z/VM Scheduler Overview

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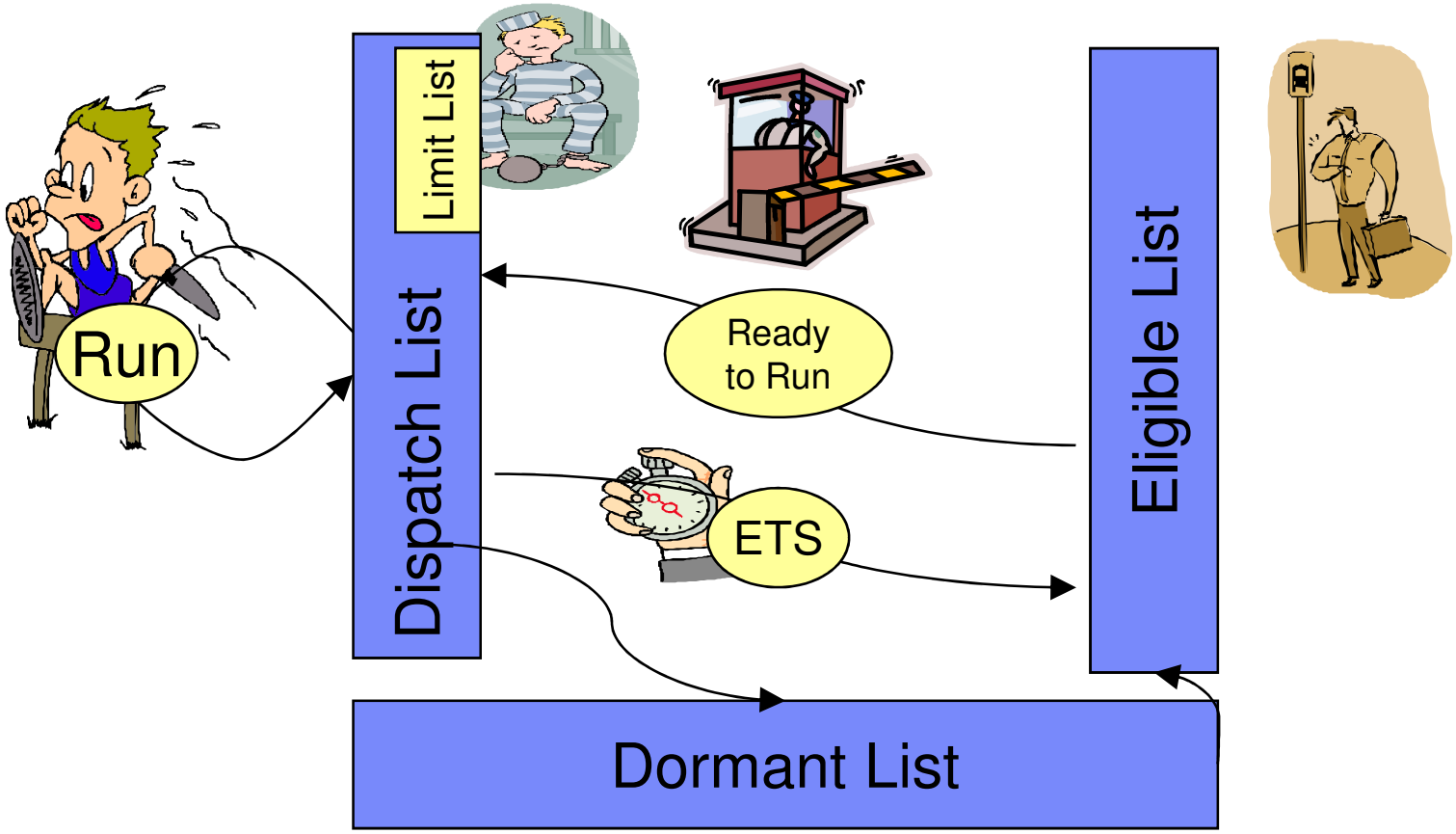
Introduction

- **Objectives**
  - Provide useful information on how the z/VM Scheduler works
  - Explore some tuning methodologies
  - This presentation will not make you an expert

- **Agenda**
  - Background on the Scheduler
  - How things work
  - Tuning guidance

The Main Loops

- **A virtual processor is in one of the following lists**
  - Dispatch List – (D-List, in Q) users ready or near-ready to run
  - Eligible List – (E-list) Delayed here when cannot "fit" in D-List
  - Dormant List – users that are idle (from view of the scheduler)



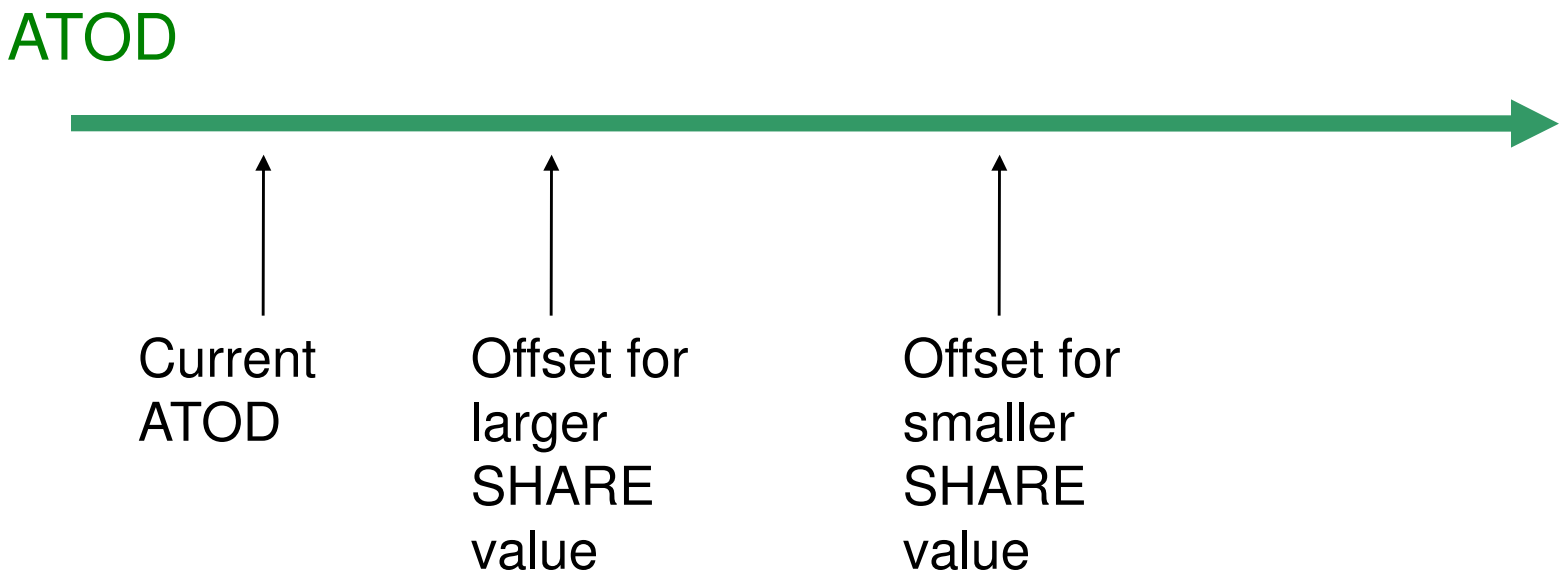
Class Structure

- **Virtual Processor belongs to one Transaction Class (at a time)**
  - 1: vCPU with “short-running” transactions
  - 2: vCPU with “medium-running” transactions
  - 3: vCPU with “long-running” transactions
  - 0: vCPU of special virtual machines or with special considerations (QUICKDSP ON, hotshot, lockshot virtual machines)
- **Elapsed Time Slice for each class**
  - Class 1 ETS is dynamic with goal of keeping n% of virtual machines in class 1
  - Class 2 ETS is 8 x C1ETS
  - Class 3 ETS is Max(48 x C1ETS, time to read in WSS)
  - Class 0 ETS is 6 x C1ETS
- **When entering E-list from Dormant list, start as class 1**
- **Move to next class when ETS expires and transaction is not complete**

Deadline Scheduling – Prioritizing Work

- Each virtual processor has a priority computed as a ‘deadline’ for when a unit of work should be completed
- This ‘deadline’ is a time value on an artificial TOD timeline often referred to as ‘ATOD’
- The ‘deadline’ is computed based on several factors, but the most significant is the normalized SHARE value
- Therefore the SHARE setting is a big knob
- Virtual processors are ordered for dispatching based on their deadlines
- With VM64721 or z/VM 6.2 and SET SRM LIMITHARD CONSUMPTION, limit SHAREs are controlled using a consumption method instead of a deadline method (more later)

ATOD and Deadline



Simplified formula used to compute deadline 'offset' from current ATOD:

$$\mathbf{OFFSET} = \frac{\mathbf{Minor\_TimeSlice + Previous\_TimeSlice\ Overrun}}{\mathbf{Normalized\_SHARE \times Number\_PUs}}$$

Entry to Eligible List

- **Determine if new transaction or Elapsed Time Slice end**
- **Establish new ETS**
- **Determine E-list priority based on**
  - User class
  - User resource consumption
  - System resource contention
  - SHARE setting
- **Determine estimated core working set size**

Stay in Eligible List or Move to Dispatch List?

- **Compute available memory for paging and largest user that can fit for each class**
- **Select vCPU to move to dispatch list**
  - Class 0 always selected
  - Not selected if user class is blocked
- **If virtual machine fits in memory then**
  - Select if also meets LDUBUF and DSPBUF limits
- **If virtual machine does not fit in memory then**
  - Select if user meets LDUBUF and DSPBUF limits and is only user in its class
  - Select if E1 and behind by certain delay factor (pre-empt another)
  - Block class if not E1 but behind schedule

Entry to Dispatch List

- **Calculate D-list priority with the following factors**
  - **ATOD**: Running timer in TOD form for user time
  - **OFFSET**: Used to initially offset from ATOD, based on other factors
  - **Paging Bias**: One-time priority boost given when the transaction is being continued and pages have been stolen
  - **IABIAS**: Interactive Bias – Priority boost based on SRM IABIAS settings
  - **Hotshot**: Priority boost given to user with transaction in progress who interacts with virtual console
- **OFFSET**

$$\frac{\text{Minor Time Slice + Previous Time Slice Overrun}}{\text{Dispatch List SHARE x Number of CPUs}}$$

- **Minor Timeslice: Minor dispatch timeslice (SRM DSPSLICE) in TOD units**
- **Previous Timeslice Overrun: Amount of time user exceeded previous minor timeslice**
- **Dispatch List SHARE: Factor of user's SHARE and time spent in eligible list**

End of Minor Timeslice (Dispatch Slice)

- Recalculate D-list priority much like the first time
- Update some statistics
- If vCPU added to dispatch list by hotshot, then set flag to drop
- Set flags to indicate if need to limit vCPU

Drop from Dispatch List

- **Give a grace period before dropping – Test Idle**
  - 300 milliseconds
- **Update statistics based on why dropping**
- **Keep track of status to help determine monitor transaction end**
- **Calculate resource consumption values for later**
  - Estimated Core Working Set Size (WSS)
  - Paging Rate
- **Record other resource statistics (user and system)**
- **Optionally cut monitor record**

Preempting Virtual Machines

- **Find user in D-list to preempt to make room for class 1 user to run that has been held in E-list**
- **Preempt user if**
  - Not class 0 or class 1
  - Not under the influence of a bias
  - Not last user in dispatch list of their class

QUERY Commands of Interest

```
CP QUERY SRM
IABIAS : INTENSITY=90%; DURATION=2
LDUBUF : Q1=200% Q2=200% Q3=200%
STORBUF: Q1=300% Q2=200% Q3=200%
DSPBUF : Q1=32767 Q2=32767 Q3=32767
DISPATCHING MINOR TIMESLICE = 5 MS
MAXWSS : LIMIT=9999%
...... : PAGES=999999
XSTORE : 0%
LIMITHARD METHOD: CONSUMPTION
```

QUERY Commands of Interest

```
CP QUERY QUICKDSP TCPIP
USER TCPIP    :  QUICKDSP = ON
Ready;
```

```
CP QUERY SHARE AVATAR
USER AVATAR  :  CP   RELATIVE SHARE = 90
                     MAXIMUM SHARE = LIMITSOFT RELATIVE 150
                ZAAP RELATIVE SHARE = 90
                     MAXIMUM SHARE = LIMITSOFT RELATIVE 150
                IFL  RELATIVE SHARE = 90
                     MAXIMUM SHARE = LIMITSOFT RELATIVE 150
                ICF  RELATIVE SHARE = 90
                     MAXIMUM SHARE = LIMITSOFT RELATIVE 150
                ZIIP RELATIVE SHARE = 90
                     MAXIMUM SHARE = LIMITSOFT RELATIVE 150
Ready;
```

INDICATE QUEUES EXPANDED command

```
CP INDICATE QUEUE EXP
EDLLIB14      Q3 IO  00002473/00002654 ..D. -.0217 A00
KAZDAKC       Q3 IO  00003964/00003572 .... -.0190 A02
BITNER        Q1 R00 00001073/00001054 .I.. -.0163 A01
LCRAMER       Q3 IO  00003122/00002850 ....  .0259 A00
DSSERV        L0 R   00007290/00007289 ....  .3229 A00
RSCS          Q0 PS  00001638/00001616 .I..  99999 A00
SICIGANO      Q3 PS  00000662/00000662 .I..  99999 A00
VMLINUX1      Q3 PS  00018063/00018063 ....  99999 A02
LNXREGR       Q3 PS  00073326/00073210 ....  99999 A02
VMLINUX       Q3 PS  00031672/00031672 ....  99999 A01
TCPIP         Q0 PS  00018863/00018397 .I..  99999 A02
EDLLNX2       Q3 PS  00032497/00032497 ....  99999 A01
EDLLNX1       Q3 PS  00015939/00015939 ....  99999 A02
```

INDICATE QUEUES EXPANDED Status Indicators

- H - Hotshot
- L - Lock-shot

- I - Interactive bias

- D - Past eligible list deadline
- M - Exceeded maximum allowed working set size
- P - Returned to eligible list because of preemption
- G - Returned to eligible list for exceeding WSS growth limit
- L - In eligible list after dispatch list lock-shot

- L - Loading user

Performance Toolkit – FCX145 SCHEDLOG (Option 3F)

Interval End Time	Total VMDBK in Q	Users in Dispatch List <- Loading -> Q0	Q1	Q2	Q3	Limit Lst	In Eligible List <Loading-> E1	E2	E3
>>Mean>>	268	2.8	2.4	4.4	258	.0	.0	.0	1.4	.0	.0	.0	.0	.0	.0	.0
10:42:00	269	2.0	4.0	19	244	.0	.0	.0	1.0	.0	.0	.0	.0	.0	.0	.0
10:43:00	271	3.0	5.0	1.0	262	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10:44:00	268	3.0	3.0	1.0	261	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10:45:00	261	2.0	1.0	1.0	257	.0	.0	.0	2.0	.0	.0	.0	.0	.0	.0	.0
10:46:00	271	3.0	3.0	2.0	263	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10:47:00	274	3.0	5.0	1.0	265	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
10:48:00	267	2.0	2.0	2.0	261	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0

Class 1 Elapsed T-Slice	Sum of Abs. Shares	Sum of Rel. Shares	Storage (Pages) Total Consid	<----- Total WSS -----> Q0	Q1	Q2	Q3
1.720	0%	252395	66509k	1353	11512	415k	78M
1.836	0%	252433	66508k	910	9092	1819k	76M
1.798	0%	255733	66509k	1021	51097	7621	78M
1.758	0%	252267	66509k	1482	13098	59224	78M
1.847	0%	244367	66509k	1199	3565	5532	79M
1.836	0%	254934	66509k	1799	3773	62344	79M
1.921	0%	257600	66509k	1746	9956	56638	78M

Performance Toolkit – FCX154 SYSSET (Option F)

```
Initial Scheduler Settings: 2011/05/11 at 10:40:31
DSPSLICE (minor) 5.000 msec.          IABIAS Intensity    90 Percent
Hotshot T-slice  1.999 msec.          IABIAS Duration      2 Minor T-slices
DSPBUF Q1        32767 Openings       STORBUF Q1 Q2 Q3   400 % Main storage
DSPBUF Q1 Q2     32767 Openings       STORBUF Q2 Q3      400 % Main storage
DSPBUF Q1 Q2 Q3  32767 Openings       STORBUF Q3         400 % Main storage
LDUBUF Q1 Q2 Q3    100 % Paging exp.  Max. working set  9999 % Main storage
LDUBUF Q2 Q3       100 % Paging exp.  Loading user        5 Pgrd / T-slice
LDUBUF Q3          100 % Paging exp.  Loading capacity   70 Paging expos.
LIMITHARD algorithm    Deadline
Changed Scheduler Settings
Date  Time      Changed
..... ........  No changes processed
```

Performance Toolkit – FCX226 UCONF (Option 28)

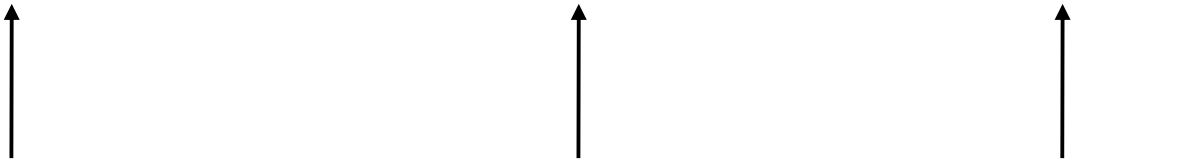
Userid	SVM	Mach Mode	Flg ReO	Qck DSP	No MDC Fair	Atta-ched XSTOR	Stor Size	Reserved Pages
BILL	**No**	**ESA**	**---**	**Off**	**No**	**0**	**32M**	**0**
LINUX001	**No**	**EME**	**---**	**Off**	**No**	**0**	**1024M**	**0**
LINUX002	**No**	**EME**	**---**	**Off**	**No**	**0**	**1024M**	**0**

	<---- Virt. CPUs ----->				
Userid	Type	Aff	Def.	Ded.	Stop
BILL	**IFL**	**On**	**1**	**0**	**0**
LINUX001	**IFL**	**On**	**1**	**0**	**0**
LINUX002	**IFL**	**On**	**1**	**0**	**0**

	<- Share -->		<-- Max Share --->		
		%			%
Userid	SRel.	SAbs.	Limit	MRel.	MAbs.
BILL	**1000**	**...**	**Hard**	**...**	**30**
LINUX001	**2000**	**...**	**...**	**...**	**...**
LINUX002	**2000**	**...**	**...**	**...**	**...**

Performance Toolkit – FCX114 USTAT (Option 23)

Userid	%ACT	%RUN	%CPU	%LDG	%PGW	%IOW	%SIM	%TIW	%CFW	%IOA	%PGA	%LIM	%OTH
>System<	**10**	**0**	**0**	**0**	**0**	**5**	**1**	**61**	**0**	**1**	**0**	**0**	**0**
PDISRV	**0**	**33**	**33**	**0**	**0**	**0**	**0**	**33**	**0**	**0**	**0**	**0**	**0**
EDLWRK15	**1**	**5**	**15**	**0**	**0**	**56**	**21**	**3**	**0**	**0**	**0**	**0**	**0**
EDLWRK10	**1**	**7**	**10**	**0**	**0**	**53**	**27**	**2**	**0**	**0**	**0**	**0**	**0**
EDLWRK12	**1**	**15**	**10**	**0**	**0**	**61**	**14**	**0**	**0**	**0**	**0**	**0**	**0**



CPU Wait

Test Idle

Limit List Delay

Other Monitor Data

- **Monitor Records:**
  - Domain 2: Scheduler Domain
    - Add/Drop to D-List
    - Add to E-list
    - Add/Drop to L-List
    - System Timer Pop
    - Various changes
  - Domain 4: User Domain
    - Transaction End information

QUICKDSP Tuning

- **Command: SET QUICKDSP userid ON**
- **Directory: OPTION QUICKDSP**
- **User becomes transaction class 0 and thus never waits in the eligible list.**
- **Affects decision to move from E-list to D-list on virtual machine basis**
- **Does not change SHARE normalization**
- **Does influence Elapsed Time Slice, making it similar to Class 2**
- **Recommended for**
  - Mission Critical Servers
  - Virtual Machines that are extensions of Operating System
    - RACF, TCP/IP, SFS, etc.
  - Key systems management virtual machines (e.g., guest you use to set tuning values)

Fitting in Storage

- **Total Available Memory =**
  - Total DPA page frames
  - Minus non-pageable frames
  - Minus system owned resident shared frames
  - Minus system owned locked frames
- **SCLADL_SRMTOTST monitor field**
- **QUERY FRAMES “Pageable” field is rough approximation**
- **Performance Toolkit FCX145 SCHEDLOG “Total Consid.”**
- **Also shows current totals for each class**
- **Add XSTORE bonus if applicable**

SRM STORBUF Tuning

- **Protects system from thrashing on memory**
- **Command: SET SRM STORBUF p1 p2 p3**
- **Affects decision to move from E-list to D-list on a class basis**
  - P1: percentage of memory available for classes 1,2,3
  - P2: percentage of memory available for class 2, 3
  - P3: percentage of memory available for class 3
- **Defaults**
  - z/VM 5.4 & 6.1: 125 105 95
  - z/VM 6.2 & 6.3: 300 250 200
- **Recommendation for Linux and other non-CMS environments: 300 250 200**

SET SRM XSTORE Tuning

- **Command: SET SRM XSTORE percentage**
- **Affects decision to move from E-list to D-list on system basis**
- **Determines how much expanded storage to view as real storage for purpose of fitting user in STORBUF limitation**
- **Percentage of existing expanded storage to add to available storage**

STORBUF Tuning Example

- **Guests showing up in E-list**
  - Get estimated WSS size and class
  - Increase STORBUF appropriately
- **Example**
  - 96GB of available memory
  - Two guests with WSS of 32GB each constantly appear as E3 users.
  - Currently: STORBUF 100 85 75
  - 64 / 96 = 67%
  - Increase STORBUF by 70 (round up the 67)
    - SET SRM STORBUF 170 155 145

SRM LDUBUF Tuning

- **Protects system from thrashing on paging devices**
- **Command: SET SRM LDUBUF p1 p2 p3**
- **Affects decision to move from E-list to D-list on a class basis**
  - P1: percentage of memory available for classes 1,2,3
  - P2: percentage of memory available for class 2, 3
  - P3: percentage of memory available for class 3
- **Defaults: 100 75 60**
- **Recommendation for Linux and other non-CMS environments:**
  - Use defaults
  - Consider increasing if you consolidate smaller paging volumes to larger ones (e.g., mod 9s to mod 27s)
  - For z/VM 6.3 – In some scenarios, increasing LDUBUF might be necessary – z/VM Development is pursuing

SRM DSPBUF Tuning

- **Controls the absolute number of virtual CPUs allowed in the D-list for each class**
- **Command: SET SRM DSPBUF n1 n2 n3**
  - N1: number of class 1 vCPUs permitted in D-list
  - N2: number of class 2 vCPUs permitted in D-list
  - N3: number of class 3 vCPUs permitted in D-list
- **Defaults: 32676 32767 32767 = basically off**
- **Leave this command alone unless instructed otherwise by a z/VM performance expert**

SHARE Tuning

- **Two flavors**
  - Absolute
  - Relative
- **Affects calculation of D-list priority on user basis (directly) and system basis (indirectly)**
- **SHAREs normalized before being used with other users in D-list and E-list per processor type**
  - If sum of absolutes is > 99%, then normalized to 99%
  - Relatives normalized to absolute remainder
- **There is a minimum (regular) SHARE and a limit (maximum) SHARE**
- **Performance Toolkit FCX145 SCHEDLOG**
  - “Sum of Abs. Shares”
  - “Sum of Rel. Shares”

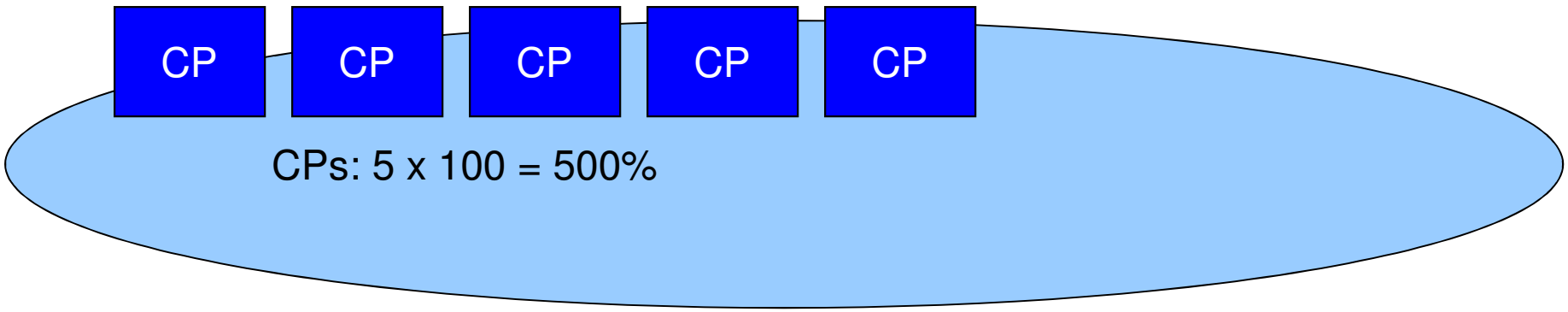
ABSOLUTE SHARE Tuning

- **Command: SET SHARE userid ABSOLUTE ppp%**
- **Directory: SHARE ABSOLUTE ppp%**
- **Percentage of system resources for user, in range 0.1 to 100%**
- **Value stays constant as long as sum < 99%**

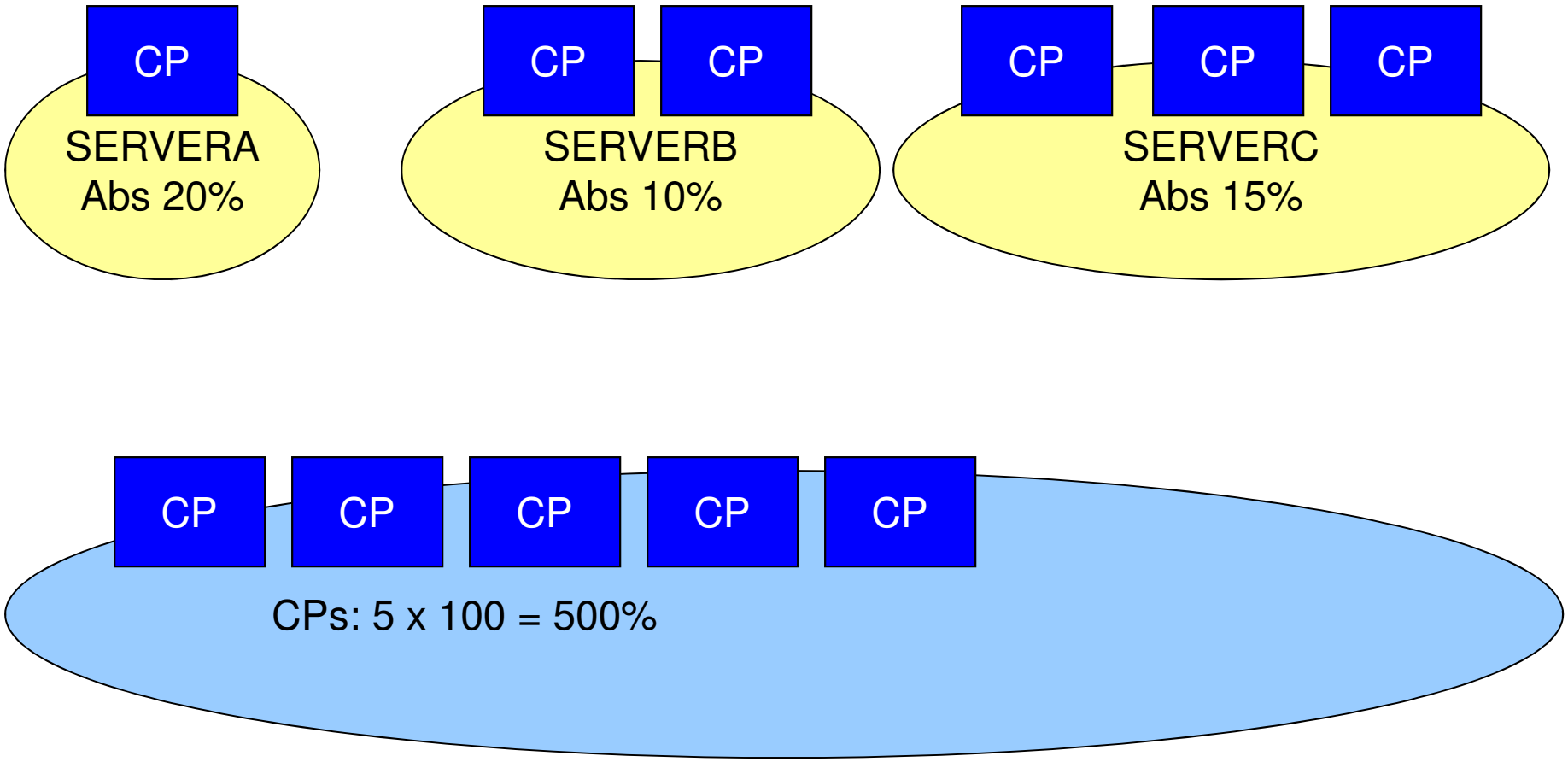
RELATIVE SHARE Tuning

- **Command: SET SHARE userid RELATIVE nnnnnn**
- **Directory: SHARE RELATIVE nnnnnn**
- **Value from 1 to 10000 (bigger being more important)**
- **As system becomes busier (more vCPUs in D-list), a relative SHARE is normalized to a smaller value**

SHARE Tuning Example

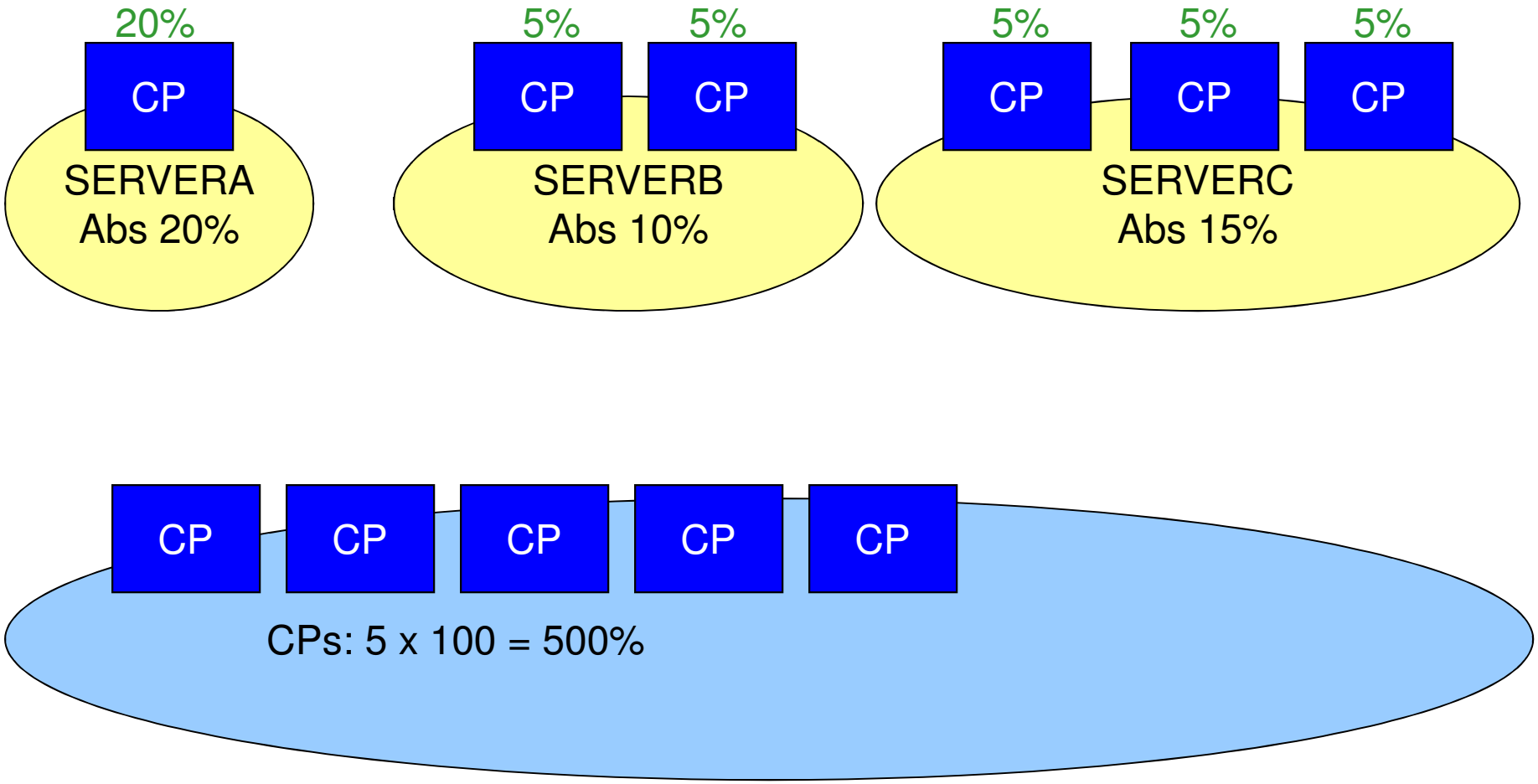


SHARE Tuning Example



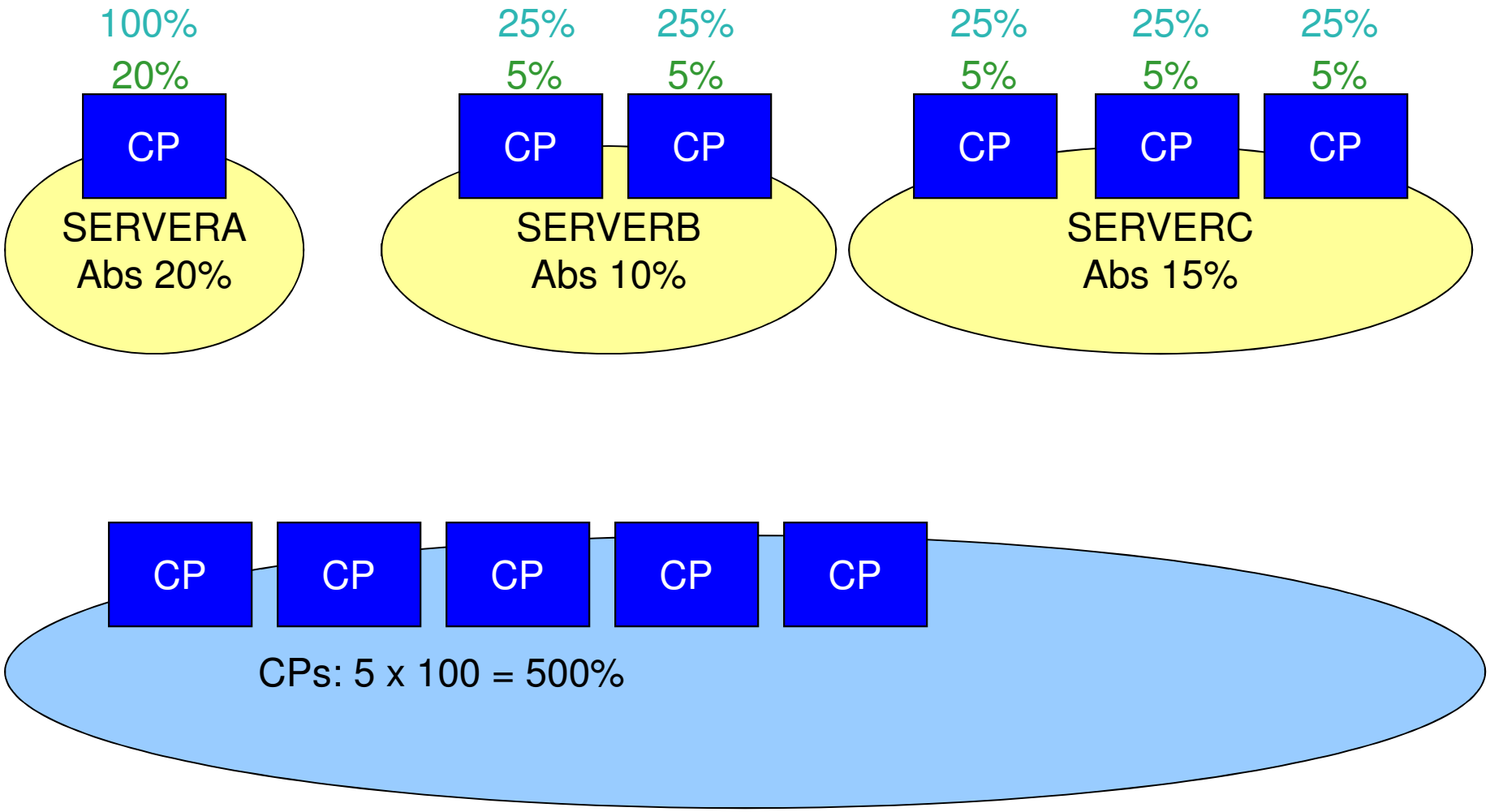
SHARE Tuning Example

NN% = split of SHARE per virtual processor



SHARE Tuning Example

NN% = (IPW) In Perfect World percentage of real processor
NN% = split of SHARE per virtual processor



Maximum and Limit SHARE Settings

- **Command and Directory have additional settings:**
  - e.g., SET SHARE userid REL 2000 ABS 20% LIMITHARD
  - Second value ('ABS 20%') is limit SHARE
- **Limit SHARE can be relative or absolute**
- **Two types**
  - LIMITSOFT: only allow virtual machine to use more than this amount of CPU if no other virtual machine needs the resources
  - LIMITHARD: do not give the virtual machine more than this amount of CPU even if available.
- **ABSOLUTE LIMITHARD managed differently based on SET SRM LIMITHARD control added by VM64721 in z/VM 5.4 and 6.1 (in base of z/VM 6.2)**
  - SET SRM LIMITHARD DEADLINE
    - Behavior default with APAR in z/VM 5.4 and 6.1
  - SET SRM LIMITHARD CONSUMPTION allows better accuracy
    - Became default in z/VM 6.2

Virtual MP Guests and Specialty Engines

- **SHARE value distributed among the virtual processors**
  - E.g., Relative 100 on virtual 4-way treated as four Relative 25 1-way virtual machines
- **SHARE of virtual CPU in architectural stopped state is redistributed to the non-stopped virtual CPUs**
- **The base VMDBK (vCPU) owns the memory of the virtual machine along with other key resources and stays in the D-list if any of the other vCPUs is there**
- **SHARE constructs and ATOD are duplicated for each processor type available to the z/VM system**
- **Virtual machine can have different SHARE settings for each processor type**

Other Considerations

- **Priority (offset) calculation based on minimum or normal SHARE**
- **Effectiveness of tuning**
  - E.g., if gated by I/O, could limit how much CPU can be used
- **Absolute does not mean “exact” or “precise”**
- **Dedicating processors requires changing how you look at things**
- **TOD Tied concept**
- **Maxfall concept**
- **Growth Limit**

Undesirable Behaviors

- **Stuck in E-list**
  - E-list deadline gets set much too far (hours) in the future in severe scenarios, even when no one else wants to run
- **Non-dormant Dormant**
  - In highly constrained systems, user waiting on what should be short process (such as a page read), appears idle because task takes over 300 milliseconds
  - Virtual machine ends up in dormant list, making analysis more difficult or misleading
- **No Control on C1ETS**
  - Sometimes being able to bound class 1 ETS would be helpful.
- **Surplus or Excess SHARE Distribution**
  - If entitled SHARE not used by virtual machines, excess or surplus is distributed to other virtual machines that can use it
  - In some scenarios, excess is not distributed proportionally to the normalized SHARE, but is given to the virtual machine with the highest normalized SHARE value

Summary

- Virtual Machines travel through various lists in VM scheduling, making various stops
- You can see where the virtual machines are and have been through various monitoring tools
- There are commands and tools that can influence the behavior of the system and of individual virtual machines