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Exquisite Modeling of VIP

by

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Agenda

- The presentation covers
  - Different Challenges faced developing an efficient VIP
    - Complex Randomization
    - High bandwidth data transfer
    - Protocol dependency
  - Case study
    - Describe each challenge through an example
    - Recommendations in developing any efficient VIP
  - Summary and Results

Context of Verification

- LSI designs AXI subsystems
- Need to verify DMA controller for correct data transfer
- Performance of DMA controller is important
  - This requires large amounts of data to be moved
  - Pre-generation of more than one descriptor/data is needed as DUT reads multiple packets based on DUT fifo size and interface bandwidth
- Pre-generation is a common need for verification of many design blocks

Challenges faced in developing VIP

Three main obstacles encountered developing the verification IP.

- Constraint solver
  - Large set of inter-related constraints
  - Performance of solver

- Pre Generating payload-data for each transaction
  - Large quantities of payload per transaction
  - Consumes significant runtime memory
  - Transaction stored in ref-models until scoreboard check is complete

- Stabilizing and coding Verification IP
  - Frequent changes in protocol, architecture reasons: better performance etc
  - Highly configurable for reuse in higher level of chip hierarchy
  - Verify the scalability of design (e.g.: configurable no. of DMAC channels)

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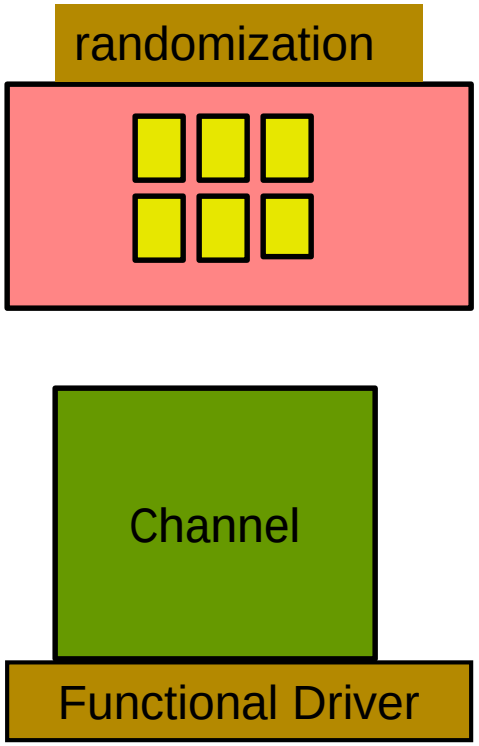
Data class – complex constraints

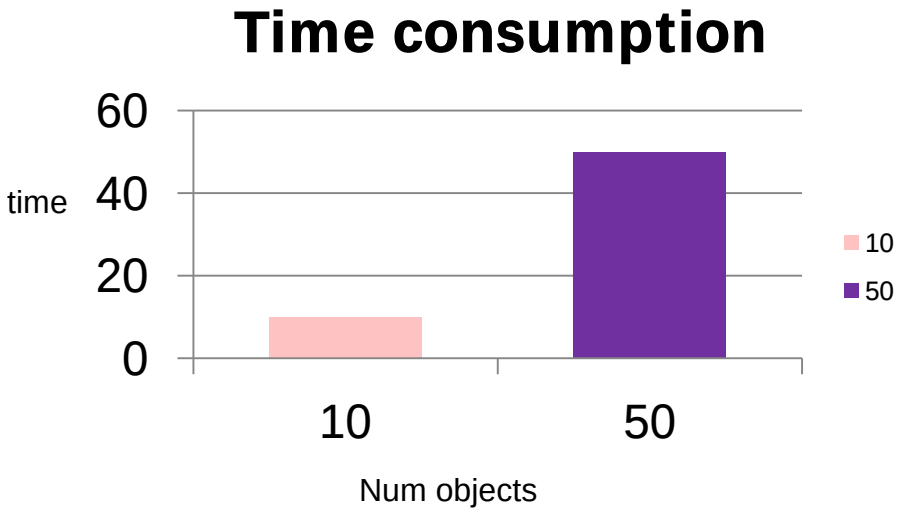
```
constraint rate_c {
   (jd_D.mode == MAX_MODE) -> (rate inside {0,2,3,4,6}); };

constraint blk_size_c {
if(jd_D.mode == MAX_MODE && rate == 0)  (jd_C.blk_size/2
   inside
   {108,120,144,180,192,216,240,480,960,1440,1920,2400}) ;
if(jd_D.mode == MAX_MODE && rate == 2)  (jd_C.blk_size
   inside {48,96,144,192,240, 288, 384, 432, 480}) ; };

constraint s_c {
   ((rep == 3) || (rep == 1))-> jd_D.mode == TE_MODE; };
constraint s_rm_c {
   (jd_C.so == 1) -> ( jd_D.byp != 0);};
constraint dyn_stop_c {
   (dyn_stop == DYN_STOP) -> (jd_C.so == 0);   };
```

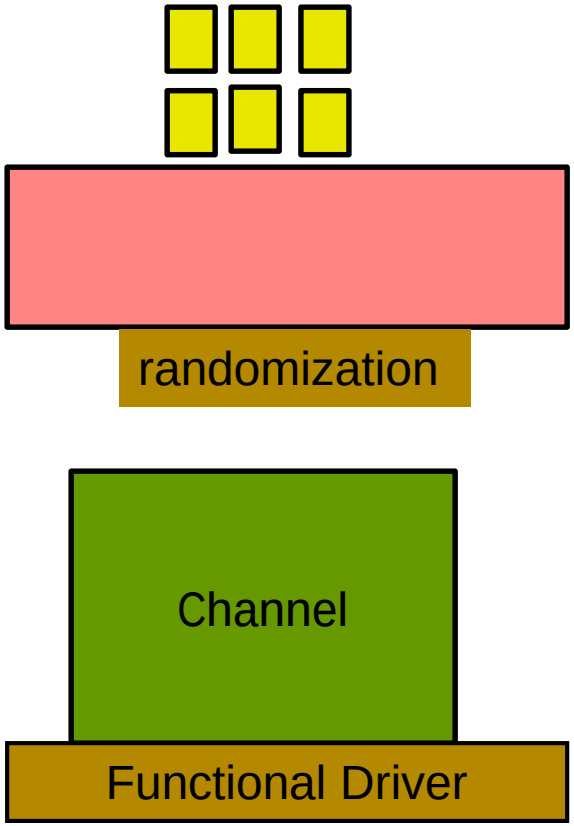
Randomization – List of complex objects





- With a smaller queue size, constraint solver easily solves the queue of objects
- With large queue size, constrain solver times out

Randomization in Phases – Objects List



- Randomization in phases for queue of class objects
- Complex class objects solved one by one and inserted in queue
- Knowledge of dependency of constraints required

Parameterized base class

```
class base_class #(type child_pkt = vmm_data)
    extends vmm_data;
      rand int q_size; //size of queue for class
     constraint q_size_c { q_size[31] == 0;};
     child_pkt pkt_obj_q[$];
     rand child_pkt pkt_obj;
    virtual function void post_randomize();
           pkt_obj_q.delete();
           $cast(pkt_obj, pkt_obj.copy(pkt_obj));
      for(int i = 0;i < q_size ; i++)     begin
          ……….
         pkt_obj.randomize();
          pkt_obj_q.push_front(pkt_h);    end
   endfunction
endclass
```

User defined base class

List of Class objects

Randomization and insertion in queue

Recommendations - constraints

- Split constraints into
  - Variables that must be solved together
  - Partition non-related variables for solving independantly
  - Per sub-object randomization called from post-randomize
- Reduction in time taken to solve complex constraints for multiple packets
- Hierarchical parameterised base class was reused in DMA and different types of decoder

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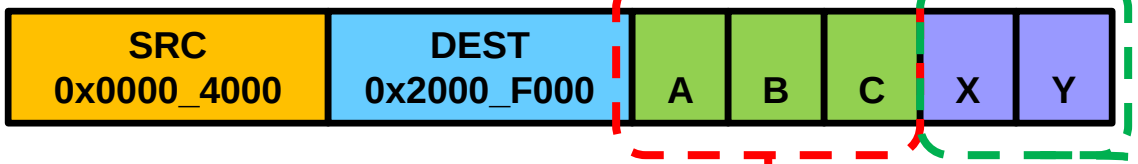
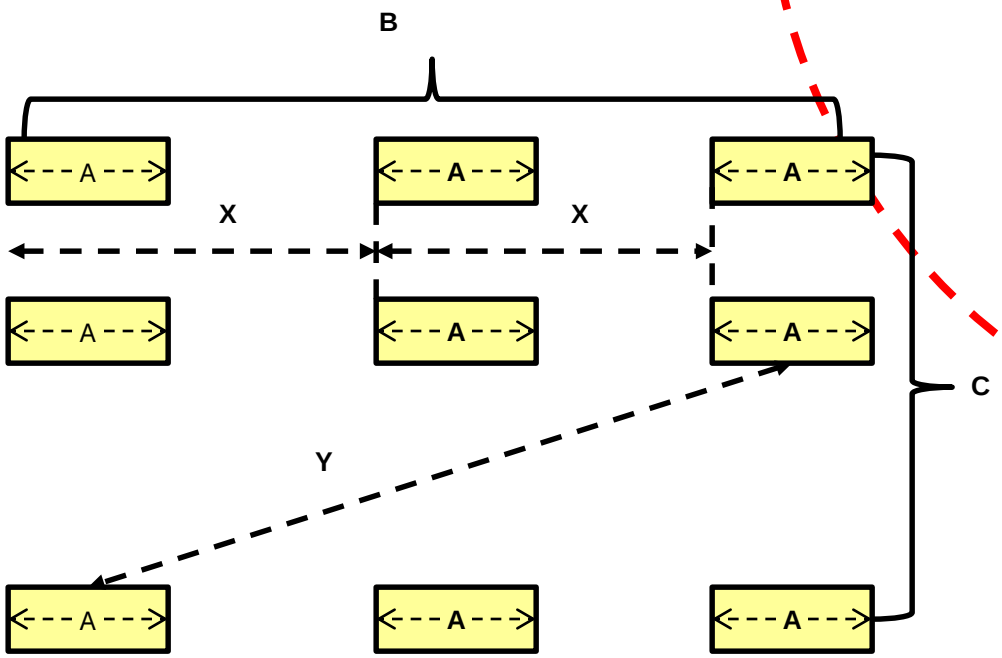
Simplified DMAC Descriptor



Simplified Descriptor format



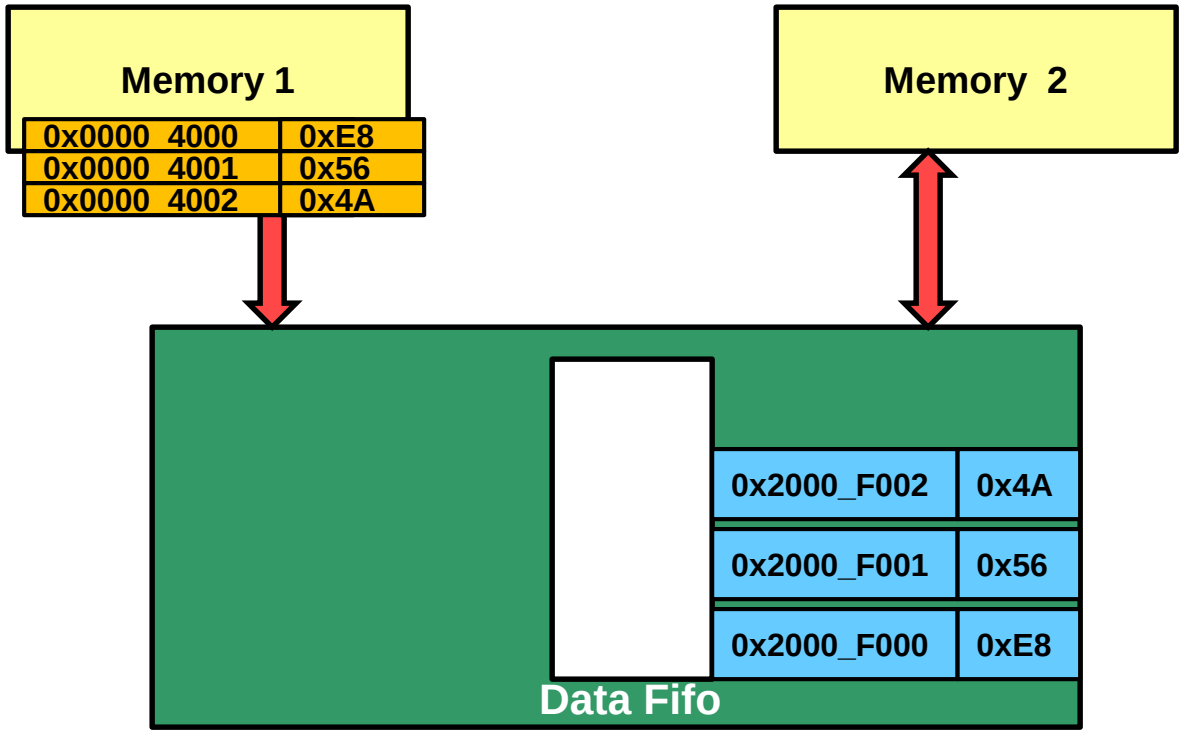
Another 2 fields X,Y controls the pattern i.e. how memory will be read/write

3 fields named A,B,C controls the total number of bytes to be read/write. A,B & C all are 16bit field . So, Theoretically 2^48 bytes can be read /write.

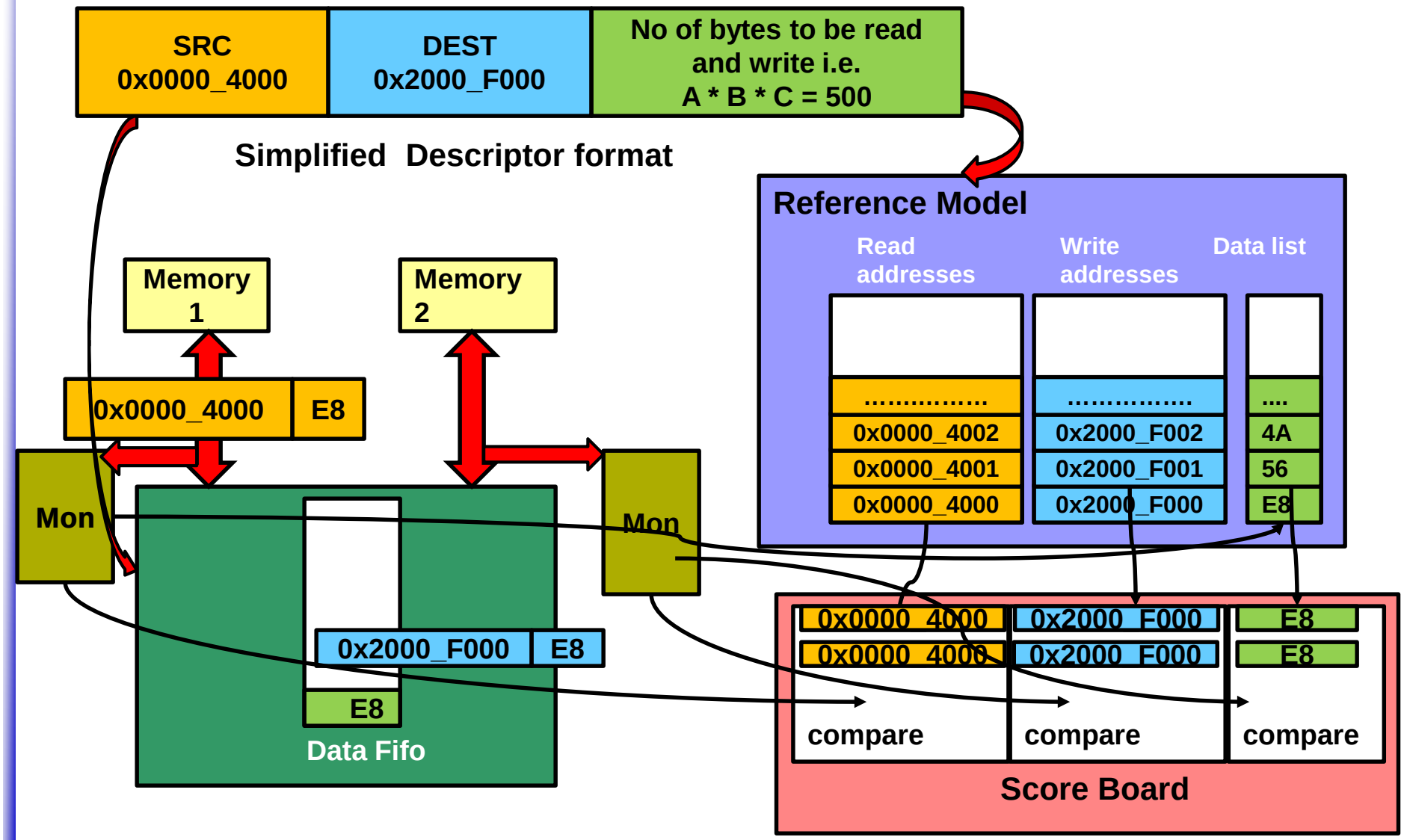
Basic DMA Functionality

SRC 0x0000_4000	DEST 0x2000_F000	No. of bytes to be read and write i.e. A * B * C = 500

Simplified Descriptor format



DMA Verification Strategy



Issue in Handling Large Queues

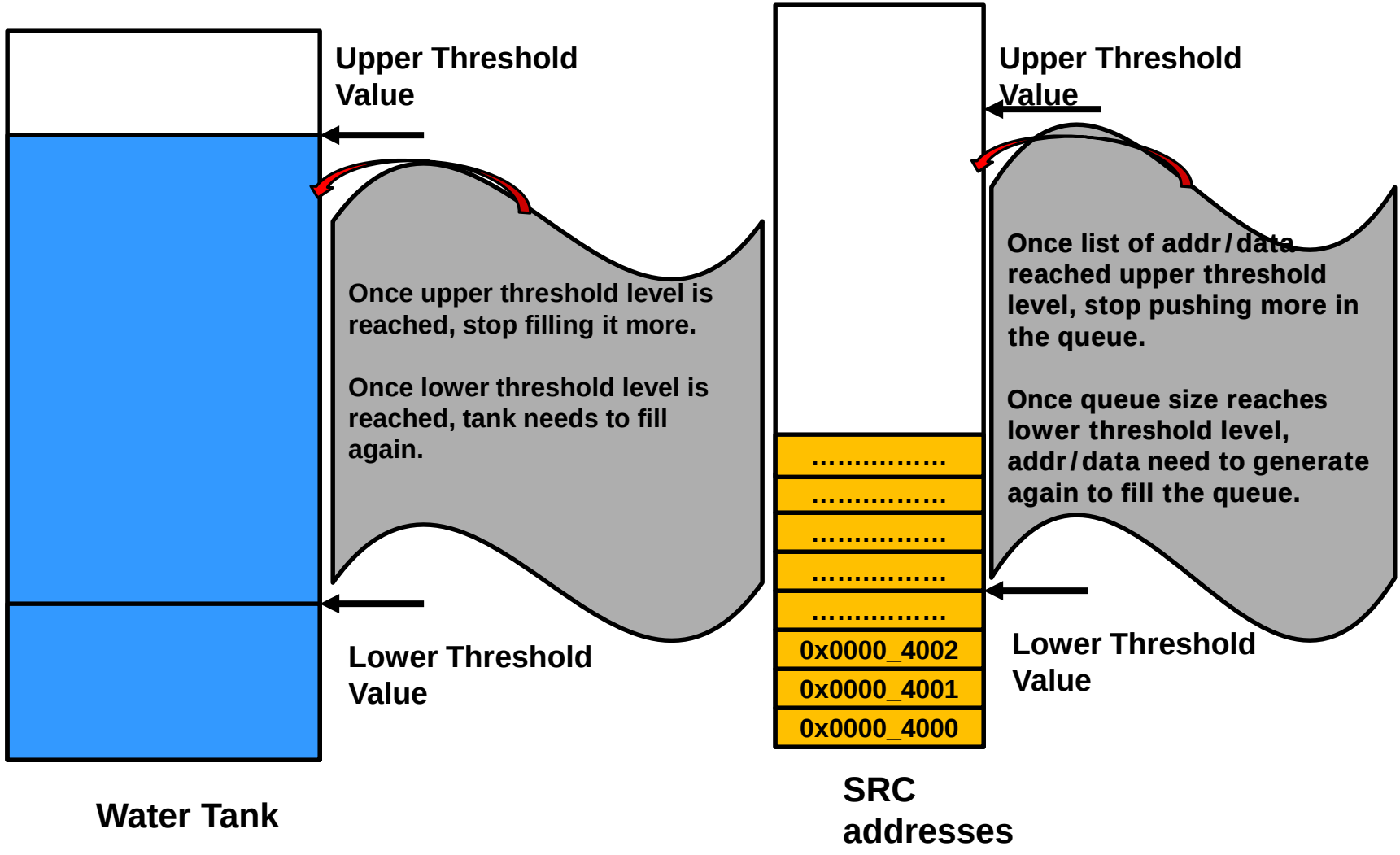
SRC 0x0000_4000	DEST 0x2000_F000	Number of bytes to read and write i.e. A * B * C = 655070000

Simplified Descriptor format

Reference Model

Read addresses	Write addresses	Data list
.....	.....	....
.....	.....	....
.....	.....	....
.....	.....	....
.....	.....	....
0x0000_4002	0x2000_F002	4A
0x0000_4001	0x2000_F001	56
0x0000_4000	0x2000_F000	E8

Water Mark Concept



Recommendations for Pre-generation

- DMA reads/writes data as a chunk of bytes. Hence we always need to keep some pre generated expected address/data ready in the queues
- Water mark concept helps to use system memory in an efficient manner
- Upper and lower threshold level can be set to any value by the user depending upon the design
- Without using Water mark concept tool runs out of memory and gives the following message :

```
Error-[OUTMEM] The tool has just run out of memory:
Memory allocated = 3684 MB, Request size = 923885568 bytes.
make: *** [run] Error 3
```

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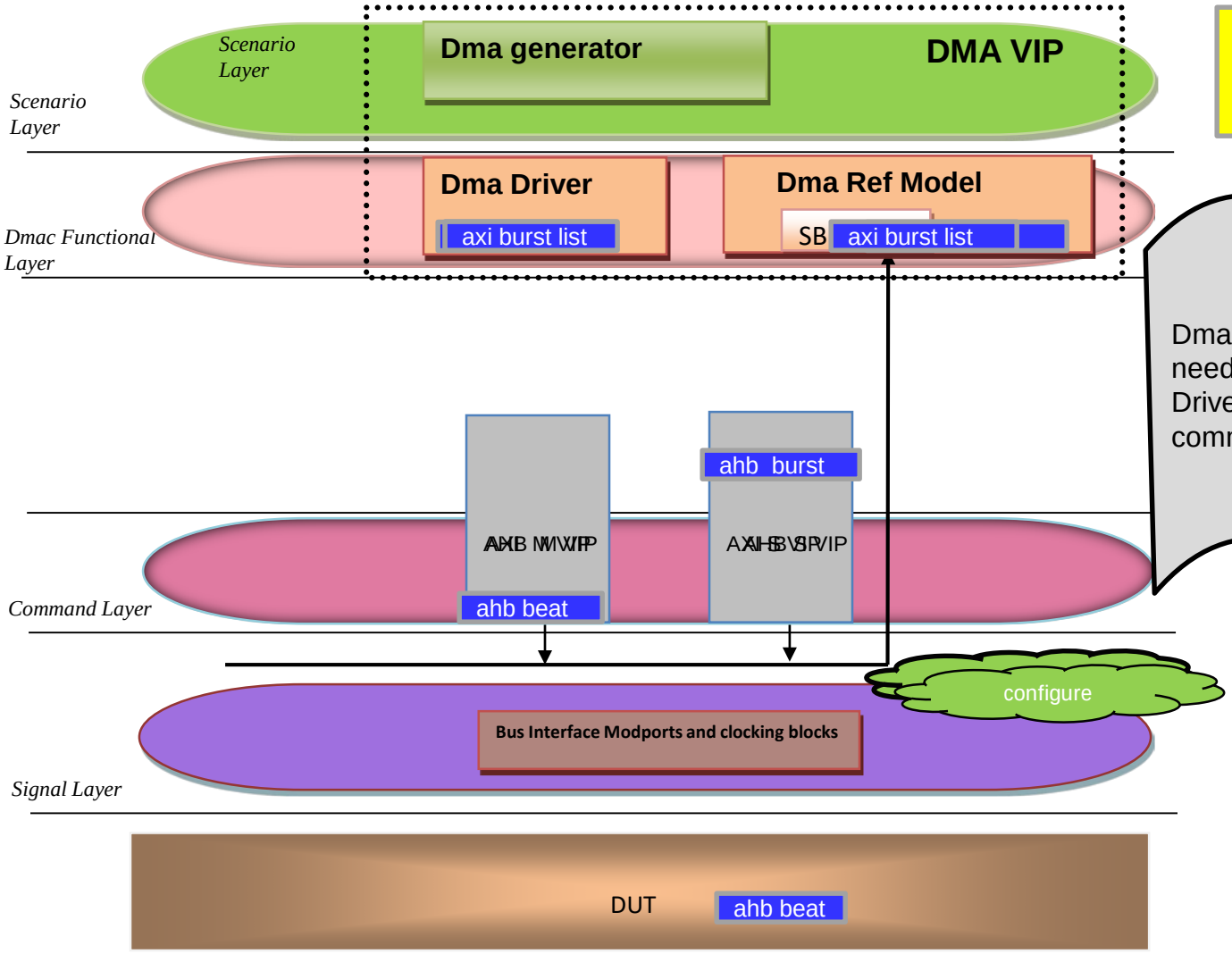
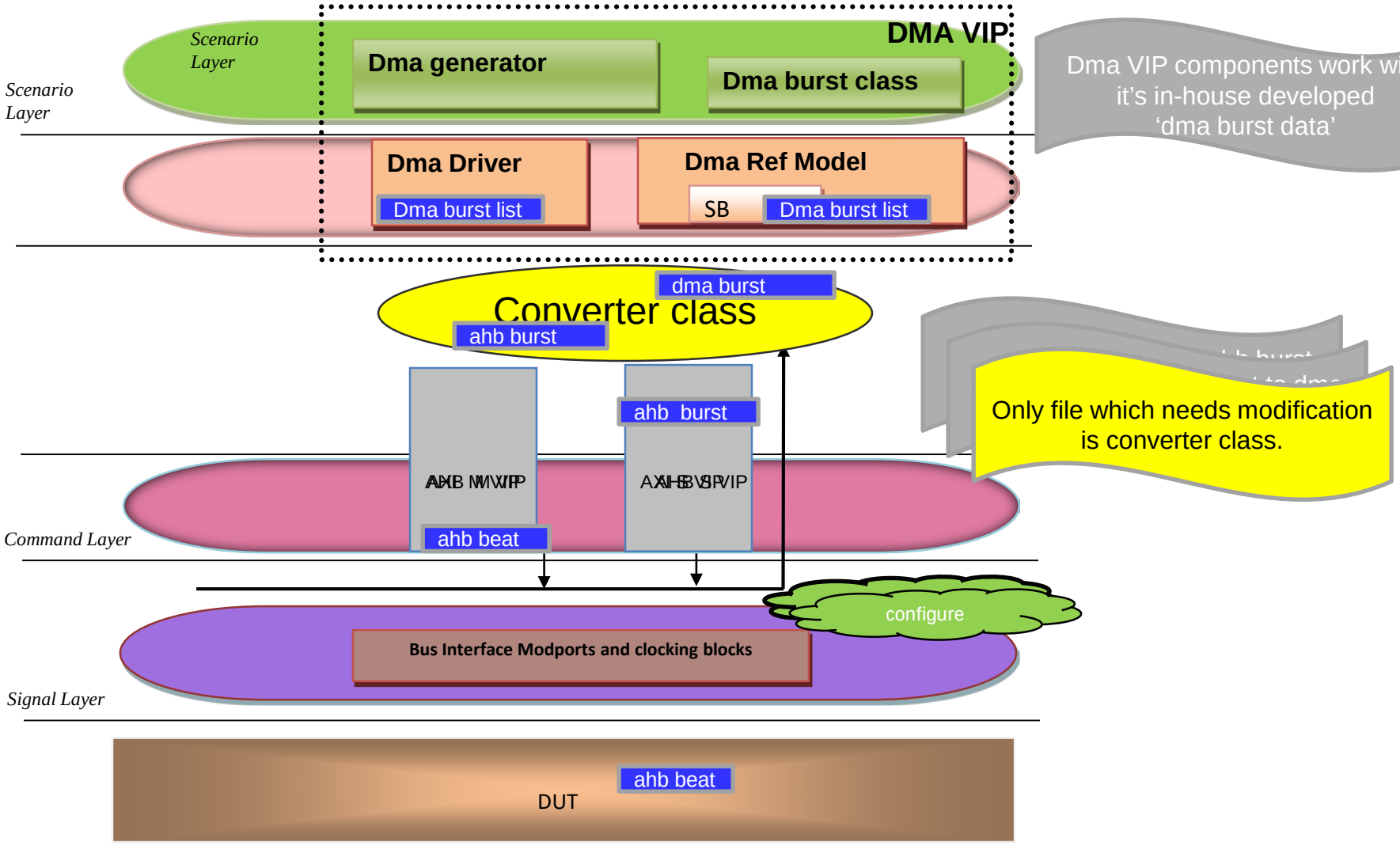
VIP dependent on Interface protocol



DMA VIP with AXI Interface

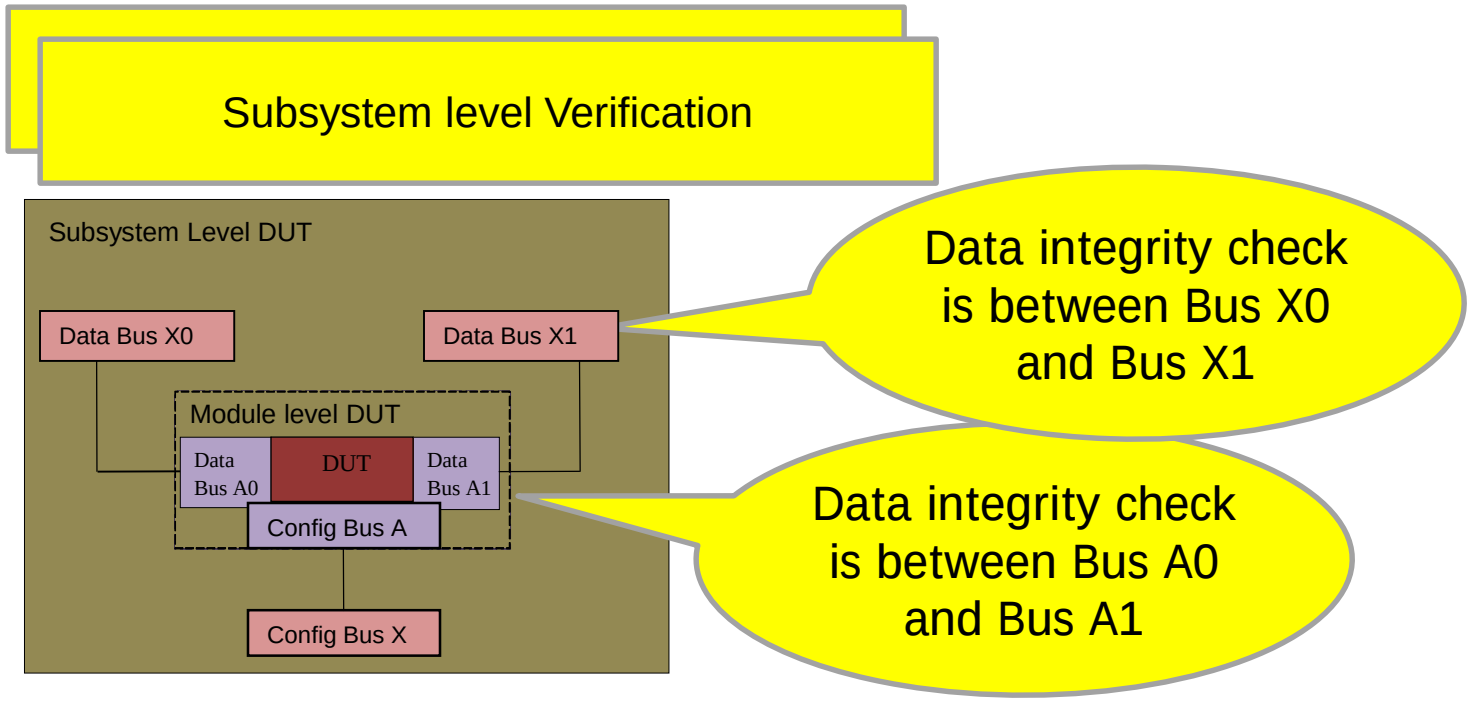
Dma VIP components which needs update are :
Driver and Ref Model other than command layer components.

Interface Independent VIP



Interface Independent VIP

- One more advantage we find with this approach is when verification is moved from block level to higher level the data integrity is checked not with immediate interface but with end interface hitting full path coverage.



VIP Interface independent benefits

- Time to migrate between VIP's significantly reduced
  - 6X faster than traditional VIP changes for DUT modifications
- Block to Top Reuse thought out upfront
- Data integrity covering any end to end data path

Summary

- Following above recommendations, a robust VIP is created to generate random packets which are constrainable and easily controlled from test case without burdening the constraint solver.
- This reusable VIP is efficient, faster, and immune to interface changes.
- Also reduces run time memory consumption.

  - Without using water mark concept tool runs out of memory when queue size reaches around 149314080 value.

Q&A

Usage - Parameterized base class

```
program test();
  initial begin
      base_class #(turbo_pkt) tr;
      turbo_pkt tpkt;
      tr.pkt_obj   = tpkt; // assigning constrained value
   // to baseclass handle
      …….
      tr.randomize();
   end
endprogram
```