Service Chain Placement in SDNs

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[1]Technion

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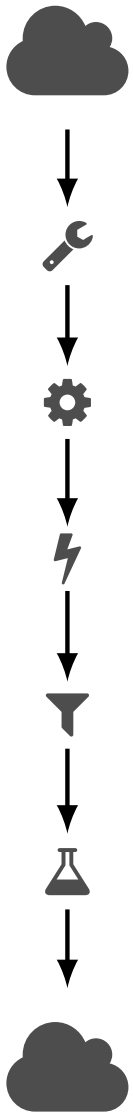
ALGOCLOUD 2017

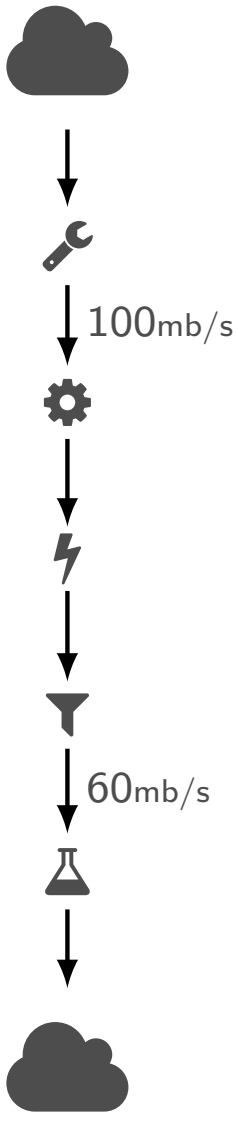
Service Chain (Customer's Perspective)

- An ordered set of Virtual Functions



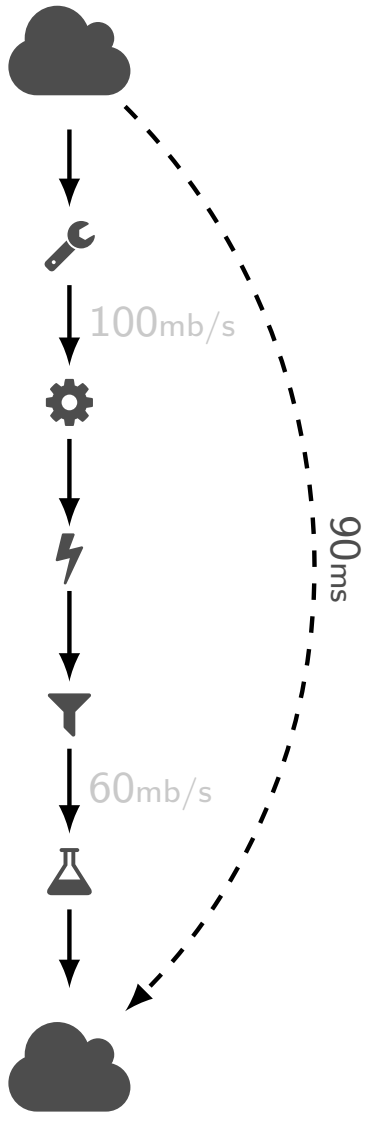
Service Chain (Customer's Perspective)

- An ordered set of Virtual Functions
- Bandwidth requirement



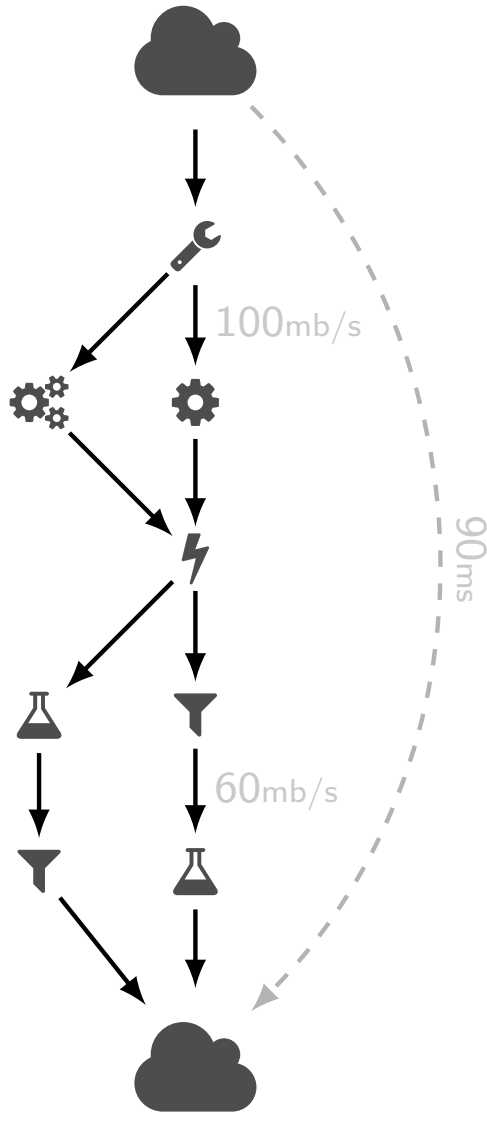
Service Chain (Customer's Perspective)

- An ordered set of Virtual Functions
- Bandwidth requirement
- Latency constraint



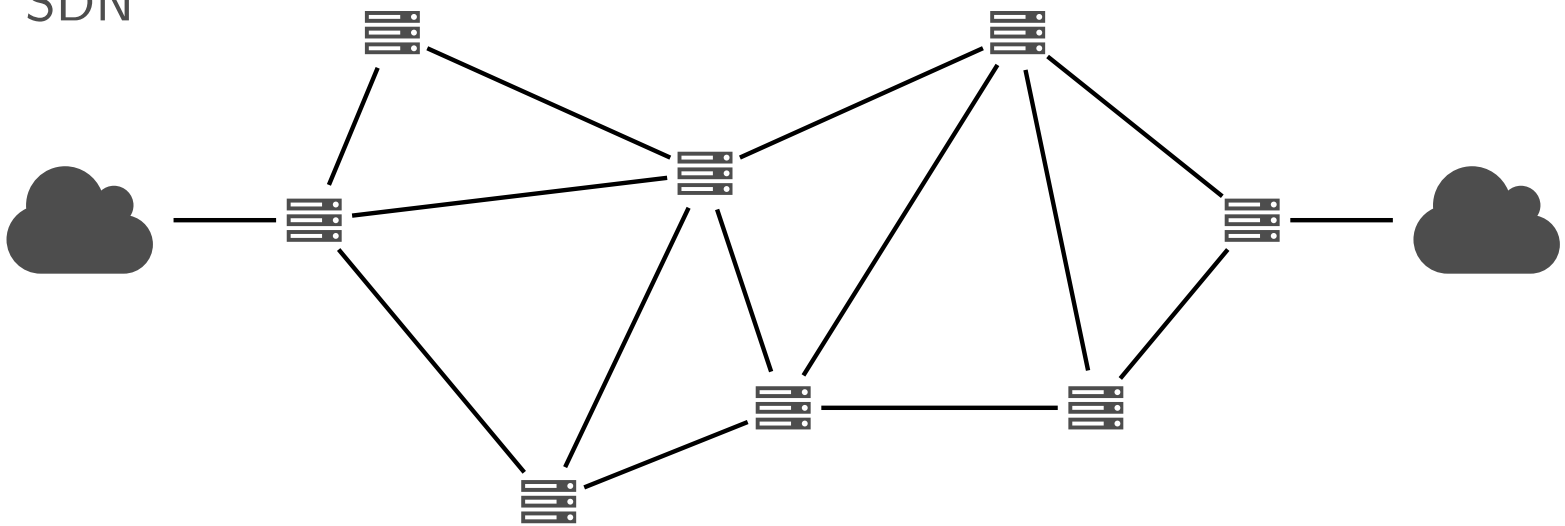
Service Chain (Customer's Perspective)

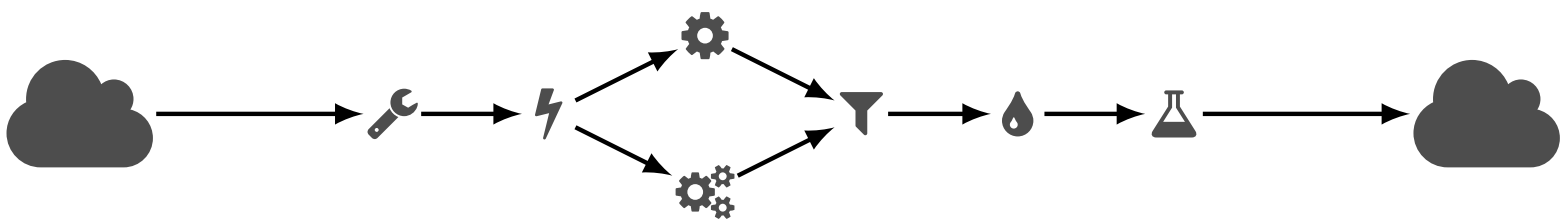
- An ordered set of Virtual Functions
- Bandwidth requirement
- Latency constraint
- Several alternatives



Problem (ISP's Perspective)

SDN





Service Chain

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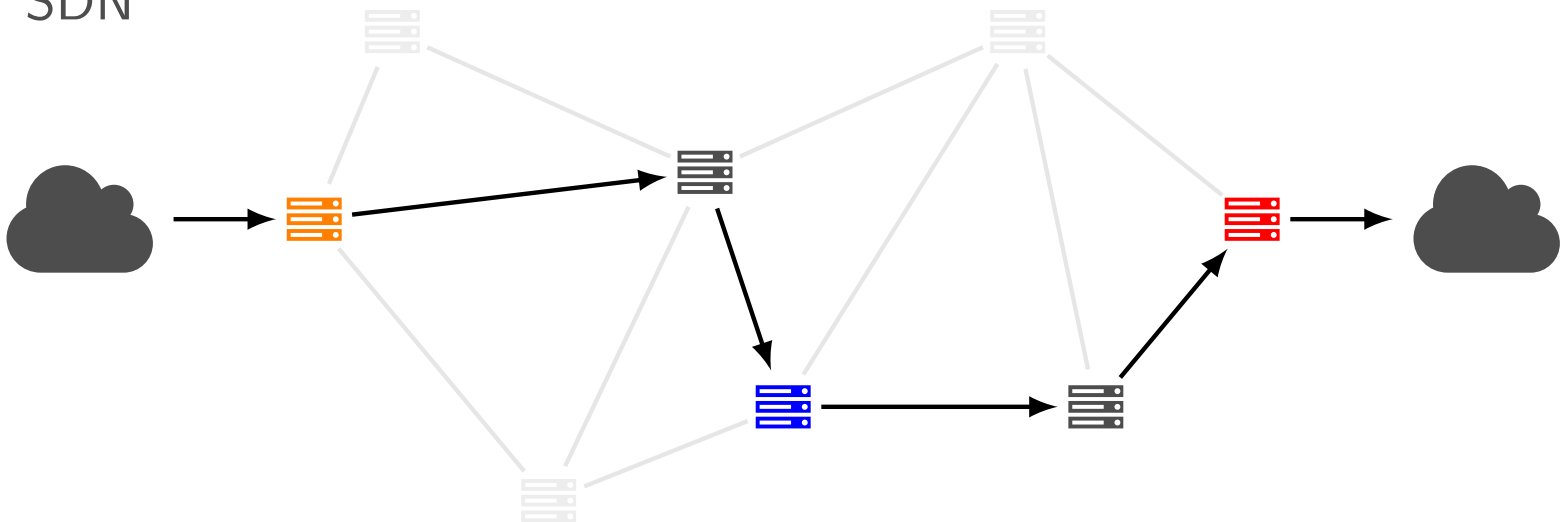
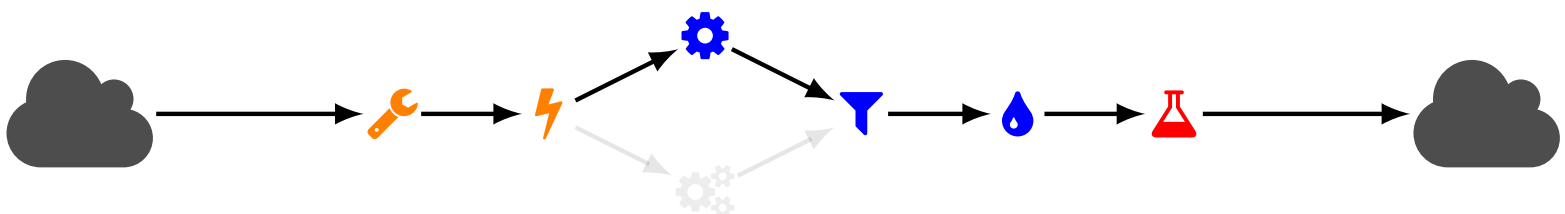


Service Chain



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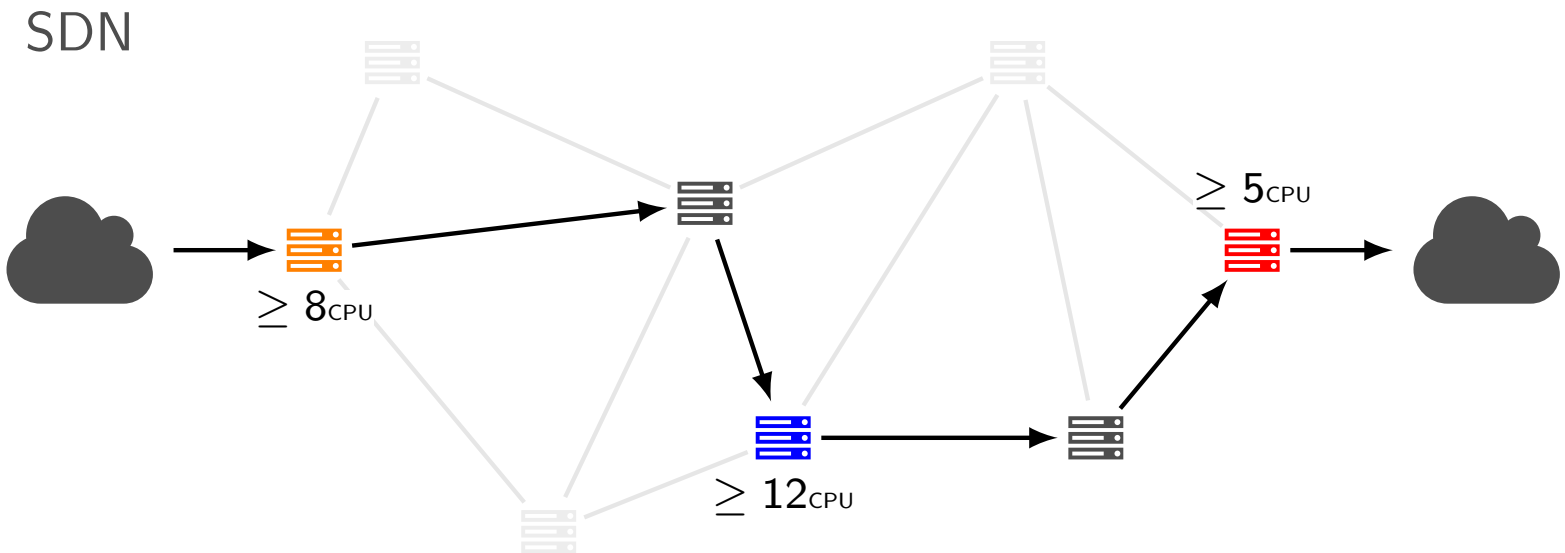

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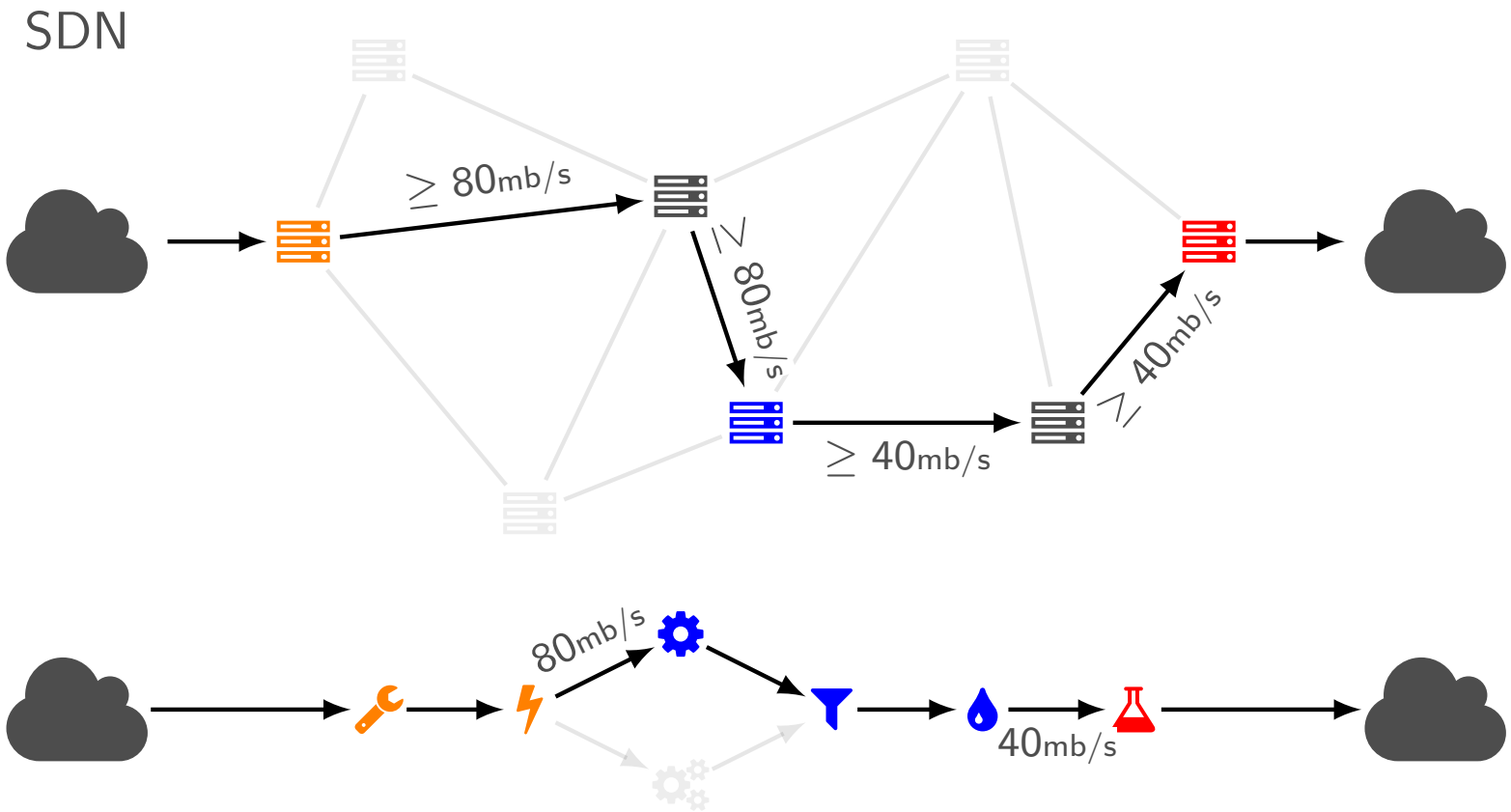

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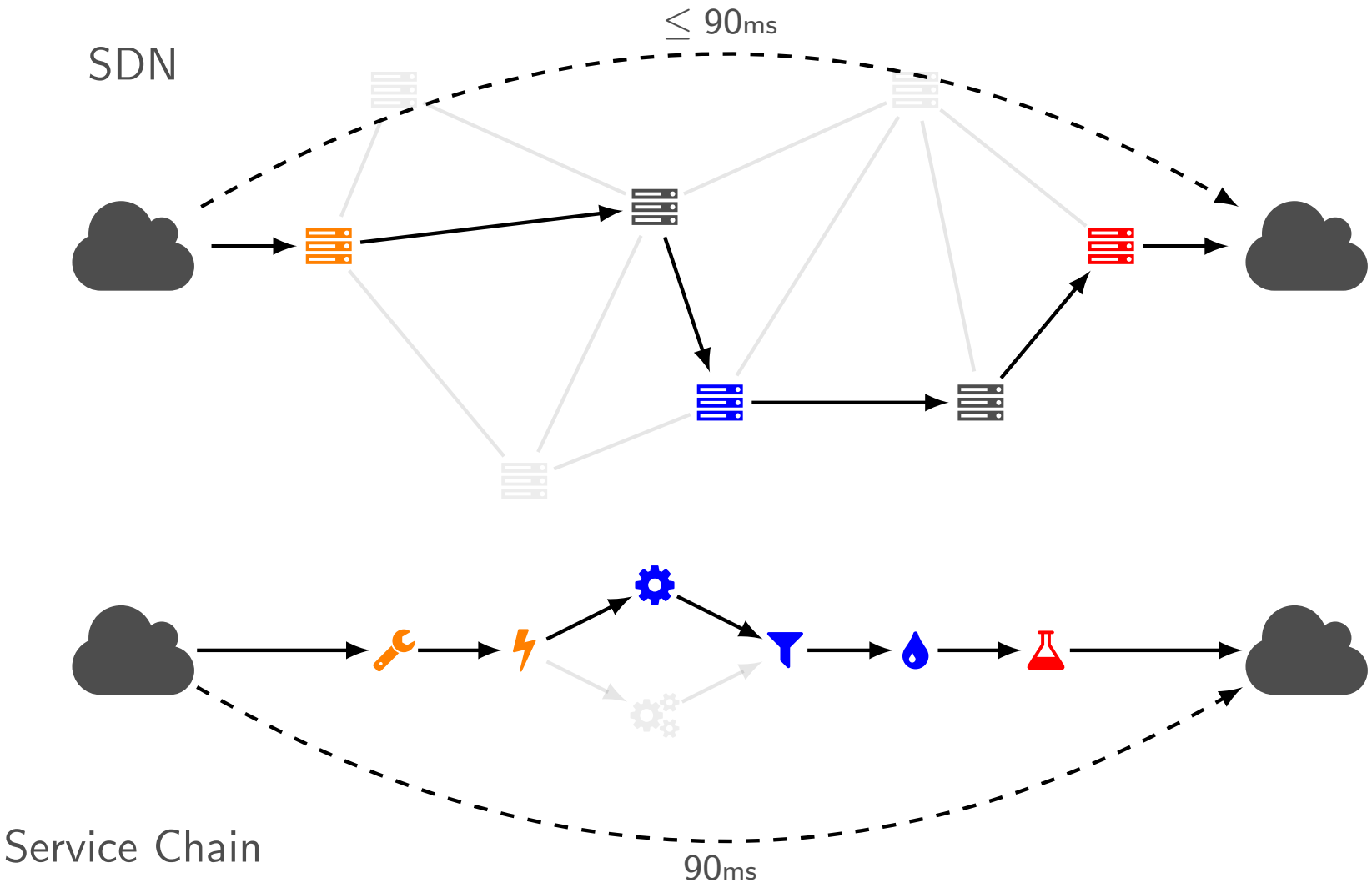

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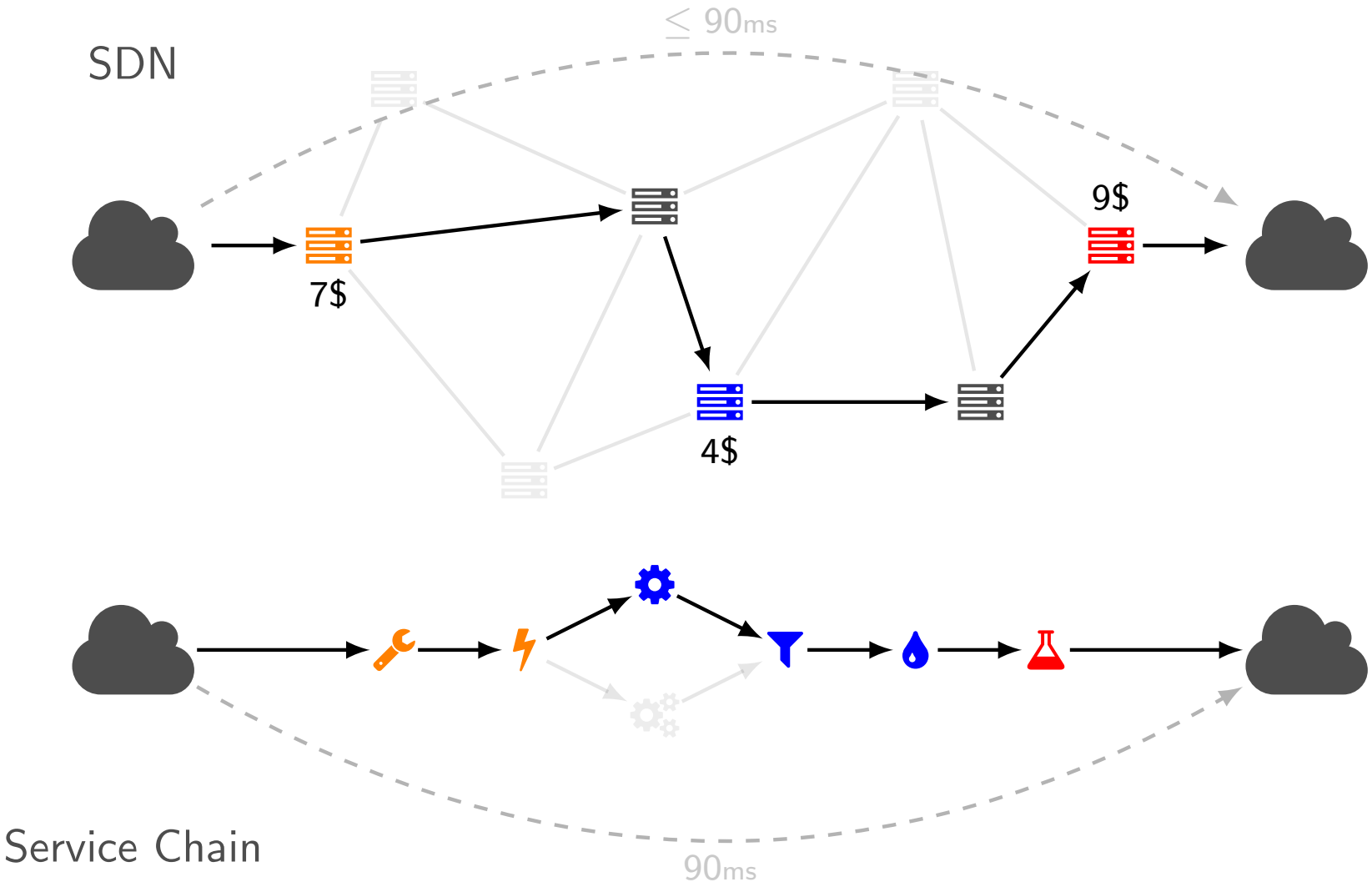

Problem cont.

Minimize Placement Cost

s.t.

- CPU
- Bandwidth
- Latency

Related Work

- System

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- System
  - A. Gember-Jacobson et al. 2014

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Our Results

- NP-hardness in many cases

1

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SDN	Costs	Our Result

1

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DAG	Integral, Polynomial	Optimal

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DAG	Any	FPTAS - $(1+\varepsilon)$-apx

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SDN	Costs	Our Result
DAG	Integral, Polynomial	Optimal
DAG	Any	FPTAS - $(1+\varepsilon)$-apx
Any	Any	FPTAS - $(1+\varepsilon)$-apx[1]

[1] running time depends on SDN's typology

Hardness (Feasibility)

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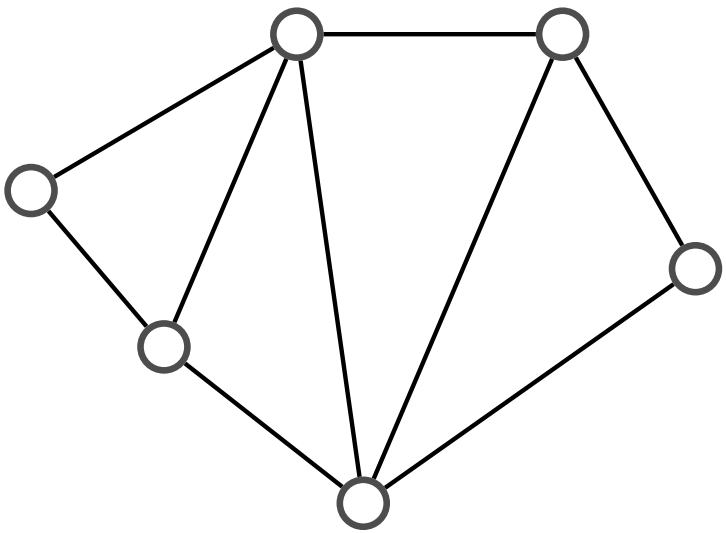
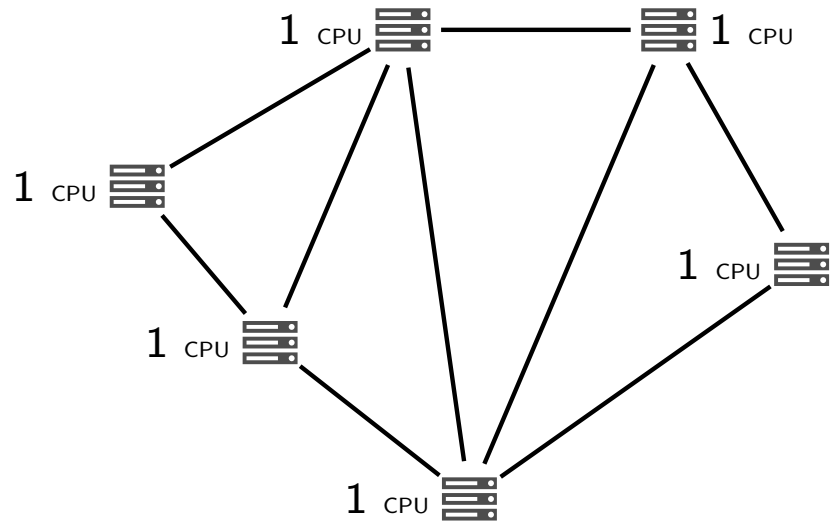


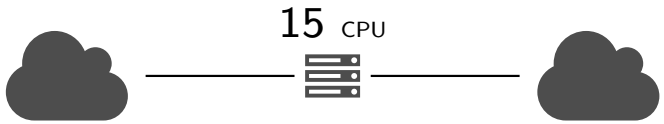


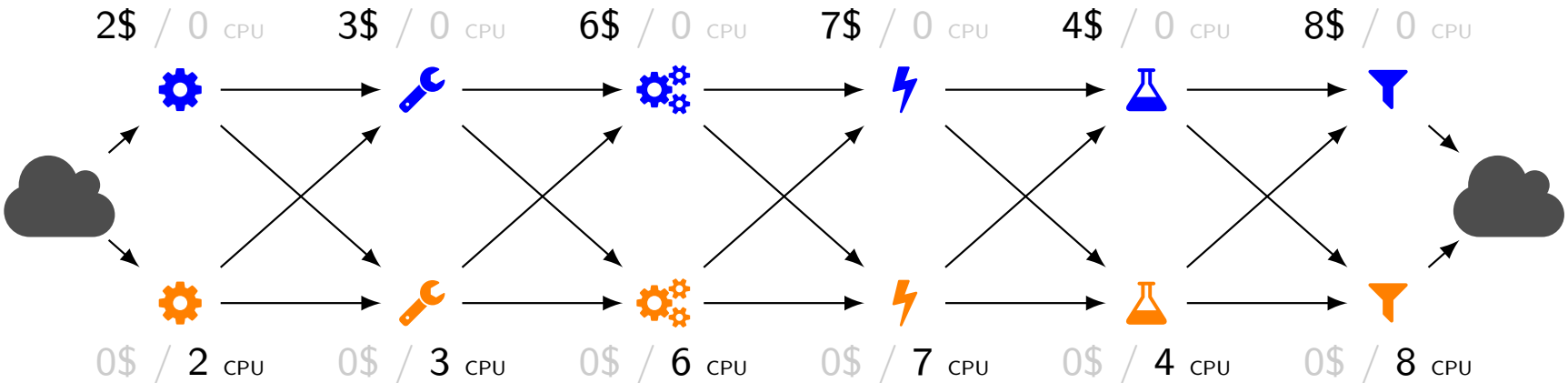
Hamiltonian path $\iff$ Feasible Placement

Hardness (SDN with a single node)

Hardness (SDN with a single node)

$$\{2, 3, 6, 7, 4, 8\}$$

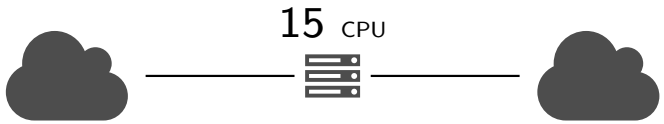


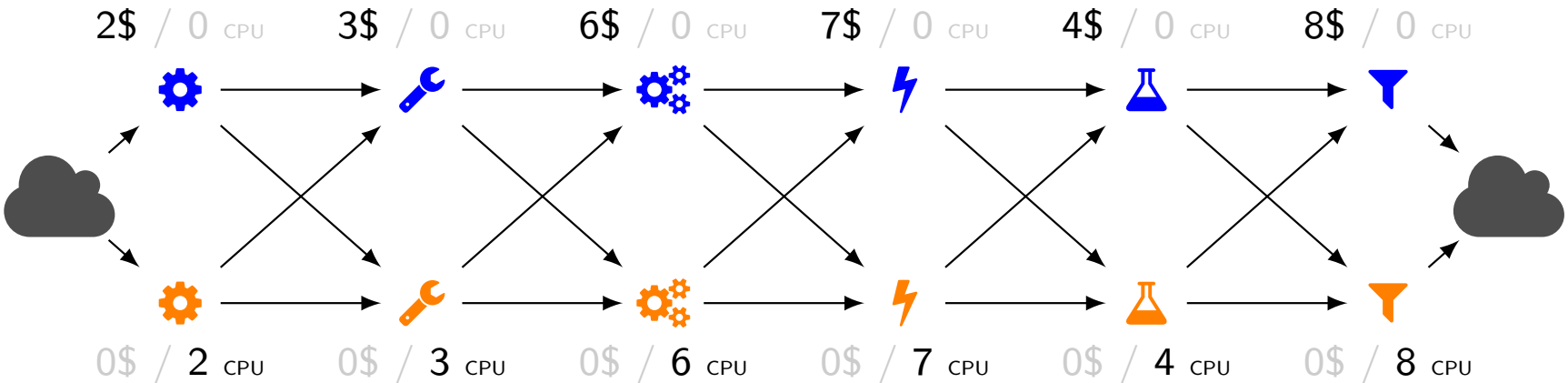


Partition $\iff$ Placement that costs 15$

Hardness (SDN with a single node)

$$\{2, 3, 6, 7, 4, 8\}$$





Partition $\iff$ Placement that costs 15$

* Not hard for integral, polynomial values

Hardness (simple paths)

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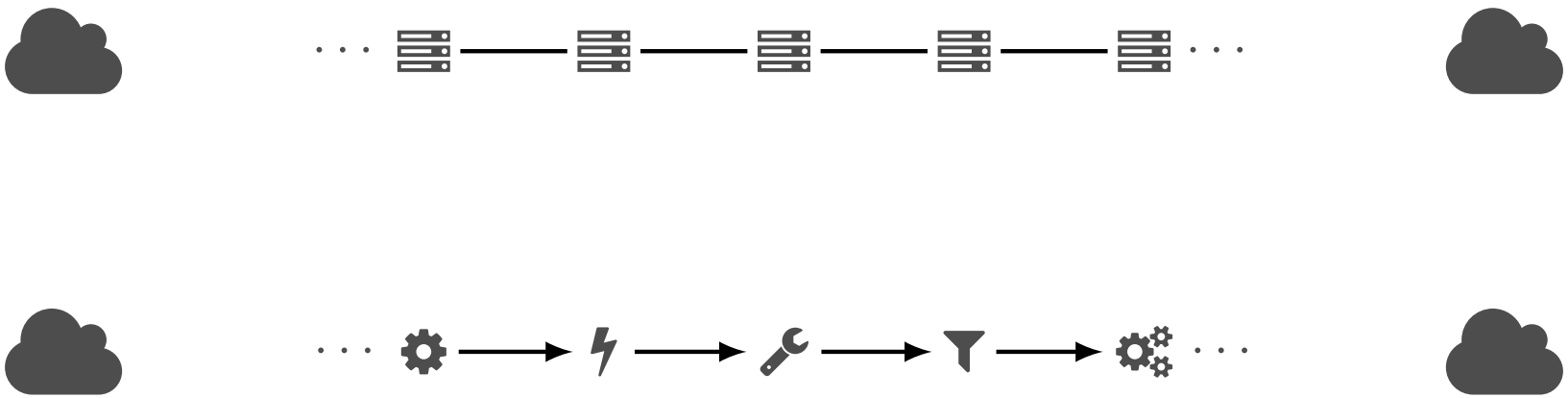

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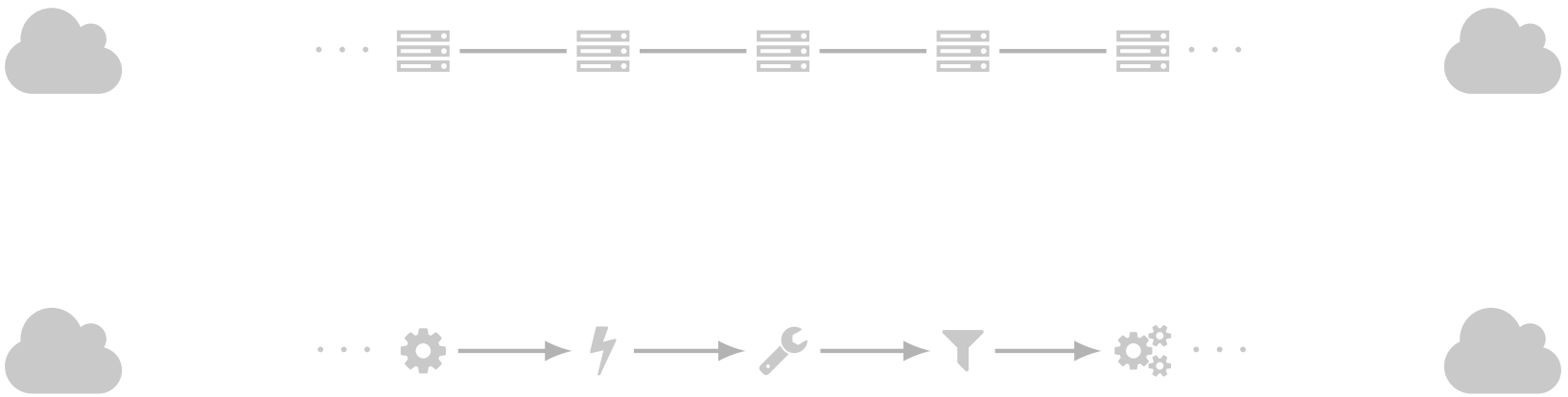
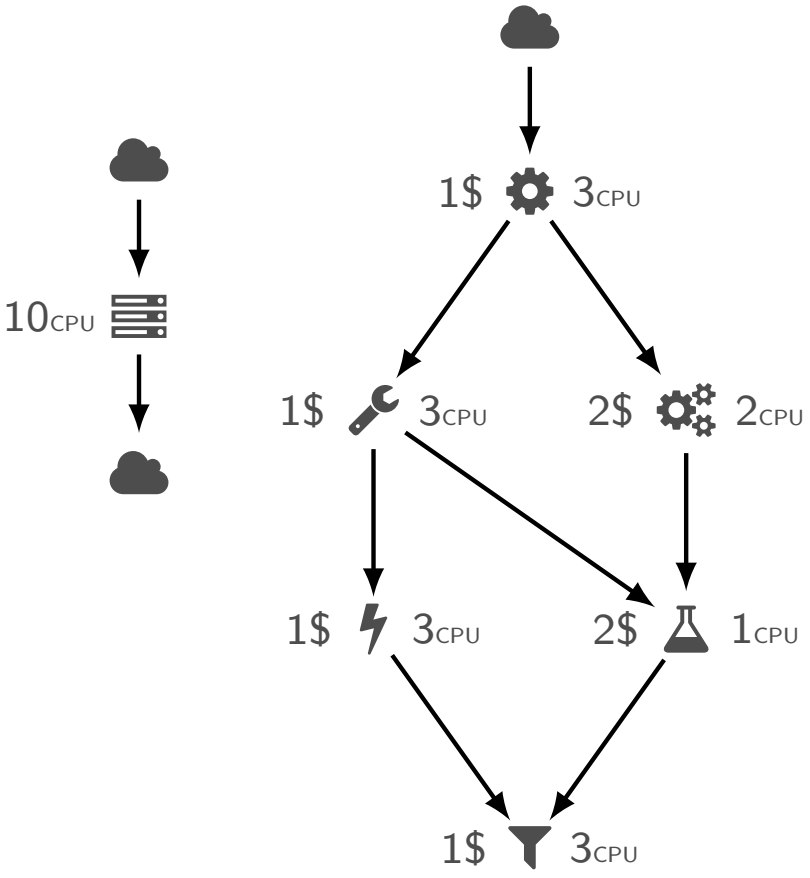


See paper...

Integral Polynomial Costs, Single Node

Min CPU per Cost Budget.



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3	0						
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1	0						
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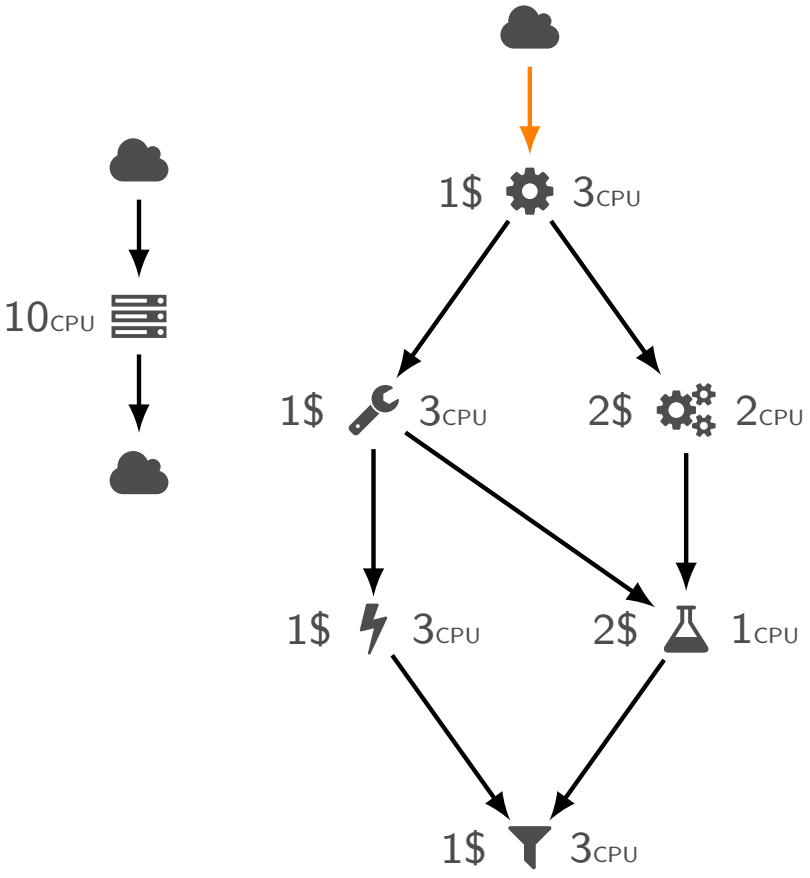

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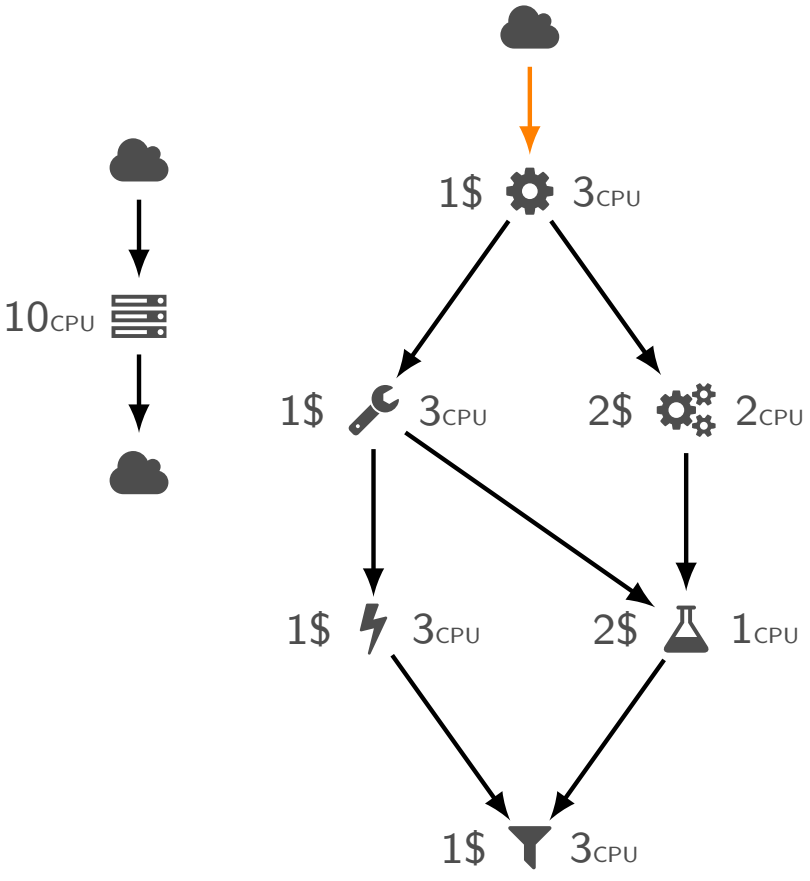

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3	0						
2	0						
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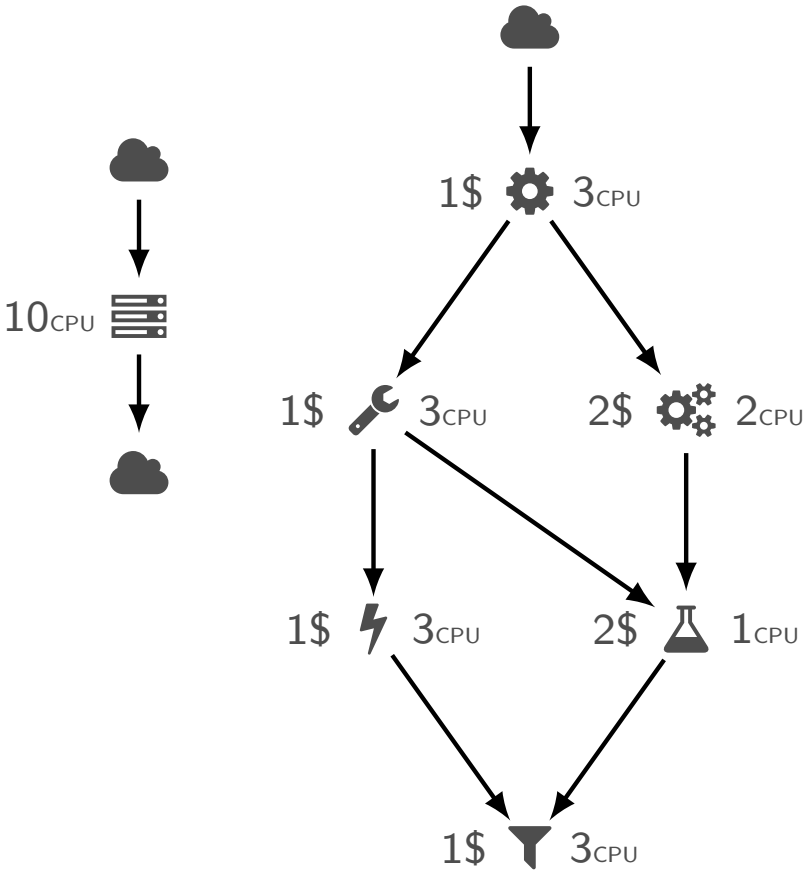

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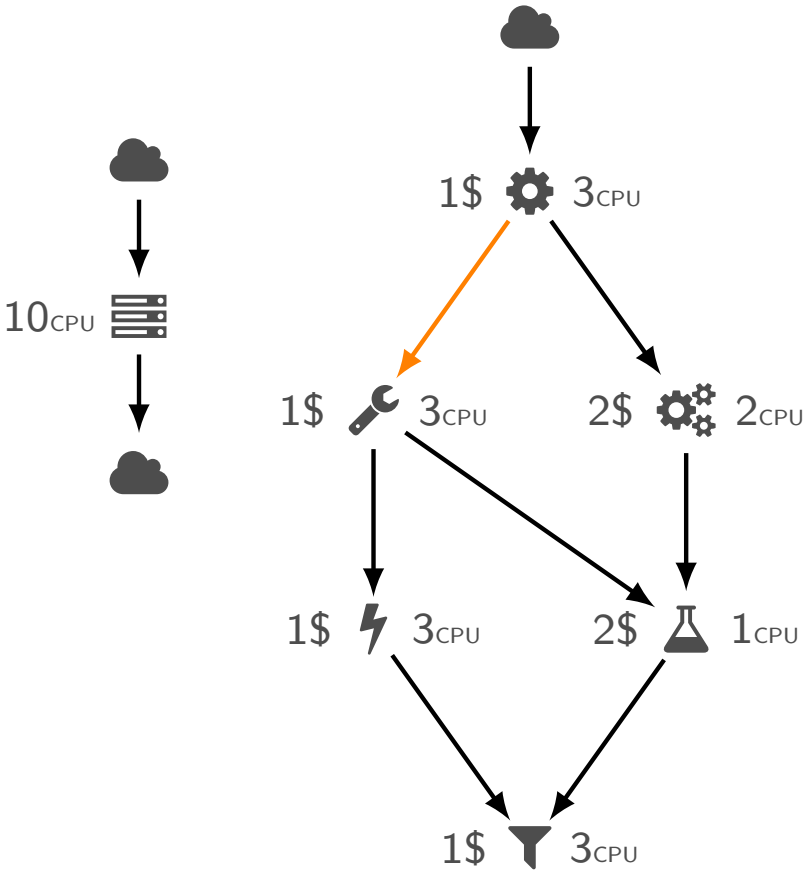

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2	0	3					
1	0	3					
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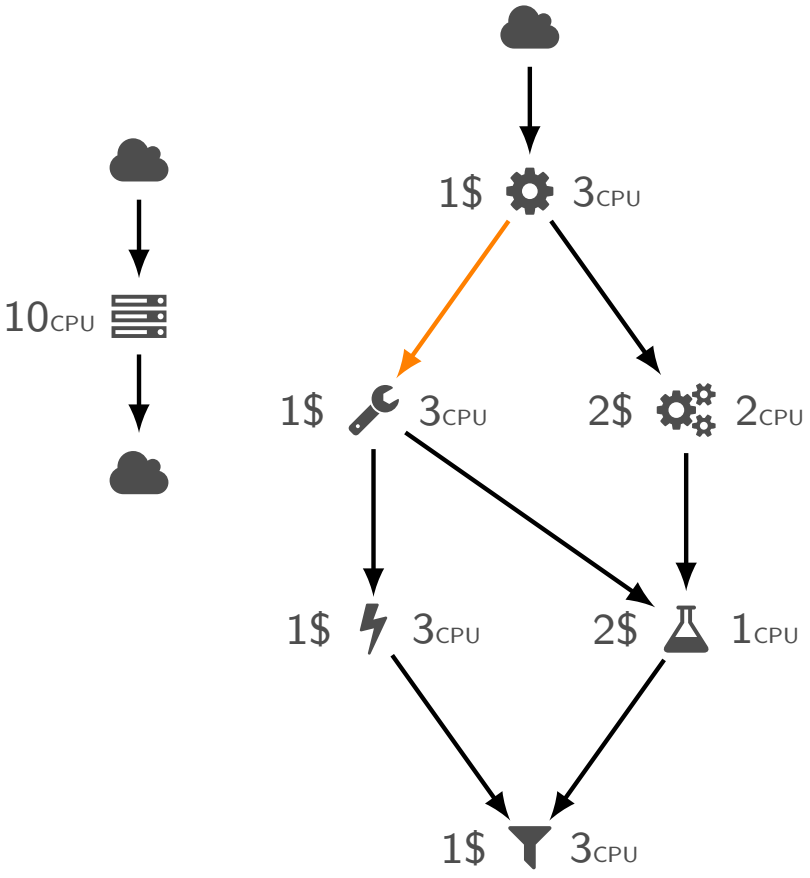

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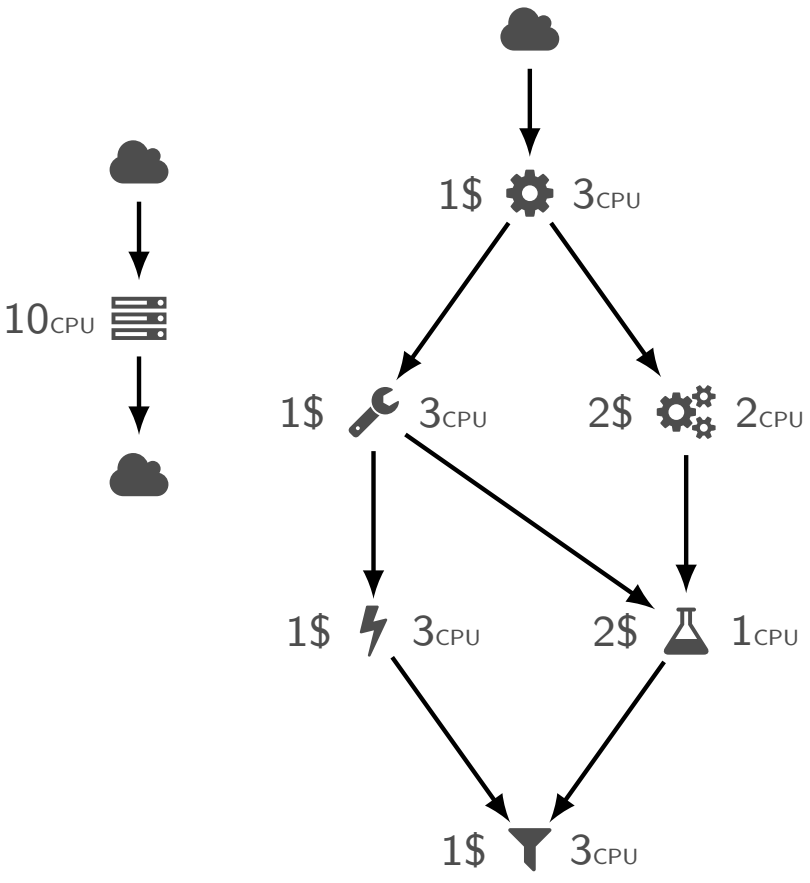

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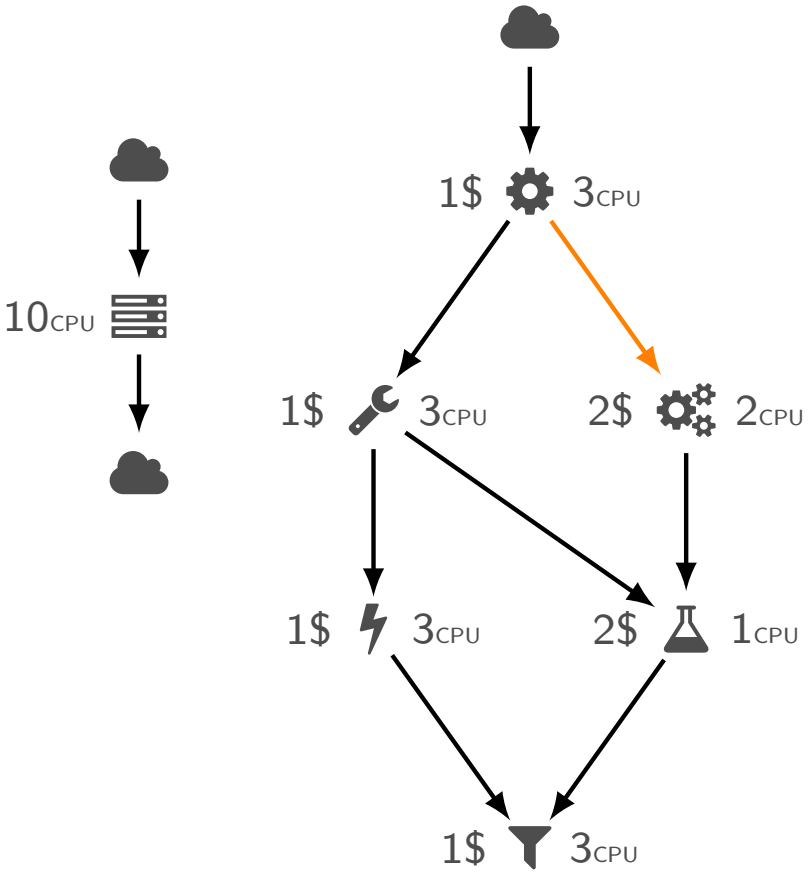

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2	0	3	6				
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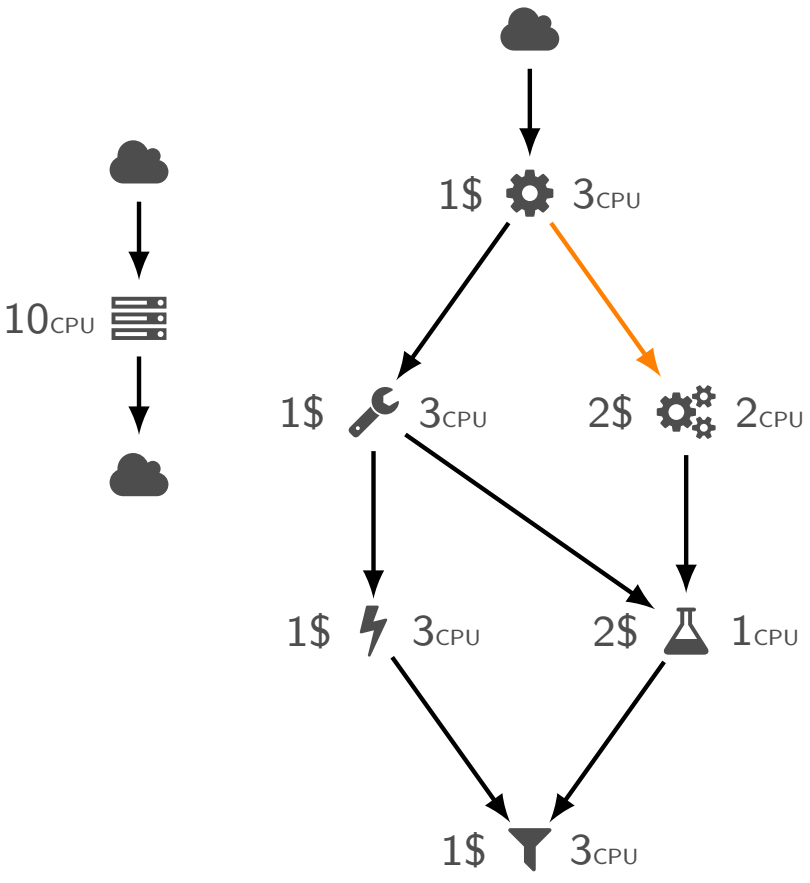

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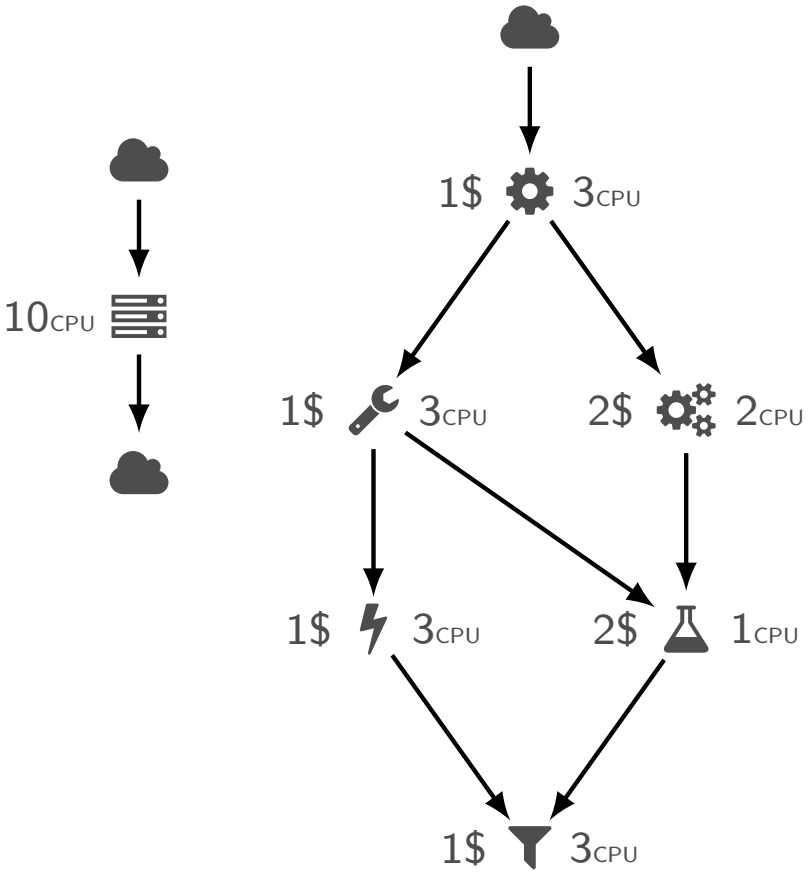

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4	0	3	6	5			
3	0	3	6	5			
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1	0	3	-	-			
0	0	-	-	-			

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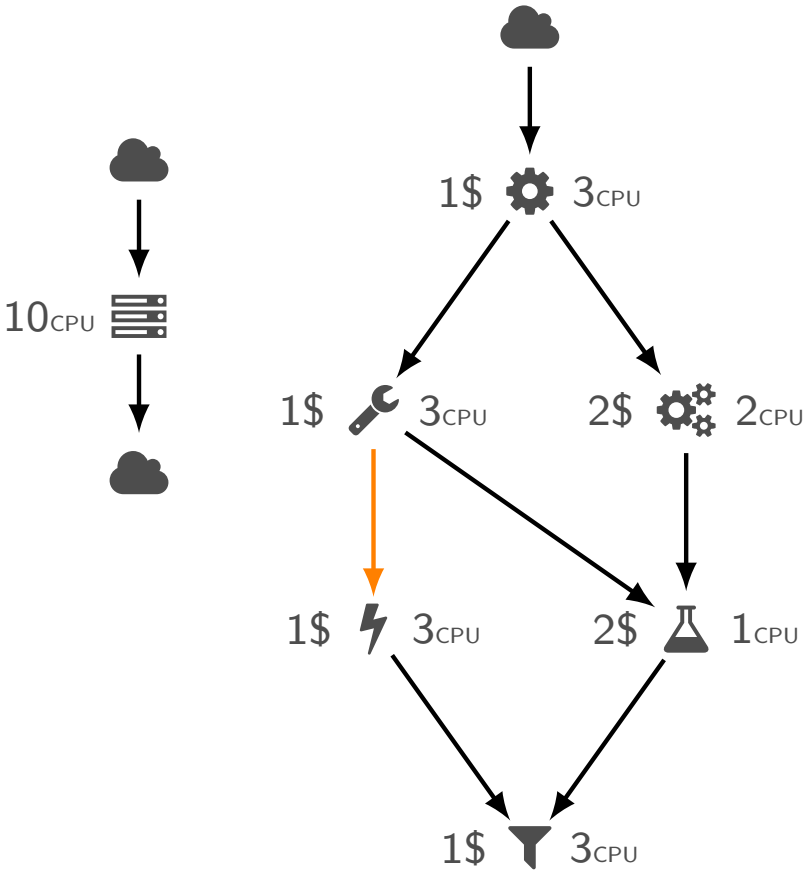

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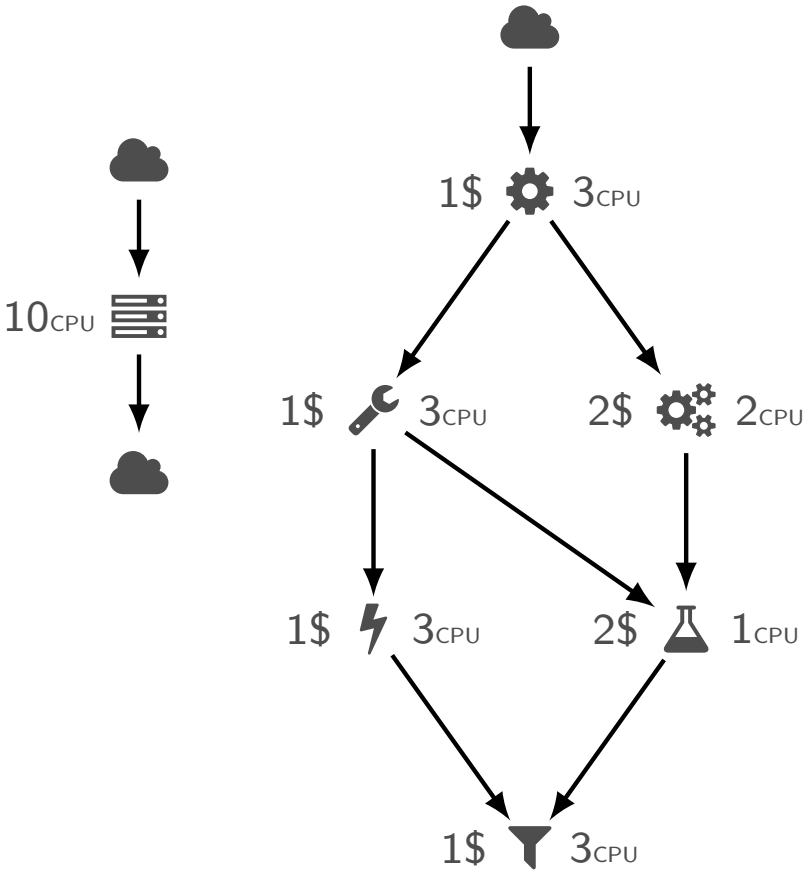

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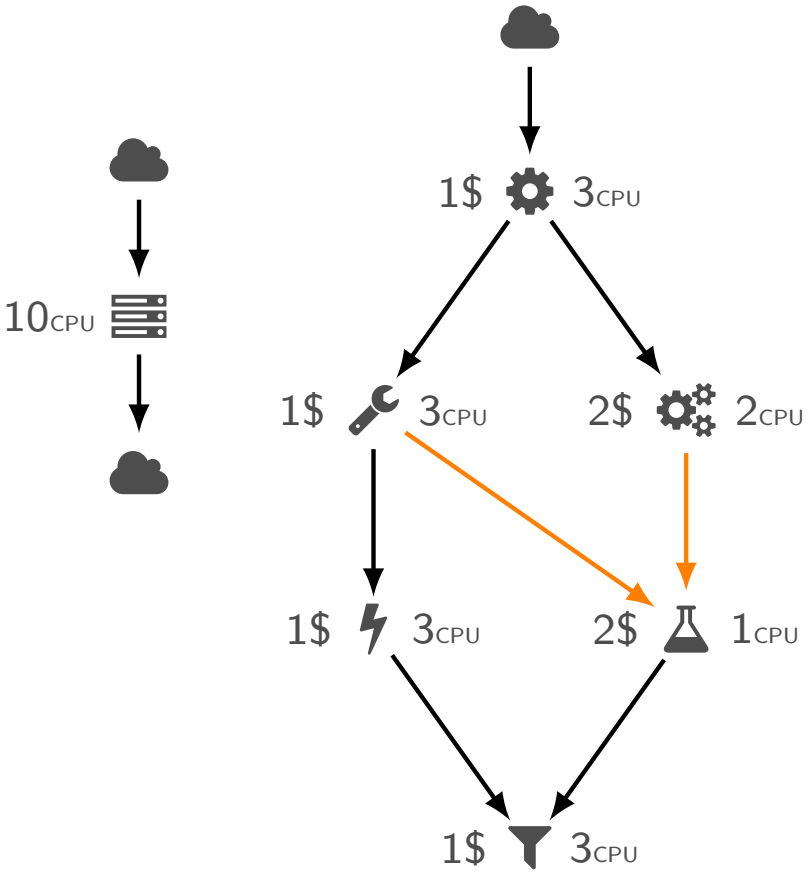

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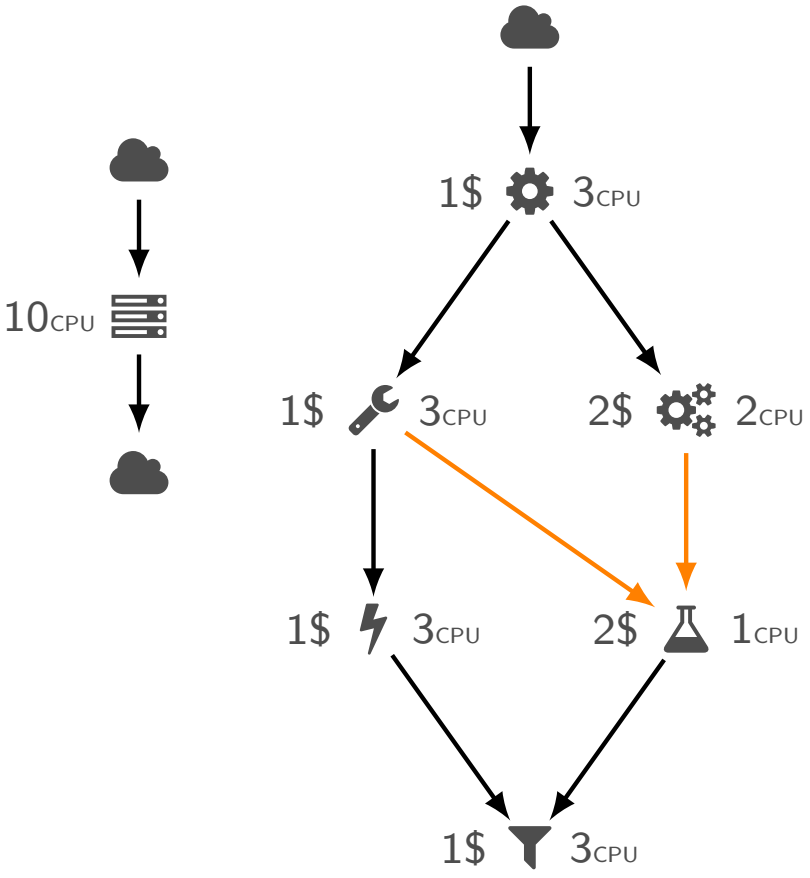

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1	0	3	-	-	-		
0	0	-	-	-	-		

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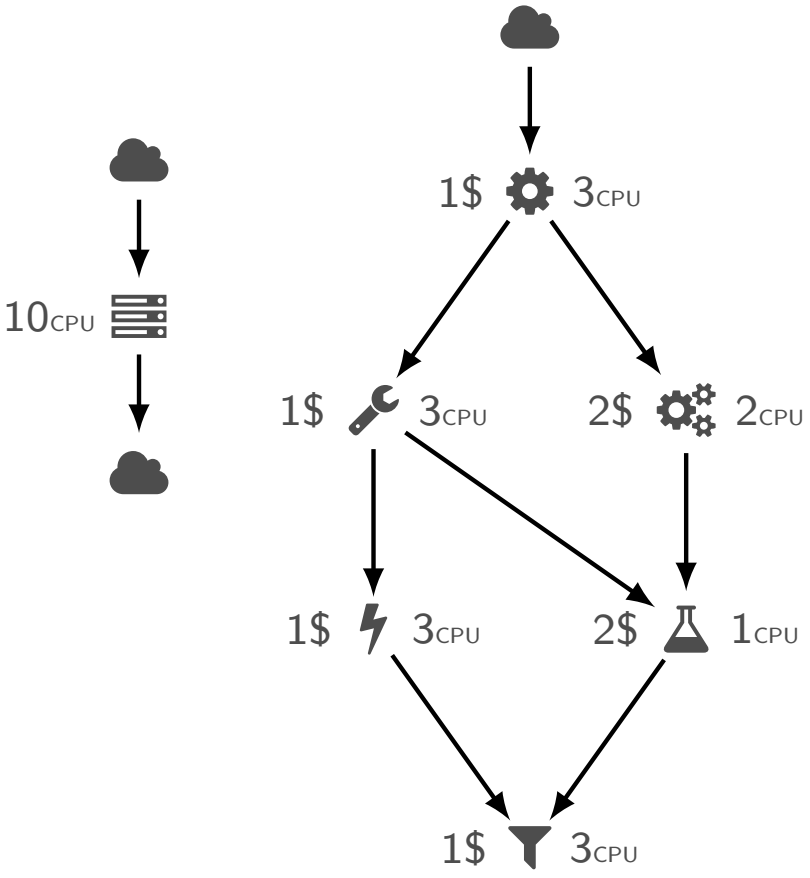

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1	0	3	-	-	-	-	
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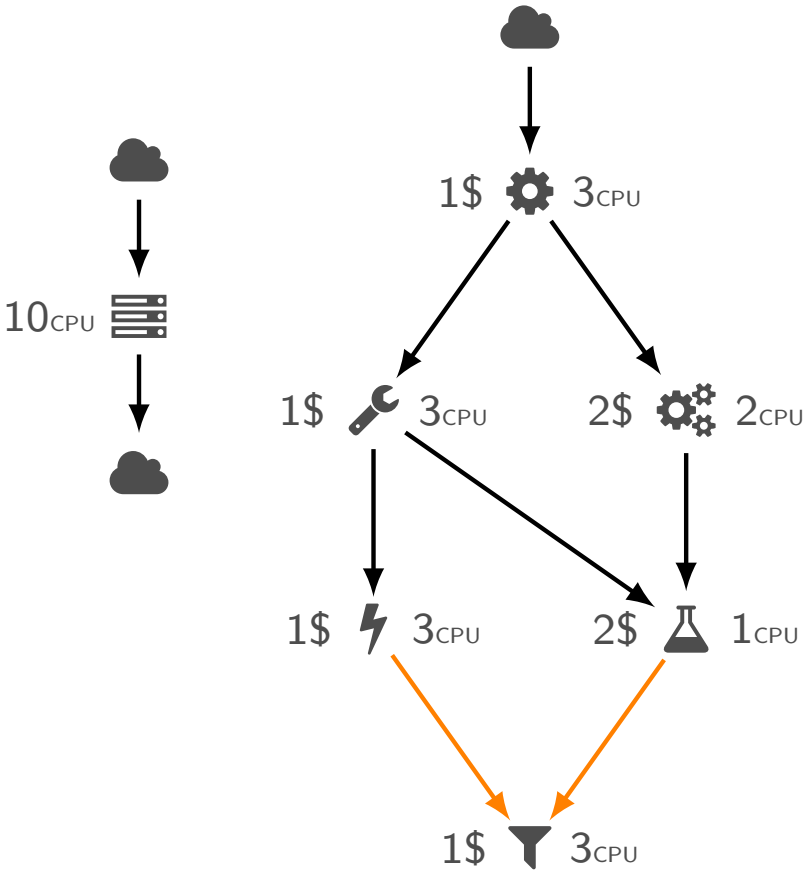

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3	0	3	6	5	9	-	
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1	0	3	-	-	-	-	
0	0	-	-	-	-	-	

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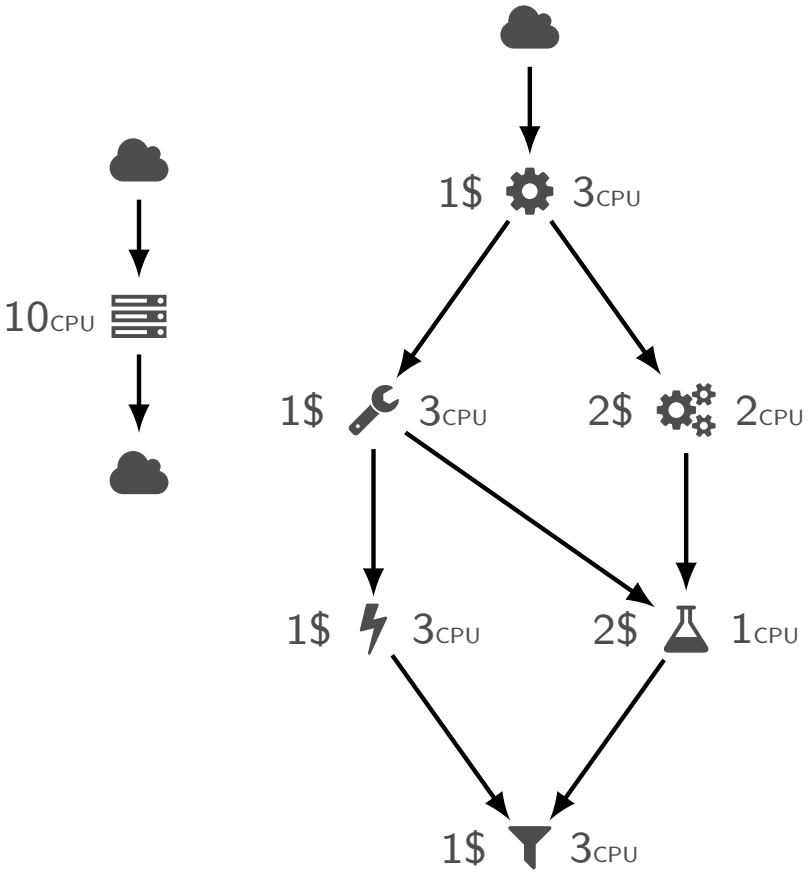
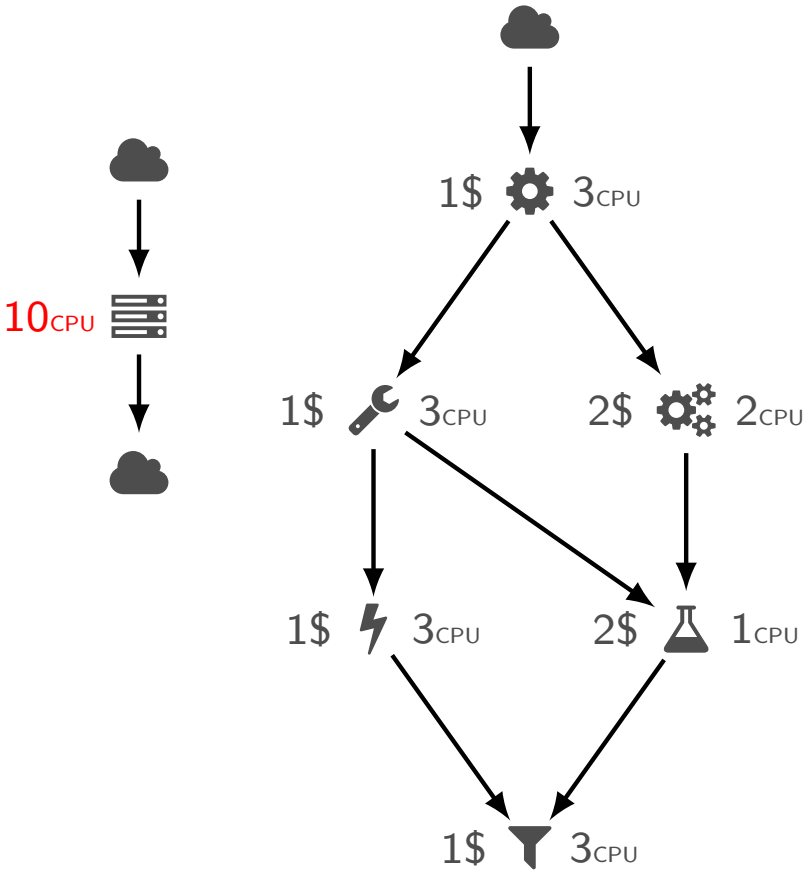


$							
7	0	3	6	5	9	6	9
6	0	3	6	5	9	6	9
5	0	3	6	5	9	6	10
4	0	3	6	5	9	7	12
3	0	3	6	5	9	-	-
2	0	3	6	-	-	-	-
1	0	3	-	-	-	-	-
0	0	-	-	-	-	-	-

Integral Polynomial Costs, Single Node

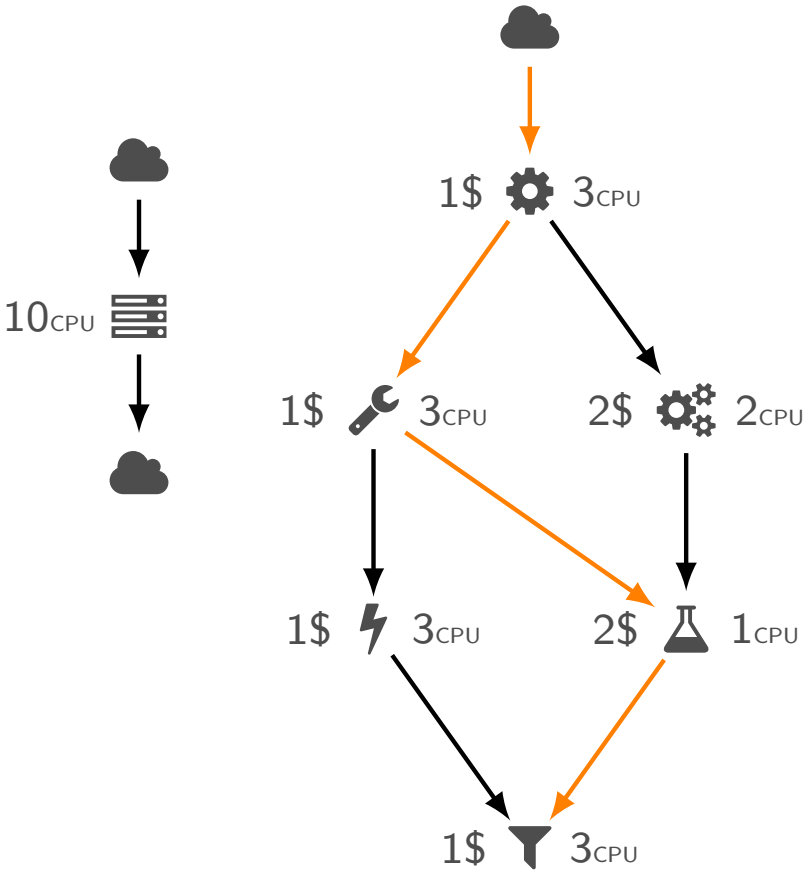
Min CPU per Cost Budget.



$	☁	⚙	🔧	⚙⚙	⚡	⚗	▼
7	0	3	6	5	9	6	9
6	0	3	6	5	9	6	9
5	0	3	6	5	9	6	10
4	0	3	6	5	9	7	12
3	0	3	6	5	9	-	-
2	0	3	6	-	-	-	-
1	0	3	-	-	-	-	-
0	0	-	-	-	-	-	-

Integral Polynomial Costs, Single Node

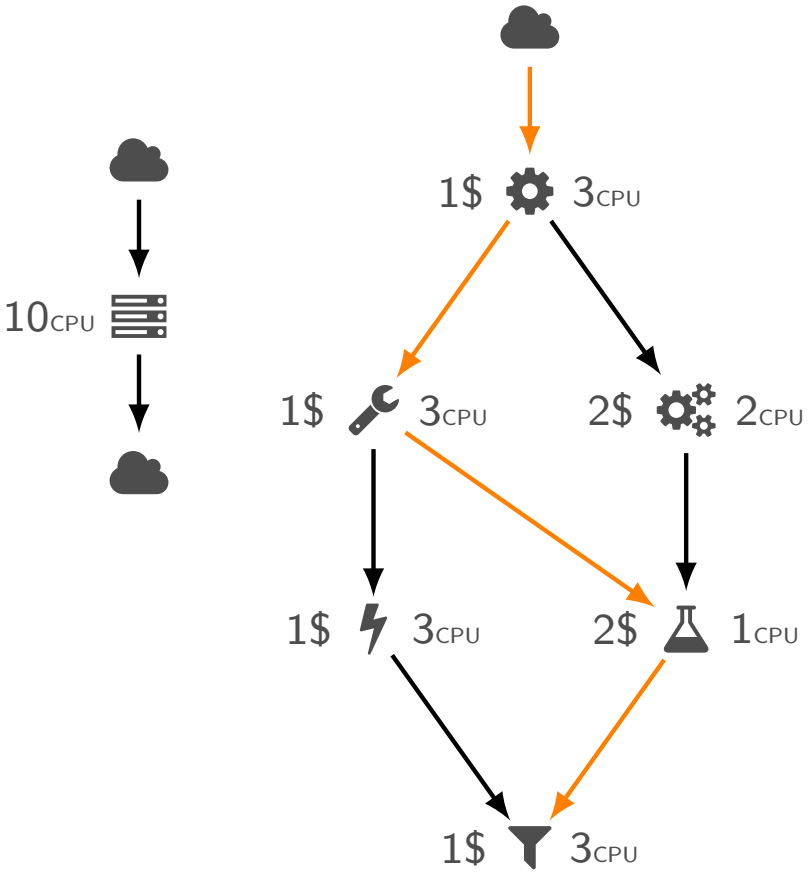
Min CPU per Cost Budget.



$	☁	⚙	🔧	⚙⚙	⚡	⚗	▼
7	0	3	6	5	9	6	9
6	0	3	6	5	9	6	9
5	0	3	6	5	9	6	10
4	0	3	6	5	9	7	12
3	0	3	6	5	9	-	-
2	0	3	6	-	-	-	-
1	0	3	-	-	-	-	-
0	0	-	-	-	-	-	-

Integral Polynomial Costs, Single Node

Min CPU per Cost Budget.

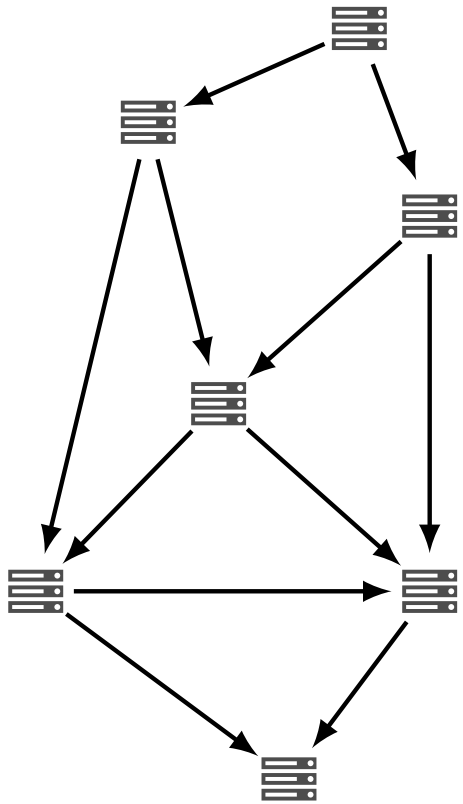


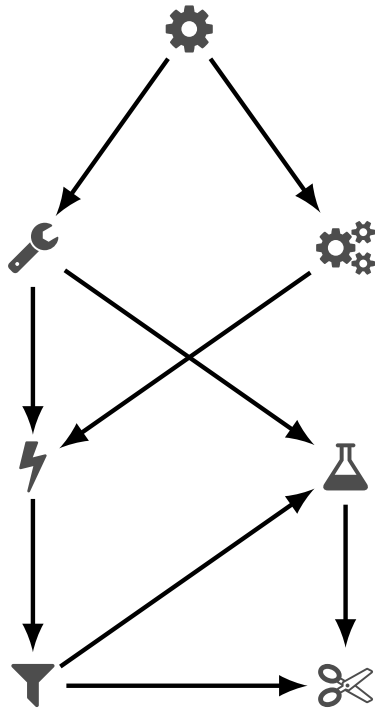
$							
7	0	3	6	5	9	6	9
6	0	3	6	5	9	6	9
5	0	3	6	5	9	6	10
4	0	3	6	5	9	7	12
3	0	3	6	5	9	-	-
2	0	3	6	-	-	-	-
1	0	3	-	-	-	-	-
0	0	-	-	-	-	-	-

Search for min Budget s.t. CPU constraint.

Small, Integral Costs, DAG

Min Latency s.t. Cost Budget.

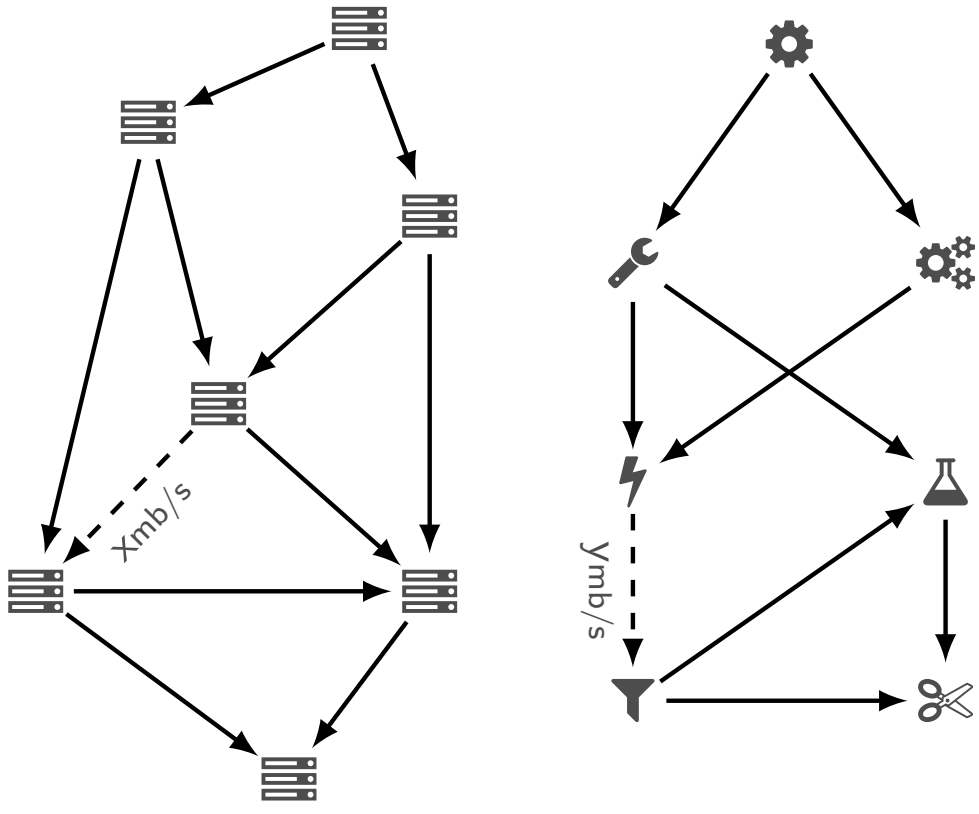




Small, Integral Costs, DAG

Min Latency s.t. Cost Budget.

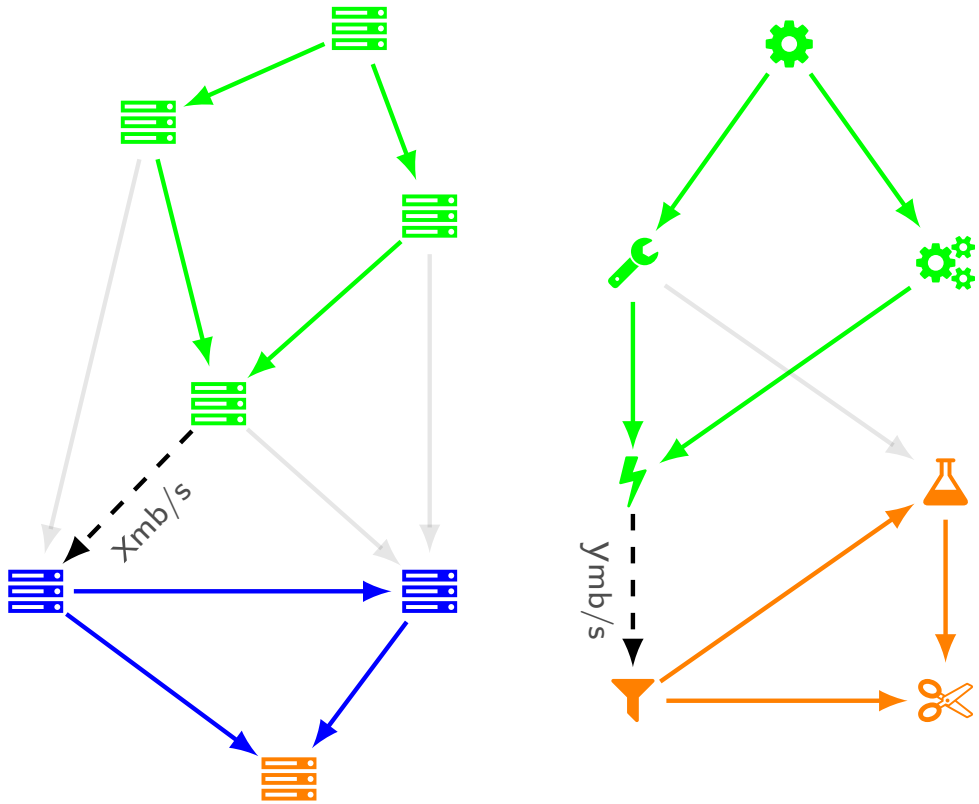
- Pick 2 arcs ($x \geq y$)



Small, Integral Costs, DAG

Min Latency s.t. Cost Budget.

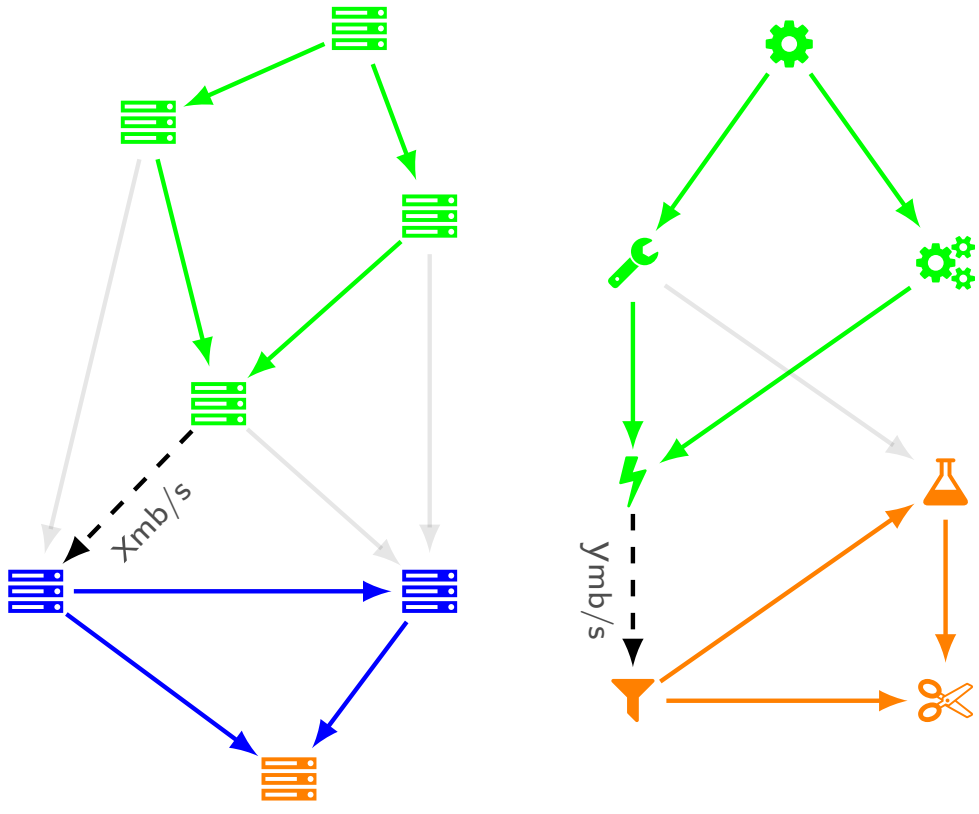
- Pick 2 arcs ($x \geq y$)
- Orange Problem - Single Node



Small, Integral Costs, DAG

Min Latency s.t. Cost Budget.

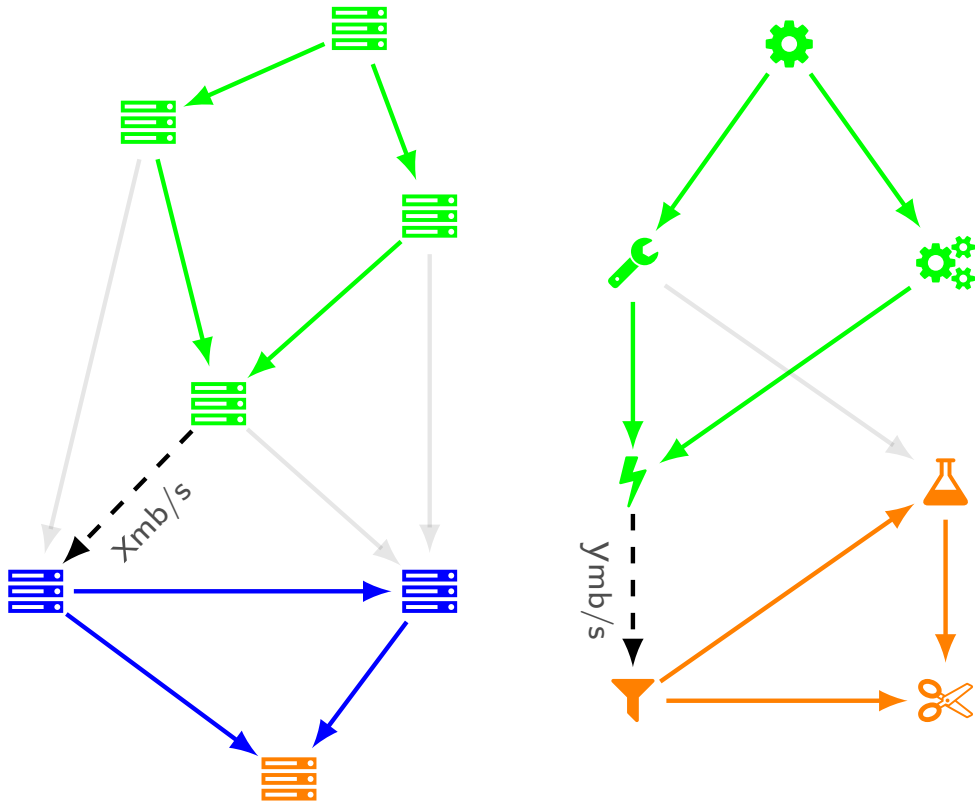
- Pick 2 arcs ($x \geq y$)
- Orange Problem - Single Node
- Blue Problem - Shortest Path



Small, Integral Costs, DAG

Min Latency s.t. Cost Budget.

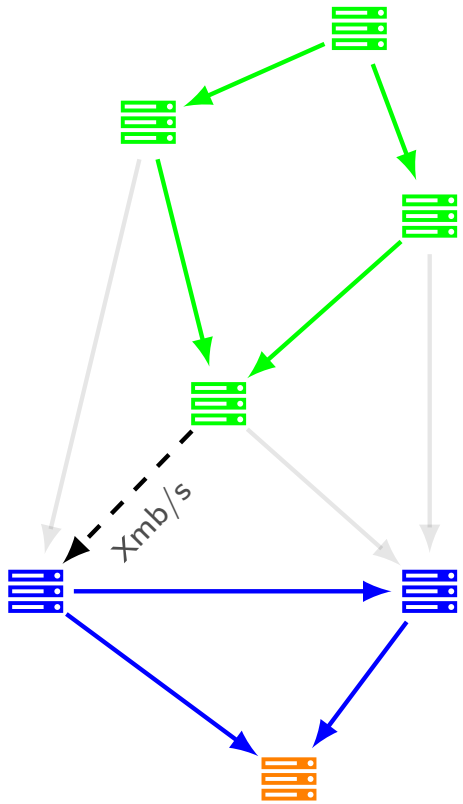
- Pick 2 arcs ($x \geq y$)
- Orange Problem - Single Node
- Blue Problem - Shortest Path
- Green Problem - Recursively

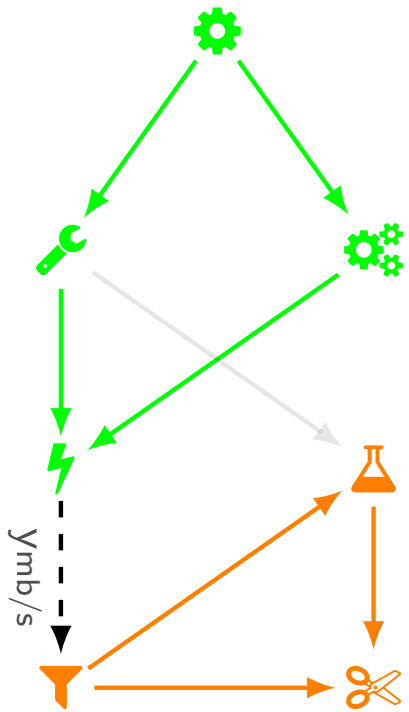


Small, Integral Costs, DAG

Min Latency s.t. Cost Budget.

- Pick 2 arcs ($x \geq y$)
- Orange Problem - Single Node
- Blue Problem - Shortest Path
- Green Problem - Recursively
  - At most $|V| \times |F| \times Cost$

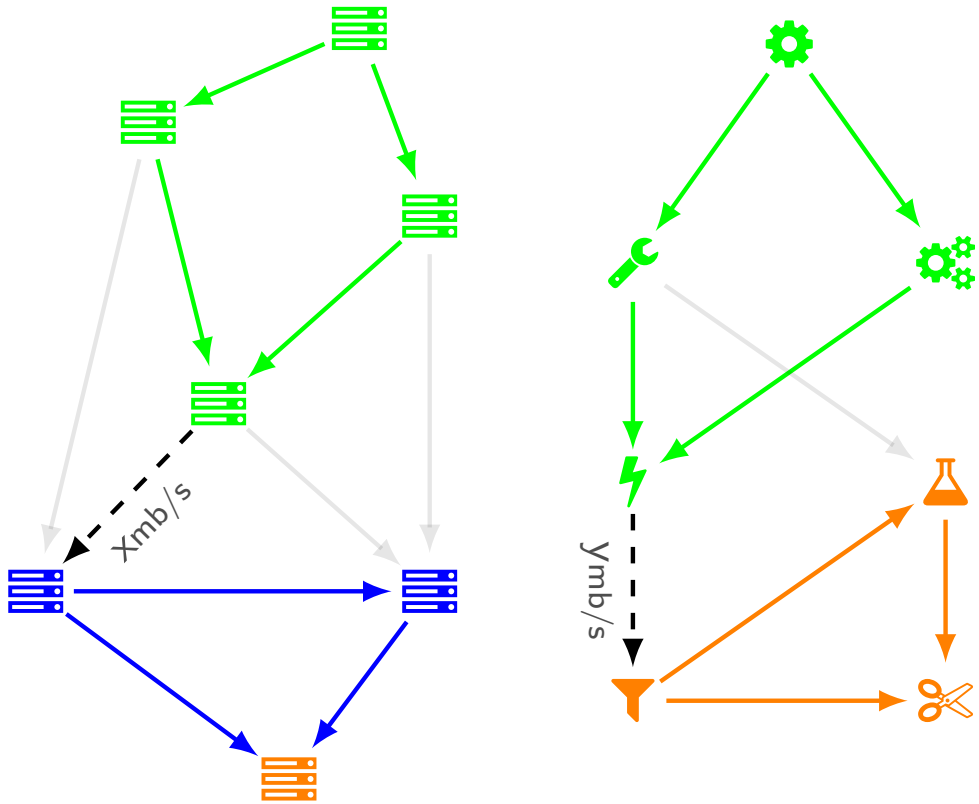




Small, Integral Costs, DAG

Min Latency s.t. Cost Budget.

- Pick 2 arcs ($x \geq y$)
- Orange Problem - Single Node
- Blue Problem - Shortest Path
- Green Problem - Recursively
  - At most $|V| \times |F| \times Cost$



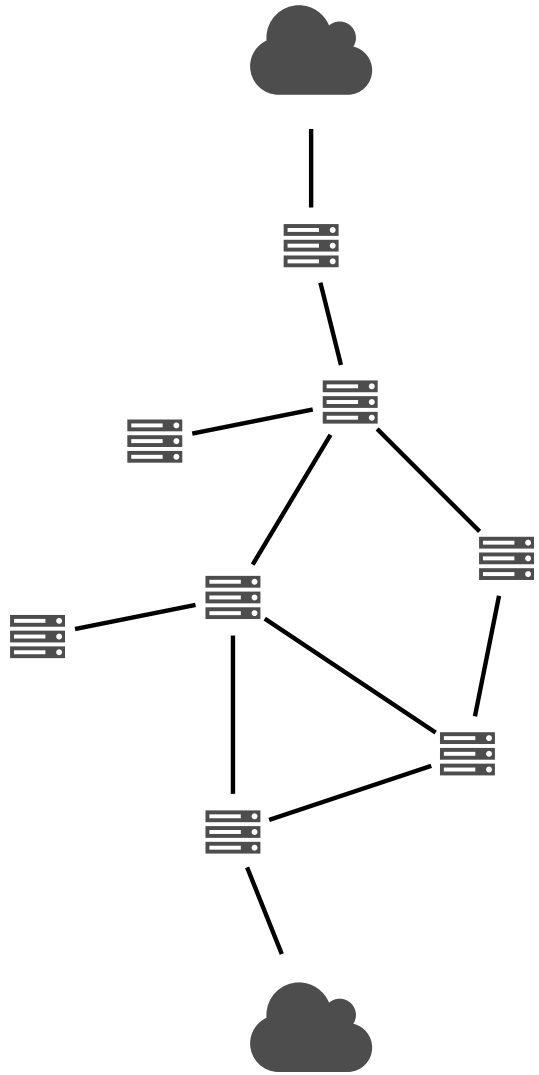
Search for the minimum budget s.t. Latency constraint.

Theorem

Costs can be scaled and rounded such that for any $\varepsilon > 0$ an optimal solution w.r.t the rounded value is a $1 + \varepsilon$-approximation for the original costs.

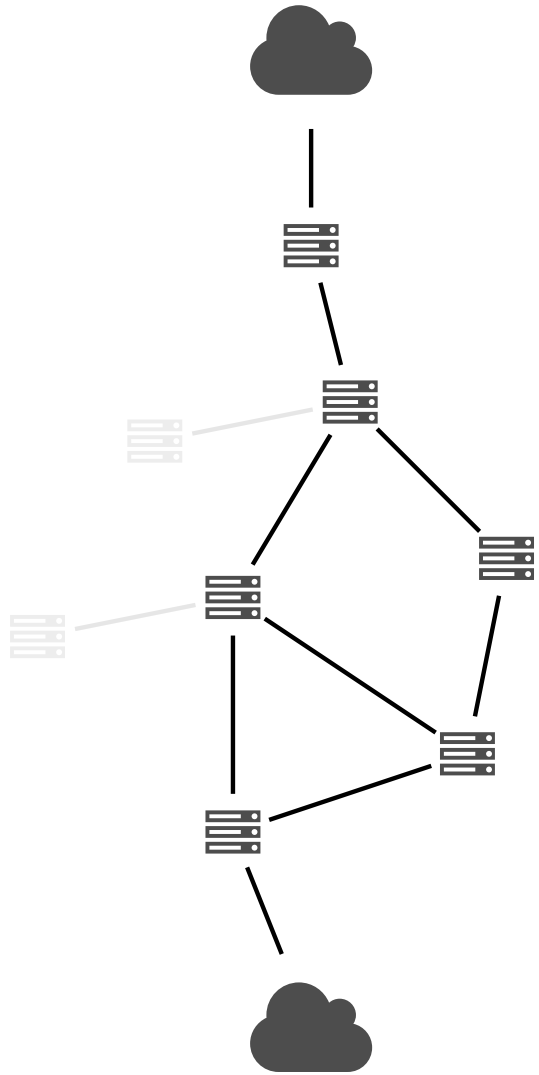
General Case

- Find unreachable nodes



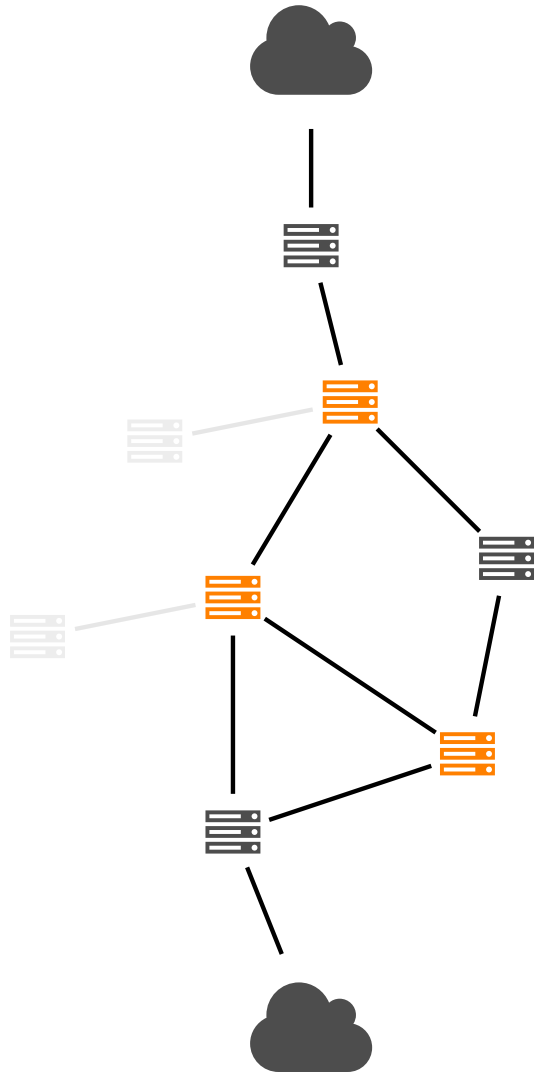
General Case

- Find unreachable nodes
- Mark nodes with deg > 2



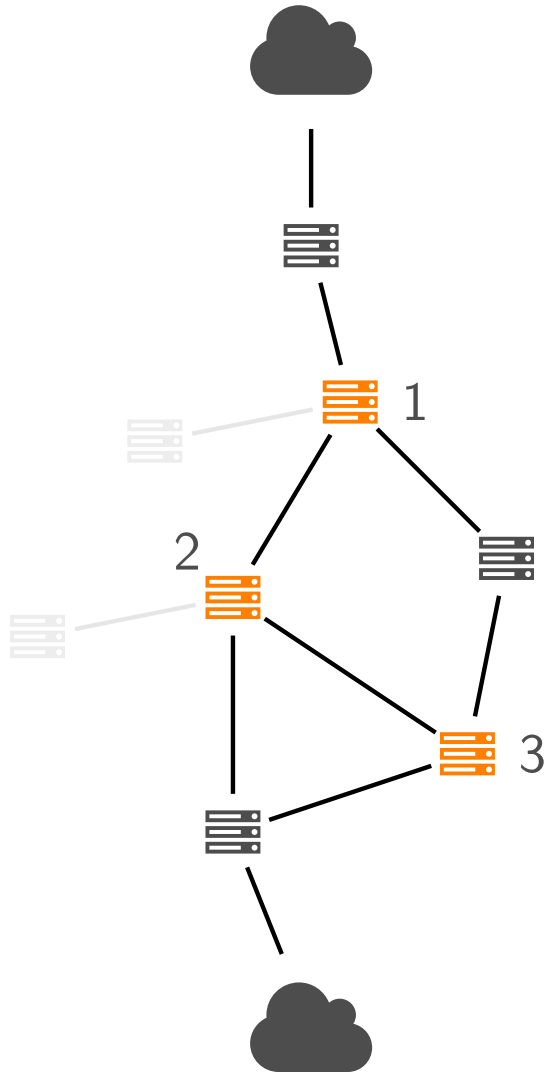
General Case

- Find unreachable nodes
- Mark nodes with deg > 2
- Choose a permutation



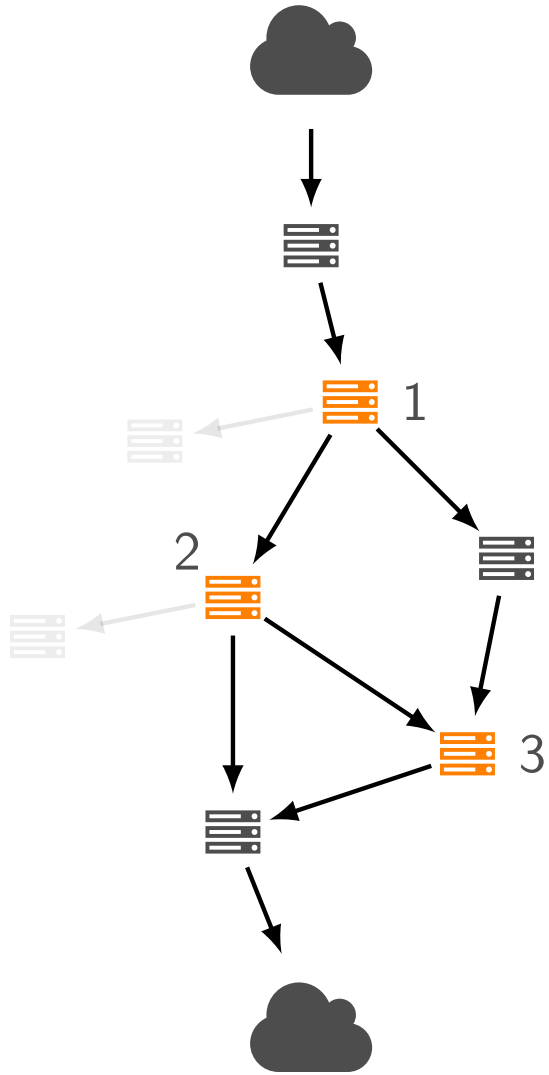
General Case

- Find unreachable nodes
- Mark nodes with deg > 2
- Choose a permutation
- Orient the network accordingly



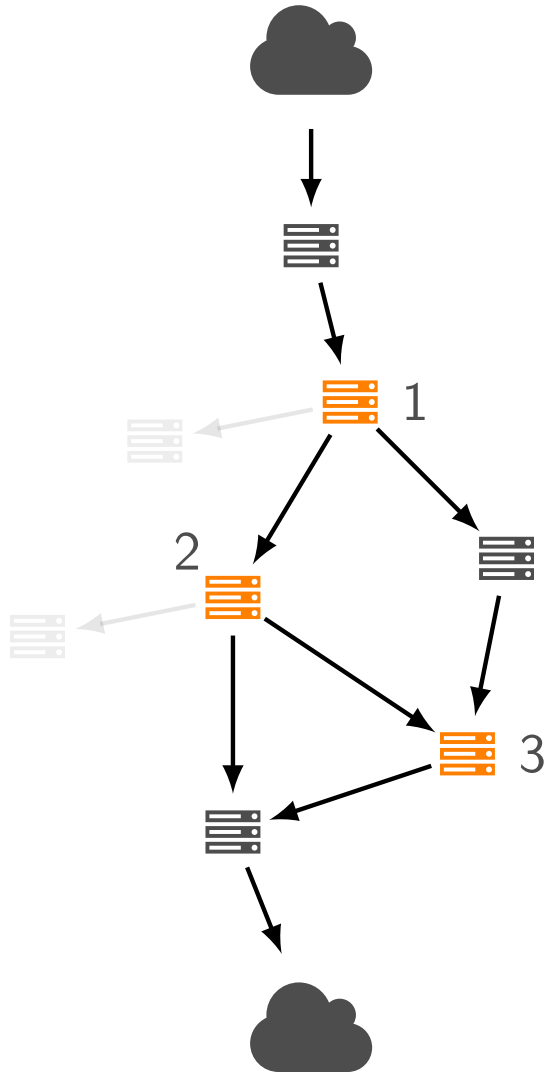
General Case

- Find unreachable nodes
- Mark nodes with deg > 2
- Choose a permutation
- Orient the network accordingly
- Use the previous algorithm



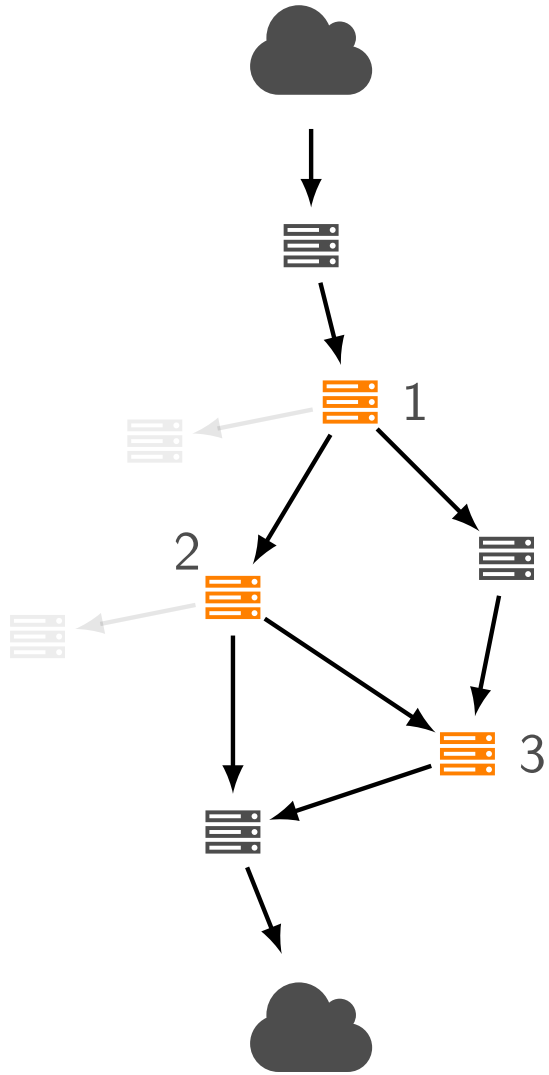
General Case

- Find unreachable nodes
- Mark nodes with deg > 2
- Choose a permutation
- Orient the network accordingly
- Use the previous algorithm
- Running time is $O(k!t(n))$ [1]



General Case

- Find unreachable nodes
- Mark nodes with deg > 2
- Choose a permutation
- Orient the network accordingly
- Use the previous algorithm
- Running time is $O(k!t(n))$ [1]



[1] Can be reduced to $O(2^k t(n))$

Conclusion

- Attracts Attention

Conclusion

- Attracts Attention
  - System

Conclusion

- Attracts Attention
  - System
  - Algorithmically

Conclusion

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  - System
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- Best we can hope solution for DAGs

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  - Best we can hope solution under some assumptions

Conclusion

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- Fault Tolerance

Conclusion

- Attracts Attention
  - System
  - Algorithmically
- Best we can hope solution for DAGs
- Open questions for general SDNs
  - Best we can hope solution under some assumptions
- Fault Tolerance
- In practice?

Thank You.