To MIPS or Not to MIPS

That is the CP Question!

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MIPS - can one number fit all?

- It's commonplace to assign IBM z Systems processors a capacity rating called MIPS
- The MIPS rating is very often used
  - to track and set workload capacity requirements
  - to select the proper size processor for the workload
- Today, we will discuss
  - just what are MIPS and where do they come from?
  - for a given processor, do all workloads run at the same MIPS?
  - how much trouble can using MIPS get us into?
    - and what to do about it

Just what are MIPS?

- Once upon a time, MIPS really meant Millions of Instructions Per Second
- As commonly used today, MIPS has become a RELATIVE indicator of AVERAGE processor CAPACITY
- MIPS are based on capacity RATIOS between processors
- MIPS are still in the ballpark of real Mi/sec
- Generally speaking,

  MIPS of new processor =

  MIPS of old processor x the AVERAGE CAPACITY RATIO new:old

Average Capacity Ratio

- IBM z Systems sets average capacity ratios among processors based on a variety of measured workloads which are published in the Large System Performance Reference (LSPR)
  - https://www.ibm.com/servers/resourcelink/lib03060.nsf/pages/lsprindex
- Old and new processors are measured in the same environment with the same workloads at high utilizations (>=90%)
- Over time, workloads and environment are updated to stay current with customer profiles
  - old processors measured with new workloads/environment may have different average capacity ratios compared to when they were originally measured

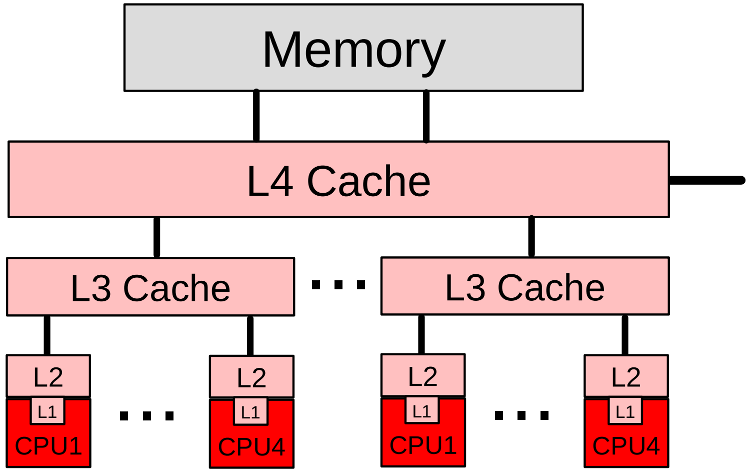
So, can one number (MIPS) fit all?

- To find out we have to ask …
  - When is it okay to use an average and when is it not?

- Sources of variation from average capacity ratio
  - System design
  - Workload characteristics
  - Workload scaling
  - CPU utilization
  - LPAR configurations
  - Coupling technology

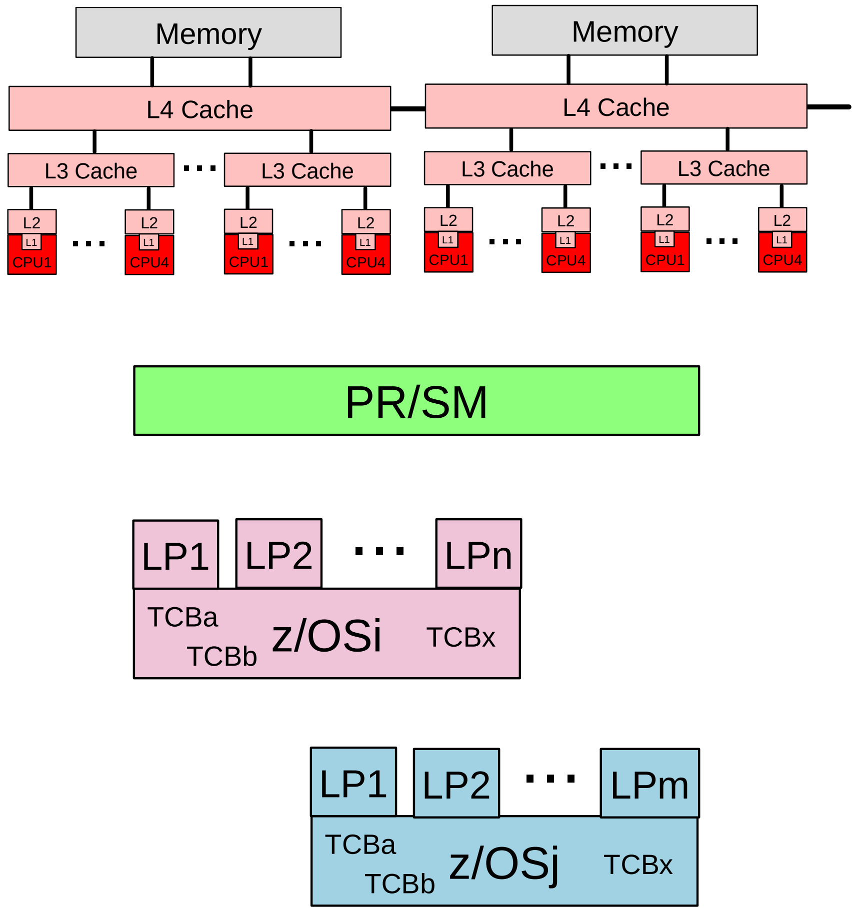
System Design: Processor

- Processor Design
  - CPU (core)
    - cycle time
    - pipeline
    - branch prediction
    - hardware vs. millicode
  - memory hierarchy (nest)
    - high speed buffers (caches)
      - on chip, on book/node
      - private, shared
    - buses
      - number, bandwidth
    - latency
      - distance
      - speed of light



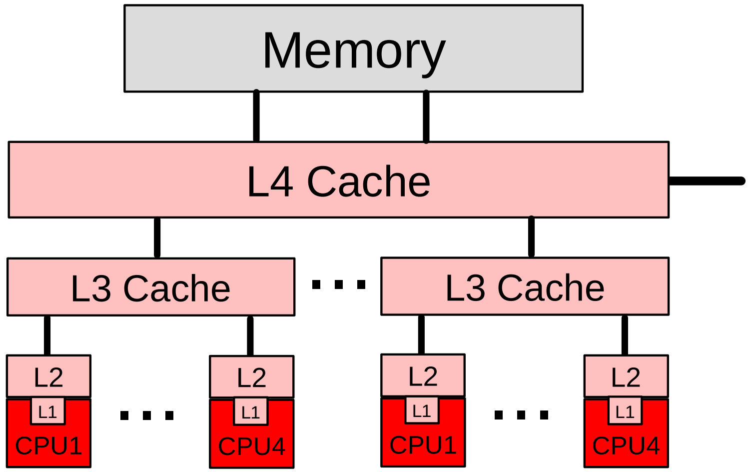
System Design: Hipervisor and OS

- Hipervisor (PR/SM)
  - virtualization layer at OS level
  - distributes physical resources
    - memory
    - processors
      - logicals dispatched on physicals
      - dedicated
      - shared
      - affinities
- OS
  - virtualization layer at addrspc level
  - distributes logical resources
    - memory
    - processors
      - tasks dispatched on logcials
- Enhanced cooperation
  - HiperDispatch
    - z/OS + PR/SM
    - z/VM + PR/SM



Workload Characteristics

- Workload Characteristics
  - CPU
    - instructions
      - mix
      - sequence
      - branch characteristics
    - task dispatch profile
      - locked in or chatty
  - memory
    - size
    - locality of reference
    - multiprogramming level
  - I/O rate



LSPR z/OS workload primitives

- CB-L commercial batch long job steps
- WASDB WebSphere-focus application server and data base
- OLTP-T traditional online transaction processing
- OLTP-W webenabled access to legacy data

CHARACTERISTICS MORE IMPORTANT THAN NAME

	CPU use profile	I/O	Memory Hierarchy
CB-L	heavy appl, light OS	light	light
WASDB	medium appl and OS	light	light/moderate
OLTP-T	medium appl and OS	heavy	moderate
OLTP-W	medium appl and OS	moderate	stress

NOW RUN IN VARIOUS MIXES TO PRODUCE WORKLOADS MATCHING CUSTOMER PROFILE OF MEMORY HIERARCHY STRESS OR RELATIVE "NEST" INTENSITY (RNI)

Relative Nest Intensity (RNI)

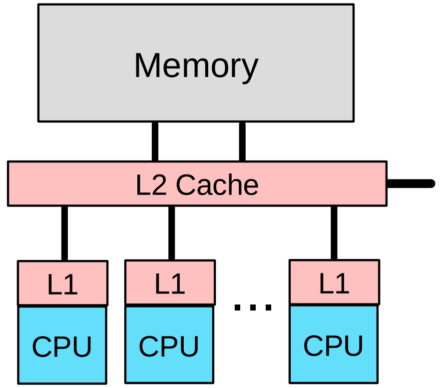
- Activity beyond private cache(s) is the most sensitive area
- Reflects distribution and latency of sourcing from shared caches and memory
- Data for calculation available from CPU MF (SMF 113) starting with z10

LSPR Workload Categories

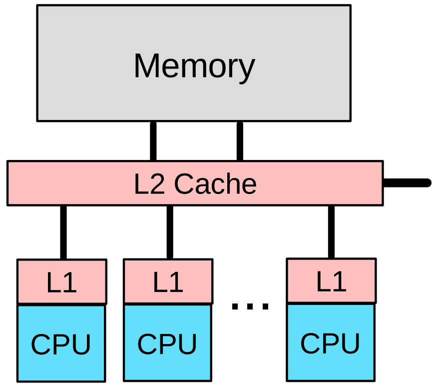
- Categories developed to match the profile of data gathered on customer systems
  - over 100 data points (LPARs) used in the profiling
- Various combinations of prior workload primitives are measured to reflect the new workload categories
  - Applications include CICS, DB2, IMS, OSAM, VSAM, WebSphere, COBOL, utilities
- **LOW** (relative nest intensity)
  - Workload curve representing light use of the memory hierarchy
  - Similar to past high Nway scaling workload primitives
- **AVERAGE** (relative nest intensity)
  - Workload curve expected to represent the majority of customer workloads
  - Similar to the past LoIO-mix curve
- **HIGH** (relative nest intensity)
  - Workload curve representing heavy use of the memory hierarchy
  - Similar to the past DI-mix curve
- zPCR extends these published categories
  - Low-Avg: 50% LOW and 50% AVERAGE
  - Avg-High: 50% AVERAGE and 50% HIGH

System Design + Workload Characteristics
Variation from Average: sometimes small
Example: z990 to z9 EC

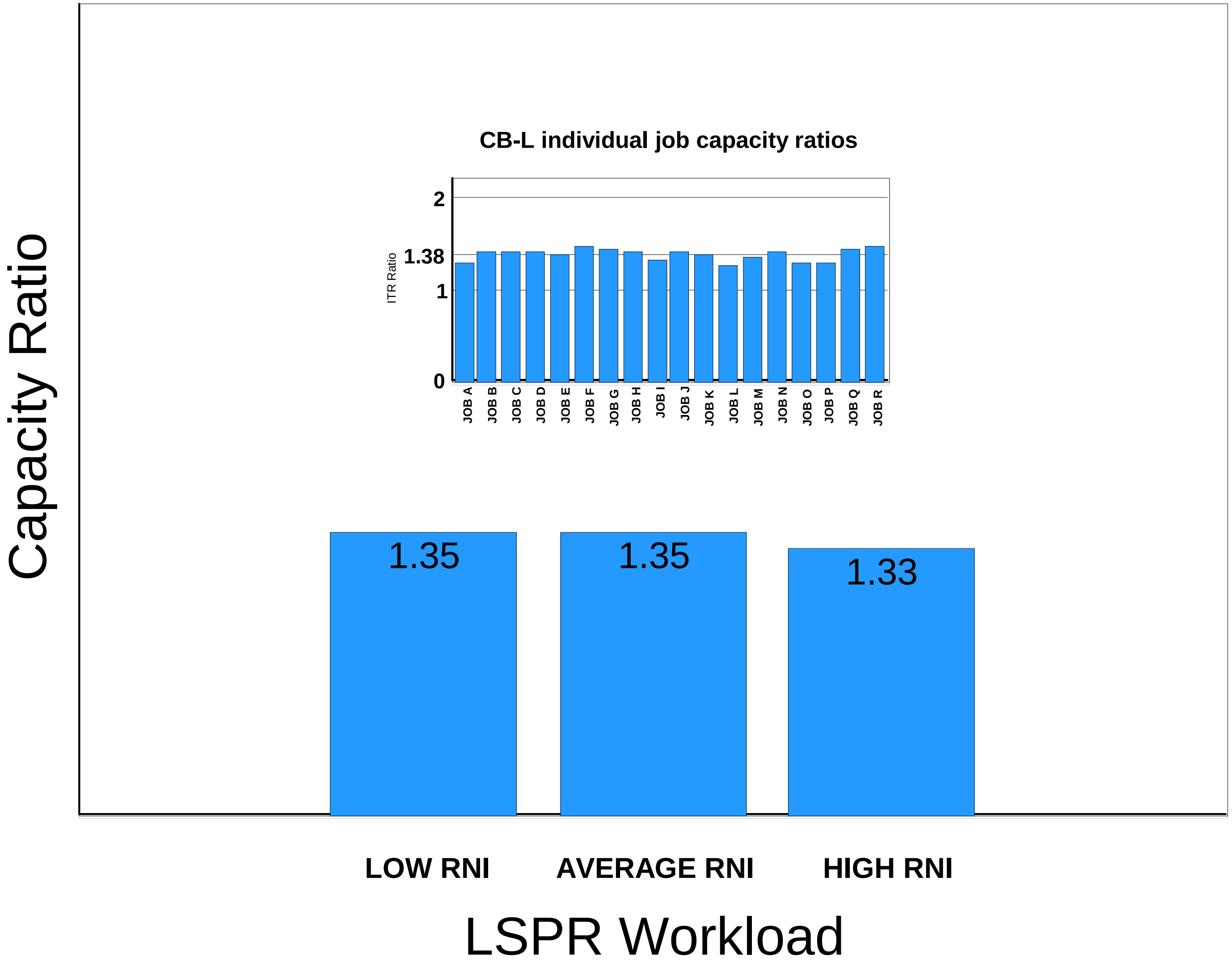
- z990
  - CPU
    - 1.2 GHz
    - superscalar
  - Caches
    - L1 private 256k i, 256k d
    - L2 shared 32 MB / book
    - book interconnect: ring



- z9 EC
  - CPU
    - 1.7 GHz
    - superscalar
  - Caches
    - L1 private 256k i, 256k d
    - L2 shared 40 MB / book
    - book interconnect: ring

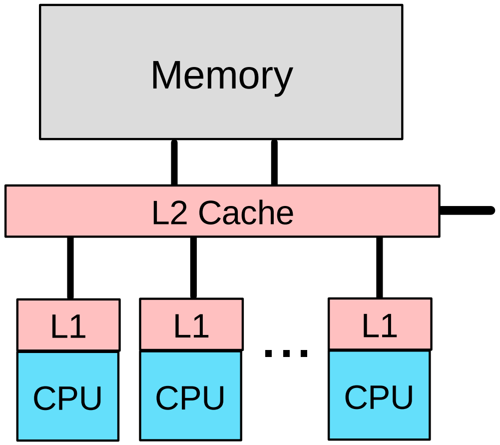


LSPR Single Image Capacity Ratios
10way: z9 EC versus z990

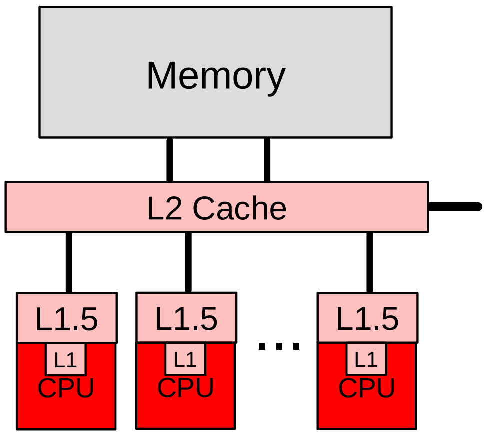


System Design + Workload Characteristics
Variation from Average: sometimes large
Example: z9 EC to z10 EC

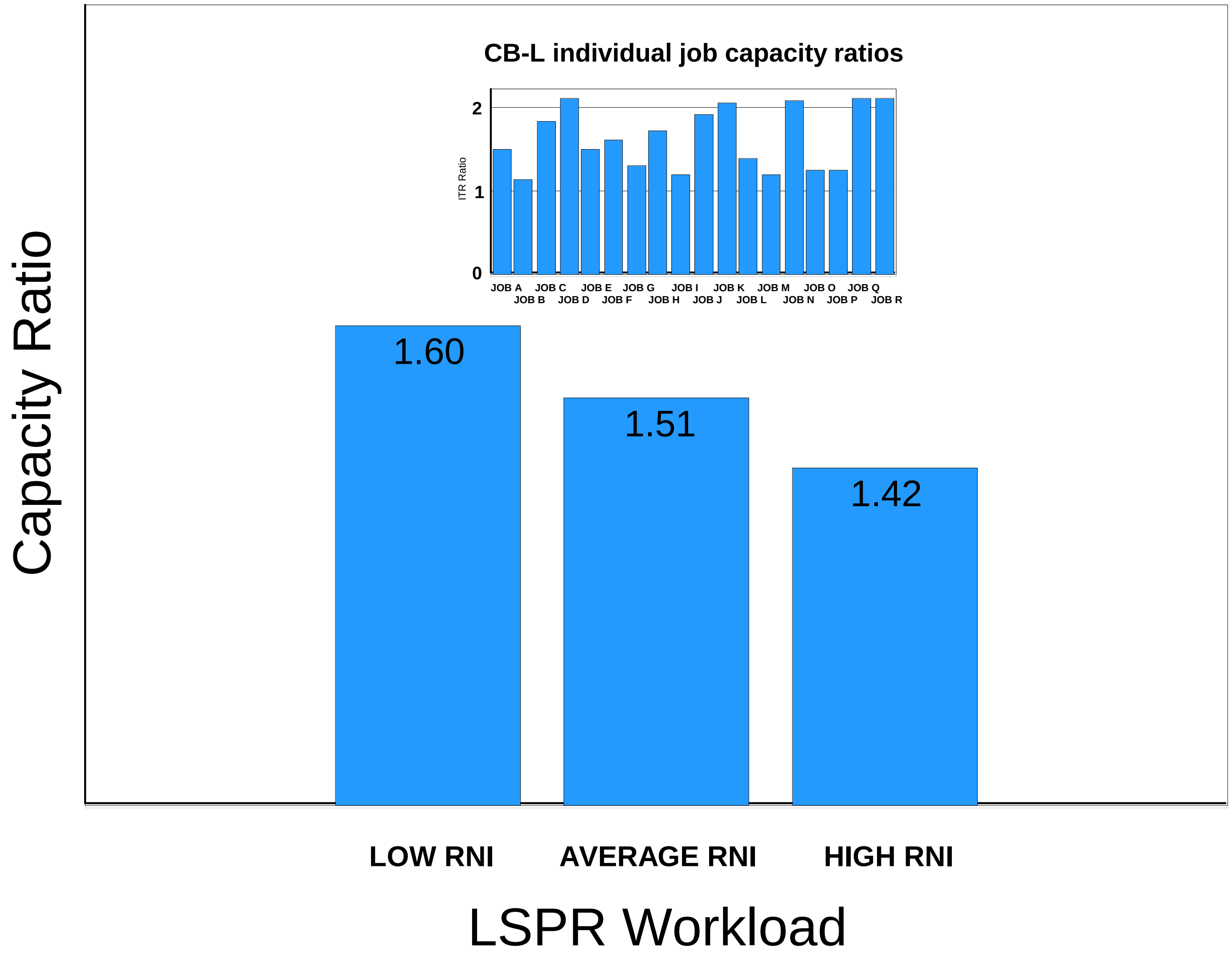
- z9 EC
  - CPU
    - 1.7 GHz
    - superscalar
  - Caches
    - L1 private 256k i, 256k d
    - L2 shared 40 MB / book
    - book interconnect: ring



- z10 EC
  - CPU
    - 4.4 GHz
    - redesigned pipeline
    - superscalar
  - Caches
    - L1 private 64k i, 128k d
    - L1.5 private 3 MB
    - L2 shared 48 MB / book
    - book interconnect: star

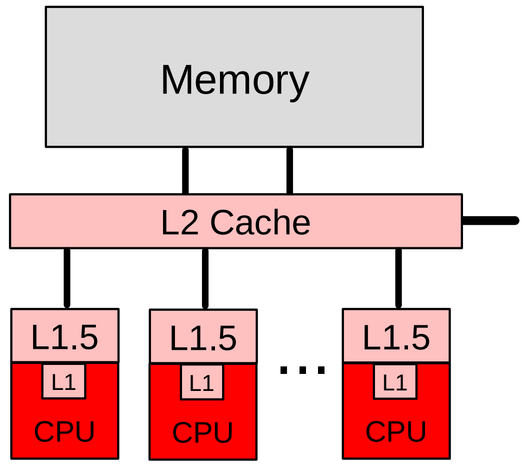


LSPR Single Image Capacity Ratios
10way: z10 EC versus z9 EC

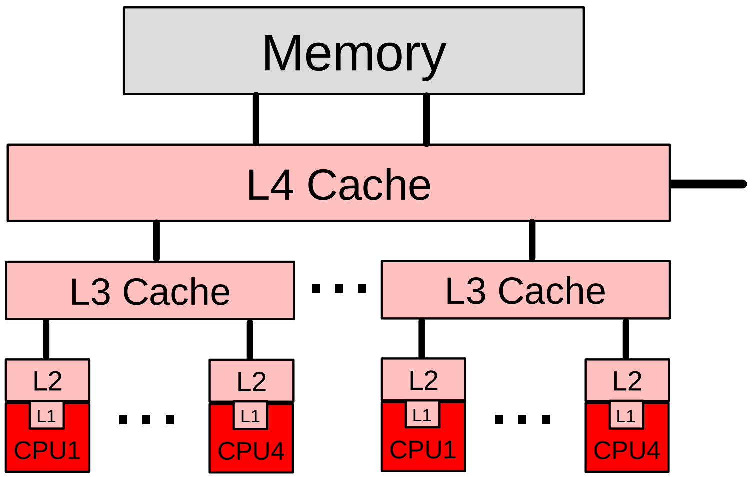


System Design + Workload Characteristics
Variation from Average: sometimes inbetween
Example: z10 EC to z196

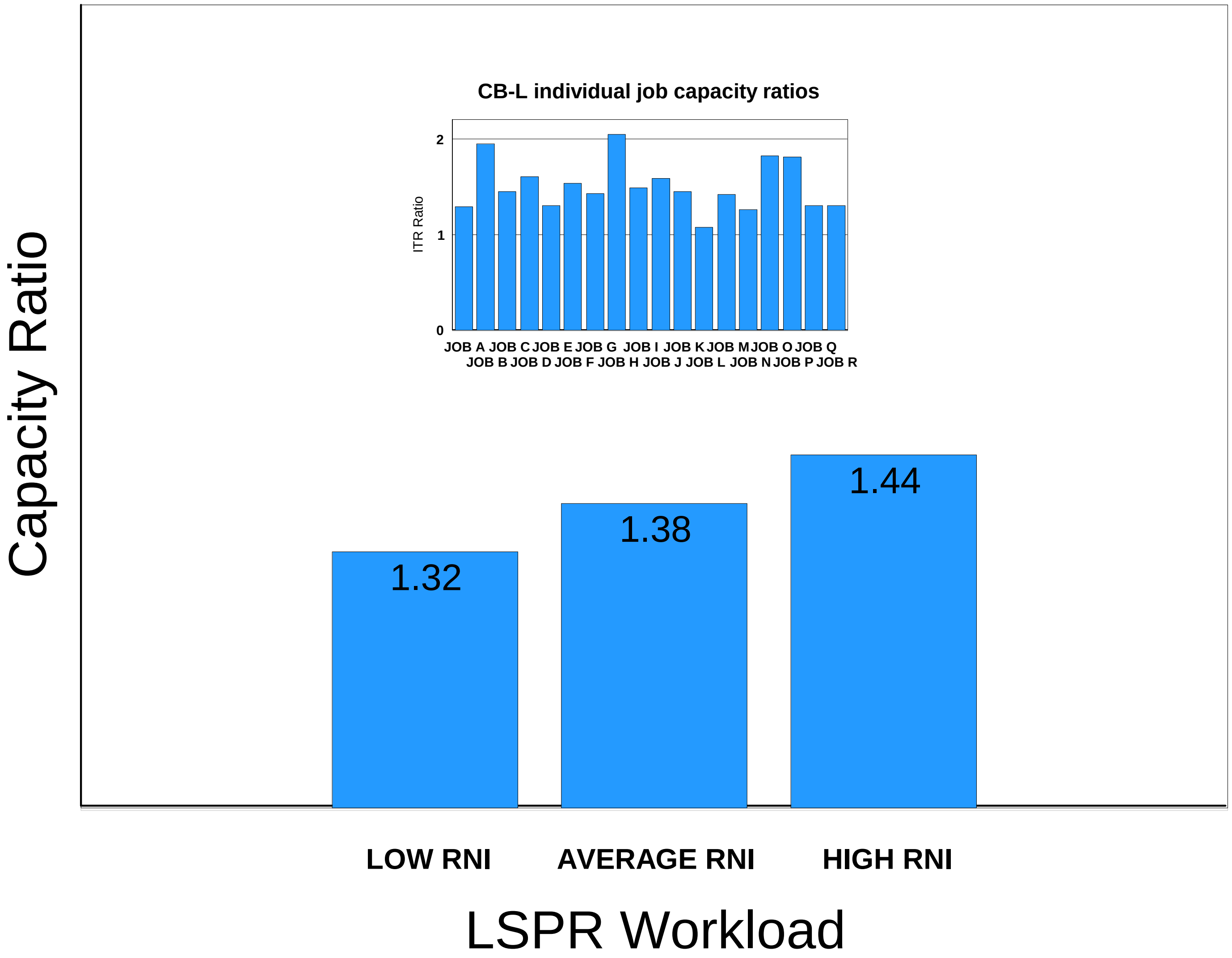
- z10 EC
  - CPU
    - 4.4 GHz
  - Caches
    - L1 private 64k i, 128k d
    - L1.5 private 3 MB
    - L2 shared 48 MB / book
    - book interconnect: star



- z196
  - CPU
    - 5.2 GHz
    - Out-Of-Order execution
  - Caches
    - L1 private 64k i, 128k d
    - L2 private 1.5 MB
    - L3 shared 24 MB / chip
    - L4 shared 192 MB / book
    - book interconnect: star

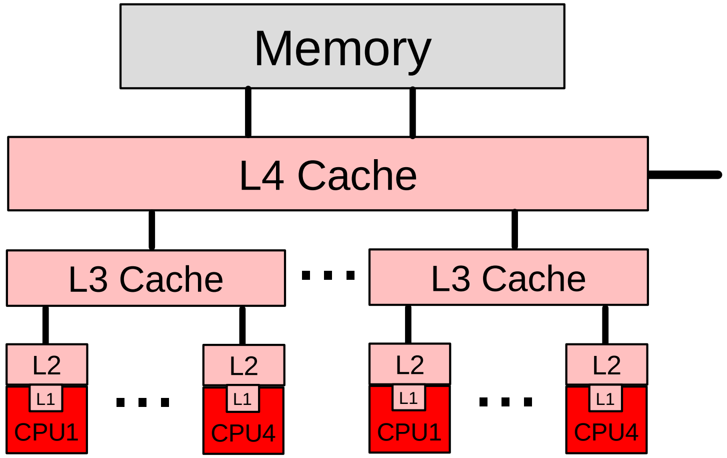


LSPR Single Image Capacity Ratios
10way: z196 versus z10 EC

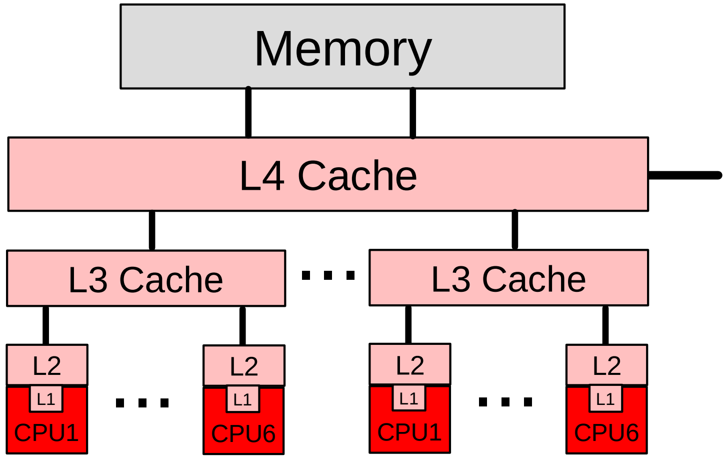


System Design + Workload Characteristics
Variation from Average: sometimes fairly small
Example: z196 to zEC12

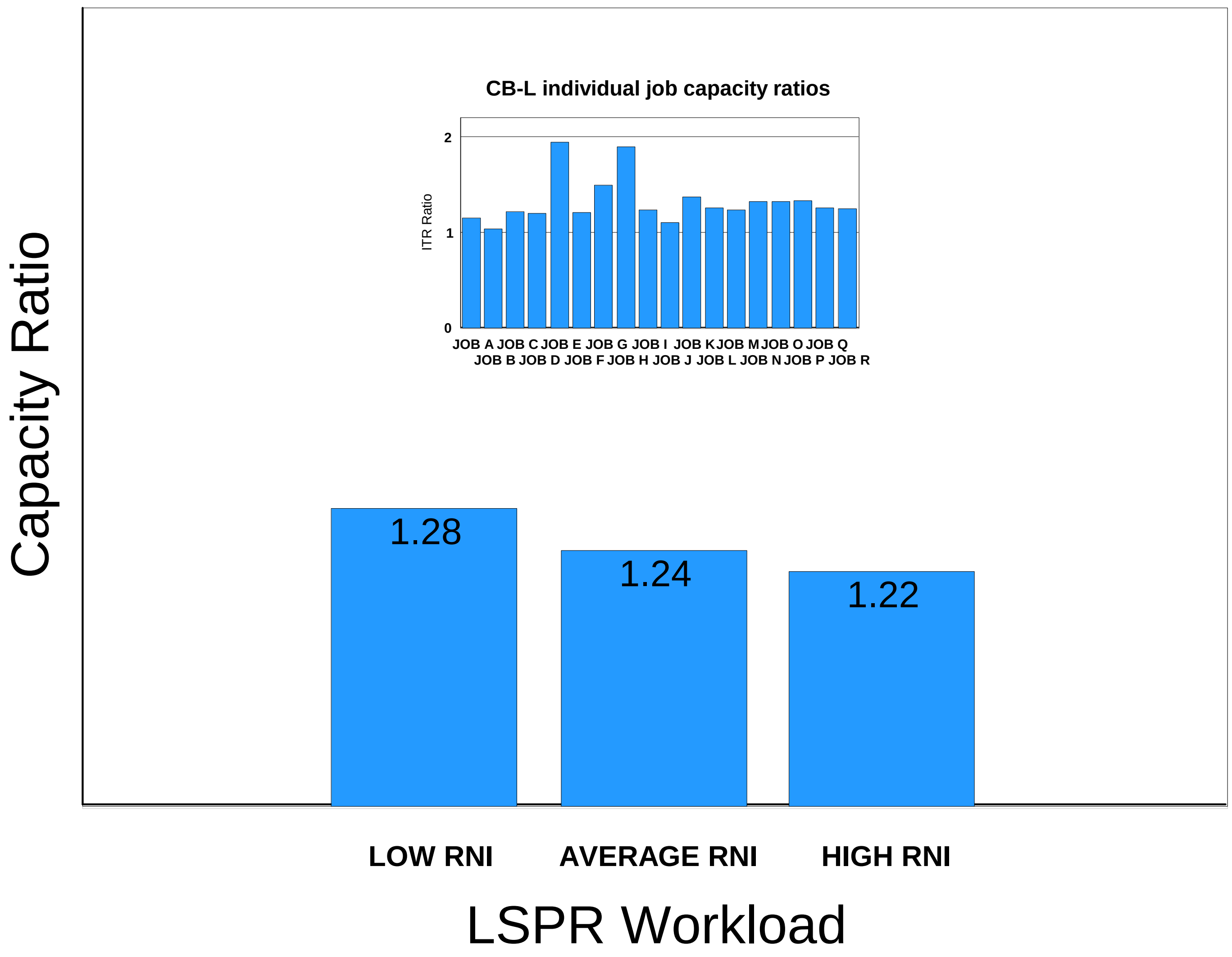
- z196
  - CPU
    - 5.2 GHz
    - Out-Of-Order execution
  - Caches
    - L1 private 64k i, 128k d
    - L2 private 1.5 MB
    - L3 shared 24 MB / chip
    - L4 shared 192 MB / book



- zEC12
  - CPU
    - 5.5 GHz
    - Enhanced Out-Of-Order
  - Caches
    - L1 private 64k i, 96k d
    - L2 private 1 MB i + 1 MB d
    - L3 shared 48 MB / chip
    - L4 shared 384 MB / book



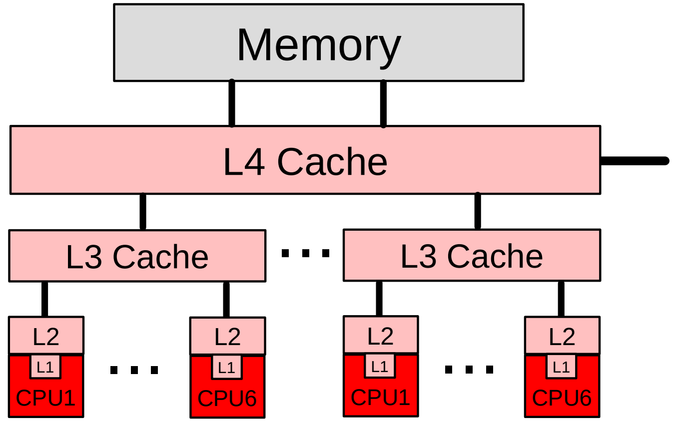
LSPR Single Image Capacity Ratios
10way: zEC12 versus z196



z13 versus zEC12 hardware comparison

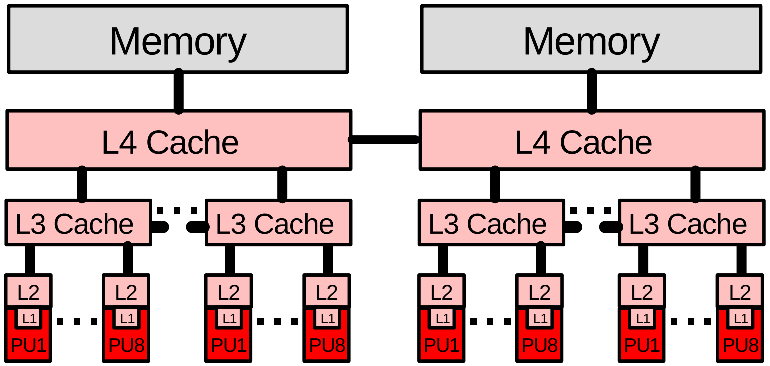
- zEC12
  - CPU
    - 5.5 GHz
    - Enhanced Out-Of-Order
  - Caches
    - L1 private 64k i, 96k d
    - L2 private 1 MB i + 1 MB d
    - L3 shared 48 MB / chip
    - L4 shared 384 MB / book

Single Book View

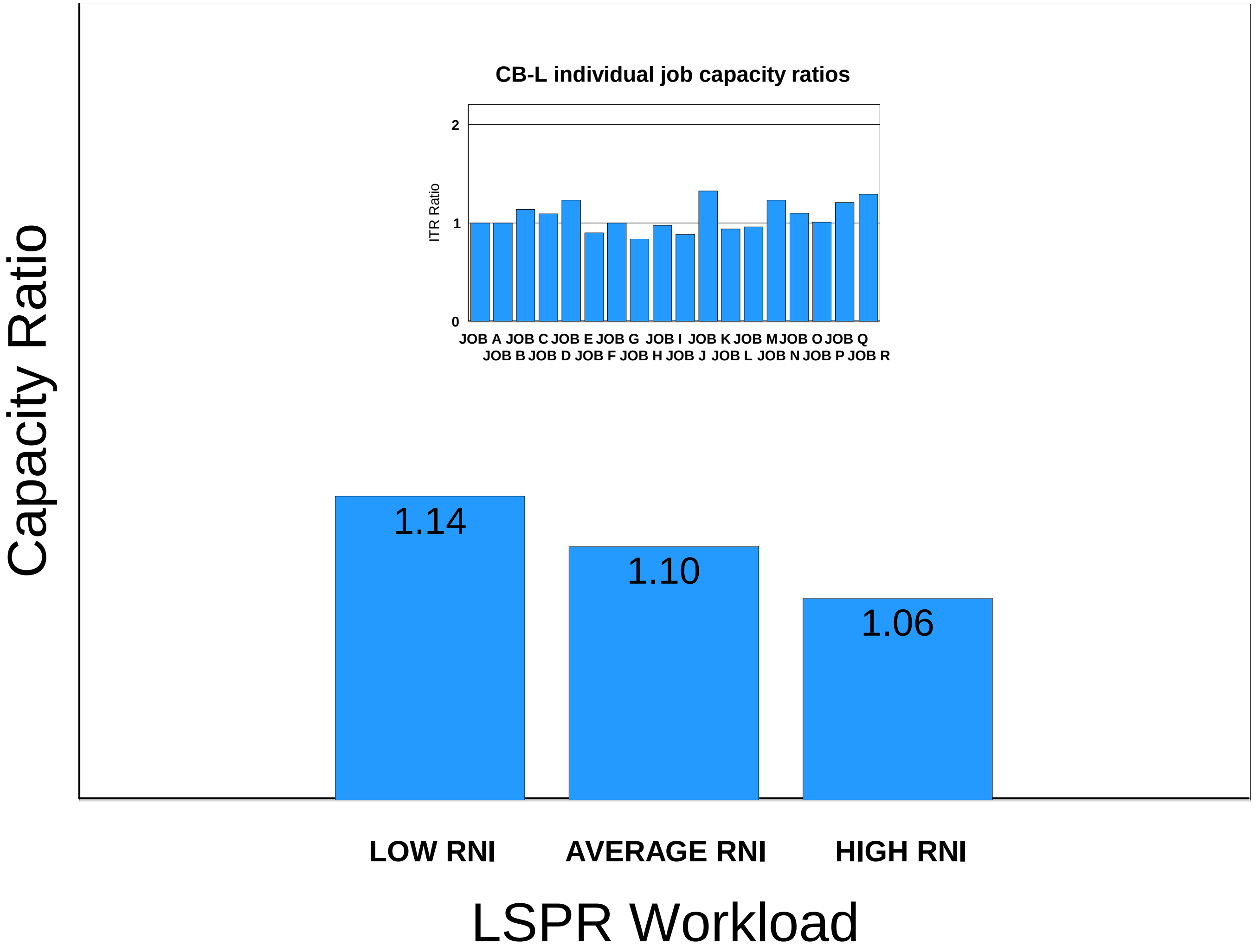


- z13
  - CPU
    - 5.0 GHz
    - Major pipeline enhancements
  - Caches
    - L1 private 96k i, 128k d
    - L2 private 2 MB i + 2 MB d
    - L3 shared 64 MB / chip
    - L4 shared 480 MB / node
      - plus 224 MB NIC

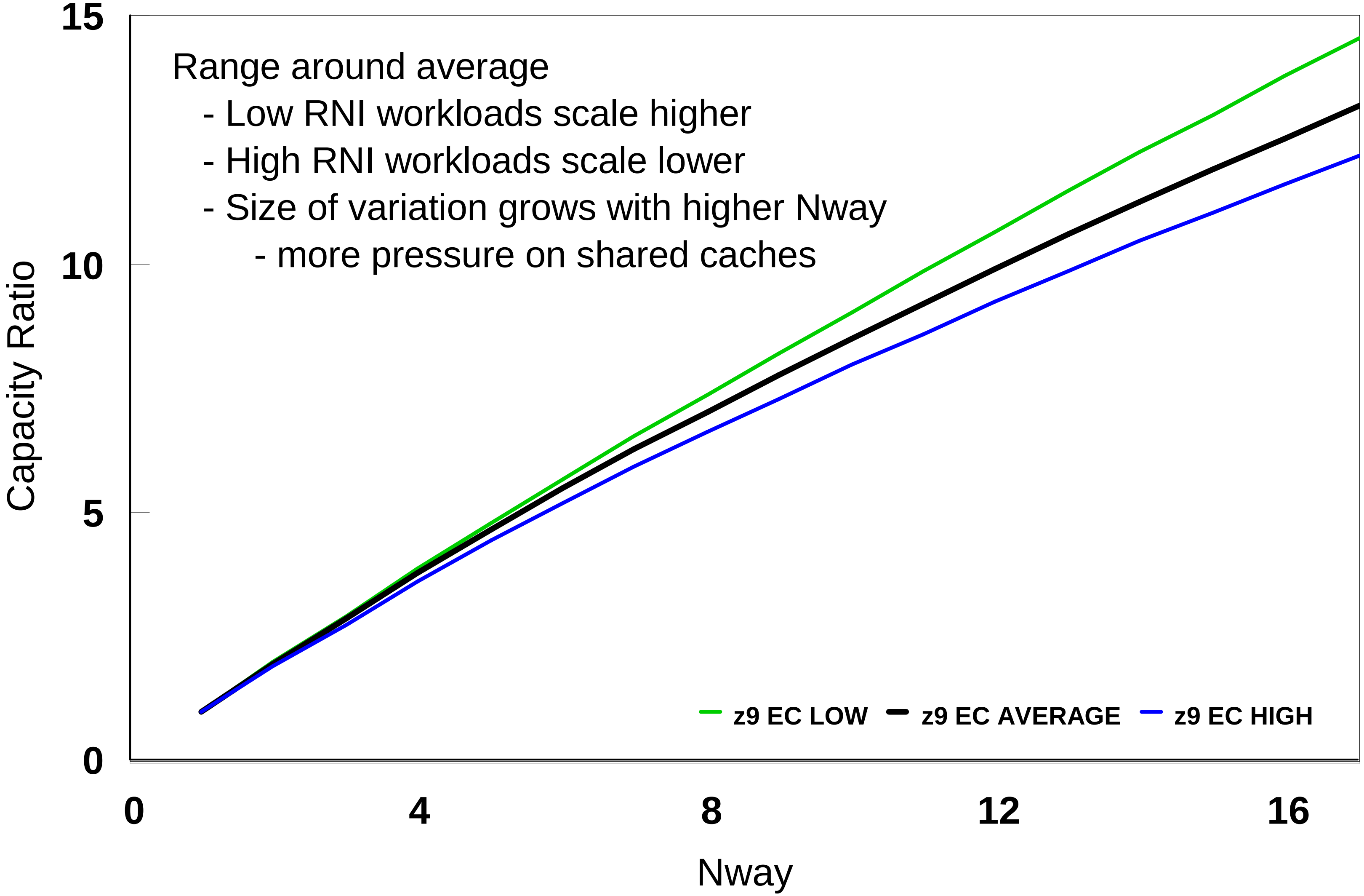
Single Drawer View



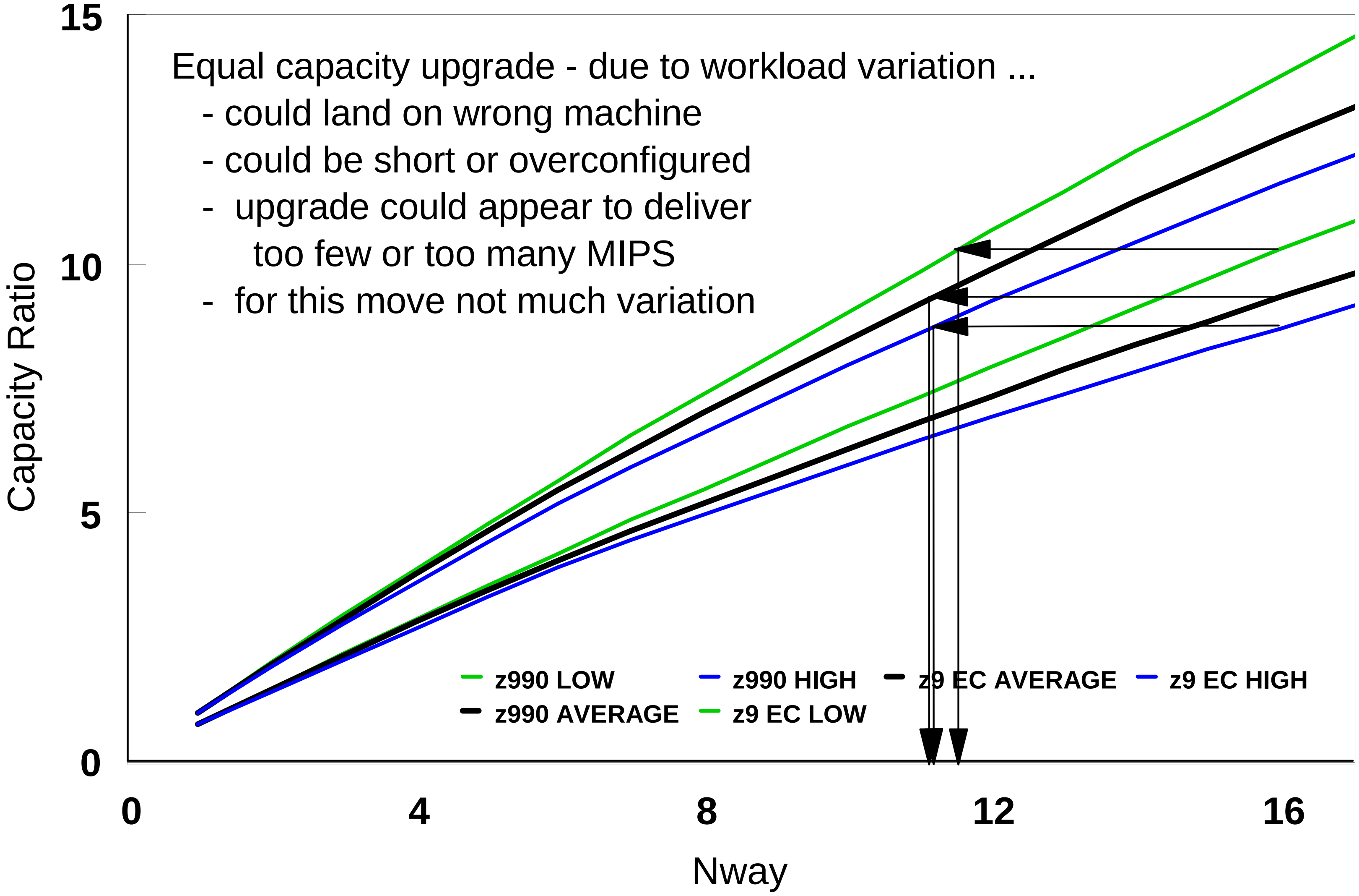
LSPR Single Image Capacity Ratios
16way: z13 versus zEC12
Example of Workload Variability



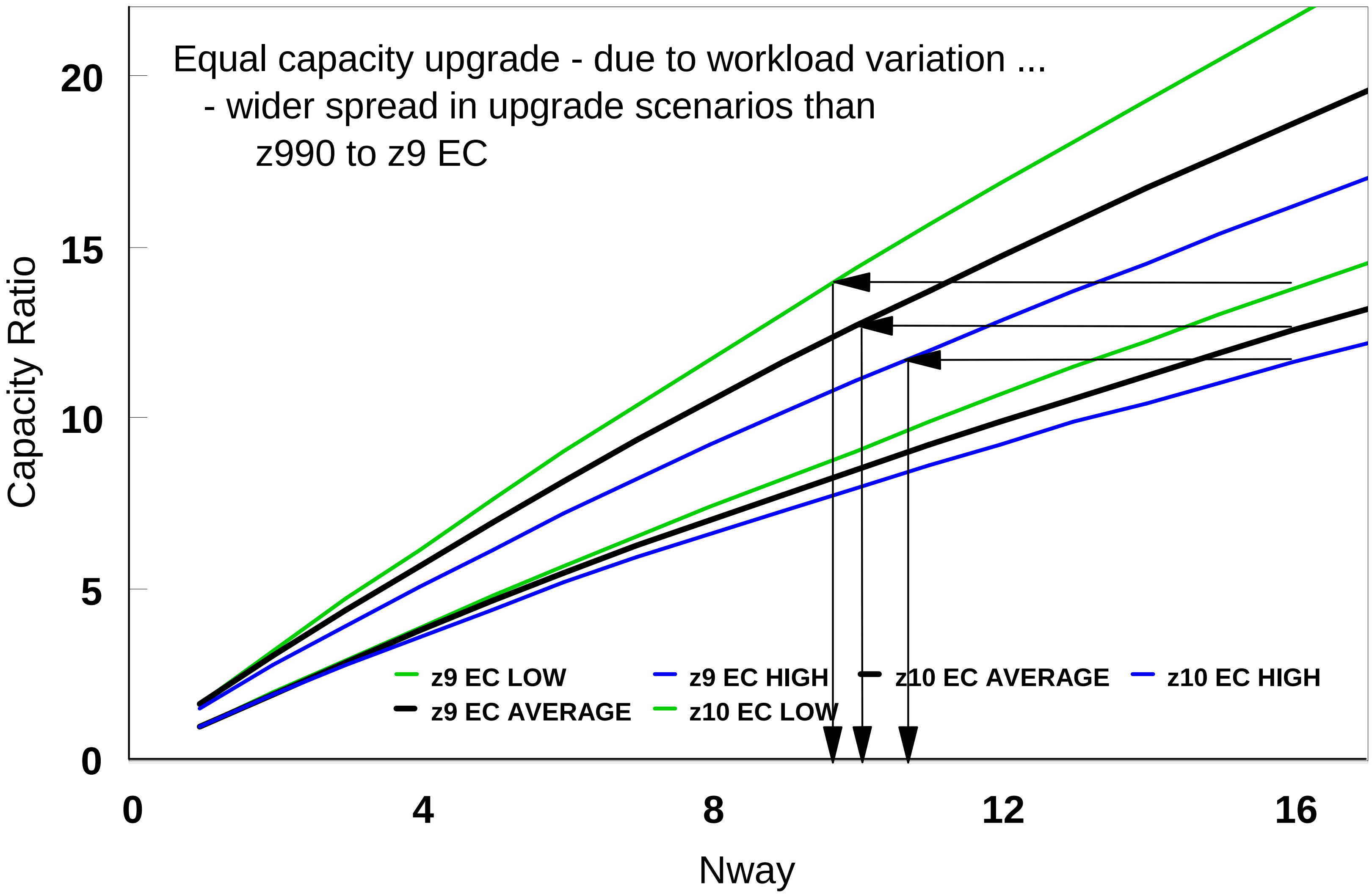
Workload Scalability
Variation from Average
Example: z9 EC



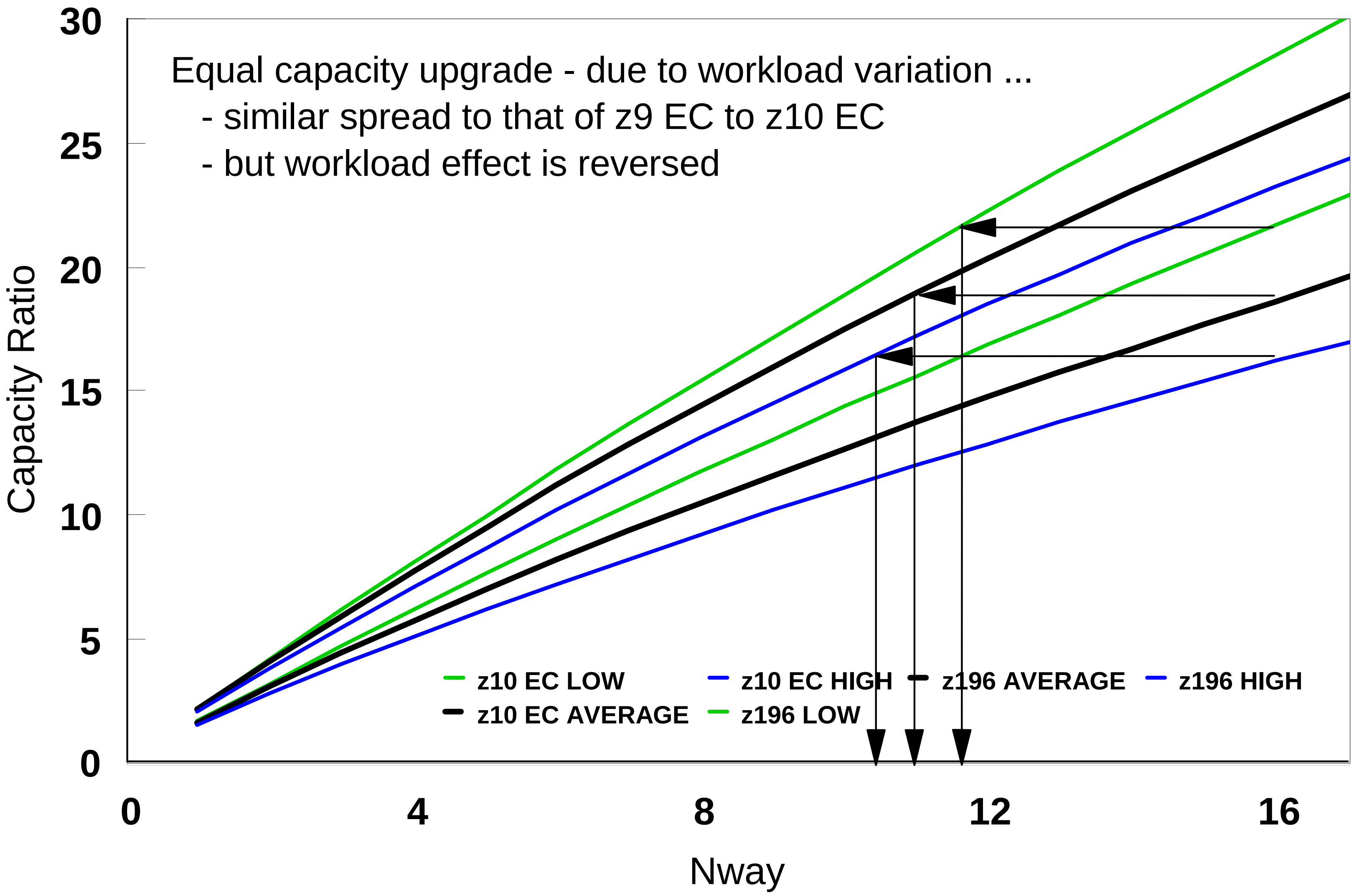
Workload Scalability
Variation from Average
Example: moving from z990 to z9 EC



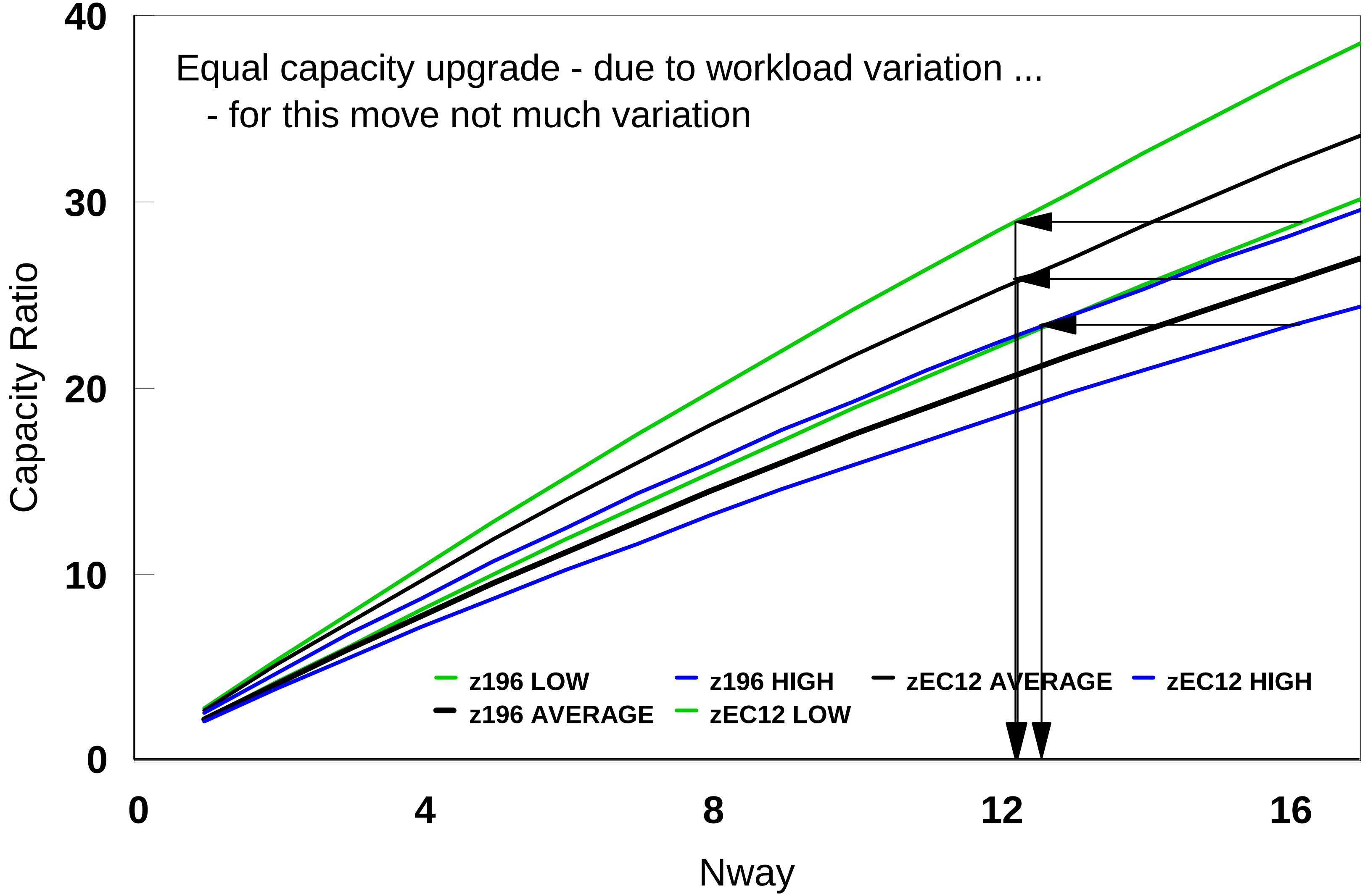
Workload Scalability
Variation from Average
Example: moving from z9 EC to z10 EC



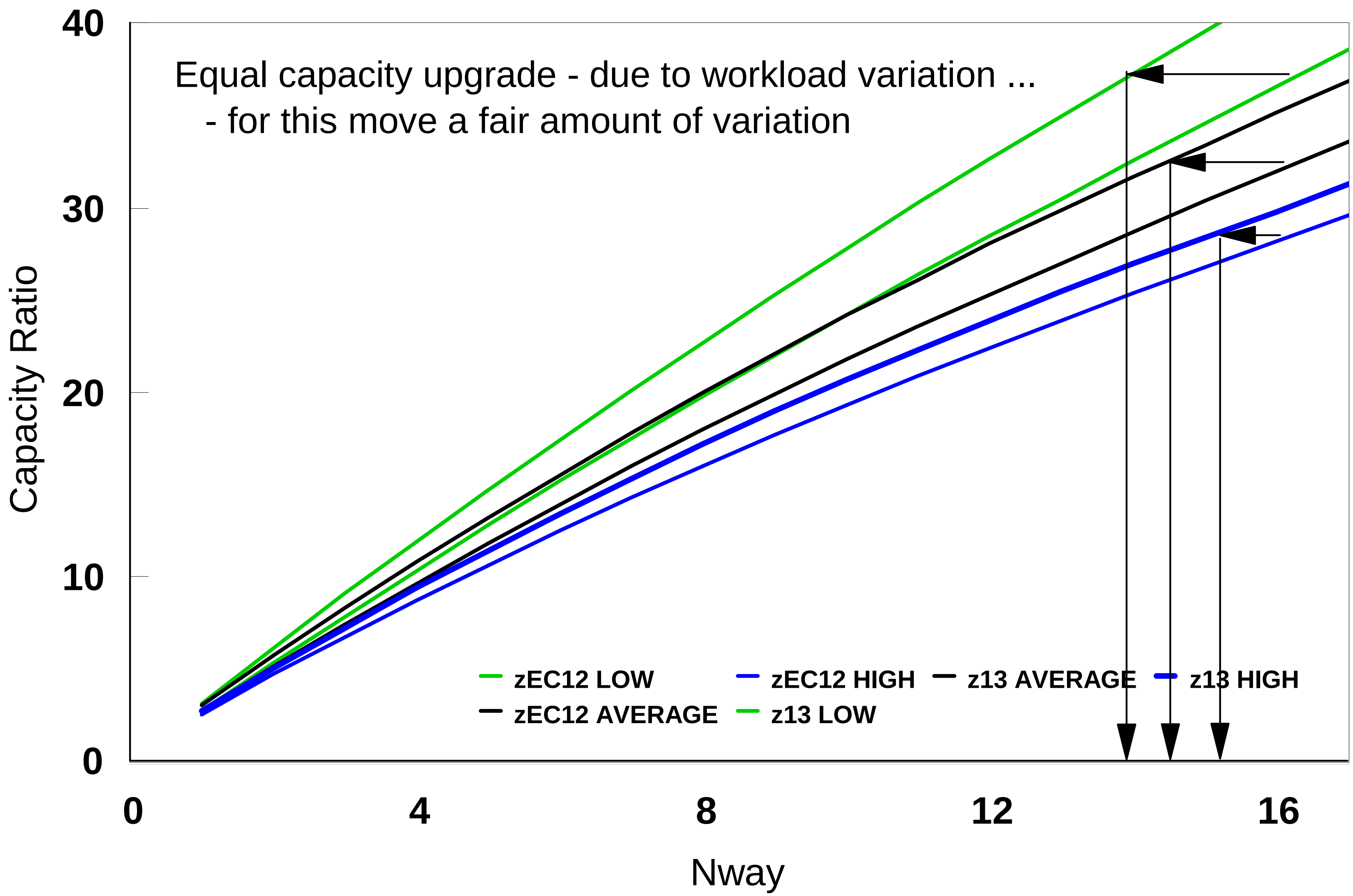
Workload Scalability
Variation from Average
Example: moving from z10 EC to z196



Workload Scalability
Variation from Average
Example: moving from z196 to zEC12



Workload Scalability
Variation from Average
Example: moving from zEC12 to z13



CPU Utilization
Source of Variation

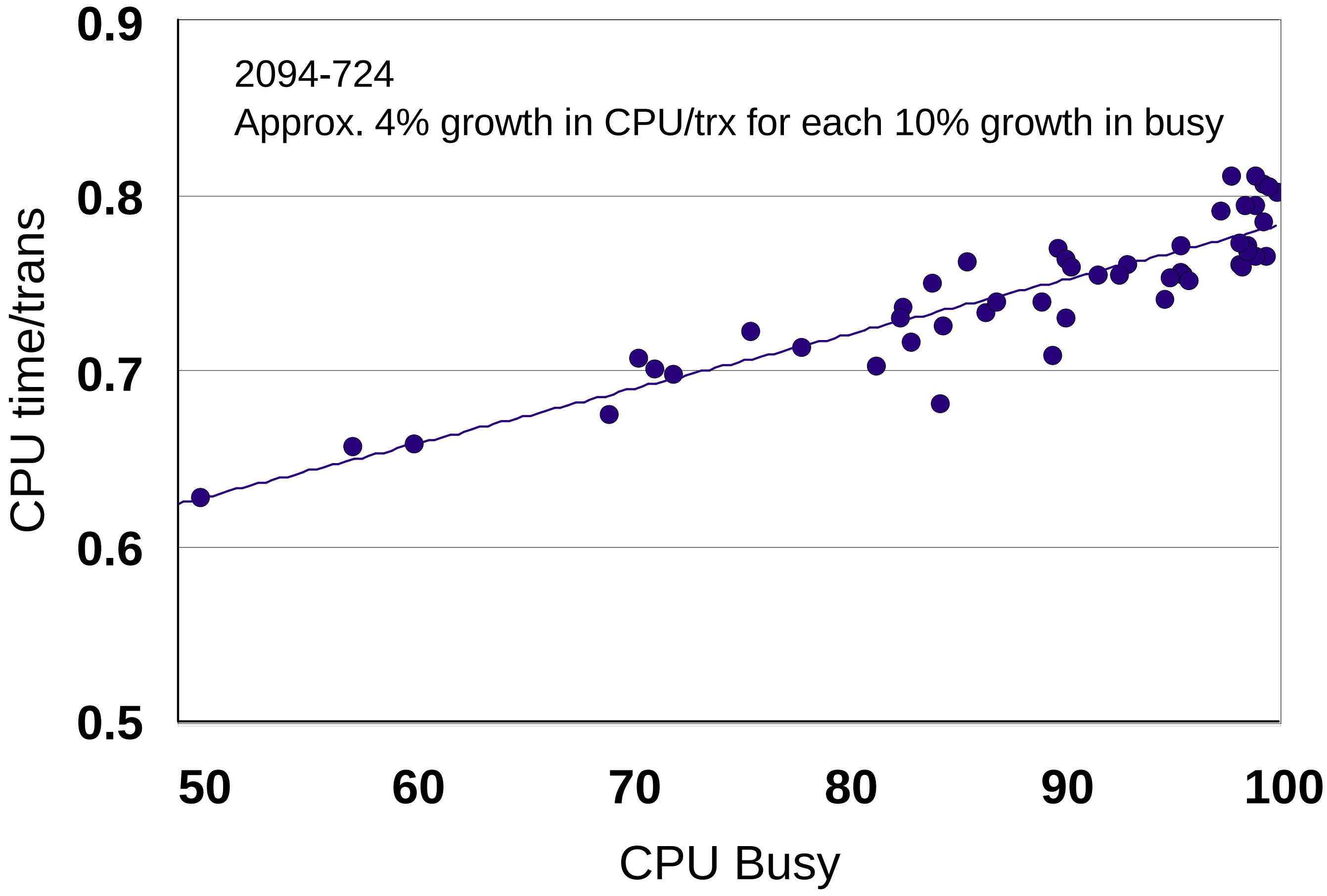
- CPU utilization generally reflects the amount of work flowing through a fixed HW/SW configuration
  - the higher the workload rate, the higher the utilization

- As more work flows through a fixed HW/SW configuration, the efficiency of the HW and SW is reduced
  - less shared HW resources (caches, buses) available to each work unit
  - SW manages more work units - longer queues, more contention
  - CPU time per transaction or job will grow

- Magnitude of the effect is related to
  - workload characteristics
    - higher RNI workloads (as measured at higher utilizations) see higher impact
  - size of the processor
    - smallest Nways (say 1-4way) are somewhat less sensitive

OLTP Client Workload Example

Growth in CPU time/trans as CPU busy increases



CPU Utilization
Impact to Capacity Planning When Using MIPS

- Impact to capacity planning comes in two flavors
  - may have less headroom on the box than you think
  - when moving a workload, it may not fit in the new container

- Example
  - assume a workload is running at 50% busy on a 2000 MIPS box
    - without factoring in utilization effect, it will be called a 1000 MIPS workload
    - in fact, it may be an 1200 MIPS workload when running at the efficiency of a 90% busy box
  - caution #1: there is NOT room to double this workload on the current box
  - caution #2: if moved to a new box or LPAR, it will likely need a 1200 MIPS container (not 1000 MIPS) to fit

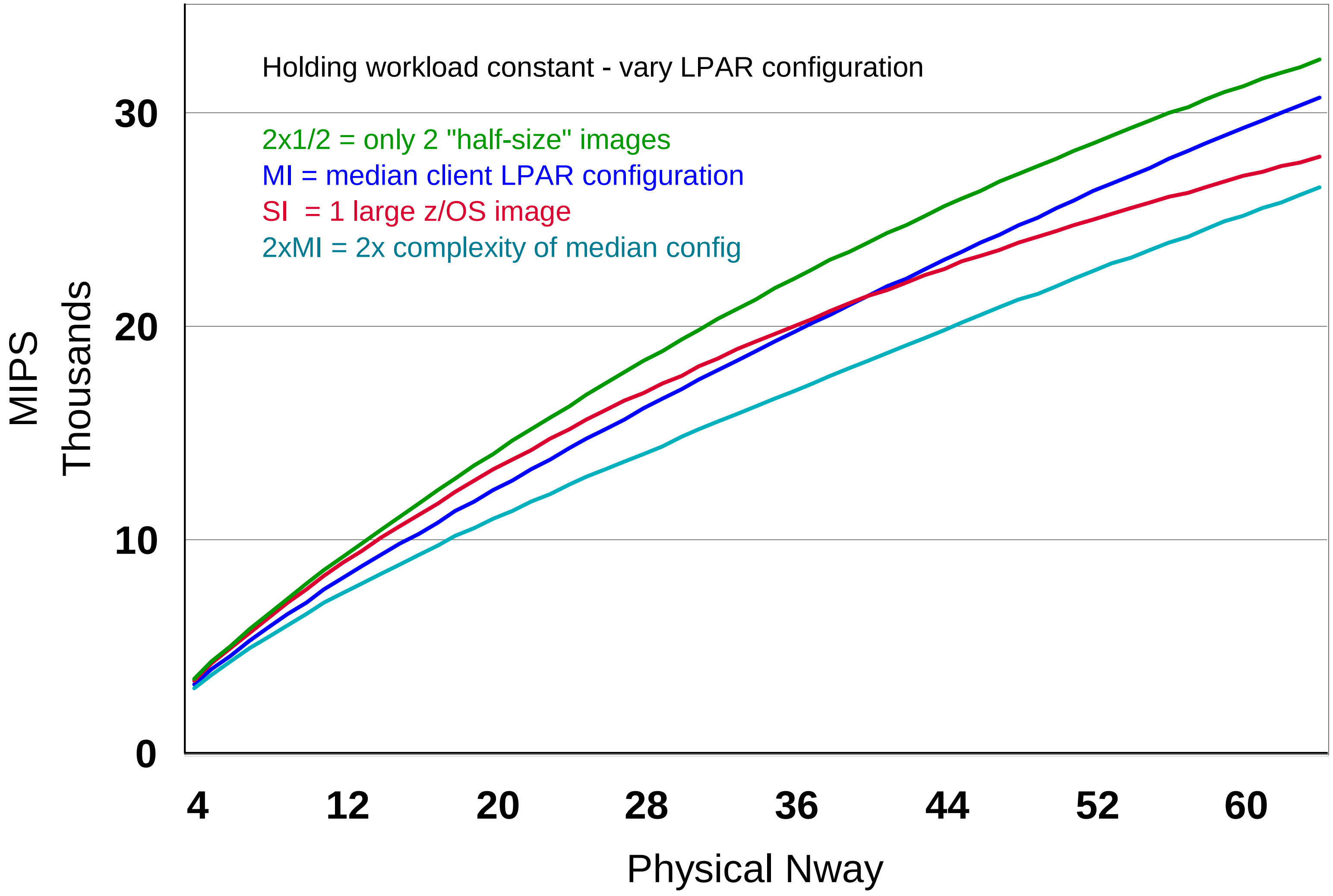
- Estimating the impact - conservative approach
  - For a change in utilization of 10%, plan for the capacity effect to be
    - 3% for LOW RNI workloads
    - 4% for AVERAGE RNI workloads
    - 5% for HIGH RNI workloads

LPAR Configurations
Variation from Average MIPS

- LPAR configurations affect the efficiency of the HW and SW
  - key factors
    - workload characteristics
    - number of LPARs
    - number of logical processors and weight of each LPAR
    - overall ratio of logical to physical processors

- MIPS ratings are based on AVERAGE wkld and median client LPAR config
  - median client LPAR configuration varies by Nway
    - number of LPARs
      - 5 at low-end, 9 at high-end
      - generally 2 are major (>20% of weight), rest are minor
    - size of major LPARs
      - close to Nway of box for low/mid-range Nways, well less than Nway at high-end
    - logical:physical ratio
      - 5:1 at low end, 2:1 for most, 1.3:1 at high end

Example LPAR Configurations
Effect on MIPS



Coupling Technology
Impact on MIPS

- Sysplex configurations affect the efficiency of the HW and SW
  - key factors
    - workload characteristics - rate of operations to the coupling facility
    - speed of coupling technology (CPU and links) versus speed of host technology
  - example host effects
    - 2% for light coupling workload
    - 5-7% for medium coupling workload with speed-matched CF technology
    - 9% for medium coupling workload with "slow" CF technology
    - 10-14% for heavy coupling workload with speed-matched CF technology
    - 18% for heavy coupling workload with "slow" CF technology
- When upgrading the host, must consider impact of CF technology on MIPS requirement

So, what have we learned about MIPS?

- When there is a big change in a sensitive factor - be careful
  - move to new processor technology
  - change in workload characteristics
  - change in CPU utilization
  - change in LPAR configuration
  - change in coupling technology
- But, most of the time, the items above are stable or change only a little
  - for example, adding an engine to an existing processor
- And over the long run many variations tend to "even out"
  - for example, when moving to a new technology, a below average workload this time is often an above average workload the next time

Conclusions about MIPS

- MIPS are fine for long term workload trending
- MIPS are okay for short term planning where there are only minor changes in any of the sensitive factors
- But whenever there is to be a major change, there is a risk of significant variation from average (MIPS) and additional analysis should be done
- Useful tool to help with "additional analysis" - zPCR

zPCR

- Capacity sizing tool available for download from
  - http://www.ibm.com/support/techdocs/atsmastr.nsf/WebIndex/PRS1381
  - or just search for "zPCR download"
- Through customization, zPCR can provide insight on many of the sensitive factors discussed in this presentation
  - system design
  - workload characteristics
  - workload scaling
  - LPAR configurations