Protocol Transducer Synthesis using Divide and Conquer approach

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Outline

- Background
- Protocol Transducer Synthesis
- Baseline Method（Passerone's Method）
- Proposed Method
- Experiment

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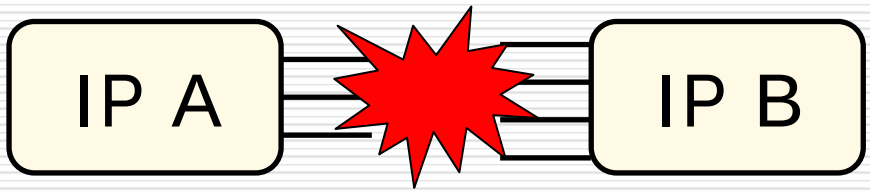
Background

- Transistors continue to be shrunk
- More number of transistors on a single LSI
- These result in long design period
- However, it is important to shorten the time-to-market

Background

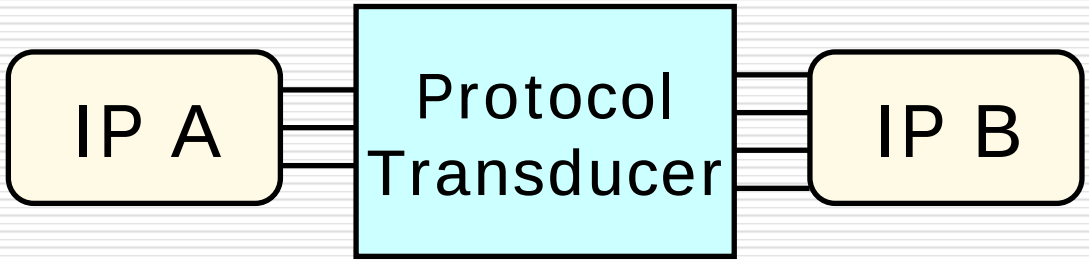
- IP reuse is an attractive solution
  - Reuse existing designs (IPs) for the new design.
  - It can also shorten verification period, because IPs are pre-verified.

- However, the interface mismatch prevents an IP from being reused…



Background

- In such case, designers usually insert a protocol transducer between incompatible interfaces.



- However, designing a protocol transducer consumes much time...
- Automatic synthesis of protocol transducer is expected to be useful.

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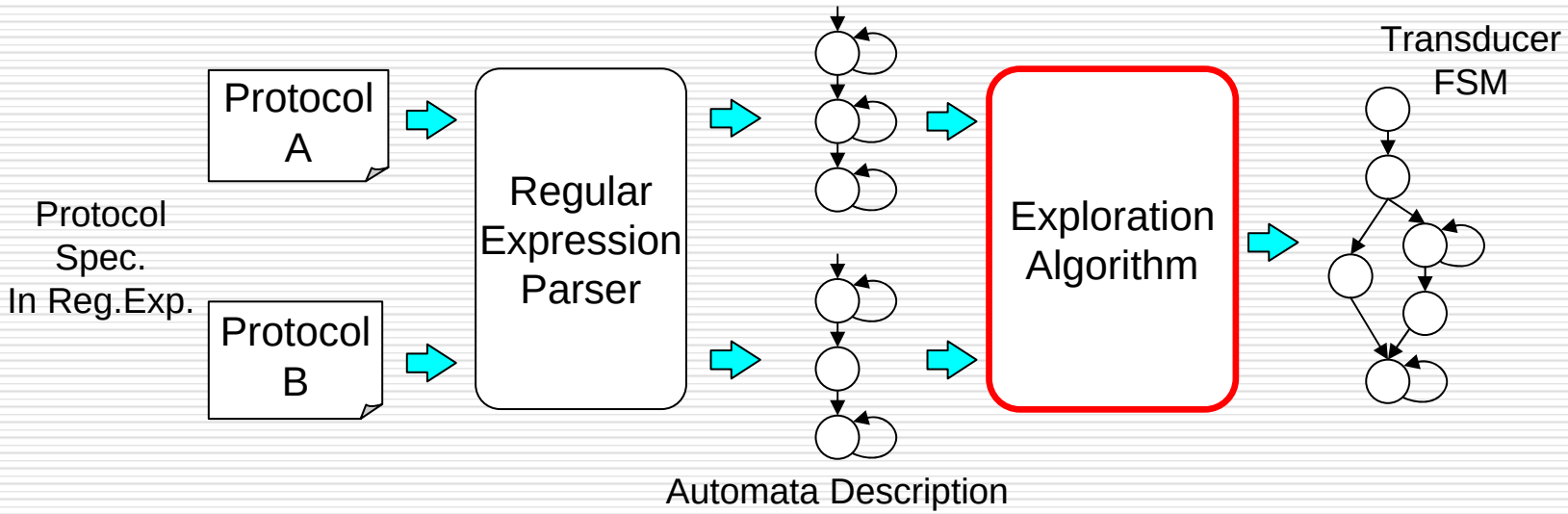
- Experiment
- Conclusion

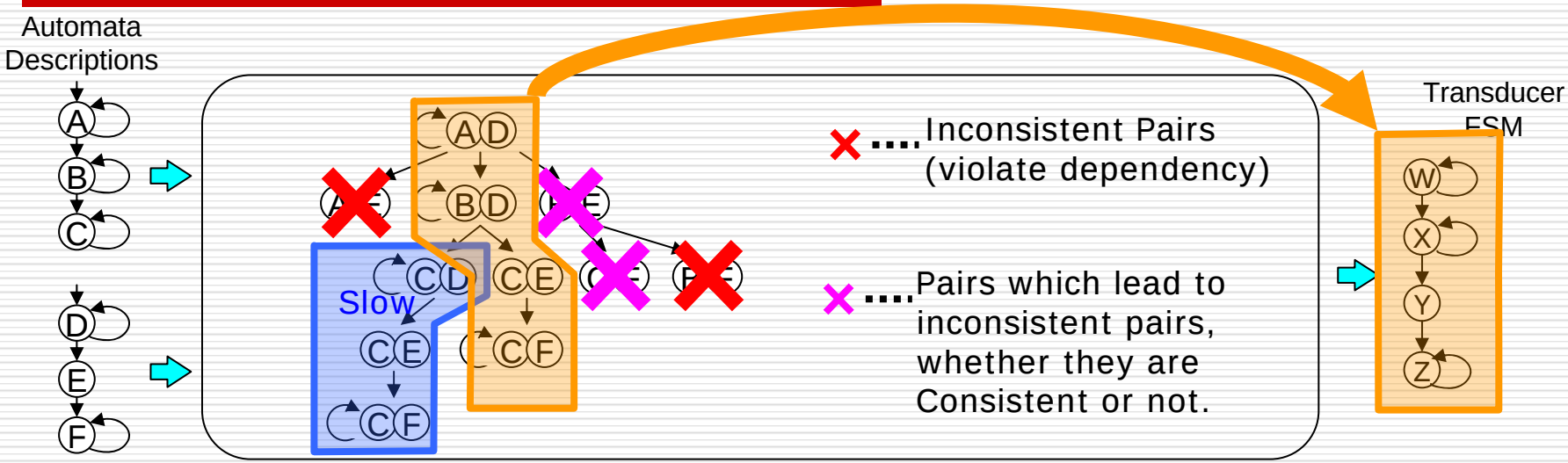
Passerone's Method

- Passerone et'al proposed a protocol transducer synthesis method in [5].



[5] R.Passerone, J.A.Rowson, A.Sangiovanni-Vincentelli,
"Automatic Transducer Synthesis of Interfaces between Incompatible Protocols" ,DAC'98 pp.8-13

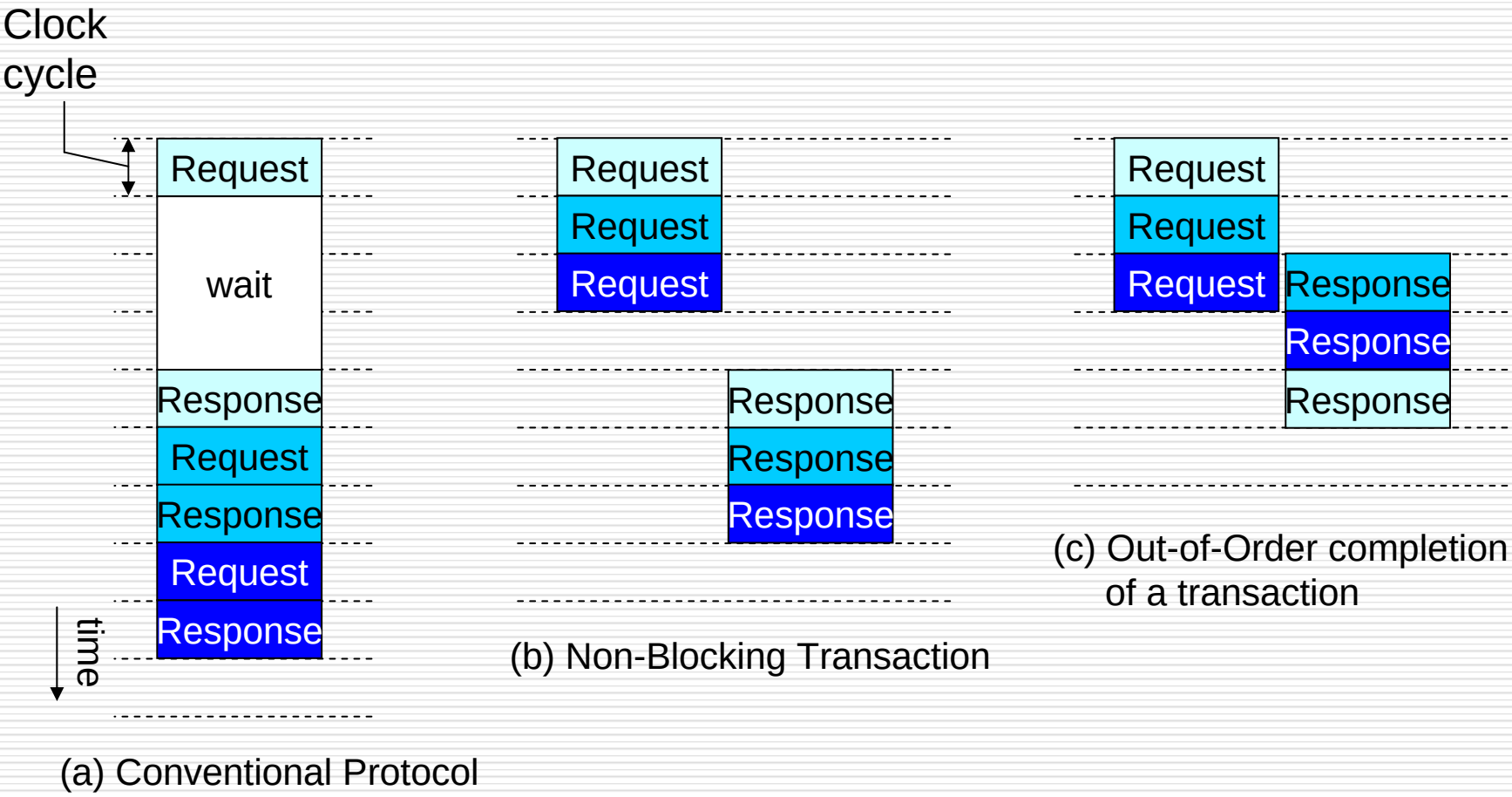
Passerone's Method –Search algorithm-



- Take a state from each automaton, and see if they are inconsistent or not.
- If not, search the next transitions.
- If more ions are available under sa hoose one having the leas

Output a value which is not arrived

The State-of-the-art Protocols



The Limitations of the existing methods

- Most of the existing methods uses a **SINGLE automaton** as a specification of a protocol.

- These features with **parallelisms** are difficult to be described in an automaton.

Outline

- ☑ Background
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- ➡ Proposed Method
- Experiment

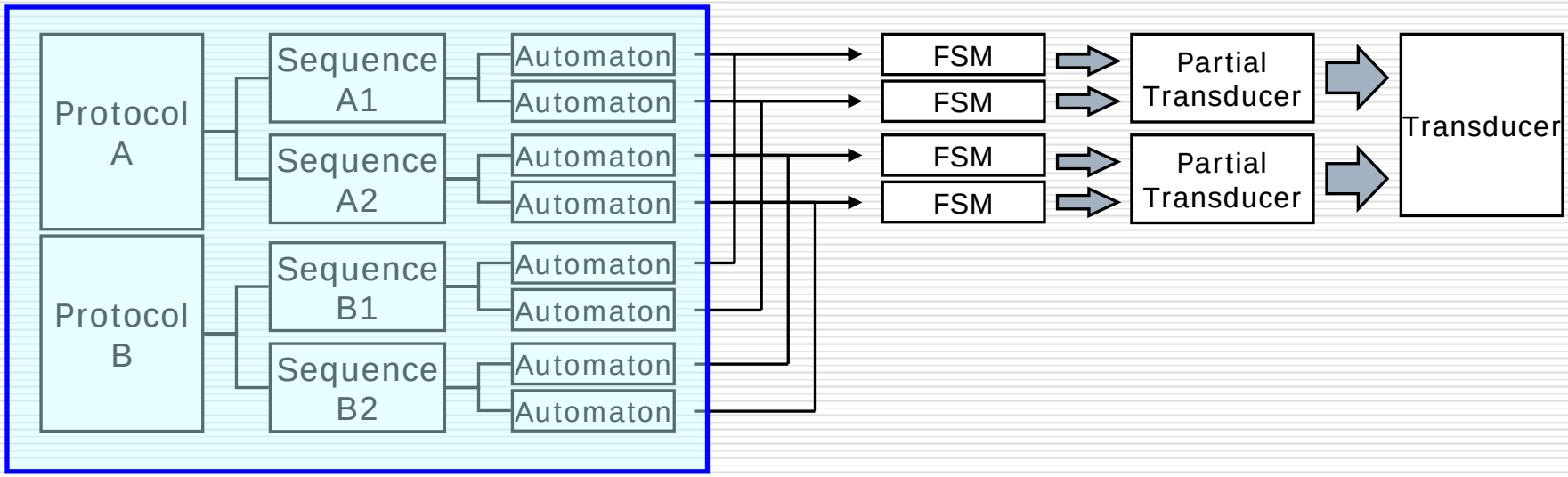
Objective

- Automatically synthesize protocol transducers even for complex protocol, by extending Passerone's Method.

- Basic Idea: Divide-and-Conquer
  - Partition the exploration space into some small ones.
  - Construct the entire transducer from the partial transducers.

Outline of Proposed Method

1. Protocol Modeling Method
2. Sequence Level Synthesis
3. Automaton Level Synthesis
4. Construction of whole Transducer



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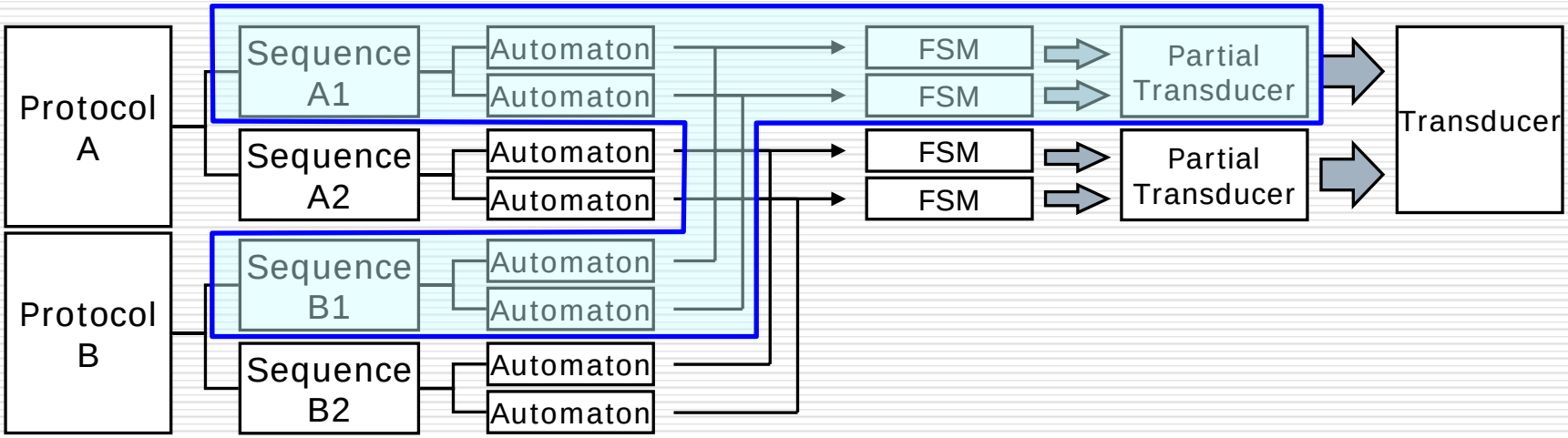

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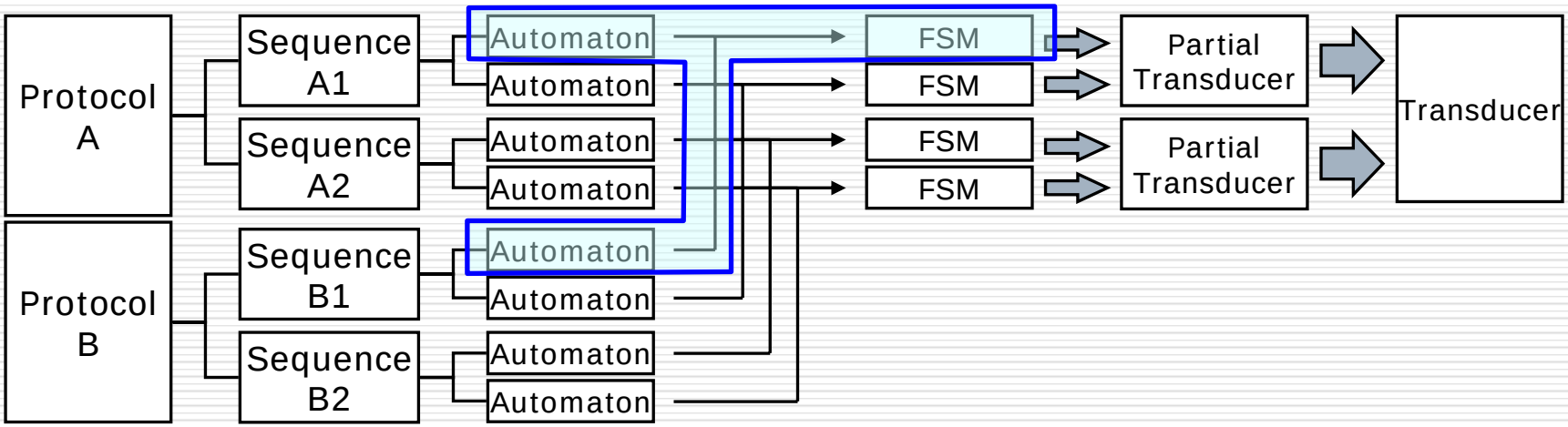

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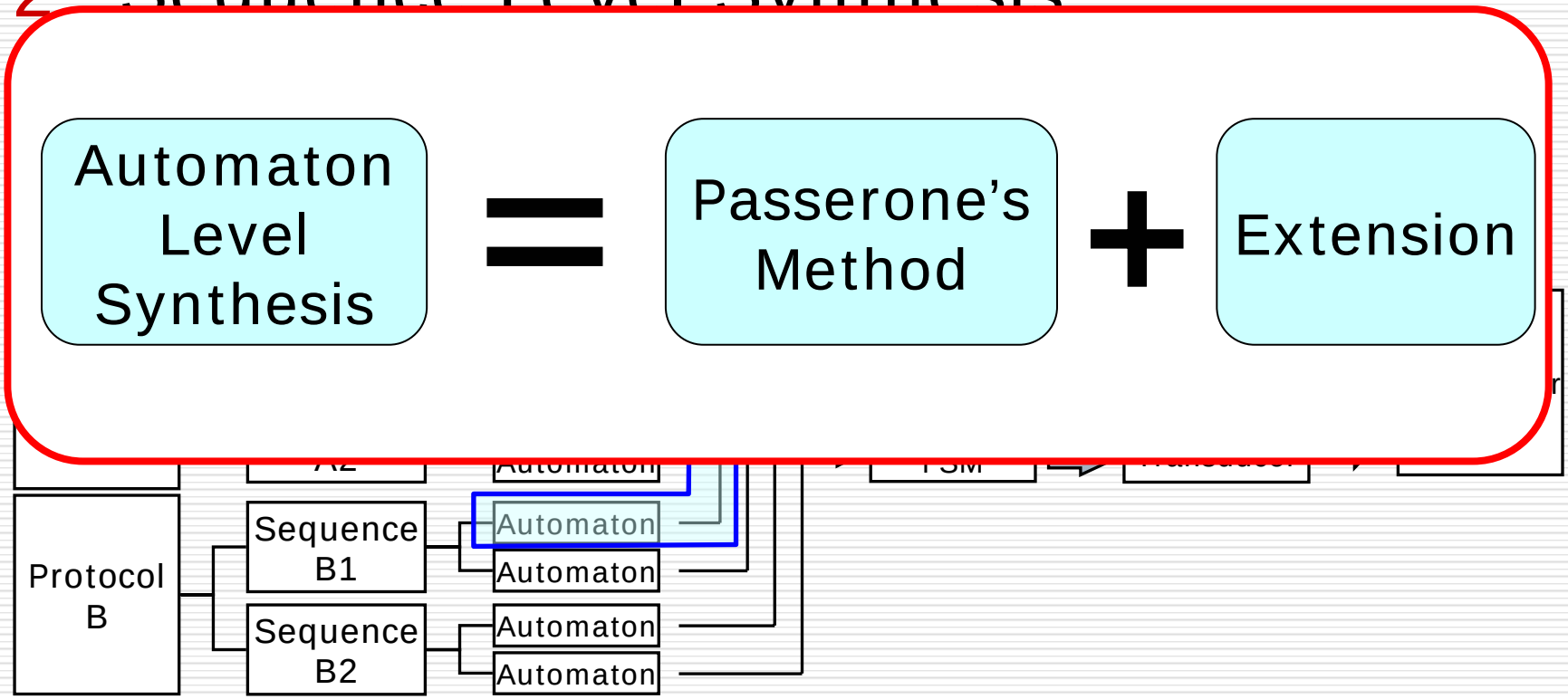

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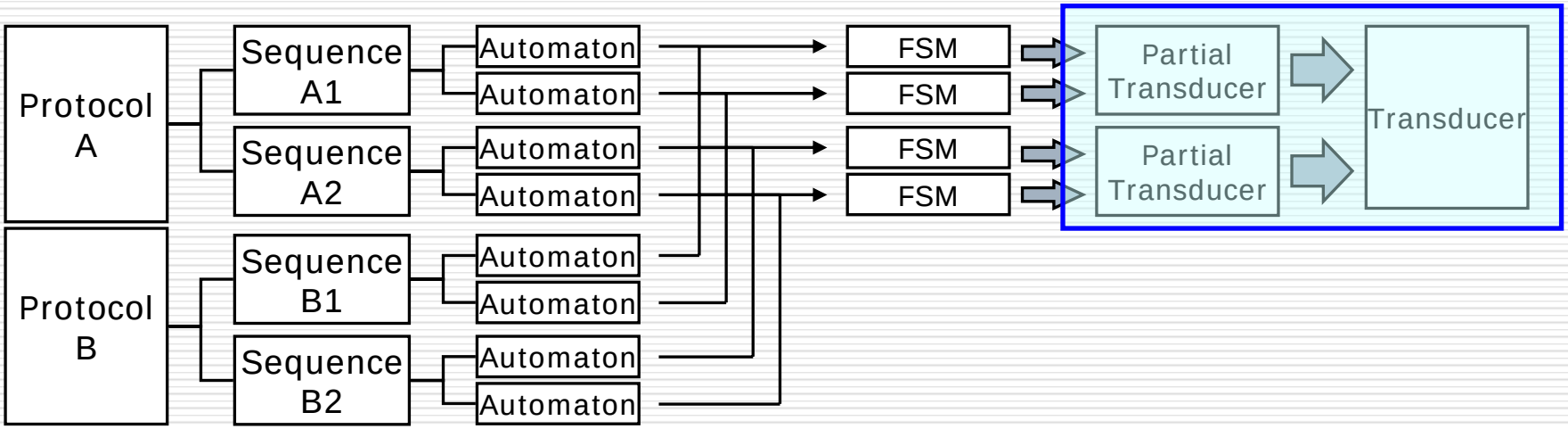

1.Protocol Modeling Method

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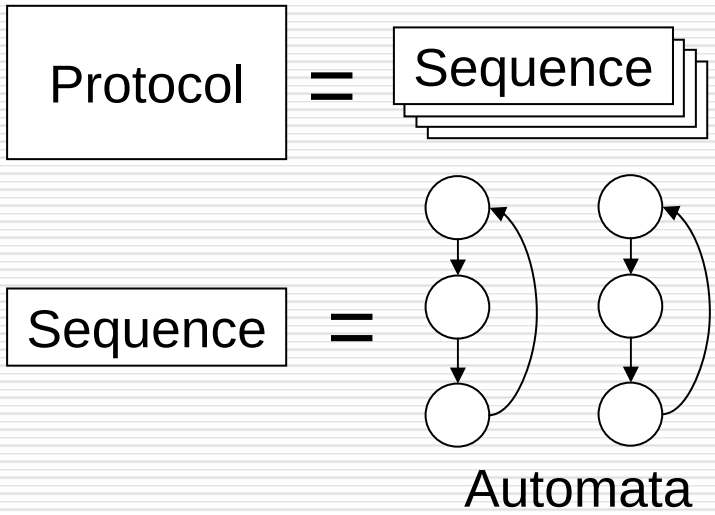
Proposed Protocol Model...

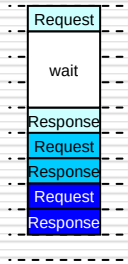


- We regard a protocol as a set of **Sequences**
- A Sequence corresponds as an operation such as “Single Read”, “4-Burst Write”, etc.
- A Sequence consists of a set of automata.

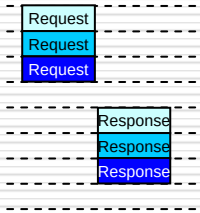
1. Protocol Modeling Method

- The **number of automata in a Sequence** depends on its protocol type.

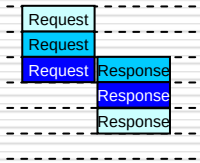
- Protocol Types:
  - **Blocking Protocol**



  - **Non-Blocking Protocol**



  - **Out-of-Order Protocol**



1. Protocol Modeling Method

- The **number of automata in a Sequence** depends on its protocol type.

- Protocol Types:
  - **Blocking Protocol**

    Sequence = an automaton

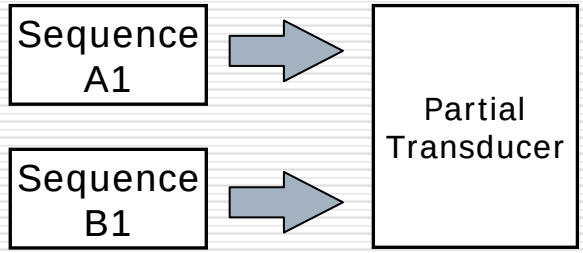
  - **Non-Blocking Protocol**

    Sequence = two automata (Request / Response)

  - **Out-of-Order Protocol**

    Sequence = two automata (Request / Response)

2.Sequence Level Synthesis



1.Protocol Modeling Method

2.Sequence Level Synthesis

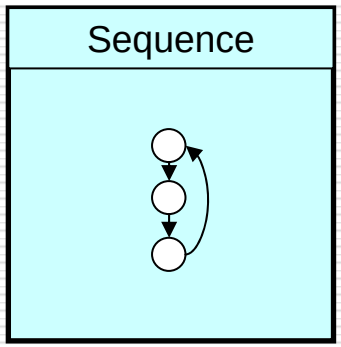
3.Automaton Level Synthesis

4.Construction of whole Transducer

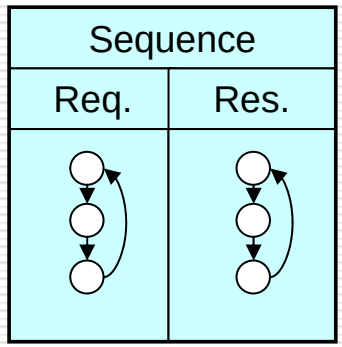
2.Sequence level Transducer Synthesis

- Synthesize a partial transducer from a pair of sequences.
- Each sequence has one or two automaton, according to its belonging protocol's type.

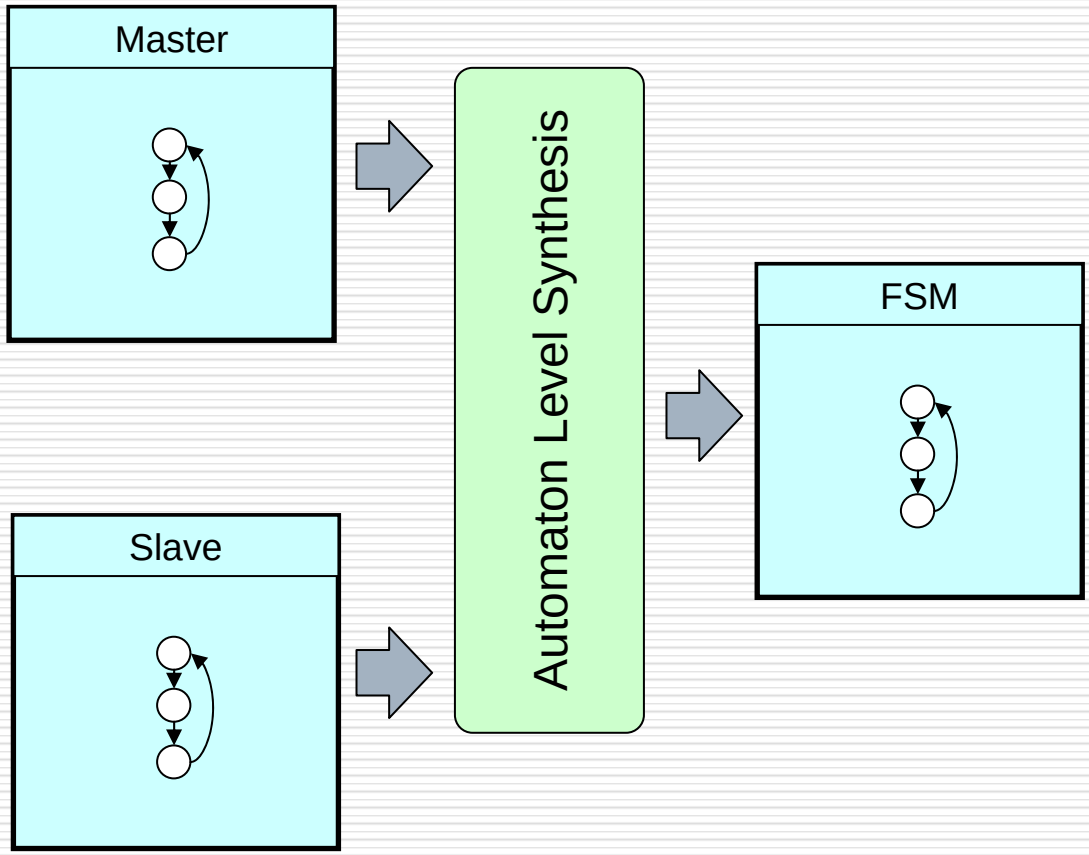
Belonging to a Blocking Protocol



Belonging to
a Non-Blocking or Out-of-Order Protocol

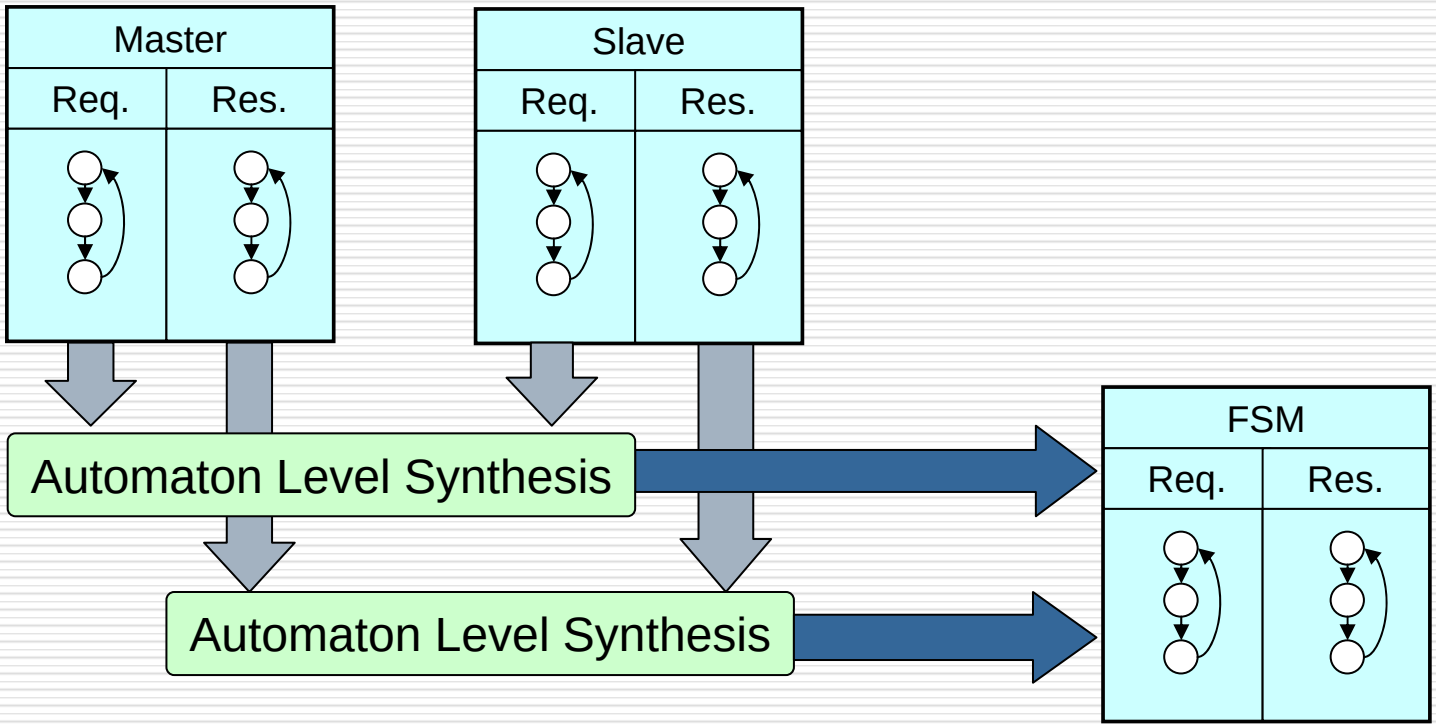


2.Sequence level Transducer Synthesis



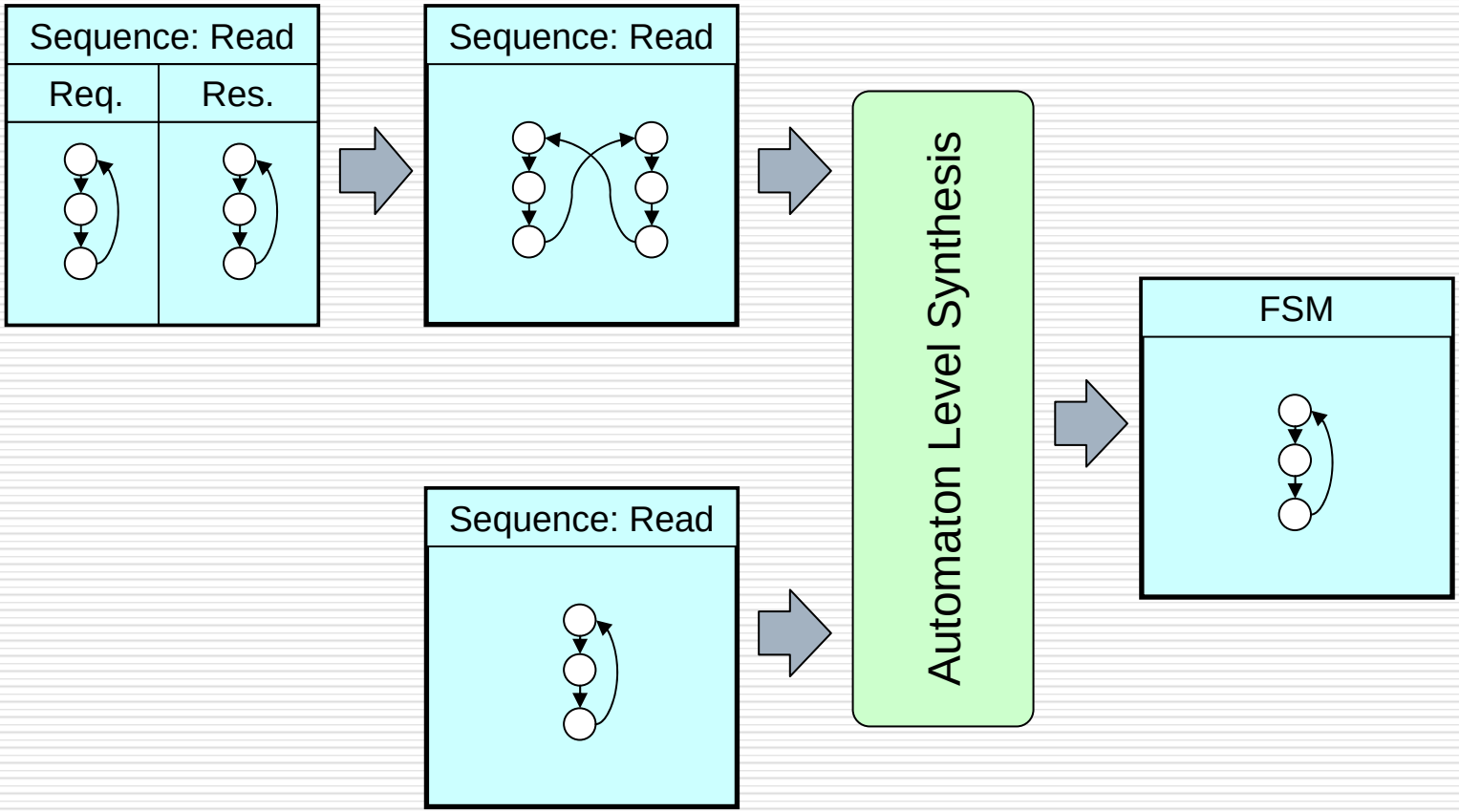
- In case both sequences are Blocking.

2.Sequence level Transducer Synthesis



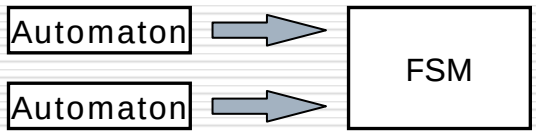
- In case both sequences are Non-Blocking or Out-of-Order.

2.Sequence level Transducer Synthesis



- In case one is Blocking,
  the other is Non-Blocking or Out-of-Order

3.Automaton Level Synthesis
(Extended Passerone's method)



1.Protocol Modeling Method

2.Sequence Level Synthesis

3.Automaton Level Synthesis

4.Construction of whole Transducer

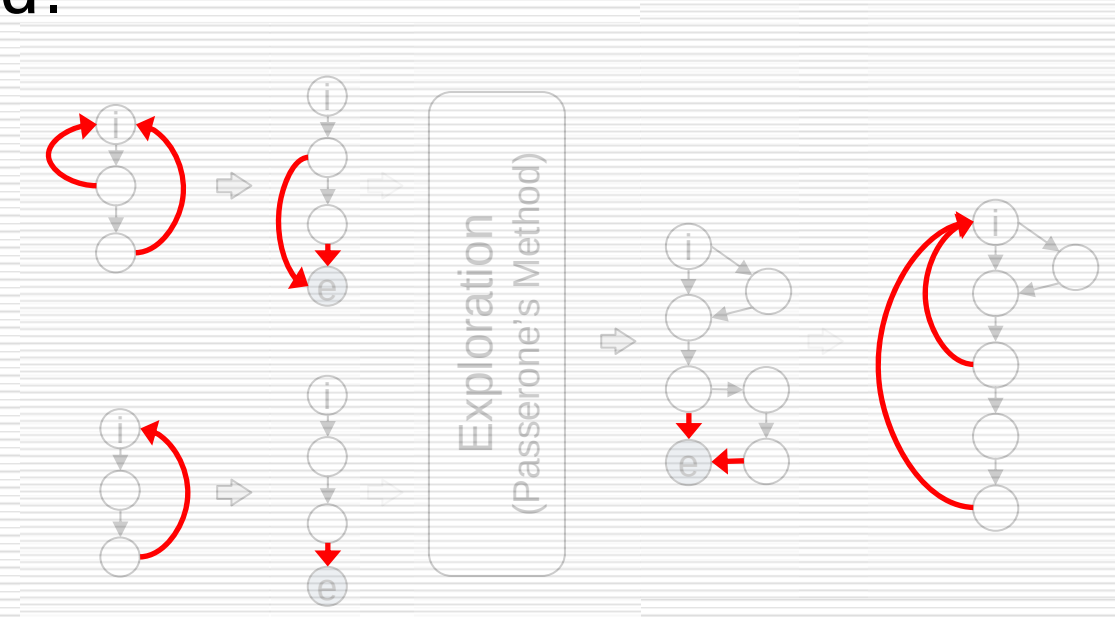
3.Automaton level Transducer Synthesis

- Automaton Level Synthesis is done by extended Passerone's Method.
- Because Passerone's method explores in depth-first-search, it cannot deal with loops in the automata.

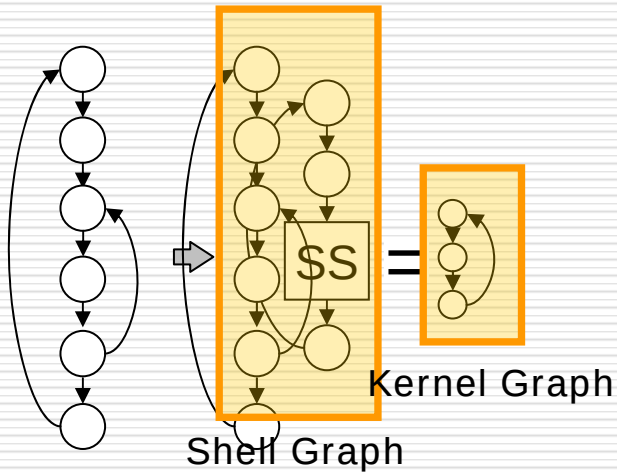
- The extensions are following:
  - Handling of Loops
  - Multiple Data Sequences

Handling of Loops in automata

- Every automaton in the sequences has paths which returns to the initial state.
- So, all automata have loops in themselves.
- This prevents from being applied Passerone's method.



Multiple Data Sequences

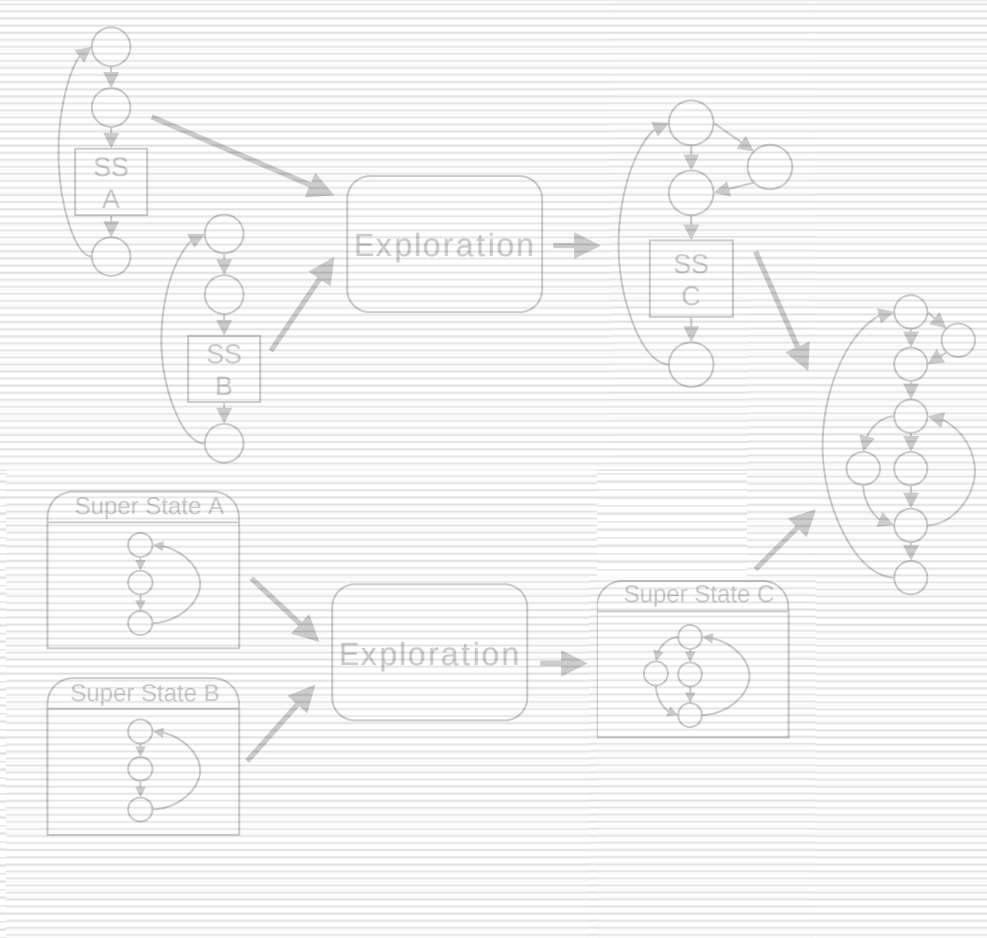


However, the insertion of “end state” cannot deal with “internal loop” shown in the figure.

We deal with Multiple Data Sequence by introducing super state

We call a sequence which includes this kind of automata “Multiple Data Sequence”.

Multiple Data Sequences



4.Construction of whole Transducer

Input : Partial Transducers
Output: Entire transducer

1.Protocol Modeling Method
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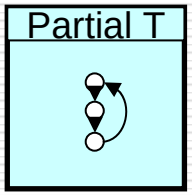
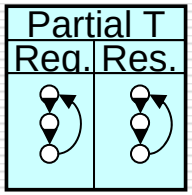
4.Construction of whole Transducer

- We have to construct whole transducer from partial transducers.

- A Partial Transducer consists of



  - An FSM : in case input protocols are
    (B,B),(NB,B),(B,NB), (OO,B),(B,OO)

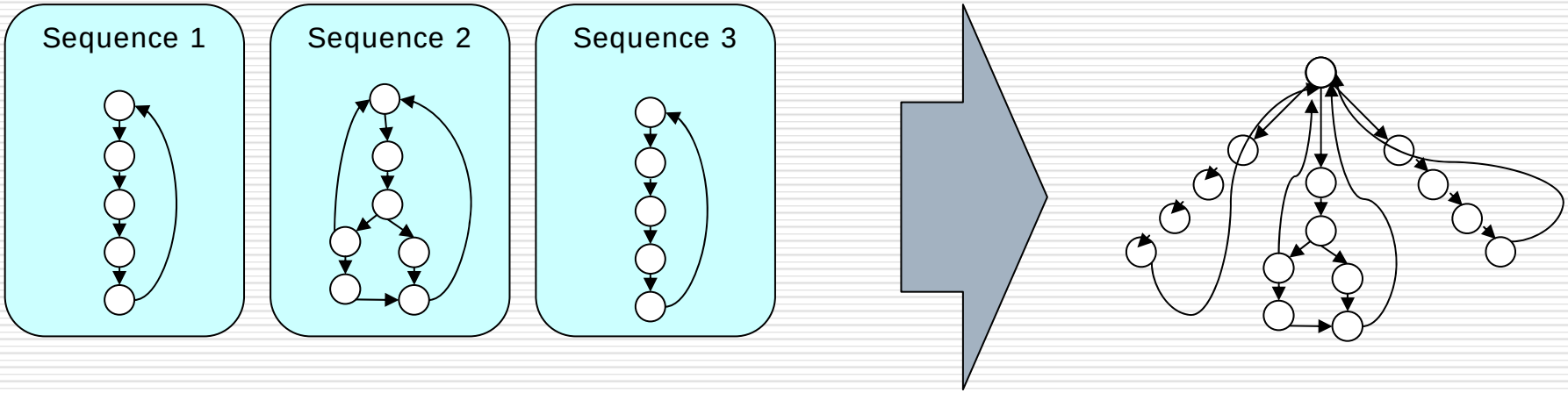


  - A request FSM and a response FSM :

In case (NB,NB),(OO,OO),(NB,OO),(OO,NB)

4.Construction of whole Transducer

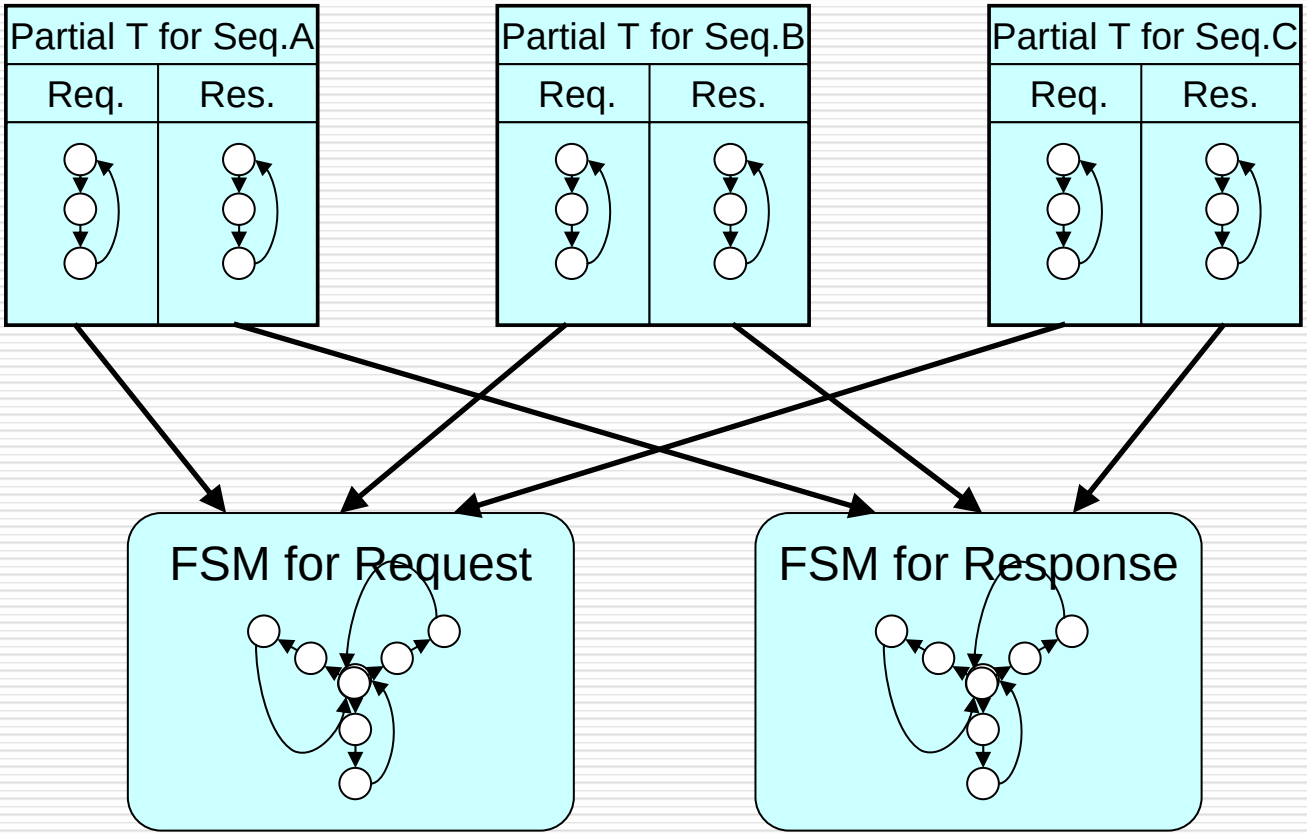
- In case at least one is BK protocol



By regarding every initial state as the same one.

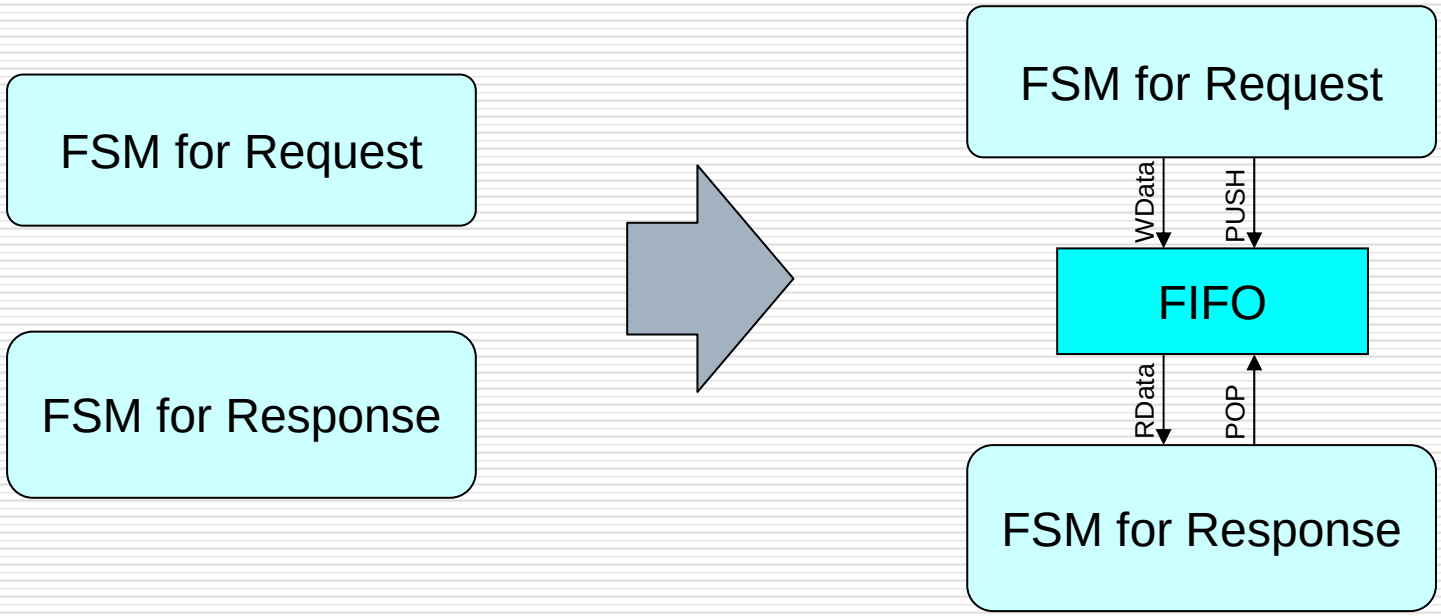
4.Construction of whole Transducer

- Otherwise (NB,NB),(OO,OO),(NB,OO),(OO,NB)



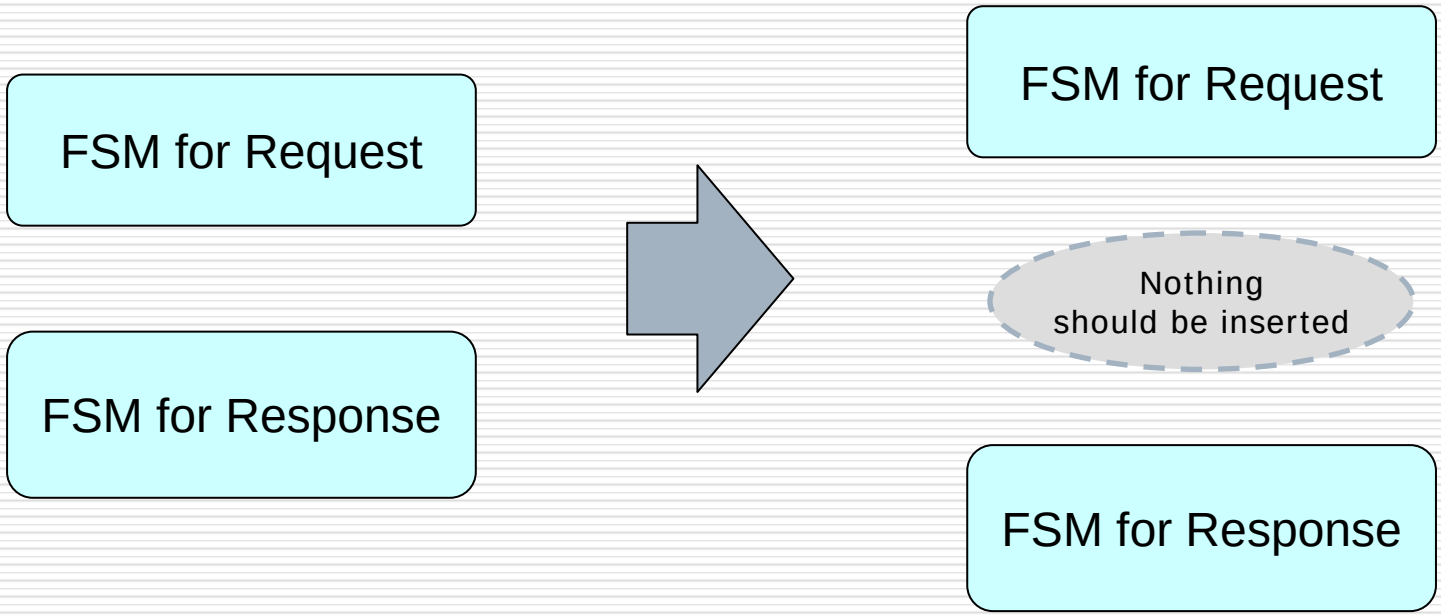
4.Construction of whole Transducer

- In case (NB,NB) or (OO,NB)



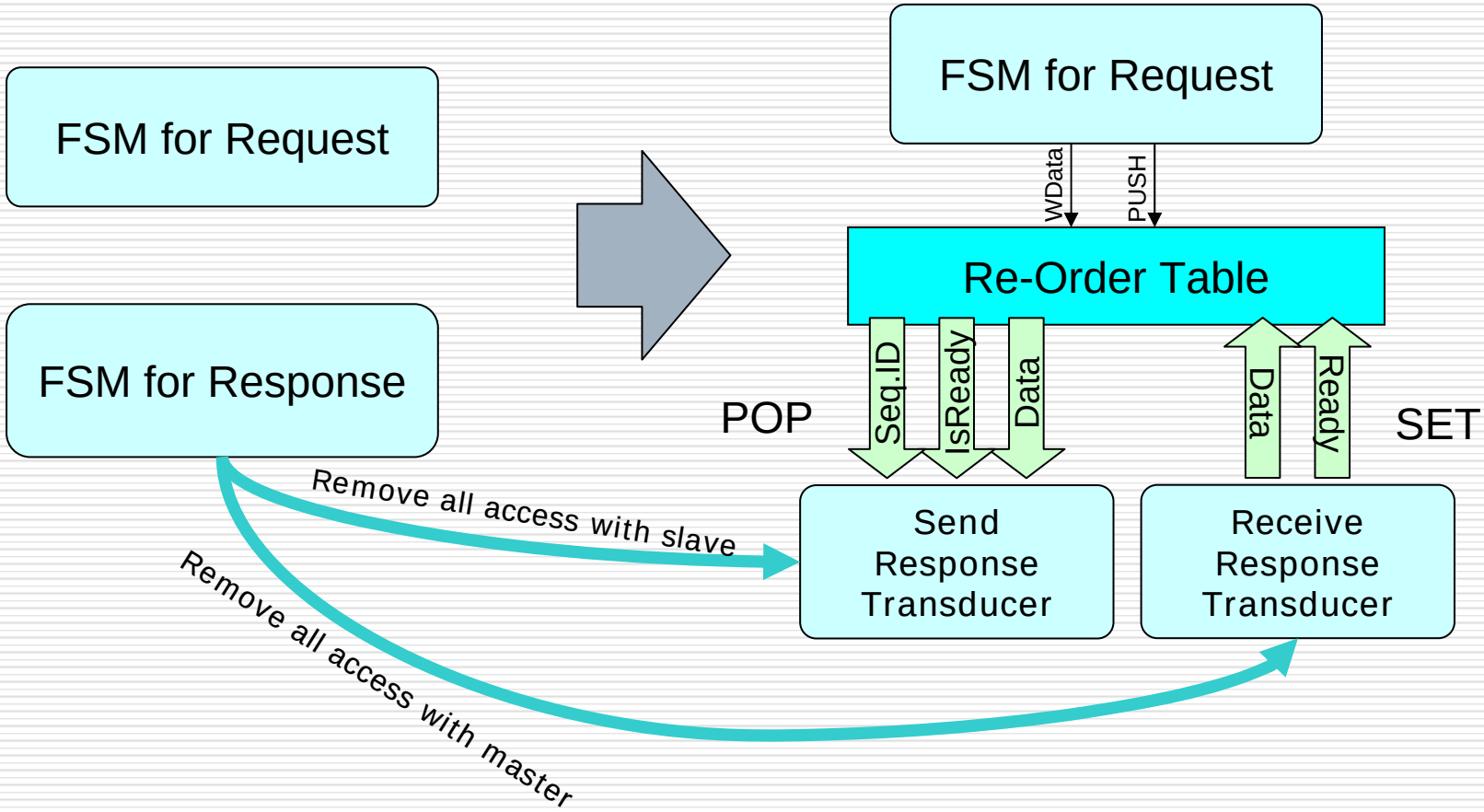
4.Construction of whole Transducer

- In case (OO,OO)



4.Construction of whole Transducer

- In case (NB,OO)



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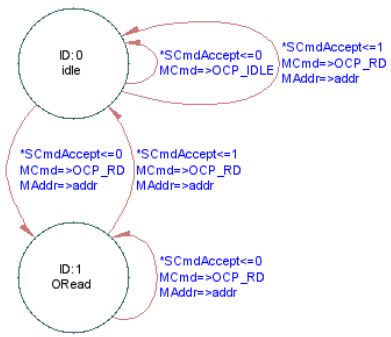
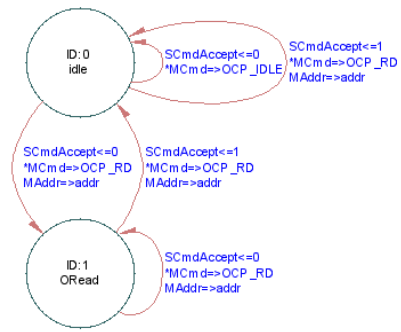
Experiment1: Non-Blocking Non-Blocking

MASTER: OCP

(Single Read, Non-Posted Write)

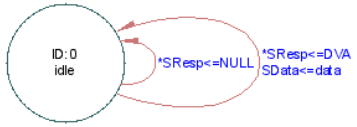
Request



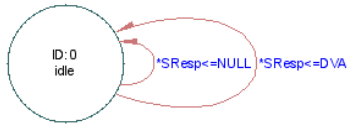


Response

Single Read



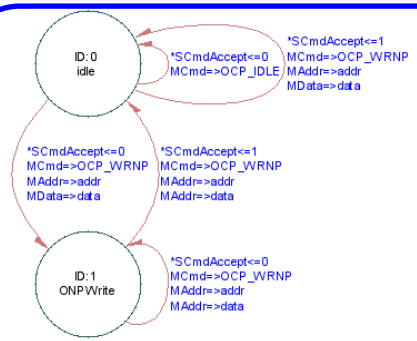
Non-Posted Write

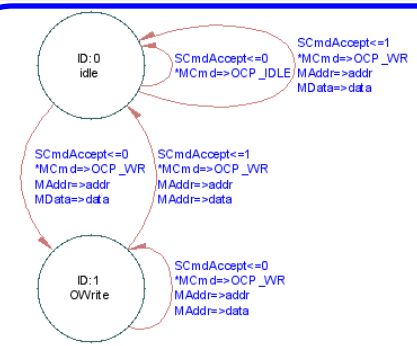


SLAVE: OCP

(Single Read, Single Write)

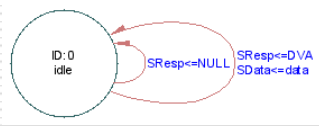
Request



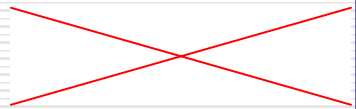


Response

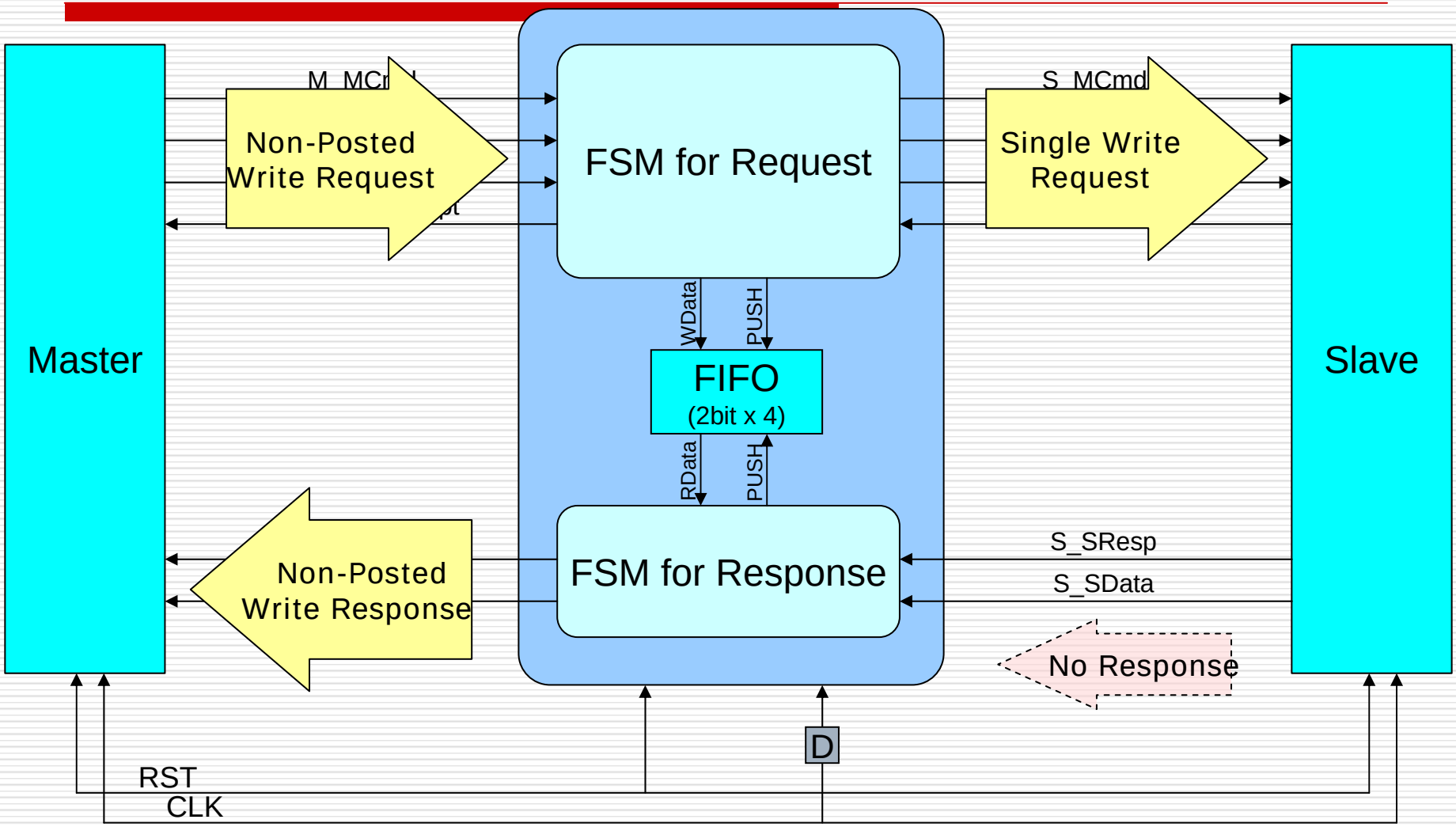
Single Read



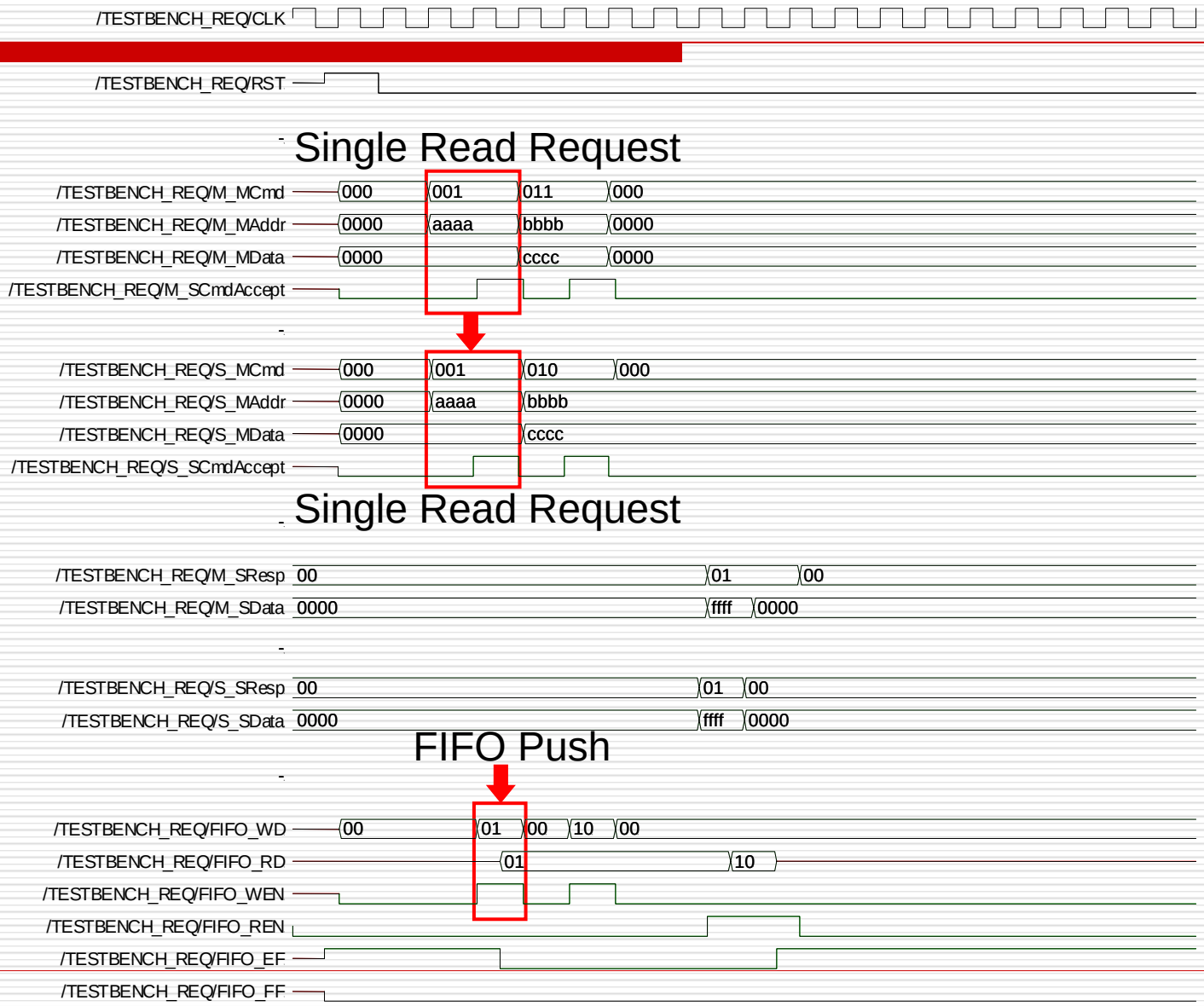
Single Write



Test Bench


Master
Non-Posted
Write Request
FSM for Request
Single Write
Request
S_MCmd
Slave
WData
PUSH
FIFO
(2bit x 4)
RData
PUSH
Non-Posted
Write Response
FSM for Response
S_SResp
S_SData
No Response
D
RST
CLK

Simulation Waveform



Simulation Waveform

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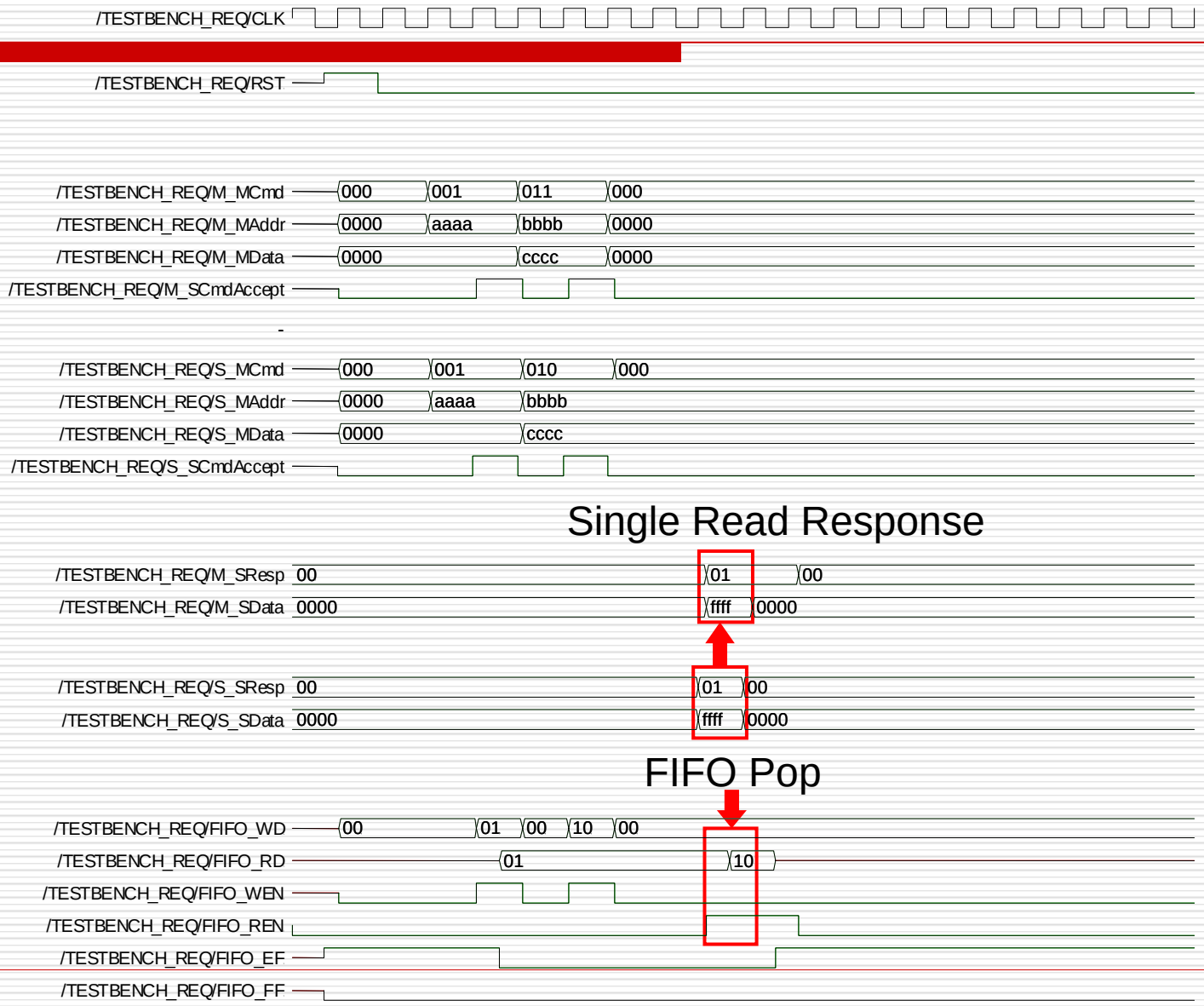

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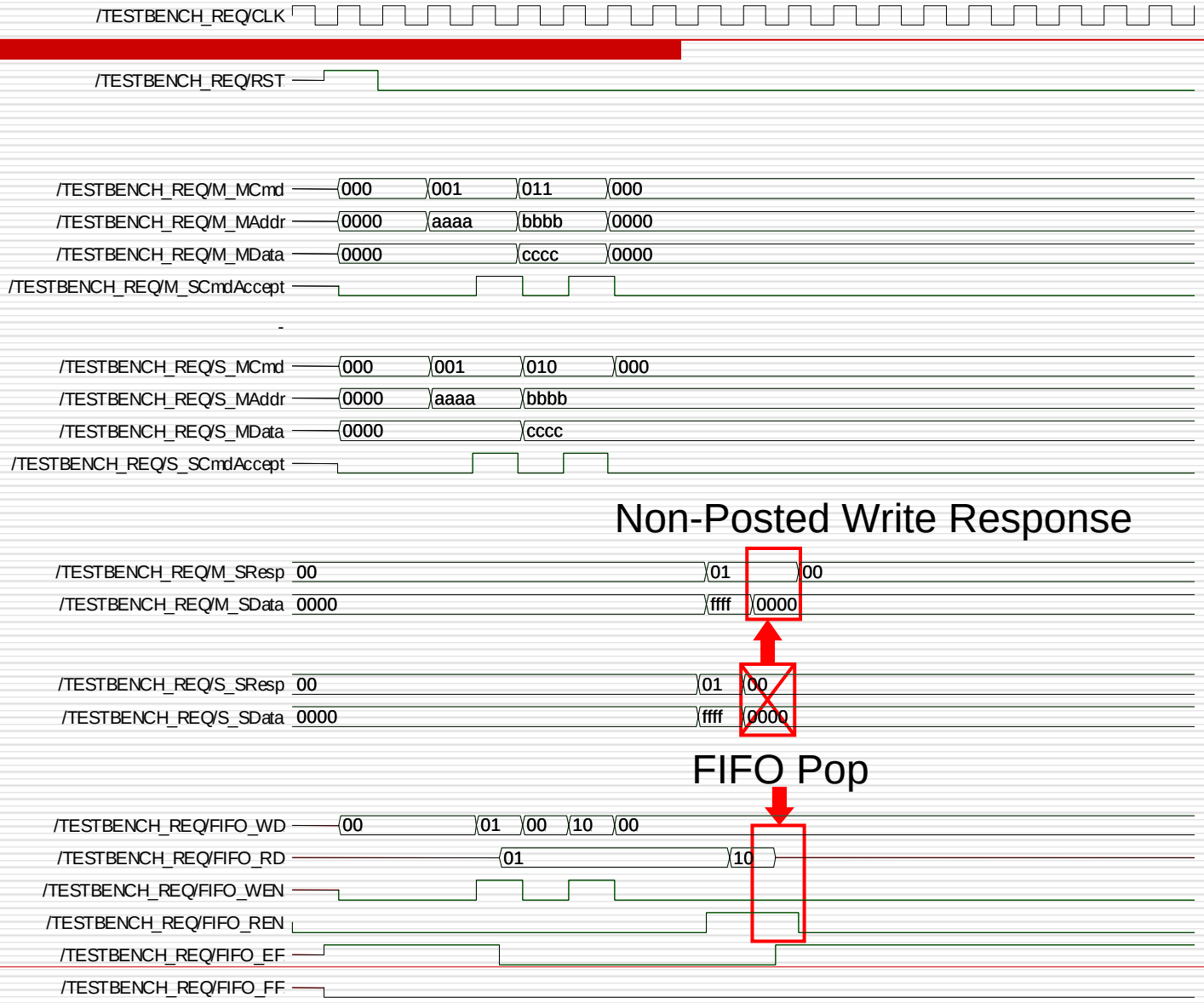

Conclusion

- We proposed a protocol transducer synthesis method using divide and conquer approach.
- Our method can be applied to the state-of-the-art protocols such as OCP, AMBA AXI, etc.
- We implemented our method on an original tool.

Demo will be available at EDS Fair

HERE!!
In University Plaza

10am～6pm
Jan. 25th,26th

Protocol Transducer Synthesis using Divide and Conquer approach

Thank you for your attention.

Any Question?

END

2007/01/24