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Linux on z/VM Performance

Understanding Disk I/O

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Agenda

- I/O Performance Model
- ECKD Architecture
- RAID Disk Subsystems
- Parallel Access Volumes
- Virtual Machine I/O
- Linux Disk I/O
- SAN Devices

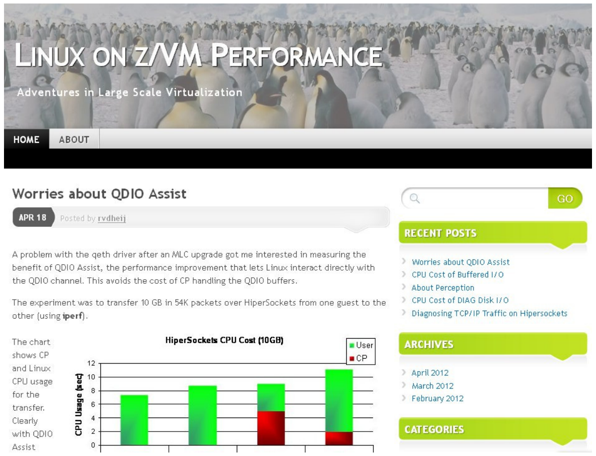
Linux on z/VM Tuning Objective

Resource Efficiency

- Achieve SLA at minimal cost
  - “As Fast As Possible” is a very expensive SLA target
- Scalability has its limitations
  - The last 10% peak capacity is often the most expensive

Recommendations are not always applicable

- Every customer environment is different
- Very Few Silver Bullets
- Consultant skills and preferences



http://zvmperf.wordpress.com/

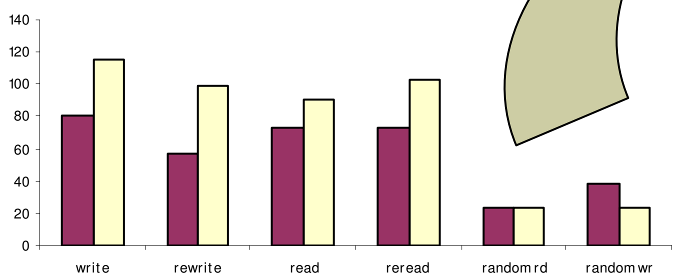
Benchmark Challenges

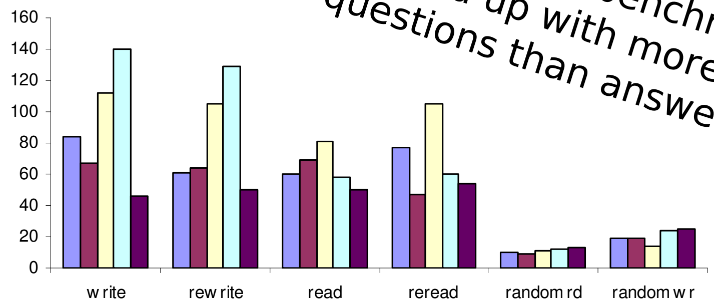
Benchmarks have limited value for real workload

- Every real life workload is different
  - All are different from synthetic benchmarks
  - There are just too many options and variations to try
- Benchmarks can help understand the mechanics
  - Provide evidence for the theoretical model

Use performance data from your real workload

- Focus on the things that really impact service levels





Given enough benchmarks, you end up with more new questions than answers…

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Anatomy of Basic Disk I/O

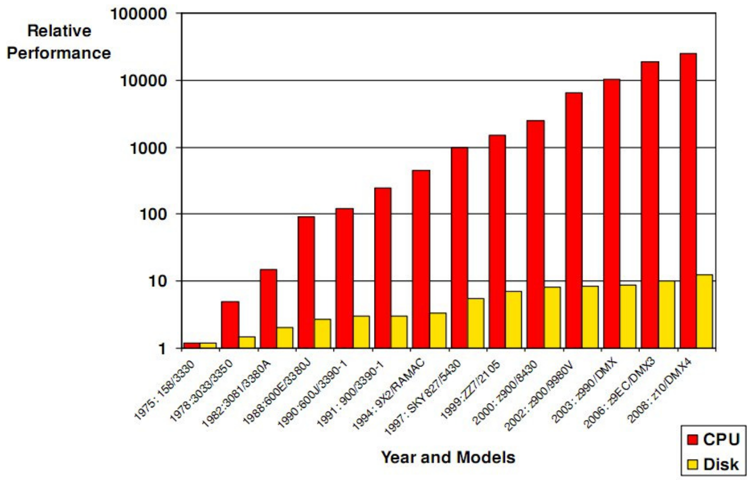
Who Cares About Disk

"Disks are very fast today"

"Our response time is a few ms"

Selection Criteria

- Capacity
- Price



© 2010 Brocade, SHARE in Seattle, "Understanding FICON I/O Performance"

	IBM 3380-AJ4 (1981)	Seagate Momentus 7200.3 (2011)
Price	$80K	$60
Capacity	2.5 GB	250 GB
Latency	8.3 ms	4.2 ms
Seek Time	12 ms	11 ms
Host Interface	3 MB/s	300 MB/s
Device Interface	2.7 MB/s	150 MB/s

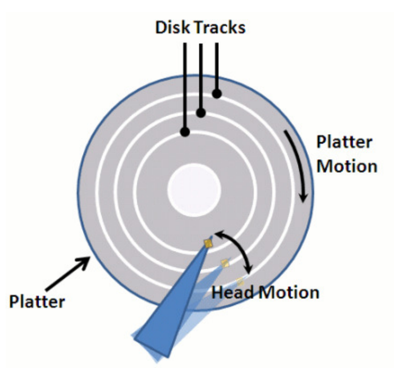
Anatomy of Basic Disk I/O

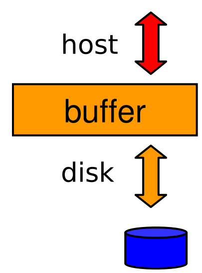
Reading from disk

- Seek – Position the heads over the right track
- Latency – Wait for the right sector
- Read – Copy the data into memory

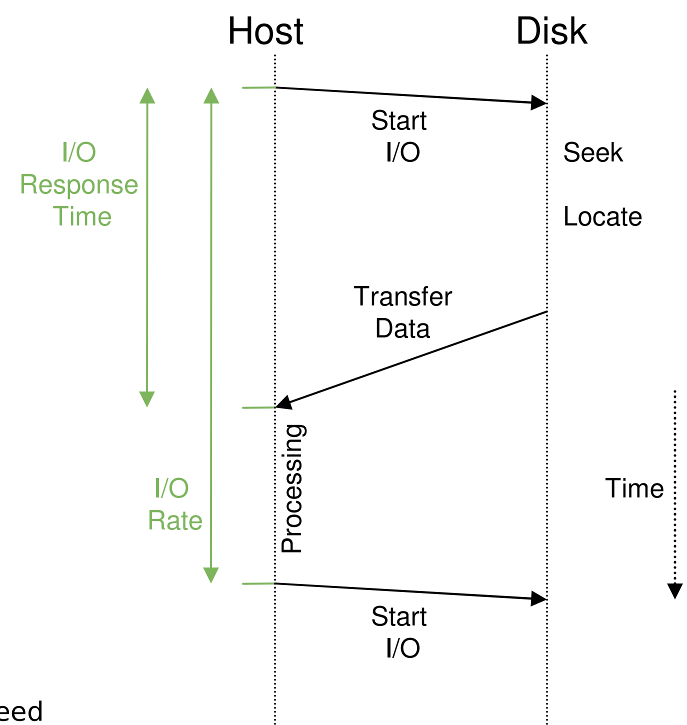
Average I/O Operation

- Seek over 1/3 of the tracks ~ 10 ms
- Wait for 1/2 a rotation ~ 3 ms
- Read the data ~ 1 ms

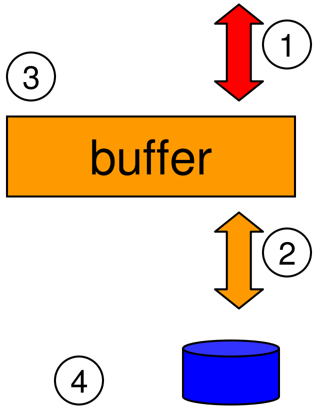




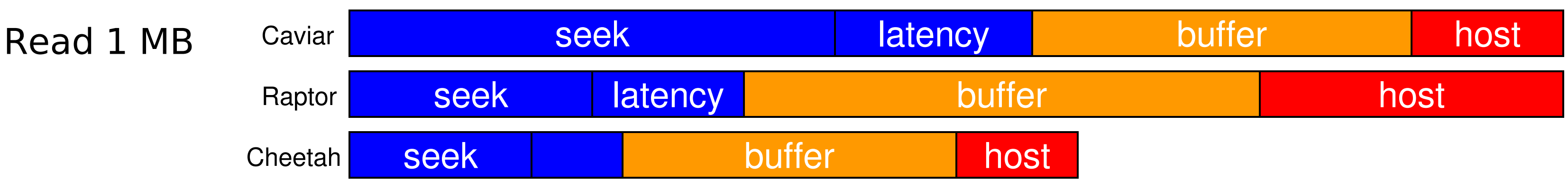
Host and disk decoupled by speed matching buffer

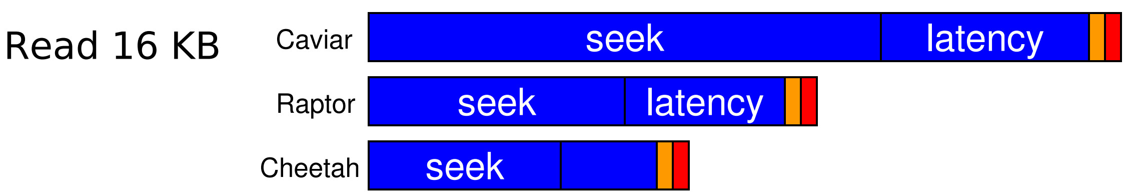


Basic Disk Read Performance



	WD Caviar SE16 500	WD Raptor 150 GB	Cheetah 15K
(1) Buffer to host	300 MB/s	150 MB/s	400 MB/s
(2) Transfer rate	120 MB/s	84 MB/s	100 MB/s
(3) Buffer size	16 MB	16 MB	16 MB
(4) Average seek	10.9 ms	5.2 ms	3.5 ms
(4) Average latency	4.2 ms	3.0 ms	2.0 ms





IOPS rating of device is just seek and latency

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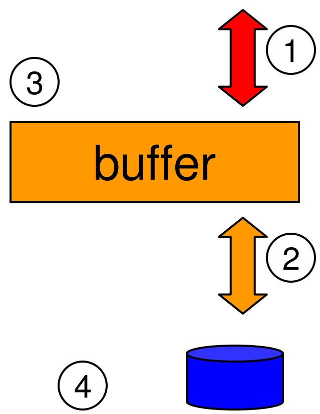
Basic Disk Write Performance



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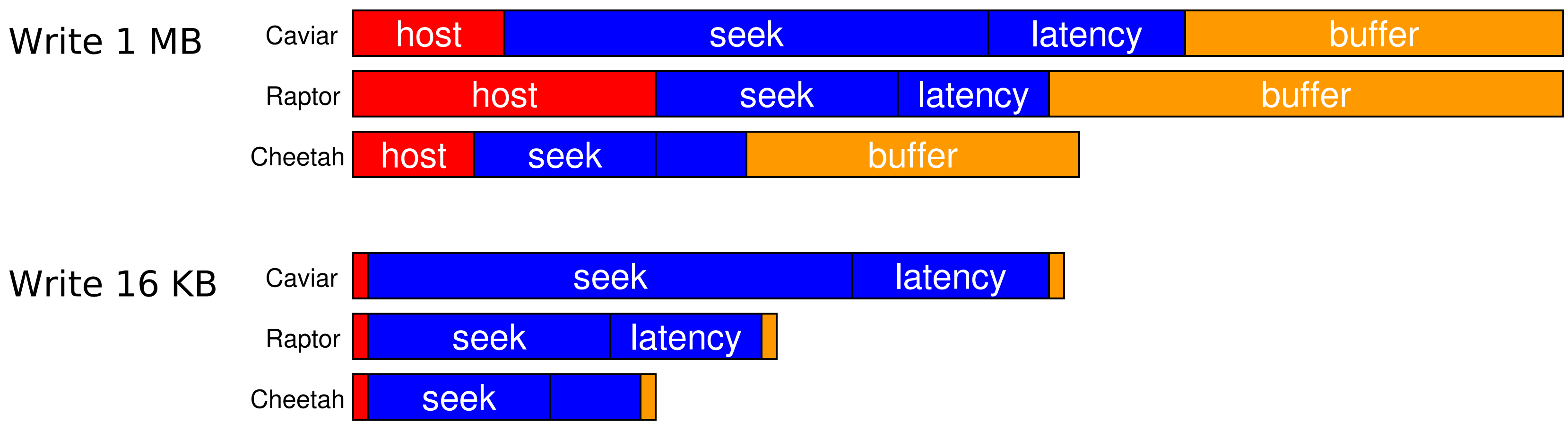


Classic DASD Configuration

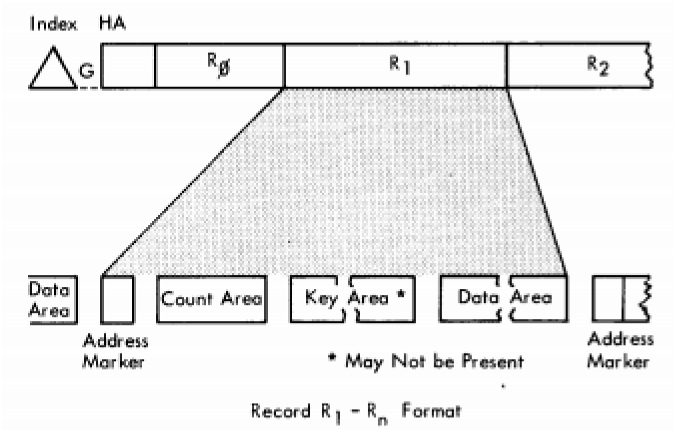
CKD – Count Key Data Architecture

- Large system disk architecture since 60’s
- Track based structure
  - Disk record size to mach application block size
- Disk I/O driven by channel programs
  - Autonomous operation of control unit and disk
  - Reduced CPU and memory requirements
- ECKD – Extended Count Key Data
  - Efficient use of cache control units
  - Improved performance with ESCON and FICON channel

Linux disk I/O does not exploit CKD features

FBA – Fixed Block Architecture

- Popular with 9370 systems
- Not supported by z/OS
- Access by block number
- Uniform block size



Classic DASD Configuration

Channel Attached DASD

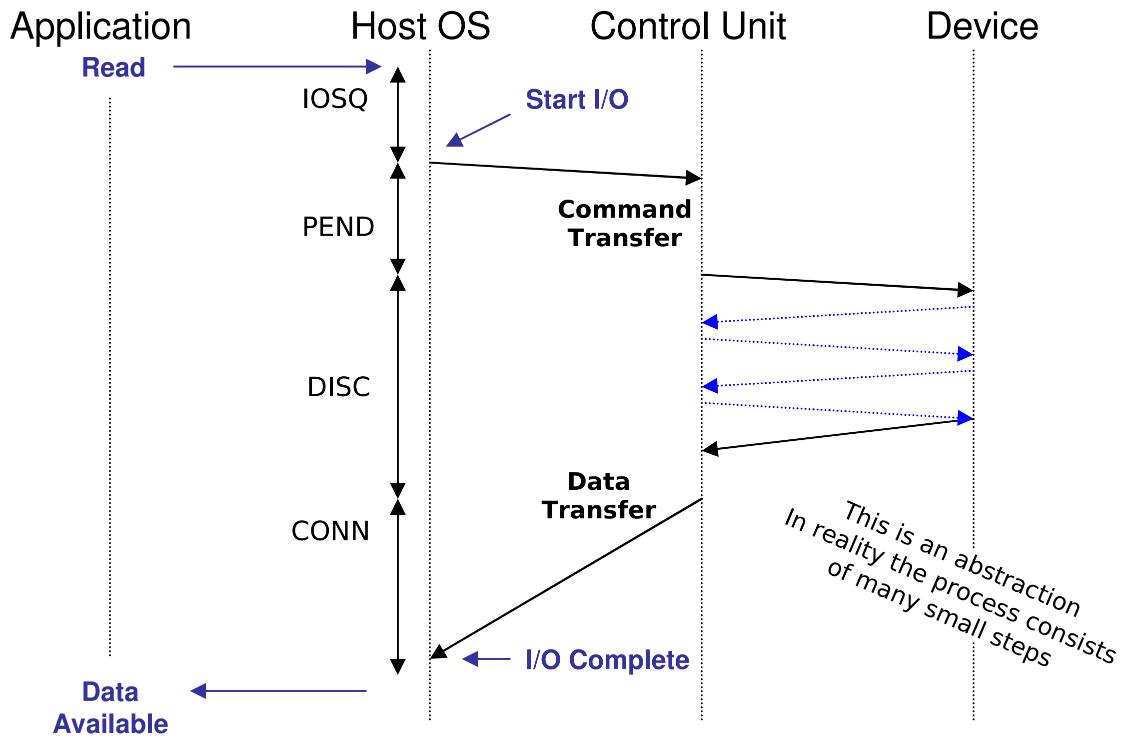
- Devices share a channel
- Disconnect and reconnect
- Track is cached in control unit buffer

IOSQ
- Device Contention
- Interrupt Latency

PEND
- **Channel Busy**
- Path Latency
- Control Unit Busy
- Device Busy

DISC
- **Seek**
- Latency
- Rotational Delay

CONN
- Data Transfer
- Channel Utilization



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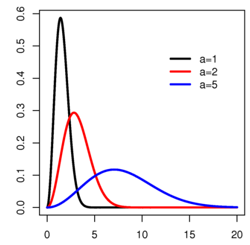
Classic DASD Configuration

Instrumentation provided by z/VM Monitor

- Metrics from z/VM and Channel
  - Traditionally used to optimize disk I/O performance
- Response time improvement through seek optimization
  - Relocating data sets to avoid multiple hot spots
  - I/O scheduling – elevator algorithm



DISC = Seek + Rotational Delay

```
Screen: ESADSD2                                 ESAMON 3.807 03/23 16:24-16:33
1 of 3  DASD Performance Analysis - Part 1      DEVICE 3505          2097


          Dev         Device %Dev <SSCH/sec-> <-----Response times (ms)--->
Time      No. Serial Type   Busy   avg  peak  Resp  Serv  Pend  Disc  Conn
-------- *--- ------ ------ ---- *---- ----- ----- ----- ----- ----- -----
16:25:00 3505 0X3505 3390-? 26.3 728.8 728.8   0.4   0.4   0.2   0.0   0.2
16:26:00 3505 0X3505 3390-? 76.9 977.4 977.4   0.8   0.8   0.3   0.1   0.4
16:27:00 3505 0X3505 3390-? 62.0 480.0 977.4   1.3   1.3   0.5   0.1   0.6
16:28:00 3505 0X3505 3390-? 15.8 198.9 977.4   0.8   0.8   0.1   0.5   0.2
```

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Contemporary Disk Subsystem

Big Round Brown Disk

- Specialized Mainframe DASD
- One-to-one map of Logical Volume on Physical Volume
- Physical tracks in CKD format
- ECKD Channel Programs to exploit hardware capability

Contemporary Disk Subsystem

- Multiple banks of commodity disk drives
  - RAID configuration
  - Dual power supply
  - Dual controller
- Microcode to emulate ECKD channel programs
  - Data spread over banks, ranks, array sites
- Lots of memory to cache the data

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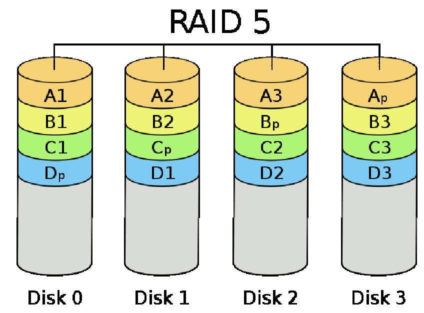
RAID Configuration

RAID: Redundant Array of Independent Disks

- Setup varies among vendors and models
- Error detection through parity data
- Error correction and hot spares
- Spreading the I/O over multiple disks

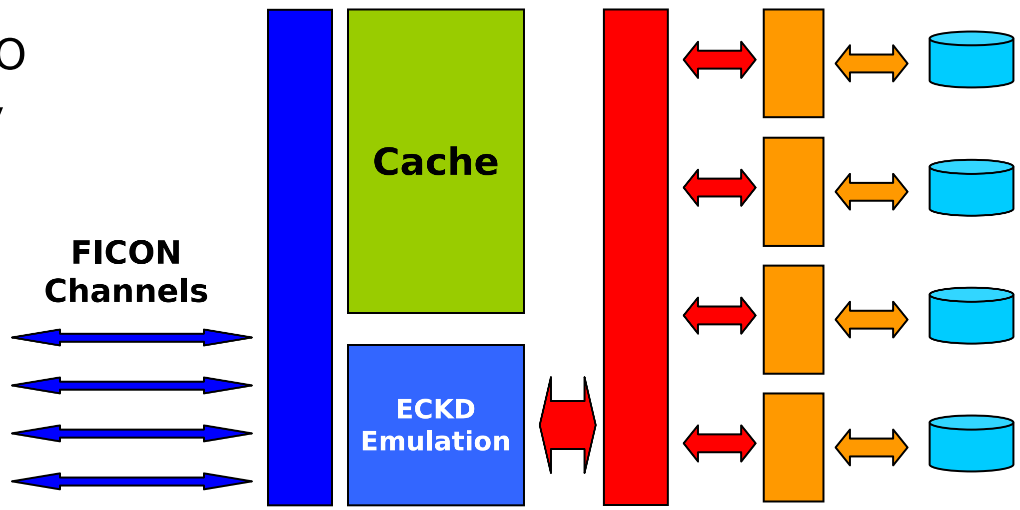


Performance Considerations

- The drives are “just disks”
- RAID does not avoid latency
- Large data cache to avoid I/O
- Cache replacement strategy

Additional Features

- Instant copy
- Autonomous backup
- Data replication



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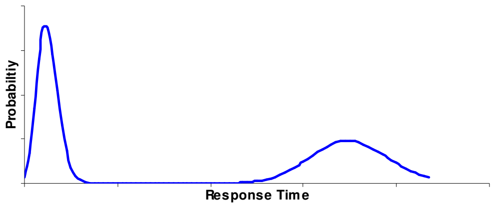
RAID Configuration

Provides Performance Metrics like 3990-3

- Model is completely different
- DISC includes all internal operations
  - Reading data into cache
  - Data duplication and synchronization

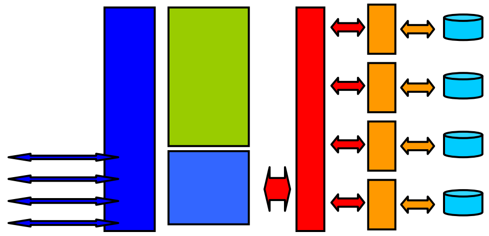
Bimodal Service Time distribution

- Cache read hit
  - Data available in subsystem cache
  - No DISC time
- Cache read miss
  - Back-end reads to collect data
  - Service time unrelated to logical I/O



Average response time is misleading

- Cache hit ratio
- Service time for cache read miss



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RAID Configuration

Statistics obtained from DASD subsystem

- Many DASD subsystems implement the 3990 metrics
  - Model is different so metrics don't map completely
  - Some vendors cheat a bit to please z/OS Storage Management
  - Additional performance data with dedicated tools

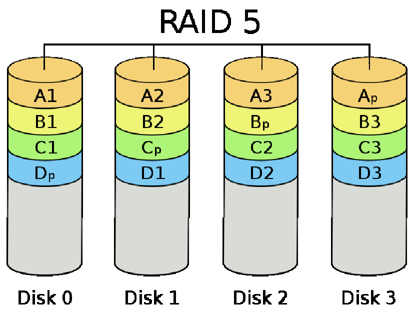
```
Screen: ESADSD5                                        ESAMON 3.807 03/23 16:24-16:33
1 of 3  3990 Cache Analysis                            DEVICE 3505          2097 40F32

                     Pct. <---- Total I/O ----> <------ Read Activity ------>
          Dev        Actv <Per Sec> Cache       <-- Random --> <-Sequential->
Time      No. Serial Samp  I/O Hits  Hit% Read%  I/O Hits Hit%  I/O Hits Hit%
-------- ---- ------ ---- ---- ---- ----- ----- ---- ---- ---- ---- ---- ----
16:27:00 3505 0X3505  100 1573 1573 100.0   0.0    0    0    .  0.0  0.0  100
16:28:00 3505 0X3505  100  199  180  90.7 100.0  174  155 89.4 24.8 24.8 99.9
16:29:00 3505 0X3505  100 1151 1069  92.9 100.0 1006  925 91.9  145  145 99.8
16:30:00 3505 0X3505  100 1291 1232  95.4 100.0 1127 1068 94.8  164  164 99.9
16:31:00 3505 0X3505  100 1407 1361  96.7 100.0 1230 1184 96.3  177  177 99.9
16:32:00 3505 0X3505  100  321  313  97.3 100.0  281  272 97.0 40.5 40.5  100
```

RAID Configuration

Example:

- Cache Hit Ratio 90%
- Average DISC 0.5 ms
- Service Time Miss 5 ms

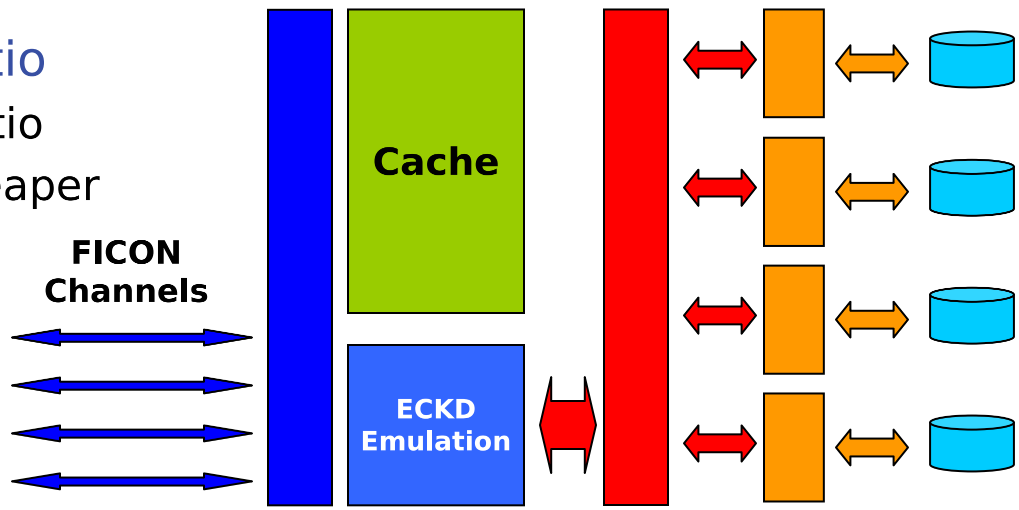


Read Prediction

- Detecting sequential I/O
- ECKD: Define Extent

RAID does not improve hit ratio

- Read ahead can improve ratio
- RAID makes read ahead cheaper



RAID Configuration

Write statistics obtained from DASD subsystem

- DFW: DASD Fast Write – Stored in Non-Volatile Storage
- Write penalty for RAID configurations

```
Screen: ESADSD5                                   ESAMON 3.807 03/23 16:24-16:33
2 of 3  3990 Cache Analysis                       DEVICE 3505          2097 40F32

                     Pct. <---- Total I/O ----> <------ Write Activity ------>
          Dev        Actv <Per Sec> Cache       Total  DFW  DFW  Seq       NVS
Time      No. Serial Samp  I/O Hits  Hit% Read%   I/O  I/O Hits  I/O Hit% Full
-------- ---- ------ ---- ---- ---- ----- ----- ----- ---- ---- ---- ---- ----
16:25:00 3505 0X3505  100  729  728 100.0   0.0 728.3  728  728   92  100    0
16:26:00 3505 0X3505  100 2070 2069 100.0   0.0  2069 2069 2069  261  100    0
16:27:00 3505 0X3505  100 1573 1573 100.0   0.0  1573 1573 1573  199  100    0
16:28:00 3505 0X3505  100  199  180  90.7 100.0   0.0    0    0    0  100    0
16:29:00 3505 0X3505  100 1151 1069  92.9 100.0   0.0    0    0    0  100    0
```

Disk I/O Example

Time	Node	Processor Pct Util Total	Syst	User	Nice	Idle Pct	Swaps In	Swaps Out	Disk IO In	Disk IO Out	Switch Rate	Intrpt Rate
15:12:00	roblnx2	5.9	5.7	0.2	0	60.2	0	0	0	**210K**	**272.1**	0

(Rates are per sec.)

210K blocks per second = 105 MB/s -> 6.3 GB written

105 MB/s & 272 context switches -> ~ 400 KB I/O's

Time	Dev No.	Serial	Device Type	Total SSCH	ERP SSCH	%Dev Busy	SSCH/sec avg	SSCH/sec peak	Resp	Serv	Pend	Disc	Conn
15:12:00	954A	PR954A	3390-9	6350	0	36.8	105.8	105.8	3.5	3.5	0.2	1.2	2.1
15:12:00	95D5	PR954A	3390-9	6677	0	35.9	111.3	111.3	3.2	3.2	0.2	1.1	1.9
15:12:00	95D6	PR954A	3390-9	6532	0	35.7	108.9	108.9	3.3	3.3	0.2	1.2	2.0

(Response times in ms.)

PAV Base + 2 Alias
326 I/O per sec

Could not keep up with writes
Every 3rd I/O had to wait

326 writes per second
eligible for DFW

DISC time 1.2 ms for 1/3 of I/O's ->
3.9 ms subsystem response for writes

Time	Dev No.	Serial	Pct. Actv Samp	Total I/O Per Sec I/O	Total I/O Per Sec Hits	Cache Hit%	Read%	Write Activity Total I/O	DFW I/O	DFW Hits	Seq I/O	Hit%	NVS Full
15:12:00	954A	PR954A	100	326	326	100.0	0	**325.7**	326	326	308	100	**123**

Time	Dev No.	Serial	Pct. Actv Samp	Total I/O Per Sec I/O	Total I/O Per Sec Hits	Cache Hit%	Read%	Cache Inhib	Cache Bypass	Tracks/second Staged Seq	Tracks/second Staged Nseq	Tracks/second De-staged
15:12:00	954A	PR954A	100	326	[illegible]	[illegible]	0	0	0	0	0	**2194**

2194 tracks @ 48KB
= 105 MB/s

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Channel Instrumentation

Instrumentation provided by Channel Subsystem

- Channels often shared with other LPARs in the system
- Channel is a little computer system of its own
  - Processor and memory, different buses with different capacity
- High channel utilization will slow down the I/O
  - FICON is packet switched – longer PEND and CONN times
  - ESCON is connection switched – longer DISC times

```
Screen: ESACHAN                                         ESAMON 3.807 03/23 16:25-16:25
1 of 3  Channel Performance Analysis                    CHANNEL 40-4F        2097 40F32

                           Pct Channel <--------------Data Units ------------>
                 <Channel> Utilization <---Reads/Second--> <--Writes/Second-->
Time     CHP Shr Class Typ  LPAR Total LPAR TOTAL Pct  Max LPAR TOTAL pct  MAX
-------- --- --- ----- --- ----- ----- ---- ----- --- ---- ---- ----- --- ----
16:26:00  48 Yes FICON FC    4.2   4.5    0    92   0 391K 5625  5645   1 391K
          4A Yes FICON FC    4.2   4.5    1    98   0 391K 5620  5643   1 391K
          4B Yes FICON FC    4.2   4.4    0    76   0 391K 5612  5634   1 391K
          4C Yes FICON FC    4.2   4.5    1    82   0 391K 5632  5655   1 391K
          4E Yes FICON FC    4.2   4.5    1    86   0 391K 5621  5646   1 391K
          4F Yes FICON FC    4.2   4.5    1    94   0 391K 5615  5635   1 391K
```

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FICON Fabric can present some challenges

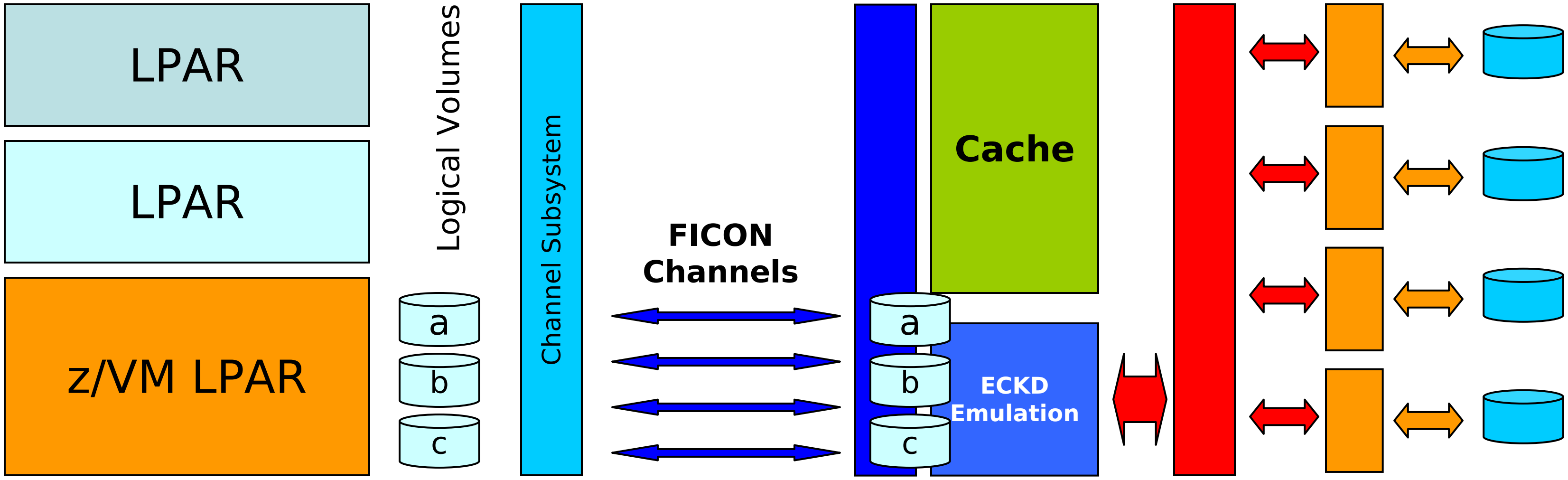
- FICON switches provide additional instrumentation
  - High bandwidth and long distance – buffer credits
- Strange numbers may indicate configuration issues
  - Channels not configured
- Report is useful to see I/O volume and block size
  - Do the math to see whether connect time makes sense

```
Screen: ESACHAN                                 ESAMON 3.808 04/16 14:33-14:34
1 of 3  Channel Performance Analysis            CHANNEL 48-FF        2097 40F32

                           Pct Channel <---------------Data Units ------------>
                 <Channel> Utilization <---Reads/Second--> <--Writes/Second-->
Time     CHP Shr Class Typ  LPAR Total LPAR TOTAL Pct  Max LPAR TOTAL pct  MAX
-------- --- --- ----- --- ----- ----- ---- ----- --- ---- ---- ----- --- ----
14:34:00  48 Yes FICON FC    0.1  10.9    0 17907   5 391K   91  2125   1 391K
          49 Yes FICON FC      0     0    0     4   0 195K    0     0   0 195K
          4A Yes FICON FC    0.1  10.9    2 17839   5 391K   91  2156   1 391K
          4B Yes FICON FC    0.1  10.8    2 17860   5 391K   92  2109   1 391K
          4C Yes FICON FC    0.1  10.9    1 17883   5 391K  101  2100   1 391K
```

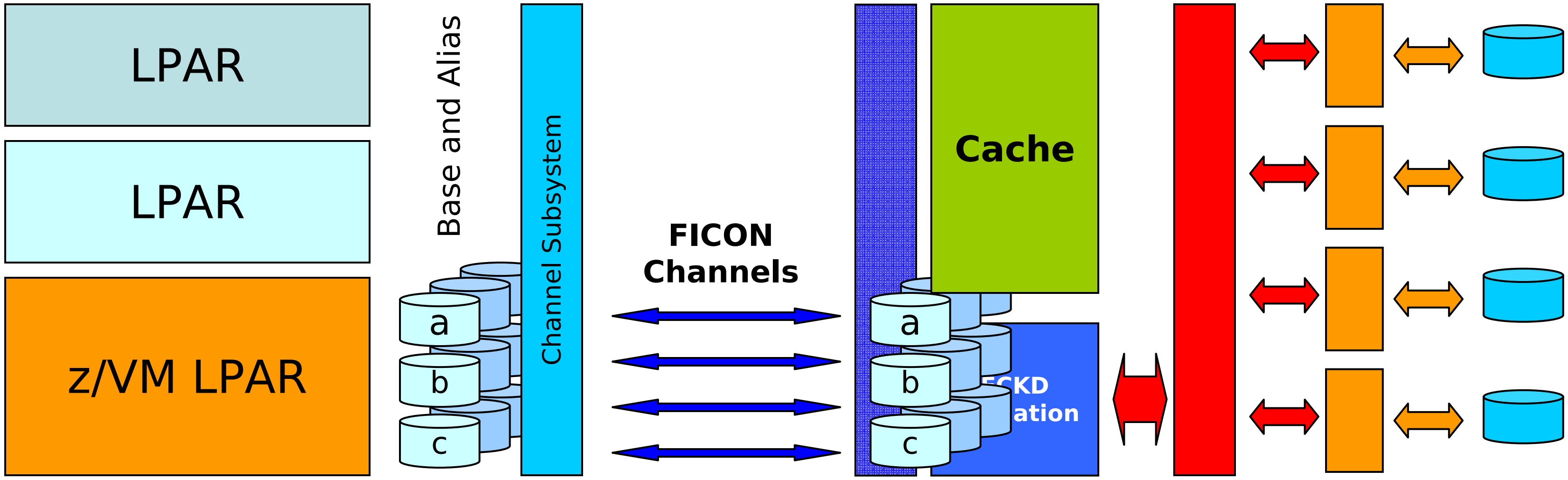
S/390 I/O Model: Single Active I/O per Logical Volume

- Made sense with one logical volume per physical volume
- Too restrictive on contemporary DASD subsystems
  - Logical volume can be striped over multiple disks
  - Cached data could be accessed without real disk I/O
  - Even more restrictive with large logical volumes



Base and Alias Subchannels

- Alias appear like normal device subchannel
  - Host and DASD subsystem know it maps on the same set of data
  - Simultaneous I/O possible on base and each alias subchannel
- DASD subsystem will run them in parallel when possible
  - Operations may be performed in different order



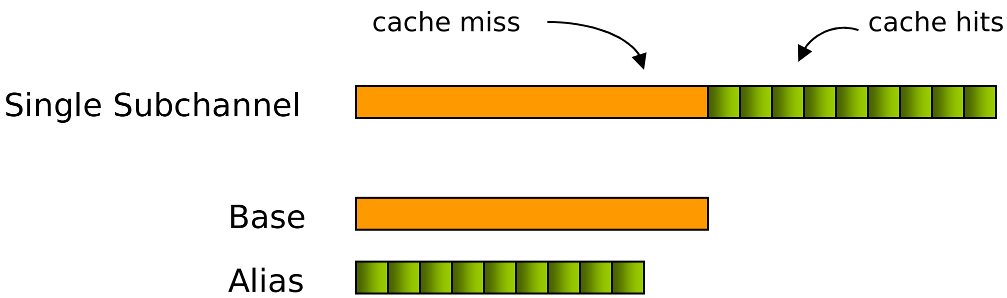
Parallel Access Volumes

Access to cached data while previous I/O is still active

- I/O throughput mainly determined by cache miss operations
  - Assumes moderate hit ratio and an alias subchannel

Example

- Cache hit ratio of 90%
  - Cache hit response time 0.5 ms
  - Cache miss response 5.5 ms




```
PEND 0.2 ms
DISC 5.0 ms
CONN 0.3 ms
```

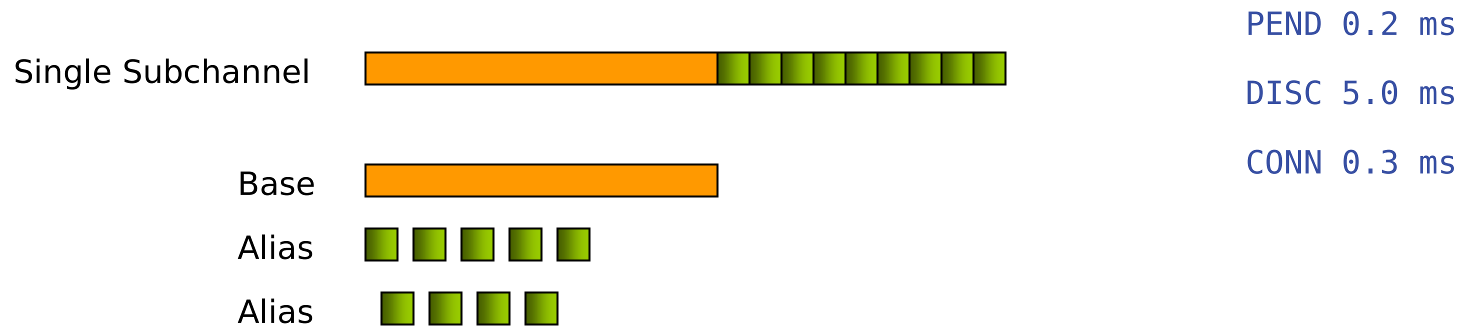
Parallel Access Volumes

Queuing of next I/O closer to the device

- Interesting with high cache hit ratio when PEND is significant
- Avoids delay due to PEND time
  - Service time for cache hit determined only by CONN time
  - Assuming sufficient alias subchannels

Example

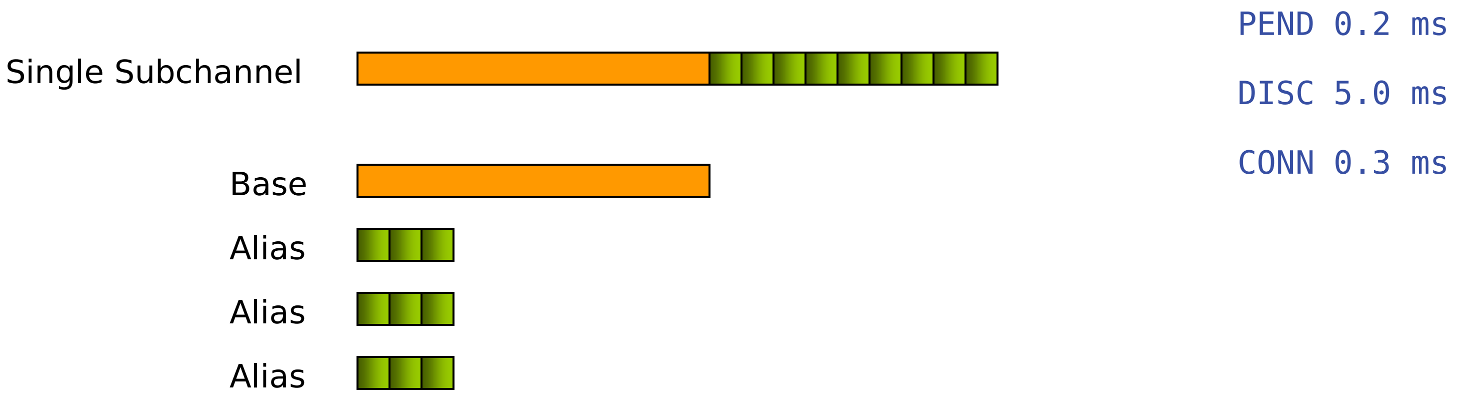
- Cache hit ratio of 90%
  - Cache hit response time 0.5 ms
  - Cache miss response 5.5 ms



Parallel Access Volumes

Multiple parallel data transfers over different channels

- Parallel operations retrieving from data cache
  - Depends on DASD subsystem architecture and bandwidth
  - Configuration aspects (ranks, banks, etc)
  - Implications on FICON capacity planning
- Cache hit service time improved by the number of channels
  - Combined effect: service time determined by aggregate bandwidth
  - Assumes infinite number of alias subchannels
  - Assumes sufficiently high cache hit ratio



Parallel Access Volumes

Performance Benefits

1. Access to cached data while previous I/O is still active
   - Avoids DISC time for cache miss
2. Queuing the request closer to the device
   - Avoid IOSQ and PEND time
3. Multiple operations in parallel retrieving data from cache
   - Utilize multiple channels for single logical volume

- Lots of things to learn about device utilization

Restrictions

- Reordering of operations must not change the function
  - Scope of operation in Define Extent CCW
- PAV is chargeable feature on DASD subsystems
  - Infinite number of alias devices is unpractical and expensive
- Workload must issue multiple independent I/O operations
  - Typically demonstrated by I/O queue for the device (IOSQ time)

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Parallel Access Volumes

Static PAV

- Alias devices assigned in DASD Subsystem configuration
- Association observed by host Operating System

Dynamic PAV

- Assignment can be changed by higher power (z/OS WLM)
- Moving an alias takes coordination between parties
- Linux and z/VM tolerate but not initiate Dynamic PAV

HyperPAV

- Pool of alias devices is associated with set of base devices
- Alias is assigned for the duration of a single I/O
- Closest to “infinite number of alias devices assumed”

Parallel Access Volumes

CP does not exploit PAV for its own I/O (page, spool)

Virtual machines can exploit PAV

	Dedicated DASD	z/VM Minidisks
PAV-unaware	Limited to single threaded I/O	Transparently exploits PAV for stacked minidisks
PAV-aware	Exploits PAV through dedicated base and alias devices	Over-committtted multi-threaded I/O

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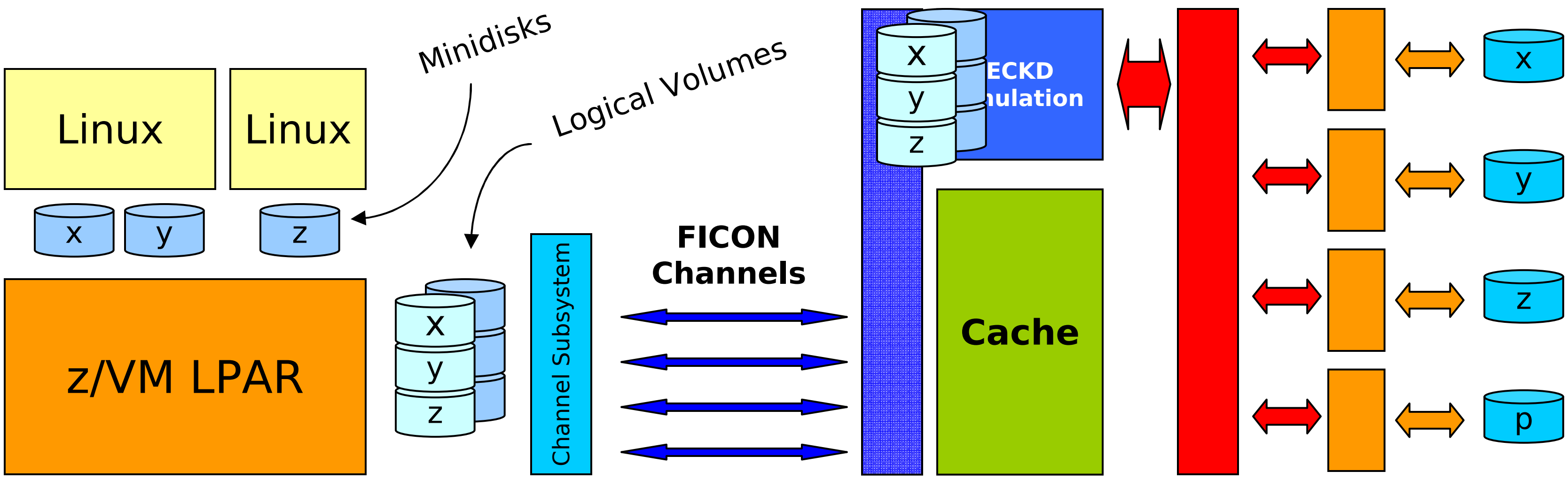
Stacked minidisks results in parallel I/O

- Different minidisks on the same logical volume
  - For different guests
  - For the same guest
- Common desire to reduce the number of subchannels
  - Small pseudo full-pack volumes without PAV
  - Large stacked volumes with PAV
  - Large pseudo full-pack volumes with PAV



Linux Disk I/O

Virtual machines are just like real machines

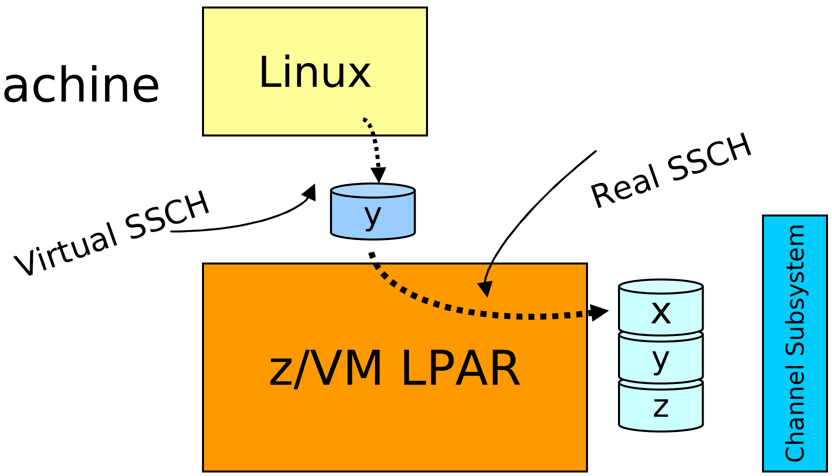
- Prepare a channel program for the I/O
- Issue a SSCH instruction to virtual DASD (minidisk)
- Handle the interrupt that signals completion

z/VM does the smoke and mirrors

- Translate the channel program
  - Virtual address translation, locking user pages
  - Fence minidisk with a Define Extent CCW
- Issue the SSCH to the real DASD
- Reflect interrupt to the virtual machine

Diagnose I/O

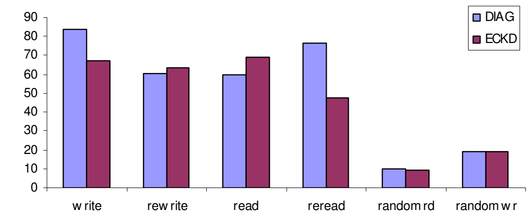
- High-level Disk I/O protocol
- Easier to manage
- Synchronous and Asynchronous



Linux Disk I/O

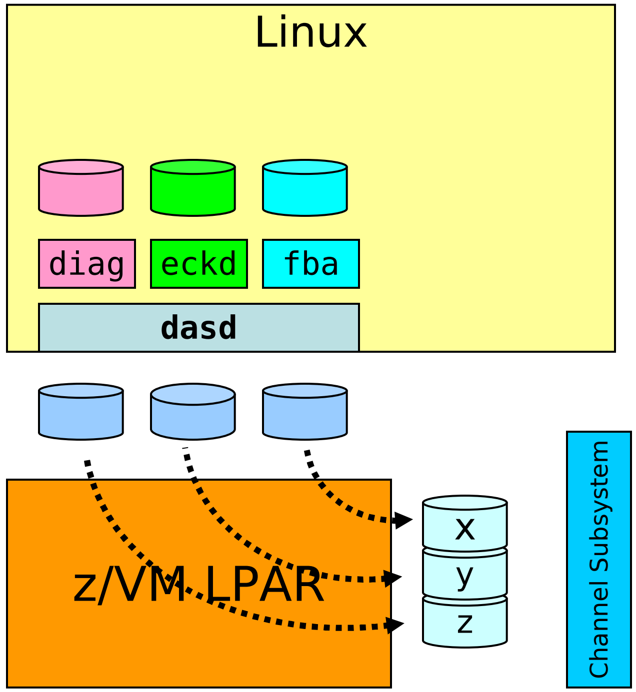
Linux provides different driver modules

- ECKD – Native ECKD DASD
  - Minidisk or dedicated DASD
  - Also for Linux in LPAR
- FBA – Native FBA DASD
  - Does not exist in real life
  - Virtual FBA – z/VM VDISK
  - Disk in CMS format
  - Emulated FBA – EDEVICE
- DIAG – z/VM Diagnose 250
  - Disk in CMS reserved format
  - Device independent



- Real I/O is done by z/VM

- No obvious performance favorite
  - Very workload dependent



VELOCITY SOFTWARE

Instrumentation provided by z/VM Monitor

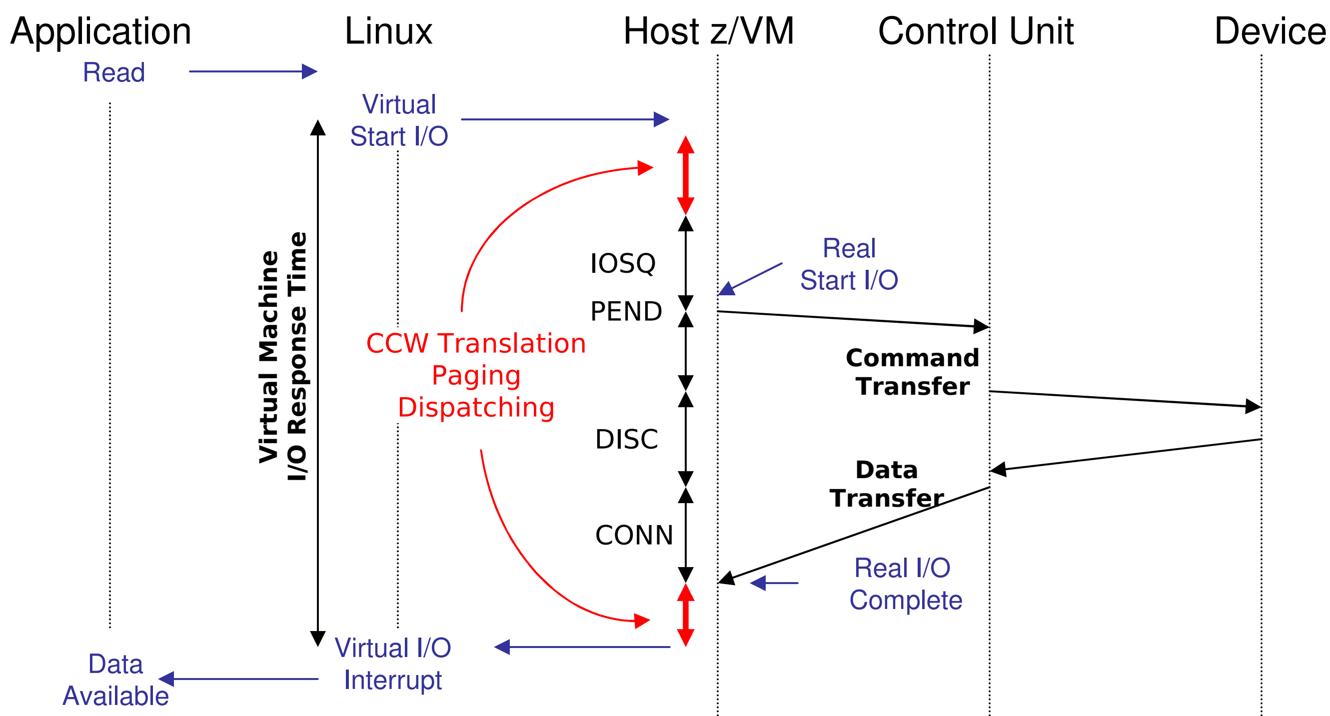
- I/O counters kept by z/VM

```
Screen: ESAUSR3
        User Resource Utilization - Part 2

                          DASD MDisk Virt Cache
         UserID    DASD Block Cache Disk   Hit
Time     /Class     I/O   I/O  Hits  I/O   Pct
-------- -------- ----- ----- ----- ---- -----
08:49:00 ROB01     1701  1059     0    0     0
08:48:00 ROB01     6542  7197    28    0   0.4
08:47:00 ROB01    16982 14720     0    0     0
08:46:00 ROB01       56     0     0    0     0
```

```
Screen: ESASEEK
        DASD Seeks Analysis

Time      Dev         Device         Mdisk <Cylinder-> Total <--non-zero-->
Time      No.  Serial Type   Ownerid  Addr Start  Stop Seeks Seeks Pct Dist
-------- ---- ------ ------ -------- ---- ----- ----- ----- ----- --- ----
08:47:00 954A PR954A 3390-9 PR954A:             0 10016  7923  7923 100  266
08:47:00                    ROB02    0300       1  3138  5471  5471 100  193
08:47:00                    ROB02    0302    6680  9729  2452  2452 100  429
```

Virtual Machine I/O also uses other resources

- CPU – CCW Translation, dispatching
- Paging – Virtual machine pages for I/O operation



Linux Disk I/O

Linux Physical Block Device

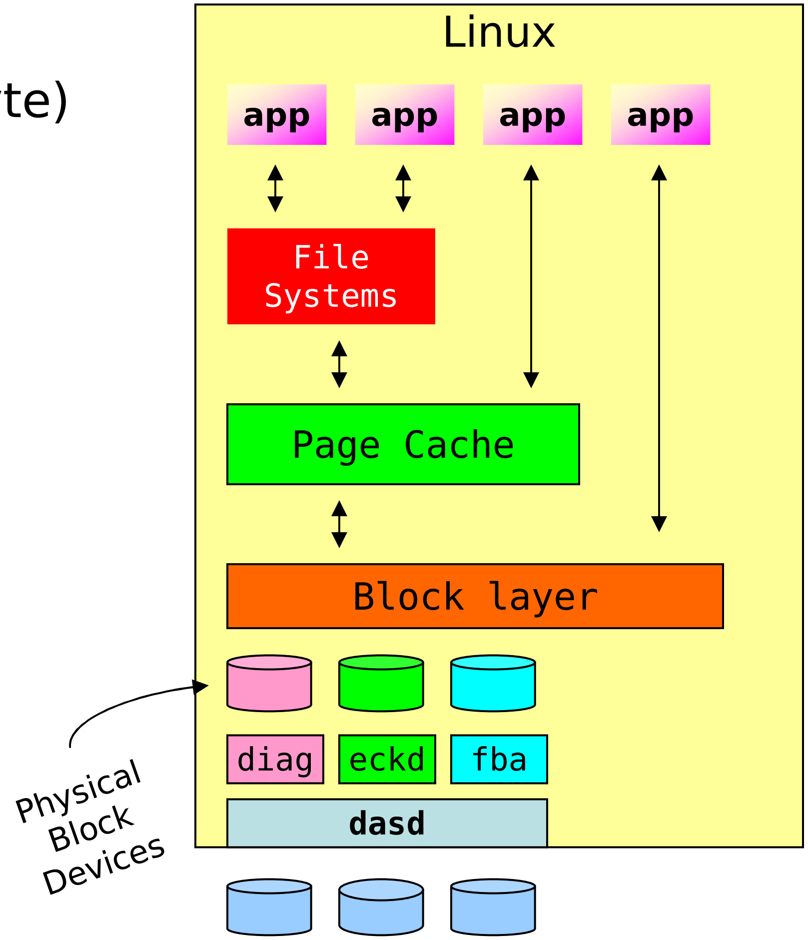
- Abstract model for a disk
  - Divided into partitions
- Data arranged in blocks (512 byte)
- Blocks referenced by number

Linux Block Device Layer

- Data block addressed by
  - Device number (major / minor)
  - Block number
- All devices look similar

Linux Page Cache

- Keep recently used data
- Buffer data to be written out

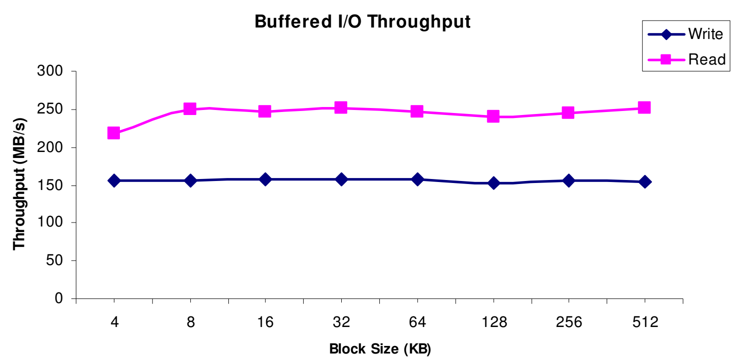


Linux Disk I/O

Buffered I/O

- By default Linux will buffer application I/O using Page Cache
  - Lazy Write – updates written to disk at “later” point in time
  - Data Cache – keep recently used data “just in case”

- Performance improvement
  - More efficient disk I/O
  - Overlap of I/O and processing



Linux Disk I/O

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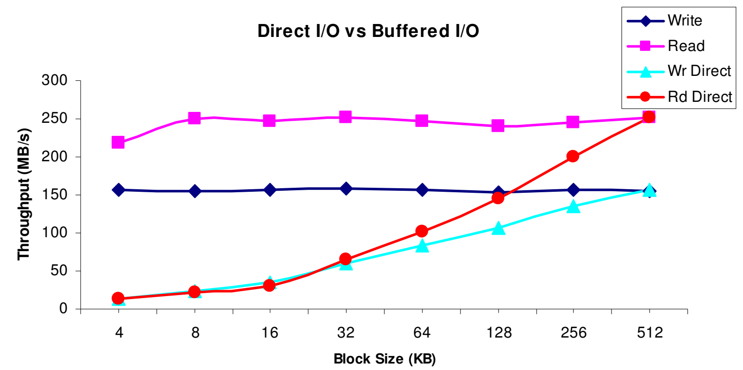
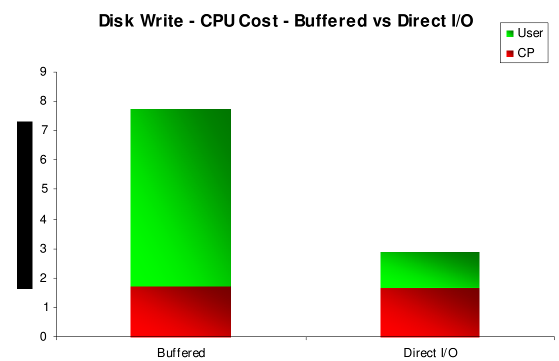


Direct I/O

- Avoids Linux page cache
  - Application decides on buffering
  - No guessing at what is needed next
- Same performance at lower cost
  - Not every application needs it

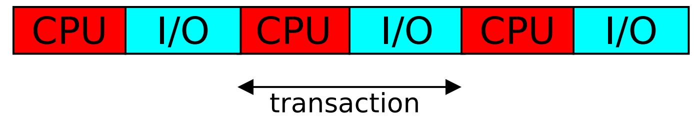


VELOCITY SOFTWARE

Linux Disk I/O

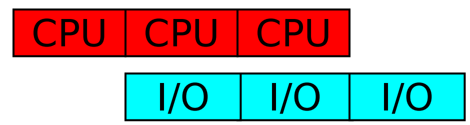
Synchronous I/O

- Single threaded application model
- Processing and I/O are interleaved



Asynchronous I/O

- Allow for overlap of processing and I/O
- Improves single application throughput
- Assumes a balance between I/O and CPU



Matter of Perspective

- From a high level everything is asynchronous
- Looking closer, everything is serialized again

Linux on z/VM

- Many virtual machines competing for resources
- Processing of one user overlaps I/O of the other
- Unused capacity is not wasted

"What is the value of good I/O response when nobody is waiting ?"

VELOCITY SOFTWARE

Myth of Linux I/O Wait Percentage

- Shown in “top” and other Linux tools
- High percentage: good or bad?
- Just shows there was idle CPU and active I/O
  - Less demand for CPU shows high iowait%
  - Adding more virtual CPUs increases iowait%
  - High iowait% does not indicate an “I/O problem”

```
top - 11:49:20 up 38 days, 21:27,  2 users,  load average: 0.57, 0.13, 0.04
Tasks:  55 total,   2 running,  53 sleeping,   0 stopped,   0 zombie
Cpu(s):  0.3%us,  1.3%sy,  0.0%ni,  0.0%id, 96.7%wa,  0.3%hi,  0.3%si,  1.0%st
```

No I/O problem
Just less CPU usage

High iowait%
I/O problem?

```
top - 11:5[illegible] up 38 days, 21:31,  2 users,  load average: 0.73, 0.38, 0.15
Tasks:  55 total,   3 running,  52 sleeping,   0 stopped,   0 zombie
Cpu(s):  0.0%us, 31.1%sy,  0.0%ni,  0.0%id, 62.5%wa,  0.3%hi,  4.3%si,  1.7%st
```

VELOCITY SOFTWARE

Linux Disk I/O

Myth of Linux Steal Time

- Shown in "top" and other Linux tools
  - "We have steal time, can the user run native in LPAR?"
- Represents time waiting for resources
  - CPU contention
  - Paging virtual machine storage
  - CP processing on behalf of the workload
- Linux on z/VM is a shared resource environment
  - Your application does not own the entire machine
  - Your expectations may not match the business priorities
- High steal time may indicate a problem
  - Need other data to analyze and explain

"It was not yours, so nothing was stolen…"

```
top - 11:53:32 up 38 days, 21:31,  2 users,  load average: 0.73, 0.38, 0.15
Tasks:  55 total,   3 running,  52 sleeping,   0 stopped,   0 zombie
Cpu(s):  0.0%us, 31.1%sy,  0.0%ni,  0.0%id, 62.5%wa,  0.3%hi,  4.3%si,  1.7%st
```

Linux Disk I/O

Logical Block Devices

- Device Mapper
- Logical Volume Manager

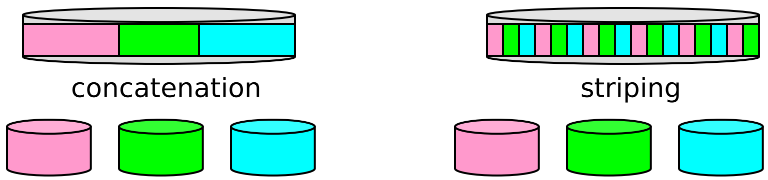
Creates new block device

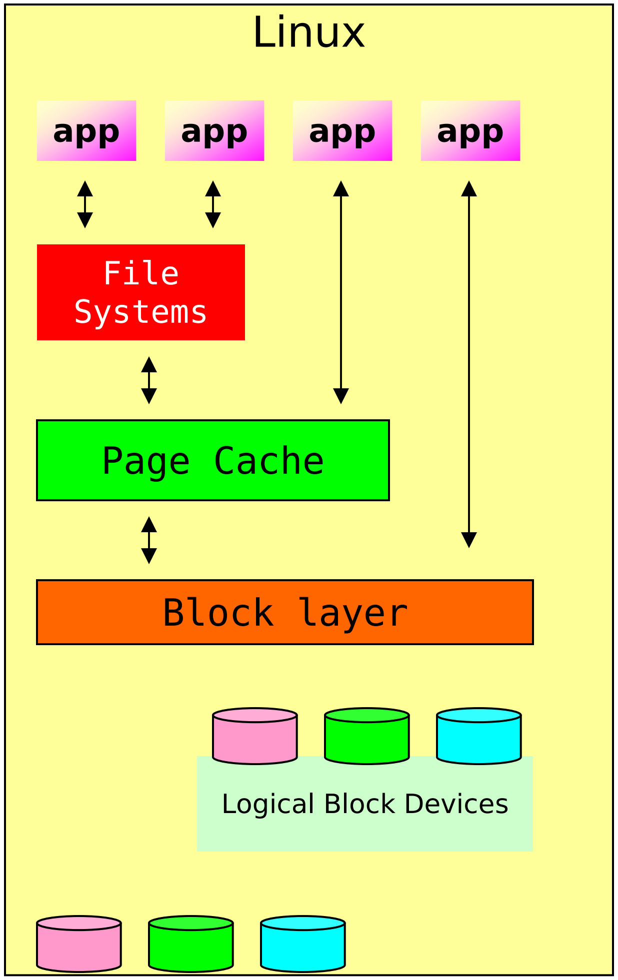
- Rearranges physical blocks

Avoid excessive mixing of data

Be aware for more exotic methods

- Mirrors and redundancy
- Anything beyond RAID 0
- Expensive overkill





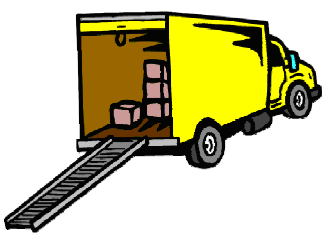
Linux Disk I/O

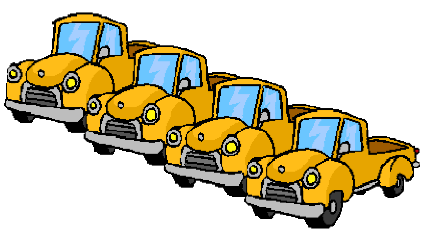
Disk Striping

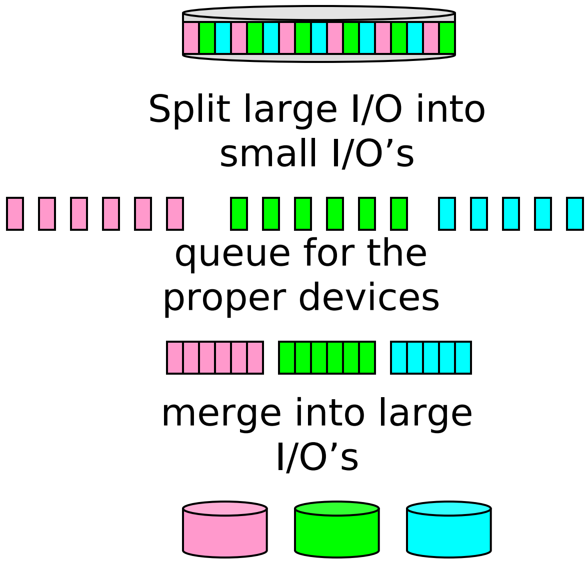
- Function provided by LVM and mdadm
- Engage multiple disks in parallel for your workload

Like shipping with many small trucks

- Will the small trucks be faster?
  - What if everyone does this?
- What is the cost of reloading the goods?
  - Extra drivers, extra fuel?
- Will there be enough small trucks?
  - Cost of another round trip?







Linux Disk I/O

Performance Aspects of Striping

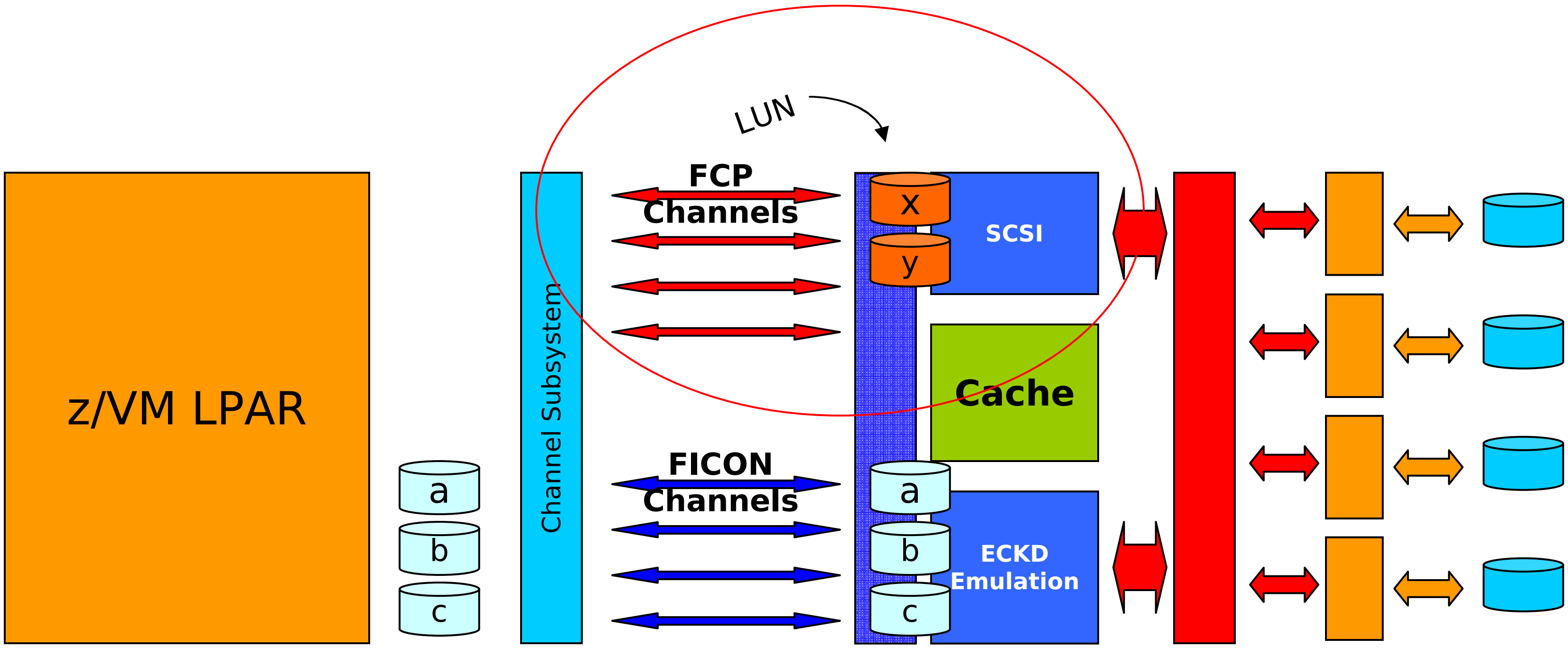
- Break up a single large I/O into many small ones
  - Expecting that small ones are quicker than a large ones
  - Expect the small ones to go in parallel
- Engage multiple I/O devices for your workload
  - No benefit if all devices already busy
  - Your disk subsystem may already engage more devices
  - You may end up just waiting on more devices

Optimal Stripe Size

- Large stripe may not result in spreading of the I/O
- Small stripe increases cost
  - Cost of split & merge proportional to number of stripes
- Some applications will also stripe the data

FCP Attached Disks - SCSI Disk Architecture

- SCSI provides Fixed Block Device
  - World Wide Port Number (WWPN)
  - Logical Unit Number (LUN)
- FCP channels instead of FICON



SAN Devices

DASD subschannel

- Corresponds to a DASD volume
  - Some amount of disk space
- Minidisk - Virtual DASD
  - Part of real volume – minidisk
- ECKD Channel programs
  - Less attractive for large volume
  - Improvements with zHPF
- I/O configuration done in IOCP

FCP subchannel

- Path that leads to the SAN
  - One FCP can access multiple LUNs
  - Distributions encourage FCP-LUN relationship
- QDIO – high-level I/O protocol
  - Suitable for large data volume
- Configuration in several places
  - Disk Subsystem
  - FCP switch
  - Linux guest

SAN Devices

Linux and ECKD is not a natural fit

- Linux expects blocks rather than tracks
  - Does not exploit ECKD features
  - ECKD channel programs are tedious for Linux disk I/O
  - Linux relies on 512-byte blocks rather than 4K blocks
- Traditional 3390 devices are small
  - Modern DASD subsystems do large volumes via EAV
  - Single I/O per subchannel limitation addressed by PAV
- Social aspects
  - It is different and “your devices have funny names”
  - ECKD “probably has a lot of overhead”
  - ECKD “is wasting disk space”

The Mystery of Lost Disk Space

Claim: ECKD formatting is less efficient

- “because it requires low-level format”

- SCSI disks do not waste disk space (no low-level formatting)

Is this likely to be true?

- Design is from when space was very expensive
- Fixed Block has low level format too – but hidden from us

ECKD allows for very efficient use of disk space

- Allows application to pick most efficient block size
- Capacity of a 3390 track varies with block size
  - 48 KB with 4K block size
  - 56 KB as single block
- Complicates emulation of 3390 tracks on fixed block device
  - Variable length track size (eg log-structured architecture)
  - Fixed size a maximum capacity (typically 64 KB for easy math)

SAN Devices

Flexibility - No limit on LUN size

Security

- LUN Masking and Zoning
  - FCP Channel is a single host port
- NPIV – N-Point ID Virtualization
  - Configured in HMC - Requires a SAN switch with NPIV

Implications on High Availability

- Administrative effort may be considerable
- Storage WWPN configured inside each Linux guest
- Dual Path configured inside each Linux guest

Performance

- Easier to get high throughput
- Instrumentation is less mature

FICON versus FCP

- Performance aspects depend heavily on the workload
  - Things are moving and change with each release
- No miracles – no obvious “always best” winner
  - Same hardware technology
- Other aspects also influence the selection
  - Existing investment in either architecture
  - Available skills and processes

SAN Devices

EDEV – Emulated Device

- Emulates a 9336 FBA device
- Data on FCP attached SCSI
- Managed by z/VM
  - Security through CP and RACF
  - Allocation with DIRMAINT
- Appears to Linux as channel attached FBA

Performance of EDEV

- Initial version in z/VM 5.1 had some issues
- Linux FBA driver limited to 32KB per I/O
  - Increased CP overhead due to number of SSCH's
    - 2 CPU seconds for reading 1 GB in 32K blocks (z9-BC)
  - Reduced throughput due to latency
- Useful with moderate I/O load

Conclusion

Avoid doing synthetic benchmarks

- Hard to correlate to real life workload

Measure application response

- Identify any workload that does not meet the SLA
- Review performance data to understand the bottleneck
  - Be aware of misleading indicators and instrumentation
  - Some Linux experts fail to understand virtualization
- Address resources that cause the problem
  - Don't get tricked into various general recommendations

Performance Monitor is a must

- Complete performance data is also good for chargeback
- Monitoring should not causes performance problems
- Consider a performance monitor with performance support