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Characterizing the Algorithmic Complexity of Reconfigurable Data Center Architectures

Klaus-T. Foerster (U. Vienna), Manya Ghobadi (Microsoft Research), Stefan Schmid (U. Vienna)

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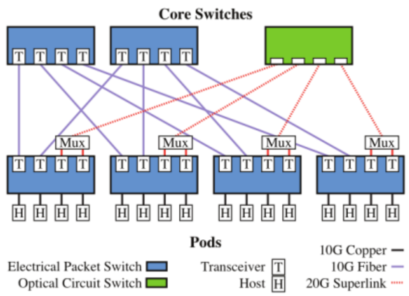
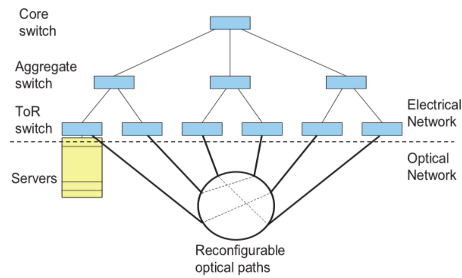
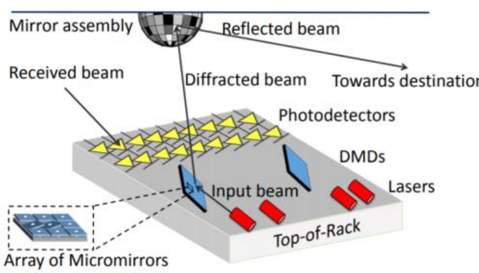
Reconfigurable Data Center Networks (DCNs)



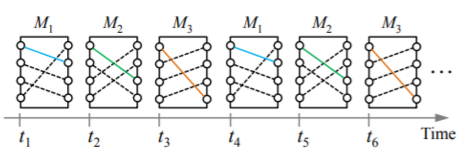
Helios (core)
Farrington *et al.,* SIGCOMM '10



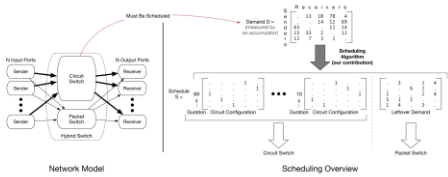
c-Through (*HyPaC* architecture)
Wang *et al.,* SIGCOMM '10



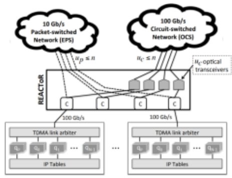
ProjecToR interconnect
Ghobadi *et al.,* SIGCOMM '16



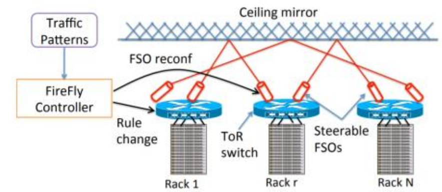
Rotornet (rotor switches)
Mellette *et al.,* SIGCOMM '17



Solstice (architecture & scheduling)
Liu *et al.,* CoNEXT '15



REACToR
Liu *et al.,* NSDI '15



FireFly
Hamedazimi *et al., SIGCOMM* '14

… and many more …

Reconfigurable Data Center Networks (DCNs)

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- Results and conclusions often not portable
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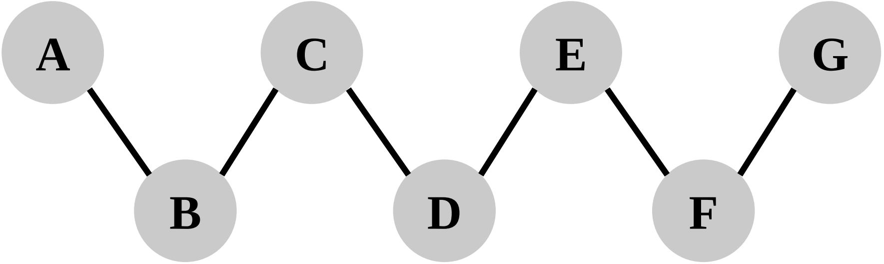
- We take a look from a theoretical perspective
  - With average path length as an objective
  - For one switch (with/without this assumption)
  - Also briefly for multiple switches

The Static Case



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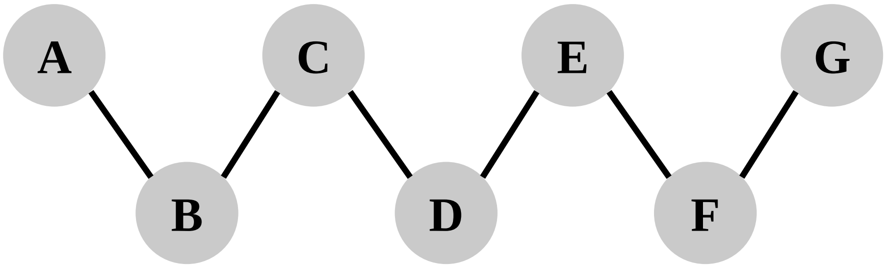

Communication frequency: **A→E: 10**, **A→G: 5**

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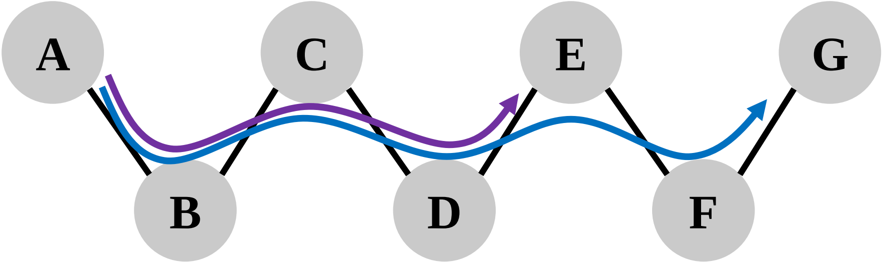

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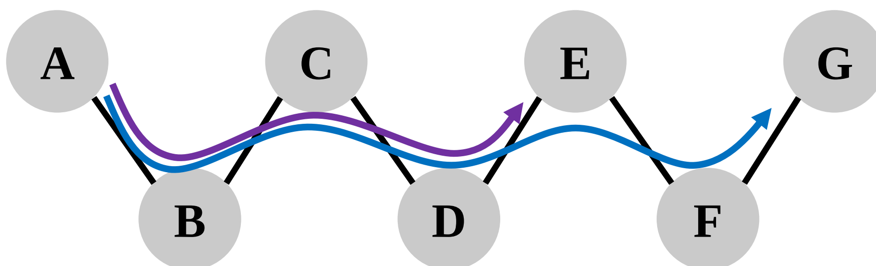
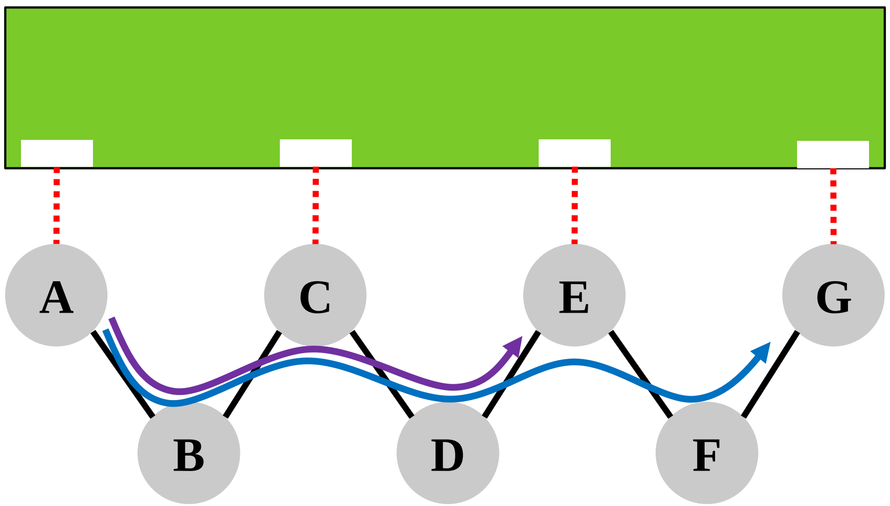


Communication frequency: **A→E: 10**, **A→G: 5**

Weighted average path length: **4*10+6*5=70**

Adding Reconfigurability



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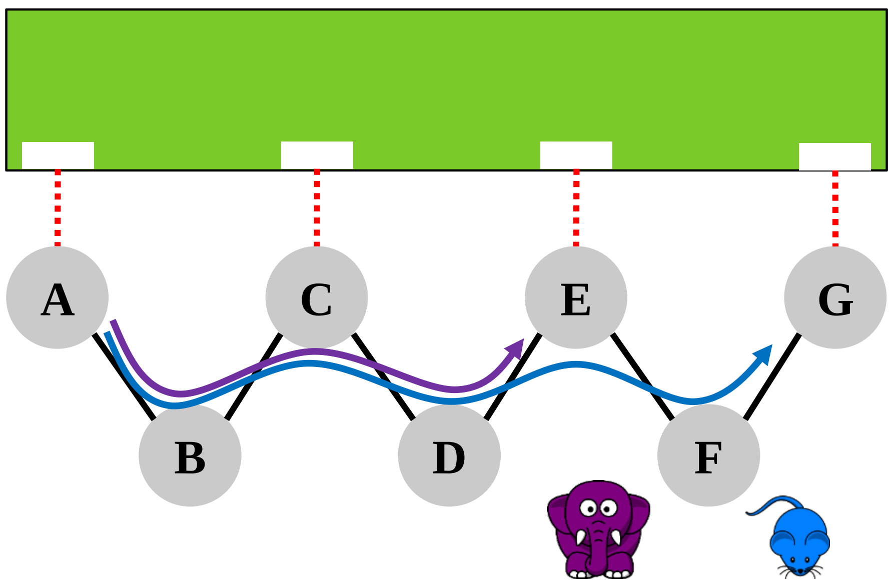

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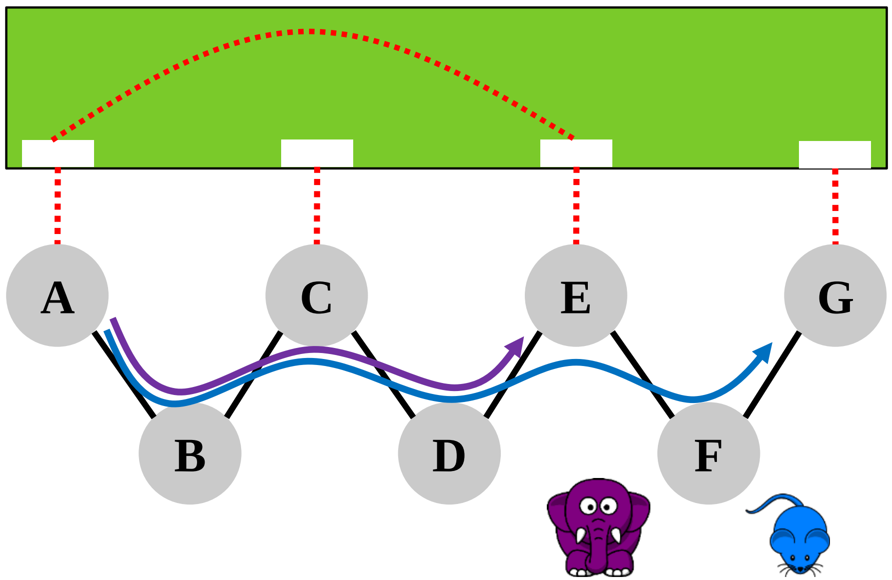

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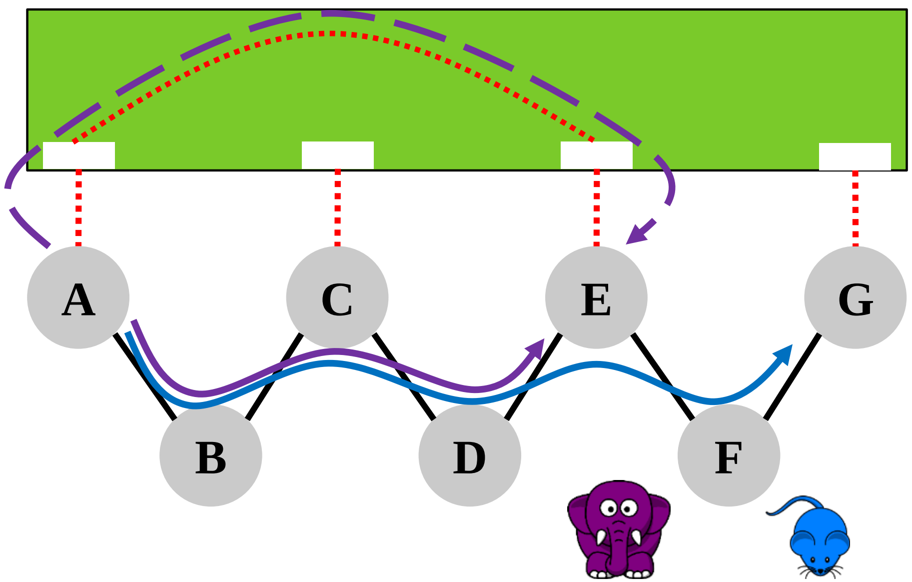

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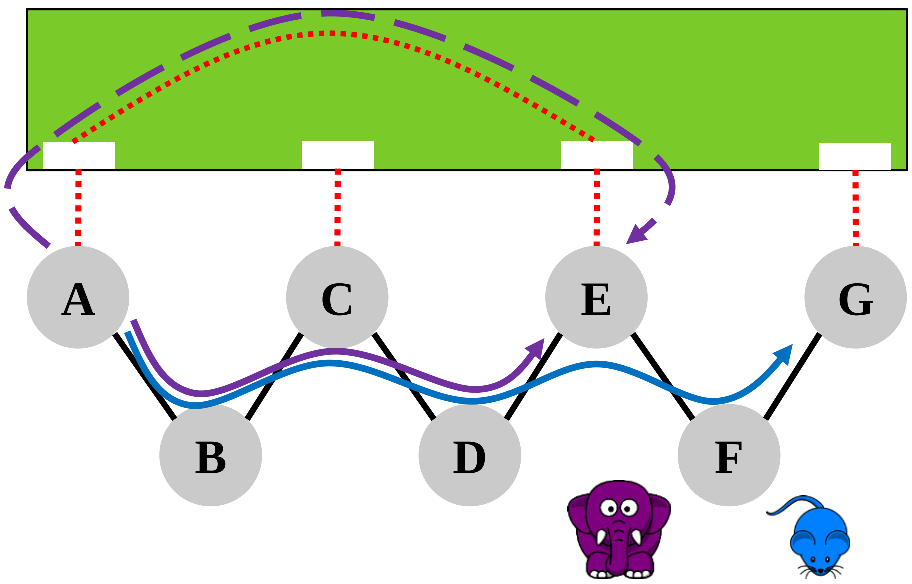
Adding Reconfigurability

reconfig

Weighted average path length: **1*10+6*5=40**



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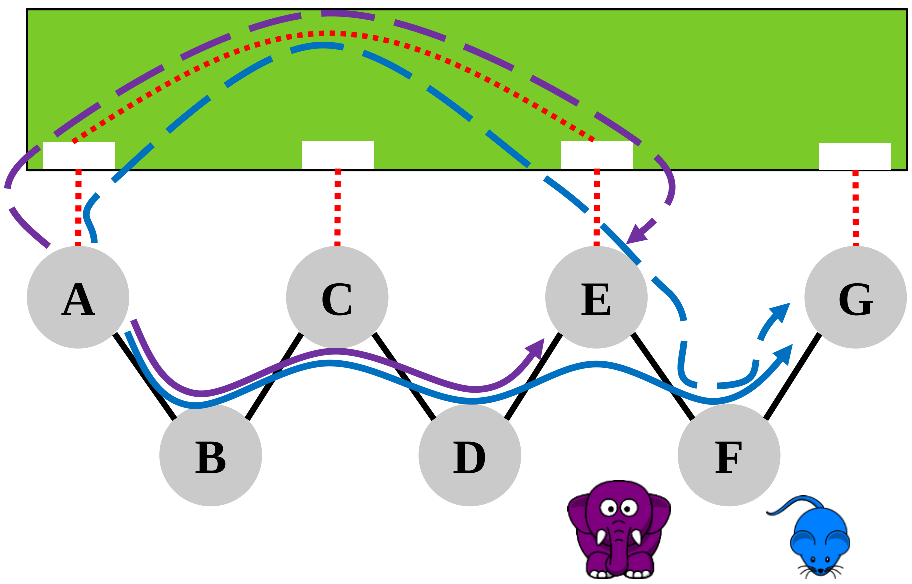

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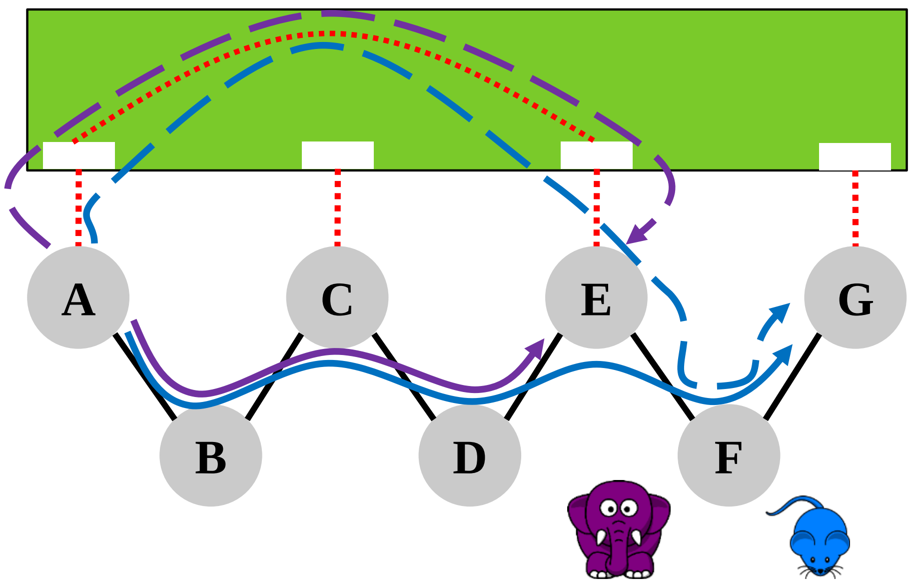

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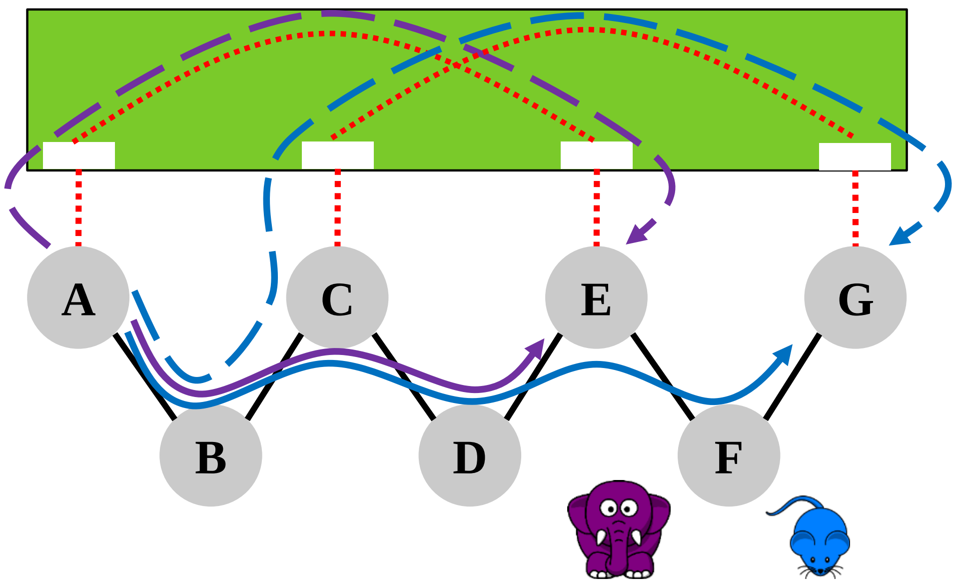

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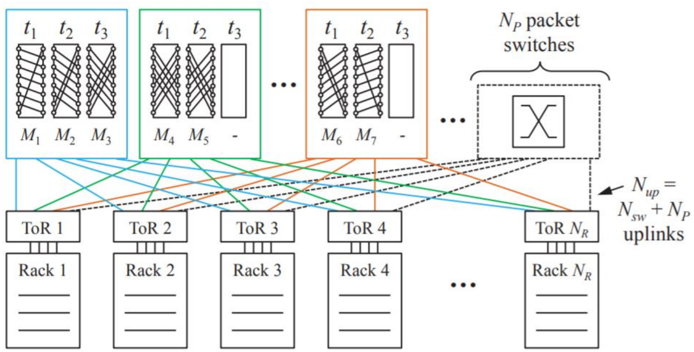
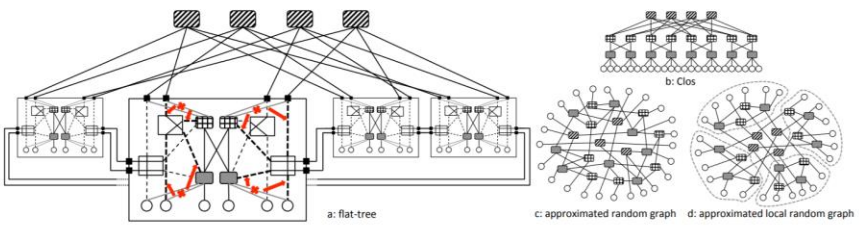
Beyond a Single Switch

- Especially important at scale: **multiple** reconfigurable switches





Rotornet
Mellette *et al.*, SIGCOMM '17

A Tale of Two Topologies
Xia *et al.*, SIGCOMM '17

One Switch: Segregated Routing Policies

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- Model: Either **just 1 reconfig** or **just static**

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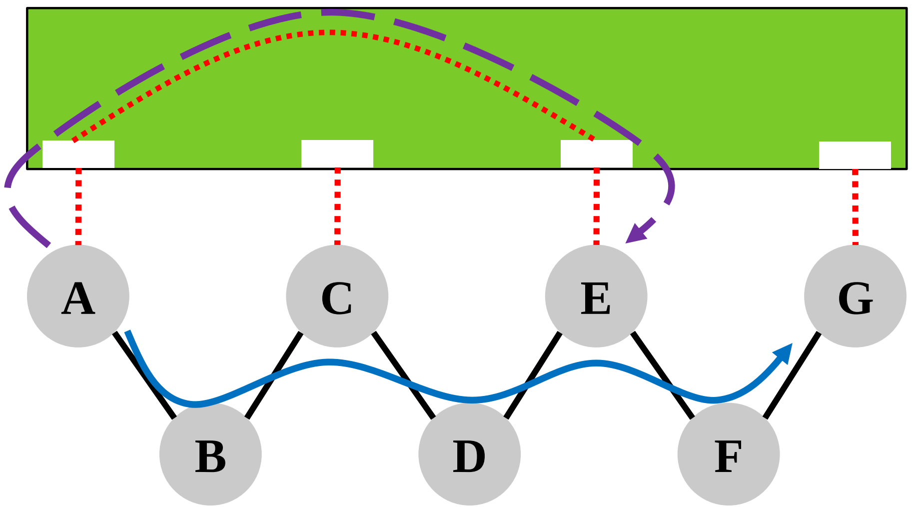

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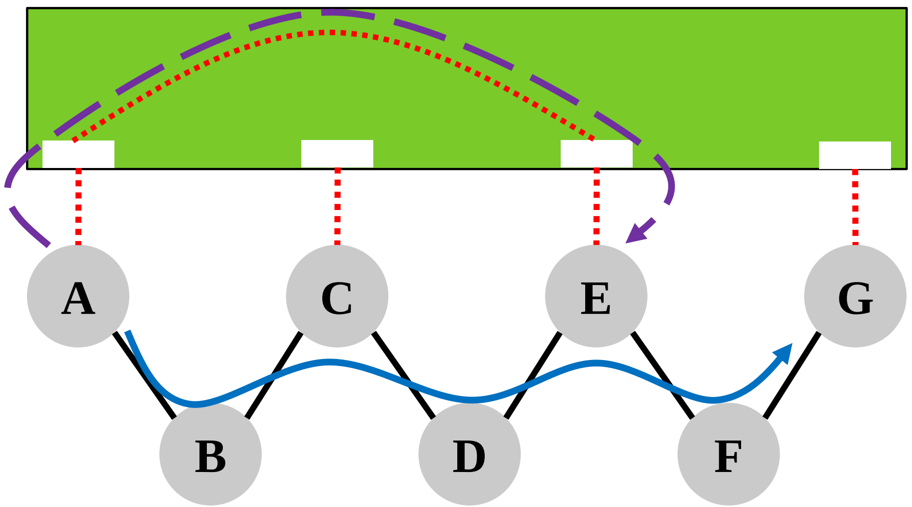

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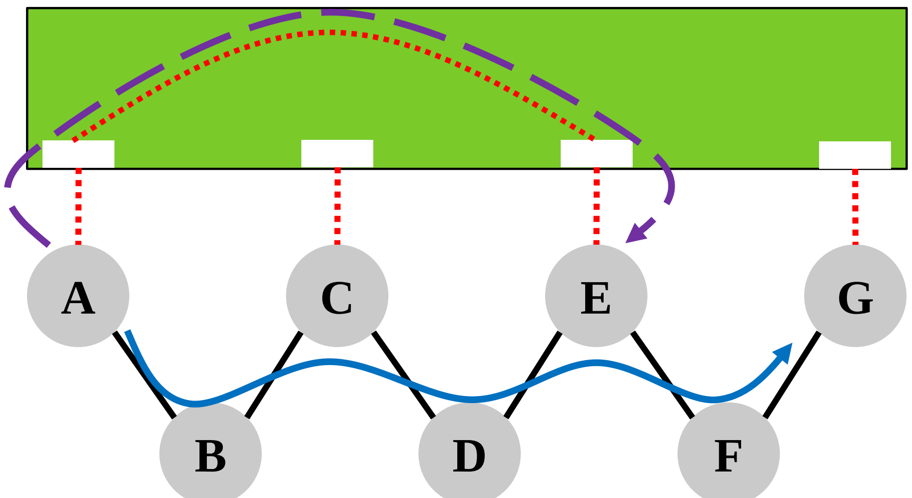

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Why this solution?

Benefit of **A→E: 10**:
- Static-Reconfig: 40-10=**30**

Benefit of **A→G: 5**:
- Static-Reconfig: 30-5=**25**

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  - *Not optimal under arbitrary routing policies*

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Approximation algorithms & restricted topologies

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Approximation algorithms & restricted topologies   Future Work

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Already some work in different settings, e.g.:

- network forms a dynamic tree [Schmid et al., ToN '16]
- constant degree and sparse demands [Avin et al., DISC '17]
- degree depends on node popularity [Avin et al., Inf. Pr. Let. '18]

(these works assume all links are reconfigurable)

Approximation algorithms & restricted topologies — Future Work

Multiple Reconfigurable Switches

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- Let's make things simpler

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Multiple Switches: One Flow

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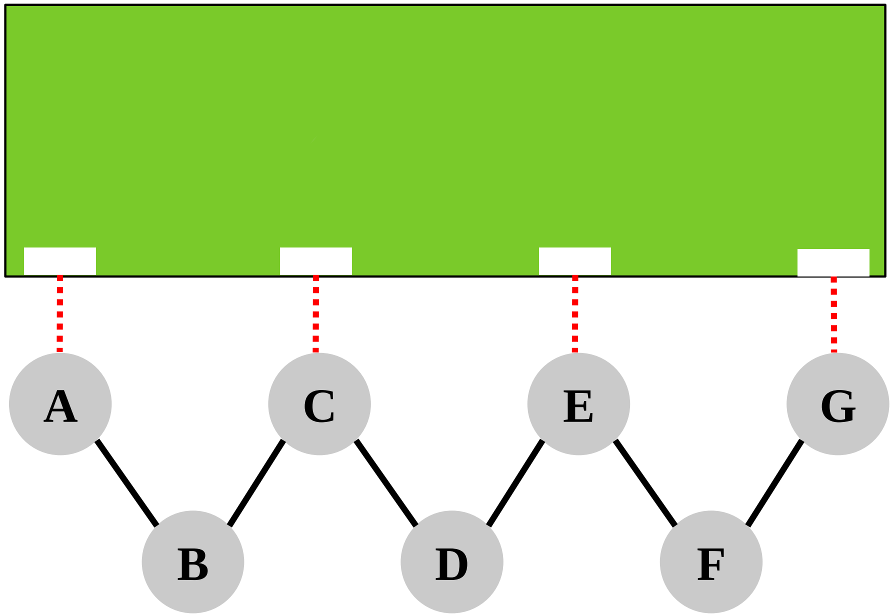
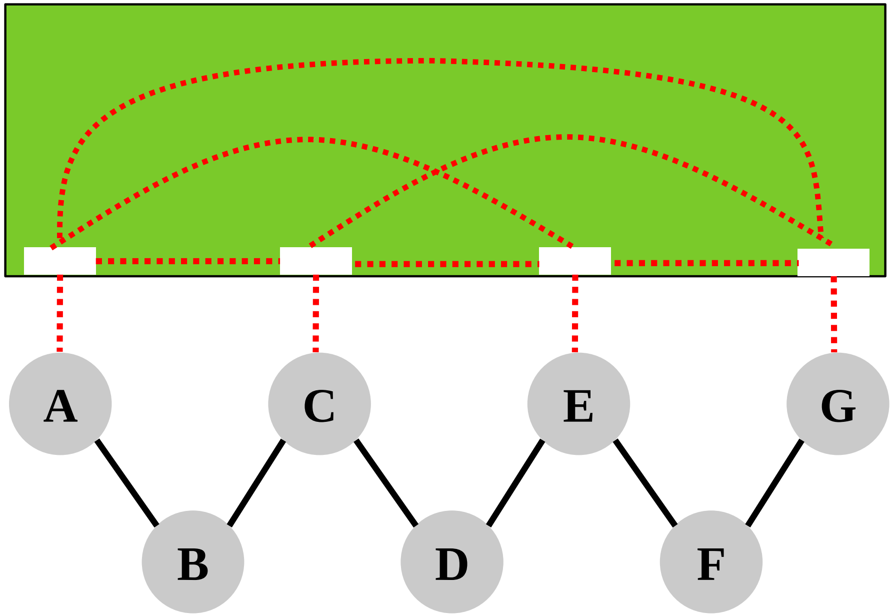


Communication frequency: **A→G: 1**

Multiple Switches: One Flow



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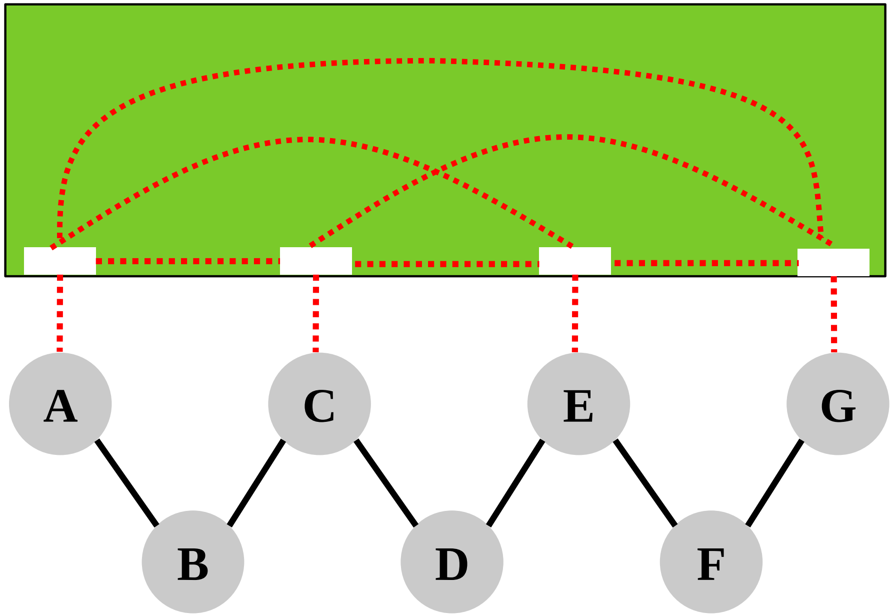

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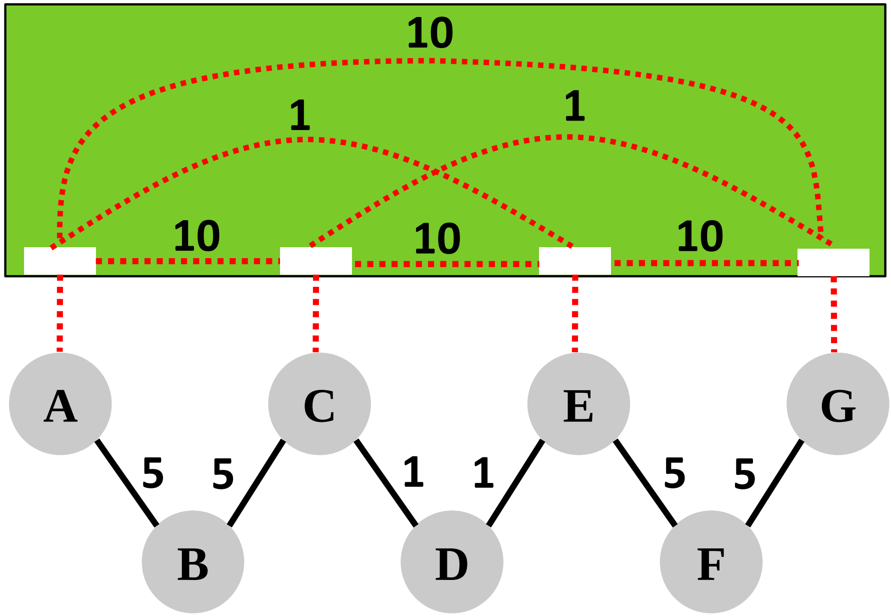

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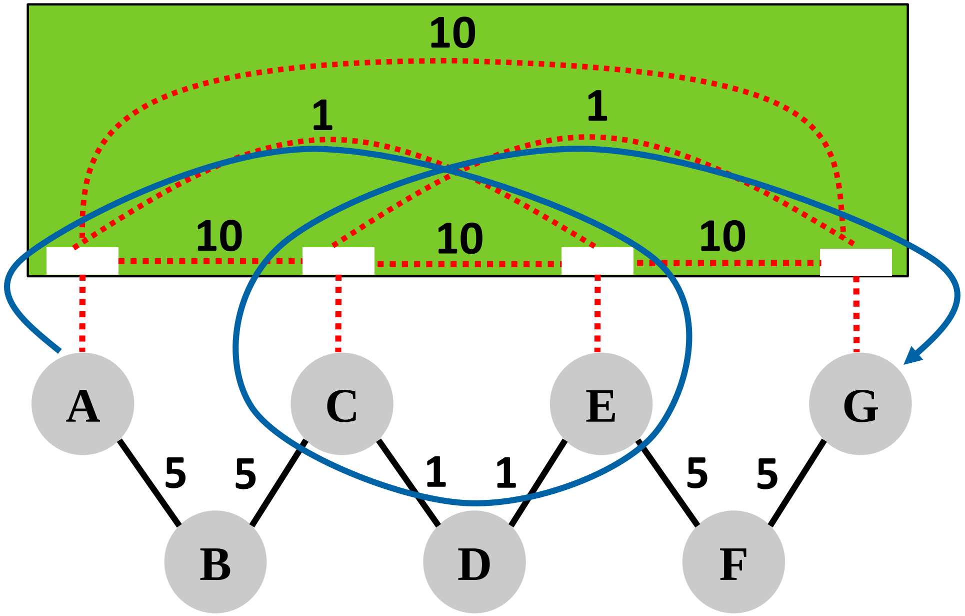

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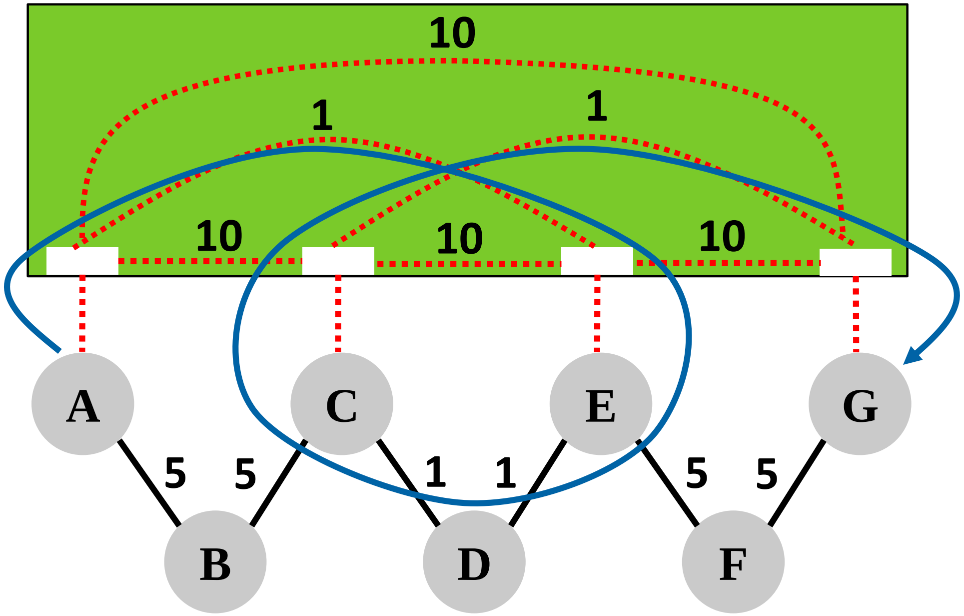

How to formalize?

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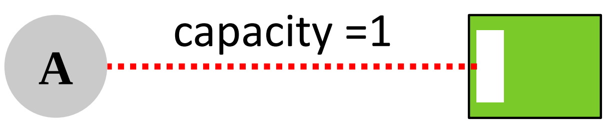

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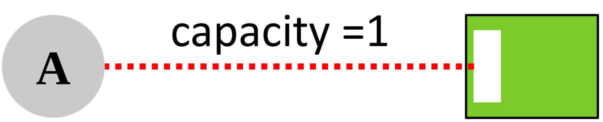

*some small strings attached

Multiple Switches: One Flow Unidirectionality

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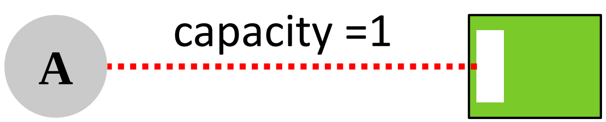

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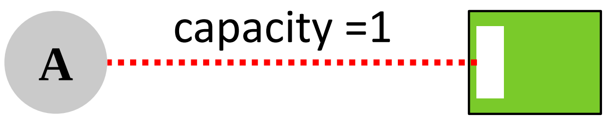

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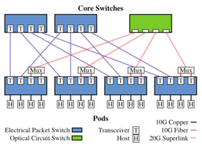

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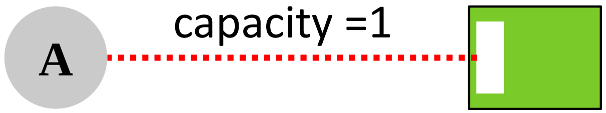

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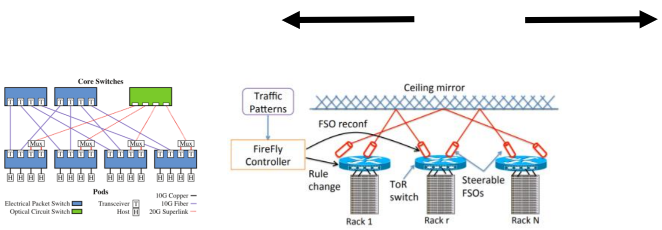

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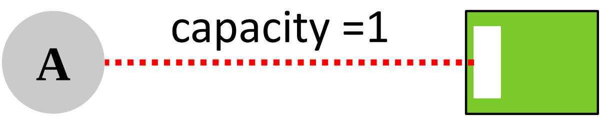

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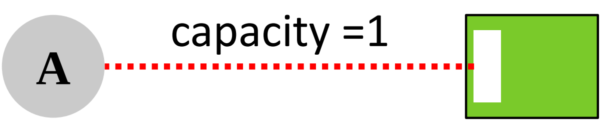

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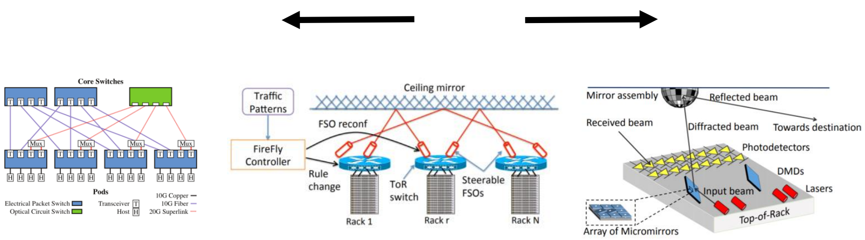

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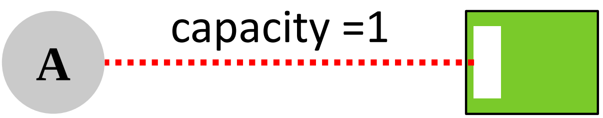

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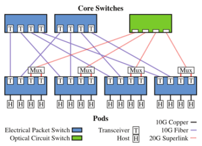

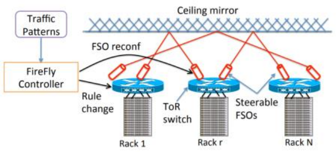

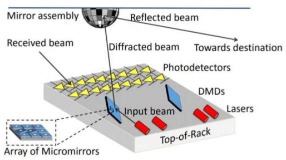

- Same conceptual idea

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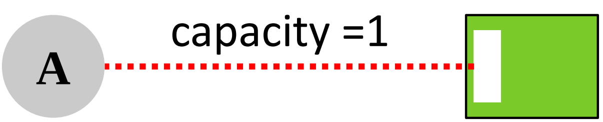

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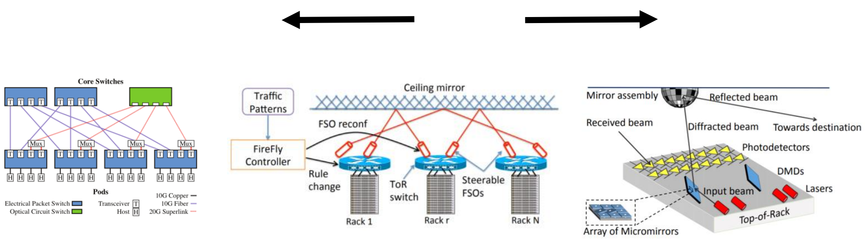
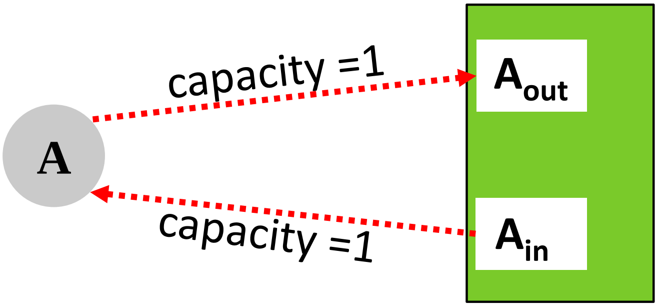


- Same conceptual idea

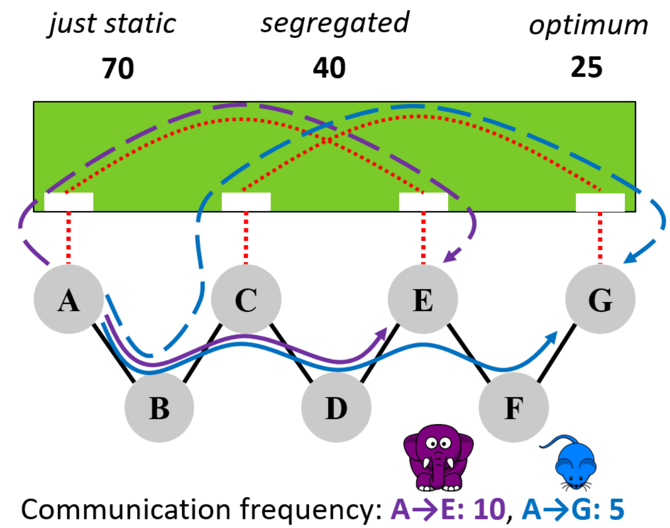


Summary and Outlook

- <u>one</u> reconfigurable switch
  - segregated: Easy. Not optimal.
  - not seg.: NP-hard. Improves solutions.

- <u>multiple</u> reconfigurable switches
  - multiple flows: NP-hard
  - just one flow: Easy.

- <u>Next</u> steps
  - approximation algorithms
  - special topologies



Characterizing the Algorithmic Complexity of Reconfigurable Data Center Architectures

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Thank you! ☺

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