Towards Cost-Effective SDN Controller Solution

SDN RG

Marcelo Santos (mabs@cin.ufpe.br)

Stenio Fernandes (sflf@cin.ufpe.br)

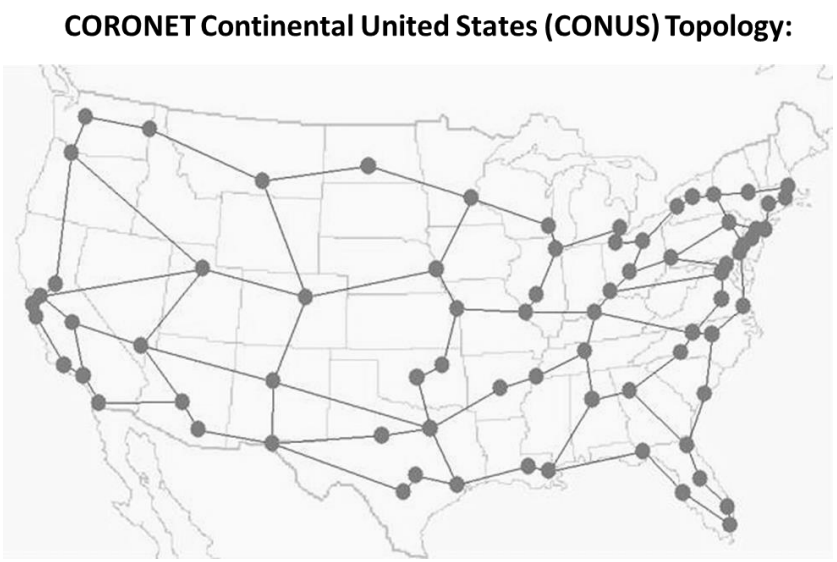
Federal University of Pernambuco,
Recife, Brazil

Agenda

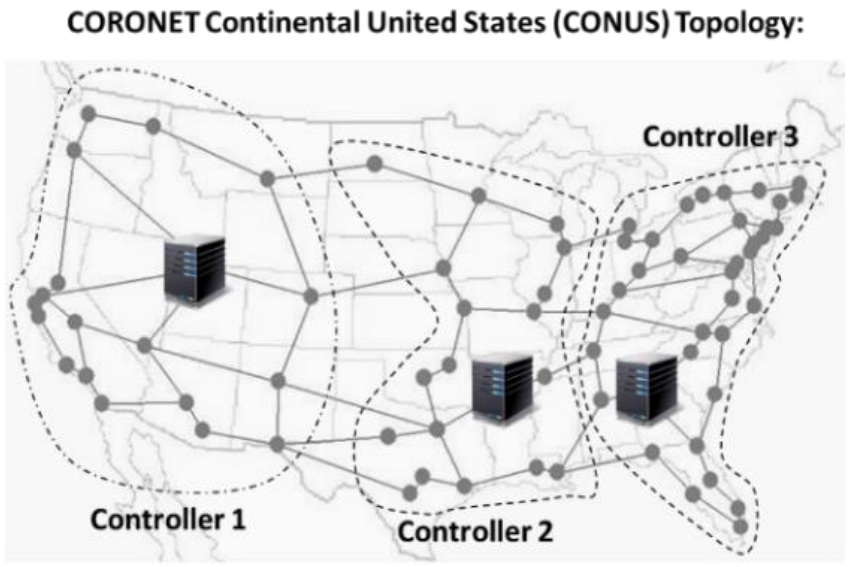
- Discuss the SDN Controller Placement Problem (CPP)
- Introduce other SDN Placement problems
- Present a model applied to CPP
- Conclude remarks and future work

SDN Placement Problem

- How many controllers are required



(a)



(b)

- Where to place them
- What is the controller domain (switches controlled by each controller)

In this context, are there other SDN placement problems to be analyzed?

SDN * Placement Problem

- SDN…
  - Controller Placement Problem:
    - Defines how many controllers should be deployed in the network and where
  - Hypervisor Placement Problem[1]:
    - A hypervisor acts as an intermediate layer between the tenant SDN controllers and their respective virtual SDN networks. How many hypervisor instances are needed? Where should the hypervisor instances be placed in the network?
  - Rule Placement Problem[2]:
    - A rule placement solution defines which rules must be deployed in the network and where

[1] Blenk, A. *et al.* "Survey on Network Virtualization Hypervisors for Software Defined Networking", *Communications Surveys & Tutorials, IEEE,* Firstquarter 2016

[2] Nguyen, Xuan-Nam, et al. "Rules Placement Problem in OpenFlow Networks: a Survey." (2016).

What is the objective of our model?

Model

- Our objective is to **minimize** the deployment cost while considering several constraints

- **Investigate** features of real network backbone topologies that affect the SDN controller deployment cost

Model

Objective: Minimizing the controller placement cost

i. Calculate the number of controllers and their respective position
ii. Assign a set of switch to a SDN controller
iii. Estimate the capacity of each SDN Controller -> the cost (software + hardware)

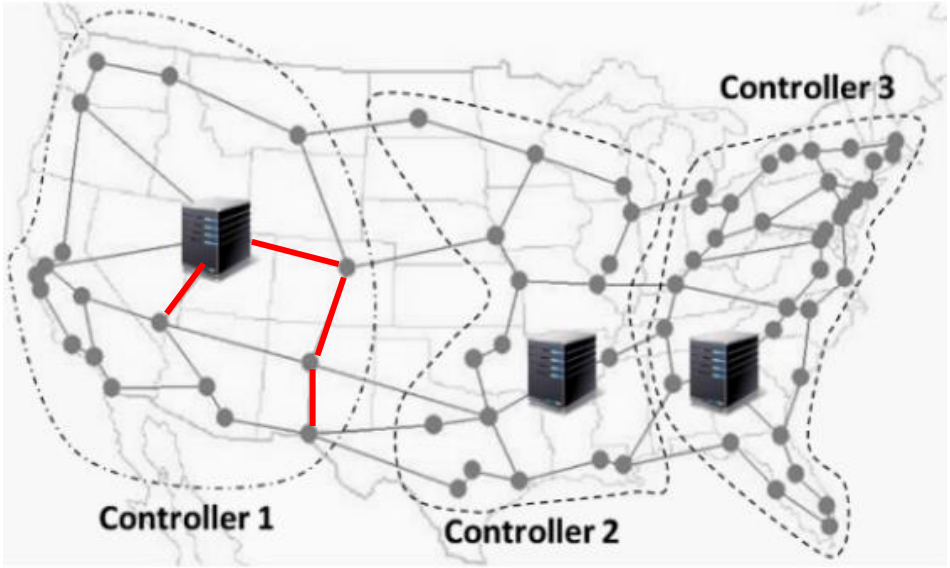
Cost = total controller cost to cover the network

Model

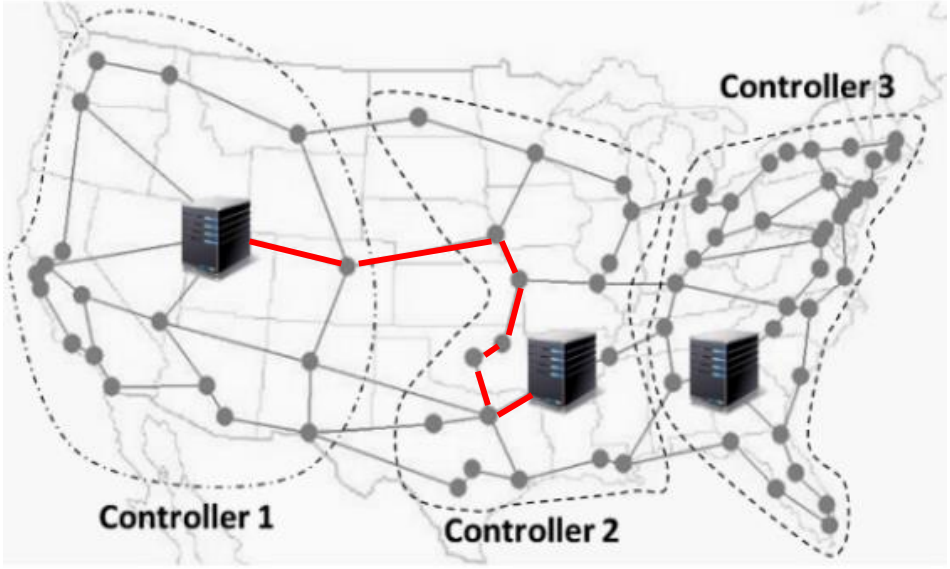
Constraints:

i. Flow setup time
ii. Delay between SDN Controllers
iii. SDN Controller Capacity

CORONET Continental United States (CONUS) Topology:

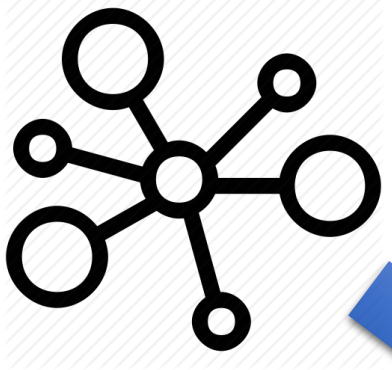


CORONET Continental United States (CONUS) Topology:



Model

Topology (links and nodes)



Parameters

Linear Programing (Model)
Solver: CPLEX

SDN Controllers Placement Solution

Methodology

- Topology-zoo currently has over 225 networks in its database.

Archived datasets used in publications can be found here
Source datasets can be found here
The graph and emulations for the European Interconnect model can be found here
Download current dataset as a zip archive.

Network (click for map)	Type	Geo Extent	Geo Location	Classification	Layer	Network Date	Download	Provenance	
AboveNet	COM	Country+	USA, Europe, Japan	Backbone, Customer, Transit	IP	2011_01	GML GraphML	Primary	
AGIS	COM	Country	USA	Backbone	IP	2011_01	GML GraphML	Secondary	No info - Layer 1 network?
Airtel	COM	Global	Global	Backbone, Customer, Transit	IP	2010_08	GML GraphML	Primary	
ANS	COM	Country	USA	Backbone	IP	2011_01	GML GraphML	Secondary	No info - Layer 1 network?
ATMnet	COM	Country	USA	Backbone	IP	2011_01	GML GraphML	Secondary	Bought out by Verio (ATMNet on Wikipedia)
ATT North America	COM	Country	USA	Backbone, Customer, Transit	IP	2007-2008	GML GraphML	Primary	
Bandcon	COM	Country+	USA, Europe	Backbone	IP	2011_01	GML GraphML	Primary	Now part of highwinds. Gray lines omitted as unclear what they

*http://www.topology-zoo.org/dataset.html

Evaluation

Factors	Unit	Levels	Value
Constraint between switches and controller	ms	8	25, 50, 75, 100, 125, 150, 175, 200
Topology (backbone)	-----	**112**	Networks from Topology-Zoo[1]
Controller Capacity	Flows (M)	3	**1, 2 or 4**
Controller Cost	USA Dollars ($)	3	**10.000, 15.000 and 20.000**

Parameters	Value
Switch Flow Load	70K
Constraint between controllers	200ms

[1]http://www.topology-zoo.org/dataset.html

Model (simplification)

We have nodes (switches) from 1 to j and k types of controllers

Decision variables:

$x_{kj} = if\ a\ controller\ of\ type\ k\ is\ deployed\ at\ j$ (binary variable)
y_{ij}=$if\ a\ switch\ i\ is\ controlled\ by\ a\ controller\ j$ (binary variable)

Notation:

$C_k = cost\ of\ SDN\ Controller\ of\ type\ k$

Model (simplification)

Objective function:

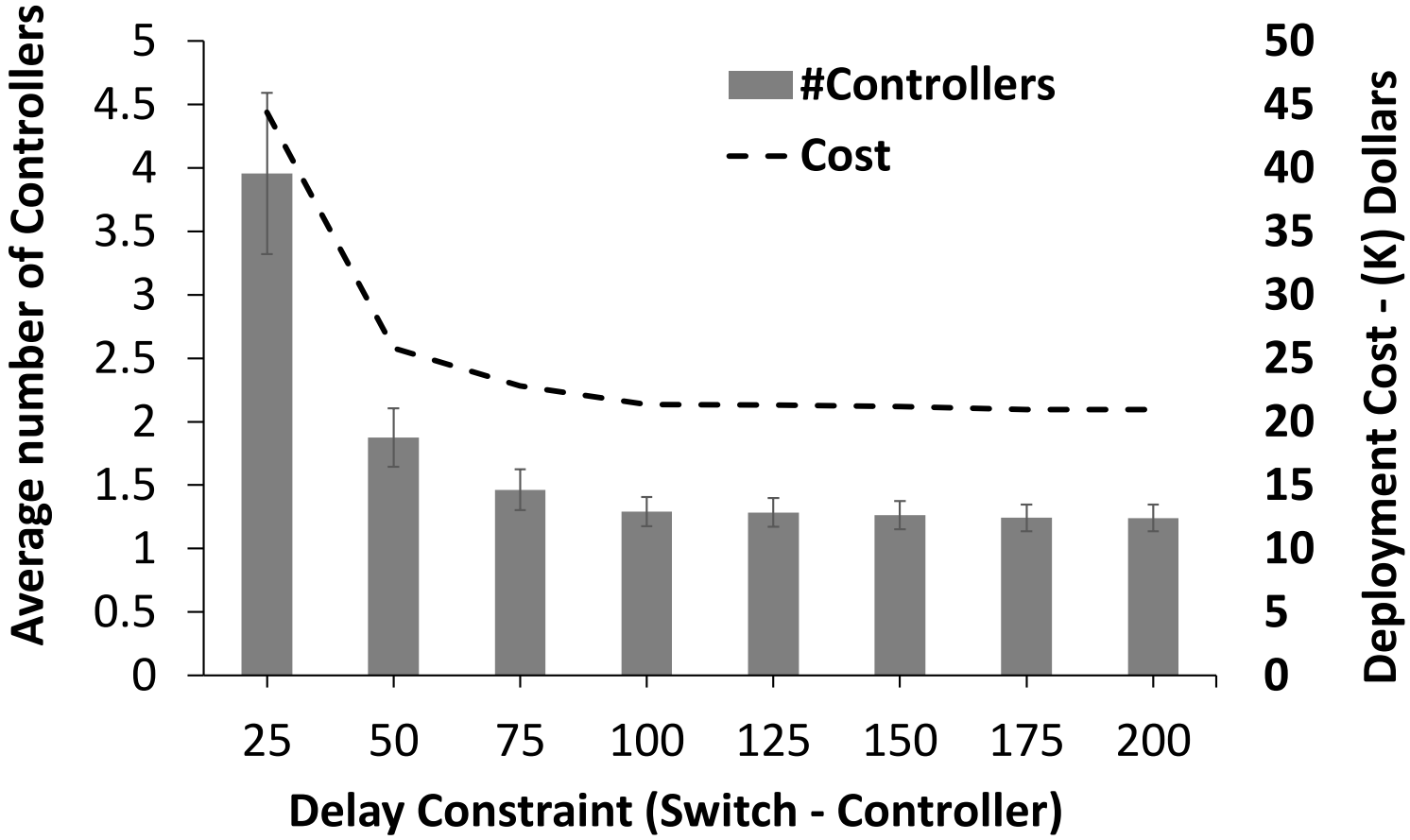
$$Min \sum_{k=1}^{M} \sum_{j=1}^{N} x_{kj} C_k \qquad (1)$$

Constraint:

$$\sum_{k=1}^{M} x_{kj} < 1, \qquad \forall j \qquad (2)$$

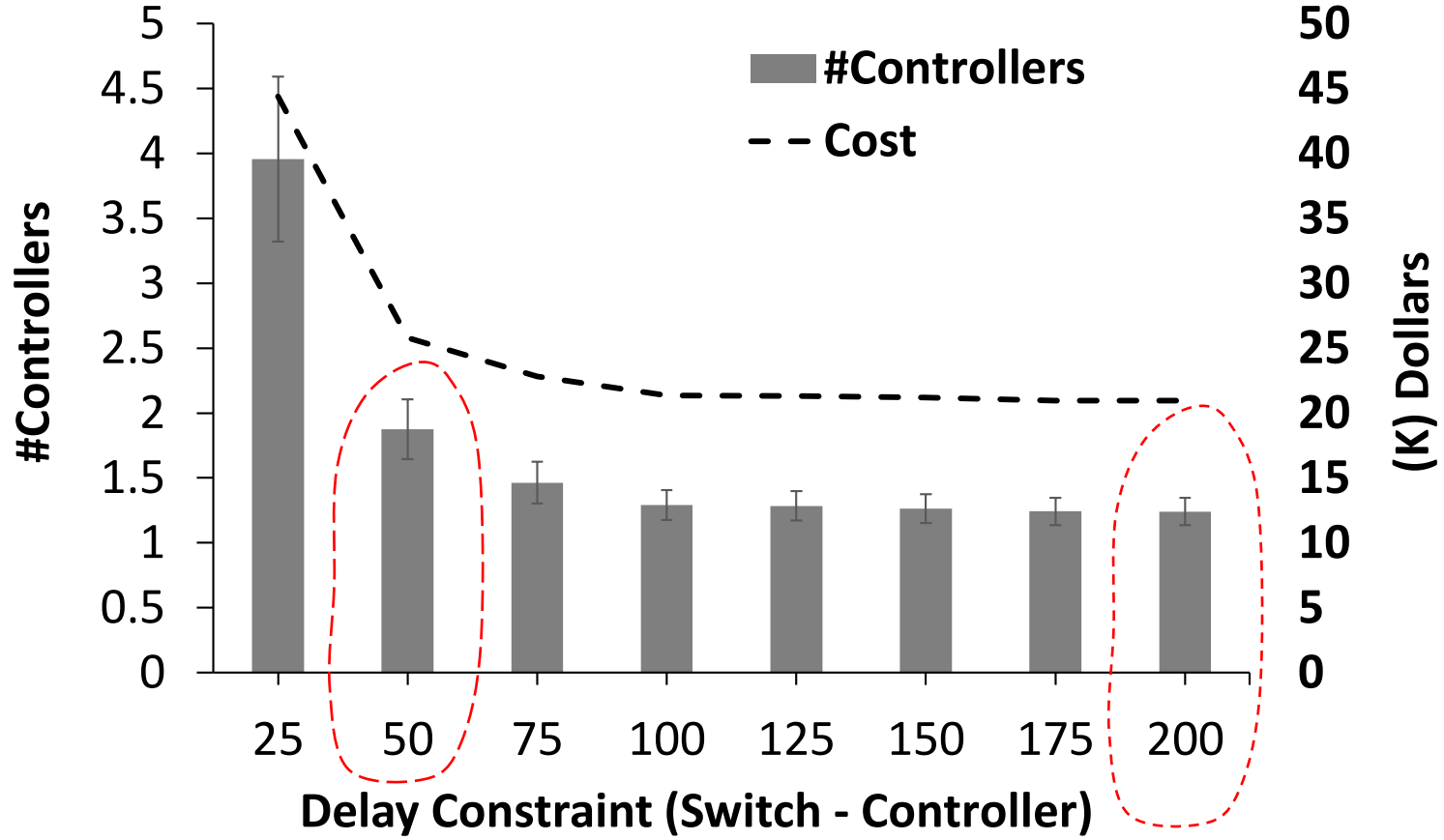
Results

- Number of controllers and cost



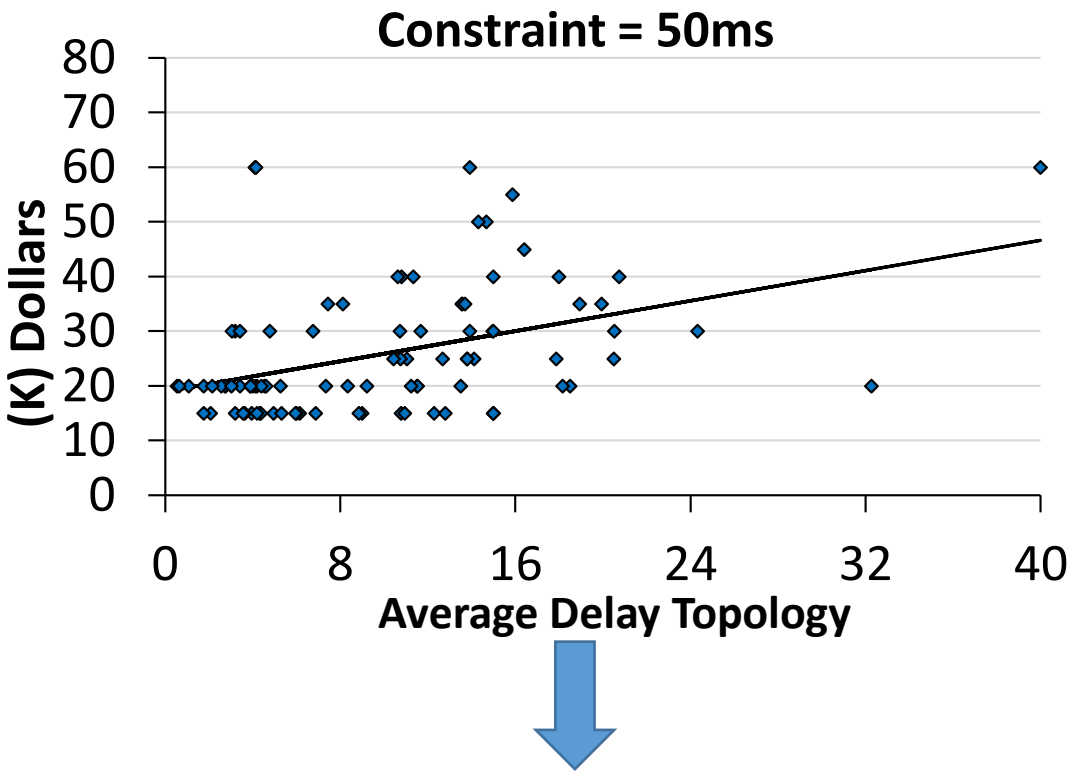
Results

- Number of controllers and cost

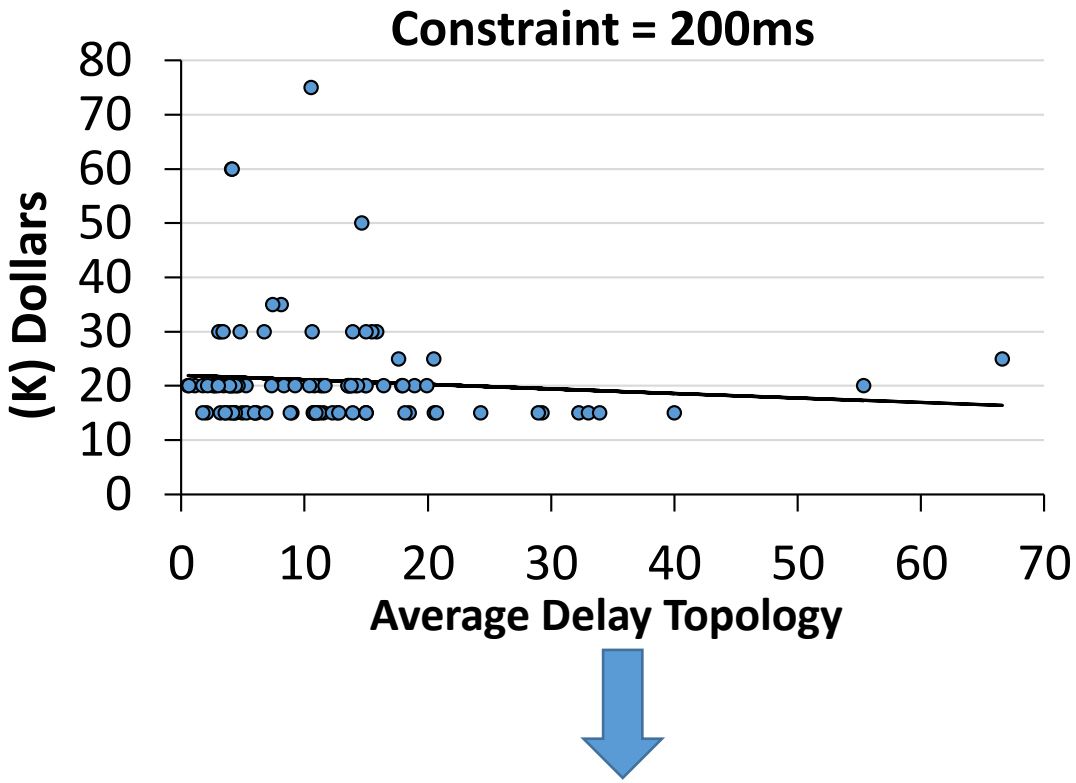


Results

- Correlation between cost and average topology delay



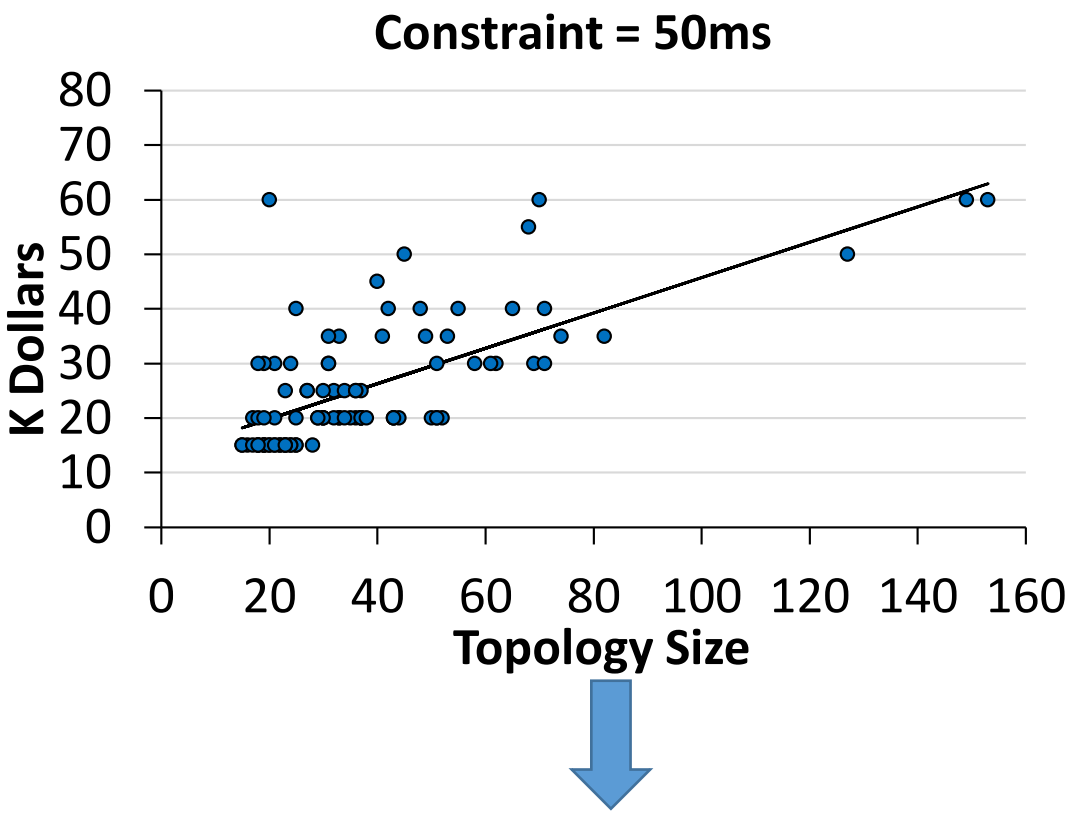
Correlation coefficient: 0.408



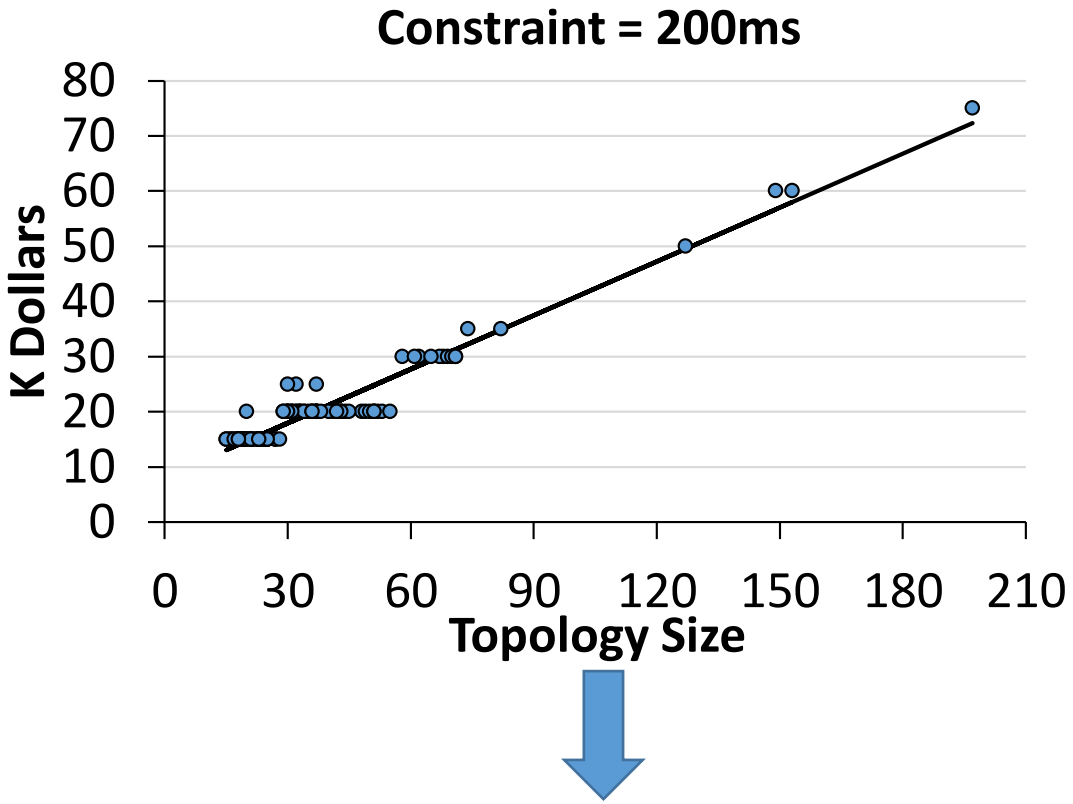
Correlation coefficient: 0.090

Results

- Correlation between cost and topology size



Correlation coefficient: 0.687365



Correlation coefficient: 0.971596

Conclusion

SDN Controller Placement Problem:

- Proposed a model based on Linear programming
- Results show that two controllers are enough to cover a backbone network
- We found no correlation between the average topology delay and the placement cost
- The delay constraint from a switch to a controller affects the correlation between topology size and cost.

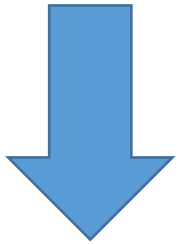
Future work

- Investigate placement techniques applied to SDN placement problems
- Draft: Overview of SDN Placement Problem - (Controller, Hypervisor, Rule)

Additional Slides

Results

(1) Constraint between controllers and (2) constraint between controller and switches



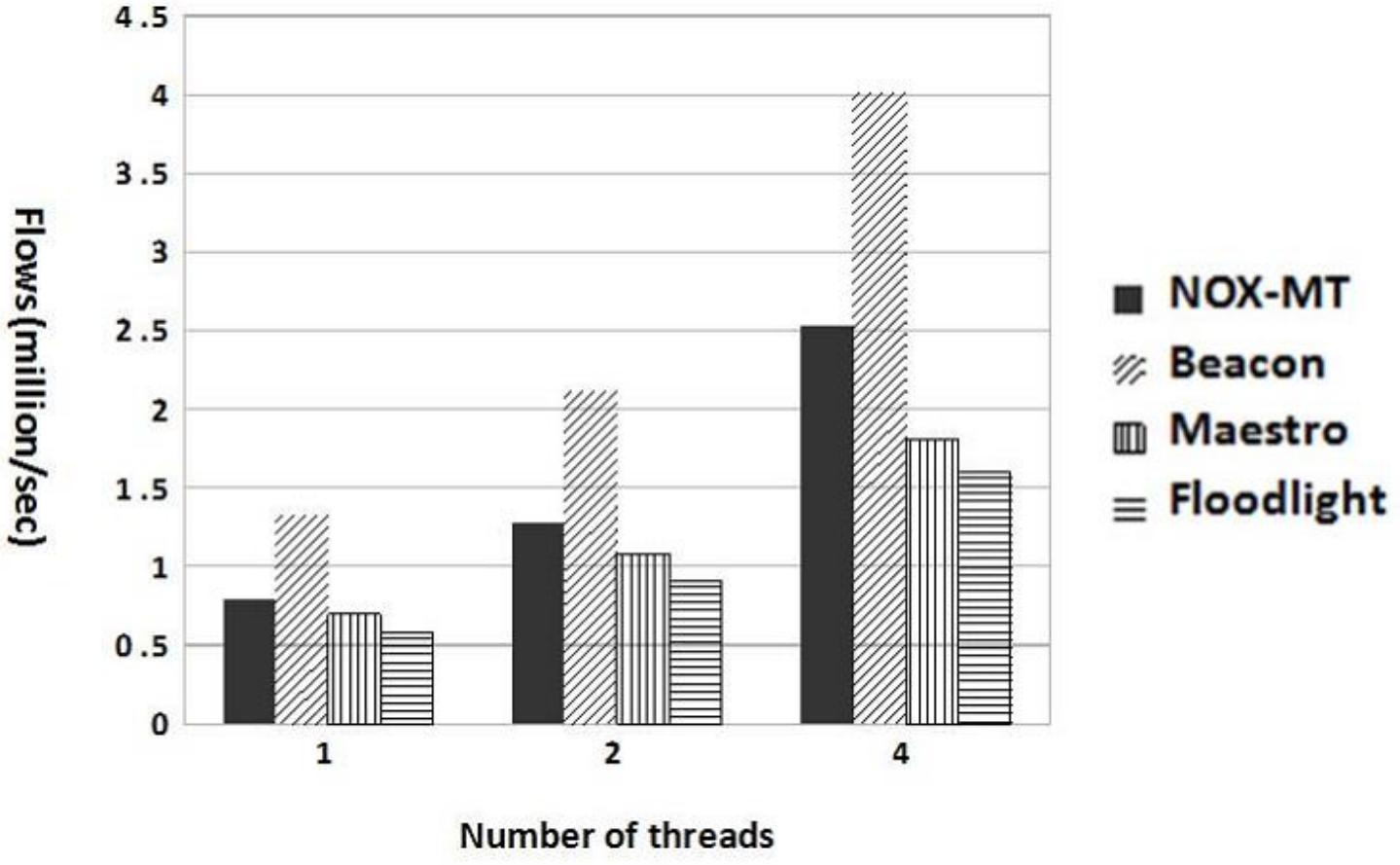
Around 12% of the problems were impossible to find a solution due to the delay constraints

Methodology

“Kandula et al. [9] found that a 1500-server cluster has a median flow arrival rate of 100k flows per second. Also, Benson et al. [2] show that a network with 100 switches can have spikes of 10M flows arrivals per second in the worst case[1]”

[1]http://research-srv.microsoft.com/pubs/138279/DC-Network-Characterization-imc2010.pdf

Methodology



*Shah, Syed Ahmar, et al. "An architectural evaluation of SDN controllers." Communications (ICC), 2013 IEEE International Conference on. IEEE, 2013.

SDN Placement Problem

Flow Setup Time:

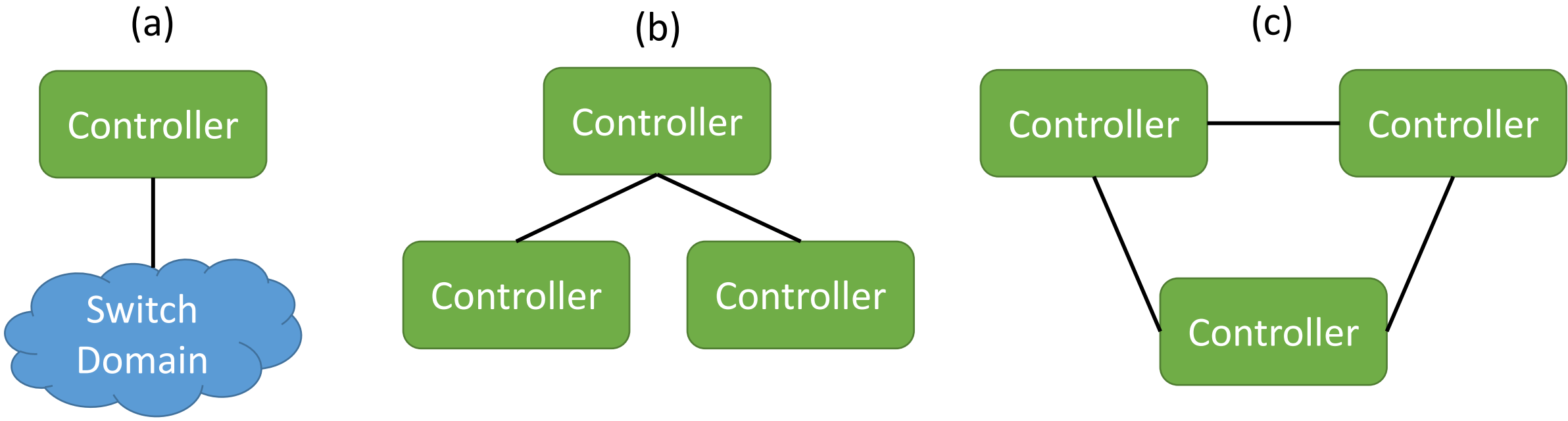
"Whenever a switch receives a new flow, it requests the controller to install appropriate forwarding rules along the desired flow path. The time required to complete this operation is known as the **flow setup time**[1]"

"The 10ms flow setup time of an SDN controller would add a 10% delay to the majority of flows (short-lived flows)[2]"

[1]"Revisiting the Controller Placement Problem" - Bari, Mf *et al*.
[2]"On Controller Performance in Software-Defined Networks" –Tootoonchian, A. *et al*.

SDN Controller Design

- How to connect SDN Controllers?



SDN Controller Design

- How to connect SDN Controllers?

- Synchronization cost (link load)
- Synchronization convergence time
- Availability