FireFly:
A Reconfigurable Wireless Datacenter Fabric using Free-Space Optics

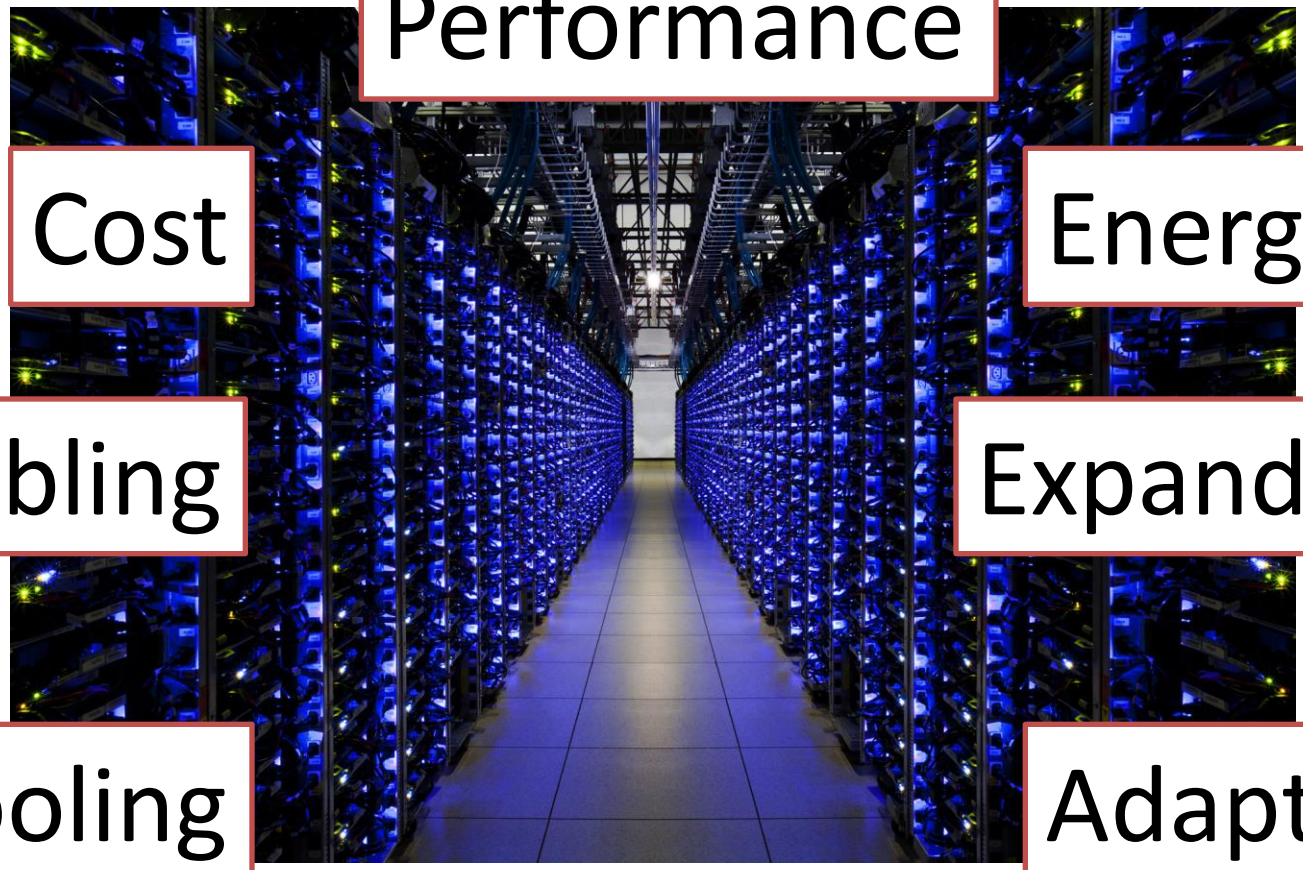
Navid Hamedazimi, Zafar Qazi, Himanshu Gupta,
Vyas Sekar, Samir Das, Jon Longtin,
Himanshu Shah, Ashish Tanwer

Stony Brook University

Carnegie Mellon

ACM SIGCOMM 2014

Datacenter network design is hard!



Performance

Cost

Energy

Cabling

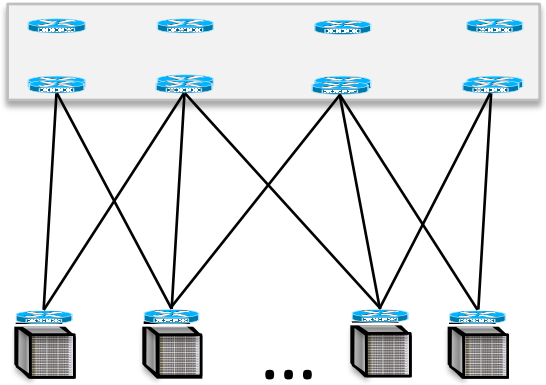
Expandability

Cooling

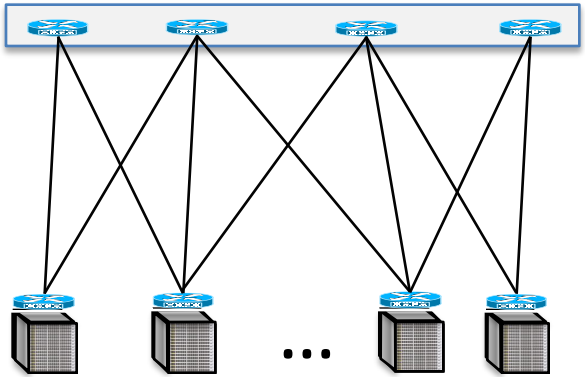
Adaptability

Existing Data Center Network Architectures

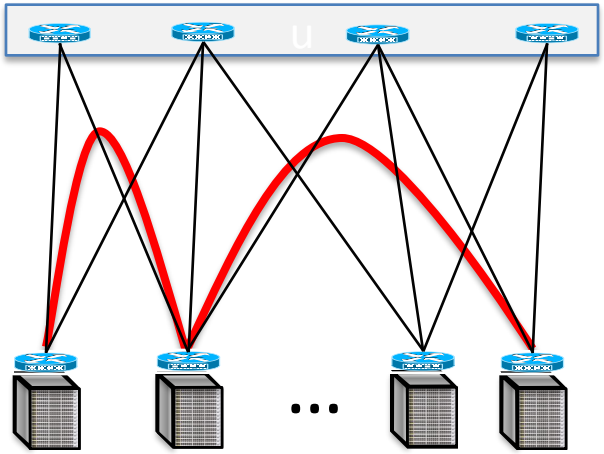
Over provisioned
(e.g. FatTree, Jellyfish)



Over subscribed
(e.g. simple tree)

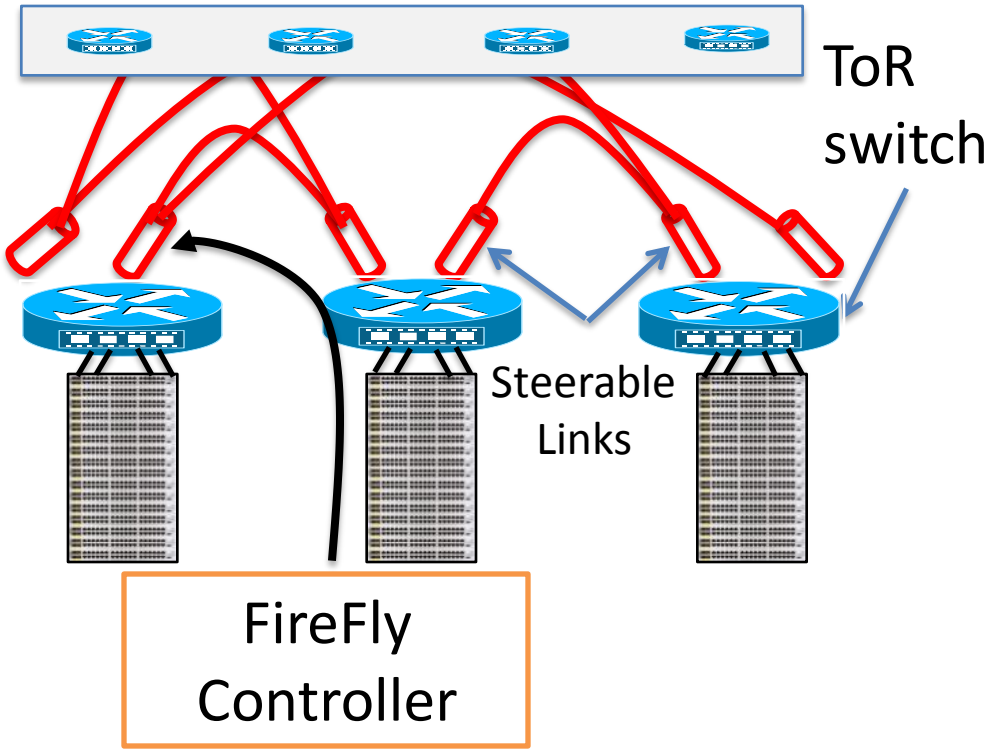


Augmented (e.g. cThrough)

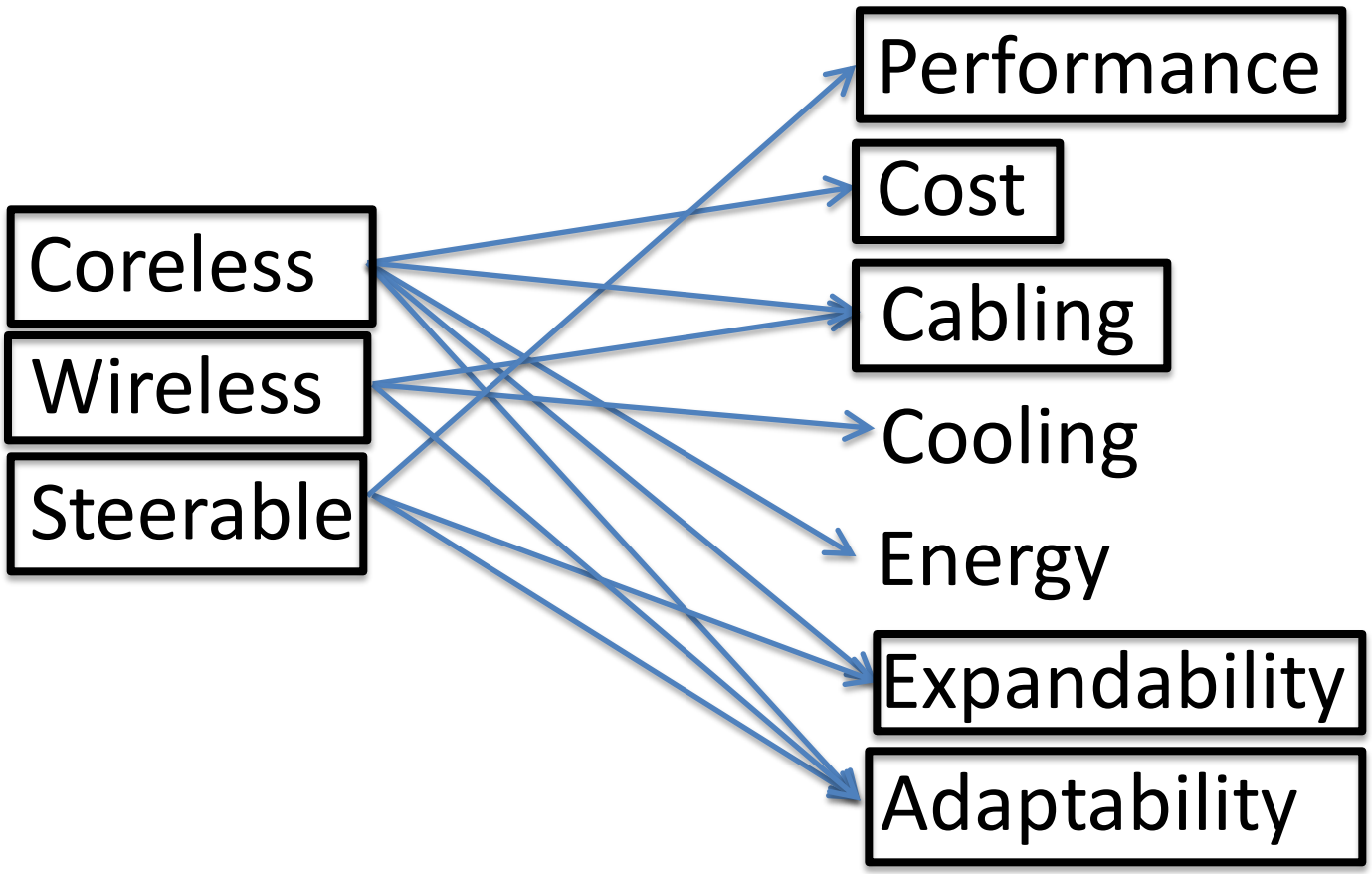


Our Vision : FireFly

- Coreless
- Wireless
- Steerable

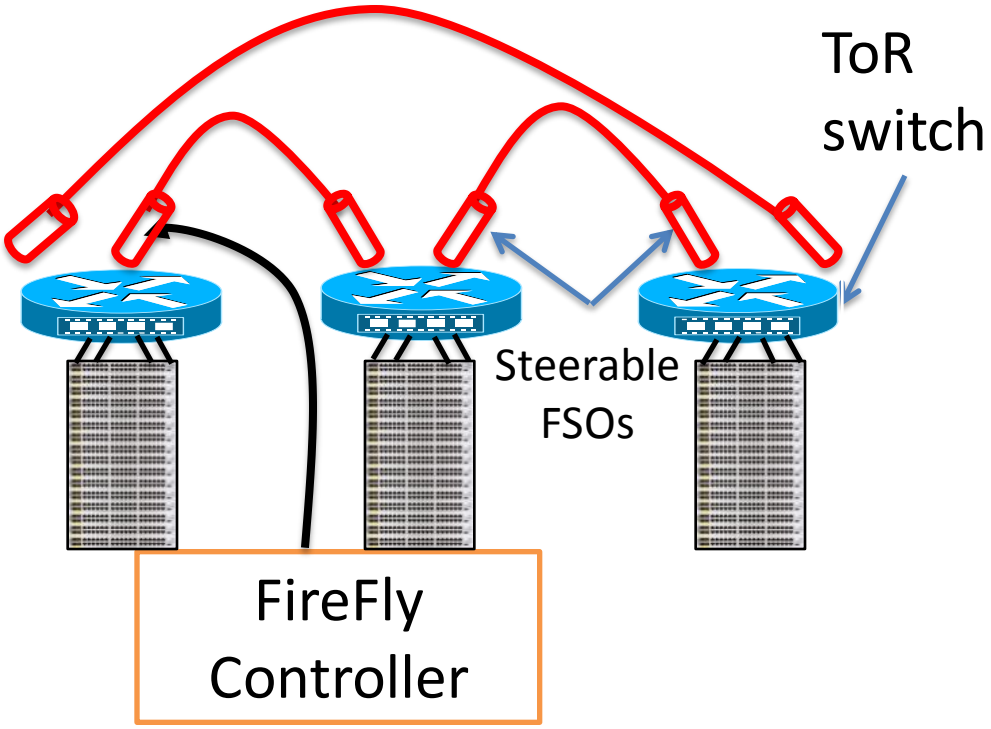


Potential Benefits of This Vision



Challenges in Realizing the Vision

- Steerable wireless links
- Network Design
- Network Management



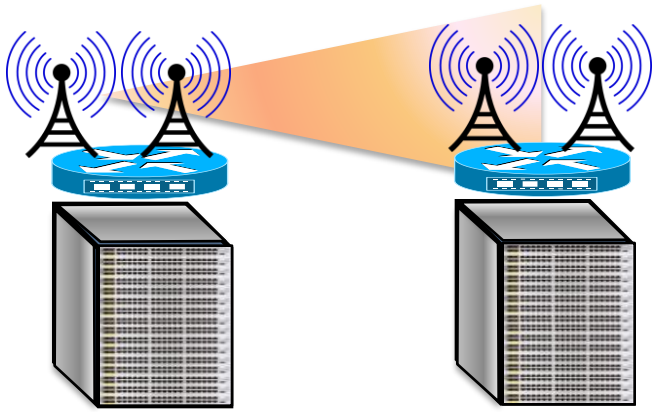
FireFly shows this vision is feasible

Outline

- Motivation
- Steerable Wireless Links
- Network Design
- Network Management
- Evaluation

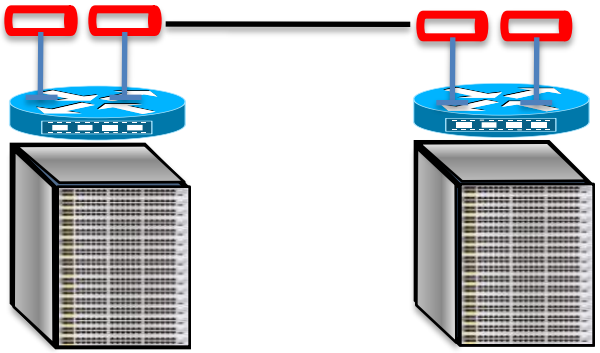
Why FSO instead of RF?

RF (e.g. 60GHZ)



Wide beam ➔
High interference
Limited active links
Limited Throughput

FSO (Free Space optical)



Narrow beam ➔
Zero interference
No limit on active links
High Throughput

Today's FSO

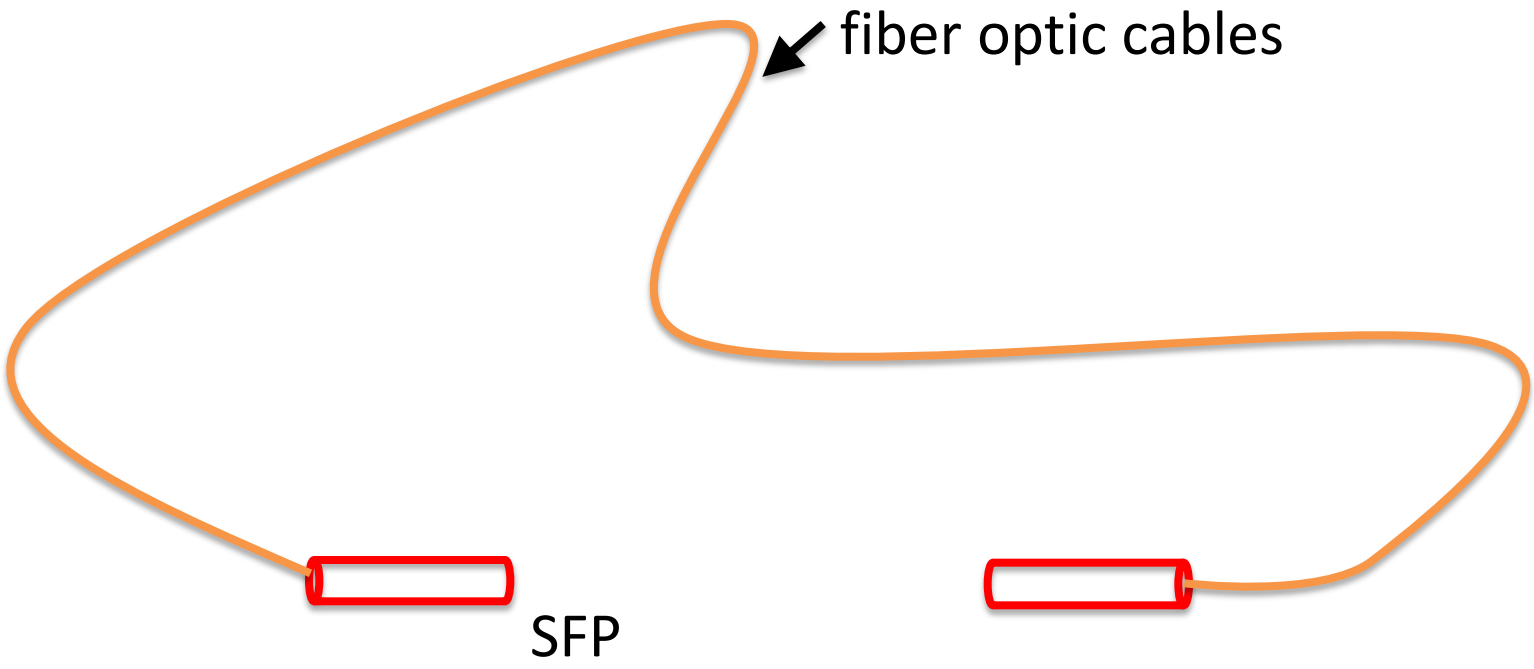
- Cost: $15K per FSO
- Size: 3 ft^3
- Power: 30w
- Non steerable

- Current: bulky, power-hungry, and expensive
- Required: small, low power and low expense

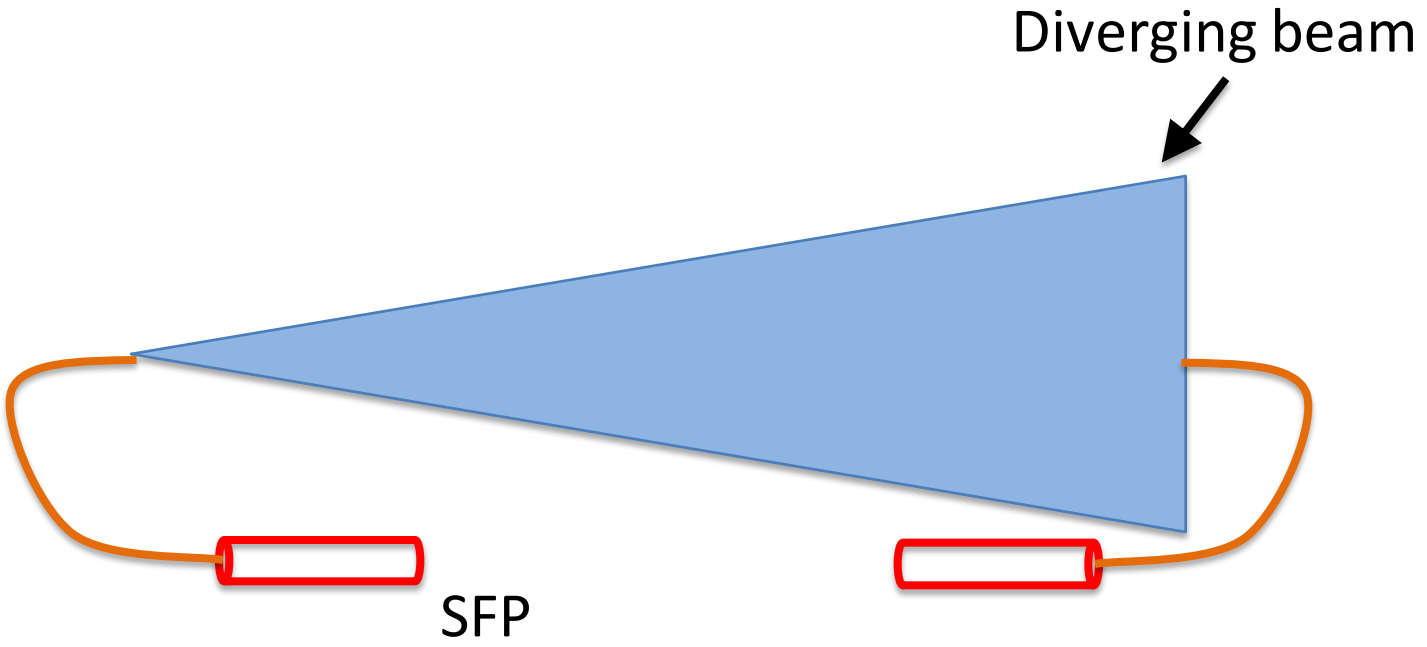
Why Size, Cost, Power Can be Reduced?

- Traditional use : outdoor, long haul
  - High power
  - Weatherproof
- Data centers: indoor, short haul
- Feasible roadmap via commodity fiber optics
  - E.g. Small form transceivers (Optical SFP)

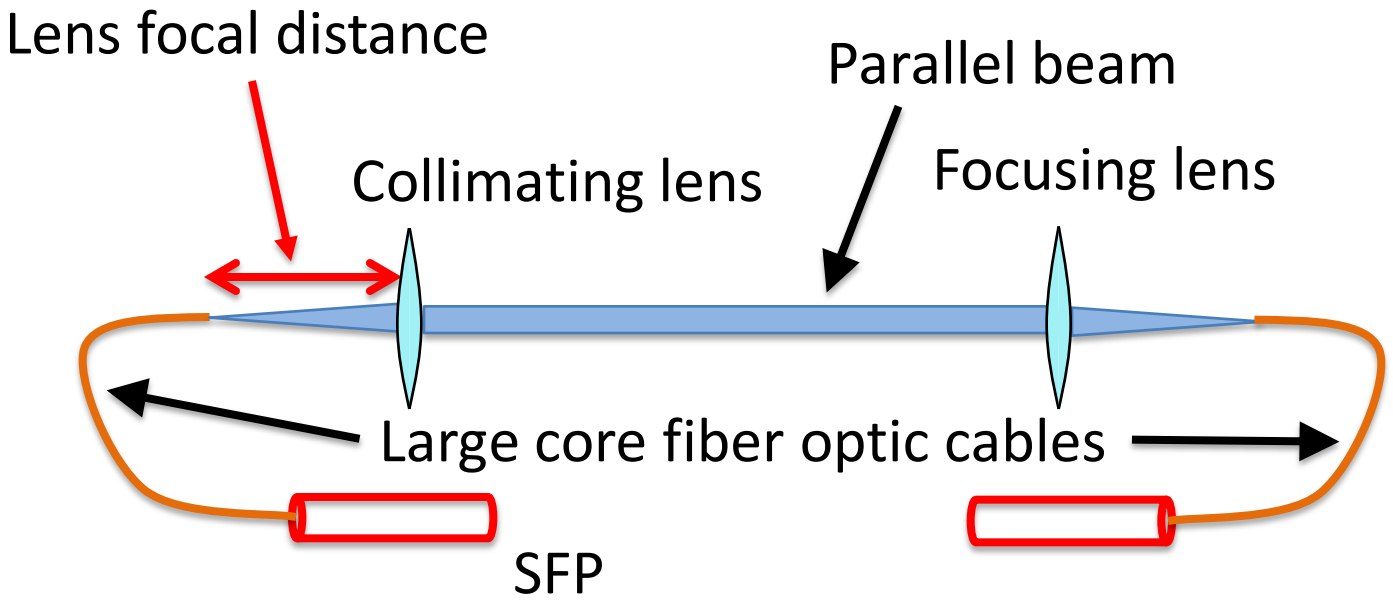
FSO Design Overview



FSO Design Overview



FSO Design Overview



- large cores (> 125 microns) are more robust

Steerability

Shortcomings of current FSOs

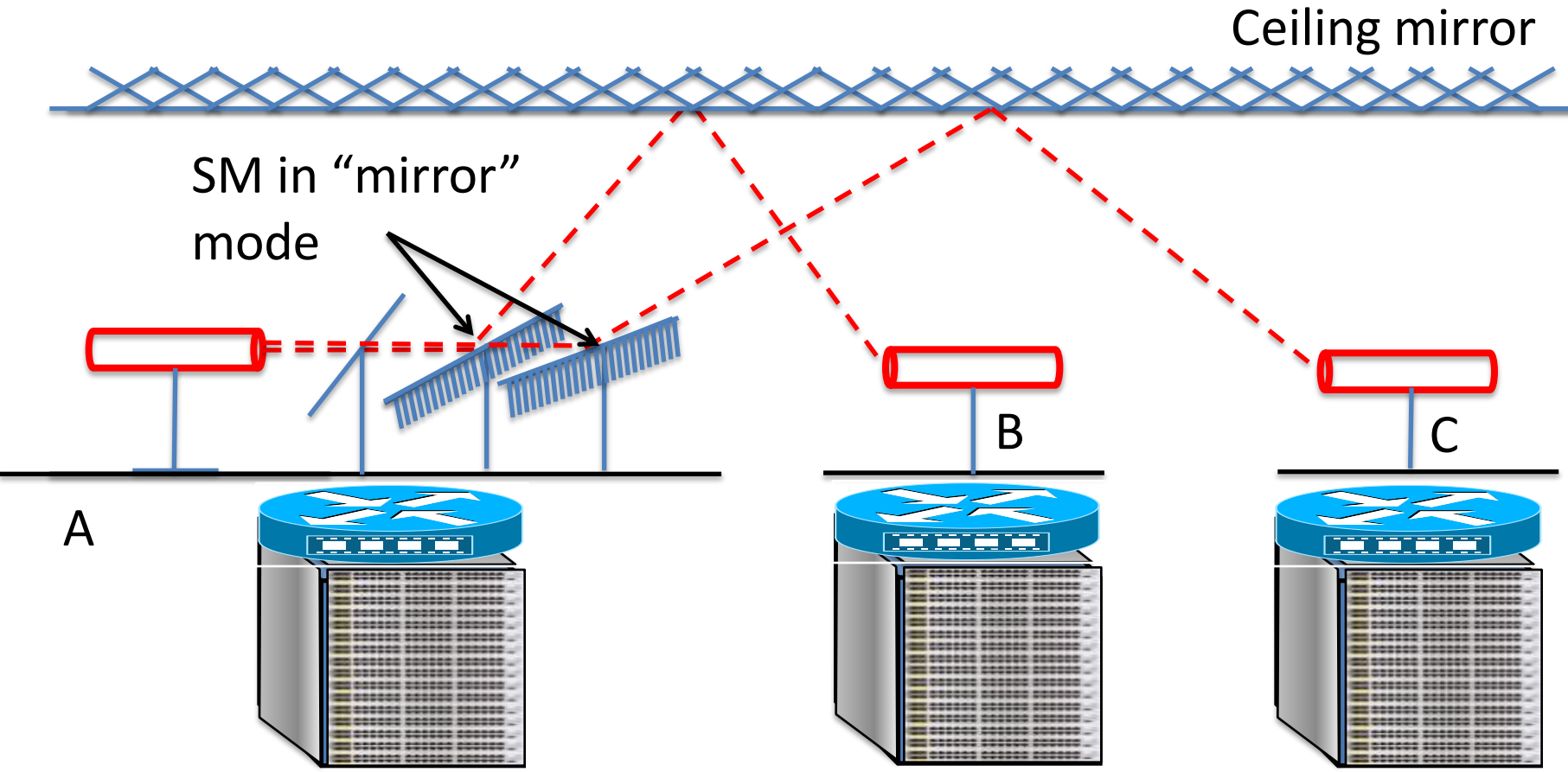
- ✓ Cost
- ✓ Size
- ✓ Power
- Not Steerable

FSO design using SFP

Via Switchable mirrors or Galvo mirrors

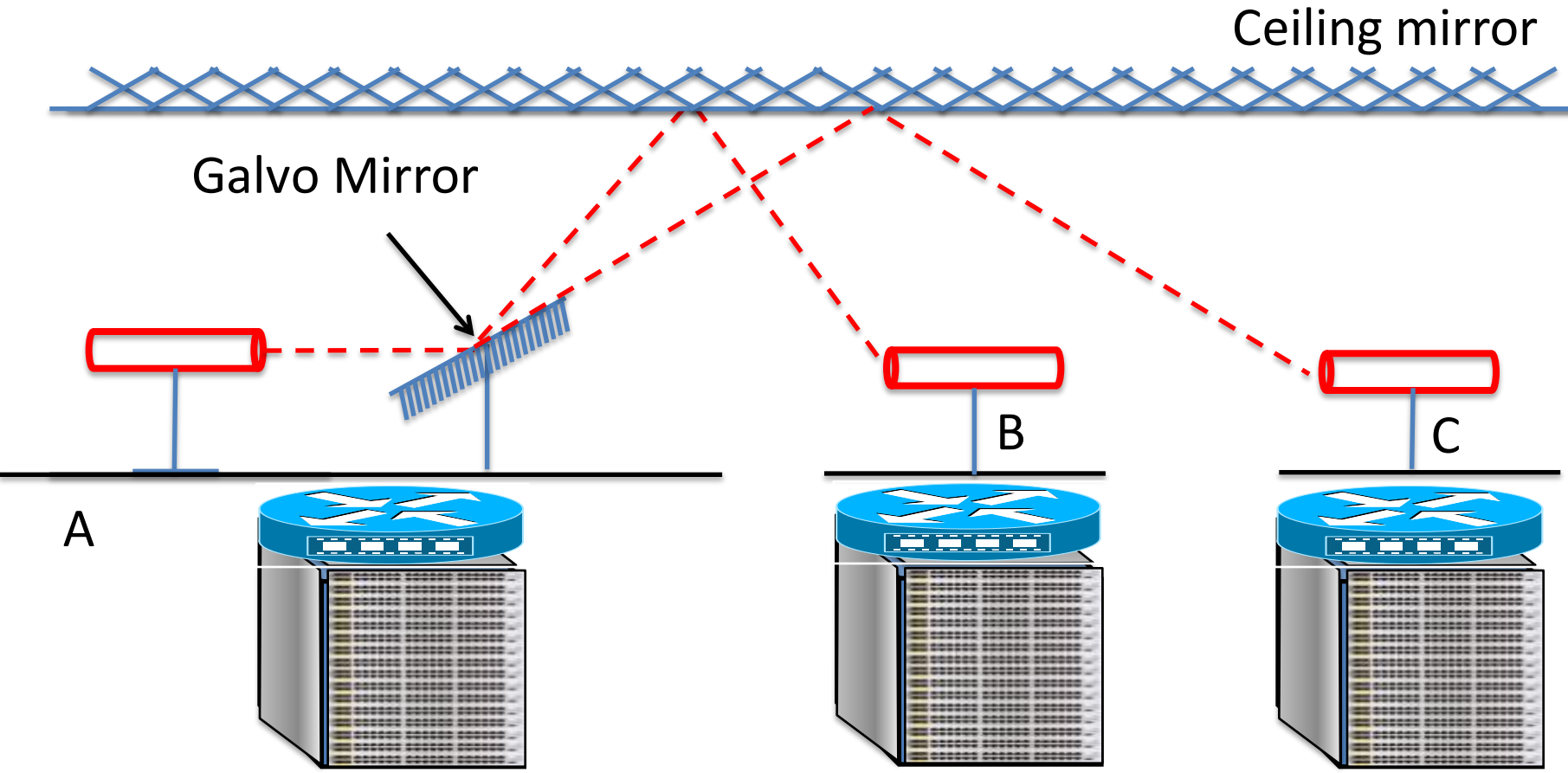
Steerability via Switchable Mirror

- Switchable Mirror: glass ⟷ mirror
- Electronic control, low latency

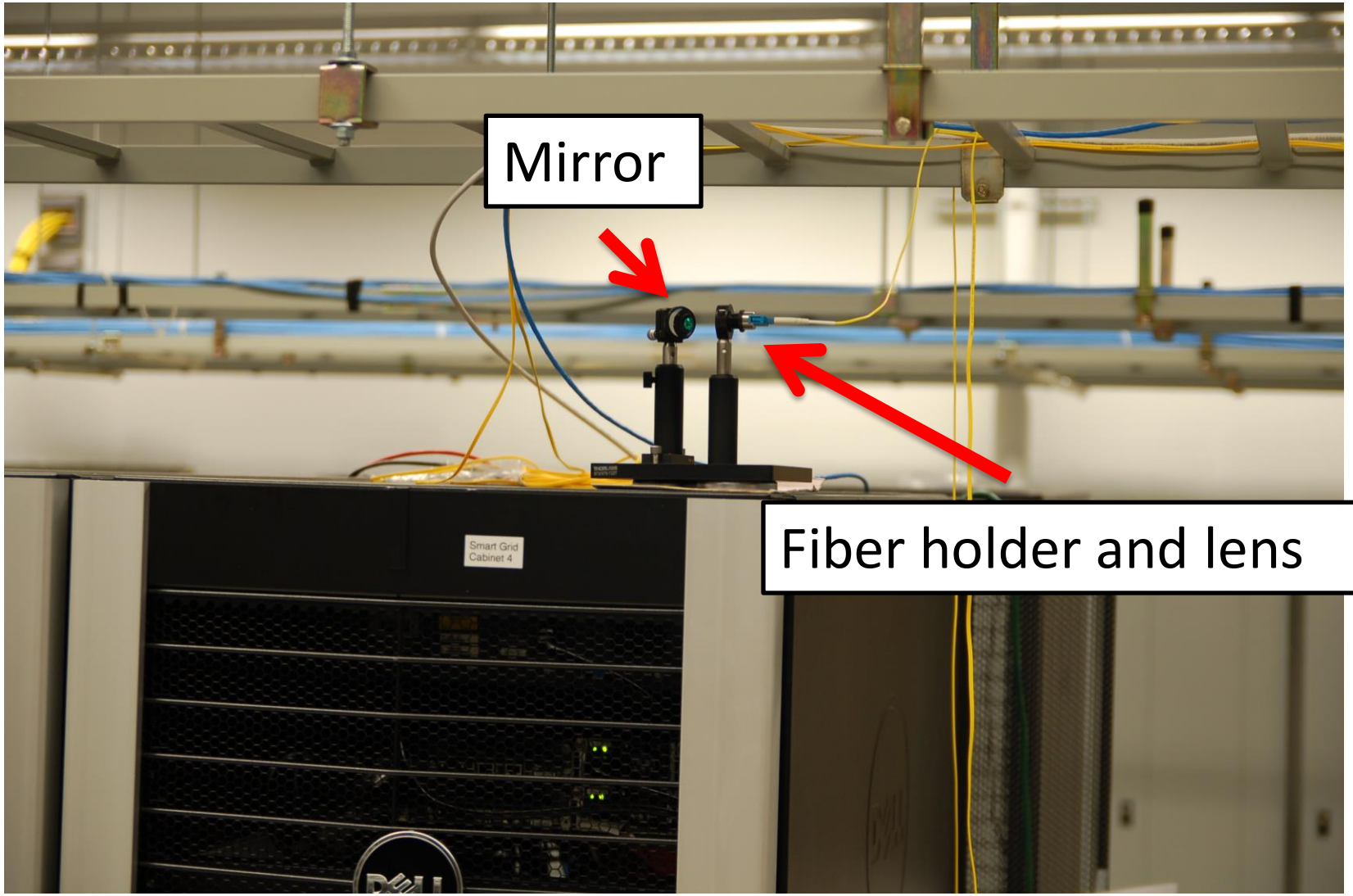


Steerability via Galvo Mirror

- Galvo Mirror: small rotating mirror
- Very low latency

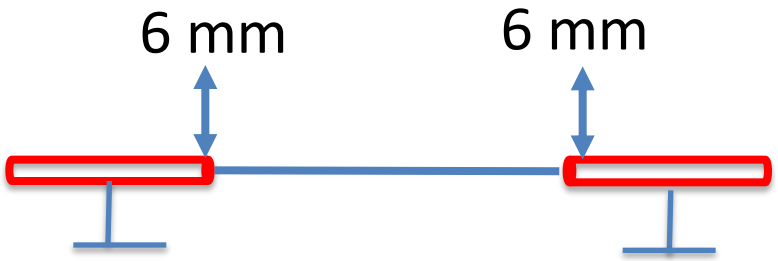


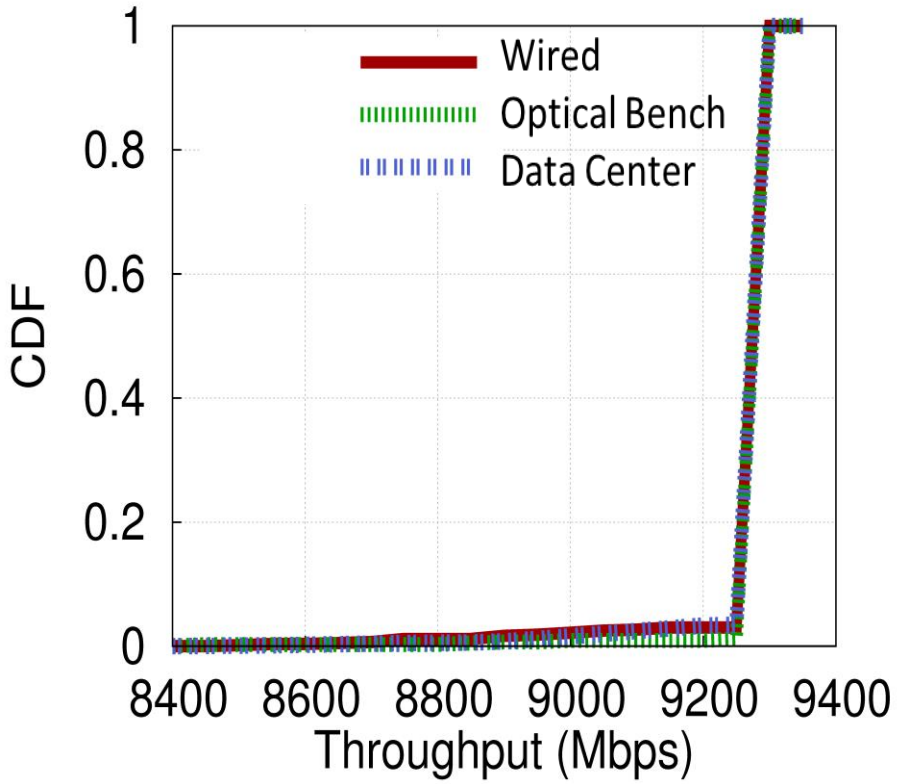
FSO Prototype in Data center



FSO Link Performance

- Effect of vibrations, etc.
- 6mm movement tolerance
- Range up to 24m tested





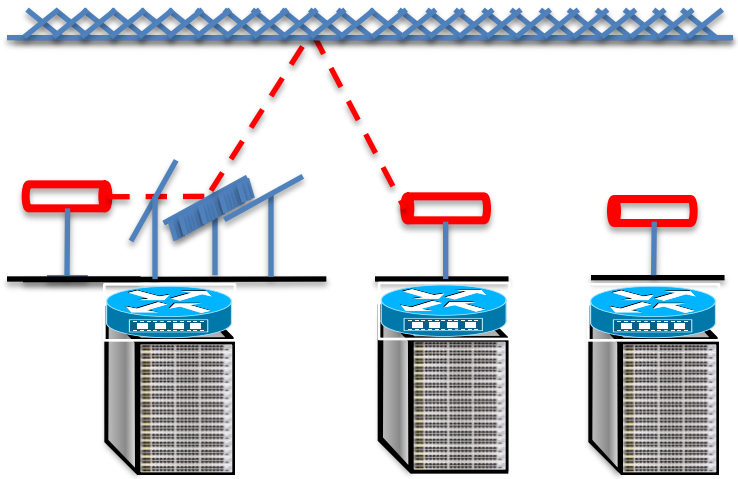
FSO link is as robust as a wired link

Outline

- Motivation
- Steerable Wireless Links
- **Network Design**
- Network Management
- Evaluation

How to design FireFly network?

- Goals: Robustness to current and future traffic
- Budget & Physical Constraints
- Design parameters
  - Number of FSOs?
  - Number of steering mirrors?
  - Initial mirrors' configuration
- Performance metric
  - Dynamic bisection bandwidth



FireFly Network Design

- # of FSOs = # of Servers
- # of Switchable Mirrors = [10-15] for up to 512 racks

  or
- # of Galvo Mirrors = 1 per FSO
- Mirror Configuration = Random graph
- less than ½ the ports of FatTree

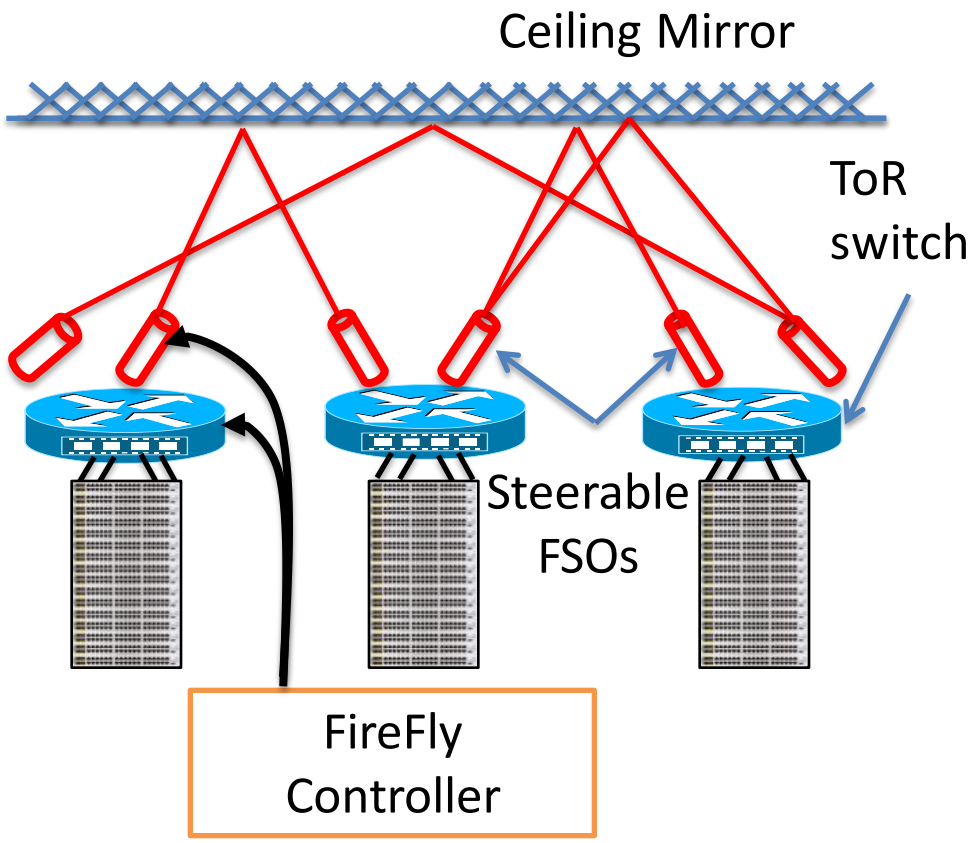
Projected Cost: 40% to 60% lower than FatTree

Outline

- Motivation
- Steerable Wireless Links
- Network Design
- **Network Management**
- Evaluation

Network Management Challenges

- Reconfiguration
  - Traffic engineering
  - Topology control
- Correctness during flux

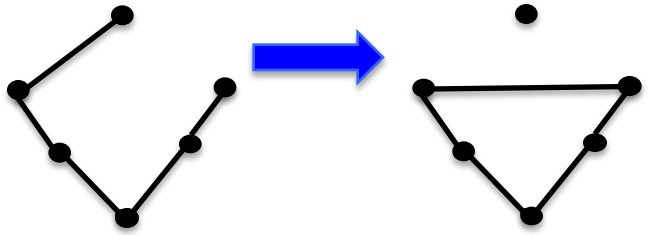


FireFly Reconfiguration Algorithm

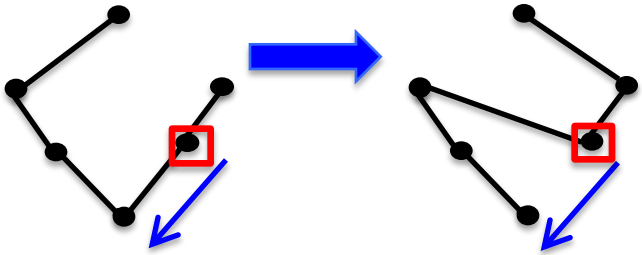
- Joint optimization problem ➢ Massive ILP
- Decouple
  - Traffic engineering ➢ Max-flow, greedy
  - Topology control ➢ Weighted Matching
- Above is done periodically
- In addition: Trigger-based reconfiguration
  - E.g. Create direct link for large flows

Correctness Problems During Flux

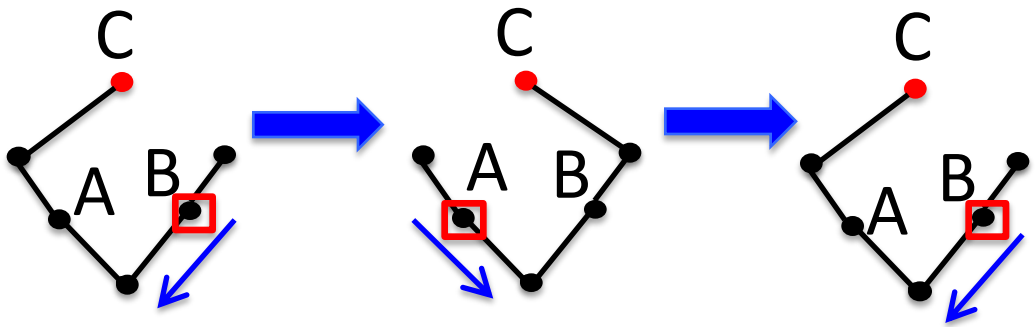
- Connectivity



- Black Holes



- Latency



Simple Rules To Ensure Correctness

- Disallow deactivations that disconnect the network.
- Stop using a link before deactivating it
- Start using a link only after activating it
- “Small” gap between reconfigurations

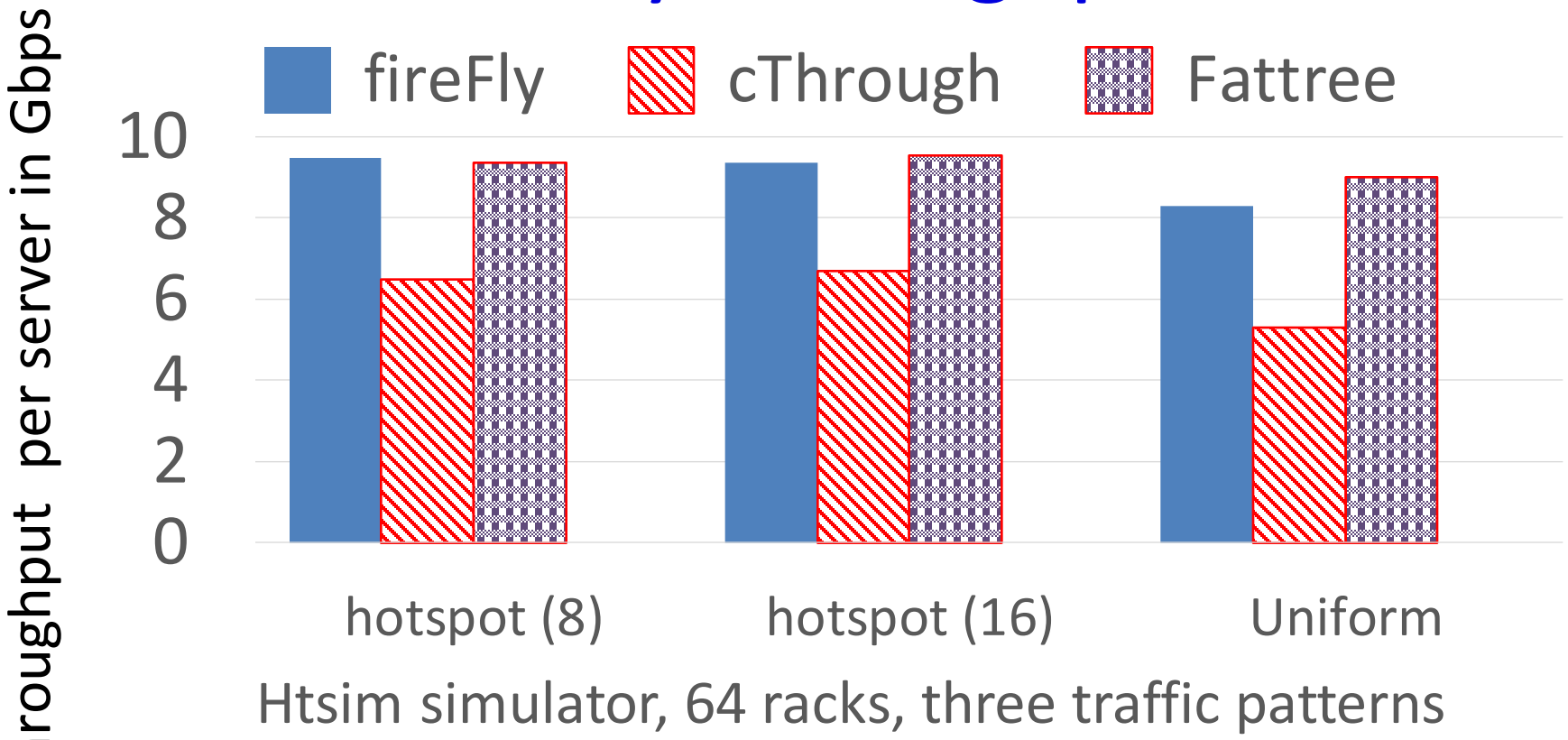
Outline

- Motivation
- Steerable Wireless Links
- Network Design
- Network Management
- **Evaluation**

FireFly Evaluation

- Packet-level
- Flow-level (for large scale networks)
- Evaluation of network in-flux
- Evaluation of Our Heuristics

FireFly Throughput



FireFly is comparable to FatTree with less than ½ the ports

Flow completion time better than FatTree

Conclusions

- Vision: Extreme DC network architecture
  - Fully Steerable, No core switches, All-wireless inter-rack
- Unprecedented benefits:
  - No Cabling, Adapt to traffic patterns, Less clutter
- Firefly shows a viable proof point
  - Practical steerable FSO for datacenters
  - Practical network design and management heuristics
  - Close to fat tree performance over several workloads
  - Less than half of FatTree ports
- Just a start .. Many directions for improvement