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

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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?

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

Today, we will present our **FlexNets 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


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Why do we think flexibility analysis 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

• Which tool is more flexible?
  • re-configuration shows more potential to be more flexible

• When can both exhibit the same flexibility?
  • maybe there is no need to change → probability of requests make a difference
  • maybe both cannot satisfy my requests → infeasible

• When can the re-configurable tool be less flexible?
  • adaptation time → re-configurable object might not be handy
  • cost → inefficient

Fixed-set tool vs. Re-configurable tool box

Source: Magazin.com
Measuring Network Flexibility (our proposal)

(comparing network designs)

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 $\tau_X$ and $c_X$
   c. If $\tau_X \leq T$ and $c_X \leq C$: $\Sigma := \Sigma + 1$
4. END
5. $\phi(T, C) := \Sigma/K$

Flexibility

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

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

<table>
<thead>
<tr>
<th>Flexibility Aspect</th>
<th>New Request</th>
<th>Flexibility Measure</th>
<th>System Objective</th>
<th>Cost in focus</th>
</tr>
</thead>
<tbody>
<tr>
<td>function placement</td>
<td>new flow arrival (from distribution)</td>
<td>fraction of successful controller placements</td>
<td>control performance: (min. avg. flow setup time)</td>
<td>operation latency (OPEX): avg. flow setup time</td>
</tr>
</tbody>
</table>
Case study: Dynamic Controller Placement

- Flexibility \rightarrow Migration Success Ratio
  - Calculate controller migration and switch reassignment time $T_{migration}$
  - If $T_{migration}$ smaller than $T \rightarrow$ count as a supported request

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

Varying traffic flow profiles

max. adaptation time threshold (will be varied)

SDN controller migration and switch reassignment can be done within $T$

$C \rightarrow \infty$ recorded
Case study: Dynamic Controller Placement

More controllers (larger migration time threshold) $\rightarrow$ higher flexibility

Single controller case: more flexible for tight time threshold as probability that single controller stays in optimal location is high

- 1 controller $\rightarrow$ marginal performance improvement vs. adaptation T
- 4 controllers $\rightarrow$ significant performance improvement vs. adaptation T

However, if we consider all cost factors, we can reach a trade-off!

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](http://networkflexibility.org)
References for this talk


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.


*many more on networkflexibility.org*

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