Minimizing Transmission and Processing Delay in a NFV-based Network

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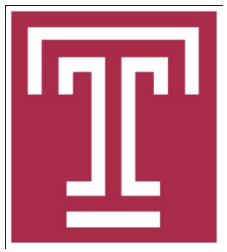
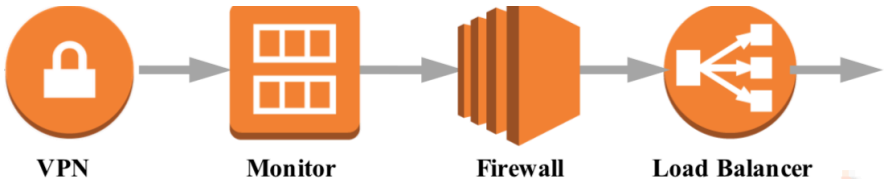


1. Introduction

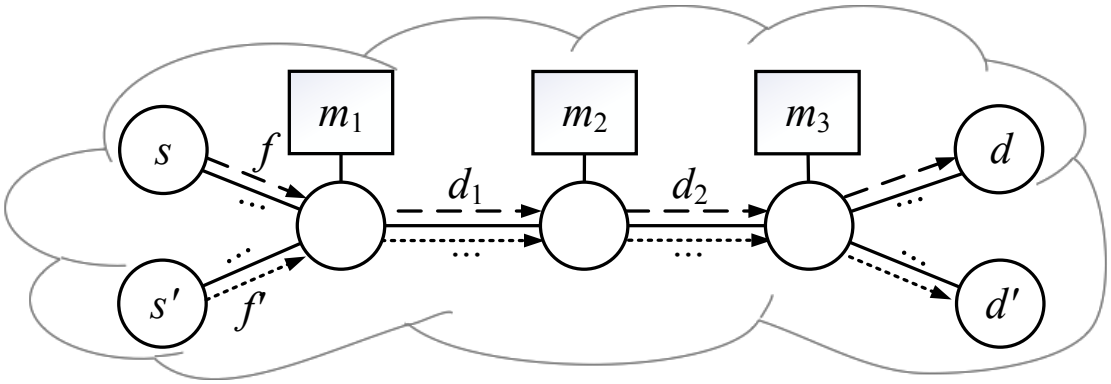
- Network Function Virtualization (NFV)
  - Virtualizing network functions into software modules
- Middlebox: software implementation of network services
  - Improve performance:
    - Web proxy, load balancer
  - Enhance security:
    - Firewall, IDS/IPS
- Service chain
  - Multiple middleboxes in a specific processing order
  - Example



2. Our Model

- Problem
  - Flow contention on a service chain
- Flow communication latency behaviors
  - Middlebox processing time
    - Distinct value for different flows on different middleboxes
  - Link transmission delay
    - Constant value for all flows on a single link
- Objective: minimizing flow completion time in two aspects
  - Minimize the makespan (longest flow completion time)
  - Minimize the average flow completion time

A Motivating Example

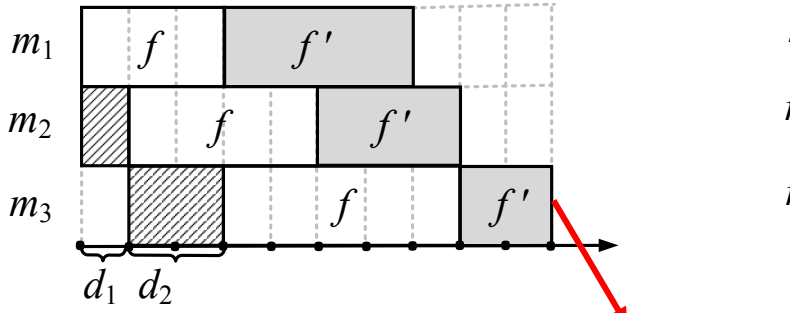


Link transmission delay

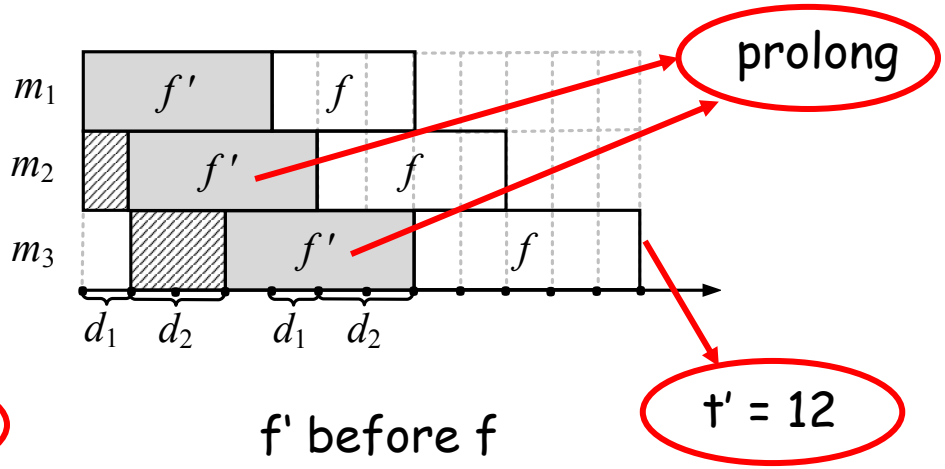
$d_1 = 1$ $d_2 = 2$

Processing time

Flows \ Middleboxes	m_1	m_2	m_3
f	3	4	5
f'	4	3	2



f before f'



f' before f

3. A Service Chain with Two Middleboxes

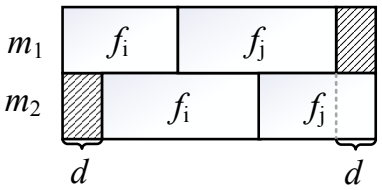
- Objective: minimizing makespan
- Solution
  - Two Set Order Schedule (TSOS)
- Solution steps
  - Sort flows in decreasing order of $p_2 - p_1$
- Insight
  - Inspired by the classic flow shop[1] problem
    - Optimal solution for two machines
  - Make the second middlebox not idle
  - Smallest completion time extension for the last flow

[1] S. M. Johnson, "Optimal two- and three-stage production schedules with setup times included," Naval Research Logistics Quarterly, 1954.

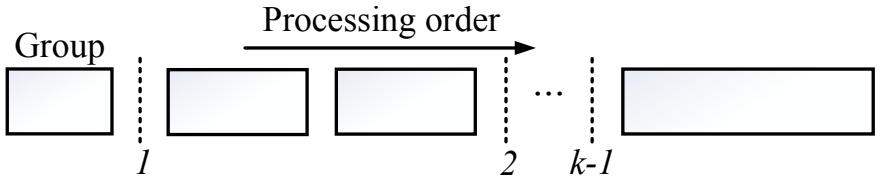
3. A Service Chain with Two Middleboxes

- Objective: minimizing average completion time
- Solution
  - Pairwise Schedule (PS)
- Solution steps
  - Sort flows in increasing order of $\max_f\{p_1^f, p_2^f\}$
  - For flows with same $\max_f\{p_1^f, p_2^f\}$
    - Select flows with $\max_f\{p_2^f - p_1^f\}$ and $\max_f\{p_1^f - p_2^f\}$ as a pair
- Pair flows and processing order illustrations

(a) A pair.

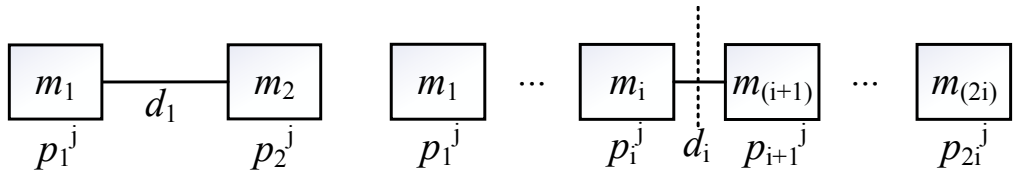


(b) A pair with a delay.



4. A Service Chain with Multiple Middleboxes

- Objective: minimizing makespan
- Problem complexity: NP-hard
- Solution
  - Slope Heuristic Algorithm (SHA)
- Solution insights
  - Cut the service chain into two same-length parts
  - Each part as a "new" middlebox
  - Modification of processing times
  - Apply our proposed Alg. TSOS
- Illustration



(a) Two ordered services. (b) Multiple ordered services.

4. A Service Chain with Multiple Middleboxes

- Objective: minimizing average completion time
- Problem complexity
  - Harder than makespan
  - NP-hard
- Solution
  - Pairwise Heuristic Schedule (PHS)
- Solution insights
  - Cut the service chain into two same-length parts
  - Each part as a "new" middlebox
  - Modification of processing times
  - Apply our proposed Alg. PS

5. Simulation

- Comparison algorithms
  - Random
    - Rank flow randomly
  - SPT
    - Rank flows by total processing times in increasing order
  - LPT
    - Rank flows by total processing times in decreasing order
- Our algorithms

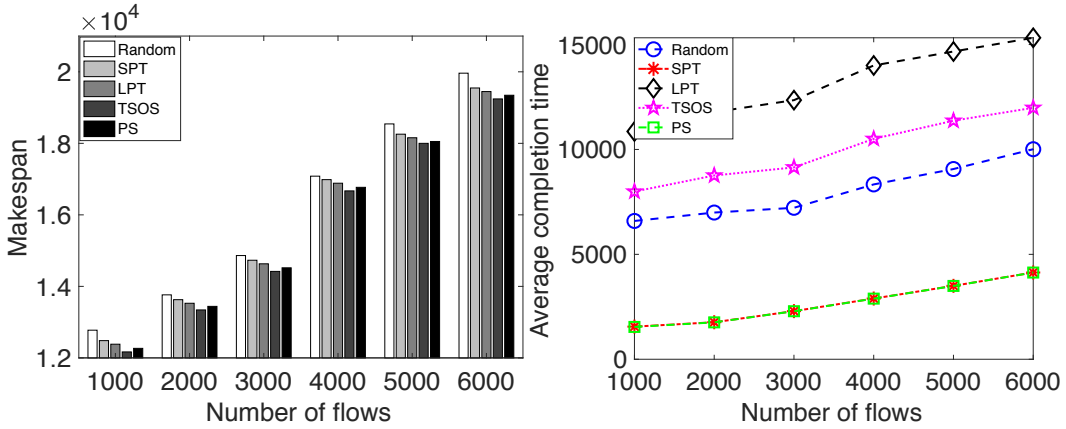
	Two middleboxes	Multiple middleboxes
Makespan	TSOS	PS
Avg completion time	SHA	PHS

Simulation settings

- Facebook data center flow distribution
  - #flow: ranging from 1000 to 6000
- Service chain
  - Include two or six middleboxes
  - Flow processing time ranging from 2 to 10
- Link transmission delay
  - Ranging 1 to 10

Simulation Results

A service chain with two middleboxes

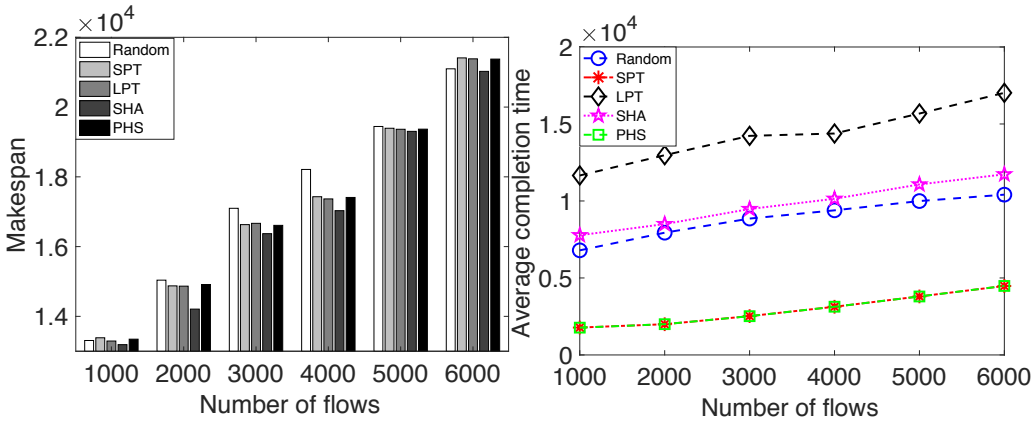


(a) Makespan. (b) Average completion time.

- TSOS achieves the smallest makespan because of its optimality in a service chain with only two middleboxes
- PS has the lowest average completion time
- The total processing time is important for minimizing the average completion time

Simulation Results

A service chain with six middleboxes



(a) Makespan. (b) Average completion time.

- Performance difference is not obvious
- Average completion time is larger than two middleboxes with the same number of flows
- SHA performs best in makespan while PHS is the best in average completion time

6. Conclusion and Future Work

- Flow contention on the same service chain
- Objectives on flow completion times
  - Makespan
  - Average completion time
- Solutions
  - With only two middleboxes
    - optimal solutions
  - With multiple (>2) middleboxes
    - heuristic solutions
- Future Work
  - Performance-guaranteed solution
  - Statistic processing time model

Questions contact:

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