2017 DESIGN AND VERIFICATION™ DVCON CONFERENCE AND EXHIBITION UNITED STATES

A Simplified Approach Using UVM Sequence Items for Layering Protocol Verification

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Agenda

- Introduction
- Example Scenario
- Alternative Solutions
- Proposed Method
- Future Work
- Conclusion

Introduction: What is a layered protocol?

- Composed of multiple layers
  - Each level is responsible for a subset of the overall functionality
- Typically used to define and move data
  - Upper level layers operate on meaningful fields
  - Lowest level responsible for interface level data transfer
- Commonly used for data transfer between IPs, chips, etc

- Examples:

SerialRapidIO®

PCI EXPRESS

mipi® alliance

Introduction: Verifying a Layered Protocol

- Layered protocol approaches in UVM
  - Model the design's structure
  - Checking can be done at one/any layer
  - Conversion needed between layers

Intuitive, flexible, controllable, visible!

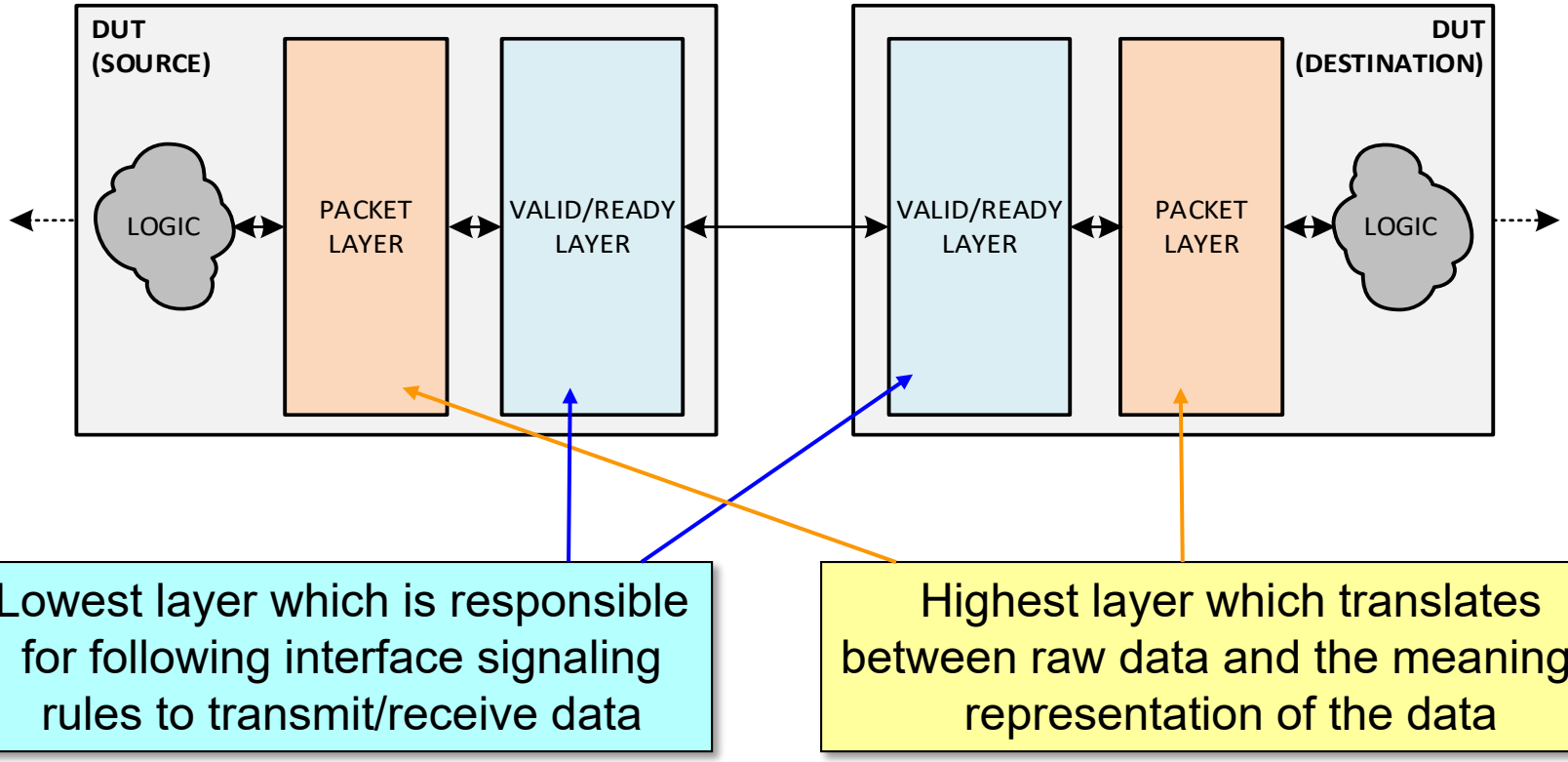
- Method should be protocol independent

GOAL:
Verification Reuse!

- What approach is the *best* approach?
  - Determine the scoping requirements
  - Determine the testbench goal

Layered Protocol Example Scenario: Valid/Ready Protocol

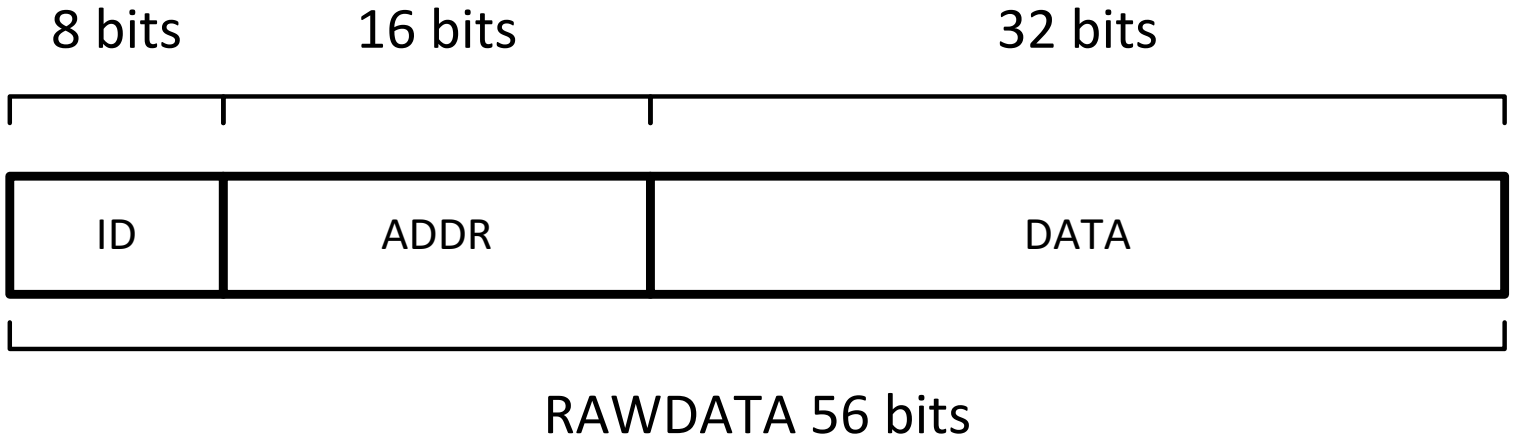
- Valid/Ready protocol implementation block diagram



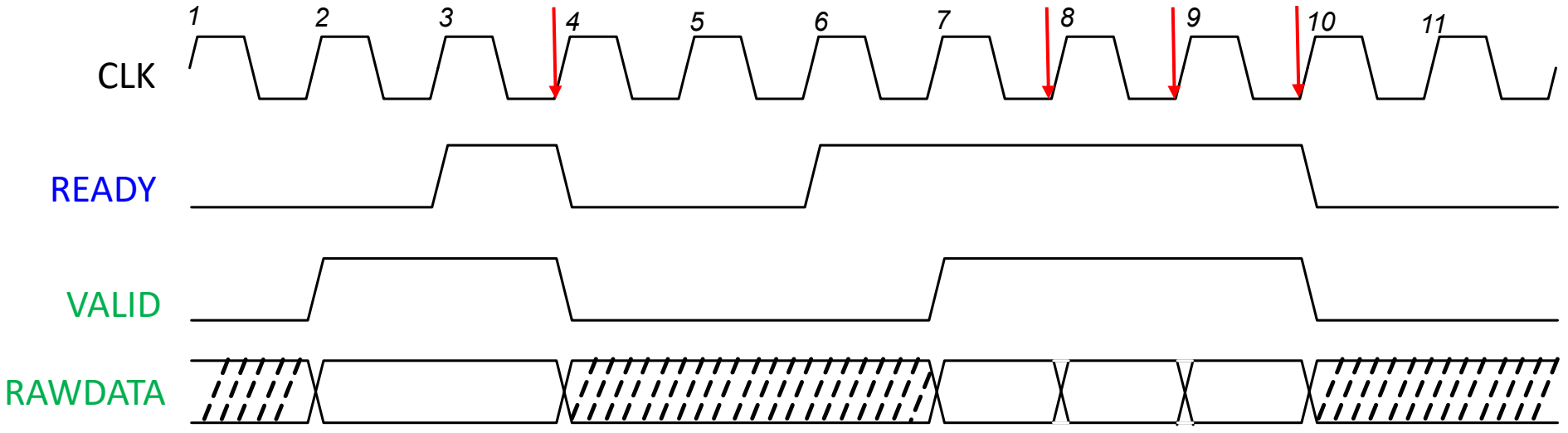
Layered Protocol Example Scenario: Valid/Ready Protocol

- Packet Layer's Data Fields
  - ID[7:0]
  - ADDR[15:0]
  - DATA[31:0]
- Valid/Ready Layer's Data Fields
  - RAWDATA[55:0]

The RAWDATA bus width is set to the total width of the Packet layer's fields. In this case: 8 + 16 + 32 = 56



Layered Protocol Example Scenario: Valid/Ready Protocol



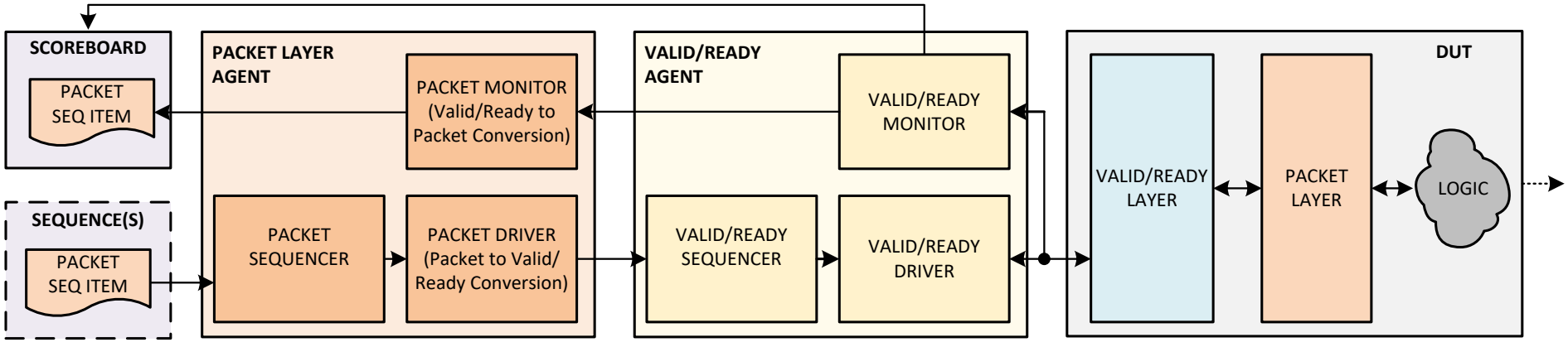
Valid/Ready Protocol Timing Diagram

Transmitter Driven Signals

Receiver Driven Signals

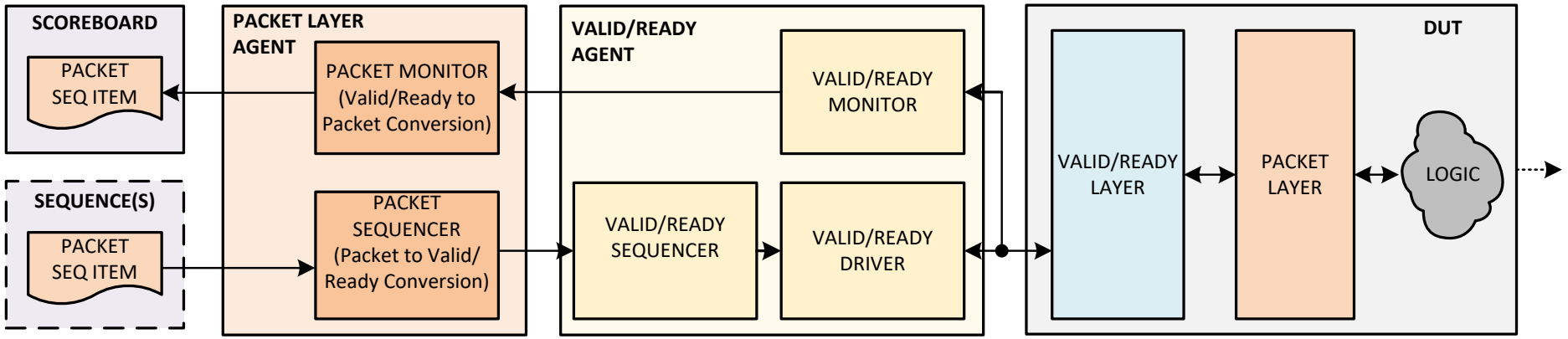
Alternative Solutions: Layered Agents

- Testbench architecture models design architecture
  - An agent is created for each design layer
  - Packet agent translates between protocol layers
    - Driver converts Packet seq items to Valid/Ready seq items
    - Monitor converts Valid/Ready seq items to Packet seq items



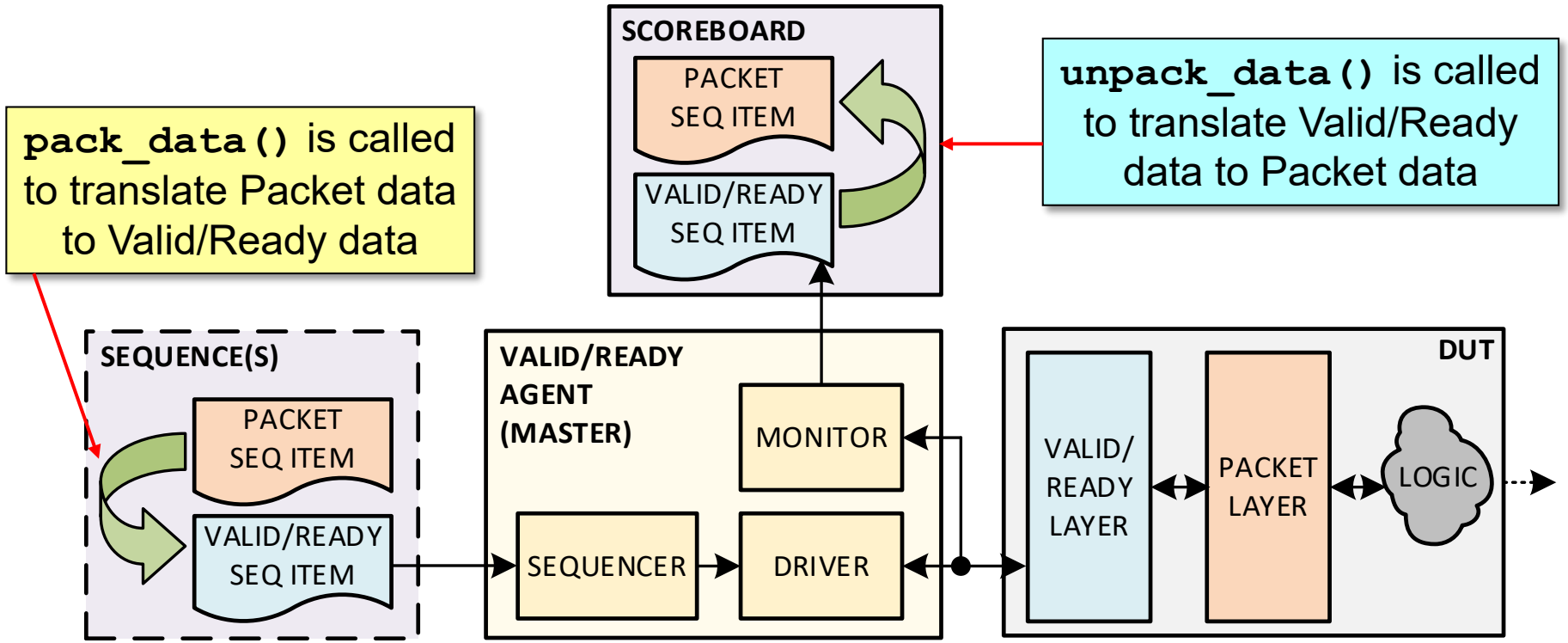
Alternative Solutions: Layered Sequencers

- Testbench architecture models design architecture
- "Trimmed down" agents are used for the high level layers
- Packet agent translates between protocol layers
  - Sequencer converts Packet seq items to Valid/Ready seq items
  - Monitor converts Valid/Ready seq items to Packet seq items



Proposed Method: Layered Sequence Items

- Sequence items are used to model the design architecture
  - One sequence item per protocol layer
  - Functions perform the translation between layers



Proposed Method: Valid/Ready Seq. Item Code

```
class vld_rdy_seq_item #(int DATA_WIDTH=56)
                                        extends uvm_sequence_item;
  rand bit                      valid;
  rand bit                      ready;
  rand bit [DATA_WIDTH-1:0] raw_data;
  ...
  // Virtual function to implement translation from
  // Packet -> Valid/Ready
  virtual function void pack_data();
  endfunction

  // Virtual function to implement translation from
  // Valid/Ready -> Packet
  virtual function void unpack_data();
  endfunction
  ...
```

Proposed Method: Packet Seq. Item Code

```
class pkt_seq_item extends vld_rdy_seq_item #(56);

  rand bit [7:0]  id;
  rand bit [15:0] addr;
  rand bit [55:0] data;
  ...

  // Packet -> Valid/Ready translation
  virtual function void pack_data();
    raw_data = {id, addr, data};
  endfunction

  // Valid/Ready -> Packet translation
  virtual function void unpack_data();
    {id, addr, data} = raw_data;
  endfunction
  ...
```

RECOMENDATION:
Call pack_data() at the end of post_randomize() to simplify sequences

Proposed Method: Example Packet Sequence

```
class pkt_rand_seq extends uvm_sequence
                                    #(vld_rdy_seq_item #(56));
  ...
  pkt_seq_item            pkt_item;
  vld_rdy_seq_item #(56)  req_item;
  vld_rdy_seq_item #(56)  resp_item;

  task body();

    // 1. Create a Packet sequence item and generate the data
    pkt_item = pkt_seq_item::type_id::create("pkt_item");

    if ( !( pkt_item.randomize() with {...} ) )
      `uvm_error("PKTSEQ", "pkt_item.randomize failed!")

    ...
    // continued on next slide
```

Proposed Method: Example Packet Sequence

```
    ...
    // 2. Data conversion from Packet layer
    // to the Valid/Ready layer
    pkt_item.pack_data();

    // 3. Cast the pkt_seq_item to a
    // vld_rdy_seq_item
    if ( !$cast(req_item, pkt_item.clone()) )
      `uvm_error("PKTSEQ","Cast failed!");

    // 4. Resume standard sequence flow
    start_item(req_item);
    finish_item(req_item);
    get_response(resp_item);
  endtask: body
  ...
endclass: pkt_rand_seq
```

Not necessary if pack_data() was added into the Packet seq. item's post_randomize() function

Proposed Method: Example Scoreboard

```
forever begin
  // Monitor Valid/Ready for valid transaction's
  vld_rdy_fifo.get(vld_rdy_item);

  // Create new Packet sequence item
  pkt_item = pkt_seq_item::type_id::create("pkt_item");

  // Convert to a Valid/Ready sequence item to a Packet
  // sequence item to access meaningful fields
  pkt_item.raw_data = vld_rdy_item.raw_data;
  pkt_item.unpack_data();

  // Fields are now populated with correct data

  // Sample coverage for meaningful fields
  pkt_item.sample();
  ...
end //end forever loop for vld_rdy_fifo
```

Benefits of Layering Sequence Items

- Eliminates the need for unique agents per layer

Reduces initial development time

Simplifies the overall architecture

Expedites bring-up

Reduces the code base

Reduces the likelihood of bugs

- Eliminates the need for wrapper UVCs, translation classes or complex layered sequences

Future Work

- Layered protocols with >2 layers
- Individual layer verification

Conclusion

- Easy to implement solution

Save development time and expedite testbench bring up

Saving increases for designs with multiple unique packet layers layered with a common base layer

- Proven in a real world design
  - Design contained multiple unique packet layers with a shared base layer

Saved approximately 8 person-days development time

- Future work

Thank You