Stack Tuning spreadsheet at the following link:

3 Ethernet flow control

Under certain conditions, packets sent from the source to the destination can overwhelm the destination endpoint. The destination is not able to process all packets at the rate that they are sent, leading to retransmits or dropped packets. Most scenarios have a fast source endpoint and a slower destination endpoint; this could be due to processing power or several source endpoints interacting with a single destination. Flow control is implemented to manage the rate of data transfer between these IP endpoints, providing an option for the destination to control the data rate, and ensuring the destination is capable of processing all of the packets from the source.

The IEEE 802.3x standard defines an Ethernet Flow Control mechanism at the data link layer. It specifies a pause flow control mechanism through MAC Control frames in full-duplex link segments. For flow control to be successfully implemented, it must be configured throughout the network hops that the source and destination endpoints communicate through. Otherwise, the pause flow control frames are not recognized and are dropped.

By default, Isilon OneFS listens for pause frames but does not transmit them, meaning it is only applicable when an Isilon node is the source. In the default behavior, OneFS recognizes pause frames from the destination. However, pause frames may be enabled for transmit, depending on the NIC.

Most networks today do not send pause frames, but certain devices still send them. In particular, Cisco Nexus Switches with the Fabric Extender Modules have been known to send pause frames.

3.1 Checking for pause frames

If the network or cluster performance does not seem optimal, it is easy to check for pause frames on an Isilon cluster.

If pause frames are reported, it is important to discuss these findings with the network engineering team before making any changes. As mentioned above, changes must be implemented across the network, ensuring all devices recognize a pause frame. Contact the switch manufacturer's support teams or account representative for specific steps and caveats for implementing flow control before proceeding.
3.1.1 4th and 5th generation Isilon nodes

On a 4th or 5th generation Isilon cluster, check for pause frames received by executing the following command from the shell:

```bash
isi_for_array -a <cluster name> sysctl dev | grep pause
```

**Check for any values greater than zero.** In the example, below, the cluster has not received any pause frames. If values greater than zero are printed consistently, flow control should be considered.

```
tme-sandbox-1# isi_for_array -a tme-sandbox sysctl dev | grep pause
tme-sandbox-3: dev.bxe.0.rx_pause_frames: 0
tme-sandbox-3: dev.bxe.0.tx_pause_frames: 0
tme-sandbox-3: dev.bxe.1.rx_pause_frames: 0
tme-sandbox-3: dev.bxe.1.tx_pause_frames: 0
```

Figure 5  Checking for pause frames

3.1.2 6th generation Isilon nodes

For 6th generation Isilon nodes with ix NICs, check for pause frames with the following commands:

```
infPerf-1# sysctl -d dev.ix.0.mac_stats.xon_txd
dev.ix.0.mac_stats.xon_txd: Link XON Transmitted <<<Pause frame sent
infPerf-1# sysctl -d dev.ix.0.mac_stats.xon_recvd
dev.ix.0.mac_stats.xon_recvd: Link XON Received <<<Pause frame received
infPerf-1# sysctl -d dev.ix.0.mac_stats.xoff_txd
dev.ix.0.mac_stats.xoff_txd: Link XOFF Transmitted <<<Resume frame sent
infPerf-1# sysctl -d dev.ix.0.mac_stats.xoff_recvd
dev.ix.0.mac_stats.xoff_recvd: Link XOFF Received <<<Resume frame received
```
4 SyncIQ considerations

Isilon SyncIQ provides asynchronous data replication for disaster recovery and business continuance, allowing failover and failback between clusters. It is configurable for either complete cluster replication or only for specific directories. Within an Isilon cluster, all nodes can participate in replication. After an initial SyncIQ replication, only changed data blocks are copied minimizing network bandwidth and resource utilization on clusters.

This section provides considerations for SyncIQ pertaining to external network connectivity. For more information on SyncIQ, refer to the Isilon SyncIQ: Architecture, Configuration, and Considerations white paper.

4.1 SyncIQ disaster recovery with SmartConnect

This section describes best practices for disaster recovery planning with OneFS SmartConnect.

Dedicated static SmartConnect zones are required for SyncIQ replication traffic. As with any static SmartConnect zone, the dedicated replication zone requires one IP address for each active logical interface. For example, in the case of two active physical interfaces, 10gige-1 and 10gige-2, requiring two IP addresses. However, if these are combined with link aggregation, interface 10gige-agg only requires one IP address. Source-restrict all SyncIQ jobs to use the dedicated static SmartConnect zone on the source cluster and repeat the same on the target cluster.

By restricting SyncIQ replication jobs to a dedicated static SmartConnect Zone, replication traffic may be assigned to specific nodes, reducing the impact of SyncIQ jobs on user or client I/O. The replication traffic is directed without reconfiguring or modifying the interfaces participating in the SmartConnect zone.

For example, consider a data ingest cluster for a sports television network. The cluster must ingest large amounts of data recorded in 4K video format. The data must be active immediately, and the cluster must store the data for extended periods of time. The sports television network administrators want to keep data ingestion and data archiving separate, to maximize performance. The sports television network purchased two types of nodes: H500s for ingesting data, and A200s for the long-term archive. Due to the extensive size of the data set, SyncIQ jobs replicating the data to the disaster recovery site, have a significant amount of work to do on each pass. The front-end interfaces are saturated on the H500 nodes for either ingesting data or performing immediate data retrieval. The CPUs of those nodes must not be effected by the SyncIQ jobs. By using a separate static SmartConnect pool, the network administrators can force all SyncIQ traffic to leave only the A200 nodes and provide maximum throughput on the H500 nodes.

4.2 Replication traffic over dedicated WAN links

Depending on the network topology and configuration, in certain cases Isilon SyncIQ data may be sent across a dedicated WAN link segregated from client traffic. Under these circumstances, the recommended option is utilizing a different subnet on the Isilon cluster for replication traffic, separated from the subnet for user data access.
Isilon OneFS ports

5 Isilon OneFS ports

Isilon OneFS uses a number of TCP and UDP ports, which are documented in the Security Configuration Guide available at the following link: [https://community.emc.com/docs/DOC-57599](https://community.emc.com/docs/DOC-57599)
SmartConnect considerations

This section provides considerations for using the Isilon SmartConnect load-balancing service. The general IP routing principles are the same with or without SmartConnect.

SmartConnect acts as a DNS delegation server to return IP addresses for SmartConnect zones, generally for load-balancing connections to the cluster. The IP traffic involved is a four-way transaction shown in Figure 6.

Figure 6  SmartConnect DNS delegation steps

In Figure 6, the arrows indicate the following steps:

1. **Blue arrow (step 1):** The client makes a DNS request for sc-zone.domain.com by sending a DNS request packet to the site DNS server.
2. **Green arrow (step 2):** The site DNS server has a delegation record for sc-zone.domain.com and sends a DNS request to the defined nameserver address in the delegation record, the SmartConnect service (SmartConnect Service IP Address).
3. **Orange arrow (step 3):** The cluster node hosting the SmartConnect Service IP (SSIP) for this zone receives the request, calculates the IP address to assign based on the configured connection policy for the pool in question (such as round robin), and sends a DNS response packet to the site DNS server.
4. **Red arrow (step 4):** The site DNS server sends the response back to the client.

6.1 SmartConnect network hierarchy

As SmartConnect subnets and pools are defined it is important to understand the SmartConnect hierarchy, as displayed in the following figure:

Figure 7  SmartConnect network hierarchy – OneFS releases prior to 8.2

Throughout the network design phase, for releases prior to OneFS 8.2, consider that a single SSIP is defined per subnet. However, under each subnet, pools are defined, and each pool will have a unique SmartConnect Zone Name. It is important to recognize that multiple pools lead to multiple SmartConnect Zones utilizing a
single SSIP. As shown in the diagram above, a DNS provider is defined per Groupnet, which is a feature in OneFS 8.0 and newer releases. In releases before 8.0, a DNS per Groupnet was not supported.

OneFS 8.2 introduces support for multiple SSIPs per subnet, as displayed in the following figure:

![SmartConnect network hierarchy – OneFS release 8.2](image)

For more information on SmartConnect multi-SSIP, refer to Section 6.13, SmartConnect Multi-SSIP.

### 6.2 Load balancing

SmartConnect load balances incoming network connections across SmartConnect Zones composed of nodes, network interfaces, and pools. The load balancing policies are Round Robin, Connection Count, CPU Utilization, and Network Throughput. The most common load balancing policies are Round Robin and Connection Count, but this may not apply to all workloads. It is important to understand whether the front-end connections are being evenly distributed, either in count or by bandwidth. Front-end connection distribution may be monitored with InsightIQ or the WebUI. It is important to understand how each Load Balancing Policy functions and testing it in a lab environment prior to a production roll-out, as each workload is unique. The table below lists suggested policies based on the workflow, but these are general suggestions, and may not always be applicable.
Generally speaking, starting with Round Robin is recommended for a new implementation or if the workload is not clearly defined. As the workload is further defined and based on the Round Robin experience, another policy can be tested in a lab environment.

### Table 2  Suggested SmartConnect load balancing policies

<table>
<thead>
<tr>
<th>Load Balancing Policy</th>
<th>General or Other</th>
<th>Few Clients with Extensive Usage</th>
<th>Many Persistent NFS &amp; SMB Connections</th>
<th>Many Transitory Connections (HTTP, FTP)</th>
<th>NFS Automounts or UNC Paths</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round Robin</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Connection Count*</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>CPU Utilization*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Network Throughput*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Metrics are gathered every 5 seconds for CPU Utilization and every 10 seconds for Connection Count and Network Throughput. In cases where many connections are created at the same time, these metrics may not be accurate, creating an imbalance across nodes.

As discussed previously, the above policies mapping to workloads are general guidelines. Each environment is unique with distinct requirements. It is recommended to confirm the best load balancing policy in a lab environment which closely mimics the production environment.

### 6.3 Static or dynamic IP address allocation

After a groupnet and subnet are defined in OneFS, the next step is configuring an IP address pool and assigning interfaces to participate in this pool.

Once the IP address pool is defined, under the ‘SmartConnect Advanced’ Section, an ‘Allocation Method’ may be selected. By default, this option is grayed out as ‘Static’ if a SmartConnect Advanced license is not installed. If a SmartConnect Advanced license is installed, the default ‘Allocation Method’ is still ‘Static’, but ‘Dynamic’ may also be selected.

The Static Allocation Method assigns a single persistent IP address to each interface selected in the pool, leaving additional IP addresses in the pool unassigned if the number of IP addresses is greater than interfaces. The lowest IP address of the pool is assigned to the lowest Logical Node Number (LNN) from the selected interfaces, subsequently for the second lowest IP address and LNN. In the event a node or interface becomes unavailable, this IP address does not move to another node or interface. Additionally, when the node or interface becomes unavailable, it is removed from the SmartConnect Zone, and new connections will not be assigned to the node. Once the node is available again, SmartConnect adds it back into the zone and assigns new connections.

On the contrary, the Dynamic Allocation Method splits all available IP addresses in the pool across all selected interfaces. Under the Dynamic Allocation Method, OneFS attempts to assign the IP addresses evenly if at all possible, but if the interface to IP address ratio is not an integer value, a single interface may have more IP addresses than another.
6.4 Dynamic failover

Combined with the Dynamic Allocation Method, Dynamic Failover provides high-availability by transparently migrating IP addresses to another node when an interface is not available. If a node becomes unavailable, all of the IP addresses it was hosting are re-allocated across the new set of available nodes in accordance with the configured failover load balancing policy. The default IP address failover policy is round-robin, which evenly distributes IP addresses from the unavailable node across available nodes. As the IP address remains consistent, irrespective of which node it resides on, this results in a transparent failover to the client, providing seamless high availability.

The other available IP address failover policies are the same as the initial client connection balancing policies, i.e., connection count, throughput, or CPU usage. In most scenarios, round-robin is not only the best option, but also the most common. However, the other failover policies are available for specific workflows. As mentioned previously, with the initial load balancing policy, test the IP failover policies in a lab environment to find the best option for a specific workflow.

6.4.1 Dynamic failover examples

In order to understand Dynamic Failover, the following examples illustrate how IP addresses move during a failover.

The examples below illustrate the concepts of how the IP address quantity impacts user experience during a failover and these are the guidelines to use when determining IP address quantity.

6.4.1.1 Dynamic zone with 1 IP address per node

This example considers a four-node cluster with one network connection per node and one dynamic SmartConnect zone with only four IP addresses. One IP address will be assigned to each node, as shown in the following figure:

![Figure 9 Dynamic zone: 4 node cluster with 1 IP address per node](image_url)

In this scenario, 150 clients are actively connected to each node over NFS using a round-robin connection policy. Most NFSv3 mounted clients perform a nslookup only the first time that they mount, never performing another nslookup to check for an updated IP address. If the IP address changes, the NFSv3 clients have a stale mount and retain that IP address.
Suppose that one of the nodes fails, as shown in Figure 10.

A SmartConnect Zone with a dynamic allocation strategy immediately hot-moves the one IP address on the failed node to one of the other three nodes in the cluster. It sends out a number of gratuitous address resolution protocol (ARP) requests to the connected switch, so that client I/O continues uninterrupted.

Although all four IP addresses are still online, two of them—and 300 clients—are now connected to one node. In practice, SmartConnect can fail only one IP to one other place, and one IP address and 150 clients are already connected to each of the other nodes. The failover process means that a failed node has just doubled the load on one of the three remaining nodes while not disrupting the other two nodes. Therefore, this process results in declining client performance, but not equally. The goal of any scale-out NAS solution must be consistency. To double the I/O on one node and not on another is inconsistent.

6.4.1.2 Dynamic zone with 3 IP addresses per node

Dynamic SmartConnect zones require a greater number of IP addresses than the number of nodes at a minimum to handle failover behavior. In the example below, the formula used to calculate the number of IP addresses required is \( N \times (N - 1) \), where 'N' is the number of nodes. The formula is used for illustration purposes only to demonstrate how IP addresses, and in turn clients, move from one node to another, and how this could potentially lead to an imbalance across nodes. Every workflow and cluster is unique, and this formula is not applicable to every scenario.

This example considers the same four node cluster as the previous example, but now following the rule of \( N \times (N - 1) \). In this case \( 4 \times (4 - 1) = 12 \), equaling three IPs per node, as shown in Figure 11.
When the same failure event as the previous example occurs, the three IP addresses are spread over all the other nodes in that SmartConnect zone. This failover results in each remaining node having 200 clients and four IP addresses. Although performance may degrade to a certain degree, it may not be as drastic as the failure in the first scenario, and the experience is consistent for all users, as shown in the following figure.

![Dynamic zone: 4 node cluster with 3 IP addresses per node, 1 node offline](image)

**Figure 12** Dynamic zone: 4 node cluster with 3 IP addresses per node, 1 node offline

### 6.5 Protocols and SmartConnect allocation methods

A common concern during an Isilon configuration is selecting between Static and Dynamic Allocation methods. The requirement for Dynamic Failover depends heavily on the protocol in use, workflow, and overall high-availability design requirements. Stateful versus stateless protocols combined with the allocation method, impact the failover experience. Certain workflows require minimal downtime, or the overarching IT requirements dictate IP address persistence. This section provides guidance on failover behavior based on the protocol.

Client access protocols are either stateful or stateless. Stateful protocols are defined by the client/server relationship having a session state for each open file. Failing over IP addresses to other nodes for these types of workflows means that the client assumes that the session state information was carried over. Session state information for each file is not shared among Isilon nodes. On the contrary, stateless protocols are generally accepting of failover without session state information being maintained, except for locks.

### 6.5.1 SMB

Typically, SMB performs best in static zones. In certain workflows, SMB is preferred in a dynamic zone, because IP address consistency is required. It may not only be a workflow requirement but could also be an IT administrative dependence. SMB actually works well with dynamic zones, but it is essential to understand the protocol limitations. SMB preserves complex state information per session on the server side. If a connection is lost and a new connection is established with dynamic failover to another node, the new node may not be able to continue the session where the previous one had left off. If the SMB workflow is primarily reads or is heavier on the read side, the impact of a dynamic failover will not be as drastic, as the client can re-open the file and continue reading.

Conversely, if an SMB workflow is primarily writes, the state information is lost, and the writes could be lost, possibly leading to file corruption. Hence, in most cases, static zones are suggested for SMB, but again it is workflow dependent. Prior to a major implementation, it is recommended to test the workflow in a lab environment, understanding limitations and the best option for a specific workflow.
6.5.2  NFS
The NFSv2 and NFSv3 protocols are stateless, and in almost all cases perform best in a dynamic zone. The client does not rely on writes unless commits have been acknowledged by the server, enabling NFS to failover dynamically from one node to another.

The NFSv4 protocol introduced state making it a better fit for static zones in most cases, as it expects the server to maintain session state information. However, OneFS 8.0 introduced session-state information across multiple nodes for NFSv4, making dynamic pools the better option. Additionally, most mountd daemons currently still behave in a v3 manner, where if the IP address it’s connected to becomes unavailable, this results in a stale mount. In this case, the client does not attempt a new nslookup and connect to a different node.

Again, as mentioned above, test the workflow in a lab environment to understand limitations and the best option for a specific workflow.

6.5.3  HDFS
The requirements for HDFS pools have been updated with the introduction of new OneFS features and as HDFS environments have evolved. During the design phases of HDFS pools, several factors must be considered. The use of static versus dynamic pools are impacted, by the following:

- Use of OneFS racks if needed
- Node Pools: is the cluster a single heterogeneous node type or do different Node Pools exist
- Availability of IP addresses

The factors above coupled with the workflow requirements determine the pool implementation. Please reference the HDFS Pool Usage and Assignments section in the EMC Isilon Best Practices Guide for Hadoop Data Storage for additional details and considerations with HDFS pool implementations.
### 6.5.4 Suggested zones by protocol

The table below lists the suggested IP allocation strategies for SmartConnect Advanced by the protocol. As noted, these are suggested, and the actual zone type is dependent on the workflow requirements, as discussed above.

#### Table 3  Suggested protocols and zone types

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Protocol Category</th>
<th>Suggested Zone Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFSv2 (not supported in OneFS 7.2 and above)</td>
<td>Stateless</td>
<td>Dynamic</td>
</tr>
<tr>
<td>NFSv3</td>
<td>Stateless</td>
<td>Dynamic</td>
</tr>
<tr>
<td>NFSv4</td>
<td>Stateful</td>
<td>Dynamic or Static – Depending on mountd daemon and OneFS version. Refer to the NFS section above.</td>
</tr>
<tr>
<td>SMBv1</td>
<td>Stateful</td>
<td>Dynamic or Static – Refer to SMB section above</td>
</tr>
<tr>
<td>SMBv2 / SMBv2.1</td>
<td>Stateful</td>
<td>Dynamic</td>
</tr>
<tr>
<td>SMBv3 Multi-Channel</td>
<td>Stateful</td>
<td>Dynamic</td>
</tr>
<tr>
<td>FTP</td>
<td>Stateful</td>
<td>Static</td>
</tr>
<tr>
<td>SFTP / SSH</td>
<td>Stateful</td>
<td>Static</td>
</tr>
<tr>
<td>HDFS</td>
<td>Stateful – Protocol is tolerant of failures</td>
<td>Refer to <a href="#">EMC Isilon Best Practices Guide for Hadoop Data Storage</a></td>
</tr>
<tr>
<td>HTTP / HTTPS</td>
<td>Stateless</td>
<td>Static</td>
</tr>
<tr>
<td>SyncIQ</td>
<td>Stateful</td>
<td>Static Required</td>
</tr>
</tbody>
</table>

### 6.6 IP address quantification

This section provides guidance for determining the number of IP addresses required for a new cluster implementation. The guidance provided below does not apply to all clusters and is provided as a reference for the process and considerations during a new cluster implementation.

During the process of implementing a new cluster and building the network topology, consider the following:

- Calculate the number of IP addresses that are needed based on future cluster size, not the initial cluster size.
- Do not share a subnet with other application servers. If more IP addresses are required, and the range is full, re-addressing an entire cluster and then moving it into a new VLAN is disruptive. These complications are prevented with proper planning.
- Static IP pools require one IP address for each logical interface that will be in the pool. Each node provides 2 interfaces for external networking. If Link Aggregation is not configured, this would require 2*N IP addresses for a static pool.
- 1 IP address for each SmartConnect Service IP (SSIP)
- For optimal load-balancing, during a node failure, IP pools with the Dynamic Allocation Method require the number of IP addresses at a minimum of the node count and a maximum of the client count. For example, a 12-node SmartConnect zone and 50 clients, would have a minimum of 12 and maximum of 50 IP addresses. In many larger configurations, defining an IP address per client is not feasible, and in those cases, the optimal number of IP addresses is workflow dependent and based on lab testing. In the previous examples, $N^*(N-1)$ is used to calculate the number of IP addresses, where $N$ is the number of nodes that will participate in the pool. For larger clusters, this formula may not be feasible due to the sheer number of IP addresses. Determining the number of IP addresses within a Dynamic Allocation pool varies depending on the workflow, node count, and the estimated number of clients that would be in a failover event.

In previous OneFS releases, a greater IP address quantity was recommended considering the typical cluster size and the workload a single node could handle during a failover. As nodes become unavailable, all the traffic hosted on that node is moved to another node with typically the same resources, which could lead to a degraded end-user experience. Isilon nodes are now in the 6th generation, and this is no longer a concern. Each node does have limitations, and those must be considered when determining the number of IP addresses and failover events creating additional overhead. Additionally, as OneFS releases have progressed, so has the typical cluster size, making it difficult to maintain the $N^*(N-1)$ formula with larger clusters.

From a load-balancing perspective, for dynamic pools, it is ideal, although optional, that all the interfaces have the same number of IP addresses, whenever possible. It is important to note that in addition to the points above, consider the workflow and failover requirements set by IT administrators.

### 6.7 SmartConnect node suspension

OneFS SmartConnect provides an option to administratively remove a node from a SmartConnect Zone during a planned outage. Planned outages could be hardware replacement or maintenance activity.

Once a node is suspended, SmartConnect prevents new client connections to the node. If the node is part of a dynamic zone, IP addresses are not assigned to this node in a suspended state. Suspending a node ensures that client access remains consistent. After the node is suspended, client connections can be monitored and allowed to gradually drop-off before a reboot or power down.

A node is suspended from the OneFS CLI or web interface. From the Isilon CLI, the command is:

```
isi network pools --scsuspend-node <groupnet.subnet.pool> <node ID>
```
Alternatively, from the web interface, click “Suspend Nodes” under the ‘Pool,’ as displayed in the following figure:

Figure 13  SmartConnect Node Suspension

After a node is suspended, new connections are not created. Prior to rebooting or shutting the node down, confirm all client connections have dropped by monitoring the web interface under the “Client Connections” tab from the “Cluster Overview” page. Also, clients may have to be manually booted from the node if they have static SMB connections with applications that maintain connections.

6.8  SmartConnect and Reverse DNS
In most cases, it is recommended that Isilon SmartConnect Service IP addresses and SmartConnect Zone names, do not have reverse DNS entries, also known as pointer (PTR) records.

In certain environments where PTR records may be required, this results in the creation of many PTR entries, as Isilon SmartConnect pools could have hundreds of IP addresses. In scenarios where PTR records are required, each time an additional IP address is added to a SmartConnect pool, DNS changes are necessary to keep the environment consistent.

Creating reverse DNS entries for the SmartConnect Service IP’s Host [address, or A] record is acceptable if the SmartConnect Service IP is referenced only with an A record in one DNS domain.

6.9  DNS delegation best practices
This section describes DNS delegation best practices for Isilon clusters.

6.9.1  Delegate to address (A) records, not to IP addresses
The SmartConnect service IP address on an Isilon cluster, in most cases, should be created in DNS as an address (A) record, also called a host entry. An A record maps a URL such as www.dell.com to its corresponding IP address. Delegating to an A record is provides simplicity during a failover. Only a single DNS A record must be updated. All other name server delegations can be left alone. In many enterprises, it is easier to have an A record updated than to update a name server record, because of the perceived complexity of the process.
Use one name server record for each SmartConnect zone name or alias
One delegation for each SmartConnect zone name or each SmartConnect zone alias on a cluster is recommended. This method permits failover of only a portion of the cluster's workflow—one SmartConnect zone—without affecting any other zones. This method is useful for scenarios such as testing disaster recovery failover and moving workflows between data centers.

It is not recommended to create a single delegation for each cluster and then create the SmartConnect zones as sub-records of that delegation. Using this method would enable Isilon administrators to change, create, or modify their SmartConnect zones and zone names as needed without involving a DNS team. The concern with this method is that it causes failover operations that involve the entire cluster and affects the entire workflow, not just the impacted SmartConnect zone.

SmartConnect in isolated network environments
SmartConnect is, effectively, a limited implementation of a custom DNS server: It answers only for the SmartConnect zone names or aliases configured on it. In order to use SmartConnect in an isolated network environment where no DNS infrastructure is available (such as a DMZ), configure the client systems using the SmartConnect service IP address as the primary DNS server. Configuring the client systems this way ensures the following:

- Requests to connect to Isilon clusters with SmartConnect zone names will succeed
- The isolated network benefits from SmartConnect features, such as load-balancing and rerouting traffic to prevent unavailable nodes, will work as expected in a typical, non-isolated deployment.
- It is important to recognize that Isilon OneFS is not a full DNS server, hence it will only answer for SmartConnect Zones.

The following commands show how to simulate and test a configuration that uses the SmartConnect service IP address as the primary DNS server.

C:\>nslookup
Default Server: 10.123.17.60
Address: 10.123.17.60

> isi01-s0.domain.com
Server: [10.123.17.60]
Address: 10.123.17.60
Name: isi01-s0.domain.com
Address: 10.123.17.64

> isi01-s0.domain.com
Server: [10.123.17.60]
Address: 10.123.17.60
Name: isi01-s0.domain.com
Address: 10.123.17.63
6.11 SmartConnect DNS, subnet, and pool design

This section provides a starting point for planning SmartConnect DNS, subnet, and SmartConnect pool layouts that meet the needs of most new cluster implementations with a SmartConnect Advanced License.

**Note:** SmartConnect Service IP Addresses (SSIPs) are only supported for use by a DNS server. Although SSIPs may be used in other configurations, the design intent was for a DNS server. Thus, other implementations with SSIPs are not supported.

6.11.1 SmartConnect zone naming

It is recommended to ensure SmartConnect Zones are named according to relevant details for clarity and simple recognition. For example, names should be composed of some or all of the following variables:

- **Cluster Name:** Active Directory (AD) uses the cluster name as the AD machine account name. For example, when a cluster named isi01 joins Active Directory, isi01 is the cluster’s machine account name. Using the cluster/machine account name in all DNS entries simplifies cluster administration and troubleshooting.

- **IP Allocation Strategy:** Each SmartConnect zone has an IP allocation strategy set to static or dynamic. The allocation strategy is allocated in the zone name, for example, by using “d” for dynamic and or “s” for static.

- **SmartConnect Pool ID:** Each SmartConnect pool has a unique name or number that identifies it. By default, the first pool called on a cluster is pool0, the second is pool1, and so on. These identifiers are recommended to be part of the zone name.

- **SSIP:** Use the SSIP in the zone name to indicate a SmartConnect Service IP zone.

The variables above together form a SmartConnect zone name. For example: isi01-s0.domain.com

The name includes the cluster name (isi01), the allocation strategy of the zone (“s” for static), and the number of the pool (pool0).

For example, a cluster with three pools:

- pool0: Static for client I/O for stateful protocols
- pool1: Dynamic for client I/O for stateless protocols
- pool2: Static for Backup and Replication

Based on the SmartConnect zone, pool, and the cluster information, the following is a sample DNS layout for the cluster named ‘isi01’:

- isi01-ssip.domain.com in [A] to 10.x.y.z
- isi01-s0.domain.com in [NS] to isi01-ssip.domain.com
- isi01-d1.domain.com in [NS] to isi01-ssip.domain.com
- isi01-s2.domain.com in [NS] to isi01-ssip.domain.com

6.11.2 SmartConnect with multiple node pools or types

From a client or application perspective, the goals for all scale-out NAS deployments are consistency and availability. Consistency, in this context, implies that every time a client connects, whether that client is an application server or a user opening their home directory, the same level of performance is provided. Dell EMC offers a number of different Isilon node types with varied performance profiles.
Many factors determine performance in network-attached storage. In an Isilon cluster, key components are the front-end performance, which consists of the network card, CPU, and memory in the node that is serving the relevant data protocol, and the back-end performance, which, in this case, is the disk tier or pool where the data resides. In the context of SmartConnect configuration, creating a connection pool that spans across different node performance levels is not recommended. For example, a pool with Isilon F800 nodes and A200 nodes would provide significantly varying protocol performance. It is imperative to understand how the nodes within a connection pool impact client experience.

### 6.12 Where the SmartConnect Service IP (SSIP) runs (pre OneFS 8.2)

The SSIP service is updated for OneFS 8.2; this section is specific to releases prior to OneFS 8.2. For more information on the SSIP in OneFS 8.2, refer to Section 6.13, SmartConnect Multi-SSIP.

The Isilon clustered compute, and storage platform has no single point of failure. However, the SmartConnect DNS service must be active on only one node at any time, per subnet. The SmartConnect Service IP resides on the node with the lowest node ID that has an interface in the given subnet, not necessarily on the node with the lowest Logical Node Number (LNN) in the cluster.

To illustrate how this works, suppose that an existing four-node cluster is refreshed with four new nodes. Assume that the cluster has only one configured subnet, all the nodes are on the network, and that there are sufficient IP addresses to handle the refresh. The first step in the cluster refresh is to add the new nodes with the existing nodes, temporarily creating an eight-node cluster. Next, the original four nodes are SmartFailed. The cluster is then composed of the four new nodes with the original data set.

As the administrators perform the refresh, they check the current configuration using the `isi config` command, with the status advanced command, as shown in the following example:

```
isic config
>status advanced
```

The SmartConnect service continues to run throughout the process as the existing nodes are refreshed. The following example illustrates where the SmartConnect service runs at each step in the refresh process.

Once the four new nodes are added to the cluster, based on the existing naming convention, they are automatically named `clusternamex`, where `x` is 5, 6, 7, and 8. At this point, the Node IDs and LNNs are displayed in the following table:

<table>
<thead>
<tr>
<th>Logical Node Number (LNN)</th>
<th>NodeID</th>
<th>Node Name</th>
<th>New or Original Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>clusternamex-1</td>
<td>Original</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>clusternamex-2</td>
<td>Original</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>clusternamex-3</td>
<td>Original</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>clusternamex-4</td>
<td>Original</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>clusternamex-5</td>
<td>New</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>clusternamex-6</td>
<td>New</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>clusternamex-7</td>
<td>New</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
<td>clusternamex-8</td>
<td>New</td>
</tr>
</tbody>
</table>
**Note:** The SmartConnect service always runs on the node with the lowest node ID; at this point, NodeID 1 is mapping to LNN 1.

Next, the original nodes are removed using SmartFail. The updated Node IDs and LNNs are displayed in the following table:

### Table 5  4-node cluster configuration, after SmartFail

<table>
<thead>
<tr>
<th>Logical Node Number (LNN)</th>
<th>Node ID</th>
<th>Node Name</th>
<th>New or Original Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>clustename-5</td>
<td>New</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>clustename-6</td>
<td>New</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>clustename-7</td>
<td>New</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>clustename-8</td>
<td>New</td>
</tr>
</tbody>
</table>

**Note:** The SmartConnect service always runs on the node with the lowest node ID; at this point, NodeID 5 is mapping to LNN 1.

Keeping the naming convention consistent, the administrators re-name the new nodes, formerly clustename-5, clustename-6, clustename-7, and clustename-8, to clustename-1, clustename-2, clustename-3, and clustename-4, respectively. The updated Node IDs and LNNs remain the same, but map to a different Node Name, as displayed in the following table:

### Table 6  4-node cluster configuration – after re-name

<table>
<thead>
<tr>
<th>Logical Node Number (LNN)</th>
<th>Node ID</th>
<th>Node Name</th>
<th>New or Original Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>clustename-1</td>
<td>New</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>clustename-2</td>
<td>New</td>
</tr>
<tr>
<td>3</td>
<td>7</td>
<td>clustename-3</td>
<td>New</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>clustename-4</td>
<td>New</td>
</tr>
</tbody>
</table>

**Note:** The SmartConnect service always runs on the node with the lowest node ID; at this point, NodeID 5 is mapping to LNN 1.

If LNN 1 is offline for maintenance, the SmartConnect service migrates to LNN 2, because LNN 2 has the next lowest NodeID number, 6.

### 6.13 SmartConnect Multi-SSIP

Isilon OneFS 8.2 introduces support for more than one SSIP per subnet. In previous releases, only a single SSIP per subnet was supported and resided on the lowest available NodeID, as explained in Section 6.12, Where the SmartConnect Service IP (SSIP) runs (pre OneFS 8.2). The dependence on a single SSIP caused problems during node maintenance, reboots, or interface flaps. The complications are further magnified,
considering the lowest available NodeID is usually the node that is rebooted or is scheduled for maintenance first.

The addition of more than a single SSIP provides fault tolerance and a failover mechanism, ensuring the SmartConnect service continues to load balance clients according to the selected policy. In previous releases of OneFS, once the node hosting the SSIP was out of service, or if the interface was flapping, client connections would fail momentarily as the SSIP migrated to a different node.

The number of SSIPs available per subnet depends on the SmartConnect license. SmartConnect Basic allows 2 SSIPs per subnet while SmartConnect Advanced allows 6 SSIPs per subnet, as displayed in Table 7.

<table>
<thead>
<tr>
<th>SmartConnect License</th>
<th>Basic</th>
<th>Advanced</th>
</tr>
</thead>
<tbody>
<tr>
<td>SSIPs per subnet</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

It is important to recognize that SmartConnect Multi-SSIP is not an additional layer of load balancing for client connections. Additional SSIPs provide redundancy and reduce failure points in the client connection sequence. Reverting to the original figure explaining SmartConnect’s connection sequence, additional connections are added at step 2, as illustrated in Figure 14.

At step 2, the site DNS server sends a DNS request to the SSIP and awaits a response in step 3 for a node’s IP address based on the client connection policy. If for any reason, the response in step 3 is not received within the timeout window, the connection times out. The DNS server tries the 2nd SSIP and awaits a response in step 3. After another timeout window, the DNS server continues cycling through subsequent SSIPs, up to the sixth SSIP with SmartConnect Advanced, if a response is not received after a request is sent to each SSIP.

Although the additional SSIPs are in place for failover, the SSIPs configured are active and respond to DNS server requests. The Multi-SSIP configuration is Active-Passive, where each node hosting an SSIP is independent and ready to respond to DNS server requests, irrespective of the previous SSIP failing. Therefore, SmartConnect continues to function correctly if the DNS server contacted the other SSIPs, providing SSIP fault tolerance. However, as each node hosts an SSIP independent of the other SSIP hosting nodes, it is unaware of the current status of the load balancing policy and starts the load balancing policy back to the first option. For example, if the SmartConnect load balancing policy is round-robin for a 50-node subnet, assume the 1st SSIP has distributed IP addresses for the first ten nodes. If the 2nd SSIP is contacted by the DNS server, it starts distributing node IP addresses at the first option again, in this case, node one,
rather than node eleven. The node hosting the SSIP is unaware of the node IP address distributed by the previous SSIP.

Note: As a best practice, do not configure the site DNS server to load balance the SSIPs. Each additional SSIP is only a failover mechanism, providing fault tolerance and SSIP failover. Allow OneFS to perform load balancing through the selected SmartConnect policy, ensuring effective load balancing.

6.13.1 Configuring OneFS for SmartConnect Multi-SSIP
Multi-SSIP is configured from the user interface or the CLI, by specifying a range of IP addresses. The range of IP addresses is applied to between 2 and 6 SSIPs per subnet, depending on the SmartConnect license.

To configure Multi-SSIP from the user interface, click Cluster Management > Network Configuration. Next, either select an existing subnet and click Edit, or if under a groupnet, click More > Add subnet and scroll to the SmartConnect service IPs section, as displayed in Figure 15.

![SmartConnect service IPs](image)

Figure 15  SmartConnect Multi-SSIP user interface configuration

To configure Multi-SSIP from the CLI, use the --sc-service-addrs option with an IP address range, as displayed in the following command:

```
isic f network subnets modify subnet0 --sc-service-addrs=192.168.25.10-192.168.25.11
```

Additionally, the IP address range may be cleared, or additional ranges may be added, using the following commands:

```
isic f network subnets modify subnet [--help | grep sc-service-addrs
  [--sc-service-addrs <ip_address_range> | --clear-sc-service-addrs |
  --add-sc-service-addrs <ip_address_range> | --remove-sc-service-addrs
  --sc-service-addrs <ip_address_range>... 
  requests. Specify --sc-service-addrs for each additional IP address.
  --clear-sc-service-addrs
  --add-sc-service-addrs <ip_address_range>...
  Add items to list of IP addresses. Specify --add-sc-service-addrs for
  --remove-sc-service-addrs <ip_address_range>...
  --remove-sc-service-addrs for each additional IP address to remove.
```

6.13.2 Configuring a DNS server for SmartConnect multi-SSIP
Multi-SSIP is a feature for SSIP failover, providing SSIP fault tolerance. It is important to configure DNS servers for SSIP failover, ensuring the next SSIP is only contacted if the first SSIP connection times out. If the SSIPs are not configured in a failover sequence, the SSIP load balancing policy resets each time a new SSIP is contacted. The SSIPs do not track the current distribution status of the other SSIPs, as they function independently, negating the function of the selected load balancing policy.
Configuring IP addresses as a failover only addresses is not supported on all DNS servers. To support Multi-SSIP as a failover only option, a DNS server with support for failover addresses is recommended. If a DNS server does not support failover addresses, Multi-SSIP still provides advantages over a single SSIP. However, increasing the number of SSIPs may impact SmartConnect's ability to load balance.

**Note:** If the DNS server does not support failover addresses, test Multi-SSIP in a lab environment mimicking the production environment to confirm the impact on SmartConnect's load balancing for a specific workflow. Only after confirming workflow impacts in a lab environment should a production cluster be updated.

### 6.13.2.1 DNS servers supporting failover IP addresses

If the site DNS server supports failover IP addresses, proceed with the configuration in this section.

As explained earlier in Section 6.9, DNS delegation best practices, the first SSIP should be created in DNS as an address (A) record, also referred to as a host entry. The additional SSIPs should be configured as DNS A record failover IP addresses. The first IP address should point to the first SSIP, followed by each configured SSIP IP addresses for failover. The additional SSIPs provide redundancy in an Active-Passive pattern.

### 6.13.2.2 DNS servers without failover IP address support

If the site DNS server does not support failover IP addresses, proceed with the configuration in this section.

**Note:** Prior to configuring a DNS server that does not support failover IP addresses, consider the load balancing status in SmartConnect is independently managed by each SSIP, as explained in Section 6.13, SmartConnect Multi-SSIP. The total impact on load balancing behavior is dependent on if the site DNS server has recursion enabled, how many SSIPs are configured, the load balancing policy, and the workflow. To confirm the impacts in a specific environment test in a lab environment mimicking the production environment, prior to updating a production cluster.

To configure a DNS server for Multi-SSIP that does not support failover IP addresses, create an NS record, and matching A/AAAA record for each SSIP. Most DNS servers us a Round Trip Time (RTT) to decide which nameserver to utilize. As an example, for OneFS and a BIND DNS server, consider the following configuration:

**OneFS configuration:**

```bash
isi network subnets modify groupnet0.subnet0 --sc-service-name=cluster-ns1.company.com --sc-service-addr=1.2.3.4-1.2.3.6
isi network pools modify groupnet0.subnet0.pool0 --sc-connect-policy round_robin --sc-dns-zone cluster.company.com
```

**BIND configuration:**

```text
cluster-ns1 IN A 1.2.3.4
cluster-ns2 IN A 1.2.3.5
cluster-ns3 IN A 1.2.3.6

$ORIGIN cluster.company.com.
@ IN NS cluster-ns1.company.com.
@ IN NS cluster-ns2.company.com.
@ IN NS cluster-ns3.company.com.
```

---

**SmartConnect considerations**

---
The configuration above may be adapted to Windows DNS servers or other DNS servers. The issue with Windows DNS server is the forced 1 second TTL, which impacts single SSIP configurations also, as noted in Section 6.14, Other SmartConnect considerations.

Additionally, in an environment where the site DNS server does not support failover IP addresses, consider the following:

- If the site DNS server has recursion enabled, consider that the nameservers may be contacted in a round-robin fashion. To confirm this behavior, check for a frequently changing nameserver through logging in OneFS. If the SmartConnect zone is configured for round-robin, try repeatedly querying the zone. If the DNS server returns an IP the same number of times as SSIPs configured, it is contacting nameservers in a round-robin configuration.
- If a site DNS server is not very sticky in terms of how it chooses name servers, load balancing will decrease as the number of SSIPs in a subnet increase. For example, consider the difference between the site DNS server returning the same IP two times in a row when two SSIPs are configured, and the site DNS server returning the same IP six times in a row when six SSIPs are configured.
- The selected SmartConnect load balancing policy is not round-robin, having multiple SSIPs and a site DNS server that is not sticky in deciding what SSIP to use can exacerbate the load balancing problem. This could result in more clients than expected, landing on the lightest weighted node.
- If the workload consists of high throughput, usage, or demanding clients, using Multi-SSIP makes the above considerations significantly more noticeable. On the contrary, if the workload consists of many smaller client connections, the impact of Multi-SSIP on Load Balancing may go unnoticed especially with round-robin policies given that SmartConnect eventually distributes each node’s IP address almost an equal number of times.

6.13.3 SSIP node assignment

Within a subnet, up to six SSIPs are available, depending on the SmartConnect license. Prior to OneFS 8.2, the single SSIP was assigned to the lowest Node ID in the specified subnet. Hosting the SSIP on the lowest Node ID created issues as in many cases, the lowest Node ID is providing other services and could be the first to reboot in a rolling upgrade.

Multi-SSIP introduces an enhancement to assigning SSIPs. Attaching an SSIP to a node is no longer dependent on the Node ID. OneFS 8.2 creates a file containing SSIP information, the SSIP Resource File. In order to host an SSIP, a node must hold a lock on this file. All the nodes that are ready to host an SSIP, attempt to lock the SSIP Resource File. The first nodes to get the lock, host the SSIP. The new process ensures the node assignment is based on a lock to nodes within the subnet, avoiding the issues from previous releases. Once the node is offline, or the interface goes down, the SSIP becomes available for lock again and the next quickest node to capture the lock hosts the SSIP, as illustrated in Figure 16. OneFS ensures that SSIPs are as evenly distributed as possible within a subnet, utilizing a feature to limit a single node from hosting multiple SSIPs. In certain scenarios, a node may host more than a single SSIP, depending on the number of nodes and SSIPs in the subnet.
OneFS 8.2 also introduces a new method for handling configuration and group changes. Prior to OneFS 8.2, any configuration or group change would result in SmartConnect stopping and unconfiguring DNS as OneFS was unaware if the same node would be able to host the SSIP. In OneFS 8.2, the SSIP is held through configuration and group changes with a re-evaluation after the change to confirm if the SSIP can be held. If it is determined that the node is no longer qualified to own the SSIP, it is released and picked up by another node, minimizing the failover impact.

To confirm which of the nodes are hosting SSIPs, use the following commands:

```bash
isi_for_array ifconfig | grep <SSIP>
isi_for_array ifconfig | grep "zone 0"
```

### 6.14 Other SmartConnect considerations

During SmartConnect configuration, consider the following points:

- It is recommended to disable client DNS caching, when possible. To handle client requests properly, SmartConnect requires that clients use the latest DNS entries. If clients cache SmartConnect DNS information, they could connect to incorrect SmartConnect zone names. In this event, SmartConnect might not appear to be functioning correctly.
- If traffic is traversing firewalls, ensure that the appropriate ports are open. For example, if UDP port 53 is opened, also ensure TCP port 53 is opened.
- Certain clients perform DNS caching and might not connect to the node with the lowest load if they make multiple connections within the lifetime of the cached address. For example, this issue occurs on macOS X for certain client configurations.
- In order to successfully distribute IP addresses, the OneFS SmartConnect DNS delegation server answers DNS queries with a time-to-live (TTL) of 0 so that the answer is not cached. Certain DNS servers, most particularly Windows Server 2003, 2008, 2012, and 2016, will update the value to one second. If many clients are requesting an address within the same second, this will cause all of them to receive the same address. If this occurs frequently, consider a different DNS server, such as bind.
- The site DNS servers must be able to communicate with the node that is currently hosting the SmartConnect service.
- Site DNS servers might not exist in the regular local subnets, or in any of the subnets that clients occupy. To enable the SmartConnect lookup process, ensure that the DNS servers use a consistent route to the cluster and back. If the site DNS server sends a lookup request that arrives through one local subnet on the cluster, but the configured cluster routing causes the response to be sent through a different subnet, it’s likely that the packet will be dropped, and the lookup will fail. The solutions and...
considerations for SmartConnect are similar to the client scenarios. Additionally, the DNS server might benefit from a static route to the subnet that contains the SSIP address or addresses.

- SmartConnect makes it possible for different nodes to have different default routes, but this is fundamentally determined by connectivity. SmartConnect enables administrators to define multiple gateways, with 1 gateway per subnet. Each gateway is assigned a priority when it is defined. On any node, SmartConnect attempts to use the highest priority gateway—the gateway that has the lowest number—that has an available functioning interface in a subnet that contains the gateway address.
7 Ethernet, MTU, and IP overhead

A Maximum Transmission Unit (MTU) is the largest packet size or frame, which may be sent along a link. The MTU is specified in octets and is utilized by TCP to determine the maximum size of a packet per transmission. A large MTU size provides less overhead as packet headers and acknowledgments are not consuming space and bandwidth. However, this could lead to retransmissions or drops if a hop does not support it. On the contrary, a small MTU size is not as efficient as overhead increases with packet headers and acknowledgments.

Generally speaking, the MTU across the internet is 1500 bytes. As such, most devices limit packet size to roughly 1472 bytes, allowing for additional overhead and remaining under the 1500-byte limit. Additional overhead may be added as the packet goes through different hops. The IEEE 802.3 standard also specifies 1500 bytes as the standard payload.

7.1 Ethernet packet

An Ethernet frame carries a payload of data and is carried by an Ethernet packet. The frame could be IPv4 or IPv6 and TCP or UDP. The IEEE 802.3 standard defines the structure of each packet. As a packet traverses different layers, the structure is modified accordingly. In the diagram below, the structure is displayed as it would traverse the wire, or Layer 1. Dissecting how a packet is structured on the wire lends to an understanding of how the packet overhead is impacted and all of the other components required to send a payload.

<table>
<thead>
<tr>
<th>Interpacket Gap</th>
<th>Preamble</th>
<th>Start Frame Delimiter</th>
<th>Destination MAC</th>
<th>Source MAC</th>
<th>VLAN 802.1Q (optional)</th>
<th>Type</th>
<th>Payload</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>12 bytes</td>
<td>7 bytes</td>
<td>1 byte</td>
<td>6 bytes</td>
<td>6 bytes</td>
<td>4 bytes</td>
<td>2 bytes</td>
<td>46-1500 bytes</td>
<td>4 bytes</td>
</tr>
</tbody>
</table>

Layer 2 Ethernet II Frame

Layer 1 Ethernet Packet “on the wire”

Figure 17 Ethernet packet

An Ethernet packet on the wire at Layer 1 is composed of the following fields:

- Interpacket Gap: Serves as a gap between each frame, similar to a spacer. The Interpacket gap is only part of Layer 1. The field originates from a time when hubs were common, and collisions were more commonplace.
- Preamble: Composed of alternating 1 and 0 bits for receiver clock synchronization. The Preamble is only part of Layer 1.
- Start Frame Delimiter: Identifies the start of an Ethernet frame.
- Destination MAC: Contains the MAC address of the destination station for which the data is intended.
- Source MAC: Contains the MAC address of the sending station.
- VLAN 802.1Q: Optional field utilized if a VLAN is identified.
- Type: Also known as the EtherType field, this defines the type of protocol that is encapsulated in the payload. In the example above, it is an Ethernet II Frame, the most widely accepted type.
Ethernet, MTU, and IP overhead

- Payload: Spans from 46 to 1500 bytes and contains user data. If it is smaller than 46 bytes, blank values are entered to bring this up to 46 bytes as it is the minimum value. The Payload consists of protocol data for TCP, UDP or RTP and IPv4 or IPv6. The next section explains the Payload field in greater depth.
- CRC: Cyclic Redundancy Check is part of the Frame Check Sequence (FCS) to detect errors within the frame. The CRC code should result in a zero if the data does not contain any errors.

### 7.2 Ethernet payload

The Ethernet payload varies based on the type of data it is carrying. It is a combination of either TCP, UDP, or RTP header combined with an IPv4 or IPv6 header, and most importantly the actual payload which contains the data that is being sent. The fields within the payload are displayed in Figure 18.

**Figure 18  Ethernet payload options**

As displayed in Figure 18, the amount of actual data sent within an Ethernet Frame is dependent upon the number of bytes consumed by the other fields. Other options are available which are not listed here. For example, Linux hosts automatically add a timestamp to the TCP stack, adding 12 bytes.

### 7.3 Jumbo frames

Jumbo frames are Ethernet frames where the MTU is greater than the standard 1500 bytes and a maximum of 9000 bytes. The larger MTU size provides greater efficiency as less overhead and fewer acknowledgments are sent across devices, drastically reducing interrupt load on endpoints. Jumbo frames are recommended for most workloads as the amount of data sent per message is far greater, reducing processing times and maximizing efficiency. While the general assumption is that Jumbo frames provide performance advantages for all workloads, it is important to measure results in a lab environment simulating a specific workload to ensure performance enhancements.

For Jumbo frames to take advantage of the greater efficiencies, they must be enabled end-to-end on all hops between endpoints. Otherwise, the MTU could be lowered through PMTUD or packets could be fragmented. The fragmentation and reassembly impact the CPU performance of each hop, which impacts the overall latency.

For example, if a client is set to an MTU of 1500 bytes while other hops are set to 9000 bytes, transmission along the path will most likely set to 1500 bytes using PMTUD, unless other options are configured.

Jumbo frames utilize the same Ethernet packet structure described in the previous section. However, the difference is the size of the data within the payload. As the byte consumption of the other components within
Ethernet, MTU, and IP overhead

the frame remain the same, each packet contains more data with the same overhead. A Jumbo frame Ethernet payload is displayed in the following figure:

![Jumbo Frames Ethernet Payload](image)

Figure 19  Jumbo frames Ethernet payload

7.4  **IP packet overhead**

Isilon nodes utilize 10 and 40 GbE NICs for front-end networking. In order to maximize throughput on these high bandwidth links, Jumbo frames are recommended for greater throughput. Standard 1500 byte and Jumbo 9000-byte packets are formed with the same packet structure at Layer 1 with the only difference pertaining to the actual data payload size. Although the overhead is identical for standard and Jumbo packets, the ratio of the data to the overhead varies significantly.

For every payload sent to Layer 1 on the wire, the following fields are required:

Interpacket Gap / Preamble / Start Frame Delimiter / Destination MAC / Source MAC / Type / CRC

In bytes, this translates to:

\[12 + 7 + 1 + 6 + 6 + 2 + 4 = 38 \text{ bytes}\]

Hence, regardless of the payload fields or size, every payload requires an additional 38 bytes to be sent. It is important to note that this does not consider the optional VLAN tag which requires an additional 4 bytes. The following sections provide examples of packet overhead based on the payload fields.

7.4.1  **Example 1: Standard 1500-byte payload – IPv4/TCP**

IPv4 and TCP headers consume the following bytes:

\[20 \text{ bytes (IPv4)} + 20 \text{ bytes (TCP)} = 40 \text{ bytes}\]

If the payload headers consume 40 bytes, the data field for a standard 1500-byte payload consumes:

\[1500 - 40 = 1460 \text{ bytes}\]

Therefore, a standard 1500-byte packet with IPv4 and TCP headers results in a data to Ethernet frame percentage as follows:

\[
\frac{(\text{Data Bytes})}{(\text{Total Ethernet Frame Bytes})} = \frac{(1500 - 40)}{(1500 + 38)} = \frac{1460}{1538} = .949 \Rightarrow 94.9\%
\]
7.4.2  **Example 2: Jumbo 9000-byte payload – IPv4/TCP**
A standard 9000-byte payload that contains IPv4 and TCP headers consumes the following bytes:

20 bytes (IPv4) + 20 bytes (TCP) = 40 bytes

If the payload headers consume 40 bytes, the data can field consumes:

9000 - 40 = 8960 bytes

Therefore, a standard 1500-byte packet with IPv4 and TCP headers results in a data to Ethernet frame percentage as follows:

(Data Bytes) / (Total Ethernet Frame Bytes) = (9000 - 40) / (9000 + 38) = 8960/9038 = .991 => 99.1%

7.4.3  **Example 3: Standard 1500-byte payload – IPv4/TCP/Linux timestamp**
Linux automatically inserts the timestamp within the payload. A standard 1500-byte payload that contains IPv4, TCP, and timestamp headers consumes the following bytes:

20 bytes (IPv4) + 20 bytes (TCP) + 12 bytes (timestamp) = 52 bytes

If the payload headers consume 40 bytes, the data field consumes:

1500 - 52 = 1448 bytes

Therefore, a standard 1500-byte packet with IPv4 and TCP headers results in a data to Ethernet frame percentage as follows:

(Data Bytes) / (Total Ethernet Frame Bytes) = (1500 - 52) / (1500 + 38) = 1448/1538 = .941 => 94.1%

7.4.4  **Example 4: Jumbo 9000-byte payload – IPv4/TCP/Linux timestamp**
Linux automatically inserts the timestamp within the payload. A standard 9000-byte payload that contains IPv4, TCP and timestamp headers consumes the following bytes:

20 bytes (IPv4) + 20 bytes (TCP) + 12 bytes (timestamp) = 52 bytes

If the payload headers consume 40 bytes, the data field consumes:

9000 - 52 = 8948 bytes

Therefore, a standard 1500-byte packet with IPv4 and TCP headers results in a data to Ethernet frame percentage as follows:

(Data Bytes) / (Total Ethernet Frame Bytes) = (9000 - 52) / (9000 + 38) = 8948/9038 = .990 => 99.0%
7.5 **Data payload to Ethernet frame efficiency**

Utilizing the calculations above, the table below provides additional examples of the amount of data that is sent per Ethernet frame for standard and Jumbo frames.

<table>
<thead>
<tr>
<th>Packet Type</th>
<th>Data to Ethernet Frame Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standard Frame</td>
</tr>
<tr>
<td>IPv4 / TCP</td>
<td>94.93%</td>
</tr>
<tr>
<td>IPv4 / TCP / Linux Timestamp</td>
<td>94.15%</td>
</tr>
<tr>
<td>IPv4 / TCP / Linux Timestamp / VLAN</td>
<td>93.90%</td>
</tr>
<tr>
<td>IPv6 / TCP</td>
<td>93.63%</td>
</tr>
<tr>
<td>IPv6 / TCP / Linux Timestamp</td>
<td>92.85%</td>
</tr>
<tr>
<td>IPv6 / TCP / Linux Timestamp / VLAN</td>
<td>92.59%</td>
</tr>
<tr>
<td>IPv4 / UDP</td>
<td>95.71%</td>
</tr>
<tr>
<td>IPv4 / UDP / Linux Timestamp</td>
<td>94.93%</td>
</tr>
<tr>
<td>IPv4 / UDP / Linux Timestamp / VLAN</td>
<td>94.67%</td>
</tr>
<tr>
<td>IPv6 / UDP</td>
<td>94.41%</td>
</tr>
<tr>
<td>IPv6 / UDP / Linux Timestamp</td>
<td>93.63%</td>
</tr>
<tr>
<td>IPv6 / UDP / Linux Timestamp / VLAN</td>
<td>93.37%</td>
</tr>
</tbody>
</table>

**Note:** NFS v2 is UDP. NFS v3 and v4 are TCP. SMB is TCP.

As displayed in the table above, Jumbo frames deliver between 98%-99% efficiency depending on the packet type. The efficiencies are only maximized when all hops from the client endpoint to an Isilon node support Jumbo frames. Otherwise, packets may be fragmented leading to additional processing overhead on devices or PMTUD finding the lowest MTU along the path. Therefore, Jumbo frames are recommended for optimal performance. However, it is important to recognize that each workload environment is unique and measuring performance enhancements in a lab are recommended prior to a production network update.

7.6 **ICMP and MTU with OneFS**

Network devices employ Internet Control Message Protocol (ICMP) to gather communications related information. ICMP is capable of sending error messages but also delivers operational information. Ping and TraceRoute both send ICMP messages to provide connectivity information including latency and network hops.

Most devices have a default MTU that is configurable and remains at the defined value. Isilon OneFS determines the MTU size specific to each transaction. After the initial TCP handshake, the Isilon node sends
an ICMP message for Path MTU Discovery (PMTUD), RFC 1191, gathering the maximum supported MTU size. If for any reason ICMP is disabled, or PMTUD is not supported, this causes OneFS to default the MTU size to 536 bytes, which typically leads to performance degradation.

7.7 OneFS MTU commands
To check the current configured MTU, enter the following command:

```
isi networks subnets list -v
```

To modify the MTU, use the isi command with the following context:

```
isi network subnets modify groupnet0.subnet1 --mtu=1500 --gateway=198.162.100.10 --gateway-priority=1
```

7.8 Confirming transmitted MTU
Manually checking a permitted MTU size ensures a configured size is transmitted. The ping command is used to confirm if an MTU size can be transmitted. It is recommended to start with the largest MTU and work down to find the limit.

For example, to check if an MTU size of 8900 bytes is transmitted to an endpoint, from the OneFS CLI, use the following command: `ping -s 8900 -D <IP Address>`. The `-s` specifies the packet size and the `-D` specifies the not to fragment the packet.

If the ping is successful, the MTU size is transmitted across. If the ping is unsuccessful, gradually lower the MTU size until it is successfully transmitted. Confirm the MTU size can be transmitted from both endpoints.

OneFS is based on FreeBSD. FreeBSD also has options for gradually increasing the MTU size by performing a ‘sweeping ping’ using the `-g` option. For more information on ping options in FreeBSD, access the FreeBSD manual at the following link: [https://www.freebsd.org/cgi/man.cgi?ping(8)](https://www.freebsd.org/cgi/man.cgi?ping(8))
8 Access Zones best practices

When Access Zones are configured, a root-based path must be defined to segment data into the appropriate Access Zone and enable the data to be compartmentalized. Access Zones carve out access to an Isilon cluster creating boundaries for multi-tenancy or multi-protocol. They permit or deny access to areas of the cluster. At the Access Zone level, authentication providers are also provisioned.

8.1 System Zone

When an Isilon cluster is first configured, the System Zone is created by default. The System Zone should only be used for management as a best practice. In certain special cases, some protocols require the system zone, but generally speaking, all protocol traffic should be moved to an Access Zone. If nothing else, NFS and SMB should have protocol specific Access Zones.

Moving client traffic to Access Zones ensures the System Zone is only used for management and accessed by administrators. Access Zones provide greater security as administration, and file access is limited to a subset of the cluster, rather than the entire cluster.

8.2 Root Based Path

SmartConnect zones map to Access Zones, which map to a Root Based Path. When an Access Zone is defined, a Root Based Path must be defined. Best practice is to use the cluster name, a numerical Access Zone number, and a directory. For example, Access Zone 1 maps to /ifs/clusternam/az1/<data directories>, Access Zone 2 maps to /ifs/clusternam/az2/<data directories>. A Root Based Path with this delineation, provides data separation, Multi-Tenancy, maintains the Unified Permission model and makes SyncIQ failover and failbacks easier.

Generally speaking, the best practice is to remove all data access from the default System Zone. Otherwise, this leads to complications in the future as the cluster grows and additional teams or workflows are added. Further, as mentioned above, create a subdirectory under the Access Zone, rather than using the root of the zone, as this makes migration and disaster recovery simpler. It is preferred not to have an overlap of Root Based Paths unless it is required for a specific workflow. Overlap is supported in 8.0 and newer releases through the CLI.

In the figure below, as Cluster 1 fails over to Cluster 2, the directory structure remains consistent, easily identifying where the files originated from. This delineation also ensures clients have the same directory structure after a failover. Once the IP address is updated in DNS, the failover is transparent to clients. As more clusters are brought together with SyncIQ, this makes it easier to manage data, understanding where it originated from and provides seamless disaster recovery.
Proceeding to discuss Root Based Paths, the preceding example demonstrated how they are utilized. Root Based Paths offer a methodical approach to organizing and accessing data, which is particularly beneficial in large-scale file systems.

### Table 9: Protocol-specific Access Zones

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Root Based Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>NFS Access</td>
<td>/ifs/cls1/AZ1/nfs</td>
</tr>
<tr>
<td>SMB Access</td>
<td>/ifs/cls1/AZ2/smb</td>
</tr>
<tr>
<td>NFS / SMB / HDFS</td>
<td>/ifs/cls1/AZ3/mp</td>
</tr>
</tbody>
</table>

**Figure 20**  Importance of Root Based Path best practices

Root Based Paths may also be based on protocol. As an example, protocols are matched with a Root Based Path in the following table:
Source-Based Routing considerations

9 Source-Based Routing considerations

Source-Based Routing (SBR) with Isilon OneFS is discussed in the Isilon OneFS 8.1.0 External Network Connectivity Guide. This section clarifies how SBR functions. The naming convention suggests that SBR is routing packets based on a source IP address. However, SBR is actually a mechanism to dynamically create per-subnet default routes. The router used as this gateway is derived from the subnet configuration. Gateways must be defined for each subnet. For example, consider a cluster with subnets A, B, and C, as illustrated in the following figure:

![Source-Based Routing Diagram](image)

Figure 21 Source-Based Routing

In the example above, each gateway has a defined priority. If SBR is not configured, the highest priority gateway, i.e. gateway with the lowest value which is reachable, is used as the default route. Once SBR is enabled, when traffic arrives from a subnet that is not reachable via the default gateway, firewall rules are added. As OneFS is FreeBSD based, these are added through ipfw. In the example above, the following ipfw rules are provisioned:

- If src-ip is in subnetA and dst-ip is not in (subnetA,B,C) set next-hop to gatewayA
- If src-ip is in subnetB and dst-ip is not in (subnetA,B,C) set next-hop to gatewayB
- If src-ip is in subnetC and dst-ip is not in (subnetA,B,C) set next-hop to gatewayC
The process of adding ipfw rules is stateless and essentially translates to per-subnet default routes. SBR is entirely dependent on the source IP address that is sending traffic to the cluster. If a session is initiated from the source subnet, the ipfw rule is created. The session must be initiated from the source subnet, otherwise the ipfw rule is not created. If the cluster has not received traffic that originated from a subnet that is not reachable via the default gateway, OneFS will transmit traffic it originates through the default gateway. Given how SBR creates per-subnet default routes, consider the following:

- A subnet setting of 0.0.0.0 is not supported and is severely problematic, as OneFS does not support RIP, RARP, or CDP.
- The default gateway is the path for all traffic intended for clients that are not on the local subnet and not covered by a routing table entry. Utilizing SBR does not negate the requirement for a default gateway, as SBR in effect overrides the default gateway, but not static routes.
- Static routes are an option when the cluster originates the traffic, and the route is not accessible via the default gateway. As mentioned above, static routes are prioritized over source-based routing rules.

9.1 Source-Based Routing and DNS

As discussed earlier in this paper, it’s important to understand the path a specific session traverses throughout the network hierarchy. If SBR is configured on a cluster, this will also impact how the cluster creates sessions with other hosts, such as a DNS server.

In certain environments, Isilon clusters with SBR enabled and multiple SmartConnect SIP (SSIP) addresses, have experienced excessive latency with DNS responses. As mentioned previously in this paper, keeping latency minimal is imperative through any transaction and the delayed DNS responses could impact DNS dependent workflows. The prior section explained how SBR dynamically assigns a gateway. In this instance, the route to the DNS server is changed as the session originated on a different interface based on the SSIP being addressed.

In order to prevent the additional latency with DNS responses, when SBR is enabled with multiple SSIP addresses, consider the following:

- If a single Access Zone is configured to have multiple SmartConnect zones and multiple subnets with SBR enabled, it is recommended to have a single SSIP.
- If a cluster is using a single DNS server, it is recommended to use a single SSIP.
- If multiple Access Zones are required within a single groupnet, then a single SSIP is recommended.
IPv6

10 IPv6

Although Internet Protocol version 4 (IPv4) is the most common version of IP today, Internet Protocol version 6 (IPv6) is the newest version and ultimately replaces IPv4. IPv4 addresses were completely allocated to specific geographic regions in 2011. IPv6 uses 128-bit addresses supporting 340 undecillion addresses. For those unfamiliar with an undecillion, this translates to 340 times 10 to the 36th power possible IP addresses.

10.1 Why IPv6?
IPv6 brings innovation and takes connectivity to a new level with enhanced user experiences.

10.1.1 Security
IPv6 supports IPSEC inherently with encryption and integrity checks. Additionally, the Secure Neighbor Discovery (SEND) protocol provides cryptographic confirmation of host identity, minimizing hostname-based attacks like Address Resolution Protocol (ARP) poisoning, leading to devices placing more trust in connections.

10.1.2 Efficiency
IPv6’s large address space means many devices no longer require NAT translation as previously with IPv4, making routers far more efficient. Overall data transmission is faster and simplified as the need for checking packet integrity is eliminated.

10.1.3 Multicast
IPv6 supports multicast rather than broadcast, allowing media streams to be sent to multiple destinations simultaneously leading to bandwidth savings.

10.1.4 Quality of Service
Quality of Service (QoS) implementation is simplified in IPv6 with a new packet header. The IPv6 header contains a new field, Flow Label, which identifies packets belonging to the same flow. The Flow Label associates packets from a specific host and head to a particular destination.
10.2 IPv6 addressing

IPv6’s address structure is defined by the IETF as part of RFC 3513 and provides many of the advantages discussed above over IPv4. At first glance, it is evident an IPv6 address looks nothing like an IPv4 address. IPv4 addresses are composed of four numerical octets, ranging from 0 to 255, separated by periods, forming a 32-bit address. IPv6 addresses are 128 bits and consisting of a series of eight segments, separated by a colon. Each segment is a 4-character hexadecimal number, ranging from 0000 to FFFF, representing 16 bits each, totaling to the 128 bits.

**IPv6 addressing**

IPv6’s address structure is defined by the IETF as part of RFC 3513 and provides many of the advantages discussed above over IPv4. At first glance, it is evident an IPv6 address looks nothing like an IPv4 address. IPv4 addresses are composed of four numerical octets, ranging from 0 to 255, separated by periods, forming a 32-bit address. IPv6 addresses are 128 bits and consisting of a series of eight segments, separated by a colon. Each segment is a 4-character hexadecimal number, ranging from 0000 to FFFF, representing 16 bits each, totaling to the 128 bits.

![IPv6 address](image)

**Figure 22** IPv6 address

For display purposes, an IPv6 address may be presented without leading zeros. For example, an IPv6 address of 2001:0DC8:E004:0001:0000:0000:00:0000:F00A could be displayed as 2001:DC8:E004:1:0:0:0:F00A.

The address may be further reduced by removing consecutive fields of zeros and replacing with a double-colon. The double-colon can only be used once in an address. The address above becomes 2001:DC8:E004:1::F00A.

IPv6 offers the following address types:

- **Unicast:** one-to-one – Single Address to Single Interface
- **Anycast:** one-to-nearest – Assigned to a group of interfaces, with packets being delivered only to a single (nearest) interface
- **Multicast:** one-to-many – Assigned to a group of interfaces and is typically delivered across multiple hosts.

An IPv6 Unicast address is composed of the Global Routing Prefix, Subnet ID, and the Interface Identifier. The Global Routing Prefix is the network ID or prefix of the address for routing. The Subnet ID is similar to the netmask in IPv4 but is not part of the IP address in IPv6. Finally, the Interface ID is a unique identifier for a particular interface. For Ethernet networks, the Ethernet MAC address (48 bits) may be used for the Interface Identifier, by inserting 16 additional bits, forming what is referred to as an EUI-64 address.

![IPv6 Unicast address format](image)

**Figure 23** IPv6 Unicast address format
10.3 **IPv6 header**

An IPv6 header is simplified in comparison to IPv4, minimizing complexity and making the header easier to process for all devices. Efficiency was one of the focus points with IPv6 from the onset, which is brought to light with the faster processing of IPv6 headers. The figure below displays the format of an IPv6 header.

![IPv6 header](image)

**Figure 24** IPv6 header

The table below defines the fields of an IPv6 header.

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Version</td>
<td>Specifies if the packet is IPv4 or IPv6</td>
<td>4 Bits</td>
</tr>
<tr>
<td>Traffic Class</td>
<td>Similar to an IPv4 Type of Service field and includes support for Differentiated Services Code Point (DSCP) providing congestion control.</td>
<td>8 Bits</td>
</tr>
<tr>
<td>Flow Label</td>
<td>Provides the ability to track certain traffic flows at the network layer for QoS management.</td>
<td>20 Bits</td>
</tr>
<tr>
<td>Payload Length</td>
<td>Similar to the IPv4 'Length' field – Provides length of the data portion</td>
<td>16 Bits</td>
</tr>
<tr>
<td>Next Header</td>
<td>Similar to the IPv4 'Protocol' field – Provides what to expect after the basic header, including options for a TCP or UDP header</td>
<td>8 Bits</td>
</tr>
<tr>
<td>Hop Limit</td>
<td>Similar to the IPv4 'Time to Live' field – Provides the maximum number of hops</td>
<td>8 Bits</td>
</tr>
</tbody>
</table>

10.4 **IPv6 to IPv4 translation**

Connecting IPv6 and IPv4 remains a challenge with the slow migration to IPv6 and support for legacy devices requiring IPv4. The three top options available to facilitate IPv4 and IPv6 communication are dual-stack networks, tunneling, and translation.

For Service Providers to deliver IPv6, they utilize translation technologies. The two major translation technologies are the Network Address Translation IPv6 to IPv4 (NAT64) and Stateless IP/ICMP Translation (SIIT). NAT64 is similar to the IPv4 Network Address Translation but is specific to IPv6. SIIT is capable of replacing IPv4 and IPv6 as part of the translation.
10.5 Configuring OneFS for IPv6

Implementing IPv6 on an Isilon cluster is a simple process as IPv6 and IPv4 are supported as a dual stack. In order to provision an IPv6 subnet with Isilon, follow these steps:

1. Select an existing Groupnet or create a new one
2. Enter DNS servers and add a Subnet
3. Create Subnet by selecting IPv6 in the IP Family
4. Create a network address pool and assign interfaces
11 Network troubleshooting
This section provides steps for assessing and troubleshooting network issues with generally available utilities.

11.1 Netstat
Netstat, short for network statistics, is a utility built into most Windows and Linux clients. It provides an array of statistics on current ports, routing, IP stats for transport layer protocols, and serves as a forensic tool to link processes with network performance while digging deeper into the current network status. Netstat bundles several actions into a single command with different options available. As Netstat is multi-platform, the syntax is similar across platforms with slight variations.

11.1.1 Netstat
In its standard form without any arguments, netstat provides an overview of the current network status broken out by each connection or socket. Each column displays the following:

- **Proto**: Protocol of the active connection. The protocol could be TCP or UDP and has a ‘4’ or ‘6’ associated specifying if it is IPv4 or IPv6, respectively.
- **Recv-Q** and **Send-Q**: Value of the receiving and sending queue in bytes. Non-zero values specify the number of bytes in the queue that are awaiting to be processed. The preferred value is zero. If several connections have non-zero values, this implies something is causing processing to be delayed.
- **Local Address** and **Foreign Address**: Lists the hosts and ports the sockets are connected with. Some of these are local connections to the host itself.
- **State**: Displays the current state of the TCP connection, based on the TCP protocol. As UDP is a stateless protocol, the ‘State’ column will be blank for UDP connections. The most common TCP states include:
  - **Listen**: Waiting for an external device to establish a connection
  - **Established**: Ready for communication on this connection
  - **Close Wait**: The remote machine has closed the connection, but the local device has not closed the connection yet.
  - **Time Wait**: The local machine is waiting for a period of time after sending an ACK to close a connection.

For more information about the states of a TCP connection, see RFC 793.

<table>
<thead>
<tr>
<th>tme-sandbox-1# netstat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Internet connections</td>
</tr>
<tr>
<td>Proto</td>
</tr>
<tr>
<td>tcp4</td>
</tr>
<tr>
<td>tcp4</td>
</tr>
<tr>
<td>tcp4</td>
</tr>
<tr>
<td>tcp4</td>
</tr>
<tr>
<td>tcp4</td>
</tr>
<tr>
<td>tcp4</td>
</tr>
<tr>
<td>tcp4</td>
</tr>
</tbody>
</table>

Figure 25 Netstat

Netstat reveals a lot of information about the current status of network connections, and it also provides information for a more thorough forensic analysis. While reviewing the output from netstat, some of the scenarios can be generalized, like the following:
Network troubleshooting

- Recv-Q has a value greater than zero but is in a 'Close Wait' state. This indicates that these sockets should be torn down but are hanging. If several sockets are in this state, it could imply the application is having difficulty tearing down the connection and may warrant additional investigation.
- Connections that have localhost as the 'Local' and 'Foreign' address denote an internal process using the TCP stack to communicate. These connections are not concerning and are standard practice.

11.1.2 netstat -s -p tcp

Netstat offers several options, but the '-s' provides statistics by protocol and '-p' displays the net to media tables. These options reveal current health and the 'tcp' limits it to the TCP protocol. Below, is a sample output of this command with the areas to examine highlighted in red.

```
netstat -s -p tcp
```

The fields highlighted in red above must be reviewed as a ratio of the total packets that are transmitted and received as a percentage. Additionally, these statistics should be monitored for sudden increments. As a rule of thumb, under 1% is not concerning but this also depends on the workload. The fields highlighted above provide the following:

- Retransmitted Packets: Packets that are retransmitted consume network bandwidth and could be the reason for further investigation. However, examining the percentage is critical. In this case, 249379 out of 235829612 were retransmitted, which is 0.105%.
- Duplicate Acknowledgements: High latency between endpoints may lead to duplicate acknowledgments, but the ratio must be examined. In this case, it is 0.419%. This number varies depending on the workload.
- Out of Order Packets: Out of order packets are placed in order by TCP before presenting to the application layer, which impacts the CPU and overall stack performance as the additional effort is
involved in analyzing the packets. Performance is impacted the most when packets arrive out of order with a significant time gap, or a number of packets are out of order. The ratio, in this case, is 0.197%, which is negligible.

### 11.1.3 netstat -i

Another option for netstat is the `–i` option, which is the interface display, listing cumulative statistics for total packets transferred, errors, MTU, and collisions by the interface. As netstat `–i` lists all available interfaces, the back-end, and front-end interfaces are displayed. A sample output of netstat `–i` is shown with the `–h` option, making it easier to interpret, in the following figure:

![netstat -i](image)

Figure 27  netstat -i

From the output above, netstat `–i`, lists the following columns:

- **Name**: Network Interface Card (NIC) name. Loopback interfaces are listed as ‘lo0,’ and ‘ib’ specifies InfiniBand.
- **MTU**: Lists the MTU specified for the interface.
- **Network**: Specifies the network associated with the interface.
- **Address**: MAC address of the interface.
- **Ipkt**: Input packets are the total number of packets received by this interface.
- **Ierrs**: Input errors are the number of errors reported by the interface when processing the ‘Ipkt’. These errors include malformed packets, buffer space limitation, checksum errors, errors generated by media, and resource limitation errors. Media errors are errors specific to the physical layer, such as the NIC, connection, cabling, or switch port. Resource limitation errors are generated at peak traffic when interface resources are exceeded by usage.
- **Idrop**: Input drops are the number of packets that were received, but not processed and consequently dropped on the wire. Dropped packets typically occur during heavy load.
- **Opkt**: Output packets are the total number of packets transmitted by this interface.
- **Oerrs**: Output errors are the number of errors reported by the interface when processing the ‘Opkt’.
- **Coll**: Collisions are the number of packet collisions that are reported. Collisions typically occur during a duplex mismatch or during high network utilization.

In general, errors and dropped packets require closer examination. However, as noted in the previous netstat section, the percentage of errors and dropped packets are the main factor. The following are some of the points to consider for further analysis:

- `Ierrs` should typically be less than 1% of the total `Ipkt`. If greater than 1%, check `netstat –m` for buffer issues and consider increasing the receive buffers. Prior to implementing changes on a
production system, buffer changes should be tested in a lab environment. Refer to the Isilon Network Stack Tuning Section for additional details.

- ‘Oerrs’ should typically be less than 1% of the total ‘Opkts.’ If greater than 1%, it could be a result of network saturation, otherwise consider increasing the send queue size.
- The ratio of ‘Coll’ to ‘Opkts,’ should typically be less than 10%. If greater than 10%, it could be a result of high network utilization.

11.1.4 netstat -m

The netstat –m option displays the current status of network memory requests as mbuf clusters. Netstat –m is a powerful option for a complete forensic analysis when one of the other netstat commands mentioned above raises concern. If mbufs are exhausted, the node cannot accept any additional network traffic.

```plaintext
netstat -m
```

The netstat –m output provides information in regard to available and used mbufs. The area highlighted in red, confirms if any memory requests have been denied. In the example above, a quick glance at this area reveals that no requests have been denied.

For more information on netstat options, visit the FreeBSD manual netstat page at https://www.freebsd.org/cgi/man.cgi?query=netstat&manpath=SuSE+Linux/i386+11.3

11.2 InsightIQ external network errors

Isilon InsightIQ reports external network errors under the “Performance Reporting” tab when the “Network Performance Report” is selected. A sample of this output is displayed in the following figure:

![InsightIQ network errors](image)
InsightIQ gathers network errors using the output from ‘netstat –i’ on external interfaces only. The total of the ‘Ierrs’ and ‘Oerrs’ is combined and displayed in the graph. Refer to the previous section for interpreting the output from ‘netstat –i.’

In order to find the exact interface errors, sort the graph by ‘Node,’ ‘Direction,’ and ‘Interface,’ as shown in the following figures:

Figure 30  InsightIQ external network errors by node

Figure 31  InsightIQ external network errors by direction

Figure 32  InsightIQ external network errors by interface
From the figures above, it is concluded that the external network errors reside on the interface ‘7/10gige-1’ of Node 7, on the input or receive side. Further analysis must be performed on this interface to conclude the root cause. Refer to the ‘netstat –i’ section in this paper for the next troubleshooting steps.

11.3 DNS

DNS or Domain Name Service resolves hostnames to IP addresses. Most enterprises have a local DNS to resolve hostnames managed by them, and then a public internet DNS resolves external hostnames. Troubleshooting DNS is performed with the utilities, ‘nslookup’ or ‘dig.’ Both provide similar information; however, ‘dig’ is more detailed. In this section, the usage of ‘dig’ is explored.

The ‘dig’ command displays results in the following sections:

- **Header**: The Header provides the version of ‘dig’, options the ‘dig’ command used and the flags that are displayed.
- **Question Section**: The Question Section displays the original input provided to the command. In the case above, dell.com was queried. The default is to query the DNS A record. Other options are available for querying MX and NS records.
- **Answer Section**: The Answer Section is the output received by dig from the DNS server queried.
- **Authority Section**: The Authority Section lists the available Name Servers of dell.com. They have the authority to respond to this query.
Network troubleshooting

- Additional Section: The Additional Section resolves the hostnames from the Authority Section to IP addresses.
- Stats Section: The footer at the end of the query is referred to as the Stats Section. It displays the when, where, and time the query consumed.

Dig supports an array of options. The most common options include a reverse look-up using 'dig –x [IP address]' to find a host name. The other is to specify a DNS server to query using 'dig @[dns server] [hostname].'

For the complete list of dig options, please refer to the FreeBSD manual page: https://www.freebsd.org/cgi/man.cgi?query=dig&sektion=1&manpath=FreeBSD%209.1-RELEASE
A Networking tools

The following tools help troubleshooting or lab configurations for testing:

Brocade Virtual Router:
B Supported network optics and transceivers

For information about the optics and transceivers supported by Isilon nodes, refer to the Isilon Supportability and Compatibility Guide.
Technical support and resources

Dell.com/support is focused on meeting customer needs with proven services and support.

Storage technical documents and videos provide expertise that helps to ensure customer success on Dell EMC storage platforms.

C.1 Related resources

Cisco Nexus 5000 Series Configuration Guide:

Cisco Catalyst 6500 Best Practices:

Brocade Switching Configuration Guide:


Configuration of Jumbo MTU on Nexus 5000 and 7000 Series:


SMBv3 Multi-Channel:

Isilon OneFS Documentation:
• OneFS 8.1.0 Documentation - Isilon Info Hub
• OneFS 8.1 Web Administration Guide
• OneFS 8.1 CLI Administration Guide
• OneFS 8.1 API Reference
• EMC Isilon SmartConnect White Paper
• EMC Isilon OneFS and IsilonSD 8.1 Technical Specifications Guide
• OneFS 8.1 Security Configuration Guide

RFCs:
• http://www.faqs.org/rfcs/rfc1812.html
• http://www.faqs.org/rfcs/rfc1122.html
• http://www.faqs.org/rfc/rfc1123.html
• https://tools.ietf.org/html/rfc3971
• https://tools.ietf.org/html/rfc792
• https://tools.ietf.org/html/rfc3513