Abstraction of Concurrency and Communication in VHDL

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VHDL in the design flow

- At the system level, specify aspects of the system
  - structure (architectural partitioning)
  - behaviour (data transforms, reactions)
  - . . .
- VHDL allows description of structure and behaviour
- Prefer single language approach
  - system level to detailed design (hardware/software)
  - aids refinement
  - avoid semantic mismatch

Problem with VHDL

- Behaviour includes concurrency and communication
- Communication performed using signals
  - assignment, resolution, waits
- Signals do not express synchronization
  - *cf.* system description and programming languages
  - assignment schedules a message for a particular time
  - receiver may miss the message
    - if it does not respond at that time

Ad hoc solutions

- Communication using handshaking protocol
  - requires extra signals
  - requires protocol implementation
- Explicitly instantiated message queues
  - extra components
- Both detract from abstraction of communication
  - introduction of extraneous artefacts

Previous extension proposals

- Vista OO-VHDL (Swamy *et al*)
- LaMI (Benzakki & Djaffri)
- Bournemouth/IBM-UK (Cabanis *et al*)

➡ Based on OO extensions to VHDL

  – entity/architecture as a class, components as objects
  – entity specifies operations invoked by other processes
  – architecture encapsulates state

⇨ Monitor semantics with concurrency control

Other description languages

for describing behaviour, eg:

- StateCharts
- Estelle
- SDL
- CSP
- . . .

➡ Concurrent processes with message passing

StateCharts

- Extended FSM
  - hierarchical states
  - concurrent composition of substates
  - transitions on *events* (optionally *guarded*)
  - communication:
    - action in one chart ⇒ event in another chart
- Used in UML
  - events can be parameterized
  - procedural actions
- States are statically specified

Estelle

- Hierarchy of extended NFAs (*tasks*)
  - instances of declared modules
  - can be statically or dynamically instantiated
  - transitions enabled by event occurrence (msg arrival)
  - actions on transitions are Pascal-like statements
  - lock-step parallelism (select-transition/fire/action)
- Communication: message passing via links
  - links can be statically or dynamically created
  - non-blocking send, buffered at receiver

SDL

- Hierarchy of statically specified process sets
- Processes: statically or dynamically instantiated
  - instances of declared process types
  - behaviour specified as extended FSM
    - transitions enabled by message arrival
    - actions: assignment, branching, process creation, procedure call, message send
- Communication: message passing via channels
  - channels between process sets
  - non-blocking send, buffered at receiver
- Also a form of RPC

CSP

- Statically specified processes
  - contain sequentially executed actions
  - variable assignment, send, receive
- Synchronous message passing
  - statically specified channels

Comparison with VHDL

- Concurrent process model with message passing
  ≡ concurrent FSMs communicating by events
- VHDL
  - statically specified processes & channels (signals)
  - asynchronous unbuffered message passing (?!)
- Alternatives
  - static vs. dynamic process instantiation
  - static vs. dynamic channel creation
  - sync vs. async message passing

Language design issues

- Message passing mechanism and semantics
- Communication abstraction in entity interface
- Dynamic process creation/termination semantics
  - Process abstraction and interface
- Integration with existing language
- Integration with other extension (eg, SUAVE)

Message passing mechanism (1)

- Alternative 1: introduce new mechanism
  - eg, message channel, send & receive operations

```
channel elevator_call : floor_number;
channel elevator_location : floor_number;

elevator : process is
begin
    . . .
    receive calling_floor from elevator_call;
    send current_floor to elevator_location;
    . . .
end process elevator;
```


Communication in entity interface (1)

- Alternative 1

```
entity operator_console is
    port ( channel status : in status_msg;
           channel command : out command_msg );
end entity operator_console;
```

Message passing mechanism (2)

- Alternative 2: generalize existing mechanism
  - eg, abstract signals
  - transactions queued without delay mechanism
  - wait receives next value from queue

```
signal elevator_call : floor_number abstract;
signal elevator_location : floor_number abstract;

elevator : process is
begin
    . . .
    wait on elevator_call;    -- receive next message
    calling_floor := elevator_call;
    elevator_location <= current_floor;   -- send message
    . . .
end process elevator;
```


Communication in entity interface (2)

- Alternative 2

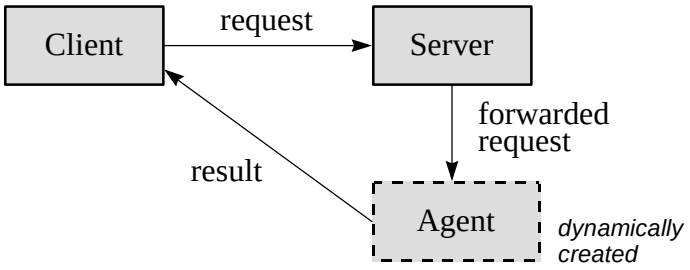
```
entity operator_console is
    port ( signal status : in status_msg abstract;
                signal command : out command_msg abstract );
end entity operator_console;
```

Dynamic process creation

- Eg, for multithreaded server
- Process types
  - needed for dynamic instantiation
  - parameterized by channel/signal
- Channel/signal types
  - needed for dynamic creation of channel/signal
  - for communication with dynamically created process

Process & channel types

- Example
  - multithreaded server creates new agent to handle each incoming request



Process & channel types

```
type result_value is . . . ;
type result_channel is channel result_value;
type result_ptr is access result_channel;

type request_info is record
        . . . ;
        result_please : result_ptr;
    end record request_info;

type client is process body
        port ( channel request : out request_info );
        variable result : result_ptr := new result_channel;
    begin
        send ( . . . , result ) to request;
        receive . . . from result.all;
    end process body client;
```


Process & channel types (cont)

```
type server is process body
        port ( channel request : in request_info );

        type agent is process body
                port ( channel request : in request_info );
                variable info : request_info;
            begin
                receive info from request;
                . . .
                send . . . to info.result_please.all;
                exit;
            end process body agent;

        . . .
```

Process & channel types (cont)

```
        . . .
        variable info : request_info;
        channel agent_request : request_info;
        type agent_ptr is access agent;
        variable new_agent : agent_ptr;
    begin  -- server
        receive info from request;
        new_agent := new agent
                                port map ( agent_request );
        send info to agent_request;
    end process body server;
```


Conclusions

- Improve support for system modeling in VHDL
  - more abstract communication
  - process abstraction
    - process and channel types
    - dynamic creation/termination
- Integrate with existing language
  - extend existing mechanism where appropriate
- Enables single-language design flow
  - hardware/software co-design