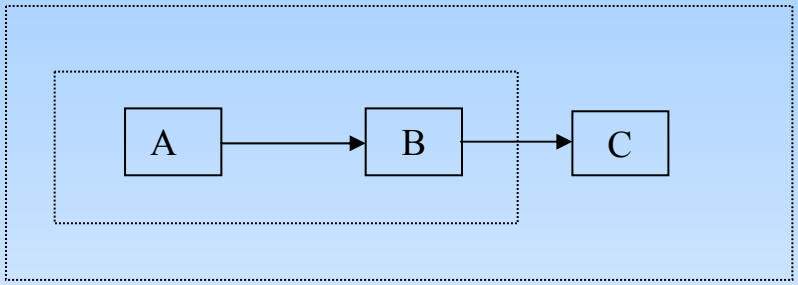
DEVS(Discrete Event Systems Specification) Formalism

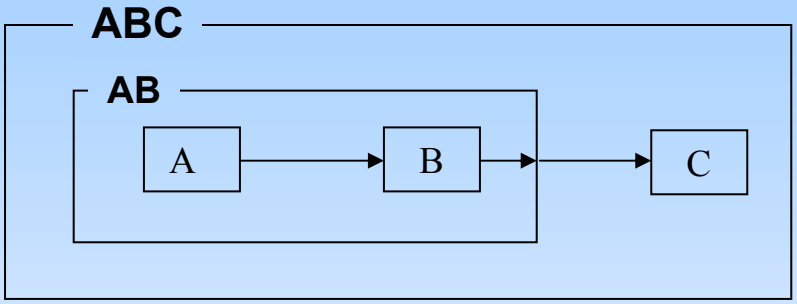
- Set-theoretic Formalism by Zeigler[1976]
  - ➔ Simple and Easy to Modeling
- System Theoretic Representation
  - ➔ Input, Output, State, State Transition
- Object-oriented Modeling
  - ➔ Parts and Whole; Models Class
- Hierarchical, Modular Specification
  - ➔ Structured Modeling

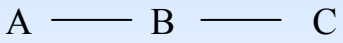
Hierarchical Modeling

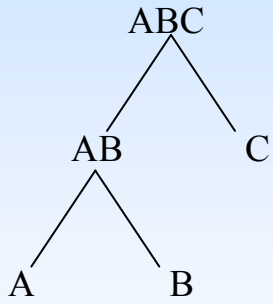
Incremental Modeling



Hierarchical Modeling







Reuse: A and B as subsystems

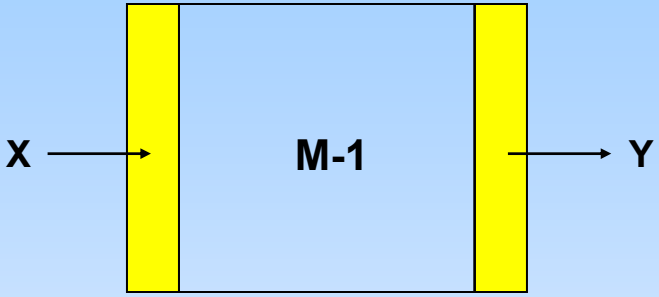
C is connected to B

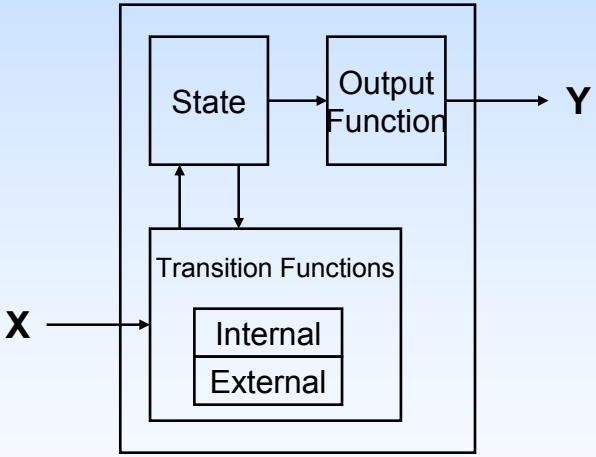
Reuse: A, B, AB as subsystems

C is connected to AB

Modular Modeling: Input/Output Interface

Input/output Interface

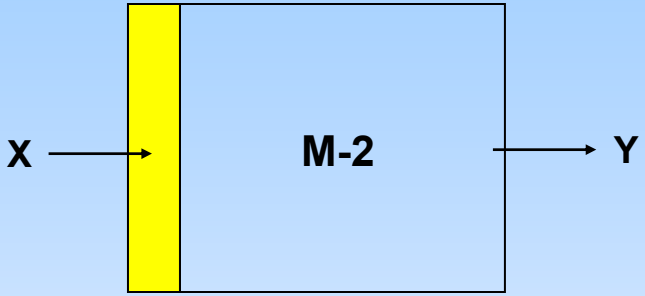


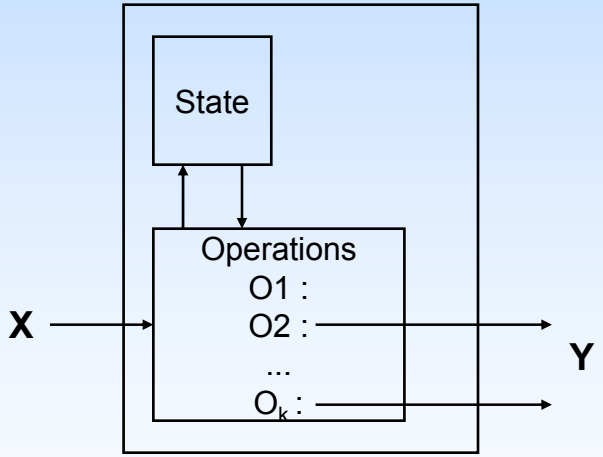


M-1 does not know where x comes;
neither knows where y goes

Change of connection ➔ No change in M-1

Input Interface/
Output No-Interface



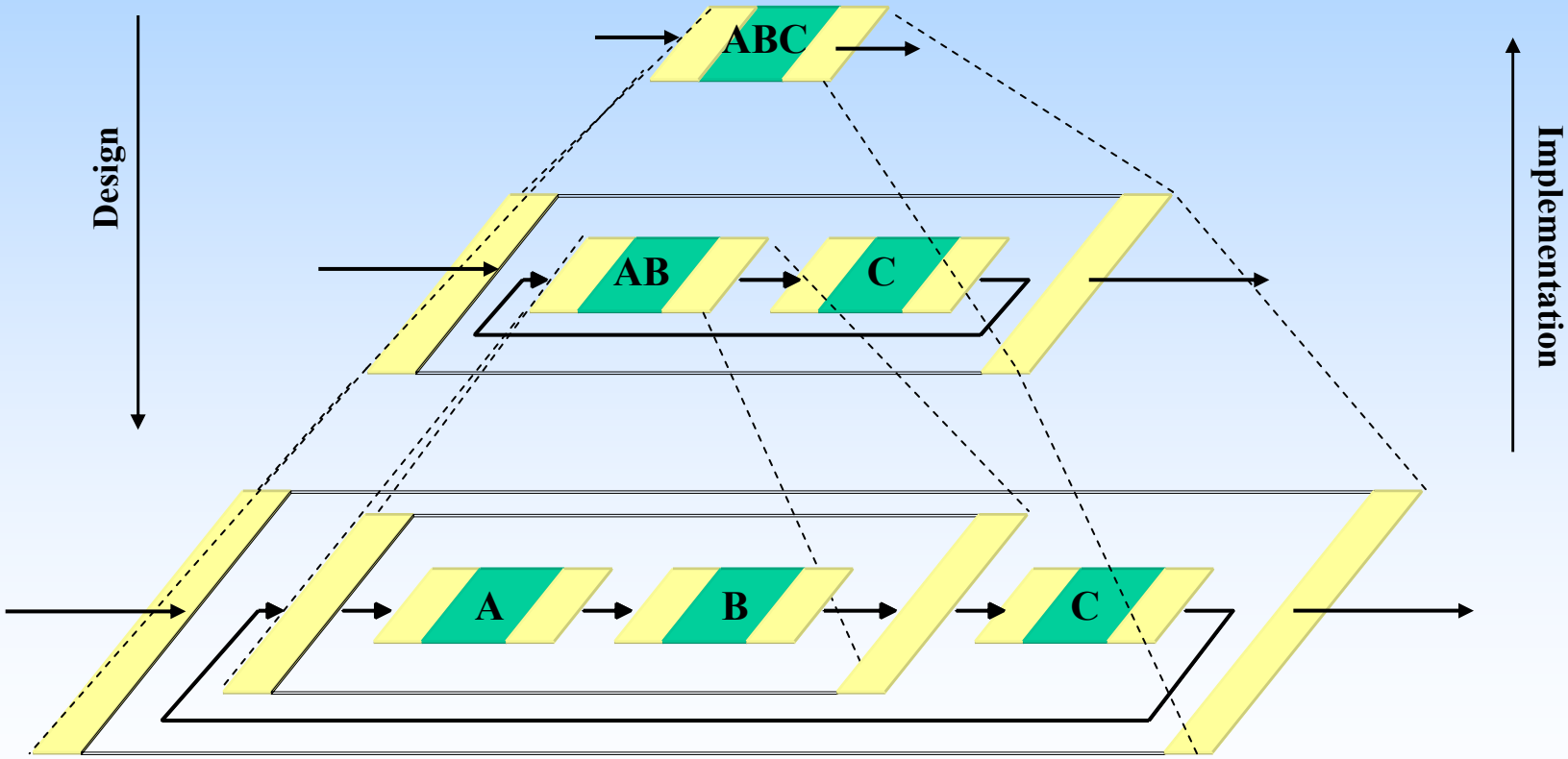


M-2 does not know where x comes
M-2 knows where y goes

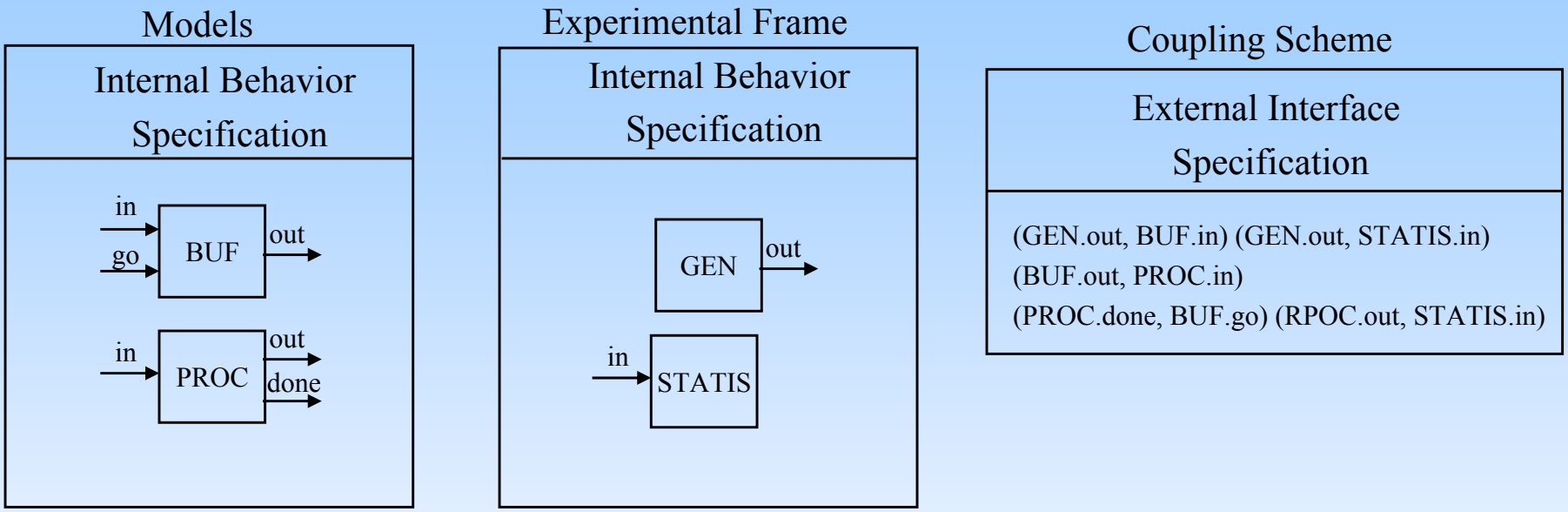
Change of connection ➔ Change in M-2

Modular + Hierarchical = Structured Modeling

- Model Design :: Top-down Approach
- Model Implementation :: Bottom-up Approach



Separation of Internal from External View



Modeling: Internal Behavior Specification + External Interface Specification

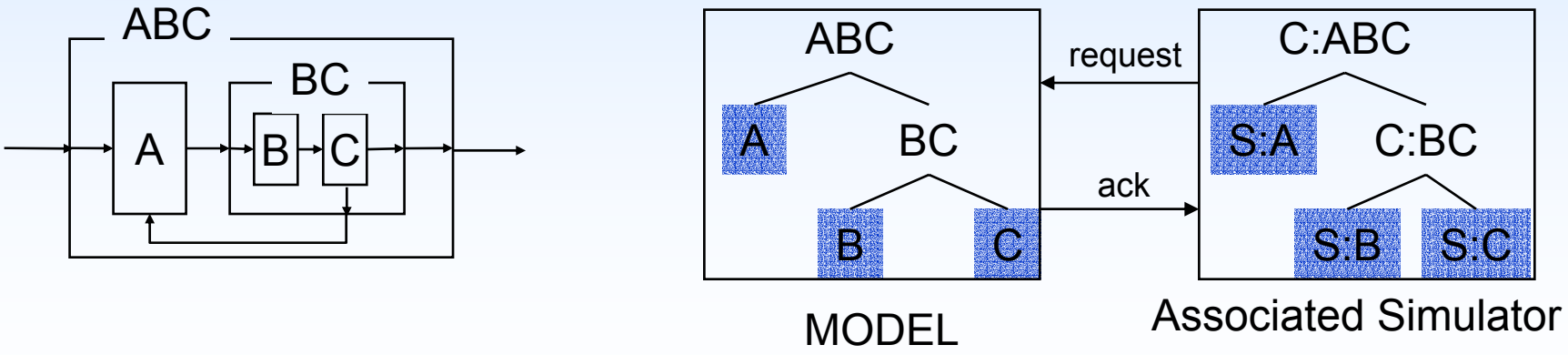
Simulation:

Internal View: Execution of Model's internal behavior (Timed state transition)

External View: Deliver messages between models through ports (Events Interaction)

DEVS M&S Concepts

- Basic DEVS Models Class
  - Atomic Model : Specification of Basic Model Behavior as Timed State Transition
  - Coupled Model : Specification of Hierarchical Model Structure
- Abstract Simulator : Interpreter for Dynamics of DEVS Models
  - Simulator (S:AM) : Attached to Atomic Model
  - Coordinator (C:CM) : Attached to Coupled Model
- DEVS Simulation Architecture

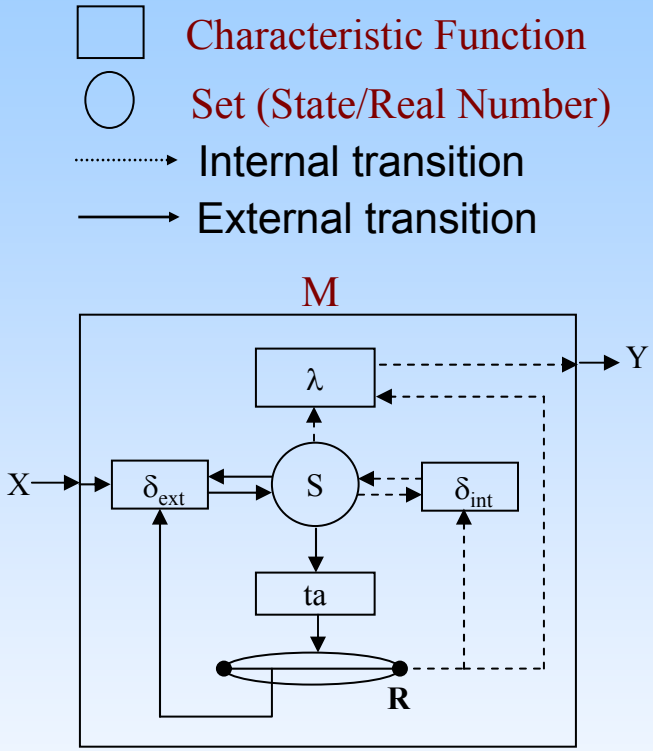


Atomic DEVS Model: Non-decomposable Basic Model

$M = < X, Y, S, \delta_{ext}, ta, \delta_{int}, \lambda >$

X : input event set ;
S : sequential states set ;
Y : output event set ;
$Q = \{(s,e) \mid s \in S, 0 \le e \le ta(s)\}$: state of M

Constraints:
$\delta_{int} : Q \rightarrow Q$: internal transition function ;
$\delta_{ext} : Q \times X \rightarrow Q$: external transition function ;
$\lambda : Q \rightarrow Y$: output function ;
$ta : S \rightarrow$ Real : time advance function



Note: System-theoretical view

$\delta = < \delta_{ext} , \delta_{int} >$

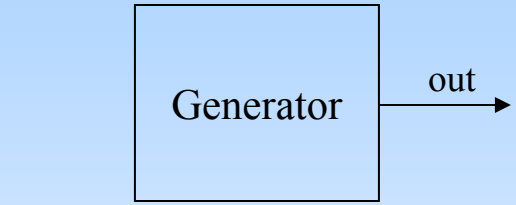
state transition = < inputted trans, input-free trans >

Interpretation of Four DEVS Functions

- time advance function [ta : S → Real]
  - Decide time for which a state remains without input
  - If (S = s1) then ta(s1) = r1
    - Every state(s1) has its predefined schedule time(r1)
    - Usually, this time is modeled by random numbers
    - ta = ∞ means waits for input
- internal transition [δ_{int} : Q → Q (or S x R → S x R)]
  - State transition without input but with timeout specified by ta
  - If (S = s1) and (R =ta(s1)) then (S = s2) and (R = 0)
    - R = ta(s1) means that a predefined schedule time at S=s1 is completely elapsed
- external transition [δ_{ext} : Q × X → Q (or S x R x X → S x R)]
  - State transition with input before a scheduled time is completely elapsed
  - If (S=s1) and (R=e) and (X=x1) then (S=s2) and (R = 0)
- output function [λ : Q → Y (or S x R → Y)]
  - Specification of output and its generation time
    - If (S=s1) and (R=ta(s1)) then generate (Y=y1)
    - R = ta(s1) mean that a predefined schedule time at S=s1 is completely elapsed
    - Output is always generated at the same time with internal transition

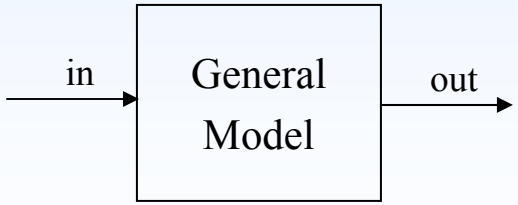
Types of Atomic DEVS Model

$M = < X, Y, S, \delta_{ext}, \delta_{int}, ta, \lambda >$



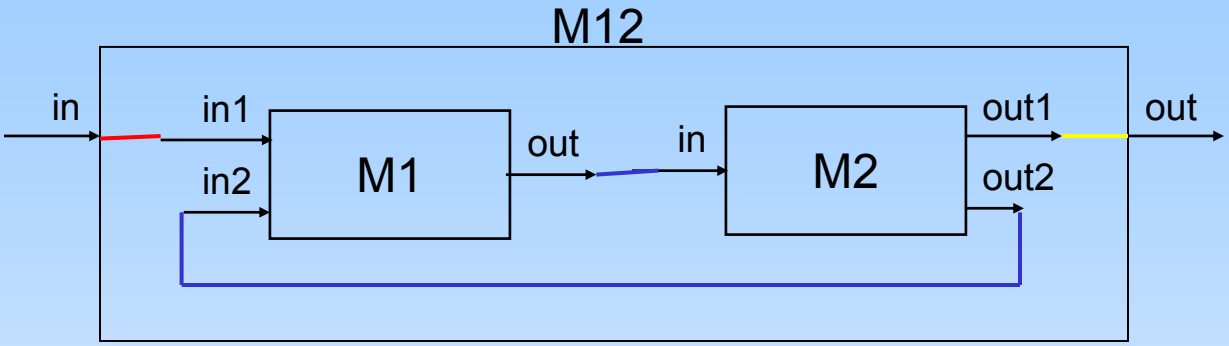
- X, δ_{ext} : not defined
- events generation to other models

- Y, λ : not defined
- δ_{int}, ta: may or may not be defined
- collect data from other models



- All are defined
- general one

Coupled DEVS Model: Composite Model



DN = < X,Y,M,EIC, EOC, IC, SELECT>

X : input event set ;

Y : output event set ;

M : set of all component models in DEVS ;

Constraints:

EIC $\subseteq$ DN.X $\times \bigcup_i M_i.X_i$: external input coupling relation ;

EOC $\subseteq \bigcup_i M_i.Y_i \times$ DN.Y : external output coupling relation ;

IC $\subseteq \bigcup_i M_i.Y_i \times \bigcup_j M_j.X_j$: internal coupling relation ;

SELECT : $2^M - \varnothing \rightarrow M$: tie-breaking selector.