Portable Stimuli over UVM
using portable stimuli in HW verification flow

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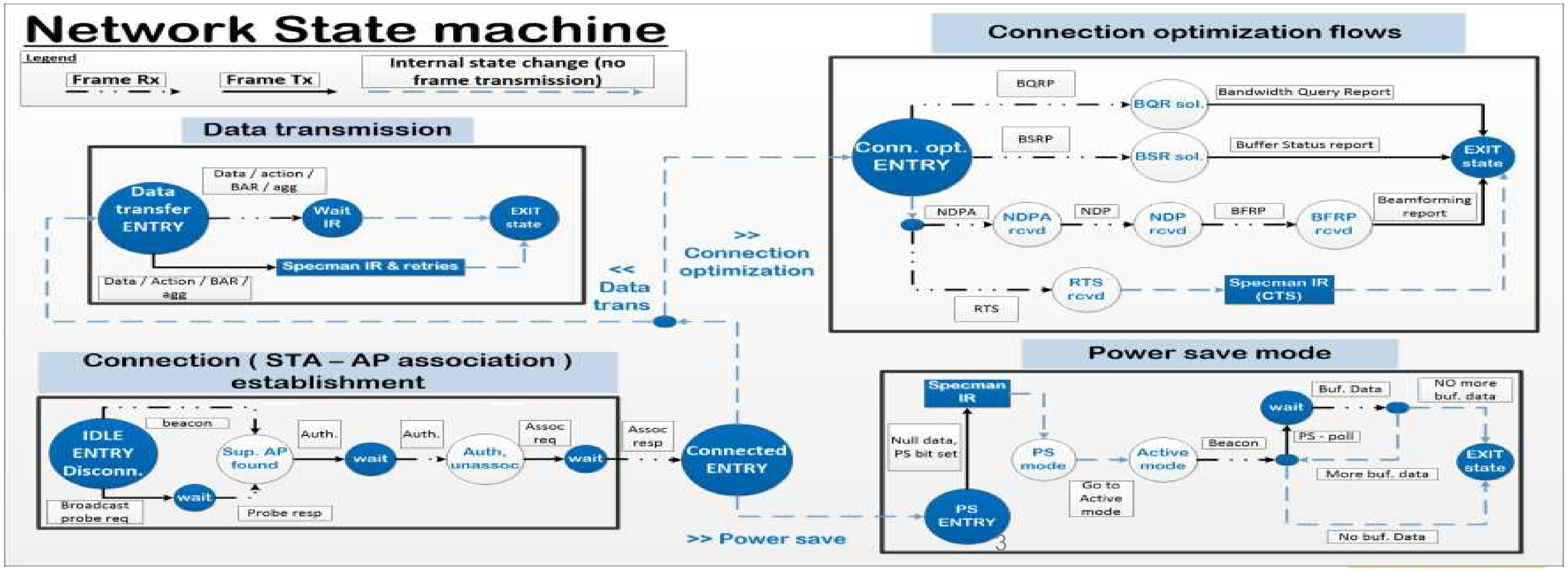
Agenda

- UVM challenges
- PSS solvability
- PSS to UVM flow
- Summary

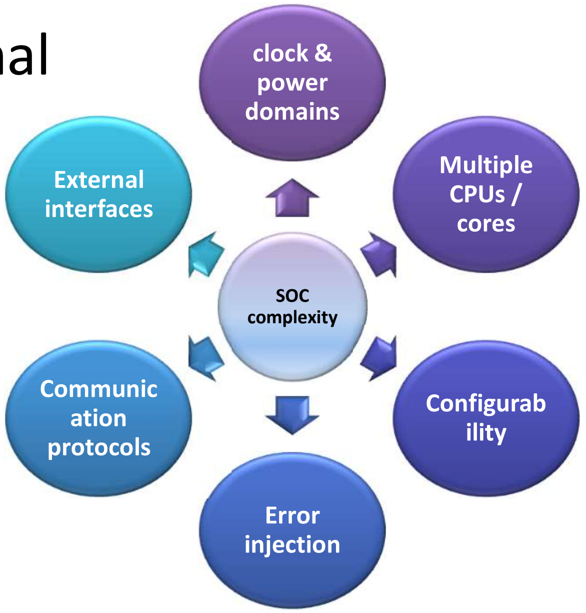
Texas Instruments Wi-Fi router

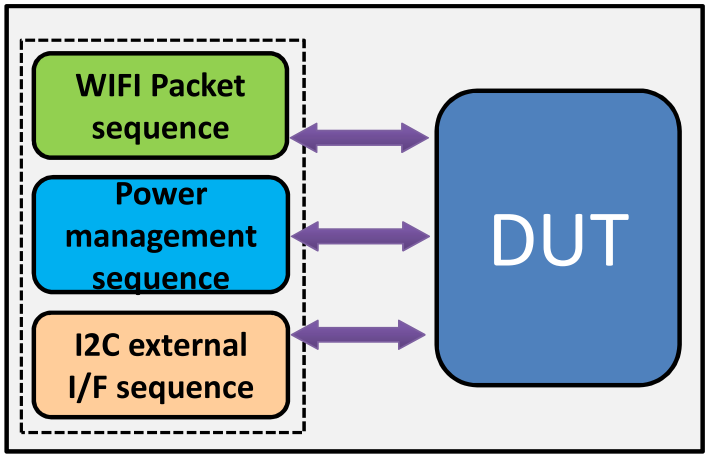
- Multiple CPU cores, power domains & HW hierarchies
- Advanced verification environments, using Specman and UVM-*e*
  - eight levels of reuse



Verification requirements, stimuli generation

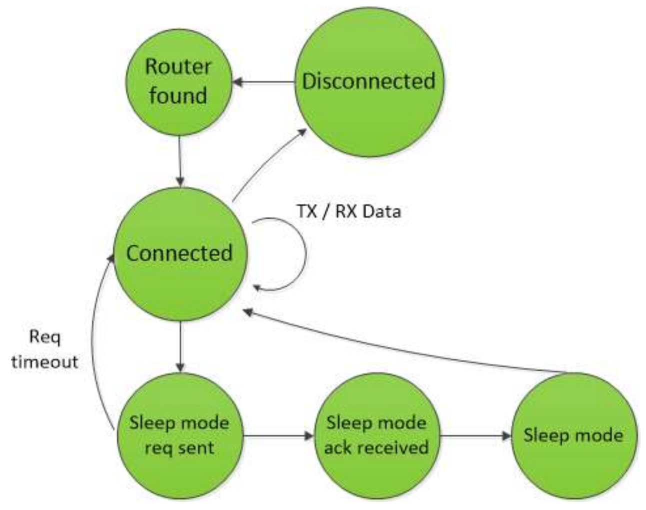
- Capture rules of system behavior
- Achieve a robust, re-usable solution for system level test composition
- Changes of DUT should not require more than minimal modifications of the TB



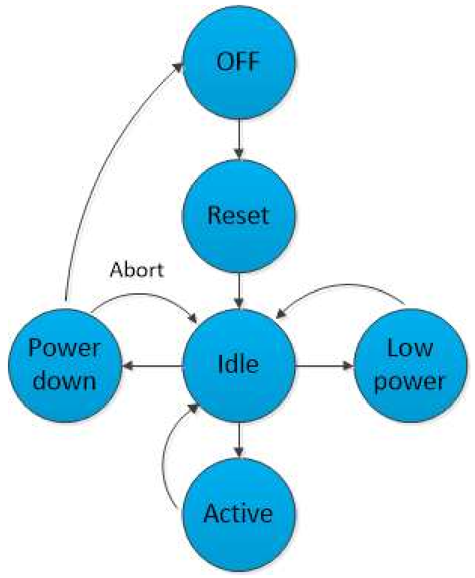


Each scenario is well defined

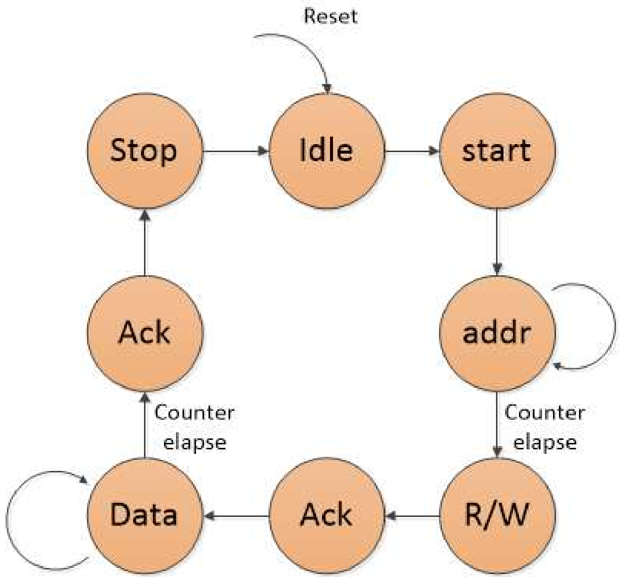
WIFI packet



Power management

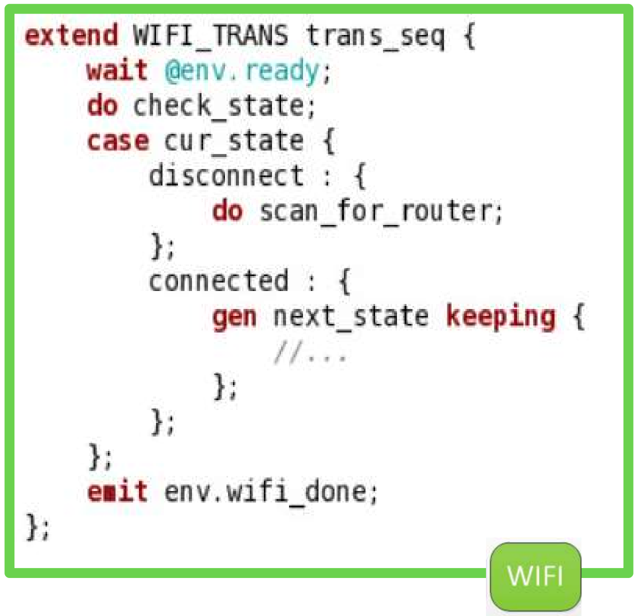


I2C external interface



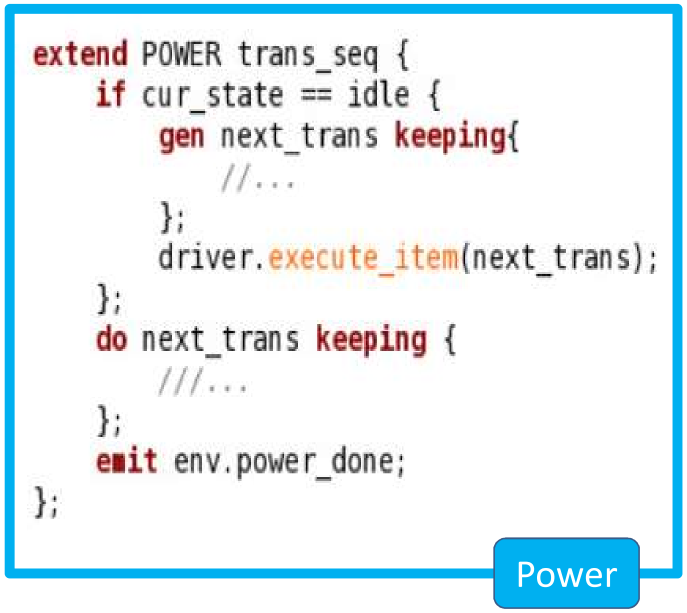
Sequences libraries

WIFI packet



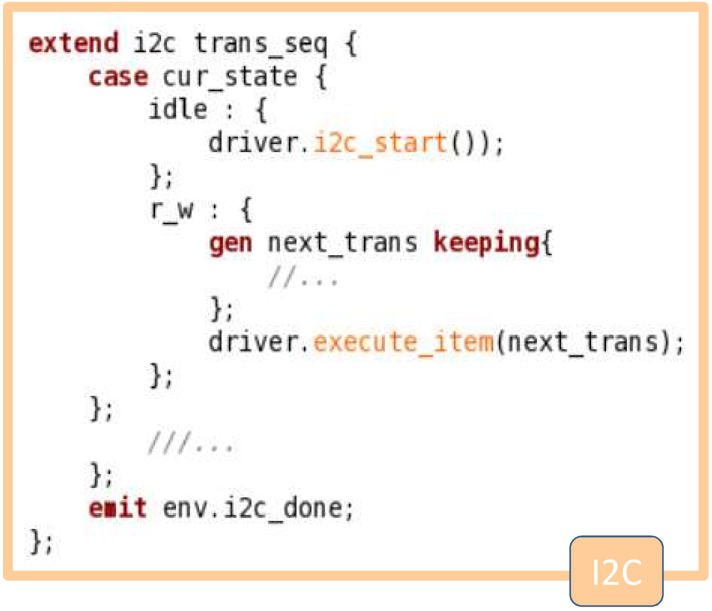
```
extend WIFI_TRANS trans_seq {
    wait @env.ready;
    do check_state;
    case cur_state {
        disconnect : {
            do scan_for_router;
        };
        connected : {
            gen next_state keeping {
                //...
            };
        };
    };
    emit env.wifi_done;
};
```

Power management



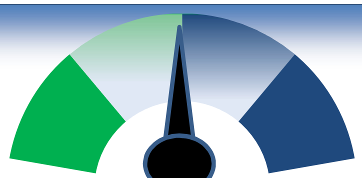
```
extend POWER trans_seq {
    if cur_state == idle {
        gen next_trans keeping{
            //...
        };
        driver.execute_item(next_trans);
    };
    do next_trans keeping {
        ///...
    };
    emit env.power_done;
};
```

I2C external interface



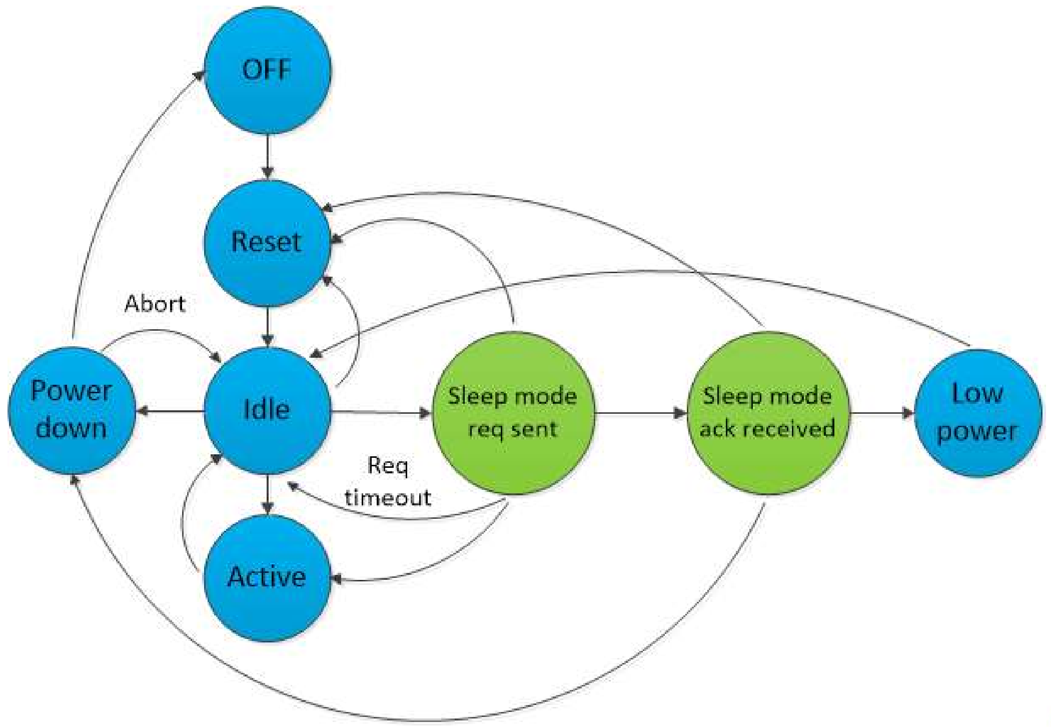
```
extend i2c trans_seq {
    case cur_state {
        idle : {
            driver.i2c_start());
        };
        r_w : {
            gen next_trans keeping{
                //...
            };
            driver.execute_item(next_trans);
        };
    };
        ///...
    };
    emit env.i2c_done;
};
```

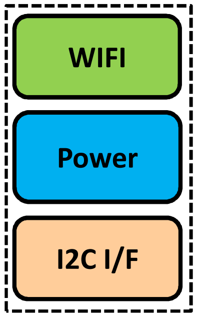
Interdependence of sub-modules



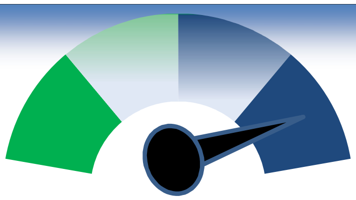
- Sequence should contain synchronization aids
- Multi-channels sequences

Device shall not enter low power mode before notifying router with a dedicated packet sequence
Device shall not send a sleep mode request from any power state but 'idle'

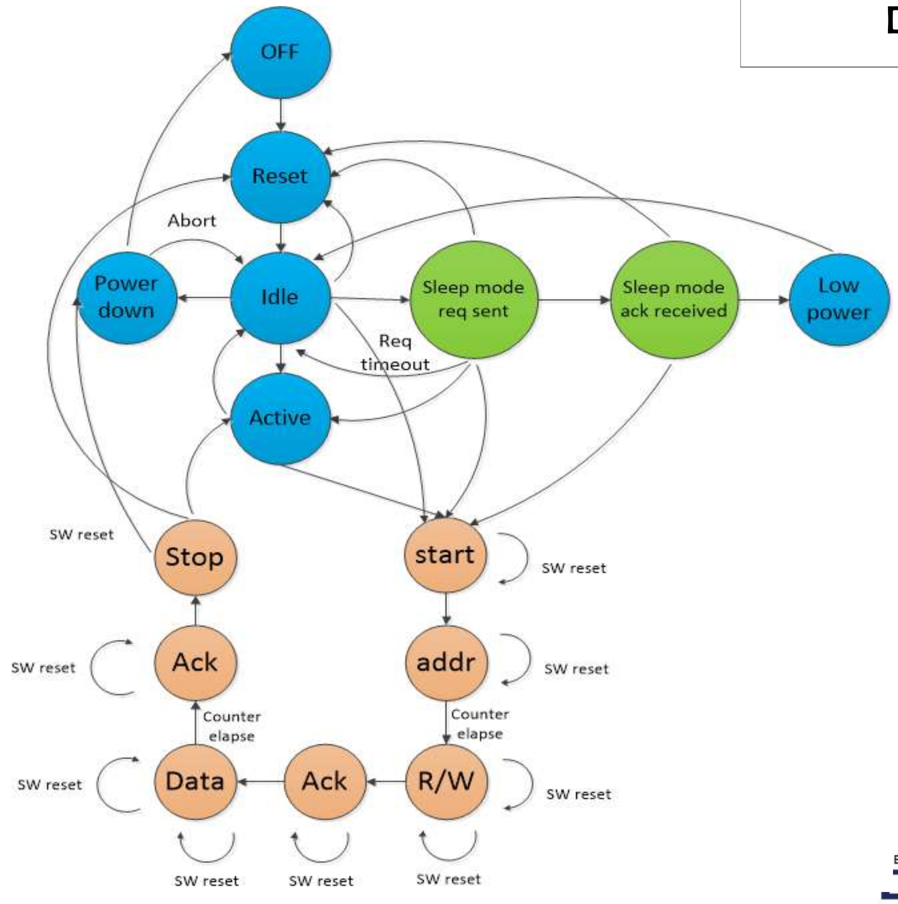




How far can we stretch UVM?



Delay SW reset requests until end of I2C transaction
Device shall not initiate I2C transaction from low power mode



🟩 WIFI
🟦 Power
🟧 I2C I/F

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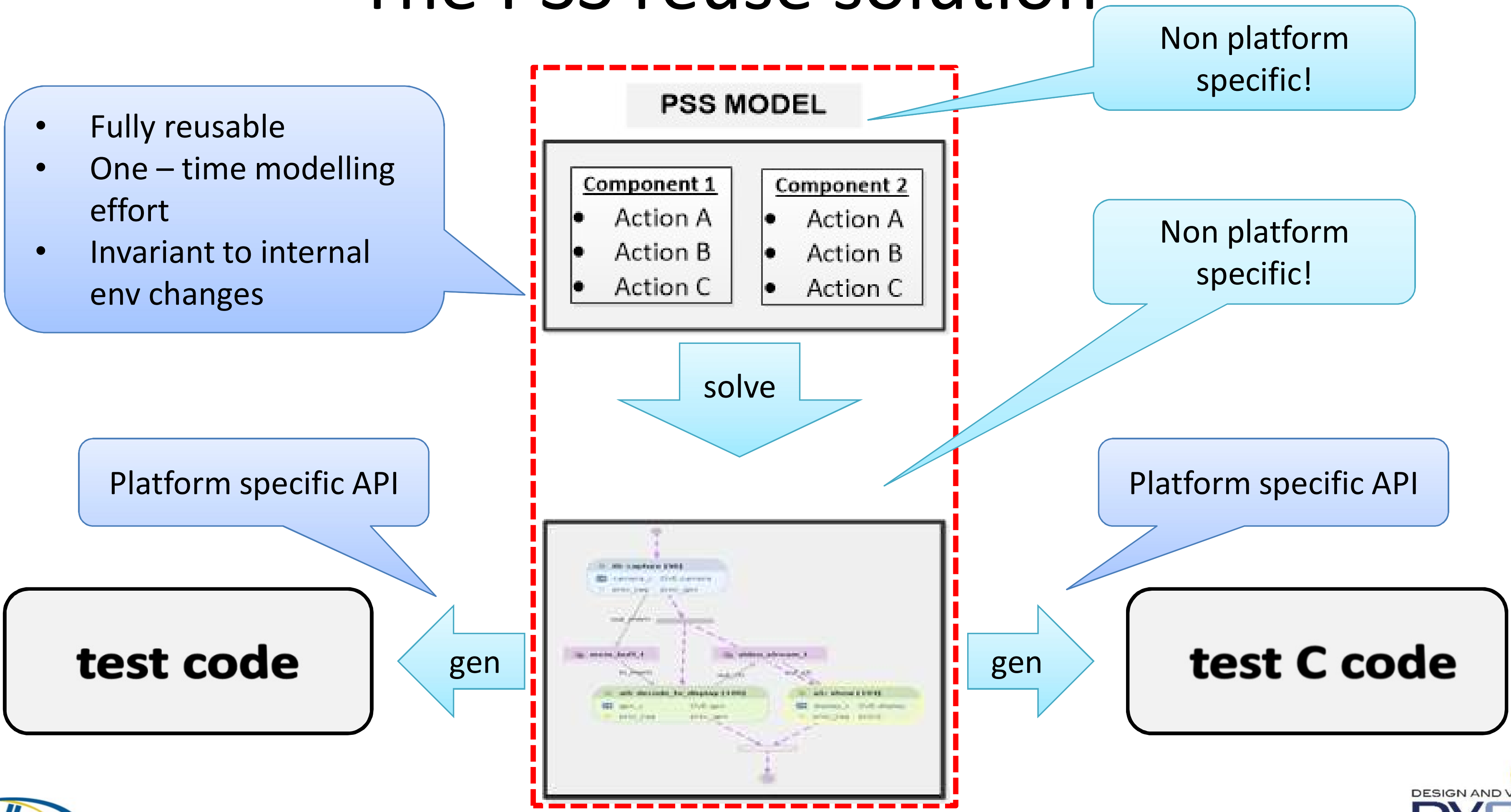
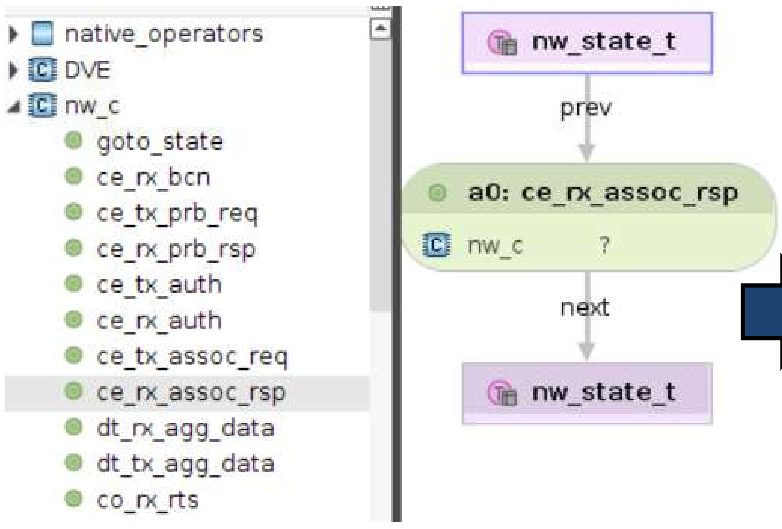
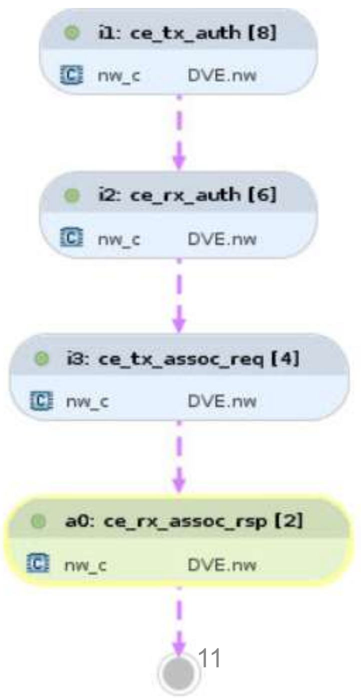
The PSS reuse solution

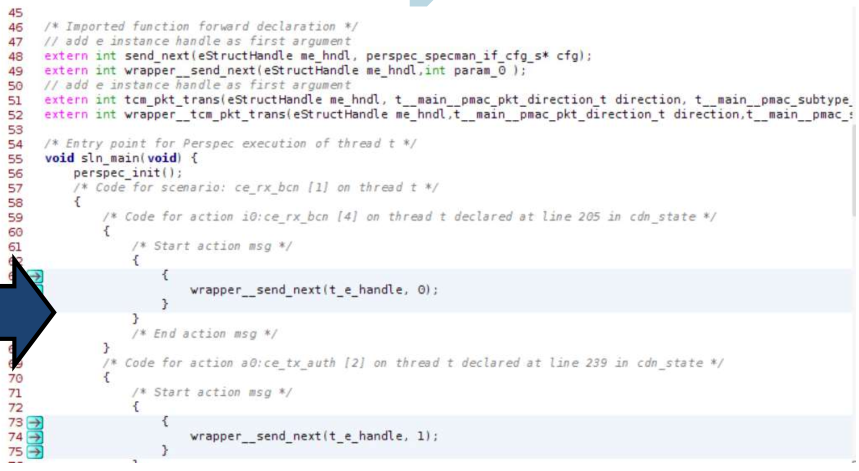


Generating Scenarios Using PSS

Drag action/s → Click 'solve' to create concrete scenario. → Click 'generate test' to create code







```
/* Imported function forward declaration */
// add e instance handle as first argument
extern int send_next(eStructHandle me_hndl, perspec_specman_if_cfg_s* cfg);
extern int wrapper__send_next(eStructHandle me_hndl,int param_0 );
// add e instance handle as first argument
extern int tcm_pkt_trans(eStructHandle me_hndl, t__main__pmac_pkt_direction_t direction, t__main__pmac_subtype_
extern int wrapper__tcm_pkt_trans(eStructHandle me_hndl,t__main__pmac_pkt_direction_t direction,t__main__pmac_s

/* Entry point for Perspec execution of thread t */
void sln_main(void) {
    perspec_init();
    /* Code for scenario: ce_rx_bcn [1] on thread t */
    {
        /* Code for action i0:ce_rx_bcn [4] on thread t declared at line 205 in cdn_state */
        {
            /* Start action msg */
            {
                {
                    wrapper__send_next(t_e_handle, 0);
                }
            }
            /* End action msg */
        }
        /* Code for action a0:ce_tx_auth [2] on thread t declared at line 239 in cdn_state */
        {
            /* Start action msg */
            {
                {
                    wrapper__send_next(t_e_handle, 1);
                }
```

Portable Stimuli actions

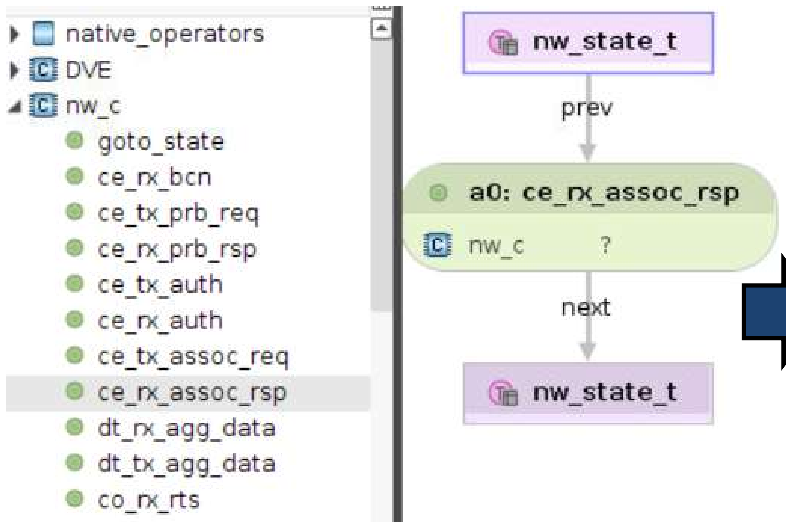
input
Action
out-
put

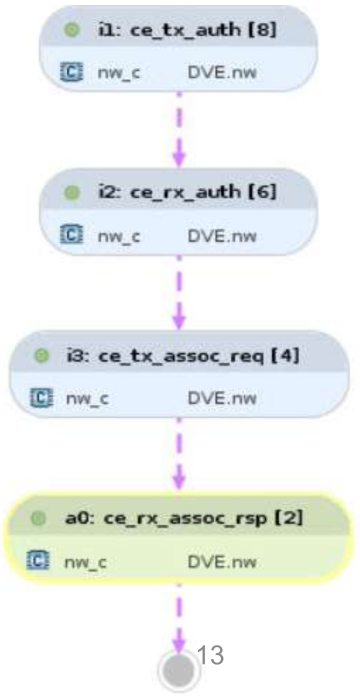
```
action ce_tx_assoc_req {
 input prev   : from state_var;
 output next : to state_var;

 constraint prev.state == auth_unassoc;
 constraint next.state == wait_assoc_rsp;
```

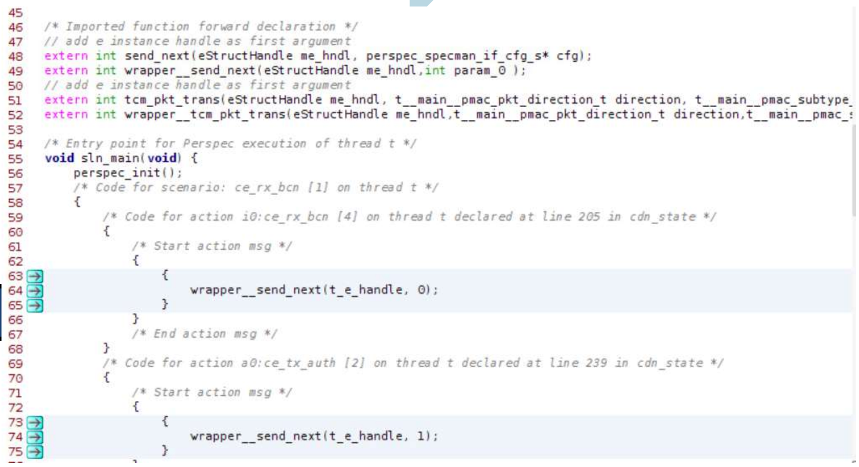
```
action ce_rx_assoc_rsp {
 input prev   : from state_var;
 output next : to state_var;

 constraint prev.state == wait_assoc_rsp;
 constraint next.state == connected_entry;
```

Generating Scenarios Using PSS

Drag action/s → Click ‘solve’ to create concrete scenario. → Click ‘generate test’ to create code







```

/* Imported function forward declaration */
// add e instance handle as first argument
extern int send_next(eStructHandle me_hndl, perspec_specman_if_cfg_s* cfg);
extern int wrapper__send_next(eStructHandle me_hndl,int param_0 );
// add e instance handle as first argument
extern int tcm_pkt_trans(eStructHandle me_hndl, t__main__pmac_pkt_direction_t direction, t__main__pmac_subtype_
extern int wrapper__tcm_pkt_trans(eStructHandle me_hndl,t__main__pmac_pkt_direction_t direction,t__main__pmac_

/* Entry point for Perspec execution of thread t */
void sln_main(void) {
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    /* Code for scenario: ce_rx_bcn [1] on thread t */
    {
        /* Code for action i0:ce_rx_bcn [4] on thread t declared at line 205 in cdn_state */
        {
            /* Start action msg */
            {
                {
                    wrapper__send_next(t_e_handle, 0);
                }
            }
            /* End action msg */
        }
        /* Code for action a0:ce_tx_auth [2] on thread t declared at line 239 in cdn_state */
        {
            /* Start action msg */
            {
                {
                    wrapper__send_next(t_e_handle, 1);
                }
```
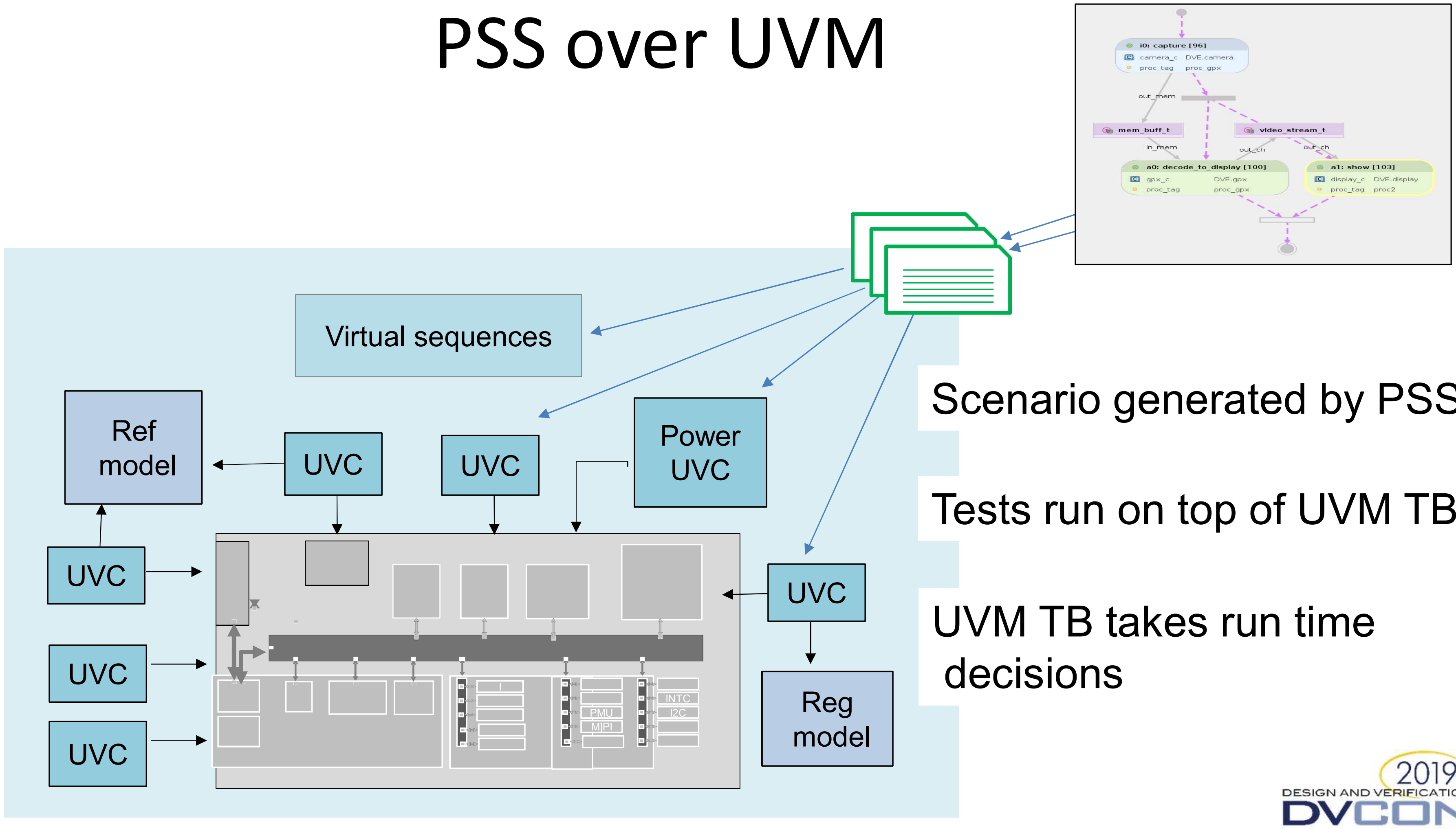

PSS over UVM



Scenario generated by PSS

Tests run on top of UVM TB

UVM TB takes run time decisions

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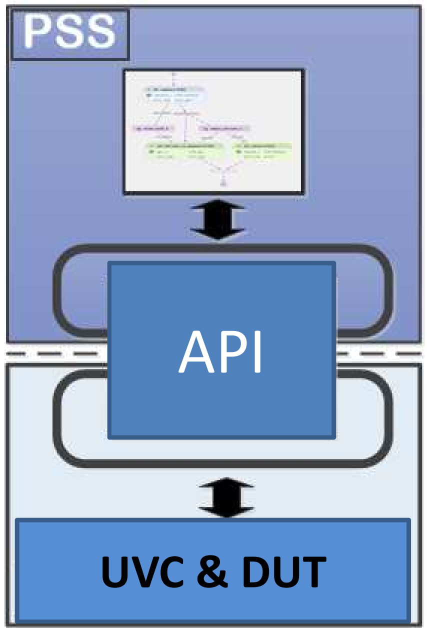
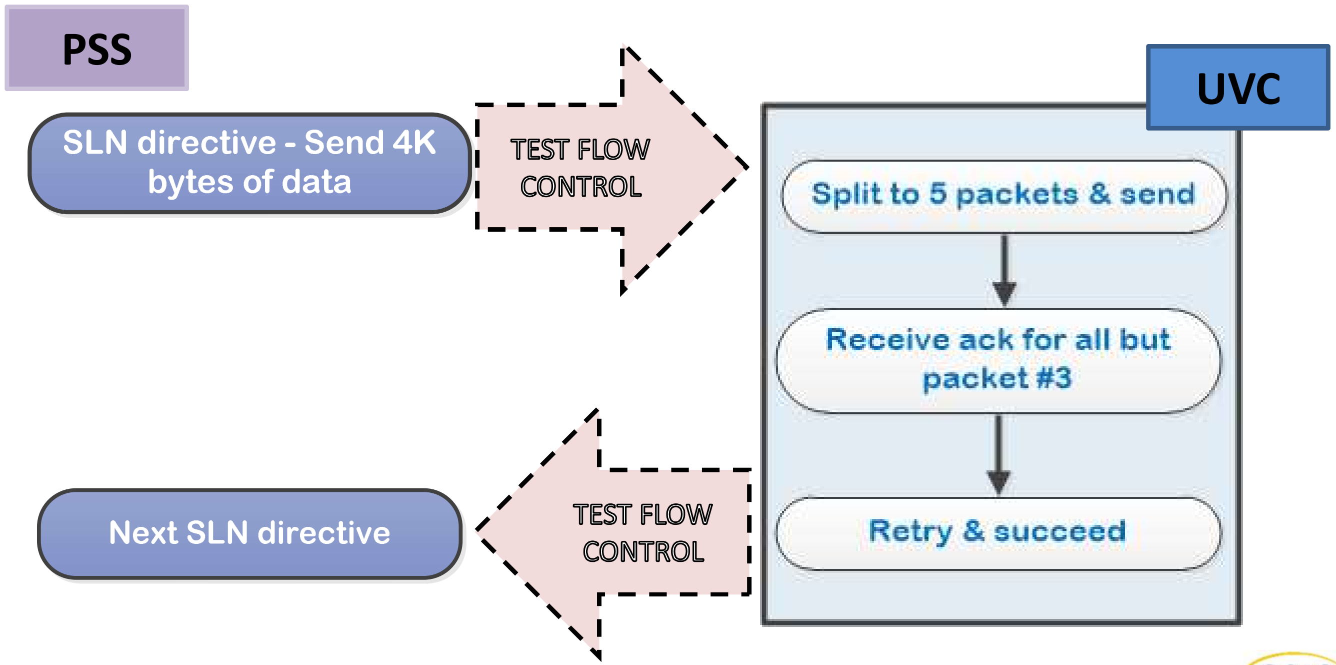
PSS/UVM Partitioning – the hybrid model

- Perspec scenario provides high level test case backbone
- UVM sequencers handle signal – level transactions

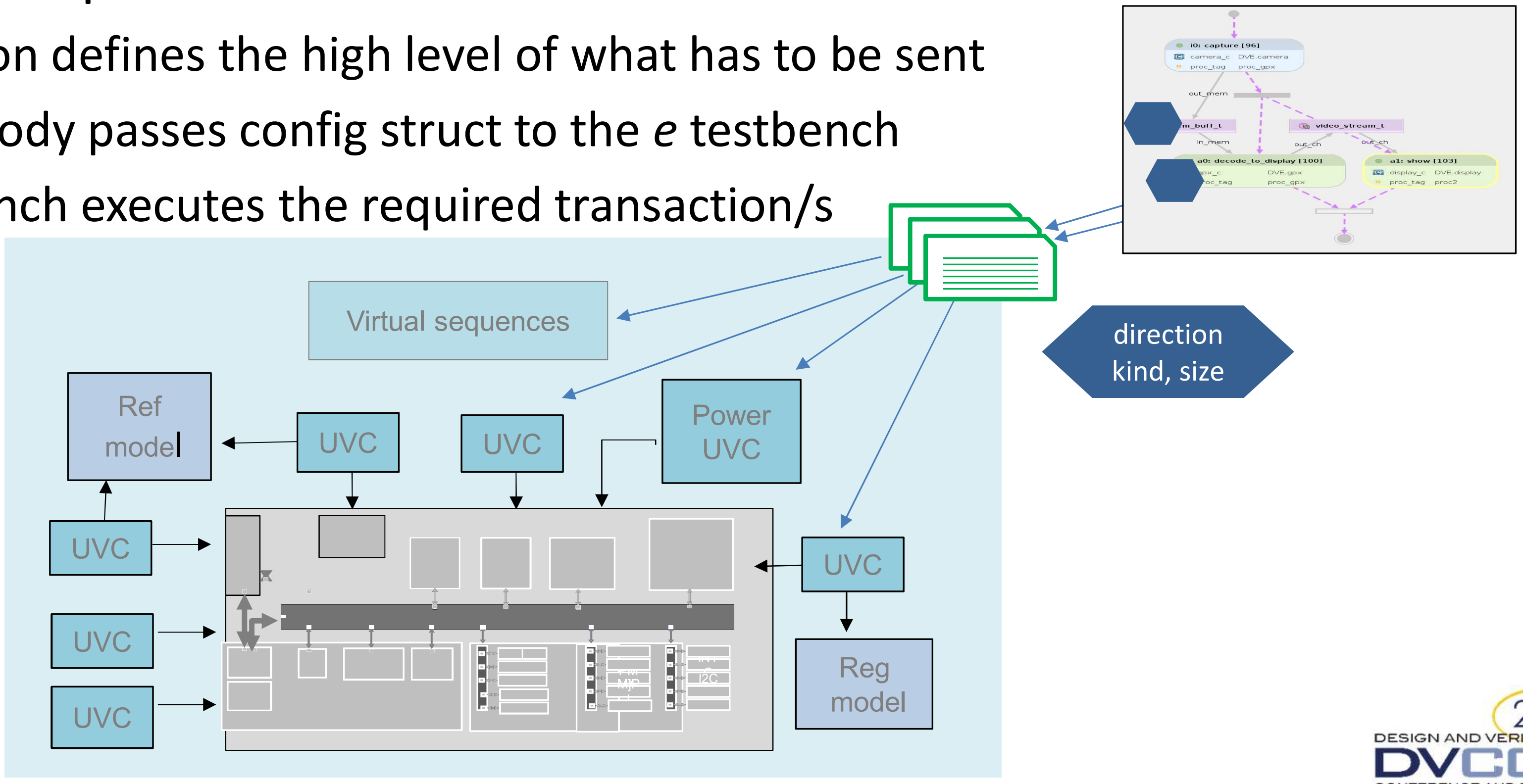




PSS
SLN directive - Send 4K bytes of data
TEST FLOW CONTROL
UVC
Split to 5 packets & send
Receive ack for all but packet #3
Retry & succeed
TEST FLOW CONTROL
Next SLN directive

Driving the scenario, from PSS to *e*

- Config struct passed information from PSS to UVM TB:
  - PSS action defines the high level of what has to be sent
  - Action body passes config struct to the *e* testbench
  - *e* testbench executes the required transaction/s



From action to test

PSS Model

```
action change_state {
    input prev  : from state_var;
    output next : to state_var;

    cfg         : cfg_s ;

    exec body {
        // Imported function
        send_next(cfg);
    };
};
```

From action to test

The action conditions – when can be executed, and what the results are

PSS Model

The required scenario

```
action tx_auth like change_state {
    constraint prev.state == sup_ap_found;
    constraint next.state == wait_auth;

    constraint cfg.direction                == TX;
    constraint cfg.transfer_kinds.size()    == 1;
    constraint cfg.transfer_kinds[0]        ==
                                   AUTHENTICATION;
```

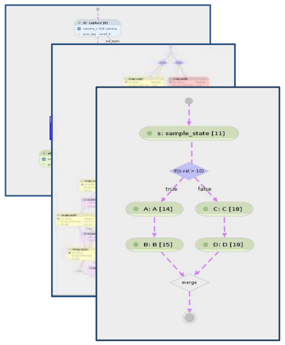
```
exec body {
   send_next(cfg);
};
```

From action to test

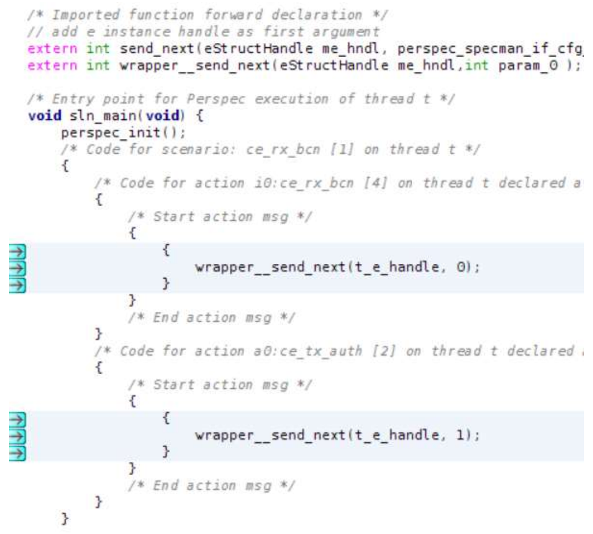
```
action tx_auth like change_state {
  constraint prev.state == sup_ap_found;
  constraint next.state == wait_auth;

  constraint cfg.direction
                                 ==  TX;
  constraint cfg.transfer_kinds.size()
                                   == 1;
  constraint cfg.transfer_kinds[0]
                       == AUTHENTICATION;
};
```

PSS Model

Perspec



Perspec



```
/* Imported function forward declaration */
// add e instance handle as first argument
extern int send_next(eStructHandle me_hndl, perspec_specman_if_cfg
extern int wrapper__send_next(eStructHandle me_hndl,int param_0 );

/* Entry point for Perspec execution of thread t */
void sln_main(void) {
    perspec_init();
    /* Code for scenario: ce_rx_bcn [1] on thread t */
    {
        /* Code for action i0:ce_rx_bcn [4] on thread t declared a
        {
            /* Start action msg */
            {
                {
                    wrapper__send_next(t_e_handle, 0);
                }
            }
            /* End action msg */
        }
        /* Code for action a0:ce_tx_auth [2] on thread t declared
        {
            /* Start action msg */
            {
                {
                    wrapper__send_next(t_e_handle, 1);
                }
            }
            /* End action msg */
        }
    }
```

```
@export_fli_c()
send_next(cfg: perspec_specman_if_cfg_s) @sys.any is {
    !seq : vir_sequence;
    gen seq keeping {
        .direction == cfg.direction;
        // ...
    };
    seq.start_sequence();
    wait @seq.ended;
};
```

Create scenario, according to config struct

All fields not constrained here will be randomized, according to UVC constraints

The test flow

e

```
extend sys {
   run() is also {
     start perspec_main();
   };

   perspec_main()@sys.any is {
     raise_objection(TEST_DONE);
     t.pss_main();
     drop_objection(TEST_DONE);
   };
};
```

This code is created automatically by the tool

The simulator and Specman start running

Specman calls the C **main** in **run** phase

From now – C test controls the scenario

C

```
void pss_main(void) {
   config(MODE_3A);
   send_next(t_e_handle, 0);
   /* …
```

In each test pss_main() is different, based on generated actions

Altering the *e*-C synchronization

e

```
extend sys {
  run() is also {
    start perspec_main();
  };

  perspec_main()@sys.any
    raise_objection(TEST_
    t.pss_main();
    drop_objection(TEST_D
  };
};
```

Created automatically

Start the test only after reach MAIN_TEST phase

e

```
extend sys {
  perspec_main()@sys.any is first {
     var tf_mgr := tf_get_domain_mgr_of(CORE);
     while TRUE {
       wait @tf_mgr.new_phase_starting;
       if tf_mgr.get_current_phase() ==
                                MAIN_TEST {
         break;
       };
     ///…
```

Created manually

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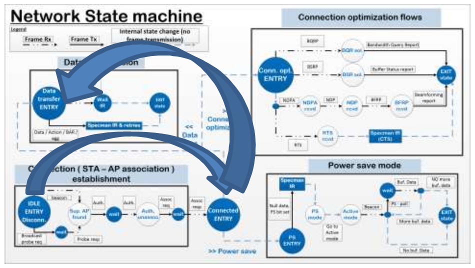
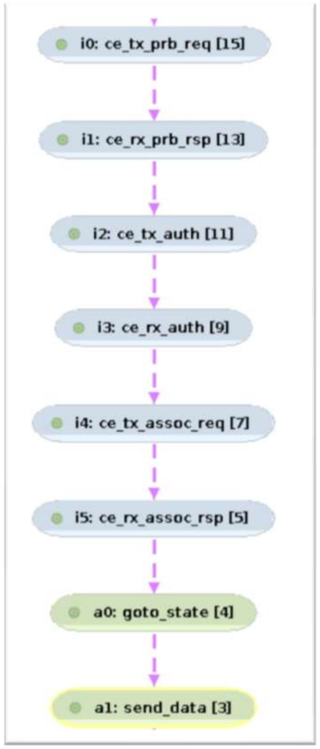
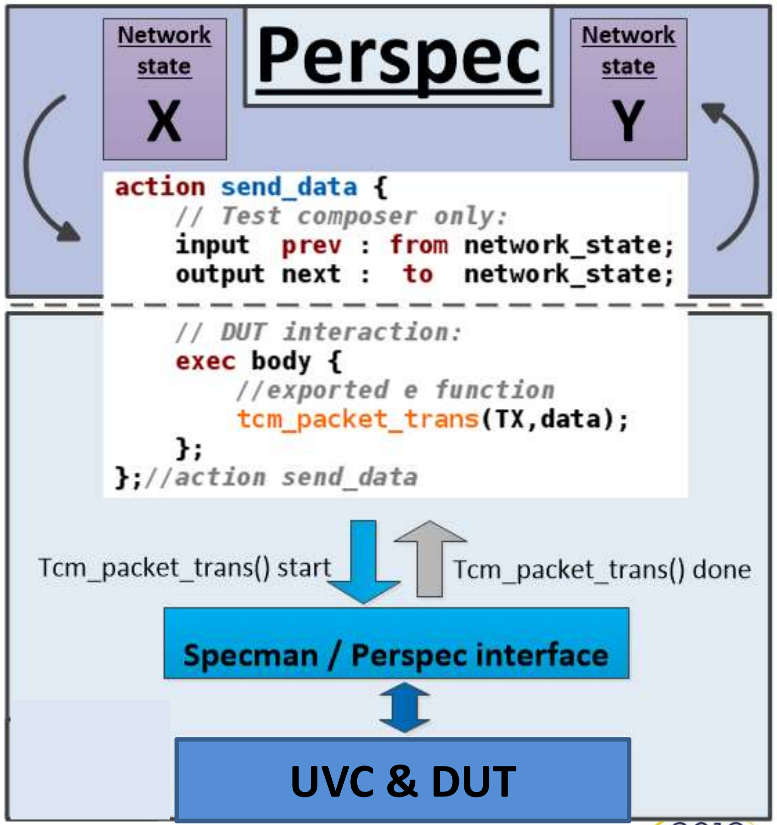
Yet to be added

- Seamless regression invocation
  - Vmanager integration, Perspec regression abilities
- Enhance Debug abilities
- Sync UVM test phases with Perspec scenarios
- Perspec/Specman migration to validation platforms (embedded C code)
- Full coverage closure using Perspec WIFI simulator

- PSS model
  - Inputs, Outputs
  - Rules of coexistence
- *e* API to test platform
  - Platform specific implementation







```
action send_data {
    // Test composer only:
    input  prev : from network_state;
    output next :  to  network_state;
    // DUT interaction:
    exec body {
        //exported e function
        tcm_packet_trans(TX,data);
    };
};//action send_data
```

Summary

- Few weeks ramp up period, hundreds of tests created
  - What usually takes several months
- Model is easily updated to new needs

- Concept shift makes integration not intuitive
- Perspec – C – Specman API impairs seamless integration
- Need to adjust debugging techniques

Bottom line: TI decided to expand the usage of Perspec over UVM

Questions?