Lustre Networking at Cray

Chris Horn
hornc@cray.com
Agenda

● Lustre Networking at Cray
  ● LNet Basics
  ● Flat vs. Fine-Grained Routing
  ● Cost Effectiveness - Bandwidth Matching
  ● Connection Reliability – Dealing with ARP Flux
  ● Serviceability – Generating and Emplacing Configuration

● Recent LNet Work in the Lustre Community
  ● Support for new Mellanox Hardware
  ● Multiple Fabric Support

● Summary

● Q&A
LNet Basics

● LNet is Lustre Networking layer
● Network type agnostic
  ● Lustre Network Drivers (LNDs) provide interface to specific network drivers
    ● gnilnd (Aries/Gemini)
    ● o2iblnd (InfiniBand/OPA)
    ● socklnd (Ethernet)
● LNet routers bridge clients on Cray’s high speed network with external Lustre servers
  ● Gemini/Aries ↔ InfiniBand
  ● Two types of routing: Flat and Fine-Grained
Flat LNet

- Simple configuration
- Any router can talk to any other peer
Flat LNet

- Performance can be optimal at small scale
Flat LNet

- Performance suffers at large scale from need to traverse inter-switch links
Fine-Grained Routing

- Define groups of peers
- Best performance at scale by avoiding ISLs
- Complex configuration
  - # Groups is total # of servers divided by # servers in each group
## Cost Effectiveness and Bandwidth Matching

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- **Need to provide sufficient IB bandwidth in cost-effective manner**
  - No network bottlenecks
  - Minimize excess bandwidth

* Average throughput of 1 Server or IB link; 2 Servers or IB links; etc.
### Bandwidth Matching

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- **Single HCA** == Bandwidth of one IB port on XC40 LNet router node with one IB HCA
- **Dual HCA** == Bandwidth of one IB port on XC40 LNet router node with two IB HCAs

* Average throughput of 1 Server or IB link; 2 Servers or IB links; etc.
### Bandwidth Matching

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- 6 Sonexion 2000 OSSes (3 SSUs) ~ 22.5 GB/s
- 5 IB Links (from single HCA routers) ~ 27.50
- Servers using ~ 82% of available network bandwidth
## Bandwidth Matching

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- 6 Sonexion 2000 OSSes (3 SSUs) ~ 22.5 GB/s
- 6 IB Links (from dual HCA routers) ~ 25.2 GB/s
- Servers using ~ 90% of available network bandwidth
- Ideal ratio \( n:n \)
Connection Reliability – Dealing with ARP Flux

● **Address Resolution Protocol (ARP)**
  ● Maps Network layer address (e.g. IPv4) to link layer address (e.g. MAC address)
  ● Broadcasts ARP “who-has” request to all peers, “Who has IP w.x.y.z?”
  ● Peer who-has IP w.x.y.z responds with its MAC address

● **“Flux” occurs when multiple interfaces are on a single host**
  ● Both interfaces may respond to ARP request
    ● non-deterministic population of the ARP cache (a.k.a. neighbor table)
  ● Breaks IPoIB 😞
ARP Flux cont.

- Can workaround by issuing “lctl ping” from routers to servers
  - Routers populate server’s ARP cache
- Investigated using kernel IP tunables but found it insufficient
  - `net.ipv4.conf.all.arp_ignore = 1`
  - `net.ipv4.conf.all.arp_announce = 2`
- Currently recommend placing interfaces on separate subnets
  - More complexity
LNet Configuration

OSS0
ib0
10.149.0.1

OSS2
ib0
10.149.0.2

OSS4
ib0
10.149.0.3

OSS1
ib0
10.149.0.4

10.149.1.4 (ib0:1)

OSS3
ib0
10.149.0.5

10.149.1.5 (ib0:1)

OSS5
ib0
10.149.0.6

10.149.1.6 (ib0:1)

TOR 1

10.149.0.7

ib0
gni

10.149.1.7

ib2

TOR 2

10.149.0.8

ib0
gni

10.149.1.8

ib2

Routers

o2ib4002

o2ib4003
Serviceability - Dealing with Complexity

- Cray LNet Configuration and Validation Tool
- Simple and descriptive input file
- Knowledge of Cray Sonexion IB switch configuration
- Generates “ip2nets” and “routes” LNet module parameters
  - Typically stored in files: “ip2nets.dat” and “routes.dat”
- Validates configuration
  - Validate IB connectivity
  - Validate LNet group membership
  - Validate LNet destinations
Add/Remove IP alias to ib0 on module load

/sbin/ip -o -4 a show ib0 | \
/usr/bin/awk '/inet/ {s=$4;\n  sub("10\.149\.0\.", "10.149.1.", s);\n  print "/sbin/ip address add dev ib0 label ib0:1", s}' | \ 
/bin/sh
/sbin/modprobe --ignore-install lnet

/sbin/modprobe -r --ignore-remove lnet &&
/sbin/ip -o -4 a show label ib0:1 | \ 
awk '{print "/sbin/ip address del dev ib0 label ib0:1", $4}' | \ 
/bin/sh

Hat tip to Dave McMillen
LNet Design/Config Overview

- Use bandwidth matching to get router:server ratio
- Determine IP addressing scheme
- Use clcvt to generate ip2nets and routes configuration
- Configure interfaces
- Plug in cables
- Emplace LNet configuration
  - ip2nets, routes, other module parameters
Configuration Emplacement

● Sharedroot in CLE < 6.0
  ● Access sharedroot from bootnode: xtopview -c lnet
  ● Edit modprobe.conf.local:
    ● options lnet ip2nets = "/path/to/ip2nets.dat"
    ● options lnet routes = "/path/to/routes.dat"

● Config sets in CLE >= 6.0
  ● Run `cfgset` command on smw:
    ● `cfgset update --service cray_lnet --mode interactive CONFIGSET`
    ● See slides at end of deck for example
  ● Advanced users can manipulate worksheets
Recent LNet Work in the Lustre Community
Memory Registration in o2ibInd

- Historically supported PMR and FMR APIs
  - Physical Memory Region (PMR) dropped
  - Fast Memory Region (FMR) deprecated
- “Fast Registration API” is the new (Linux 2.6.27) hotness
- Mellanox hardware utilizing mlx5 drivers do not support FMR
- LU-5783: Adds support for Fast Registration API
  - Fallback for FMR
  - Landed for upcoming Lustre 2.9 release
Mixed Fabric Concerns

- How to optimize ko2iblnd in presence of multiple HCAs?
  - OPA & EDR; EDR & FDR; Aries & FDR(ib0) & EDR(ib2)
- LU-7101: per NI map_on_demand values
  - FMR enhances performance of OPA
  - FMR enabled by setting: $0 < \text{map\_on\_demand} \leq 256$
  - MLX5 does not support FMR, so needs map_on_demand = 0
  - Works in conjunction with LU-3322 to allow optimal settings
  - Landed for upcoming Lustre 2.9 release
- LU-3322: Allow different peer_credits and map_on_demand values
  - Available in just released Lustre 2.8
Summary

- Covered some LNet basics:
  - Flat vs. Fine Grained Routing
- Cost/Reliability/Serviceability:
  - Bandwidth Matching
  - ARP Flux
  - Cray LNet Configuration and Validation Tool - clcvt
- New configuration emplacement
  - Bye Bye Sharedroot! Hello config sets!
- Recent changes in Lustre for new IB technology
  - LU-5783, LU-3322, others
- Mixed fabric
  - Dealing with different HCAs that use ko2ibln4d
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Q&A

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What is Multi-Rail

- Use multiple independent networks, or “rails”, to overcome bandwidth limitations or increase fault tolerance
- Allow communication between two hosts across multiple interfaces
  - One or more networks
  - Interfaces used concurrently
- Cray utilizes multiple interfaces in non-multi-rail configuration
Multi-Rail LNet

- **Basic capability**
  - Multiplex across interfaces, as opposed to striping
  - Need multiple streams to see any benefit

- **Extend peer discover to simplify configuration**
  - Discover a peer’s interfaces and multi-rail capability

- **Enable run-time configuration changes**
  - add/remove interfaces, etc., via lnetctl

- **Compatibility with non-multi-rail nodes**

- **Increase resiliency by using alternate paths**

- **Targeted for Lustre 2.10**

- **http://wiki.lustre.org/Multi-Rail_LNet**
smw:~ # cfgset update --service cray_lnet --mode interactive hornc-p2

Service Configuration Menu (Config Set: hornc-p2, type: cle)

cray_lnet [ status: enabled ] [ validation: valid ]

<table>
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<th>#</th>
<th>Settings</th>
<th>Value/Status (level=basic)</th>
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<td>5)</td>
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<td>[ 6 sub-settings unconfigured, select and enter C to add entries ]</td>
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### Selected Settings

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#### Select Options

- **a:** all
- **n:** none
- **c:** configured
- **u:** unconfigured
- **#:** toggle #

#### Actions on Selected (1 settings)

- **C:** configure
- **@:** show guidance

#### Other Actions

- **?:** help
- **l:** switch level
- **E:** toggle enable
- **I:** toggle inherit
- **^:** go to service list
- **r:** refresh
- **$:** view changelog
- **Q:** save & exit
- **x:** exit without save

---

**Enter “6”**
**Enter “C”**
Cray LNet Settings: FGR Routes

**fgr_routes**
Enter all external LNets which will be reached via Fine-Grained Routing (FGR). The information entered for each of these flat LNets will be used to set up ip2nets on the routers and routes to reach the external LNets through the routers on the clients.

Configured Values:

(none)

Inputs: menu commands (? for help)

- Enter “+”
**fgr_routes**

Enter all external LNets which will be reached via Fine-Grained Routing (FGR). The information entered for each of these flat LNets will be used to set up ip2nets on the routers and routes to reach the external LNets through the routers on the clients.

**dest_name -- Destination name**

Enter the name of the destination. This is not functionally important. A good convention would be to use the name of the destination. For example, if the destination is the husk2 external file system, enter 'husk2'.

Default: (none) Current: not configured yet

Value: string, blank values not allowed

level=basic, state=unset

Inputs: <string> -- OR -- menu commands (? for help)

```
cray_lnet.settings.fgr_routes.data.dest_name
[cr]=set'',<new value>,?=help,@=less] $ snx8675309
```

• Enter “snx8675309”
fgr_routes (current key: snx8675309)
Enter all external LNets which will be reached via Fine-Grained Routing (FGR). The information entered for each of these flat LNets will be used to set up ip2nets on the routers and routes to reach the external LNets through the routers on the clients.

routers -- LNet router nodes
Enter a list of router cnames which will be used to route from the source LNet to the destination LNet. If the router nodes are managed externally (e.g. you are currently configuring LNet on servers) this can be left empty.

Default: (none)  Current: (none)

Value: list, blank values allowed, regex=^c\(d+\)-(d+)c\([0-2]\)s\([d[0-5]?n\([0-3]\)\$|^\([d{1,3})/(\.[d{1,3})\{3}\$

level=basic, state=unset

Inputs: menu commands (? for help)

Enter “+”

<cr>=set 0 entries, +=add an entry, ?=help, @=less] $ +
Add routers (Ctrl-d to exit) $ c0-0c0s2n1
Add routers (Ctrl-d to exit) $ c0-0c0s2n2
Add routers (Ctrl-d to exit) $ c0-0c0s3n1
Add routers (Ctrl-d to exit) $ c0-0c0s3n2
Add routers (Ctrl-d to exit) $ c0-0c1s2n1
Add routers (Ctrl-d to exit) $ c0-0c1s2n2
Add routers (Ctrl-d to exit) $
fgr_routes (current key: snx8675309)
   Enter all external LNets which will be reached via Fine-Grained Routing (FGR). The information entered for each of these flat LNets will be used to set up ip2nets on the routers and routes to reach the external LNets through the routers on the clients.

ip2nets_file -- FGR ip2nets file
   Enter the name of the ip2nets file for this FGR config. The file must be placed in the config_set at
   smw:/var/opt/cray/imps/config/sets/<config_set>/files/roles/lnet/.
   This file must be generated using an external tool, such as clcvt.

Default: (none)               Current: not configured yet
Value: string, blank values not allowed, regex=^[!-0-~]+$  
   level=basic, state=unset

Inputs: <string> -- OR -- menu commands (? for help)

 cray_lnet.settings.fgr_routes.data.snx8675309.ip2nets_file 
[<cr>=set '', <new value>, ?=help, @=less] $ ip2nets.dat
frg_routes (current key: snx8675309)
  Enter all external LNets which will be reached via Fine-Grained Routing (FGR). The information entered for each of these flat LNets will be used to set up ip2nets on the routers and routes to reach the external LNets through the routers on the clients.

routes_file -- FGR routes file
  Enter the name of the routes file for this FGR config. The file must be placed in the config_set at 
  smw:/var/opt/cray/imps/config/sets/<config_set>/files/roles/lnet/.
  This file must be generated using an external tool, such as clcvt.

  Default: (none) Current: not configured yet

  Value: string, blank values not allowed, regex=^[!-.0-~]+$
  level=basic, state=unset

Inputs: <string> -- OR -- menu commands (? for help)

cray_lnet.settings.fgr_routes.data.snx8675309.routes_file
[<cr>=set '', <new value>, ?=help, @=less] $ routes.dat
fgr_routes (current key: snx8675309)
   Enter all external LNets which will be reached via Fine-Grained Routing (FGR). The information entered for each of these flat LNets will be used to set up ip2nets on the routers and routes to reach the external LNets through the routers on the clients.

ko2iblnd_peer_credits -- ko2iblnd peer_credits
   The number of concurrent sends allowed to a single peer. Cray recommends setting this to 126. peer_credits must be consistent across all peers on the IB network. This means it must be the same on the routers and the Lustre servers. If there is a mismatch, the file system will be unmountable. This value is specific to the routers specified in this FGR config, and it will override the general ko2iblnd peer_credits setting specified earlier.

   Default: 126        Current: not configured yet

   Value: integer, blank values allowed, regex=^[1-9]d*$
   level=basic, state=unset

   Inputs: <integer> -- OR -- menu commands (? for help)
fgr_routes (current key: snx8675309)
Enter all external LNets which will be reached via Fine-Grained Routing (FGR). The information entered for each of these flat LNets will be used to set up ip2nets on the routers and routes to reach the external LNets through the routers on the clients.

ko2iblnd_concurrent_sends -- ko2iblnd concurrent_sends
Determines send work-queue sizing. If this option is omitted, the default is calculated based on peer_credits and map_on_demand. Cray recommends setting this to 63. concurrent_sends must be consistent across all peers on the IB network. This means it must be the same on the routers and the Lustre servers. If there is a mismatch, the file system will be unmountable. This value is specific to the routers specified in this FGR config, and it will override the general ko2iblnd concurrent_sends setting specified earlier.

Default:          Current:  
63                not configured yet  

Value: integer, blank values allowed, regex=^[1-9]\d*$  
level=basic, state=unset  

Inputs: <integer> -- OR -- menu commands (? for help)  

```
cray_lnet.settings.fgr_routes.data.snx8675309.ko2iblnd_concurrent_sends  
[<cr>=set '63', <new value>, ?=help, @=less] $
```
fgr_routes
Enter all external L Nets which will be reached via Fine-Grained Routing (FGR). The information entered for each of these flat L Nets will be used to set up ip2nets on the routers and routes to reach the external L Nets through the routers on the clients.

Configured Values:

1) 'snx8675309'
   a) routers:
      c0-c0s2n1
      c0-c0s2n2
      c0-c0s3n1
      c0-c0s3n2
      c0-c1s2n1
      c0-c1s2n2
   b) ip2nets_file: ip2nets.dat
   c) routes_file: routes.dat
   d) ko2ibnlnd_peer_credits: 63
   e) ko2ibnlnd_concurrent_sends: 63

Inputs: menu commands (? for help)