COS 318: Operating Systems

Message Passing

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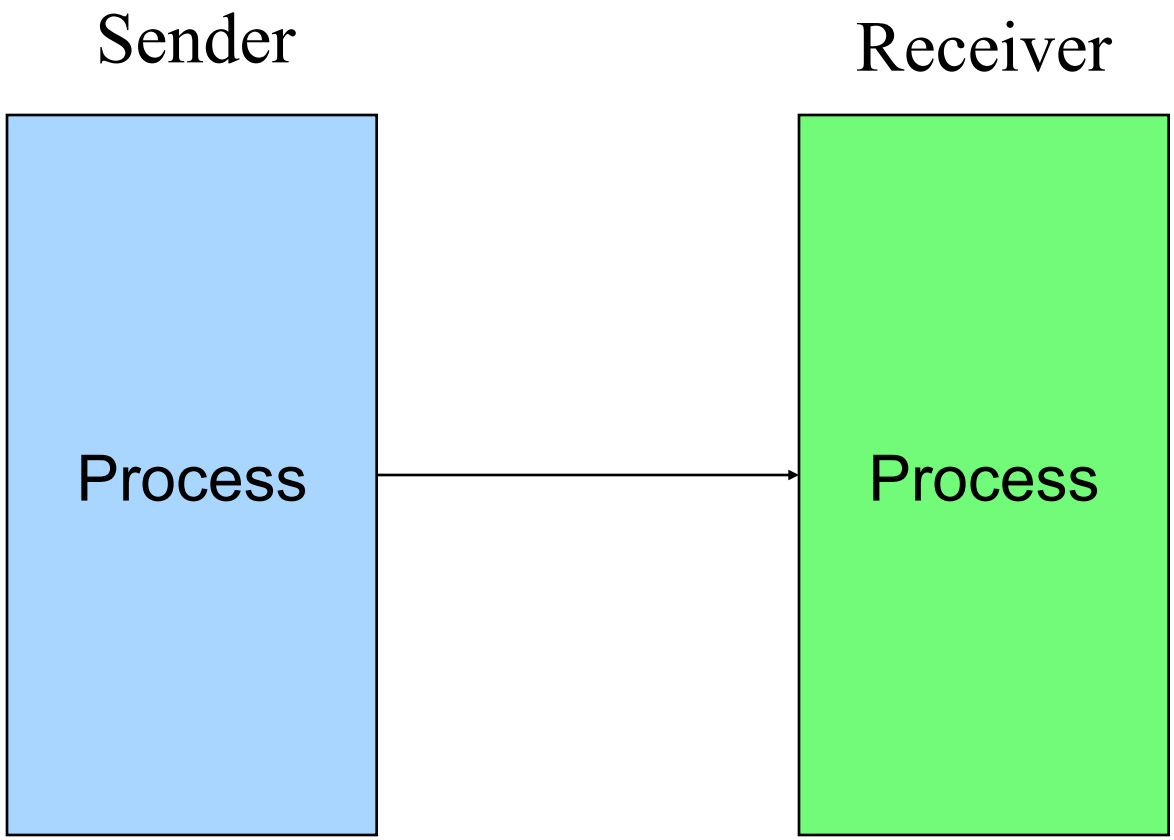
(http://www.cs.princeton.edu/courses/cos318/)

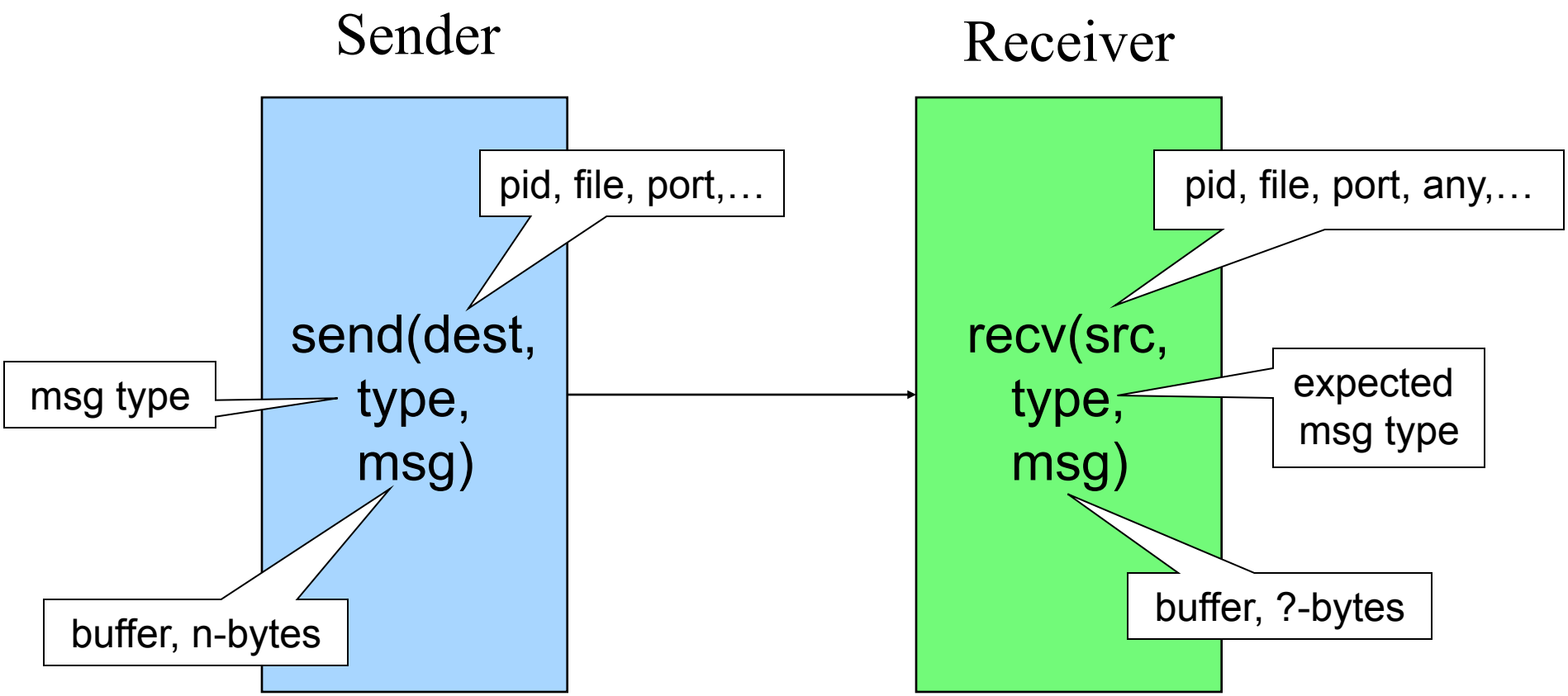
Today's Topics

- Message passing
  - Semantics
  - How to use
- Implementation issues
  - Synchronous vs. asynchronous
  - Buffering
  - Indirection
  - Exceptions

Big Picture



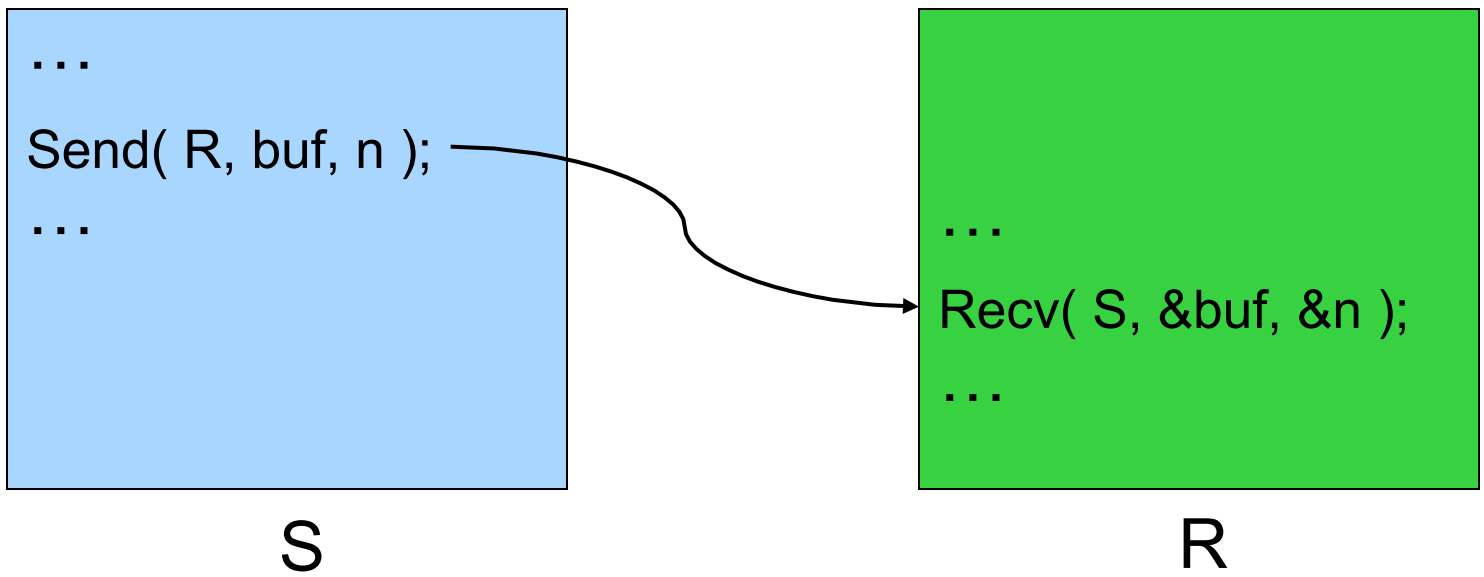
Send and Receive Primitives



Many ways to design the message passing API

Synchronous Message Passing

- Move data between processes
  - Sender: when data is ready, send it to the receiver process
  - Receiver: when the data has arrived and when the receive process is ready to take the data, move the data
- Synchronization
  - Sender: signal the receiver process that a particular event happens
  - Receiver: block until the event has happened



Example: Producer-Consumer

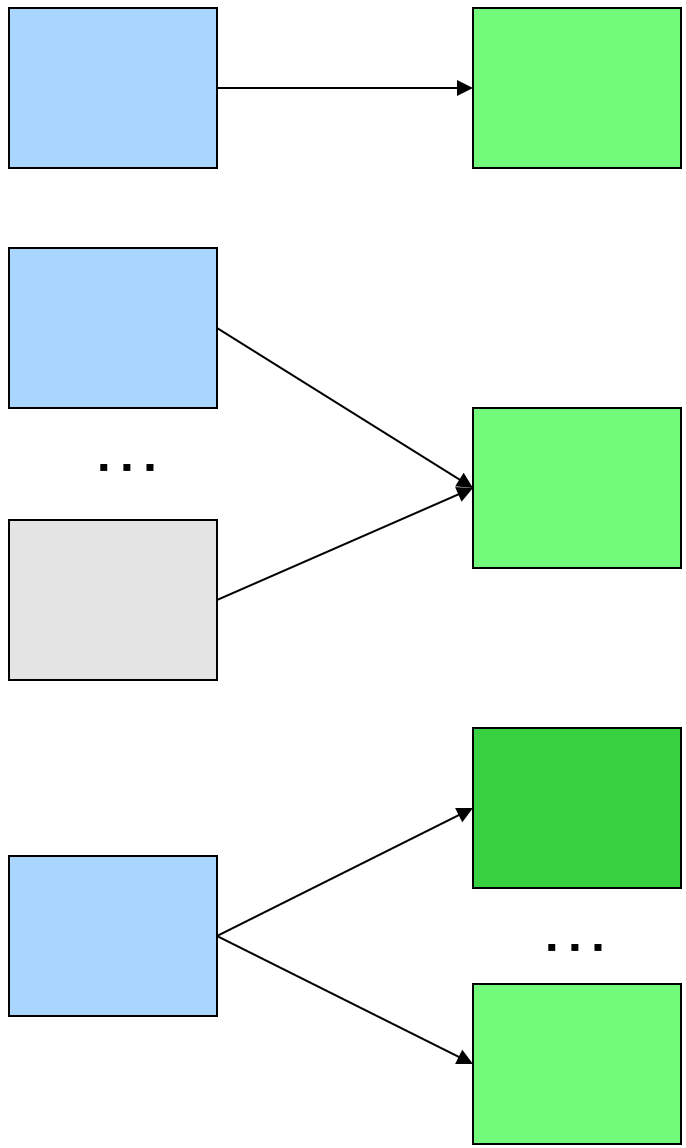
```
Producer(){
   ...
   while (1) {
      produce item;
      recv(Consumer, &credit);
      send(Consumer, item);
   }
}
```

```
Consumer(){
   ...
   for (i=0; i<N; i++)
      send(Producer, credit);
   while (1) {
      recv(Producer, &item);
      send(Producer, credit);
      consume item;
   }
}
```

- Questions
  - Does this work?
  - Would it work with multiple producers and 1 consumer?
  - Would it work with 1 producer and multiple consumers?
  - What about multiple producers and multiple consumers?

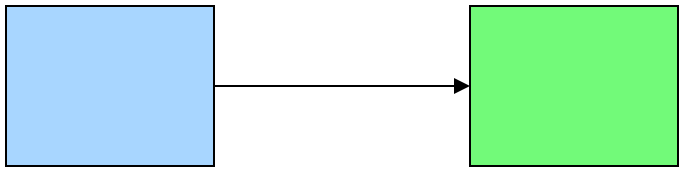
Implementation Issues

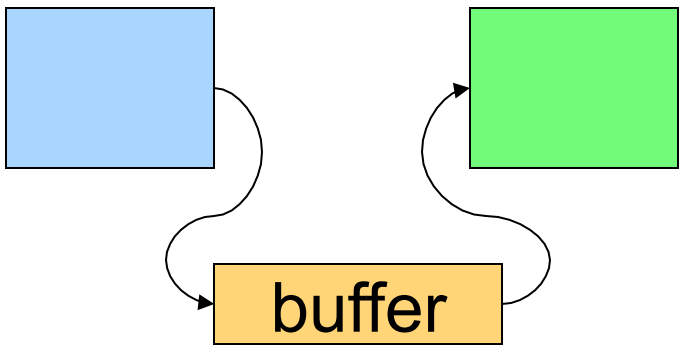
- Buffering messages
- Direct vs. indirect
- Unidirectional vs. bidirectional
- Asynchronous vs. synchronous
- Event handler vs. receive
- How to handle exceptions?



Buffering Messages

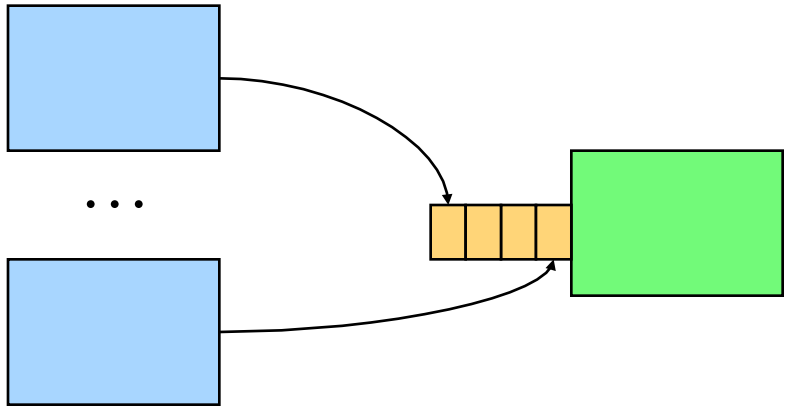
- No buffering
  - Sender must wait until the receiver receives the message
  - Rendezvous on each message
- Bounded buffer
  - Finite size
  - Sender blocks on buffer full
  - Use mesa-monitor to solve the problem
- Unbounded buffer
  - “Infinite” size
  - Sender never blocks



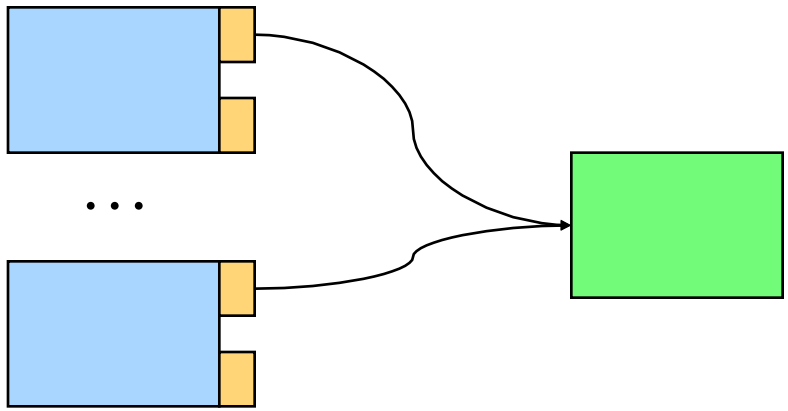


Direct Communication

- A single buffer at the receiver
  - More than one process may send messages to the receiver
  - To receive from a specific sender, it requires searching through the whole buffer

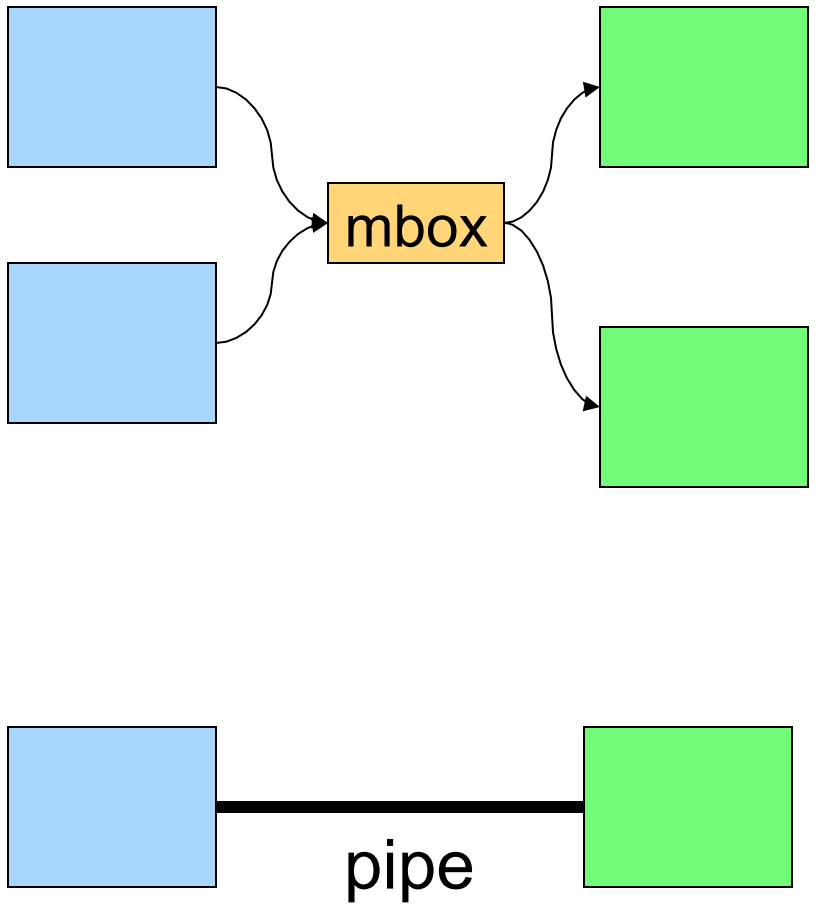


- A buffer at each sender
  - A sender may send messages to multiple receivers
  - To get a message, it also requires searching through the whole buffer



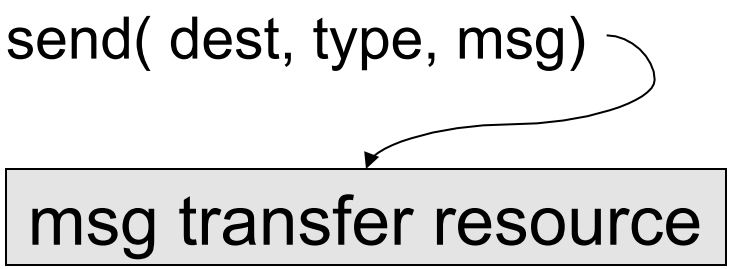
Indirect Communication

- Use mailbox as the abstraction
  - Allow many-to-many communication
  - Require open/close a mailbox
- Buffering
  - A buffer, its mutex and condition variables should be at the mailbox
- Message size
  - Not necessarily. One can break a large message into packets
- Mailbox vs. pipe
  - A mailbox allows many to many communication
  - A pipe implies one sender and one receiver



Synchronous vs. Asynchronous: Send

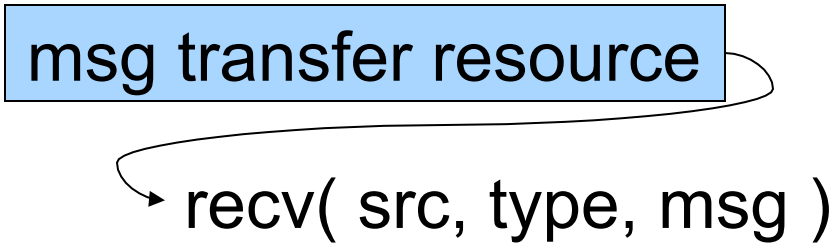
- Synchronous
  - Block on if resource is busy
  - Initiate data transfer
  - Block until data is out of its source memory
- Asynchronous
  - Block if resource is busy
  - Initiate data transfer and return
  - Completion
    - Require applications to check status
    - Notify or signal the application




```
status = async_send( dest, type, msg )
…
if !send_complete( status )
    wait for completion;
…
use msg data structure;
…
```

Synchronous vs. Asynchronous: Receive

- Synchronous
  - Return data if there is a message



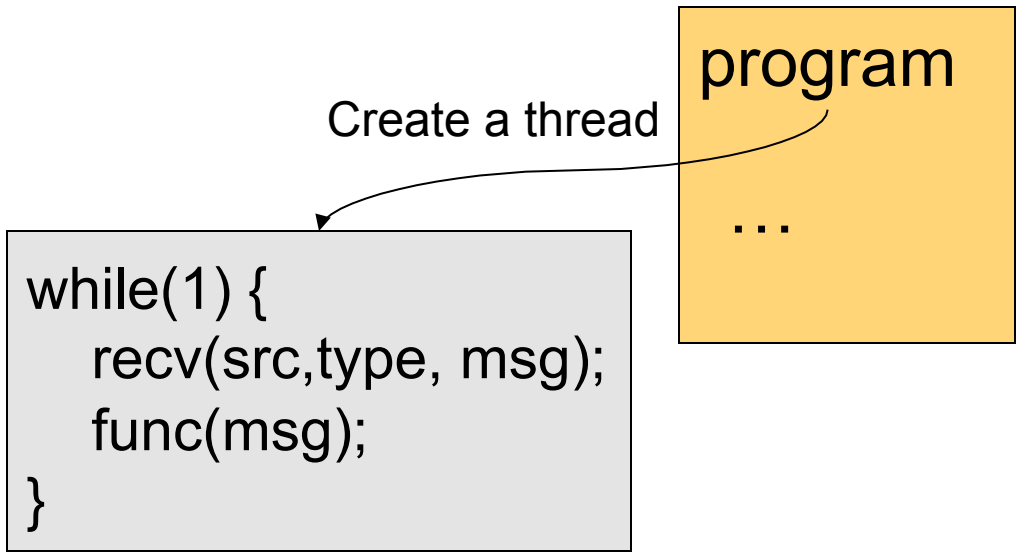
- Asynchronous
  - Return data if there is a message
  - Return status if there is no message (probe)

```
status = async_recv( src, type, msg );
if ( status == SUCCESS )
    consume msg;

while ( probe(src) != HaveMSG )
    wait for msg arrival
recv( src, type, msg );
consume msg;
```

Event Handler vs. Receive

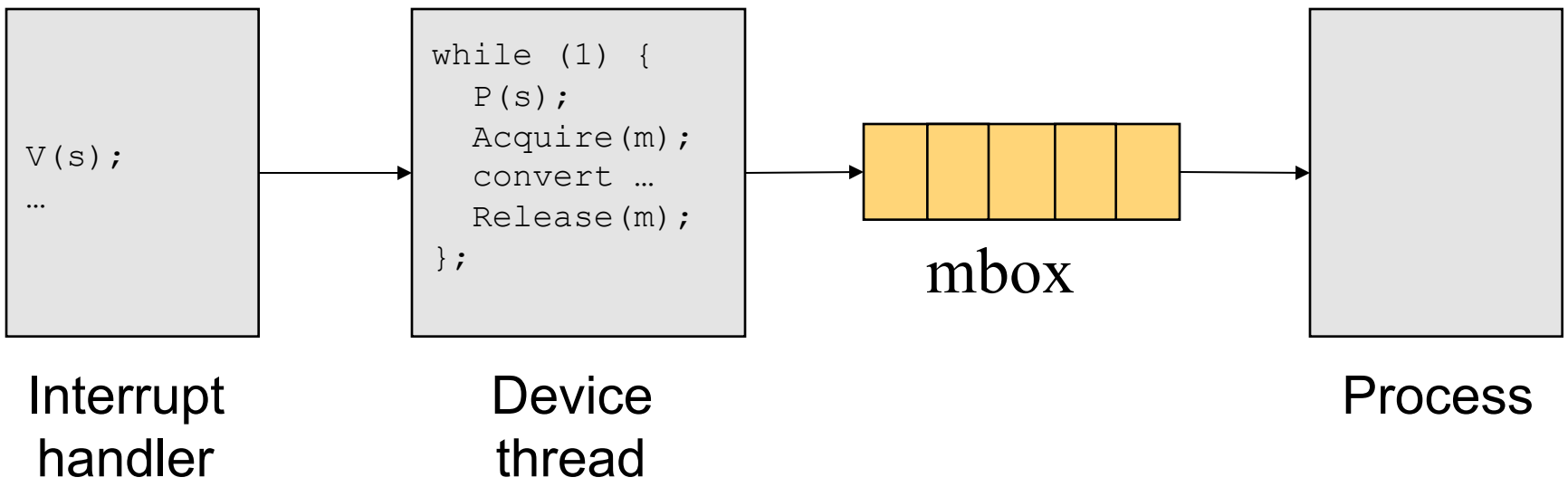
- hrecv(src, type, msg, func)
  - msg is an arg of func
  - Execute “func” on a message arrival
- Which one is more powerful?
  - Recv with a thread can emulate a Handler
  - Handler can be used to emulate recv by using Monitor
- Pros and Cons

```
void func( char * msg ) {
   …
}

…
hrecv( src, type, msg, func)
…
```



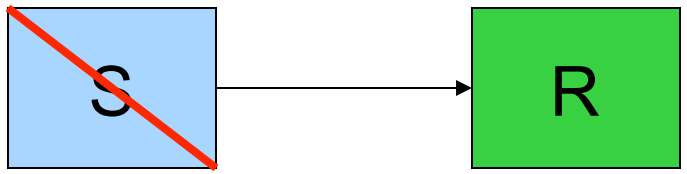
Example: Keyboard Input

- How do you implement keyboard input?
  - Need an interrupt handler
  - Generate a mbox message from the interrupt handler
- Suppose a keyboard device thread converts input characters into an mbox message
  - How would you synchronize between the keyboard interrupt handler and device thread?
  - How can a device thread convert input into mbox messages?

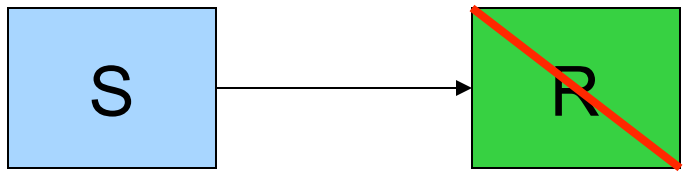


Exception: Process Termination

- R waits for a message from S, but S has terminated
  - Problem: R may be blocked forever

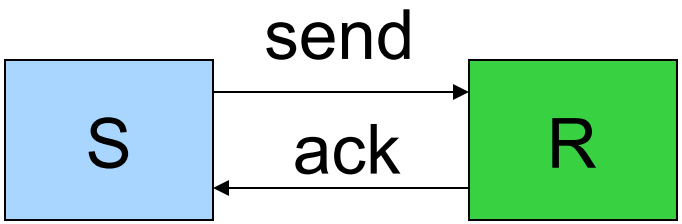


- S sends a message to R, but R has terminated
  - Problem: S has no buffer and will be blocked forever



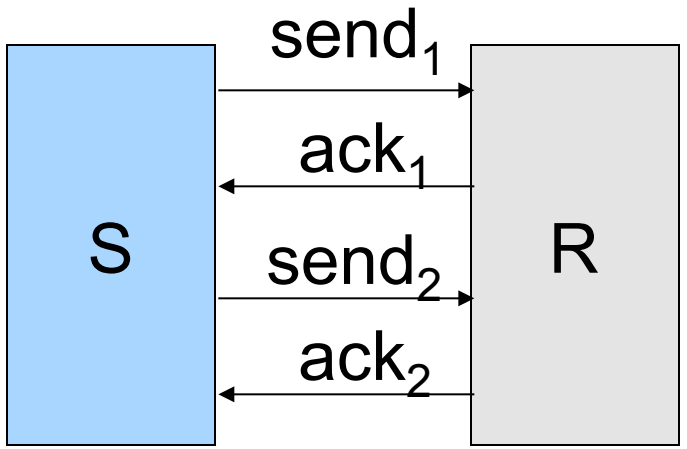
Exception: Message Loss

- Use ack and timeout to detect and retransmit a lost message
  - Require the receiver to send an ack message for each message
  - Sender blocks until an ack message is back or timeout
    status = send(dest, msg, timeout);
  - If timeout happens and no ack, then retransmit the message
- Issues
  - Duplicates
  - Losing ack messages

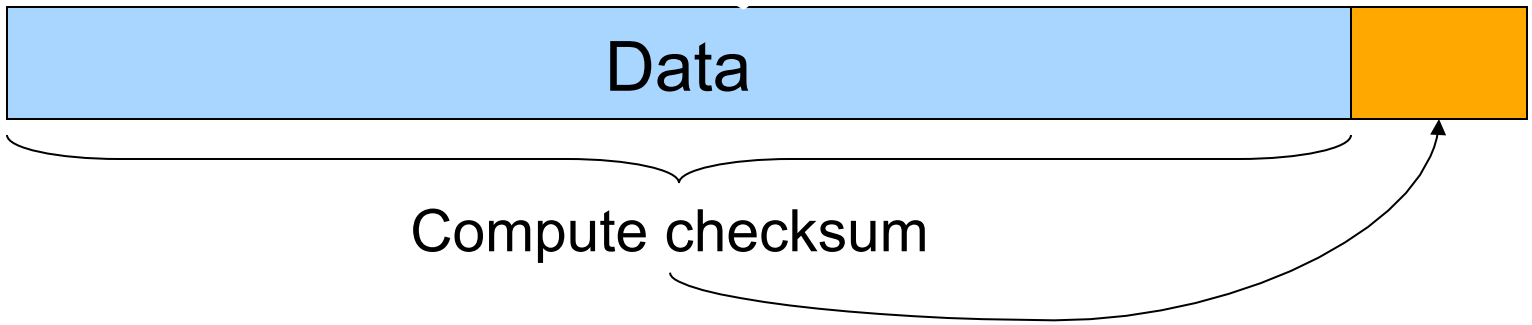


Exception: Message Loss, cont'd

- Retransmission must handle
  - Duplicate messages on receiver side
  - Out-of-sequence ack messages on sender side
- Retransmission
  - Use sequence number for each message to identify duplicates
  - Remove duplicates on receiver side
  - Sender retransmits on an out-of-sequence ack
- Reduce ack messages
  - Bundle ack messages
  - Receiver sends noack messages: can be complex
  - Piggy-back acks in send messages



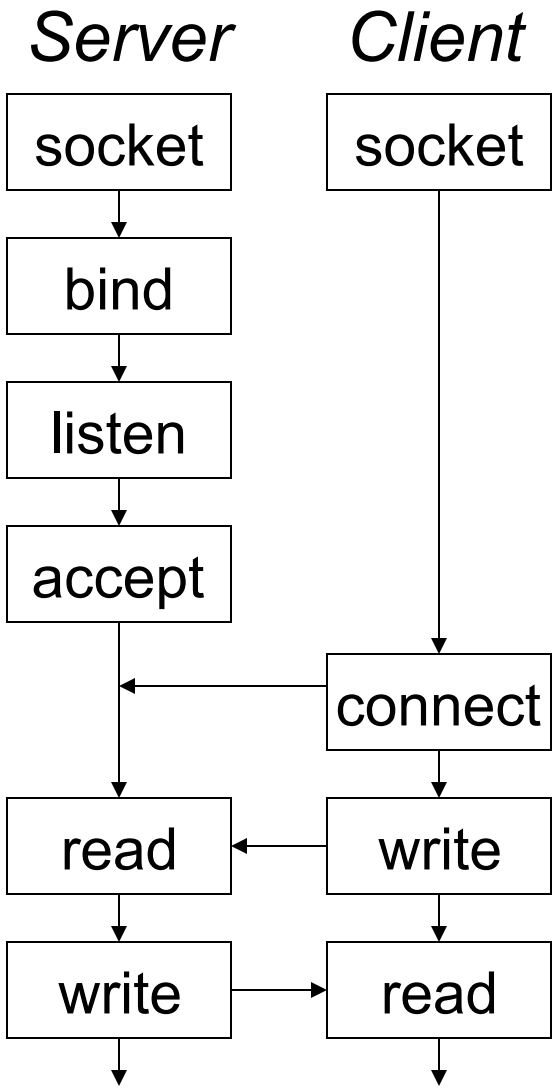
Exception: Message Corruption



- Detection
  - Compute a checksum over the entire message and send the checksum (e.g. CRC code) as part of the message
  - Recompute a checksum on receive and compare with the checksum in the message
- Correction
  - Trigger retransmission
  - Use correction codes to recover

Example: Sockets API

- Abstraction for TCP and UDP
  - Guest lecture by Prof. Rexford on 11/29
- Addressing
  - IP address and port number (2^{16} ports available for users)
- Create and close a socket
  - `sockid = socket(af, type, protocol);`
  - `Sockerr = close(sockid);`
- Bind a socket to a local address
  - `sockerr = bind(sockid, localaddr, addrlength);`
- Negotiate the connection
  - `listen(sockid, length);`
  - `accept(sockid, addr, length);`
- Connect a socket to destimation
  - `connect(sockid, destaddr, addrlength);`



Summary

- Message passing
  - Move data between processes
  - Implicit synchronization
  - API design is important

- Implementation issues
  - Synchronous method is most common
  - Asynchronous method provides overlapping but requires careful design considerations
  - Indirection makes implementation flexible
  - Exception needs to be carefully handled