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How Flexible is Your Network?
A Proposal to Quantify Flexibility in Softwarized Networks

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www.networkflexibility.org

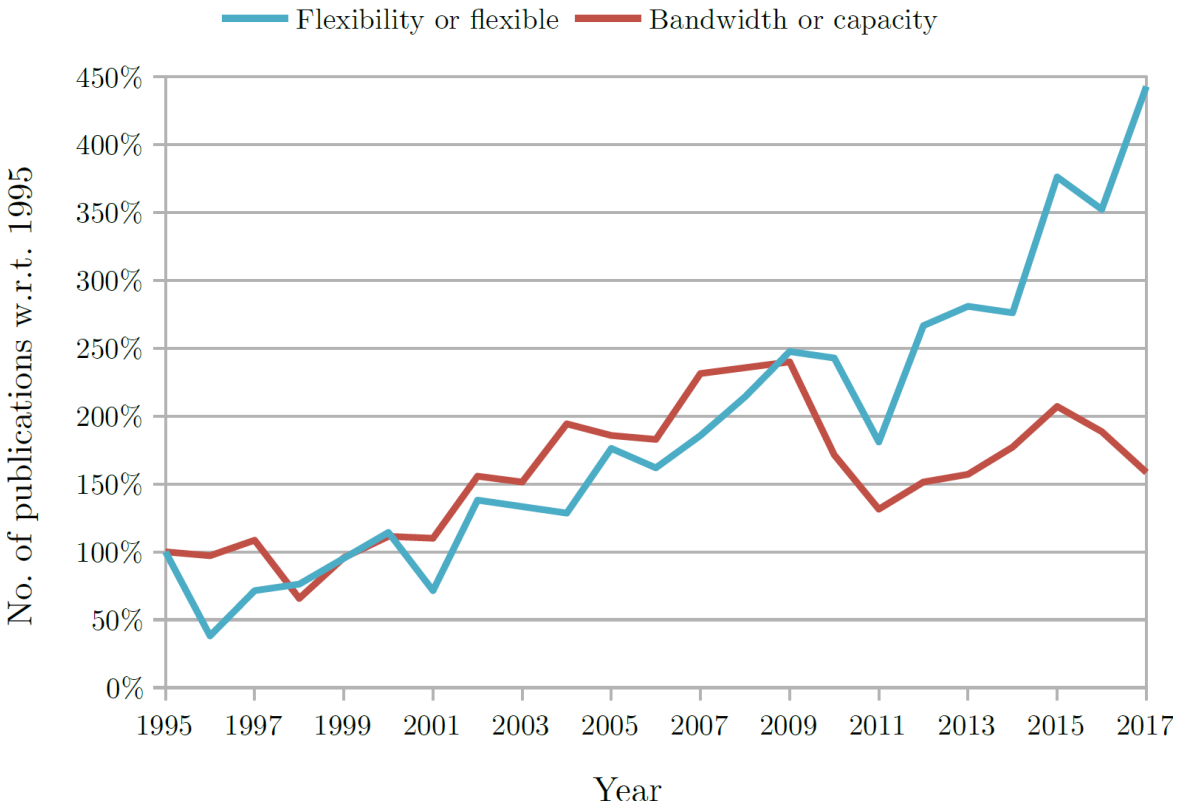
FlexNets

This work is part of a project that has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program grant agreement No 647158 – **FlexNets (2015 – 2020)**.

European Research Council
Established by the European Commission

The rise of flexibility

- Flexibility is gaining increasing **attention** and **importance**



Evolution of the number of publications containing the words ”flexible” or ”flexibility” in contrast with those containing ”bandwidth” or ”capacity” in four major IEEE journals and magazines on communication, with respect to the number of publications in 1995.

Why?

- Evolution tells us that the more flexible species can better survive
- What about networks? Will they survive?

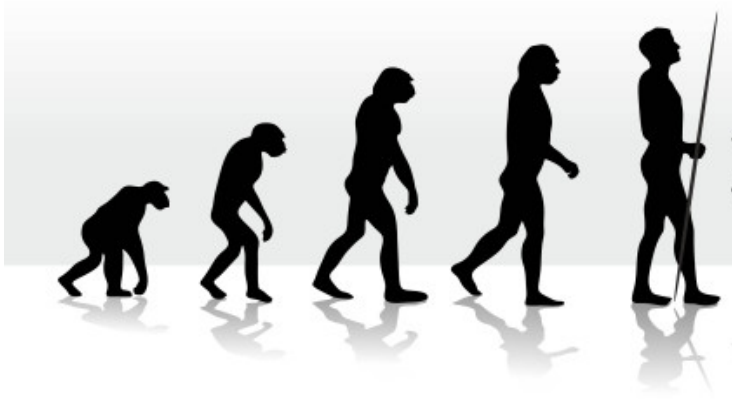


Image source: http://www.paleoplan.com

- So far less explicitly addressed: ***flexibility*** and hence ***adaptation***

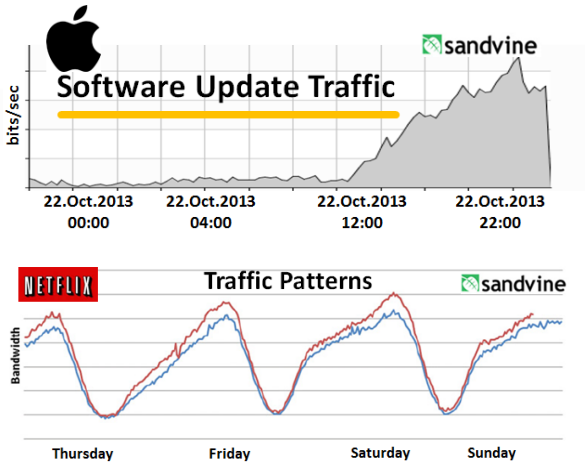
- Today, we will present our ***Flex*****Nets** project, comprising of ...
  … a definition of network flexibility and a flexibility measure …
  … and give examples of how to apply to stimulate discussions.

Towards softwarized networks

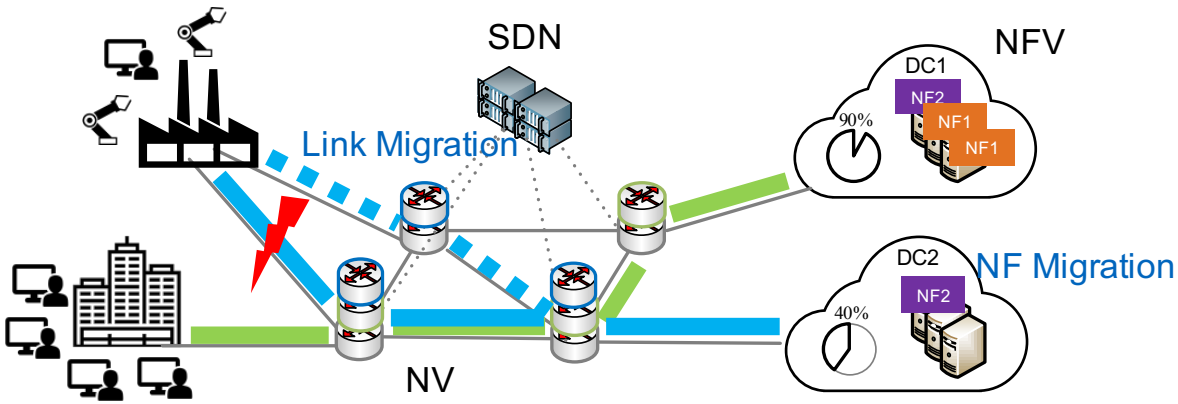
The Internet is able to adapt its resources … *somehow* (best-effort, TCP,…)

early-days simplicity → ossified network system

very slow adaptation to new requirements
→ reaction to dynamic changes hardly possible



Softwarized Networks (SDN, NFV and Network Virtualization)
promise to adapt networks and functions on demand



All problems solved?

- Are we fully flexible already?
- How far can we go? What is the optimal network design?

We need
- a **fundamental understanding** of how to provide flexibility
- a **quantitative measure** for flexibility pro and contra certain designs

Network **flexibility** = ability to support *adaptation requests (challenges)* (e.g., new requirements or traffic patterns) in a *timely* and *efficient* manner

W. Kellerer, *et al.*, "How to measure network flexibility? A proposal for evaluating softwarized networks," *IEEE Communications Magazine*, 2018.

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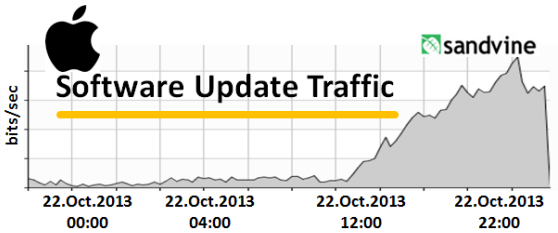
FlexNets
2015 - 2020

European Research Council

Why do we think flexibility analyis is important?



- Enables operators to **cover the future**!
  - react to regulatory changes and fast arrival of new technologies

- A key **decision factor** between network designs
  - can be a tie-breaking decisive advantage for a certain network design (e.g., centralized vs. distributed? edge computing? CloudRAN?)

- For research and development
  - which technical concepts lead to more flexibility in network design ?
    → **optimize** networks **for flexibility**
    → **design guidelines** for more flexible networks

- SoA: lack of a concrete definition and a quantitative analysis!
- *We need a proper definition and a measure!*

Flexibility qualitative measure exercise

vs.

Source: Magazin.com

Fixed-set tool **Re-configurable tool box**

- Which tool is more flexible?
  - re-configuration shows more potential to be **more flexible**
- When can both exihbit the same flexibility?
  - maybe there is **no need to change** → probability of requests make a difference
  - maybe both cannot satsify my requests → **infeasible**
- When can the re-configurable tool be less flexible?
  - **adaptation time** → re-configurable object might not be handy
  - **cost** → inefficient

Screwdriver

Measuring Network Flexibility (our proposal)

(comparing network designs)

adaptation time threshold (T) and cost budget (C)

Input: Constraints T, C

1. Design sequence $\mathbb{C} = \{s_{i_1,j_1}, s_{i_2,j_2}, \ldots\}$ with $\nu(s_{i,j}) = V$
2. Initialize $\Sigma := 0$
3. FOR k = 1:K
   a. Challenge state switch $S_{i_k} \mapsto S_{j_k}$
   b. Observe τ_X and c_X
   c. If $\tau_X \leq T$ and $c_X \leq C$: $\Sigma := \Sigma + 1$
4. END
5. $\varphi(T, C) := \Sigma / K$

challenges: request sequence

check if system can adapt and record time and cost

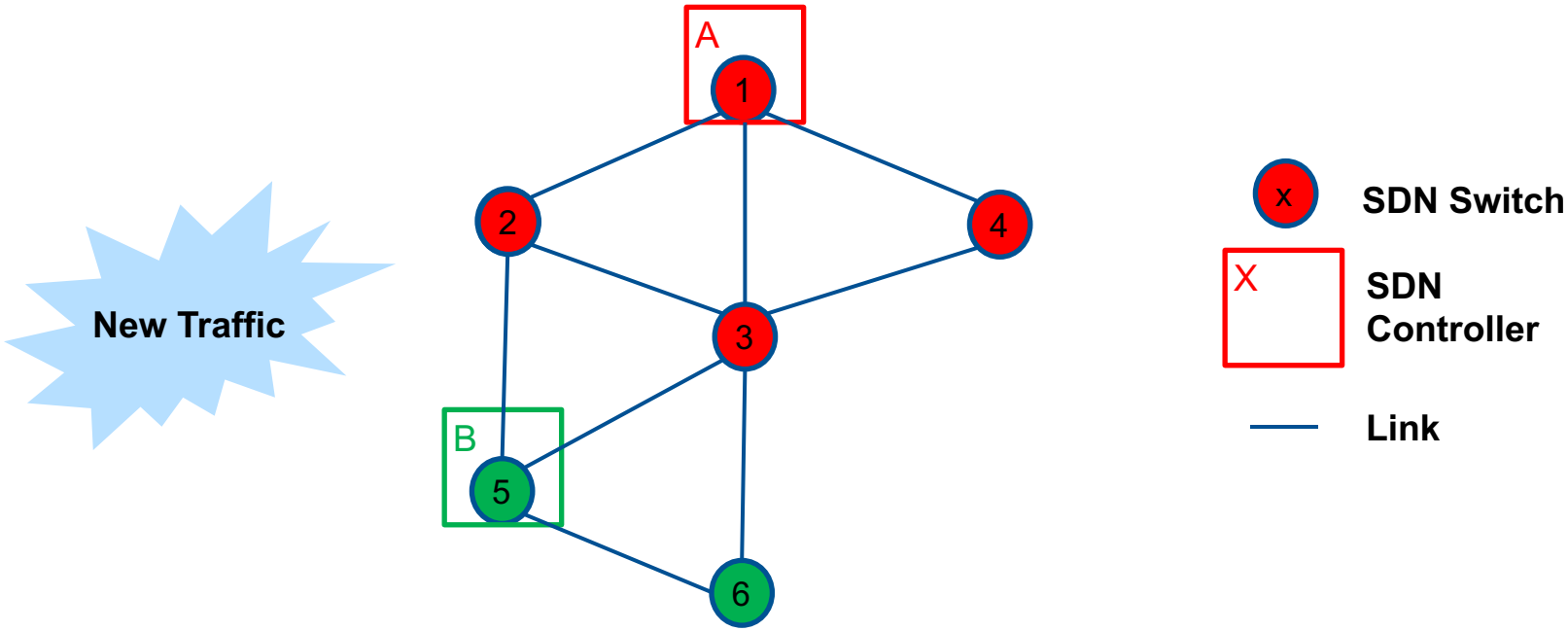
count successes

Flexibility

$$\varphi(T, C) = \frac{|\text{supported requests within constraints } (T, C)|}{|\text{Number of requests}|}$$

based on mathematical foundation

Case study: Dynamic Controller Placement



- Traffic fluctuations require control plane to adapt in order to achieve better control performance → *Dynamic Control Plane*
  - SDN controller migration & SDN switch reassignment

Flexibility Aspect	New Request	Flexibility Measure	System Objective	Cost in focus
function placement	new flow arrival (from distribution)	fraction of successful controller placements	control performance: (min. avg. flow setup time)	operation latency (OPEX): avg. flow setup time

Case study: Dynamic Controller Placement

Varying traffic flow profiles

max. adaptation time threshold (will be varied)

$$\varphi_T(S) = \frac{|supported\ requests\ within\ T|}{|given\ new\ requests|}$$

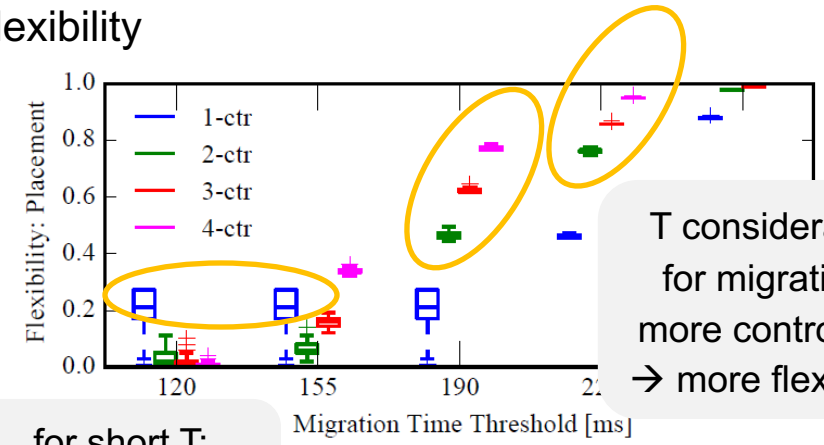
$C \rightarrow \infty$ recorded

SDN controller migration and switch reassignment can be done within T

- Flexibility → Migration Success Ratio
  - Calculate controller migration and switch reassignment time *T_migration*
  - If *T_migration* smaller than T → count as a supported request

Case study: Dynamic Controller Placement

Flexibility

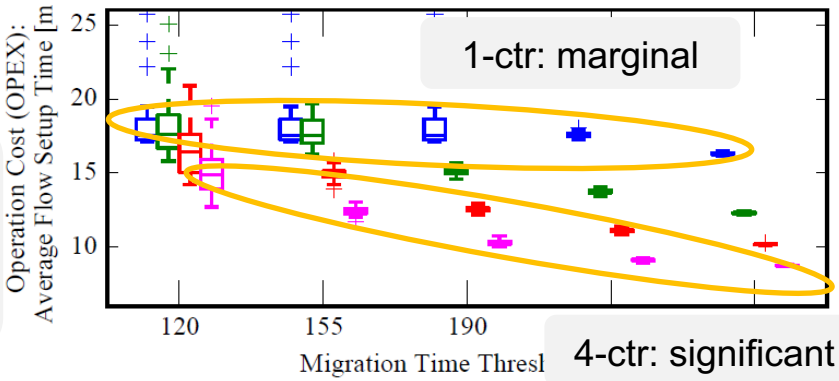


T considerable for migration: more controllers → more flexibility

for short T: 1 controller is more flexible

in terms of successful control plane migration.

Cost



(b) Operation cost (OPEX) in terms of the average flow setup time.

intuitive

- **More controllers** (larger migration time threshold) → higher flexibility
- **Single controller** case: more flexible for **tight time threshold** as probability that single controller stays in optimal location is high

unexpected!

- 1 controller → **marginal** performance improvement vs. adaptation T
- 4 controllers → **significant** performance improvement vs. adaptation T
- However, if we consider **all cost factors**, we can reach a trade-off!

M. He, A. Basta, A. Blenk, W. Kellerer, *How Flexible is Dynamic SDN Control Plane?,* IEEE INFOCOM Workshop, SWFAN'17, Atlanta, USA, May 2017.

Key takeaways: Flexibility matters!

for a meaningful system analysis a

flexibility definition is important

to compare and design networks for flexibility

our **flexibility measure**

supports a quantitative ***comparison*** between multiple systems

can be used to ***optimize for flexibility***

join us on networkflexibility.org

References for this talk

W. Kellerer, A. Basta *et al.*, “How to measure network flexibility? A proposal for evaluating softwarized networks,” *IEEE Communications Magazine*, 2018.

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

M. He, A. Basta, A. Blenk, W. Kellerer, *How Flexible is Dynamic SDN Control Plane?,* IEEE INFOCOM Workshop, SWFAN‘17, Atlanta, USA, May 2017.

many more on **networkflexibility.org**
and

P. Kalmbach, J. Zerwas, P. Babarczi, A. Blenk, W. Kellerer, S. Schmid, Empowering Self-Driving Networks.
ACM SIGCOMM 2018 Workshop on Self-Driving Networks - SelfDN 2018
- in the afternoon