Dynamic Controller Provisioning in Software Defined Networks

Presented By

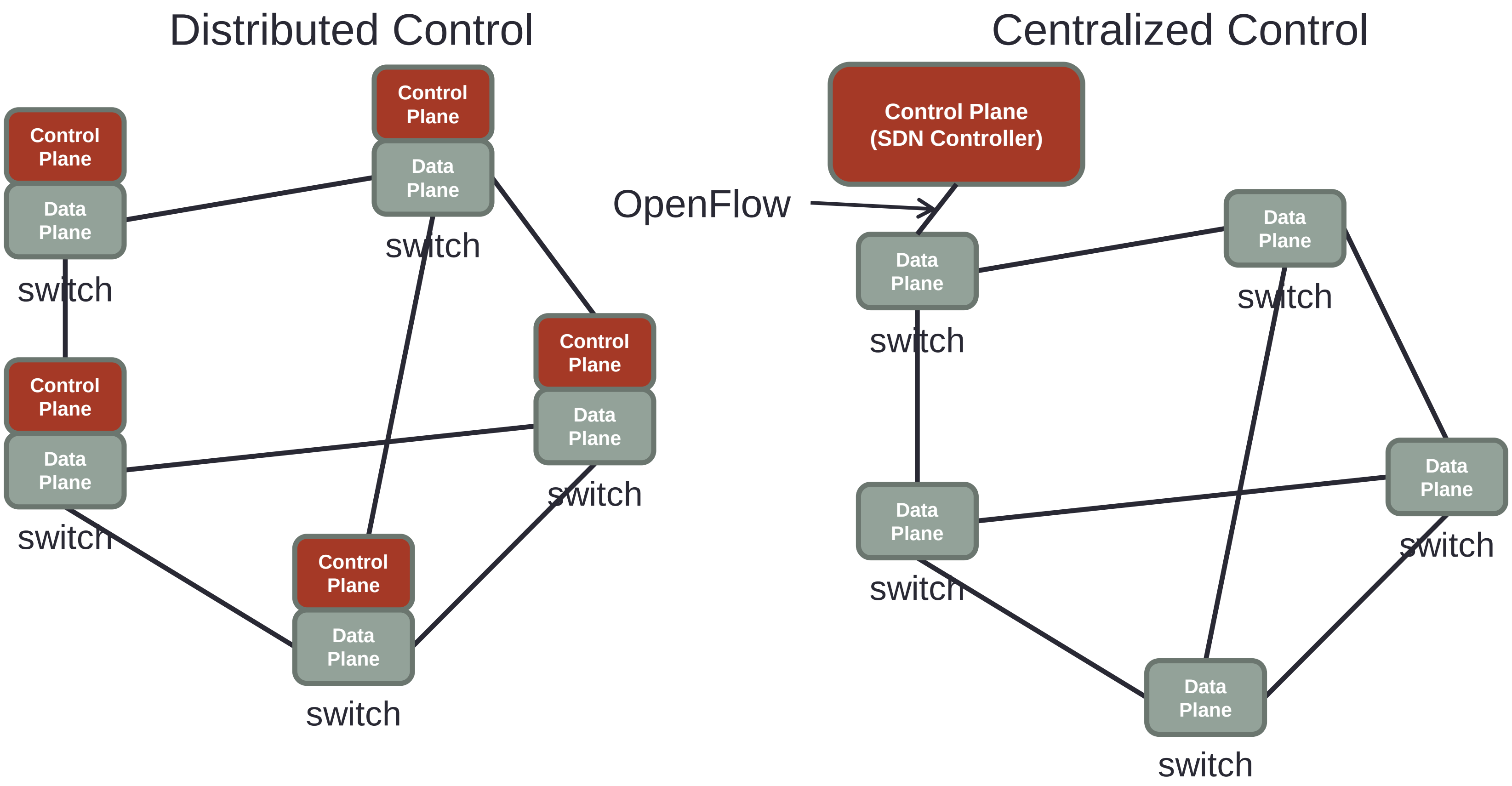
Md. Faizul Bari
David R. Cheriton School of Computer science
University of Waterloo

with *Arup Raton Roy, Shihabur Rahman Chowdhury, Qi Zhang, Mohamed Faten Zhani, Reaz Ahmed, and Raouf Boutaba,*

Outline

- Overview of SDN
- Motivation
- Proposed management framework
- Problem formulation
- Proposed heuristics
- Simulation results
- Conclusion & future work

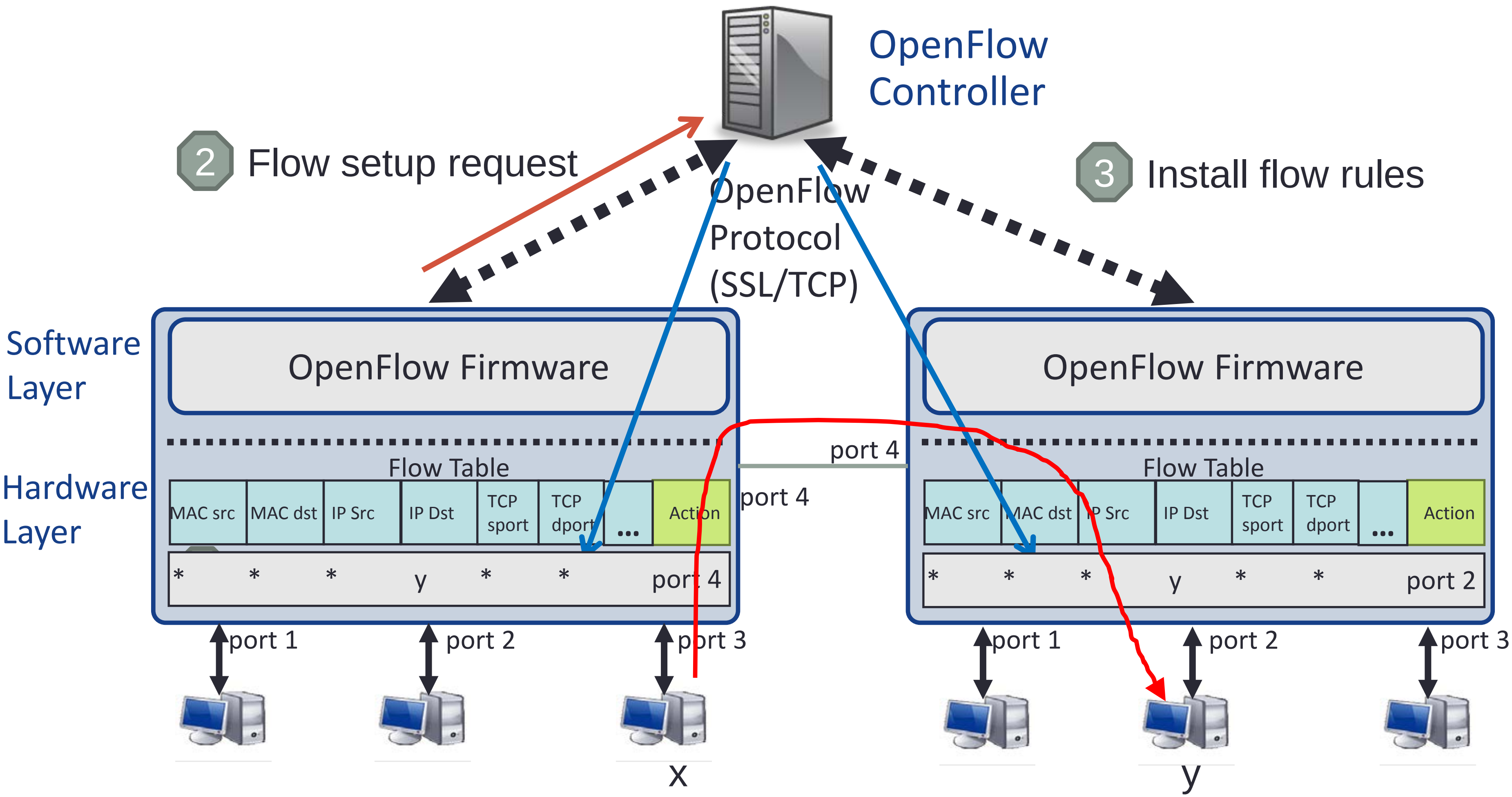
Traditional vs. Software Define Networking



Traditional Networking

Software Defined Networking

SDN and OpenFlow



Flow setup time: time needed to set up the rules associated with a new flow in switches involved in the routing path.

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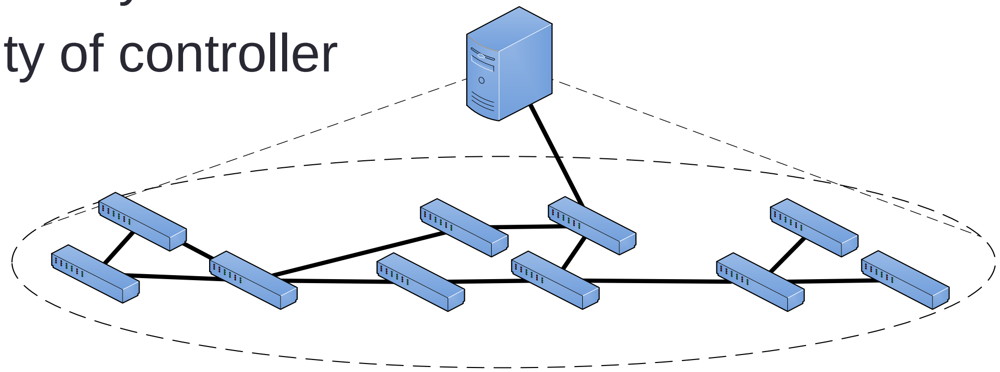
Traditional SDN with a Single Controller

- A single controller controls all switches in the network
- Advantages:
  - Centralized control
  - Ease of management
  - Network-wide view
- Disadvantages:
  - High switch-to-controller latency
  - Limited processing capacity of controller

  →Higher flow setup time

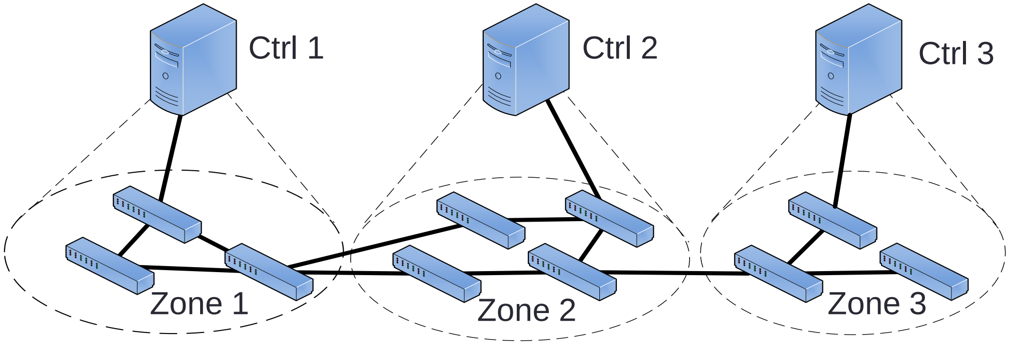


Multiple Controller

- Each controller controls a subset of the switches
- A switch communicates with just one controller
- Advantages:
  - Less processing capacity is required for each controller
  - Lower switch-to-controller latency
- Disadvantages:
  - Require state synchronization between controllers

  → Large control traffic overhead
  - Static switch-to-controller assignment

  → Overloaded controllers



Dynamic Controller Provisioning Problem (DCPP)

- Dynamically provision controllers based on
  - Changing network conditions (traffic dynamics)
  - Switch-to-controller latency requirement
- Goals
  - Dynamically decide the number of controllers and their locations
  - Minimize flow setup time and control traffic
  - Minimize switch-to-controller reassignments

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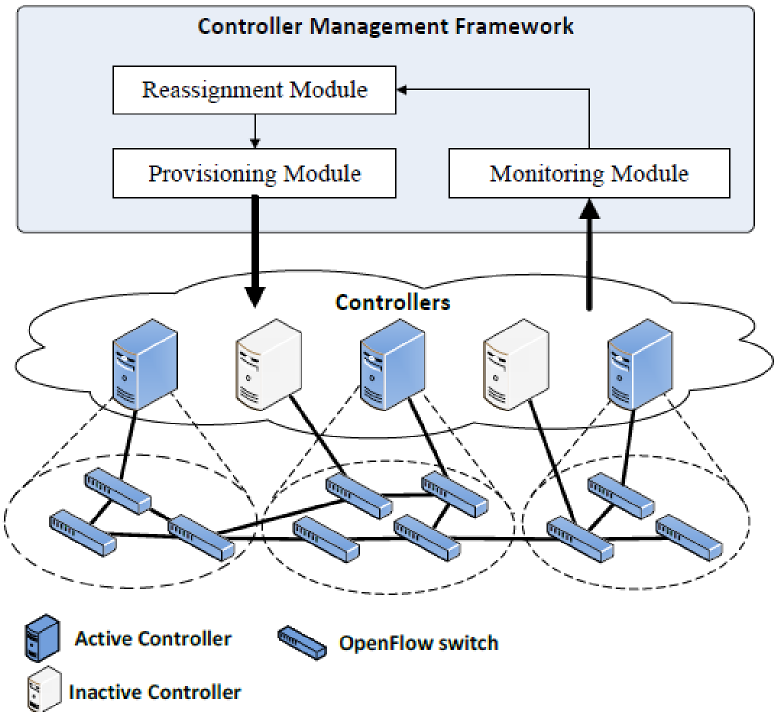
Management Framework



- Monitoring Module
  - Monitors controllers and collects statistics about the traffic
- Reassignment Module
  - Decides the number of controllers, their locations and the switch-to-controller assignment based on network conditions
- Provisioning Module
  - Provisions controllers and assigns switches to them

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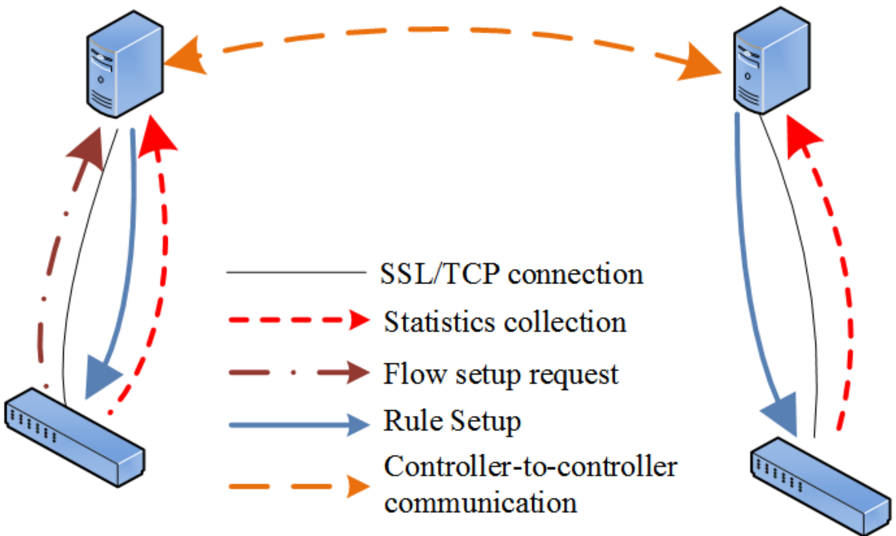
Problem Formulation

- DCPP can be formulated as an ILP
- Objective function

$$\textbf{Minimize } \alpha C_l + \beta C_p + \gamma C_s + \lambda C_r$$

- Where
  - C_l = Statistics collection cost
  - C_p = Flow setup cost
  - C_s = Synchronization cost
  - C_r = Switch reassignment cost
- Constraints
  - Controller capacity constraint
  - Switch-to-controller delay constraint



→ DCPP is NP-hard.

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Proposed Heuristics

- We propose two heuristics to solve DCPP
  - Greedy Knapsack based (DCP-GK)
  - Simulated Annealing based (DCP-SA)

- DCP-GK provides quick but inferior solutions
- DCP-SA provides good solutions, but requires longer time to find solutions

Greedy Knapsack Based (DCP-GK)

- Each controller is modeled as a knapsack
  - Capacity of the knapsack = number of flow-setups/sec
- Each switch is an object to be included in a knapsack
  - Weight = number of flow setup requests/sec
  - Profit = Inverse of switch to current controller's distance
- Procedure
  1. Repeat the following steps until either all switches are assigned to a controller or the controller set is exhausts
     - Step 1: Pick the controller with minimum total distance from all switches
     - Step 2: Use Greedy Knapsack approach to assign unassigned switches to the controller (subject to delay constraint)
  2. Randomly assign the remaining switches

Simulated Annealing Based (DCP-SA)

- DCPP is solved in two phases:
  - Phase 1: find a feasible assignment from the current one
    - For each overloaded controller
      - Select the switch sending maximum requests to it
      - Assign the switch to the most underused controller if the delay and capacity constraint are satisfied
      - Otherwise provision a new controller
    - Repeat until capacity and delay constraints are satisfied for all controllers
  - Phase 2: optimize the assignment by local search moves
    - Relocate switch
    - Swap switches
    - Activate a new controller
    - Merge controllers

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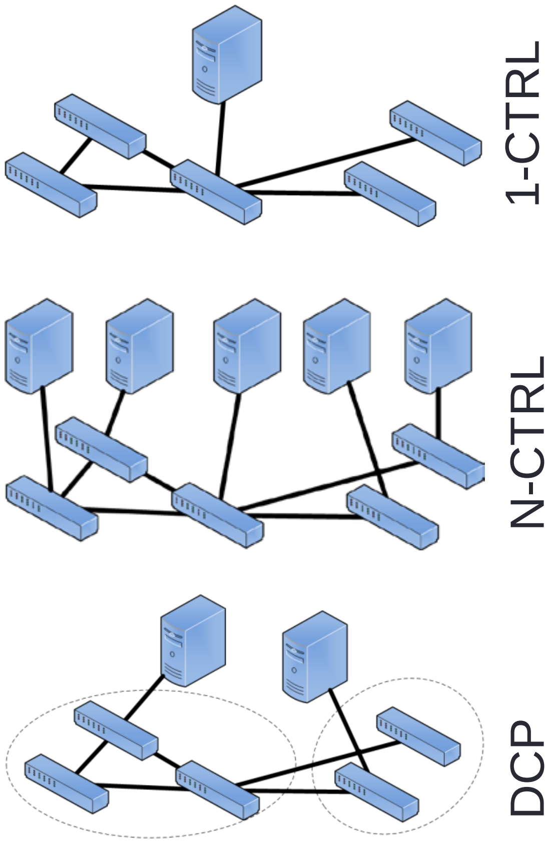
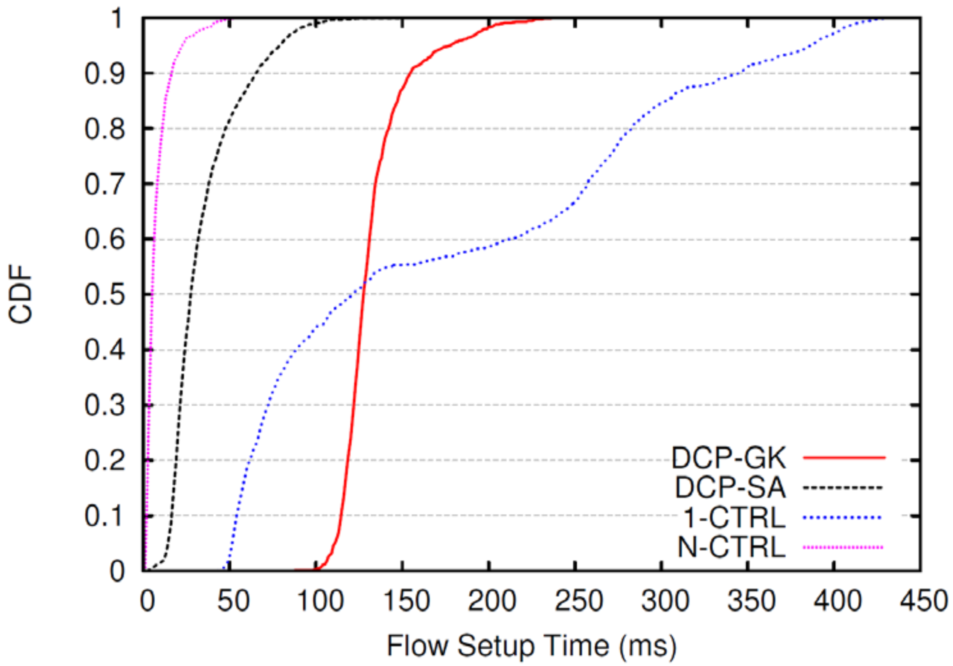
Simulation Results

- We consider 3 scenarios
  - 1-CTRL: A single controller for all switches
  - N-CTRL: One controller for each switch
  - DCP: Dynamic controller provisioning
- Topology
  - 108 nodes, 306 links (from RocketFuel [1])
- Traffic
  - Based on a realistic traffic trace [2]
  - End-to-end TCP flows



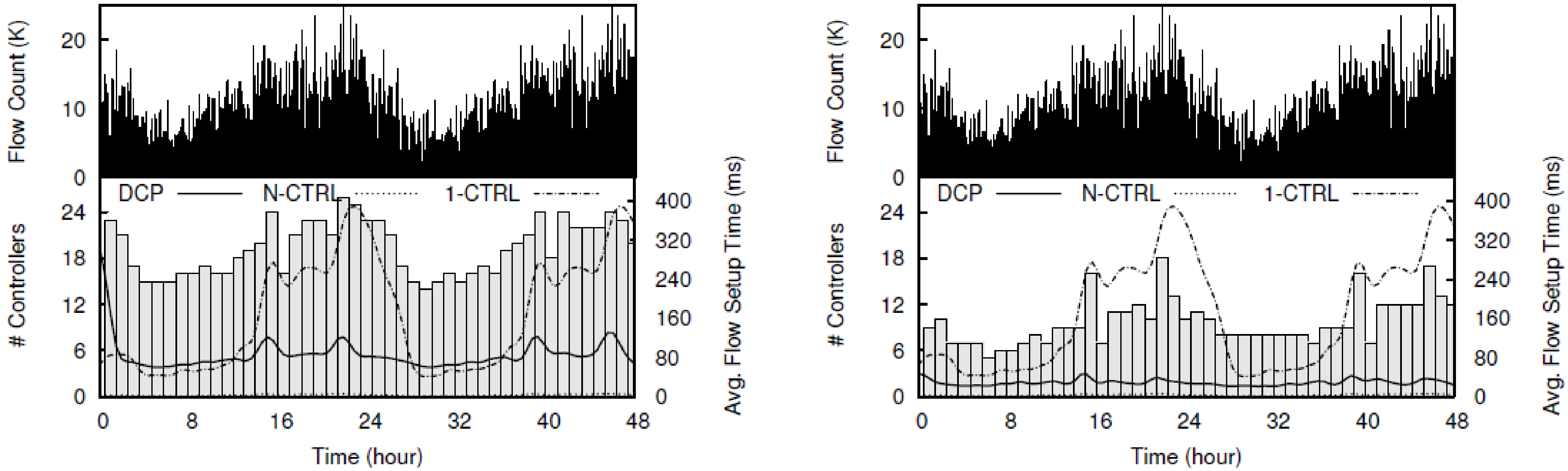
[1] N. Spring, R. Mahajan, and D. Wetherall. Measuring ISP topologies with rocketfuel. In SIGCOMM 2002, pages 133–145.
[2] S. Gebert, R. Pries, D. Schlosser, and K. Heck. Internet access traffic measurement and analysis. In Traffic Monitoring and Analysis, volume 7189 of LNCS, pages 29–42. 2012.

Flow-setup Time CDF



- N-CTRL provides minimal flow-setup time
- DCP-GK and DCP-SA both are better than 1-CTRL
- DCP-SA performs better than DCP-GK

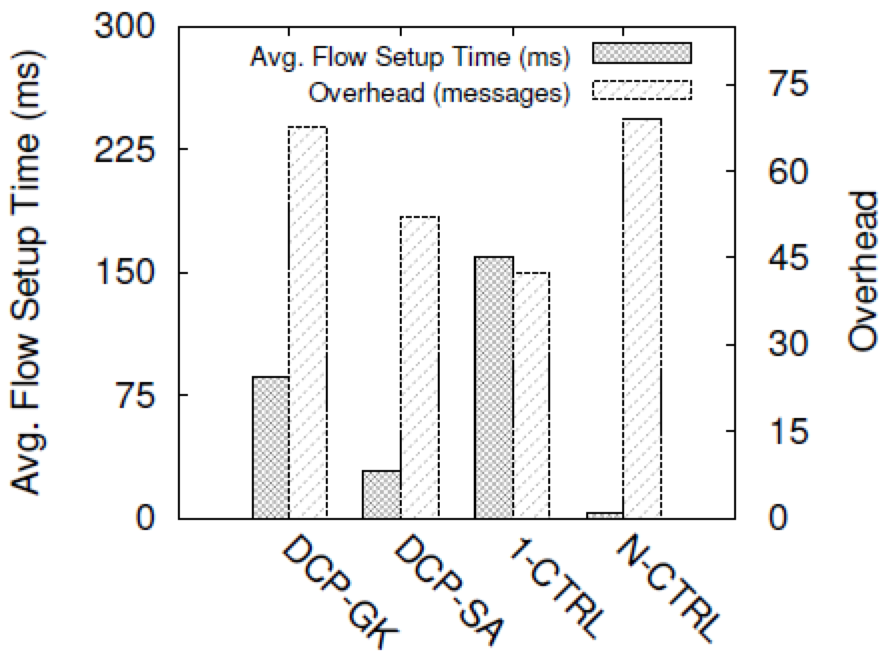
Number of Controllers and Flow-setup Time



(a) DCP-GK on RF-I (b) DCP-SA on RF-I

- DCP-SA required less controllers than DCP-GK
- In case of 1-CTRL flow-setup time varies with traffic
- DCP-GK and DCP-SA adapt to traffic changes

Summary of Overhead and Flow Setup Time



- N-CTRL has lowest flow-setup time, but largest overhead
- 1-CTRL has lowest overhead, but highest flow-setup time
- DCP-SA performs much better than DCP-GK

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Conclusion

- We identified the Dynamic Controller Provisioning Problem (DCPP)
- Proposed a management framework for dynamically deploying multiple controllers
- Provided a mathematical formulation of DCPP as an ILP
- Proposed two heuristic algorithms to solve DCPP
- Identified the trade-off between flow-setup time and communication overhead

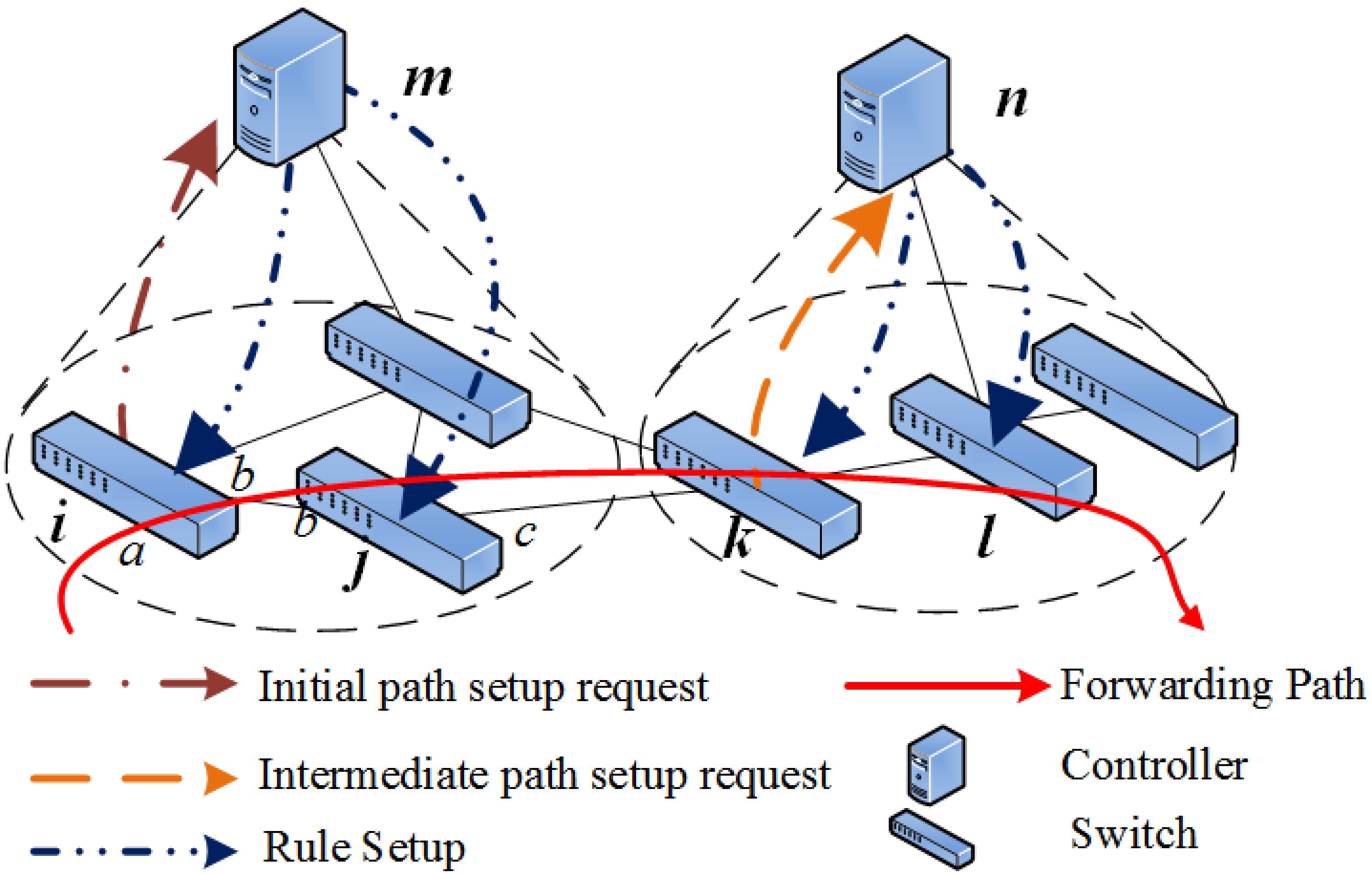
Future Work

- Improve the convergence time of DCP-SA
  - Generate quick solutions using DCP-GK and then optimizing them using DCP-SA.
- Explore other heuristic algorithms
- Perform experiments on a real testbed
  - Distributed OpenFlow Testbed (DOT) [dothub.org]

Questions?

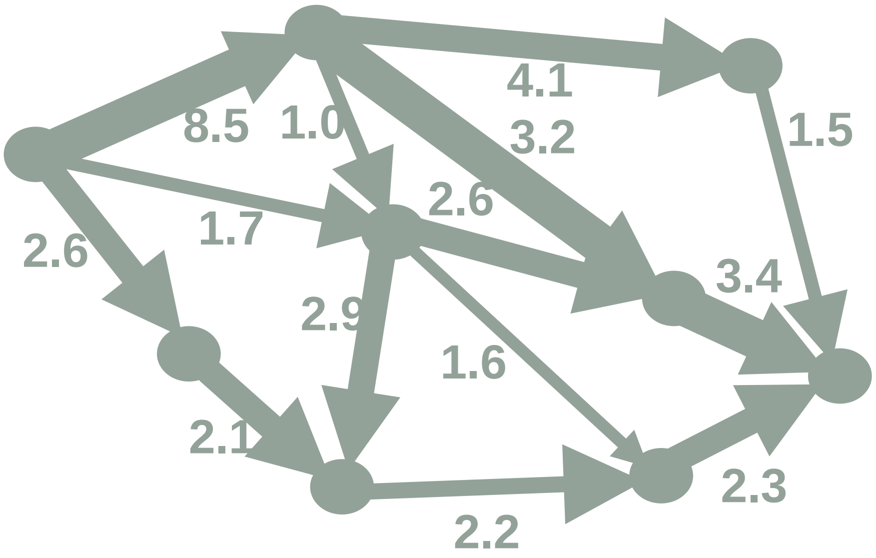
Background Slides

Path Setup Model



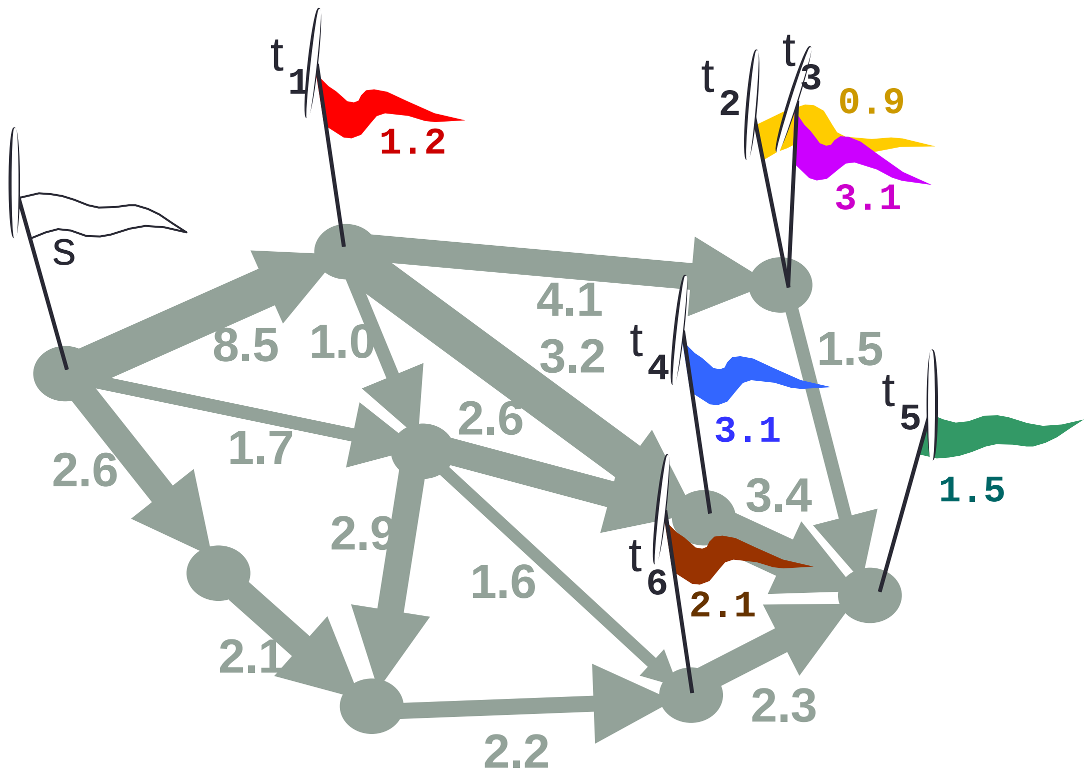
Single-source Unsplittable Flow Problem

- Directed graph G(V,E)
- Capacity on edges $\quad c : E \rightarrow \mathbf{R}^{+}$



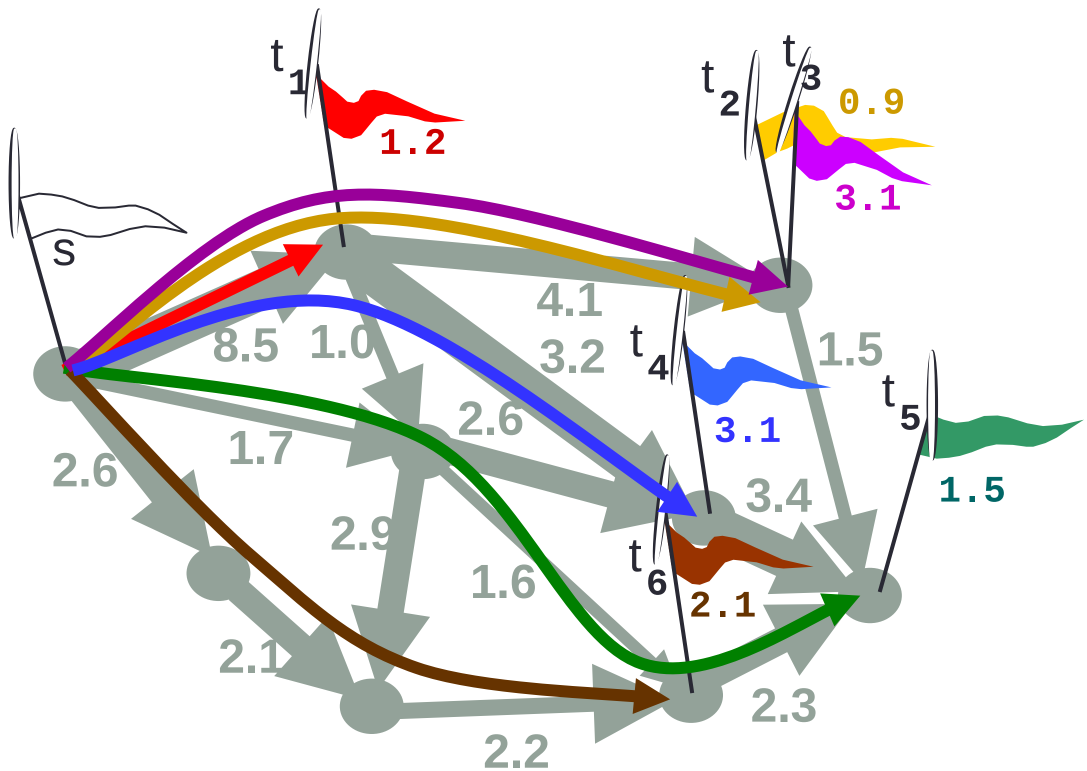
Single-source Unsplittable Flow Problem

- A single source s and k terminals t_i with demands $d_i \in \mathbf{R}^+$
- A vertex may contain an arbitrary number of terminals

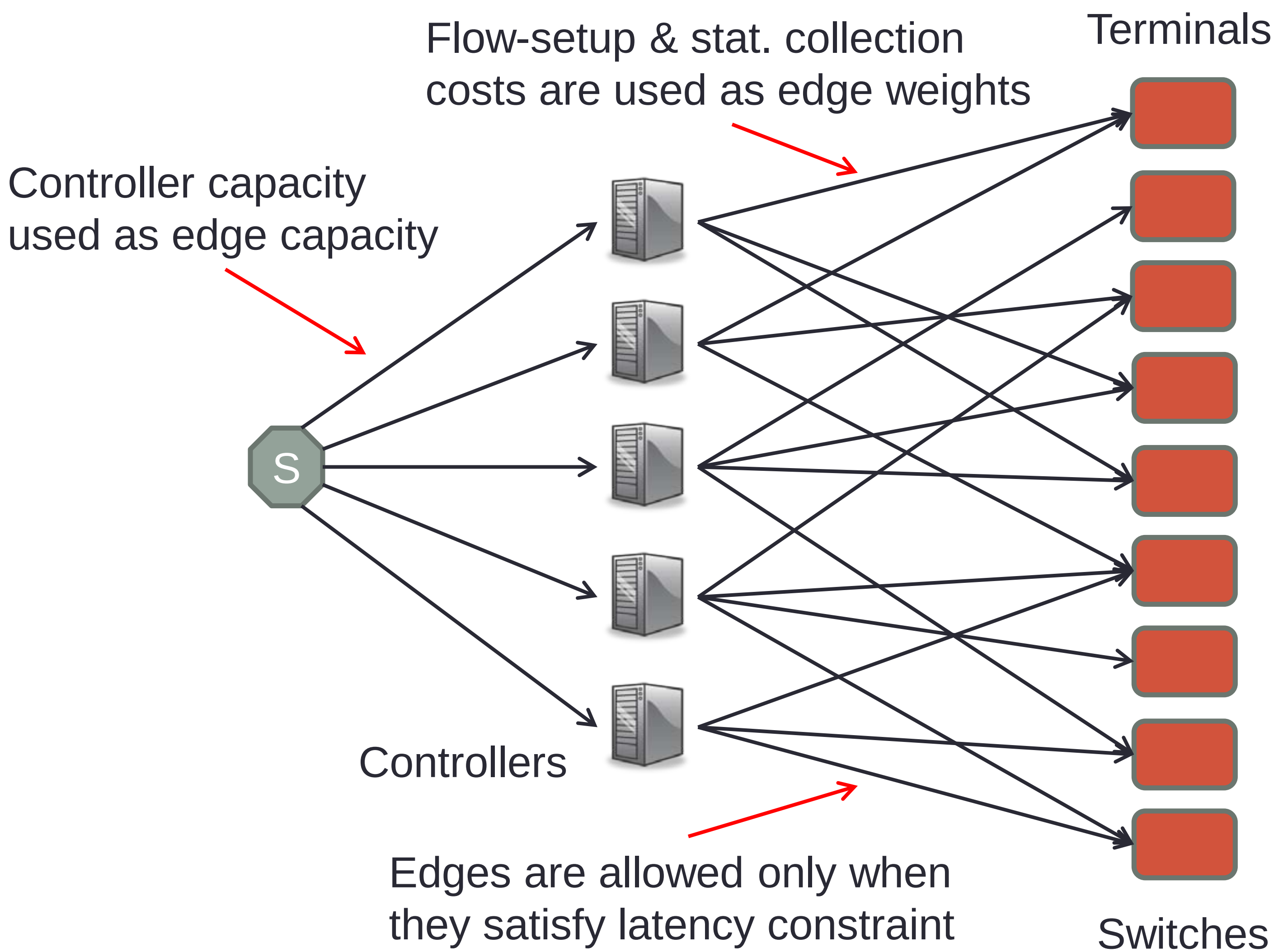


Single-source Unsplittable Flow Problem

- Each commodity flows along a single path from *s* to t_i (*unsplittable*)
- Must satisfy edge capacity
- There are many variabltions of this problem
- In our case, we minimize the sum of edge weights



DCPP → SSUFP


Flow-setup & stat. collection
costs are used as edge weights
Terminals
Controller capacity
used as edge capacity
S
Controllers
Edges are allowed only when
they satisfy latency constraint
Switches