Route Me, Workload Manager
WLM Functions for Dynamic Workload Routing

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Agenda

- **Concepts**
  - Importance levels
  - Displaceable capacity
  - Free capacity

- WLM Sysplex Routing Services
  - IWMWSYSQ
  - IWMSRSRS
  - IWM4SRSC
  - Basic capacity-based weights and additional influencers

- Observations, best practices and optimization approaches
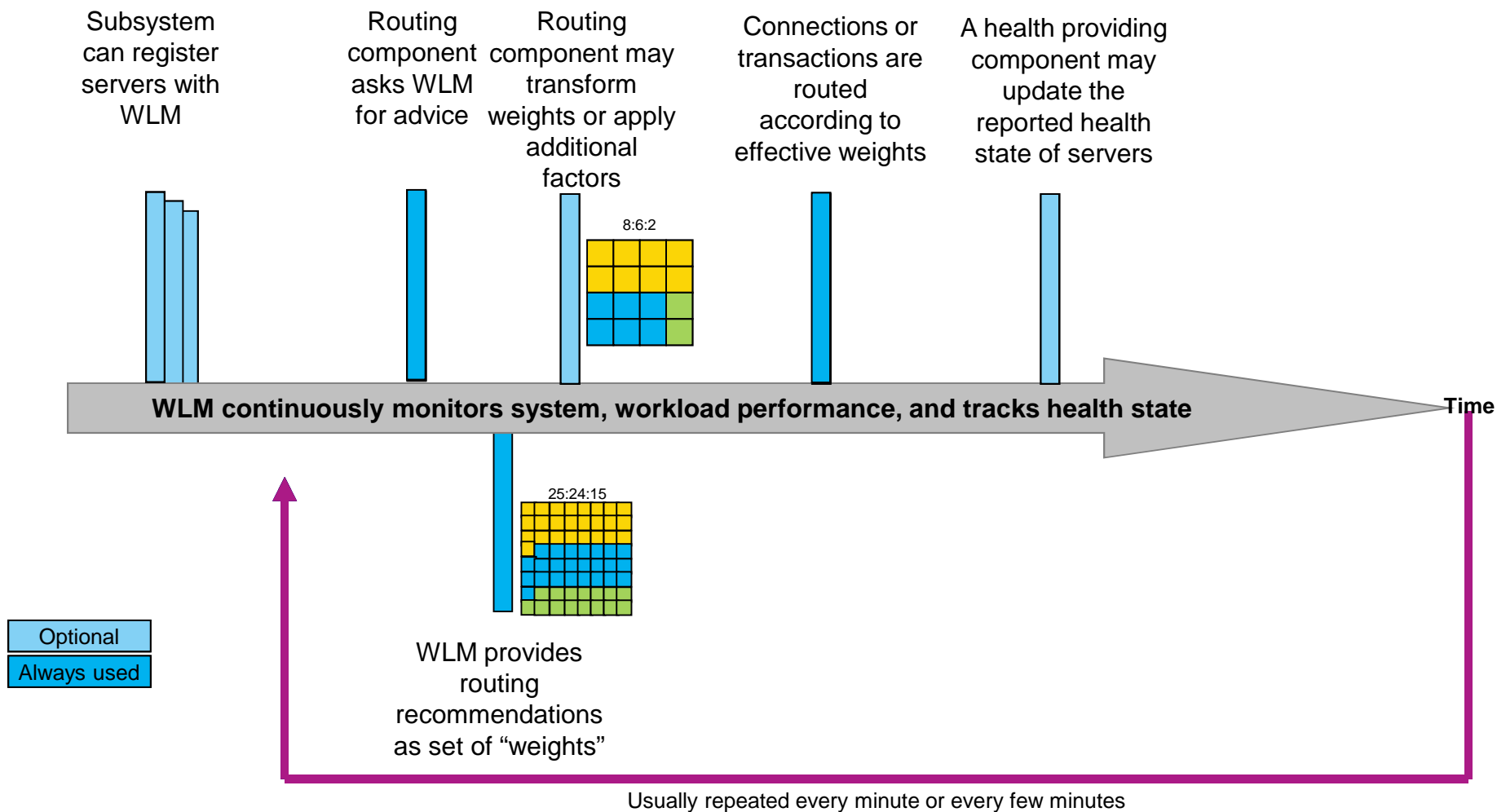
WLM Dynamic Workload Routing Services

- WLM Sysplex routing services provide guidance to routing components on how to distribute
  - Transactions
  - Connections

- Multiple sets of routing APIs are offered by WLM
  - Same underlying capacity view but
    different algorithms and influencing parameters

- Scope
  - Multiple systems of one Sysplex, one or more servers per system
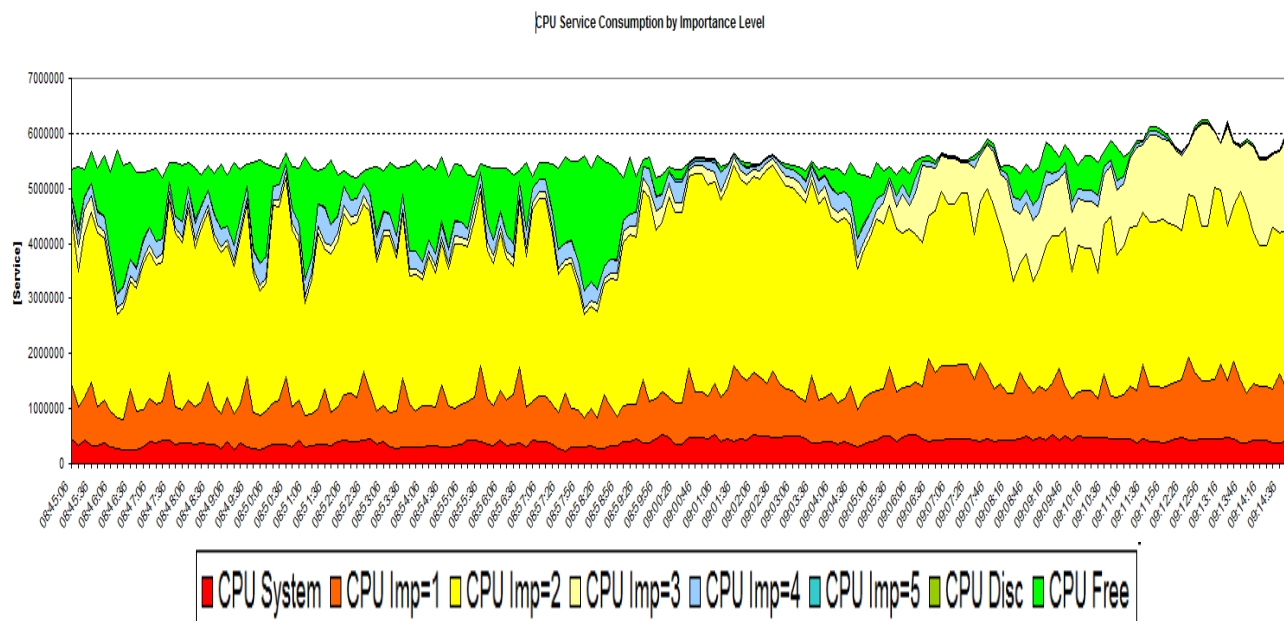
- Primary objectives for balancing:
  - Capacity – Route work according to capacity available
  - Performance – WLM goal attainment
  - Integrity – Avoid shortages
  - Reliability – Avoid not healthy work consumers

The life cycle of workload routing recommendations

Subsystem can register servers with WLM

Routing component asks WLM for advice

Routing component may transform weights or apply additional factors

8:6:2

Connections or transactions are routed according to effective weights

A health providing component may update the reported health state of servers

WLM continuously monitors system, workload performance, and tracks health state

Time

25:24:15

Optional

Always used

WLM provides routing recommendations as set of "weights"

Usually repeated every minute or every few minutes

Concepts: Service consumption by importance level

- WLM/SRM tracks the consumption of *CPU service* by importance level

- WLM management will sacrifice less important work to allow more important work to achieve the goals. Less important work may be *displaced* entirely.

CPU Service Consumption by Importance Level

Legend: CPU System ▪ CPU Imp=1 ▪ CPU Imp=2 ▪ CPU Imp=3 ▪ CPU Imp=4 ▪ CPU Imp=5 ▪ CPU Disc ▪ CPU Free

- Level 0:
  SYSTEM and SYSSTC
  ▪ CPU System

- Level 1-5:
  Importance 1 through 5
  ▪ CPU Imp=1 ▪ CPU Imp=2 ▪ CPU Imp=3 ▪ CPU Imp=4 ▪ CPU Imp=5

- Level 6:
  Discretionary
  ▪ CPU Disc

- Level 7:
  Free (unused) capacity
  ▪ CPU Free

Concepts: WLM determination of displaceable capacity

- An important metric for routing decisions is the *displaceable capacity* at a given importance level (i):

$$DisplaceableCapacity_i = FreeCapacity + \sum_{j=i+1}^{6} CapacityConsumed_j$$

or

$$DisplaceableCapacity_i = \sum_{j=i+1}^{7} CapacityConsumed_j$$

- For the purpose of routing the **3 min rolling averages** of consumption and free capacity are considered

- The *consumed capacity* is usually well understood
  - *Free capacity* may be harder to understand
  - Needs to reflect many different constraints that could limit the capacity that can be consumed by an LPAR.

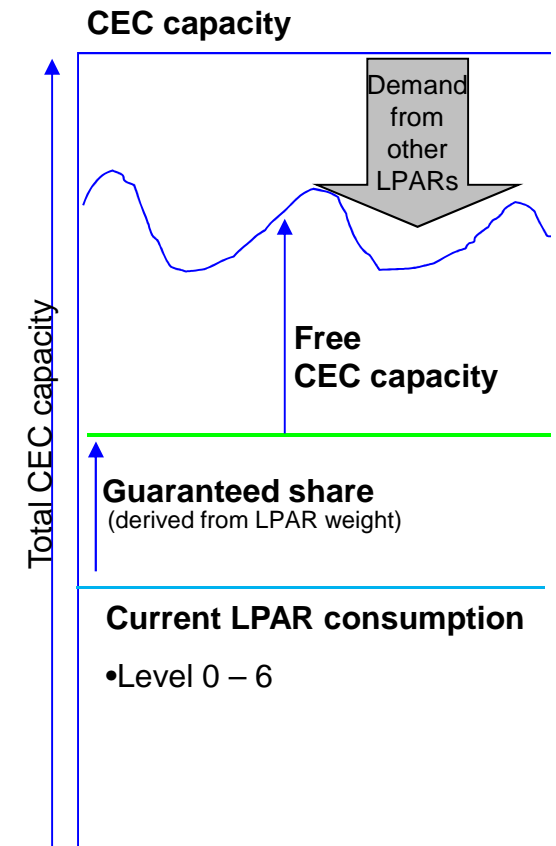- All processor types to be assessed independently

- Logical capacity (number of logical processors)

- LPAR initial cap (*hard cap*), LPAR absolute cap (zEC12 GA2)

- Defined capacity (*soft cap*)

  - LPAR level defined capacity
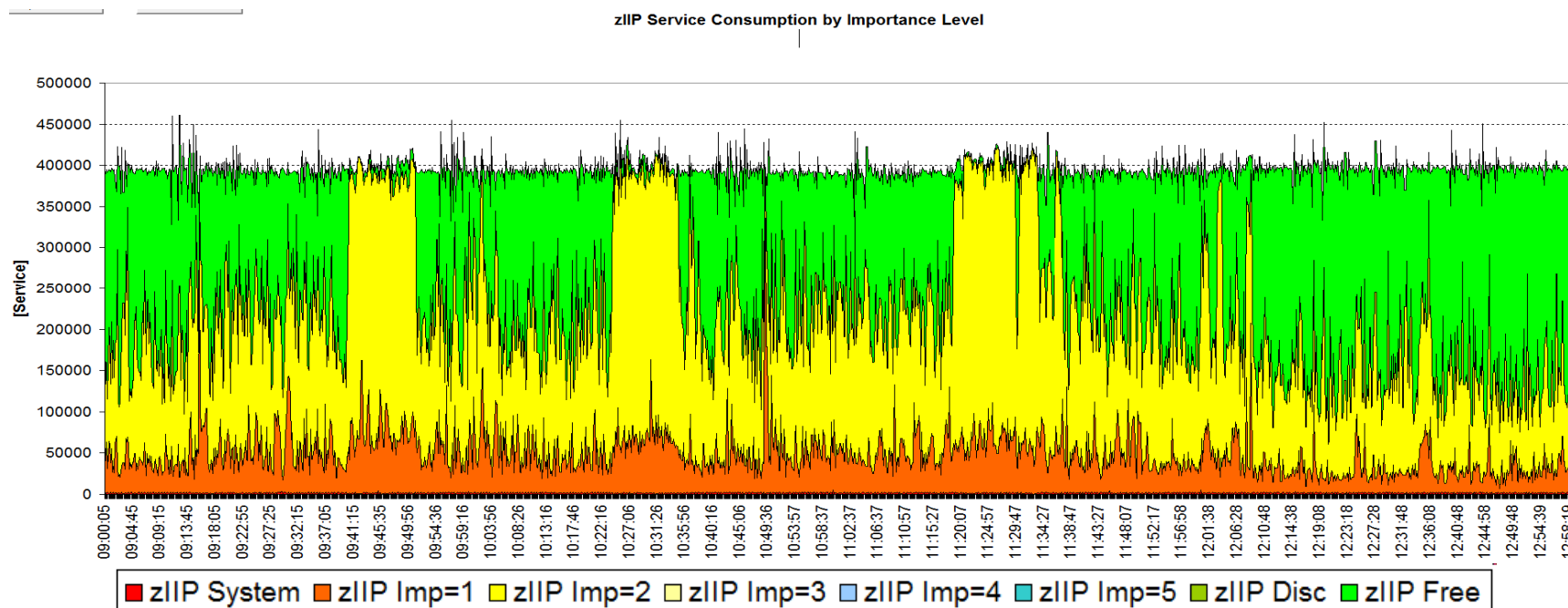
  - Group capacity

  Defined capacity is only considered while capping is in effect

- LPAR weight

  - Guaranteed capacity unless configuration parameters prohibit the guaranteed capacity to be consumed

  - IRD weight management may change weights dynamically hence guaranteed capacity changes

- Available CEC capacity – unused CEC capacity can be consumed beyond weight
  In addition, consider

  - MVS Busy (MVS wait time)

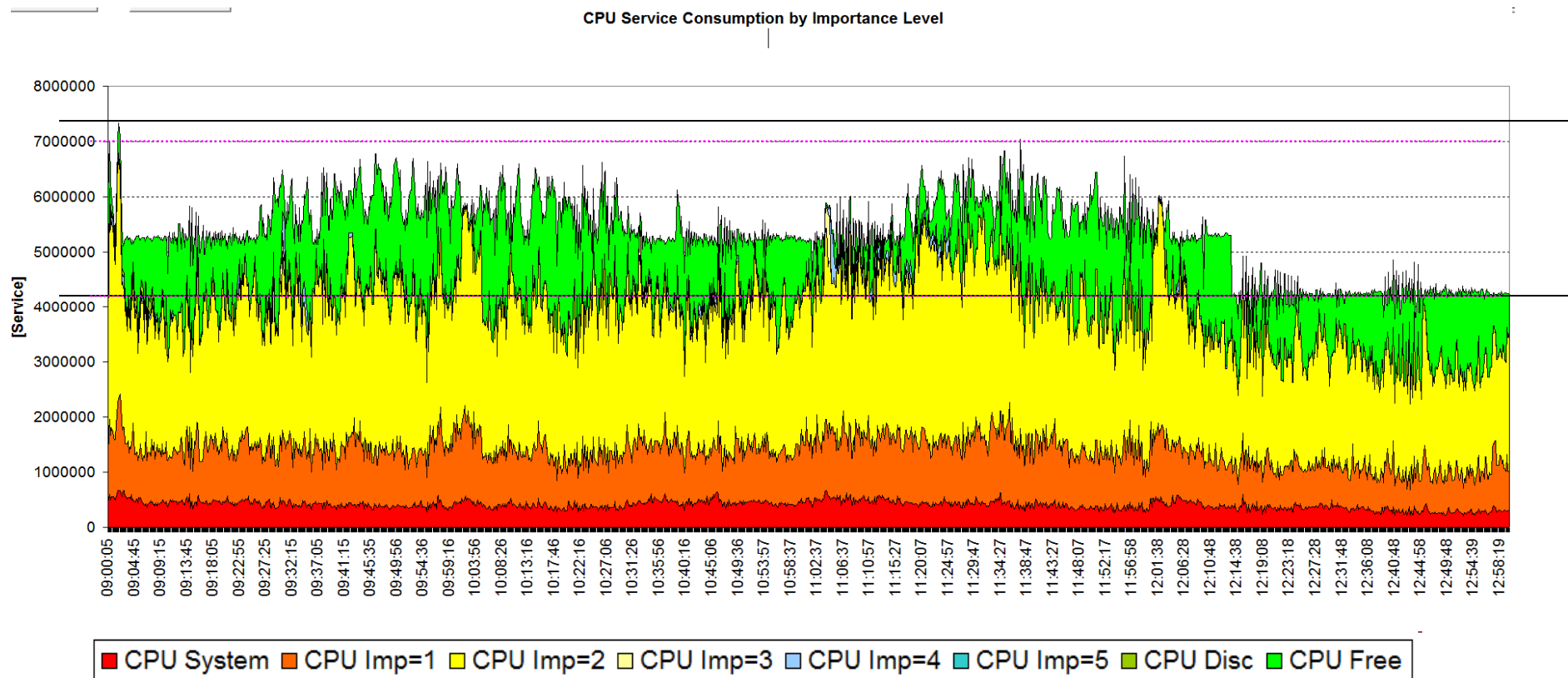 - LPAR configuration: shared vs. dedicated

CEC capacity

Demand from other LPARs

Free CEC capacity

Total CEC capacity

Guaranteed share
(derived from LPAR weight)

Current LPAR consumption

• Level 0 – 6

Free LPAR Capacity - Example 1

zIIP Service Consumption by Importance Level

Legend: ■ zIIP System ■ zIIP Imp=1 □ zIIP Imp=2 □ zIIP Imp=3 ■ zIIP Imp=4 ■ zIIP Imp=5 ■ zIIP Disc ■ zIIP Free

- While an LPAR is running below its weight entitlement and no capping is in effect the total consumed plus free capacity is usually pretty constant.

Free LPAR Capacity - Example 2

CPU Service Consumption by Importance Level

Legend: CPU System | CPU Imp=1 | CPU Imp=2 | CPU Imp=3 | CPU Imp=4 | CPU Imp=5 | CPU Disc | CPU Free

- Capping, group capping, and influences by other LPARs can **heavily** and **frequently** change the total capacity available to an LPAR

Free LPAR Capacity – some considerations

- *A single capacity value can hardly represent all the different preferences that installations may have.*

  Examples:

  - Preferentially displace the lowest importance work

  - Minimize/control crossover of zIIP/zAAP work to CPs

  - Equal distribution of used capacity

  - Preferential use of guaranteed capacity vs. free CEC capacity

  - Leave whitespace for expected workloads, e.g. batch

  - Anticipation of capping before capping becomes active

  - Availability/anticipation of not activated temporary capacity (On/Off Capacity on Demand)

  - Avoid usage of activated temporary capacity

  - …

Blue: Controls are available

Agenda

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  - Importance levels
  - Displaceable capacity
  - Free capacity

- WLM Sysplex Routing Services
  - IWMWSYSQ
  - IWMSRSRS
  - IWM4SRSC
  - Basic capacity-based weights and additional influencers

- Observations, best practices and optimization approaches

WLM Sysplex Routing Services Overview

Interface	Purpose	Typical Use (not exhaustive)
IWMWSYSQ	Obtain free & displaceable capacity of systems in Sysplex (1, 3, and 10 min rolling averages).	Customer applications and subsystems that want to consider free and displaceable capacity.
IWMSRSRS FUNCTION=SELECT (IWMSRSRG,DRS)	Obtain best suited registered servers to route work to. Only **capacity** considered.	**Sysplex Distributor BASEWLM**,
IWMSRSRS FUNCTION=SPECIFIC (IWMSRSRG,DRS)	Obtain list of registered eligible servers and recommended weights. Besides **capacity** goal achievement (**PI**), **queue time** for enclaves, **health** indicator is considered.	**DDF**
IWM4SRSC	For a specific server address space obtain recommendation how suitable a server is. No registration required. Besides **server-specific capacity** goal achievement (**PI**), **abnormal termination** rate, **health** indicator is considered.	**Sysplex Distributor SERVERWLM**
IWM4HLTH	Provide health status for an address space. Value is considered by IWM4SRSC and IWMSRSRS FUNCTION=SPECIFIC	CICS Transaction Gateway, DDF, LDAP.

Routing Services: IWMWSYSQ

- Provides displaceable capacity at each importance level

  - The system level contains the total system capacity, including SYSTEM work

  - Rolling average over 60, 180, and 600 sec.

- Data are returned for all processor types

- In addition: System shortages information, uniprocessor speed of a single processor, zAAP and zIIP normalization factors– required for subcapacity models

  - Use EXTENDED_DATA=YES for comprehensive information
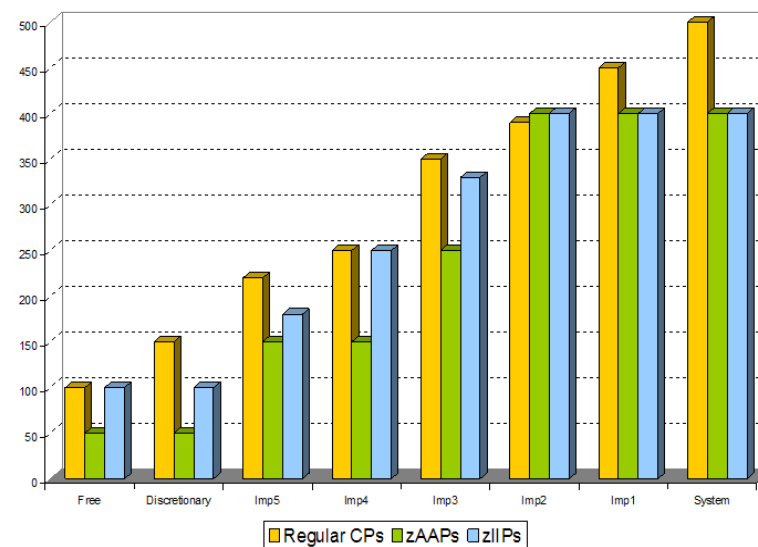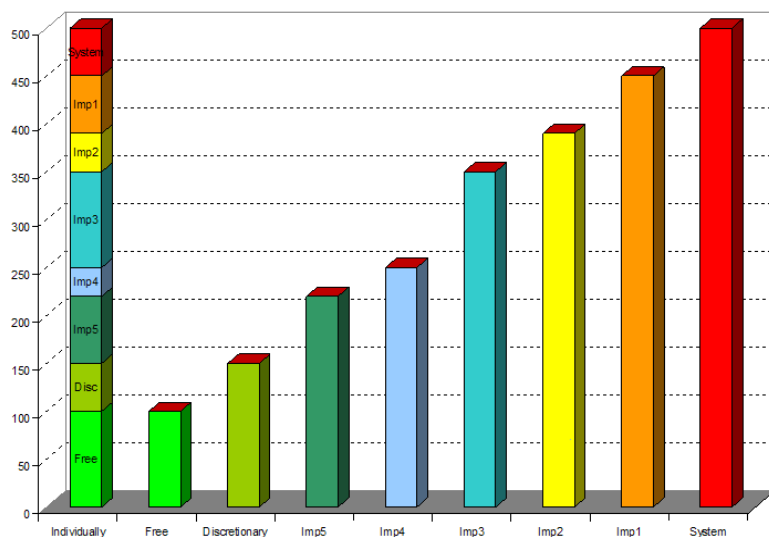
WLM Routing Weights Computation
Overview: *Steps Involved*

- Compute capacity-based weights for systems

  - Includes adjustment for specialty processor capacity, crossover cost, and importance level weighting

  - Return weights for each processor type and combined weight

  - Frequently scaled to 64

- When multiple servers run on a system divide the system weight by #servers to derive a server's weight

- Only for IWMSRSRS SPECIFIC and IWM4SRSC, modify weights based on

  - Performance index

  - Queue time ratio

  - Health indicator

IWMSRSRS vs. IWM4SRSC
Capacity calculations

- **BASEWLM (WLM service IWMSRSRS)**

  - Locate the importance level –searching bottom-up- where at least 5% of free/ displaceable capacity is available on one system

  - Possible disadvantages

    - Importance of work to be routed is not considered

    - May result in oscillations

  - Advantage

    - Considers the low important work because it is a bottom up approach

- **SERVERWLM (WLM service IWM4SRSC)**

  - Calculates the weight based on the *displaceable capacity at the importance level that the work will run* on the systems.
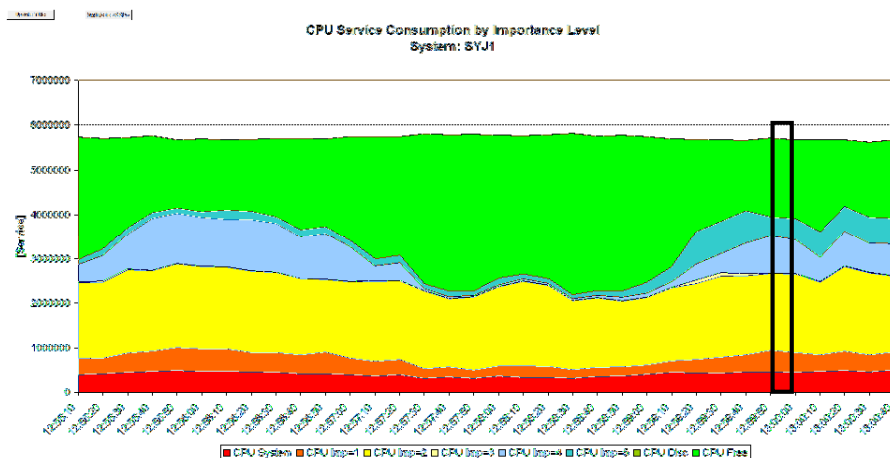
  - Advantages

    - Considers the importance of the work

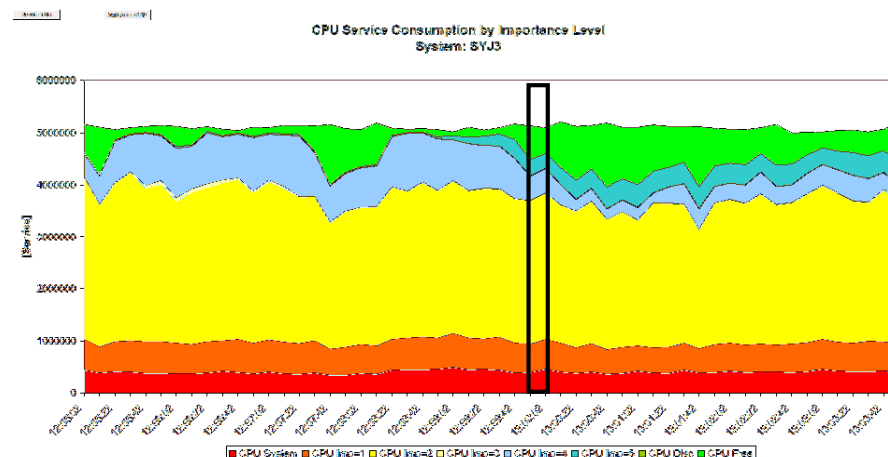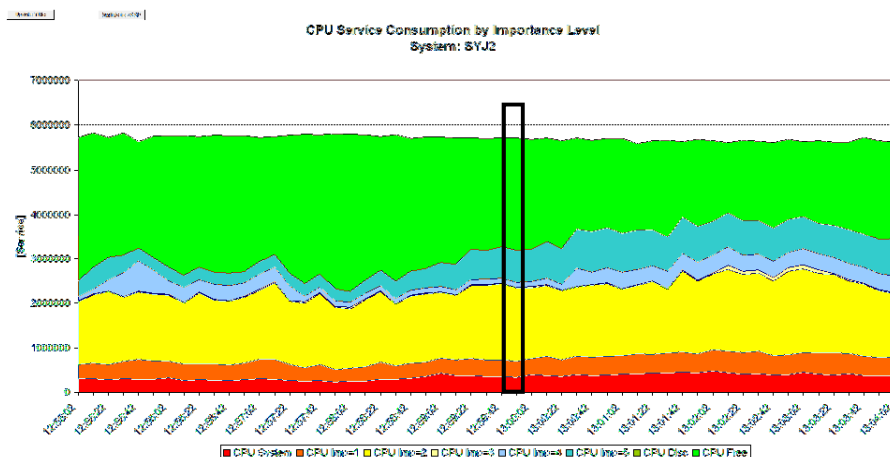   - Avoids the oscillation of routing recommendations

  - Possible disadvantage

    - Lower important work is not distinguished from free capacity (➜Importance Level Weighting)
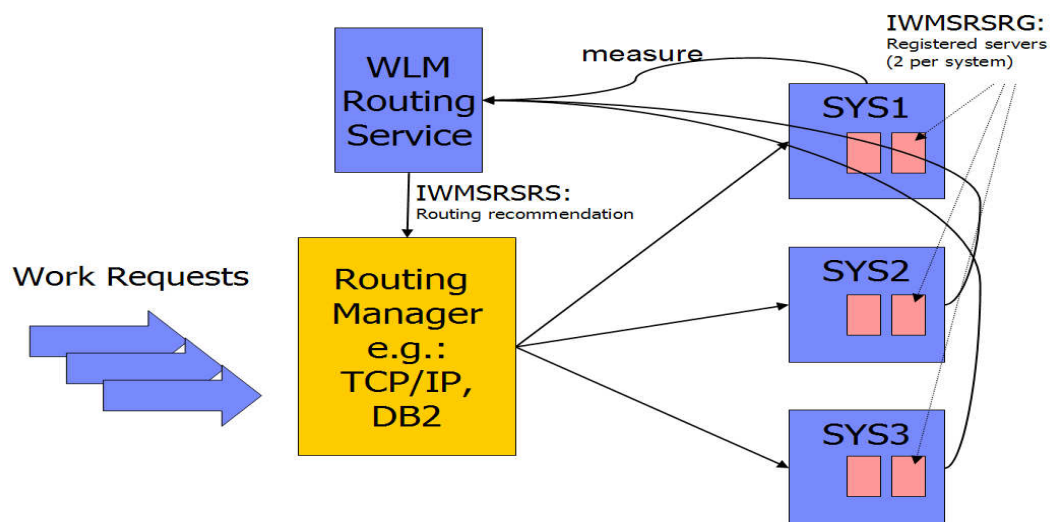
Example: How WLM computes weights
Base data for subsequent examples

The consumption at importance level 1 is similar on all systems. But SYJ3 shows a much higher importance 2 consumption,

Sysplex Routing with IWMSRSRS:
Bottom-Up Weight Calculation

Algorithm

1. Select the importance level that provides at least **5% of cumulative capacity on at least one** system

2. Calculate system weight on each system

$$\text{System Weight} = \frac{\text{SUs}_{\text{at selected level}}[\text{this system}]}{\sum_{\text{I for all systems}} \text{SUs}_{\text{at selected level}}[\text{i}]} \bullet 64$$

3. Calculate server weight:

$$\text{Server Weight} = \frac{\text{System Weight}}{\text{\# of servers on system}}$$

Example: System weights for IWMSRSRS ("BASEWLM")

DATA

Time/System	13:00:00/J1			13:00:02/J2			13:00:02/J3		
	SU/IL	Sum	%	SU/IL	Sum	%	SU/IL	Sum	%
System	450307	5668854	100%	392443	5683002	100%	450802	5097430	100%
IL 1	438985	5218547	92%	366208	5290559	93%	578145	4646628	91%
IL 2	1762932	4779562	84%	1584407	4924351	87%	2813465	4068483	80%
IL 3	14875	3016630	53%	31141	3339944	59%	6443	1255018	25%
IL 4	773676	3001755	53%	116617	3308803	58%	473513	1248575	24%
IL 5	473036	2228079	39%	723396	3192186	56%	284036	775062	15%
Disc	0	1755043	31%	0	2468790	43%	0	491026	10%
Free	1755043	1755043	31%	2468790	2468790	43%	491026	491026	10%

BASEWLM

Selected Importance Level=		7
Capacity at the Importance Level=	1755043+2468790+491026	4714859
Weight for System J1=	1755043/4714859*64	24
Weight for System J2=	2468790/4714859*64	34
Weight for System J3=	491026/4714859*64	7

Example: System weights for IWM4SRSC ("SERVERWLM") at importance 1

DATA

Time/System	13:00:00/J1			13:00:02/J2			13:00:02/J3		
	SU/IL	Sum	%	SU/IL	Sum	%	SU/IL	Sum	%
System	450307	5668854	100%	392443	5683002	100%	450802	5097430	100%
IL 1	438985	5218547	92%	366208	5290559	93%	578145	4646628	91%
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IL 5	473036	2228079	39%	723396	3192186	56%	284036	775062	15%
Disc	0	1755043	31%	0	2468790	43%	0	491026	10%
Free	1755043	1755043	31%	2468790	2468790	43%	491026	491026	10%

SERVERWLM

Selected Importance Level=		1
Max Capacity at the Importance Level=	System J2	5290559
Weight for System J1=	5218547/5290559*64	63
Weight for System J2=	5290559/5290559*64	64
Weight for System J3=	4646628/5290559*64	56

WLM Routing: Crossover to CP cost

- By default: Assumption is that there is no penalty when zAAP or zIIP work is executed on regular CPs

    - For IFAHONORPRIORITY=YES or IIPHONORPRIORITY=YES

- In Reality:

    – Executing zAAP or zIIP work on regular CPs may incur costs

        - Work is priced by its consumption on regular CPs

    – Systems to which work is routed to may have different configurations

        - Number of zIIPs or zAAPs may differ between systems

        - It might be of advantage to route the work to systems with more zIIP or zAAP capacity

- Solution

    – SERVERWLM allows to specify ProcXCost for zAAPs and zIIPs

        - Begin with small cost values

- As a result WLM will use a different method to calculate the routing weights which reflects capacities of different processor types much better

WLM Routing: Importance level weighting

												Weighted Sus				IWM4SRSC weights		
Time	System	System	IL 1	IL 2	IL 3	IL 4	IL 5	Disc	Free		Constant	Square Root	Linear	Quadratic	Constant	Square Root	Linear	Quadratic
13:00:00	J1		450307	438985	1762932	14875	773676	473036	0	1755043	5218547	10206412	21754659	117826411	63	59	56	51
13:00:02	J2		392443	366208	1584407	31141	116617	723396	0	2468790	5290559	11043437	24993423	147905587	64	64	64	64
13:00:02	J3		450802	578145	2813465	6443	473513	284036	0	491026	4646628	7449427	12975818	50627374	56	43	33	22

Square Root	IL_Weighting=1	1.00	1.41	1.73	2.00	2.24	2.45	2.65
Linear	IL_Weighting=2	1	2	3	4	5	6	7
Quadratic	IL_Weighting=3	1	4	9	16	25	36	49

- Importance Level Weighting is available with service IWM4SRSC (SD SERVERWLM)

- Default routing algorithm uses "Constant" - no weighting of the lower importance levels

    - As a result the weights returned by service IWM4SRSC to Sysplex Distributor are nearly identical for all three systems (see column "Constant")
      With importance level weighting it is possible to factor in the work running at lower importance levels.

  – Three weighting levels exist: Square Root (mildly – recommended initial setting), Linear and Quadratic (heavy) weighting

  – You can observe that the biggest effect is for system J3 on which much more work runs at importance level 2

  – Concern: A too high weighting can cause oscillation effects

If PI>1 the weight will be divided by the performance index

• with default IEAOPT RTPIFACTOR = 100

System	Avail Capacity	Orig. Server weight	PI	WLM weight
SYS1	110	18	1.3	14
SYS2	100	16	0.8	16
SYS3	95	15	1.0	15
SYS4	95	15	2.0	8
Total		64		53

Health indicator effect on routing weight

- A health indicator may be set per server address space

- Health=100 is default and remains in effect until a different value is set
  via IWM4HLTH
    - Each IWM4HLTH invocation replaces previous health indicator
      values

- If the health indicator of a server is <100 its capability is reduced

- The server weight will be reduced by applying a factor of health/100
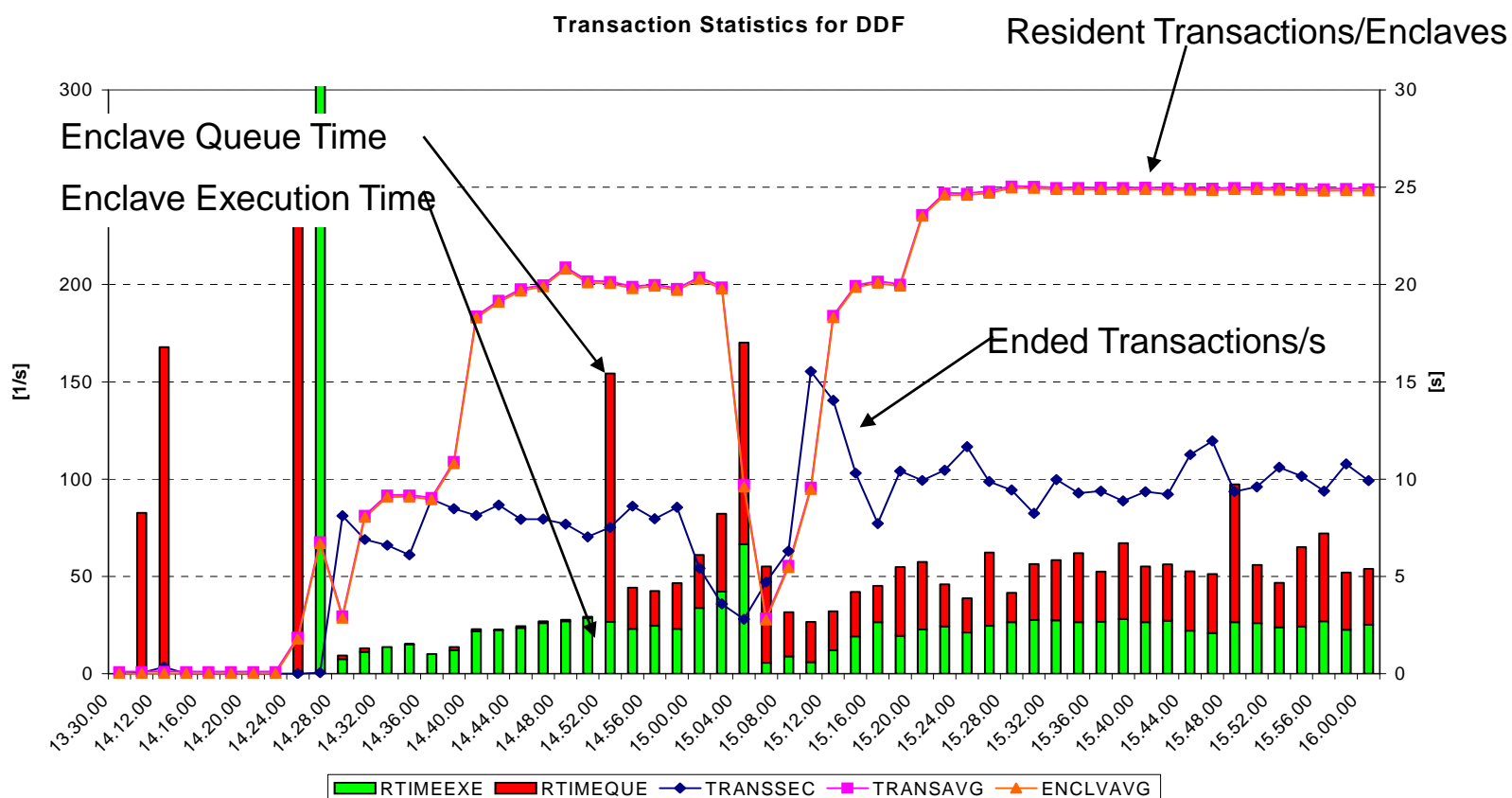
Background: Routing Services: DB2

DDF address spaces register as routing servers to WLM. DDF address spaces also periodically retrieve the routing list and ship it to the gateway which routes the requests.
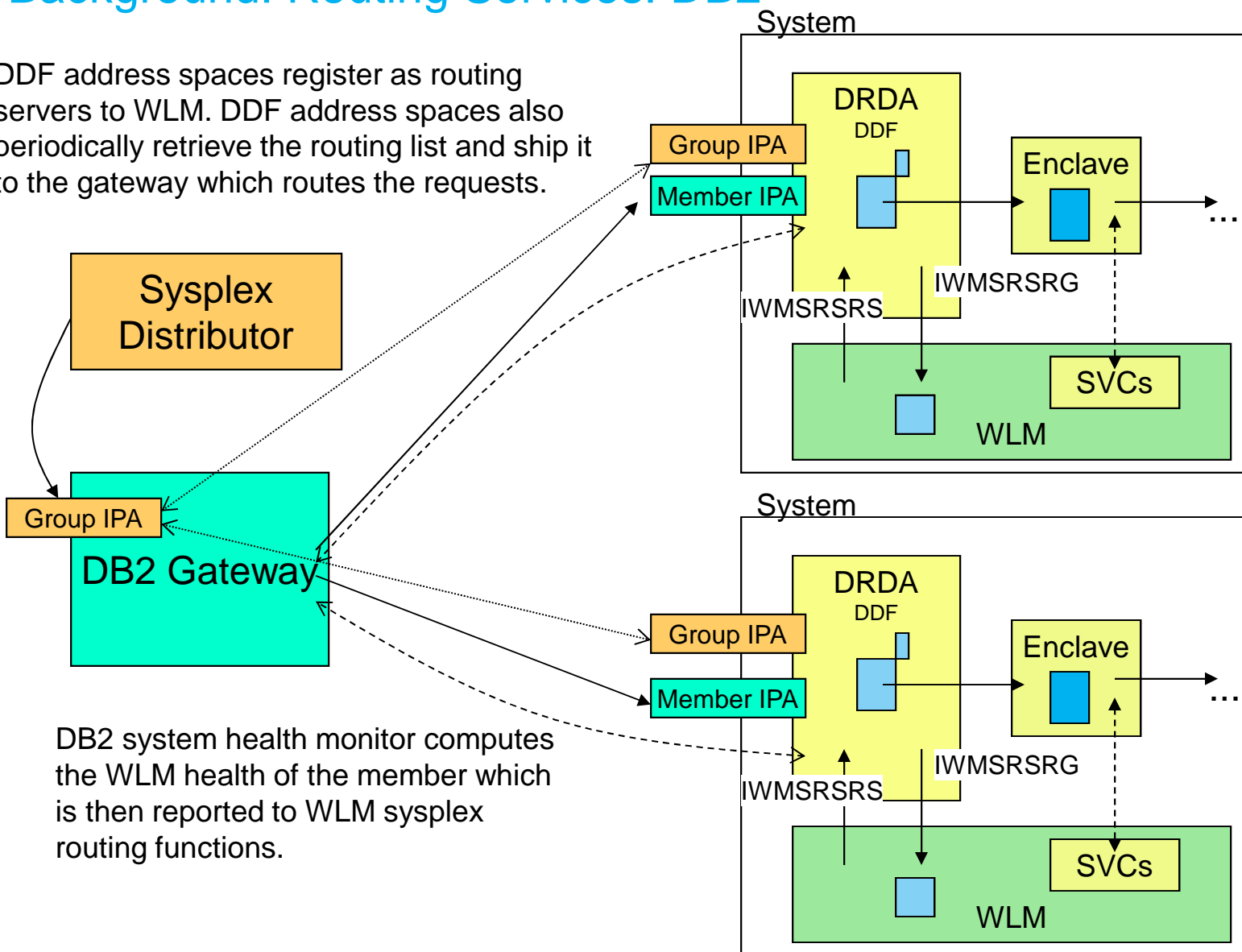
DB2 system health monitor computes the WLM health of the member which is then reported to WLM sysplex routing functions.

Sysplex Distributor

DB2 Gateway

Group IPA

System

DRDA
DDF

Group IPA

Member IPA

Enclave

...

IWMSRSRS

IWMSRSRG

SVCs

WLM

System

DRDA
DDF

Group IPA

Member IPA

Enclave

...

IWMSRSRS

IWMSRSRG

SVCs

WLM

Sysplex Routing for DB2: Example Queue Time Ratio

- Servers with a better enclave queue time : execution time ratio will be favored

  - Server weight reduced by factor execution time / (execution time+ queue time)

- Only effective if DB2 is configured with "DDF Threads" INACTIVE

Transaction Statistics for DDF

Resident Transactions/Enclaves

Enclave Queue Time

Enclave Execution Time

Ended Transactions/s

Legend: RTIMEEXE · RTIMEQUE · TRANSSEC · TRANSAVG · ENCLVAVG

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  - IWM4SRSC
  - Basic capacity-based weights and additional influencers

- Observations, best practices and optimization approaches

- Actual workload distribution may deviate from anticipated or warranted distribution

- Understanding and optimizing workload routing may require skills from multiple domains:

  - Applications
  - Subsystems involved
  - Routing product & configuration
    - Routing provide usually commands to understand WLM-provided weights and overrides
    - First step to understand raw WLM weights
    - Most routing services parameters are specified here
  - LPAR configuration & WLM

Drill-down into balancing issues

- Use routing component commands to understand WLM recommendations vs. routed work

- What routing mechanism is being used?

- Understand impact due to
  - Capacity
  - Performance Index
  - Health

  Use CPU activity report and Workload activity reports to understand LPAR/CEC configuration, load and performance index
  - RMF Mon III data can provide better granularity

```
$ netstat -O –
  P15150


MVS TCP/IP NETSTAT CS
  V1R12        TCPIP Name:
  TCPIP             10:31:18

Dynamic VIPA Destination Port Table
  for TCP/IP stacks:

Dest:          …..15150


  DestXCF:    …


  TotalConn: 0000059767  Rdy: 001
  WLM: 12   TSR: 100

  DistMethod: ServerWLM
```

- The WLM weight in this summary display is derived by the weight value returned by IWM4SRSC (ServerWLM)

  - However, it has been post processed by Sysplex Distributor

    - Potentially reduced based on a number of health factors and

    - Normalized (divided by 4 to yield a value between 0-16 vs 0-64).

  - This value is what SD will use for load balancing and can be compared to the values of the other targets

- TSR (target server responsiveness) the SD view of responsiveness of target servers in accepting new connections. The TSR values are used to modify the weight used to favor servers that are more successfully accepting new connection requests. A value of 100 indicates full responsiveness and zero indicates no responsiveness.

```
VIPA Distribute:
  IP Address       Port    XCF Address       SysPt  TimAff  Flg
  ----------       ----    -----------       -----  ------  ----
  201.2.10.11      n/a     ALL               Yes    200     R
    DistMethod: Roundrobin
    OptLoc: No
  201.2.10.13      243     ALL               No     No      0
    DistMethod: BaseWLM
    OptLoc: 1
    ProcType:
      CP: 60  zAAP: 00  zIIP: 40
  201.2.10.14      243     ALL               No     No      1
    DistMethod: ServerWLM
    OptLoc: No
    ProcXCost:
      zAAP: 003  zIIP: 001
    ILWeighting: 1
```
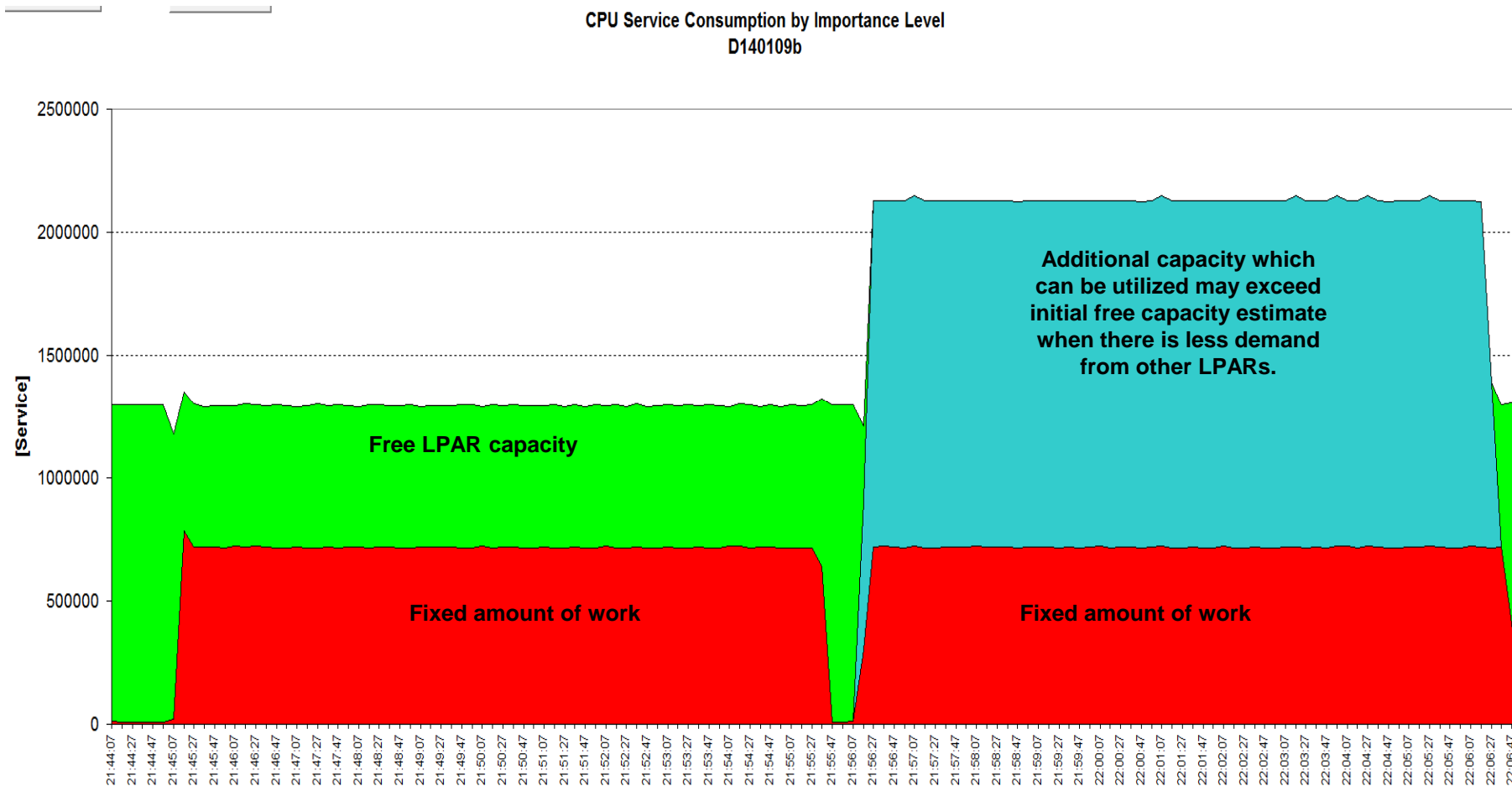
DDF DISPLAY Command

- -DIS DDF [DETAIL] returns WLM weight information
  - The following server list entry information is displayed for each DDF location that registered to WLM as part of the data sharing group:
  - DSNL100I LOCATION SERVER LIST: DSNL101I WT IPADDR IPADDR DSNL102I *weight ipv4-address ipv6-address*

```
-DISPLAY DDF DETAIL
```

With the DETAIL option, the following additional information is included in the output:

```
DSNL090I DT=       A CONDBAT=  64 MDBAT=     64
DSNL092I ADBAT=    1 QUEDBAT=   0 INADBAT=   0 CONQUED=        0
DSNL093I DSCDBAT= 0 INACONN=   0
DSNL100I      LOCATION SERVER LIST:
DSNL101I     WT IPADDR                IPADDR
DSNL102I     64 ::9.110.115.111    2002:91E:610:1::111
DSNL102I        ::9.110.115.112    2002:91E:610:1::112
DSNL099I DSNLTDDF DISPLAY DDF REPORT COMPLETE
```

Example: Initial Free LPAR capacity may be under-estimated

CPU Service Consumption by Importance Level
D140109b

Additional capacity which can be utilized may exceed initial free capacity estimate when there is less demand from other LPARs.

Free LPAR capacity

Fixed amount of work

Fixed amount of work

Performance Index (PI) effect on routing weight

- Heavily fluctuating PI values can distort routing recommendations.

- In such cases it can be beneficial to scale back the impact of the PI via the IEAOPT RTPIFACTOR control.
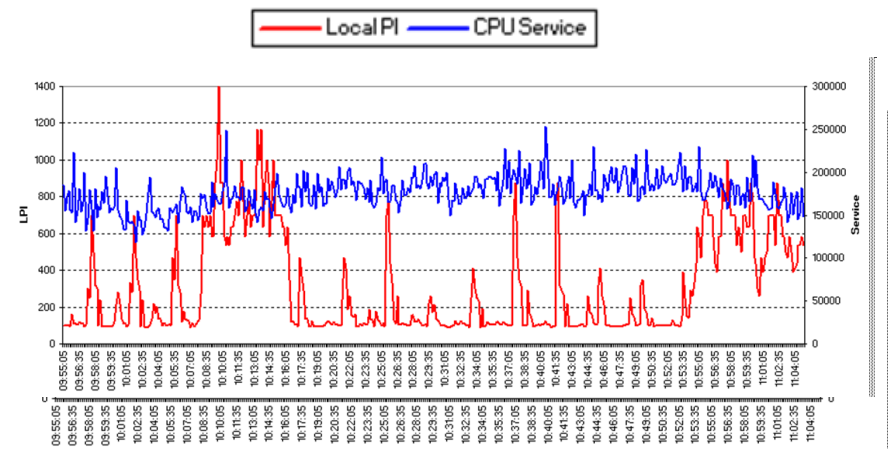
- When RTPIFACTOR=0, the server weight is independent from the server PI

- When RTPIFACTOR=100 and server PI >1, the server weight is divided by the server PI.

- When 0<RTPIFACTOR<100 it results in a proportional influence of the server PI on the server weight.

Observation: Connections vs. transaction routing

- Long living connections are… long living
  - May be established due to a given load distribution but not redistributed until connections are broken up and re-established

- The number of transactions routed to some systems may be *not proportional* to the number of connections that were established

- Usually not a problem at all - unless a specific distribution is warranted

- Asymmetric configuration may result in biased weights
  – E.g. different weights, different CEC configurations
    • Consider zIIP, zAAP pools, too, when relevant
  – Depending on subsystems the routed transactions could deviate more

- Consider
  – SERVERWLM - if PI is a good indicator for overload
  – IL Weighting
    • IL weighting=1 is usually a good starting point
  – Round-robin or another, non-WLM based distribution method

Sysplex Distributor and DB2 DDF
- More Information -

- Gus Kassimis:
  Sysplex Networking Technologies and Considerations,
  SHARE in Pittsburgh, 2014, Session: 15507

- Jim Pickel:
  DB2 9 for z/OS Data Sharing: Distributed
  Load Balancing and Fault Tolerant Configuration
  http://www.redbooks.ibm.com/abstracts/redp4449.html

z/OS Workload Management
- More Information -

Workload Manager
Welcome to WLM/SRM

Overview | What's New | FAQs | Further Information

- z/OS WLM Homepage:
  http://www.ibm.com/systems/z/os/zos/features/wlm/

- z/OS MVS documentation
  – z/OS MVS Planning: Workload Management:
    http://publibz.boulder.ibm.com/epubs/pdf/iea2w1c0.pdf
  – z/OS MVS Programming: Workload Management Services:
    http://publibz.boulder.ibm.com/epubs/pdf/iea2w2c0.pdf

- *IBM Redbooks publication*s:
  – System Programmer's Guide to: Workload Manager:
    http://publib-b.boulder.ibm.com/abstracts/sg246472.html?Open
  – ABCs of z/OS System Programming Volume 12
    http://publib-b.boulder.ibm.com/abstracts/sg247621.html?Open

What is a DDF Transactions?

- ACTIVE MODE threads are treated as a single enclave from the time they are created until the time they are terminated. This means that the entire life of the database access thread is reported regardless of whether SQL work is actually being processed.

- INACTIVE MODE threads are treated differently. If the thread is always active, the duration of the thread is the duration of the enclave. When the thread is pooled, such as during think time, it is not using an enclave. In this case, inactive periods are not reported.