



Capping Technologies and 4HRA Optimization

- Comparison of Hard and Soft-capping Controls
- Capping Implementation
- Defined Capacity and Group Capacity Management using z/OS Capacity Provisioning

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Agenda

- **Overview of capping types**
- Initial capping
- Absolute capping
- Defined capacity & group capacity
- Resource group capping and Tenant Resource Group (*) capping
- 4HRA management
- Additional Material



Reasons you would consider capping techniques...

Technical motivation

- Protect/isolate LPARs against other LPARs, e.g. multi-tenancy
- Influence capacity-based workload routing
- Guarantee unused CPC processor capacity
- Protect workloads (sets of service classes) against other workloads

Financial motivation

- Limit software cost
 - Guaranteed capacity limit for one or more LPARs
 - Four hour rolling average (4HRA) consumption
- Take benefit of Container Pricing for IBM Z solutions based on “Tenant Resource Group (TRG) technology (*)

- Possible impact of capping needs to be monitored and accepted
- Cap limits should be adjusted as appropriate
 - Watch your SLAs

Comparison of capping types

* Statements regarding IBM future direction and intent are subject to change or withdrawal, and represent goals and objectives only.

Type of capping	Scope	Specification unit	Proc types	Suitable to isolate LPAR(s), or or enforce hard consumption limit	Control point
Initial (hard) capping	LPAR	LPAR share of CPC capacity	Any	Yes	SE/HMC
LPAR Absolute capping (zEC12 GA2 and later)	LPAR	Fractional #processors		Yes	
LPAR Group Absolute Capping (z13 GA2 and later)	Group of LPARs	Fractional #processors		Yes	
Defined capacity (DC, soft capping)	LPAR	MSU (4HRA)	CP	No	SE/HMC + IEAOPT
LPAR group capacity (GC, soft capping)	Group of LPARs	MSU (4HRA)		No	
Absolute MSU Capping	LPAR or Group	MSU		Yes -Only for CPs-	
Resource group or Tenant Resource Group (*) capping	Groups of service classes or Tenant Report Classes in Sysplex or per LPAR	Unweighted CPU SU/sec, fraction of LPAR share, or fractional #CPs	CP or combined	N/A	WLM Policy
Logical configuration	LPAR	Integer #processors	Any	Yes	HMC+OS

PR/SM controlled

WLM controlled, PR/SM enforced

WLM controlled

Which capping techniques may be combined?

– For same processor type. See next chart for legend–

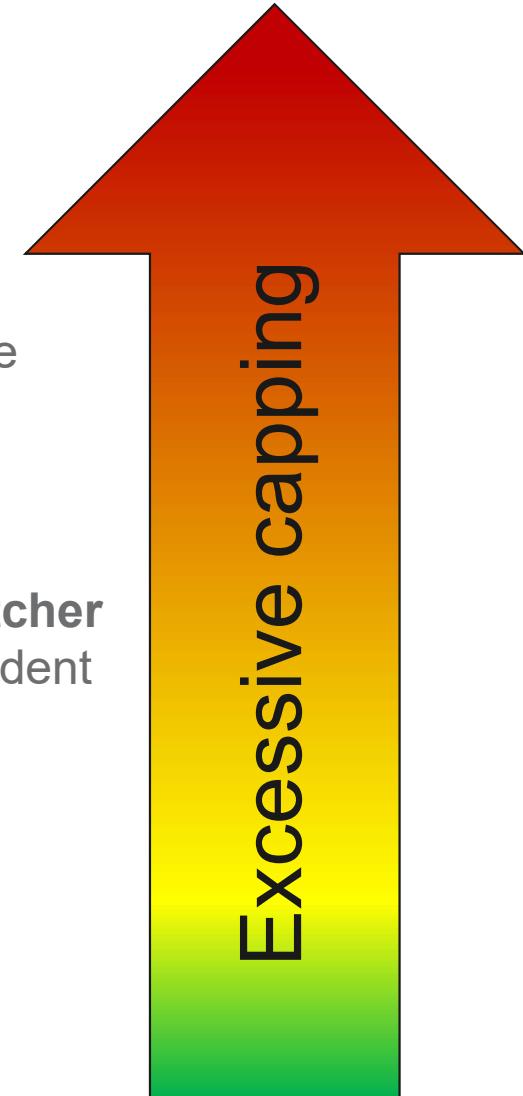
Type of capping ➔	Initial (hard capping)	LPAR Absolute capping	LPAR Absolute group capping ⁽²⁾	Defined capacity ⁽¹⁾	LPAR group capacity ^(1,2)	Resource group capping	Tenant Resource Group capping (*)
Initial (hard capping)		+	+	– (3)	– (3)	+	+
LPAR Absolute capping			+	+	+	+	+
LPAR Group Absolute capping ⁽²⁾				+	+	+	+
Defined capacity ⁽¹⁾					+	+	+
LPAR group capacity ^(1,2)						+	+
Resource group capping							+ (4)
Tenant Resource Group capping(*)							

Legend for *Which capping techniques may be combined?*

- 1) Includes ABSMSUCAPPING=NO and ABSMSUCAPPING=YES
- 2) Any LPAR can be defined to one group at most:
Therefore, the group used for LPAR absolute group is the same as the group capping group
- 3) When initial capping is in effect, WLM cannot control capping:
 - Any defined capacity limit, if specified, will be ignored
 - The LPAR will not join a capacity group, or leave it, respectively.
- 4) Resource group and Tenant Resource Group capping may be combined within a service definition, but
 - A service class that is associated with a resource group cannot be assigned a Tenant Report Class. In other words:
Any work unit may be capped through a resource group, or tenant resource group, but never both.

Possible impacts of (excessive) capping

- **Sysplex / multi system outage**
 - E.g. for LOCKs or RESERVEs not being freed timely
- **System outage**
 - E.g. for resources not being freed timely
 - Storage shortages
 - Work (e.g. SRBs) backed up, common storage shortage
- **Important work displaced**
- **Service levels missed**
- **Contention and increased promotion by SRM or dispatcher**
 - Can be unproblematic if displaced work is truly independent from important work – no shared resources
- **Less important work displaced**
- **Goals missed**
- **Increased response times**
- **Increased CPU delays**



Container Pricing for IBM Z

- **Announcement** excerpt:

IBM is introducing Container Pricing for IBM Z for qualified solutions running on IBM z13 and z14 servers. Container Pricing will provide simplified software pricing for qualified solutions, combining flexible deployment options with competitive economics that are directly relevant to those solutions.

- Container Pricing can scale from collocated solutions within existing LPARs, through to separate LPARs, up to multiple-LPAR solutions, without directly impacting the cost of unrelated workloads. Additionally, Container Pricing will simplify pricing and billing on the IBM Z platform, by superseding a number of existing price offerings and by fully automating the billing process.
- IBM initially announces three solutions that will be enabled with Container Pricing:
 - The New Application Solution will provide a highly competitive stand-alone priced offering for new z/OS applications, such as CICS® TS or WebSphere applications. The New Application Solution is the strategic replacement for the current zCAP and IWP priced offerings.
 - The Application Development and Test Solution will provide highly competitive stand-alone pricing for z/OS based development and test workloads. Modern DevOps tooling can be optionally added at uniquely discounted prices.
 - The Payments Solution will provide a "per payment" pricing option for IBM Financial Transaction Manager for z/OS deployments. This new offering directly ties operational cost to business value by basing the price on the number of payments processed, rather than capacity used to process them.
- Container Pricing for IBM Z is planned to be available by year end 2017 and enabled in z/OS V2.2 and z/OS V2.3 with the PTFs for APARs associated with fix category IBM.Function.PricingInfrastructure. z/OS will enhance both the Workload Manager capability of z/OS (z/OS WLM) and the Sub-Capacity Reporting Tool (SCRT) to support Container Pricing. This includes:
 - The introduction of a new Tenant Resource Group capability within z/OS WLM to allow the metering and optional capping of workloads, along with the ability to map those workloads directly to Container Pricing.
 - Enhancements to SCRT to capture eligible Container Pricing workloads, allowing for the billing of those solutions independently of traditional Sub-Capacity pricing.
- For more information, see Whitepaper <https://www-03.ibm.com/support/techdocs/atsmastr.nsf/WebIndex/WP102719> or <https://www-03.ibm.com/systems/z/resources/swprice/container.html>

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- Overview of capping types
- **Initial capping**
- Absolute capping
 - H/W absolute capping
 - WLM Absolute capping
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Initial capping (aka “hard capping”)

- Defined to PR/SM per processor type. Managed by PR/SM through limiting the processor time available to the LP's logical processors
- The LPAR capacity is capped to LPAR share of CPC shared capacity

$$\text{LPAR}_i \text{ share} = \frac{\text{Weight}_i}{\sum_{\text{All activated LPARs}} \text{Weight}_j}$$

- LPAR weight is distributed across online CPs of the given type
- With HiperDispatch=NO an LP's share is divided by the number of online logical CPs
 - Capping is done on a logical CP basis.
May result in over capping if not all LCPs can be utilized
 - Consider following example:
zEC12-732, 10 CPs online, Share=5.6%, low CPC utilization
Workload: 2 TCBs

Initial Capping with HiperDispatch=Yes vs. No

CPU Activity Reports

▪ CPU	2827	CPC CAPACITY	3665	SEQUENCE CODE	000000000000	
▪ MODEL	732	CHANGE REASON=NONE		HIPERDISPATCH=YES		
▪ H/W MODEL	H43					
▪ ---CPU---		TIME %		LOG PROC		
▪ NUM	TYPE	ONLINE	LPAR BUSY	MVS BUSY	PARKED	SHARE %
▪ 0	CP	100.00	89.12	97.67	0.00	100.0 HIGH
▪ 1	CP	100.00	87.50	97.83	0.00	80.4 MED
▪ 2	CP	100.00	2.51	82.33	96.54	0.0 LOW
▪ 3	CP	100.00	1.87	63.68	96.54	0.0 LOW
▪ 4	CP	100.00	0.01	-----	100.00	0.0 LOW
▪ 5	CP	100.00	0.01	-----	100.00	0.0 LOW
▪ 6	CP	100.00	0.01	-----	100.00	0.0 LOW
▪ 7	CP	100.00	0.01	-----	100.00	0.0 LOW
▪ A	CP	100.00	0.01	-----	100.00	0.0 LOW
▪ B	CP	100.00	0.01	-----	100.00	0.0 LOW
▪ TOTAL/AVERAGE		18.10	96.92		180.4	

With HiperDispatch=Yes
the high/medium
processors receive a
higher processor share.

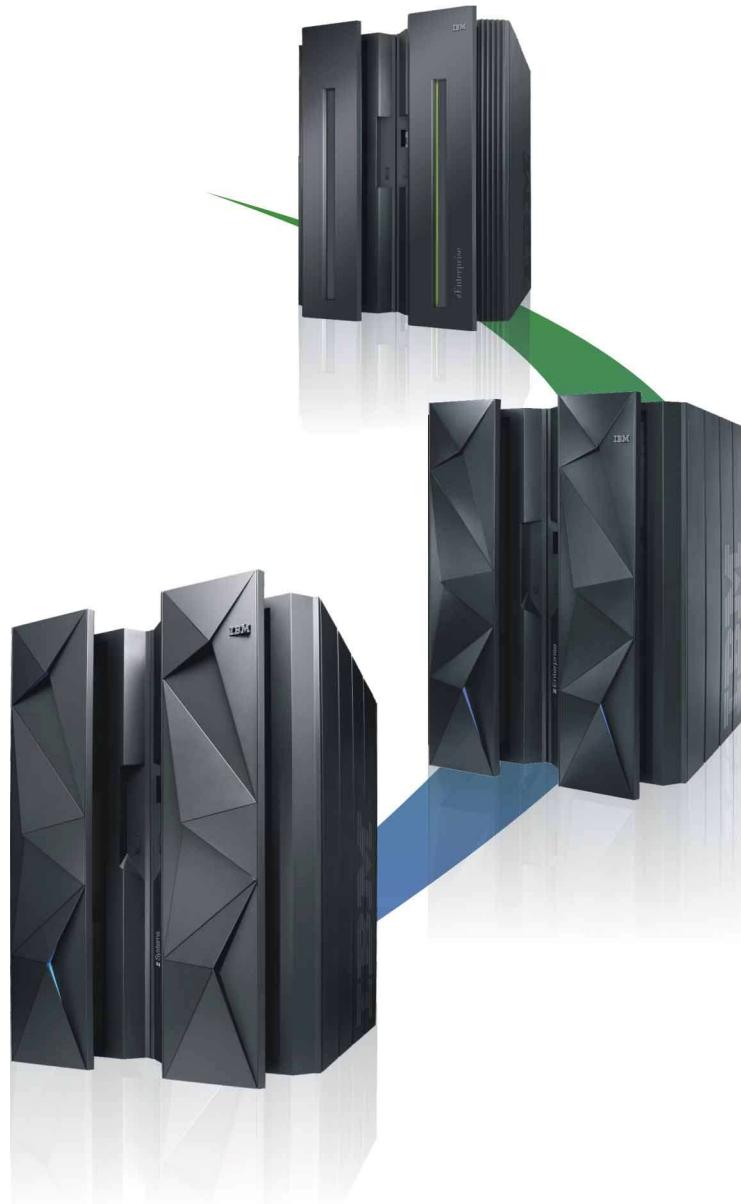
• MODEL	732	CHANGE REASON=NONE	HIPERDISPATCH=NO			
• H/W MODEL	H43					
• ---CPU---		TIME %		LOG PROC		
• NUM	TYPE	ONLINE	LPAR BUSY	MVS BUSY	PARKED	SHARE %
• 0	CP	100.00	14.61	54.28	-----	18.0
• 1	CP	100.00	13.00	46.80	-----	18.0
• 2	CP	100.00	10.71	31.82	-----	18.0
• 3	CP	100.00	6.77	18.55	-----	18.0
• 4	CP	100.00	4.22	6.44	-----	18.0
• 5	CP	100.00	4.87	13.16	-----	18.0
• 6	CP	100.00	1.75	2.72	-----	18.0
• 7	CP	100.00	4.54	13.05	-----	18.0
• A	CP	100.00	4.02	10.40	-----	18.0
• B	CP	100.00	3.08	6.88	-----	18.0
• TOTAL/AVERAGE		6.76	20.41		180.0	

Stability of initial cap limits

- The **MSU equivalent** for an initial cap limit changes when...
 - The initial weight of the capped LPAR is changed
 - LPARs are de/activated or the total weight changes due to initial weight changes
 - Temporary capacity is de/activated
 - CBU, On/Off CoD...
- May require manual intervention when
 - A particular MSU/MIPS number is guaranteed for an LPAR
 - A particular MSU number must not be exceeded for licensing reasons

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LPAR Absolute Capping and Group Capping

- We use “Absolute” to refer to capping independently of the four hour rolling average consumption
- Defined to PR/SM per processor type. Managed by PR/SM through limiting the number of PR/SM time slices available to the LPAR’s logical processors
- Specification in terms of (fractional) number of processors per processor type
 - E.g., 3.75 CPs
- LPAR absolute capping introduced with zEC12 GA2
LPAR absolute group capping introduced with z13 GA2
- Primarily intended for non z/OS images
 - Not capping to a MSU figure, not aware of 4h rolling average consumption
- Can be specified independently from the LPAR weight
 - But recommended to specify absolute cap above weight
 - WLM algorithms consider weight

Absolute Capping Limit

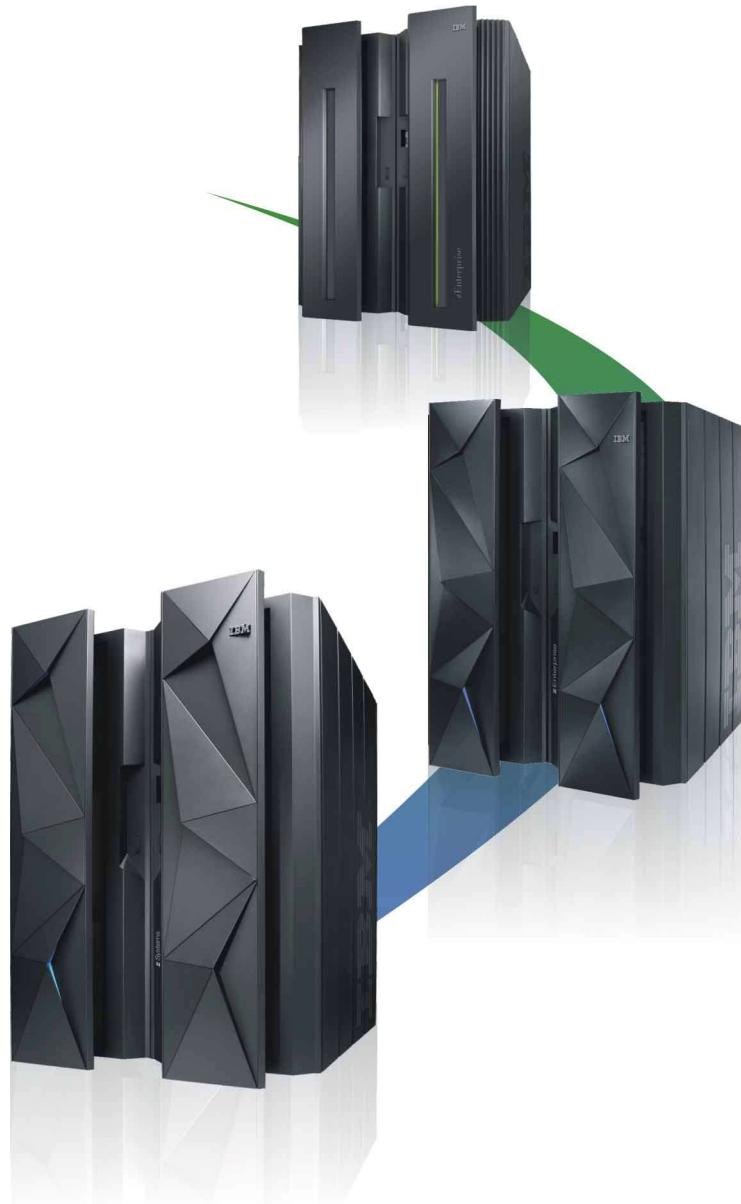
- Absolute capping may be used *concurrently* with defined capacity and group capacity management
 - The minimum of all limits becomes effective.
 - WLM/SRM is aware of the absolute cap, e.g. for routing decisions.
 - Partition capacity RCTIMGWU =
$$\text{MIN}(\text{absolute cap}, \text{absolute group cap}, \text{defined capacity}, \text{group cap}, \dots)$$
when all capping types are in effect
 - RMF provides RCTIMGWU in SMF70WLA
 - In addition, SMF70HW_Cap_Limit value in hundredths of CPUs

Stability of H/W absolute cap limits

- The effective limit for an absolute cap can change significantly when
 - the absolute cap value of the capped LPAR is changed, or
 - temporary capacity is de/activated AND the capacity level (processor speed) changes
 - I.e., general purpose processor CBU, On/Off CoD to/from subcapacity models
- But: the effective MSU rating for an absolute cap changes also when just the number of physical processors changes
 - I.e. CBU, On/Off CoD to/from within same capacity level, such as 7xx
 - If this effect is not desired, WLM absolute capping can be considered

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WLM Absolute capping (Permanent capping)

Function	z/OS release	V2.2	V2.1
<i>z13 GA2 LPAR Absolute group capping</i>		OA47752	OA47752
Absolute MSU capping		OA49201	OA49201

- Function of WLM provided by APAR OA49201
- Technically, based on [WLM defined capacity or group capacity](#)
 - BUT: LPAR will always be capped, independent of 4 hour rolling average consumption.
 - Only general purpose processor
 - Same underlying mechanisms
- Specified in IEAOPTxx.

Limit is the LPAR defined capacity or group capacity specified on the HMC **in MSU**.

- [z/OS Capacity Provisioning](#) will not manage partitions capped through WLM absolute capping
 - Provisioning Manager commands can be used when limit changes desired

Using absolute MSU capping

IEAOPTxx ABSMSUCAPPING=	
<u>NO</u>	Defined capacity limits and group capacity limits should be enforced only while the long term four hour rolling average consumption exceeds the respective limit (existing and usually desired behavior).
YES	Defined capacity limits and group capacity limit should be enforced permanently, independently of the long term four hour rolling average consumption.

- AbsMSUcapping=Yes limits LPAR consumption to a certain MSU number at all times.
 - I.e., the system loses the flexibility of consuming above the defined capacity limit while the four hour rolling average is below the limit.
- Limit remains stable even when CEC configuration changes, e.g. through On/Off CoD or CBU activations or deactivations.
 - Absolute MSU capping is an effective means to permanently limit the consumption of an LPAR to a specific MSU figure at all times
 - including times when the *four-hour rolling average* does not exceed the defined limit.
- The Capacity Provisioning Manager (CPM) will not change limits of AbsMSUCapping=YES systems.

²²

Using absolute MSU capping with group capacity

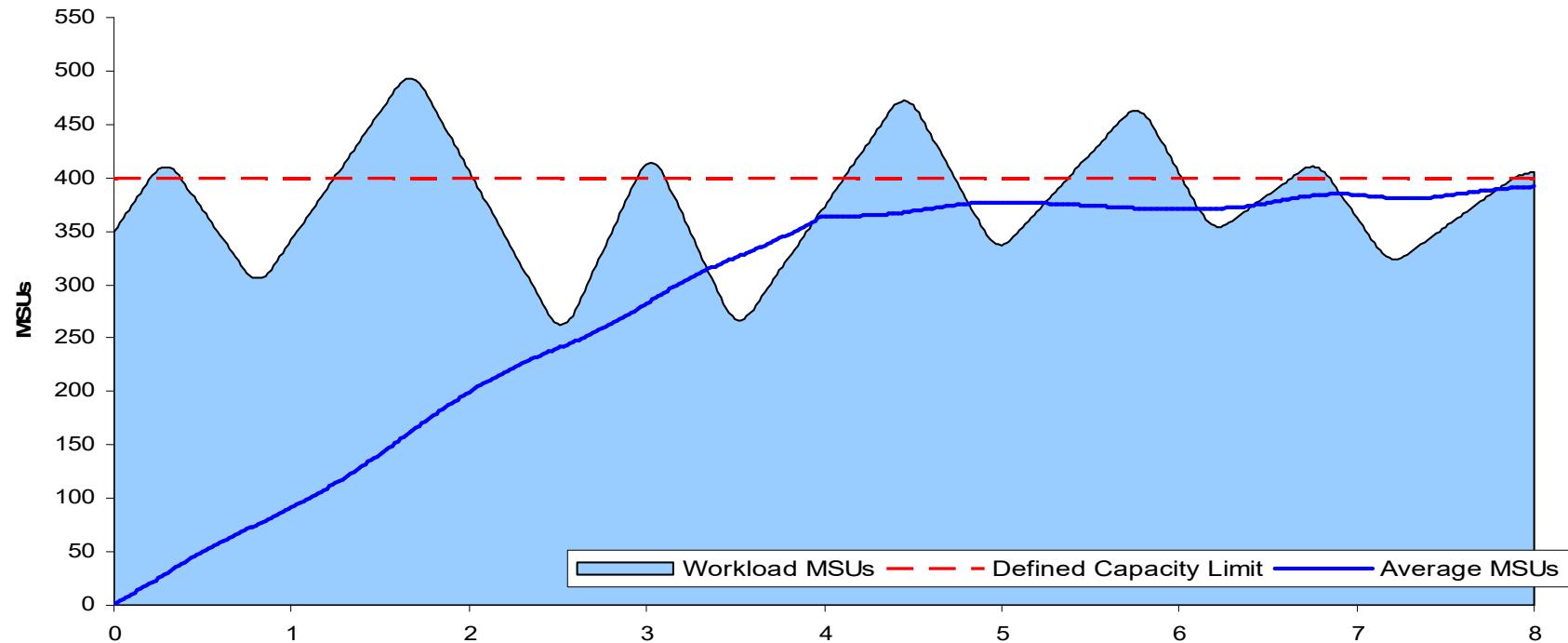
- When used with an LPAR capacity group:
 - Limit on behalf of the group entitlement will always be enforced
 - Regardless of the *four-hour rolling group average* consumption.
 - As with AbsMSUcapping=NO, an LPAR is allowed to take benefit of the unused group capacity
 - Unless the LPAR is also capped via other LPAR limits.
 - All members of a capacity group that use AbsMSUcapping=YES will permanently enforce the limit on behalf of the capacity group.
 - All members of a capacity group that do *not* use AbsMSUcapping=YES will be capped while the group *four-hour rolling group average* consumption is greater or equal to the group limit

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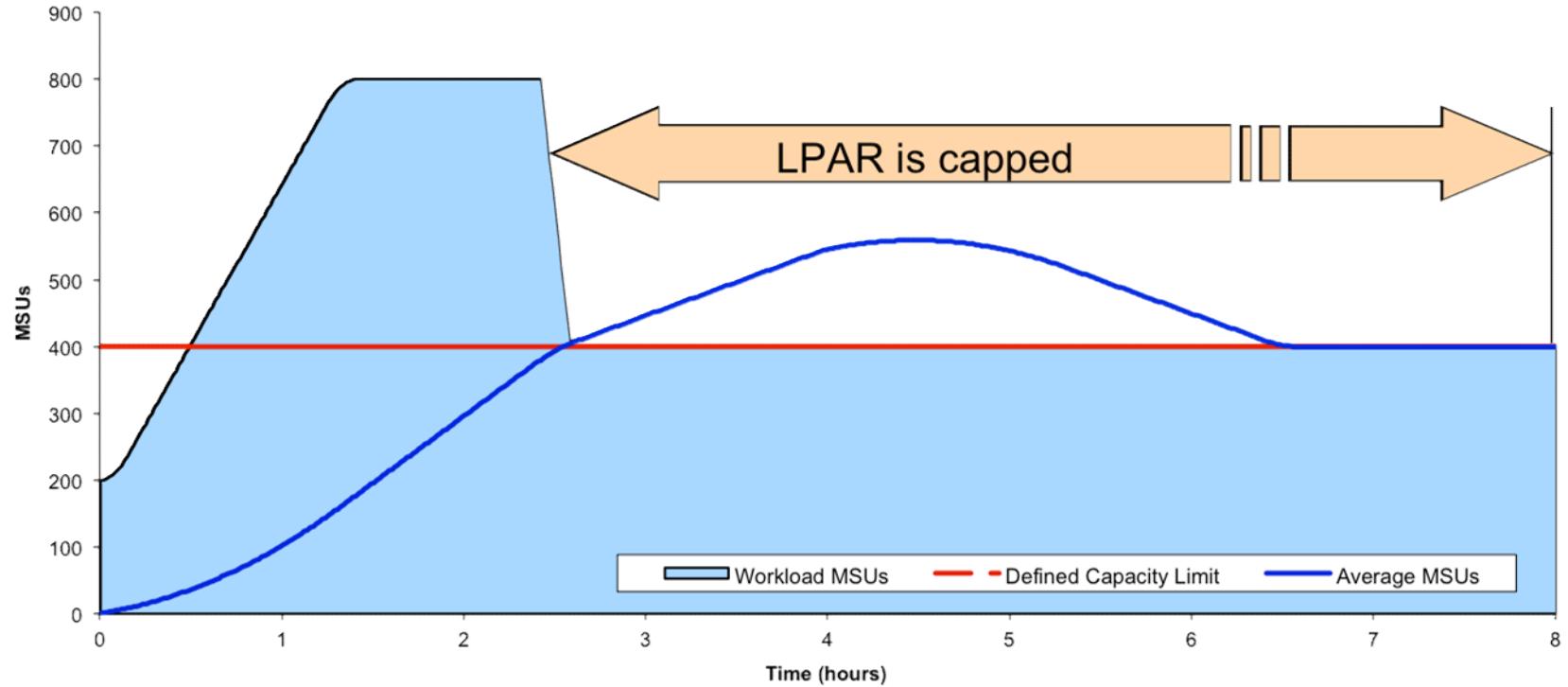


4 Hour Rolling Average (“4HRA”)



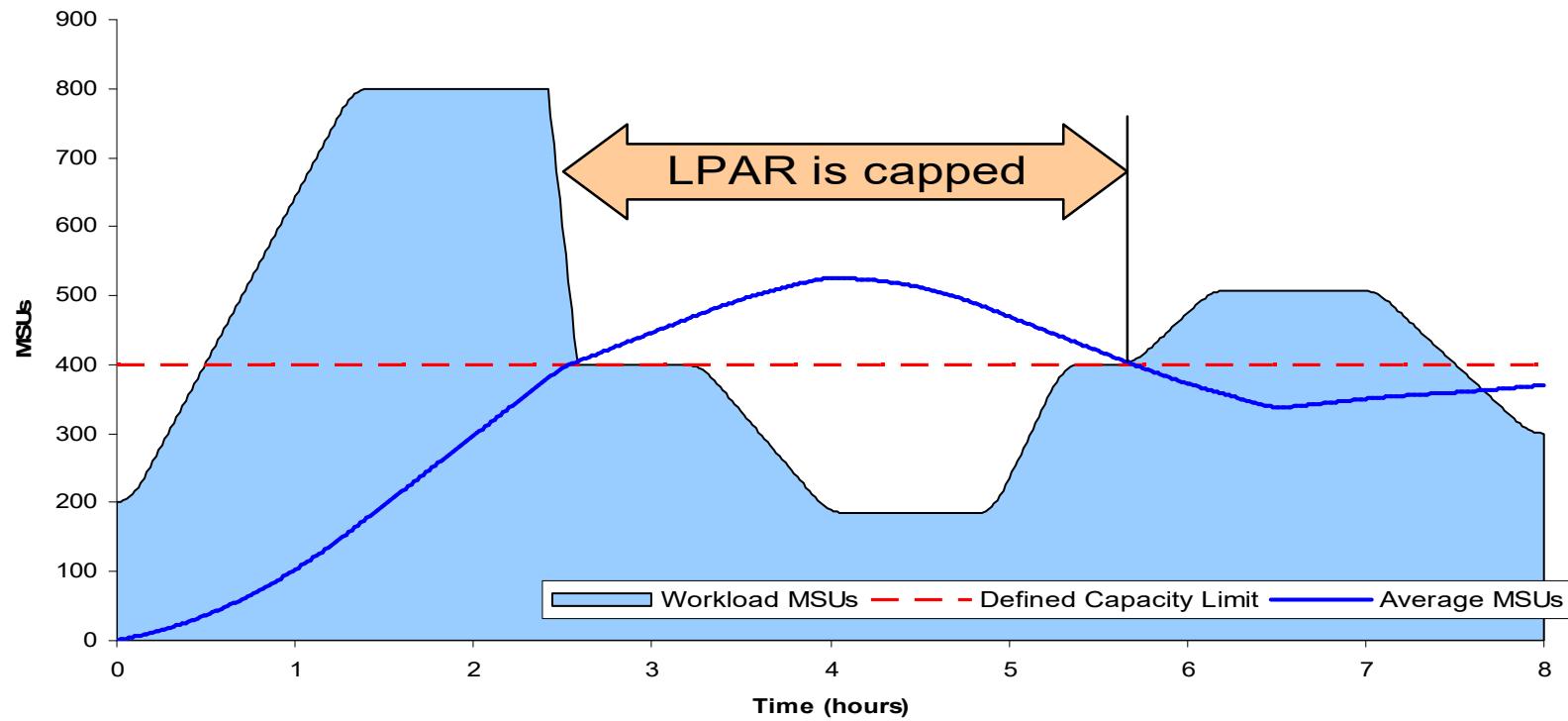
- Average consumption in LPAR over last 4h (rolling)
- Measured in MSU \equiv “Million Service Units per hour”
 \neq Service Units \bullet $3600 / 1000000$
- Tracked as array of 48 intervals of 5 min = 4h

LPAR Capping



- An LPAR is -soft- capped when the 4HRA exceeds the defined capacity limit
- It remains capped until the 4HRA is below the defined limit
- While capped, the consumption is limited to the defined limit
- WLM advises PR/SM how to cap the LPAR

End of capping phase



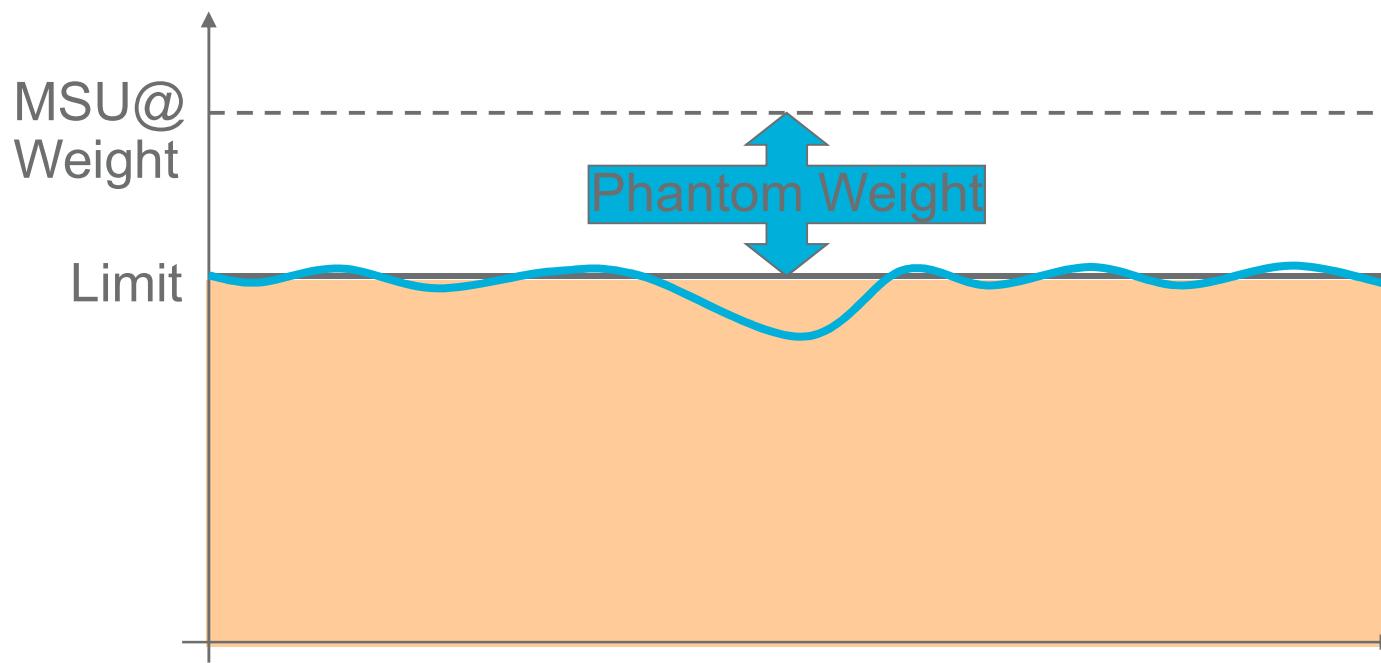
- Capping ends when the 4 hour average is below the softcap

Underlying soft capping techniques

- Historically, PR/SM algorithms were designed to cap a partition at its weight (hard capping)
- Therefore, WLM and PR/SM use particular interfaces to cap a partition to an arbitrary MSU figure

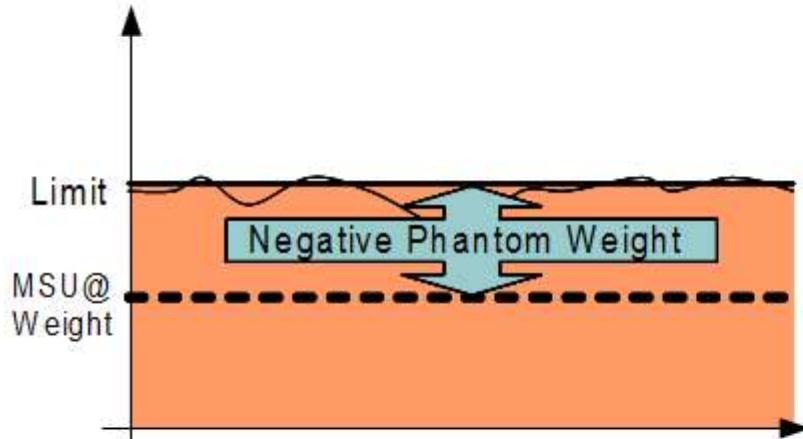
Weight vs. defined capacity limit	Hardware/Software level	Selected capping technique
MSU@weight > MSU limit	Any	Phantom weight
MSU@weight ≤ MSU limit	zEC12 GA2 and z/OS V2.1 or later	Negative phantom weight
	Other	Pattern capping

Phantom weight

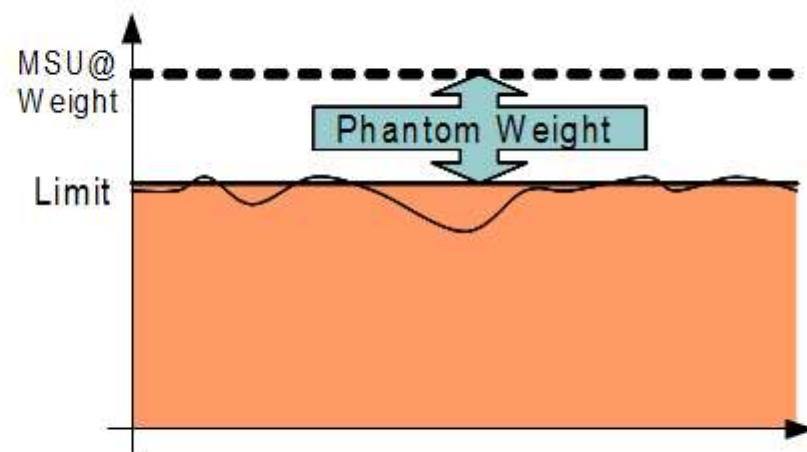


- Phantom weight is used to modify the PR/SM share of an LPAR
- WLM does not change a phantom weight as long as the limit and configuration do not change
→smooth capping

Capping with phantom weight



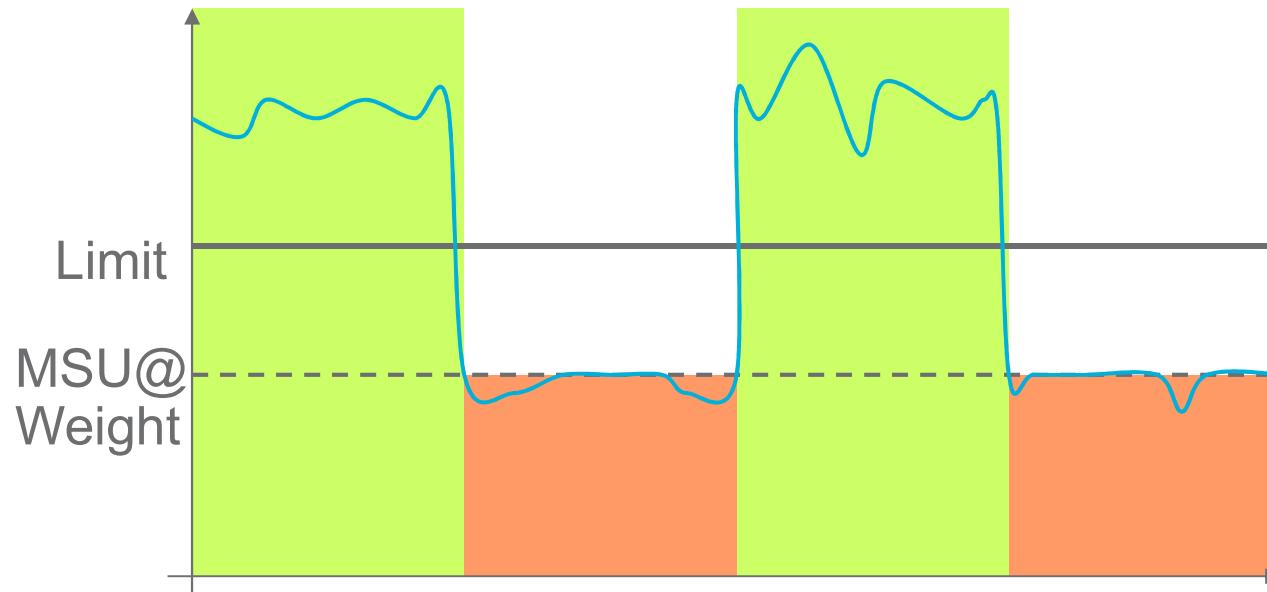
MSU@Weight < Limit



MSU@Weight > Limit

- zEC12 with z/OS V2.1 and above support not only positive but also negative phantom weights.
 - Note: While a positive phantom weight changes the PR/SM entitlement of a partition, a negative phantom does not elevate the PR/SM dispatching priority.
→ Only the capacity defined by the weight is guaranteed.

Cap pattern (only used with pre-EC12 GA2 H/W or older software levels)



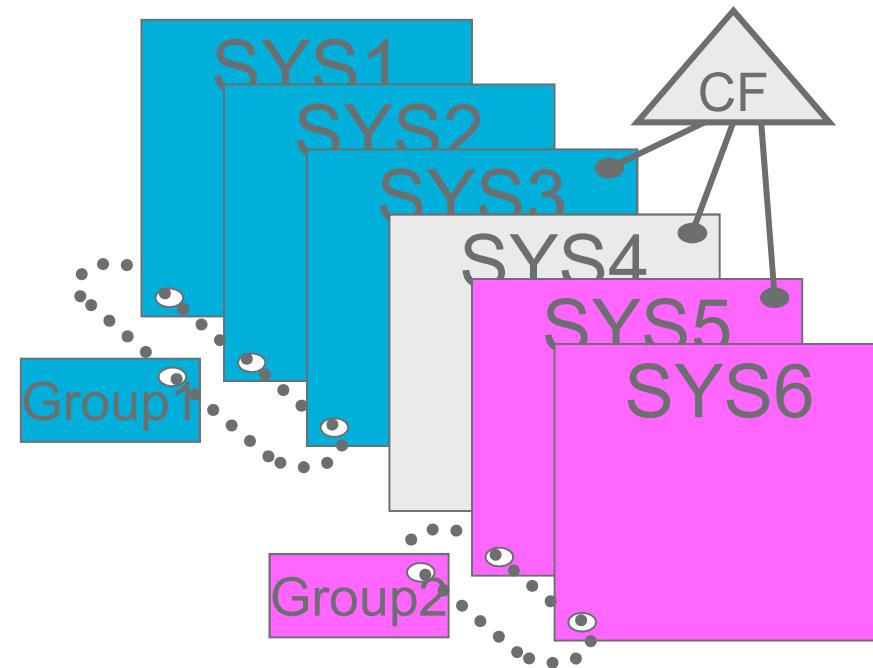
Prior to negative phantom weights WLM set up a cap pattern:
Alternating periods of

- LP capped to MSU@Weight, and
- LP uncapped

On average the MSU limit is enforced
...but interactive workloads can experience “pulsing”

Group Capping

An LPAR capacity group can be used to enforce a MSU limit for a set of one or more LPARs.



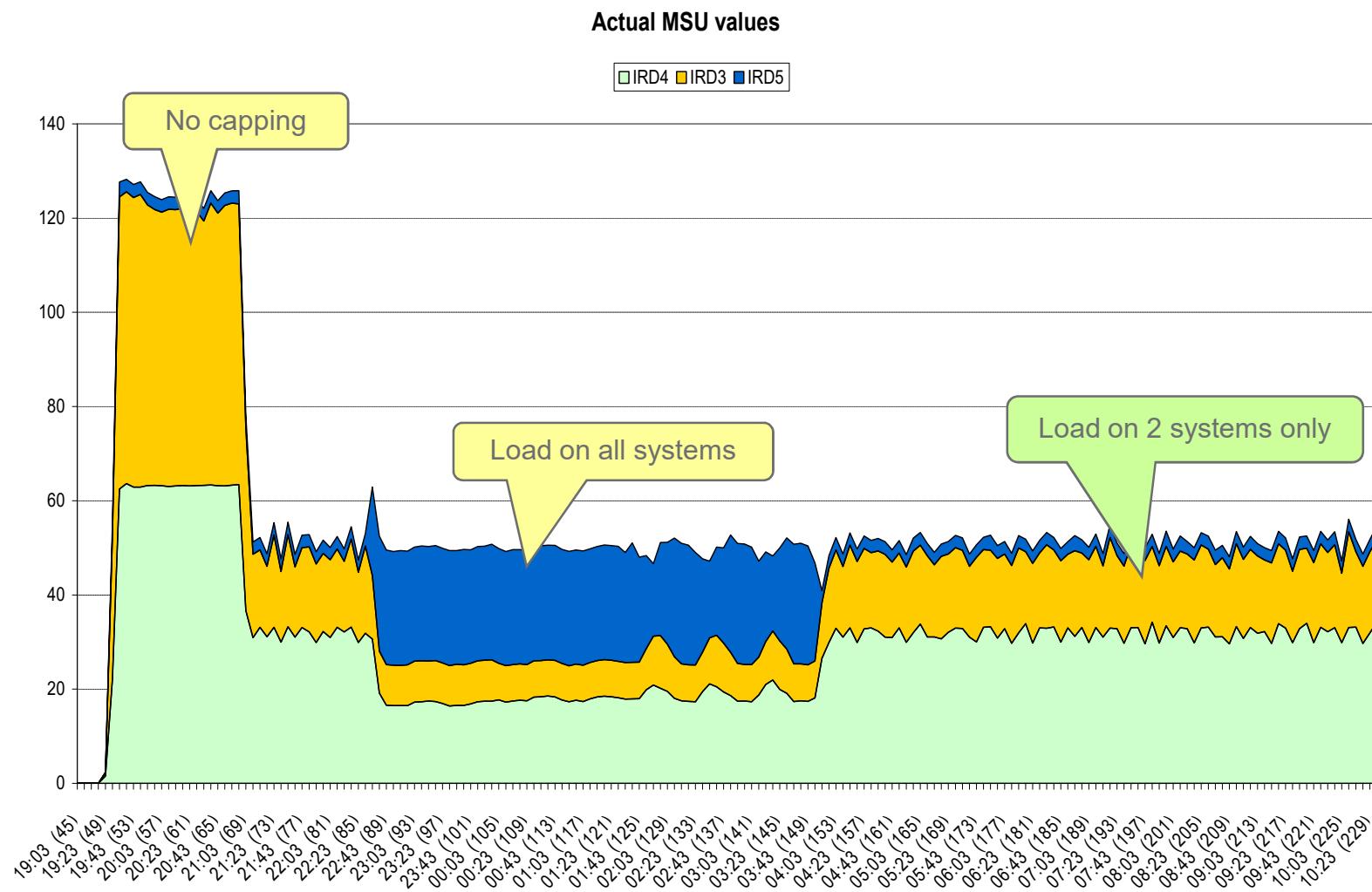
- A capacity group is limited to a **single CPC** but independent from the Sysplex
- A system can be joined to one group at most
- A system **will not join or will leave the capacity group** when requirements not met
 - Namely, **initial capping must not be active**

Group capping example

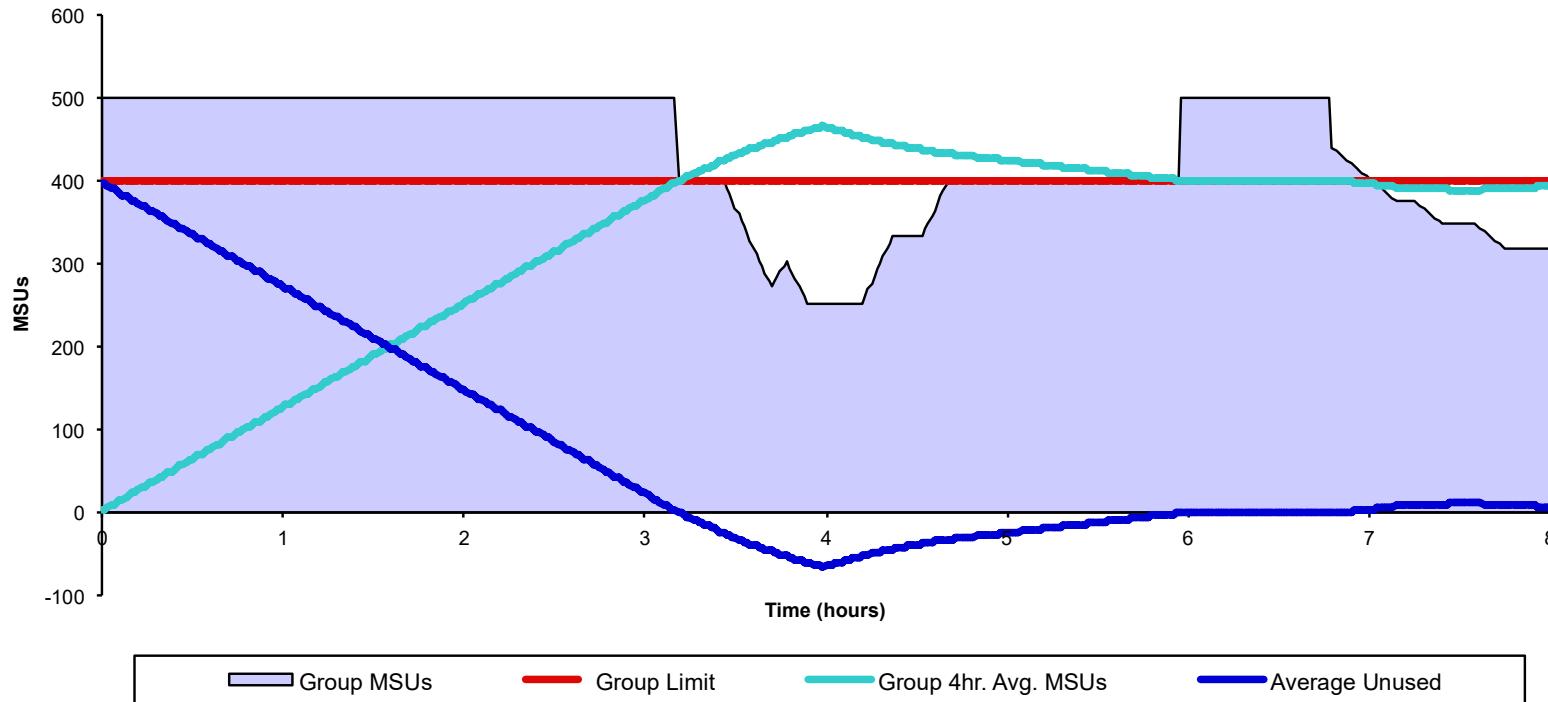
System	Weight	DC (MSU)	GC (MSU)	Initial GC Share (MSU)	Donation at full demand (MSU)	GC Entitle ment (MSU)
SYS1	600	-	400	200	-	240
SYS2	300	-		100	-	120
SYS3	300	40		100	60	40

- The **share of a group member is based on its *weight***
 - With IRD with zEC12 GA2 & z/OS V2.1: initial weight
 - With IRD in prior environments: current weight
- Unused capacity is donated to other group members
 - ...and re-distributed based on weight
- The minimum of DC and GC entitlement is used for capping an LPAR

Group Capping behavior



Unused vector (group capping)



- Group capacity is tracked via an **unused group capacity array** of 48 intervals of 5 min
- Group capping is active when average unused group capacity negative
- Each system tracks unused capacity while joined to a capacity group
 - Not synchronized upon group changes: systems may have a different view for up to 4h

RMF: Partition Data Report

PARTITION DATA REPORT											PAGE	2
z/OS V1R12			SYSTEM ID SYS1 RPT VERSION V1R12 RMF			DATE 10/13/10 TIME 09.30.00			INTERVAL 14.59.678 CYCLE 1.000 SECONDS			
MVS PARTITION NAME			SYS1	NUMBER OF PHYSICAL PROCESSORS			9	GROUP NAME			N/A	
IMAGE CAPACITY			100	CP			7	LIMIT			N/A	
NUMBER OF CONFIGURED PARTITIONS			9	ICF			2	AVAILABLE			N/A	
WAIT COMPLETION			NO									
DISPATCH INTERVAL			DYNAMIC									
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RMF: Partition Data Report

1. **MSU DEF DC** limit for this partition in MSU as specified on HMC
2. **MSU ACT** Actual avg. MSU consumption of this LPAR
3. **CAPPING DEF** Indicates whether this partition uses initial capping
4. **CAPPING WLM%** Portion of time the LPAR was capped during the RMF interval
 - Does not necessarily imply that the cap constrained the LPAR's consumption.

RMF: CPC Capacity

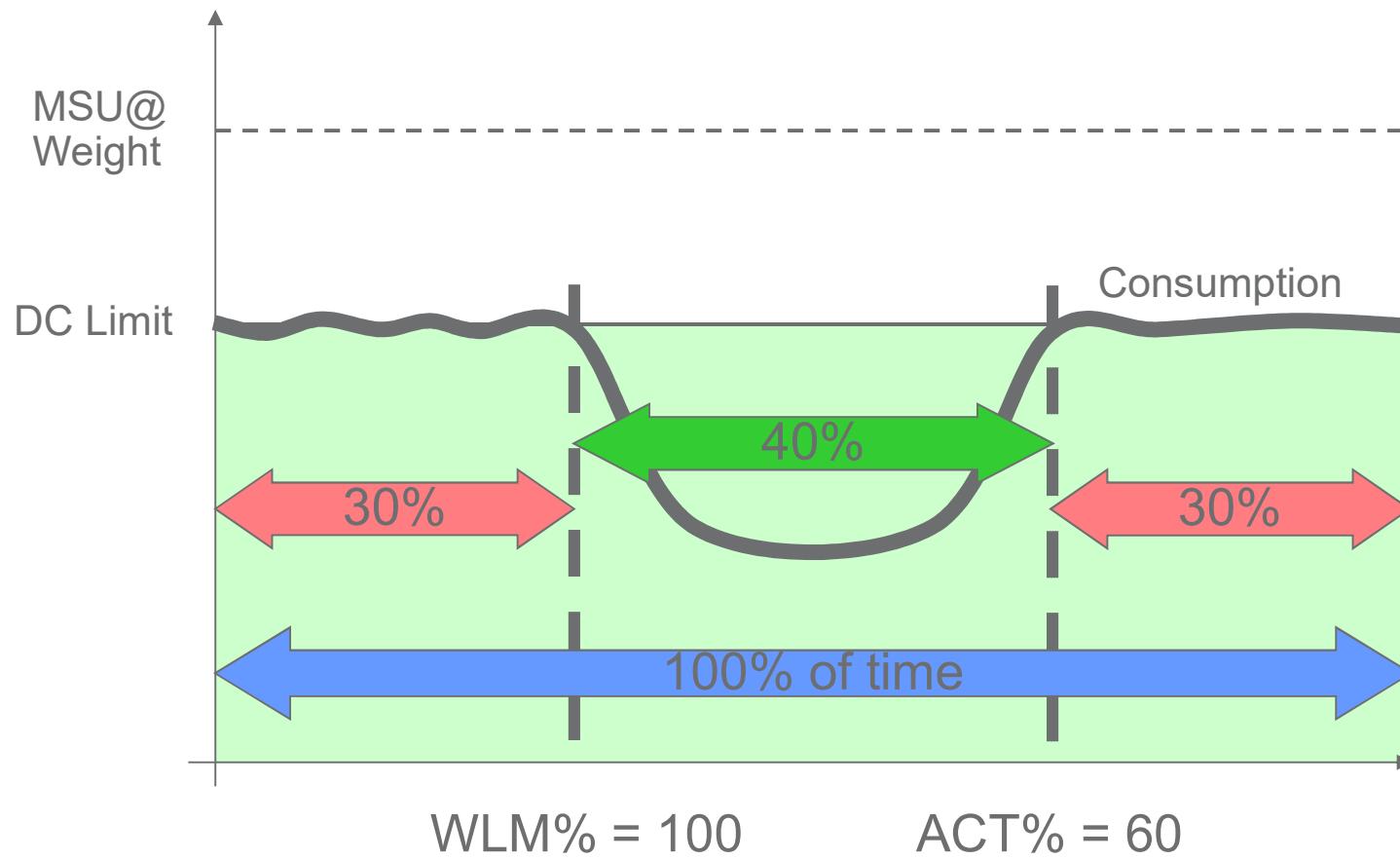
1. **CPC Capacity**
Total capacity of the CPC in MSU/h
2. **Image Capacity**
Maximum capacity available to this partition
3. **Weight % of Max**
Average weighting factor relative to the maximum defined weight for this partition.
4. **WLM Capping %**
Percentage of time that WLM had advised PR/SM to cap the LPAR
5. **4h Avg**
Average consumed MSU/h during the last 4 hours
6. **4h Max**
Maximum consumed MSUs during the last 4 hours

RMF: Group Capacity report

GROUP CAPACITY REPORT												
z/OS V1R12 SYSTEM ID SYS1			DATE 10/13/2010			INTERVAL 14.59.968						
RPT VERSION V1R12 RMF			TIME 15.15.00			CYCLE 1.000 SECONDS						
----GROUP-CAPACITY----												
NAME	LIMIT	AVAIL	PARTITION	SYSTEM	-- MSU --	WGT	--- CAPPING ---	- ENTITLEMENT -				
				DEF ACT	DEF ACT	WLM%	ACT%	MINIMUM	MAXIMUM			
1 GROUP1	2 1500	3 -22	SYS1	SYS1	4 80	5 3	6 600	7 NO	8 25	9 23	10 80	
			SYS2	SYS2	80	3	500	100	46	80	30	
	TOTAL				6 1100							

1. NAME Name of the WLM capacity group
2. LIMIT Group limit
3. AVAIL Average unused capacity in MSUs (avg. unused vector)
4. MSU DEF Defined capacity limit
5. MSU ACT Average used capacity
6. CAPPING DEF YES indicates that initial capping is active
7. CAPPING WLM% Percentage of time that WLM had set up a cap for the partition
8. CAPPING ACT% Percentage of time found capping actually limited the usage of processor resources for the partition
9. MINIMUM ENT. Minimum of the GC member share and the DC limit
10. MAXIMUM ENT. Minimum of the GC limit and the DC limit

Phantom weight: WLM% vs. ACT% in RMF



- RMF: WLM% capping is always 100 in case of phantom weight

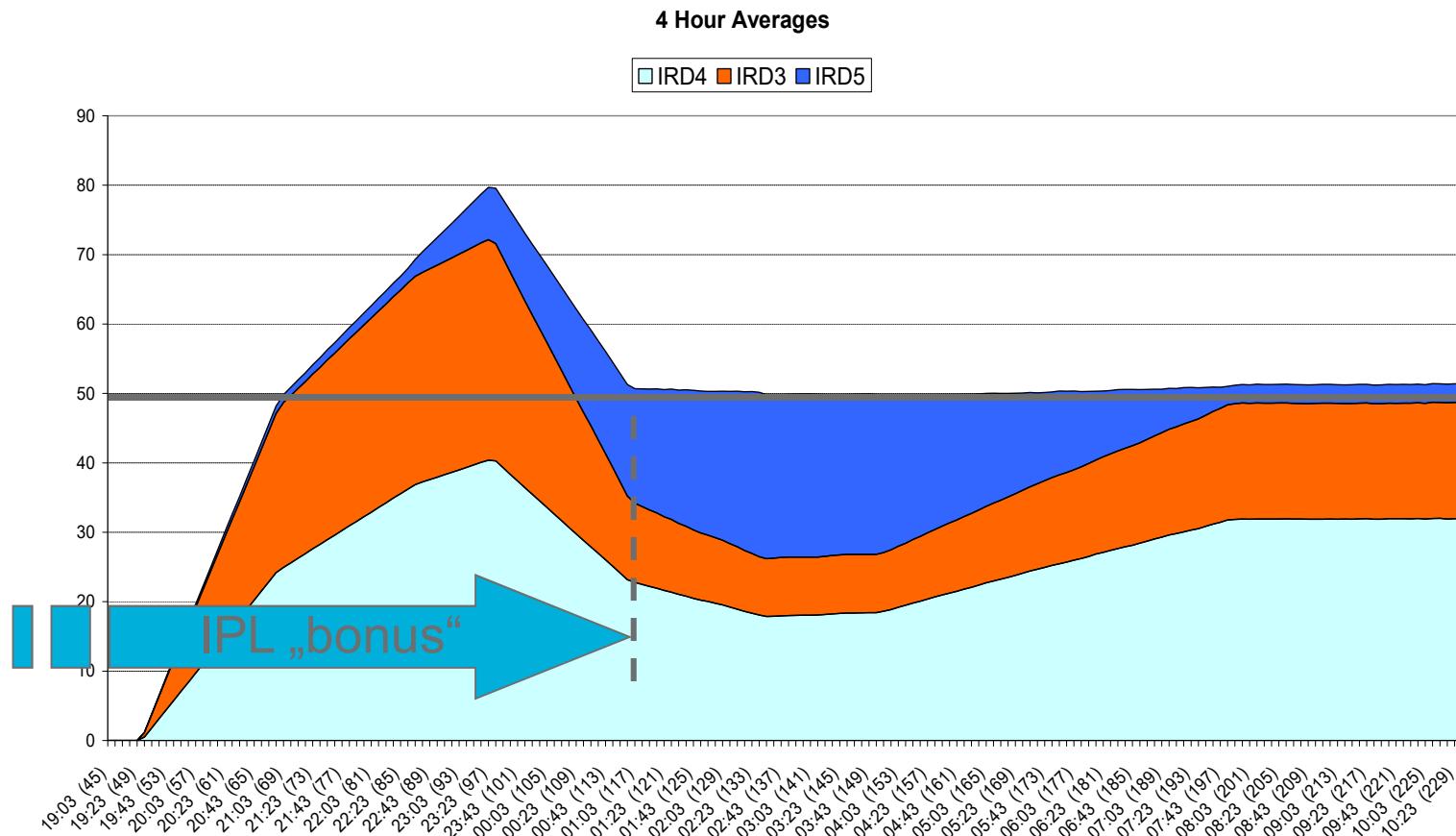
RMF Data Portal

The screenshot shows the RMF Monitor III Data Portal for z/OS running in Mozilla Firefox. The main content area displays a table of CPC (Central Processor Complex) statistics. Several rows in the table are highlighted with colored boxes: a row for 'Weight % of Max' is highlighted with an orange box; a row for 'WLM Capping %' and another for 'Proj Time until Capping' are highlighted with blue boxes; and a row for 'CPC sequence number' is also highlighted with a blue box. The table includes columns for Partition Name, CPU Type, CPU Model, CPC Capacity (MSU/h), Weight % of Max, 4h MSU Average, Capacity Group Name, Image Capacity, WLM Capping %, 4h MSU Maximum, Capacity Group Limit, Less than 4h in Capacity Group, Proj Time until Capping, Proj Time until Group Capping, 4h Unused Group Capacity Average, CPC sequence number, # CP Processors, # ICF+IFL+AAP Processors, # AAP Processors, # ICF Processors, # IFL Processors, # IIP processors, Configured Partitions, Wait Completion, % Capacity Used, # Dedicated CPs, # Dedicated AAPs, # Dedicated IIPs, # Shared physical CPs, # Shared physical AAPs, # Shared physical IIPs, Vary CPU management available, WLM LPAR management enabled, Physical Total % of shared CPs, Physical Total % of shared AAPs, Physical Total % of shared IIPs, Physical Total % of shared ICFs, and Physical Total % of shared IFLs.

Partition Name: TRX2	CPU Type: 2097	CPU Model: 704	CPC Capacity (MSU/h): 401
Weight % of Max: 19.9	4h MSU Average: 2	Capacity Group Name: RMFGRP	Image Capacity: 60
WLM Capping %: 0.0	4h MSU Maximum: 3	Capacity Group Limit: 150	Less than 4h in Capacity Group: N
Proj Time until Capping: 14400	Proj Time until Group Capping: 14400	4h Unused Group Capacity Average: 142	CPC sequence number: 00000000001EBAE
# CP Processors: 4	# ICF+IFL+AAP Processors: 0	# AAP Processors: 1	# ICF Processors: 2
# IFL Processors: 18	# IIP processors: 1	Configured Partitions: 58	Wait Completion: NO
% Capacity Used: 7	# Dedicated CPs: 0	# Dedicated AAPs: 0	# Dedicated IIPs: 0
# Shared physical CPs: 4	# Shared physical AAPs: 1	# Shared physical IIPs: 1	Vary CPU management available: NO
WLM LPAR management enabled: YES	Physical Total % of shared CPs: 5.1	Physical Total % of shared AAPs: 0.0	Physical Total % of shared IIPs: 0.0
Physical Total % of shared ICFs: 61.1	Physical Total % of shared IFLs: 0.0		

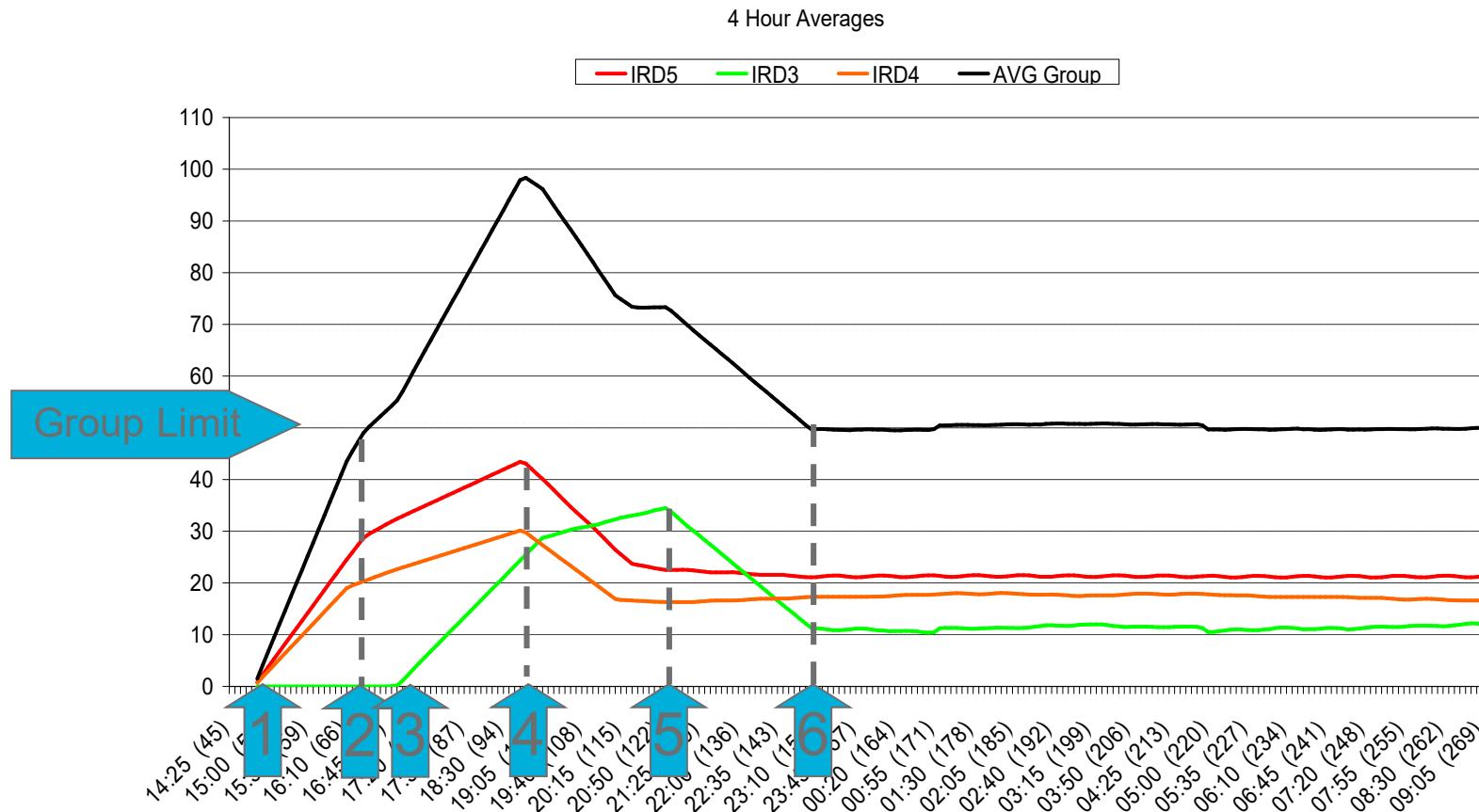
Many capping related fields are available in RMF Monitor III Data Portal

4 hour rolling average at IPL



Average is always for 4 hours even when the IPL was less than 4 hours ago

A member joins the capacity group



1. Workloads begin on IRD4 & 5
2. Group limit reached
3. System IRD3 joins group
4. IRD4 & 5: Four hours since (1.)
5. IRD3: Four hours since (3.). All systems have same GC view.
6. Group Avg. = Group limit

Capping and HiperDispatch

- WLM capping can influence the HiperDispatch configuration of an LPAR:
 - *limit<MSU@weight* : Capping through positive phantom weight reduces the PR/SM priority of an LPAR. Therefore, the number of Vertical High or Medium (VH, VM) processors may be reduced.
 - *Limit>MSU@weight*: Capping through negative phantom weight does not increase the PR/SM priority of a partition and the HiperDispatch configuration of the capped LPAR remains unchanged
- z/OS V2.2 and V2.1 with APAR OA43622 provide some HiperDispatch enhancements that become effective when running capped, or when capped LPARs are present on the CPC.

<i>Function</i>		<i>z/OS release</i>		
<i>Hiper- Dispatch z13 & zEC12</i>	<i>Unpark while capped Unused capacity refinement Prime cycle elimination</i>	V2.2	V2.1	V1.13
		+	OA43622	

HiperDispatch “Unpark while capped”

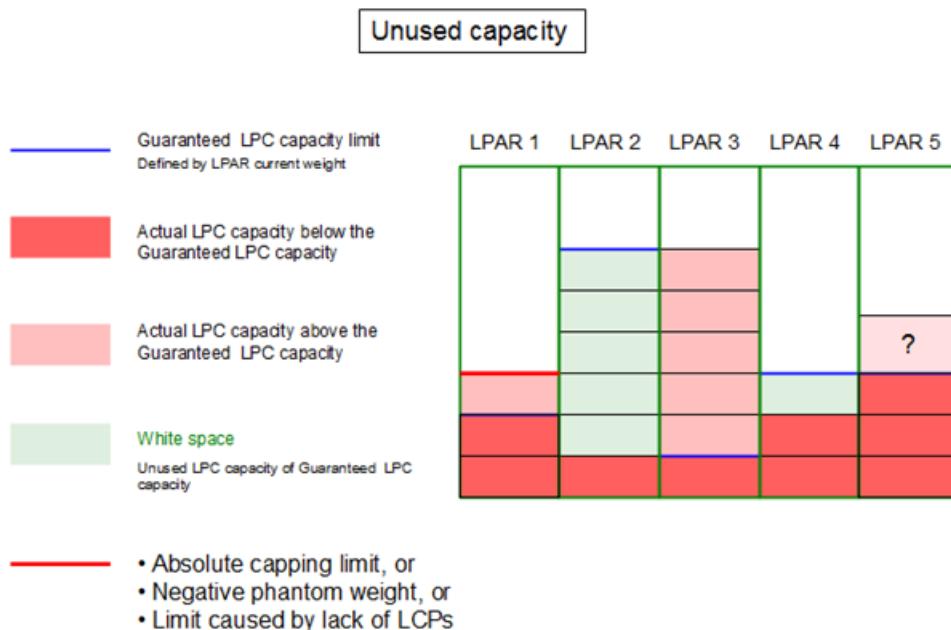
- Previously, HiperDispatch
 - Parked all Vertical Low (VL) processors when a system capped via positive phantom weight
 - VLs are used for discretionary capacity and not required to absorb the LPAR weight
 - However, it was seen that, for some workloads, the reduced number of logical processors made it difficult to fully utilize the cap target capacity.
 - Unparked all VL processors when a system was capped by negative phantom weight, or some cases of PR/SM absolute capping
- Now, HiperDispatch can unpark VL processors if the processors can be used efficiently.

* Statements regarding IBM future direction and intent are subject to change or withdrawal, and represent goals and objectives only.

HiperDispatch refinement of “unused capacity” use

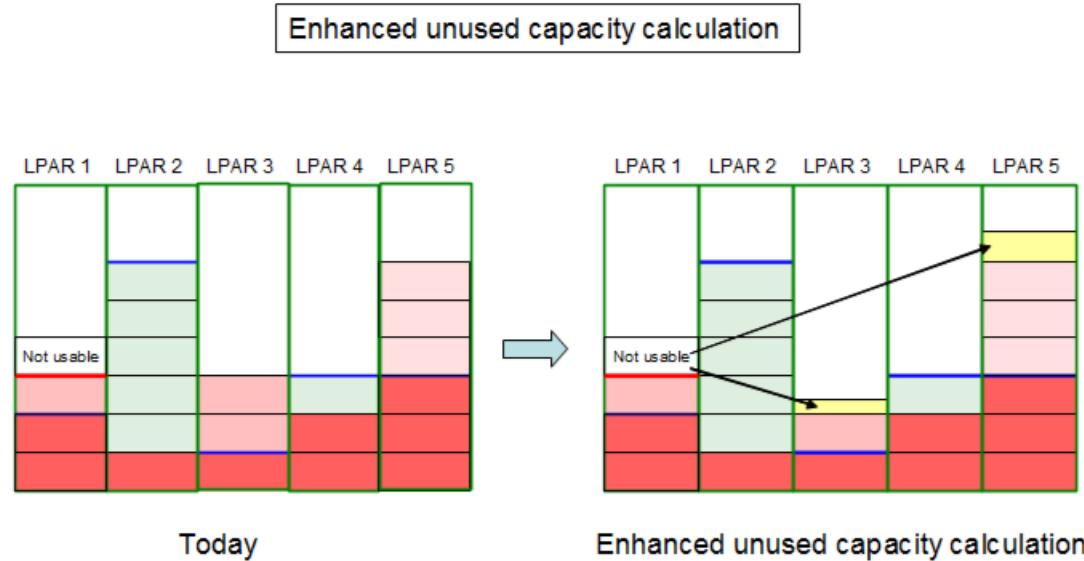
- HiperDispatch decisions are based on the CPC-wide unused capacity situation
- The ‘unused capacity share’ calculation was enhanced to also consider the LPAR configuration values
 - absolute capping value
 - negative phantom weight
 - number of logical processors
 - effective defined capacity and group capacity limit of possible ‘unused capacity’ receivers

CPC with 5 LPARs. LPAR1 has an absolute capping limit, which is indicated with the red line. LPAR2, and LPAR4 are unused capacity donors, while LPAR1 / 3 / 5 are unused capacity receivers.



* Statements regarding IBM future direction and intent are subject to change or withdrawal, and represent goals and objectives only.

HiperDispatch refinement of “unused capacity” use



- Figure on the left shows today's unused capacity calculation, which does not consider LPAR capping limits.
- Unused capacity calculation is only based on the receiver's weight share.
- Figure on the right shows an example of enhanced unused capacity calculation. It considers the capping limits of the receivers.
- Because LPAR1 is not able to use its total unused capacity share its 'not usable' unused capacity share portion increases the unused capacity share of LPAR5.

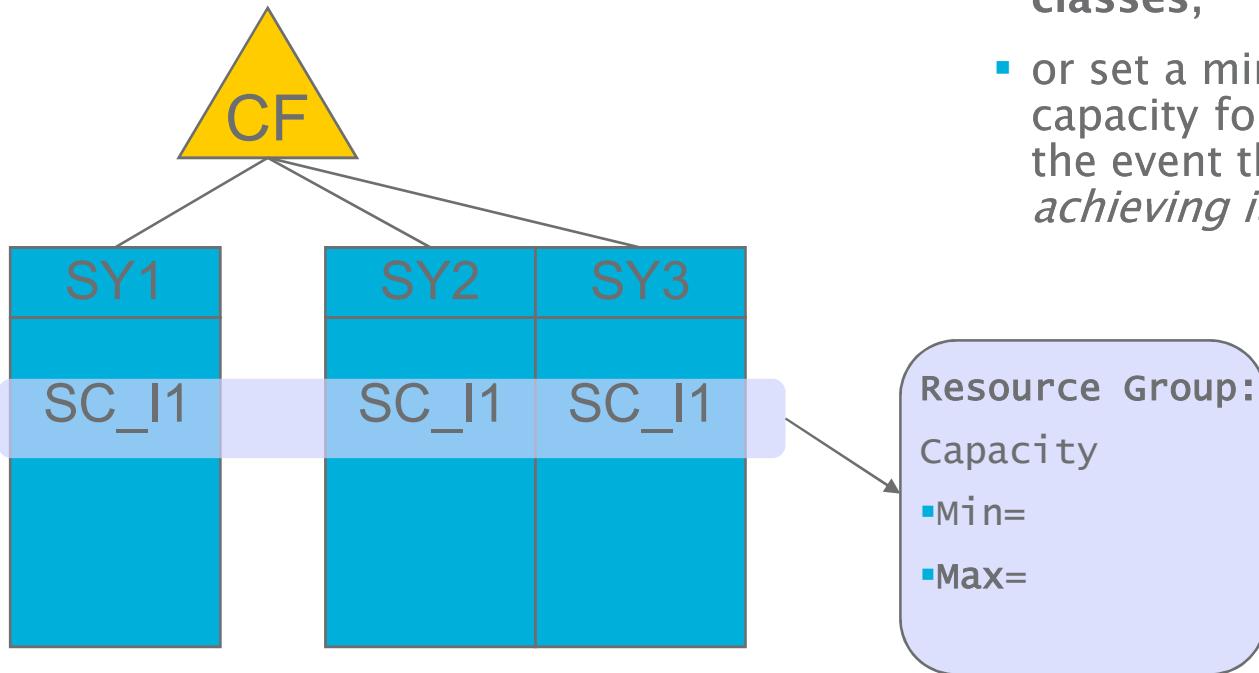
* Statements regarding IBM future direction and intent are subject to change or withdrawal, and represent goals and objectives only.

Agenda

- Overview of capping types
- Initial capping
- Absolute capping
- Defined capacity & group capacity
- **Resource group capping**
- 4HRA management
- Additional Material

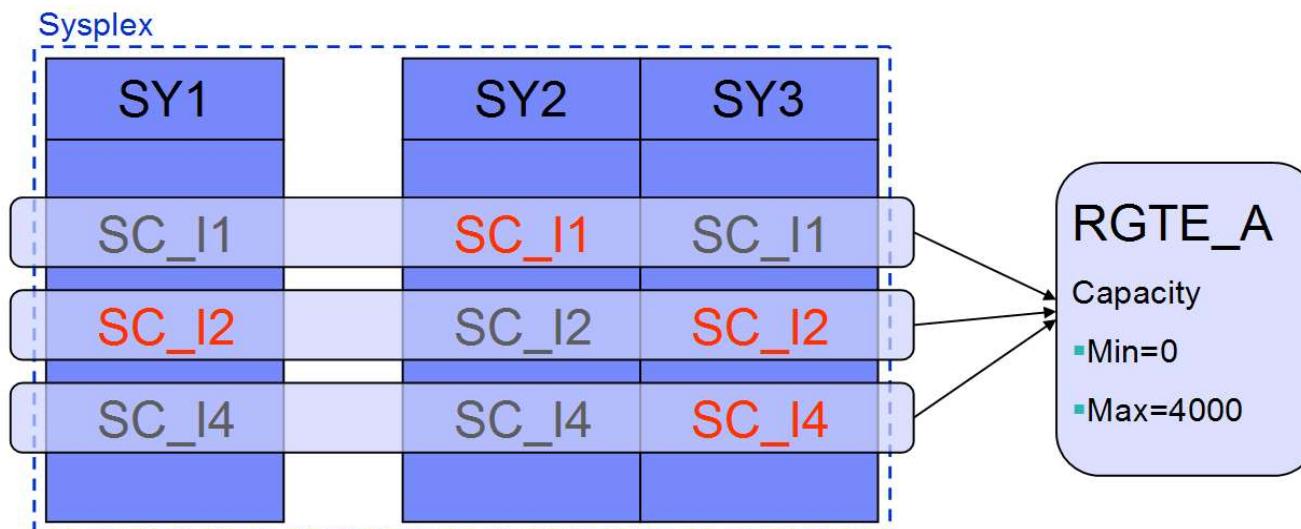
What is a Resource Group?

- Resource groups are a means to limit or protect work *when proper classification, goals and importance are not sufficient.*
- A Resource Group is associated to one or more Service Classes
- Defines the service that the related Service Class(es) are managed to. Either
 - **limit the amount of processing capacity available to the service classes,**
 - or set a minimum processing capacity for the service classes in the event that the work is *not achieving its goals*



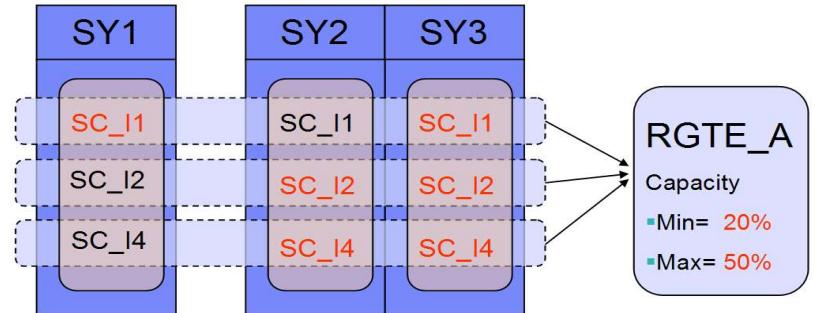
Type 1 Resource Groups

- Sysplex-wide defined in **unweighted service units per second**
 - “Unweighted” or “raw” meaning that the CPU and SRB service definition coefficients are **not** applied
- Sysplex-wide managed
- General Considerations
 - Multiple service classes may be assigned to a resource group
 - Different utilizations on the different systems and mix of importance levels make it difficult to predict actual consumption
 - Systems may have different capacities



Type 2 and 3 Resource Groups

- Sysplex-wide defined, but definition applies to each system
- Managed by each system
- General Considerations
 - Multiple service classes can be assigned to a resource group but this has no sysplex-wide effect
 - Definition is based on one of two possible units:
 - **Type 2: Percentage of LPAR capacity**
 - **Type 3: In number of processors (100 = 1 CP)**



Locating LPAR SU/sec Numbers

The service units that

- The Service Unit information can be located in the “z/OS MVS Planning: Workload Management” [manual](#) CPU Capacity Table
- Or on IBM Resource Link <https://ibm.biz/BdFHFv> :

IBM zEnterprise EC12

Processor	STIDP Type	STSI Model Name	CPs	SU/SEC	SRMsec/RealSec
2827-701	2827	701	1	78048.7805	1811.5932
2827-702	2827	702	2	73394.4954	1811.5932
2827-703	2827	703	3	71428.5714	1811.5932
2827-704	2827	704	4	69868.9956	1811.5932
2827-705	2827	705	5	68085.1064	1811.5932
2827-706	2827	706	6	66945.6067	1811.5932
2827-707	2827	707	7	65843.6214	1811.5932

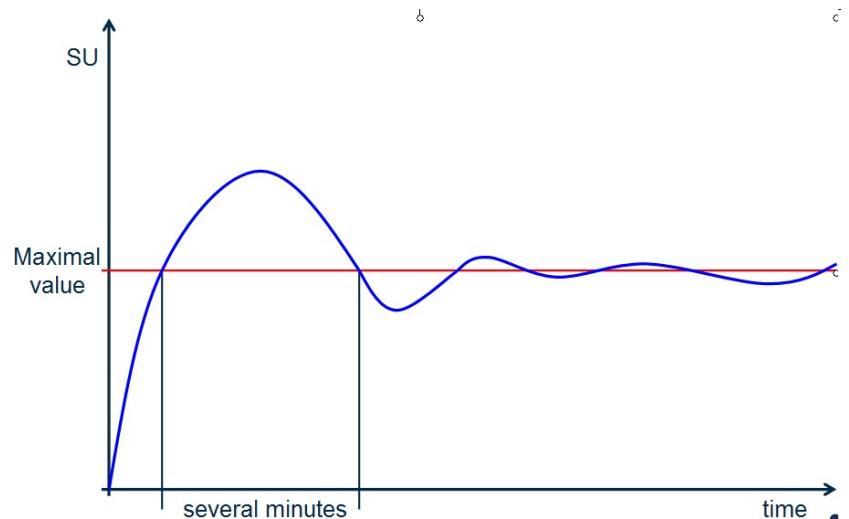
A 4-way LPAR on a zEC12 model 7xx server can deliver approx.
4 * 69869
~ **279476 SU/sec**

Resource Group Management

- To implement capping, the elapsed time is divided into 256 slices. (64 before z/OS V2.1). Each cap slice then represents 1/256th of the total elapsed time.
- Dispatchable units from address spaces or enclaves belonging to a resource group are made nondispatchable during some slices in order to reduce access to the CPU to enforce the resource group maximum.
- The time where address spaces or enclaves in a resource group are set non-dispatchable is called a **CAP SLICE**.
- The time where address spaces or enclaves in a resource group are set dispatchable is called an **AWAKE SLICE**.

Resource Group Maximum continued...

- Every 10 seconds the policy adjustment code re-evaluates the resource groups and adjusts the cap pattern accordingly
- The forecast for the next 10 seconds is based on the average data from the last minute
- Because of the 1 minute average data, during a ramp up period, the max may be exceeded. Also, during periods of workload oscillation WLM may tend to under cap on the up swing but over cap when the workload is dropping off.



Resource Group Maximum continued...

Under certain conditions work may continue consuming service even while being capped

- Any locked work will continue to be dispatched as long as the lock is held
 - Check promoted times in RMF workload activity report
- The region control task is exempt from this nondispatchability.
- The address space will not be marked nondispatchable until the next dispatch.

Resource Group Considerations with zAAP/zIIPs

- Resource Groups are managed based on their general purpose processor consumption (TCB+SRB)
- Difficult to predict result of assigning RGs to service classes that execute on specialty processors
 - Especially when IFAHONORPRIORITY=YES or IIIPHONORPRIORITY=YES is in effect.

1	9	17	25	33	41	49	57
2	10	18	26	34	42	50	58
3	11	19	27	35	43	51	59
4	12	20	28	36	44	52	60
5	13	21	29	37	45	53	61
6	14	22	30	38	46	54	62
7	15	23	31	39	47	55	63
8	16	24	32	40	48	56	64

Other considerations for Resource Groups

- **Not valid for transaction oriented work, such as CICS or IMS transactions.**
 - In order to assign a minimum or maximum capacity to CICS or IMS transactions, the region service classes can be assigned to a resource group.
 - Such interactive work can respond harshly to CPU bottlenecks:
Evaluate what cap level can be tolerated
- **Given the combination of the goals, the importance level, and the resource capacity, some goals may not be achievable when capacity is restricted.**
- Unless there is a specific need for limiting or protecting capacity for a group of work, it is best to not define resource groups and to just let workload management manage the processor resources to meet performance goals.

Identifying Resource Group Capping

- In the RMF Workload Activity report, RG capping is identified in the Execution Delays section as CAP delays
- CAP delays may also be incurred by service classes that have not been associated with resource groups
→ Discretionary Goal Management (DGM)

GOAL: EXECUTION VELOCITY 20.0%				VELOCITY MIGRATION:				I/O	MGMT	93.9%	INIT	MGMT	90.1%
SYSTEM	RESPONSE	TIME	EX	PERF	AVG	--EXEC USING%--	-----	EXEC	DELAYS	%	-----	-USING%-	
	VEL%	INDX	ADRSP	CPU	AAP	IIP	I/O	TOT	CPU	CAP	I/O	CRY	CNT
SYS1	--N/A--	93.9	0.2	0.0	46	N/A	N/A	43	5.8	4.3	1.2	0.3	0.0 0.0

Discretionary Goal Management (DGM)

- Allows an *eligible over-achieving* service class to donate CPU to a discretionary period
 - Objective is to improve service that discretionary periods receive when no non-discretionary periods need help and goals are vastly overachieved
- The donation is implemented through resource group capping.
- To be considered as a donor a period must meet several requirements, including
 - Not a member of a Resource Group (RG)
 - Non-aggressive goal:
 - If it has a velocity goal, the goal must be ≤ 30
 - If it has a response time goal, the goal must be > 60 sec
 - The performance index PI must be < 0.7
- If a period should never donate due to DGM, define appropriately:
 - Velocity goal > 30 or response time goal ≤ 60 sec, or
 - Define resource group with MIN=MAX=0 and associate service classes to be protected with that RG

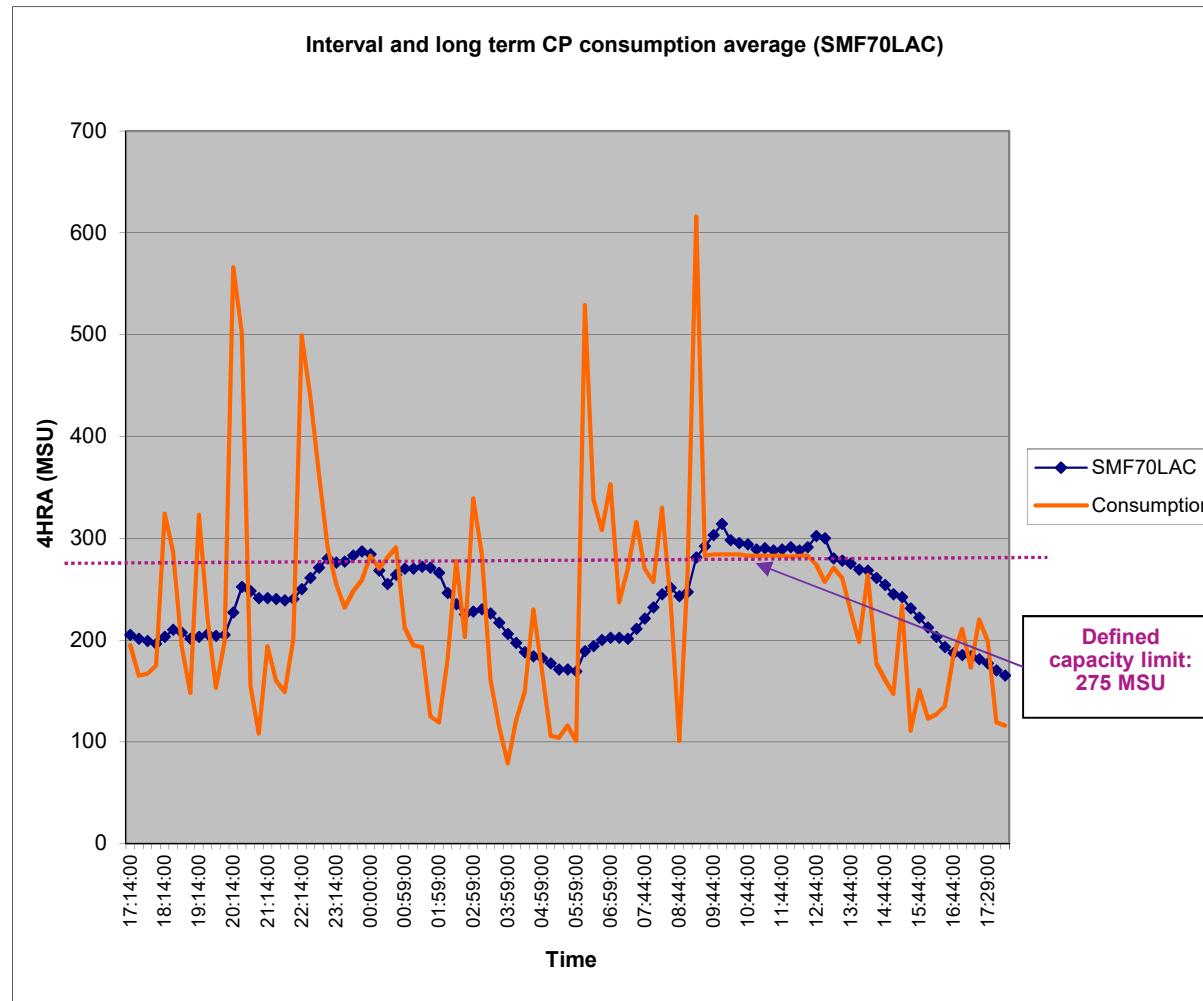
Agenda

- Overview of capping types
- Initial capping
- Absolute capping
- Defined capacity & group capacity
- Resource group capping
- **4HRA management**
- Additional Material

4HRA business aspects

- Peak value of $\text{MIN}(4\text{HRA}, \text{defined capacity limit})$ over billing period determines software charges
 - 4HRA peaks may exceed the defined limit
- Periods of low utilization can be used to “save” capacity for subsequent peak times
 - No capping when $4\text{HRA} < \text{limit}$
- Utilization peaks drive up the 4HRA
- From a cost perspective it is usually desirable to **limit the peak consumption**
- Seek for technical means to
 - Limit consumption (\rightarrow peak consumption)
 - Primarily of less important work
 - Also during –previously uncapped– periods
 - Maintain service levels, responsiveness and system integrity
 - Especially for important work

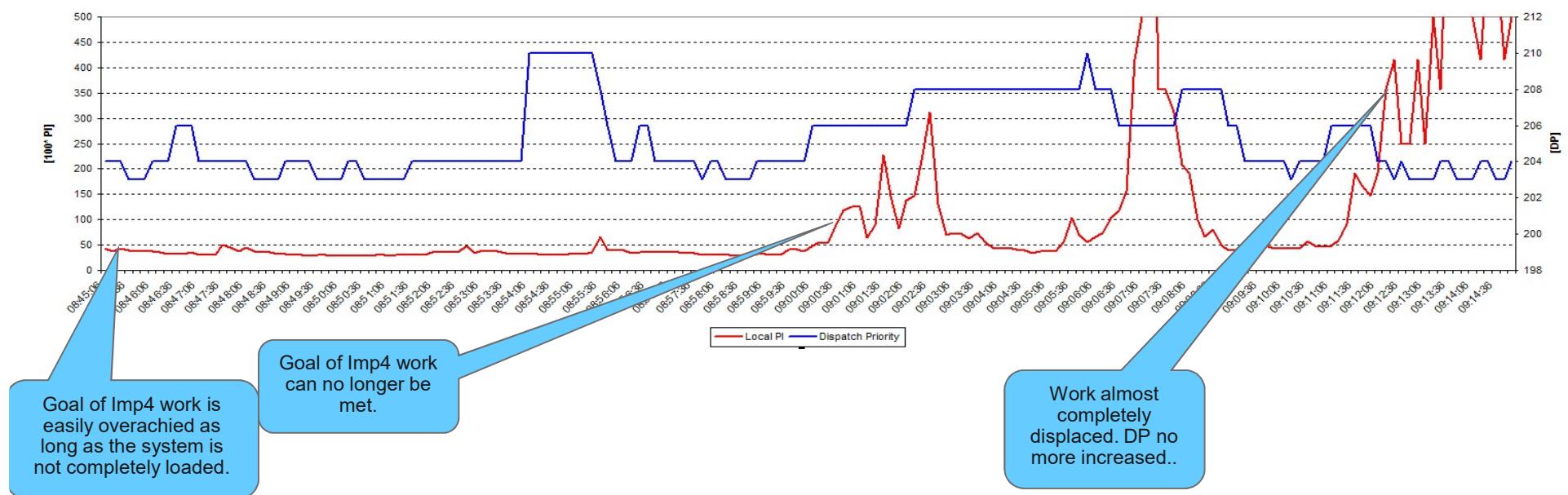
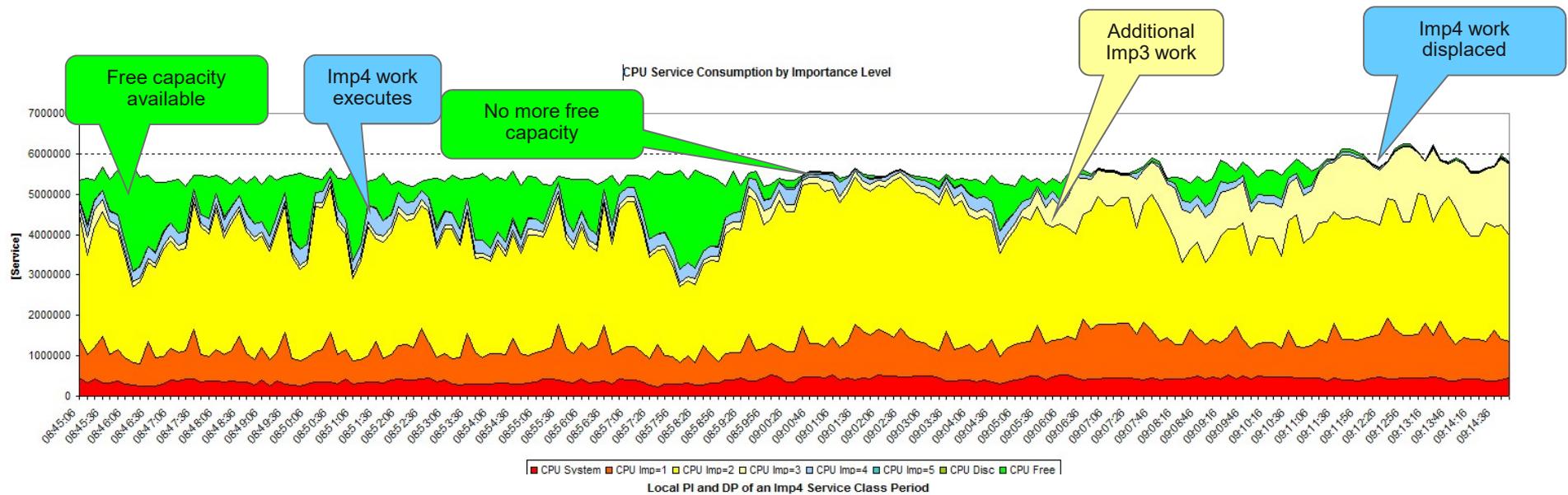
Interval consumption and the 4 hour rolling average: A sample day



Techniques for managing the 4HRA

- Schedule work into off-peak hours
- Limit consumption at an LPAR level
 - Defined or group capacity
 - WLM importance level determines what work gets sacrificed first
 - 4HRA-wise irrelevant, but technically - beware of reduced preemption, promotion
- Selectively limit work within a system
 - Limit demand or parallelism
 - E.g. number of initiators
 - Resource groups
 - But not suitable for every work.
- Any combination of the above
 - Can also help to mitigate impacts of capping

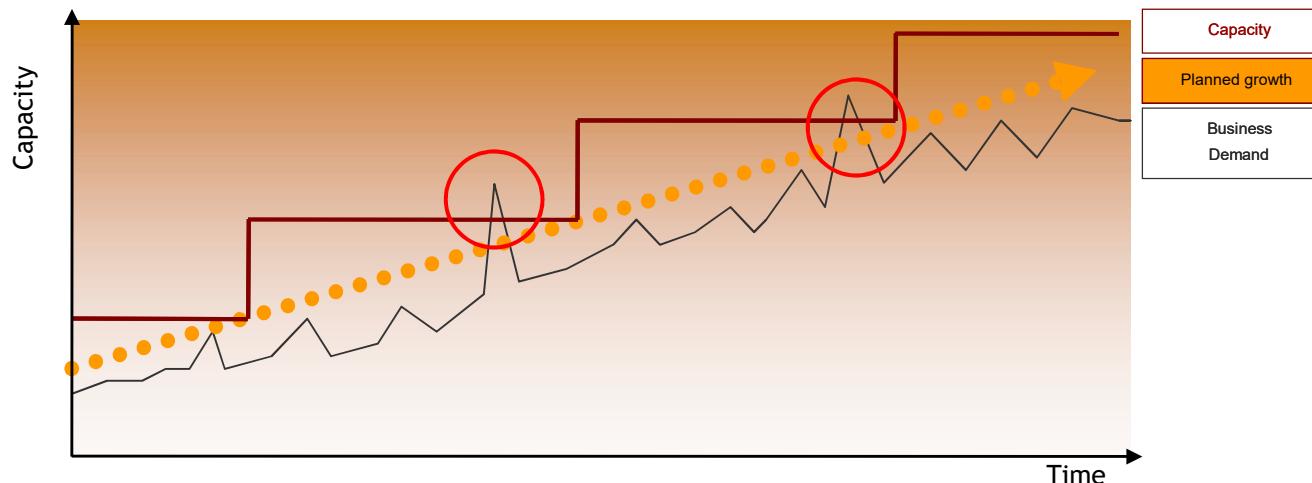
Importance Distribution and Displacement of Work



IBM z/OS Capacity Provisioning Basics



- **Contained in z/OS base component free of charge**
 - Requires a monitoring component, such as z/OS RMF, or equivalent
 - Base element since z/OS V1.9
- **Exploits on System z On/Off Capacity on Demand Feature**
 - IBM zEnterprise System z10 or later
 - If On/Off CoD is not used CPM “analysis” mode may be used for monitoring and alerts
- **Exploits Defined Capacity and Group Capacity**
 - Defined Capacity with IBM System z10 or later
 - Group Capacity with IBM zEnterprise z196 or later



Capacity Provisioning Capabilities Overview

- The Capacity Provisioning Manager (CPM) can control additional capacity on IBM zEC12, z196, or z10 (plus BC10 and later)
 - Number of temporary zAAPs or zIIPs
 - Temporary general purpose capacity
- Considers different capacity levels (i.e. effective processor speeds) for subcapacity processors (general purpose capacity)
 - Can advise on logical processors
 - **Defined capacity and group capacity limits**
 - Can control one or more IBM zEnterprise or System z10 servers
 - Including multiple Sysplexes
 - Provides commands to control z196 and later static power save mode
 - Provides commands to control temporary IFLs

CPM allows for different types of provisioning requests:

- Manually at the z/OS console through Capacity Provisioning Manager commands
- Via user defined policy at specified schedules
- **Via user defined policy by observing workload performance on z/OS**

Policy Approach

The Capacity Provisioning policy defines the circumstances under which additional capacity may be provisioned:

- Three “dimensions” of criteria considered:
 - **When** is provisioning allowed
 - **Which** work qualifies for provisioning
 - **How much** additional capacity may be activated
- These criteria are specified as “rules” in the policy:

```
If
{
    in the specified time interval
    the specified work "suffers"
}
Then up to
{
    - the defined additional capacity
    may be activated
}
```

- The specified rules and conditions are named and may be activated or deactivated selectively by operator commands

Key benefit of CPM is the real time in-depth analysis of bottlenecks

```
MODIFY CPOSERV,APPL=REPORT WORKLOAD TYPE=DETAILED

Workload is analyzed for 1 system(s)
Workload for system PROD1 of sysplex PRODPLEX on CPC CPC1
  CICSHIGH.1 PL/PD/DL/DD/S 1.8 5 1.2 12 System
    PI from 11/16/2012 07:43 is 2.76
      Last limit crossing was 12/16/2012 07:27
      Demand for additional physical zIIPs not recognized
        System zIIP-utilization too low
      Demand for additional physical zAAPs not recognized
        System zAAP-utilization too low
      Demand for additional defined capacity recognized
      Demand for additional physical CPs not recognized
      Demand for capacity level increase not recognized
      Demand for additional logical CPs not recognized
        CPC-wide CP-utilization too low
```

- Key benefit of CPM is the real time in-depth analysis of workload constraints and demands
 - Based on WLM-provided metrics
- Can identify what type of capacity (if any) will help
- Timely reaction, even before capping begins

Capacity Provisioning Policy Strategies... for cost optimization

- Baseline defined or group capacity (DC/GC) limit relatively low
 - but still realistic for periods of low to average utilization
- Use Capacity Provisioning Manager rules to increase DC/GC limit
 - only when required by a qualifying workload during a qualifying time period
 - Time & workload conditions:
Allow for higher DC/GC limits as required by workload
 - unconditionally during a qualifying time period
 - Time conditions without workload conditions:
Unconditionally provision full rule scope
 - When needed, can differentiate between different systems, service definitions, or override policies

Capacity Provisioning Policy sample scenario for cost optimization with LPAR defined capacity

- Sample scenario defines two qualifying workloads
 - Important online work
 - Monday through Friday, 07:45 – 18:00
 - Comprised of two service classes
 - DB2HIGH
 - ONLSTC
 - Up to +300 MSU may be provided in addition
 - Early evening batch
 - Monday through Friday, 20:00 – 22:00
 - Comprised of one service classe
 - BATCRIT
 - Up to +70 MSU may be provided in addition

Capacity Provisioning Policy Sample... ... with LPAR defined capacity (1)

- Two workloads that may warrant higher DC limits during different times of day:

Actions			Rules
Name Filter	Description Filter	Default Status Filter	
<input type="checkbox"/> WeekNight	Weekdays DC pre midnight batch	<input checked="" type="checkbox"/> Enabled	
<input type="checkbox"/> WeekdayDC	Weekdays DC for online work	<input checked="" type="checkbox"/> Enabled	

- WeekdayDC rule scope allows for up to +300 (additional) MSU:

Processor Scope				Defined Capacity Scope	Group Capacity Scope	Conditions
Actions						
	System Filter	Sysplex Filter	Max. Increase (MSU) Filter			
<input type="checkbox"/>	SYS1	PLEX1	300			

Capacity Provisioning Policy Sample... ... with LPAR defined capacity (2)

- Rule is enabled for all weekdays prime time

Nonrecurring Time Conditions		Recurring Time Conditions		Workload Conditions											
<input checked="" type="checkbox"/> <input type="checkbox"/> Actions ▾		Name Filter	Start Date Filter	End Date Filter	Mon Filter	Tue Filter	Wed Filter	Thu Filter	Fri Filter	Sat Filter	Sun Filter	Start Time ▲ Filter	Deadline Filter	End Time Filter	
<input type="checkbox"/>	AllWeekD		Jan 2, 2014	Dec 31, 2014	<input type="checkbox"/>	<input checked="" type="checkbox"/>	7:45 AM	6:00 PM	6:30 PM						

- Workload is defined by specific service classes

Importance Filters		Included Service Classes		Excluded Service Classes					
<input checked="" type="checkbox"/> <input type="checkbox"/> Actions ▾		Service Definition Filter	Service Policy Filter	Service Class Filter	Period Filter	Provisioning PI Filter	Provisioning Duration (Minutes) Filter	Deprovisioning PI Filter	Deprovisioning Duration (Minutes) Filter
<input type="checkbox"/>	Any service definition	Any service policy		DB2HI	1	1.4	2	1.1	10
<input checked="" type="checkbox"/>	Any service definition	Any service policy		ONLSTC	1	1.5	5	1.1	10

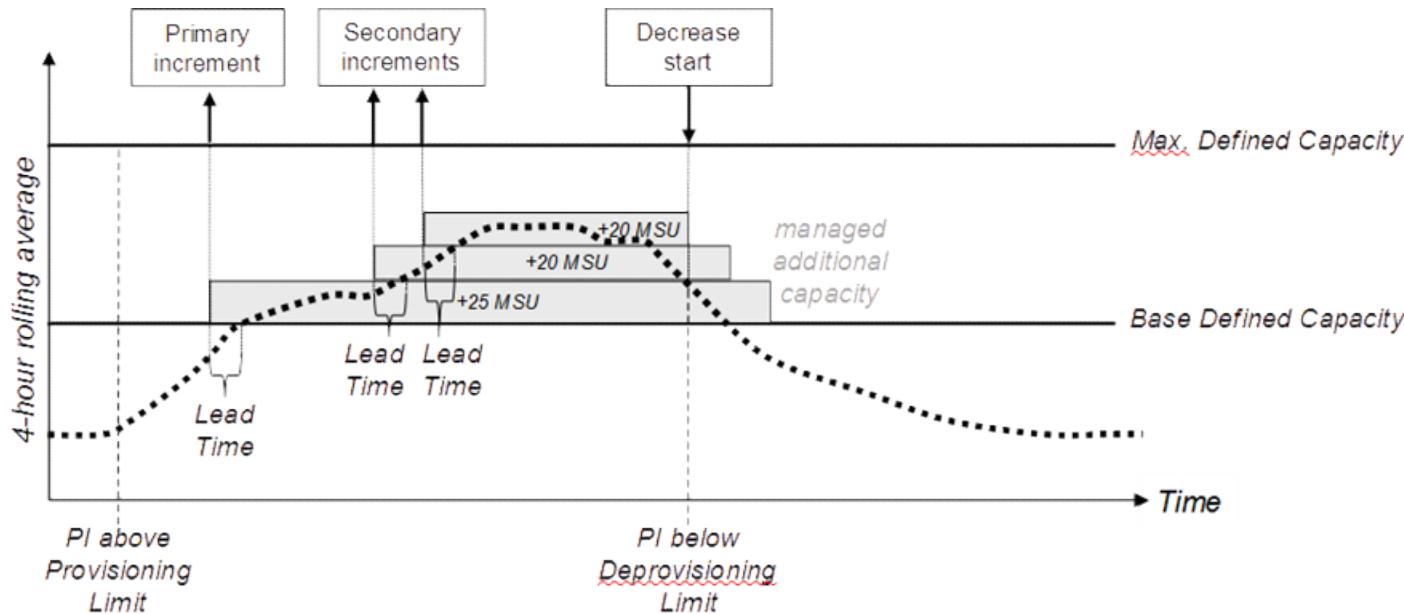
Capacity Provisioning Policy Sample... ... with LPAR defined capacity (3)

- Similarly, another rule is defined to cover a batch workload
 - Up to +70 MSU for a single batch service class

Nonrecurring Time Conditions		Recurring Time Conditions		Workload Conditions									
				Actions ▾									
	Name Filter	Start Date Filter	End Date Filter	Mon Filter	Tue Filter	Wed Filter	Thu Filter	Fri Filter	Sat Filter	Sun Filter	Start Time ▲ Filter	Deadline Filter	End Time Filter
<input type="checkbox"/>	AllWeekN	Jan 2, 2014	Dec 31, 2014	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	8:00 PM	10:00 PM	10:00 PM				

Importance Filters	Included Service Classes	Excluded Service Classes						
<input checked="" type="checkbox"/> <input type="checkbox"/> Actions ▾								
Service Definition Filter	Service Policy Filter	Service Class Filter	Period Filter	Provisioning PI Filter	Provisioning Duration (Minutes) Filter	Deprovisioning PI Filter	Deprovisioning Duration (Minutes) Filter	PI Scope Filter
<input type="checkbox"/> Any service definition	Any service policy	BATCRIT	1	1.8	5	1.3	10	System

Capacity Provisioning Defined Capacity Management



- When required by the defined workload the CPM will increase the defined capacity limit while the workload criteria are met
- The additional defined capacity will be managed down as the workload permits
 - Or deferred, based on user specification
- Additional user-initiated DC/GC activations are recognized and tolerated.

Conclusion

z/OS provides the tools to monitor
and tightly manage
the rolling 4 hour average consumption
for efficient cost management.

z/OS Capacity Provisioning Documentation

- For more information contact: IBMCPCM@de.ibm.com
- z/OS Capacity Provisioning: Introduction and Update for z/OS V2.1, SHARE in Anaheim, Session 14210, 8/2013
- Website <http://www.ibm.com/systems/z/os/zos/features/cpm>
- z/OS MVS Capacity Provisioning User's Guide, SC34-2661, at <http://publibz.boulder.ibm.com/epubs/pdf/iea3u110.pdf>

