11 Communication with Messages

Up until now, discussion has been about communication using shared data. Messages provide for communication without shared data. One process or the other owns the data, never two at the same time.

Message = a piece of information that is passed from one process to another. Mailbox = a place where messages are stored between the time they are sent and the time they are received.

Operations:

- Send: copy a message into mailbox. If the mailbox is full, wait until there is enough space in the mailbox.
- Receive: copy message out of mailbox, delete from mailbox. If the mailbox is empty, then wait until a message arrives.

Is there really no shared data?

There are two general styles of message communication:

- 1-way: messages flow in a single direction (Unix pipes, or producer/consumer, or stream).
- 2-way: messages flow back-and-forth (remote procedure call, or client/server, or request/response).

Producer & consumer example:

Producer:

```c
int msg1[1000];
while (1)
{
    – prepare msg1 –
    send(msg1, mbox);
}
```
Consumer:
\[
\text{int } \text{msg2}[1000]; \\
\text{while } (1) \\
\{ \\
\text{receive}(\text{msg2}, \text{mbox}); \\
\text{– process } \text{msg2} – \\
\}
\]

In this implementation the buffer recycling is implicit, whereas it was explicit in the semaphore implementation.

Client & Server example:

Client:
\[
\text{char } \text{response}[1000]; \\
\text{send}(\text{“read rutabaga”}, \text{mbox1}); \\
\text{receive}(\text{response}, \text{mbox2});
\]

Server:
\[
\text{char } \text{command}[100]; \\
\text{char } \text{answer}[1000]; \\
\text{receive}(\text{command}, \text{mbox1}); \\
\text{– decode command –} \\
\text{– read file into } \text{answer} – \\
\text{send}(\text{answer}, \text{mbox2});
\]

Note that this looks a lot like a procedure call\&return. Analogs between procedure calls and message operations:

- Parameters: read rutabaga
- Result: buffer2
- Name of procedure: mbox1
- Return address: mbox2. Note that this is hardwired in this example. How could we make it variable?
Why use messages?

- Many kinds of applications fit into the model of processing a sequential flow of information, including all of the Unix filters.
- The communicating parties can be totally separate, except for the mailbox:
  - Less error-prone, because no invisible side effects: no process has access to another’s memory.
  - They might not trust each other (OS vs. user).
  - They might have been written at different times by different programmers who knew nothing about each other.
  - They might be running on different processors on a network, so procedure calls are out of the question;
  - Or on a machine with non-uniform memory access, where it is expensive to access another processor’s memory.

Message systems vary along several dimensions:

- Relationship between mailboxes and processes:
  - One mailbox per process, use process name in send, no name in receive (simple but restrictive) [RC4000, V].
  - No strict mailbox-process association, use mailbox name (can have multiple mailboxes per process, can pass mailboxes from process to process, but trickier to implement) [Unix].

- Extent of buffering:
  - Buffering (more efficient for large transfers when sender and receiver run at varying speeds).
  - None – rendezvous protocols (simple, OK for call-return type communication, know that message was received).

- Blocking vs. non-blocking ops:
  - Blocking receive: return message if mailbox isn’t empty, otherwise wait until message arrives.
– Non-blocking receive: return message if mailbox isn’t empty, otherwise return special “empty” value.
– Blocking send: wait until mailbox has space.
– Non-blocking send: return “full” if no space in mailbox.

What happens with rendezvous protocols and non-blocking operations? Show how either sender, receiver, or data must wait.

• Additional forms of waiting:

  – Almost all systems allow many processes to wait on the same mailbox at the same time. Messages get passed to processes in order.
  – A few systems allow each process to wait on several mailboxes at once (e.g. select in UNIX). The process gets the first message to arrive on any of the mailboxes. This is quite useful. Network services, window systems are examples.

• Constraints on what gets passed in messages:

  – None: just a stream of bytes (Unix pipes).
  – Enforce message boundaries (send and receive in same chunks).
  – Protected objects (e.g. process id of sender, or a token for a mailbox).

How do the following mechanisms relate to the above classifications?

• Condition variables

• Unix pipes

Messages and shared-data approaches are equally powerful, but result in very different-looking styles of programming. Most people find shared-data approach easier to work with. But, it is easier to make message-passing programs perform well on machines that don’t have shared memory.