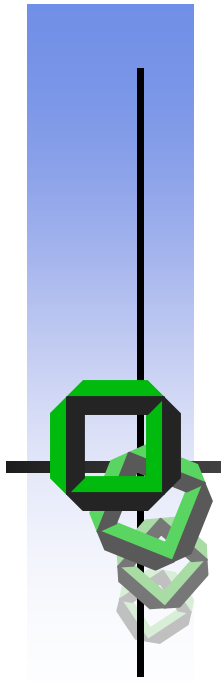


Systems Design and Implementation

II.1 – L4 API Crash Course Part II

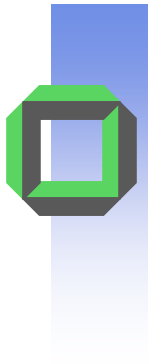
System Architecture Group, SS 2009

University of Karlsruhe

April 30, 2009

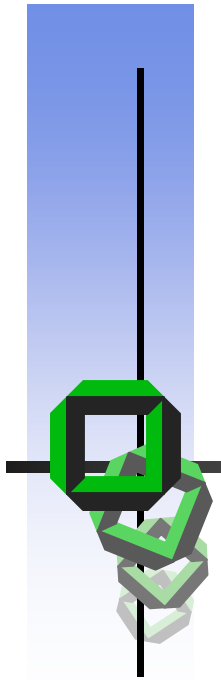
Jan Stoess

University of Karlsruhe



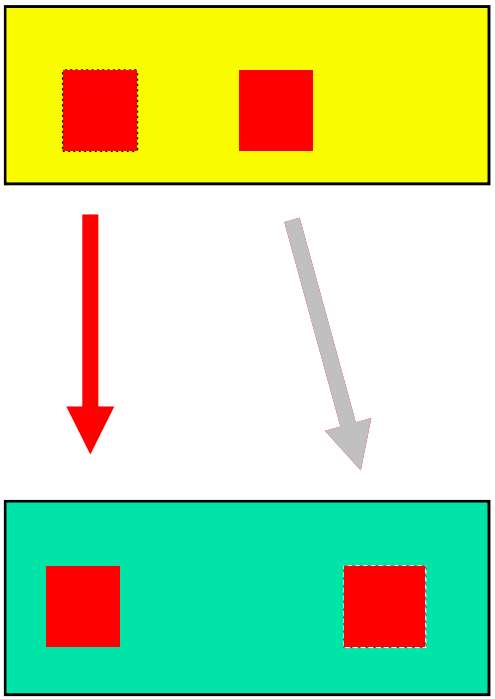
Microkernel System Calls

KernelInterface
IPC
Unmap
ExchangeRegisters
ThreadSwitch
Schedule
SystemClock
ThreadControl
SpaceControl
ProcessorControl
MemoryControl



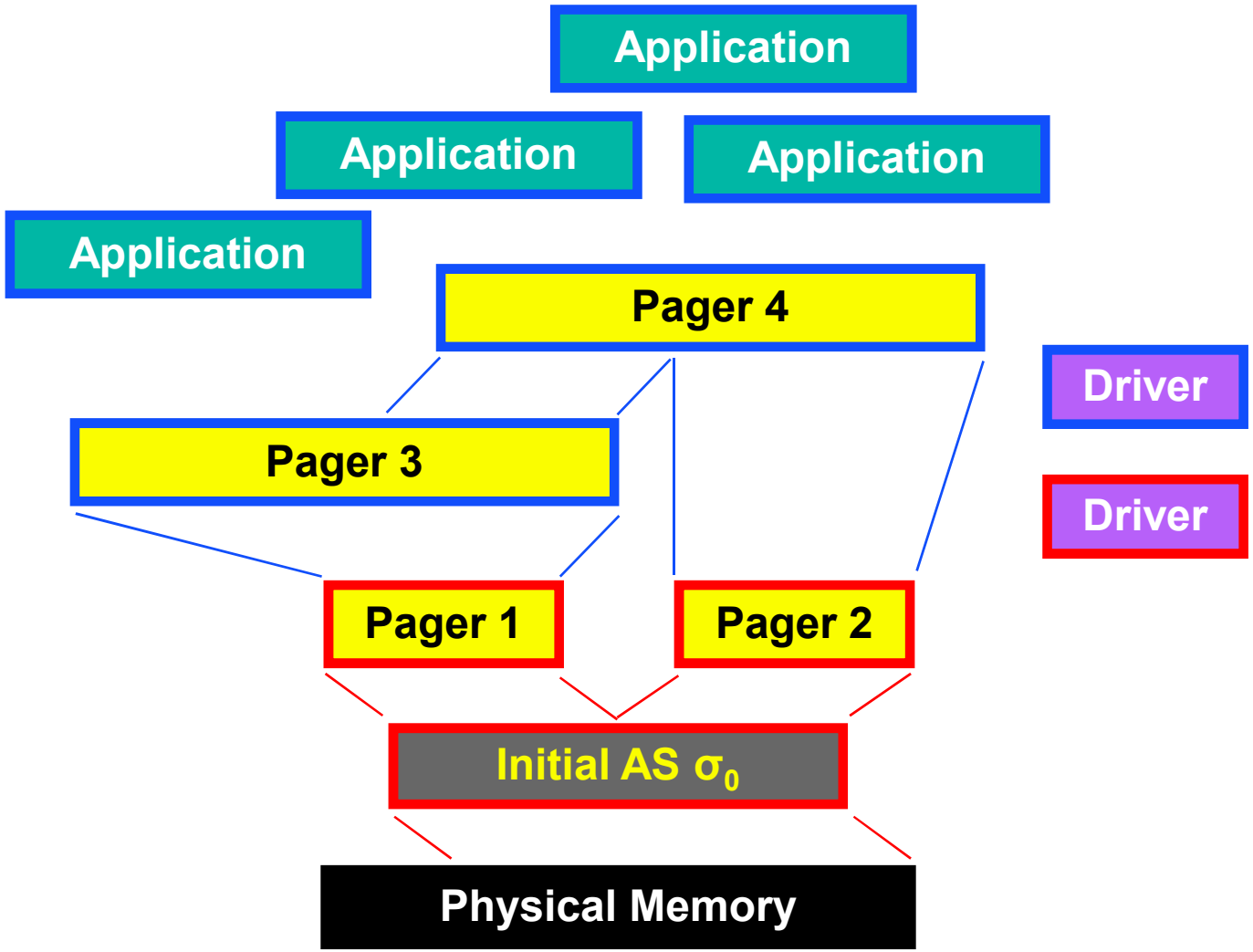
Address Spaces and Mapping

Basic Operations

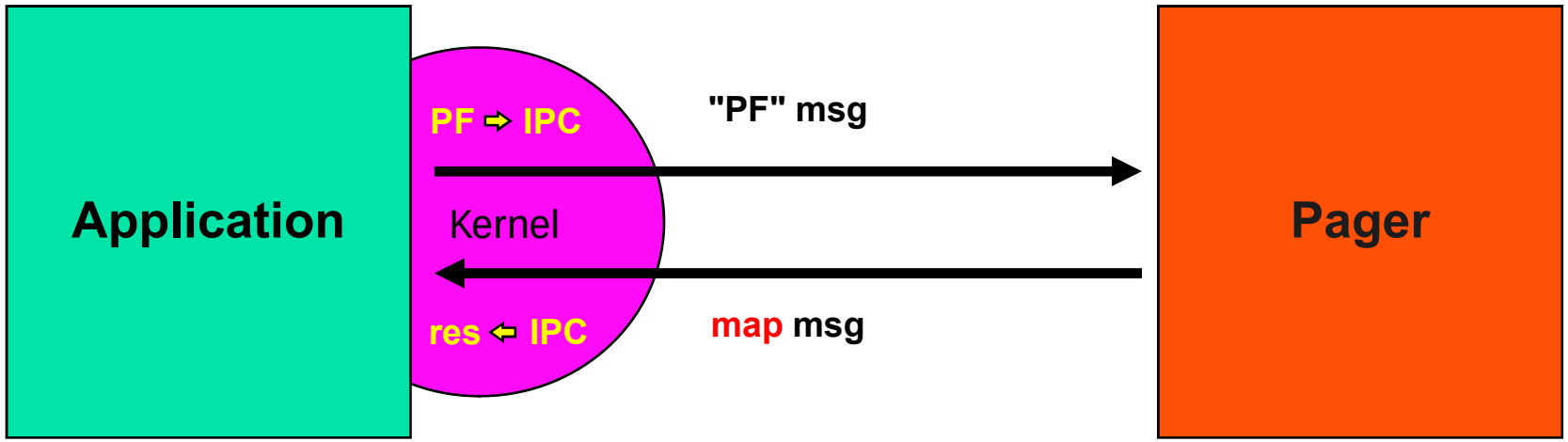


- **Map**
- **Unmap**
- **Grant**

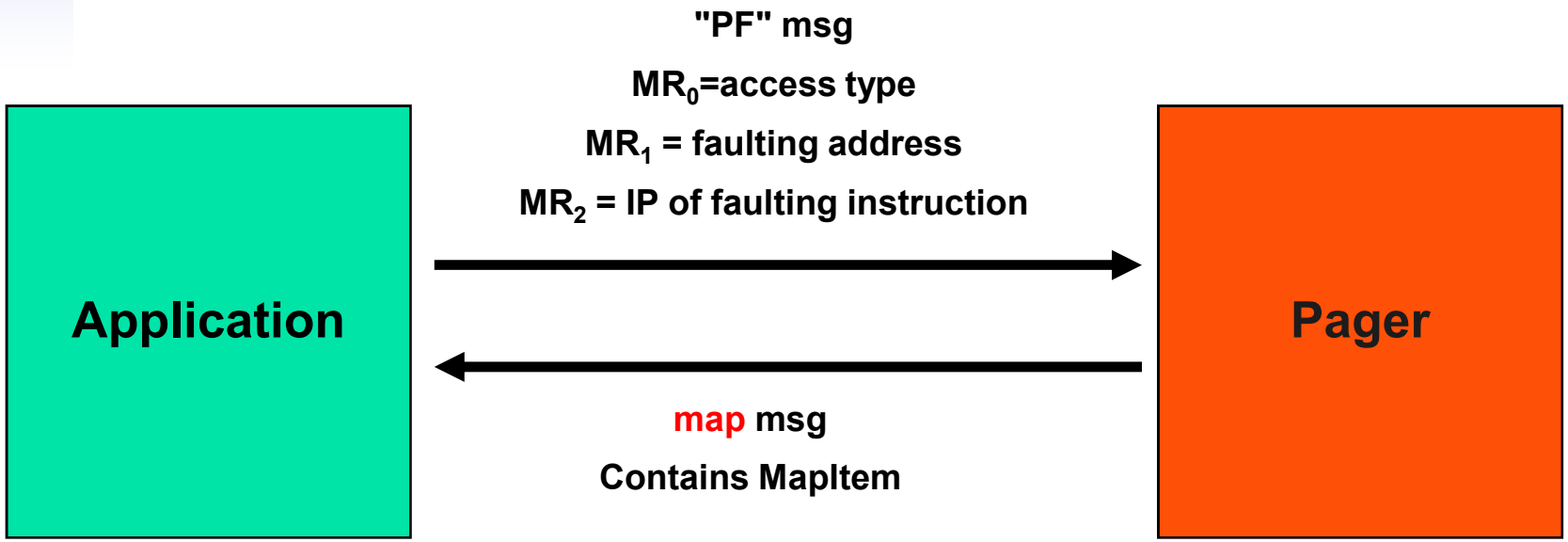
Recursive Address Spaces

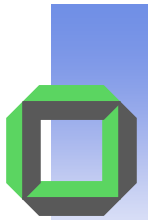


Page Fault Handling



Page Fault Protocol

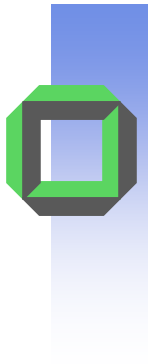




Page Fault Message

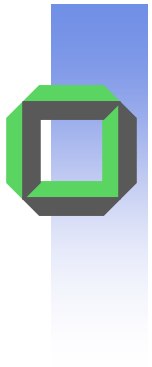
Faulting user-level IP					MR_2
Fault address					MR_1
-2	***0rwx***	$0_{(4)}$	*0*	*2*	MR_0

- Short message
  - No further page faults
- Applications can synthesize page fault messages
  - Not a problem - the application could do it anyway by directly accessing the memory it wishes to cause a fault on



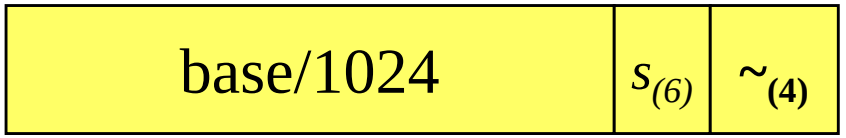
Mapping Questions

- How is the mapping to be sent specified?
- How is the mapping to be received specified?
- How do they combine? What is the result?

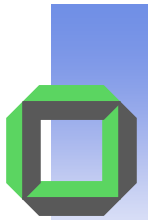


Fpage Data Type

- Fpage
  - fpage size = 2^s

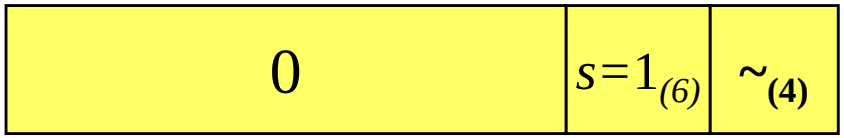


- Specifies a region of the address space that is
  - A power of 2 in size
  - Aligned to its size
- Note: Smallest supported size is architecture specific
  - IA-32 supports 4K (s = 12)

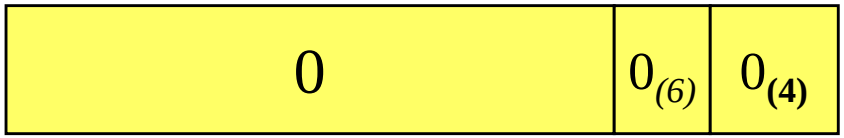


Fpage Data Type

- Complete Address Space

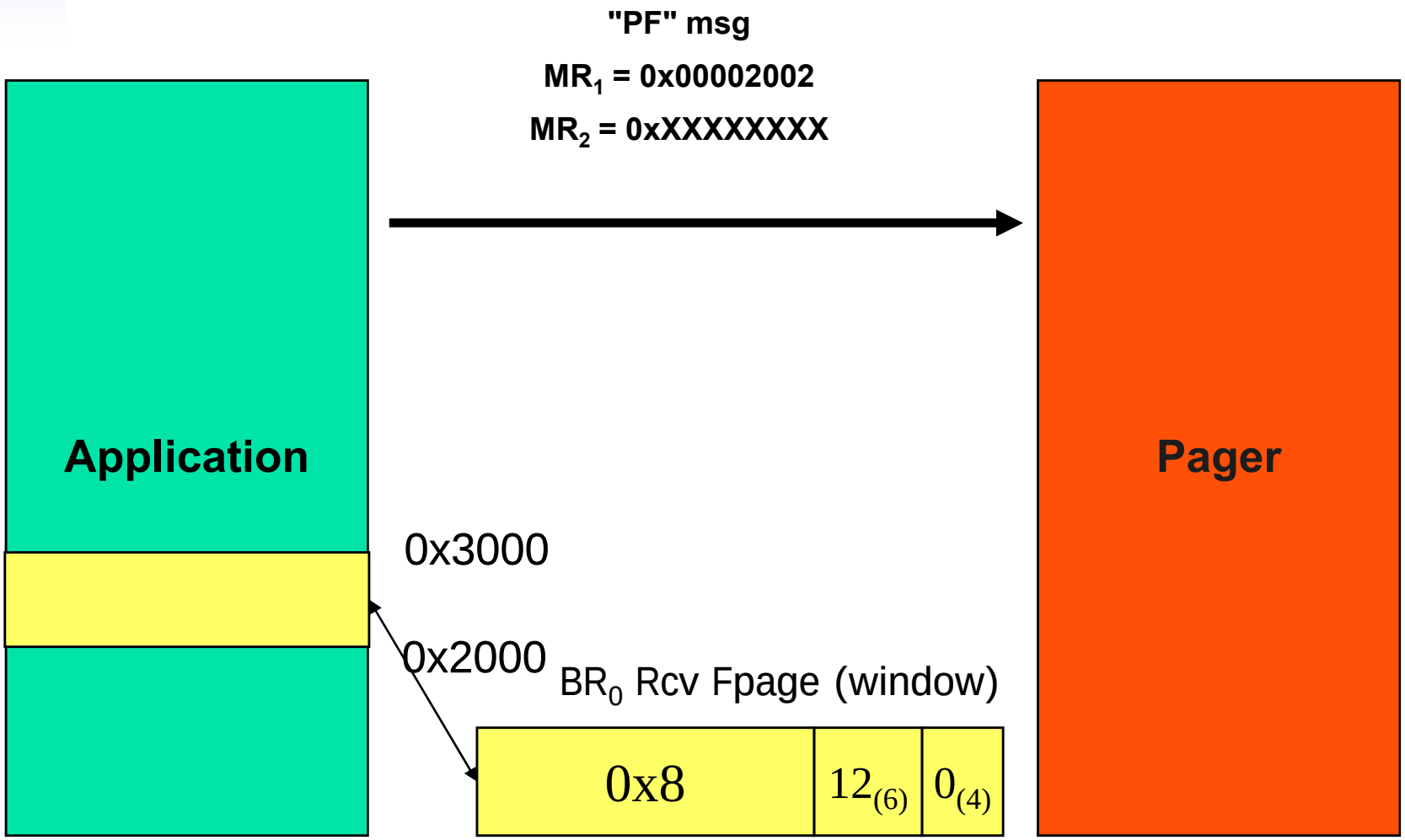


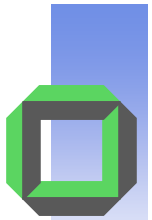
- Nilpage



- See l4/types.h

Receiving a mapping



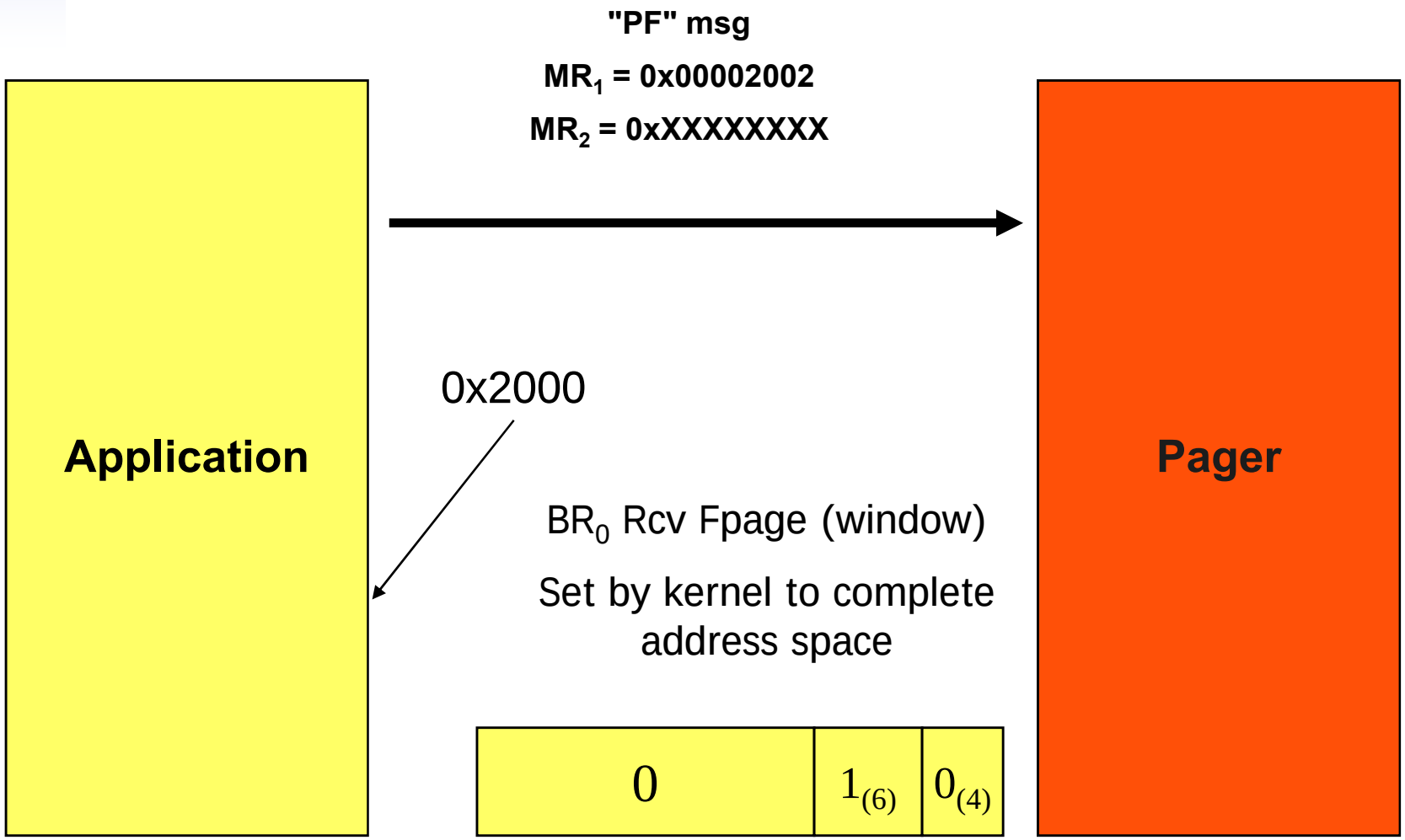


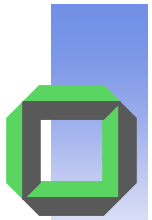
Buffer Register 0

Rcv Window (fpage)	000s

- BR_0 Specifies
  - Willingness to receive StringItems
    - s = 1
    - Target sting locations in other BRs
  - The receive window for mappings
    - Region of the address space to accept mappings
    - Nilpage: No mappings accepted

Normal Page Fault



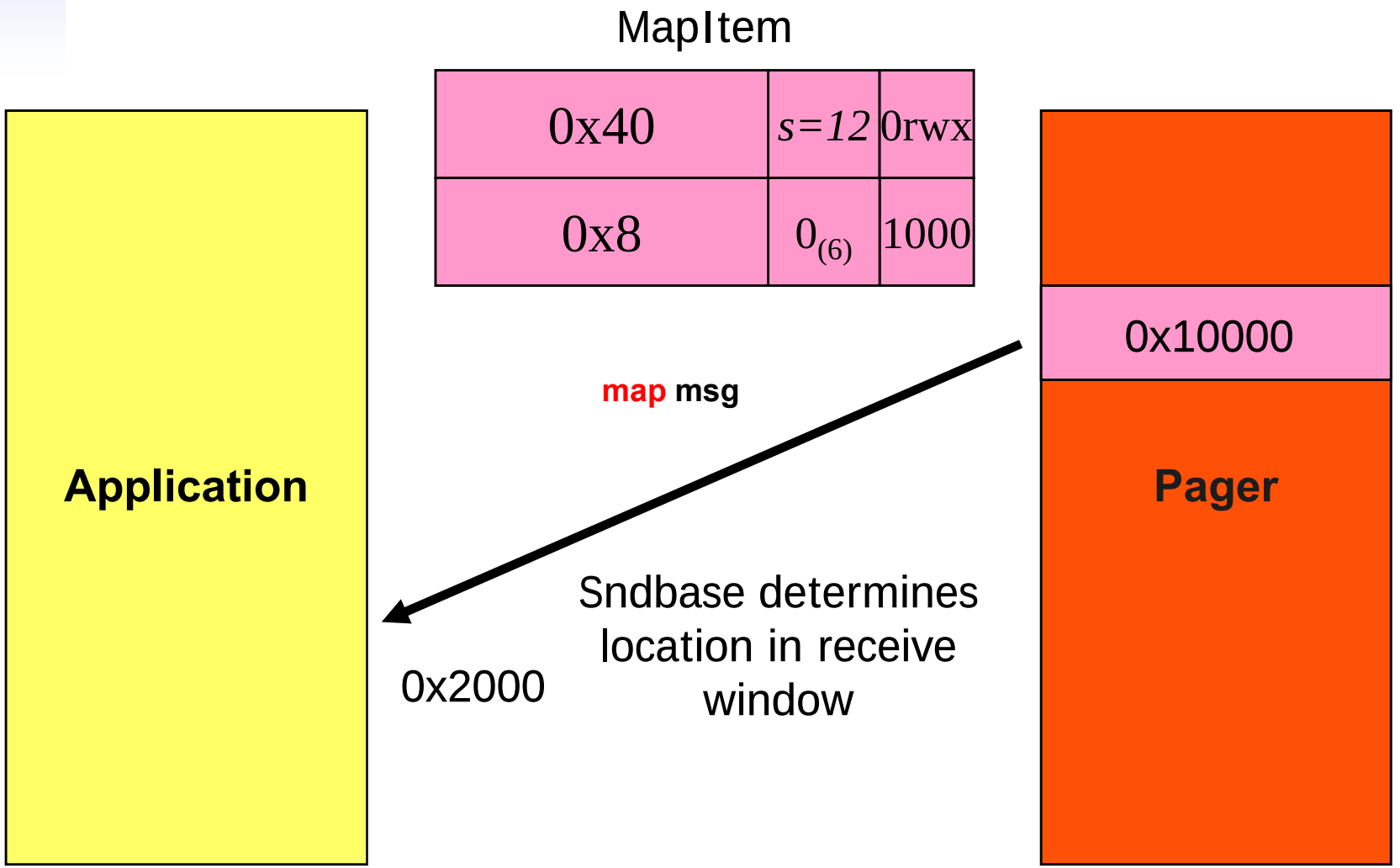


MapItem/GrantItem Data Type

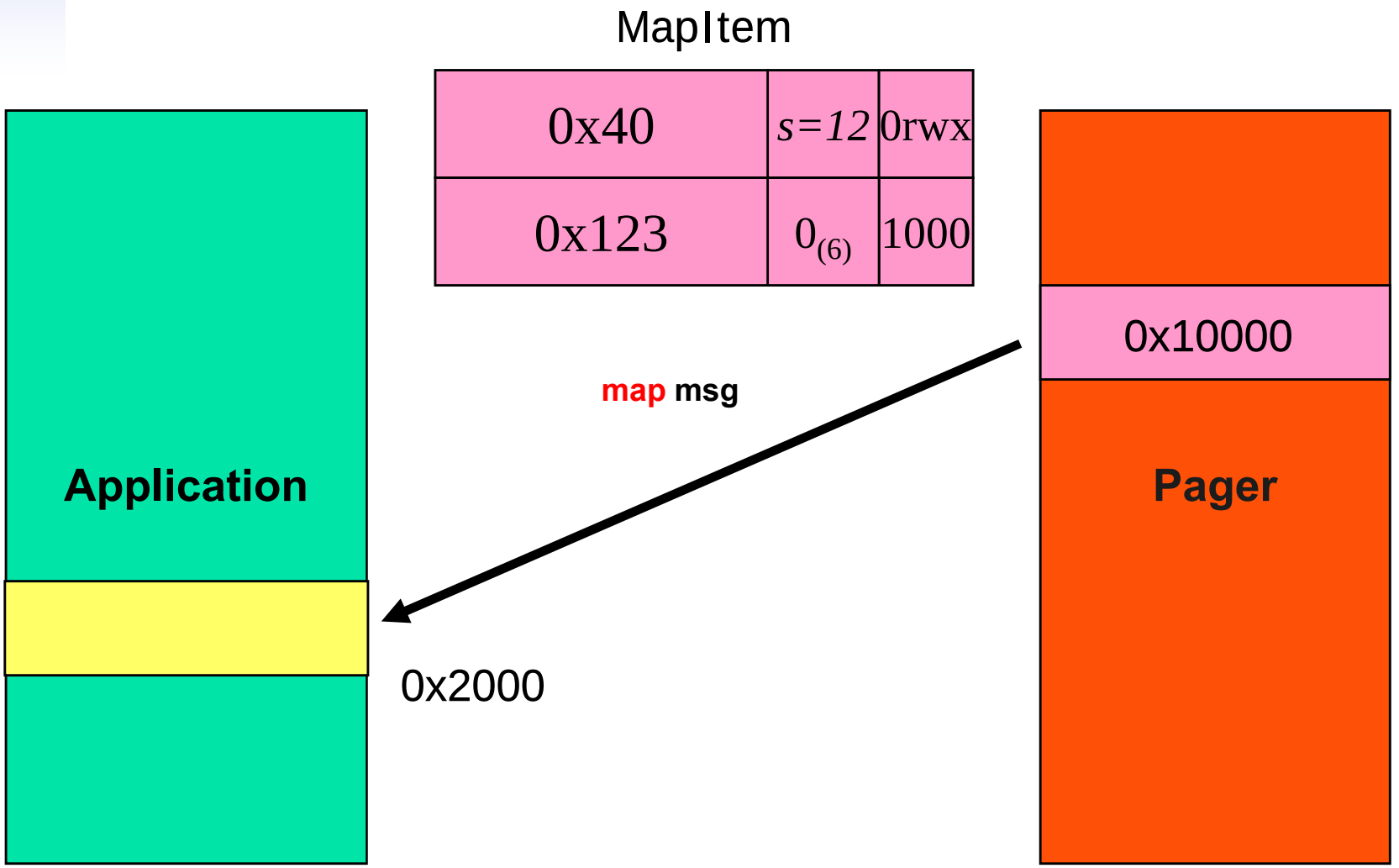
Snd Fpage		**0***rwx*
Snd base/1024	**0**$_{(6)}$	**10***gC*

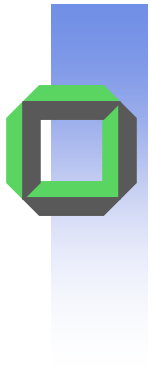
- Permissions
  - r: read
  - w: write
  - x: execute
  - Note: Not all architectures support all combinations
    - IA-32: rx and rwx are supported by hardware
- g: mapping (0) or granting (1)

Receive window > mapping size



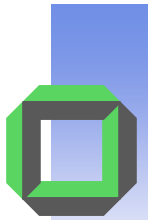
Sending a mapping





Mappings and Window Sizes

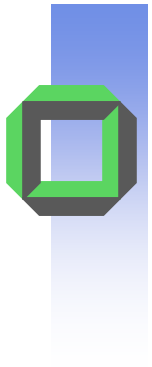
- See reference manual for precise definition of what happens for mismatched mappings and window sizes
- Advice:
  - Simply use 4K pages for all mappings



A Map Message

- For page faults, the kernel expects the following map message response
  - No untyped words
  - 1 MapItem

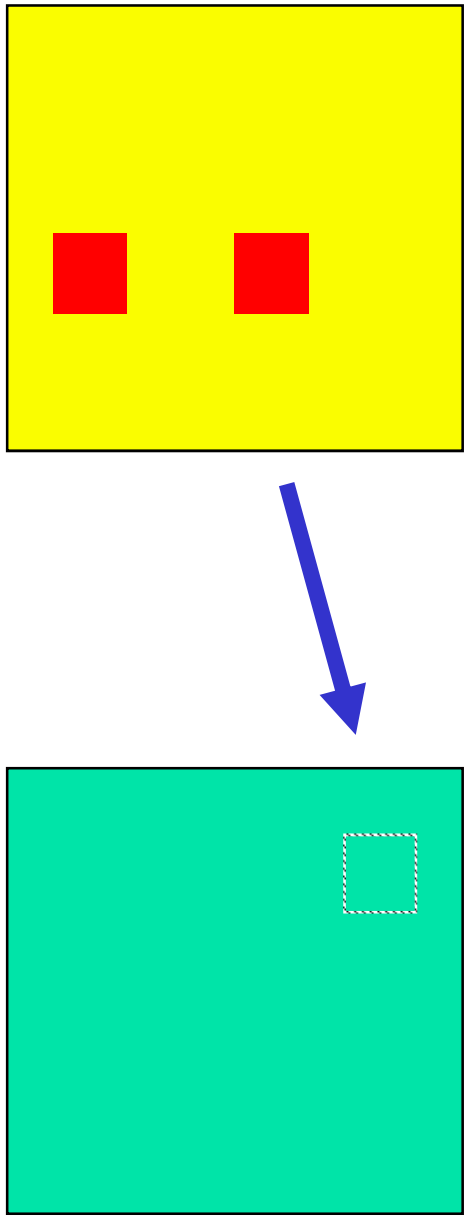
Snd Fpage			***0rwx***
Snd base/1024		***$0_{(6)}$***	***10gC***
label	***0***	***2***	***0***



Explicit Mapping Receive

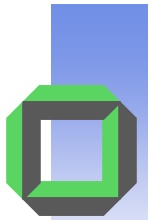
- BR_0 determines whether a receive/wait IPC can include strings or a mapping
  - Set it prior to invoking IPC receive/wait

```
L4_Acceptor_t L4_UntypedWordsAcceptor
L4_Acceptor_t L4_StringItemsAcceptor
L4_Acceptor_t L4_MapGrantItems (
        L4_Fpage_t RcvWindow
)
void L4_Accept (L4_Acceptor_t a)
```



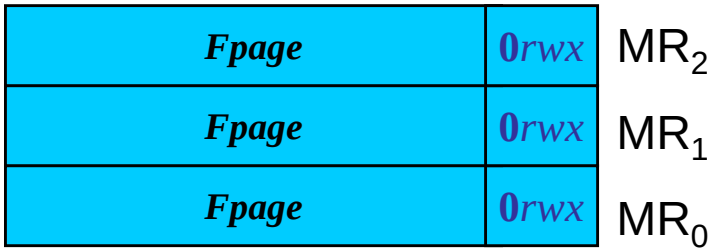
Unmap

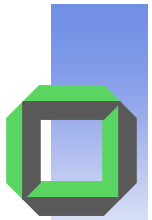
- Revoke mappings
  - That were derived from mappings in the current address space
- Revoke access rights
  - To existing mappings
  - Example: RW -> RO
- The mappings to revoke are specified by fpages in MRs



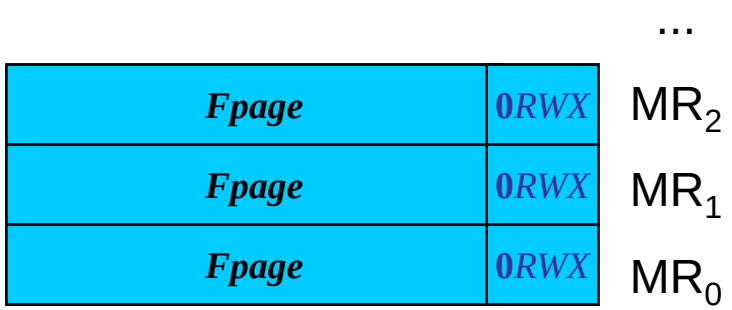
Unmap Arguments

- Control
  - *f:* specifies whether fpages are *flushed* from the current address space in addition to revoking derived mapping
  - *k*: specifies the highest number MR that contains an Fpage to unmap
- Fpages
  - Fpages specify the regions in the local address space
  - *rwx:* the access rights to revoke

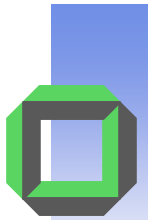




Unmap Results



- RWX
  - Reference (r), Dirty (w), and Executed (x) bits
    - Bit returned set if corresponding access has occurred on any derived mapping
    - Reset as a result of the unmap operation
- Supported combinations are arch-dependent



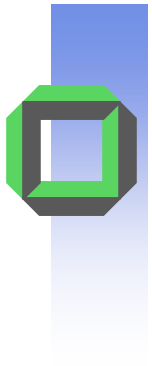
Unmap

- Derived mappings in other address spaces

```
L4_Fpage_t L4_UnmapFpage (L4_Fpage_t f)
```

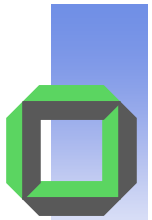
- Derived mappings in own address space as well

```
L4_Fpage_t L4_Flush (L4_Fpage_t f)

void L4_UnmapFpages (L4_Word_t n,
                     L4_Fpage_t * fpages)
void L4_FlushFpages (L4_Word_t n,
                     L4_Fpage_t * fpages)

L4_Bool_t L4_WasWritten (L4_Fpage_t f)
L4_Bool_t L4_WasReferenced (L4_Fpage_t f)
L4_Bool_t L4_WaseXecuted (L4_Fpage_t f)
```



SpaceControl

- Used to control the layout of newly created address spaces
  - Specifically
    - Location of Kernel Info Page - fpage
    - Location of UTCB region - fpage
- Redirector
  - All IPC from threads within the address space is redirected to a controlling thread
    - Used to enforce security policy
- Note: Should not need to change what is already done in the example code



Microkernel System Calls

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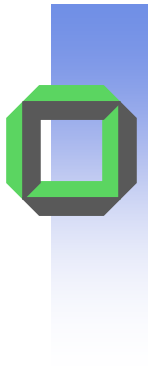
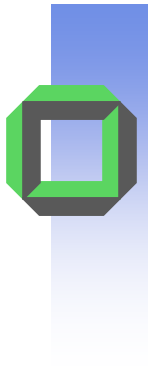
ThreadSwitch
Schedule
SystemClock
ThreadControl
SpaceControl
ProcessorControl
MemoryControl



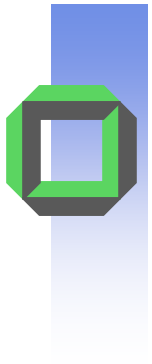
ProcessorControl

- Privileged system call
- Sets processor frequency, voltage and other processor specific stuff
  - … once implemented



MemoryControl

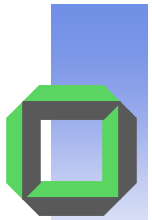
- Privileged system call
- Set cache architecture attributes on pages in memory
  - Machine specific
  - Not implemented for IA-32
  - Obsoleted by MapControl proposal



Microkernel System Calls

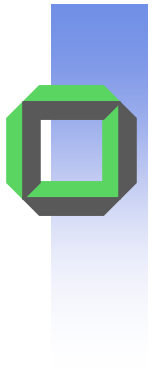
KernelInterface
IPC
Unmap
ExchangeRegisters
ThreadSwitch
Schedule
SystemClock
ThreadControl
SpaceControl
ProcessorControl
MemoryControl

That's it.



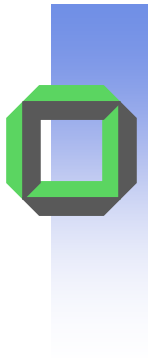
Protocols

- Page Fault
- Thread Start
- Interrupt
- Preemption
- Exception
- Sigma0



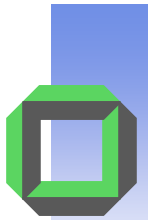
Exception Protocol

- Exception IPC to exception handler thread
  - On behalf of faulting thread
  - The IPC contains
    - IP of where to resume the thread after handling the exception
    - Exception type
    - Other machine specific stuff
  - The exception handler can respond with an IPC specifying a new IP and other state to recover from the exception
    - See the IA-32 appendix in the manual



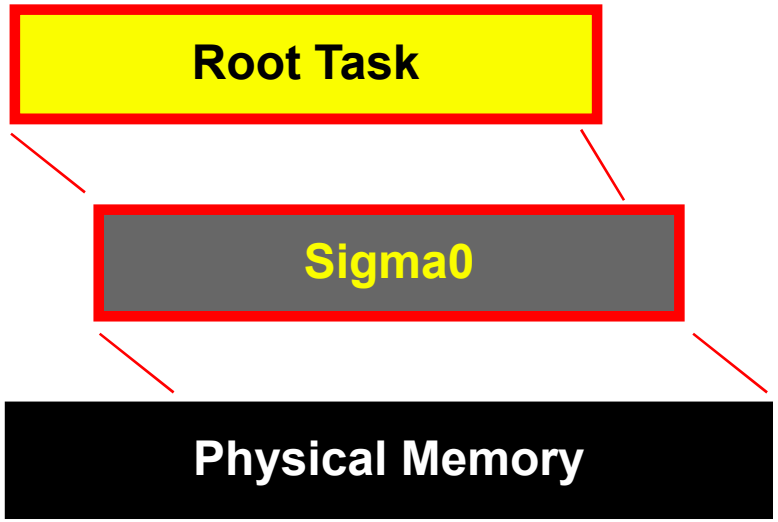
Sigma0

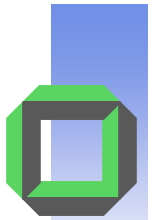
- Owns all physical memory in the machine
  - Except that reserved for kernel use
  - Mapped idempotently
    - One-to-one
  - Various memory classes
    - Conventional
    - Shared (VGA screen memory, ...)
    - Architecture-specific (ACPI tables, ...)
    - Boot-loader specific (modules, initial servers, ...)
  - Maps each page once (and once only)
- Sigma0 protocol
  - Request specific page
  - Request any page
  - Request larger regions



Sigma0 – Root Pager

- Pager of initial threads (root task)
  - Also implements page fault protocol
  - Responds with idempotent mapping

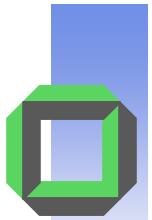




Sigma0 Request Message

Requested attributes					MR_2
B = Requested Fpage/1024			$s_{(6)}$	$0rwx_{(4)}$	MR_1
-6	$0_{(4)}$	$0_{(4)}$	$0_{(6)}$	2	MR_0

- Requested attributes
  - Architecture specific
    - Use default = 0
- Requested Fpage
  - B != -1
    - Request a specific region of physical memory



Some Sigma0 Helpers

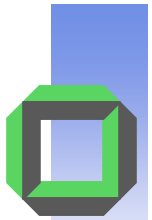
- Found in l4/sigma0.h

- Request a specific page

```
L4_Fpage_t L4_Sigma0_GetPage (L4_ThreadId_t s0,
                              L4_Fpage_t f,
                              L4_Fpage_t RcvWindow)
```

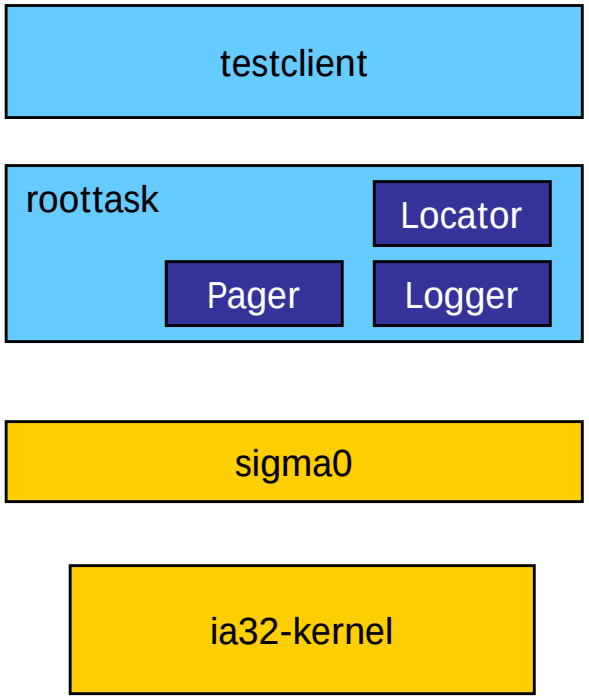
- Request some page

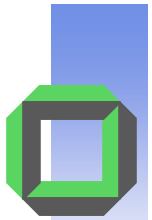
```
L4_Fpage_t L4_Sigma0_GetAny (L4_ThreadId_t s0,
                             L4_Word_t s,
                             L4_Fpage_t RcvWindow)
```



Example Code

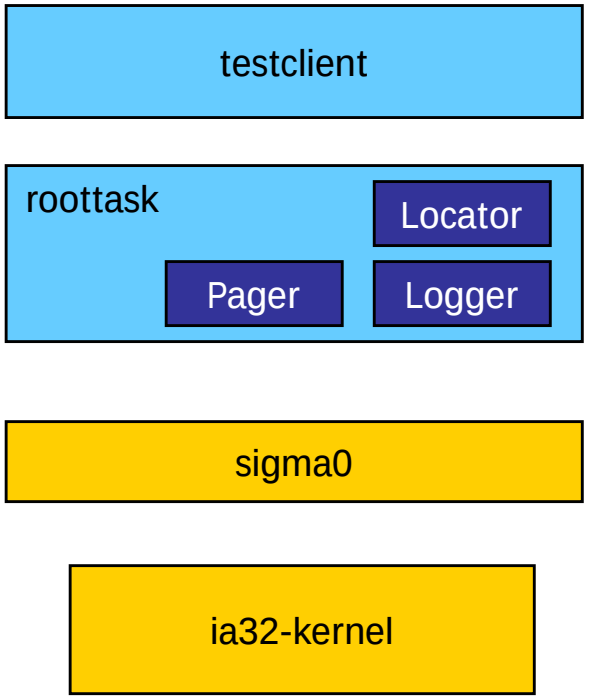
- Kernel
  - L4Ka::Pistachio 0.4 ia32-kernel
- Supporting applications
  - Kickstart
  - Sigma0
- Custom applications
  - Roottask
  - Test client

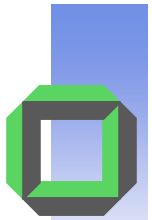




Custom Applications

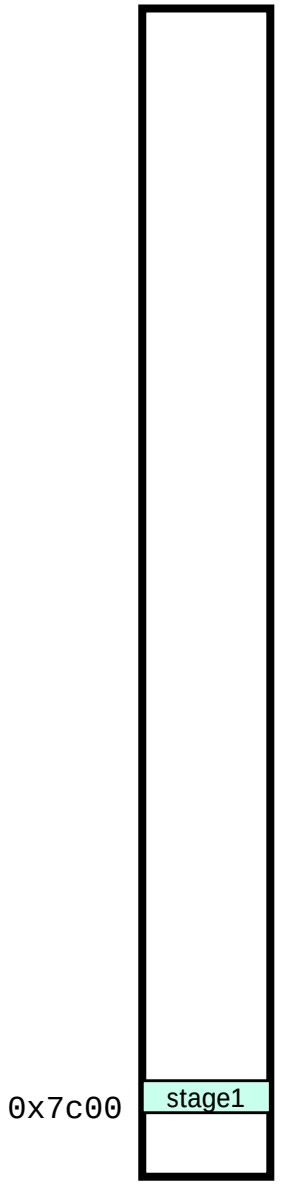
- Roottask
  - Locator
  - Log server
  - Pager
- Test Client
  - Locates log server
  - Sends a message to the log server

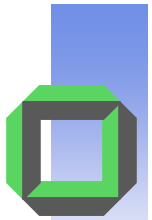




The Boot Sequence (1)

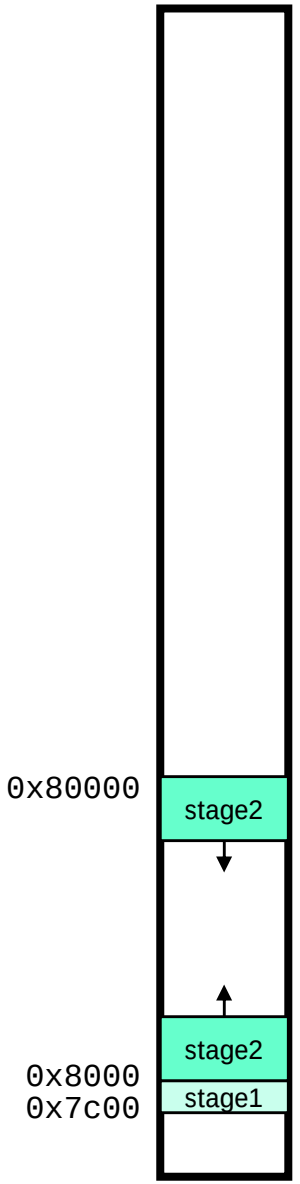
- BIOS loads the boot block
  - Small loader, GRUB stage1
  - Only 512 bytes available
- Stage1 starts
  - Searches disks for stage2
  - Loads GRUB stage2





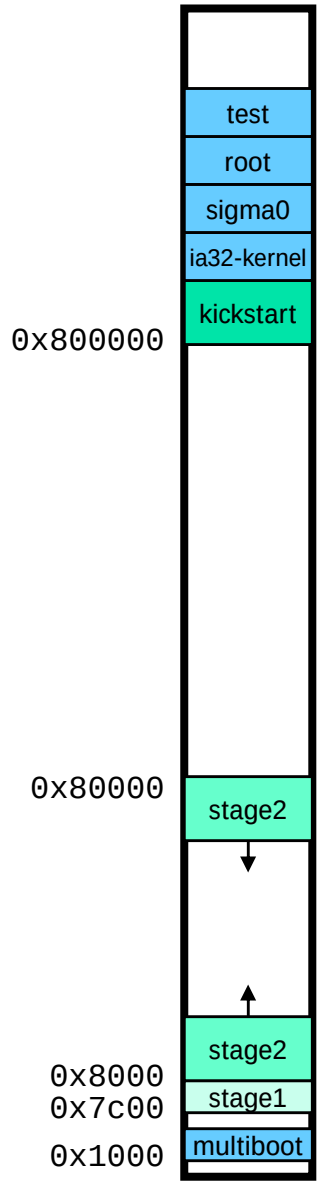
The Boot Sequence (2)

- Stage2
  - more complex part of GRUB
    - Understands various file systems
    - Supports network
    - Supports a menu
    - 60kb – 80kb in size
    - Supports ELF loading
  - Searches for menu.lst



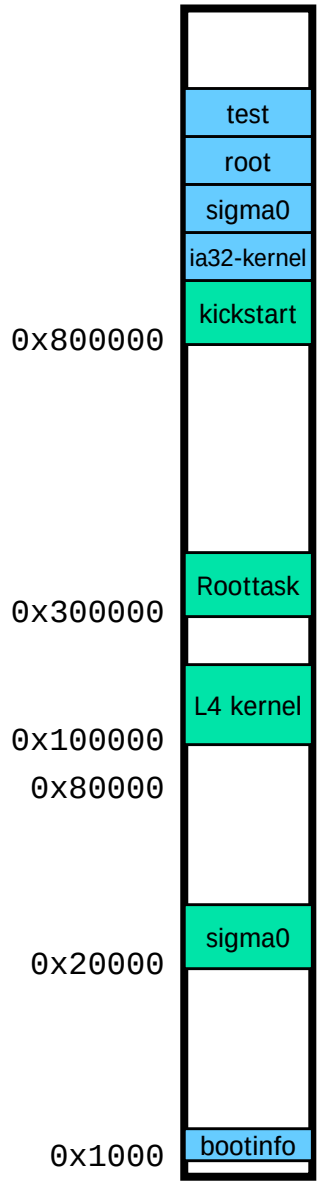
The Boot Sequence (3)

- Stage2 continues
  - ELF-loads kickstart
  - Appends additional modules after kickstart
  - Generates multiboot info
  - Passes pointer to multiboot info to kickstart
  - Hands over execution to kickstart



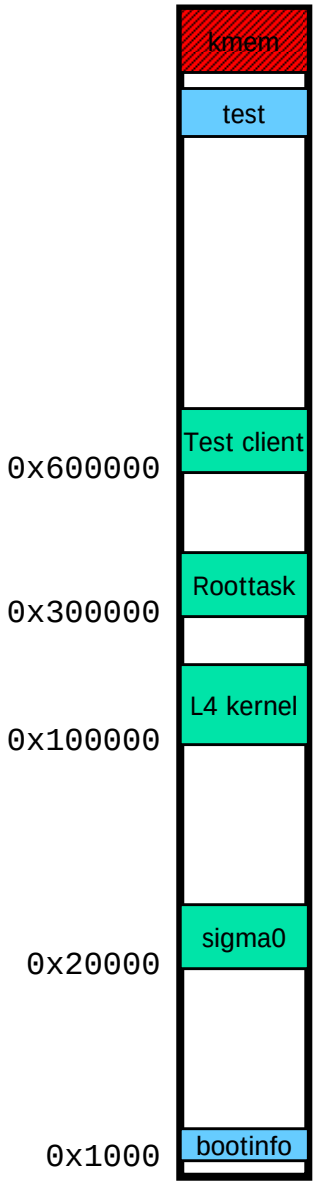
The Boot Sequence (4)

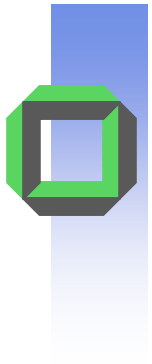
- Kickstart starts
  - Converts multiboot info into generic bootinfo
  - ELF-loads
    - L4 kernel
    - Sigma 0
    - Roottask
  - Configures L4 via Kernel Configuration Page
  - Hands over control to kernel



The Boot Sequence (5)

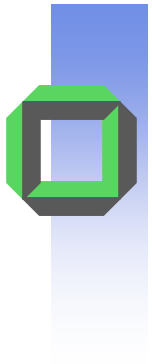
- L4 starts
  - allocates some upper memory for internal data structures
  - starts sigma0 and roottask
- Roottask starts
  - parses generic bootinfo
  - ELF-loads test client
  - starts test client





The Directory Structure

- /include
  - Global header files
  - Subdirectories
    - /l4 - L4 systemcalls
    - /sdi - Header for our system library
- /if
  - Global interface descriptions
- /lib/sdi
  - Our system library code
- /src
  - Custom application code



Next Week

- Tuesday : OS Interfaces
- Thursday: IDL4, Debugging on L4
- Homework
  - Change your group's password in the lab (R.149)
    - We will lock accounts with default passwords on Thursday
  - Get your build environment going
    - See the SDI Wiki at http://i30www.ira.uka.de/~sdi/wiki/
  - Create two threads in the roottask's address space
    - Let them send a few untyped words back and forth
  - Create an additional testclient-like binary
    - Run it in its own address space
  - Also available as assignment01.pdf