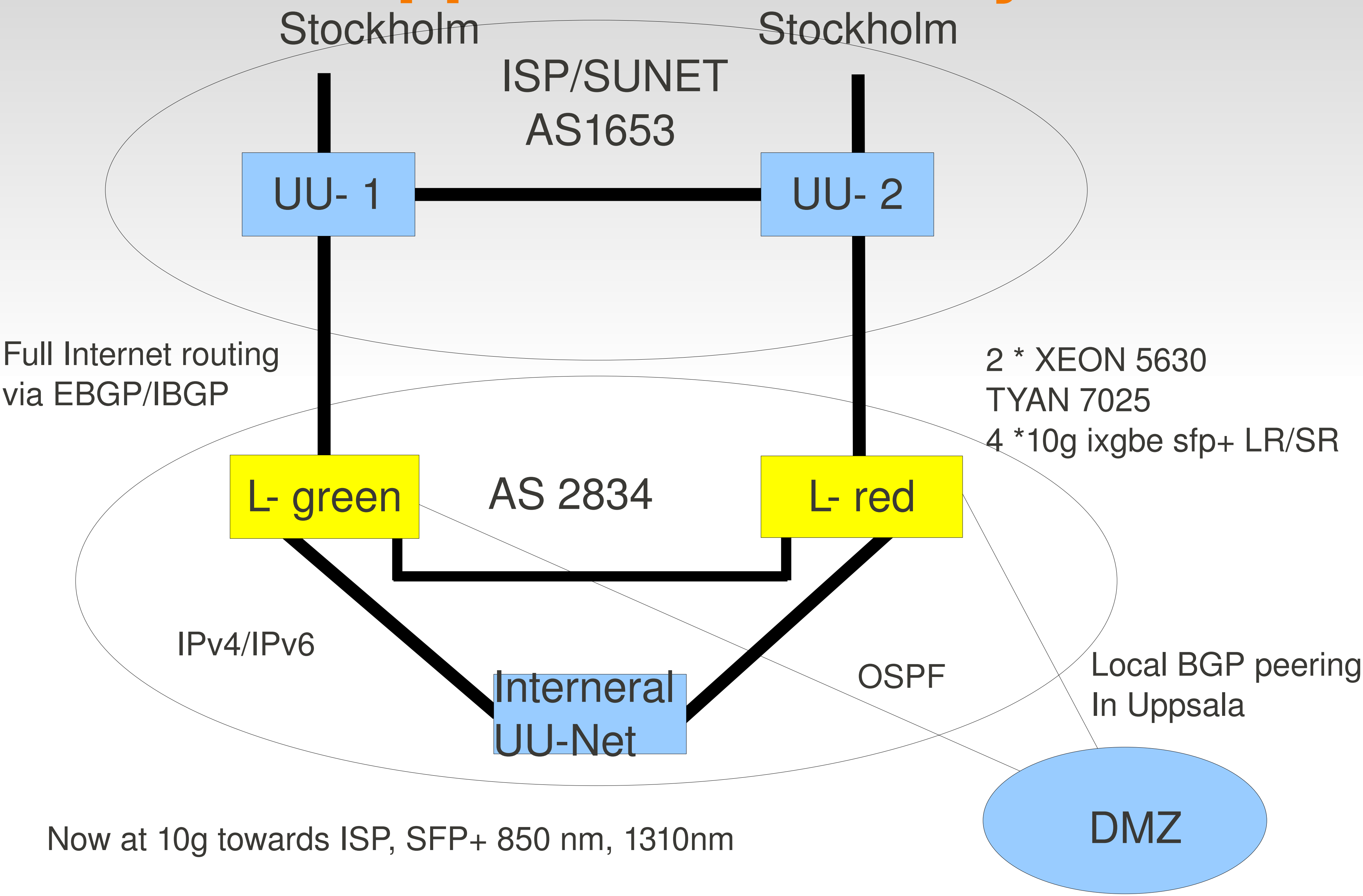
Control and forwarding plane separation on an open-source router

Linux Kongress
2010-09-23 in Nürnberg

Robert Olsson, Uppsala University
Olof Hagsand, KTH

More than 10 year in production at Uppsala University

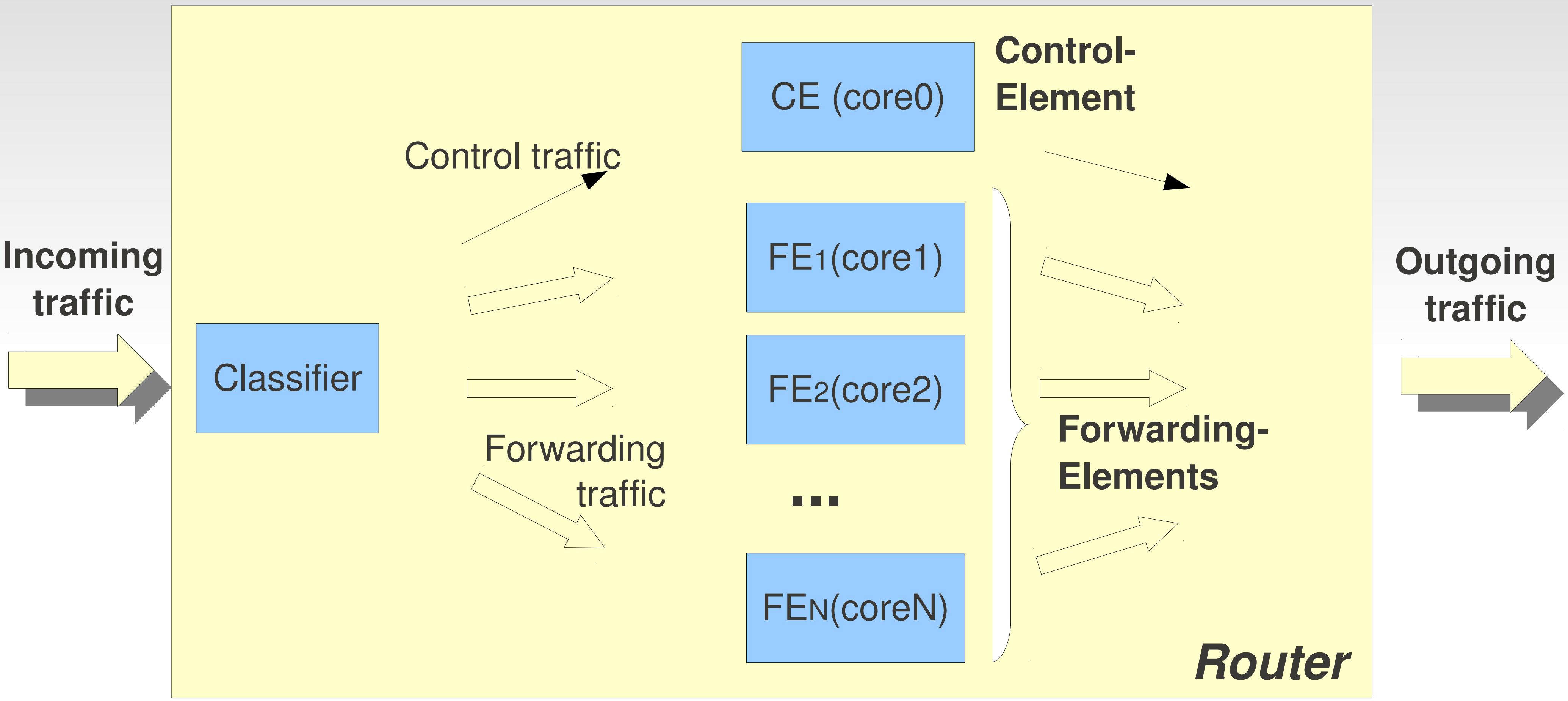


Now at 10g towards ISP, SFP+ 850 nm, 1310nm

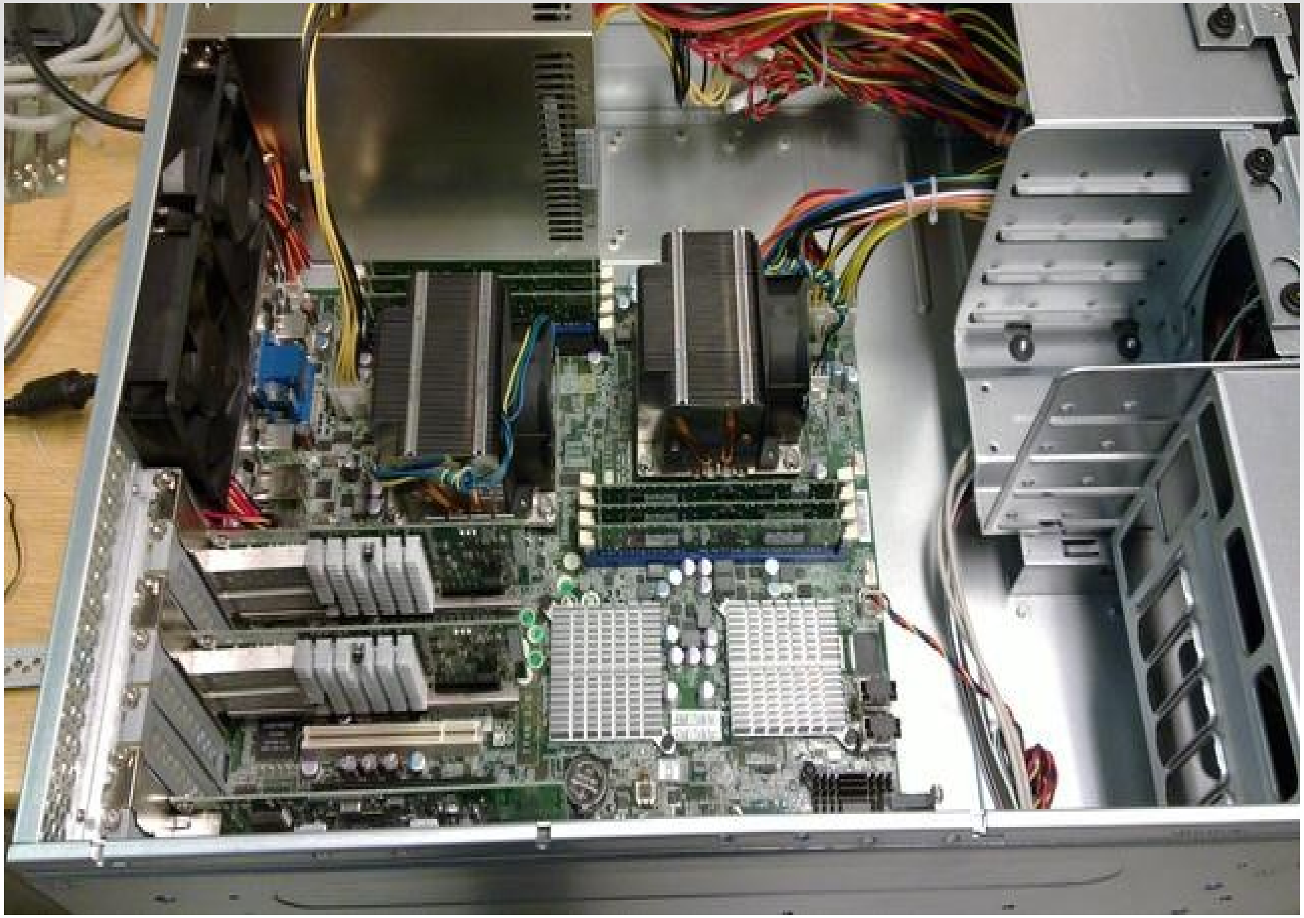
Motivation

- Separate control-plane from forwarding plane
  A la IETF FORCES
- Control-plane: sshd, bgp, stats, etc on CPU core 0
- Forwarding-plane: Bulk forwarding on core1,..,coreN
- This leads to robustness of service against overload and DOS attacks, etc
- Enabled by:
  - multi-core CPUs
  - NIC hw classifiers
  - Fast Buses (QPI/PCI-E gen2)

Control-plane separation on a multi-core

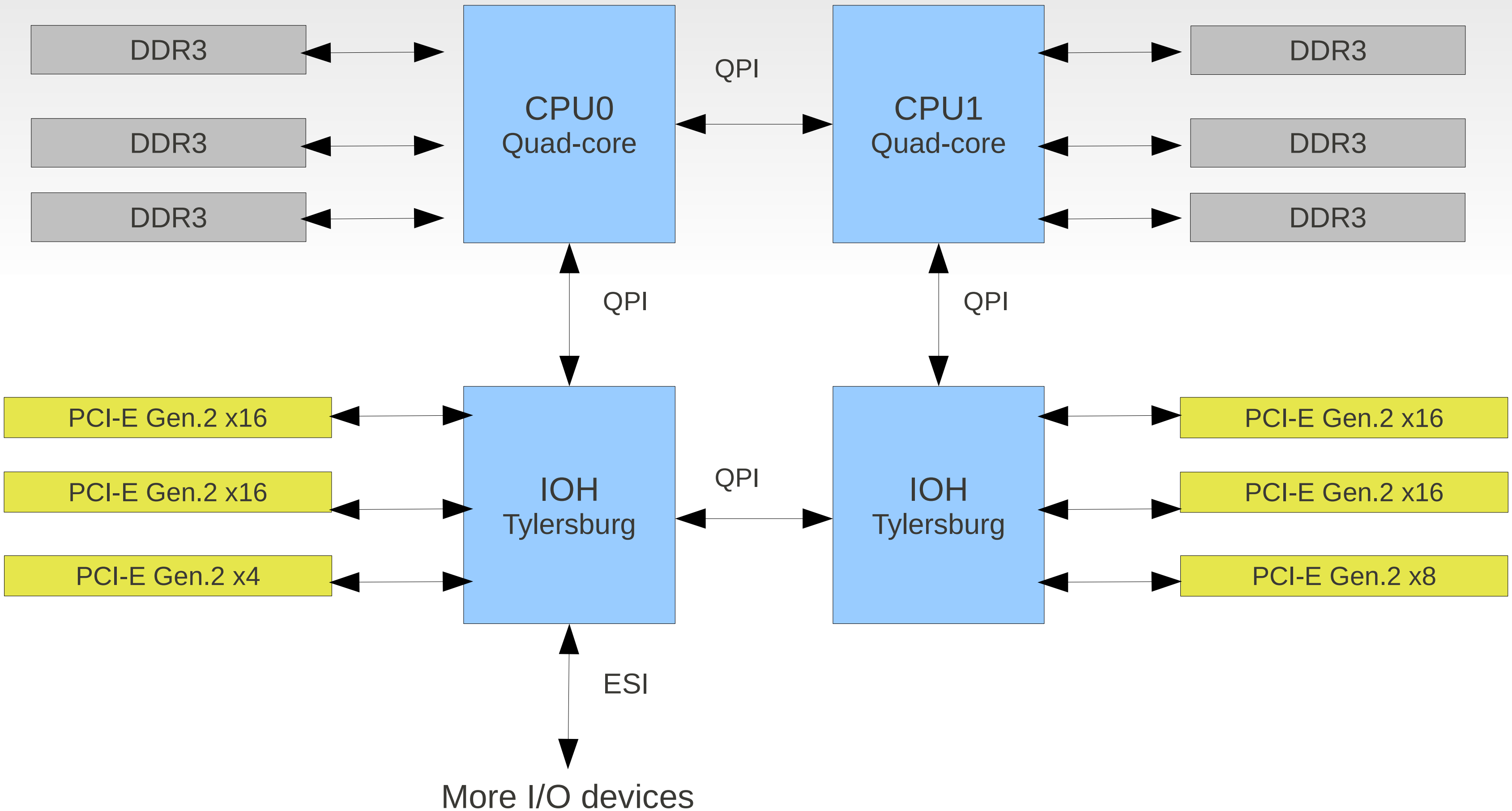


Hi-End Hardware

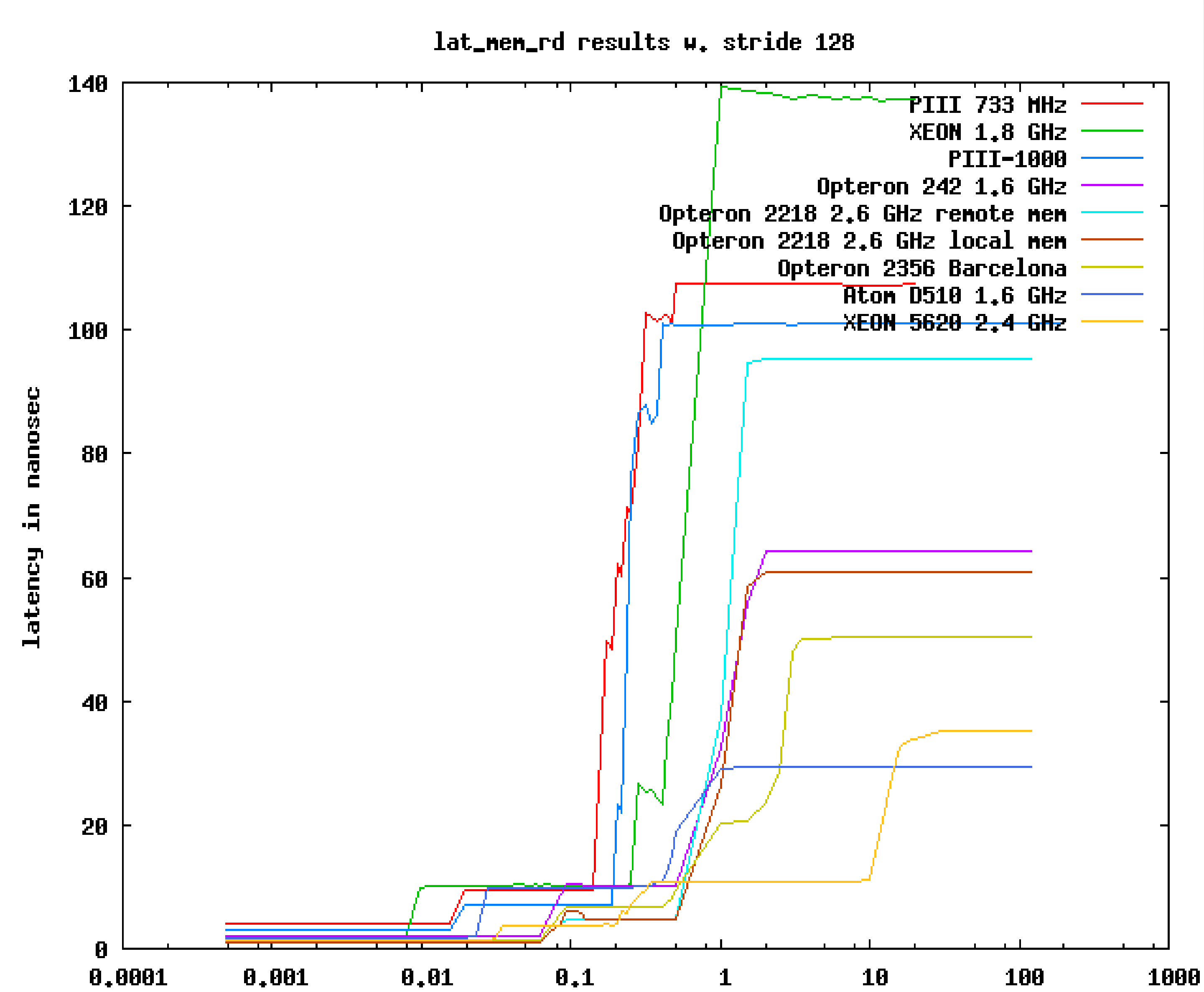


XEON 2 x E5630
TYAN S7025 Motherboard
Intel 82599

Block hardware structure



Hi-End Hardware/Latency



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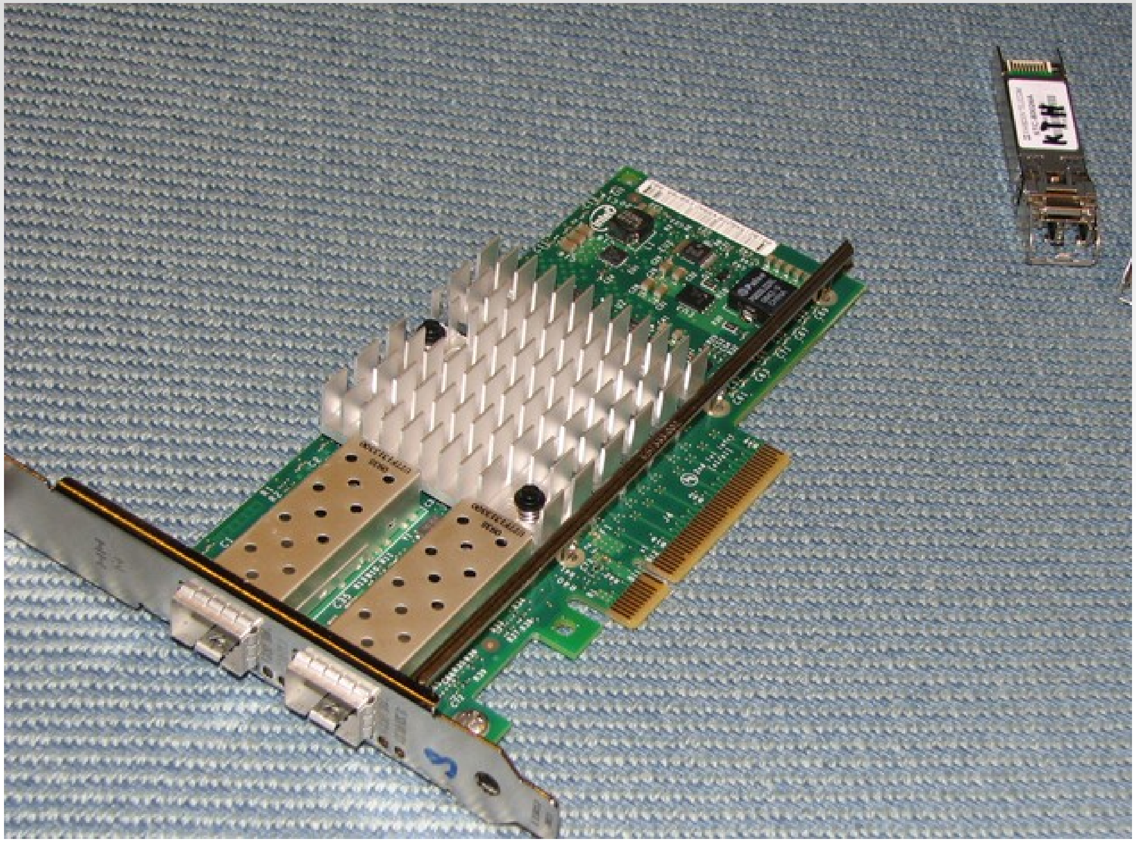


Intel 10g board Chipset 82599 with SFP+

Open chip specs. Thanks Intel!

Classification in the Intel 82599

The classification in the Intel 82599 consists of several steps, each is programmable.
This includes:
- ***RSS*** (Receiver-side scaling): hashing of headers and load-balancing
- ***N-tuples***: explicit packet header matches
- ***Flow-director***: implicit matching of individual flows.

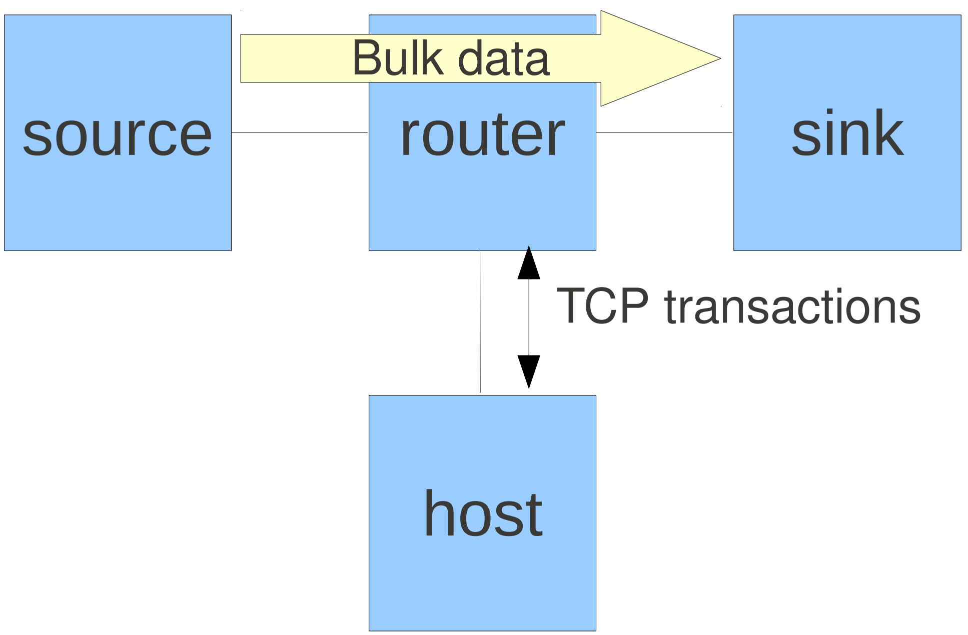
Routing daemons

Packet forwarding is done in Linux kernel
Routing protocols is run in user-space daemons

Currently tested versions of quagga
Bgp, OSPF both IPv4, iPv6
Cisco API

Experiment 1:
flow separation external source

- Bulk forwarding data from source to sink (10Gb/s mixed packet lengths): mixed flow and packet lengths
- Netperf's TCP transactions emulated control data from a separate host
- Study latency of TCP transactions



N-tuple or Flowdirector

```
ethtool -K eth0 ntuple on

ethtool -U eth0 flow-type tcp4 src-ip 0x0a0a0a01 src-ip-mask
          0xFFFFFFFF dst-ip 0 dst-ip-mask 0 src-port 0 src-port-mask 0
          dst-port 0 dst-port-mask 0 vlan 0 vlan-mask 0   user-def 0
          user-def-mask 0 action 0

ethtool -u eth0
```

N-tuple is supported by SUN Niu and Intel ixgbe driver.

Actions are: 1) queue 2) drop

But we were lazy and patched ixgbe for ssh and BGP to use CPU0

N-tuple or Flowdirector

Even more lazy... we found the flow-director was implicitly programmed by outgoing flows. So both incoming and outgoing would use the same queue.

So if we set affinity for BGP, sshd etc we could avoid the N-tuple filters

Example:
taskset -c 0 /usr/bin/sshd

Neat....

RSS is still using CPU0

So we both got our “selected traffic”
Plus the bulk traffic from RSS

We just want RSS to use “other” CPU's

Patching RSS

Just a one-liner...

```
diff --git a/drivers/net/ixgbe/ixgbe_main.c b/drivers/net/ixgbe/ixgbe_main.c
index 1b1419c..08bbd85 100644
--- a/drivers/net/ixgbe/ixgbe_main.c
+++ b/drivers/net/ixgbe/ixgbe_main.c
@@ -2379,10 +2379,10 @@ static void ixgbe_configure_rx(struct ixgbe_adapter *adapter)
        mrqc = ixgbe_setup_mrqc(adapter);

        if (adapter->flags & IXGBE_FLAG_RSS_ENABLED) {
-               /* Fill out redirection table */
-               for (i = 0, j = 0; i < 128; i++, j++) {
+               /* Fill out redirection table but skip index 0 */
+               for (i = 0, j = 1; i < 128; i++, j++) {
                        if (j == adapter->ring_feature[RING_F_RSS].indices)
-                               j = 0;
+                               j = 1;
                        /* reta = 4-byte sliding window of
                         * 0x00..(indices-1)(indices-1)00..etc. */
                        reta = (reta << 8) | (j * 0x11);
```

Patching RSS

CPU-core	0	1	2	3	4	5	6	7
Number of packets	0	196830	200860	186922	191866	186876	190106	190412

No traffic to CPU core 0 still RSS gives fairness between other cores

Transaction Performance netperf TCP_RR

On "router"

taskset -c 0 netserver

Don't let forwarded packets program the flowdirector

A new one-liner patch....

```
@@ -5555,6 +5555,11 @@ static void ixgbe_atr(struct ixgbe_adapter *adapter, struct
sk_buff *skb,
        u32 src_ipv4_addr, dst_ipv4_addr;
        u8 l4type = 0;

+       if(!skb->sk) {
+         /* ignore nonlocal traffic */
+         return;
+       }
+
        /* check if we're UDP or TCP */
        if (iph->protocol == IPPROTO_TCP) {
                th = tcp_hdr(skb);
```

Instrumenting the flow-director

```
ethtool -S eth0 | grep fdir
```

Flow-director stats/1

```
fdir_maxlen: 0
fdir_maxhash: 0
fdir_free: 8191
fdir_coll: 0
fdir_match: 195
fdir_miss: 573632813   <--- Bulk forwarded data from RSS
fdir_ustat_add: 1      <--- Old ssh session
fdir_ustat_remove: 0
fdir_fstat_add: 6
fdir_fstat_remove: 0
fdir_maxlen: 0
```

ustat → user stats
fstat → failed stats

Flow-director stats/2

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fdir_maxhash: 0
fdir_free: 8190
fdir_coll: 0
fdir_match: 196
fdir_miss: 630653401
fdir_ustat_add: 2    <--- New ssh session
fdir_ustat_remove: 0
fdir_fstat_add: 6
fdir_fstat_remove: 0
```

Flow-director stats/3

```
fdir_maxlen: 0
fdir_maxhash: 0
fdir_free: 8190
fdir_coll: 0
fdir_match: 206      <--- ssh packets are matched
fdir_miss: 645067311
fdir_ustat_add: 2
fdir_ustat_remove: 0
fdir_fstat_add: 6
fdir_fstat_remove: 0
```

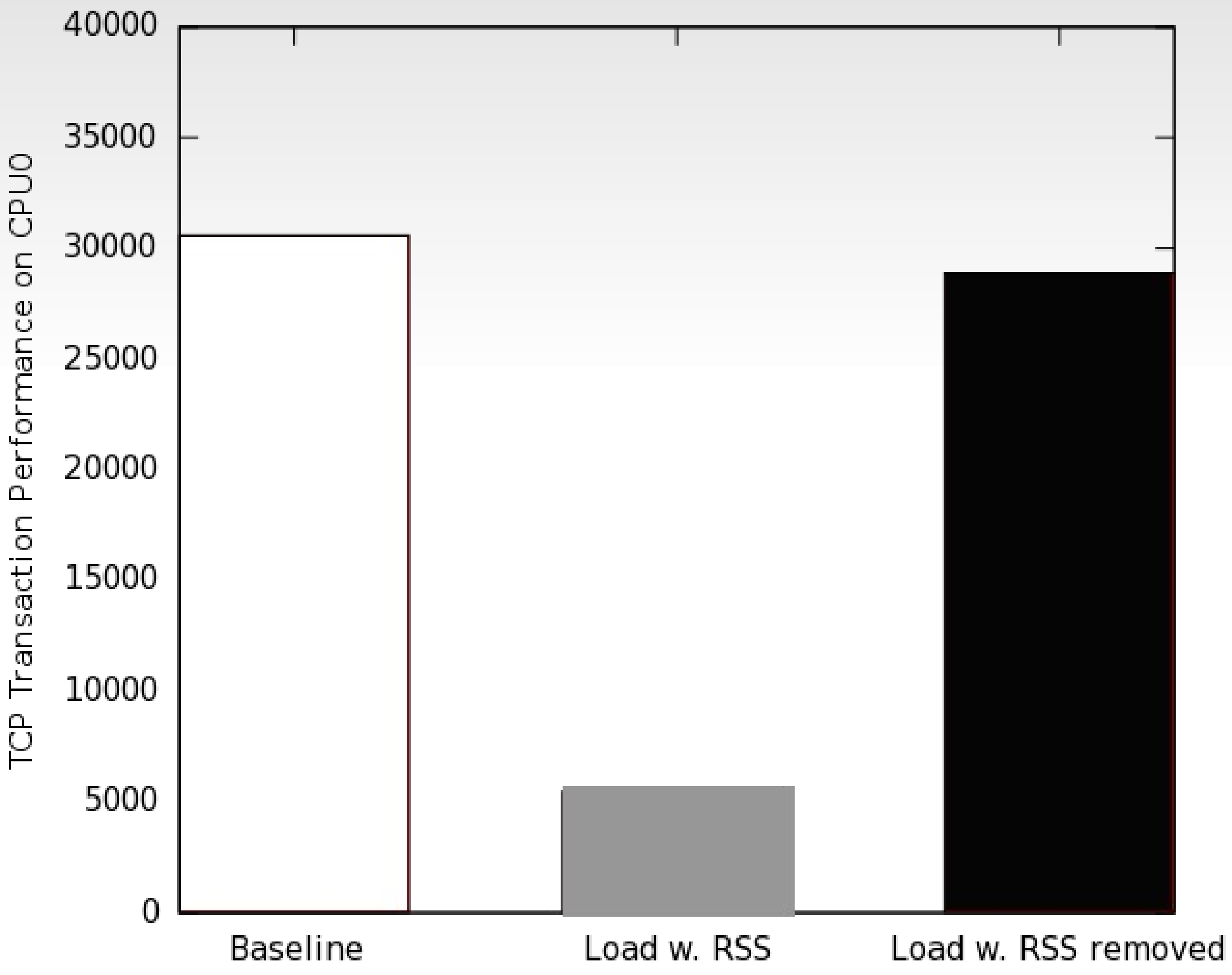
Flow-director stats/4

```
fdir_maxlen: 0
fdir_maxhash: 0
fdir_free: 32768   <-- Now incresed 32k
fdir_coll: 0
fdir_match: 0
fdir_miss: 196502463
fdir_ustat_add: 0
fdir_ustat_remove: 0
fdir_fstat_add: 0
fdir_fstat_remove: 0
```

Flow-director stats/5

```
fdir_maxlen: 0
fdir_maxhash: 0
fdir_free: 32764
fdir_coll: 0
fdir_match: 948      <-- netperf TCP_RR
fdir_miss: 529004675
fdir_ustat_add: 4
fdir_ustat_remove: 0
fdir_fstat_add: 44
fdir_fstat_remove: 0
```

Transaction latency using flow separation

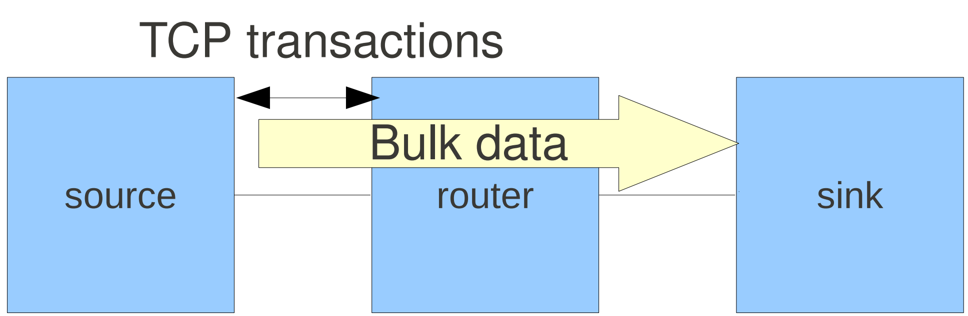


Experiment 1 results

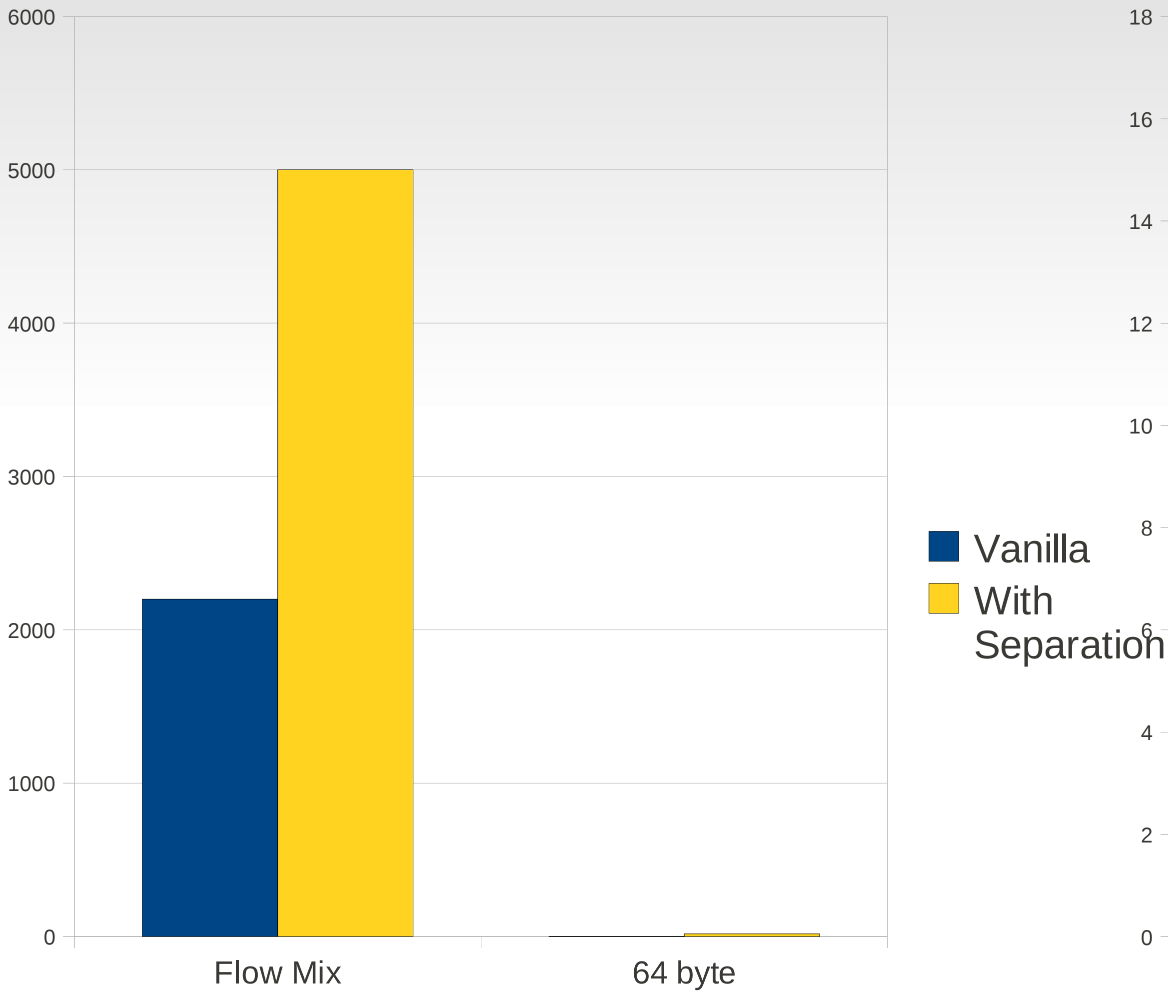
- Baseline (no background traffic) gives 30000 transactions per second
- With background traffic using RSS over all cores gives increase in transaction latency reducing transactions per second to ~5000
- The RSS patch (dont forward traffic on core 0) brings the transaction latency back to (almost) the same case as the baseline
- In all cases the control traffic is bound to core 0

Experiment 2:
Flow separation in-line traffic

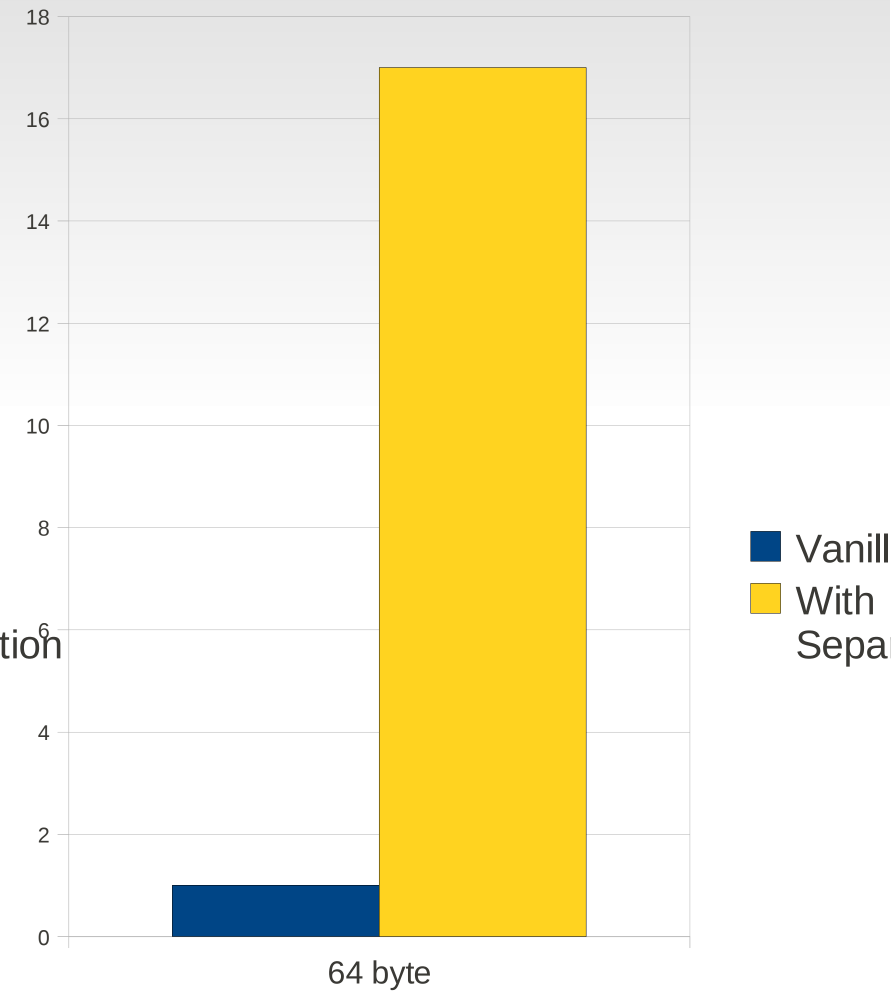
- Inline control within bulk data (on same incoming interface)
- Study latency of TCP transactions
- Work in progress



Results in-line



Transaction latency wo/w RSS path
Flow mix and 64 byte packets



Zoom in of 64 byte packets

Classifier small packet problem

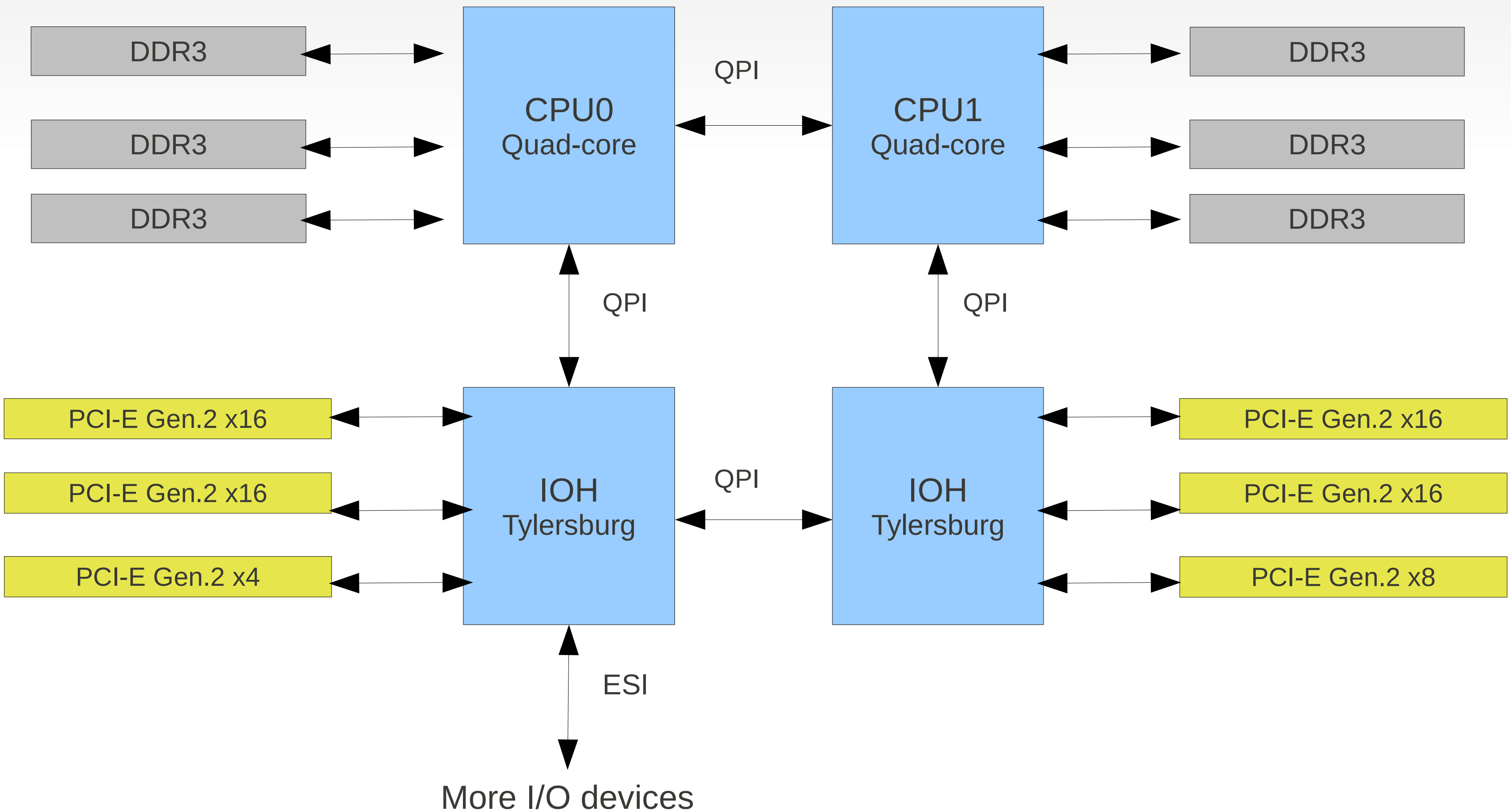
Seems we drop a lot packets before they are classified

DCB (Data Center Bridging) has a lot of features to prioritize different type of traffic. But only for IEEE 802.1Q

VMDq2 suggested by Peter Waskiewicz Jr at Intel

Experiment 3:
Transmit limits

Investigate hardware limits by transmitting as much as possible from all cores simultaneously.

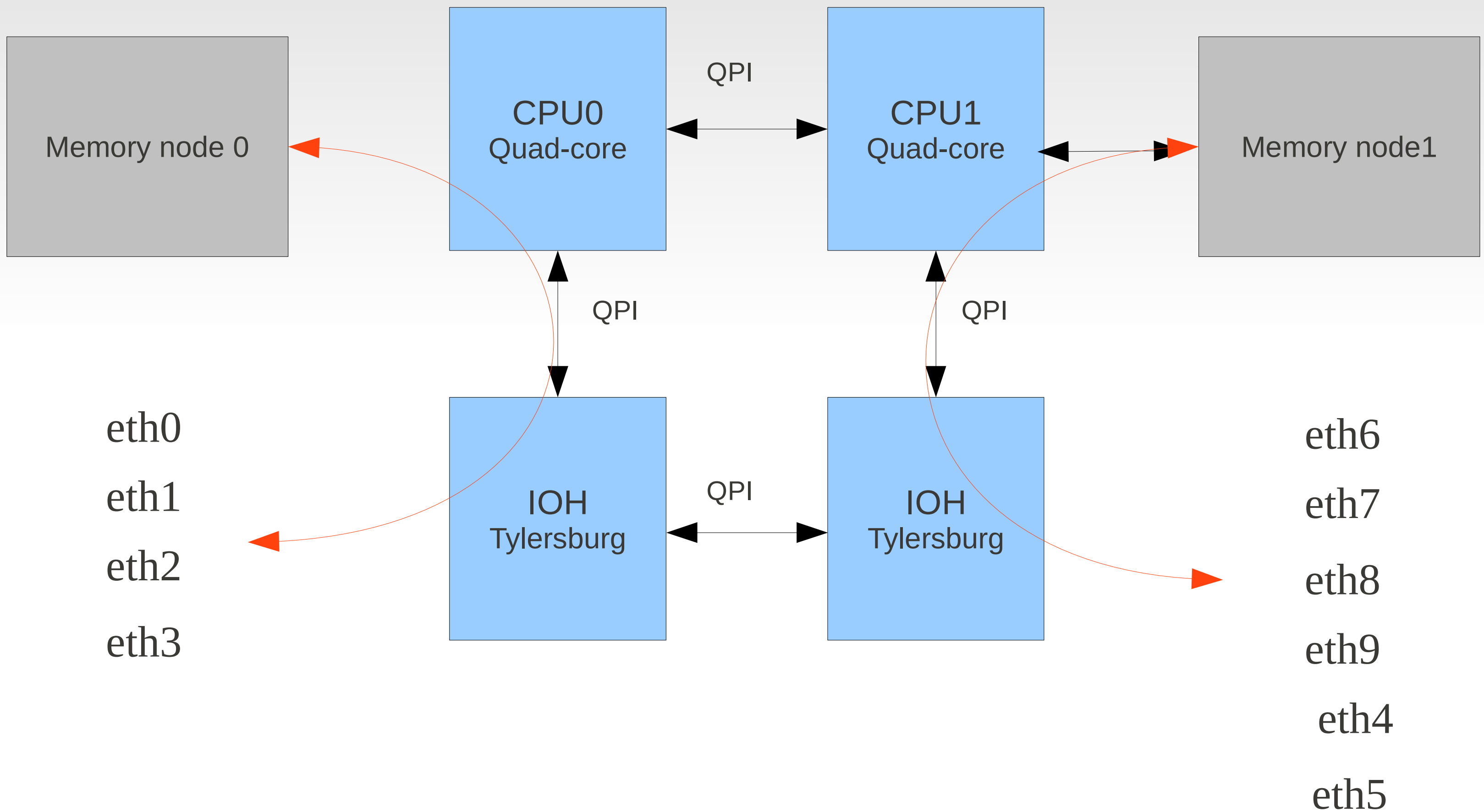


pktgen/setup

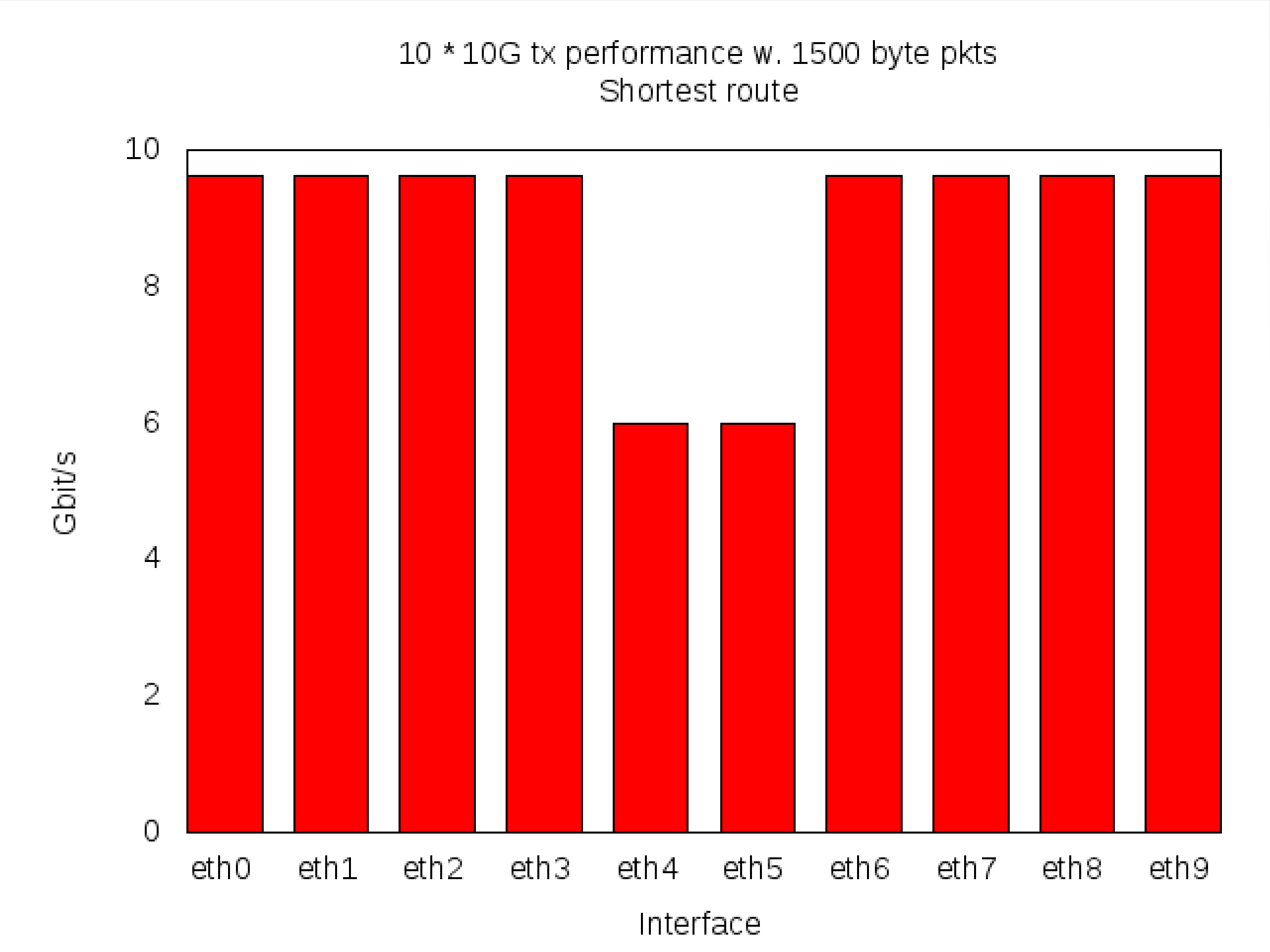
Inter-face	eth0	eth1	eth2	eth3	eth4	eth5	eth6	eth7	eth8	eth9
CPU-core	0	1	2	3	4	5	6	7	12	13
Mem node	0	0	0	0	1	1	1	1	1	1

eth4, eth5 on x4 slot

Setup


Memory node 0
CPU0
Quad-core
QPI
CPU1
Quad-core
Memory node1
QPI
QPI
eth0
eth1
eth2
eth3
IOH
Tylersburg
QPI
IOH
Tylersburg
eth6
eth7
eth8
eth9
eth4
eth5

TX w. 10 * 10g ports 93Gb/s “Optimal”



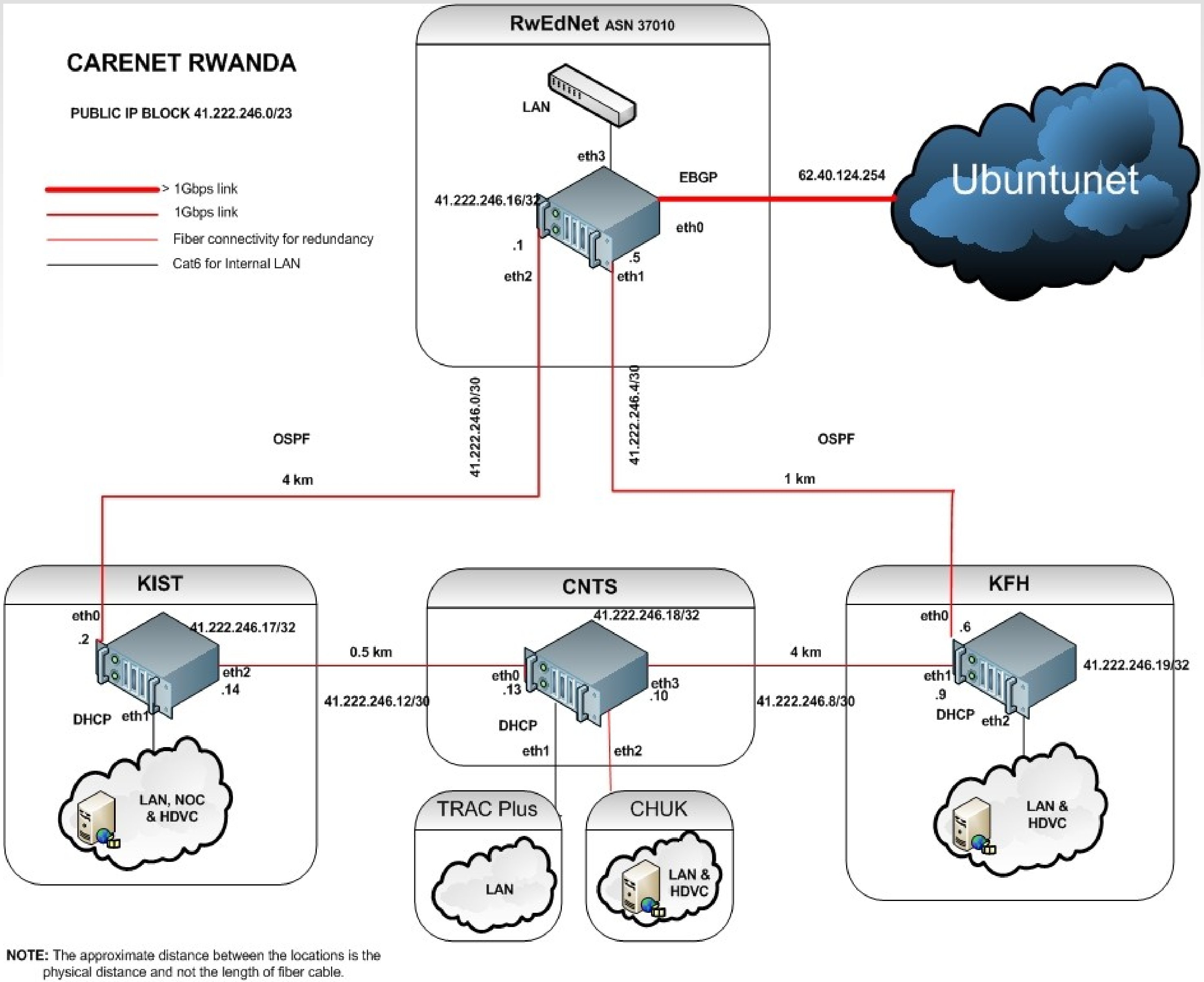
Conclusions

- We have shown traffic separation in a high-end multi-core PC with classifier NICs by assigning one CPU core as control and the other as forwarding cores. Our method:
  - Interrupt affinity to bind control traffic to core 0
  - Modified RSS to spread forwarding traffic over all except core 0
  - Modified the flow-director implementation slightly by only letting local (control) traffic populate the flowdir table.
- There are remaining issues with packet drops in in-line separation
- We have shown 93Gb/s simplex transmission bandwidth on a fully equipped PC platform

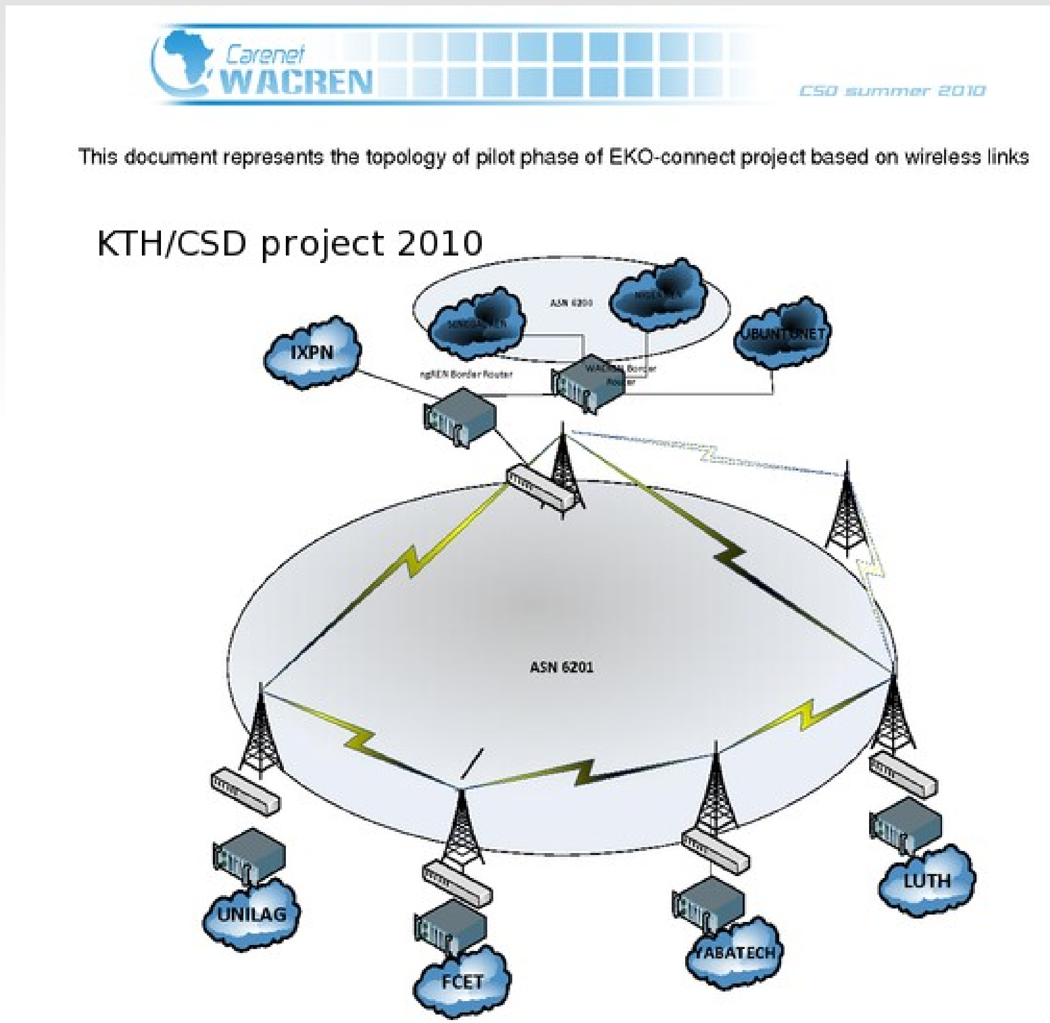
That's all

Questions?

Rwanda example



Lagos next


Carenet
WACREN
CSD summer 2010
This document represents the topology of pilot phase of EKO-connect project based on wireless links
KTH/CSD project 2010
ASN 6200
IXPN
UBUNTUNET
ngREN Border Router
ASN 6201
UNILAG
FCET
YABATECH
LUTH

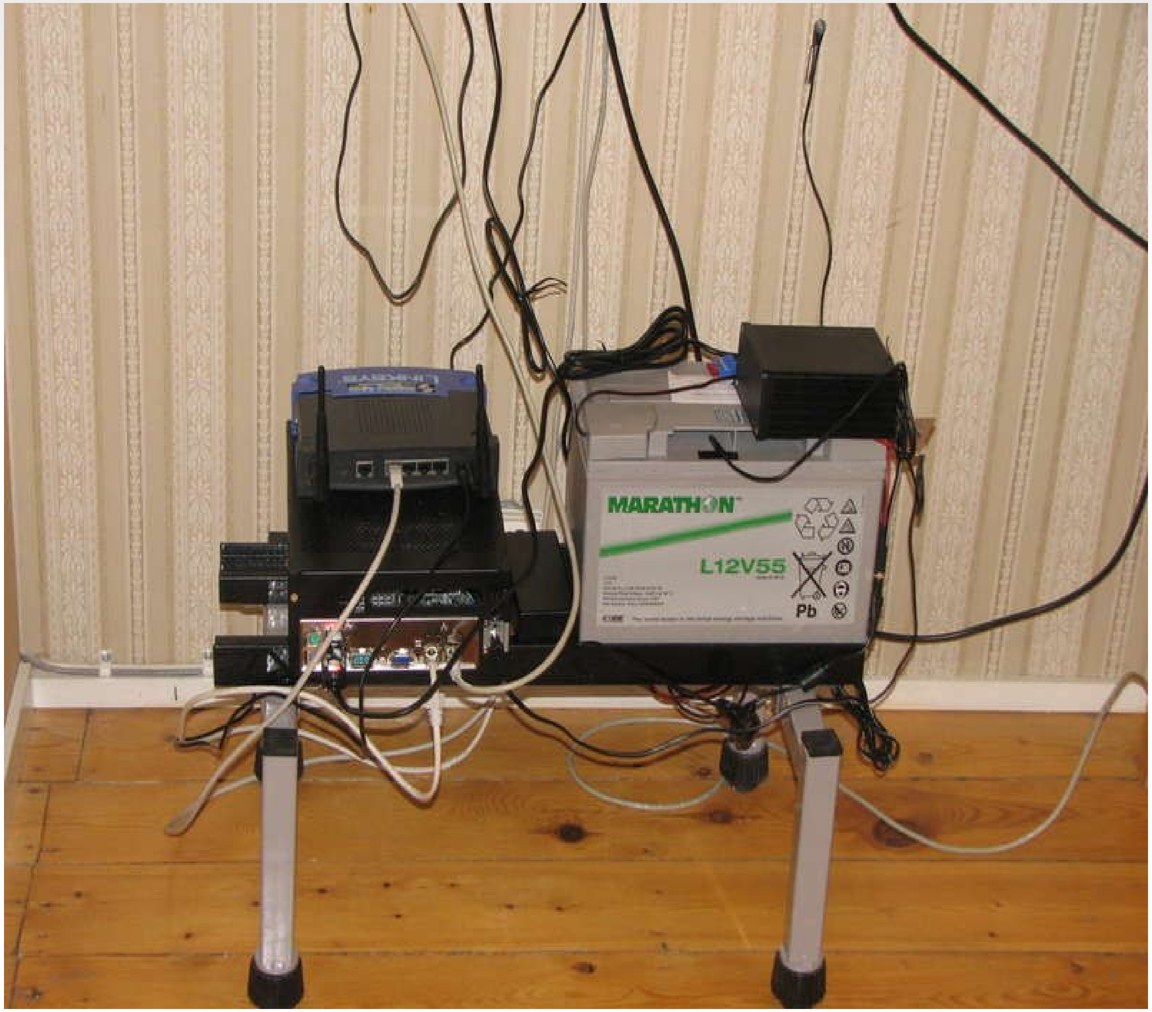
Low-Power Development
Some ideas

```
               Power consumption
SuperMicro X7SPA @ 16.5 Volt with picoPSU

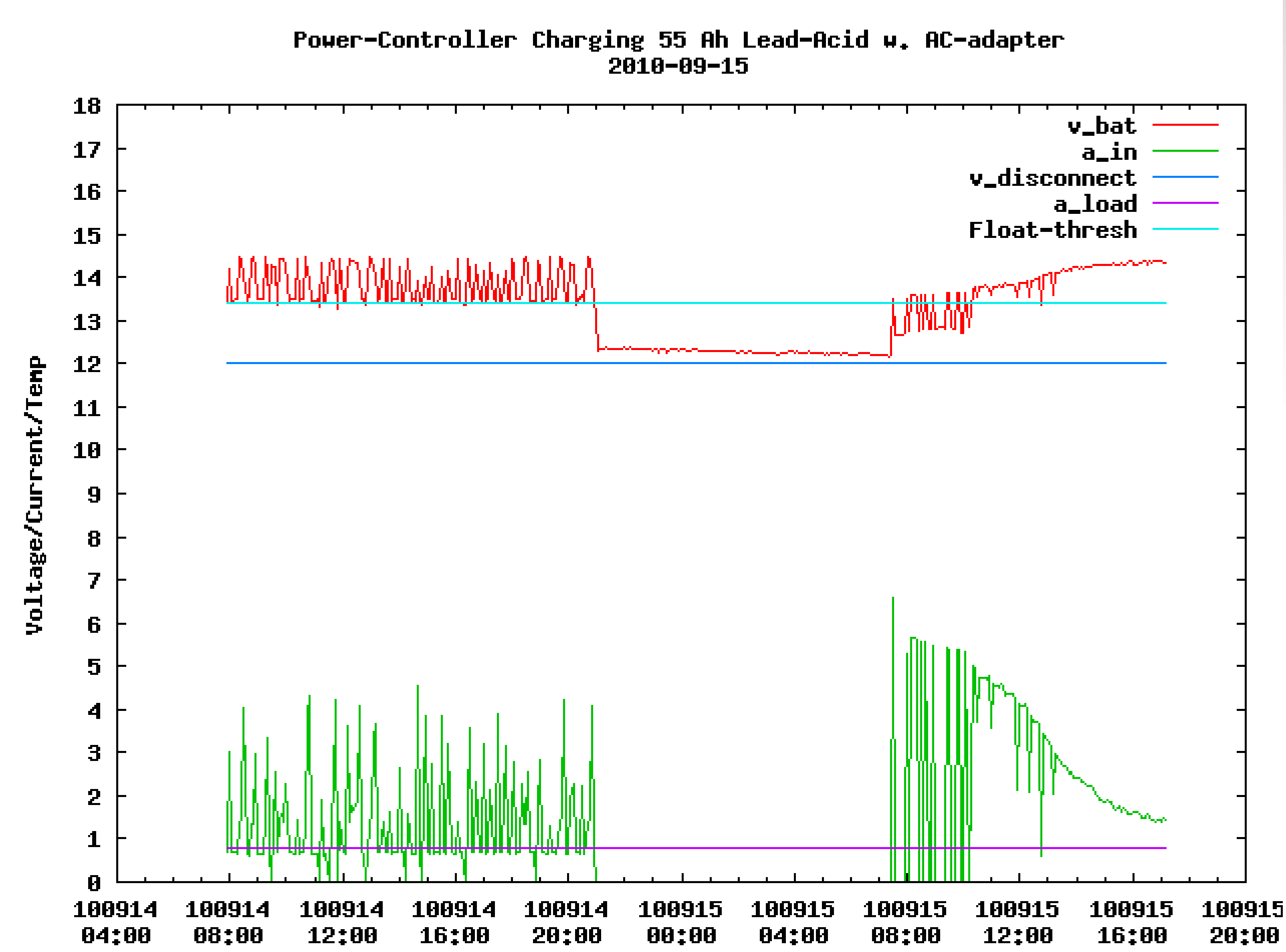
Watt        Test
-------------------
1.98       Power-Off
13.53       Idle
14.35       1 core
15.51       2 Core
15.84       3 Core
16.50       4 Core

Routing Performance about 500.000 packet/sec
in optimal setup.
```

Example herjulf.se
14 Watt by 55Ah battery
bifrost/USB + lowpower disk



Running on battery



SuperCapacitors

DOM - Optical Monitoring

Optical modules can support optical link monitoring
RX, TX power, temperatuers, alarms etc

Newly added support to Bifrost/Linux

DOM

ethtool -D eth3

Int-Calbr: Avr RX-Power: RATE_SELECT: Wavelength: 1310 nm

- Temp: 25.5 C
- Vcc: 3.28 V
- Tx-Bias: 20.5 mA
- TX-pwr: -3.4 dBm (0.46 mW)
- RX-pwr: -15.9 dBm (0.03 mW)

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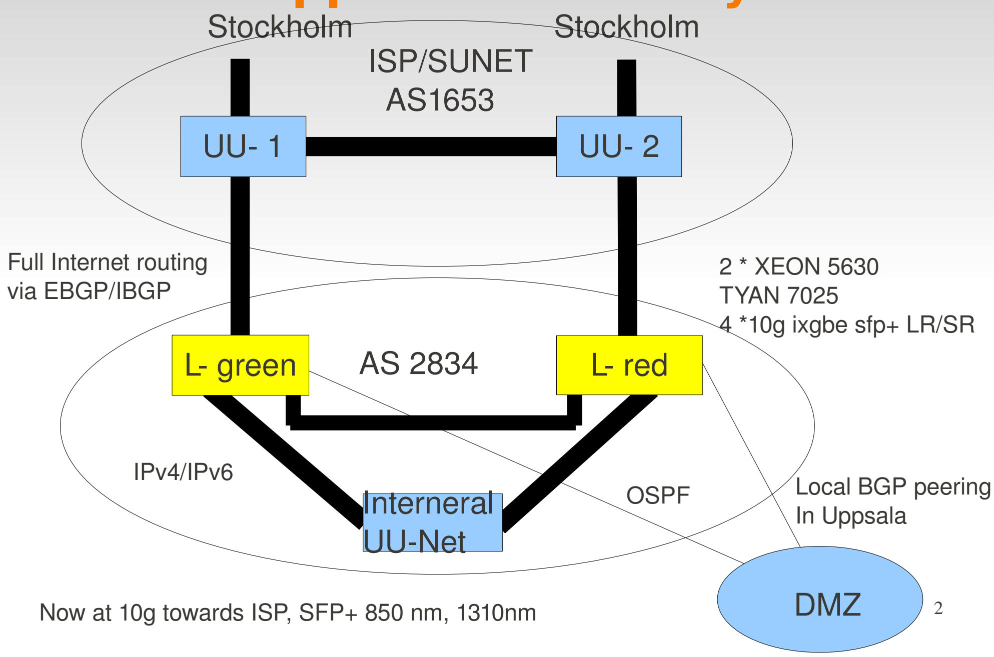

Now at 10g towards ISP, SFP+ 850 nm, 1310nm

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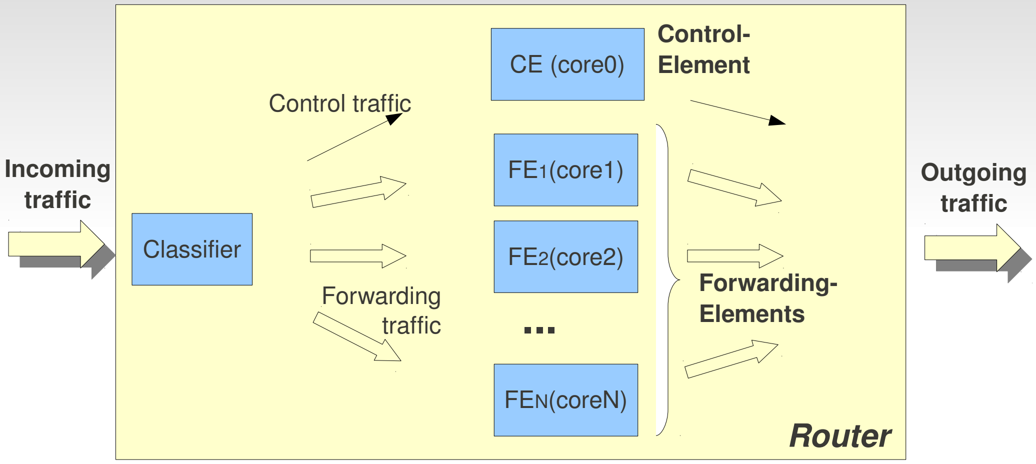

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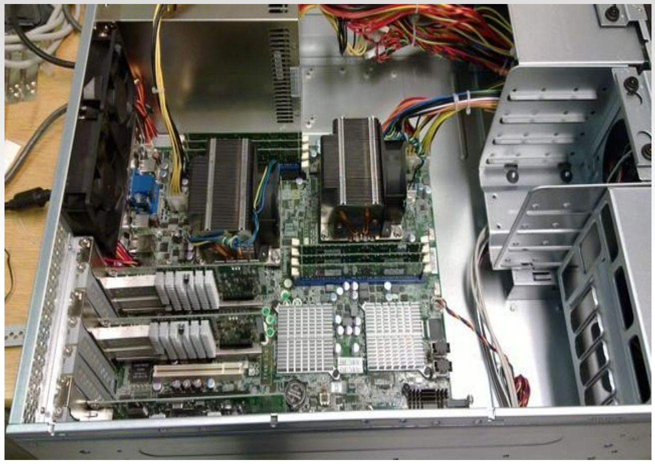

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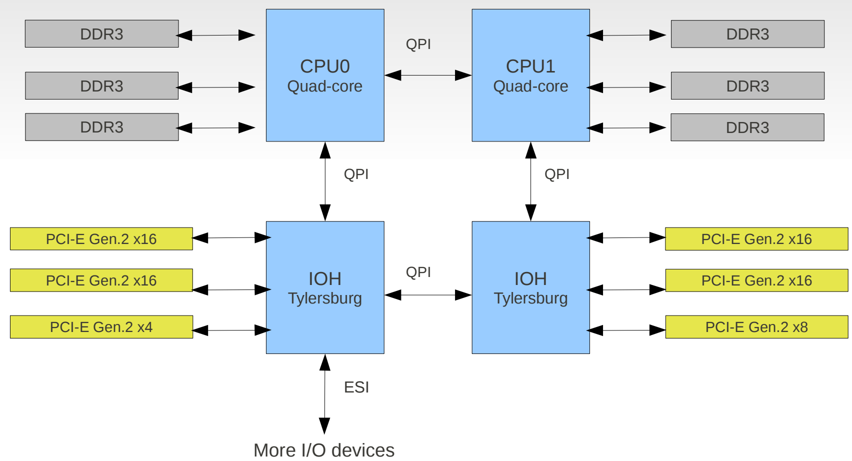

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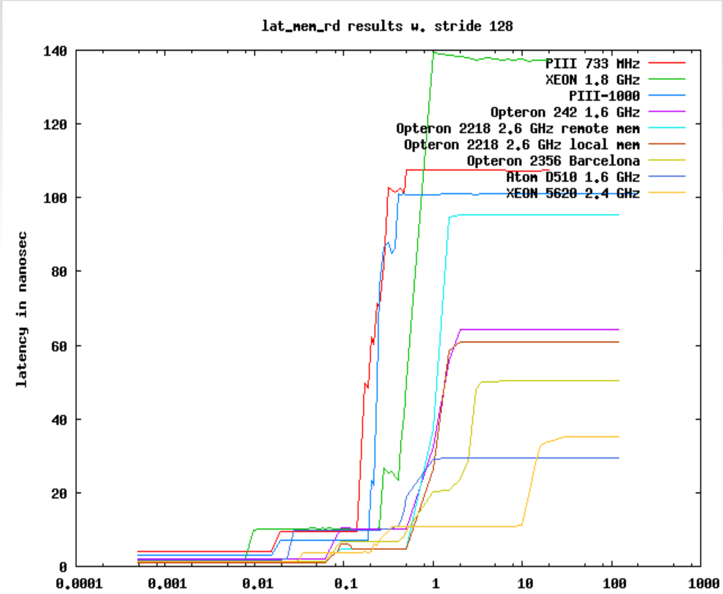
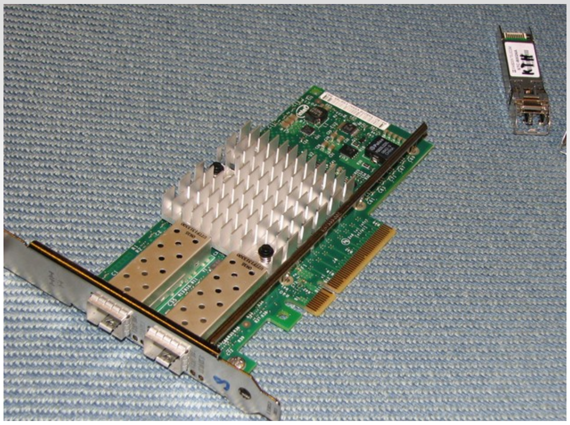


Hardware - NIC



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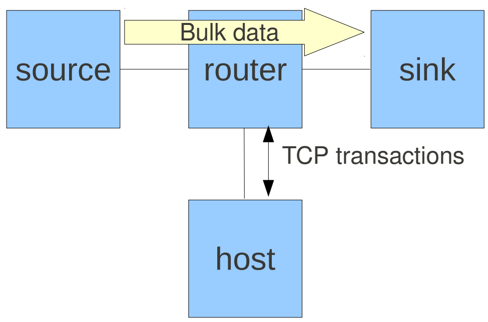

N-tuple or Flowdirector

ethtool -K eth0 ntuple on

ethtool -U eth0 flow-type tcp4 src-ip 0x0a0a0a01 src-ip-mask 0xFFFFFFFF dst-ip 0 dst-ip-mask 0 src-port 0 src-port-mask 0 dst-port 0 dst-port-mask 0 vlan 0 vlan-mask 0 user-def 0 user-def-mask 0 action 0

ethtool -u eth0

N-tuple is supported by SUN Niu and Intel ixgbe driver.

Actions are: 1) queue 2) drop

But we were lazy and patched ixgbe for ssh and BGP to use CPU0

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                        if (j == adapter->ring_feature[RING_F_RSS].indices)
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```

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No traffic to CPU core 0 still RSS gives fairness between other cores

Transaction Performance netperf TCP_RR

On “router”
taskset -c 0 netserver

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```

Instrumenting the flow-director

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Flow-director stats/1

```
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fdir_ustat_add: 1      <--- Old ssh session
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```

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```
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Flow-director stats/3

```
fdir_maxlen: 0
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fdir_fstat_remove: 0
```

Flow-director stats/4

```
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fdir_maxhash: 0
fdir_free: 32768   <-- Now incresed 32k
fdir_coll: 0
fdir_match: 0
fdir_miss: 196502463
fdir_ustat_add: 0
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```
fdir_maxlen: 0
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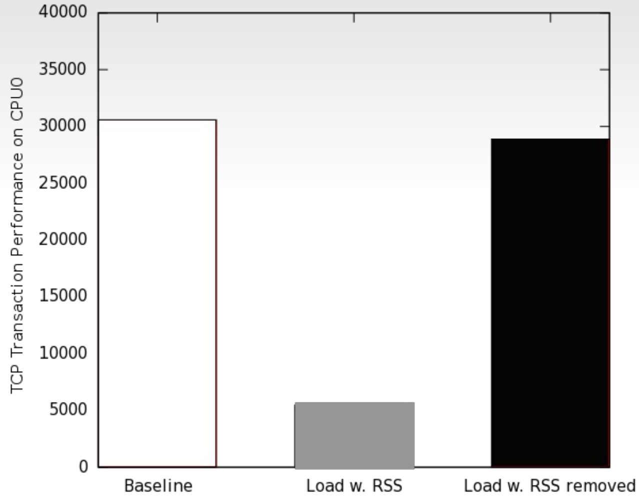
```

Transaction latency using flow separation



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Flow separation in-line traffic

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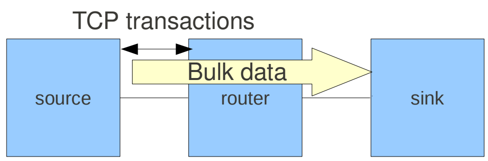
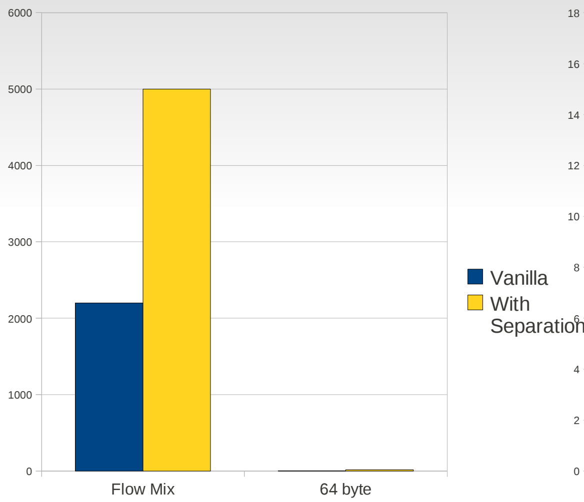
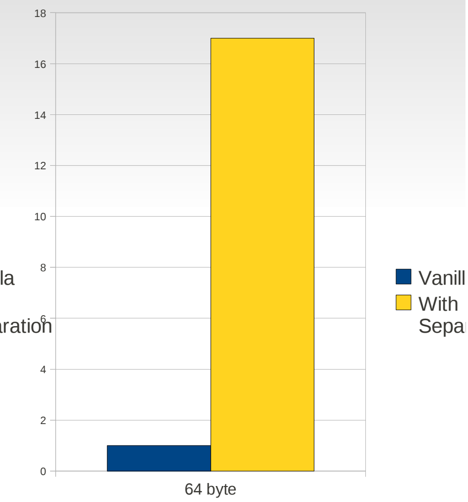
- Work in progress



Results in-line



Transaction latency wo/w RSS path
Flow mix and 64 byte packets



Zoom in of 64 byte packets

Classifier small packet problem

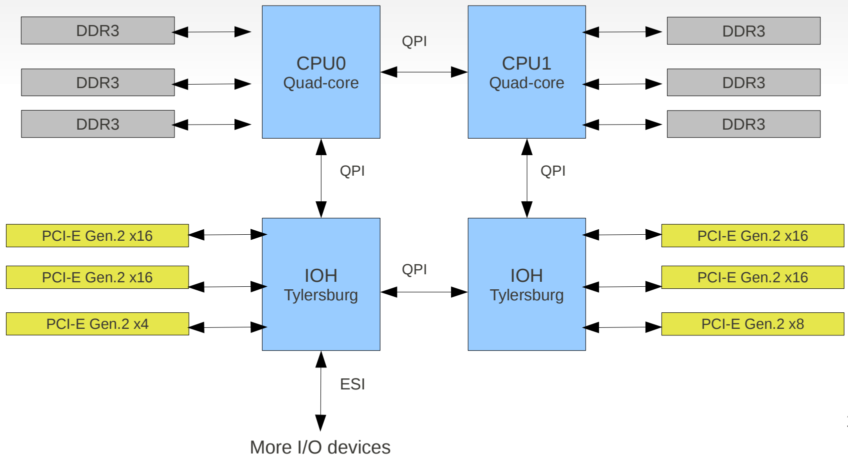
Seems we drop a lot packets before they are classified

DCB (Data Center Bridging) has a lot of features to prioritize different type of traffic. But only for IEEE 802.1Q

VMDq2 suggested by Peter Waskiewicz Jr at Intel

Experiment 3:
Transmit limits

Investigate hardware limits by transmitting as much as possible from all cores simultaneously.

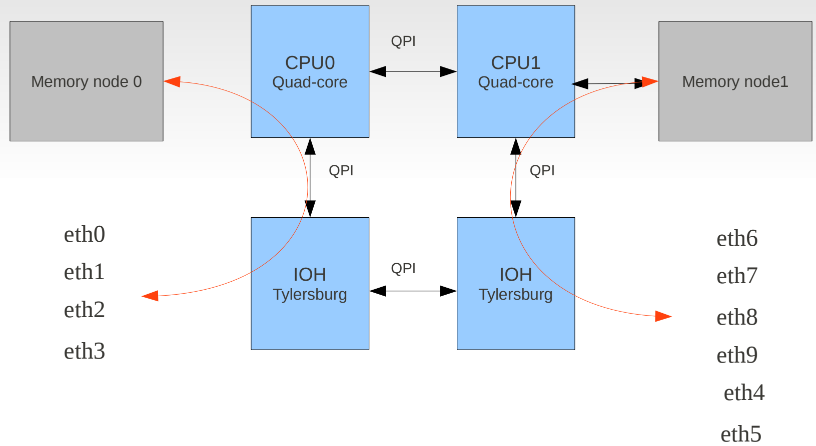


pktgen/setup

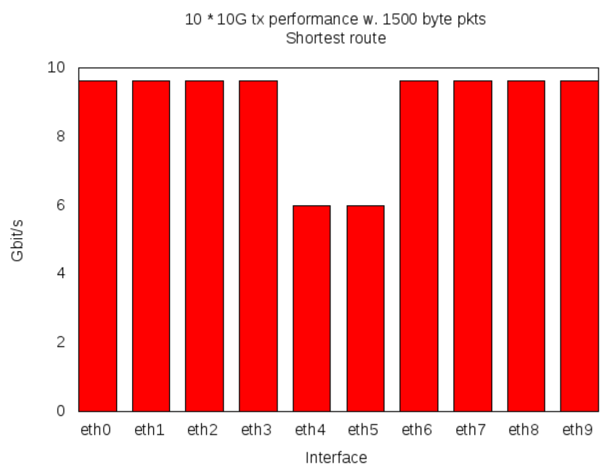
Inter-face	eth0	eth1	eth2	eth3	eth4	eth5	eth6	eth7	eth8	eth9
CPU-core	0	1	2	3	4	5	6	7	12	13
Mem node	0	0	0	0	1	1	1	1	1	1

eth4, eth5 on x4 slot

Setup


Memory node 0
CPU0
Quad-core
QPI
CPU1
Quad-core
Memory node1
QPI
QPI
eth0
eth1
eth2
eth3
IOH
Tylersburg
QPI
IOH
Tylersburg
eth6
eth7
eth8
eth9
eth4
eth5

TX w. 10 * 10g ports 93Gb/s "Optimal"



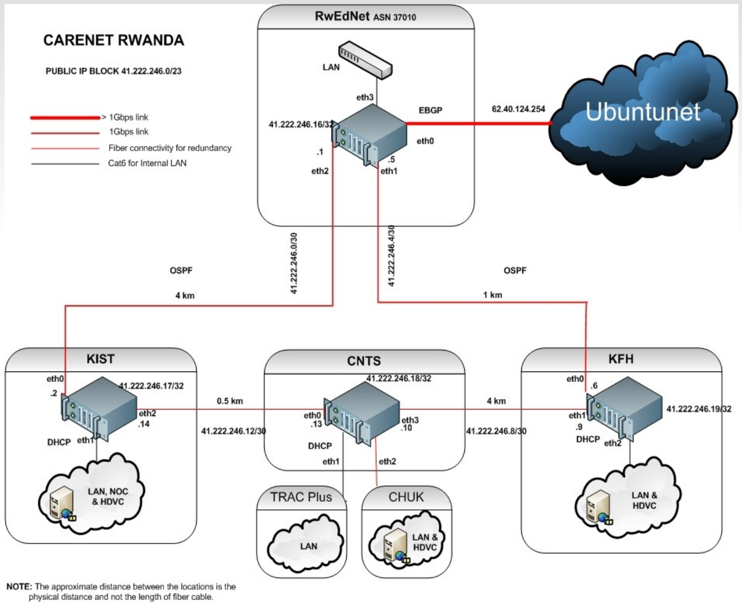
Conclusions

- We have shown traffic separation in a high-end multi-core PC with classifier NICs by assigning one CPU core as control and the other as forwarding cores. Our method:
  - Interrupt affinity to bind control traffic to core 0
  - Modified RSS to spread forwarding traffic over all except core 0
  - Modified the flow-director implementation slightly by only letting local (control) traffic populate the flowdir table.
- There are remaining issues with packet drops in in-line separation
- We have shown 93Gb/s simplex transmission bandwidth on a fully equipped PC platform

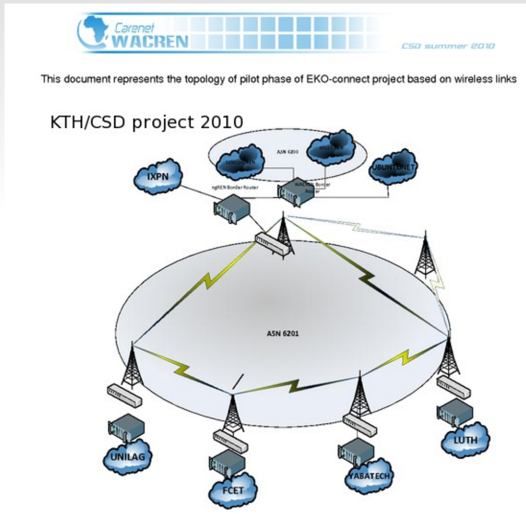
That's all

Questions?

Rwanda example



Lagos next



Carenet
WACREN
CSD summer 2010
This document represents the topology of pilot phase of EKO-connect project based on wireless links
KTH/CSD project 2010
IXPN
ASN 6201
UNILAG
FCET
YABATECH
LUTH

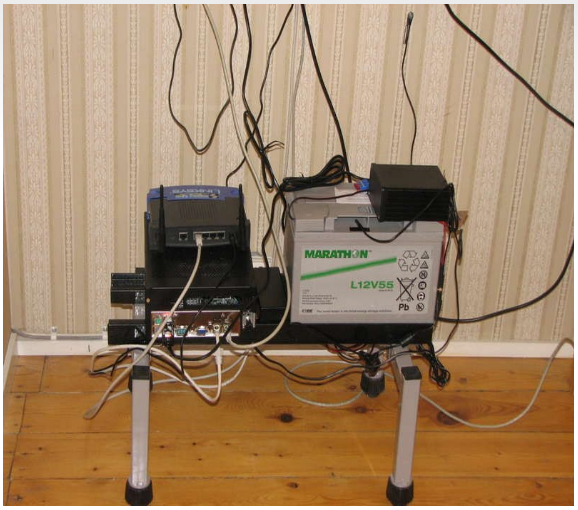
Low-Power Development Some ideas

```
            Power consumption
SuperMicro X7SPA @ 16.5 Volt with picoPSU

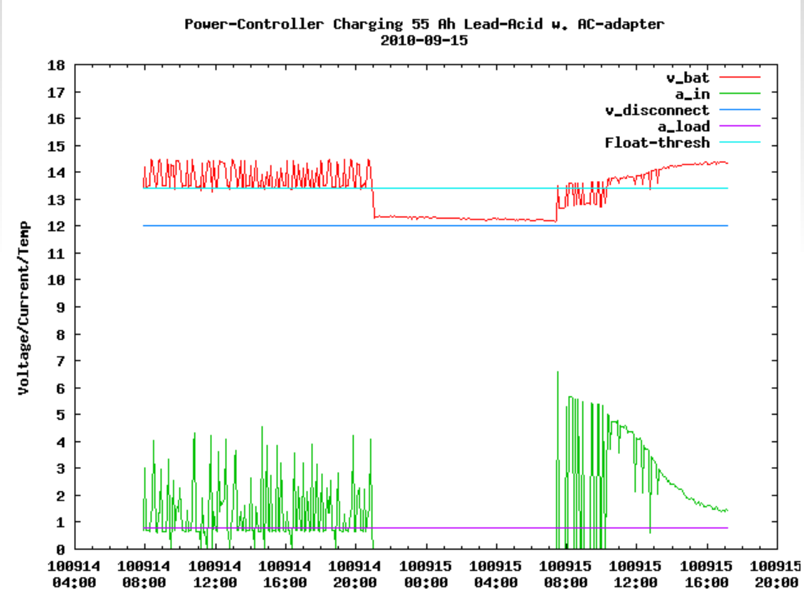
Watt       Test
-------------------
1.98      Power-Off
13.53      Idle
14.35      1 core
15.51      2 Core
15.84      3 Core
16.50      4 Core

Routing Performance about 500.000 packet/sec
in optimal setup.
```

Example herjulf.se
14 Watt by 55Ah battery
bifrost/USB + lowpower disk



Running on battery



SuperCapacitors

DOM - Optical Monitoring

Optical modules can support optical link monitoring
RX, TX power, temperatuers, alarms etc

Newly added support to Bifrost/Linux

DOM

ethtool -D eth3

Int-Calbr: Avr RX-Power: RATE_SELECT: Wavelength: 1310 nm

- Temp: 25.5 C
- Vcc: 3.28 V
- Tx-Bias: 20.5 mA
- TX-pwr: -3.4 dBm (0.46 mW)
- RX-pwr: -15.9 dBm (0.03 mW)