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Execute-in-place technology for SLES9

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Set up process overview

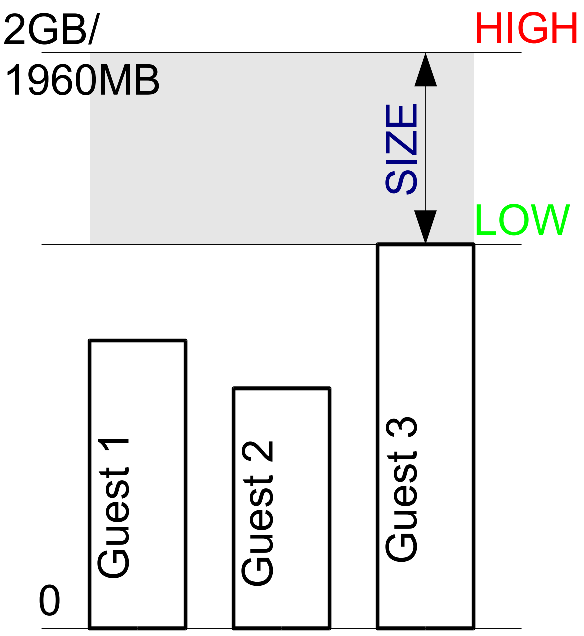
- Plan the layout of the file system
- Provide a script to over-mount shared directories on startup
- Create a file system image
- Create a DCSS from the image file
- Change the kernel parameter line
- Test the DCSS
- Activate execute in place

Documentation and scripts used in this presentation are available at

http://awlinux1.alphaworks.ibm.com/developerworks/linux390/april2004_documentation.shtml

Plan the layout of the file system

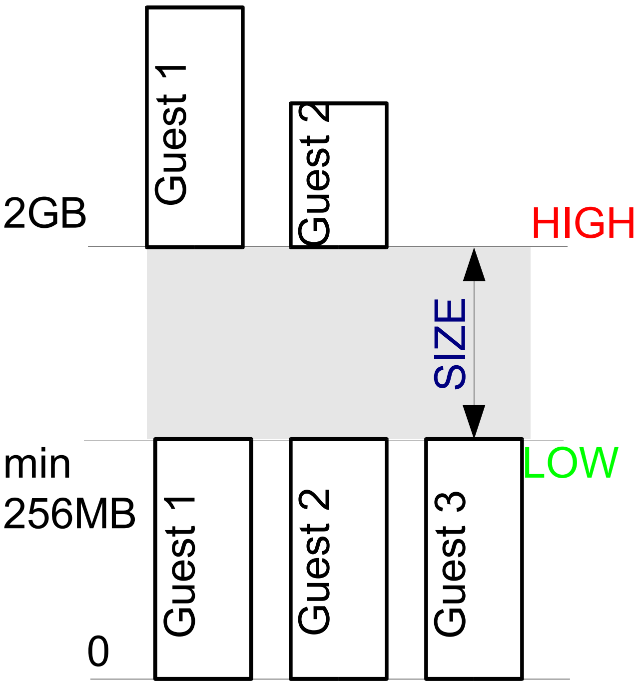
- determine the maximum size of the DCSS (SIZE)
  - lower limit of the DCSS address range (LOW)
    - may not overlap virtual guest storage
    - equals the end of virtual guest storage of the largest guest
  - upper limit of the DCSS address range (HIGH)
    - 2GB for 64-bit Linux images (z/VM limitation)
    - 1960 MB for 31-bit Linux images (Linux limitation)
  - subtract the lower limit from the upper limit to obtain the maximum possible DCSS size



SIZE = HIGH - LOW

Plan the layout of the file system

- alternative memory layout with 64bit guests allows to use more virtual guest storage
  - a minimum of 256 Mbyte below the 2GB line is required for reliable operation
  - the amount of virtual guest storage per guest is not limited by DCSS
  - the maximum size of the DCSS can be 1792 Mbyte



SIZE = HIGH - LOW

Plan the layout of the file system – which directories

- On servers, identify directories containing frequently executed files
  - issue the "**`ps`**" command on a typical server running typical workload to identify what processes are running
  - use "**`which`**" to find out where the executable files are stored
  - use "**`ldd`**" to find out what libraries are required

```
# ldd /bin/bash
                libreadline.so.4 => /lib64/libreadline.so.4 (0x0000010000021000)
                libhistory.so.4 => /lib64/libhistory.so.4 (0x0000010000063000)
                libncurses.so.5 => /lib64/libncurses.so.5 (0x000001000006c000)
                libdl.so.2 => /lib64/libdl.so.2 (0x00000100000d4000)
                libc.so.6 => /lib64/libc.so.6 (0x00000100000d8000)
                /lib/ld64.so.1 => /lib/ld64.so.1 (0x0000010000000000)
```

  - check for symbolic links

```
# find <directory> -type l -exec ls -lisa {} \;
```

Plan the layout of the file system – which directories

- Interactive systems
  - use the same rules as before
  - check the **`PATH`** environment variable for the superuser and for regular users
  - check **`/etc/ld.so.conf`** for paths containing libraries
- what NOT to share?

  - be sure not to share directories that are written to. Note that the process described here shares subdirectories as well.
  - sharing scripts and java bytecode is ineffective, they are not executed directly but interpreted
  - do not share **`/etc`** and **`/var`**
  - use the file command to check the file type

Plan the layout of the file system – segment size

- calculate space requirements
  - issue **"du -sk"** for each directory to find the space occupied by each directory (including subdirectories)
  - build the sum of the individual spaces to find the total space occupied
  - add 4KB per shared file as filesystem overhead
  - add extra space for future software updates like security fixes
  - check that the required size does not exceed the maximum DCSS size
- calculate the page frame numbers for start and end address
  - a page is 4096 bytes in size
  - DCSS needs to start on a page boundary
  - start address should be the first page frame after the virtual guest storage of the largest guest
  - end address: add start address and size, round up to next page, -1

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Example – segment planning

- 5 guests 128MB, 1 guest 256MB, 4 guests 160MB
- /bin/, /sbin/, /usr/bin/, /usr/sbin/, /lib/, and /usr/lib/ are identified for sharing
- 1. querying the size:

```
# du -skc /bin/ /sbin/ /lib/ /usr/bin/ /usr/sbin/ /usr/lib
8619    /bin
11518   /sbin
16335   /lib
29934   /usr/bin
4687    /usr/sbin
148722  /usr/lib
219813  total
```

- 219813kb of files to share
- 2. getting the amount of files

```
# find /bin/ /sbin/ /lib/ /usr/bin/ /usr/sbin/ /usr/lib | wc -l
      8929
```

- 4kb * 8929 = 35716kb as additional overhead
- You need 219813kb + 35716 kb = 255529kb
- adding some space for updates ,300MB seems a reasonable size

Example – segment planning

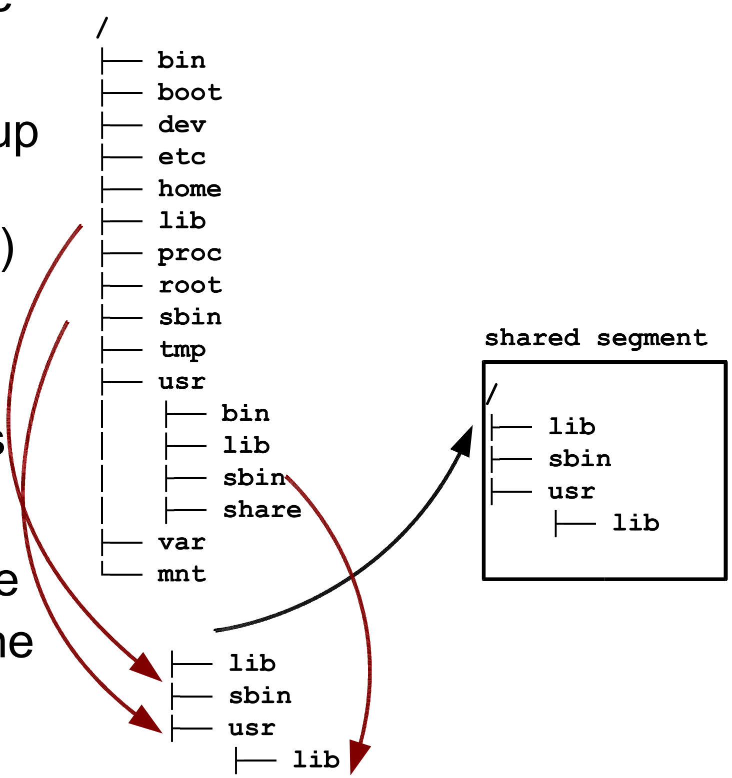
- The largest guest has 256MB of memory: largest address `0xfffffff`
- DCSS can start at 256MB ~ `0x10000000`
- considering 300MB of size: end address is 556 MB-1 ~ `0x22BFFFFF`
- size fits well between 256MB and 1960MB
- defseg command needs the address in pages (without the last 3 digits)

```
00: CP DEFSEG LINSEG1 10000-22BFF SR
00: HCPNSD440I Saved segment LINSEG1 was successfully defined in fileid 0203.
```

- now the segment is waiting to be filled
- next step is to prepare the linux guests

Provide a script to over-mount shared directories on startup

- over-mount in this context means directories are replaced by their shared copies in DCSS
- directories need to be replaced on system startup before services are being started (otherwise services and libraries will be loaded from DASD)
- the best way to do to this is running a script as initial process that mounts the DCSS, over-mounts all directories in 2 steps, and then starts the original **`/sbin/init`**
- note that **`/etc/mtab`** is not writeable at the time the script runs, therefore mount will not report the mounts later on. check **`/proc/mounts`** for a complete list of mounted filesystems
- the example script can be found in the execute-in-place Howto on IBM developerWorks



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Create a file system image (one time setup)

- get a DASD large enough to store your file system image with the size calculated earlier and prepare the dasd with a file system

```
# dasdfmt -b 4096 -d cdl -f /dev/dasdb
# fdasd -a /dev/dasdb
# mke2fs /dev/dasdb1
# mount /dev/dasdb1 /mnt
```

- create a file with the size of the planned DCSS on the newly mounted disk
- create an ext2 file system on the file

```
# dd if=/dev/zero of=/mnt/filesystem bs=1M count=300
# mke2fs -b 4096 /mnt/filesystem
/mnt/filesystem is not a block special device.
Proceed anyway? (y,n)
```

- answer the question with yes

Create a file system image

- create a mount point for the file system and mount it using the “-o loop” mount option

```
# mkdir /segment
# mount /mnt/filesystem /segment -o loop
```

- copy all directories you want to share into the file system image
- unmount the file system image

- a script that generates a file system image automatically can be found in the execute-in-place Howto on IBM developerWorks

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Fill a newly created DCSS using the image file

- prepare the disk containing the image file for IPL. Use the zipl command with the -s parameter along with the image file name and the DCSS start address:

```
zipl -t /mnt -s /mnt/filesystem,0x10000000
```

start address DCSS in bytes

- take down linux and IPL CMS in your guest machine
- if not already done, define the DCSS

```
00: CP DEFSEG LINSEG1 10000-22BFF SR
00: HCPNSD440I Saved segment LINSEG1 was successfully defined in fileid 0203.
```

- use "**`#cp define store <amount>`**" to define the virtual guest storage size large enough that the entire DCSS fits in
- IPL the DASD and wait for the CPU to enter disabled wait
- save the DCSS: "**`#cp saveseg <name of DCSS>`**"
- log off and back in to restore system defaults (storage)

Change the kernel parameter line

- when using the DCSS above all virtual guest storage, the kernel parameter line needs to be changed as follows:
- start up the Linux system
- add "`mem=<value>`" to the kernel parameter line, where <value> equals the end address of the DCSS
- run zipl with the new kernel parameter file
- reboot Linux
- issue "`cat /proc/cmdline`" to verify that Linux is using the new parameter

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Changing the storage configuration

- when using virtual guest storage above the 2GByte line, use CP storage configuration to create your memory setup:

```
#cp define storage config 0.256m 2g.1g
```

- result:

```
00: CP DEF STORE CONFIG 0.256M 2G.1G
00: STORAGE = 1280M
00: Storage Configuration:
00: 0.256M 2G.1G
00: Extent Specification                 Address Range
00: ----------- -----------------------------------
00: 0.256M     0000000000000000 - 000000000FFFFFFF
00: 2G.1G      0000000080000000 - 00000000BFFFFFFF
00: Storage cleared - system reset.
```


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Testing the DCSS

- if the Linux kernel has got the xip2 file system as a module, issue **`"modprobe xip2"`** to load the module into memory (optional)
- mount the xip2 file system using the mount command like **`"mount -t xip2 -o ro,memarea=<name> none <mount point>"`**
- if the segment is large, mounting might take a while
- verify that the file system has been mounted correctly by looking at **`/proc/mounts`**
- check with **`"dmesg"`**, if an error has occurred. If yes, then check:
  - mem parameter is >= end address of dcss
  - guest storage does not collide with dcss
  - no other loaded segment collides with the new segment (! segments need a megabyte boundary to other segments)
- verify that the files you copied to the file system image are accessible

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Activate execute-in-place

- unmount the file system again
- test the init script prepared earlier:
  - run the script as super user root
  - look at `/proc/mounts` to verify that
    - the file system has been mounted at the mount point created earlier
    - all directories that have been chosen earlier are over-mounted
- add “init=<full path of script>” to the kernel parameter line
- run zipl with the new kernel parameter line
- reboot Linux
- after reboot, check `/proc/mounts` to verify that
    - the file system has been mounted at its mount point
    - all chosen directories are over-mounted

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Introducing the DCSS block device driver

- DCSS block device driver is able to access a DCSS as a block device
- can be built-in or is available as a module called dcssblk.ko
- is controlled using files that are located in **`/sys/devices/dcssblk`**
- cannot be used to create new DCSSes
- motivation: XIP filesystem is readonly. DCSS block device driver can be used with ext2 to update DCSSes containing a filesystem image for XIP2:
  - the structure of a XIP filesystem equals the structure of ext2
  - ext2 needs block device to operate
- usable for other scenarios as well
- ext2 + block device driver does currently not implement execute in place!

Adding and removing DCSSes

```
echo LINSEG1 > /sys/devices/dcssblk/add
```

- add a DCSS as a block device
  - may take a while
  - driver will log a message informing about success/failure to syslog
  - a new subdirectory **/sys/devices/dcssblk/DCSSNAME/** appears

```
/sys/devices/
--- dcssblk
    --- add
    --- remove
```

```
/sys/devices/
--- dcssblk
    --- add
    --- remove
    --- LINSEG1/
        --- save
        --- shared
```

- remove the block device associated with a DCSS
  - driver will log a message informing about success/failure to syslog
  - subdirectory **/sys/devices/dcssblk/DCSSNAME/** disappears

```
echo LINSEG1 > /sys/devices/dcssblk/remove
```


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The “shared” state

- Every DCSS is by default in shared state.
  - the file /sys/devices/dcssblk/DCSSNAME/shared contains the value “1”
  - Linux uses the global copy of the DCSS
  - can be switched to non-shared mode by writing “0” to /sys/devices/dcssblk/DCSSNAME/shared when idle
- non-shared DCSSes:
  - the file /sys/devices/dcssblk/DCSSNAME/shared contains the value “0”
  - Linux uses a private copy of the DCSS
  - can be switched back to shared mode by writing “1” to /sys/devices/dcssblk/DCSSNAME/shared

The "save" state

- Linux can only save DCSSes when they are idle
- Linux remembers save requests while the DCSS is busy and saves the DCSS as soon as the DCSS becomes idle
- by default the save state is "0" meaning that the DCSS will not be saved
- by writing the value "1" to /sys/devices/dcssblk/DCSSNAME/save:
  - Linux is triggered save the DCSS immediately in case it is idle
  - Linux remembers to save the DCSS when it becomes idle
- you need Class E to write a segment!
- by writing the value "0" to /proc/dcssblk/DCSSNAME/save
  - a pending save on a DCSS that is in use can be canceled
- Linux reports all above operations in the syslog and the value in /sys/devices/dcssblk/DCSSNAME/save can be read to check if there is a pending request to save a DCSS

using the block-device node

- no partitioning
  - do not use fdasd or fdisk
- any block device and filesystem tool can be used with the DCSS block device (like mke2fs, e2fsck, etc.)
- 4096 bytes block size
  - use -b 4096 for mke2fs or other tools depending on the block size
- any file system that supports 4096 bytes block size can be used with the DCSS block device driver (like ext2, ext3, ReiserFS, GFS)
- only ext2 is compatible with xip2 and can be used to process DCSSes intended to be used with the xip2 file system
- can be used as well for doing the first time setup. Just create a segment filled with random garbage and update this segment: use defseg + saveseg to create an active segment

DCSSes as swap space

- why use a dcss for swapping?
  - fast write into z/VMs storage and swap caching when guest is memory constrained but z/VM is not
  - allows to shrink guest virtual memory size while maintaining acceptable performance for peak workloads (move overcommitment to guest level)
  - can be much faster than vdisk
  - no hypervisor calls required
- what is required?
  - the block device kernel parameter and support for mixed EW/EN segments – both included in upcoming SLES9 SP2
  - a lot of paging space assigned to z/VM
  - address space for using dcss (same as with execute in place)

DCSSes as swap space

- create an empty DCSS in CMS, first page should be EW, the rest EN

```
#cp defseg SWAPPING 20000-20000 EW 20001-6ffff EN
#cp saveseg SWAPPING
```

- in Linux initialize the segment (one time setup only!)

```
echo "SWAPPING" >/sys/devices/dcssblk/add
mkswap /dev/dcssblk0
echo 1 >/sys/devices/dcssblk/SWAPPING/save
swapon /dev/dcssblk0
```

After above setup, syslog should indicate that the segment SWAPPING was saved. In addition, /proc/swaps should mention the segment as active swap space.

DCSSes as swap space

- in order to activate swap, you need to add the following kernel parameter and re-run zipl:

```
dcssblk.segments=SWAPPING
```

- add this line to your /etc/fstab file:

```
/dev/dcssblk0        swap sw 0 0
```

After rebooting the system swap should now be activated. You can check /proc/swaps to verify this.

- In case of a mixed swap setup with both DCSS and DASD as swap target, DCSS needs to get a higher swap priority than DASD for optimal performance.

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Outlook

- SLES9 is GA
  - SLES9 includes execute-in-place
  - all new file system features like Access Control Lists
  - device node creation is made automatically by udev
- SLES9 SP2 soon
  - adds support for EW/EN mixed mode segments (swapping)
  - provides much better system messages for dcss (cleanup)
  - adds support for the dcssblk.segments parameter (swapping, root dev)
  - new “Howto” documentation on developerworks
- integration into the ext2 file system
- union mount for overlaying DCSS with normal file system
- better management and update solutions

Questions and Discussion

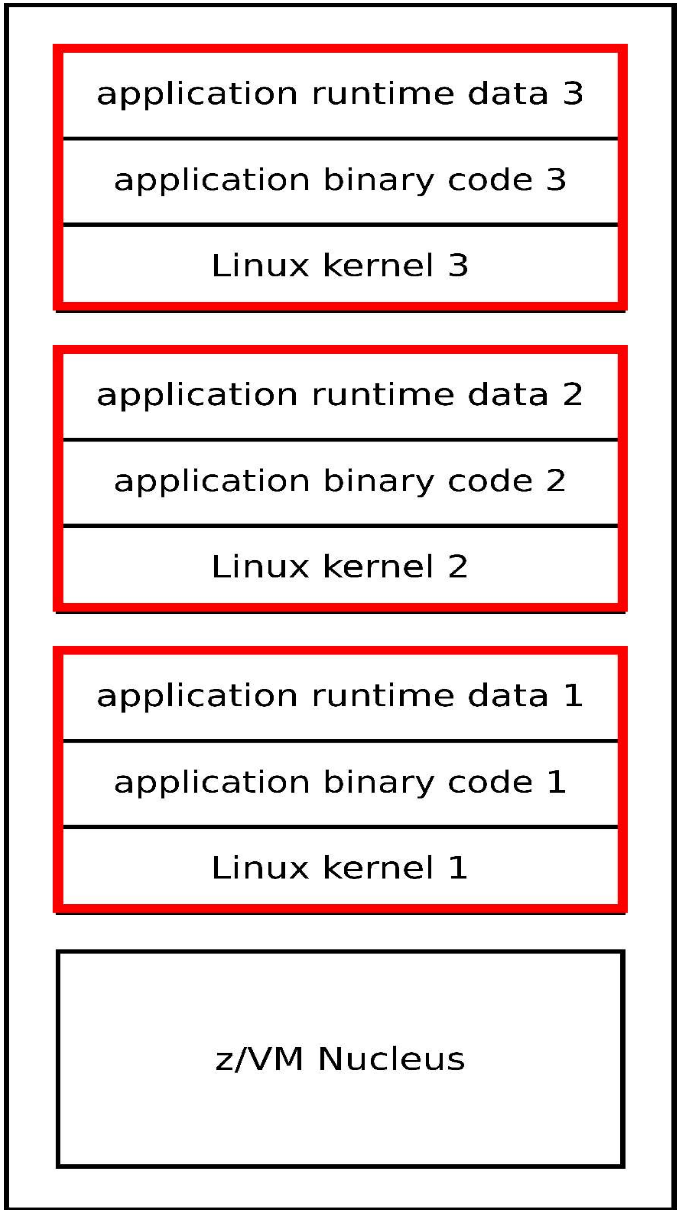
- Now
  - After this session
  - Any time during WAVV
  - Email:
    - cborntra@de.ibm.com
    - cotte@de.ibm.com
- Thank you for your attention

Background

technical background

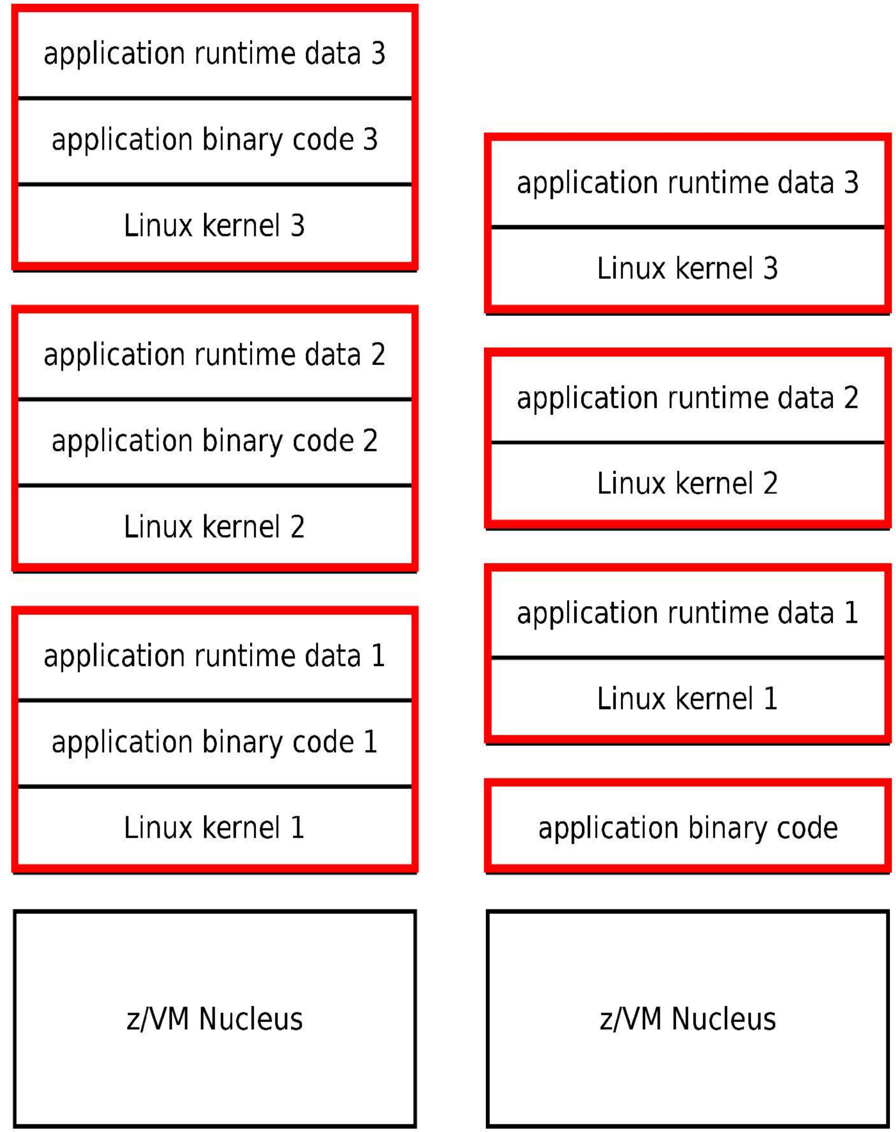
Illustration of the problem

- Linux running as guest operating system on z/VM requires a similar amount of memory to Linux on a dedicated server while it is active
- when running multiple Linux servers that run the same application, the application is present multiple times in physical memory
- storing the same data multiple times in memory is inefficient



Basic idea of the solution

- store only one copy of the application in memory
- share access to the application among multiple servers
- let z/VM load the application into memory
- restrict write access to the application for servers (security!)
- allows running the same workload with less memory consumption
- allows to run more workload with the same memory consumption as before



What is “execute in place”?

- applications are being executed directly from where they are permanently stored
- was invented for embedded systems that do not have disk drives
- applications can be run directly in flash or ROM memory
- execute in place is a popular feature of embedded operating systems such as uCLinux

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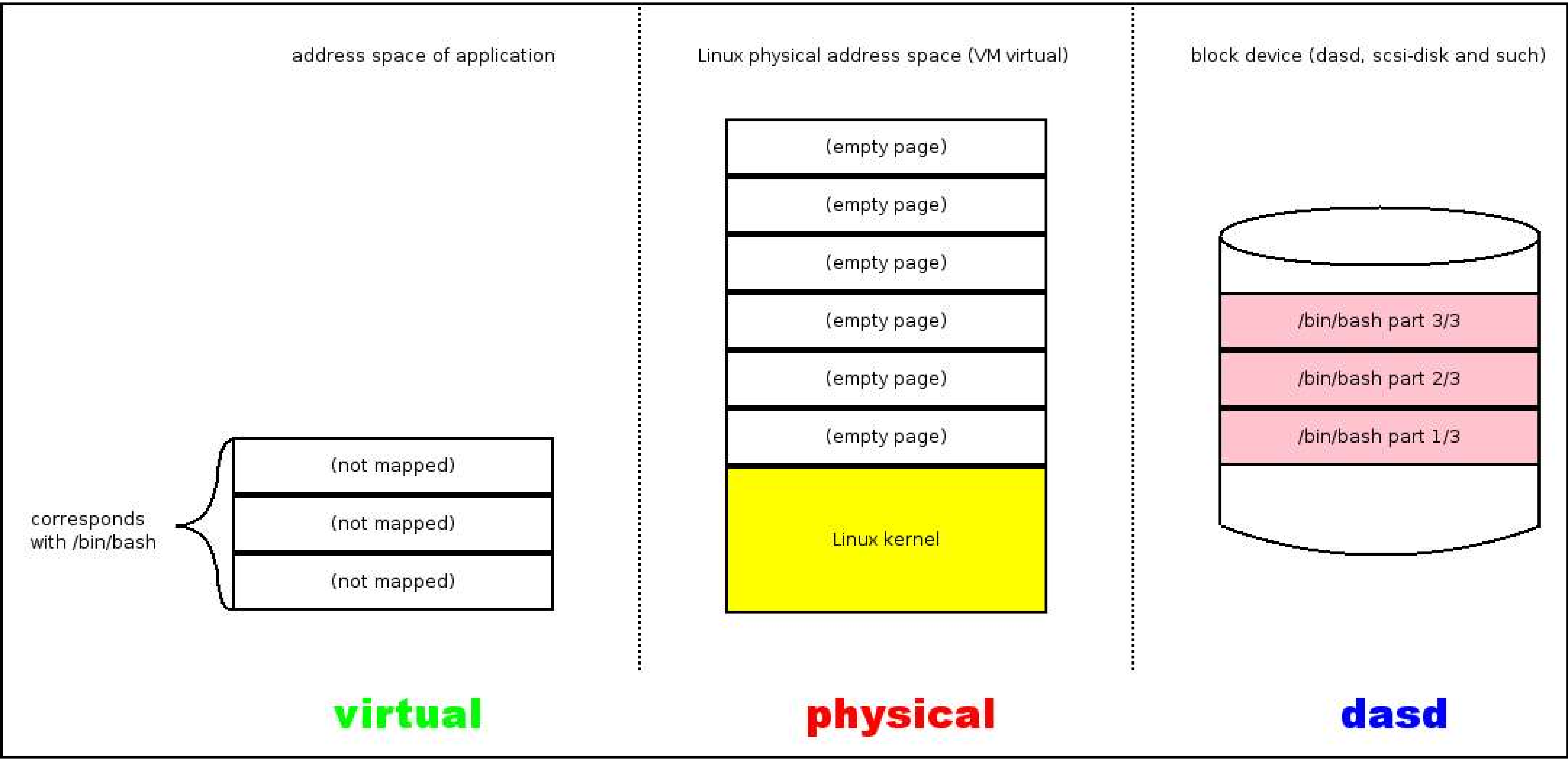
How applications are launched in Linux

- when Linux launches an application, it does not load it into memory immediately
- for application binary files and libraries, Linux:
  - remembers the position in the application address space
  - remembers the corresponding file on disk
- when the application accesses a page in memory that has not been loaded yet:
  - Linux interrupts the application
  - the page is loaded into memory
  - the application is resumed, and it retries to access the page

How applications are launched in Linux



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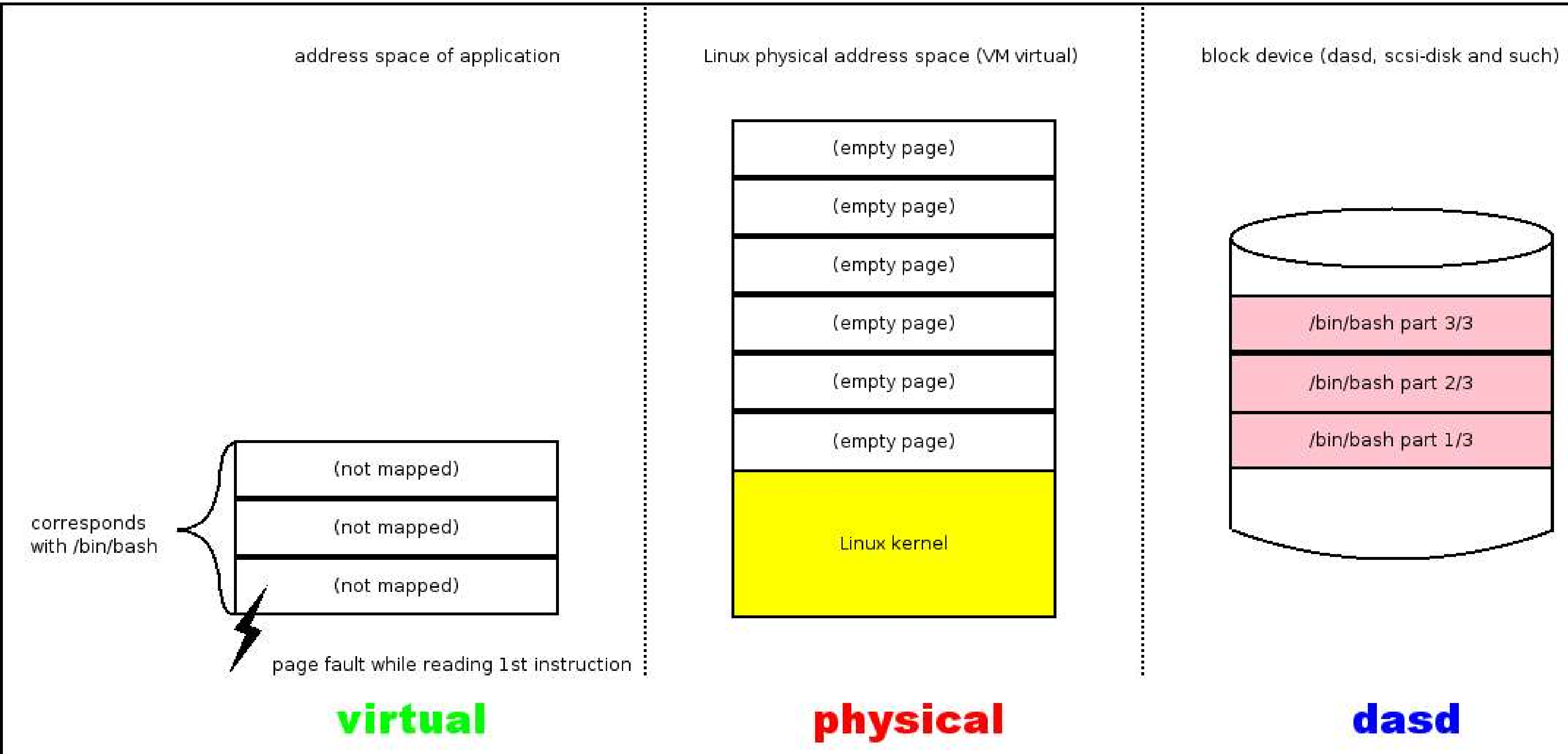

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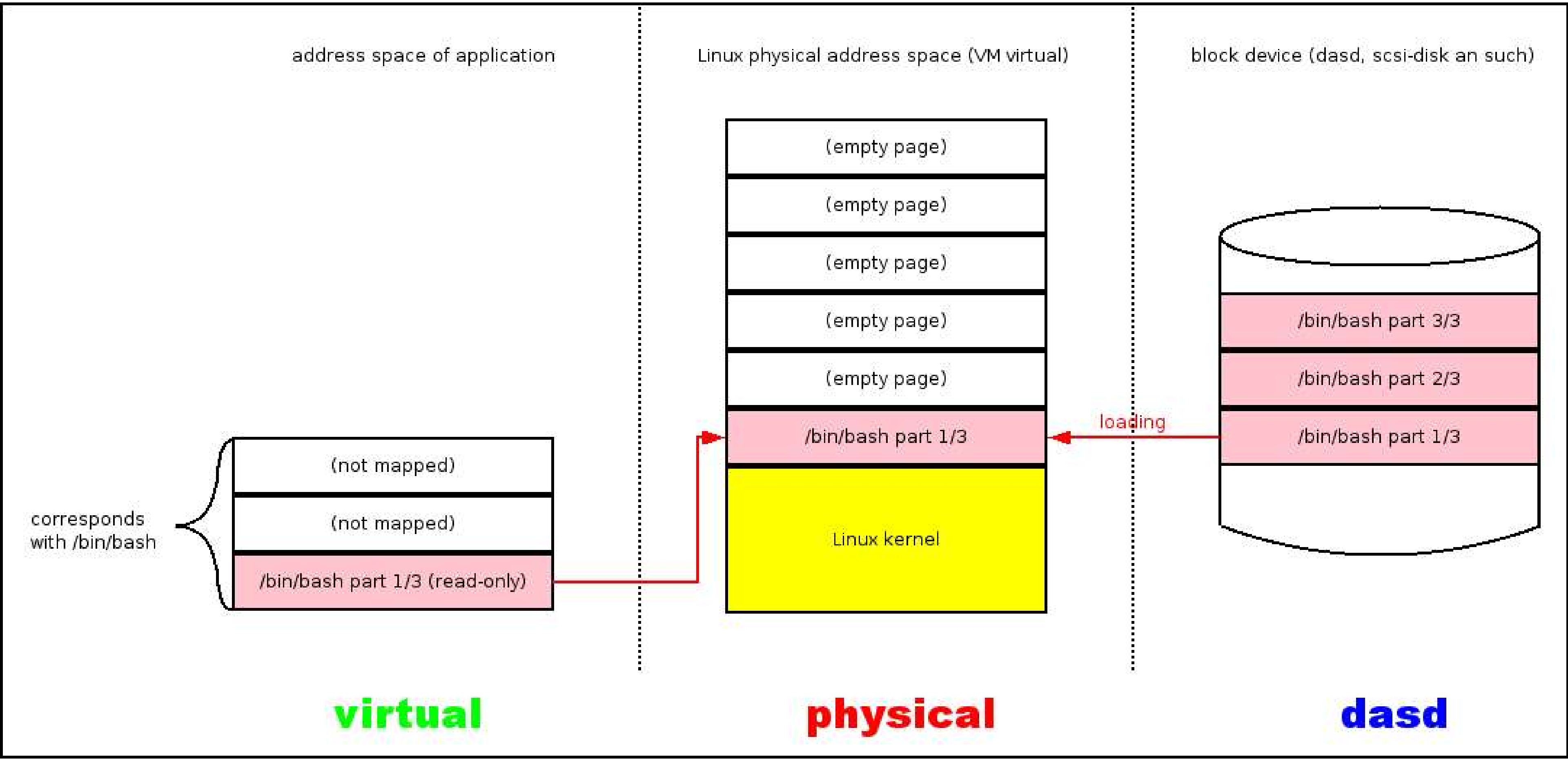

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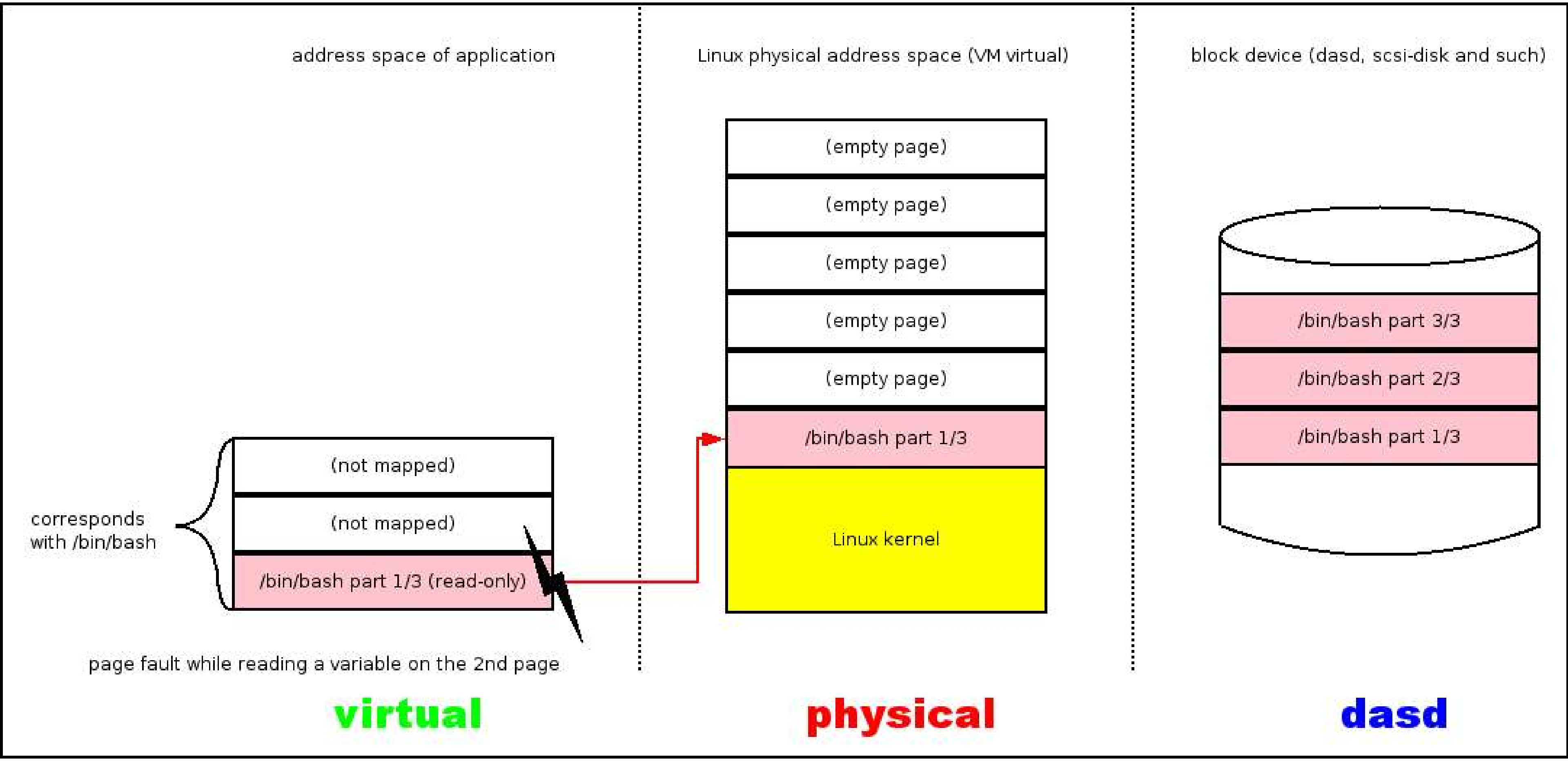

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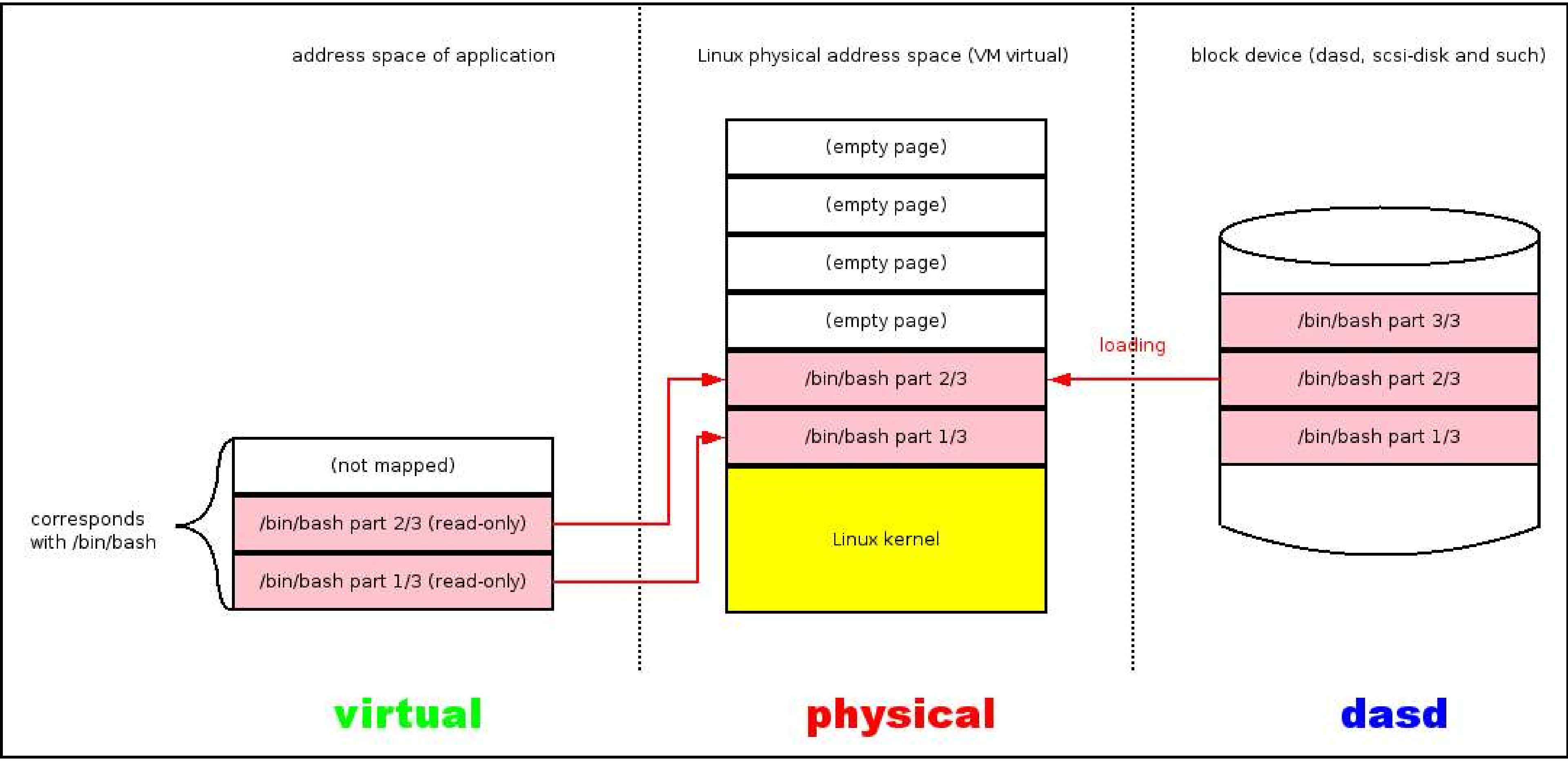

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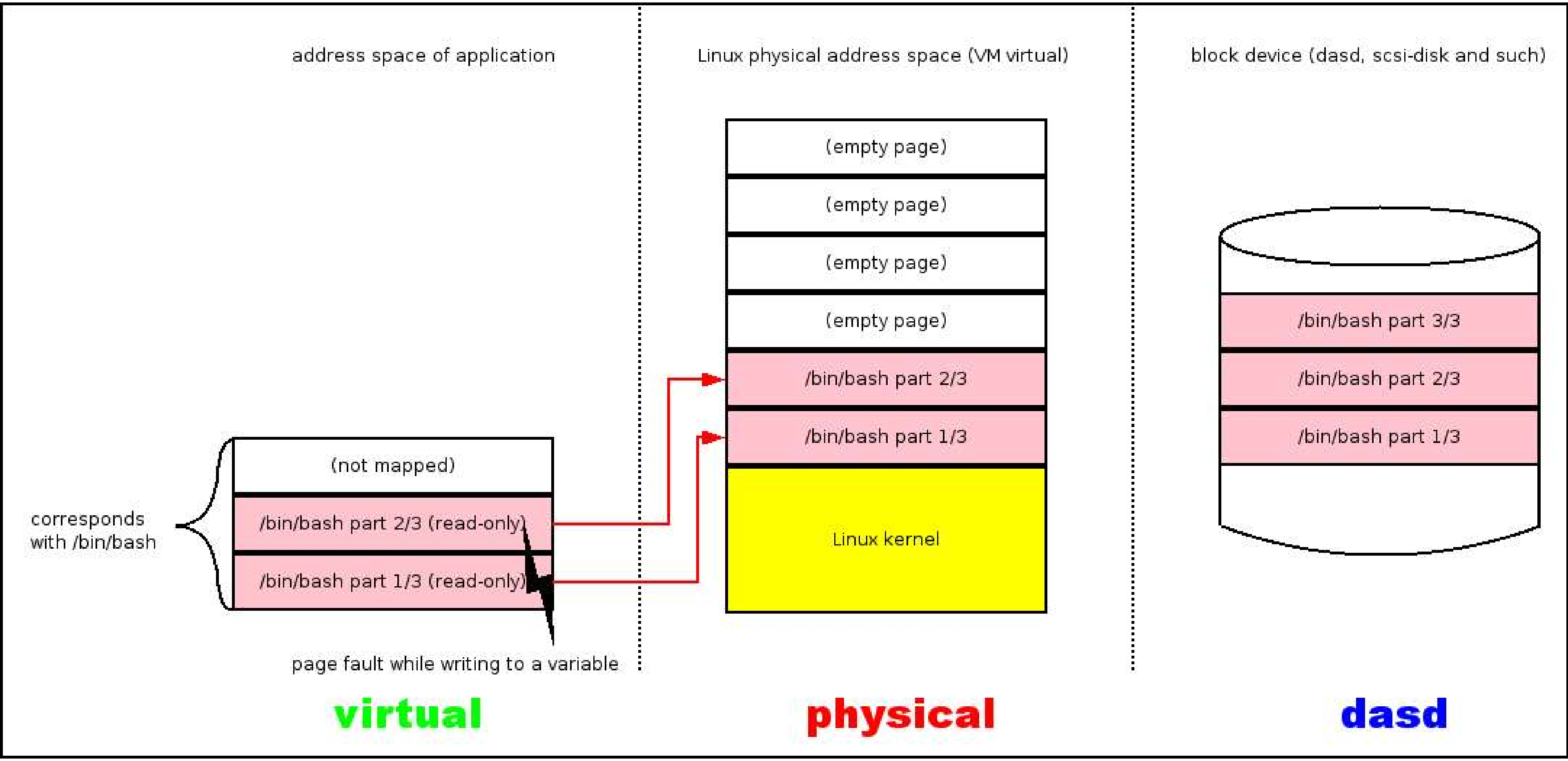

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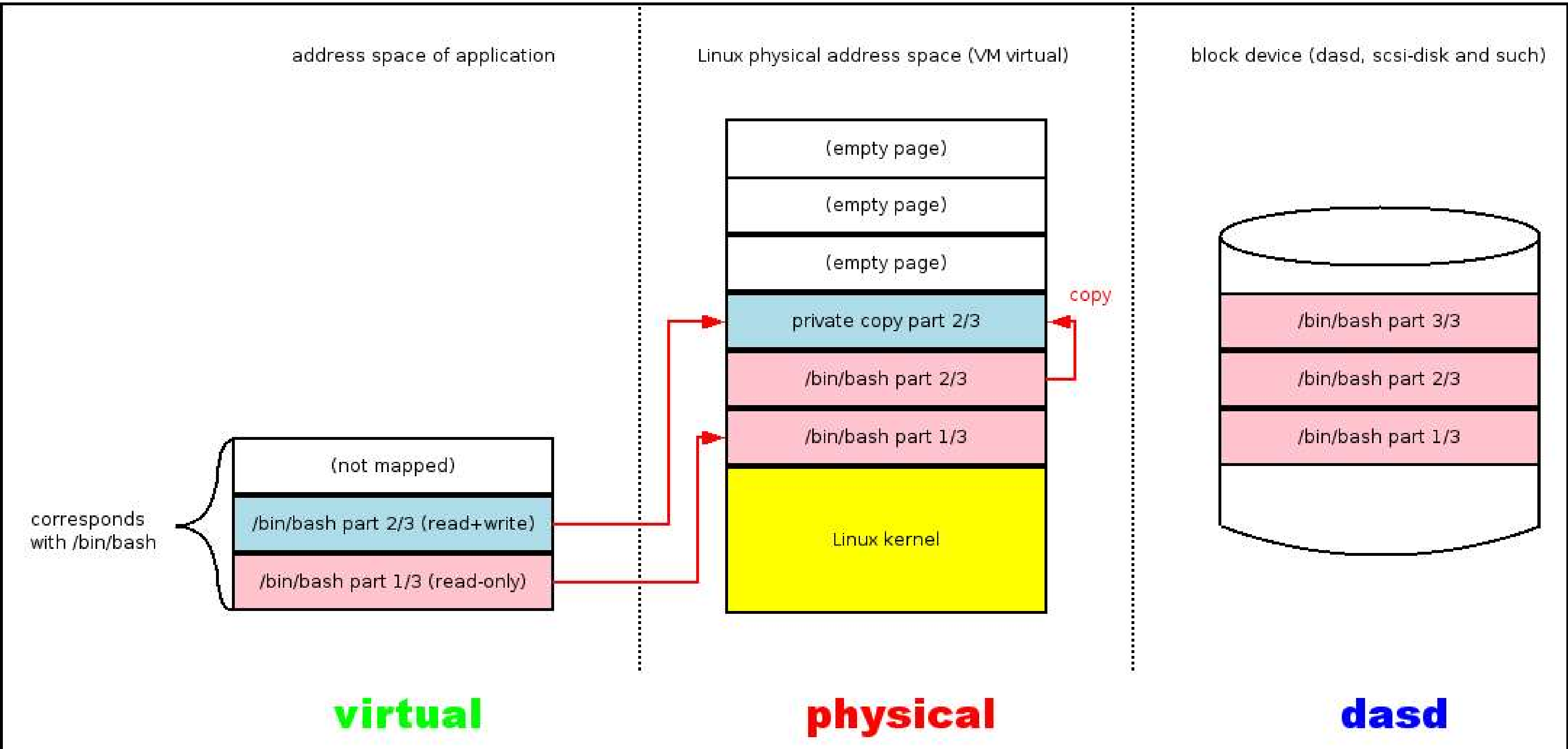

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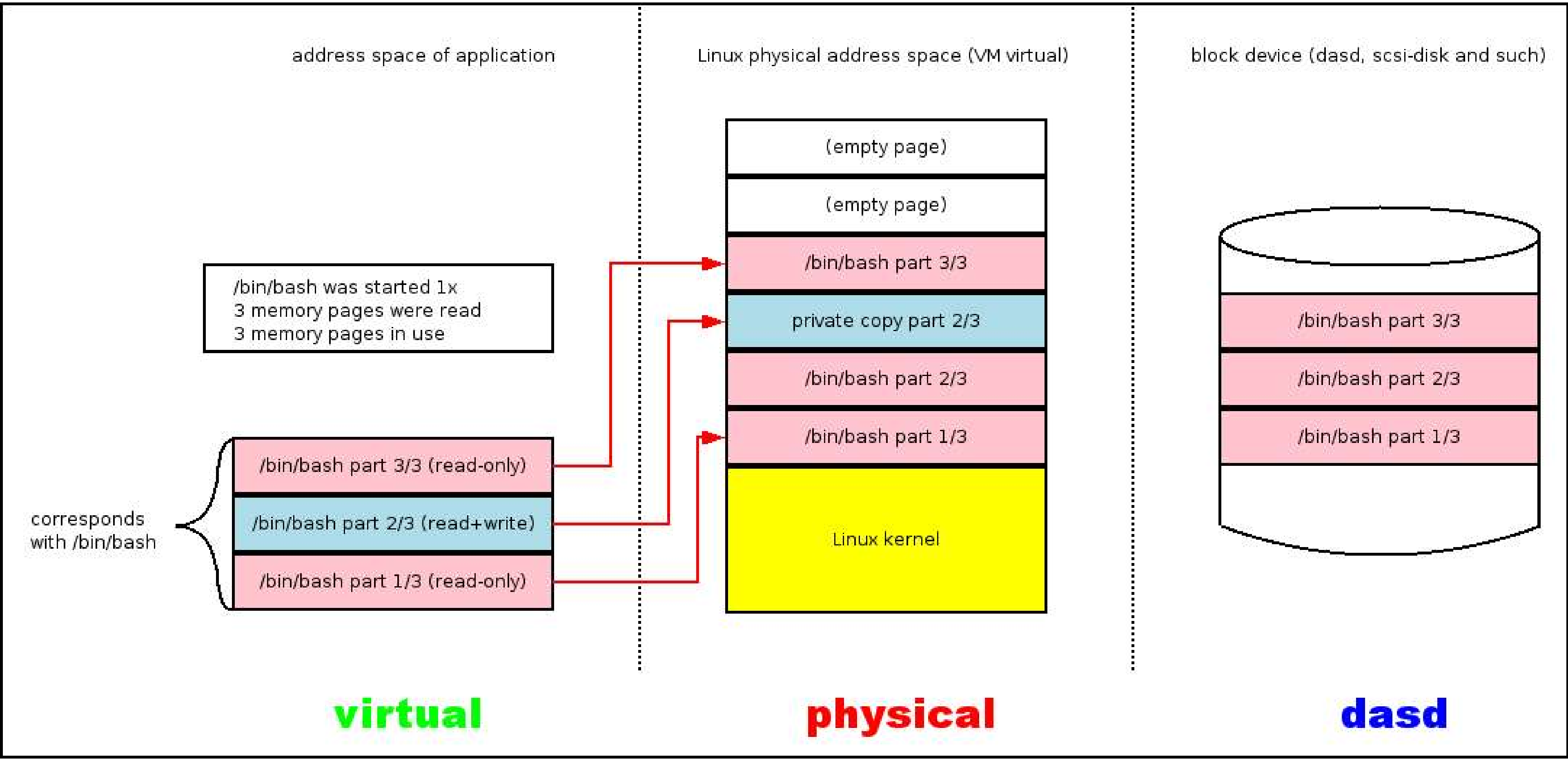

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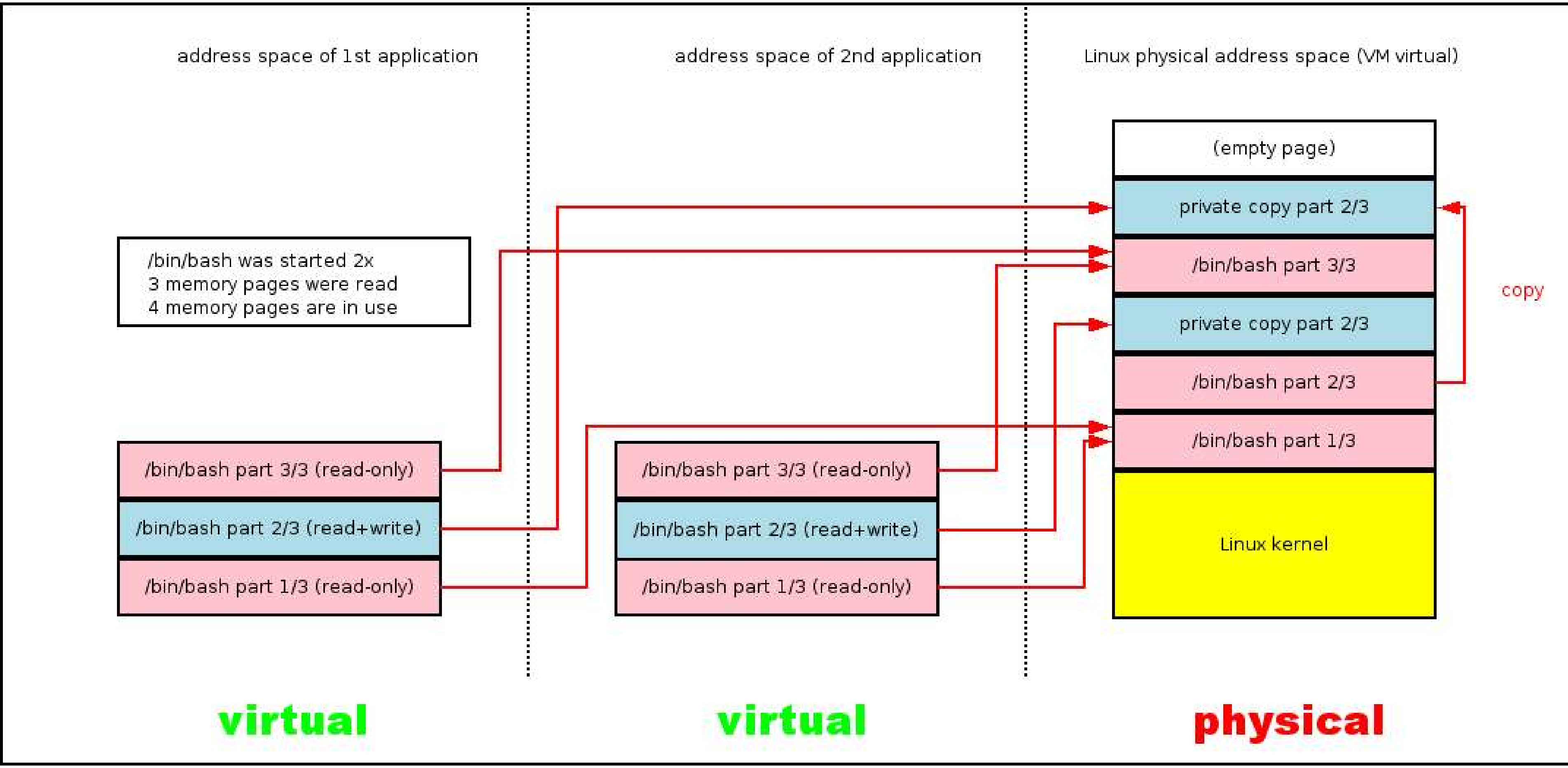

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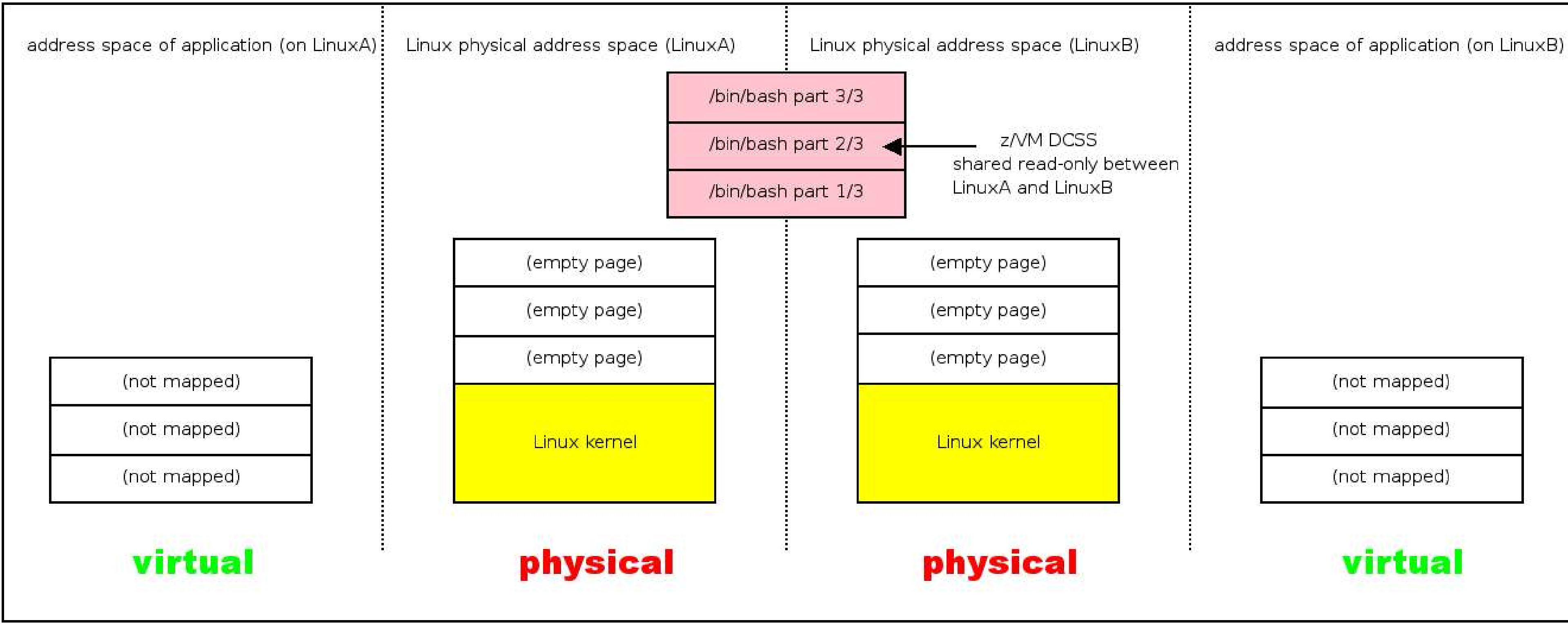
Goals for “execute in place” with Linux on z/VM

- improve resource usage in a virtual environment
- reduce memory requirements
- reduce I/O bandwidth requirements
- keep individual servers separated for security reasons

How “execute in place” works



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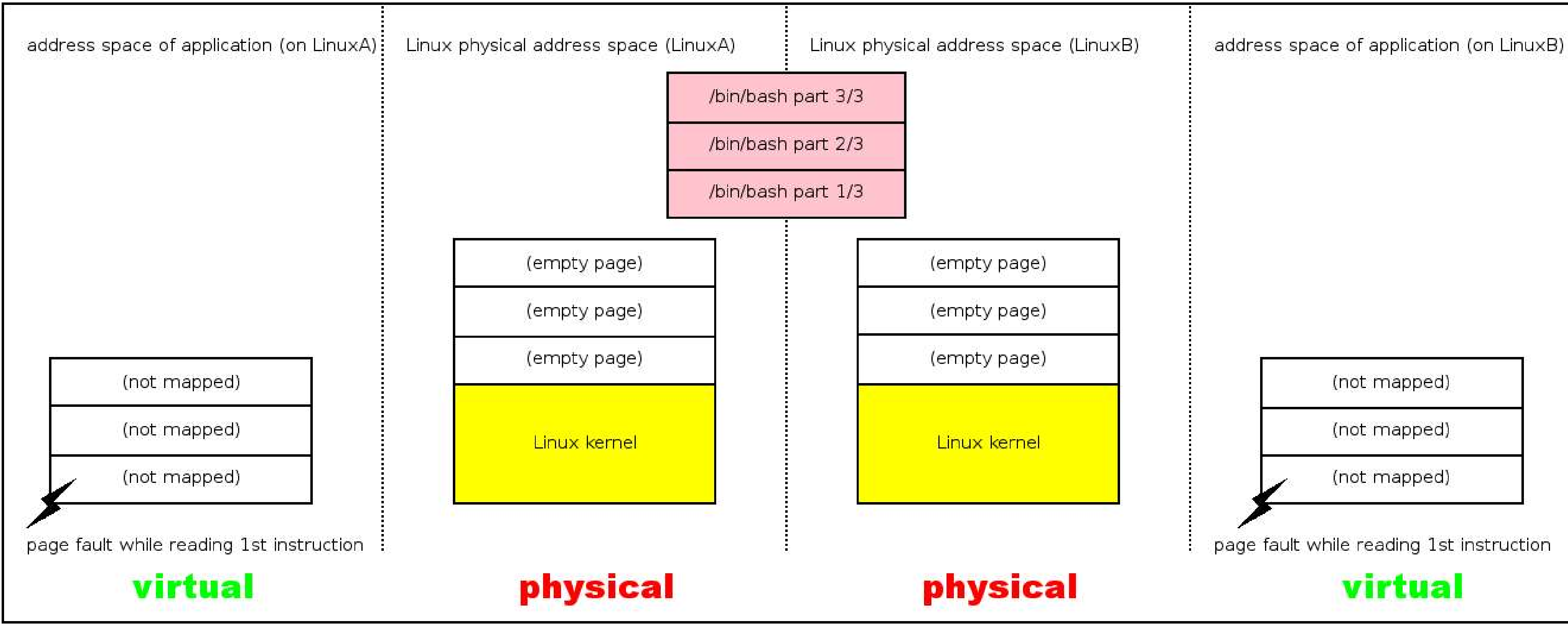

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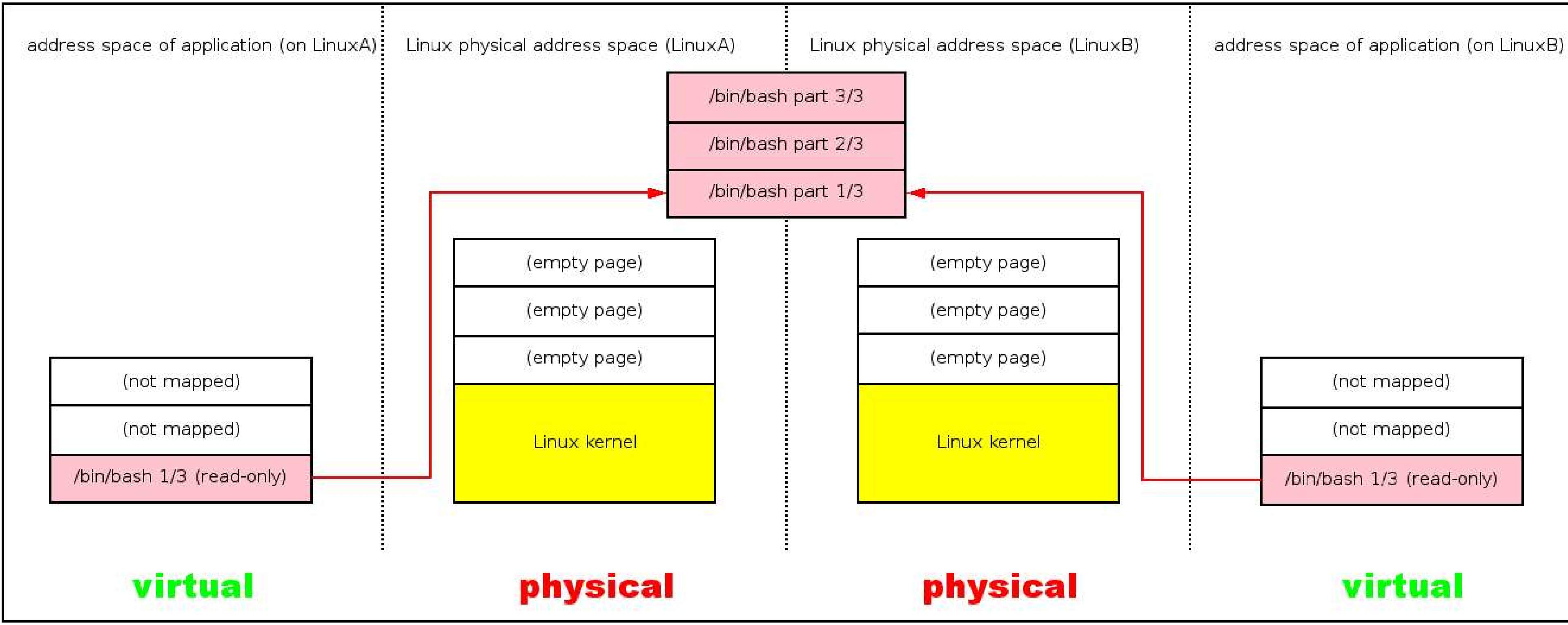

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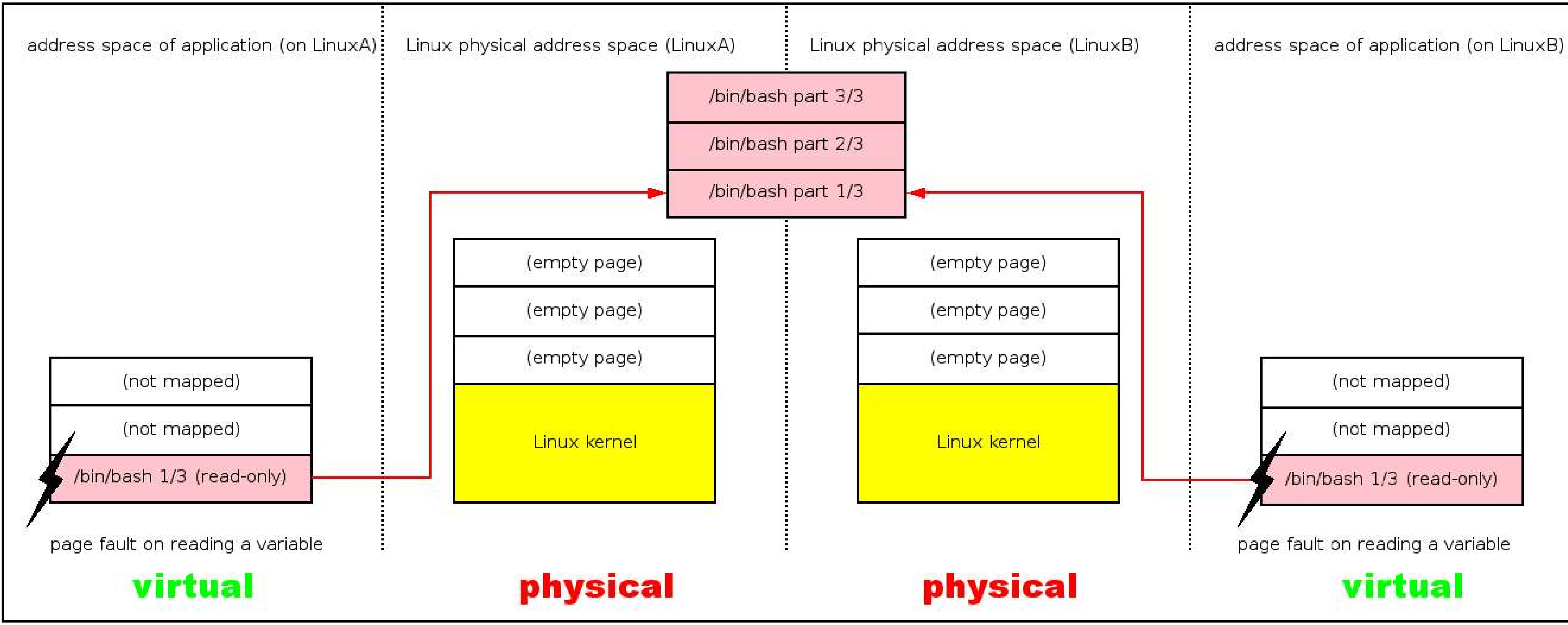

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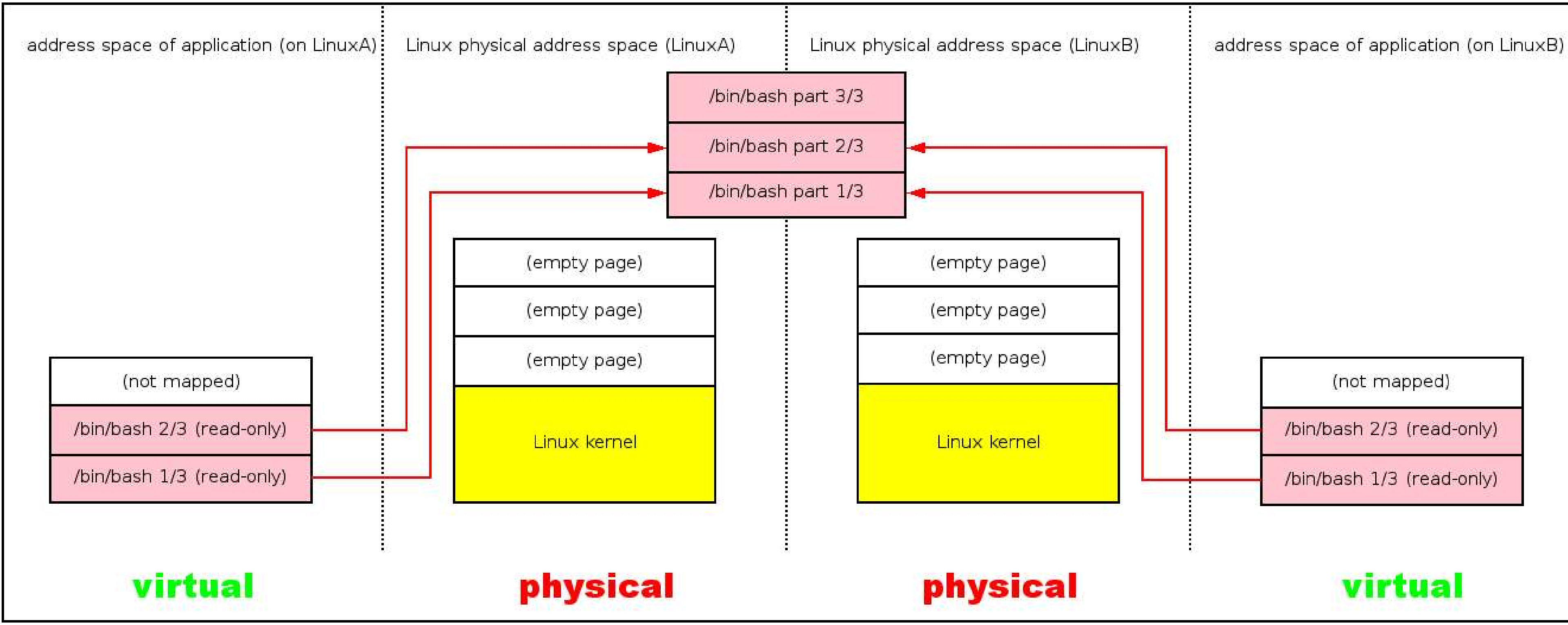

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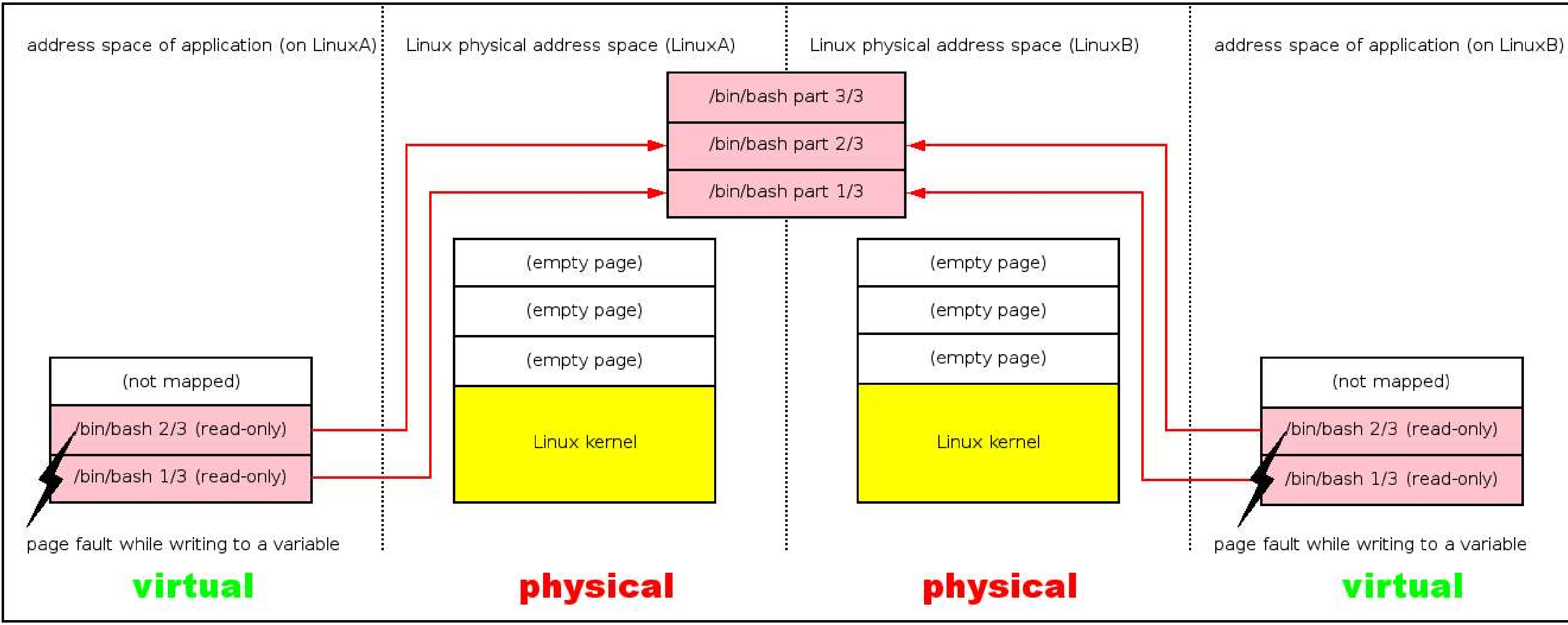

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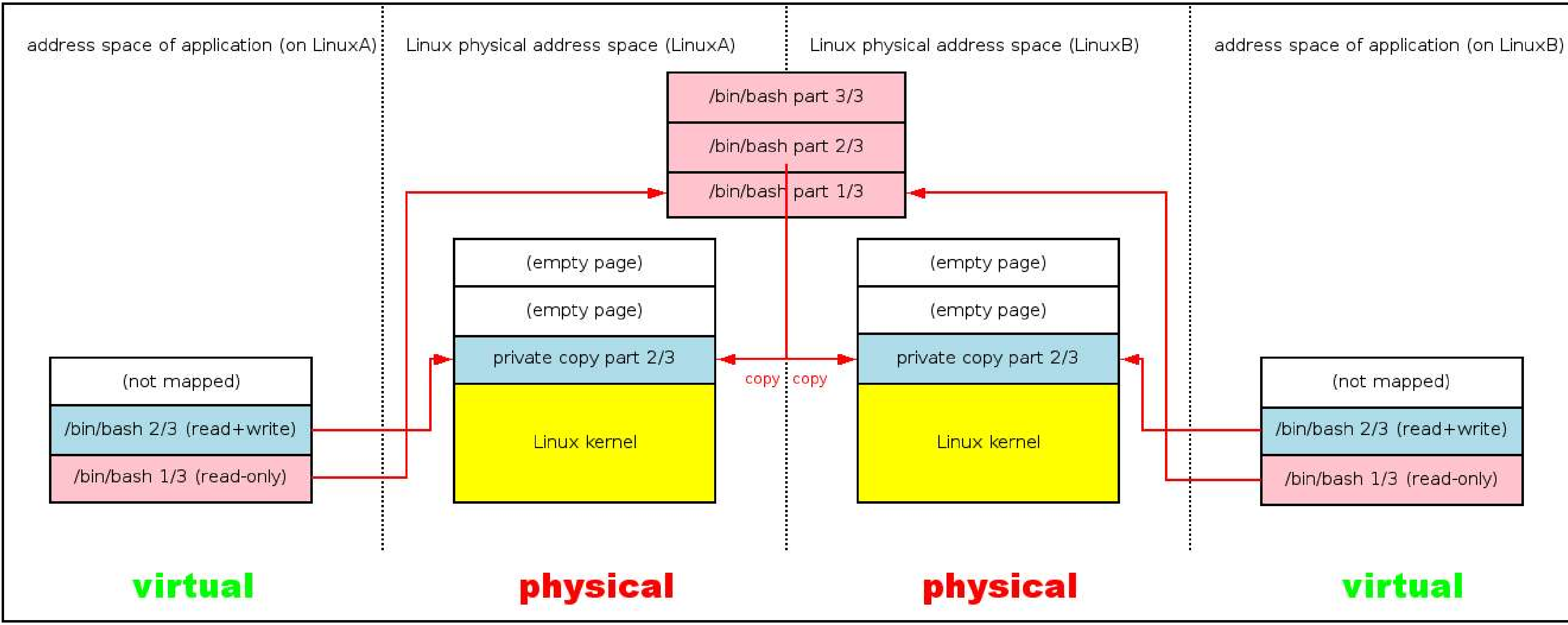

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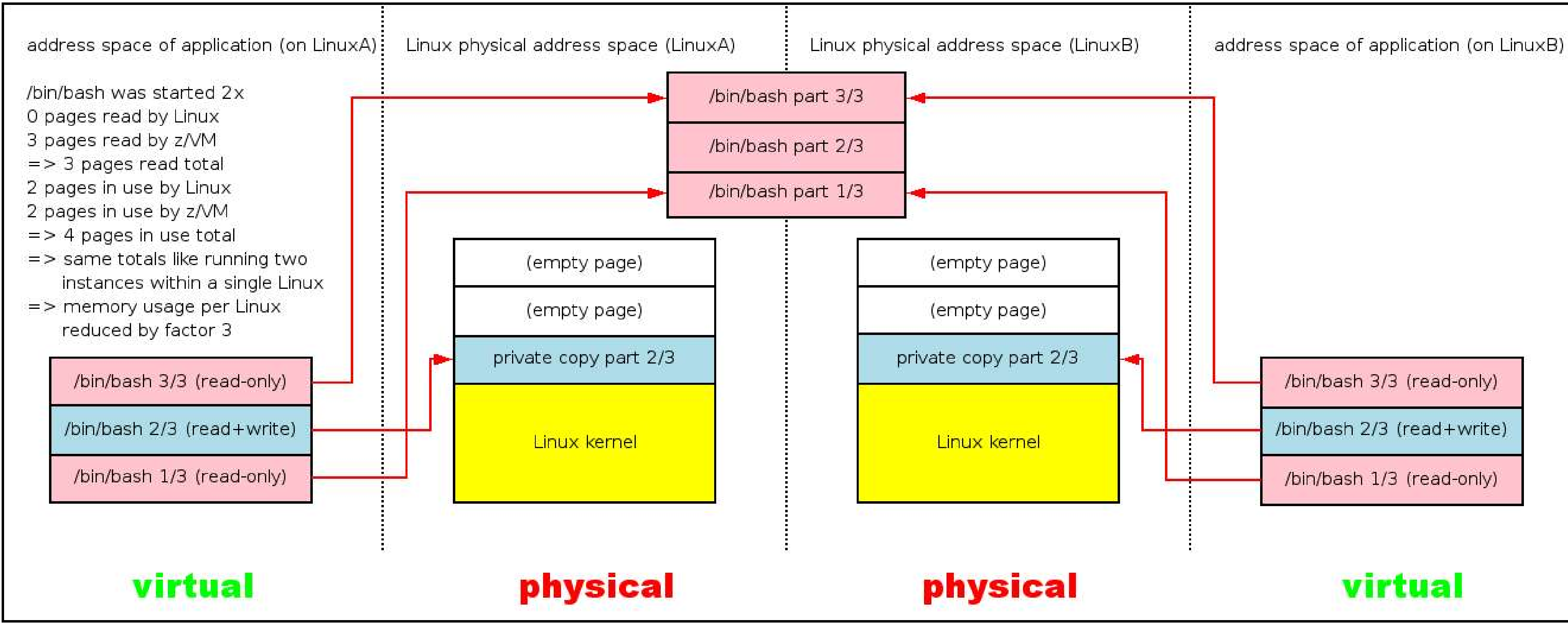

Characteristics of Linux on z/VM with execute in place

- implemented as filesystem type “xip2”
- can only be used read-only, writing is not supported
- the filesystem layout is compatible with ext2
- requires z/VM DCSS as storage
- does not need write access to the DCSS, individual servers remain strictly separated in memory (security!)
- the DCSS block device driver can be used with ext2 to write data to the DCSS

Characteristics of Linux on z/VM with execute in place

- no changes to the operating system outside the filesystem module
- no changes to applications, existing applications can benefit without modifications
- provides major improvement for memory consumption of servers
- allows to run more active servers with given resources
- source code is available at http://www.linuxvm.org/Patches
- is available as update to SuSE Linux Enterprise Server Version 8
- is integrated in SuSE Linux Enterprise Server Version 9
  - new ext2 features supported (dirindex, acl...)
  - remove memory restriction to 2GByte