

# **EXERCISE 2: IPC**

## **Inter-Process Communication**

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# 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

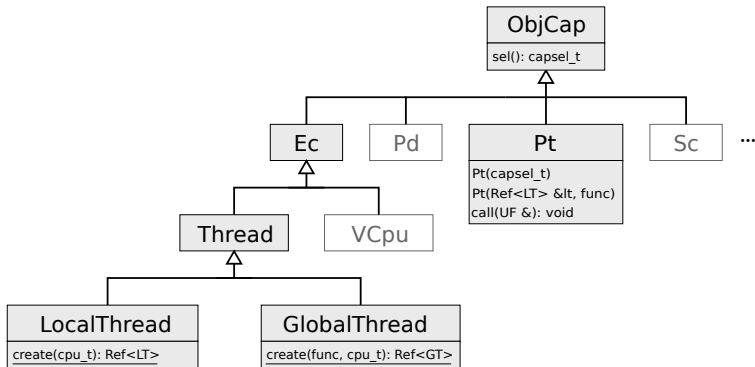
# Setup

- Download the source archive from `http://os.inf.tu-dresden.de/~nils/nova-nre.tar.gz`
- `tar xfz 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`

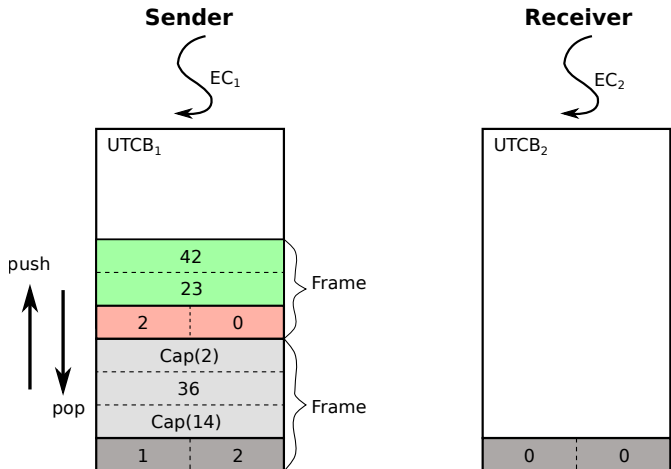
# NOVA Abstractions

- 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

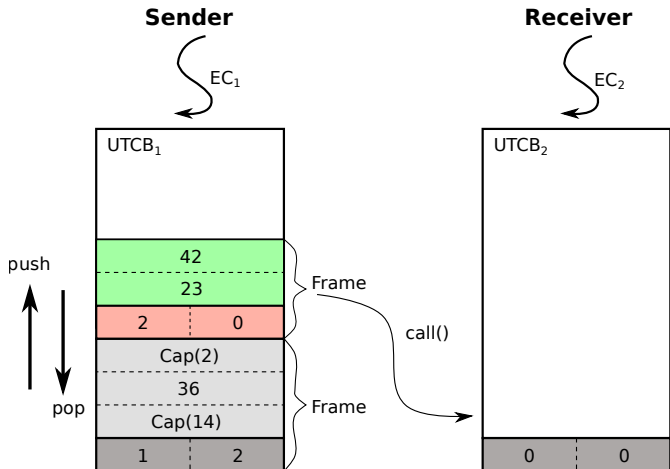
# NRE Capability Hierarchy



## NRE UTCB Frames

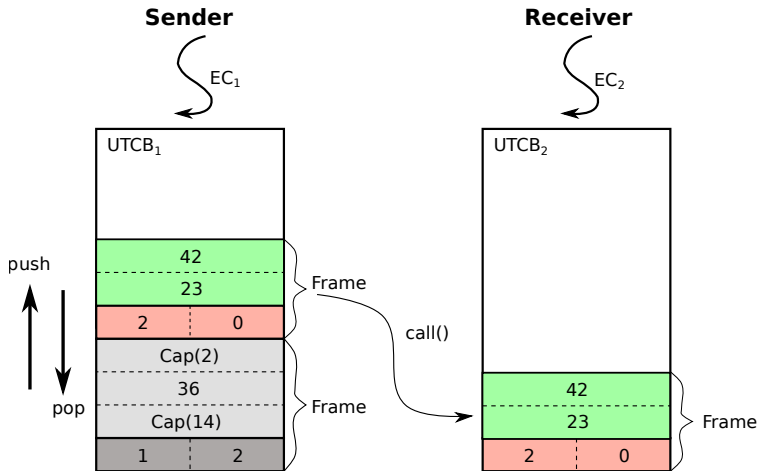


## NRE UTCB Frames





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## 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)

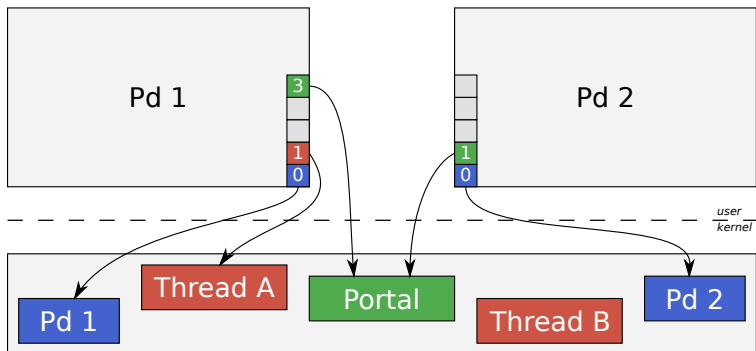
```
// create a new thread
Reference<LocalThread> lt = LocalThread::create(
    CPU::current().log_id());
// create a new portal for this thread
// Pt::Pt(const Reference<LocalThread>&, func_ptr);
Pt echo(lt, portal_echo);

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

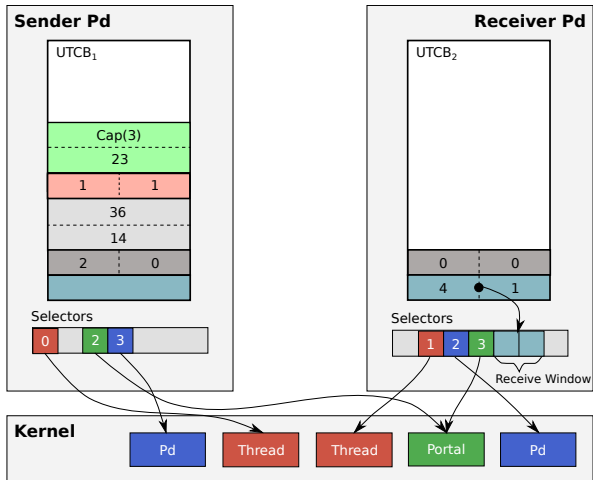
# 1. Echo server (apps/echo)

- 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

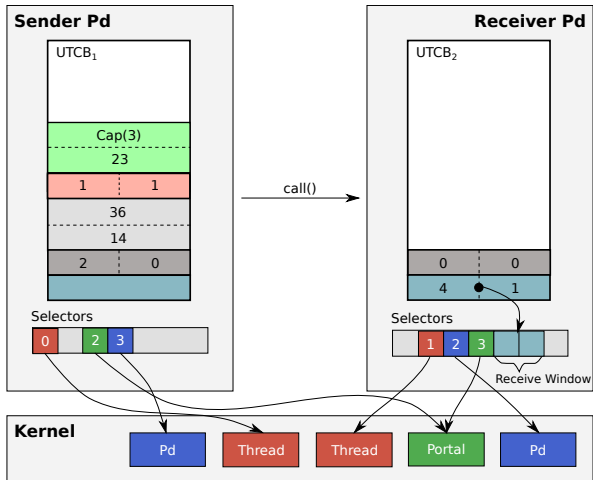


# Capability Delegation over IPC

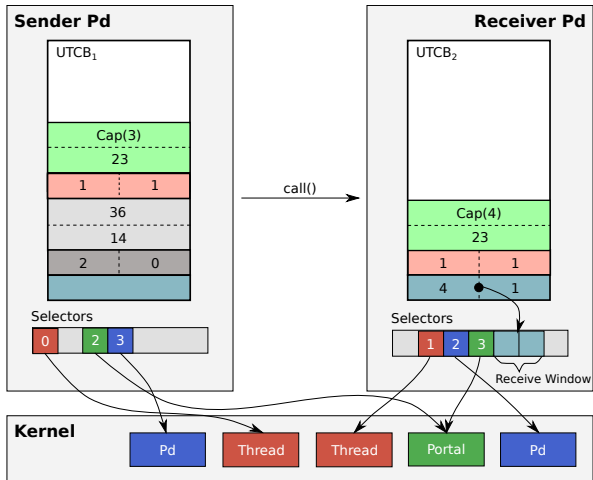




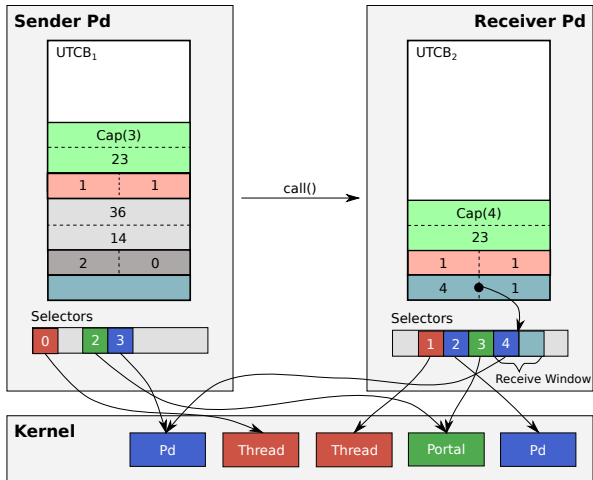
# Capability Delegation over IPC



# Capability Delegation over IPC



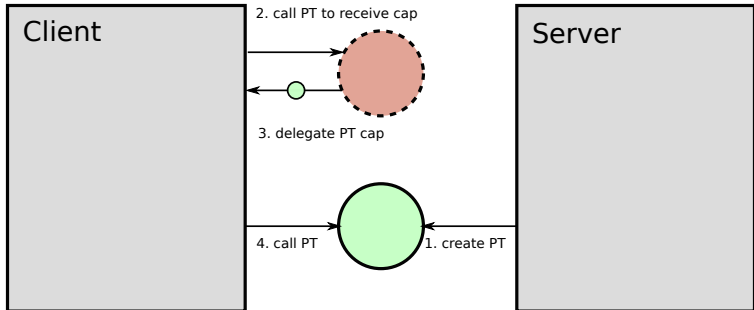
# Capability Delegation over IPC



## 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)



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

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

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

// 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);
}
```