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Linux on z/VM Performance

Large Linux Guests

Session 13486

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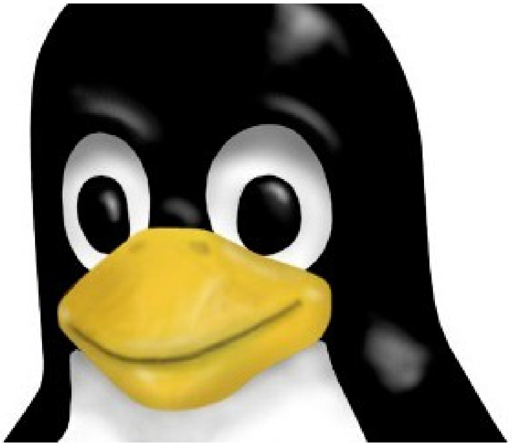
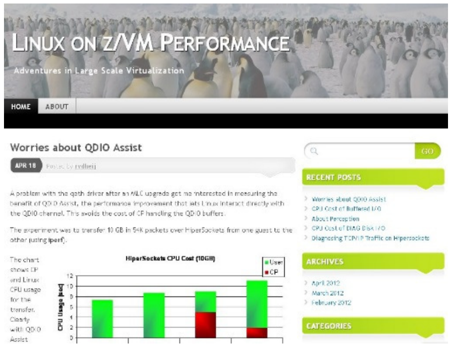
Agenda

What do you consider large?
Why use large Linux guests?
Managing performance data



Encounters with large guests
- Linux Large Pages
- Virtual CPUs
- Single guest or multiple guests
- Taming the Page Cache
- Java applications



http://zvmperf.wordpress.com/

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What do you consider large?

Experiment in 2006

z/VM on P/390

- 3-4 MIPS
- 128 MB Main Memory
- 100 Linux Guests

This was small,
even was in 2006…

Penguins on a Pin Head

Experiences with tuning Linux on a P/390

Rob van der Heij
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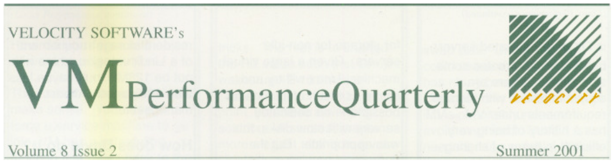
http://velocitysoftware.com/

A complete System/390 processor on a single PCI card.



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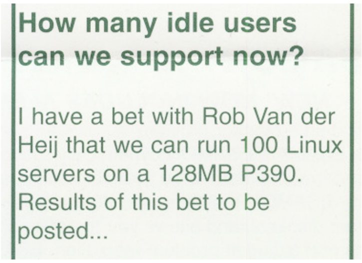
VMPerformanceQuarterly

Volume 8 Issue 2 — Summer 2001



How many idle users can we support now?

I have a bet with Rob Van der Heij that we can run 100 Linux servers on a 128MB P390. Results of this bet to be posted...

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What do you consider large?

Penguins on a Pin Head

- 3-4 MIPS
- 128 MB Main Memory
- 100 Linux Guests
  - Virtual machines 30 MB
  - Resident 0.5 – 4 MB
  - Overcommit 3-4

Customer in 2013

- 50,000 MIPS
- 1500 GB Main Memory
- 100 Linux Guests
  - Virtual machines 20-80 GB
  - Resident 20-50 GB
  - Overcommit 2-3

This is bigger

- CPU 10,000
- Memory 10,000
- Guest size 10,000

Number of guests is about the same

What do you consider large?

Hypervisor

- z/VM image today maximum 1 TB
- z/VM supports up to 32 logical CPUs

Linux Guest

- Wide range of possible configurations
- Depends on the number of virtual machines sharing
- Often around 1-10% of the hypervisor resources

How big should the guest be so that we do not have any performance problems?

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Why use large Linux guests?

Average guest is larger than a few years ago

- Less focus on resource efficiency
  - Different style of applications and application design
- Enterprise Application Ecosystems
  - Manage their own resource pool
- Increased workload
  - More data and higher transaction rates

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Less Focus on Resource Efficiency

Content-rich user interface

- Dynamic Content Management
- Customized and personalized application interface
- Integration of other data sources in user interface
  - Correlation with social network or shopping history

Different style of application design

- Building-block application development
  - Often takes more memory and CPU cycles
  - Not always perfect fit
  - May encourage adding additional eye candy
- Java-based application frameworks
  - Table-driven application design
  - Platform independent

Enterprise Application Ecosystems

Multi-threaded application middleware

- Acquires resources from Linux operating system
- Uses internal strategy to run and optimize the workload
- Assumes sole ownership of resources (no shared resources)
- Memory resources are retained until service is stopped

Many popular enterprise applications

- JVM with Java Application (WebSphere AS, JBoss)
- Databases (DB2, Oracle)
- ERP / CRM Applications (Siebel, SAP)

Performance Challenges

- Resource usage may not correlate with workload patterns
- Configuration of guest and application must match

Increased Workload

More data and higher transaction rates

- It is all just much more and bigger than before
  - It helps to look at other metrics too
  - At best it scales linear, sometimes much worse
- Linux on z/VM is part of many enterprise solutions
  - Applications deal with much larger workload than before
  - Aspect of being a mainstream platform
- Platform serves a very wide range of workloads
  - Scalability is normally taken for granted
  - Do not expect it to work without additional resources
  - Expectation sometimes scales less well

"I know this is inefficient, but if it works for 100,000 records, why would it be a problem with 107,000,000 records ?"

Managing performance data

All performance data is needed to understand performance

- It does not work with just part of the data
- Production and Development share resources
- Systems are often used 24 hours per day
- Chargeback data is needed
  - Even if only to encourage resource efficiency

Managing performance data is critical

- Especially with that much more resources

Performance management must scale for large systems

- Group data in different ways with full capture
- Apply thresholds to keep only interesting data
- Summarize complete data for chargeback and planning
- Condense older data to allow long term archival

Needle in a haystack

Data from many processes

- Can be a challenge to manage
- Thresholds to keep interesting data
- Condense the data in larger intervals
  - Still 10,000 lines of process data per day
- Grouping by application or user

Last week we used 60% even at night
Now we are down to 50% Why?

node/	<-Process Ident->			Nice	PRTY	<------CPU Percents---->				
Name	ID	PPID	GRP	Valu	Valu	Tot	sys	user	syst	usrt
00:30:00										
SPOOKY16	0	0	0	0	0	0.59	0.20	0.39	0.00	0.00
SPOOKY18	0	0	0	0	0	1.14	0.35	0.78	0.00	0.00
SPOOKY13	0	0	0	0	0	1.10	0.29	0.48	0.14	0.19
SPOOKY3	0	0	0	0	0	0.70	0.31	0.26	0.02	0.12
snmpd	1294	1	1293	-10	6	0.55	0.30	0.23	0.01	0.01
SPOOKY33	0	0	0	0	0	2.73	0.89	1.49	0.06	0.30
java	4151	1	4151	0	20	1.46	0.50	0.96	0	0
SPOOKY34	0	0	0	0	0	1.48	0.48	0.99	0.00	0.00
java	5237	1	5237	0	20	0.63	0.16	0.47	0	0
SPOOKY30	0	0	0	0	0	1.98	0.87	1.10	0.00	0.00
db2sysc	4621	4619	4621	0	20	1.11	0.44	0.67	0	0
SPOOKY20	0	0	0	0	0	0.64	0.28	0.35	0.00	0.00
SPOOKY25	0	0	0	0	0	2.32	0.47	1.06	0.37	0.43
db2fmcd	3008	1	3008	0	20	0.81	0.01	0.00	0.37	0.43
db2sysc	3620	3618	3620	0	20	0.60	0.09	0.51	0	0

Needle in a haystack

Grouping data from different servers

- Grouping in user class or node groups
- Aggregated usage from related servers
  - Tiers that make up an application
  - Servers that share the load
- Helps to manage performance data

Node/ Date Time	Process/ Application name	ID	<---Processor Percent---> Total	<Process> sys	user	<Children> syst	usrt
Node Groups							
*Spooky	*Totals*	0	24.1	7.0	12.5	1.4	3.2
	cogboots	0	2.9	0.8	2.1	0	0
	db2fmcd	0	2.0	0.0	0.0	0.9	1.1
	db2syscr	0	2.4	0.4	2.0	0	0
	init	0	2.1	0.0	0.0	0.3	1.7
	java	0	5.9	1.8	4.1	0	0
	kr4agent	0	1.4	0.1	1.3	0	0
	kynagent	0	0.5	0.1	0.4	0	0
	snmpd	0	4.9	3.2	1.6	0.0	0.0

Node/ Date Time	Process/ Application name	ID	<---Processor Percent---> Total	<Process> sys	user	<Children> syst	usrt
Node Groups							
*Spooky	*Totals*	0	30.3	7.5	18.8	1.5	2.5
	cogboots	0	1.5	0.8	0.7	0	0
	db2fmcd	0	2.2	0.0	0.0	1.0	1.2
	db2syscr	0	1.8	0.3	1.5	0	0
	httpd2-p	0	6.6	0.1	6.5	0	0
	init	0	1.4	0.0	0.0	0.4	1.0
	java	0	6.0	1.6	4.4	0	0
	kr4agent	0	1.5	0.1	1.4	0	0
	mysqld	0	1.5	0.3	1.2	0	0
	snmpd	0	5.4	3.6	1.7	0.0	0.0

Encounters with large guests

Inspired by real customer scenarios

- Sometimes reproduced in lab environment
- Often simulated with artificial workload

Relevant for both small and large systems

- Ignorance and personal taste may not scale
- Bad ideas show best in extreme cases

Data presented here has been collected with zVPS on real customer systems, sometimes reproduced in a lab environment to avoid distraction.

Linux Large Pages

With large memory size, 4K page granularity is overkill

- Enterprise application will manage the memory itself

Virtual Memory hardware supports larger pages

- Efficient use of hardware address cache
- Enhanced DAT (z10) provides both 4K and 1M page size

z/VM does not support large pages

- z/VM guest will see hardware without the EDAT feature

Linux can emulate large pages using 4K pages

- Does not exploit the hardware advantages
- Still requires manipulation of 4K pages in Linux
- … but it can save memory resources for Oracle database

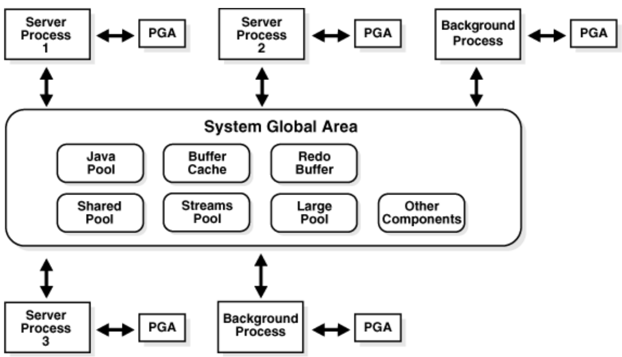
Oracle process uses SGA and PGA

- SGA is shared among all database processes
- Mapped into each process virtual memory
- Page tables duplicated for each process
- Adds up to 2 MB of tables per GB of memory, per process

```
Example:

SGA                 32 GB
Page Tables         64 MB
x 512 processes
= Total Tables      32 GB
```

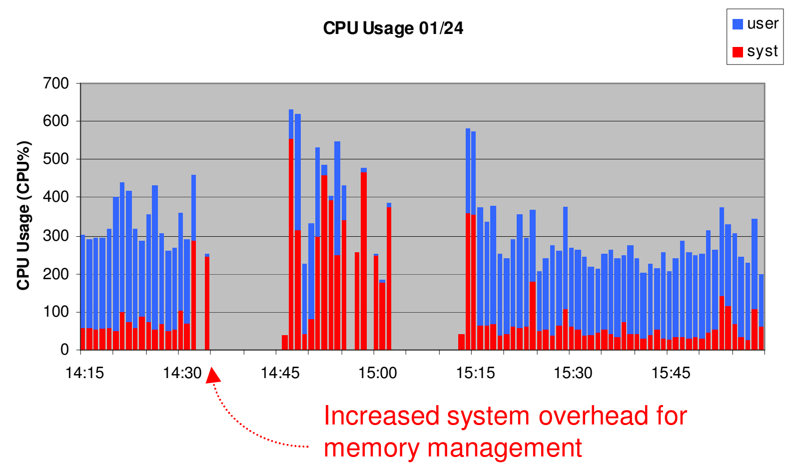
Rule of Thumb: With 500 Oracle connections, tables for 4K pages double your memory requirement

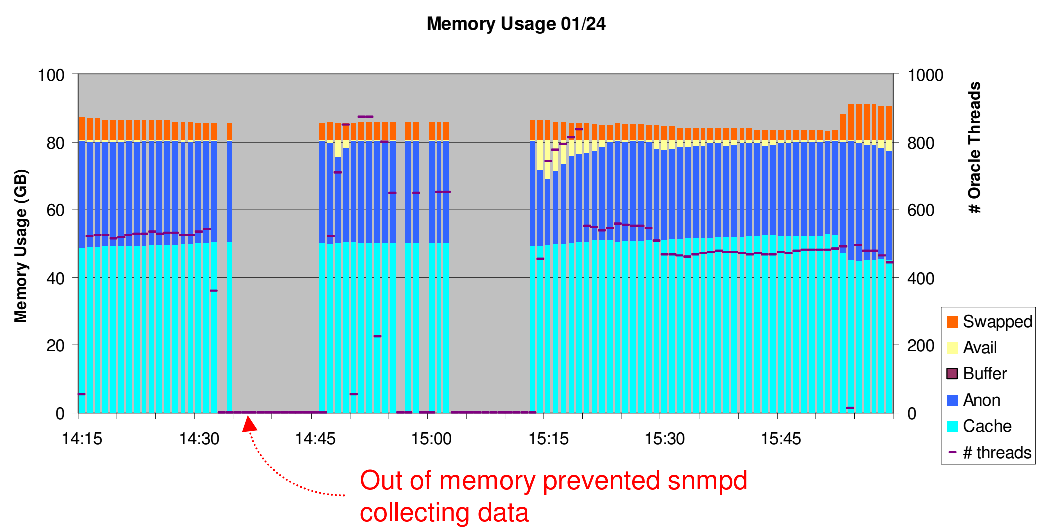


Example: Oracle Database

- SGA ~50G
- Connections ~500
- Linux Guest 80G

- 50G + 50G > 80G
- Only part of SGA actually used
  - Per process less than 50G mapped





Urgent Recommendation:
- Limit Number of Connections
- Use Large Pages

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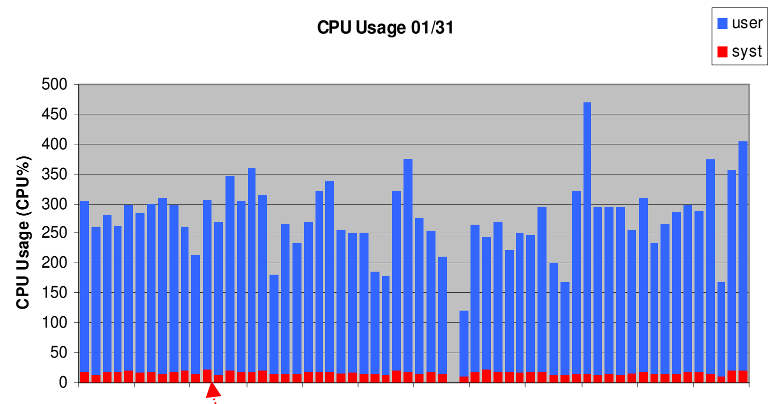
Linux Large Pages

Example: Oracle Database

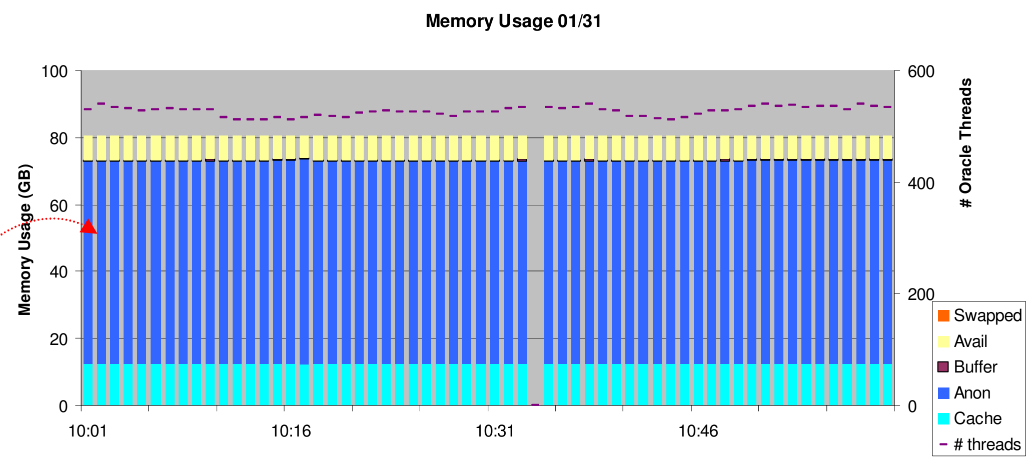
- SGA ~50G
- Connections ~500
- Linux Guest 80G

Using Large Pages for SGA

- Reserved 50G of Linux memory
- System overhead is gone
- All productive Oracle work



Almost no system overhead



SGA now outside cache

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Linux Large Pages

Oracle SGA using Linux Large Pages

- Savings can be substantial
  - Especially with large number of database connections
- Part of guest memory set aside as “huge pages”
  - Through kernel parameter at boot or dynamic
  - When dynamic, do it early to avoid fragmentation
  - Must be large enough to hold the SGA, anything more is wasted
    - Check the page size (1M versus 2M)
- Disable Oracle Automated Memory Management (AMM)
  - Use SGA_TARGET and PGA_TARGET
- Even with large pages: do not make SGA bigger than necessary
- Do not use Linux “transparent large pages” support

Does not apply to DB2 LUW or JVM Heap

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z/VM Page Reorder

Part of z/VM memory management

- Identify unreferenced user pages for page-out
- Less useful for most Linux on z/VM systems
- Freezes the entire virtual machine for some time
  - Approximately 1 second for every 8 GB of memory
  - Happens more often on busy Linux guests

Fixed in z/VM 6.3

CP command to disable page reorder

- For all virtual machines or specific ones

Ensure enough expanded memory for paging

- Reduces impact when wrong pages are selected

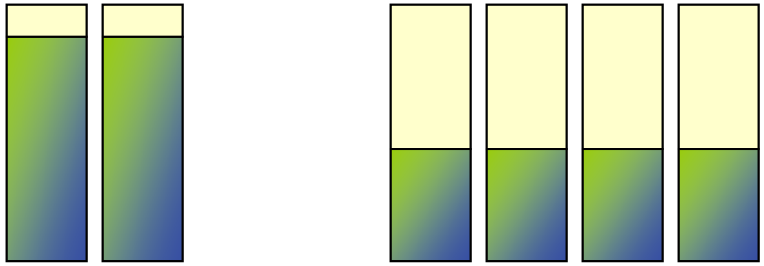
Virtual CPUs

Large workload takes more CPU resources

- Add virtual CPUs to provide peak capacity
- Not more virtual CPUs than expected available
  - Often less than number of logical CPUs
- Extra virtual CPUs don't provide more capacity
  - Scheduler share options determine capacity
- Linux assumes exclusive usage of resources
  - Not guaranteed in shared resource environment
  - When there is a virtual CPU, Linux assumes it will run
  - With more CPUs than capacity, z/VM will spread capacity

Example

- Linux runs 2 important tasks and 2 less important
- With 2 virtual CPUs
  - First run important tasks, other work when time permits
- With 4 virtual CPUs
  - Run all 4 tasks at the same time
  - z/VM will spread CPU capacity equal over virtual CPUs
  - Important work takes longer to complete



180% in 2 CPUs
90% each

180% in 4 CPUs
45% each

Virtual CPUs

Important Configuration Trade-Off

- More virtual CPUs
  - Deliver peak capacity when resources are available
- Less virtual CPUs
  - Improve single-thread throughput
  - Ensure predictable response times when little resources available
- As few as possible to deliver peak capacity

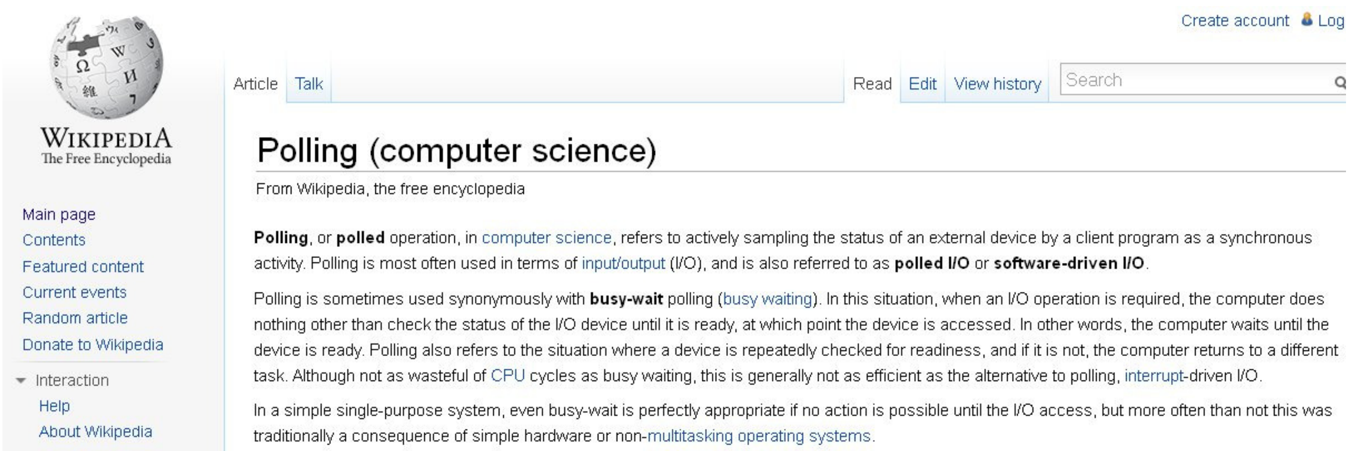
Understand CPU requirement

- CPU usage for peak and average in recent history
  - Shows what he got, not what he wanted
- Virtual CPU wait state analysis shows CPU queue
  - Virtual CPU in queue waiting to run

Virtual CPUs

Application Polling

- Frequent checking the status, busy-wait for service
- Poor design for shared resource environment
  - Mitigated by only installing the actual application
- Virtual CPUs get in queue for no reason
  - Do not consume much CPU and do not need more
  - It does not help much to wait faster



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Polling (computer science)

From Wikipedia, the free encyclopedia

Polling, or **polled** operation, in computer science, refers to actively sampling the status of an external device by a client program as a synchronous activity. Polling is most often used in terms of input/output (I/O), and is also referred to as **polled I/O** or **software-driven I/O**.

Polling is sometimes used synonymously with **busy-wait** polling (busy waiting). In this situation, when an I/O operation is required, the computer does nothing other than check the status of the I/O device until it is ready, at which point the device is accessed. In other words, the computer waits until the device is ready. Polling also refers to the situation where a device is repeatedly checked for readiness, and if it is not, the computer returns to a different task. Although not as wasteful of CPU cycles as busy waiting, this is generally not as efficient as the alternative to polling, interrupt-driven I/O.

In a simple single-purpose system, even busy-wait is perfectly appropriate if no action is possible until the I/O access, but more often than not this was traditionally a consequence of simple hardware or non-multitasking operating systems.

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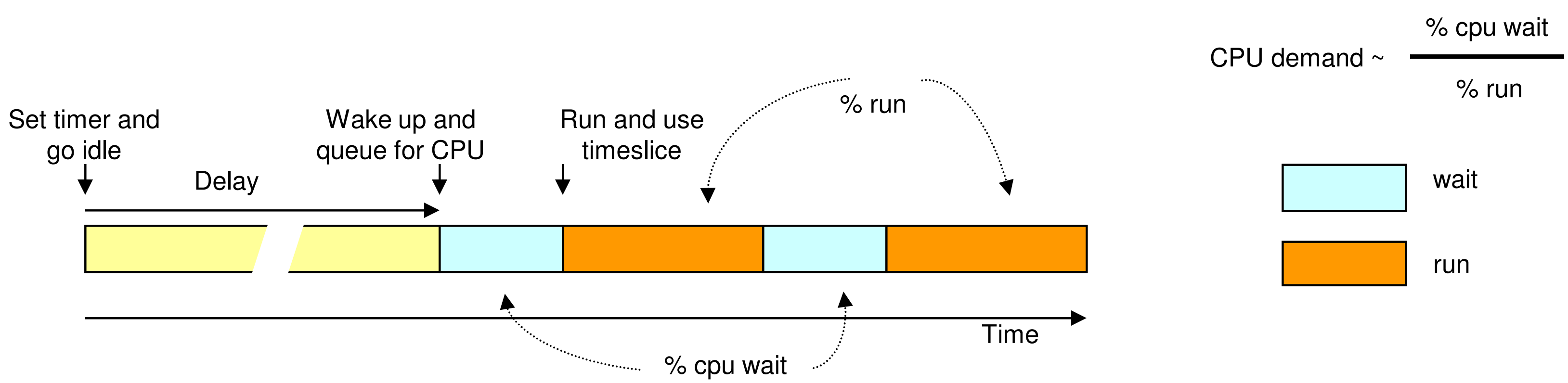
Virtual CPU State Sampling

- Done by z/VM monitor sampling, typically once per second
  - Counts how often running, waiting for CPU, idle, etc
  - CPU wait ratio indicates CPU contention



Polling process:
- Minimal CPU usage
- Short delay
- Mostly waiting for CPU

http://zvmperf.wordpress.com/2012/07/30/when-cpu-wait-is-misleading/

Polling and CPU State Sampling

- Polling inflates the CPU-wait numbers
  - As long as there is polling, Linux still has idle time
- Additional CPU capacity will only make it wait faster
  - CPU wait does not go away

```
1 of 1  Virtual CPU Wait State                    USER ROB01           2097 40F32
                  <--------- Virtual CPU State Percentage --------->  Poll
Time     User       Run CPUwt  CPwt Limit  IOwt PAGwt Othr Idle Dorm  Rate CPU%
-------- -------- ----- ----- ----- ----- ----- ----- ---- ---- ---- ----- ----
15:38:00 ROB01     20.0  26.7     0     0     0     0    0  253    0 648.0 27.1
15:54:00 ROB01     28.3   3.3     0     0     0     0    0 68.3  200 428.5 22.5
```

Virtual 3-way, 250% idle
Goes asleep 650 times/sec
Average 1.5 ms cycle
Using 0.3 ms per cycle

2 CPUs dormant, 70% idle
Less polling
CPUwt numbers are lower

Taming the Page Cache

Linux tries to find use for any excess memory

- Will cache data just-in-case
- Strategy is unproductive in shared environment
- Reference patterns interfere with z/VM paging

Just small enough, avoid excess memory

- Commonly suggested approach
- Even smaller with swap in VDISK to satisfy peaks

Hard to do with varying memory requirements

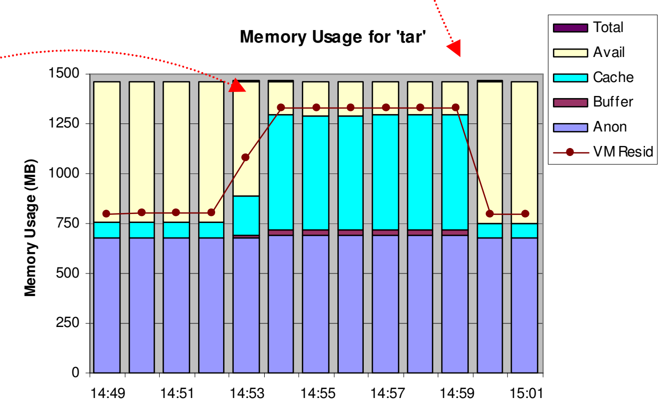
- Re-use of page cache may cause z/VM paging delays
- Large virtual machines require a lot of paging
- Tuning with cpuplugd is too slow to be effective

cmmflush - Flush out unused cached data at useful moments

- Removes all cached data and returns memory to z/VM
  - Use CMM driver to temporarily take away memory from Linux
- Challenge is to find good moment
  - After completion of unusual workload – avoids page-out of data
  - Before starting unusual workload – avoids page-in of data
- Disadvantages
  - Removes also useful data from cache
  - During flush process, the system may run out of memory
  - CPU overhead for returning pages to z/VM

cmmflush

Reading from disk



http://zvmperf.wordpress.com/2012/07/06/using-cmm-to-flush-a-linux-guests-memory/

nocache – Discourage Linux to Cache Data

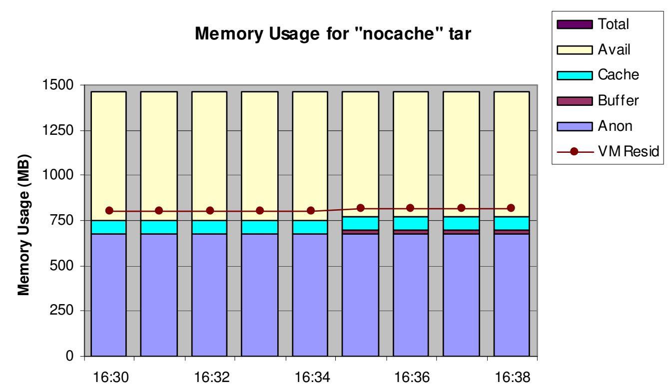
- Wrapper around application that wipes data from cache
  - Applies only to data touched by the application
  - Additional tools to selectively drop files from cache
- Useful for non-core applications
  - Backups, log file archival, security scanning, database load
- Experimental – Unsure yet how to package the function
  - Interested in feedback from users who want to try

total

cached

```
rvdheij@roblnx1:~> md5sum jvm-trc*
dbdeffb03e8e7c4659d869a52a99c202  jvm-trc5.txt
36e1b490a40dc7b01cdb0ea29d7867d2  jvm-trc6.txt
rvdheij@roblnx1:~> minc jvm-trc*
     450       450 jvm-trc5.txt
     450       450 jvm-trc6.txt
rvdheij@roblnx1:~> drop jvm-trc6.txt
rvdheij@roblnx1:~> minc jvm-trc*
     450       450 jvm-trc5.txt
     450         0 jvm-trc6.txt
```

dropped



http://zvmperf.wordpress.com/2013/01/31/the-nocache-approach/

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Single Guest or Multiple Guests

Single Guest

- No duplication of Linux infrastructure
- Less things to manage
- Obvious approach without virtualized servers
- No communication overhead, less latency
- Less components to break, simple availability

Multiple Guests

- Separation of applications
- Tune each guest separately
- Software levels specifically for application
- Easier to identify performance problems
- Simple charge back and accounting

Single Guest or Multiple Guests

Be prepared to efficiently manage multiple guests

- Invest in processes to create additional guests
  - Often most complexity is beyond actual creating the servers
  - Be aware of manual tasks that need repeated for each server
- Use something that matches skills and tools
  - Shared R/O disks versus "minimal install"
- Look at simplified reporting

Keep unrelated applications in separate guests

- Take advantage of server idle periods
  - Avoid a big guest with "always something going on"
- Simplify software upgrades and availability requirements

Keep related applications apart as long as it makes sense

- Many exceptions (small MySQL or DB2 configuration database)
- Be aware of the level of interaction between tiers

Single Guest or Multiple Guests

Example: Rehost z/OS application on Linux

- z/OS with DB2 and COBOL jobs
- Linux on z/VM with Micro Focus COBOL and DB2 LUW

Initial Configuration

- Linux guest running MF COBOL
- Linux guest with DB2 LUW
- Resulted in excessive run times and high CPU usage

High CPU Usage and Latency

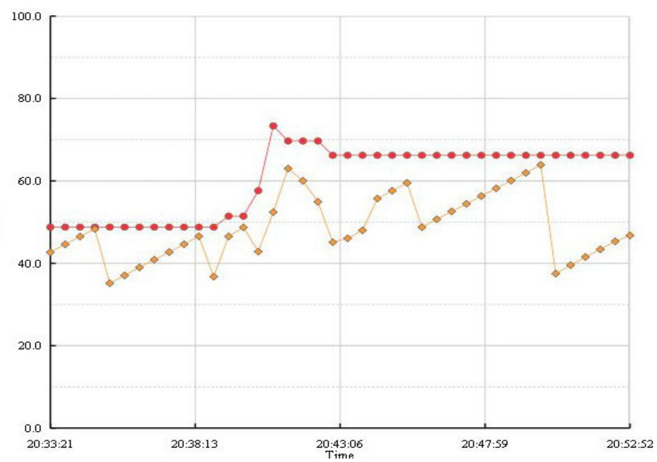
- Introduction of DRDA layer and TCP/IP comminication
  - More expensive than shared memory access under z/OS
- Less efficient cursor-based database access
- Run application and database in a single guest
  - Avoids overhead of DRDA and TCP/IP layer

Java heap size is one of most prominent parameters

- Java applications use the heap to store data
- Both temporary and persistent data
- Managed by regular Garbage Collection scans

Heap size is specified at JVM startup

- Usually kept in properties managed by application
- Defined by min and max heap size
- Heap grows until above configured minimum
  - Garbage collect tries to reclaim space
  - Extends heap until maximum
  - Returns excess beyond minimum



Heap size determines application footprint

- Requirement is determined by the application
  - Number of classes, active users, context size
  - Heap analyzers can reveal requirements
- Dedicated server approach sets min and max the same
  - Retains the full heap during JVM lifetime
  - Reduces GC overhead
  - Less attractive with shared resources
  - Hides heap requirements from Linux tools
- Alternative approach
  - Start with low minimum to see base requirement
  - Later adjust minimum to just above base requirement
  - Set maximum to absorb peaks

Java Applications

Garbage Collector Threads

- Option to spread GC over multiple CPUs
  - Only helps when they really will run
  - Consider to override the default of N slaves

Some applications require multiple JVM's

- Each will need its heap to be sized right
  - Total must fit in Linux memory
- Lower minimum heap size may be effective
  - One JVM can use what the other released
- Ignore single-shot Java programs

Keep production systems clean

- Do not install sample programs there
  - Security exposure
  - More than just disk space

Conclusion

Sizing does matter

- Linux on z/VM scales for large range of workloads
- Configuration options need to be coordinated
- Collect and study performance data
  - Compute normalized resource usage
  - Investigate exceptional usage
  - Your Linux admin may not have seen it that big either

Take advantage of virtualization

- Keep different workloads apart
- Tune the guest for that particular workload

Linux on z/VM Performance

Large Linux Guests

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