

Microkernel Construction

Capabilities

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- Introduction
 - Global Names
 - ACL
- Capabilities in General
- Capabilities in NOVA

- How do you find/access resources?
- How do you restrict access to resources?

- One global namespace for (one type of) resources
- Example: semaphores, processes, devices, ... on UNIX

Pros & Cons

- + Simple
- Name clashes: people need to agree on names.
- What if a malicious process registers a name first?
- All resources are visible: just try to access them

- Attach a list of permissions (subjects) to each object
- Permission depends on who you are, not what you have

Pros & Cons

- + No need to give permissions explicitly
- + Makes it easy to restrict access to specific objects
- Makes it hard to restrict specific subjects
- POLA is more difficult to achieve
- Requires global names
- Confused deputy problem

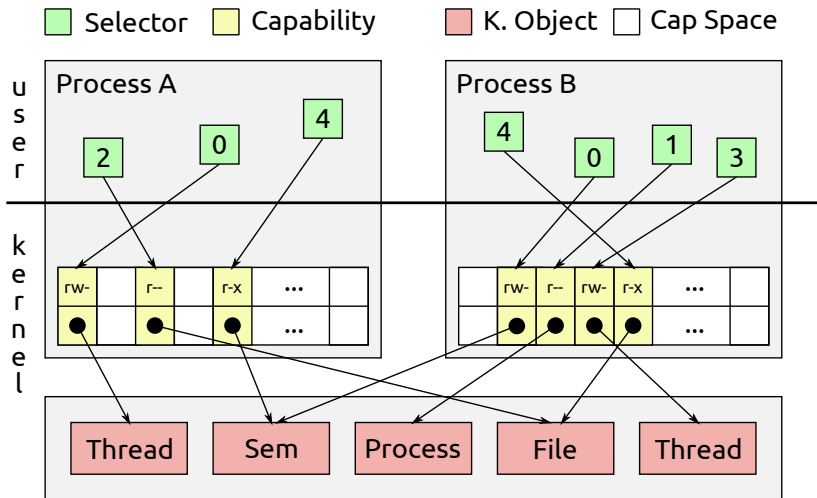
- Introduction
- Capabilities in General
 - Overview
 - Operations
- Capabilities in NOVA

- Give each subject a local namespace
- Operations to exchange objects between namespaces
- Permission depends on what you have

Pros & Cons

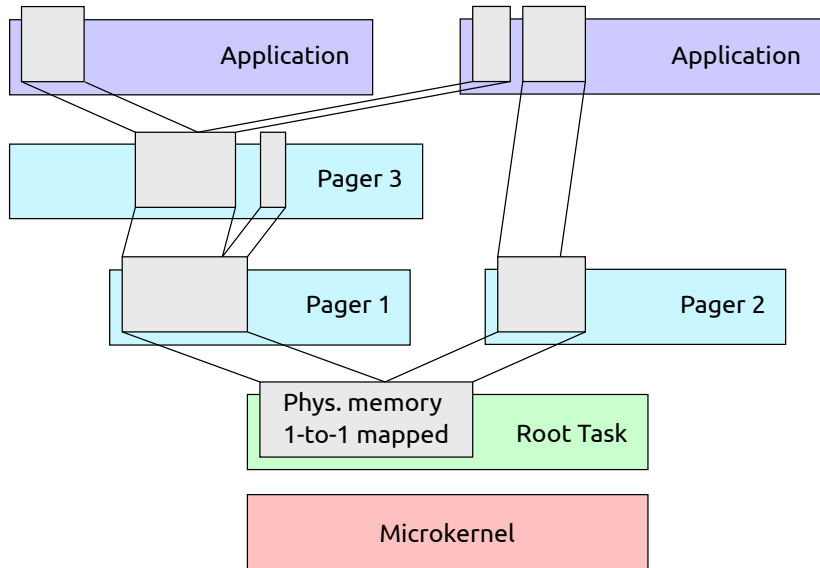
- + Makes it easy to restrict specific subjects
- + Separation of subsystems, composable, independent
- + POLA is easy to achieve
- Need to give permissions explicitly
- Exchanging, especially revoking, capabilities is difficult

Overview



- Map/delegate:
 - Copy capability from one Cap Space to the other
- Grant:
 - Move capability from one Cap Space to the other
- Revoke:
 - Remove capability, recursively
- Lookup:
 - Search capability by selector and return its permissions
- Translate:
 - Translate selector from one Cap Space to the other

Hierarchical Organization



- Introduction
- Capabilities in General
- Capabilities in NOVA
 - Capability Spaces
 - Mapping Database
 - Delegate, Translate and Revoke
 - Data Types
 - Receive Windows

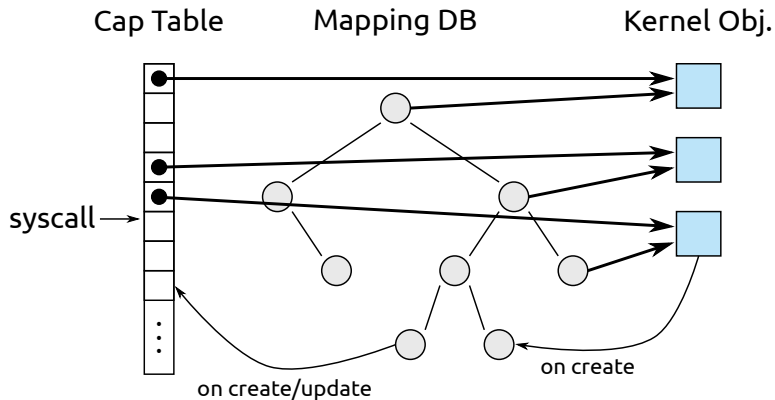
Each protection domain (Pd) has

- Space_obj: object capabilities
- Space_mem: memory capabilities (pages)
- Space_pio: I/O port capabilities

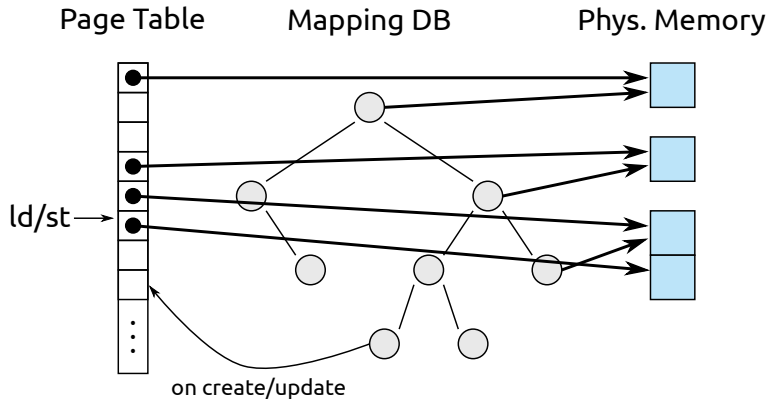
Similarities and differences

- Shared: capability delegation, revocation, ...
- Differences:
 - Object caps are created and used via system calls
 - Port and memory caps are referring to existing resources
 - Passed to root task, distributed in the system via delegation
 - Memory capabilities lead to page table entries
 - Port capabilities lead to bits set in the I/O bitmap

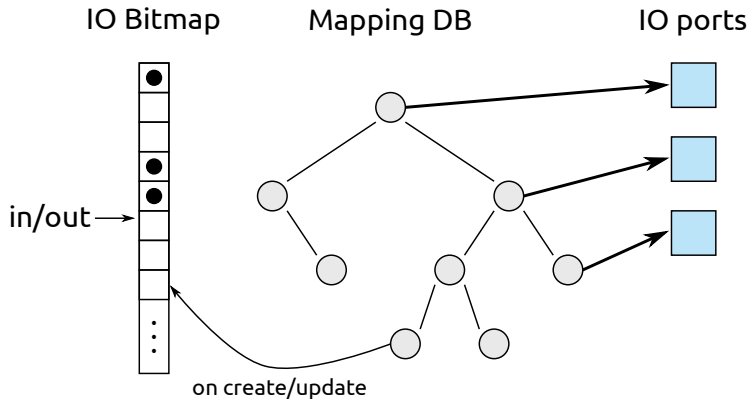
Object Capability Space

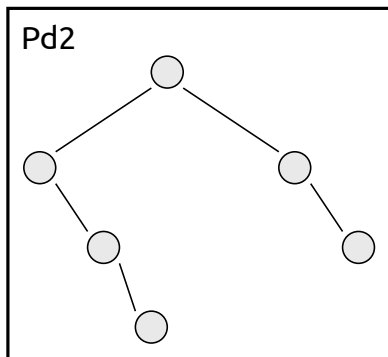
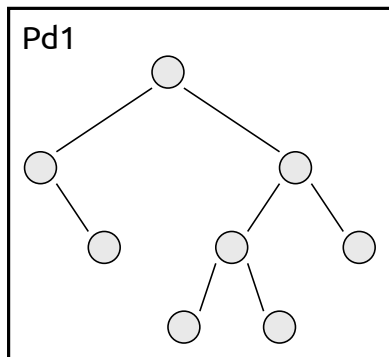


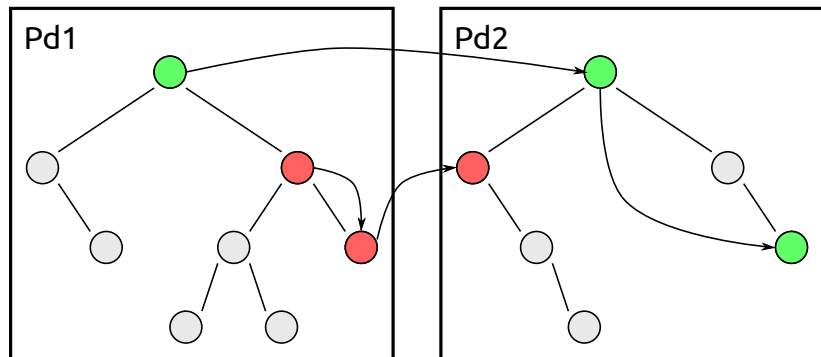
Memory Capability Space



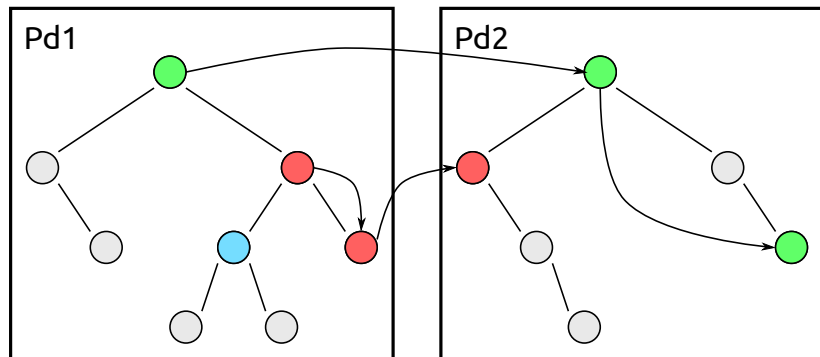
I/O Capability Space



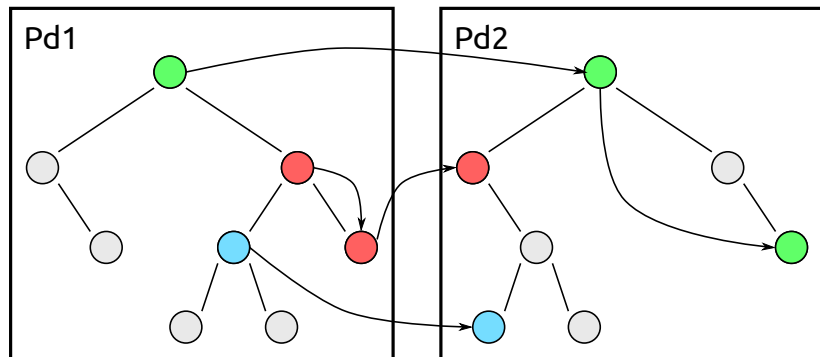




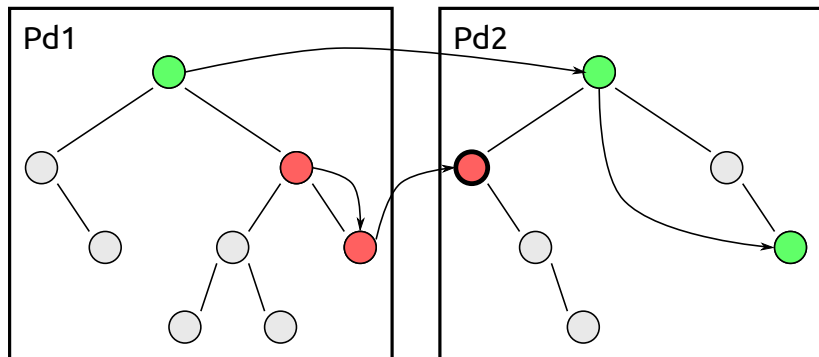
Mapping Database – Delegate



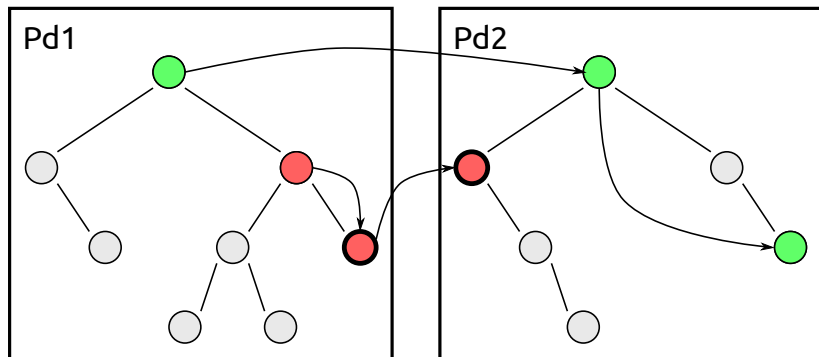
Mapping Database – Delegate



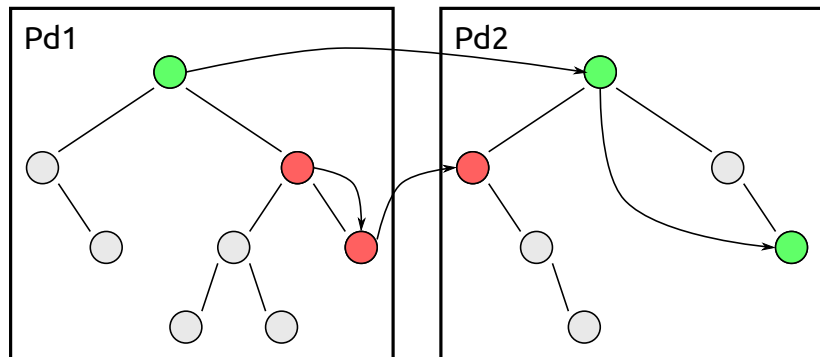
Mapping Database – Translate



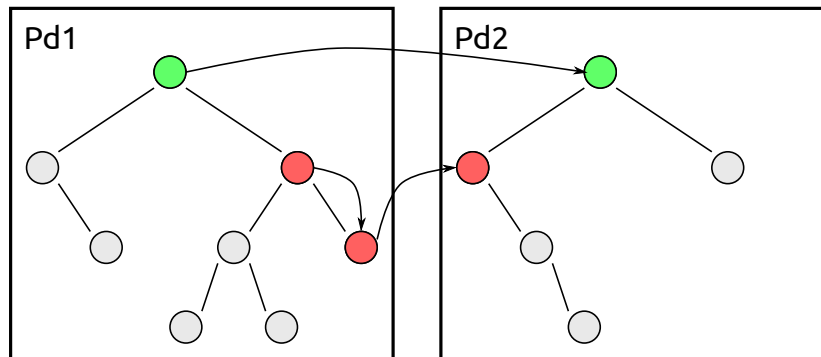
Mapping Database – Translate



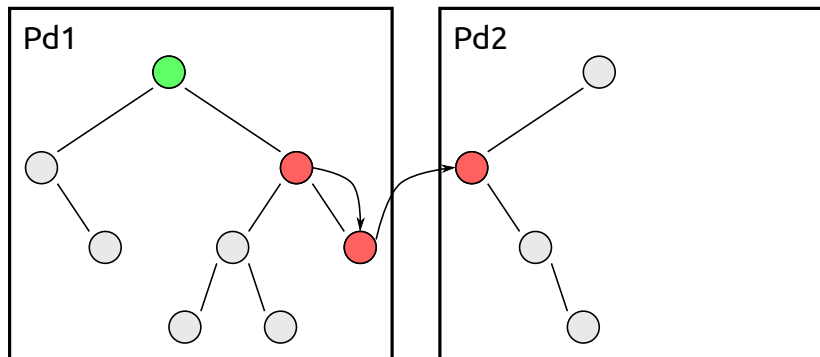
Mapping Database – Revoke



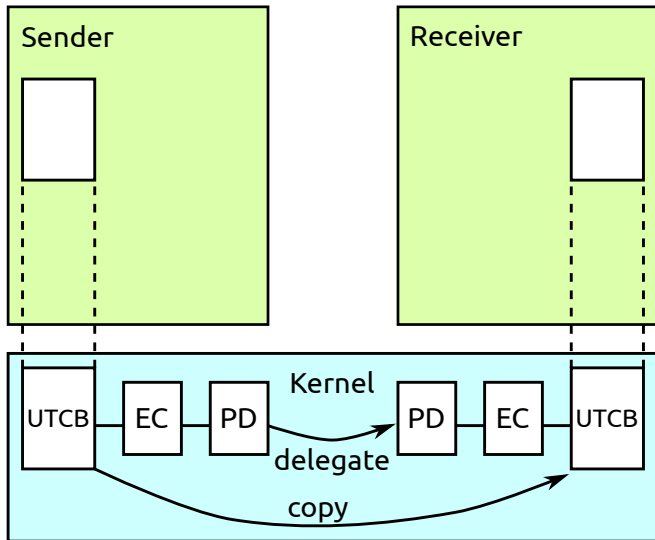
Mapping Database – Revoke



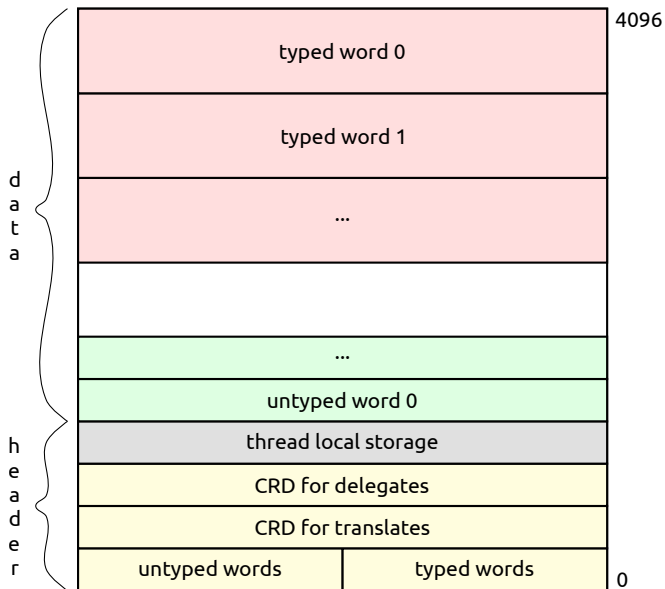
Mapping Database – Revoke



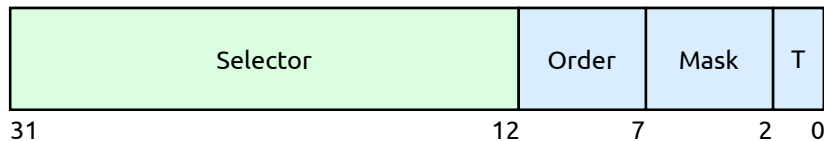
IPC with Delegate



UTCB Layout



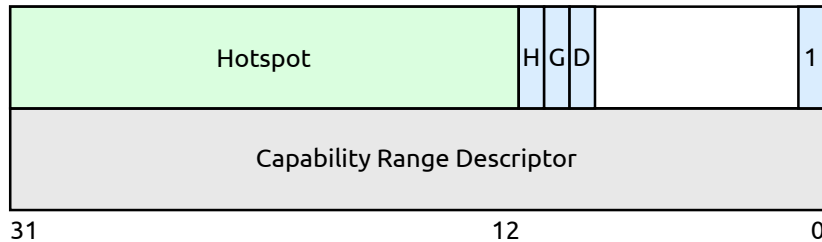
Capability Range Descriptor



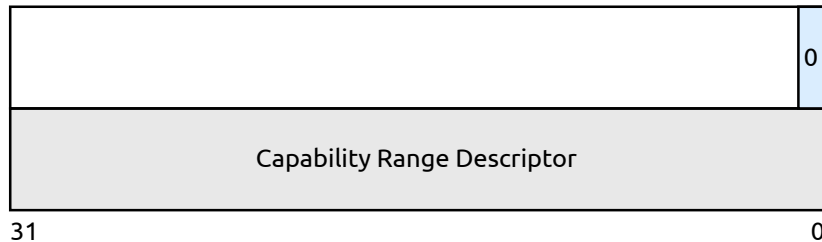
- Order specifies the number of capabilities (2^{order})
- Selector specifies the first capability
- Selector has to be size aligned, i.e., a multiple of 2^{order}
- **wrong:** order=2, selector=6, okay: order=2, selector=8
- Mask allows to reduce permissions
- T specifies capability space (objects, memory, I/O)

Typed Words

Delegate:



Translate:



- Receiver sets up receive window (writes CRD into UTCB)
- Receiver waits for IPC
- Sender puts typed item into UTCB
- Sender calls portal
- Kernel delegates typed item
- Kernel puts typed item into UTCB, telling receiver about caps
- Kernel switches to receiver
- But: what if receive window and sent caps don't match?

Matching Send and Receive Window (1)

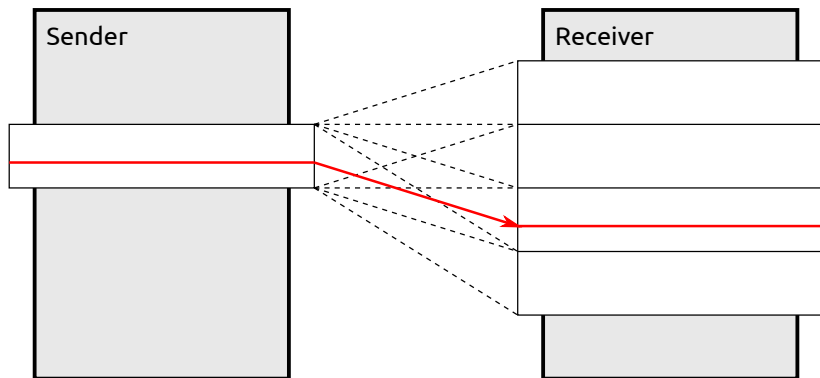


Figure: Send window is smaller than receive window

Matching Send and Receive Window (2)

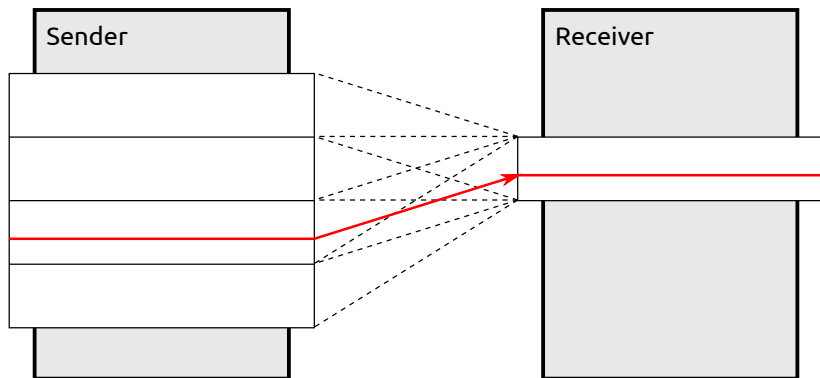


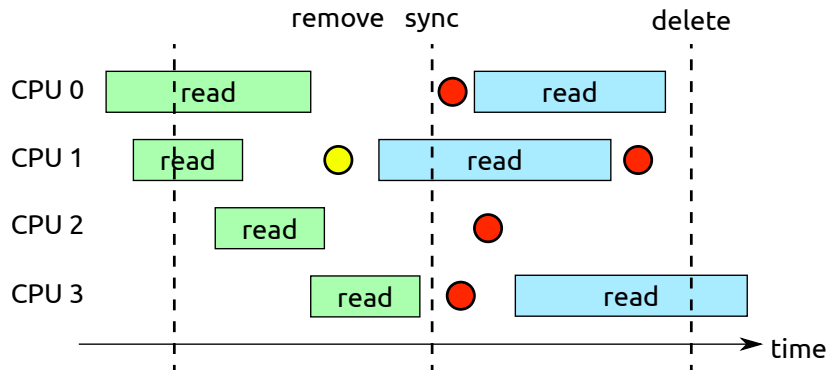
Figure: Send window is larger than receive window

Deleting Mapping DB Nodes and Kernel Objects

- When revoking, kernel objects should be destructed
- But what if somebody accesses them at the same time?
- We could lock them during each access
- But this is expensive
- We don't care that much when exactly they are destructed
- Can't we destruct them if nobody accesses them anymore?

- Basically: copy-on-write with lazy delete
- Don't change objects, but copy them and change the copy
- Don't delete objects immediately, but when readers are done
- In case of NOVA: no copy-on-write, but only lazy delete
- On revoke, object is removed first
- Then, the object is registered for deletion
- Timer IRQ is used to delete only if all readers are gone

RCU Grace Period



- 29th June: M3
- 7th July: L4Re
- 13th July: Escape