Linux for System z performance update

Session number 2590

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Notes:
Performance is in Internal Throughput Rate (ITR) ratio based on measurements and projections using standard IBM benchmarks in a controlled environment. The actual throughput that any user will experience will vary depending upon considerations such as the amount of multiprogramming in the user's job stream, the I/O configuration, the storage configuration, and the workload processed. Therefore, no assurance can be given that an individual user will achieve throughput improvements equivalent to the performance ratios stated here.
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Agenda

- **System z hardware**
- **Hardware improvements**
  - Processor
  - Networking
  - Disk / Tape
  - Cryptography
- **Software improvements**
  - Compiler
  - Java
  - WebSEAL
  - Tivoli Storage Manager
- **Distribution improvements**
  - Red Hat
  - Novell SUSE
Our hardware for measurements

**2084-B16 (z990)**
- 0.83ns (1.2 GHz)
- 2 Books, 16 CPUs
- 2 * 32 MB L2 Cache
- 80 GB
- FICON-Express2

**2094-S18 (z9-109)**
- 0.58ns (1.7GHz)
- 2 Books, 18 CPUs
- 2*40 MB L2 Cache
- 128 GB
- FICON-Express4

**2105-800 (Shark)**
- 32 GB Cache
- 1 GB NVS
- 128 * 72 GB disks
- 15,000 RPM
- FCP (2 Gbps)
- FICON (2 Gbps)

**2107-922 (DS8000)**
- 256 GB Cache
- 8 GB NVS
- 256 * 72 GB disks
- 15,000 RPM
- FCP (4 Gbps)
- FICON (4 Gbps)

**HiperSockets**
**OSA-Express2 (10)GbE**
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OSA-Express2

- Newest member – 10 Gb Ethernet LR (long reach)
  - One port per feature

- New – Gb Ethernet features
  - Gigabit Ethernet LX (long wavelength)
  - Gigabit Ethernet SX (short wavelength)

- Support offered by both 10 GbE and 1 GbE
  - Layer 2 support
  - Up to 1920 TCP/IP stacks for improved virtualization
  - Large send for CPU efficiency
Networking benchmark

- AWM
- Several workload models
  - transactional workload
  - streaming workload
  - mixed workload
- Measured with GbE (QDIO), Hipersockets, and virtual connections in z/VM
- Throughput and cost (CPU) measurements
Response times

Single-Session 1B/1B RR Round-Trip Time
2 OSAs, 2 TCP/IP stacks

- More than 20% improvement with OSA-Express2
Advantage for 10 Gb over 1 Gb is increasing with data size
Improvements up to 3.4x
Disk I/O benchmark

- IOzone
- Threaded file system benchmark used to measure synchronous I/O
- Sequential/random write, rewrite, read of a large enough file (700MB = almost 3x of memory size)
- Main memory was restricted to 256MB
- 1, 2, 4, 8, 16, 32, 64 threads, each operating on its private disk or using a Logical Volume
- Used on FICON and SCSI disks
Configuration for 4Gbps disk I/O measurements

- 2094
- DS8K
- 4 GBIT FICON/FCP SWITCH
- 8 FICON 8 FCP
- 8 FICON 8 FCP

4 Gbit FICON Port
4 Gbit FCP Port
Disk I/O performance with 4Gbps links - FICON

- Strong throughput increase (average 1.6x)
- The best increase is with sequential read at 2x

Compare FICON 4 GBit - 2 GBit

![Throughput in MB/sec Chart]

- SQ Write
- SQ RWrite
- SQ Read
- R Read
- R Write
Disk I/O performance with 4Gbps links - FCP

- Moderate throughput increase
- Best improvement with sequential read at 1.25x

Compare FCP 4 GBit - 2 GBit
Disk I/O performance with 4Gbps links – FICON versus FCP

- Throughput for sequential write is similar
- FCP throughput for random I/O is 40% higher

Compare FICON to FCP - 4 GBit
Disk I/O performance with 4Gbps links – FICON versus FCP / direct I/O

- Bypassing the Linux page cache improves throughput for FCP up to 2x, for FICON up to 1.6x.

- Read operations are much faster on FCP

Compare FICON to FCP - 4 GBit

Throughput in MB/sec

<table>
<thead>
<tr>
<th></th>
<th>SQ Write</th>
<th>SQ RWrite</th>
<th>SQ Read</th>
<th>R Read</th>
<th>R Write</th>
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<tbody>
<tr>
<td>FICON page cache</td>
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<td>FICON dio</td>
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<td>FCP dio</td>
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</table>

*SQ Write, SQ RWrite, SQ Read, R Read, R Write*
FCP/SCSI single path versus multipath

- Use failover instead of multibus
FCP/SCSI single path versus multipath (2)

- Use LVM2 instead of EVMS
- Costs for multipathing are about 10%
Disk I/O considerations

• Higher throughput rates with the new storage server generation require also higher CPU utilization

• This applies also to FCP/SCSI I/O when there is a throughput win versus FICON/ECKD I/O

• Take care that any specific path assignments for FCP/SCSI disks are still valid after re-IPL.

SCSI tape performance

- Measurements on IBM 3590 with optimal compression, compression of real life data (Linux source code), without compression
- Tests were done with dd, 1 FCP channel to the tape.
- Select a large blocksize for the tape, e.g. 256 KB
Linux software SSL stack
Crypto Express2 - SSL handshakes

- The number of handshakes is up to 4x higher with HW support
- In the 32 connections case we save about 50% of the CPU resources

![Graph showing connections/s vs number of parallel connections](image1)

- 4 CPUs - 40b data

![Graph showing CPU load in %](image2)

- No HW
- 1 CEX2A

32 parallel connections

- idle
- system
- user

- CPU load in %
- no HW
- CEX2A

- The number of handshakes is up to 4x higher with HW support
- In the 32 connections case we save about 50% of the CPU resources
System z9 CPACF feature

- **CPU cost per throughput**
- **Processes doing AES-128**

- **Graph**
  - Bar chart showing CPU cost per throughput for different numbers of processes doing AES-128:
    - No CPACF
    - 1-8 CPACF

- **Legend**
  - [no CPACF]
  - [1-8 CPACF]
Crypto Express2 – CPACF and CEX2

- The use of both hardware features show leads to 3.5x more throughput
- Using software encryption costs about 6x more CPU
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gcc 64bit compiler – SLES9 (gcc-3.3.3) versus SLES10 (gcc-4.1.0)

- gcc 4.1 supports -mtune=z9-109 and -march=z9-109

![Graph showing performance comparison between SLES9 SP3 gcc-3.3.3 and SLES10 gcc-4.1.0]
Compiler - why isn't 64-bit for free?

- **Hardware effects**
  - Primarily D-cache "pressure"
  - z/Architecture supports both 31-bit and 64-bit addressability
    - Data cache is fixed size for machine
    - 64-bit pointers "twice" as large as 31-bit pointers
  - Also impacts I-cache performance
    - 64-bit instructions tend to be 6-byte instead of 2 or 4

- **Software effects**
  - some 31-bit instructions have no 64-bit equivalent
    - must be implemented with series of 64-bit opcodes
    - = additional pathlength for same function
  - increased cost for entry/exit linkage
    - registers are twice as wide
Java Results 64-bit

- Improvements through Java (JVM and JIT)
- Improvements through new hardware
- 64-bit Java is production ready
The connection from the client to the WebSEAL server runs encrypted using SSL (AES-128).

- Scaling the size of the requested page
- Uses mostly CPACF
- Improvement up to factor 2.4 for hardware encryption versus software encryption
Special study with Tivoli Storage Manager

• ECKD versus SCSI

• Configured and measured on our system together with TSM performance specialist

• Entry statement from TSM, based on their tests in 2005 for backing up 70 GB data:
  • “execution time with SCSI is 25% shorter than with ECKD”
  • “average CPU consumption with SCSI is 67% more than with ECKD”

• Common exit statement from after the tests:
  • “execution time with SCSI is 50% shorter than with ECKD”
  • “costs were almost equal (more CPU resources need to be provided for SCSI)”
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Comparison SLES10 / RHEL5

<table>
<thead>
<tr>
<th>measurement portfolio SLES10 GA versus RHEL5 GA</th>
<th>LPAR 64</th>
<th>LPAR 31 (emu)</th>
<th>z/VM 64</th>
<th>z/VM 31 (emu)</th>
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<td>Scaling</td>
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<td>Java</td>
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Legend: n/a, better, equal, worse
SLES9 improved resource usage

- The Linux kernel uses spin locks to wait for exclusive use of kernel resources
- On System z it is not desirable to use processors for active waiting
- The old solution was to issue a DIAG 44 to the LPAR hypervisor or to z/VM to give the CPU back instead of looping on the lock, to allow other more useful work to be done.
- 2 new features:
  - spin_retry counter in Linux to avoid excessive use of diagnose instructions
  - use of DIAG 9C to pass information along with the instruction, who should get the processor
Avoiding spin locks on System z

CPU1 instruction stream

Critical section

CPU2 instruction stream

Spinning (other hw)

DIAG 44

Spinning (count) + DIAG 44

Spinning (count) + DIAG 9C
SLES10 virtual CPU time accounting

- The standard Linux implementation is based on a heuristic model with a 10 ms timer interrupt
  - The complete time slice is accounted to the interrupted context
- On systems with virtual CPUs this approach is too inaccurate
- The new implementation is based on the System z virtual timer
  - CPU times get now accounted whenever the execution context changes
  - A new category of Linux wait state is showing, how often the Linux system is waiting for CPU (current sysstat version required)
  - The feature is enabled by default in SLES10 and RHEL5
Linux command 'top' – the snapshot tool

- Adds new field “CPU steal time”
  - Is time Linux wanted to run, but the hypervisor was not able to schedule CPU
  - Is included in SLES10 and RHEL5

```
Top - 09:50:20 up 11 min,  3 users,  load average: 8.94, 7.17, 3.82
Tasks:  78 total,   8 running,  70 sleeping,   0 stopped,   0 zombie
 Cpu0 : 38.7%us,  4.2%sy,  0.0%ni,  0.0%id,  2.4%wa,  1.8%hi,  0.0%si,  53.0%st
 Cpu1 : 38.5%us,  0.6%sy,  0.0%ni,  5.1%id,  1.3%wa,  1.9%hi,  0.0%si,  52.6%st
 Cpu2 : 54.0%us,  0.6%sy,  0.0%ni,  0.6%id,  4.9%wa,  1.2%hi,  0.0%si,  38.7%st
 Cpu3 : 49.1%us,  0.6%sy,  0.0%ni,  1.2%id,  0.0%wa,  0.0%hi,  0.0%si,  49.1%st
 Cpu4 : 35.9%us,  1.2%sy,  0.0%ni, 15.0%id,  0.6%wa,  1.8%hi,  0.0%si,  45.5%st
 Cpu5 : 43.0%us,  2.1%sy,  0.7%ni,  0.0%id,  4.2%wa,  1.4%hi,  0.0%si,  48.6%st
Mem:    251832k total,   155448k used,   96384k free,   1212k buffers
Swap:   524248k total,  17716k used,  506532k free,  18096k cached
```
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