z/VM CPU Pooling and ILMT

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IBM z Systems

Architecture and Technology

SHARE Orlando, August 2015
OMEGAMON® Performance Toolkit for VM
Power* PowerVM PR/SM
FICON® GDPS® HiperSockets HyperSwap IBM z13*

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Agenda

- IBM software pricing methodologies
- Brief review of z/VM scheduling options
- Overview of CPU Pooling in z/VM V6.3
- Update to IBM License Metric Tool (ILMT) 9.0.1
- Software Pricing with CPU Pooling
- Use case examples
- CPU Pooling with IBM z13 and SMT
- Summary and References
z Systems Software Pricing Objectives

- Price-to-value
- Flexibility to run software where it is most efficient
- Capability to predict software charges
- Help with cost of new applications
- Flexibility to pay for software based on workload requirements
Pricing Metrics for z/VM IPLA Products

- z/VM V5 and V6 and certain z/VM related products have pricing based on the number of engines
  - *Engine-based Value Unit* pricing allows for a lower cost of incremental growth with additional engine-based licenses purchased

- Most IBM middleware for Linux is also priced based on the number of engines
  - The number of engines is converted into *Processor Value Units* (PVUs) under the Passport Advantage® terms and conditions

- z/VM 6.3 (with APAR) allows *CPU pooling*
  - *ILMT enhancements* enable using ILMT with pooling
Limiting Single Guests

- Existing **LIMITHARD** option of **SET SHARE** command bounds guest processor resource consumption

  - **SET SHARE userid RELATIVE 2000 ABSOLUTE 40% LIMITHARD**
    - **RELATIVE 2000** defines entitlement: guest is allotted 20 times as much processor resource as the default (RELATIVE 100) user
    - **ABSOLUTE 40% LIMITHARD** sets the cap: guest cannot consume more than 40% of the processor resource on the z/VM system (e.g., 2 IFLs in a 5-IFL VM partition)

- Applies to processor resource of type where the guest is dispatched

- Scheduler divides limit evenly among virtual CPUs in a virtual MP
  - Omits stopped vCPUs (e.g., via `cpuplugd`)

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Limiting Single Guests …

• **SET SHARE LIMITHARD** can be used to
  – Prevent “runaway” virtual machines
  – Limit consumption by less important virtual machines (e.g., test)
  – Help to ensure department budgets are not exceeded
  – Control resources available to contracting clients (service bureau)

• **Drawbacks**
  – Change in number of logical processors (Capacity on Demand, VARY PROCESSOR ON/OFF) affects actual limit imposed
  – Imposed at the individual guest level
    – Limiting a set of guests may require over-limiting the individuals
  – Not recognized as a means of limiting capacity for IBM sub-capacity software licensing purposes
Environment Information Interface

- New interface allows guest to capture execution environment
  - Processor configuration and capacity information
  - Various Levels: Machine, logical partition, hypervisor, virtual machine

- New unprivileged instruction Store Hypervisor Information (STHYI)

- Includes support for CPU Pooling

- Exploited by ILMT 9.0.1 for sub-capacity pricing of Linux on System z middleware

- Support details:
  - z/VM 6.3 with APAR VM65419 (included in RSU 1501)
CPU Pooling with z/VM V6.3

- Create a pool of processor resources available for a group of virtual machines in a z/VM system
- Allows capping of processor utilization for a set of guests to better balance resource utilization
- Allows Live Guest Relocation (LGR) as long as both definitions are compatible
  - Pools are defined and managed independently on each SSI member system
- Available with z/VM V6.3 and APAR VM65418 (in RSU 1501)
Flexible Pool Configuration

• Define named CPU pools with associated capacity
  – Number of CPUs of particular type (CP, IFL)
  – Percentage of CPUs of particular type

• Associate guests with CPU pools

• Limit aggregate guest consumption to pool capacity
  – Coexists with individual guest LIMITHARD setting; both limits enforced
  – Otherwise, resource allotted to group members on demand (“first come, first served”)

• Allows overcommit – no restriction on number of pools or aggregate capacity

• New Environment Information Interface obtains pool capacity information
  – Eliminates manual configuration of data collection
Defining CPU Pools

- Use the **DEFINE CPUPOOL** command to define named pools
  - Define for a particular **TYPE** of core (**CP** or **IFL**)
    - Default is primary core type (**IFL** in an IFL-only partition, otherwise **CP**)
  - **CAPACITY** – number of CPUs’ worth of processing power
    - Limit recognized for sub-capacity licensing purposes
    - Can overcommit (i.e., Sum of CPUPOOL CPUs > Logical processors)
  - **LIMITTHARD** – % of system CPU resources of that type
    - Same enforcement mechanism as SET SHARE LIMITTHARD
    - Does not qualify for sub-capacity licensing
Enrolling Virtual Machines in Pools

- Assign a guest to or remove it from a CPU pool with the SCHEDULE command
  - Specified CPU pool must be already defined
  - Type of CPU in specified CPU pool must match the guest's primary CPU type
    - CPU affinity must be on for the guest
    - If guest already assigned to a CPU pool it is removed from that pool and added to the specified pool
Changing Pool CPU Allocation

• Limits can be changed with the **SET CPUPOOL** command
Displaying CPU Pool information

- Use **QUERY CPUPOOL** to see information about the pools defined on your system
Displaying CPU Pool Information

- Display all pool definitions
  
  ```
  query cpupool all
  CPU pool    Limit     Type   Members
  LINUXP2    8.0 CPUs    IFL      0
  CPPOOL10    12 %       CP        8
  LINUXP3    30 %       IFL        20
  LINUXP1    2.5 CPUs    IFL        6
  ```

- Display one pool definition and member names
  
  ```
  query cpupool linuxp1 members
  CPU pool    Limit     Type   Members
  LINUXP1    2.5 CPUs    IFL        6
  The following users are members of CPU pool LINUXP1:
  D70LIN12 D79LIN03 D79ADM D79LIN10 D79LIN07 D79LIN04
  ```

- Display user’s pool name
  
  ```
  query cpupool user d79adm
  User D79ADM is in CPU pool LINUXP1
  ```
DELETE CPUPOOL

- Use **DELETE CPUPOOL** to delete a pool definition
- Pool must be empty
  - Use SCHEDULE ... NOPOOL first to remove each member

```
Delete-CPUPool-poolname
```
Automating CPU Pool Management

- Complication
  - At VM IPL, no pools are defined (not remembered from prior IPL)
  - Cannot add users to pool until it is defined

- Solutions

1. COMMAND statements in directory definition of OPERATOR or AUTOLOG1

   USER OPERATOR . . .
   
   . . .
   
   COMMAND DEFINE CPUPOOL WEBSPH CAPACITY 5 TYPE IFL
   COMMAND DEFINE CPUPOOL DB2 CAPACITY 3 TYPE IFL
   COMMAND DEFINE CPUPOOL QADEPT LIMITHARD 10% TYPE CP

   ...Or include CP DEFINE commands in AUTOLOG1’s PROFILE EXEC

2. COMMAND statements in virtual machine definitions to place them into pools when they log on

   USER WASPROD1 . . .
   
   . . .
   
   COMMAND SCHEDULE * WITHIN POOL WEBSPH
Single System Image Considerations

- CPU pools are defined and managed independently on each member of an SSI cluster

- A guest in a CPU pool can relocate to another system if a CPU pool with the same name and type is defined on the target system
  - Need not have the same limits

- Administrator is responsible for adjusting pool limits if needed
  - May affect software license requirements
Track License Requirements with IBM License Metric Tool

• IBM License Metric Tool (ILMT) is a no-charge tool used to determine PVU licensing requirements

• New Linux interface exploited by ILMT to assess software license requirements
  – Invokes z/VM Environment Information Interface

• Ability to track CPU pools available in ILMT 9.0.1, August 12, 2014
  – Improvements also made to reduce CPU overhead incurred with ILMT

• Using ILMT you are only charged for the CPU pool capacity assigned to Passport Advantage PVU-based software
ILMT Architecture Overview
Software Licensing Key Points

- IBM’s two Software Categories are z Systems software and Distributed software (entitlements are not interchangeable)

- Value Units (VUs) are used to license z Systems IPLA software and Processor Value Units (PVUs) are used to license Distributed Passport Advantage software

- Distributed Sub-Capacity Terms require customers to keep track of the maximum processor capacity available to a program
  - IBM License Metric Tool calculates this
  - Customers run the tool and retain the reports

- When running z/VM virtual machines or LPARs, a customer is required to obtain licenses for the real hardware resources actually available to each program, not necessarily for all the resources

- PVUs are based on the processor family, for example
  - IFL on z114 is 100 PVUs while IFL on zEC12 is 120 PVUs
  - See IBM pricing expert for details

- On the z13, licensing granularity is one core’s worth of processing power
  - No thread-based licensing
Linux Guest Software Pricing Without CPU Pooling

Pricing rule for products in z/VM guests: The lower of the sum of the virtual engines available to guests running a product or the engine capacity of the z/VM LPAR from which the guests obtain their resources.
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![Diagram showing virtual, logical, and physical CPUs with IFL]

**Virtual CPUs**

**Logical CPUs**

**Physical CPUs**
Linux Guest Software Pricing Without CPU Pooling

**Pricing rule for products in z/VM guests:** The lower of the sum of the virtual engines available to guests running a product or the engine capacity of the z/VM LPAR from which the guests obtain their resources.

Maximum consumption: 2 IFLs
Linux Guest Software Pricing With CPU Pooling

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Maximum consumption: 2 IFLs
Use cases for CPU Pooling

• Department budgeting
  – Assign each department’s guests to CPU pool with contracted capacity

• Grow workloads without affecting the budget
  – Add New Workload
  – Add Capacity
  – Combine LPARs
  – Handle fractional workload requirements

• Prevent resource over-consumption
  – Limit aggressive workloads
Add New Workload Without CPU Pooling

- 4 WAS production guests
  - Requires 4-engine WAS entitlement
- Add 2 DB2 production guests
  - Requires 2-engine DB2 entitlement

Note: All PVU Entitlement examples based on zEC12 (120 PVU per IFL) – will look proportionally the same on zBC12 (100 PVU per IFL)
Add New Workload With CPU Pooling

- 4 WAS production guests
  - Requires 4-engine WAS entitlement
- Create a 1-IFL pool
- Put the 2 DB2 production guests in pool
  - Requires 1-engine DB2 entitlement
  (avoiding the need for 2-engine DB2 entitlement)

- Allows new workloads to be added cost effectively
- Encourages additional workload consolidation after initial success

Note: All PVU Entitlement examples based on zEC12 (120 PVU per IFL) – will look proportionally the same on zBC12 (100 PVU per IFL)
Add Capacity Without CPU Pooling

- 4 WAS production guests
  - Requires 4-engine WAS entitlement
- Add another IFL to the LPAR
  - Requires increase to 5-engine WAS entitlement

Note: All PVU Entitlement examples based on zEC12 (120 PVU per IFL) – will look proportionally the same on zBC12 (100 PVU per IFL)
Add Capacity With CPU Pooling

- LPAR with 4 IFLs
- Set up CPU Pooling for 4 IFLs
  - 4 WAS production guests require 4-engine WAS entitlement
- Add another IFL to the LPAR
- Avoids an incremental WAS entitlement license – allows capacity to be added without increasing software license charges
- Encourages adding capacity for other workloads (e.g., open source applications)

Note: All PVU Entitlement examples based on zEC12 (120 PVU per IFL) – will look proportionally the same on zBC12 (100 PVU per IFL)
Combine LPARs Without CPU Pooling

- LPAR with 4 IFLs and 4 WAS production guests
  - Requires 4-engine WAS entitlement
- LPAR with 1 IFL and 2 DB2 production guests
  - Requires 1-engine DB2 entitlement

Note: All PVU Entitlement examples based on zEC12 (120 PVU per IFL) – will look proportionally the same on zBC12 (100 PVU per IFL)
Combine LPARs Without CPU Pooling

- LPAR with 4 IFLs and 4 WAS production guests
  - Requires 4-engine WAS entitlement
- LPAR with 1 IFL and 2 DB2 production guests
  - Requires 1-engine DB2 entitlement
- LPARs merge to one LPAR with 5 IFLs
  - Requires increase to 5-engine WAS entitlement
  - Requires increase to 2-engine DB2 entitlement

Note: All PVU Entitlement examples based on zEC12 (120 PVU per IFL) - will look proportionally the same on zBC12 (100 PVU per IFL)
Combine LPARs With CPU Pooling

- LPAR with 5 IFLs
- Create two Pools – one with 4 IFLs and one with 1 IFL
- Place the four WAS guests in the 4-IFL pool and the two DB2 guests in the 1-IFL pool
  - Requires 4-engine WAS entitlement
  - Requires 1-engine DB2 entitlement

Avoids increase in software license requirements (and costs)
Reduces z/VM system management and maintenance workload
Consolidates resources (memory, paging, network) for greater efficiency

Note: All PVU Entitlement examples based on zEC12 (120 PVU per IFL) – will look proportionally the same on zBC12 (100 PVU per IFL)

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CPU Pools that Overcommit

- **LPAR with 5 IFLs**
- Create two Pools – one with 4 IFLs and one with 2 IFLs
- Place the four WAS guests in the 4-IFL pool and the two DB2 guests in the 2-IFL pool
  - Requires 4-engine WAS entitlement
  - Requires 2-engine DB2 entitlement

**Avoids increase in software license requirements (and costs)**

**Reduces z/VM system management and maintenance workload**

Note: All PVU Entitlement examples based on zEC12 (120 PVU per IFL) – will look proportionally the same on zBC12 (100 PVU per IFL)
Large system with virtual machines that require fractional IFL capacity

- **LPAR with 25 IFLs**
- **2 DB2 production guests**
  - Requires 6-engine DB2 entitlement
- **3 WAS production guests and 12 small WAS test guests**
  - Requires 25-engine WAS entitlement

Note: All PVU Entitlement examples based on zEC12 (120 PVU per IFL) – will look proportionally the same on zBC12 (100 PVU per IFL)
Align fractional capacity virtual machines to small CPU pools

- LPAR with 25-IFLs
- Set up a 1-IFL pool
  - 2 DB2 production guests
    - Requires 6-engine DB2 entitlement
  - 3 WAS production guests and 1-IFL pool
    - 12 small WAS test guests
    - Requires 19-engine WAS entitlement

Note: All PVU Entitlement examples based on zEC12 (120 PVU per IFL) – will look proportionally the same on zBC12 (100 PVU per IFL)
Contain workloads that take too many resources

- LPAR with 18-IFLs
- 2 DB2 production guests and 3 WAS production guests are sharing the 18-IFLs
- Month-end processing or nightly backup uses any available capacity – could take from production guests
- Set up a 1 IFL CPU pool for running these tasks

Note: All PVU Entitlement examples based on zEC12 (120 PVU per IFL) – will look proportionally the same on zBC12 (100 PVU per IFL)
Simultaneous Multithreading (SMT)

- Objective is to improve capacity, not performance
- Allows z/VM to dispatch work on up to two threads of a z13 IFL
  - VM65586 for z/VM 6.3 only
    - PTFs available March 13, 2015
- At least z13 millicode bundle 11
- Transparent to virtual machine
  - Guest does not need to be SMT aware
  - SMT is not virtualized to the guest
- z13 SMT support limited to IFLs and zIIPs
  - z/VM support is only for IFLs
- SMT is disabled by default
  - Change requires System Configuration setting and re-IPL
  - Applies to entire z/VM partition
- Potential to increase overall capacity of system
  - Workload dependent

*Illustrative numbers only
Additional Work Capacity

IFL (SMT disabled) – Time Slice Rate: 10

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

IFL (SMT enabled) – Time Slice Rate: 7

Thread 0

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |

Thread 1

| 1 | 2 | 3 | 4 | 5 | 6 | 7 |

- Numbers are for illustrative purposes only
- Without SMT: 10/second
- With SMT: 7/second but two threads yields capacity of 14/second
Interleaving Virtual CPUs of Guests

- In single core, we time slice access with each guest getting 5 time slices
- With SMT, each guest gets 7 time slices for total of 14

IFL (SMT disabled) – Time Slice Rate: 10

IFL (SMT enabled) – Time Slice Rate: 7

Thread 0

Thread 1
### Potential Need to Increase Virtual CPUs

Consider a guest that hits maximum of its virtual resources.

- With a single core, it can receive 10 time slices, but only 7 with SMT, as there is only one virtual CPU to dispatch.

**IFL (SMT disabled) – Time Slice Rate: 10**

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**IFL (SMT enabled) – Time Slice Rate: 7**

- Thread 0: `1 2 3 4 5 6 7`
- Thread 1: `6 7`

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Potential Need to Increase Virtual CPUs …

• Taking that guest and giving it a second virtual CPU allows additional work to be completed (if application can exploit multiple virtual CPUs)

IFL (SMT disabled) – Time Slice Rate: 10

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SMT - CPU Pooling Implications

- With SMT enabled
  
  - **CAPACITY** limit for CPU pools is defined as processing power of a number of IFL cores .... but limit enforcement is based on thread utilization (raw time)
  
  - In some cases, guests in a CPU pool will not be able to complete the same amount of work as without SMT with the same capacity limit
    - Capacity limits for CPU pools might need to be increased
    - More problematic when trying to match experience from zEC12 processor than from older, slower processors

![Work per Virtual CPU-second chart](chart.png)
Prorated Core Time

- Prorated core time divides core dispatch time proportionally among the threads dispatched in an interval
  - Full time charged while a vCPU runs alongside an idle thread
  - Half time charged while a vCPU is dispatched beside another active thread

- Therefore
  - CPU pool capacity consumed as if by cores
  - Suitable for core-based software licensing

- When SMT is enabled, prorated core time will be calculated for users who are
  - In a CPU pool limited by the CAPACITY or LIMITHARD option
  - Limited by the SET SHARE LIMITHARD command
    (currently raw time is used; raw time will continue to be used when SMT is disabled)

- QUERY CPUPOOL will report capacity in terms of cores of processing power instead of CPUs

- Prorated core time will be reported in monitor records and new Type F accounting record

- Watch for APAR VM65680
Summary

- CPU Pooling offers greater control over resource allocation
  - By workload
  - By department
  - By software product

- Together with ILMT 9.0.1, can limit software license costs, particularly where multiple software products run in the same z/VM system
  - Enables organic growth of individual workloads
  - Avoids paying for capacity not used by a software product
  - Broadens options for workload consolidation, lowering overhead and administrative costs

- New implications for capacity and licensing with IBM z13 and Simultaneous Multithreading
  - Watch for Prorated Core Time enhancement
More Information

- IBM z Systems Software Pricing

- Processor Value Unit (PVU) Licensing for Distributed Software

- Passport Advantage Sub-Capacity FAQ:

- Virtualization Capacity License Counting Rules

- ILMT 9.0.1 Blog on August Update with new CPU pooling support
  - [http://ibm.biz/cpupoolilmt](http://ibm.biz/cpupoolilmt)

- IBM Redpaper – Simplify Software Audits and Cut Costs by Using the IBM License Metric Tool (September 2014)

- ILMT Youtube page
  - [https://www.youtube.com/user/IBMLicenseMetricTool](https://www.youtube.com/user/IBMLicenseMetricTool)
Thanks!

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