Chair of Communication Networks
Department of Electrical and Computer Engineering
Technical University of Munich

FlexNets: It's all about flexibility!

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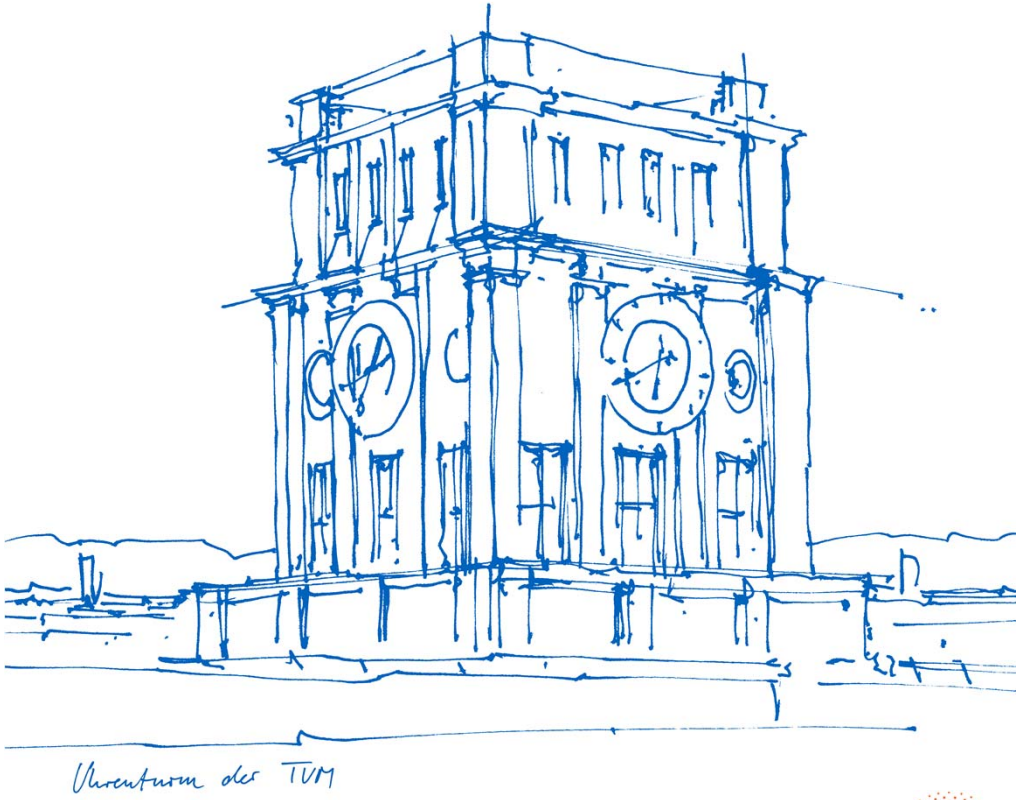
based on a keynote given at the
Intl. Teletraffic Congress, ITC 2016



with the support of my PhD students:
A. Blenk, A. Basta, R. Durner, J. Guck,
M. He, A. Van Bemten,…

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European Research Council
Established by the European Commission

Introduction

- Networking today
  - new requirements from vertical industries
  - new requirements from dynamically changing user behavior
  - new requirements from global digitalization

5G cellular, Industrie 4.0, Smart Grid, Big Data, ITS, Cyber Physical Networking,…

- One challenge that is less (explicitly) addressed is ***flexibility***

- Evolution tells us: be adaptive → network evolution?

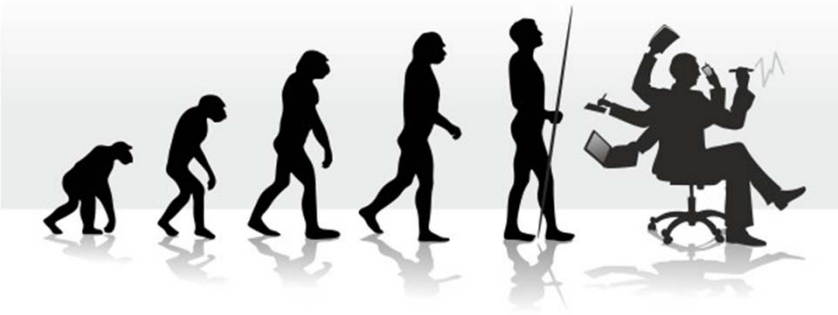

Image source: http://www.paleoplan.com

FlexNets

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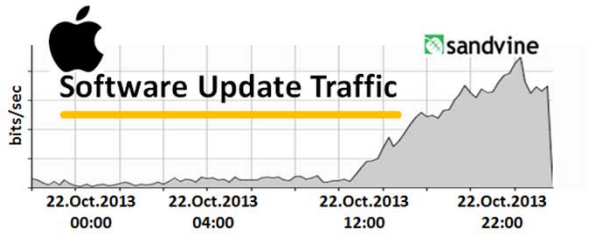
The Internet

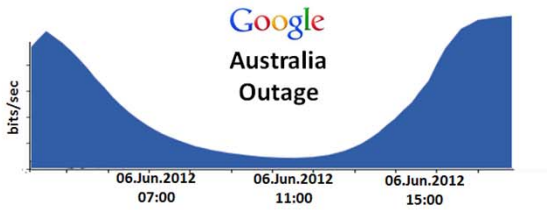
… is able to adapt its resources

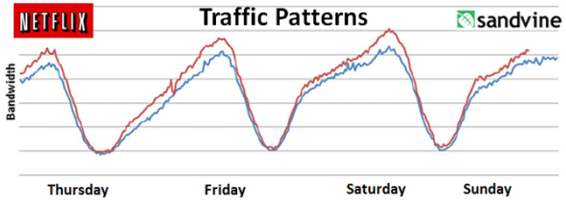
… *somehow*

early-days simplicity → complex and ossified network system

→ reaction to dynamic changes hardly possible



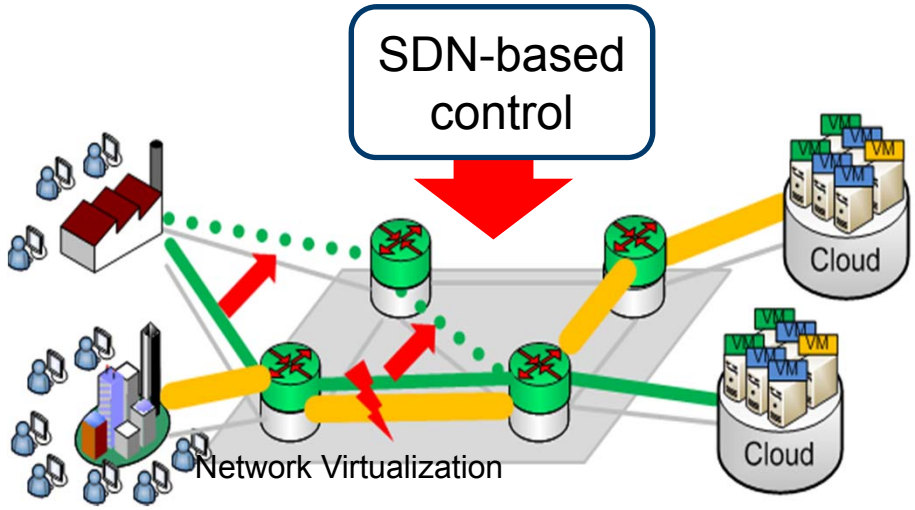


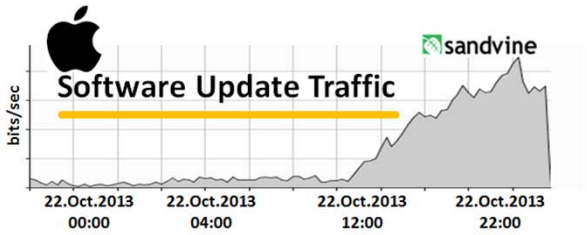


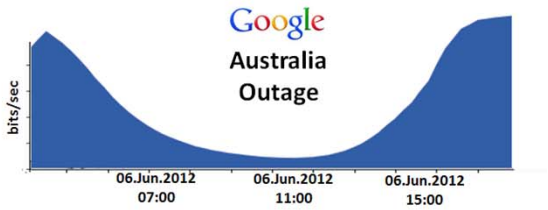
New concepts such as …

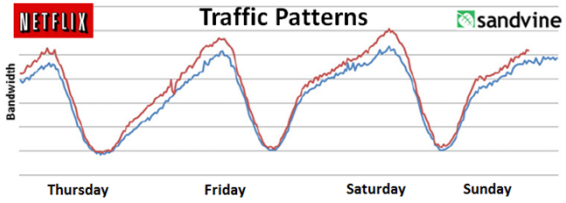
Network Virtualization, Software Defined Networking and Network Function Virtualization

…*promise* to create and adapt networks and functions on demand in software









All problems solved?

- A deeper understanding of what flexibility means and how it could be quantified to compare different network designs remains open

For networks, **flexibility** = ability to *adapt* resources (flows, topology,…) *to changes* of design requirements (dynamic traffic, shorter latencies,…)

- How far can we go? What is the right network design?

We need

- a **fundamental understanding** of how to provide flexibility
- a set of **quantitative arguments** pro and contra certain design choices
- a set of **guidelines** of how software-based network shall **be designed**

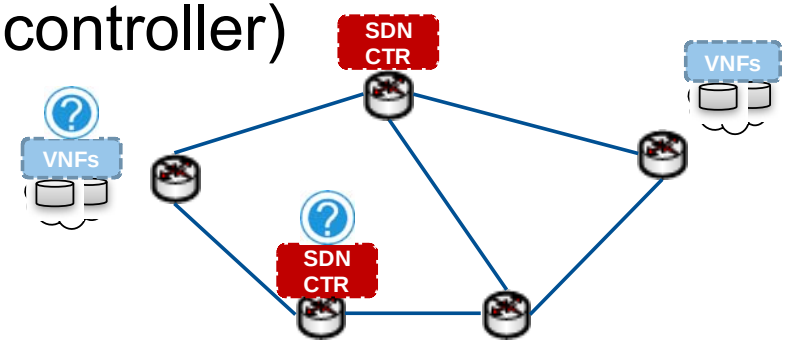
Flexibility: a new measure? – Yes!

- no single quality indicator for a ***Quality of Flexibilty (QoF)*** (similar to QoS)
- to be regarded case by case (requirements, design goals, ...)

we propose: ***flexibility aspects***

- similar as we do with QoS (rate, delay, throughput, jitter,…)
- shall allow us to compare different designs

- e.g., Function Placement (an SDN controller)
  - para: locations, supported requirements (latency),...



W. Kellerer, A. Basta, A. Blenk, Using a Flexibility Measure for Network Design Space Analysis of SDN and NFV, SWFAN'16, IEEE INFOCOM Workshop, April 2016.

A simple measure

e.g., *placement*

$$\varphi^{aspect}(S) = \frac{|supported\ requests|}{|possible\ requests|}$$

- fraction of the number of **change requests** that can be supported
  of all possible change requests
- w.r.t. to a certain **flexibility aspect** of a system S

- φ (S) ϵ [0,1] „percentage“

Something missing?
The time aspect of flexibility

"Heatposter" by Source. Licensed under Fair use via Wikipedia – http://en.wikipedia.org/wiki/File:Heatposter.jpg#/media/File:Heatposter.jpg

What Robert de Niro says on ***flexibility***

in HEAT (1995) as Neil McCauley:
"Don't get attached to anything you can't walk out on in 30 seconds flat if you feel the heat around the corner."

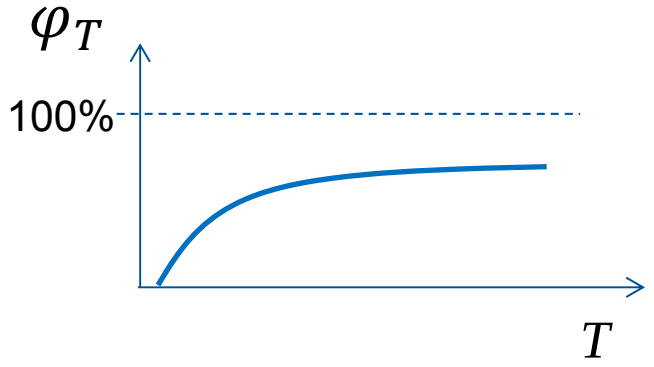
Not only the number of options, but the time matters for ***flexibility***

Quality of Flexibility – proposed definition

$$\varphi_T^{aspect}\ (S \mid \text{state i}) = \frac{|supported\ requests\ fulfilled\ in\ T|}{|possible\ requests|}$$

- fraction of the number of change requests that can be supported in a time interval T of all possible change requests
- T is small to capture system and request dynamics (sec to ms)

$$\varphi_{T->\infty}^{aspect}\ (S) = \frac{|supported\ requests|}{|possible\ requests|}$$

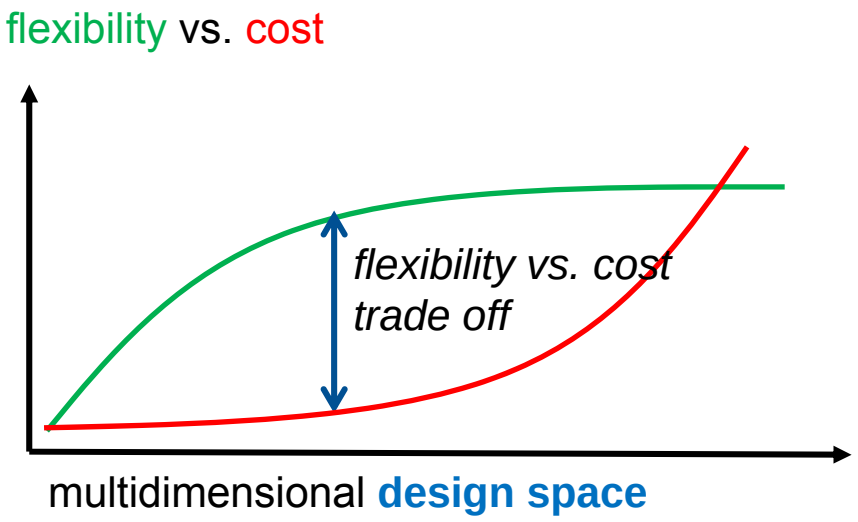


Nothing is for free: Cost of Flexibility

What are the costs of a design for flexibility?

- in terms of signaling overhead, number of data centers,…

Possible relationship (to be confirmed):



Use Case: Dynamic Controller Placement Problem

- Controller Placement Problem:
  find optimal position for 1,…,n controllers given flow input

- Dynamic Controller Placement Problem:
  do the above for time varying input → controller migration/reconfiguration

- Evaluation parameters
  - Abilene network topology (11 nodes, 14 links)
  - 100 different flow profile requests over time (random)
  - N = 1,…, 4 controllers *(designs for comparison)*
  - Algorithm finds optimal controller placement and flow to controller assignment
  - How many controllers can be migrated (incl. control plane update) in time T? (success ratio → **Flexibility**)
  - Migrations and reconfigurations → **Cost**

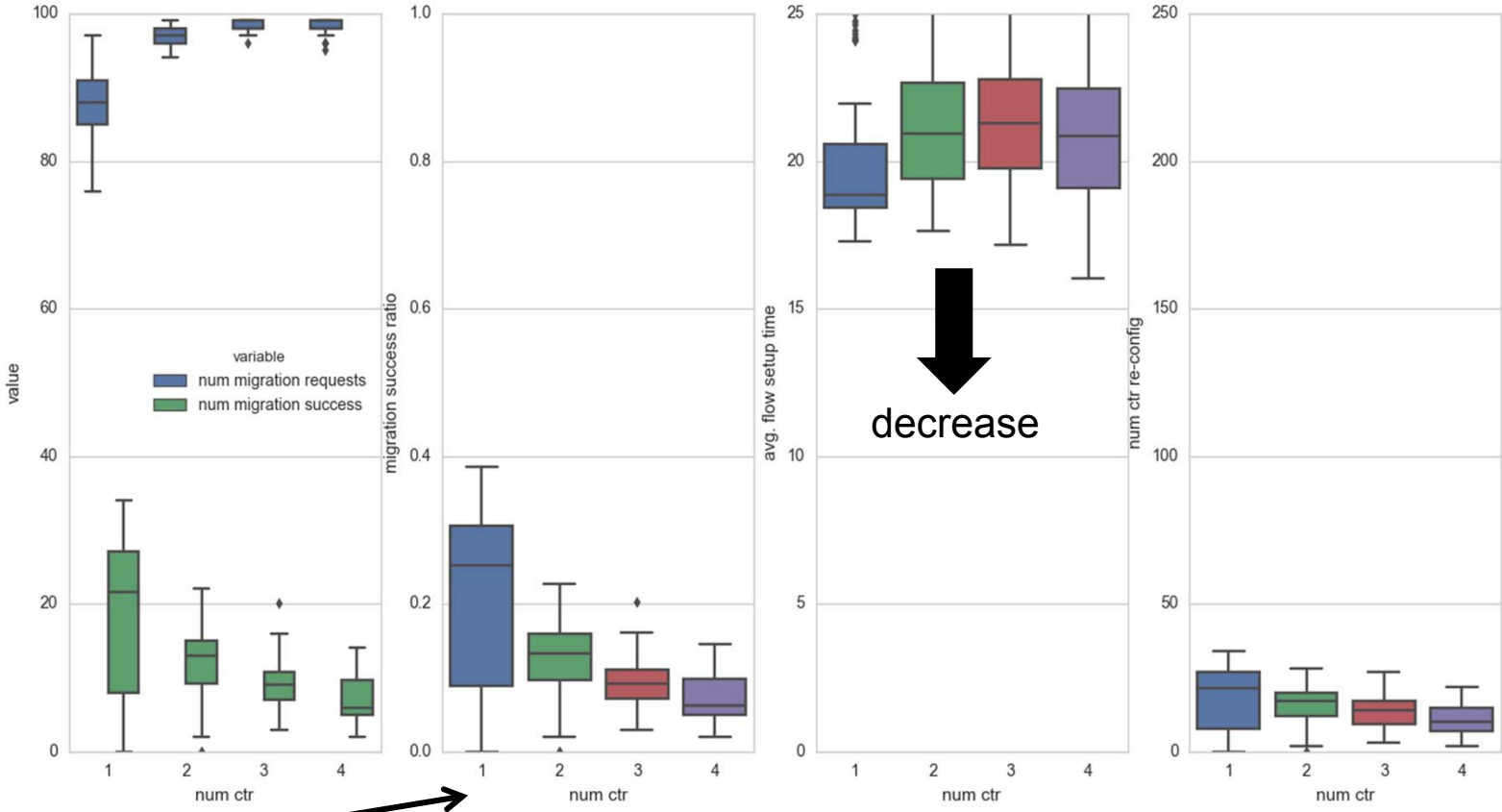
B. Heller, R. Sherwood, N. McKeown. The controller placement problem. HOTSDN 2012, Helsinki, Finland, Aug. 2012.

Simulation Results

Use Case

Flexibility **Performance** **Cost**

success ratio avg. flow setup time reconfigurations



Number of controllers N

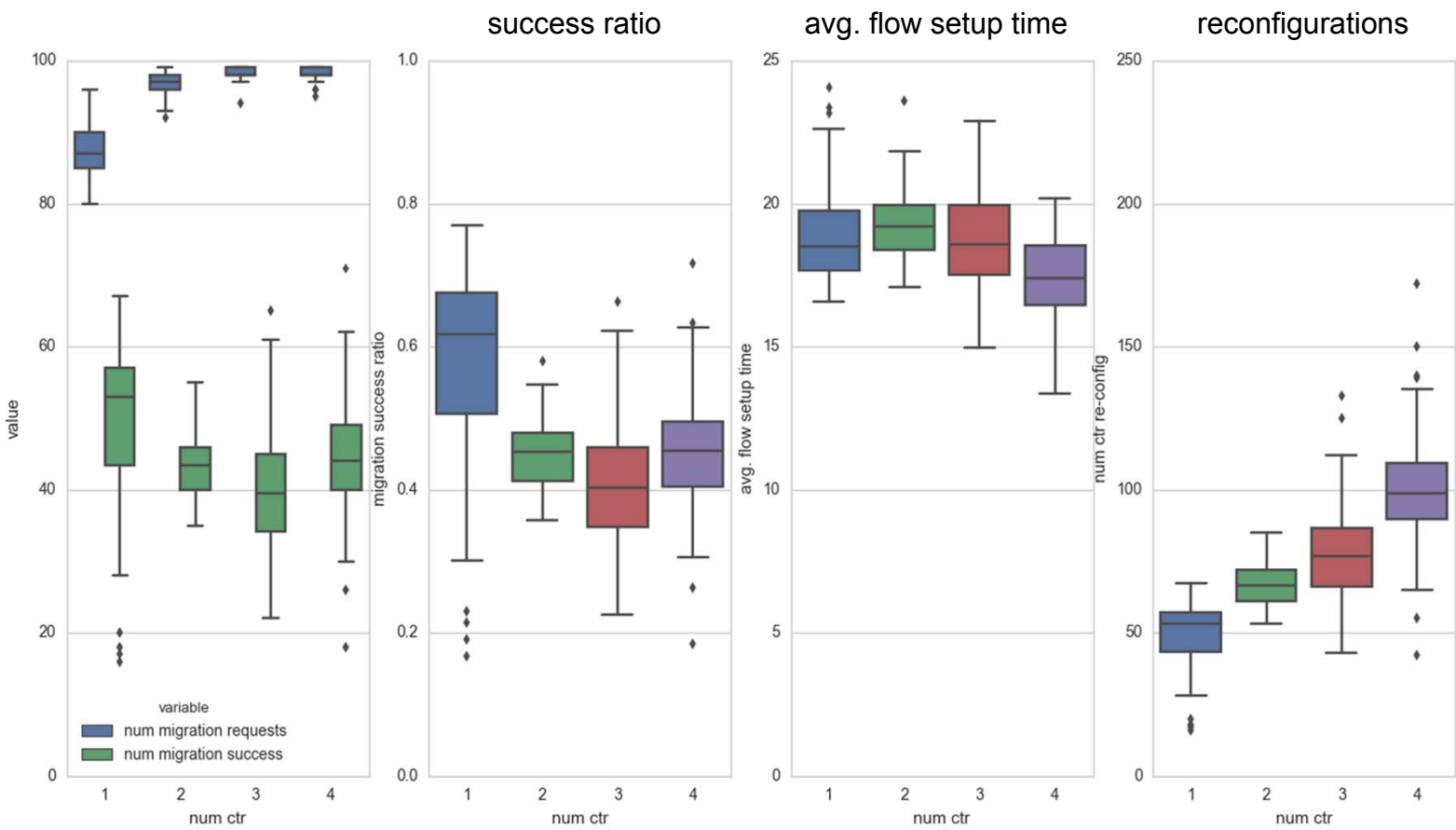
migration time threshold = 803 ms

T is very short (800 ms is transmission delay of 1 controller)

Simulation Results

Use Case

Flexibility **Performance** **Cost**



migration time threshold = 806 ms

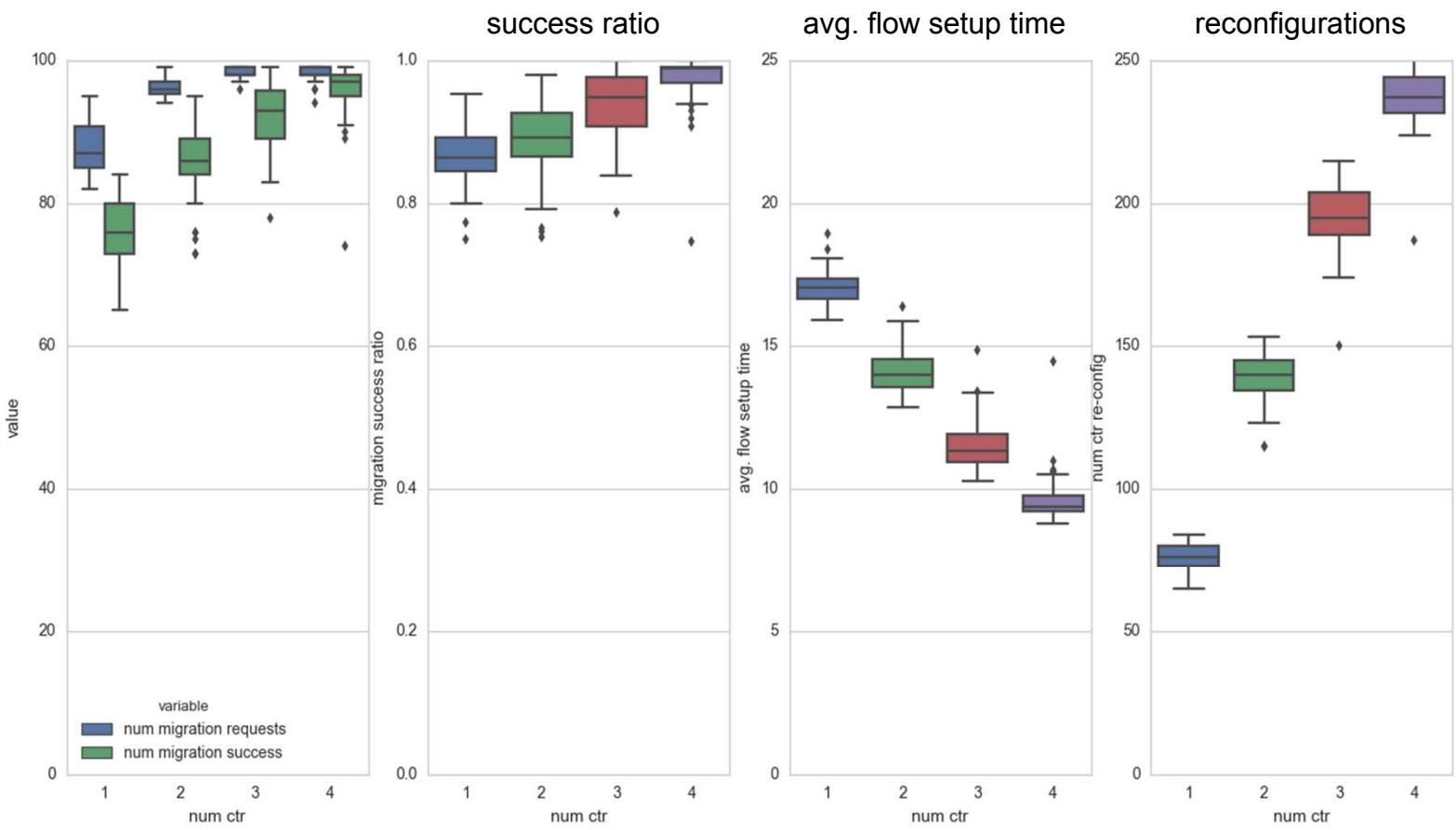
1 controller has highest flexibility at low cost

But: performance is not good (flow setup time)

Simulation Results

Use Case

Flexibility **Performance** **Cost**



migration time threshold = 811 ms

T is moderate: more controllers → higher flexibility at higher cost

Conclusion

Key Takeaways

- Network research is faced with **new requirements** from emerging networked industries
- These include **flexibility**
- Need for: new **flexible concepts** (→ HyperFlex Poster)
- Need for: a **measure** to compare flexibility among designs
- Network **dynamics** → time matters

Our flexibility testbed (SDN switches)
www.lkn.ei.tum.de

Rack 1

10x DELL switches

(Bare metal switches)
8 DELL S3048 - 48x1G,4*10G
2 DELL S4048 - 48x10G

- FTOS (OF 1.3)
- Cumulus Linux,
- Switch Light OS (big switch)

2x HP switches

Rack 2

2x Pronto switches

2x Pica8 switches

2x NEC switches

2x Net Optics traffic monitors

2x Sun Fire Servers

Spirent TestCenter C1
Provides layer 2-7 router, switch, application and security test solutions.
Supports line-rate 1GE or 10GE test ports.