Automated Runtime Recovery for QoS-based Service Composition

Presenter: Tian Huat Tan

Tian Huat Tan[1] , Manman Chen[2] , Étienne André[3] ,
Jun Sun[1] , Yang Liu[4] , Jin Song Dong[2]

[1]Singapore University of Technology and Design,
[2]National University of Singapore,
[3]Université Paris 13, France,
[4]Nanyang Technological University, Singapore

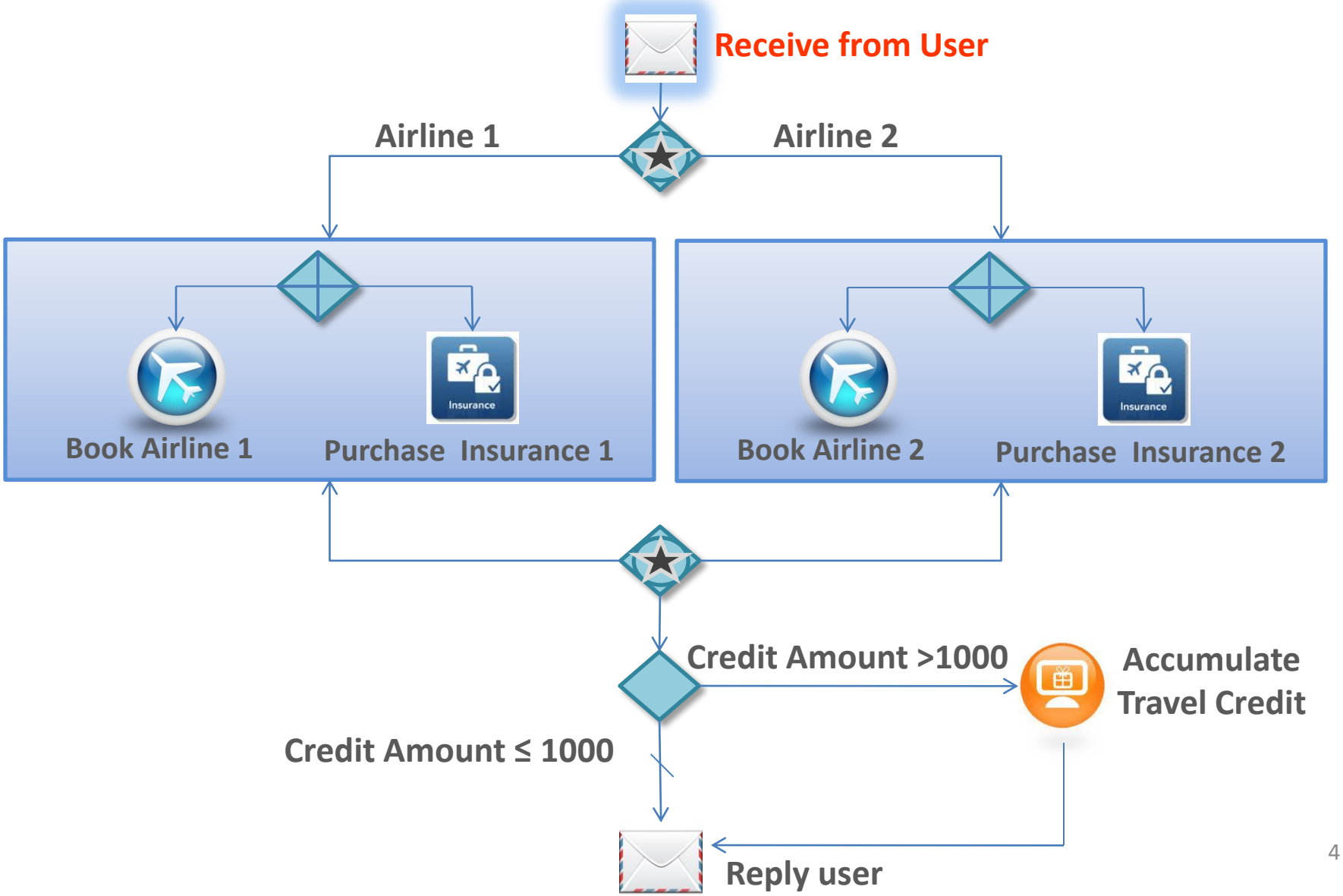
Service Oriented Architecture (SOA)

- Promotes the use of services as building blocks.
- Interaction of heterogeneous applications.
- Making use of open standards, like WSDL and SOAP.
- Lower cost of ownership for enterprise.

What is Service Composition?

Reuse of other services to achieve a business goal.

Travel Booking Service (TBS)



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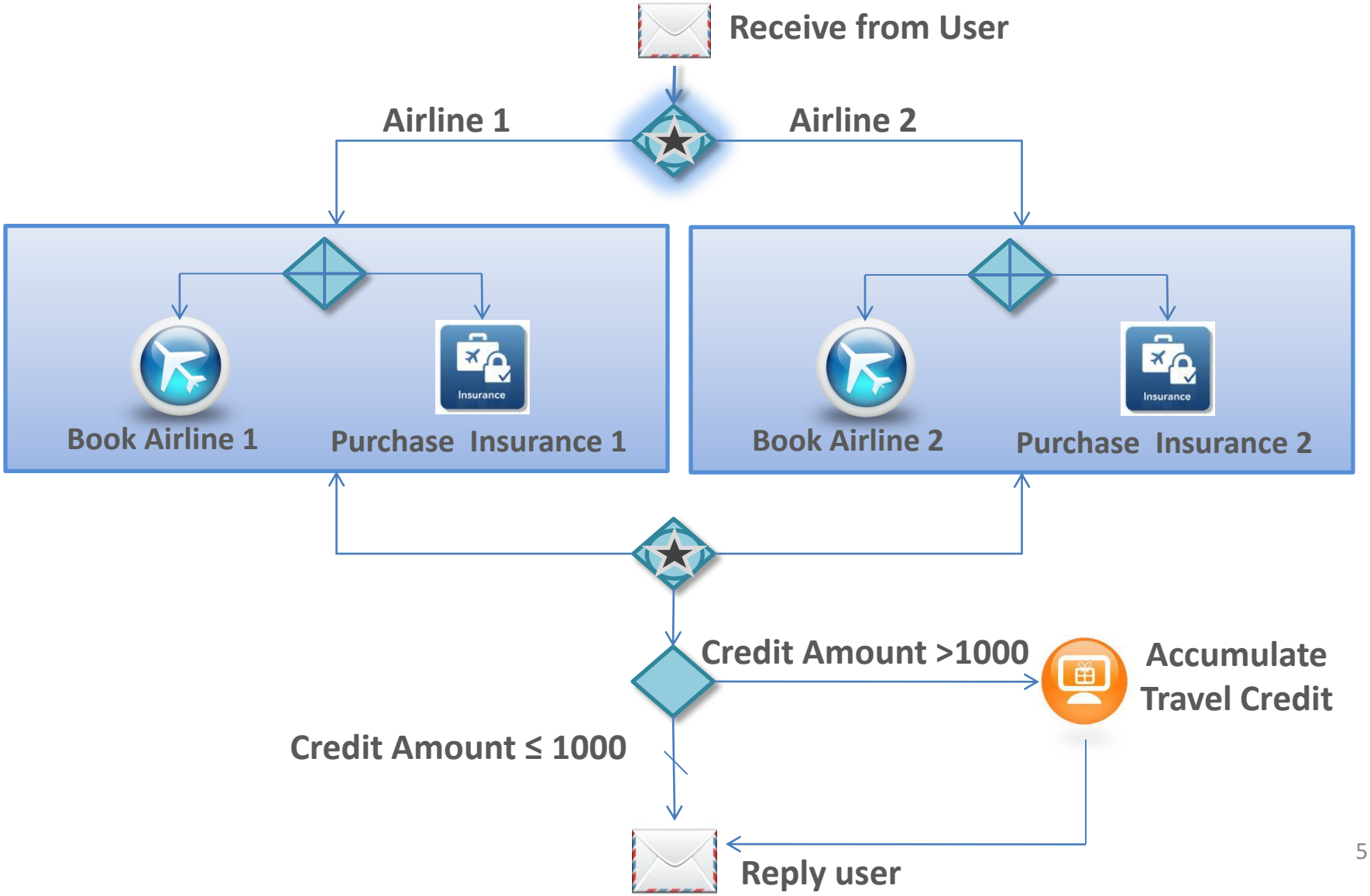

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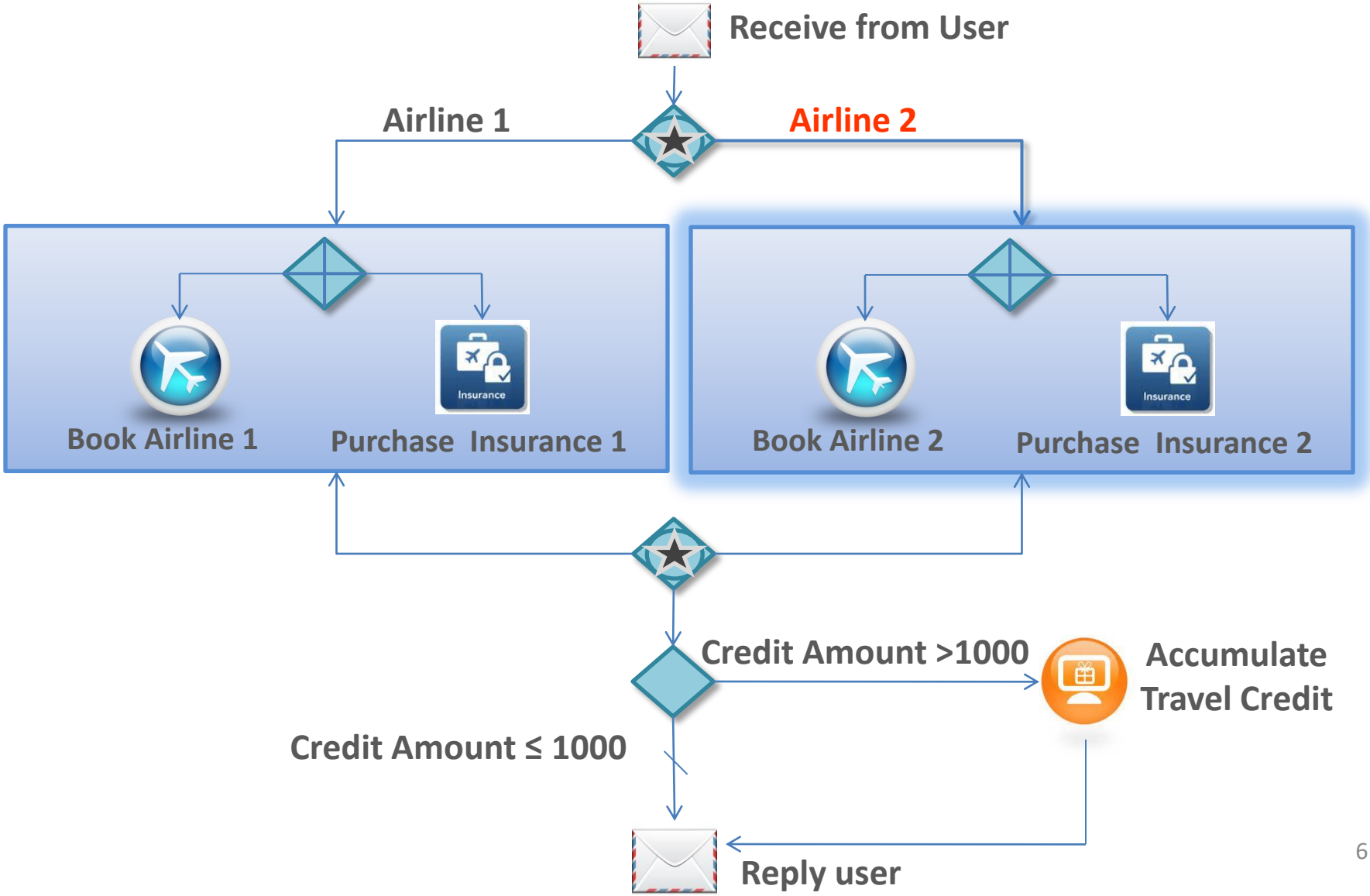

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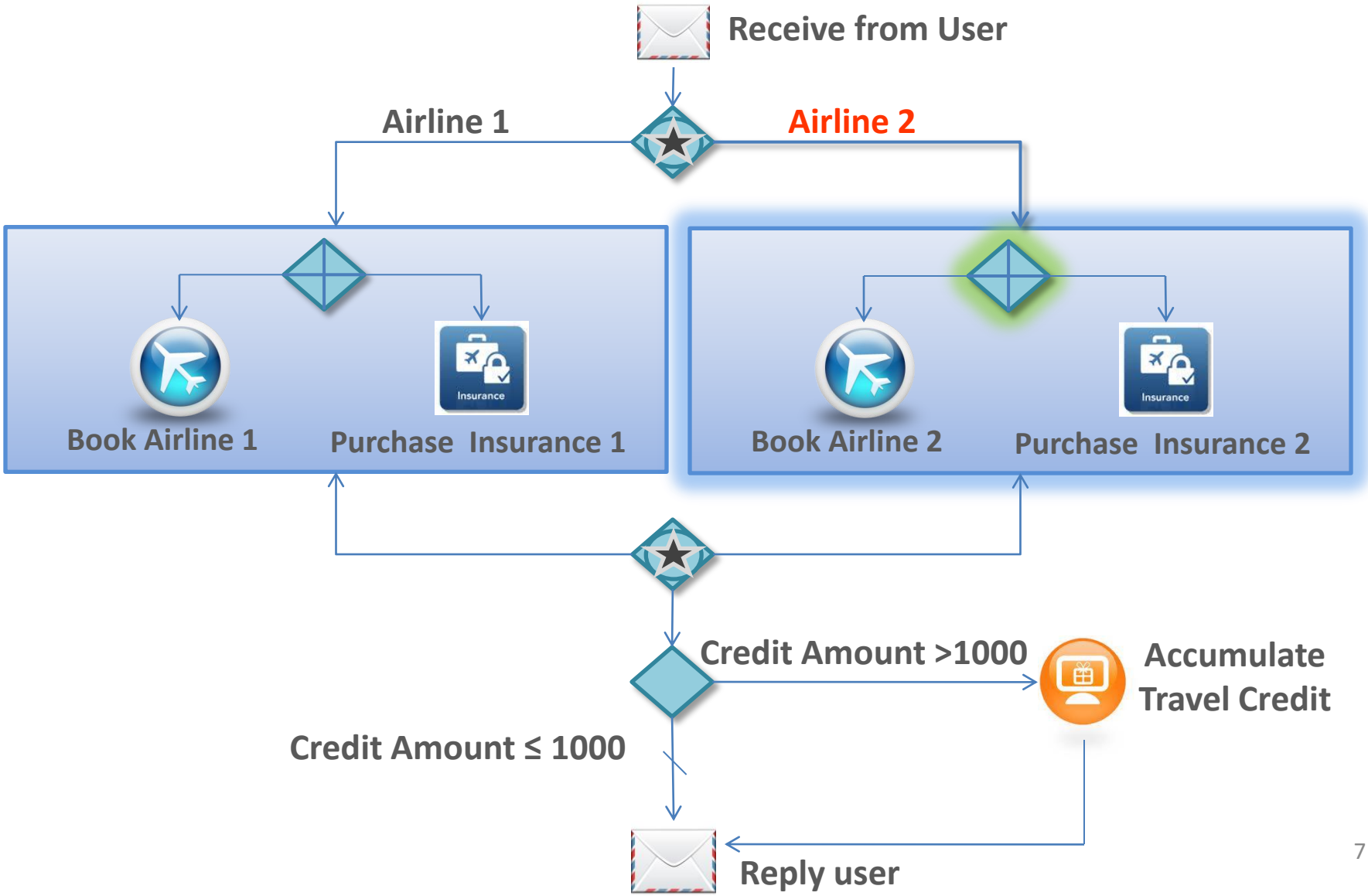

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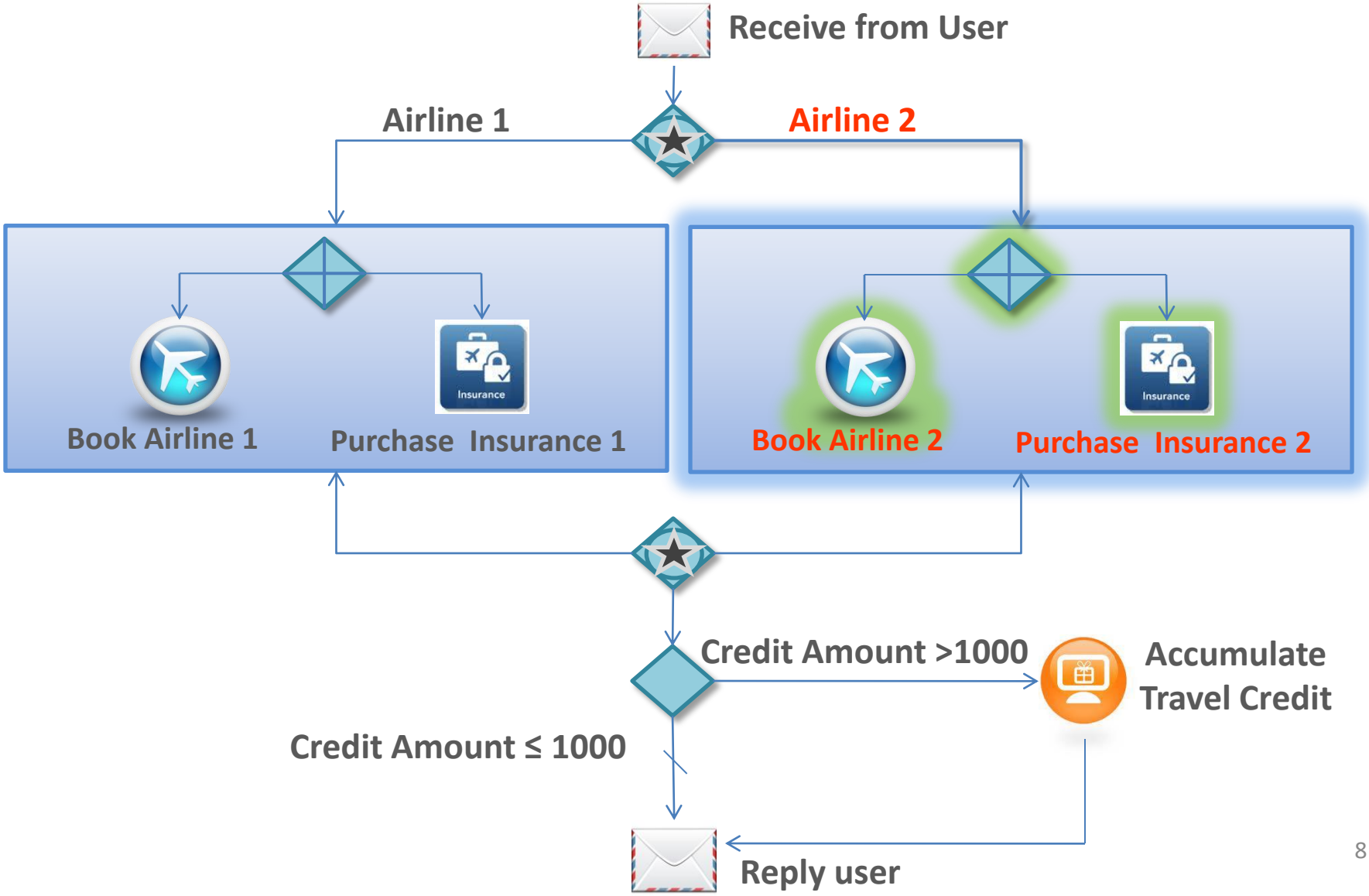

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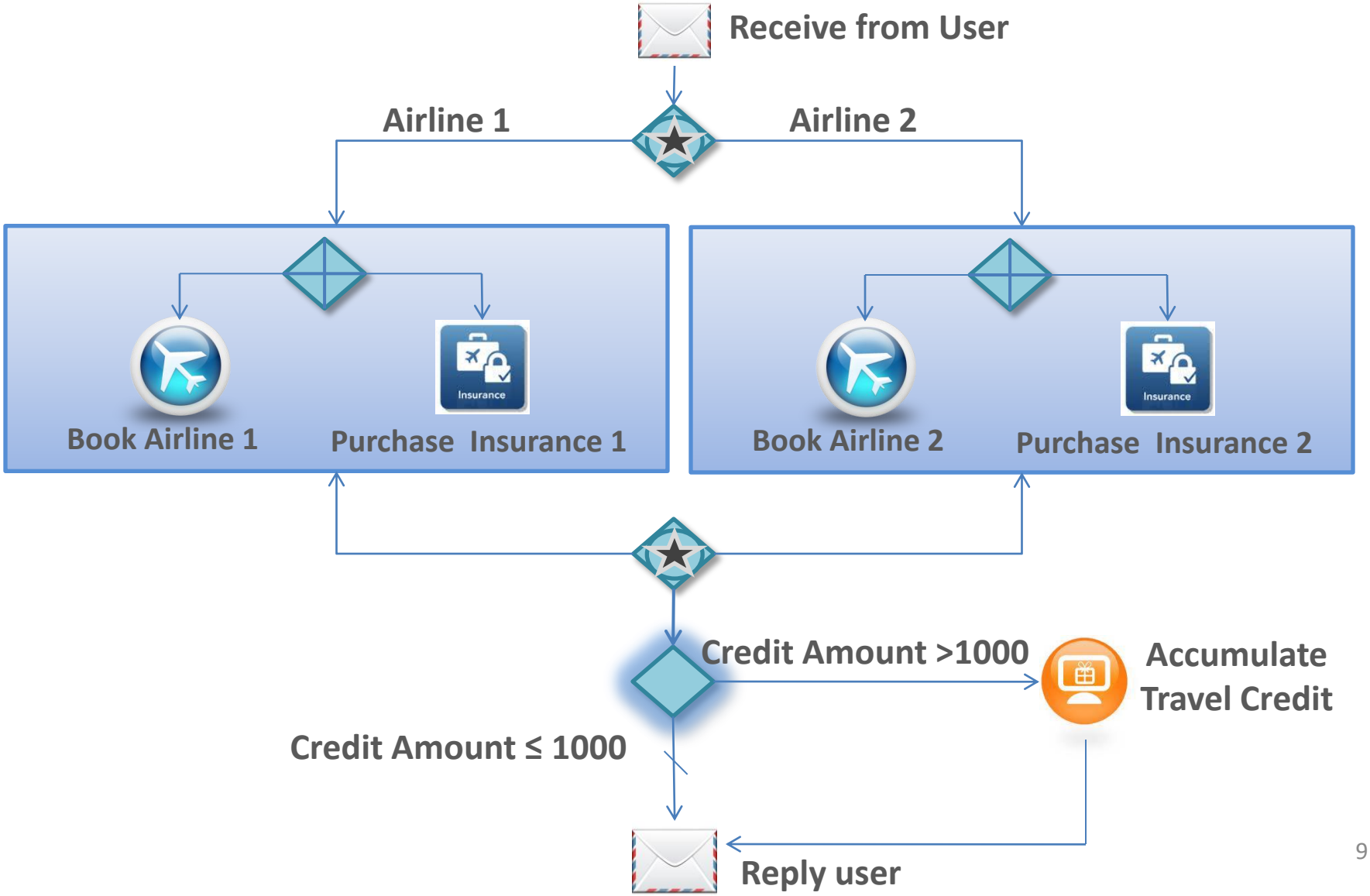

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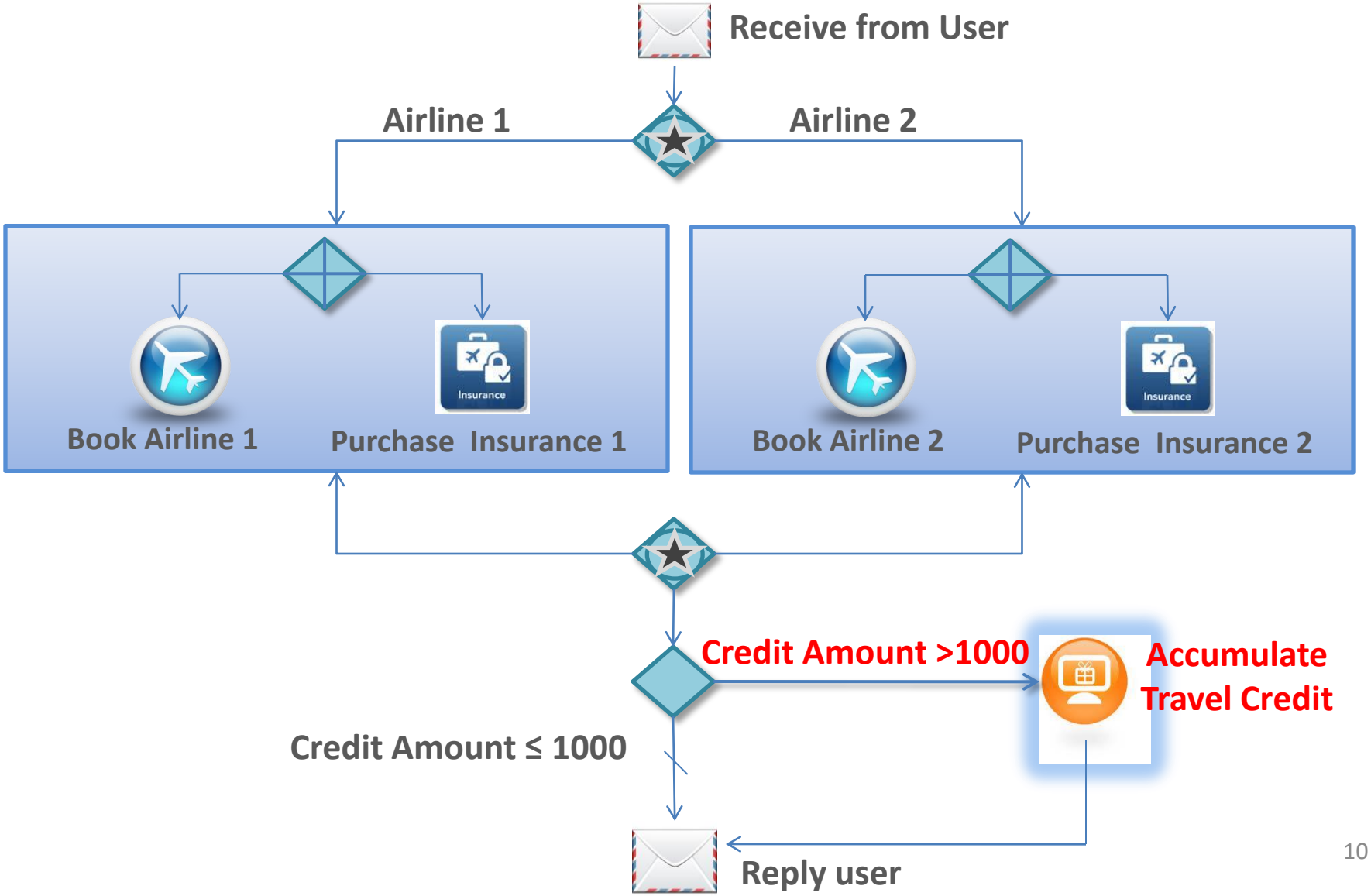

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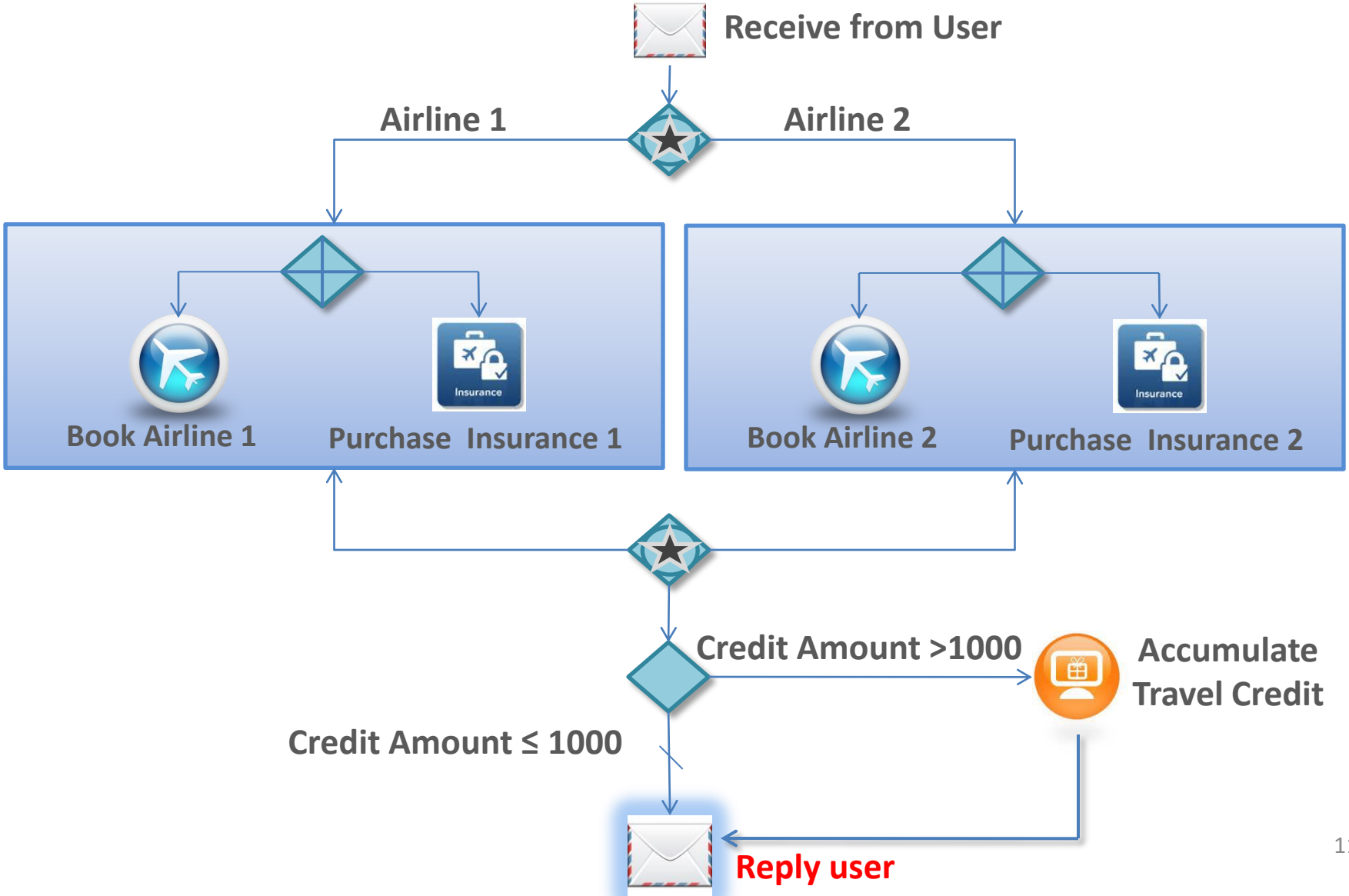


Service Composition

- **Composite service** – Made use of other services to achieve a business goal.

  E.g., Travel Booking Service (TBS)

- **Component services** – Services made used by the composite service.

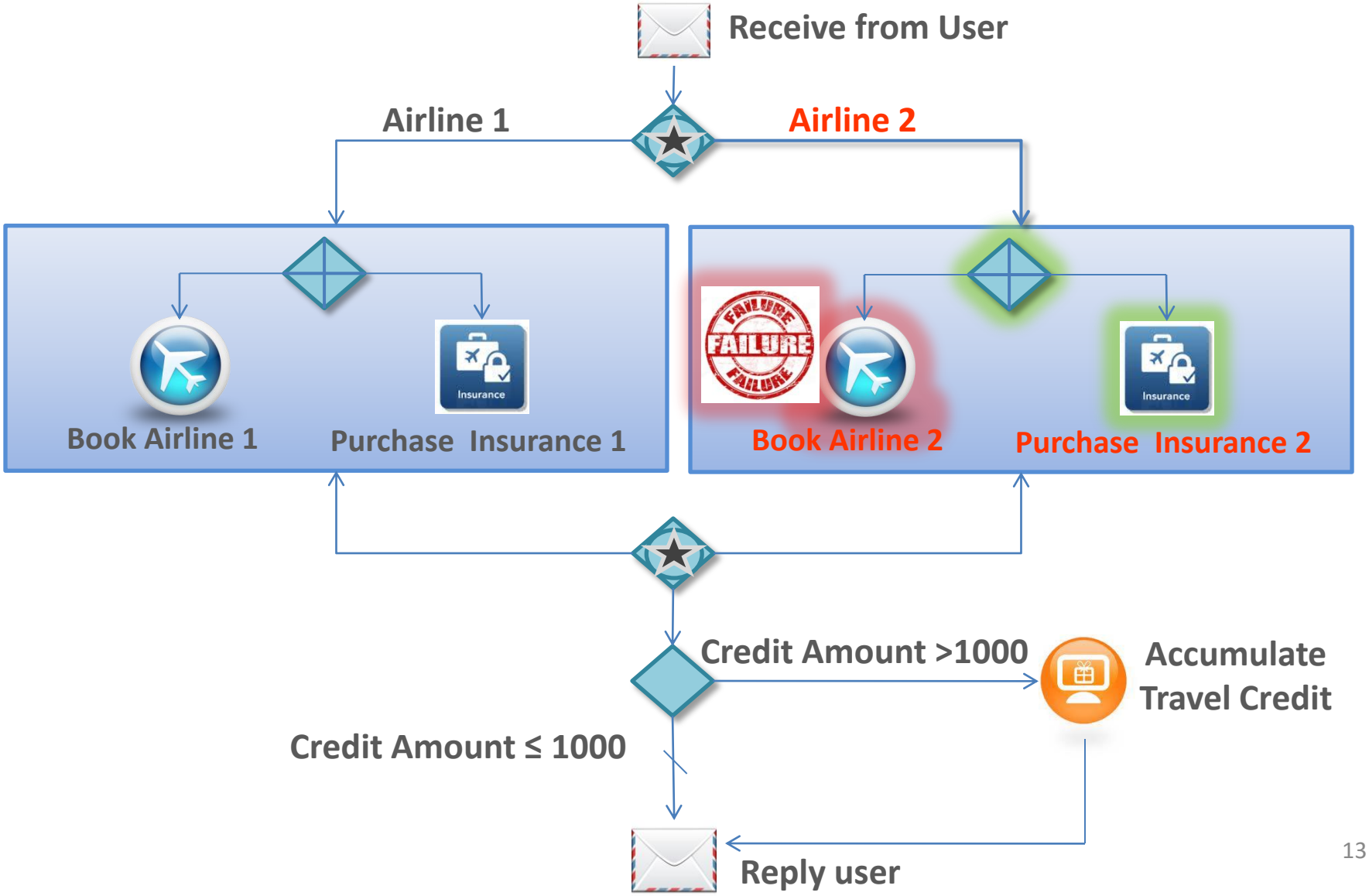
  E.g.,  Airline Booking Service

  Insurance Purchasing Service

   Travel Credit Accumulating Service

Service Failure



Problem Statement

Finding an optimal recovery plan that

- Satisfies the functional properties of the service composition after recovery.
- Optimize the Quality of Service (QoS) of service composition before and after the recovery.

Recovery Strategy

1. **Point Recovery Strategy**

   - Retry the service or switch it to an alternative service.

2. **Workflow Recovery Strategy**

   - Modifying the workflow
   - Backtracking to a previous state
   - Find an alternative path for execution

Dealing with Service Failure

Compensation - An application-specific way to reverse completed activities.

Problem

- It is uncertain whether the compensation will lead to a system state that satisfies the functional properties.

Recovery Plan

A plan that leads the service from the failure state to a correct state.

Contribution

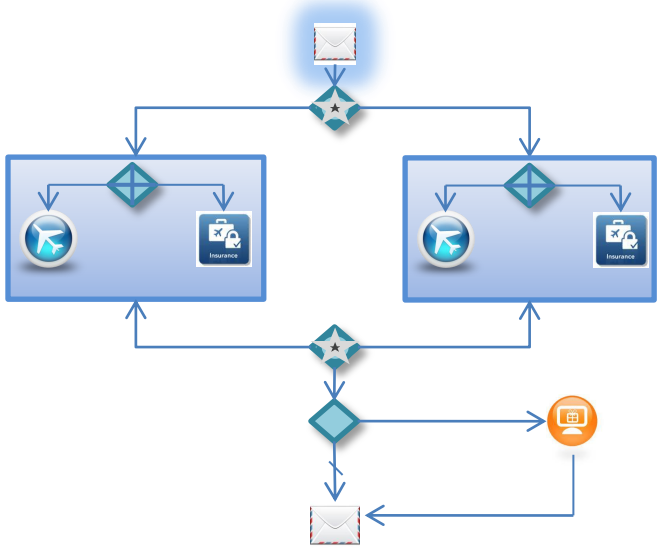
#1 Calculation of Recovery Plan in a Scalable way

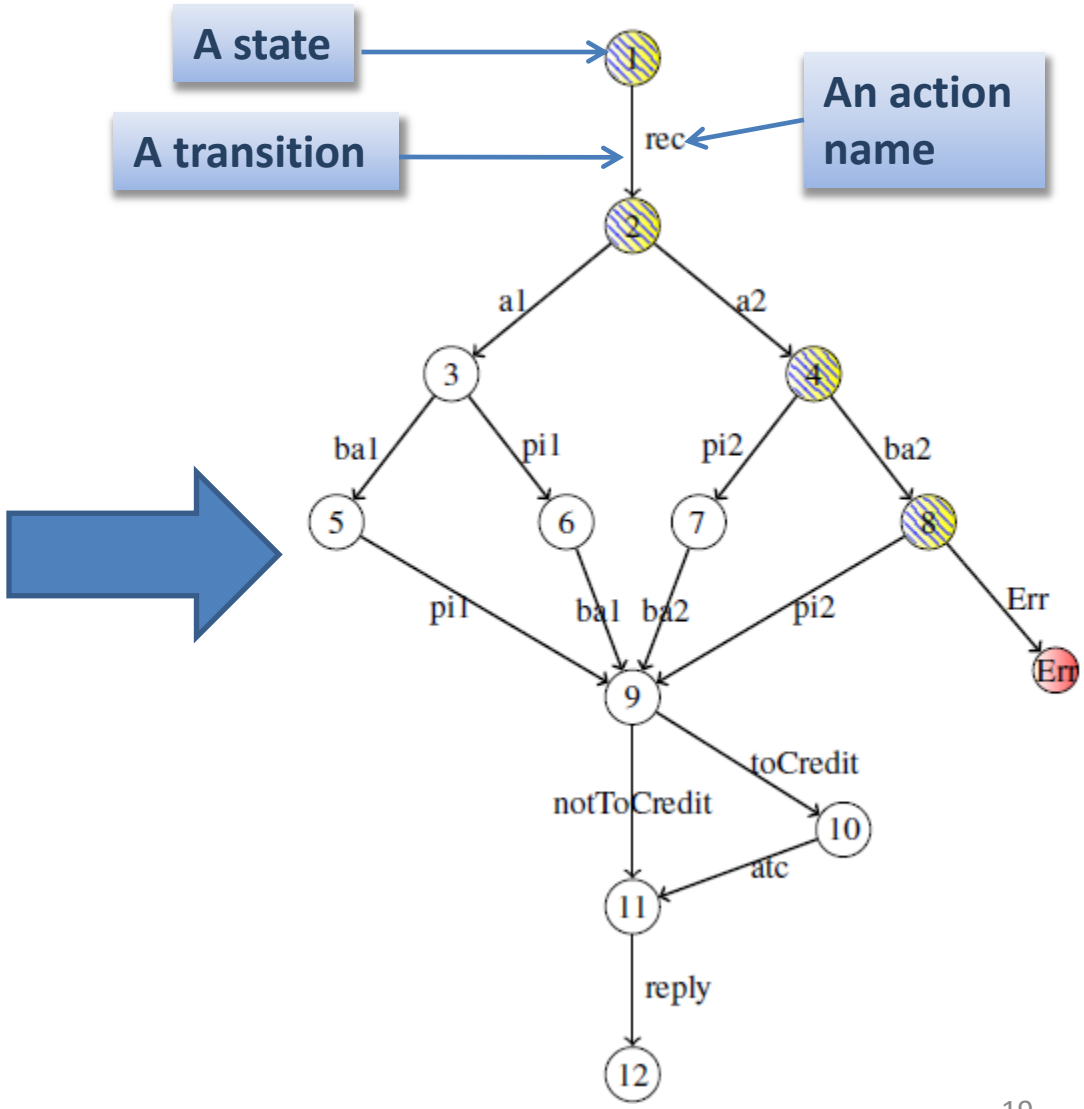
By partially exploring the state space.

#2 Effective Recovery from the State of Failure

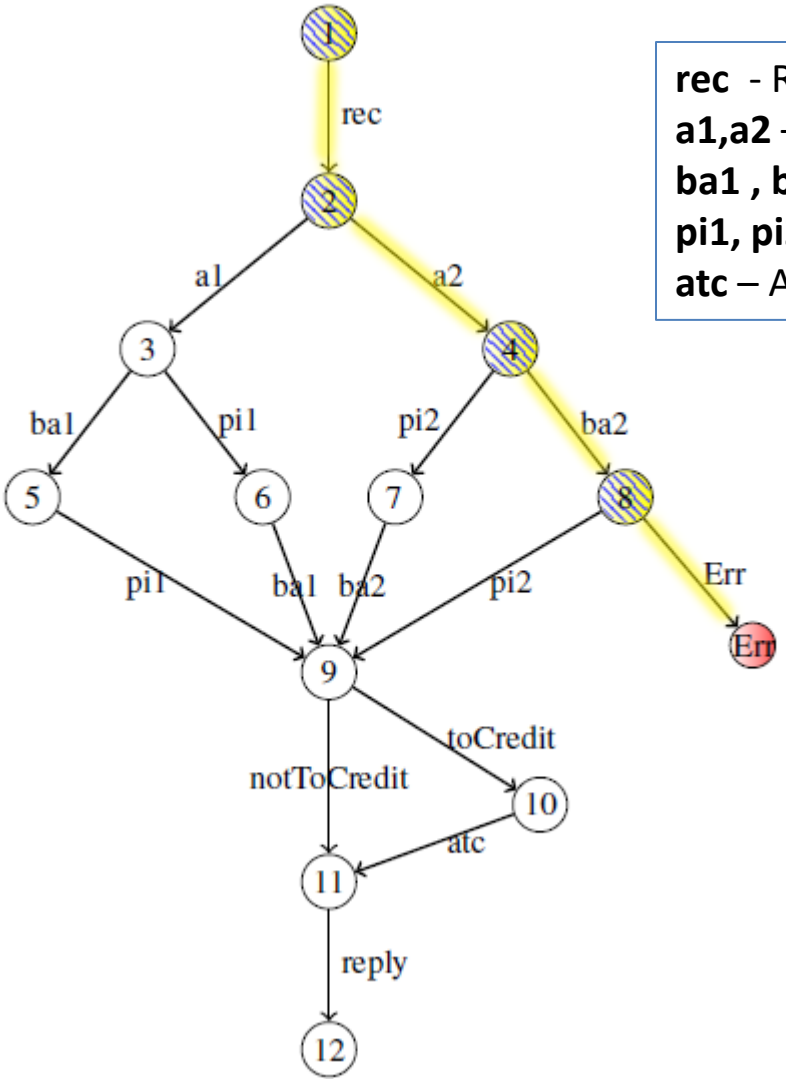
By selecting the recovery plan based on QoS.

Labelled Transition System of TBS



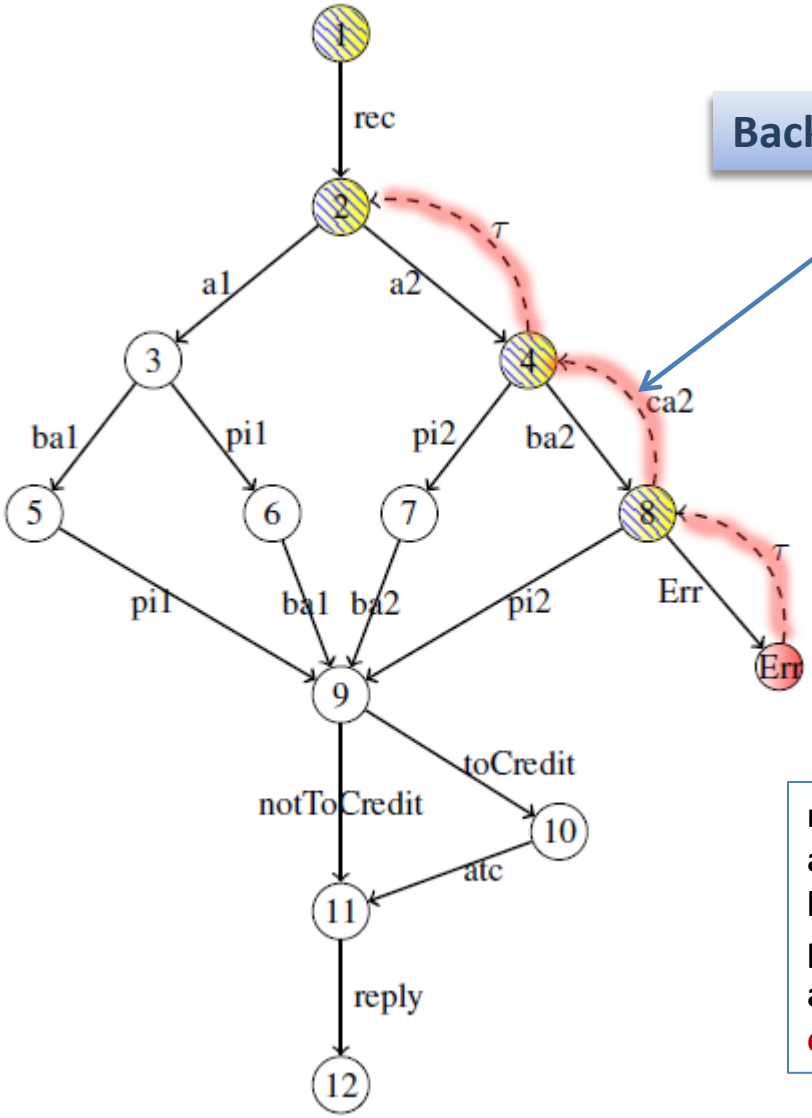


Normal Flow



rec - Receive from User
a1,a2 – Airline 1/2
ba1 , ba2– Book Airline 1/2
pi1, pi2 – Purchase Insurance 1/2
atc – Accumulate Travel Credit

Recovery Plan- Backtracking



Backward Actions

rec - Receive from User
a1,a2 – Airline 1/2
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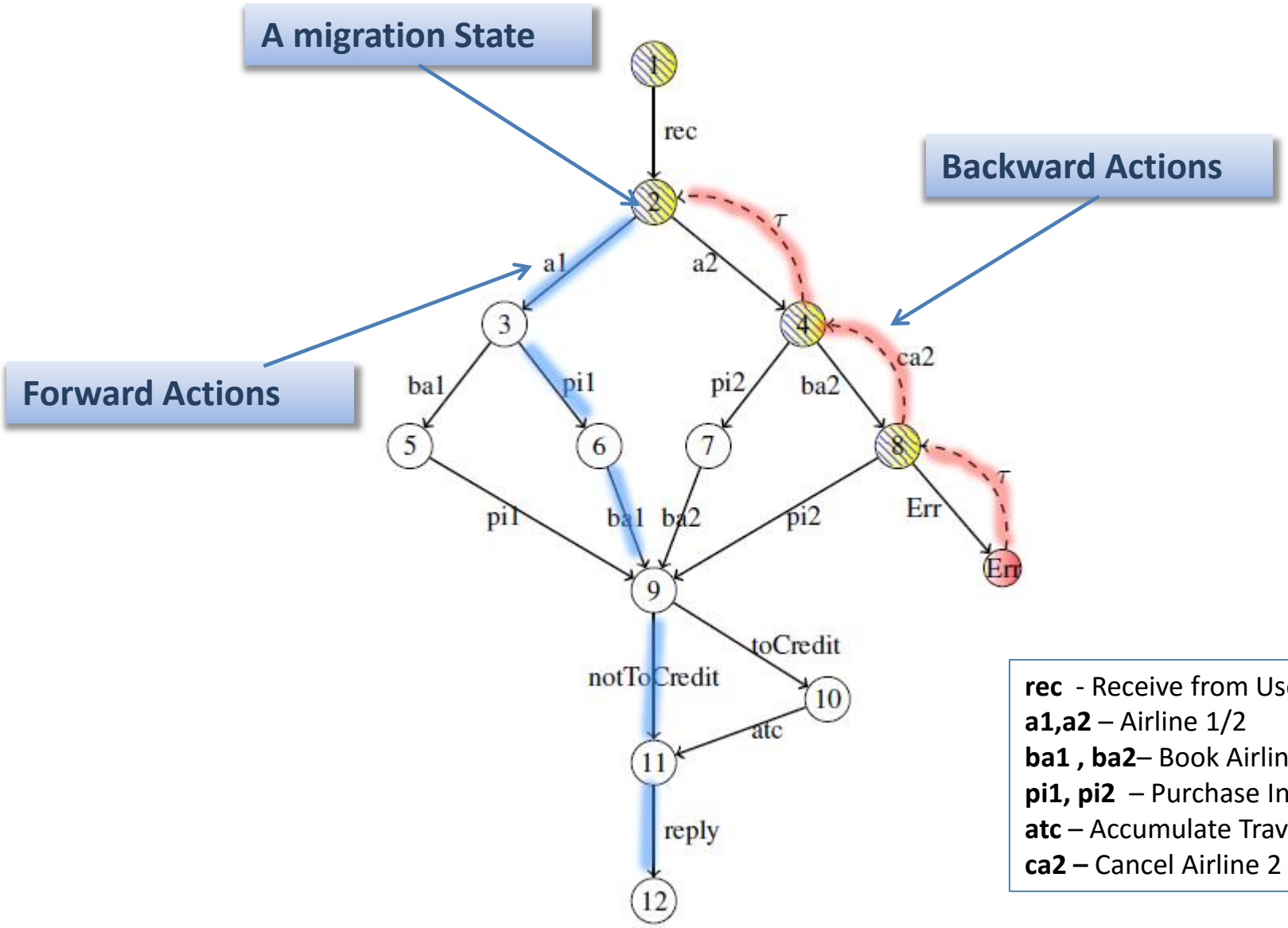
atc – Accumulate Travel Credit
ca2 – Cancel Airline 2

Full Recovery Plan



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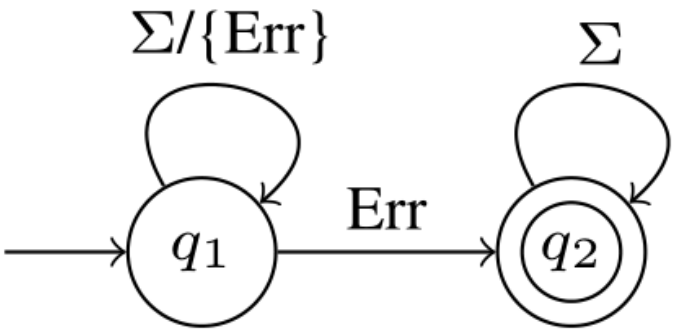
Monitoring of Functional Properties

- Using a set of monitoring automata to monitor the functional properties
- E.g., Unreachability of a component service can never happen in TBS.



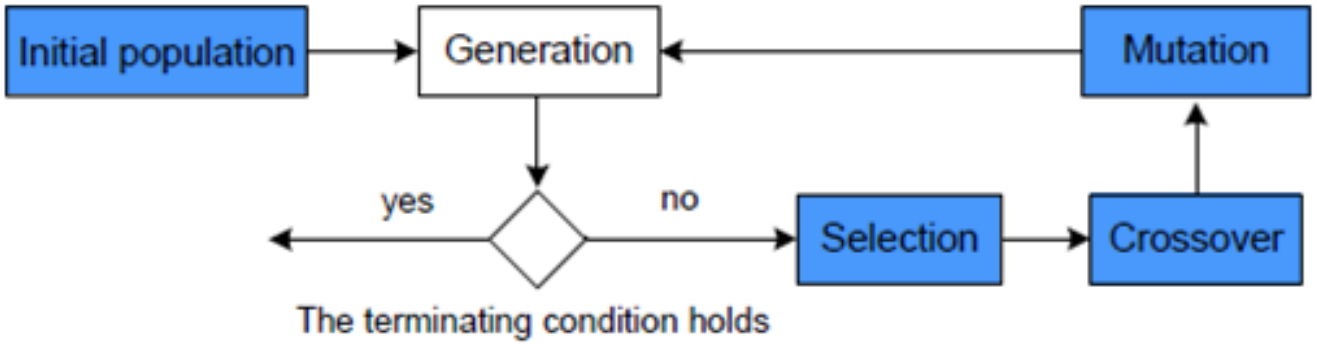
Workflow


Service Runtime Engine (RE)
actions
recovery plan
Service Monitoring and Recovery Module (SMR)
QoS Database

Our Approach - rGA

- We named our approach rGA (recovery genetic algorithm)

Each recovery plan are represented by a chromosome



Genetic Encoding

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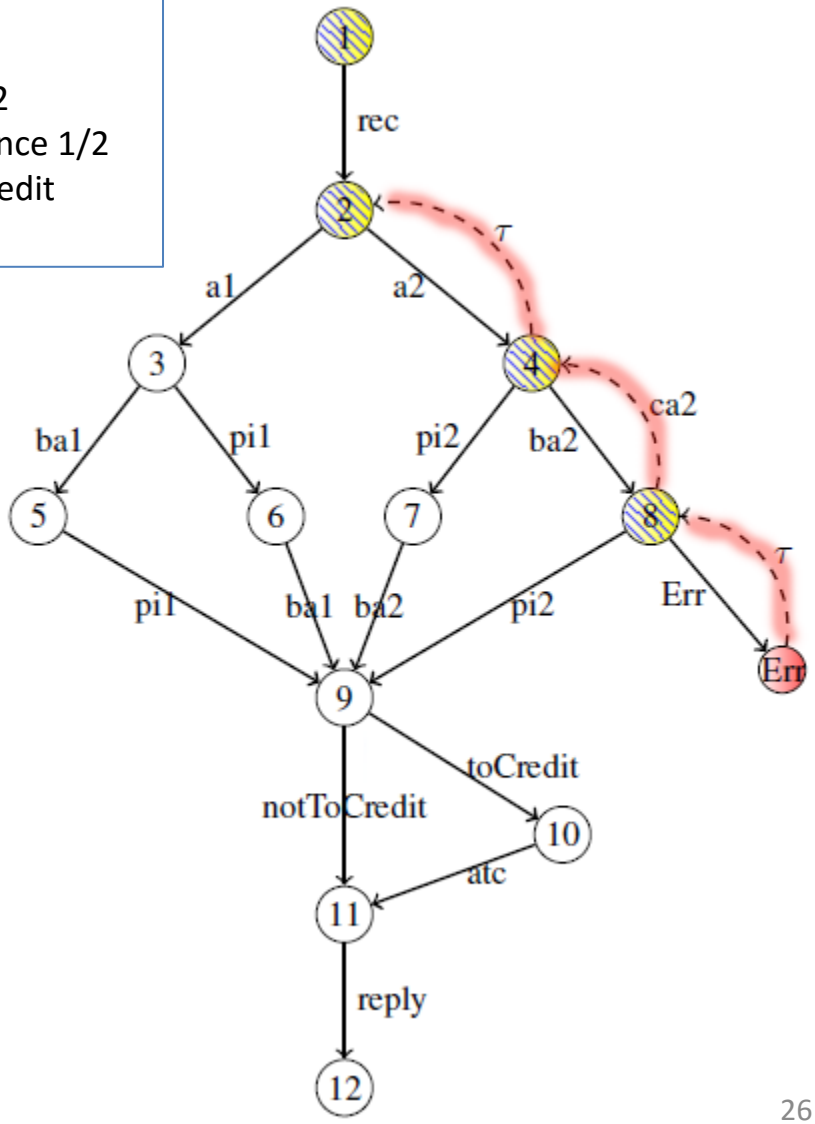
Chromosome

Global state array

Green: Backward Gene (b-gene)
Blue: Forward Genes (f-genes)



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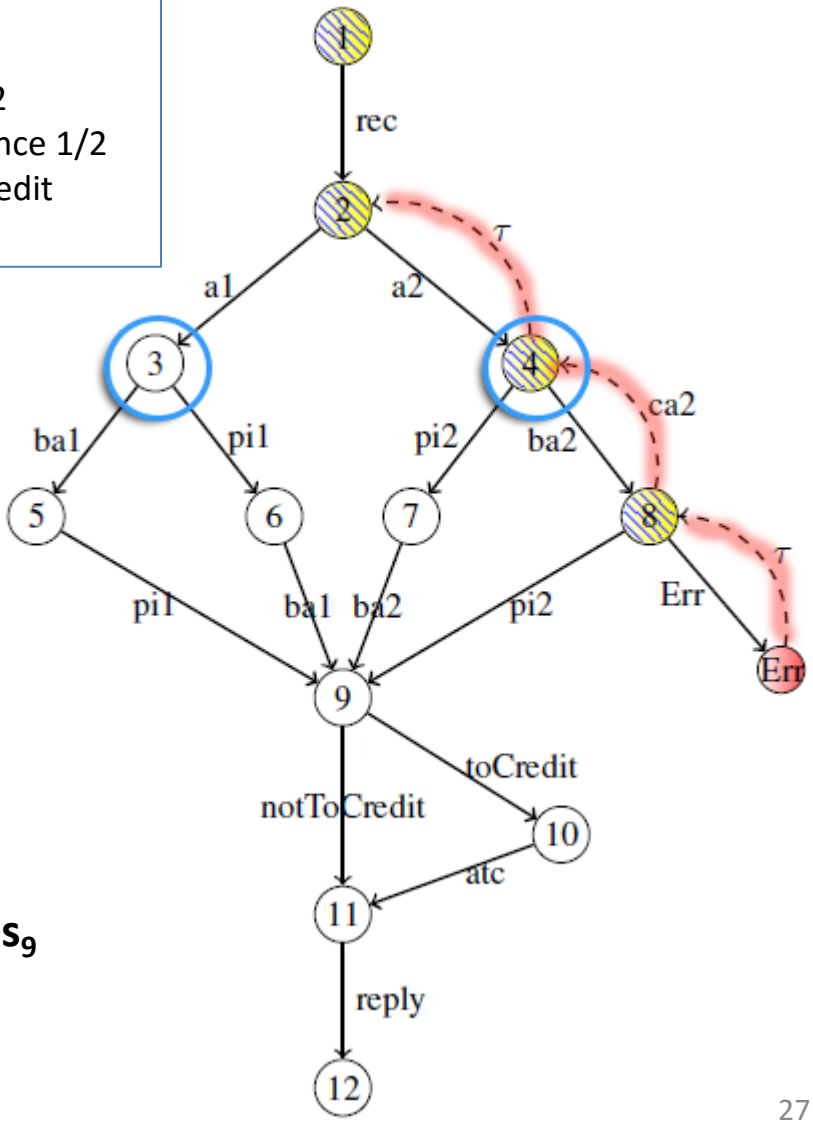
State S_3 has higher priority then State s_9



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Chromosome

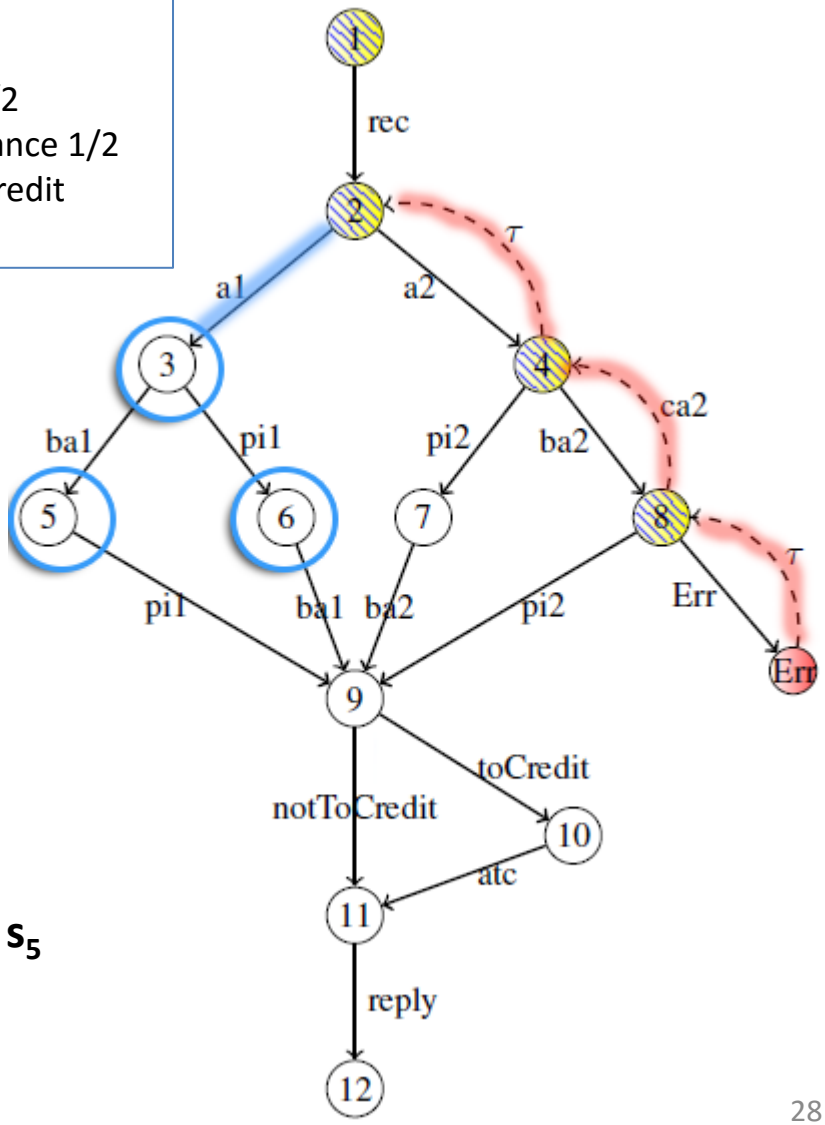
3	2	1	3	4

Global state array

	S_3	S_4	S_5	S_6

Green: Backward Gene (b-gene)
Blue: Forward Genes (f-genes)

State S_6 has higher priority then State s_5



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Chromosome

3	2	1	3	4

Global state array

	S_3	S_4	S_5	S_6

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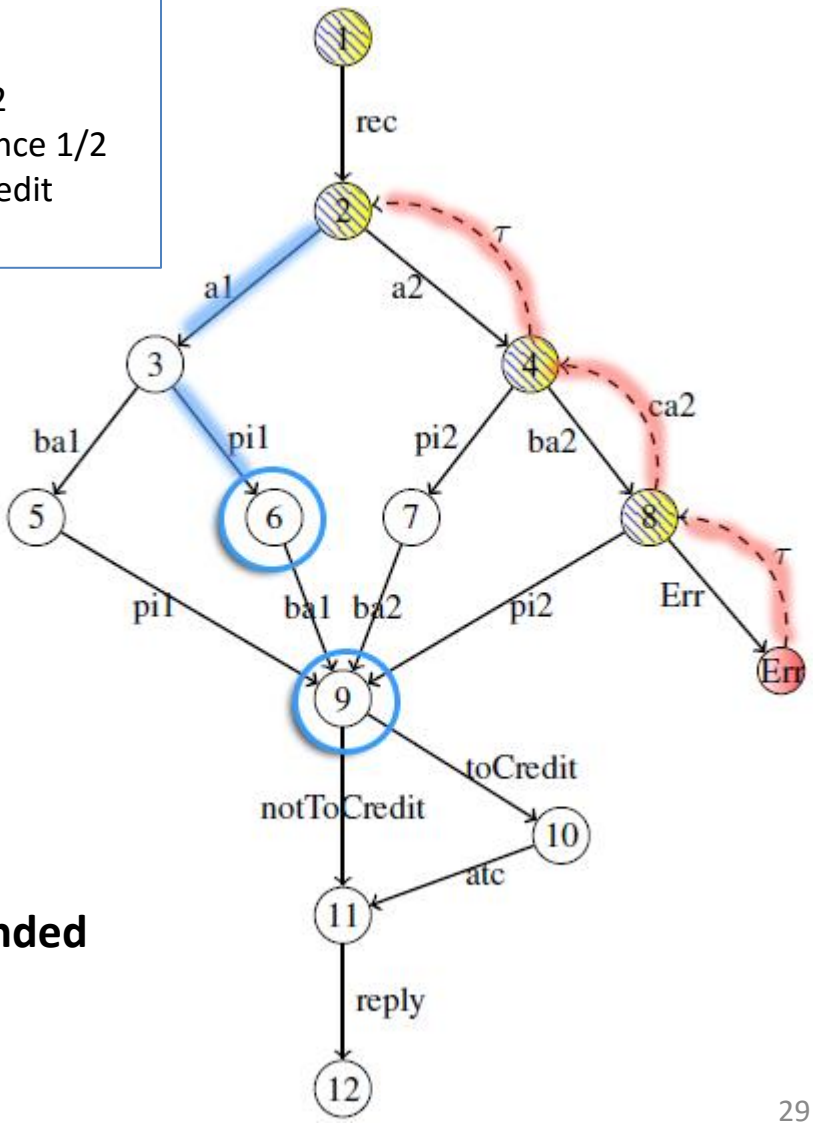
Blue: Forward Genes (f-genes)

Not Enough Spaces, Dynamically expanded



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Chromosome

3	2	1	3	4				

Global state array

	S_3	S_4	S_5	S_6				

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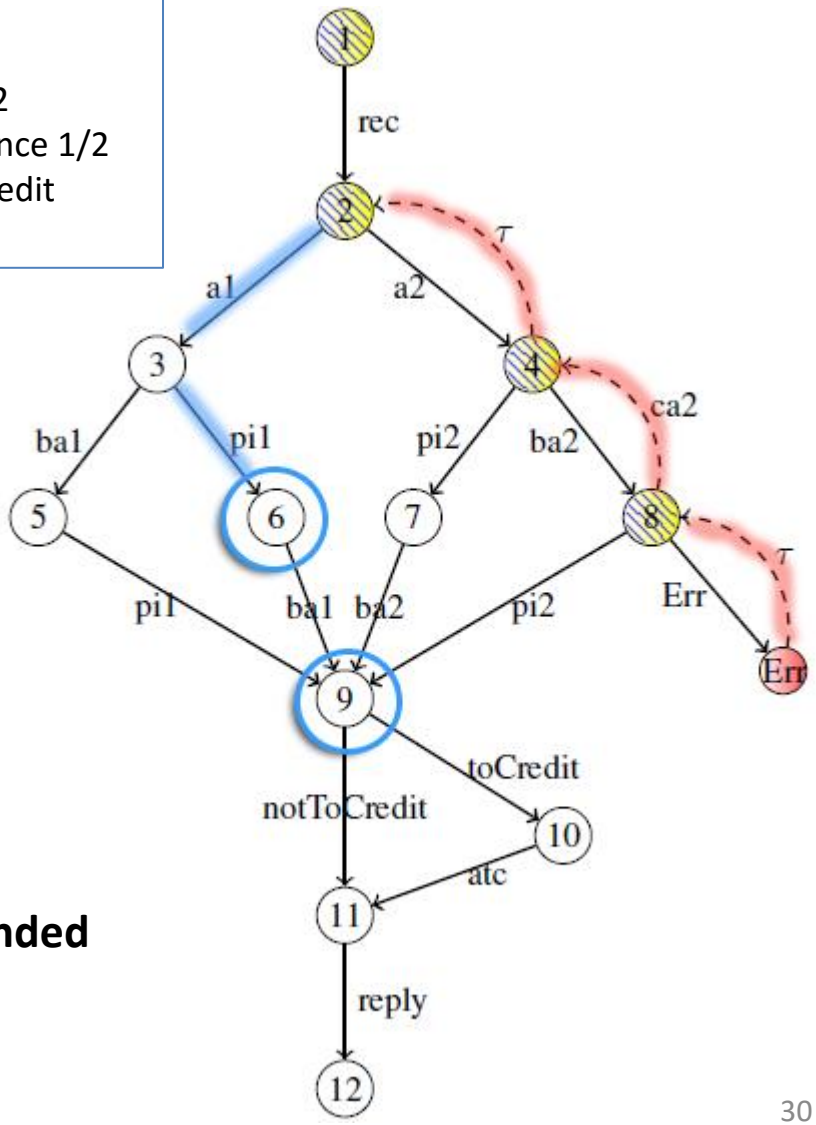

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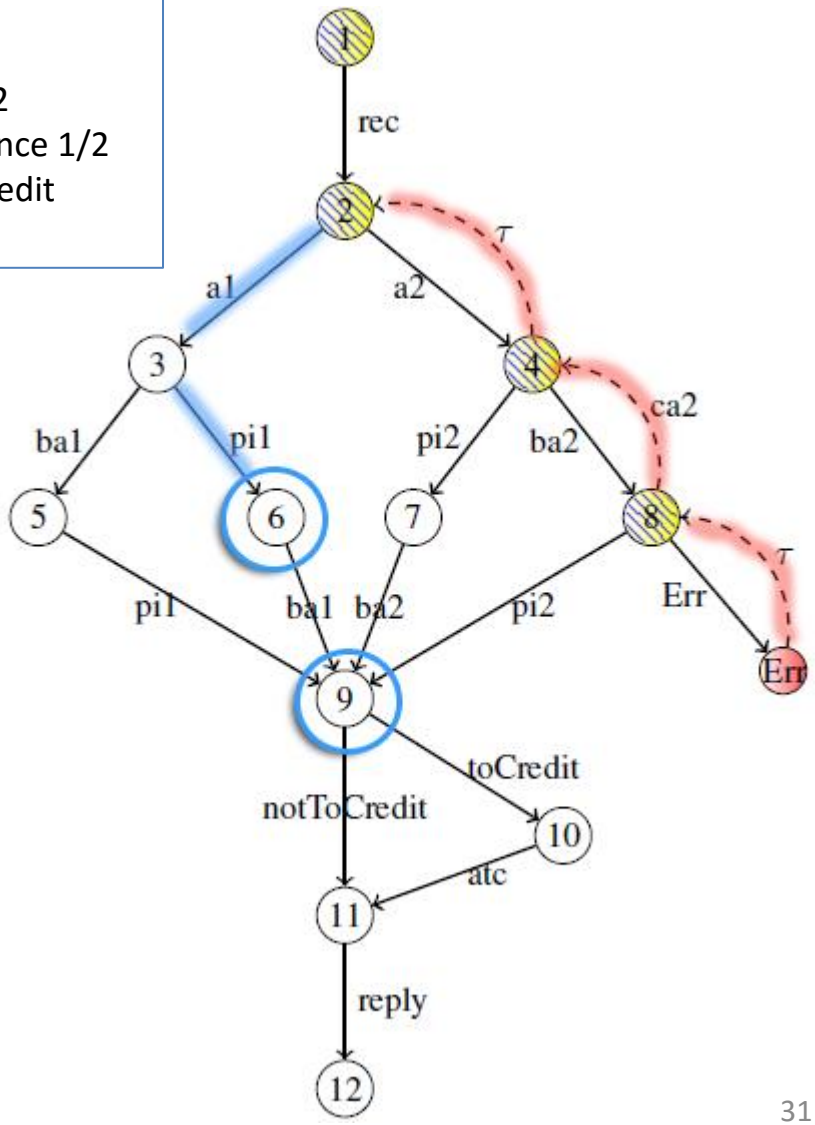
Chromosome

3	2	1	3	4	5			

Global state array

	S_3	S_4	S_5	S_6	S_9			

Green: Backward Gene (b-gene)
Blue: Forward Genes (f-genes)



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Chromosome

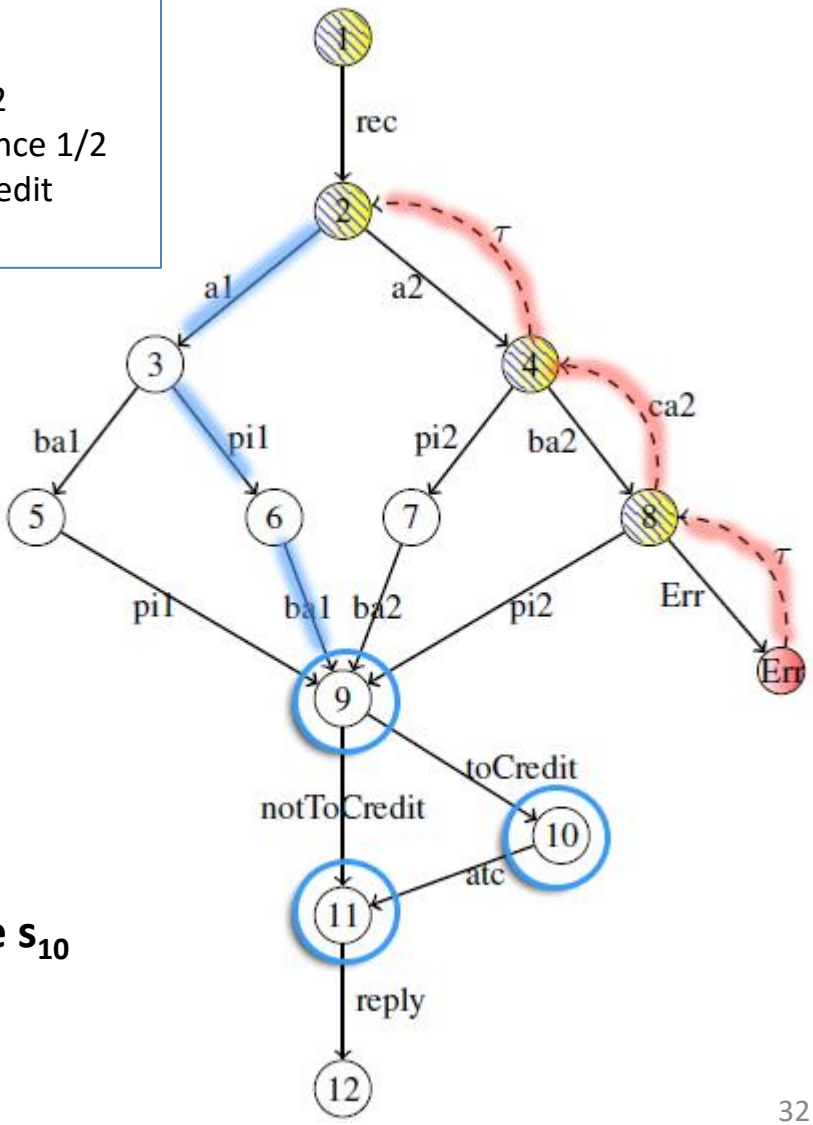
3	2	1	3	4	5	6	7	

Global state array

	S_3	S_4	S_5	S_6	S_9	S_{10}	S_{11}	

Green: Backward Gene (b-gene)
Blue: Forward Genes (f-genes)

State S_{11} has higher priority then State s_{10}



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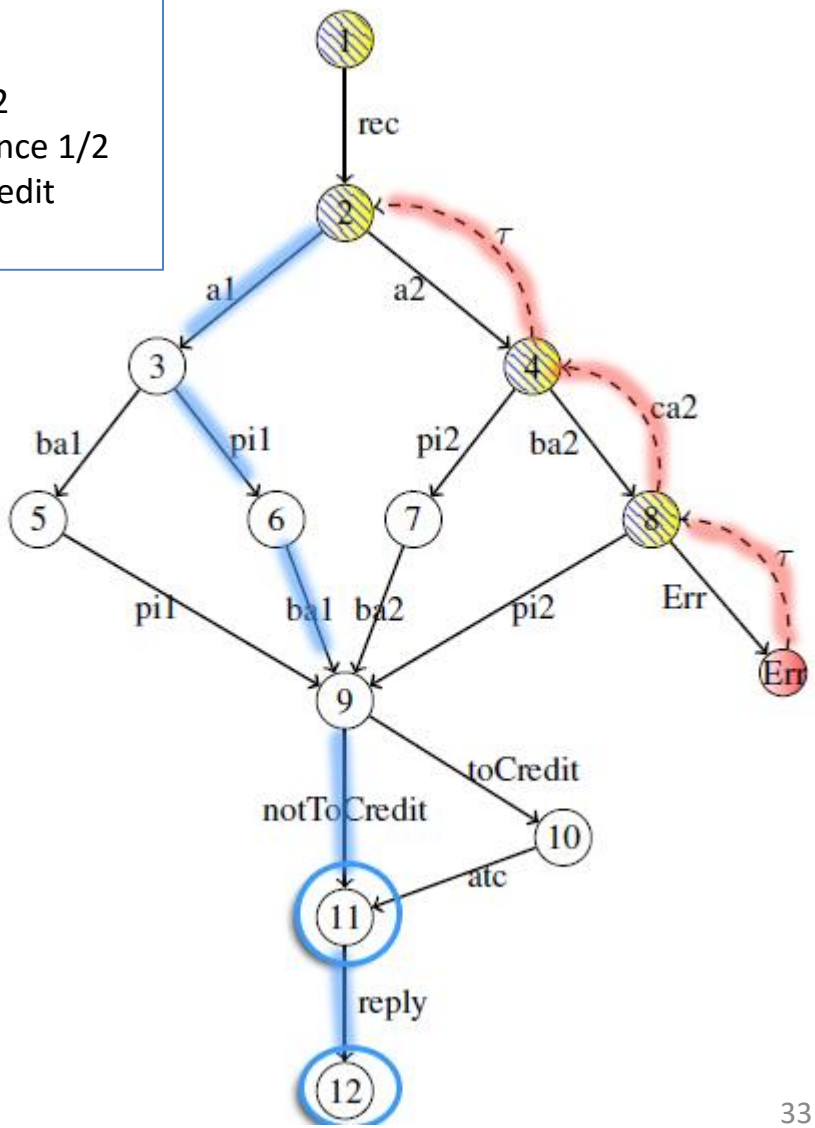
Chromosome

3	2	1	3	4	5	6	7	8

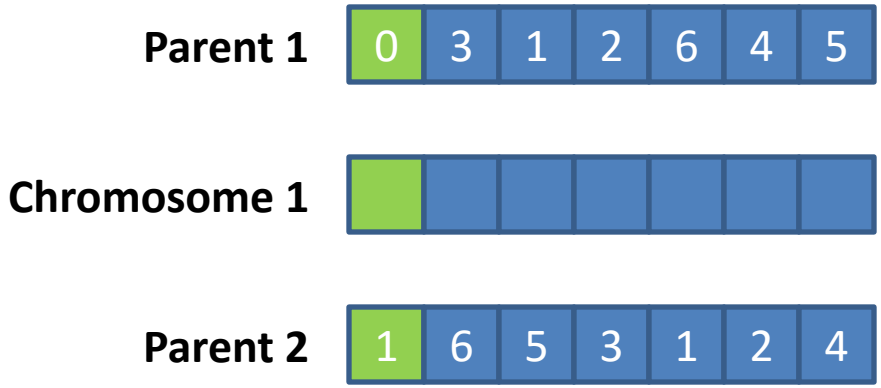
Global state array

	S_3	S_4	S_5	S_6	S_9	S_{10}	S_{11}	S_{12}

Green: Backward Gene (b-gene)
Blue: Forward Genes (f-genes)



Positional Crossover



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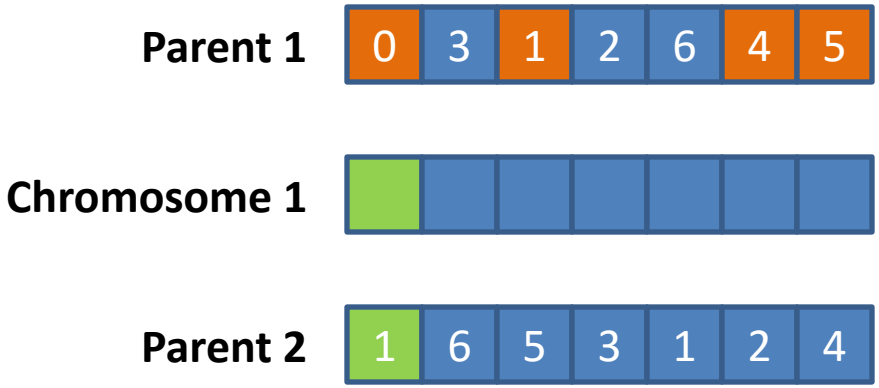

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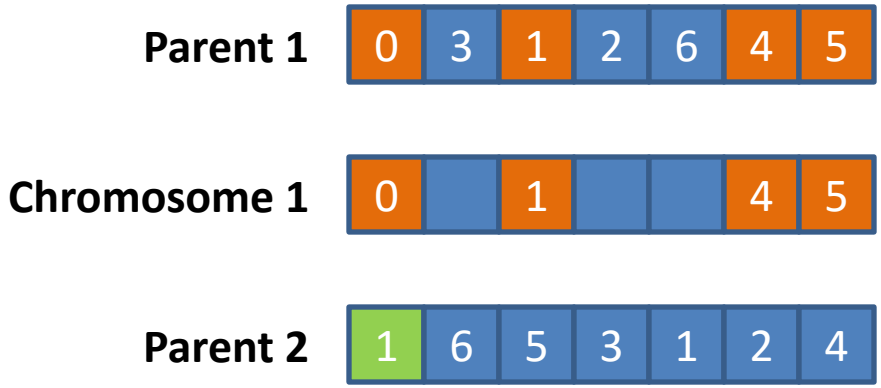

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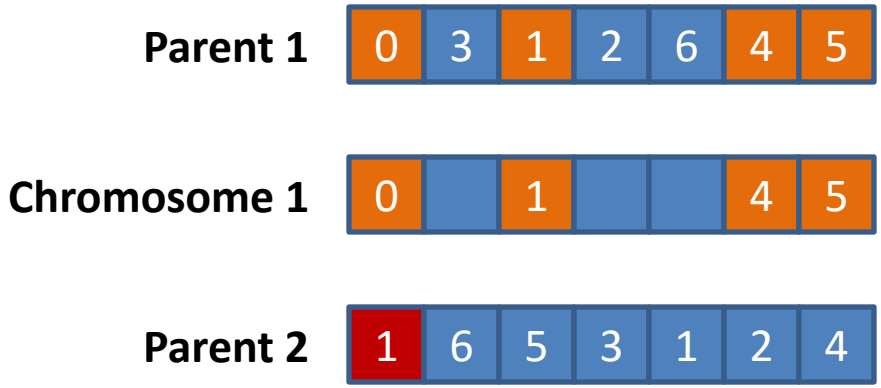

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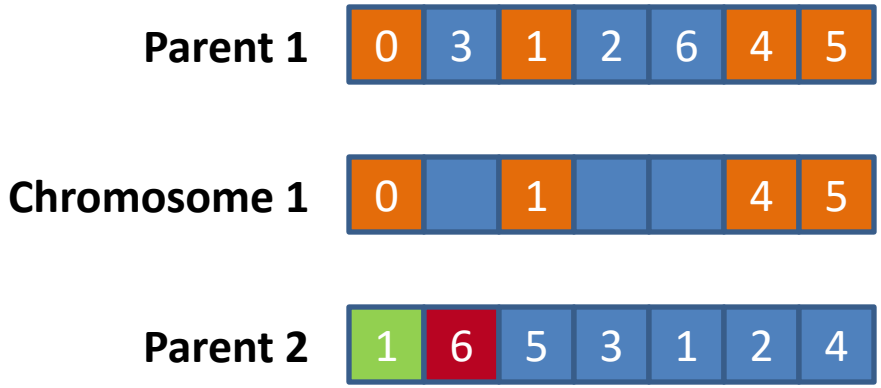

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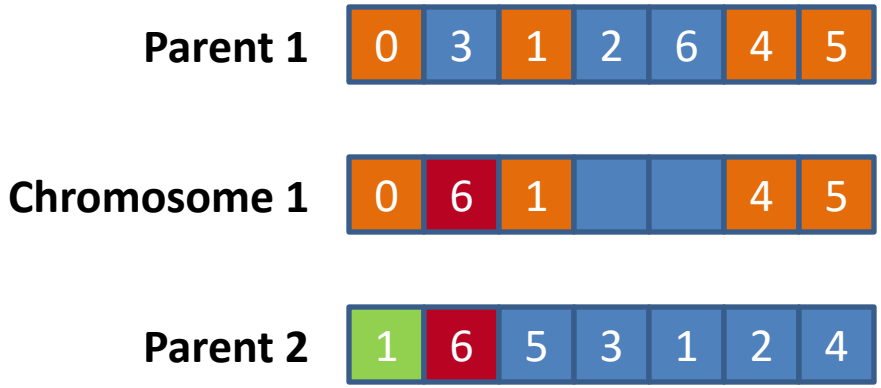

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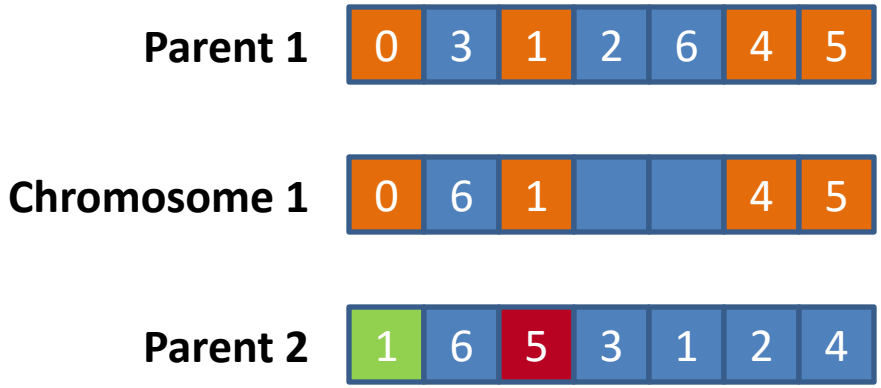

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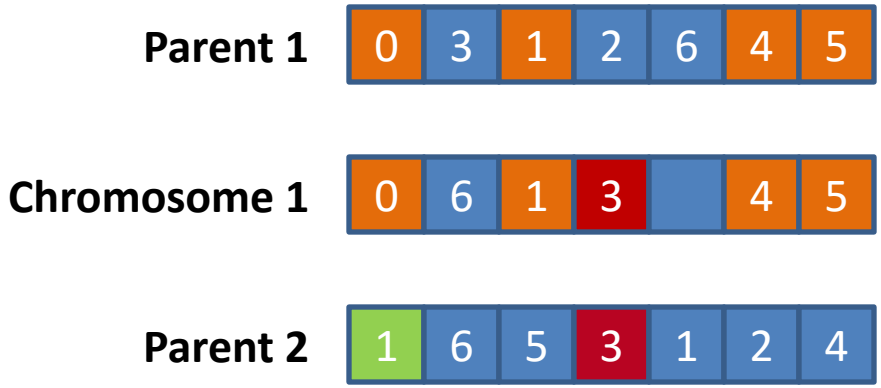

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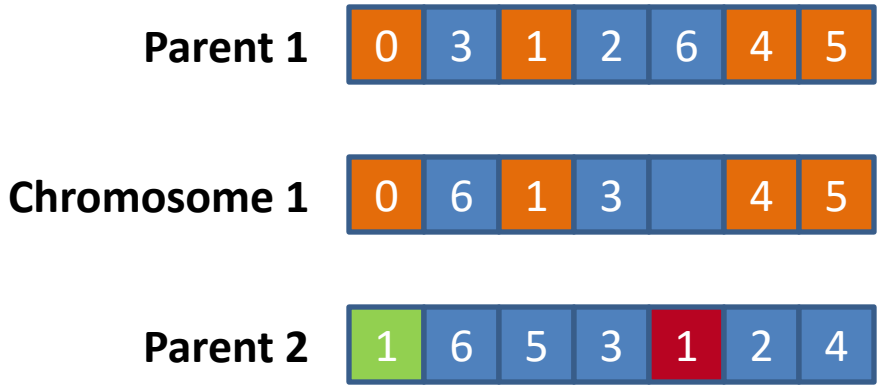

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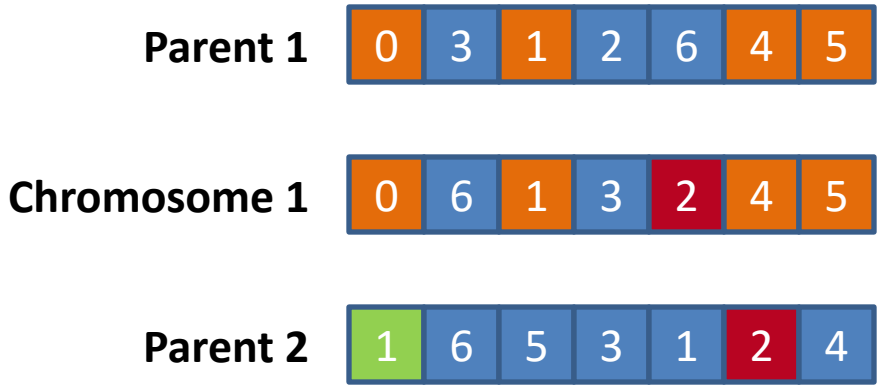

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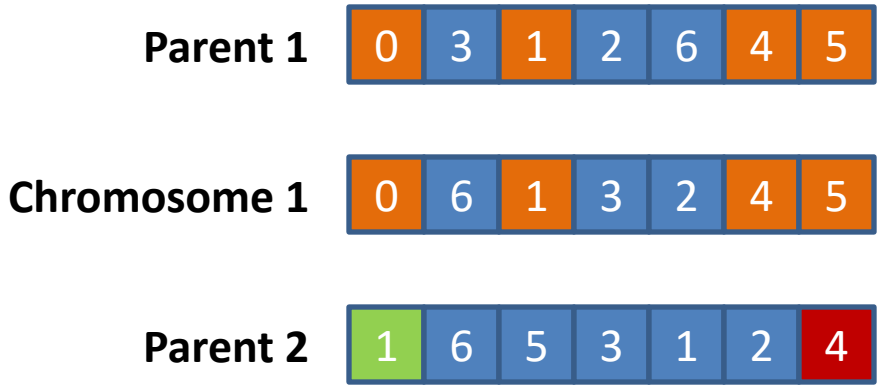
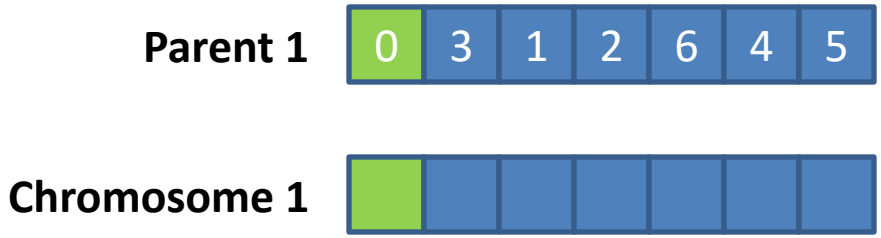


Mutation



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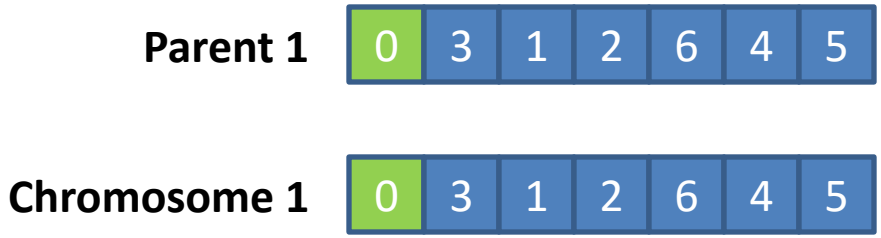

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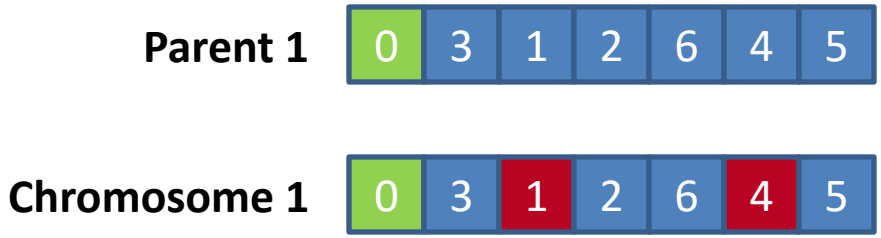

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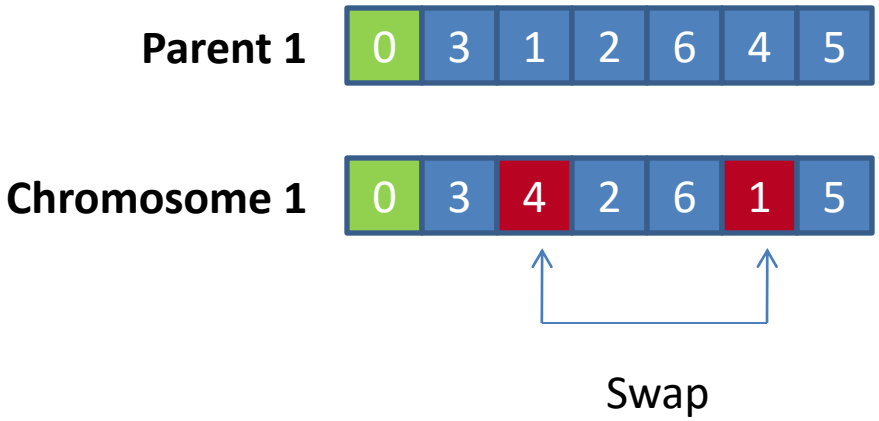


Fitness Function

- **QoS Optimality, Q(r):** The overall QoS of a plan r.

$$Q(r) = \sum_{k=1}^{r} q'_k(r) \cdot w_k \qquad \sum_{k=1}^{r} w_k = 1$$

- **Global Optimality G(r):** The recovery plan that is **functionally correct** will have **higher** QoS than recovery plan that is **functionally incorrect**.

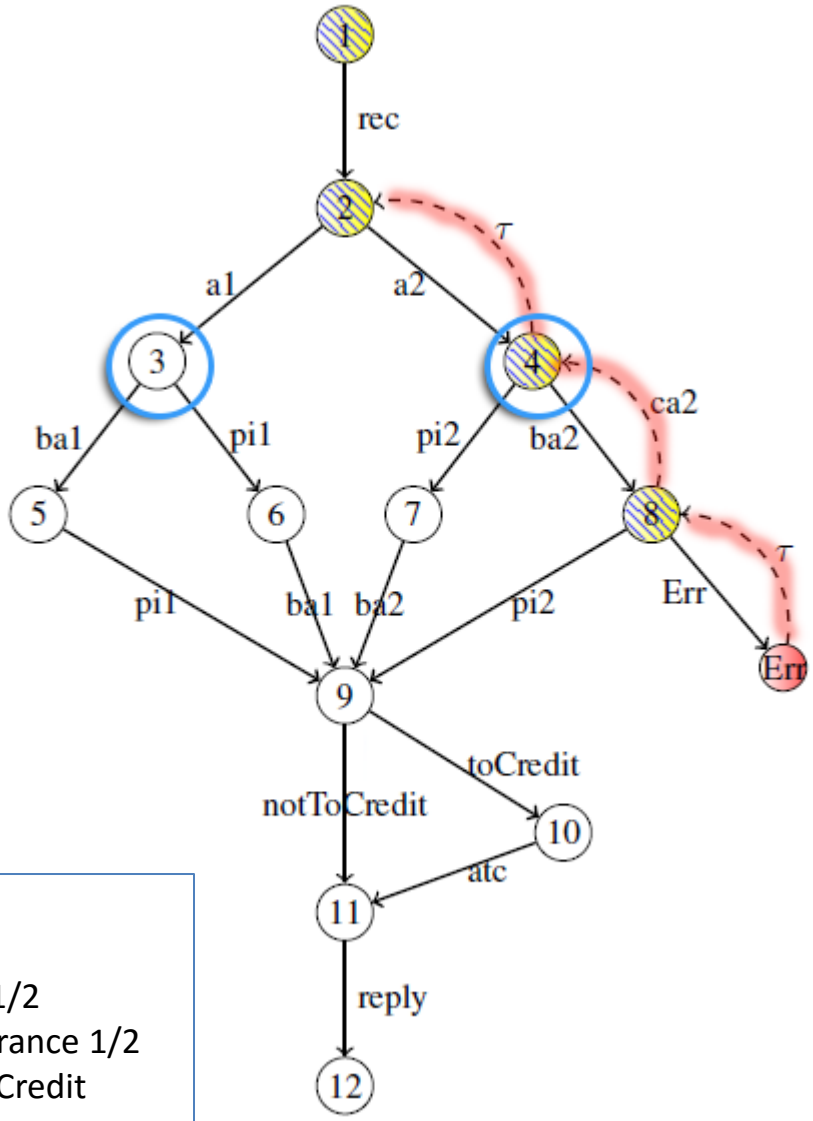
$$G(r) = \begin{cases} 0.5 + 0.5 \cdot Q(r) & \text{If r is functionally correct} \\ 0.5 \cdot Q(r) & \text{If r is functionally incorrect} \end{cases}$$

Enhanced Initial Population Policy

Goal: Overcome the shortcoming of randomness of the genetic algorithm, and be able to converge faster.

Local Optimality

- Choosing state s_4 require invocation of the failure service.
- Higher probability in choosing state s_3.



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Evaluation

Approach to compare (SAT)

- Using SAT solver **[FSE'10].**
- Given length *k,* calculate all feasible recovery plans up to length *k.*

Problem

- Exponentially many choices – State explosion
- Does not account explicitly on Quality of Service (QoS).

[FSE'10] J. Simmonds, S.B. David, M. Checchik Guided Recovery for Web Service Applications.

Evaluation

rGA				SAT	
case study	time (s)	quality	gen.	length	time (s)
FV	0.7	1	10	42	3.12
FC	0.12	1	6	20	1.38
TAS	0.22	1	6	13	0.27
TBS(2)	0.47	1	6	N/A	N/A
TBS(30)	0.54	1	8	N/A	N/A
TBS(60)	0.87	1	8	N/A	N/A
TBS(120)	1.24	1	10	N/A	N/A
TBS(200)	1.97	1	10	N/A	N/A
LSS(30)	0.85	0.97	7	N/A	N/A
LSS(60)	0.96	0.97	7	N/A	N/A
LSS(80)	1.42	0.96	8	N/A	N/A
LSS(120)	1.92	0.95	8	N/A	N/A
LSS(200)	2.57	0.94	8	N/A	N/A

$$quality = \frac{G(r)}{G(r_{exact})}$$

Conclusion

- We propose a method for calculating recovery plan.
- **Efficiency**: Partial and guided exploration of state space is supported by using genetic algorithm.
- **Effectiveness**: QoS is explicitly taken into account.

Thank you!