SPIN: Exercises*

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*These slides are derived from those by Stefano Tonetta, Alberto Griggio, Silvia Tomasi, Thi Thieu Hoa Le, Alessandra Giordani for FM lab 2005/14

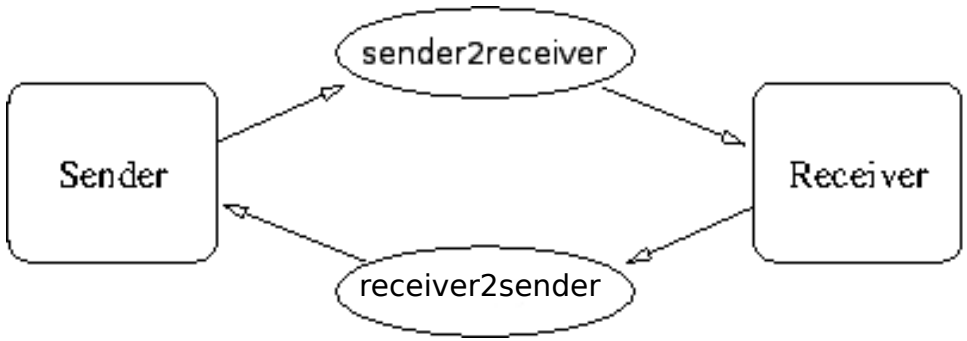
Contents

Reliable FIFO Communication

Goal: design a reliable FIFO communication over a non-reliable channel.

Alternating Bit Protocol:

- *Sender* and *Receiver* communicate over a couple of channels *sender2receiver* and *receiver2sender*
- the channels *sender2receiver* and *receiver2sender* are unreliable: messages might be lost or duplicated



Alternating Bit Protocol: Skeleton

```
mtype = { MESSAGE, ACK };

chan sender2receiver = [2] of { mtype, bit, int};
chan receiver2sender = [2] of { mtype, bit, int};

active proctype Sender () {
    ...
}

active proctype Receiver () {
    ...
}
```

Alternating Bit Protocol: Sender [1/2]

Sender specs:

- the *Sender* tags the messages with an alternating bit (e.g. it sends `(msg1, 0)`, `(msg2, 1)`, `(msg3, 0)`, ...).
- the *Sender* repeatedly sends a message with a tag value until it receives an acknowledgment from the *Receiver*.
- Suppose *Sender* has sent `(msg, out_bit)` and receives `in_bit` as acknowledgment:
  - if `in_bit` is equal to `out_bit`, then it means that *Receiver* has received the right message, so it sends a new message with a different value for `out_bit`.
  - otherwise it sends `(msg, out_bit)` again.
- the *Sender* attaches to each message a `sequence_number`, which is increased each time the tag value is changed.

Alternating Bit Protocol: Sender [2/2]

```
active proctype Sender () {
    bit in_bit, out_bit;
    int seq_no;

    do
        :: sender2receiver!MESSAGE(out_bit, seq_no) ->
            receiver2sender?ACK(in_bit, 0);
            if
                :: in_bit == out_bit ->
                    out_bit = 1 - out_bit;
                    seq_no++;
                :: else ->
                    skip
            fi
    od
}
```

Alternating Bit Protocol: Receiver [1/2]

Receiver specs:

- suppose *Receiver* receives `(msg, tag)`:
  - if `tag` is different from the last received bit, then it means that it is a new message;
  - otherwise, the message is old.
- When the *Receiver* receives a message, it sends the `tag` back to the *Sender* to communicate the correct receival of the message.

Alternating Bit Protocol: Receiver [2/2]

```
active proctype Receiver () {
    bit in_bit, old_bit;
    int seq_no;

    do
        :: sender2receiver?MESSAGE(in_bit, seq_no) ->
            if
                :: in_bit != old_bit ->
                    printf("received: %d\n", seq_no);
                    old_bit = in_bit;
                :: else ->
                    skip
            fi
            receiver2sender!ACK(in_bit, 0);
    od
}
```

Alternating Bit Protocol: Unreliability

```
inline unreliable_send(channel, type, tag, seqno) {
    bool loss = false;
    bool duplicate = true;
    if
        :: channel!type(tag, seqno);
            if
                :: channel!type(tag, seqno);
                :: duplicate = false;
            fi
        :: loss = true;
    fi
}

// + modify Sender and Receiver to use this function
```

Q: what happens with the unreliable channel? (why?)

Alternating Bit Protocol: Unreliability

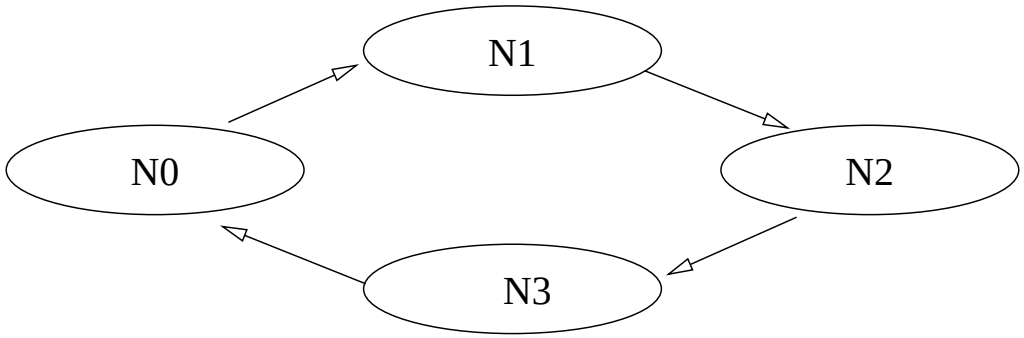
```
inline unreliable_send(channel, type, tag, seqno) {
    bool loss = false;
    bool duplicate = false;
    if
        :: channel!type(tag, seqno);
            if
                :: channel!type(tag, seqno);
                :: duplicate=true;
            fi
        :: loss=true;
    fi
}

// + modify Sender and Receiver to use this function
```

Q: what happens with the unreliable channel? (why?) deadlock

Contents

Leader Election Problem

- N processes are the nodes of a unidirectional ring network: each process can send messages to its clockwise neighbor and receive messages from its counterclockwise neighbor.
- The requirement is that, eventually, **only one** process will output that it is the **leader**.
- We assume that every process has a **unique id**.
- The leader must have the **highest id**.



Le Lann, Chang, Roberts (LCR) solution

The algorithm:

- Initially, every process passes its identifier to its successor.
- When a process receives an identifier from its predecessor, then:
  - if it is greater than its own, it keeps passing on the identifier.
  - if it is smaller than its own, it discards the identifier.
  - if it is equal to its own identifier, it declares itself leader:
    - the leader communicates to its successor that now it is the leader.
    - after a process relayed the message with the leader id, it exits.

Complexity: at worst, n^2 messages.

Peterson/Dolev, Klawe, Rodeh solution

The algorithm:

- If a process is "active", it compares its identifier with the two couterclockwise predecessors:
  - if the highest of the three is the counterclock neighbor, the process proposes the neighbor as leader,
  - otherwise, it becomes a "relay".
- If the process is in "relay" mode, it keeps passing whatever incoming message.

Complexity: at worst, $n \cdot log(n)$ messages.

Exercise 1: Reliable FIFO Communication

- configure *Sender* and *Receiver* to use `unreliable_send()`.
- fix the *Alternating Bit Protocol* so that there is no more **deadlock** and the input specification is still respected.

Exercise 2: Leader Election

```
mtype = { candidate, leader };
chan c[N] = [BUFSIZE] of { mtype, byte };

proctype node(chan prev, next; byte id) { ... }

init {
    byte proc, i;
    atomic {
        // TODO: set i random in [0,N]
        ...
        do
            :: proc < N ->
                run node(c[proc], c[(proc+1)%N], (N+i-proc)%N);
                proc++
            :: else ->
                break
        od
    }
}
```

- Implement a `leader election` algorithm of your choice.
- Verify that there is at most one leader.

$\longrightarrow$ strong solution hint!

Exercises Solutions

- will be uploaded on course website later this week
- send me an email if you need help or you just want to propose your own solution for a review

- learning programming languages requires practice: try to come up with your own solutions first!