Bandwidth Reservation: Opportunities and Challenges

Presented by

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About Me

- I am an associate professor at Saginaw Valley State University (SVSU) in the Computer Science and Information Systems Dept. I am an IEEE senior member.

- I have published my research work in top-tier conferences, including ICCCN, GLOBECOM, NOMS, and LCN. I have received faculty grants from SVSU to support my research work.

Current projects

- Analyzing and designing bandwidth scheduling algorithms to support big-data transfer and high-end real-time multimedia applications in Software-Defined Networks (SDN) to provide enhanced Quality of Service to users' applications.
- Machine learning techniques to identify possible health issues by analyzing the patient records and provide recommendations to the physicians accordingly.

Outline

- Overview of our research problems
- Our contributions
- Our current research work and direction
- Conclusion

Overview of our research problems

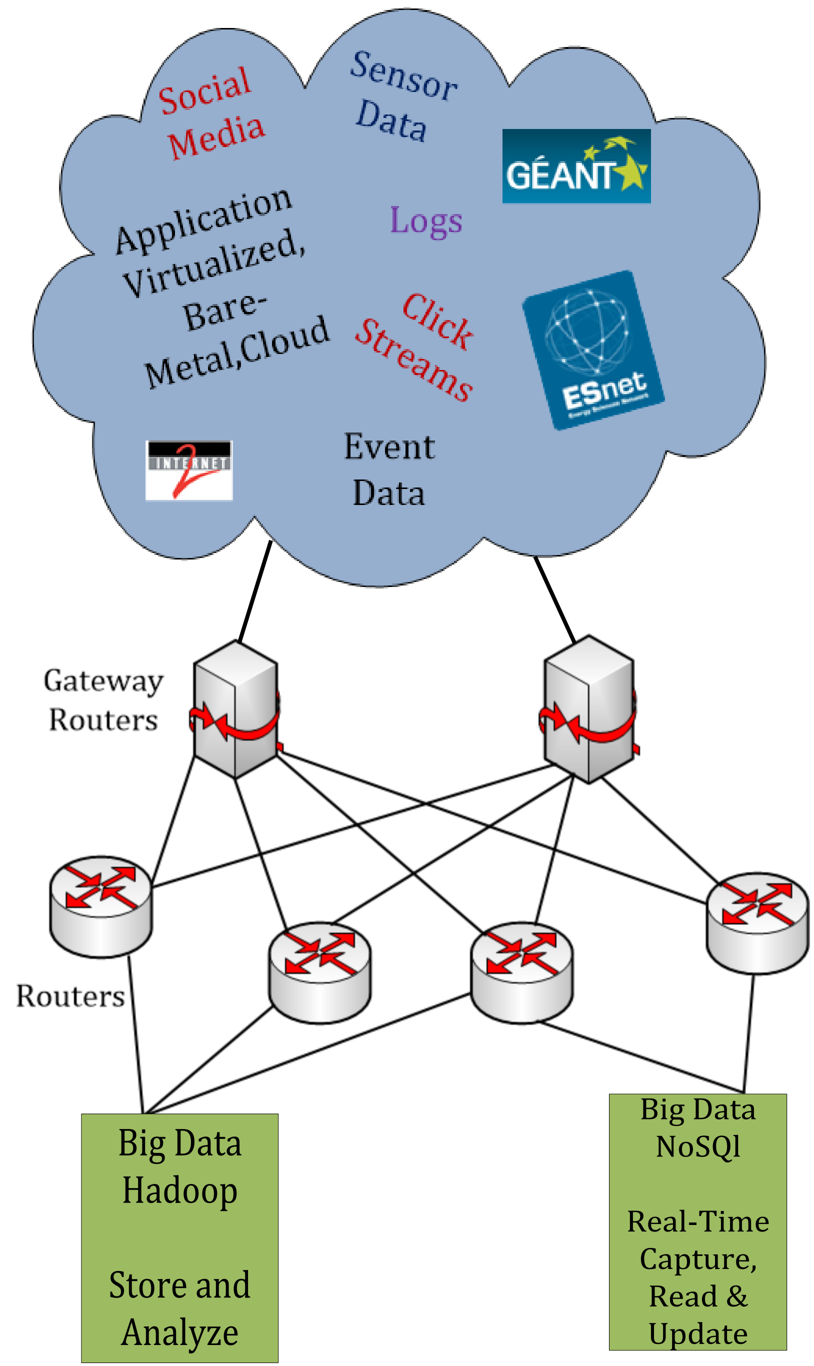
Big Data Transfer

Big Data

- Terabytes to petabytes of data
- Generated by many applications in different domains
- Used for online processing, analysis, and storage

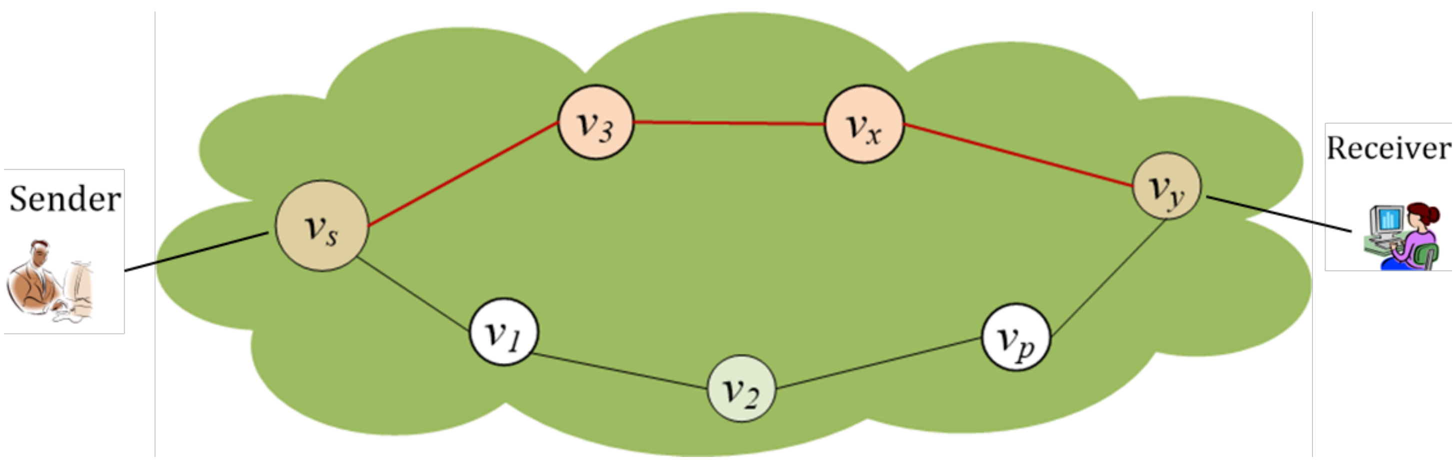
Network Requirements

- Availability
- Quality of Service
- Capable of provisioning dedicated paths with reserved networks resources



Solution:
Bandwidth Scheduling or Bandwidth Reservation

- Reserve bandwidth prior to data transfer



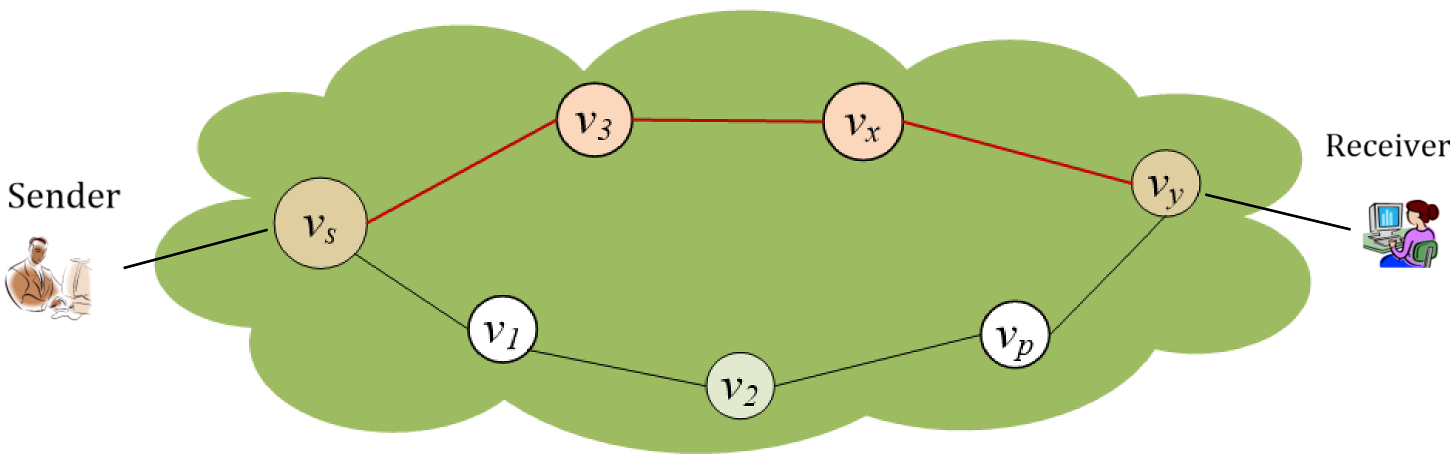
Solution:
Bandwidth Scheduling or Bandwidth Reservation

- Reserve bandwidth prior to data transfer
- Types of reservations:
  - Immediate Reservation (IR)
    - Reserve bandwidth immediately, and start data transfer
    - Immediate start time
    - Unknown duration
  - Advance Reservation(AR)
    - Reserve bandwidth ahead of time for a future time slot
    - Known start time and duration
- AR is given a higher priority than IR

Research Problem-1: Bandwidth Scheduling in Traditional Networks

Drawbacks:

- Poor network management
- No centralized network control



Research Problem-2: IR-preemption

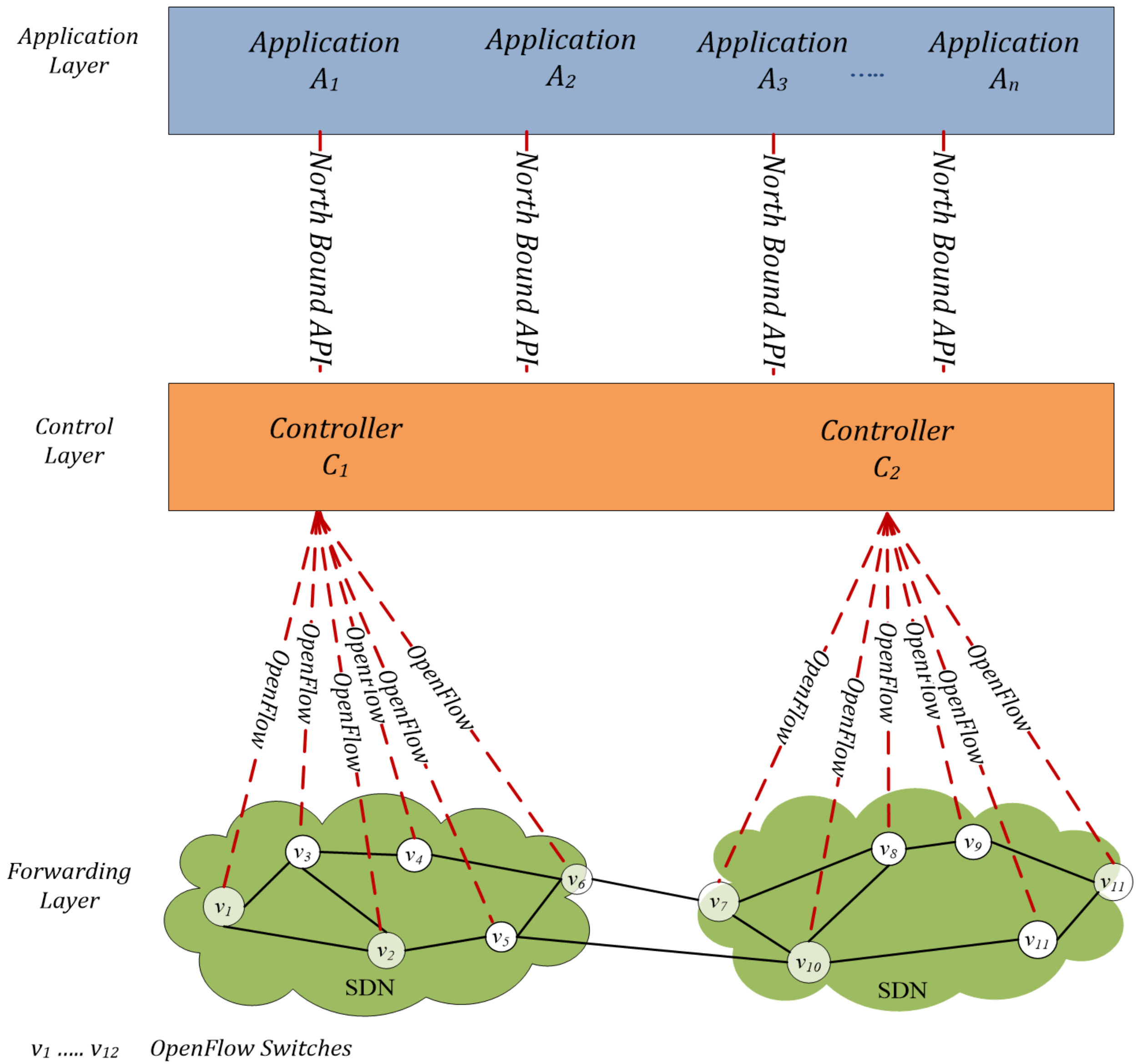
- **IR-based data transfer preempted due to high priority AR**
  - Soft Preemption

    Assigned to a lower priority, e.g. demoted to the best-effort traffic class
  - Hard Preemption

    Simply dropped completely

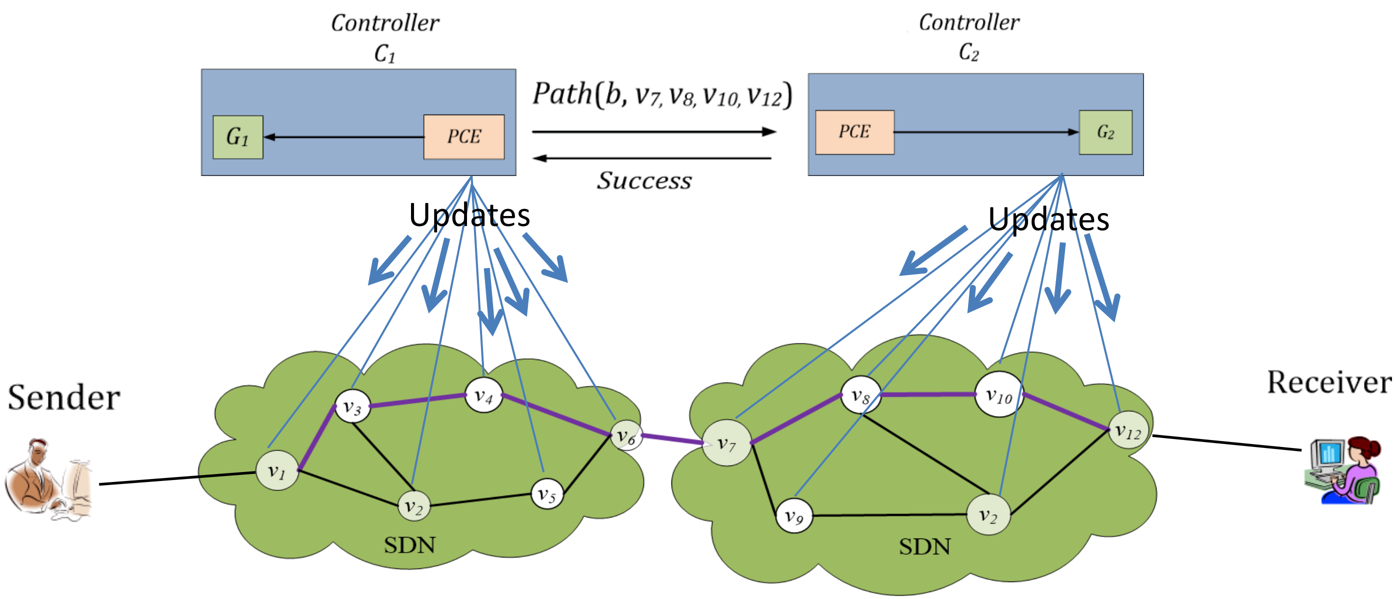
- **Preemption degrades the Quality of Service of network users**
  - Packets might be lost during transmission
  - Reduced reliability and security
  - Reduce network utilization
  - Nested preemption
  - Increased congestion

Software-Defined Network Architecture



Bandwidth Scheduling in Software – Defined Networks

G_1, G_2 GNV at C_1 and C_2 respectively
PCE Path Computation Element
$v_1 .. v_{12}$ OpenFlow Switches



Research Problem-3: Controller Failover in Distributed SDN

- When a controller in a domain fails, the control plane connectivity with the switches and neighboring domains is lost
- Detecting the failure of a controller and reassigning the orphaned switches, connected to the failed controller, to a neighboring one is necessary for the continuous operation of the network

Our Contributions

Contributions

- Minimized the number of preempted IR users
- Performed statistical analysis of the reservation dynamics
- Designed following schemes to route AR requests:
    - AR-BandwidthRouting
    - AR-DelayRouting
    - AR-DeadlineRouting
- Designed a preemption scheme, MinIRP-Preemption, to identify the minimum number of users to be preempted
- To propose an efficient framework to detect controller failure and redistribute the orphan switches, to multiple available controllers such that the total number of switches handled by each available controller is almost the same

AR-BandwidthRouting

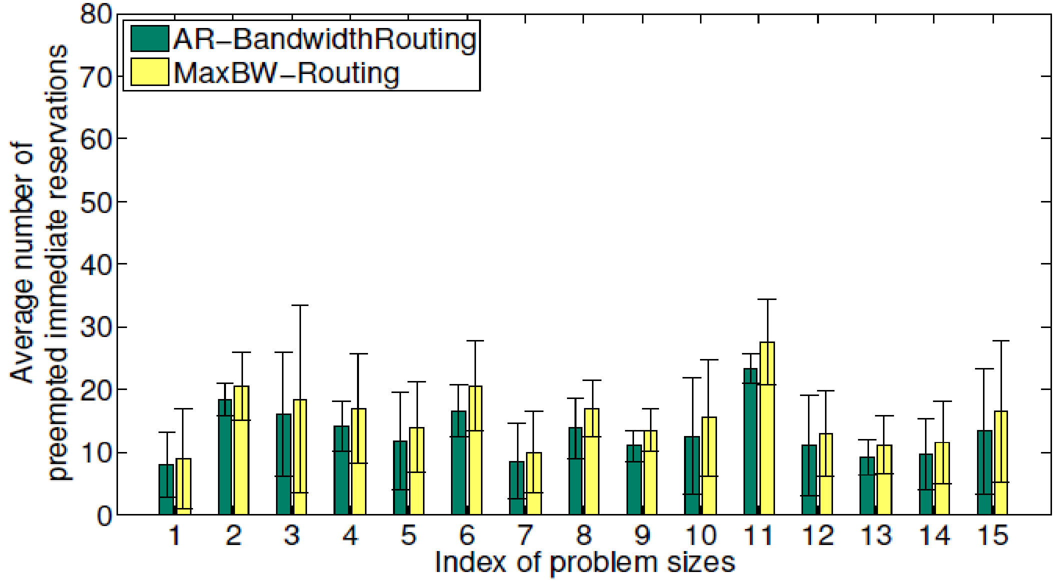
- **Input:**
  - Graph $G_j(V, E, B)$ at controller C_j
  - AR request $r^a(v_s^a, v_d^a, t_s^a, t_e^a, b^a)$
- **Output:**
  - Path p^a to route r^a successfully

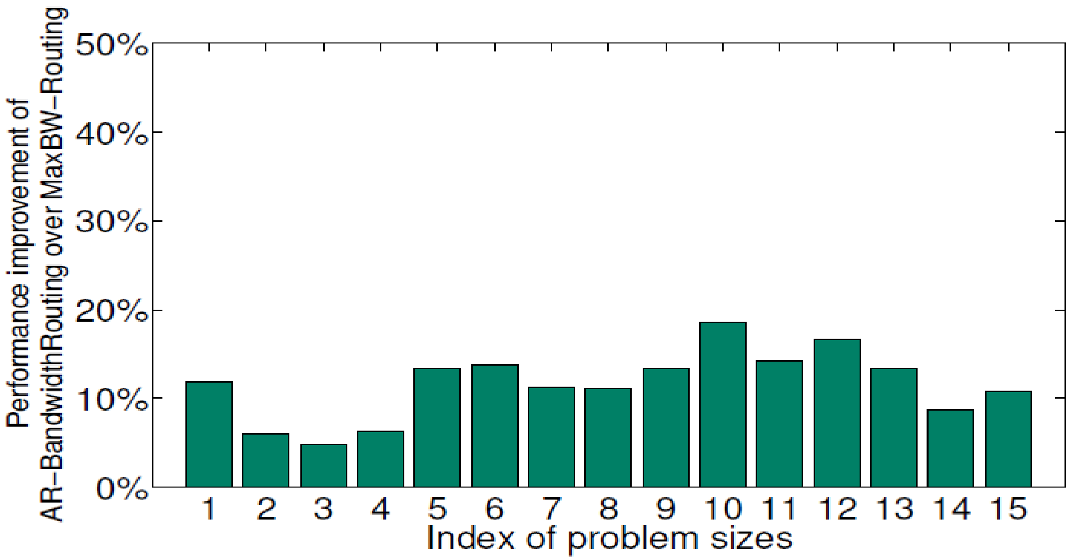
Simulation Setup

- The simulation considers
  - 15 network topologies
- Immediate Reservation request:
  - Single class of traffic
  - Average bandwidth demand of 25 Mbps
  - Transfer duration of 90 seconds
- Advance Reservation request
  - Random bandwidth demand
  - Random transfer duration.
- MaxBW-Routing
  - Employs Dijkstra's algorithm to find a routing path

Index of problem sizes	# of Nodes	# of Links
1	5	12
2	10	20
3	15	34
4	20	42
5	25	51
6	30	65
7	35	74
8	40	88
9	45	91
10	50	12
11	55	120
12	60	134
13	65	146
14	70	171
15	75	180

Simulation Results

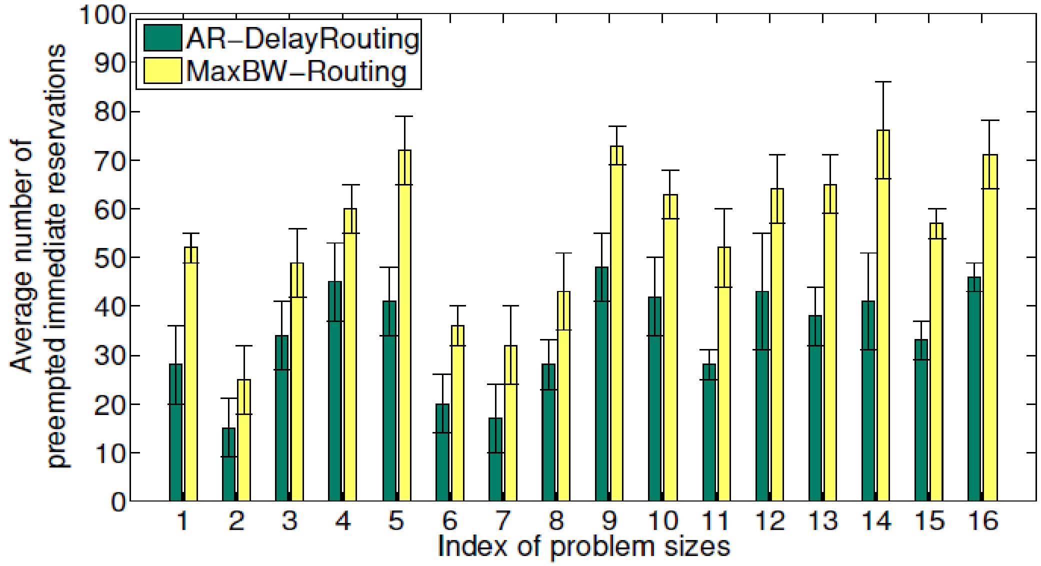


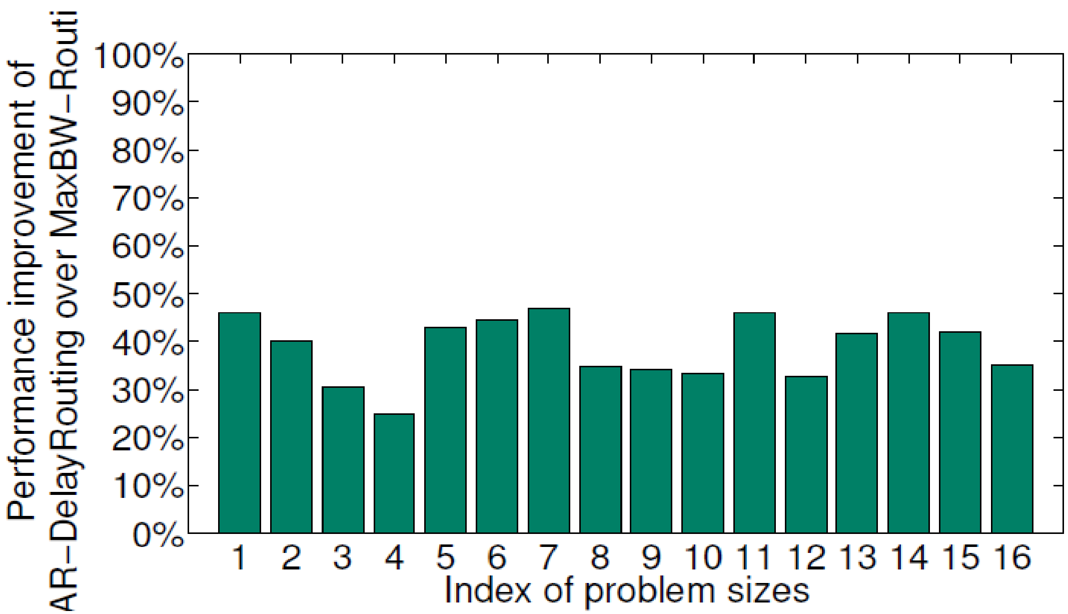


AR-DelayRouting

- **Input:**
  - Graph $G_j(V, E, B)$ at controller C_j
  - AR request $r^a(v_s^a, v_d^a, t_s^a, t_e^a, b^a, D)$
- **Output:**
  - Path p^a to route r^a successfully

Simulation Results





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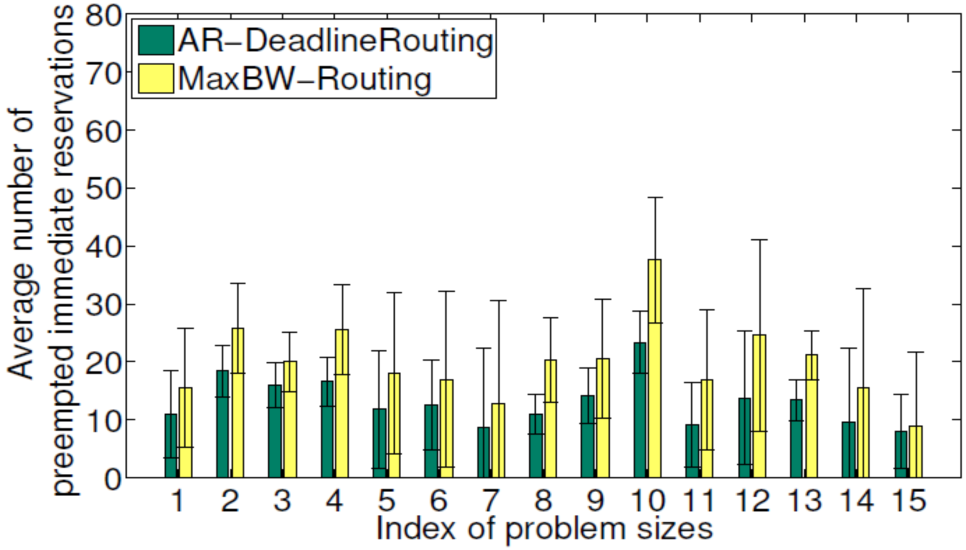
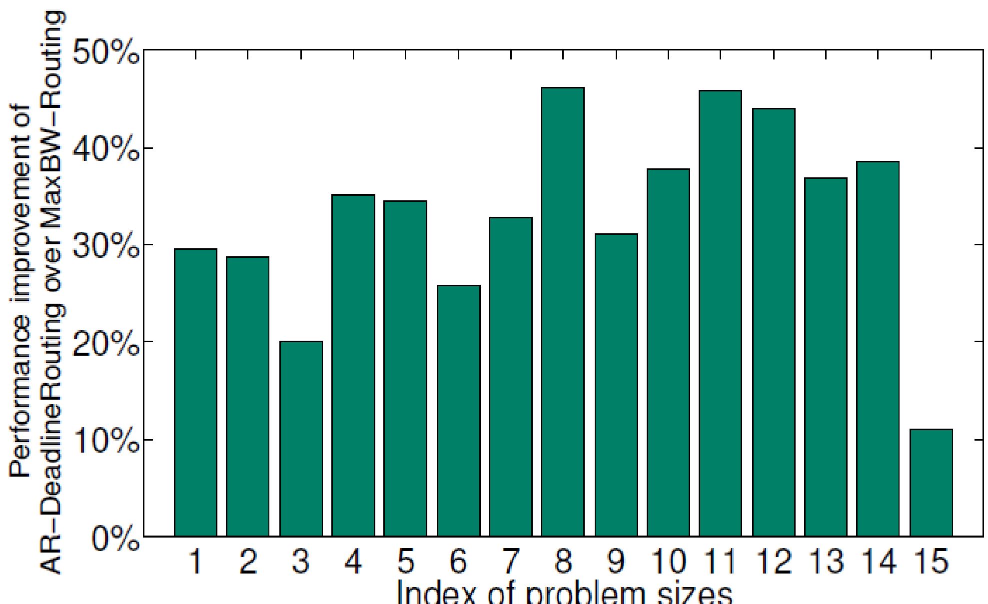
AR-DeadlineRouting

- **Input:**
  - Graph $G_j(V, E, B)$ at controller C_j
  - AR request $r^a(v_s^a, v_d^a, t_s^a, t_e^a, ð)$
- **Output:**
  - Path p^a to route r^a successfully

Simulation Results





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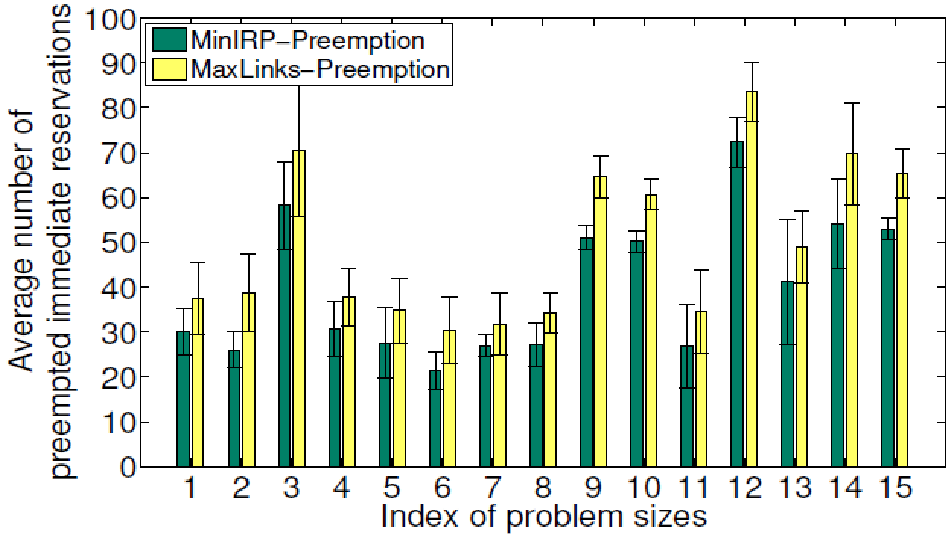
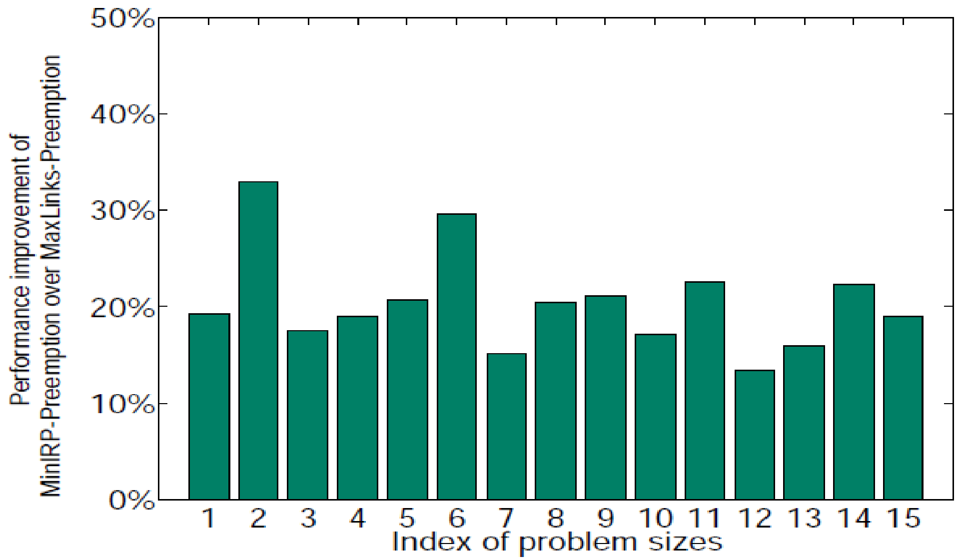
MinIRP-Preemption

- **Input:**
  - Graph $G_j(V, E, B)$ at controller C_j
  - AR request $r^a(v_s^a, v_d^a, t_s^a, t_e^a, \eth)$
  - Path p^a to route r^a
  - L^{need} - set of links with insufficient bandwidth at t_s^a
- **Output:**
  - R^{pre} - set of IRs to be preempted, such that r^a can be activated in G_j

Simulation Results





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AR-blocking

- Blocking of AR-based data transfer due to inconsistent/inaccurate Global Network View in SDNs with multiple controllers
- Blocking results in:
  - Increased overhead to establish connection
  - Nested blocking
  - Degraded Quality of Service
  - Reduced network utilization

Contributions

- **MinBlock-Routing**
  - Goal: Minimize the number of blocked users
  - Designed a periodic randomization based routing scheme to route a set of incoming AR requests

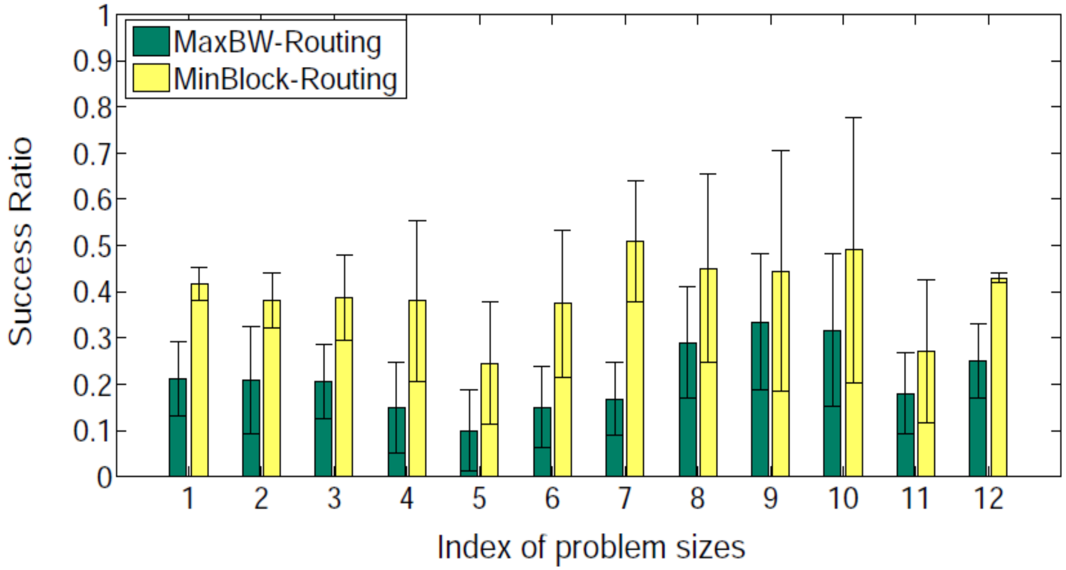
MinBlock-Routing

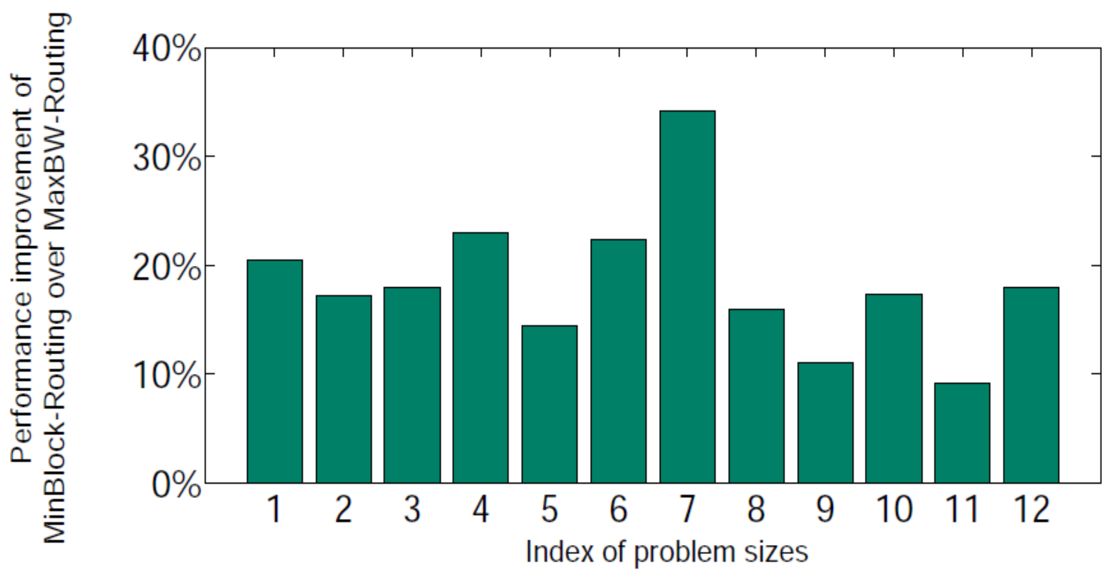
- **Input:**
  - Graph $G_j(V, E, B)$ at controller C_j
  - Set R_j consisting of n AR requests arriving at controller C_j

$$R_j = \{r_1, r_2, \ldots, r_i, \ldots, r_n\}$$

- **Output:**
  - $R^{ad} \subset R_j$ such that for every reservation r_i in R^{ad}, there is a path $p(r_i)$ that satisfies all its requirements

Simulation Results





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Research Contributions

We proposed two solutions to handle controller failure in Software Defined Networks:

1) **RandomWeightLoadBalancing** - The idea is to assign random weights for each link and then finding shortest paths
2) **ProgressiveAssignmentLoadBalancing-** The idea is to choose the controllers that have the least load i.e. lower number of switches to take over the orphan switches

Our current research question

How to design networks that are stable and manageable?

Research Questions

- How to Setup a Virtual Circuit Network (VCN) in a single-Autonomous Systems (AS)/intra-AS SDN?
  - SDN with a single controller
  - SDN with multiple controllers
- How to Setup VCN in inter-AS SDN?
- How to monitor health of the flows? How to ensure the strong quality of connection?
- How to setup connections before use?
- How to route a request with given requirements on the Internet?
- How to secure the exchanged data?

Thank you!