

EXERCISE 2: IPC

Inter-Process Communication

Nils Asmussen

Dresden, 12/19/2023

Recap

- Inter-Process Communication
 - Send
 - Wait (open/closed)
 - Call: Send + closed Wait
 - Reply and Wait
- Message Payload
 - Plain data : copy
 - Capabilities (memory, kernel objects) : map
- Sync / Async
 - Sync: Rendezvous, direct copy sender → receiver
 - Async: Queues, buffers, fire and forget

The Plan

- Echo server
 - Send a string to a local echo server
 - Return the message to the caller
- Capability Delegation
 - Create your own echo server (Endpoint + Thread) and send a capability for this server to another thread
- Client-Server
 - Connection and Session management, server registers a service, client looks it up

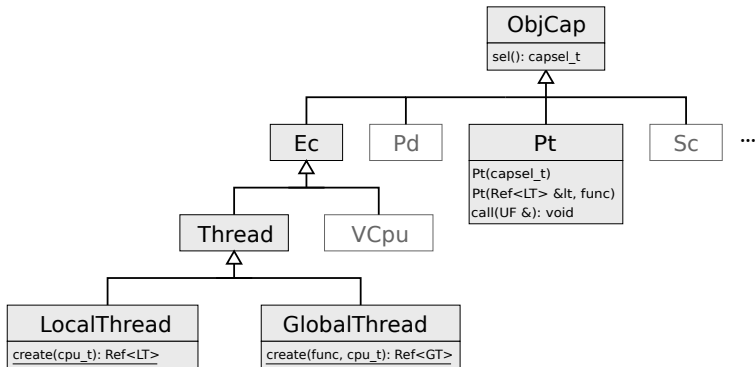
Setup

- Download the source archive from `http://os.inf.tu-dresden.de/~nils/nova-nre.tar.gz`
- `tar xzf nova-nre.tar.gz`
- `cd cross && ./download.sh x86_64 (XOR ./build.sh)`
- Choose host platform (Ubuntu 18.04 x86_64)
- `cd ../nre (your working directory)`
- Build via: `./b`
- Build and run via: `./b qemu boot/echo`
- `<DIR>/nre/apps: echo, delegate, client, server`
- `<DIR>/nre/include: headers, e.g. UtcbFrame.h`

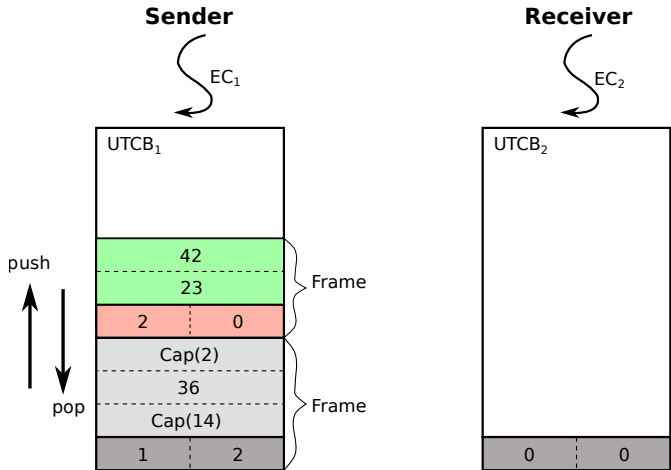
NOVA Abstractions

- Thread / Execution Context (EC)
 - Unit of execution, thread or virtual machine
- Portal (PT)
 - Communication endpoint
 - Messages (data, capabilities) are sent to portals
 - Bound thread receives the messages
- Local Threads (services)
 - Wait/block in portals until get invoked/called
 - Return to the portal after request completion
- Global Threads
 - Run on their own

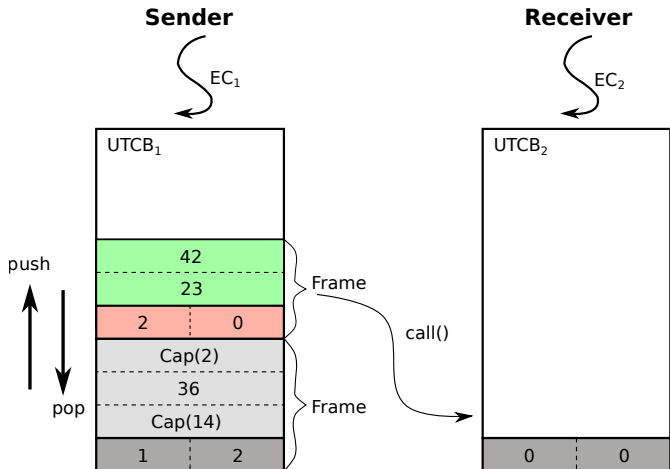
NRE Capability Hierarchy



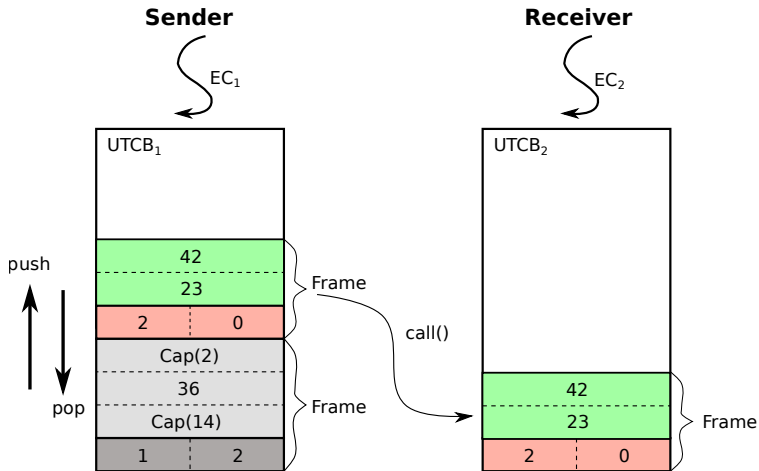
NRE UTCB Frames



NRE UTCB Frames



NRE UTCB Frames



NRE UTCB Usage

- Data accessed via stream operators:
 - read: `UtcbFrame >> value;`
 - write: `UtcbFrame << value;`
- `UtcbFrame::finish_input()`
 - Only required when reading AND writing
 - Needs to be done if reading is finished
- `UtcbFrame` constructor pushes a new frame on the UTCB, the destructor pops it again

Usage example

```
UtcbFrameRef uf;    // UTCB frame
uf >> x;            // read argument
uf.finish_input(); // end of input
uf << 2 * x;        // write result back
```

Service "Loop"

Fiasco.OC/L4Re Style

```
for(; receive(&utcb); reply(utcb)) {  
    process_message(utcb);  
    generate_reply(&utcb);  
}
```

- Receive: waits for incoming message which is copied into receiver's UTCB
- Handle message and generate reply
- Reply: copy reply into caller's UTCB and await next message

Service "Loop"

NOVA/NRE Style

```
PORTAL void portal_function() {  
    process_message(utcb);  
    generate_reply(&utcb);  
}
```

- Receive: waits for incoming message which is copied into receiver's UTCB
- Handle message and generate reply
- Reply: copy reply into caller's UTCB and await next message

1. Echo server (apps/echo)

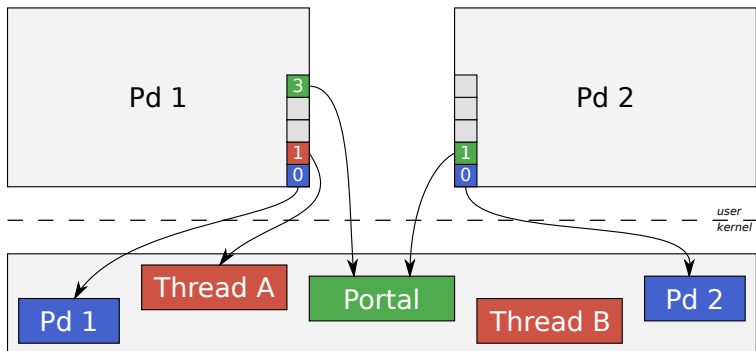
```
// create a new thread
Reference<LocalThread> lt = LocalThread::create(
    CPU::current().log_id());
// create a new portal for this thread
// Pt::Pt(const Reference<LocalThread>&, func_ptr);
Pt echo(lt, portal_echo);

{
    UtcbFrame uf;    // new UTCB frame
    uf << 42;        // fill in argument
    echo.call(uf);  // call server
    int res;
    uf >> res;      // read result
}
```

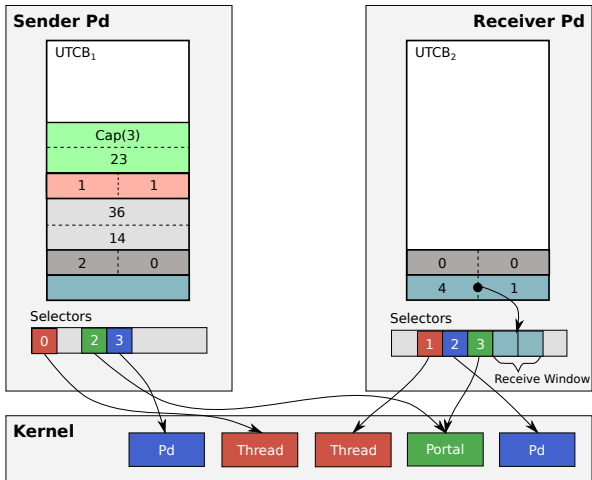
1. Echo server (apps/echo)

- Implement service functionality
- Read argument, send it back to the caller
- Improvement: send two numbers a and b , send back $a+b$ / $a-b$ / $a*b$ / a/b ...

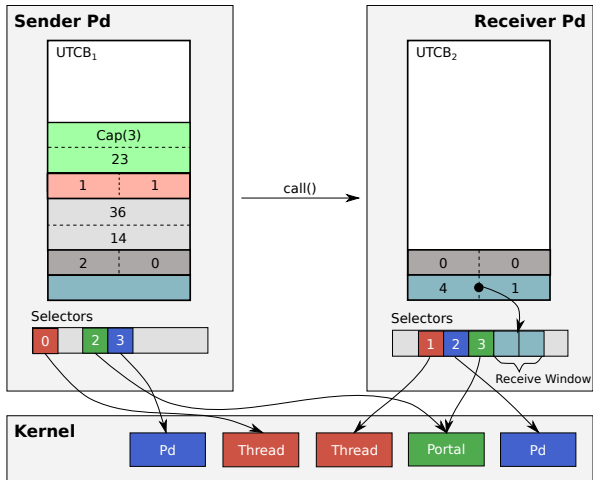
Capability Space



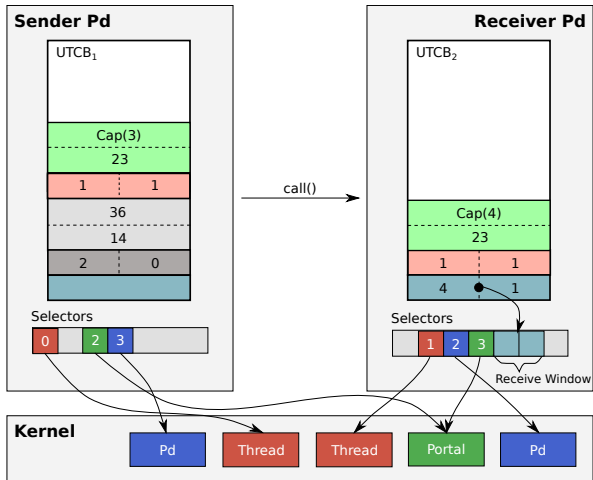
Capability Delegation over IPC



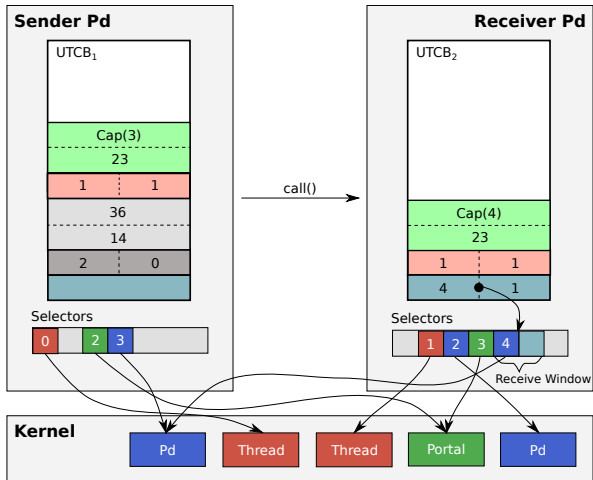
Capability Delegation over IPC



Capability Delegation over IPC



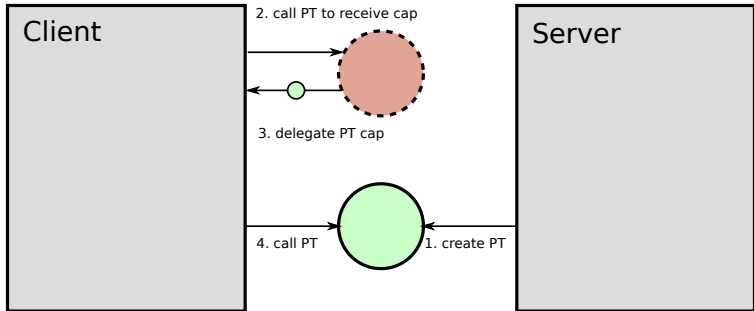
Capability Delegation over IPC



Capability Range Descriptor (Crd)

- Capabilities exchanged via:
 - send: `UtcBFrame::delegate(cap);`
 - receive: `UtcBFrame::delegation_window(Crd);`
- Denote caps via Crd: type, offset and size
- power-of-two sized, size-aligned, e.g:
 - Offset 0, size = 1 → cap index 0
 - Offset 0, size = 2 → cap index 0-1
 - Offset 8, size = 4 → cap index 8-11
 - Offset 16, size = 32 → illegal, misaligned

2. Delegation (apps/delegate)



2. Delegation (apps/delegate)

```
// allocate/reserve num cap space indices
CapSelSpace &CapSelSpace::get();
capsel_t CapSelSpace::allocate(uint num);

// open receive window for new caps
// see include/Desc.h for Crd details
Crd::crd(start, order, Crd::OBJ_ALL);
UtcbFrame::delegation_window(Crd crd);

// cap delegation: add cap to UTCB for sending
UtcbFrame::delegate(capsel_t sel);

// invoke portal, thereby receiving cap(s)
Pt::call(UtcbFrame &uf);

// create portal, bound to <sel>
Pt::Pt(capsel_t sel);
```

3. Client/Server

```
// SERVER
PORTAL static void echo_func(void*) {
    // ... service implementation
}

int main() {
    Service *s = new Service("echo",
        CPUSet(CPUSet::ALL), echo_func);
    s->start();
}

// CLIENT
int main() {
    PtClientSession sess("echo");
    UtcbFrame uf;
    sess.pt().call(uf);
}
```