論文進度報告

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Agenda

- Degree of Separation (DOS)
- Average DOS
- Problem Description
- Problem Formulation

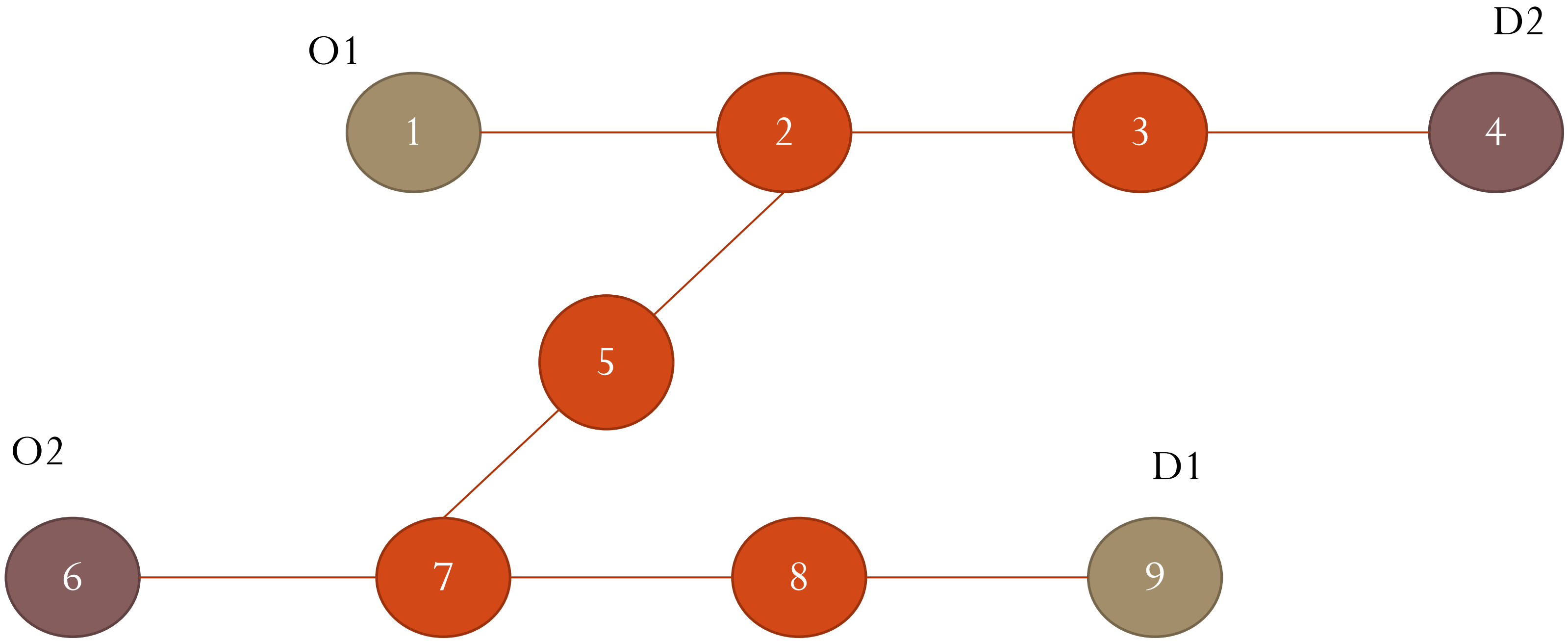
Degree of Separation (DOS)

DOS

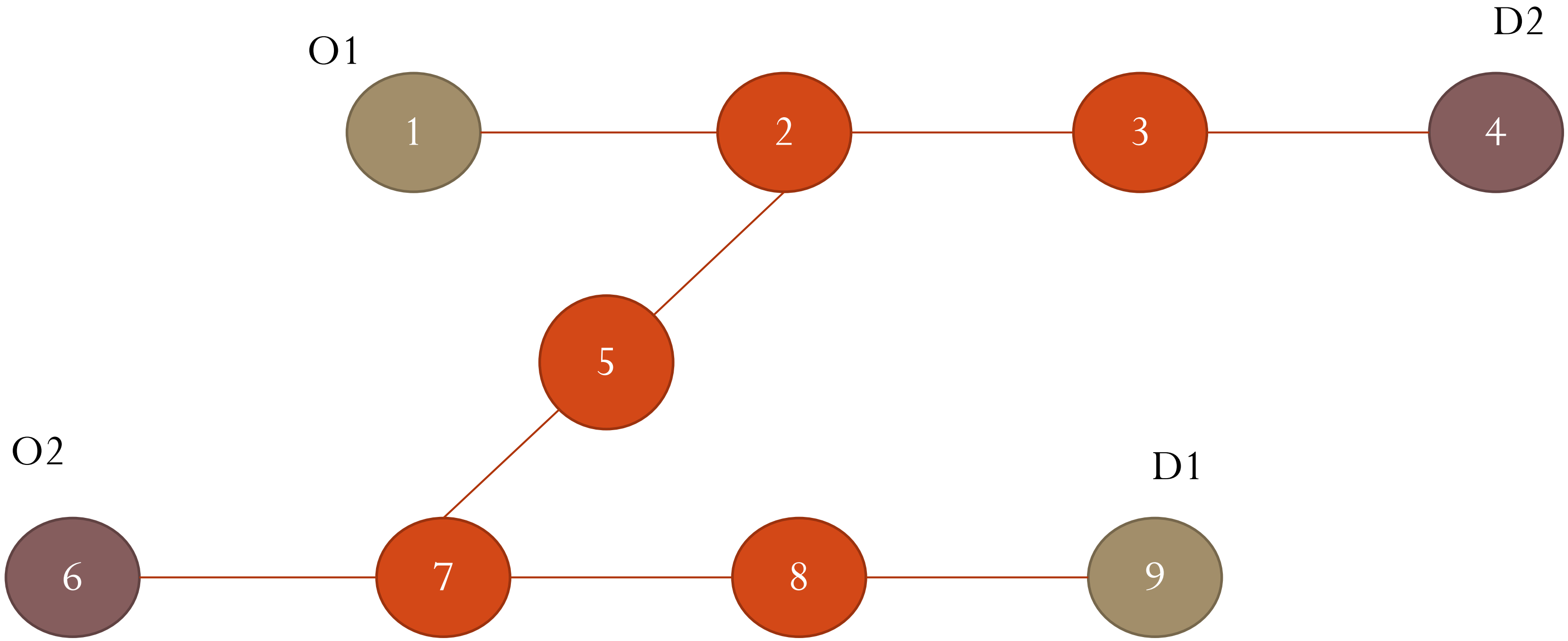
- A metric of network survivability
- Average broken nodes of an OD pair
- Definition

$$\frac{\sum(\#\ \text{of broken nodes of each OD pair})}{\#\ \text{of OD pairs in a network}}$$

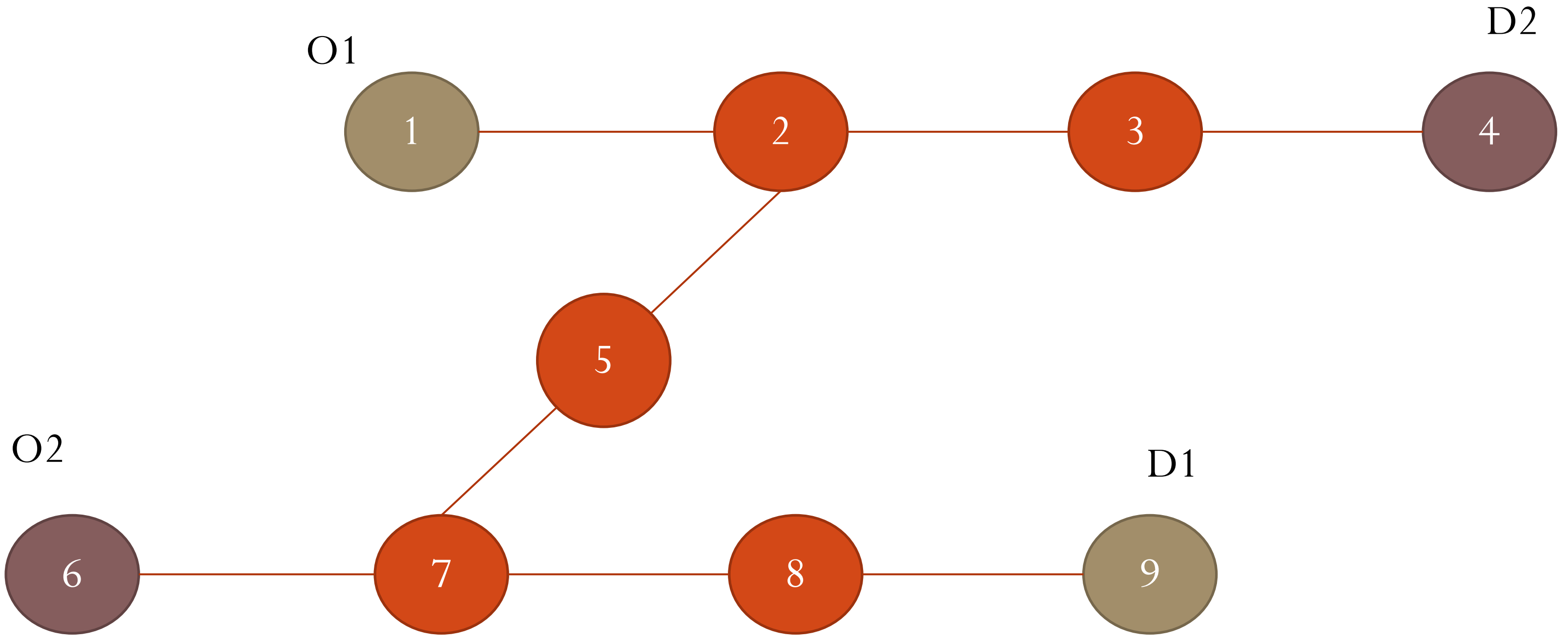
DOS



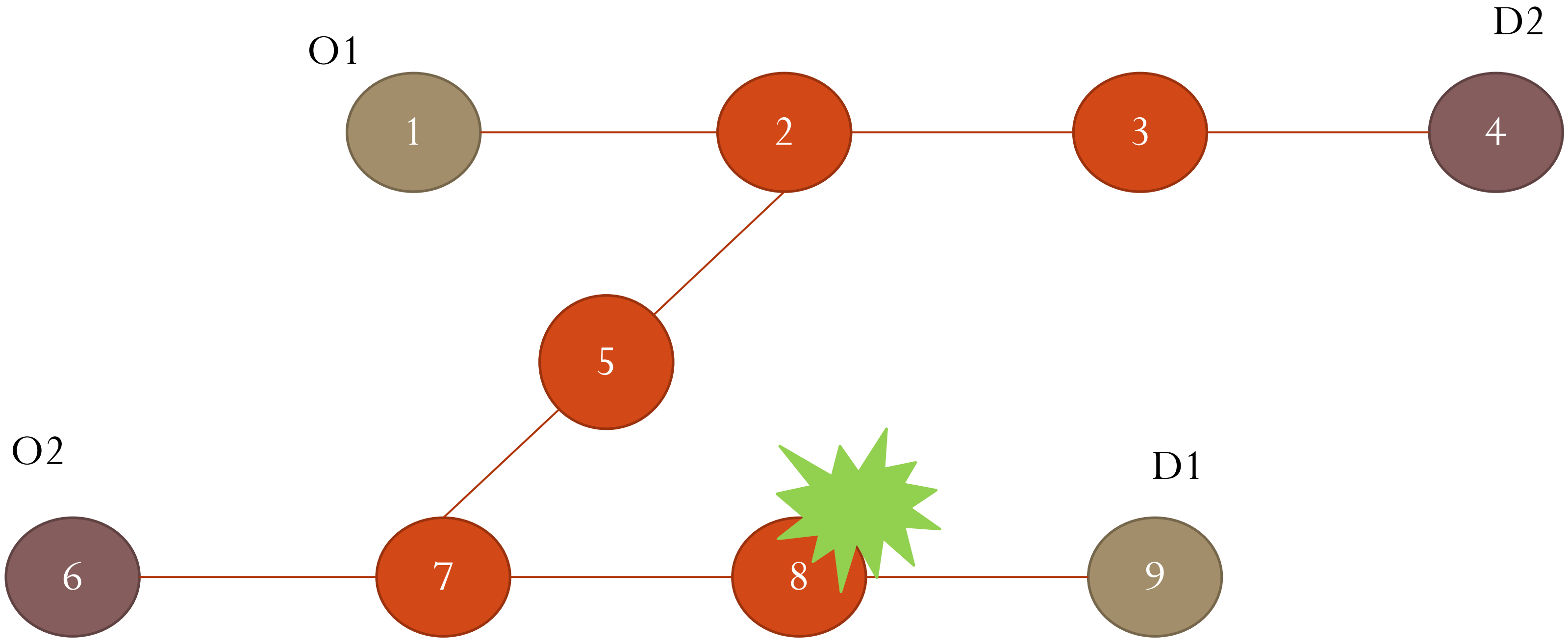
DOS



DOS

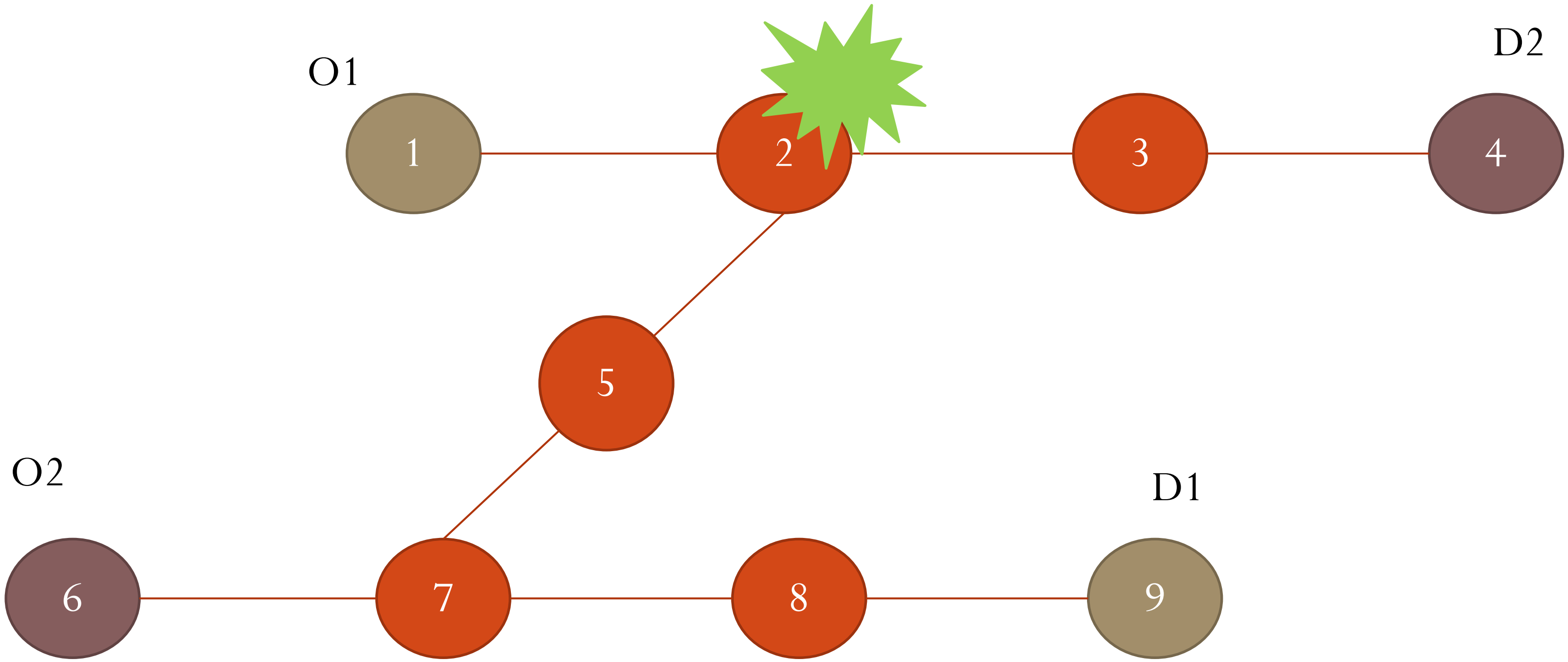


DOS



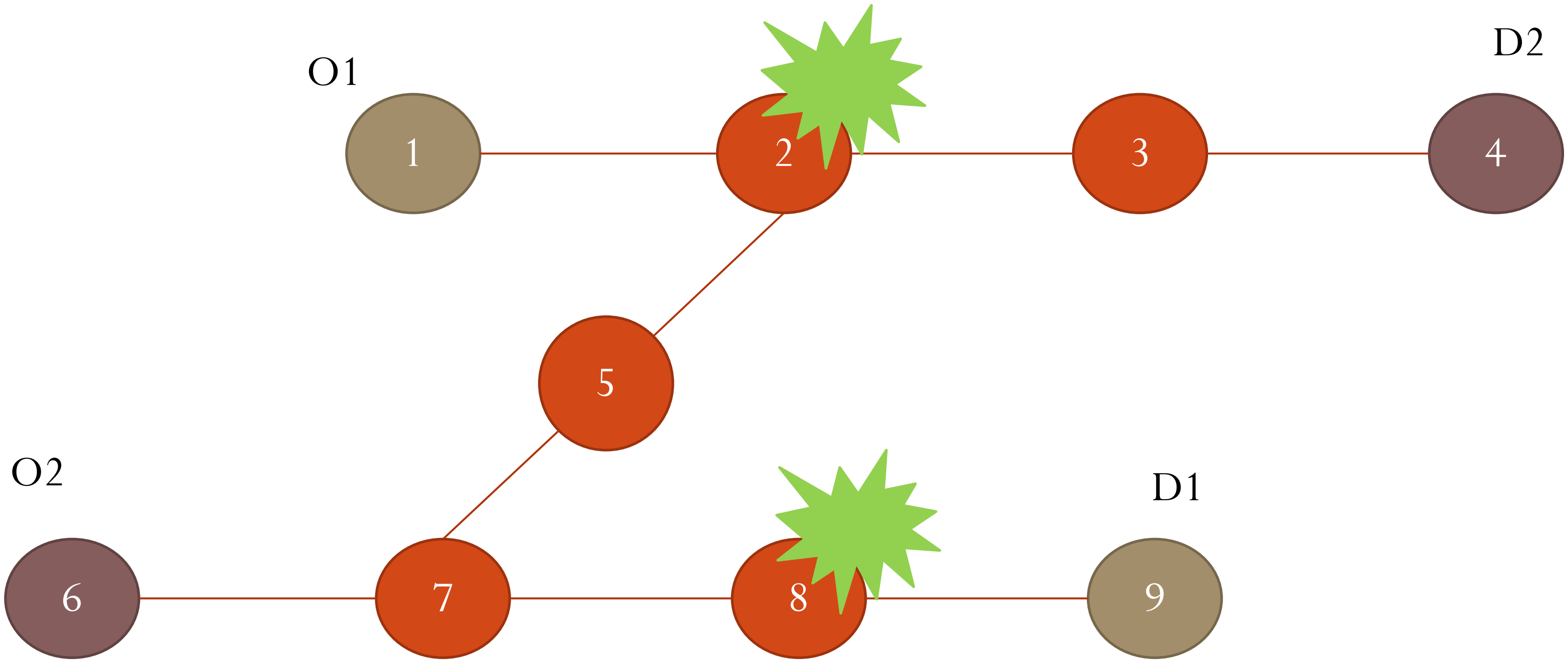
$$\frac{1+0}{2} = \frac{1}{2}$$

DOS



$$\frac{1+1}{2}=1$$

DOS



$$\frac{2+1}{2}=\frac{3}{2}$$

DOS

- The greater value of DOS, the smaller the network survivability.

Average DOS

Average DOS

- Traditionally, assuming that the attacker wants to compromise the node only needing to put the budgets more than the defender is not suitable, because nothing is one hundred percent successful.

- Therefore, we introduce the concept of the probability (using the **contest success function**) into the DOS.

Contest Success Function(CSF)

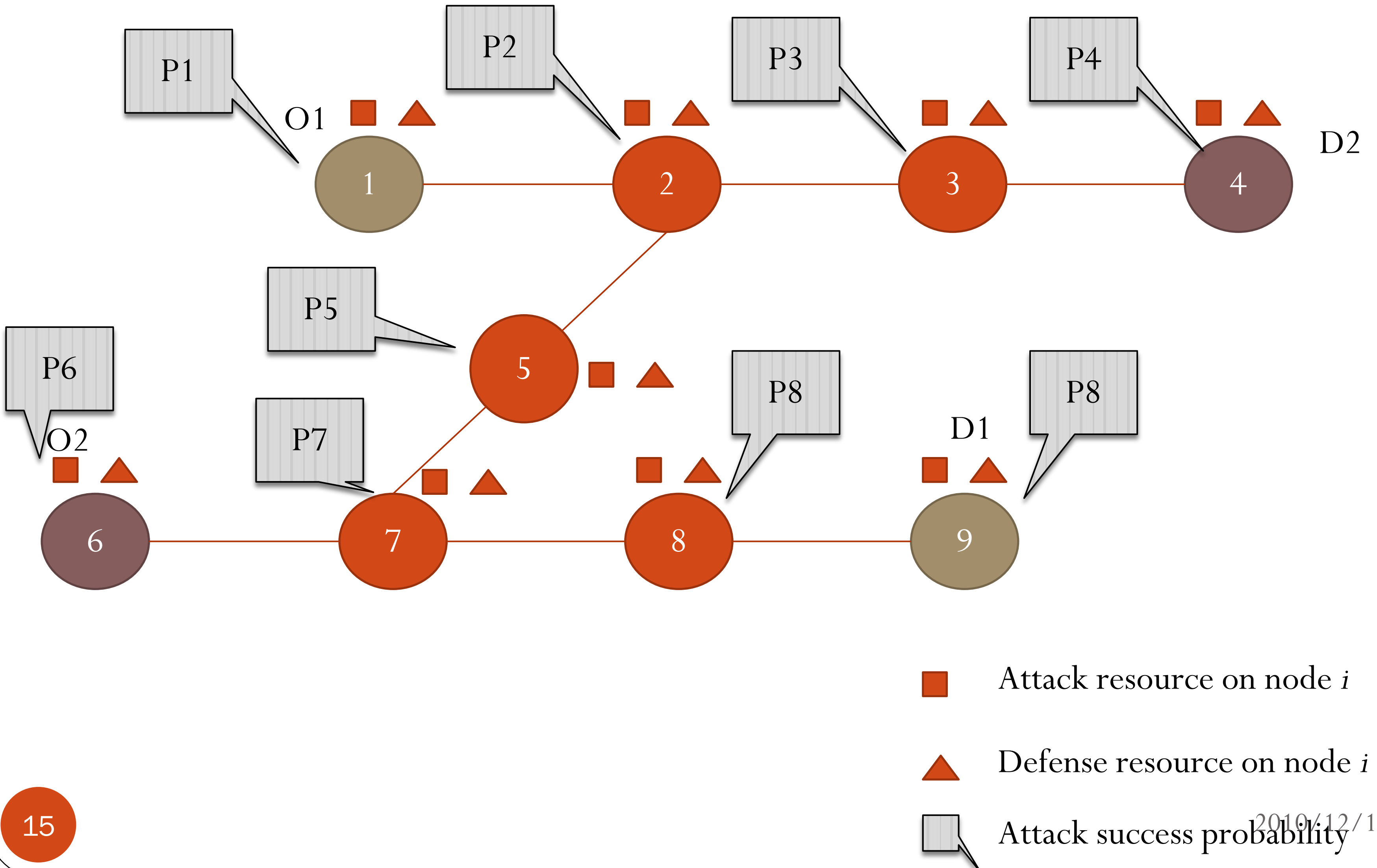
- Skaperdas, S., 1996. Contest success functions. Economic Theory 7, 283–290.

  - Definition

$$s(a,b)=\frac{a^m}{a^m+b^m}=\frac{1}{1+(\frac{b}{a})^m}$$

a ： the attacker's budget
b ： the defender's budget
m ： contest intensity
s ： attack success probability

Average DOS


P1
O1
P2
P3
P4
D2
1
2
3
4
P5
5
P6
O2
P7
P8
P8
D1
6
7
8
9
Attack resource on node *i*
Defense resource on node *i*
Attack success probability

Average DOS

Node states	Success Probability(P)	DOS	P *DOS
1,2,3,4,5,6,7,8,9	(1-P1)*(1-P2)(1-P3)(1-P4)(1-P5)(1-P6)(1-P7)(1-P8)(1-P9)	0	0
1,2,3,4,5,6,7,8,9	P1*(1-P2)(1-P3)(1-P4)(1-P5)(1-P6)(1-P7)(1-P8)(1-P9)	(1+0)/2	(1/2)*P1*(1-P2)(1-P3)(1-P4)(1-P5)(1-P6)(1-P7) (1-P8)(1-P9)
. . . . . .			
1,2,3,4,5,6,7,8,9	P1*P2*P3*P4*P5*P6*P7*P8*P9	(6+6)/2	6*P1*P2*P3*P4*P5*P6*P7*P8*P9

Average DOS

Average DOS

- The greater value of average DOS, the smaller the network survivability.

Problem Description

Problem Description

- Role
  - Defender
  - Attacker

- The network survivability is measured by **average DOS**.

Defender

- Objective

  The defender tried to minimize the damage of the network (Average DOS).

- Budget Constraint (reallocating & new allocated budget)
  - deploying the defense budget in nodes
  - repairing the compromised node

Attacker

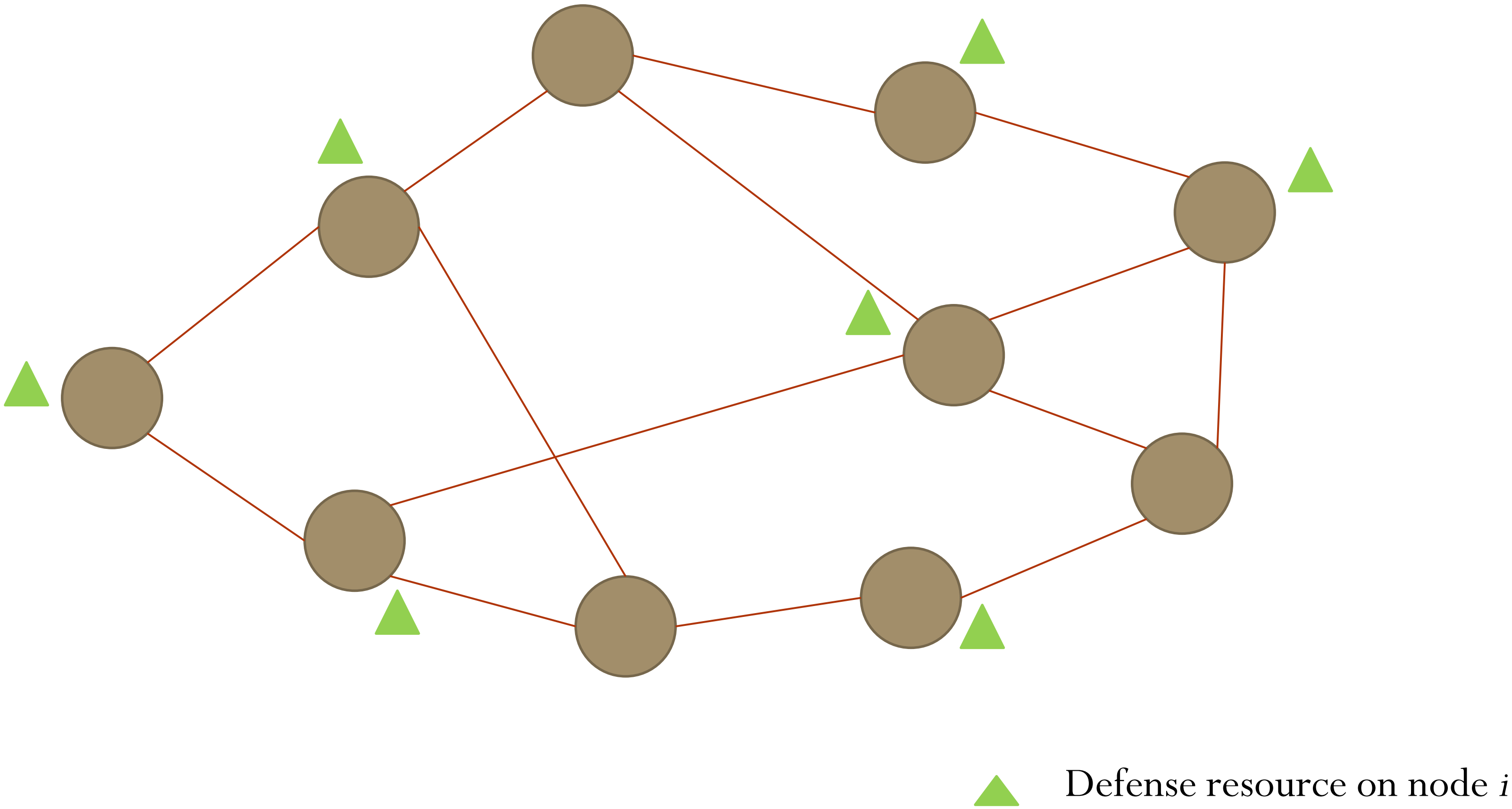
- Objective

  The attacker tried to maximize the damage of the network (Average DOS)

- Budget Constraint
  - deploying the attack budget in nodes

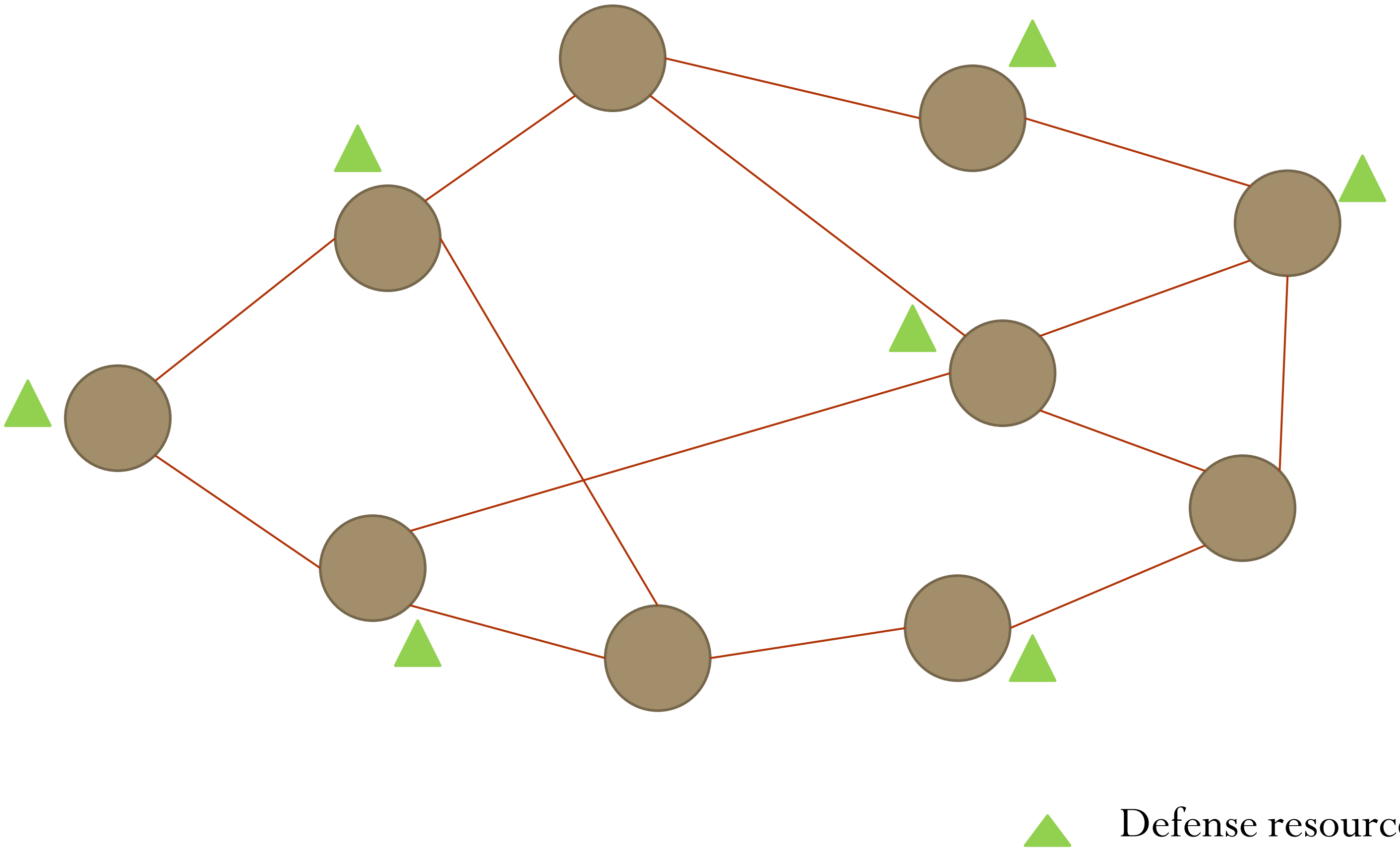
Scenario In Each Round

Scenario (Defender)



Scenario (Defender)

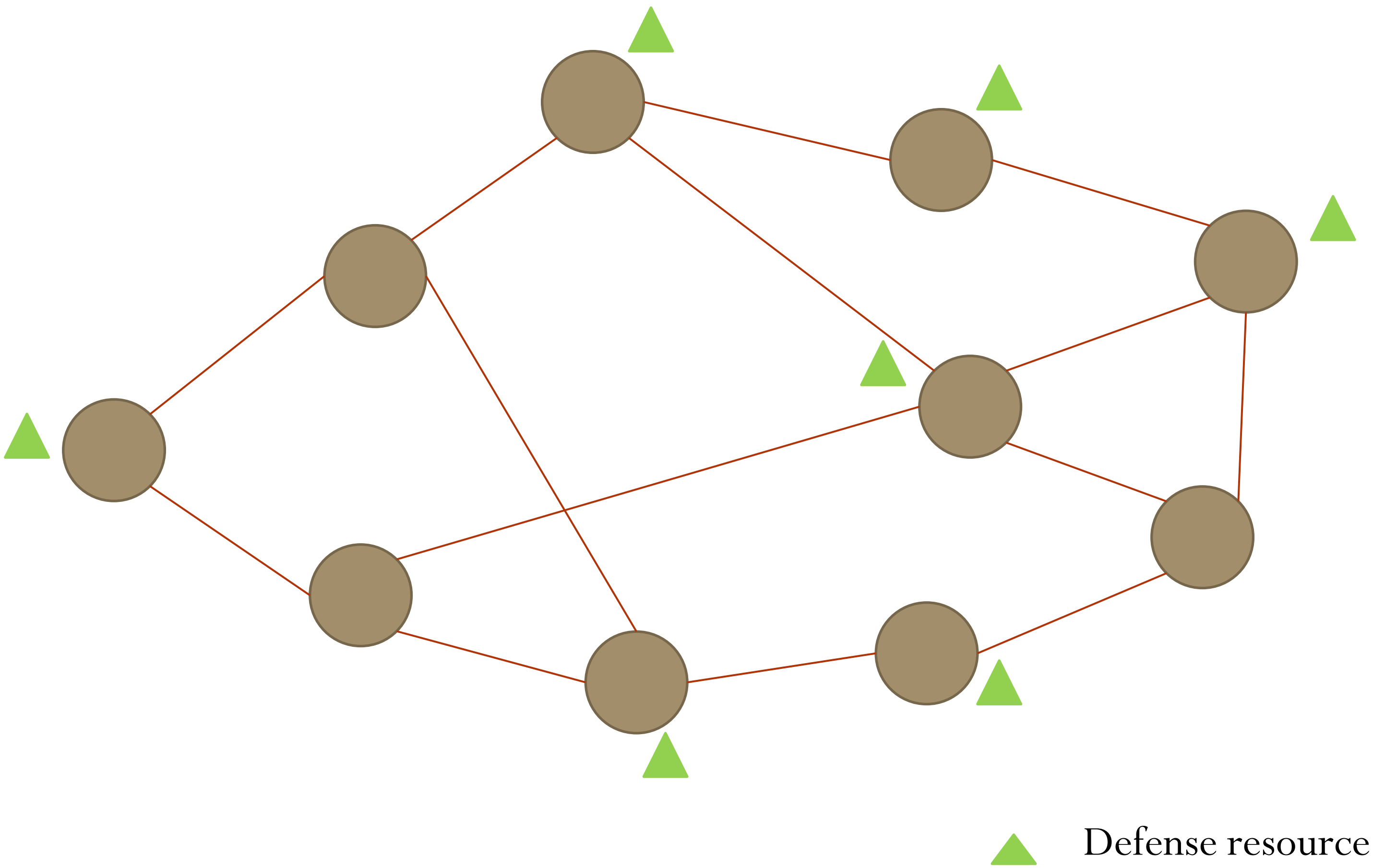
withdraw the resources



Defense resource on node i

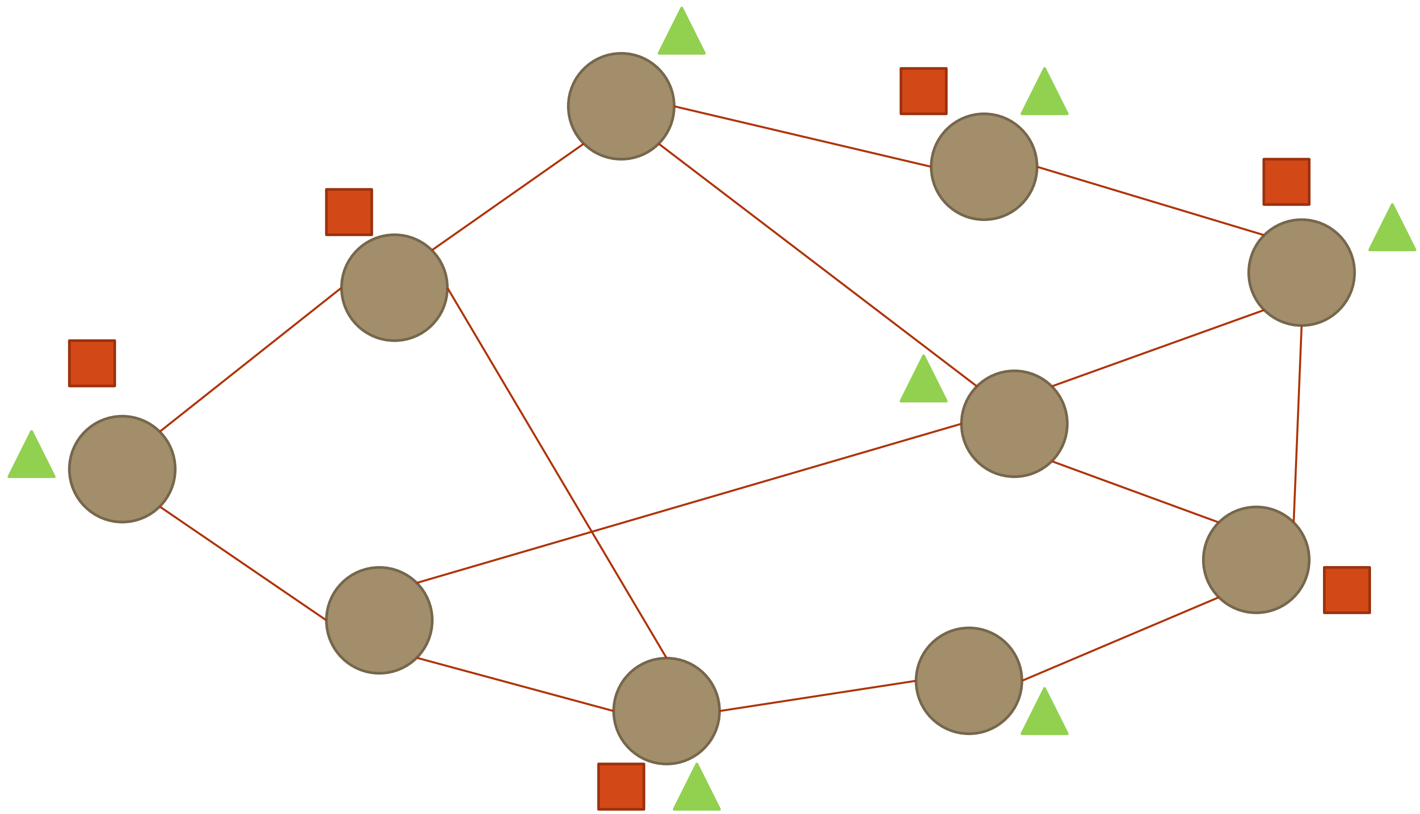
Scenario (Defender)

reallocating & new allocated budget



Defense resource on node *i*

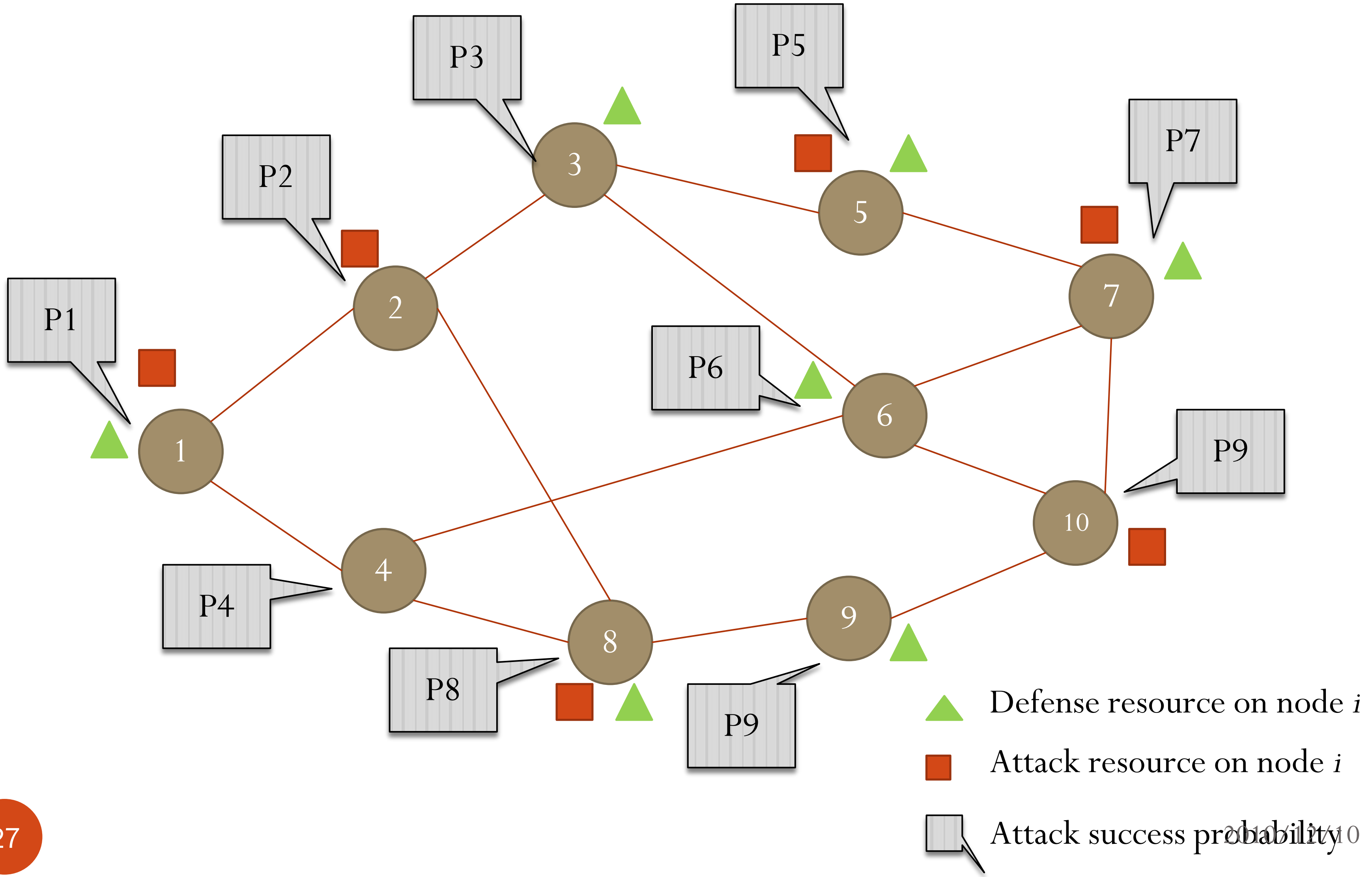
Scenario (Attacker)



Defense resource on node i

Attack resource on node i

Scenario


P1
P2
P3
P5
P7
P6
P9
P4
P8
P9
1
2
3
4
5
6
7
8
9
10
Defense resource on node *i*
Attack resource on node *i*
Attack success probability

Problem Formulation

Problem Assumption

- 1. The problem involves attacker and defender.
- 2. Both attacker and defender have **complete information about the network topology**.
- 3. Both attacker and defender are limited by budget.
- 4. Only node attack is considered. (Link attack is not considered)
- 5. Only malicious attack is considered. (We do not consider random error)
- 6. The attacker can accumulate experience.

Problem Assumption

- 7. For the defender, the budget can be **reallocated** and the **discount factor** is considered.
- 8. For the defender, the compromised node can be repaired.
- 9. Only static network is considered. (We do not consider the growth of network overtime)
- 10. The network survivability is measured by average DOS.
- 11. Any two nodes of the network can form an OD pair.
- 12. We determined the probability of the attack success using by **contest success function**, considering the resource allocation of both parties.

Given

- 1.The network topology
- 2.Attacker's total budget
- 3.Defender's total budget

Objective

- To minimum the maximized damage of the network (i.e. the average DOS)

Subject To

- Budget constraint for attacker
- Budget constraint for defender

To Determine

- Attacker
  - How to allocate attack budget to each node in each round
- Defender
  - How to allocate defense budget to each node in each round
  - Whether to repair the compromised node in each round

Given Parameter

Given parameter	
Notation	Description
V	Index set of nodes
R	Index set of rounds in the attack and defense actions
$\hat{A}$	Total budget of attacker
$\hat{B}$	Total budget of defender
θ_i	Existing defense resource allocated on node i, where $i \in V$
e_i	Repair cost of defender when node i, is dysfunctional, where $i \in V$
d_{ri}	The discount rate of defender reallocate resources on node i, where $i \in V$ and $r \in R$
t_i	1 if node i is a dysfunctional node, 0 otherwise, where $i \in V$
$\bar{D}(\vec{a}_r, \vec{b}_r)$	The average DOS, which is considering under attacker's and defender's budget allocation are $\vec{a}_r$ and $\vec{b}_r$ in round r, where $r \in R$

Decision Variable

Decision variable	
Notation	Description
z_i	1 if node i is repaired by defender, 0 otherwise, where $i \in V$
$\vec{a}_r$	Attacker's budget allocation, which is a vector of defense resource $a_{r1,}$ a_{r2} to a_{ri} in round r, where $i \in V$ and $r \in R$
$\vec{b}_r$	Defender's budget allocation, which is a vector of attack cost $b_{r1,}$ b_{r2} to $b_{ri,}$ in round r, where $i \in V$ and $r \in R$.
a_{ri}	Attacker's budget allocation on node i in round r, where $i \in V$ and $r \in R$.
b_{ri}	Defender's budget allocation on node i in round r, where $i \in V$ and $r \in R$.
A_r	Attacker's total budget in round r, where $r \in R$
B_r	Defender's defense budget in round r, where $r \in R$

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Formulation

Objective function:

$$\min_{\vec{b}_r} \max_{\vec{a}_r} \bar{D}(\vec{a}_r, \vec{b}_r) \quad , \qquad \text{(IP 1)}$$

Subject to:

$$\sum_{i \in V} b_{ri} + \sum_{i \in V} e_{ri} z_{ri} \le B_r + \sum_{i \in V} \theta_i d_{ri} \qquad \forall\ r \in R \qquad \text{(IP 1.1)}$$

$$\sum_{i \in V} a_{ri} \le A_r \qquad \forall\ r \in R \qquad \text{(IP 1.2)}$$

$$z_{ri} - t_i \le 0 \qquad \forall\ r \in R,\ i \in V \qquad \text{(IP 1.3)}$$

$$\sum_{r \in R} B_r \le \hat{B} \qquad \text{(IP 1.4)}$$

$$\sum_{r \in R} A_r \le \hat{A} \qquad \text{(IP 1.5)}$$

Thank you for your listening！