TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Computer Science Institute of Systems Architecture, Operating Systems Group

RESOURCE MANAGEMENT

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AGENDA

- done: time, drivers
- today: misc. resources
  - architectures for resource management
  - solutions for specific resources
  - capabilities to manage resource access
- upcoming: applications, legacy support

KERNEL RESOURCES

PROBLEM

- kernel needs memory for its abstractions
  - tasks: page tables
  - threads: kernel-TCB
  - capability tables
  - IPC wait queues
  - mapping database
- kernel memory is limited
- opens the possibility of DoS attacks

IDEA

- memory management policy should not be in the kernel
- account all memory to the application it is needed for (directly or indirectly)
- kernel provides memory control mechanism
- exception for bootstrapping:
  initial kernel memory is managed by kernel

SOLUTION

- untyped memory in seL4
- all physical memory unused after bootstrap is represented by untyped memory capabilities
- can be granted, split or retyped
- restricted to powers of 2 (see flexpages)
- initial resource manager gets all (see σ_0)
- user code decides how to use them

SOLUTION

- application retype UM to kernel objects
  - TCB, endpoint, CNode, VNode, frame, interrupt
  - all kernel bookkeeping for the object uses the underlying physical memory
  - no implicit memory allocation by the kernel
- retyping and splitting is remembered in capability derivation tree
  - revoking recursively destroys all derived capabilities and kernel objects

PRINCIPLE

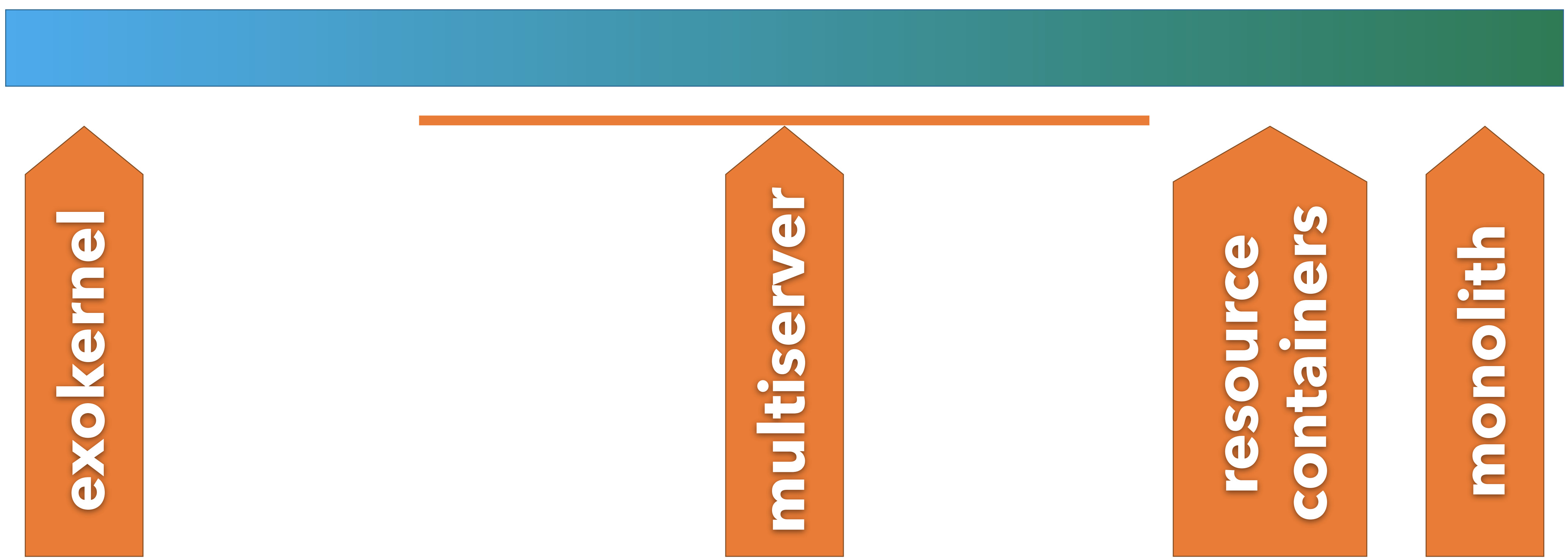
separate **enforcement** and **management**

ARCHITECTURES

SPECTRUM

low-level resource abstractions
explicit management

high-level resource abstractions
implicit management



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MONOLITHS

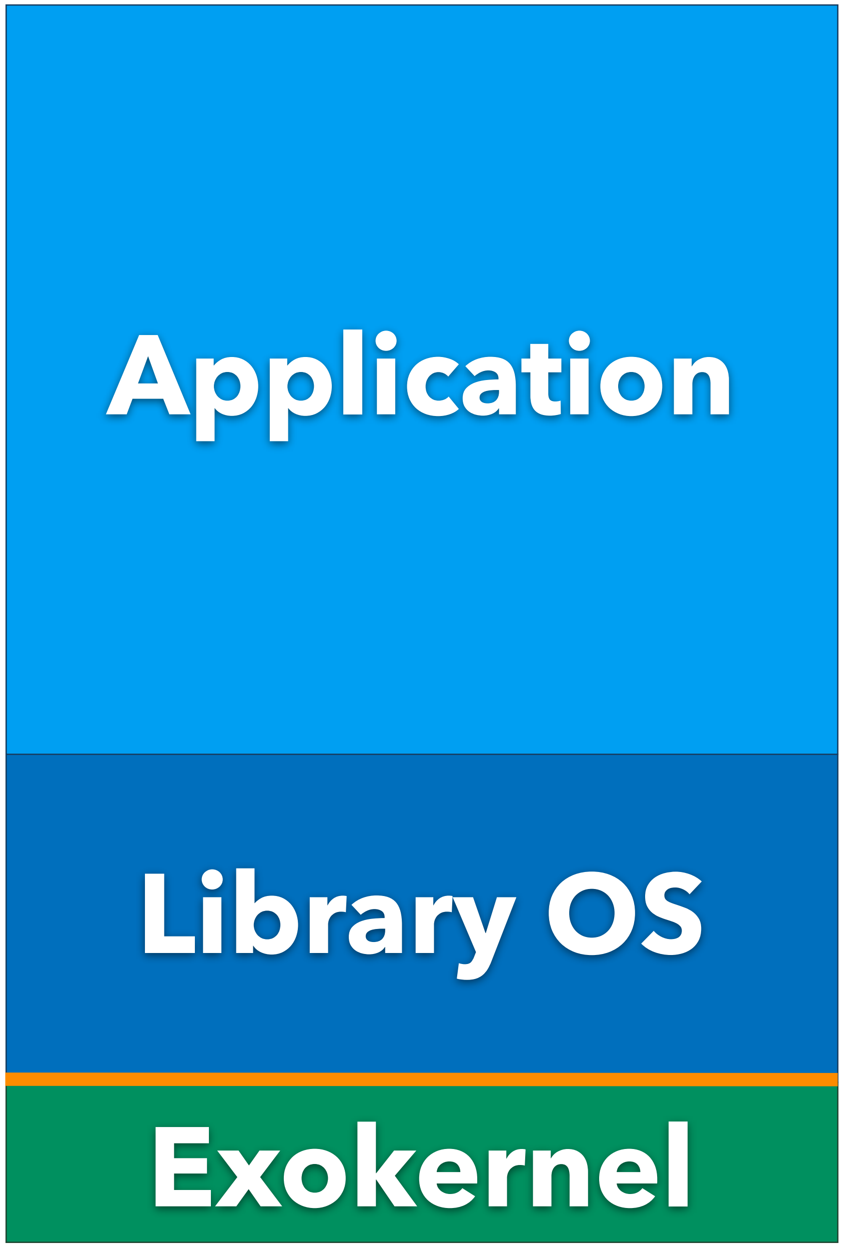
- enforcement and management implicitly tied to process abstraction

- resource containers were proposed to make resource management explicit
- bags of resources assigned to subsystems

EXOKERNEL

Management

Enforcement



DESIGN

- provide primitives at the lowest possible level necessary for protection
- use physical names wherever possible
- resource management primitives:
  - explicit allocation
  - exposed revocation
  - protected sharing
  - ownership tracking

CONSEQUENCES

- applications can use their own library OS
- library OS'es cannot trust each other
- no global management for resources
- think of a file system
  - kernel manages disk block ownership
  - each library OS comes with its own filesystem implementation
- one partition per application?

SHARING

- invariants in shared resources must be maintained
- 4 mechanisms provided by the exokernel
  - software regions for sub-page memory protection, allows to share state
  - capabilities for access control
  - critical sections
  - wakeup predicates: code downloaded into the kernel for arbitrary checks

MULTISERVER

works on monolithic kernels too

LEVELS

different abstraction levels for resources

basic resources	**memory, CPU, IO-ports, interrupts**
hardware	**block device, framebuffer, network card**
compound resources	**file, GUI window, TCP session**

HIERARCHIES

- applications can access resource on the abstraction level they need
- servers implementing a resource can use other, lower-level resources
- isolation allows managers to provide real-time guarantees for their specific resource
- DROPS:
  Dresden Real-time OPerating System

EXAMPLES

ANKH

- driver for physical network card
- built with DDE using Linux 2.6 drivers
- provides multiple virtual network cards
- implements a simple virtual bridge

LWIP

- light-weight IP Stack
- TCP/IP, UDP, ICMP

WGET

- clients can use standard BSD socket interface

BLOCK SERVER

L4Re VFS

Filesystem

Windhoek

- IDE driver to access hard disks
- includes disk request scheduling
- based on DDE
- provides block device
- ongoing work on USB block devices

FILESYSTEM

L4Re VFS

Filesystem

Windhoek

- no real one implemented yet
- we have a tmpfs using RAM as backing store
- VPFS: securely reuse a Linux filesystem

L4RE VFS

L4Re VFS

Filesystem

Windhoek

- hierarchical name space
- connects subtrees to different backend servers
- aka mounting

MAG

- multiplexes the frame buffer
- no virtual desktops, but window merging
- details in the legacy / security lectures

DOPE

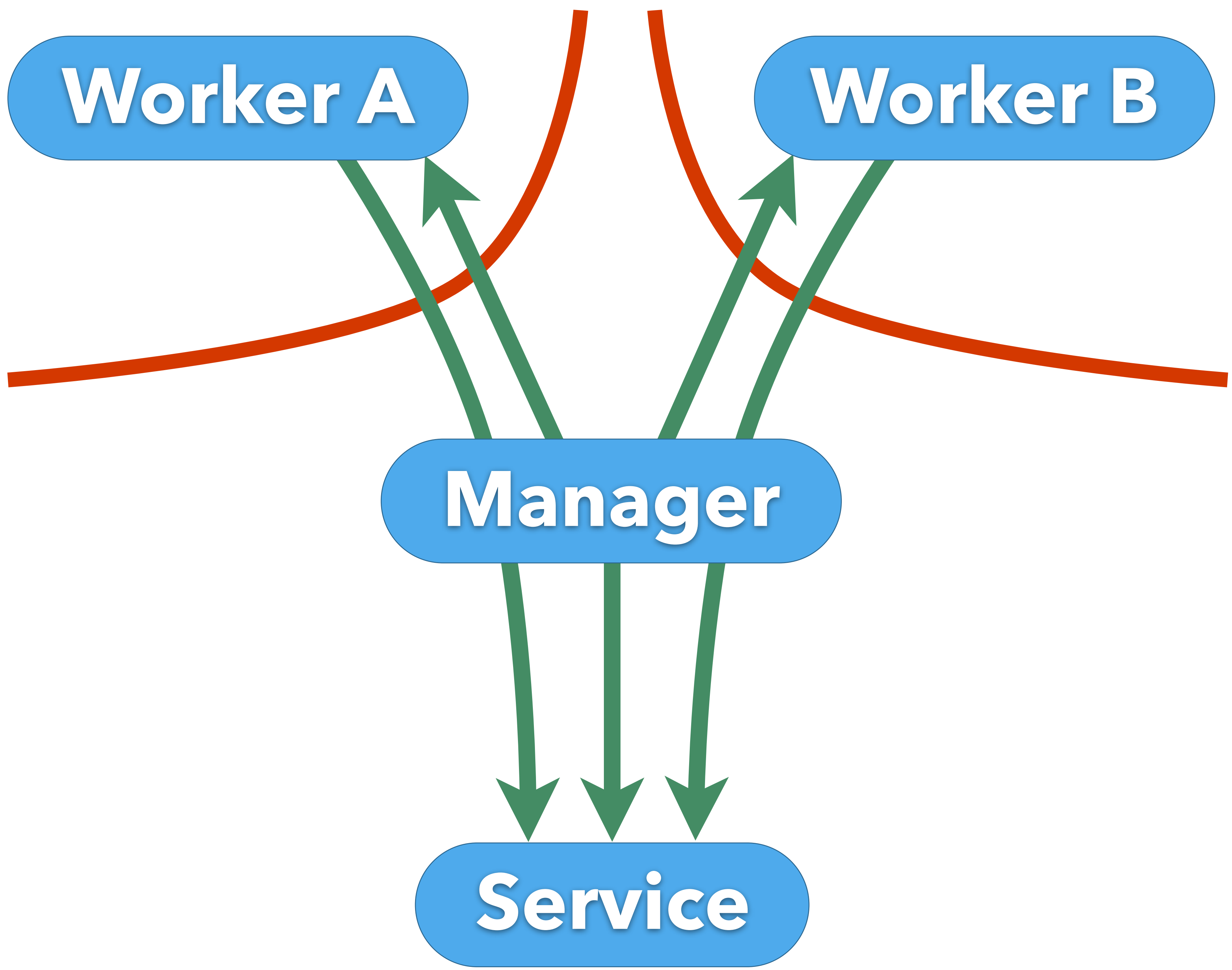
- widget drawing server
- handles mouse and keyboard input
- can also operate on raw framebuffer
- real-time capable

TERMINAL

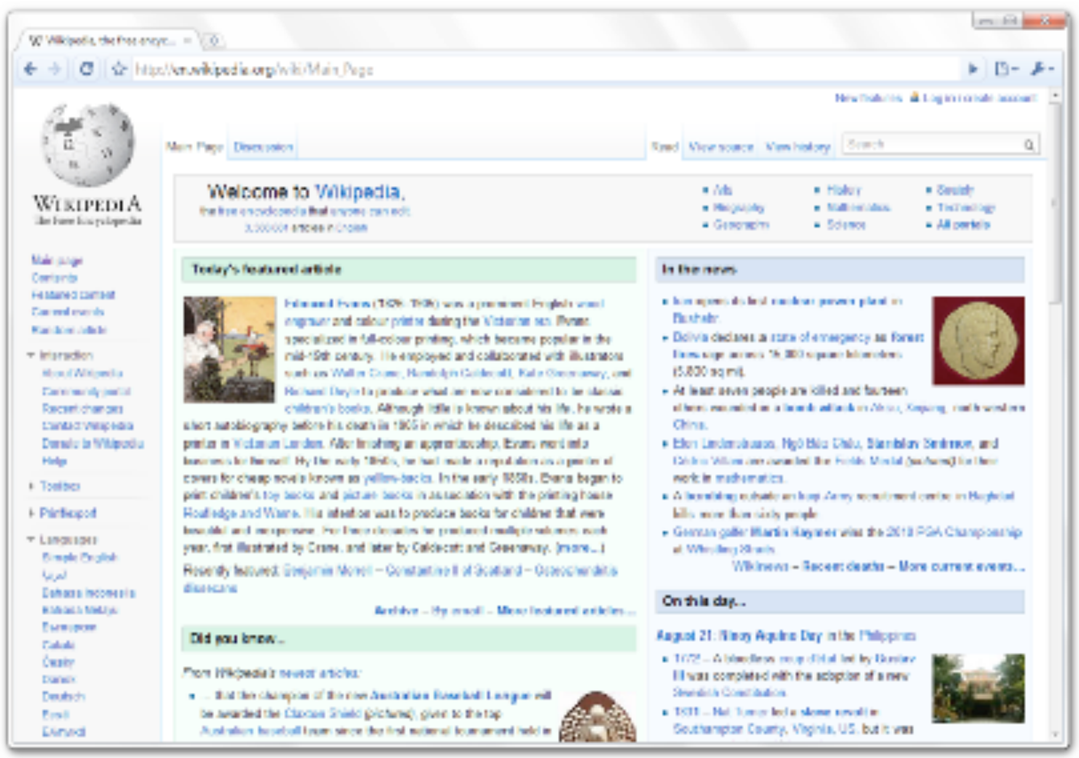
- DOpE client providing a terminal window
- VT100 emulation
- can support readline applications
  - shell
  - python

RESOURCE ACCESS

EXAMPLE



GOOGLE CHROME



- separate processes
  - chrome parent
  - sandboxes for tabs
- implementation on Linux: glorious mix of chroot(), clone() and setuid()
- there must be a better way…

TWO WORLDS

POSIX	POLA
operations allowed by default	nothing allowed by default
some limited restrictions apply	every right must be granted
ambient authority	explicit authority

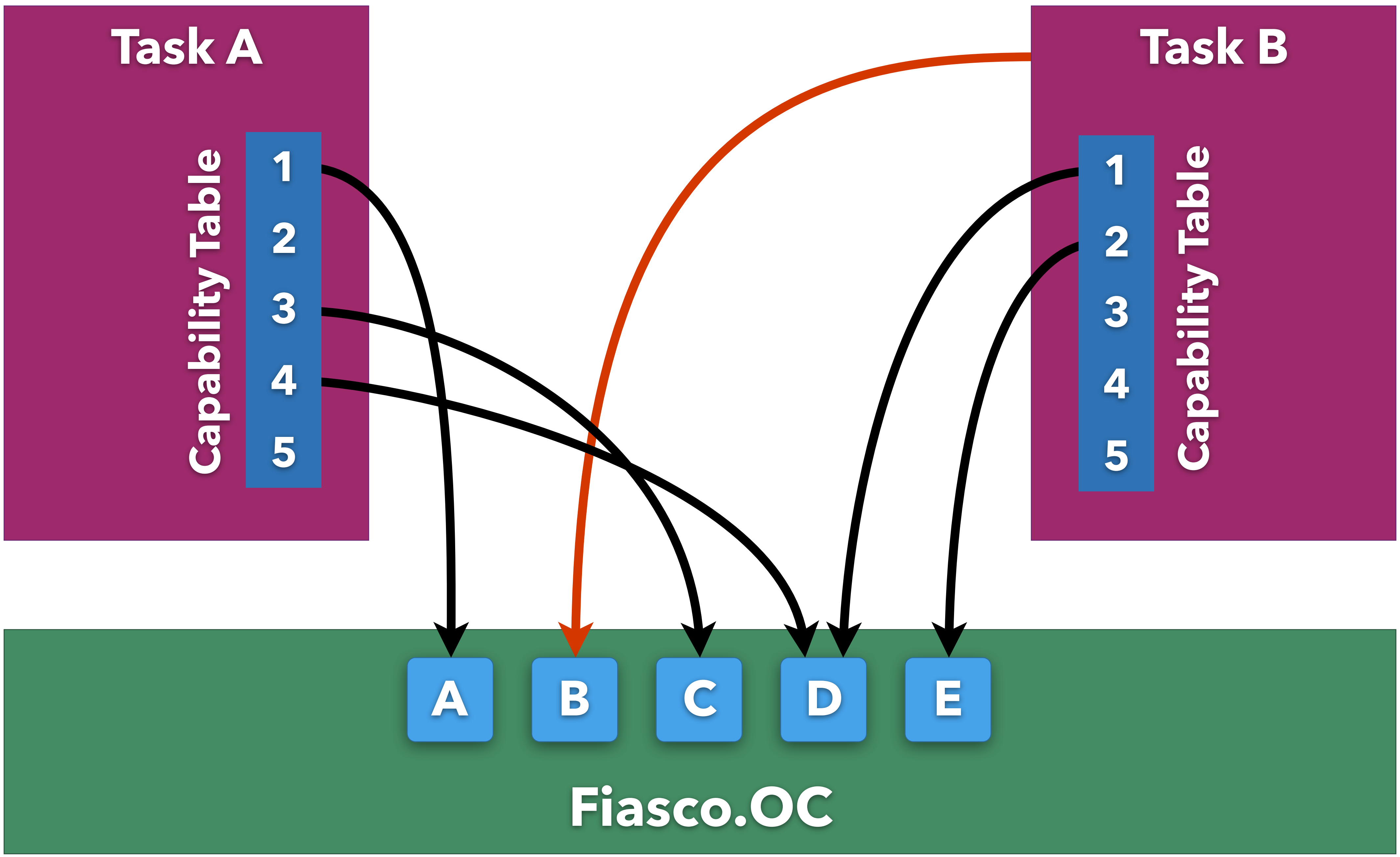
L4Re – the L4 Runtime Environment

set of libraries and system services on top of the Fiasco.OC microkernel

CAPABILITIES

- Fiasco.OC and L4Re form an object-capability system
- actors in the system are objects
  - objects have local state and behavior
- capabilities are references to objects
  - any object interaction requires a capability
  - unseparable and unforgeable combination of reference and access right

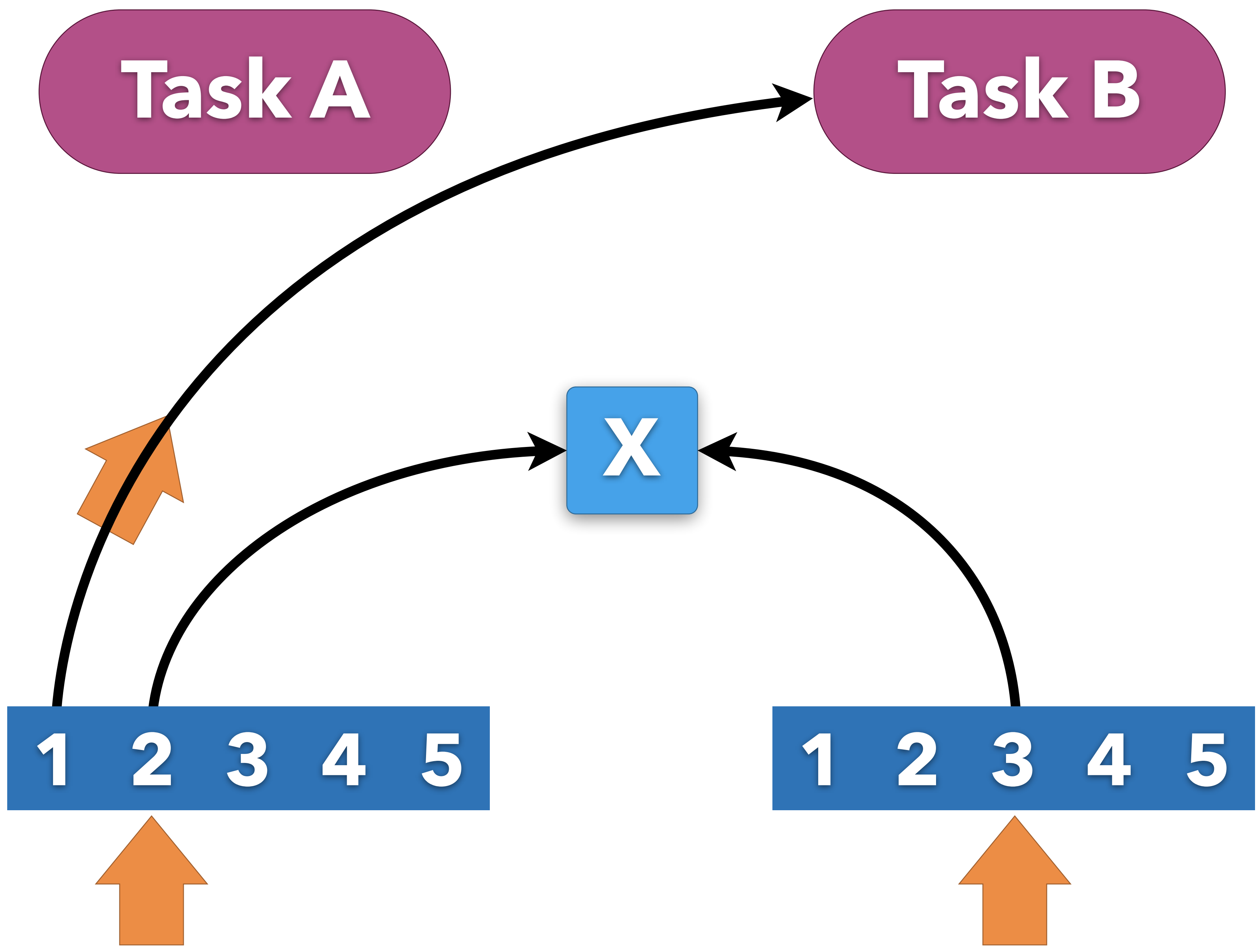
CAPABILITIES



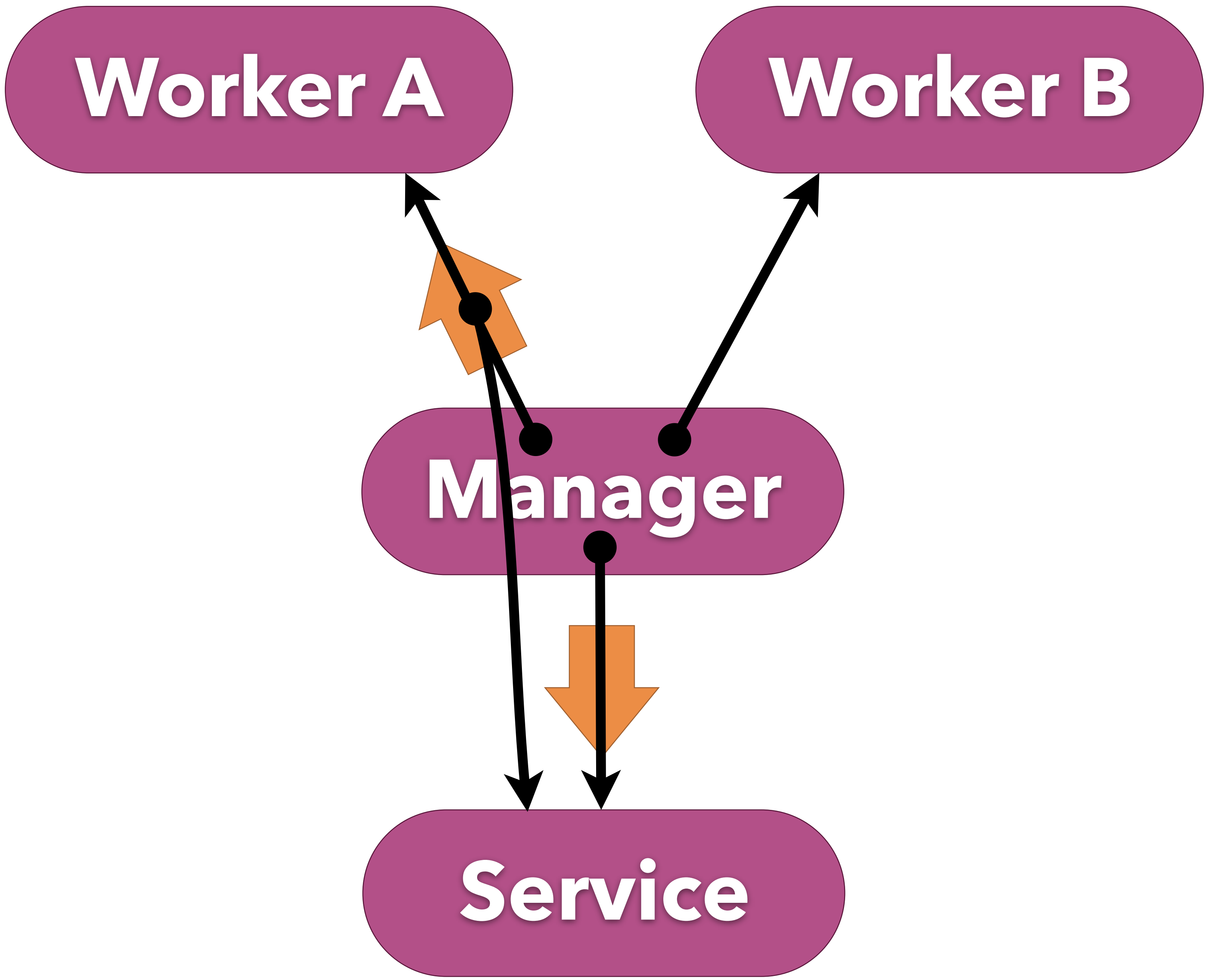
HOW TO USE?

- invocation of any object requires a capability to that object
  - no global names
- no sophisticated rights representation beyond capability ownership
  - just four rights bits on objects
- C++ language integration
- capabilities passed as message payload

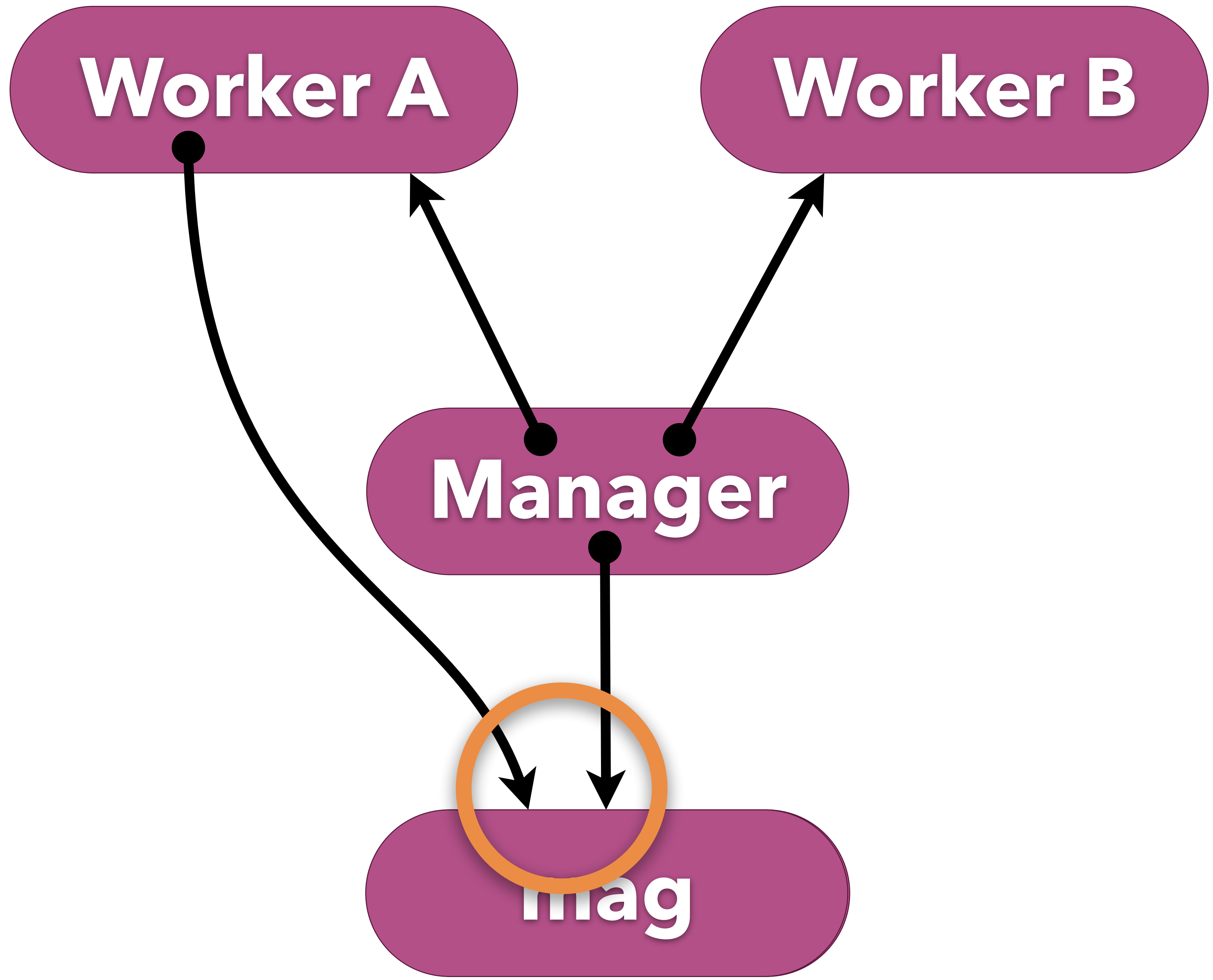
CAP TRANSFER



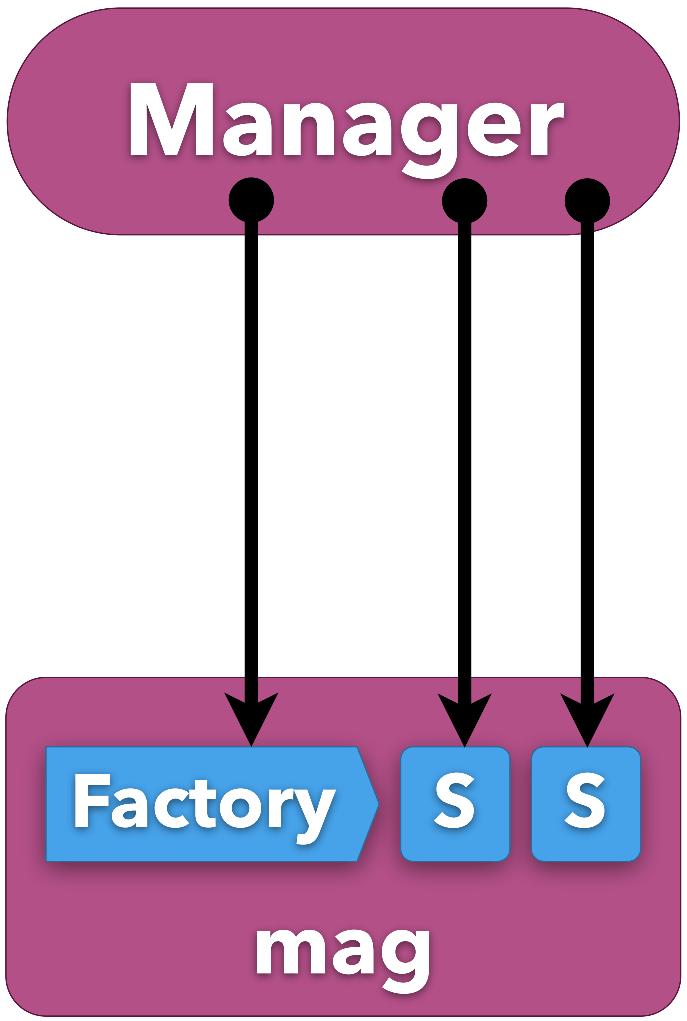
EXAMPLE



EXAMPLE

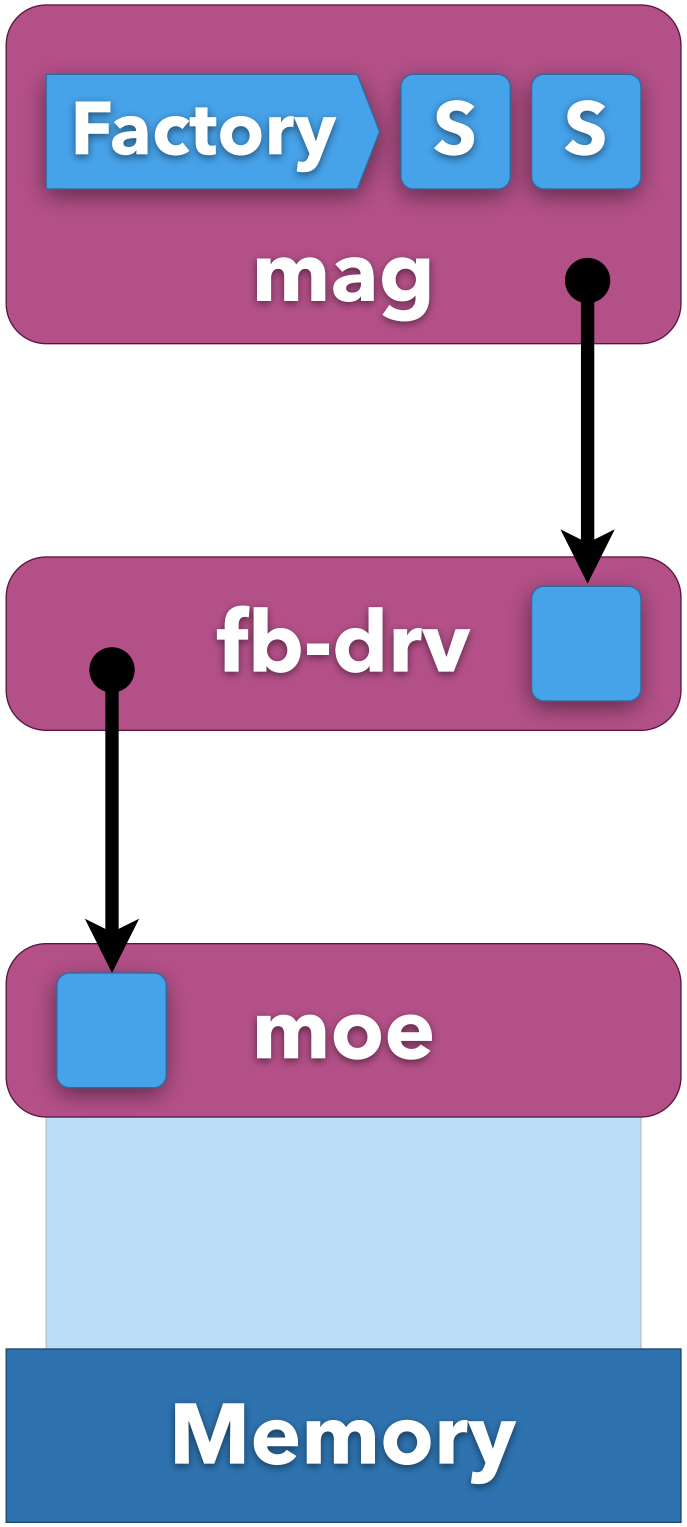


MAG



- factory for new framebuffer sessions
- session object
  - backing store memory
  - view: visible rectangle on the backing store
  - metadata, refresh method
- How does it appear on the screen?

MAG



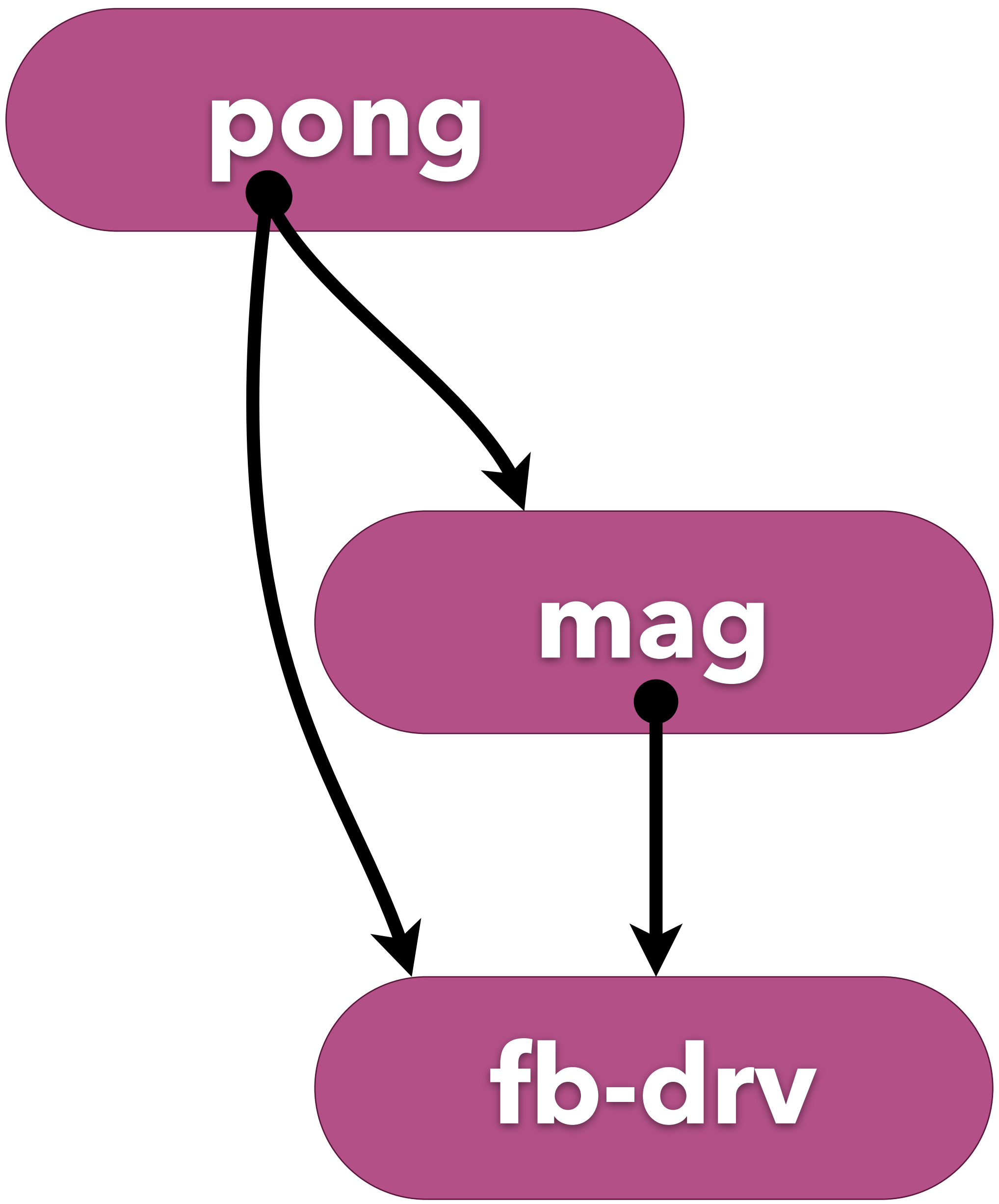
- hardware framebuffer is memory with side effect
- all memory is initially mapped to the root task
- **framebuffer driver**
  - find framebuffer memory
  - wrap in FB-interface
- same interface as mag's

INTERFACES

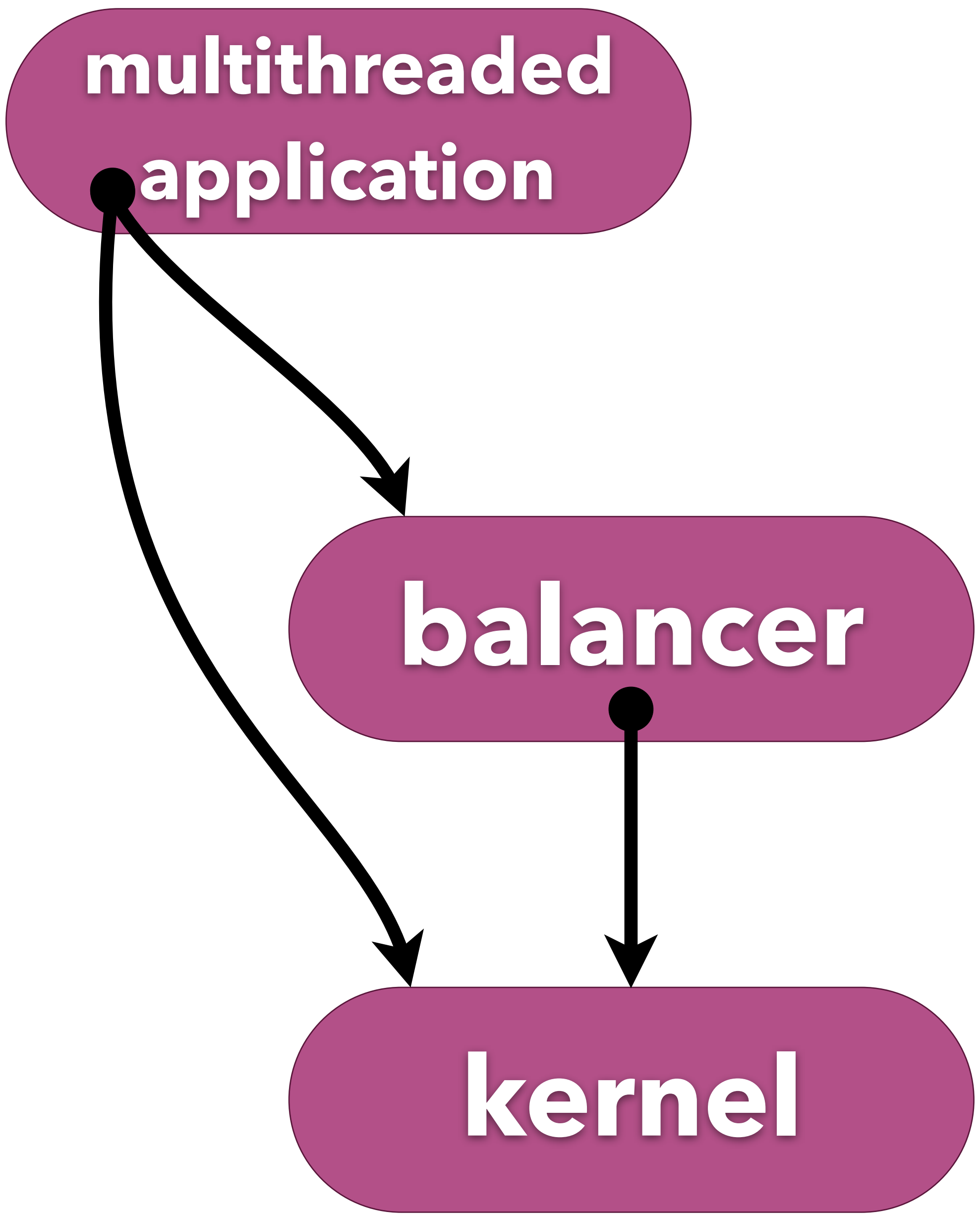
- **virtualizable interfaces**
- L4Re uses one interface per resource
  - independent of the implementation
  - servers can (re-)implement any interface
- the kernel is a special server: provides low-level objects that need CPU privileges
  - minimal policy
  - userland servers can augment

EXAMPLES

Graphics



Thread scheduling



CONCLUSION

- all services provided as objects
- uniform access control with capabilities
- invocation is the only system call
- virtualizable: all interfaces can be interposed
- resource refinement and multiplexing transparent to clients

SUMMARY

- kernel resource management
- basic resource management concepts
  - resource containers
  - exokernel
  - multiserver
- management details for specific resources
- object capabilities and virtualizable interfaces