BIT

Enabling Fast Forwarding in Hybrid Software-Defined Networks

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Outline

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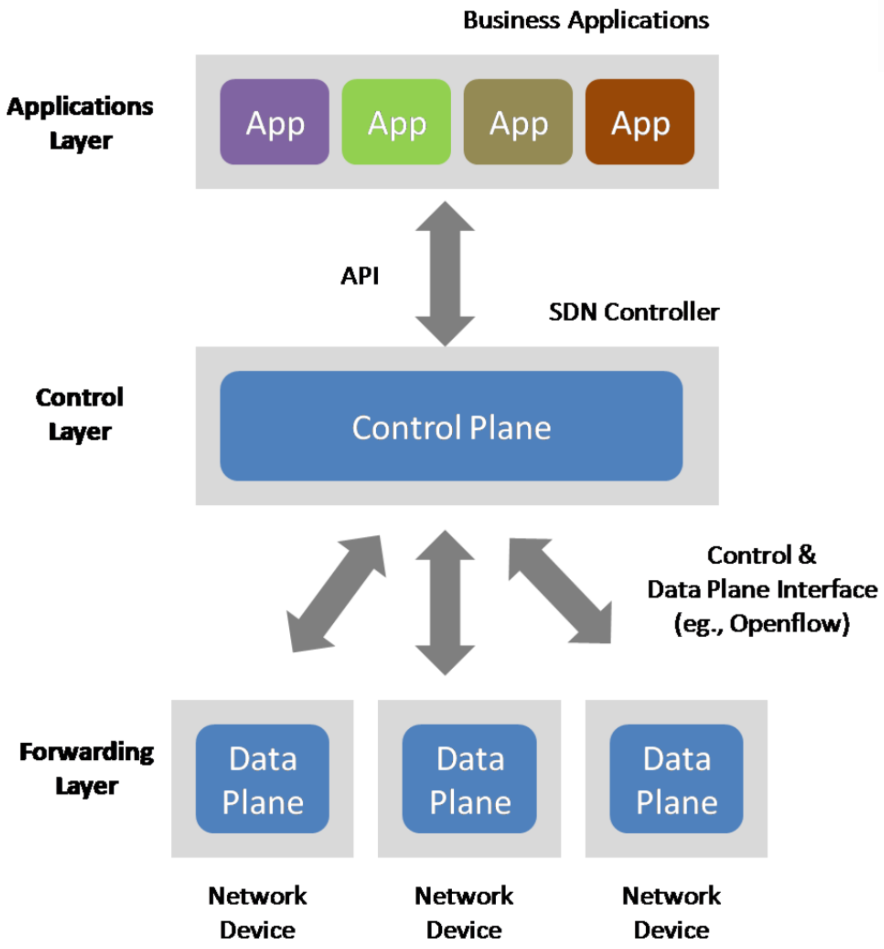
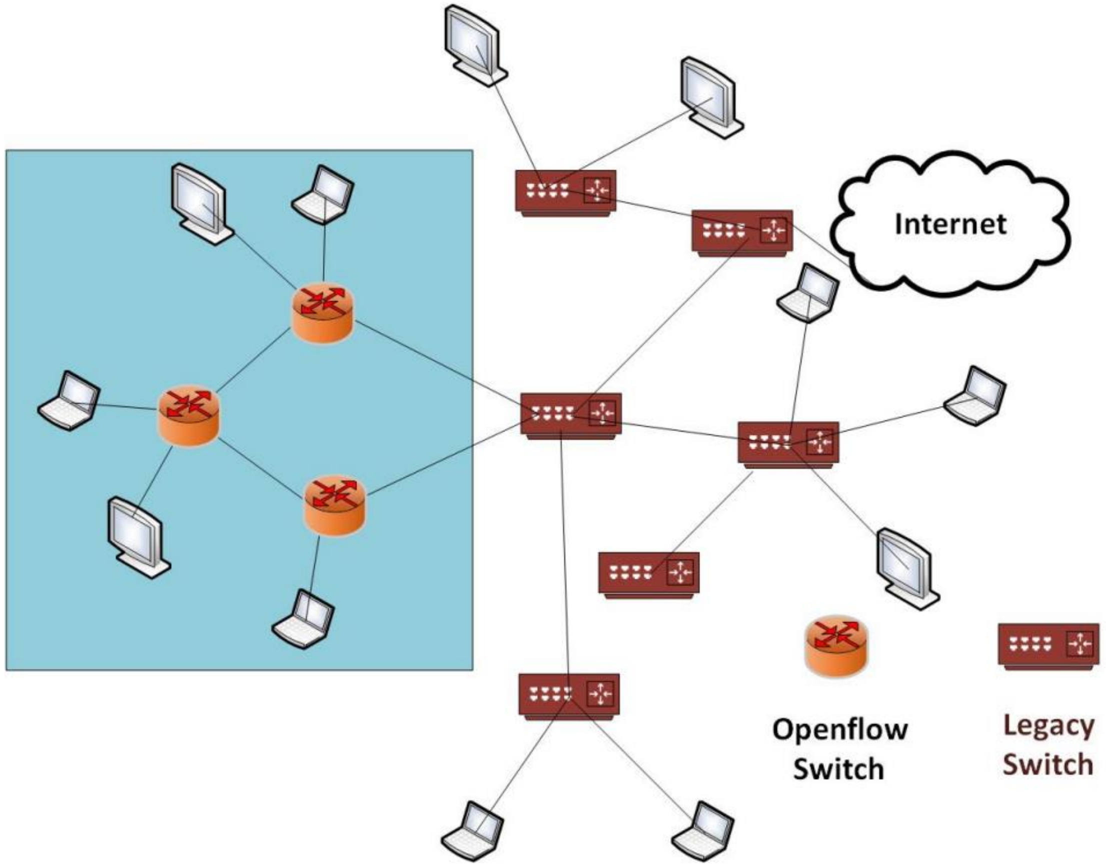
1 Introduction

SDN and Hybrid SDN

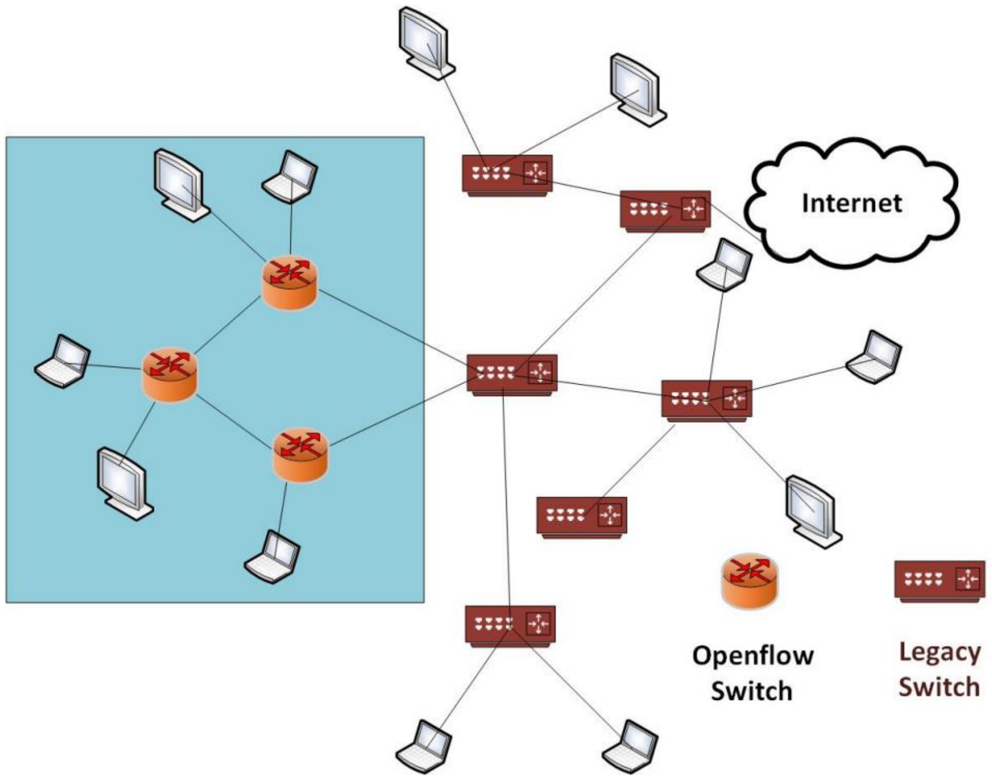


Software-Defined Networking (SDN)



Hybrid SDN

SDN and Hybrid SDN



Hybrid-SDN

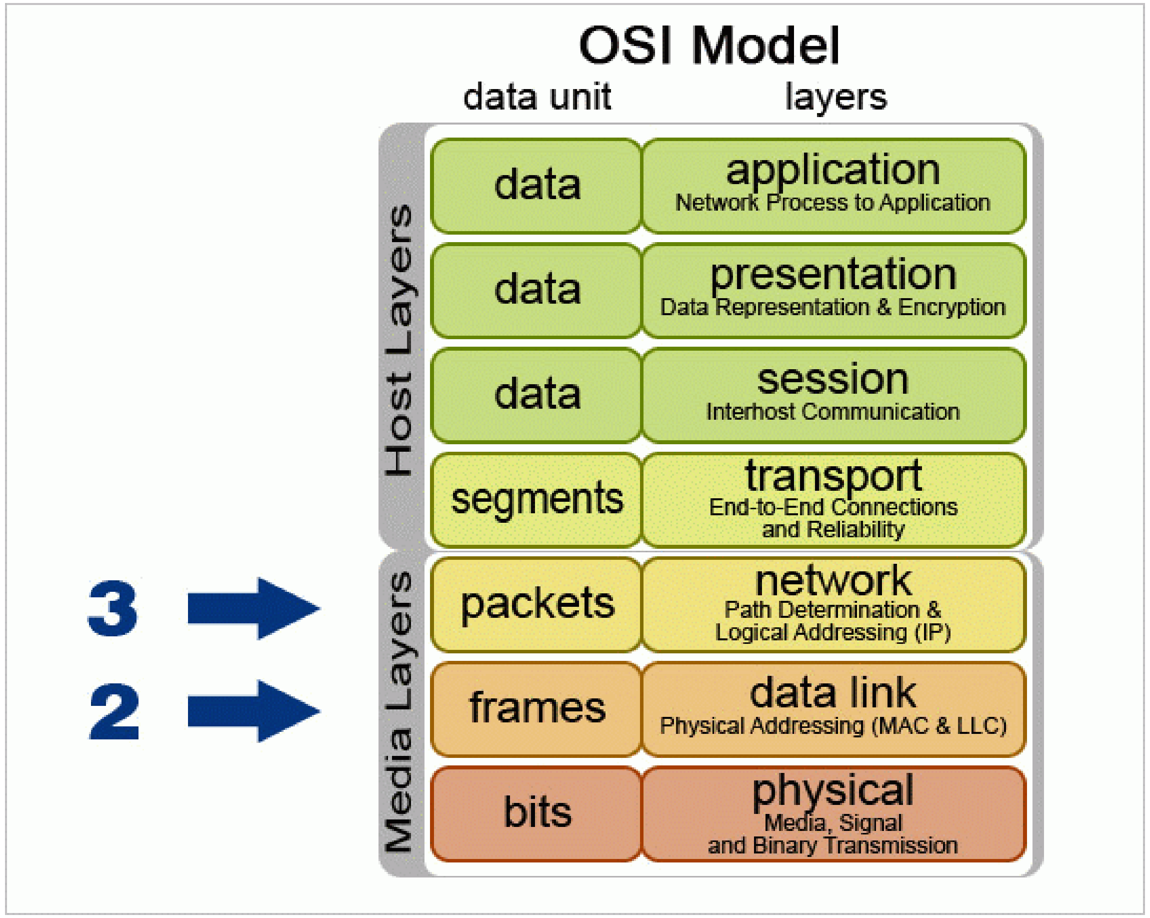
Key issue:

maximize network programmability for SDN by upgrading a given number of legacy devices to SDN devices.

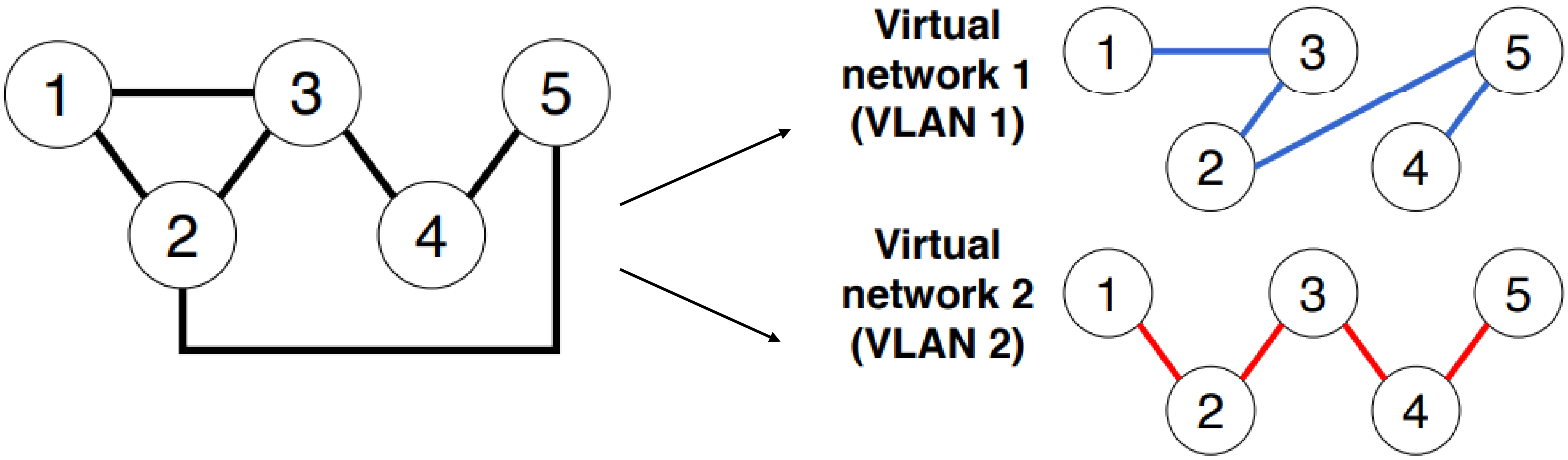
Layer-2 network

Layer-2 network:

- MAC address
- VLAN and STP
- Campus and enterprise network



Opportunity

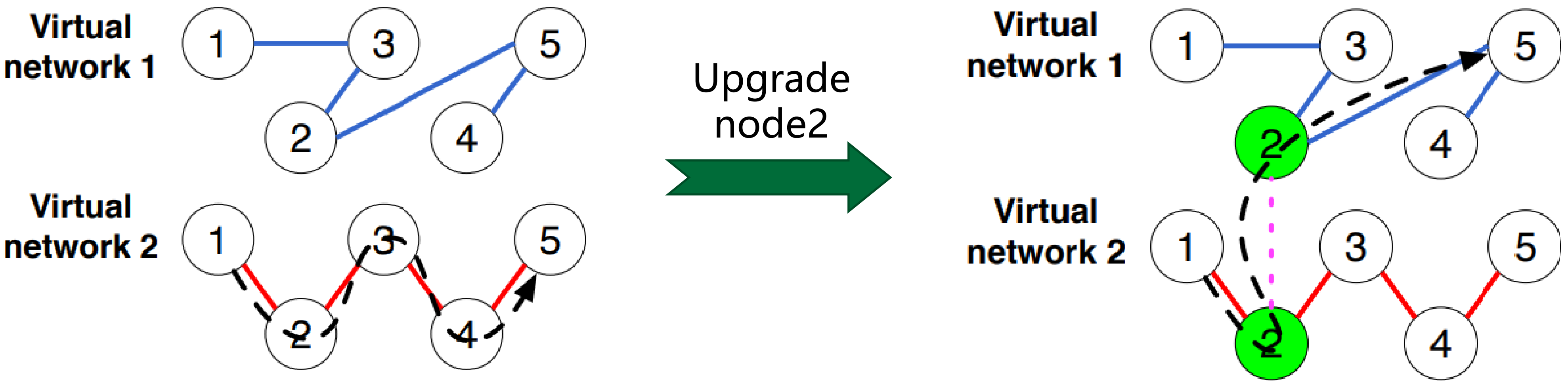


Network topology

Two virtual networks

Opportunity

Flow f: 1->5 in virtual network 2



Path: 1->2->3->4->5 in virtual network 2
Path length: 4

Path: 1->2->5, 1->2 in virtual network 2, 2->5 in virtual network 1
Path length: 2

Upgrade benefit: reducing the forwarding path’s length

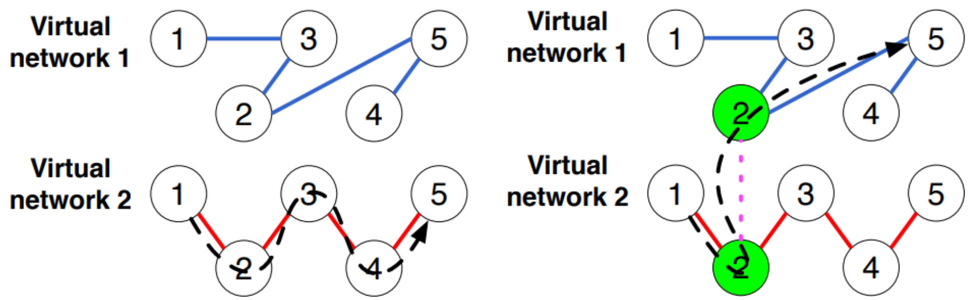
2 Problem analysis and solution

Problem analysis-Formulation

L: the number of virtual networks, each of which is a spanning tree
N: the number of nodes at each virtual network
M: the number of nodes to be upgraded
dis(i,j): the shortest path's length between node i and node j among different virtual networks

Upgrade = add edge across the same node at different virtual networks

$$Upgrade\ benefit = \sum_{i=1}^{N}\sum_{j=1}^{N}(dis_{old}(i,j)) - \sum_{i=1}^{N}\sum_{j=1}^{N}(dis_{new}\ (i,j))$$



L=2,N=5

Add an edge(2,2)

Challenges

Challenge1:

The sequence of node upgrade matters.

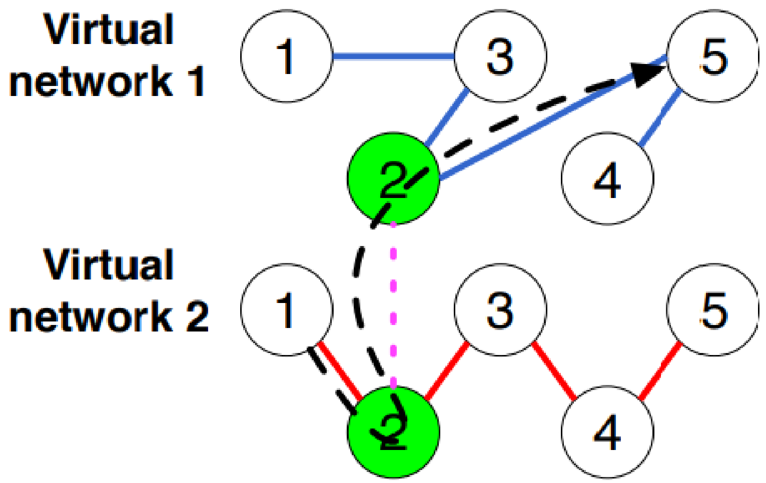
(Greedy selection may not be the optimal solution)

Challenge2:

The solution space is huge.

(**N** could be thousands, and **L** could be dozens)

Reducing the path length



Some paths could not get any benefit from upgrading node 2. For example, flow g from node 4 to node 5:

$$\min_{u=1..L}\{\boxed{dis^{u}_{old}\,(4{,}5)}\} \geq \min_{u=1..L}\{dis^{u}_{old}\,(4{,}2)\} + \min_{u=1..L}\{dis^{u}_{old}\,(2{,}5)\}$$

Only the path that traverses node 2 can get benefit from upgrading node2. For example, flow f from node 2 to node 5

$$\boxed{dis_{new}(1{,}5)} = \min_{u=1..L}\{dis^{u}_{old}\,(1{,}2)\} + \min_{u=1..L}\{dis^{u}_{old}\,(2{,}5)\}$$

$dis^{u}_{old}\,(4{,}5)$: distance between node 4 and node 5 in virtual network 5

$dis_{new}(1{,}5)$: distance between node 4 and node 5 in real network

Shortcutter

Upgrade the first node k

$$dis_{new}(i,j) = \min\{\min_{u=1..L}\{dis_{old}^{u}(i,k)\} + \min_{u=1..L}\{dis_{old}^{u}(k,j)\}, \min_{u=1..L}\{dis_{old}^{u}(i,j)\}\}$$

Upgrade another node p

$$dis_{new}(i,j) = \min\{dis_{old}(i,k) + dis_{old}(k,j), dis_{old}(i,j)\}$$

$$Upgrade\ benefit = \sum_{i=1}^{N}\sum_{j=1}^{N}(dis_{old}(i,j)) - \sum_{i=1}^{N}\sum_{j=1}^{N}(dis_{new}(i,j))$$

Shortcutter

(1)Start
(2)Calculate the upgrade benefit of nodes from S1
(3)Select the node with the maximum upgrade benefit from S1
(4)Upgrade node j, which is selected at step 3
(5)Delete node j in S1 and add node j into S2
(6)$dis_{old} = dis_{new}$
(7)If |S2| < M, go to step 1
(8)End

Floyd or Dijkstra is too slow since it calculates too many meaningless repeated paths.
Shortcutter's complexity: $O(n^2)$

S1 records nodes that have not been upgraded
S2 records all upgraded nodes

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3 Preliminary result

Comparison algorithms

Degree-centric: it sequentially upgrades nodes following the decreasing order of these nodes’ degrees

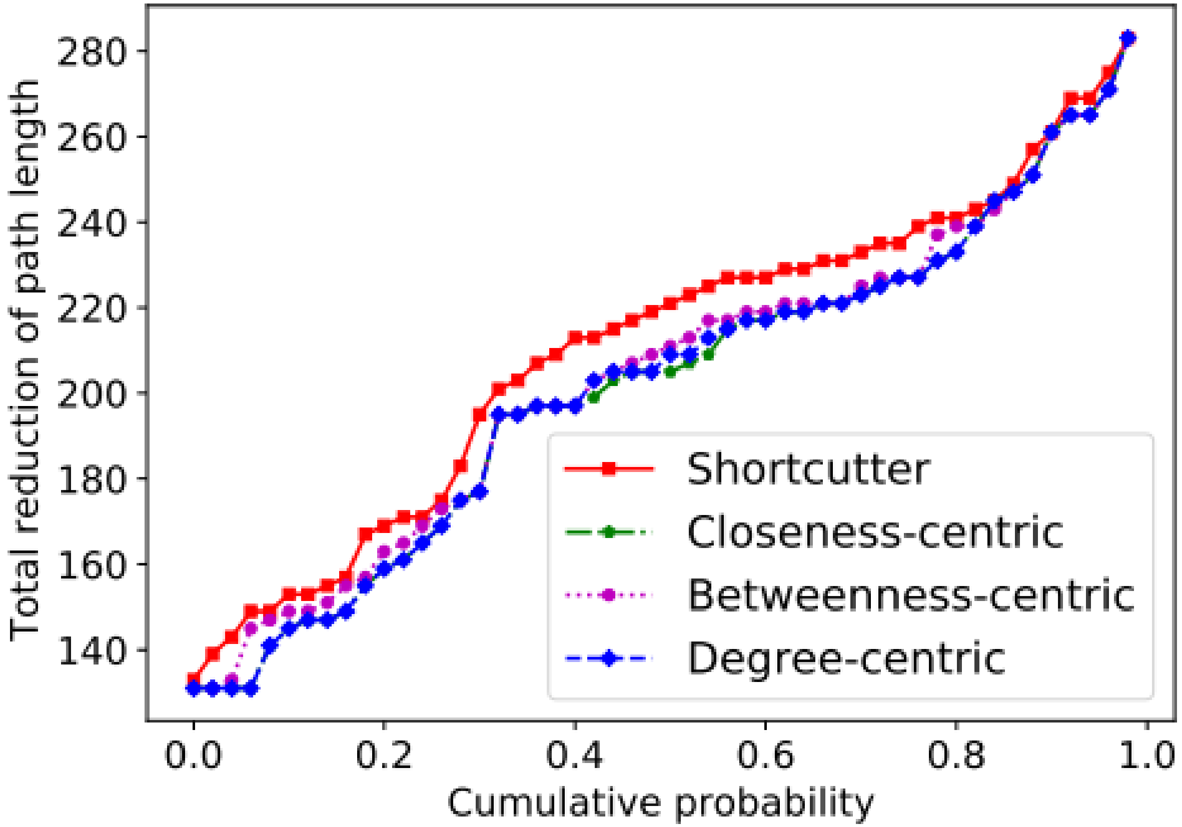
Betweenness-centric: it sequentially upgrades nodes following the decreasing order of these nodes’ betweenness centrality.

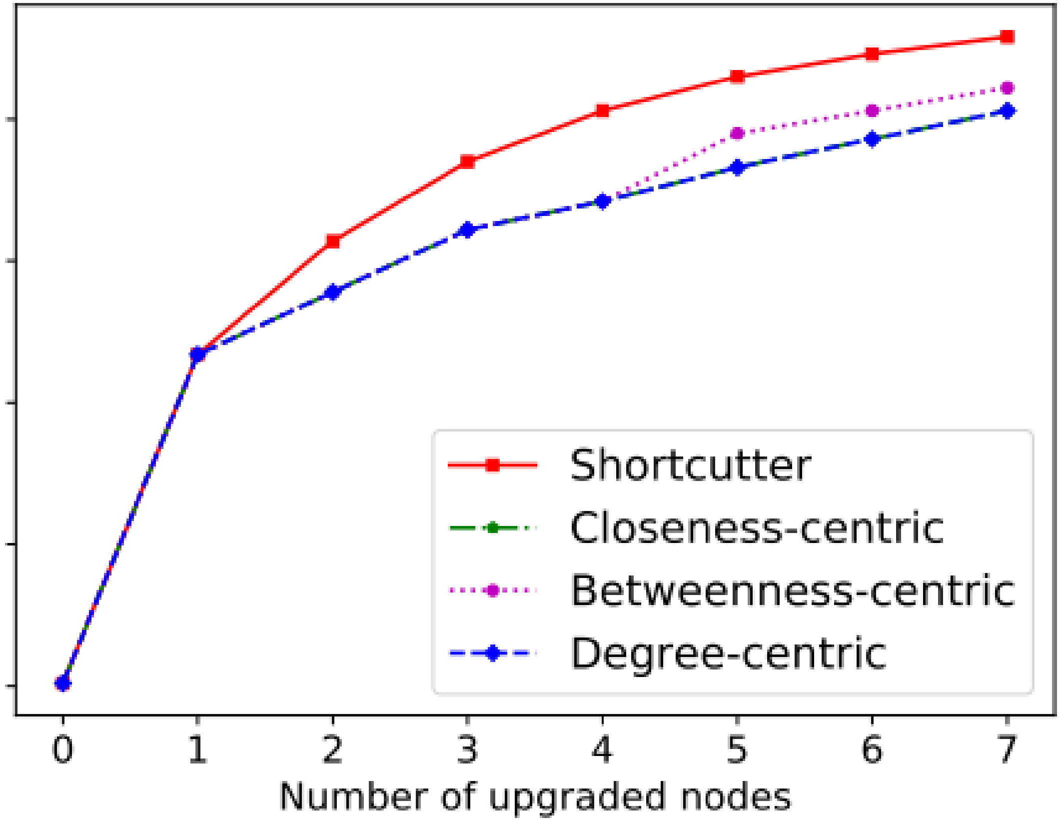
Closeness-centric: it sequentially upgrades nodes following the decreasing order of these nodes 'closeness centrality.

Simulation setup

Settings	Value
Power law degree distribution-Number of nodes	30
Power law degree distribution-Number of edges connected to the new node	1
Power law degree distribution-Probability of adding a ring	0
Number of virtual networks	5

Result


Total reduction of path length
280
260
240
220
200
180
160
140
0.0
0.2
0.4
0.6
0.8
1.0
Cumulative probability
Shortcutter
Closeness-centric
Betweenness-centric
Degree-centric


0
1
2
3
4
5
6
7
Number of upgraded nodes
Shortcutter
Closeness-centric
Betweenness-centric
Degree-centric

Thanks for your attention

Q&A

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