How To Turn a Penguin Into a Dog

…or…

Things To Do That Will Avoid Linux on z Success

Phil Smith III

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Goals

Examine Linux on z historical roadmap

Learn from others' hard-won experiences

Understand some things ***not*** to do—and why

Linux on z: Ancient History

1999: Linux released for (then) System/390

- IBM "skunkworks" effort
- Works, but not a "real" IBM product

2000: "41,000 Linux guests on a VM system"

- Proof-of-concept, no relation to reality
- Garnered tremendous press attention
- Vendors jump in: Linuxcare, Aduva, BMC…

Linux on z: Where We've Been

2001–2006: z/Linux growth slow

- IBM pushes Linux on z hard (IFL loaners, etc.)
- Many failed pilots, ROI not realized in many cases
- zSeries CPUs not fast enough to compete with Intel
- Levanta (Linuxcare), BMC, Aduva(?) quit market
- Rocket enters with Linux Provisioning Expert
- IBM adds Director for z

The Dirty Little Secret:

An *untuned* penguin can be a *dog!*

- But they're easily trained, with some tools and effort

Linux on z: Where We Are

2006–present: z/Linux starts to grow up

- New, faster processors (z9) make z competitive
- Nationwide, Wells Fargo, Citi, other “poster children” validate ROI

“Now it gets real…”

- …and now performance ***must*** be tamed!

Nationwide

WELLS FARGO

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Important History

Mainframes have been around for a while…

- z/OS (OS/390, MVS/ESA, MVS/XA, MVS, MVT, MFT): **43 years** (OS/360, 1964)
- z/VM (VM/ESA, VM/XA, VM/SP, VM/370, CP/67): **43 years** (CP/40, 1964)
- z/TPF (TPF, ACP): **43 years** (PARS, 1964)
- z/VSE (VSE/ESA, VSE/SP, DOS/VSE, DOS/VS): the youngster, **42 years** (DOS/360, 1965)

We’re spoiled by decades of experience

- We expect that someone, somewhere has done it all

The New Kid on the Block

Linux is just sixteen years old

- Elderly in penguin years…
- …still immature as an OS

Only seven years of mainframe Linux

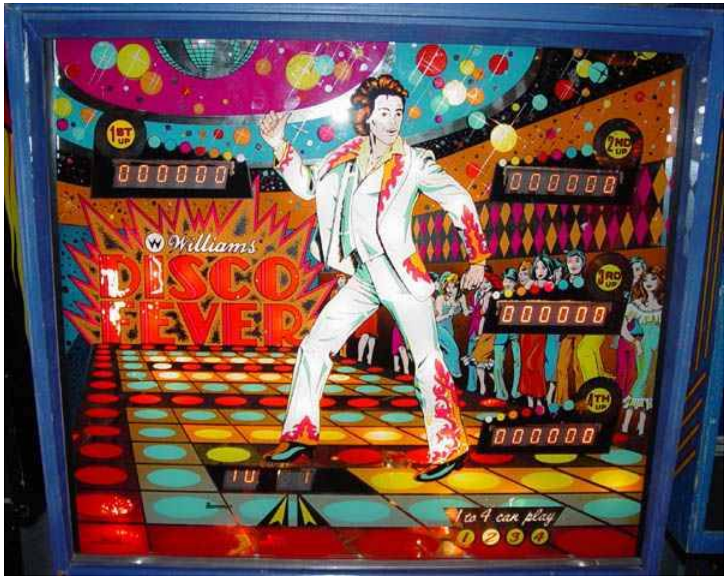
- Adult in dog or penguin years…
- Progress made, but many apps still ***not*** well-behaved!

z/Linux tuning and capacity planning still largely unknown territory to many

- Each new kernel level offers new opportunities (and old opportunities return with kernel changes!)

Nobody really knows all the answers yet

- This is like tuning MVS circa 1980
- …or maybe more like tuning VM/370 circa 1975



Not a reason to avoid Linux!

- Just something to keep awareness of
- You ***cannot*** believe everything you hear, good or bad

Linux Success Requirements

Management buy-in and distributed support group support

- Without both of these, either:
  - Management won’t care about success
  - Distributed folks will protect their turf and torpedo you
- Management can force distributed folks’ support

Appropriate application choices

- No fractal reductions, SETI@home
- Java OK in moderation (many apps are evil, though)
- VMware has similar constraints (plus no memory overcommitment)

More Success Requirements

A willingness to say “I was wrong”

- Some applications may turn out to be poor choices
- Some tuning choices will have the opposite effect
- **Requires a political climate that lets you say so**

Monitoring, tuning, and capacity planning

- IYDMIYWGS*
- Many Linux apps are ***not*** well-behaved, mature!
- Must make ***correct*** tuning choices

* If You Don’t Measure It You Will Get Screwed

Reasons Linux POCs Fail

Lack of management buy-in leading to distributed group non-support

- “They just didn’t show up for the meetings”

Inappropriate application choices

- “The application we chose just didn’t perform”
- “Management lost patience”

Disappointed by performance

- Without tools, no way to understand
- “There is no think, only do” — Master Yoda

The Real Cause

Inappropriate expectations

- Running thousands of Linuxen on one system
- “Just port it and it will run”
- “Mainframes are large and fast”

The reality

- Plan dozens or hundreds of Linuxen per system, ***tops***
- Porting requires understanding, (maybe) rearchitecting
- Mainframes are ***fairly*** large and ***fairly*** fast—now (z9)

How To Guarantee Failure

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Unmeasured Equals Unsuccessful

Make unjustified assumptions

- "Tune it like MVS" (aka "Linux apps are well-behaved")
- "The app needs 4GB on Intel, so we'll give it 4 on z"
- "More CPUs are good"
- "Swapping is bad"
- "z/VM is 64-bit, so we should run 64-bit Linux"

➢ Critical requirement: You ***must*** measure it!

- I've believed this since long before joining Velocity

Performance Tuning "Back in the day"

VM in days of old

- Hundreds (or thousands!) of CMS users
- Relatively small, well-behaved applications
- Performance degradation was typically gradual

Performance tuning was easier ***and*** harder

- **Easier**: smaller problems, smaller changes
- **Harder**: smaller changes, smaller effects

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Why Linux is Different

z/VM today

- Tens (or hundreds) of z/Linux guests
- Very large, often poorly behaved Linux applications
- Performance degradation can be precipitous

Performance tuning is harder ***and*** easier

- **Harder**: bigger problems, bigger changes
- **Easier**: bigger changes, bigger effects

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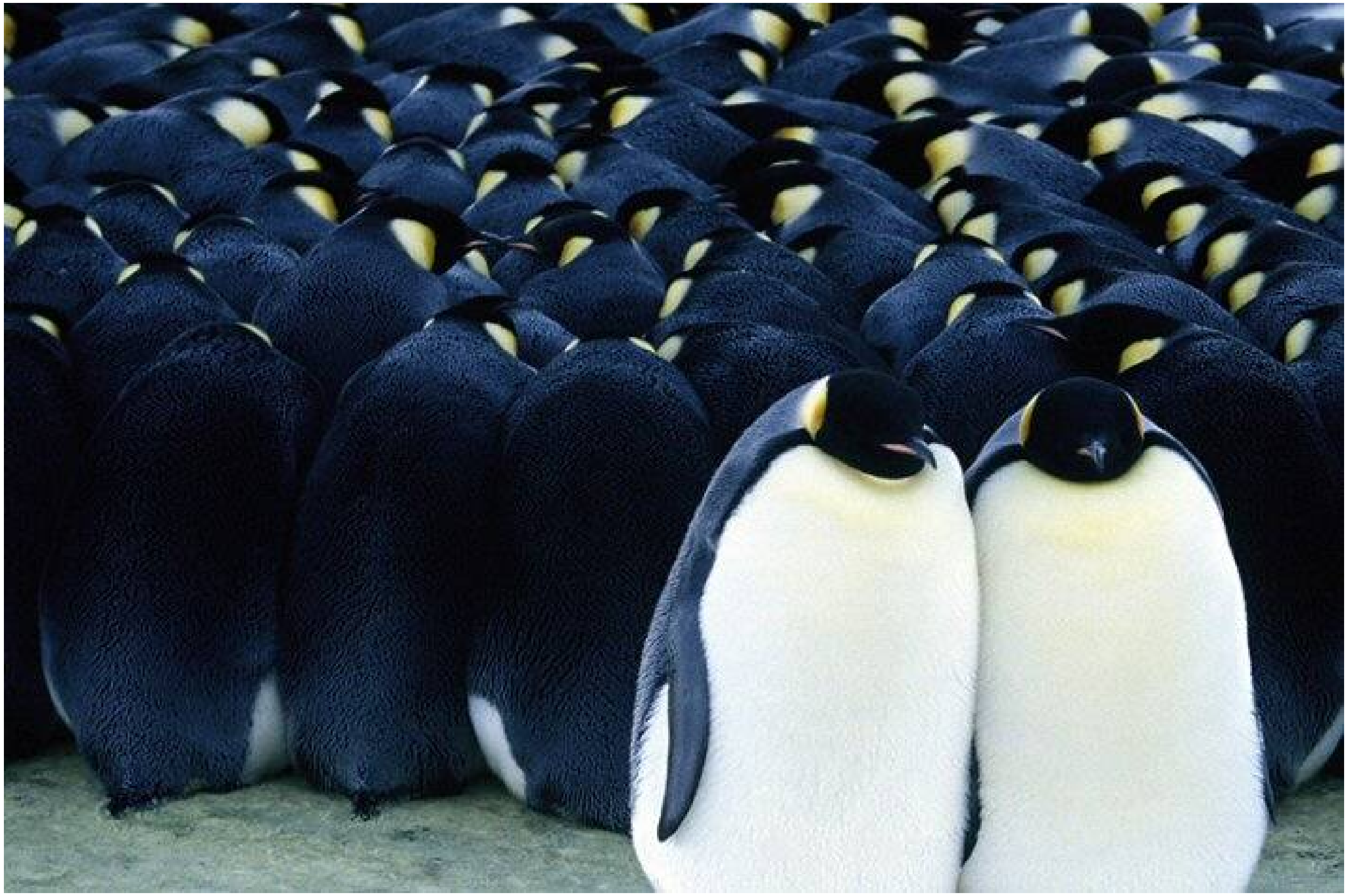

Herding Penguins

The single
most important
lesson in
this presentation

(but easier
than
herding cats)

*Your Penguins Must Sleep!**

Your idle Linux guests ***must*** go ***truly*** idle

- This is a ***memory*** (storage) management issue, ***not*** a CPU usage issue

What does “idle” mean?

- Means “transaction” complete, guest drops from queue
- CP defines 300ms of idle time = end of transaction
- Theoretically represents interactive user “think time”
- Less meaningful for s … er metric?

* Thanks to Rob van der Heij for this line!

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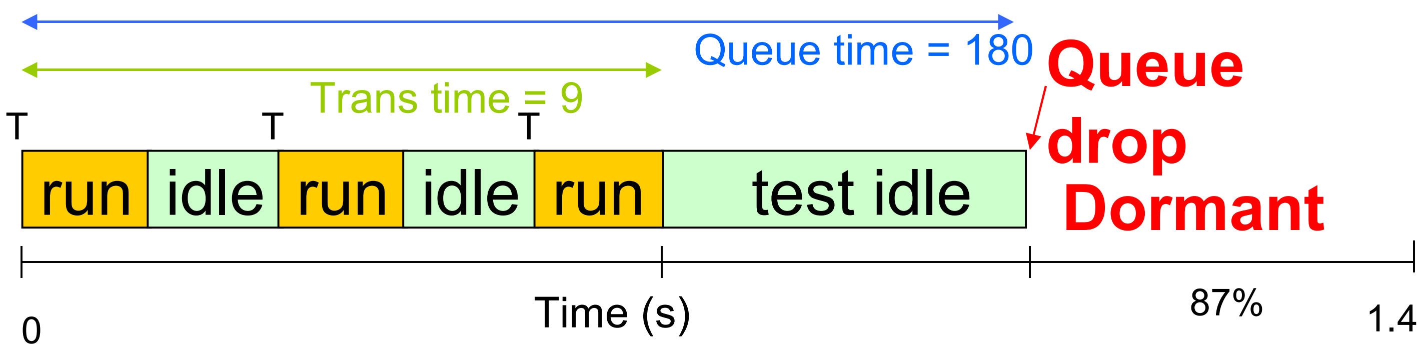
What's a "Transaction"?

Anatomy of the average transaction

- Periods of activity with short idle time between them
- Starts with a timer interrupt (or perhaps I/O interrupt)
- Longer idle period at end is followed by queue drop

Example:



Some critical concepts

- Guests must be ***runnable*** to do work
- CP must be willing to schedule the guest
- CP must be willing to dispatch the guest

A guest is always in one of three lists:

- **Dormant** list: guest has no work to do
- **Dispatch** list: guest is active, CP is allowing it to run
- **Eligible** list: guest is active, CP is not allowing it to run
- (Can also be **running**…special case of Dispatch list!)

CP **scheduler** analyzes resources, decides whether enough to give guest service

- Entirely storage-related (memory)
- If not enough available, guests get put on the E-list

CP **dispatcher** gives guests access to CPUs

- If multiple guests are active, they take turns
- VM is very good at this — supports tens of thousands of active users with excellent response time

Dispatch Classes – Class 1

When first dispatched, guest is Class 1 (“Q1”)

- CP waits one Class 1 Elapsed Timeslice (C1ETS) to see if it goes idle voluntarily
- Guests that do not go idle within that timeslice are preemptively stopped from execution— sent back to the scheduler
- C1ETS is dynamically calculated to keep a fixed % of guests in class 1
- C1ETS should be enough for short, interactive transactions (minor CMS commands)

Dispatch Classes – Class 2

If guest does not go idle in one C1ETS, it enters Class 2 (“Q2”)

- Next time CP runs it, given 8x C1ETS
- Guests that do not go idle within that amount of time are rescheduled
- Such guests are presumed to be running a command, but not necessarily doing something “major”

Dispatch Classes – Class 3

If guest does not go idle within class 2 C1ETS multiple, it enters Class 3 ("Q3")

- Next time CP runs it, given 6x Class 2 = 48x C1ETS
- Guests that do not go idle within that amount of time are rescheduled
- Such users are presumed to be running a long-running command

Dispatch Classes – Class 0

`QUICKDSP ON` bypasses some rules

- Still get rescheduled, but never held in eligible list

Interactive guests (on terminals, hitting keys) also get Q0 stays ("hotshot" stays)

- Still get rescheduled, but "go to head of line" briefly
- Return to their previous queue level after Q0 stay
- Virtual machines holding certain short-term system locks are also considered to be in Q0

Leaving the Dispatch List

Guests leave dispatch list because they:

- Use up their current C*n*ETS multiple
- Go idle voluntarily (load a wait PSW)—see below

300ms **test idle timer** set when guest loads wait PSW

- Guest resuming activity within that period are reinserted into previous place in queue
- Guests that don’t go idle never get queue dropped!

How This Plays Out…

CP scheduling is based on storage analysis

- If not enough, guests are held in **Eligible list** (**E-list**)
- Assumption: other guests will go idle, storage will become available soon
- If not, E-listed guests never get scheduled

Why This Goes Wrong

Linux real storage requirements higher than CMS guests because Linux guests:

- Are quite large (virtual storage size)
- Use all storage (working set = virtual storage size)
- Don't interact with CP to release unused storage
- Stay active (rarely/never go idle)

If enough Linux guests are logged on, CP notices it will overcommit real storage

- One or more such guests "lose", are E-listed — and stay there!

How Does This Manifest?

System is running along fine

- One guest too many is started
- Things “just stop”!

Dispatched guests “should” go idle

- Linux guests typically don’t, stay runnable all the time

Historically, guests doing I/O were “active”

- Recent releases have mostly eliminated this

Remember the test idle timer

- Guests never go idle (as far as CP can tell)
- Never get scheduled properly, so E-listing permanent!

`CP INDICATE QUEUES EXPANDED` shows:

```
LINUX902       Q3 PS  00013577/00013567 ....  -232.0 A00
LINUX901       Q3 PS  00030109/00030099 ....  -231.7 A00
VSCS           Q1 R   00000128/00000106 .I..  -208.7 A00
VMLINUX3       Q3 IO  00052962/00051162 ....  -.9398 A00
VMLINUX3 MP01  Q3 PS  00000000/00000000 ....   .0612 A00
LINUX123       E3 R   00177823/00196608 ....   5255. A00
```

- **`HELP INDICATE QUEUES`** shows meaning of output
- CP privilege class E required
- **Note:** “deadline time” (sixth column) indicates when CP thinks the guest will run
- Guest **`LINUX123`** is not running any time soon…

Remediation

Buy lots more storage ($<6K/GB — cheap!)

Tune applications so guests do queue drop

- Obviously only meaningful if guests are nominally idle
- Remember **cron** et al. may wake them anyway

Log off some guests

- You didn't need that WAS application, did you?

➢ **Tune guest storage sizes**

- Linux uses "extra" storage for file buffers
- Smaller guests may actually perform ***better***

Why Idle Guests are Important

CP analyzes storage use when guests go idle

- Avoids taking pages from active guests

Three-pass process

- First pass analyzes users on dormant list—never happens if Linux guests never go idle!
- Result: CP must steal pages, makes wrong guesses
- Causes thrashing—pages go out, come right back in

Linux and z/VM paging algorithms collide

- When Linux wants a page, where does it look? (LRU)
- Where is that page most likely to be?

Care and Feeding of Aptenodytes

Keeping
your penguins
from
becoming dogs

"Jiffies": Frequent Linux timer pops

- Controlled via setting in **`/proc`**

"Correct" setting is perhaps unintuitive

- 0 is what you want:
  `echo 0 > /proc/sys/kernel/hz_timer`

Why do "jiffies" hurt?

- 10ms is a lot less than the CP idle timer of 300ms
- Guests with the timer ON never go idle

Make sure "jiffies" are off!

Virtual Multiprocessors

Don’t use virtual MPs without ***good*** reason

- Most Linux applications don’t exploit MP
- Exception: apps that use more than one CPU of MIPS

Bogus advice, frequently heard: “Define as many vCPUs as real CPUs”

- Valid ***only*** in lab, single-Linux-guest environment

Note: Linux doesn’t report MP usage

- Harder to prove MP need (or lack thereof)

Virtual Multiprocessors

Why does this hurt?

- Guest isn't idle until all vCPUs are idle
- Virtual MP spreads timer events over vCPUs
- Thus MP = more transactions = more in-queue time

Bigger problem: significant CPU wastage

- Inter-vCPU management isn't free
- Linux spin locks can use an ***entire CPU***

Use virtual MP only if proven need

Extra Services

Be careful about **`cron`** and friends

- Services such as **`cron`** wake guests up from idle
- Obviously necessary in some cases, but examine, understand, and experiment!

Understand requirement for every service

- Watch for the "thundering herd" phenomenon
  - Things like Red Hat Network
  - All your guests waking up at once is ***not*** a good thing!
  - Examine, understand, and stagger the wakeups

- Avoid/aggregate services such as updates
  - Why check for updates on ***every*** guest?
  - Use a single update server!

z/VM no longer runs on 31-bit hardware

- 31-bit guests still supported, but…

Natural assumption: 64-bit guests “better”

- 64-bit guests require significantly more resources
- Page tables alone are twice as large (16MB per GB)
- Other control structures can also be significant

Use 64-bit guests only when > 2G virtual memory or specific application requirement

Large Virtual Storage (Memory)

Intel boxes have fast CPU, RAM; slow disk

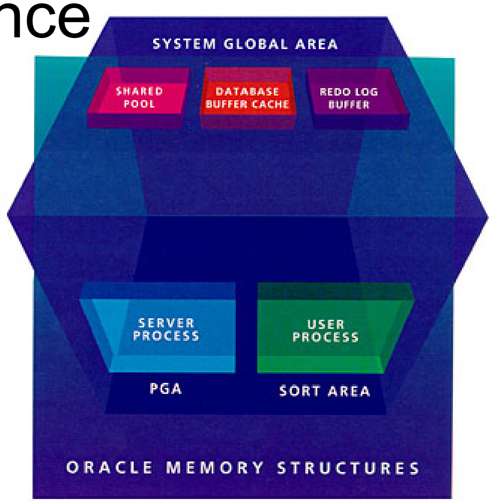
- Conventional wisdom: “Swapping is bad”

z/VM paging subsystem is pretty darned fast

- Conventional wisdom thus ***mostly wrong*** under z/VM

Most applications can stand to swap some

- Exception: Oracle Shared Global Area (SGA) ***must*** stay in-memory for reasonable performance
- Other exceptions surely exist



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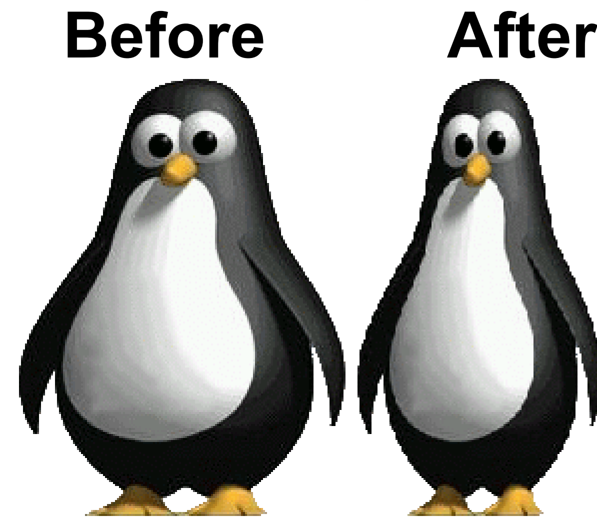
Large Virtual Storage (Memory)

Example: 256MB virtual storage vs. 1024MB

- 8MB more real storage required just for page tables
- 16MB if 64-bit guest!
- Significant even without actually **using** the storage!

Tune virtual storage sizes

- “Squeeze until it hurts”
- Then give it a bit more (or not)



Virtual Storage and Linux Caching

Linux caches data (read ***and*** write)

- Data may be replicated five times:
  1. Linux file buffers
  2. z/VM minidisk cache/paging subsystem
  3. Controller cache
  4. Device cache
  5. “Brown, round, & spinning”

Multiply cached data probably not helpful!

- Tuning virtual storage size controls this

VDISK vs. DASD

Swapping to DASD is slow

- Same as Intel, hence “Swapping is bad” ‘wisdom’
- ***But*** z/VM has VDISK (virtual disk in storage)
- “Minidisks” that exist in z/VM paging subsystem

Swapping to VDISK is ***way*** fast

- Linux still does I/O, but CP intercepts and handles
- Only slightly worse than page fault—and CP can manage VDISK better (LRU problem again)

Use small virtual storage + Swap to DASD to slow down guest that’s too fast ;-)

VDISK Myths and Realities

Fear: “VDISK will use too much real storage”

- Reality: VDISK lives in VM paging subsystem
- Linux virtual storage lives in VM paging subsystem
- Real storage use not really affected

Reality: VM does better managing both

- Use smaller Linux virtual storage + VDISK for swap
- VM controls both, rather than Linux caching data, causing VM paging through LRU mismatch

Myth: “VDISK pages never migrate to DASD”

- Fact: CP Monitor records prove otherwise

VDISK Notes and Recommendation

VDISK notes:

- Max size: 2G-1 page (4194296 512-byte blocks)
- Control via CP **`SET VDISK`** command (privileged)

Use *two* VDISKs, prioritized

- Linux “moving cursor” algorithm wanders across disk
- With one, large VDISK, entire disk winds up “dirty”
- With two, Linux will use higher priority first
- Avoids old, “dirty” pages lingering in VM paging space
- Note: “higher priority” is numeric — 10 is higher than 1 (unlike your tasks at work!)

Minidisk Cache

Minidisk cache (MDC) is a powerful tool

- But only for data that actually gets reread
- And not if the data is cached by Linux too…

Default: MDC uses both main and XSTORE

- CP “Arbiter” that controls XSTORE use seems broken
- MDC can use huge amounts of XSTORE for no gain
- Even decent MDC hit ratio may not justify increased paging load due to reduced main/XSTORE available

`CP SET MDCACHE XSTORE 0M 0M`

CP `SET QUICKDSP ON` *sounds* good

- "This guest is important, we want it to run fast!"

Reality: makes guest avoid scheduler, ***not*** "run faster"

- Circumvents scheduler "smarts"
- Result: when storage overcommitted, CP thrashes
- Result: worse performance for everyone

Use `QUICKDSP` only by prescription*

* And for MAINT, when you're doing performance tuning…!

SHAREs

ABSOLUTE SHAREs ***sound*** good

- "We can ensure that this machine gets *xx*% of a CPU!"

Reality: Difficult to manage with many guests

- With one or two, quite feasible—but at that point, RELATIVE SHAREs work just as well
- Use ABSOLUTE for TCPIP et al (machines others depend on) to ensure service even when system busy
- Note ABSOLUTE SHAREs are % of ***entire system***

Leave SHARE at **`RELATIVE 100`** unless addressing ***specific*** performance problem

CP SRM settings provide some system performance management "knobs"

- Be careful: These are ***big*** knobs
  - ➢ Misapplied, they ***will hurt!***

Default SRM settings based on CMS users

- Most are still OK for z/Linux
- Be careful of "lore" suggesting changes unsupported by measured results

SRM LDUBUF

Some "lore" suggests raising **`SRM LDUBUF`** is a good idea

- Actual measured results suggest otherwise
- Controls the number of "loading" users (users with significant paging activity) allowed in-queue

***Never never* increase this with z/Linux!**

- In large shops, may actually want to ***lower*** it
- E.g., 50 page packs on 8 CHPIDs—CP probably can't really support that many loading users

SRM STORBUF and XSTOR

STORBUF controls CP's storage usage calculations by queue

- Linux guests are always Q3, so default incorrect
- Best to essentially disable its function
- Default: **SET SRM STORBUF 125 95 75**
- Suggest: **SET SRM STORBUF 300 300 300**

Also: **SET SRM XSTOR 50%**

- Includes 50% of expanded storage in calculations

Measure results on your system!

z/VM 5.2 and 5.3

IBM has done ***tons*** of work to make z/VM a better host for Linux

- Example: fixes allow queue drop when I/O outstanding

z/VM 5.2/5.3 continue the tradition

- Many small enhancements that make Linux run better
- z/VM upgrades aren't a big deal any more

If you aren't on 5.2 or 5.3, get there ASAP!

- 5.3 is better, but is also brand-new
- You decide whether "bleeding edge" is appropriate for your shop

CMM: Collaborative Memory Management*

- Allows dynamic Linux storage tuning

Driver from IBM Böblingen

- Accepts commands via CP **`SMSG`**, allocates storage within Linux, tells CP “fuhgeddaboudit”
- CP no longer has to manage those pages

Lets you “inflate a balloon” within Linux

- Linux continues operation, working set greatly reduced
- If swapping becomes a problem, release some pages!

* Or possibly “Cooperative Memory Management” — nobody seems to be sure!

CMM In Action

Linux without CMM

4GB
virtual
storage

Linux with CMM

4GB
virtual
storage
minus *nn*
pages

Linux still ***thinks*** it has 4GB

“Rest” of storage ***not managed by VM***

Multiply savings by ***n*** guests…

CMM Benefits

- CMM avoids most of the complaints about storage tuning
  - “We don’t want to reboot”
  - “This isn’t peak load, and we can’t reboot when it is!”
- Critical for Linux success in some shops
  - Real example: Oracle said “App needs 4GB”; Linuxen have 4GB, but only 1GB ***really*** available!
  - Apps folks still ***think*** they have 4GB
  - Without CMM, *n* x 4GB = $$$ for more real storage (or unacceptable performance)

CMM2

z9 adds hardware support for "CMM2", aka "CMMA" ("CMM Assist")

- Cooperative z/VM–z/Linux page management
- Intended to reduce double paging, LRU thrashing

Adds CP **`SET`** and **`QUERY MEMASSIST`**

- Requires z/VM 5.2 with PTFs UM31784, UM31868
- SLES 10 SP1 supports via **`cmma=on`** IPL option
- No support in RHEL4 or RHEL5 (yet?)

No proven success in the field

- Stick with CMM(1) for now

XIP = eXecute-In-Place

- DCSSs under Linux, containing stored, shared data
- Manifest as special filesystem type

Use XIP when possible to share static data

- Common applications can save significant real storage
- Requires some management and care
- Evolving area, stay tuned!

Explore for common apps (SNMP, etc.)

Summary

Summary

Linux on System z is reaching adolescence

- Much progress made, lots more to do

Tuning Linux on z is an emerging science

- We're still learning, and it's a moving target

As always, use the community

z/Linux mailing list: **`LINUX-390@marist.edu`**

z/VM mailing list: **`IBM-VM@listserv.uark.edu`**

➢ **Measure, test, *prove* — don't rely on rumor, innuendo, and lore!**

Questions?

Contact Info

Phil Smith III

703.476.4511 (direct)

650.964.8867 (company)

phil@velocity-software.com

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