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SiMPLE: Survivability in Multi-Path Link Embedding

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Check List

1. I have confirmed that there is no flow chart, sudo code or equations, except in the appendix. I will not show them unless the reader asks for details.
2. I have confirmed that any examples are properly labelled/indexed/colored and a complete walk-through is given with all parameters. Base on these parameters, I have to calculate all values used in examples.
3. I have confirmed that I am fully aware of the "problems/procedures/algorithms" and examples according to rule #2 are also given to illustrate them.

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Outline

- Introduction
- Survivable Virtual Network Embedding (SVNE)
- Survivability in Multi-Path Link Embedding (SiMPLE)
- Conclusions
- Results

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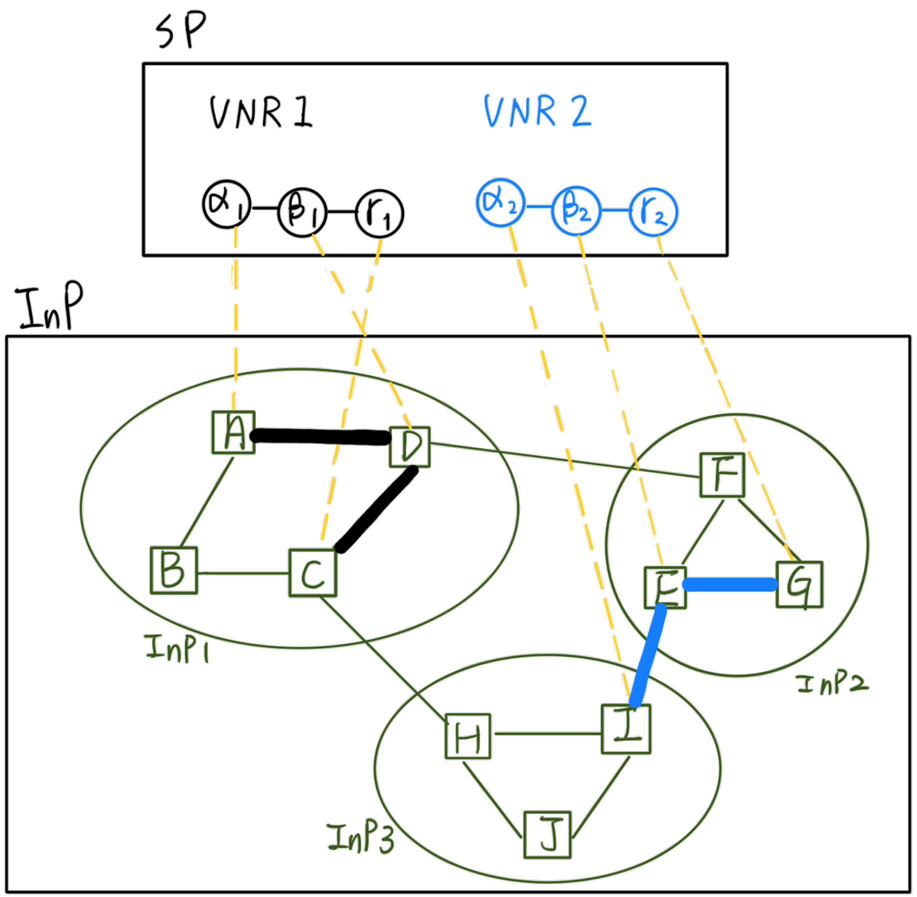
Introduction-VNE problem

- In the VNE problem, there will be two roles: InPs and SPs.
    1. InPs are responsible for managing and running underlying network infrastructures and resources.
    2. SPs can dynamically construct different VNs to fulfill different demands of end-users by renting underlying resources from the InPs.
- Embedding VNs, requested by different end-users, onto the shared substrate network(s) is known as VN embedding (VNE).



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Introduction-failure

- Most VNE algorithms are proposed on the assumption that there will be no more physical failures, and by optimizing the network model to improve resource utilization and increase revenue.
- However, in the process of VNE, that there will be equipment failure, malicious attacks, and other issues. It will lead to VN request service failure, reduced service performance, and other issues.

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Survivable Virtual Network Embedding(SVNE)

- Majority of the works on SVNE focus on **link failures**, as they occur more frequently than node failures.
- SVNE approaches, allocate redundant bandwidth for each (or selected) virtual link(s).

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Survivable Virtual Network Embedding(SVNE)

- Survivability of VNs is usually achieved through allocation of redundant (i.e., backup) resources, which introduces additional challenges to the VNE problem.
  1. The failure characteristics and repair time are unpredictable. Reserving the full demand of a virtual link as backup is expensive, since backup resources remain idle when there are no failures.
  2. Primary and backup resources need to be disjoint in the SN.

➢ A key challenge in the SVNE problem is to ensure VN survivability with minimal resource redundancy.

Survivability in Multi-Path Link Embedding (SiMPLE)

- By exploiting path diversity in the physical network, SiMPLE provides guaranteed VN survivability against **single link failure**.
- SiMPLE focuses on survivability against arbitrary **substrate link failures**.

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Goal

- SiMPLE is to find a trade-off between maximizing survivability and minimizing redundant resources and path splitting.

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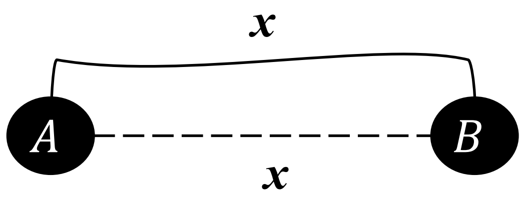
SiMPLE - Base case



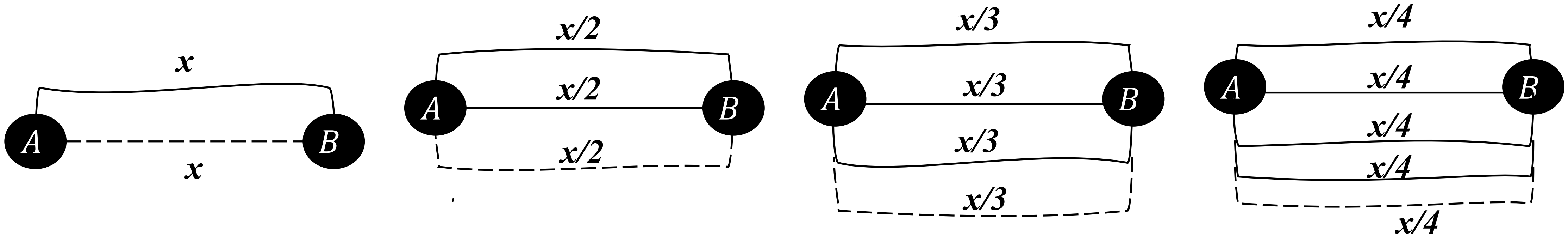
(a) two splits

Full Backup Scheme(FBS)

BW Requirement = $x + x$

Backup BW Saving = ***0%***

SiMPLE



(a) two splits | (b) three splits | (c) four splits | (d) five splits

Base case (FBS)
BW Requirement = $x + x$
Backup BW Saving = ***0%***

BW Requirement = $x + x/2$
Backup BW Saving = ***50%***

BW Requirement = $x + x/3$
Backup BW Saving = ***67%***

BW Requirement = $x + x/4$
Backup BW Saving = ***75%***

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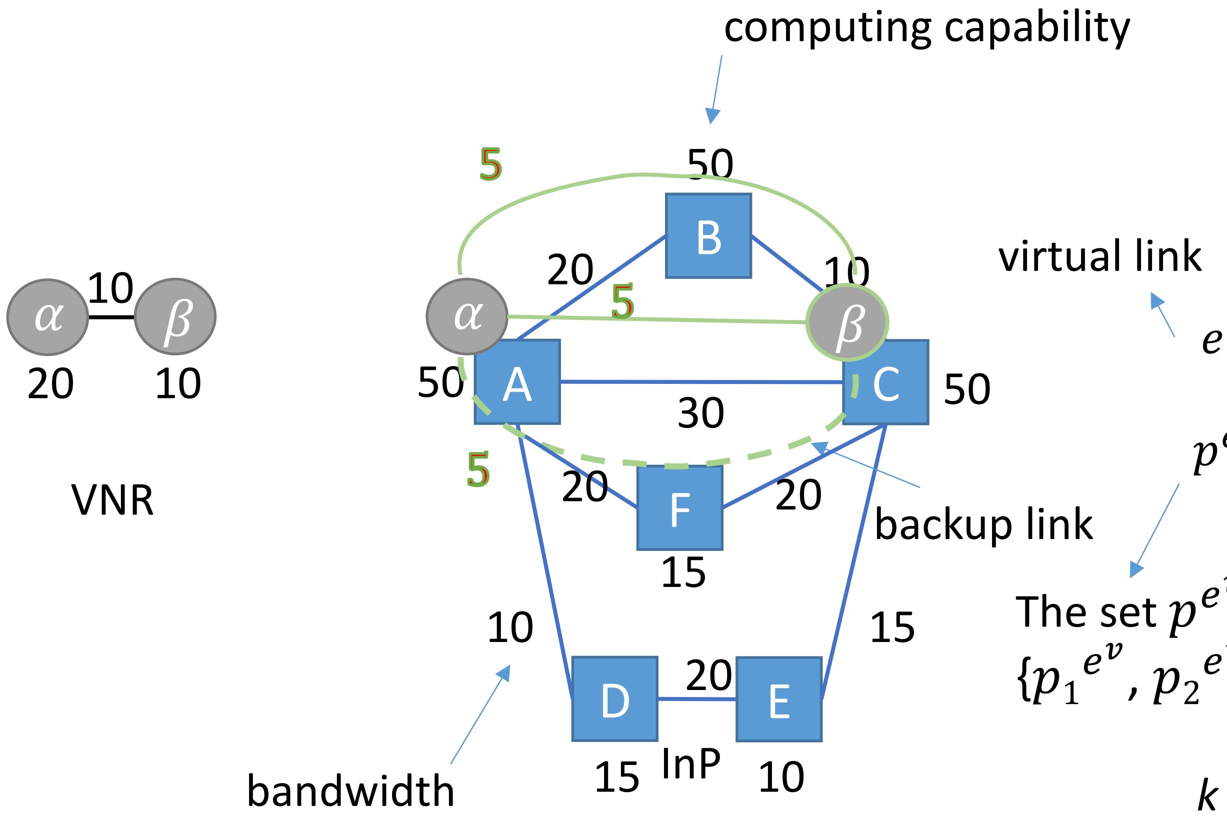
SiMPLE – ILP Model

- Optimize both the number of splits and the set of substrate paths for each VLink of a VN such that the overall embedding cost is minimized.
- The corresponding VLinks are mapped to optimal sets of paths.

SiMPLE – VN embedding cost



$e^v = \alpha\beta$

p^{e^v} = { AC , ABC , AFC}

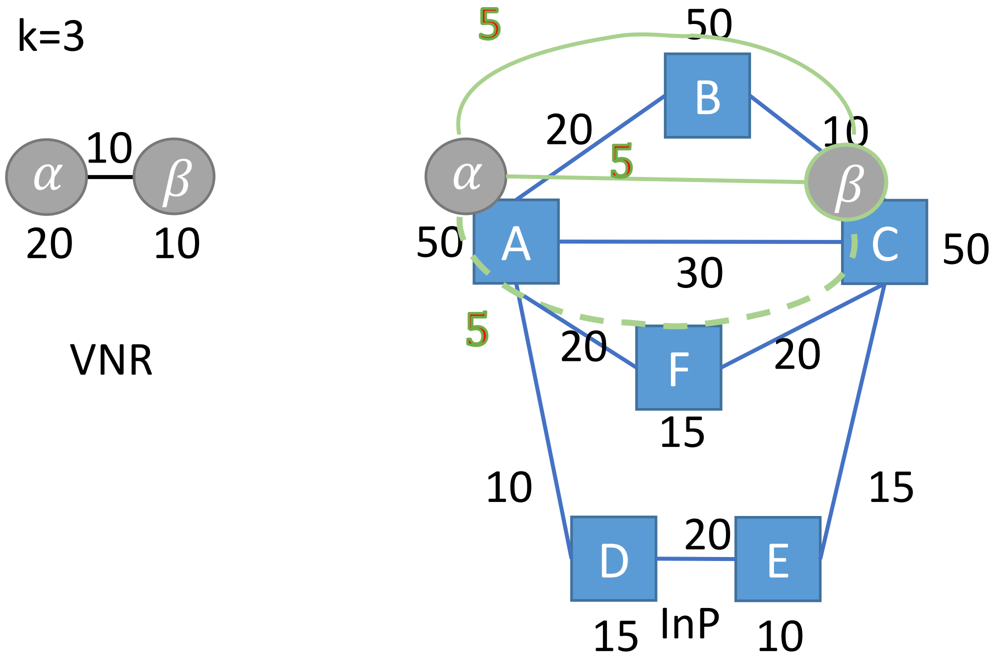
The set p^{e^v} represents a set of disjoint paths $\{p_1{}^{e^v}, p_2{}^{e^v}, p_3{}^{e^v}, \ldots, p_k{}^{e^v}\}$ in SN where e^v is embedded.

k = 3

k為p^{e^v}的path數量

SiMPLE – VN embedding cost

1. Split and Join Cost ($I(e^v, p^{e^v}, k)$) :
   This is because each data stream is split at the ingress switch, and subsequently joined at the egress switch.
   - $I(e^v, p^{e^v}, k)$ = D(ingress node , k) + D(egress node , k)
   - D(n^s, k) = d1(n^s, k) + d2(n^s, k) , d1→splitting cost , d2→joining cost



$e^v = \alpha\beta$

p^{e^v} = { AC , ABC , AFC }

per split/join =1

以A點為例：
D(A,3) = d1(A,3) + d2(A,3) = 1*3+ 0*3
同理，C點： D(A,3) = 3
$I(\alpha\beta, p^{\alpha\beta}, 3) = 3+3$

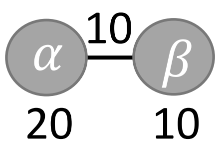
SiMPLE – VN embedding cost

這個意義是，相對於飽和的SNode，
給予負載較少的SNode更高的特權。

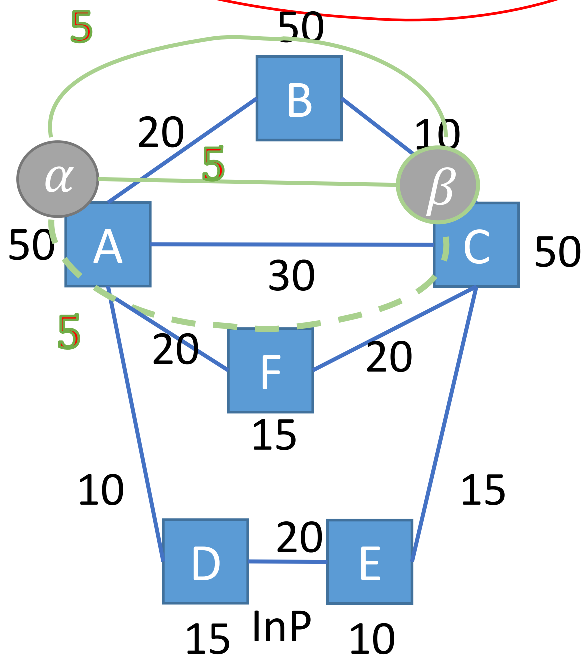
2. Switching Cost (S(e^v, $p_i^{e^v}$)):
   This cost is associated with each mapped path of e^v due to forwarding the fragmented data stream between the source and destination SNodes.

- $S(e^v, p_i^{e^v}) = \sum(\frac{\text{初始node的capacity}}{\text{當下該node的capacity}} * \text{switching cost})$

k=3



VNR



$e^v = \alpha\beta$

p^{e^v} = { AC , ABC , AFC }

k = 3 , node switching cost = 2

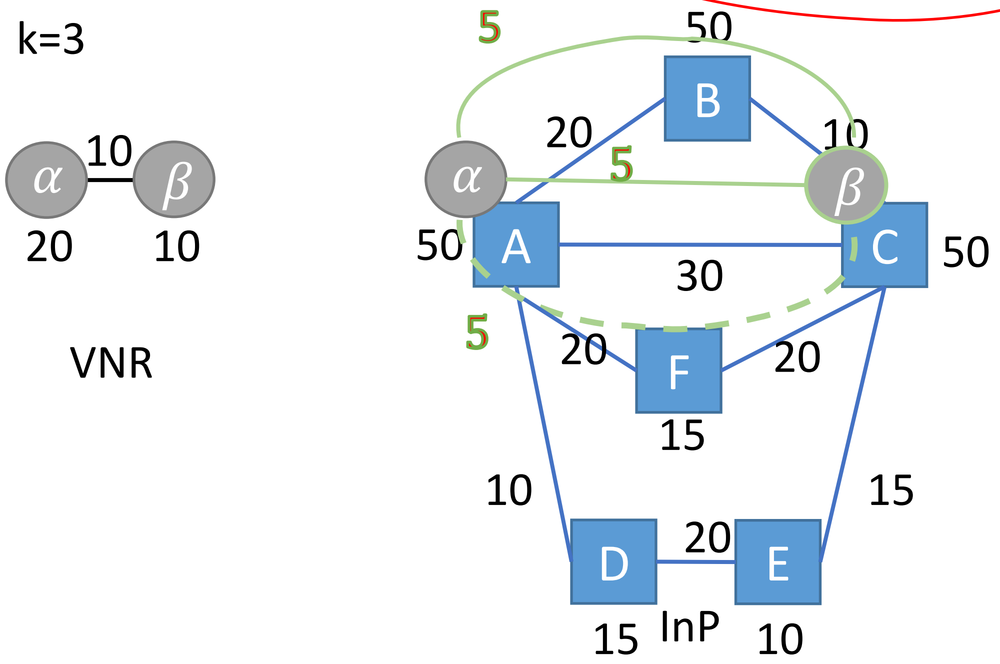
switching node有B、F兩點
以ABC為例：
S($\alpha\beta$,ABC) = 50/50*2 = 2
同理，AFC的switching cost：
S($\alpha\beta$,AFC) = 15/15*2 = 2

SiMPLE – VN embedding cost

這個意義是，相對於飽和的SLink，
給予負載較少的SLink更高的特權。

3. SLink Cost ($L(e^v, p_i^{e^v}, k)$):
This cost represents the sum of allocated substrate bandwidth cost along the SLinks on $p_i^{e^v}$.

- $L(e^v, p_i^{e^v}, k) = \sum\left(\frac{初始link的bandwidth}{當下該link的bandwidth} * \frac{VNR所需的bandwidth}{k-1}\right)$



$e^v = \alpha\beta$

p^{e^v} = { AC , ABC , AFC }

$k = 3$

$L(\alpha\beta, AC, 3) = \frac{30}{30} * \frac{10}{3-1} = 5$

$L(\alpha\beta, ABC, 3) = \frac{20}{20} * \frac{10}{3-1} + \frac{10}{10} * \frac{10}{3-1} = 10$

$L(\alpha\beta, AFC, 3) = 10$

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SiMPLE objective function

- The goal is to minimize the cost.

$$\mathbf{min}(\sum_{e^v} [\ \mathbf{I}{*}\mathbf{w} + \sum_{p_i} (\ \mathbf{S}{*}\mathbf{w} + \mathbf{L}\ )\ ]\ )\ , \mathbf{w}<\mathbf{1}$$

- In this equation, I and S have units in MIPS (for split, join, switching costs involving CPU resources), whereas L has Mbps unit.
- To unify these different units, we multiply the split, join, and switching costs with a weight, w.

SiMPLE

- The splitting of each VLink into multiple substrate paths improves the possibility of VN request acceptance; even if the full requested bandwidth is not available in any of the SLinks, a VLink can be embedded by splitting the required bandwidth over multiple paths.
- In other words, it utilizes the links more efficiently than FBS, and increases the number of accepted VNs.
- However, increasing the number of splits introduces additional overhead, which must be considered.

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Conclusions

- SiMPLE provides provable survivability guarantee in presence of a single link failure without allocating full bandwidth of the virtual link's demand as backup.

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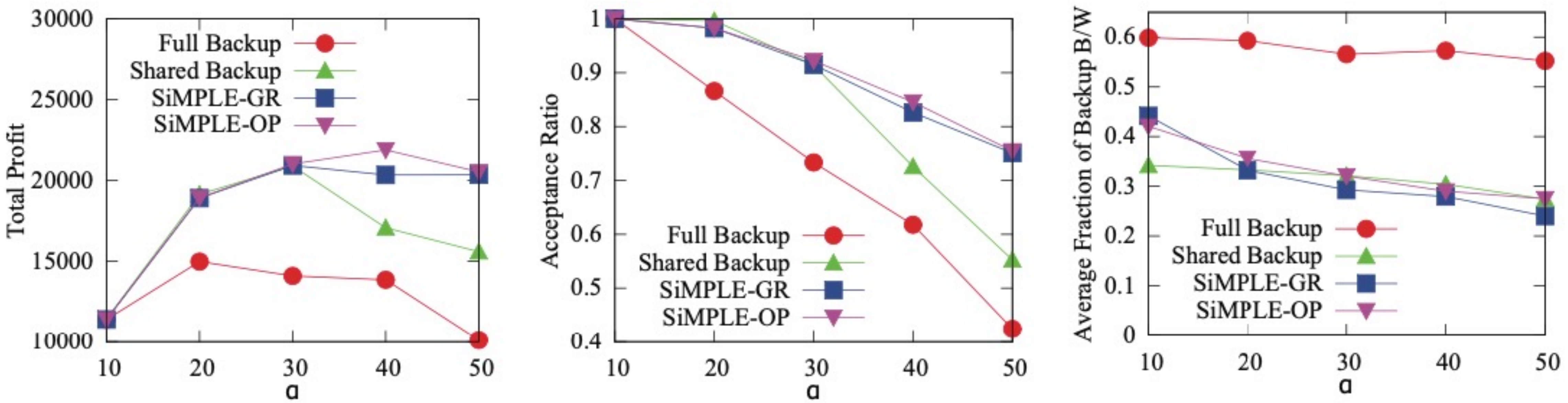
Results



(a) Profit, Ψ vs. α (b) Acceptance Ratio vs. α (c) Backup B/W, $\hat{\mathbb{B}}$ vs. α