Is It Virtual, Real or Auxiliary?

zSTSU 2004

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Advanced Technical Support

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Agenda

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- **Storage evolution**
- **Storage overview**
  - Virtual storage
  - Real storage
  - Auxiliary storage
- **Paging**
  - Demand paging
  - Page stealing
  - Relationship of virtual, real, and auxiliary storage
  - Reports for paging activity
- **Summary**

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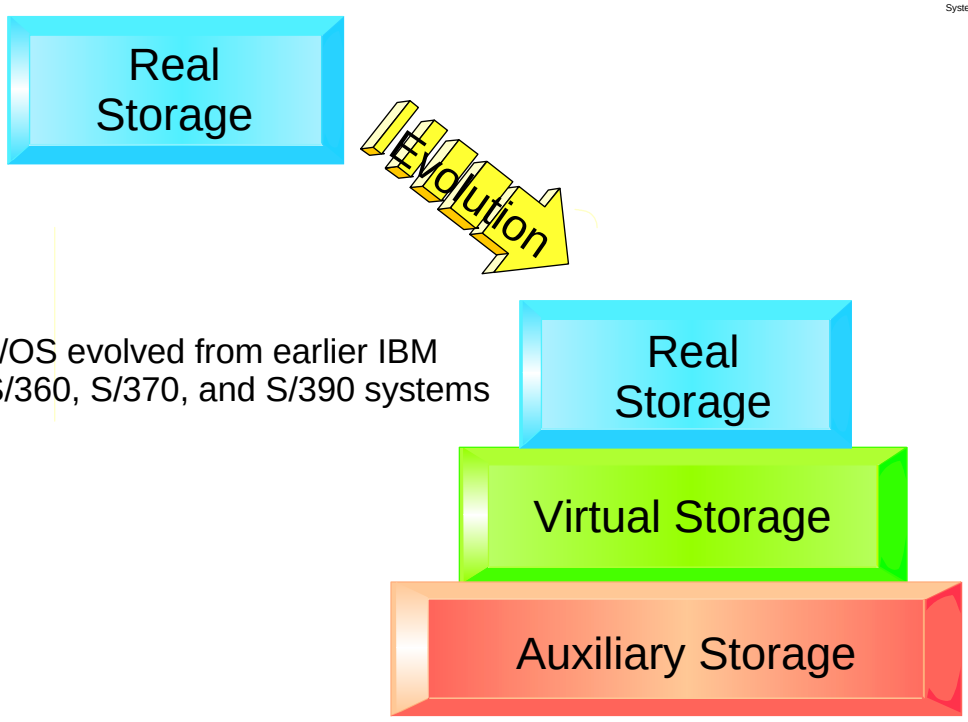
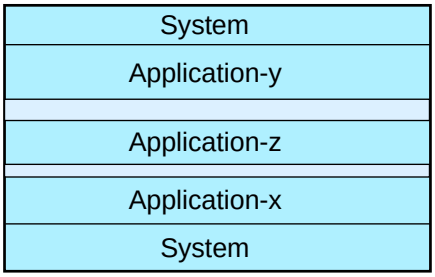


z/OS evolved from earlier IBM S/360, S/370, and S/390 systems

In the Past

- S/360 MVT - only real storage
- Real storage contained
  - Operating system code and control blocks
  - Application programs and data
- Disadvantages
  - Storage occupied by inactive routines
  - Limited number of applications could run concurrently
  - Storage fragmentation, prevented larger applications from running

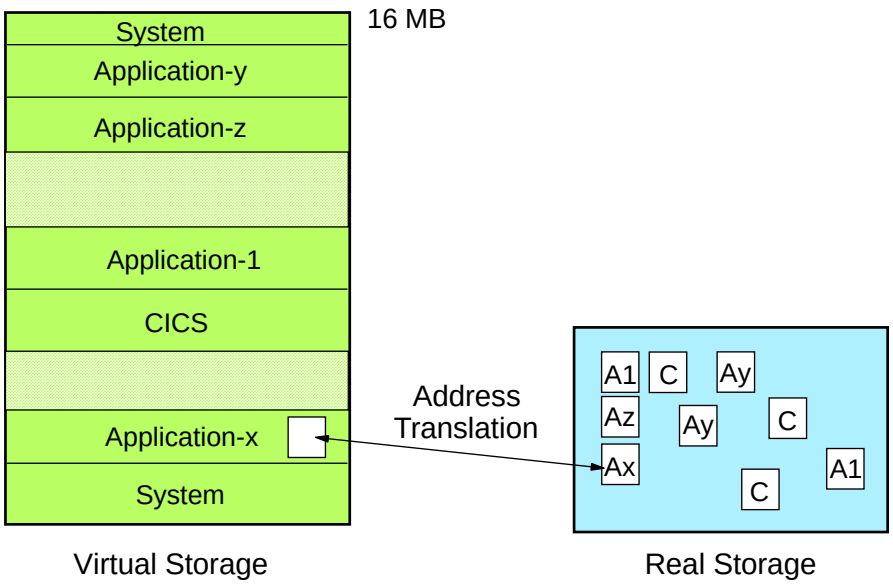
Real Storage is size of storage on processor



Introduction of Virtual Storage

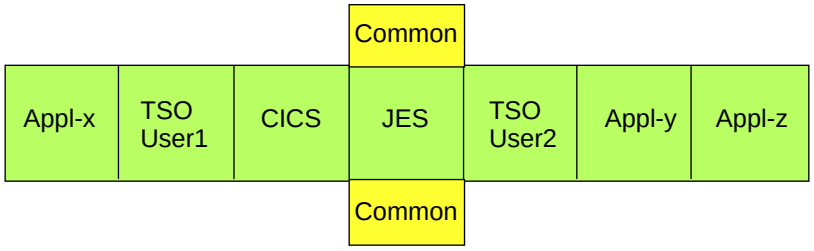
- S/370 SVS (Single Virtual Storage)
- Virtual storage is a concept created by the architecture and implemented through system page tables and the dynamic address translation (DAT) hardware feature
- Allowed more efficient use of real storage
  - Inactive portions of programs are no longer in real storage
  - Unused portions of the region are not in real storage
- Single virtual storage region of 16 MB
  - Virtual storage larger than real storage
  - Divided into pages
- Disadvantage
  - Limited number of applications could run concurrently

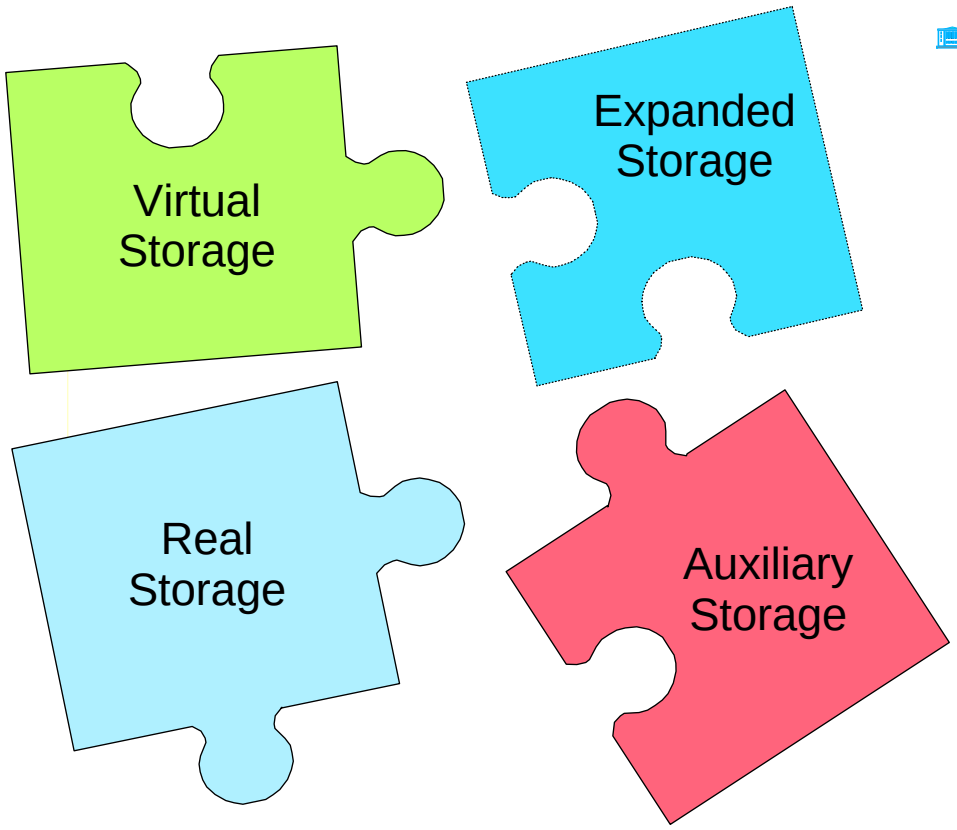
Single Virtual Storage



Multiple Virtual Address Spaces

- **S/370 MVS (Multiple Virtual Storage)**
- **Each user has its own virtual 16MB address space**
  - **Common storage shared by all address spaces**
  - **Private area is unique for each address space**
  - **Isolated each application's virtual storage from other applications**
- **Increased number of concurrent applications**





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Virtual Storage

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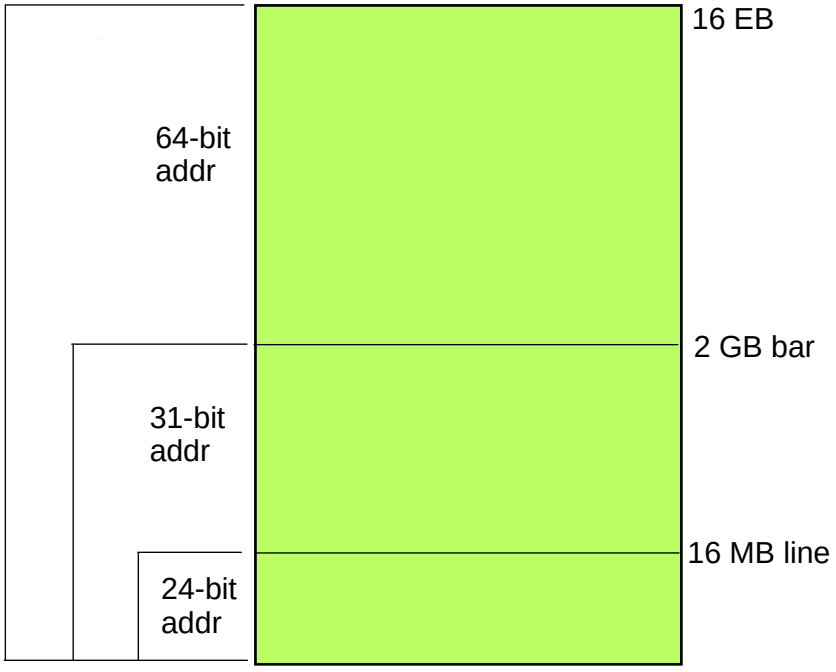
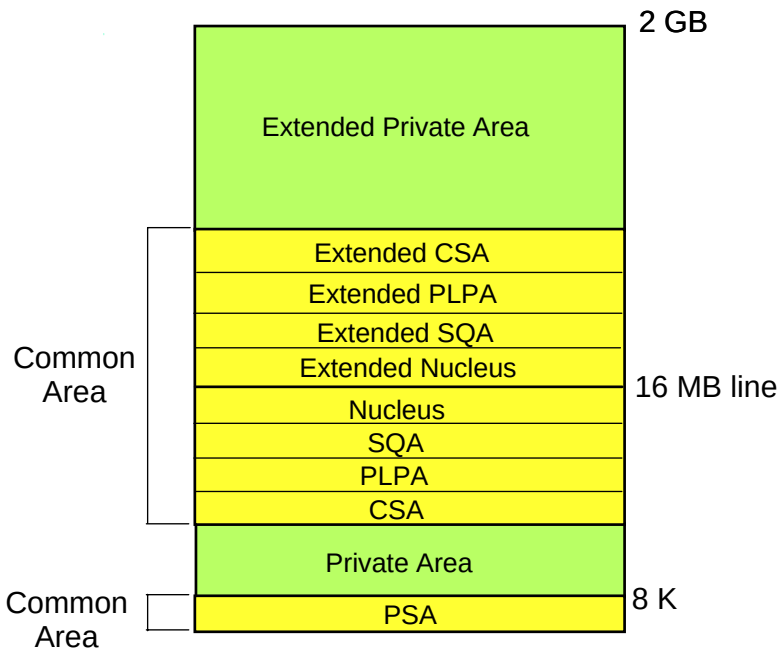
- Logical view of address space storage
- Divided into 4K increments called pages
- Common areas are shared by all address spaces
- Private areas are unique to each address space
- Programs are placed in contiguous virtual storage
- Addressing mode determines size of virtual address space
  - AMODE 24 = 16 bit address = 16 megabytes
  - AMODE 31 = 31 bit address = 2 gigabytes
  - AMODE 64 = 64 bit address = 16 exabytes
- Storage above the 2 GB bar is used for data and is obtained in 1 MB blocks
- Virtual storage is managed by the virtual storage manager (VSM)

Virtual is Unreal ...

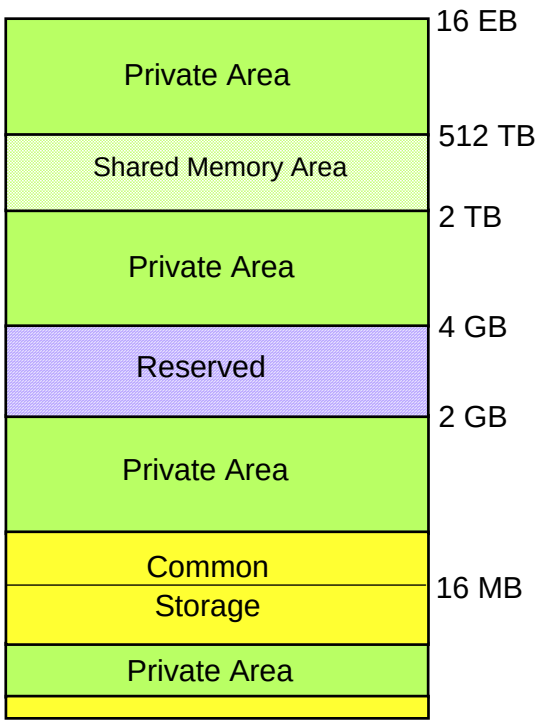
Virtual Storage Addressing



2 GB Address Space



64-bit Address Space

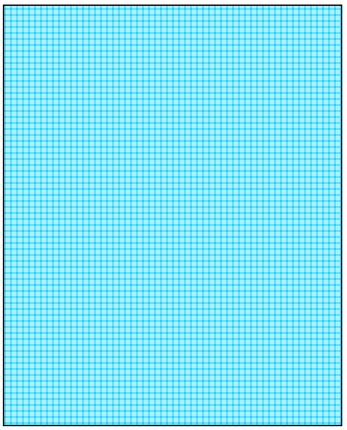


Common Storage

- **PSA - prefixed storage area**
  - Contains old PSWs, new PSWs, and register save areas
- **CSA / Extended CSA - common service area**
  - Contains data and programs shared across address spaces
  - Size specified with CSA parameter in IEASYSxx
- **PLPA / Extended PLPA - pageable link pack area**
  - Contains read-only, reentrant programs
  - Programs read into storage at IPL
- **SQA / Extended SQA- system queue area**
  - Contains system tables and queues
  - Size may be specified on SQA parameter in IEASYSxx
  - If no SQA is available, system will extend SQA into CSA
- **Nucleus - fixed and non-swappable**
  - Contains nucleus load module and extensions
  - Created during IPL

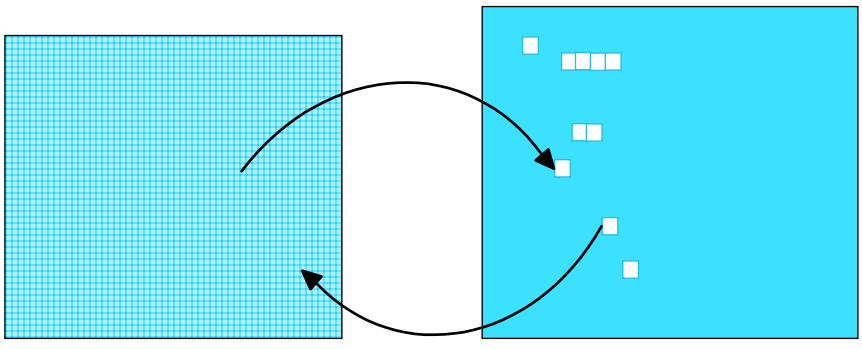
Real Storage

- Storage with directly addressable byte locations
- Each byte location is assigned a real storage address
- Also called central storage or main storage
- Size depends upon amount of processor storage purchased and amount assigned to logical partition
- Storage is divided into 4K blocks called page frames
- Programs must reside in real storage to be executed
- Real storage is managed by the real storage manager (RSM)



Expanded Storage

- Storage purchased on a processor may be divided into central storage and expanded storage
- Expanded storage is an extension to central storage, which is addressed in 4K blocks
- Expanded storage is not available in z/Archictecture mode
- The contents of a 4K storage frame (a page) may be moved between central and expanded storage



Auxiliary Storage

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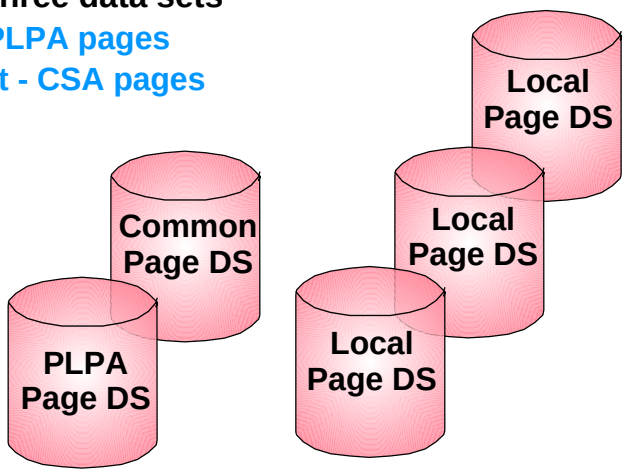
- VSAM data sets residing on DASD called page data sets
- Each data set is divided into 4K slots
- Contain 4K pages for common storage and address spaces
- Specified on the PAGE parameter in IEASYSxx
- Must specify at least three data sets
  - PLPA page data set - PLPA pages
  - Common page data set - CSA pages
  - Local page data set
- May have multiple local page data sets
- Auxiliary storage is managed by the auxiliary storage manager (ASM)



z/OS Storage

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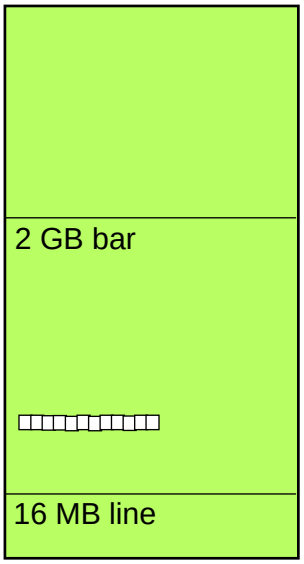
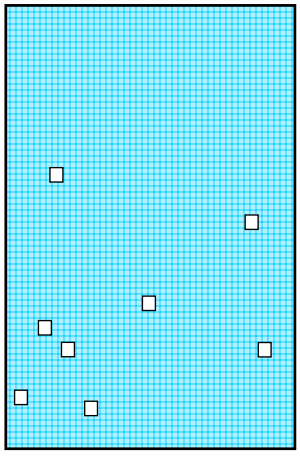
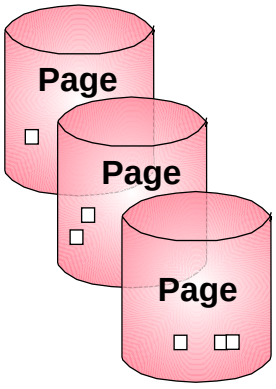


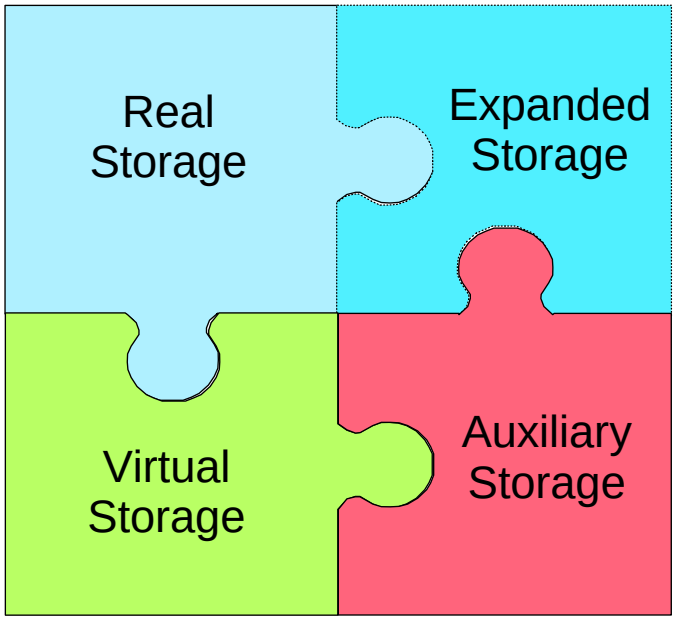
Virtual Storage Pages



Real Storage Page Frames

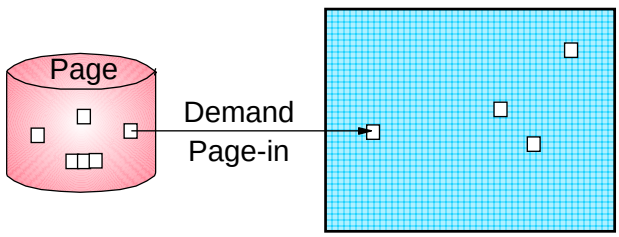


Auxiliary Storage Page Slots



Demand Paging

- The virtual storage for all the address spaces on the z/OS system is greater than the size of central storage
- Programs and their data must be in central storage to run
- When a program is running and references a page which is not in storage a page fault occurs
- To resolve the page fault, the page demanded by the application is brought into central storage from auxiliary storage - this is called demand paging
- This results in a page-in, as it is bringing a page into a real storage frame



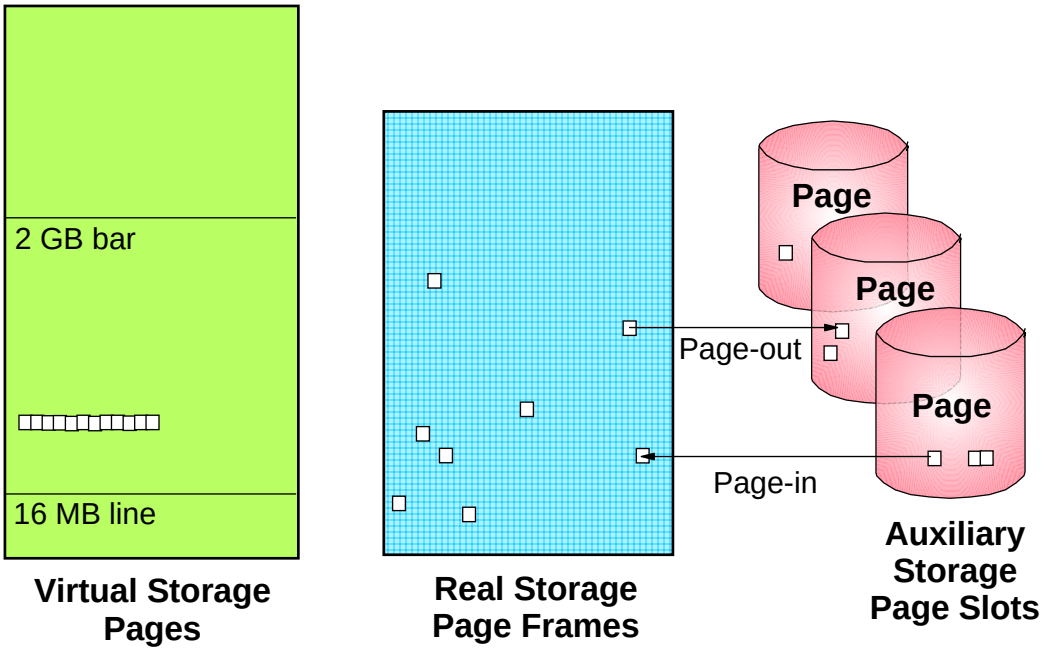
Least Recently Used Pages

- z/OS keeps information about each page in real storage
  - Change bit - whether the page has been changed
  - Reference bit - whether the page has been referenced
  - Unreferenced Interval Count (UIC) - measure of how long a page has not been referenced
- The change bit is turn on when a change is made to a page
- The reference bit is turned on when a program references a page
- Periodically the storage frames are scanned
  - If the reference bit is on, then the UIC is set to 0
  - If the reference bit is not on, then the UIC is incremented
  - UIC is a measure of how frequently frames are referenced, thus it is an indicator of the "stress" on real storage

Page Stealing

- To ensure a real storage frame is available when needed for a page, RSM maintains a queue of available frames
- To replenish the available frame queue, RSM will periodically steal frames containing pages
  - A least recently used (LRU) algorithm is used to identify the pages to be stolen
  - The UIC is used to identify the least recently used pages
- If a stolen page has the change bit on, the page will be written to auxiliary storage - this is called a page-out
- If a stolen page does not have the change bit on, it is not written to auxiliary storage as there is a current copy of it already on auxiliary storage

Paging - Big Picture



Paging Considerations

- There is a "cost" for obtaining a page from DASD
- On a page fault the application waits for the page to be brought into storage
- If no expanded storage, paging will be to auxiliary (DASD) storage
- System paging information is available on the Resource Measurement Facility (RMF) Paging Activity Report
  - Page-in rates
  - Page-out rates
  - Page fault rate

Paging Activity - Page Rates

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```
                                   P A G I N G   A C T I V I T Y
                                                                                          PAGE    1
z/OS V1R4                    SYSTEM ID SYSA             START 12/12/2003-12.54.00  INTERVAL 001.25.59
                             RPT VERSION V1R2 RMF       END   12/12/2003-14.20.00  CYCLE 1.000 SECONDS
OPT = IEAOPT00    MODE = ESAME              CENTRAL STORAGE PAGING RATES - IN PAGES PER SECOND
------------------------------------------------------------------------------------------------------
                            PAGE IN                                    PAGE OUT
                 ------------------------------------          ----------------------------
                                NON              %                                      %
                        NON     SWAP,            OF                                     OF
                        SWAP,   NON      TOTAL   TOTL                 NON     TOTAL     TOTL
CATEGORY         SWAP   BLOCK   BLOCK    RATE    SUM           SWAP   SWAP    RATE      SUM
PAGEABLE SYSTEM
AREAS (NON VIO)
     LPA                  0.00    0.00     0.00    0
     CSA                  0.00    0.00     0.00    0                    0.00    0.00     0
                        ------  ------   ------ ----                  ------  ------  ----
     SUM                  0.00    0.00     0.00    0                    0.00    0.00     0
ADDRESS SPACES
     HIPERSPACE           0.00             0.00    0                    0.00    0.00     0
     VIO                  0.00             0.00    0                    0.00    0.00     0
     NON VIO     0.00     0.97    0.02     0.99  100            0.00    0.80    0.80   100
                 ------ ------  ------   ------ ----          ------  ------  ------  ----
     SUM         0.00     0.97    0.02     0.99  100            0.00    0.80    0.80   100
TOTAL SYSTEM
     HIPERSPACE           0.00             0.00    0                    0.00    0.00     0
     VIO                  0.00             0.00    0                    0.00    0.00     0
     NON VIO     0.00     0.97    0.02     0.99  100            0.00    0.80    0.80   100
                 ------ ------  ------   ------ ----          ------  ------  ------  ----
     SUM         0.00     0.97    0.02     0.99  100            0.00    0.80    0.80   100
     SHARED                       0.00     0.00                         0.00    0.00

PAGE MOVEMENT WITHIN CENTRAL STORAGE       6.64            PAGE MOVEMENT TIME %     0.0
AVERAGE NUMBER OF PAGES PER BLOCK          9.9
BLOCKS PER SECOND                          0.10
PAGE-IN EVENTS (PAGE FAULT RATE)           0.12
```

Central Storage Planning

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- To reduce paging, reduce demand for central storage
  - Increase the amount of central storage
  - Decrease the amount of central storage used by applications
- Estimate amount of central storage needed for applications
  - Number of real storage pages required by each application also called the working set
  - Evaluate impact of paging on system and applications
- Central storage contains fixed pages and pageable pages
  - Fixed pages reduce the number of pageable frames available
- Calculate amount of central storage required for fixed pages and the working sets of active applications
- Central storage usage information is available on the RMF Paging Activity Report

Paging Activity - Storage Usage


```
                                    P A G I N G   A C T I V I T Y

z/OS V1R4                      SYSTEM ID SYSA             START 12/12/2003-12.54.00  INTERVAL 001.25.59
                               RPT VERSION V1R2 RMF       END   12/12/2003-14.20.00  CYCLE 1.000 SECONDS
OPT = IEAOPT00    MODE = ESAME                 CENTRAL STORAGE PAGING RATES - IN PAGES PER SECOND
-------------------------------------------------------------------------------------------------------------

                                                FRAME AND SLOT COUNTS
-------------------------------------------------------------------------------------------------------------
                            CENTRAL STORAGE
                          ----------------------------
   (585 SAMPLES)              MIN        MAX        AVG
   AVAILABLE              185,685    2145457    257,978
   SQA                      8,400      8,648      8,524
   LPA                      4,489      4,489      4,489
   CSA                     12,106     12,624     12,346
   LSQA                    15,411     23,933     23,586
   REGIONS+SWA            957,636    2908558    2836569
   TOTAL FRAMES           3145728    3145728    3145716

                           FIXED FRAMES
                          ----------------------------
   NUCLEUS                  2,227      2,227      2,227
   SQA                      7,172      7,418      7,293
   LPA                         78         78         78
   CSA                        619        806        622
   LSQA                    10,909     18,550     18,270
   REGIONS+SWA              4,247      7,700      4,370
   BELOW 16 MEG                86        122        110
   BETWEEN 16M-2G          14,767     17,648     16,792
   TOTAL FRAMES            25,257     36,399     32,861
```

Expanded Storage Considerations

- **Expanded storage is available in ESA/390 mode**
  - Systems with expanded storage may experience less paging activity to auxiliary storage
  - Page movement between expanded and central is much faster than between auxiliary and central storage
  - The maximum central storage allowed is 2 GB
- **Expanded storage is not available in z/Architecture**
  - Larger central storage sizes
  - Paging will be done to auxiliary storage page data sets
  - Page data set configuration should be able to efficiently handle the system paging
  - There must be sufficient space on the page data sets

Auxiliary Storage Considerations

- Suggest multiple local page data sets
- Verify page data sets have sufficient space
  - Common area pages + private area pages of address spaces
  - Prevent auxiliary storage shortage
  - May wish to define and format an "extra" page data set
- If auxiliary storage shortage is detected
  - LOGON, MOUNT and START commands are rejected
  - Initiators are prevented from executing new jobs
  - Cannot run a job to create a new page data set
  - Can use PAGEADD command to add "extra" page data set
- Information on page data set slot usage is available on the RMF Page Dataset Activity Report

Page Dataset Report

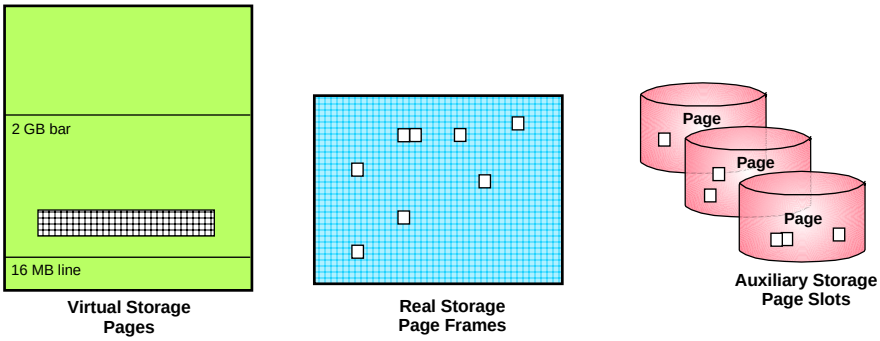

```
                    P A G E / S W A P  D A T A S E T  A C T I V I T Y                PAGE  1

 z/OS V1R4              SYSTEM ID SYSA            START 12/12/2003-12.54.00  INTERVAL 001.25.59
                        RPT VERSION V1R2 RMF      END   12/12/2003-14.20.00  CYCLE 1.000 SECONDS


NUMBER OF SAMPLES =   5,160                        PAGE DATA SET USAGE
                                                  -------------------------
PAGE
SPACE   VOLUME  DEV  DEVICE    SLOTS  ---- SLOTS USED ---  BAD
TYPE    SERIAL  NUM  TYPE      ALLOC    MIN    MAX   AVG   SLOTS     ...     DATA SET NAME
PLPA    WPAGE1  DD11 33903       179    179    179    179      0     ...     SYSA.PLPA
COMMON  WPAGE1  DD11 33903     89999  15549  15549  15549      0     ...     SYSA.CSA
LOCAL   WPAGE3  7022 33903    539999  47290  48004  47658      0     ...     SYSA.LOCAL1
LOCAL   WPAGE2  DD0B 33903    539999  25236  25942  25542      0     ...     SYSA.LOCAL2
LOCAL   WPAGE1  DD11 33903    503999  25582  26282  25902      0     ...     SYSA.LOCAL3
LOCAL   WPAGE4  702D 33903    575999  46394  47103  46755      0     ...     SYSA.LOCAL4
LOCAL   WPAGE5  702E 33903    575999  46803  47566  47187      0     ...     SYSA.LOCAL5
```

Summary

Virtual storage is implemented by the archecture and is a logical layout for address space storage. The virtual storage pages used by the address space reside in central or auxiliary storage.

Paging is the movement of between central and auxiliary storage.

Information on real storage frame usage, auxiliary storage slot usage, and paging rates is available on RMF reports.



Publications

Product Information - z/OS

z/OS MVS Initialization and Tuning Guide , SA22-7591
z/OS MVS Extended Addressability Guide, SA22-7614
z/OS RMF Report Analysis, SC33-7991
z/Architecture Principles of Operation, SA22-7832

Websites

z/OS publications
www.ibm.com/servers/eserver/zseries/zos/bkserv/

Technical Document: "z/OS Performance Managing Processor Storage in a 64-bit Environment"
www.ibm.com/support/techdocs/atsmastr.nsf/WebIndex/WP100269