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2020 OFA Virtual Workshop

LUSTRE NETWORK MULTI-RAIL FEATURE SET

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DDN® STORAGE

AGENDA

- **Overview of Multi-Rail Features**
- **Base Multi-Rail**
- **Multi-Rail Health and Resiliency**
- **Multi-Rail Routing**
- **Multi-Rail Network Selection Policies**
- **Summary**

MULTI-RAIL FEATURE SET OVERVIEW

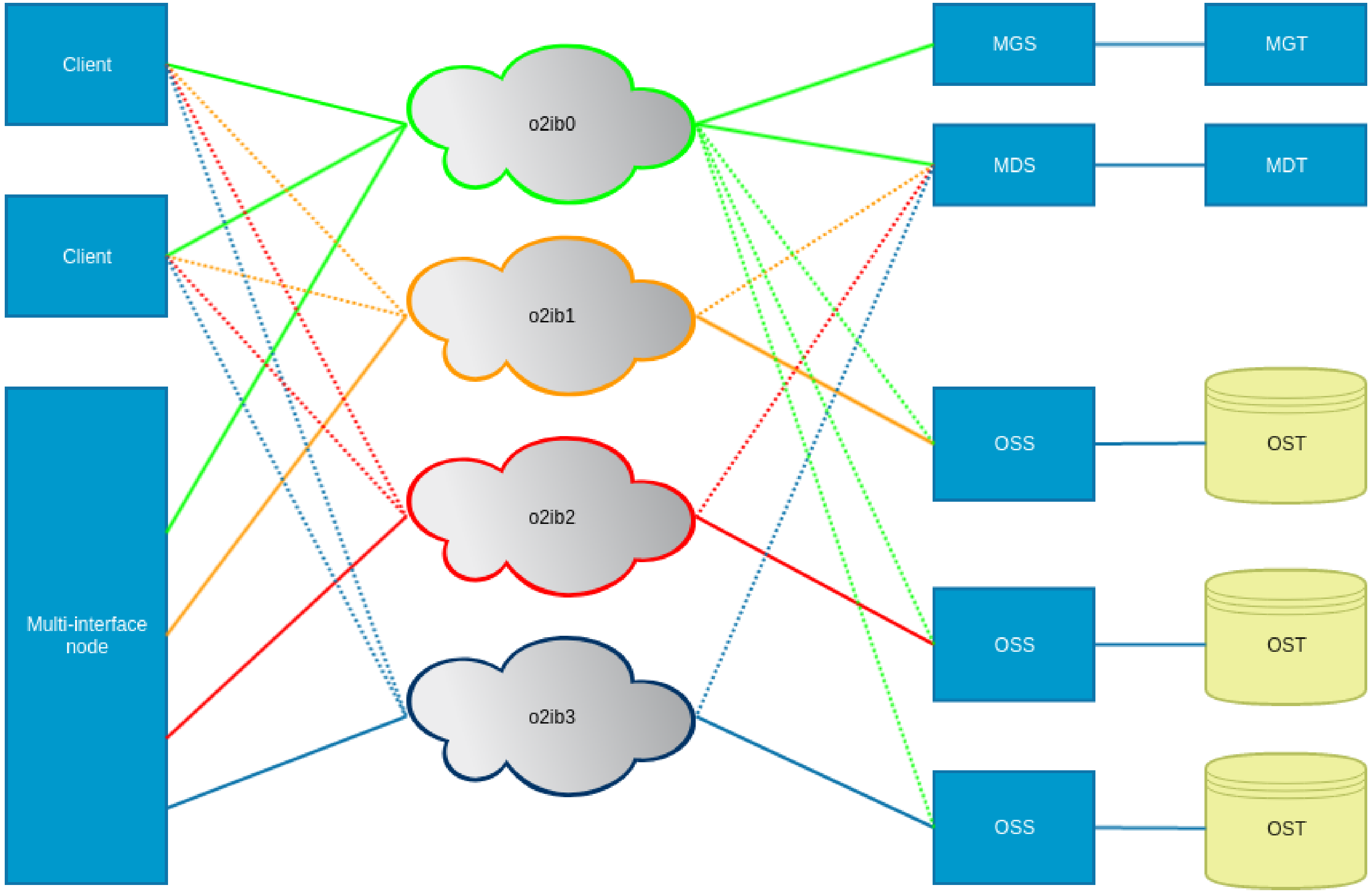
OVERVIEW

- **Lustre has its own networking abstraction layer, LNet**
- **Different types of LNet networks are configured to encapsulate traffic**
- **Each network type has its own driver, LND**
  - IB/RoCE/OPA (verbs) Traffic, o2iblnd - o2ibX
  - Ethernet traffic, socklnd - tcpX

ONE NETWORK INTERFACE PER NETWORK

- **Traditionally, LNet allowed only one network interface per LNet network**
- **If a node had multiple interface, multiple LNet Networks need to be configured**

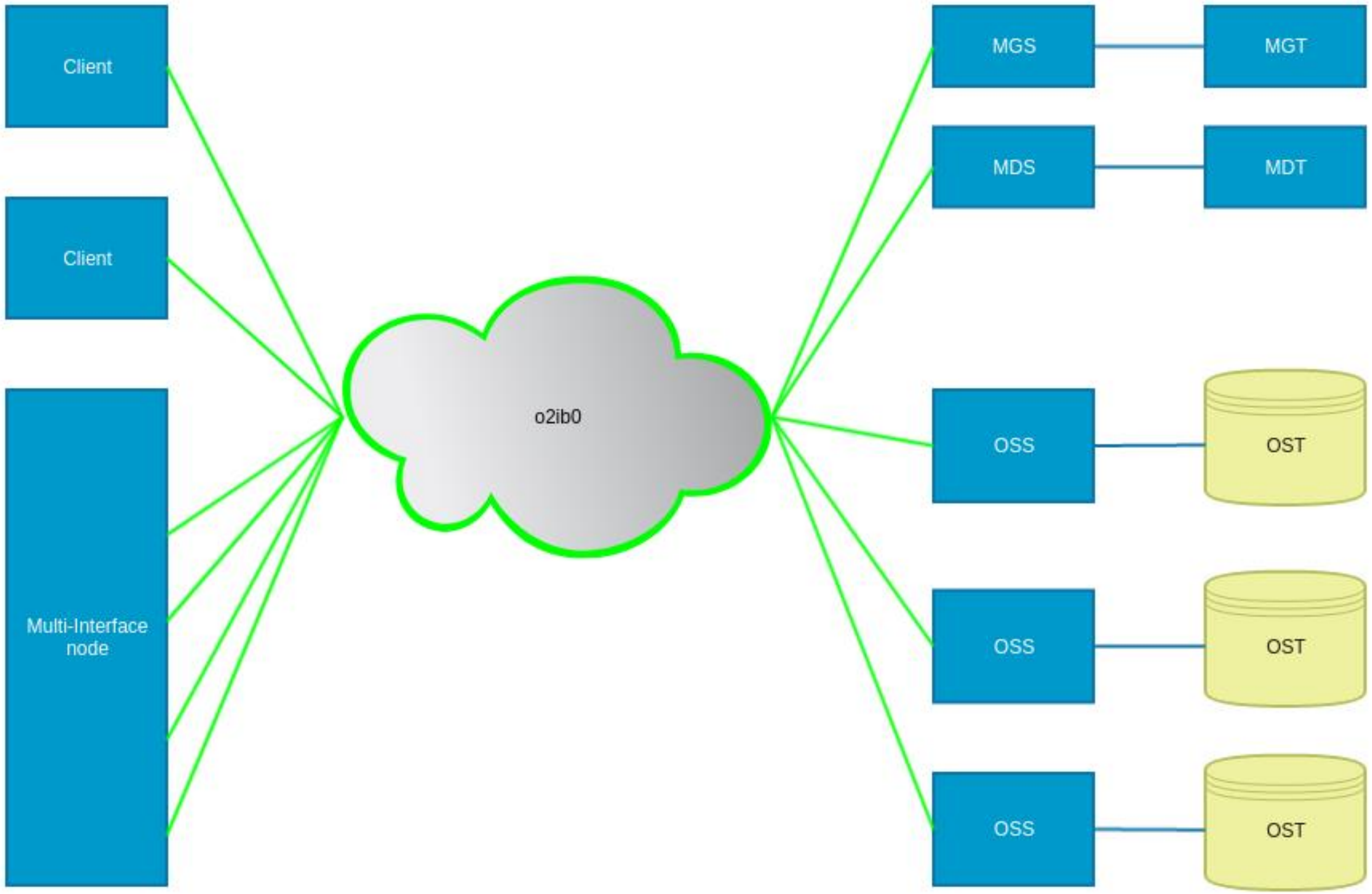
TRADITIONAL LNET



WHAT IS MULTI-RAIL

- **LNet Level Multi-Rail Solution**
- **Multi-Rail allows nodes to communicate across multiple interfaces:**
  - Using Multiple interfaces connected to one network
  - Using multiple interfaces connected to different networks
  - These interfaces are used simultaneously

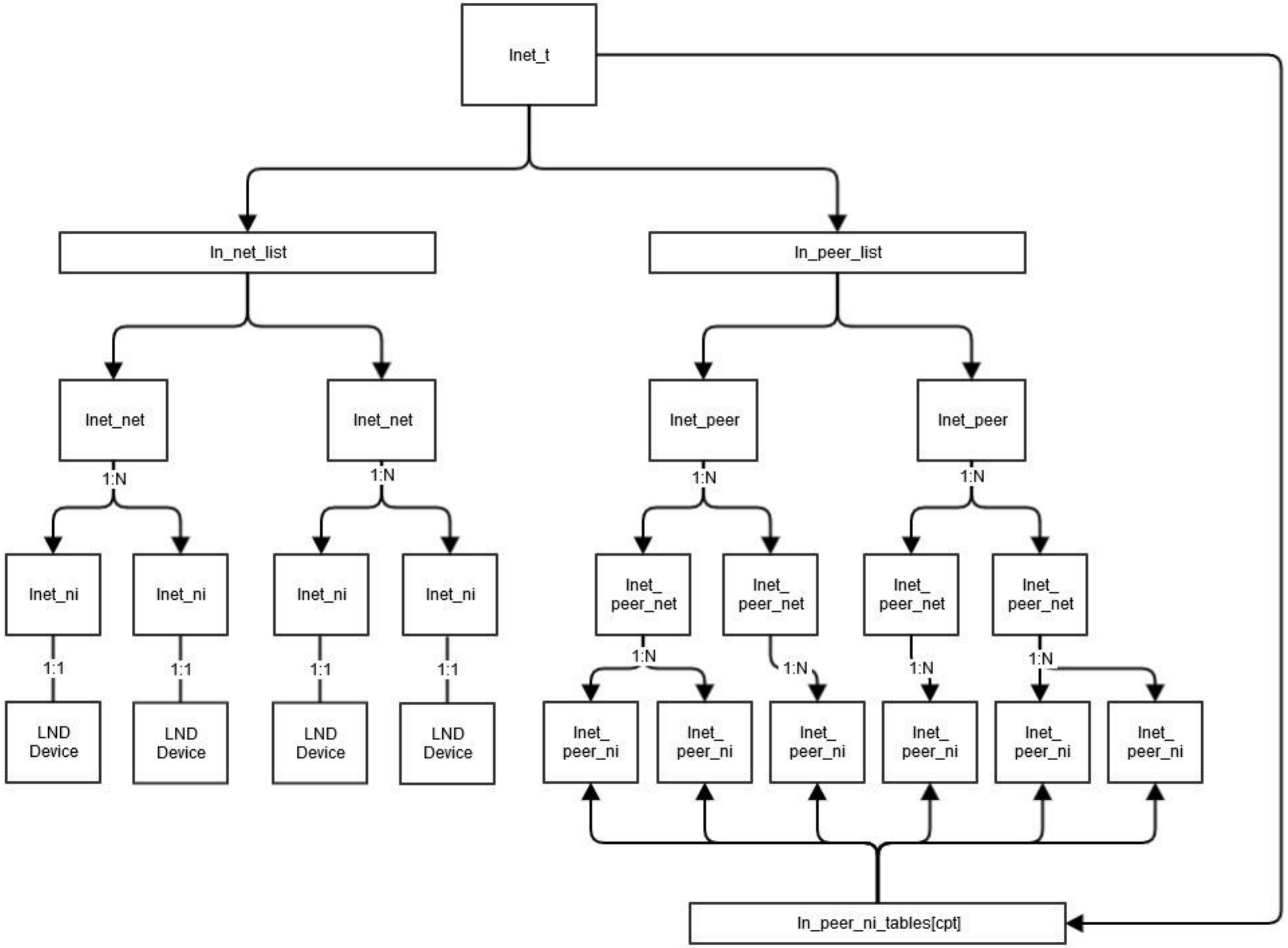
MULTI-RAIL LNET



MULT-RAIL GOALS

- **Goals**
  - Allow multiple interfaces to be configured in the same LNet Network
  - Allow automatic interface discovery of peers
  - Allow all interfaces in the same network to be used in Active/Active mode
  - Allow heterogeneous networks (ex: tcp3 and o2ib1) to be used simultaneously
  - Monitor Interface/network health and use the healthiest interface
  - Apply selection criteria on which interface to use
  - Apply user specified network selection policies

MULTI-RAIL LNET



lnet_t

ln_net_list

ln_peer_list

lnet_net

lnet_net

lnet_peer

lnet_peer

1:N

1:N

1:N

1:N

lnet_ni

lnet_ni

lnet_ni

lnet_ni

lnet_peer_net

lnet_peer_net

lnet_peer_net

lnet_peer_net

1:1

1:1

1:1

1:1

1:N

1:N

1:N

1:N

LND Device

LND Device

LND Device

LND Device

lnet_peer_ni

lnet_peer_ni

lnet_peer_ni

lnet_peer_ni

lnet_peer_ni

lnet_peer_ni

ln_peer_ni_tables[cpt]

LNET LEVEL MULT-RAIL

- **LNet Level Multi-Rail Solution**
- **Advantages**
  - Simpler configuration and automatic discovery
  - Support different HW (MLX, ETH, OPA, ...)
  - Aggregate throughput of interfaces
  - Resiliency against network failure
  - Control over interface selection based on internal consideration such as NUMA configuration, health, credits
  - Control over network pathway selection based on physical network characteristics

BASE MULTI-RAIL

LNET LEVEL MULT-RAIL

- **Why LNet Multi-Rail not lower level interface bonding?**
  - Finer grained control over network interface selection
  - Finer grained control over network path selection
  - Finer grained control over network interface health monitoring
  - LNet level message control
  - Other Interface types can be configured and leverage the Multi-Rail capabilities
- **The Multi-Rail solution was implemented in multiple phases**
- **Phase one and two was to get LNet using multiple interfaces and simplify configuration**

LNET INTERFACE SELECTION

- **What criteria should be used to select an interface?**
- **Keep RDMA performance in mind**
- **Criteria**
  - NUMA closeness
  - Credits available per interface
  - Round Robin
- **Flexibility:**
  - Algorithm needs to be flexible to allow other criteria.
    - Health
    - Buffer source restrictions beside NUMA

MULTI-RAIL CONFIGURATION

- **When configuring an LNet network specify the interfaces on this network**
  - options lnet network=“o2ib(ib0,ib1),tcp(eth0,eth1)”
    - or
  - lnetctl net add --net o2ib --if ib0,ib1
  - lnetctl net add --net tcp --if eth0,eth1
- **First interface configured on the node becomes its Primary NID**
  - The Primary NID becomes the unique identifier of the node
- **Nodes can automatically discover the list of interfaces of other peers. No extra configuration required**
- **Considerations:**
  - Group interfaces on the same subnet in the same LNet
  - Group homogeneous interfaces in the same LNet.

NETWORK PERFORMANCE

- **Network interface performance is aggregated**
  - EX: 2x EDR IB interfaces with 12.5GB/s performance --> ~23 GB/s LNet level Performance (almost line rate)
    - 1MB block size RDMA write

LUSTRE PERFORMANCE

- **Lustre File system doesn’t approach line rate but performance is still improved**
  - 32 socket of Xeon Processors
  - 16 TB of memory
  - 8 Omni-Path network interfaces
  - 8 C2112-GP2-EX Object Storage Systems (OSS)
  - 4 P3700 NVMedevices LDISKFS Object Storage Target (OST) per OSS
- **Theoretical maximum performance of the system:**
  - P3700 Sequential Write: 34560 MB/s
  - Sequential Read: 86400 MB/s
- **Multi-Rail performance:**
  - Sequential Write: 31990.18 MB/s
  - Sequential Read: 68593.35 M

MULTI-RAIL HEALTH & RESILIENCY

INTERFACE HEALTH MONITORING

- **Need to monitor health in order to use the healthiest interface**
- **Assign a maximum health value to each interface**
- **Whenever failure occurs on the interface decrement the health value**
- **When selecting an interface prefer the healthiest interface**
  - Add this as a criteria to the interface selection algorithm
- **Handle protocol layer events, such as:**
  - IB_EVENT_DEVICE_FATAL
  - IB_EVENT_PORT_ERR
- **The above two IB events lead to the interface going out of service until the corresponding up events are sent.**

LNET LEVEL RETRIES

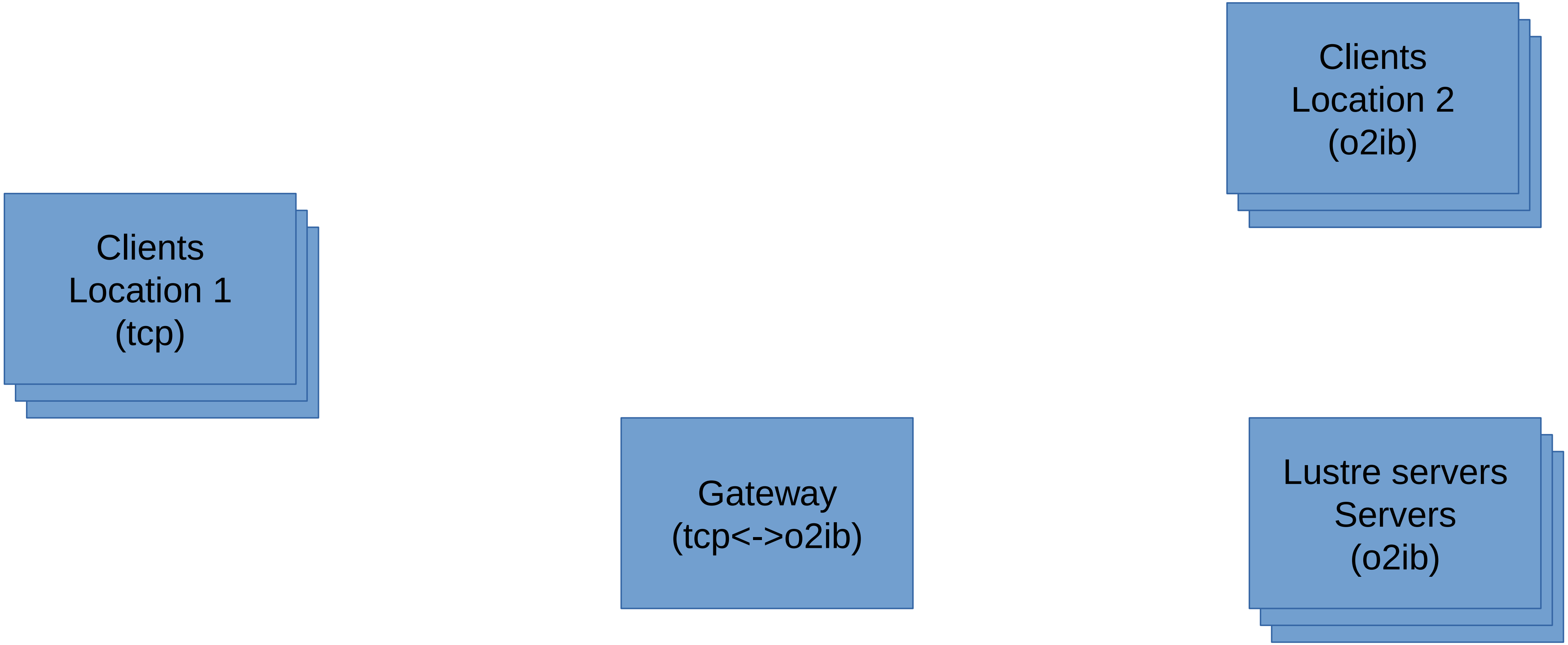
- **Lustre Level RPCs are composed of one or more LNet messages**
- **LNet message send failures can be handled at the LNet level before passing the failure up to Lustre for handling.**
- **There are restrictions on failure handling**
  - local send failures are handled. IE: messages didn’t make it to the wire
  - Remote messages are not received. IE: remote didn’t process the message
  - Retry only if multiple interfaces are available
- **In this case an LNet message can be retried on a different interface**
- **Maximum number of retries is configurable**
- **Ensure retries do not over flow Lustre timeouts in order not to introduce further delays**

MULTI-RAIL ROUTING

LNET ROUTERS

- **What are LNet Routers?**
  - They route LNet messages to across different types of networks: tcp, o2ib
- **What are they used for?**
  - There are cases where two clusters separated by great geographical distance need to be connected
  - Each clustre can use IB but messages traversing the clusters go over ethernet
  - Routers are used to route IB LNet traffic over ethernet from one cluster to another
- **What is an MR Router?**
  - An MR node acting as a router with multiple interfaces
  - Always referenced by its Primary NID

LNET ROUTERS



Clients
Location 2
(o2ib)

Clients
Location 1
(tcp)

Gateway
(tcp<->o2ib)

Lustre servers
Servers
(o2ib)

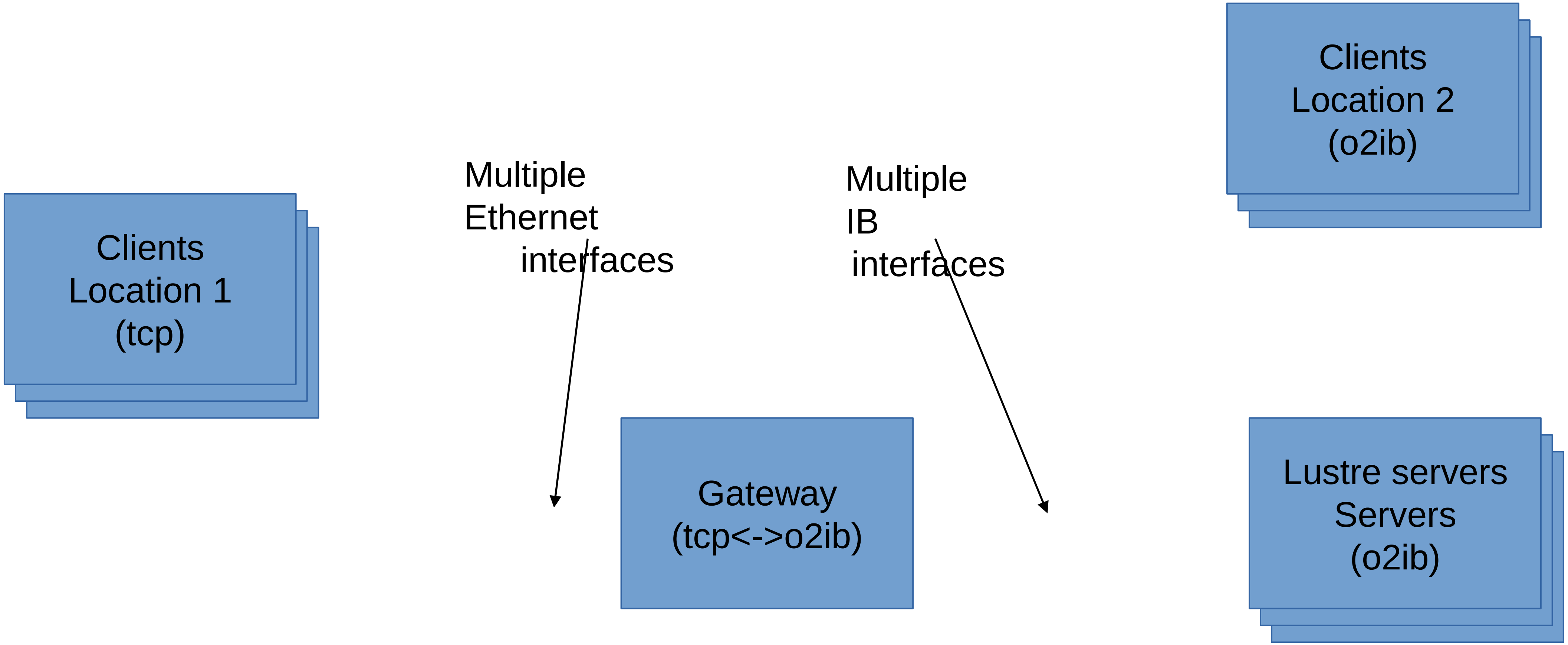
CONFIGURING ROUTES

- A route is usually configured as follows:
  - lnetctl route add --net <remote net> --gateway <gateway NID> [--hop <number of hops --priority <prio>]
- The remote net is a network we are not directly connected to which we want to reach
- The gateway NID is the NID to send messages destined to the remote NID to
- hop is the number of hops to the final destination
- priority is the priority of that route
- Multiple routes can be configured to the same remote network over different gateways
- LNet will select the route with the highest priority or least number of hops
- If all is the same, it’ll round robin.

MRR GOALS

- **Multi-Rail Routing Goals**
  - Deal with gateway as Multi-Rail nodes in order to leverage MR advantages, higher throughput, performance
  - Can reduce the number of gateways if we just need to increase the throughput
  - Use existing health mechanism to monitor the health of the gateway instead of having a separate mechanism
  - Simplify routing configuration
    - No need to configure multiple routes which go to different interfaces of the same gateway
    - Use only the Primary NID of the gateway node
    - LNet will use all the gateway’s interfaces

LNET ROUTERS



Clients
Location 1
(tcp)

Multiple
Ethernet
interfaces

Gateway
(tcp<->o2ib)

Multiple
IB
interfaces

Clients
Location 2
(o2ib)

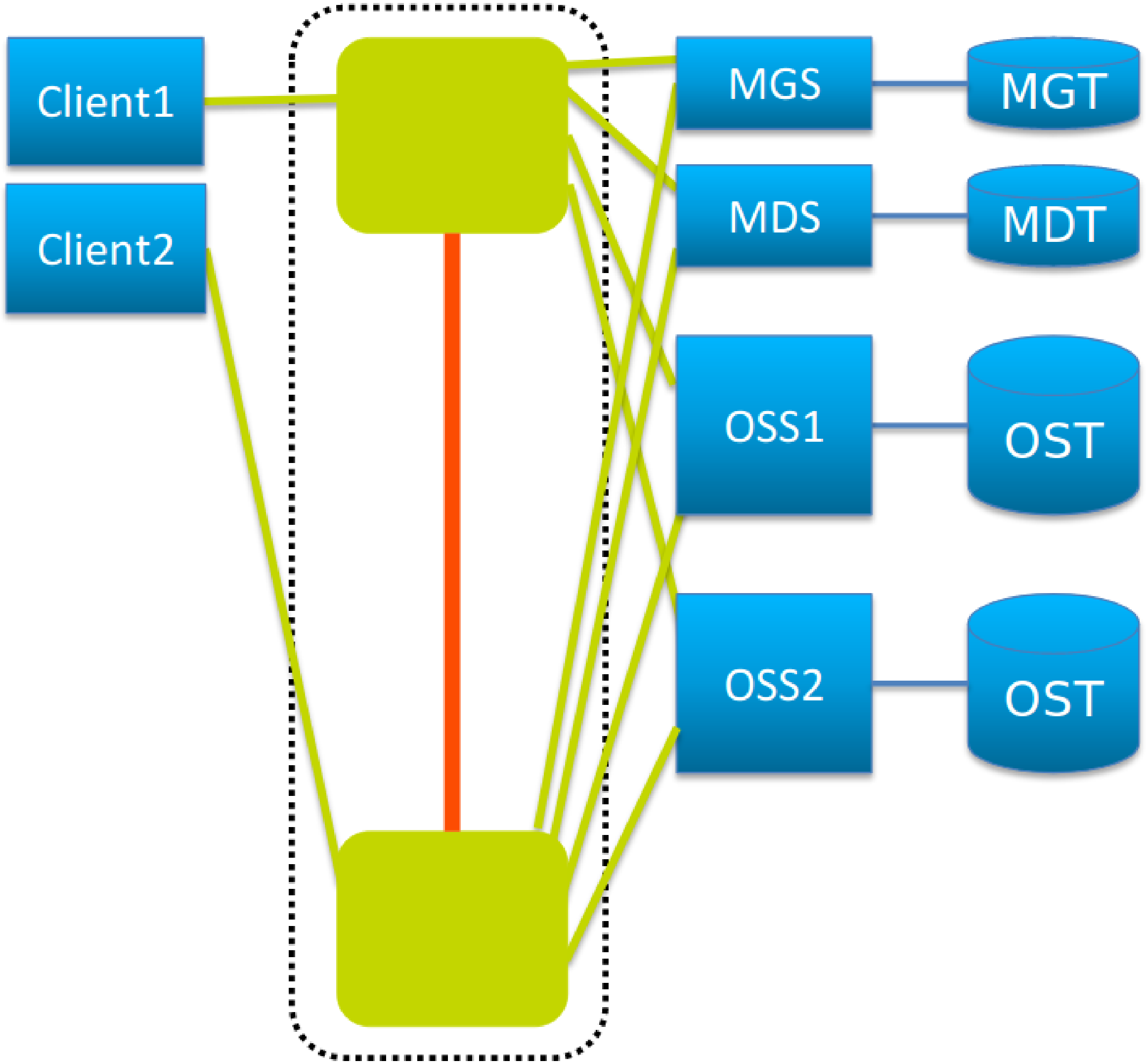
Lustre servers
Servers
(o2ib)

NETWORK SELECTION POLICIES

NETWORK SELECTION

- **What are network selection policies**
  - Policies designed to allow the administrator to fine grained control traffic
  - They govern the selection of:
    - Networks
    - Interfaces
    - Pairs of Networks or interfaces
    - Gateway interfaces
- **Why do we need it?**
  - There are some scenarios where the cluster administrators might want to configure two networks but keep one of them in standby
    - EX: o2ib network should be used for all traffic, unless it's not available then use tcp
  - There could be physical network limitation which create a specific bottle neck which we try to avoid

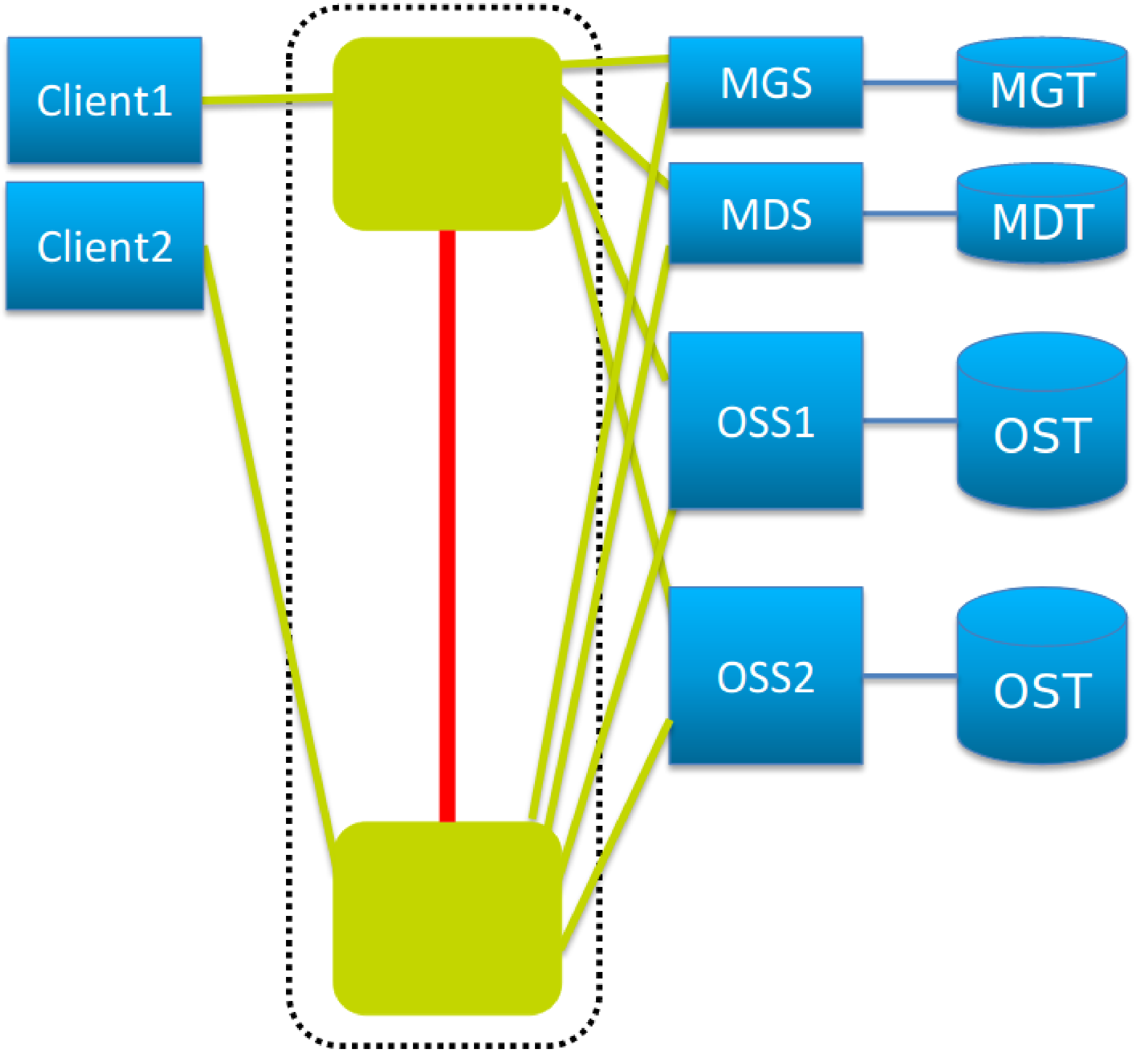
FINE GRAINED TRAFFIC CONTROL



This is a single fabric with a bottleneck.

Client1: 10.10.10.2@o2ib
Client2: 10.10.10.3@o2ib
MGS-1: 10.10.10.4@o2ib
MGS-2: 10.10.10.5@o2ib
MDS-1: 10.10.10.6@o2ib
MDS-2: 10.10.10.7@o2ib
OSS1-1: 10.10.10.8@o2ib
OSS1-2: 10.10.10.9@o2ib
OSS2-1: 10.10.10.10@o2ib
OSS2-2: 10.10.10.11@o2ib

FINE GRAINED TRAFFIC CONTROL



This rule makes *Client1* avoid the **red** path:

```
selection:
  - type: peer
    local: 10.10.10.2@o2ib
    remote: 10.10.10.[4-10/2]@o2ib
    priority: 0 # highest priority
```

Client1 will only use the **red** path if there is no other option.

POLICY MANAGEMENT

- **Configuration is done from user space tool: lnetctl**
  - Add/Delete/Show policies
- **Policies are created in user space, serialized and passed to LNet kernel module**
- **Polices are stored and applied on existing LNet constructs**
  - This is done in order not traverse the policy tree on the fast path
- **When new constructs are added, like Networks or Peers, the stored policies are automatically applied to them.**

SUMMARY

SUMMARY

- **Multi-Rail feature set was designed for the following main purposes**
  - Increase throughput
  - Increase resiliency
  - Simplify Configuration
  - Fine control over traffic
- **Multi-Rail allows for intelligent selection of interfaces to maximize performance**
  - NUMA awareness is one example
  - But if other RDMA sources introduce other criteria, they can be integrated into the selection algorithm
- **Multi-Rail was designed in LNet to allow for using heterogeneous networks**
- **Other Network Interface types can be added later and benefit from the Multi-Rail feature without having to implement their own.**

QUESTIONS

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THANK YOU

John Smith, President and CEO

COMPANY XYZ

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