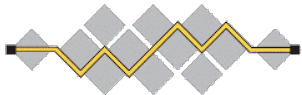


Using Flexibility as a Measure to Evaluate Softwarized Networks

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Prague, July 17, 2017



I E T F[®]

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IRTF NFVRG

- Networking today: **new requirements** from vertical industries, dynamically changing user behavior, and global digitalization
- Less (explicitly) addressed: **flexibility** and hence **adaptation**

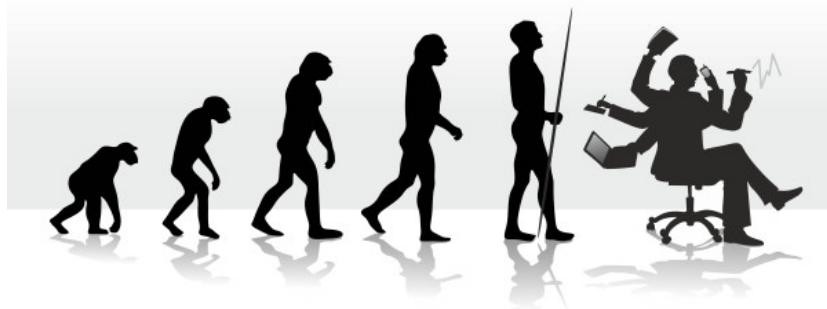


Image source: <http://www.paleoplan.com>

- In this talk, I will ...
 - ... present our definition of a measure for network flexibility ...
 - ... give concrete use cases of how to apply ..
 - ... raise more questions



2015 - 2020



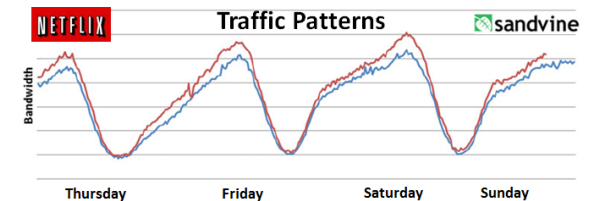
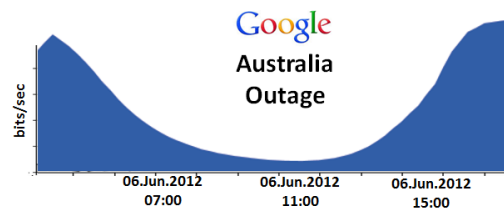
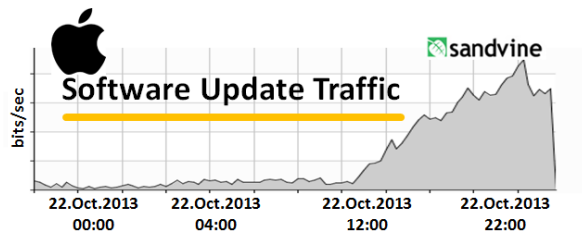
European Research Council
Established by the European Commission

The Internet

... is able to adapt its resources
... *somehow* (best-effort, TCP elasticity, BGP, OSPF)

early-days simplicity
→ complex and ossified network system

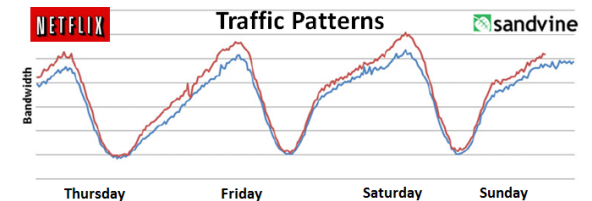
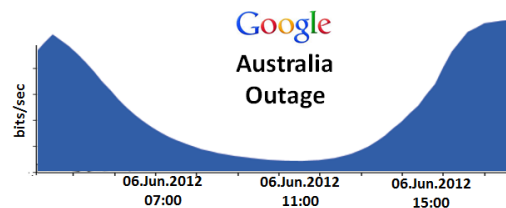
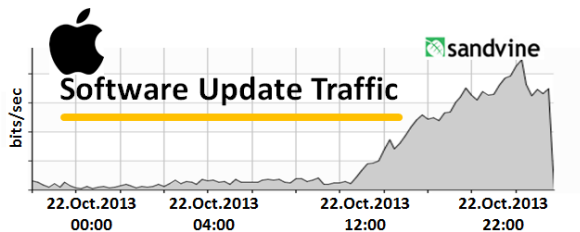
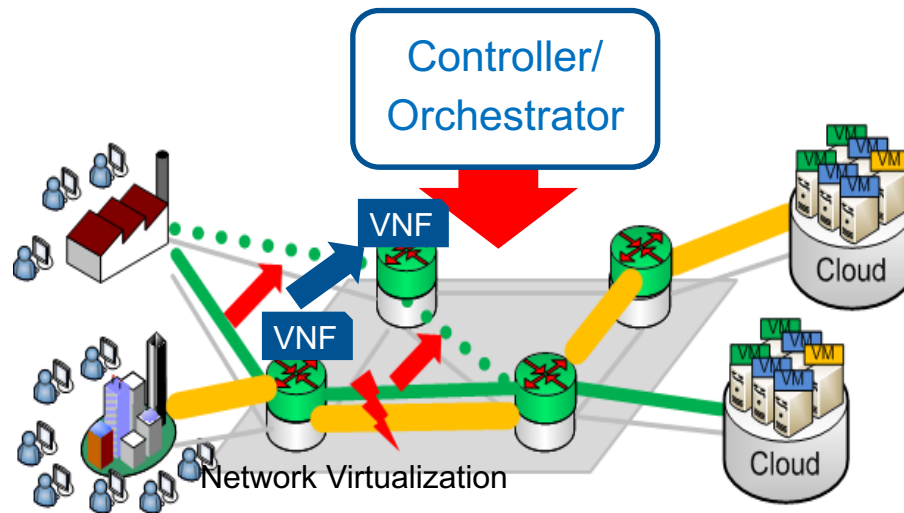
very slow adaptation to new requirements
→ reaction to dynamic changes hardly possible



New concepts such as ...

Network Function Virtualization (NFV) and Software Defined Networking (SDN)

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



All problems solved?

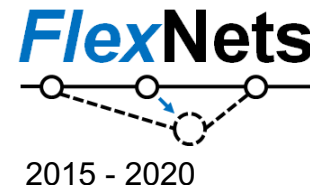
- Are we fully flexible already?
- How far can we go? What is the right network design?

We need

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

For networks, **flexibility** = ability to *support new requests* to change design requirements (traffic pattern, latencies,...) in a *timely* manner via adaptation of resources (topology, capacity, ...) if needed

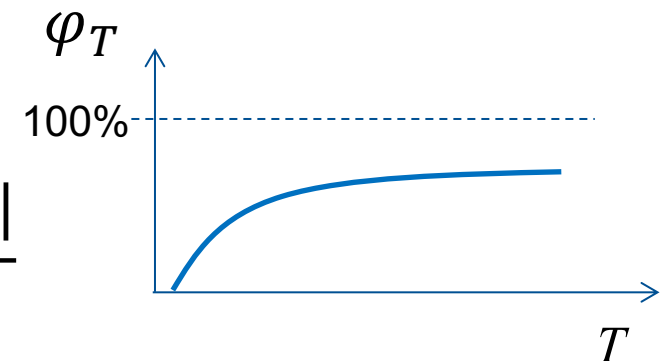
This work is part of a project that has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 program grant agreement No 647158 – **FlexNets (2015 – 2020)**.



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

- fraction of the number of **new requests** that can be supported in a **time interval T** of all given new requests

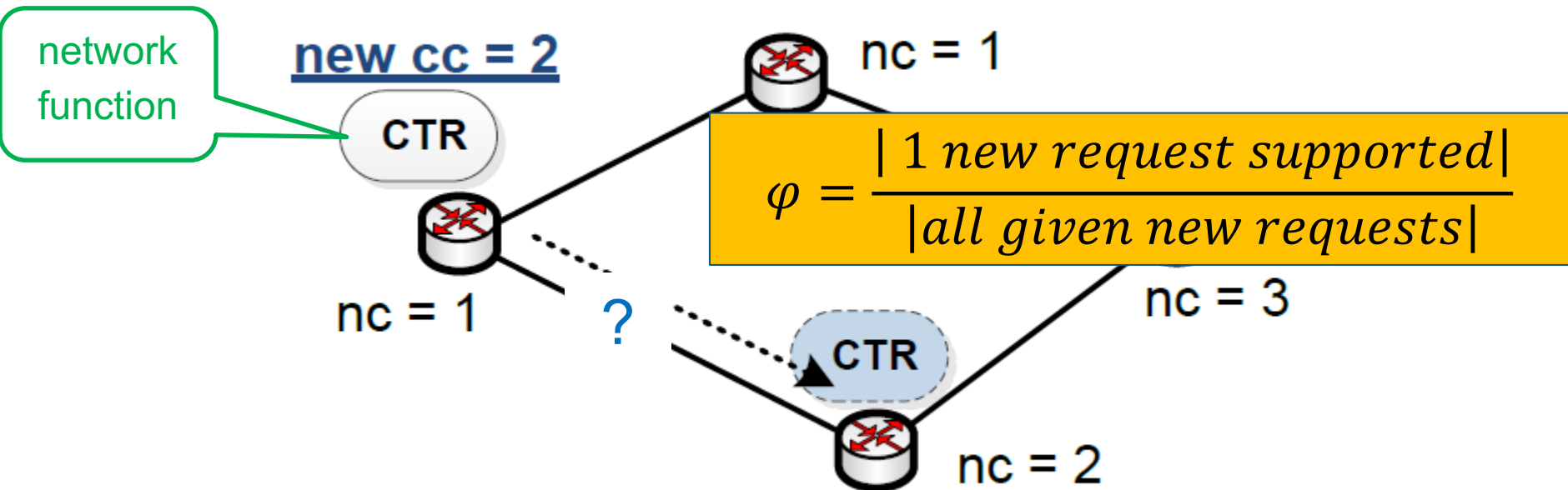
$$\varphi_{T \rightarrow \infty}(S) = \frac{|supported\ new\ requests|}{|all\ given\ new\ requests|}$$



A simple illustration (1)

network function: SDN controller

- New request to an SDN-network: Controller Capacity (cc) is increased
- Can such new request be supported?
e.g. by migrating the controller to a node with higher capacity (NC)
- BUT: migration time cannot exceed “1 hop” (T)
max. migration time $T = 1$ hop



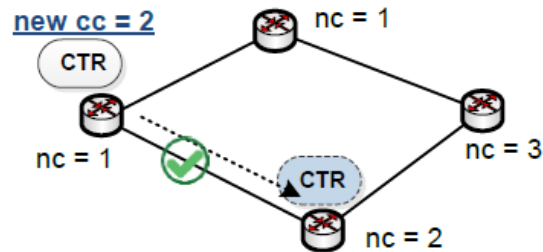
A simple illustration (2): more requests

$$\varphi_{T=1hop} = \frac{|1 \text{ new request supported}|}{|3 \text{ given new requests}|} = \frac{1}{3} = 33\%$$

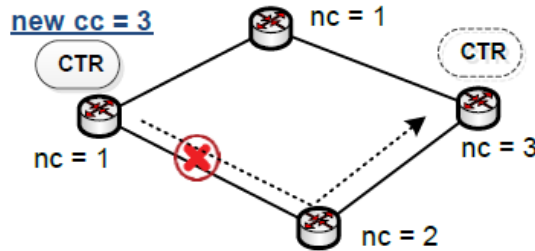
max. migration time $T = 1 \text{ hop}$

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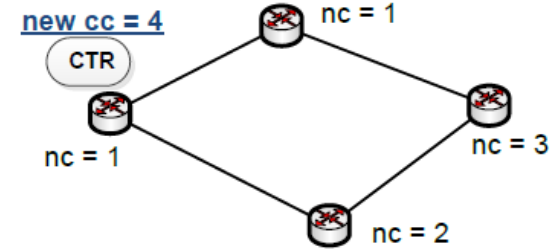
max. migration time $T = 1 \text{ hop}$



new request can be supported



new request can not be supported

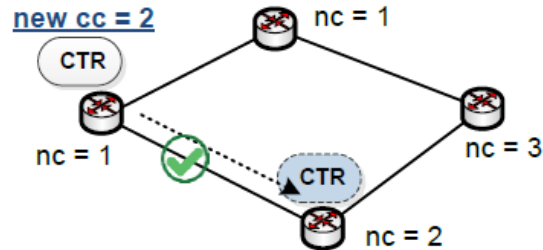


new request can not be supported

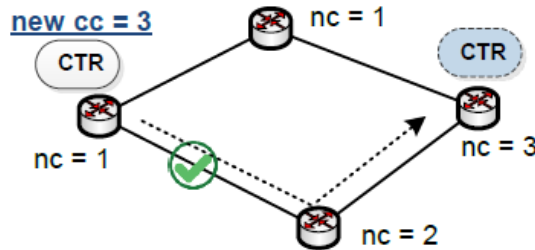
max. migration time $T = \infty$

max. migration time $T = \infty$

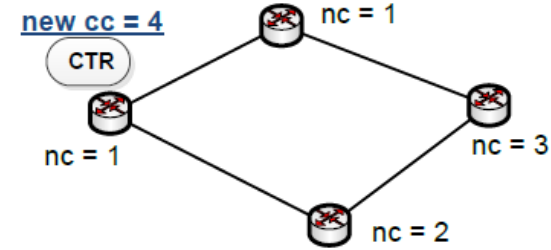
max. migration time $T = \infty$



new request can be supported



new request can be supported



new request can not be supported

$$\varphi_{T \rightarrow \infty} = \frac{|2 \text{ new request supported}|}{|3 \text{ given new requests}|} = \frac{2}{3} = 66\%$$

Flexibility a new measure? - Yes

no single quality indicator for a **Quality of Flexibility (QoF)**

- similar to QoS
- to be regarded by case (requirements, design goals, system)

we propose: **flexibility aspects** [1, 2]

- similar as we do with QoS (rate, delay, throughput, jitter,...)
- shall allow us to quantitatively compare two different system designs
- Examples: *flow steering, function placement*

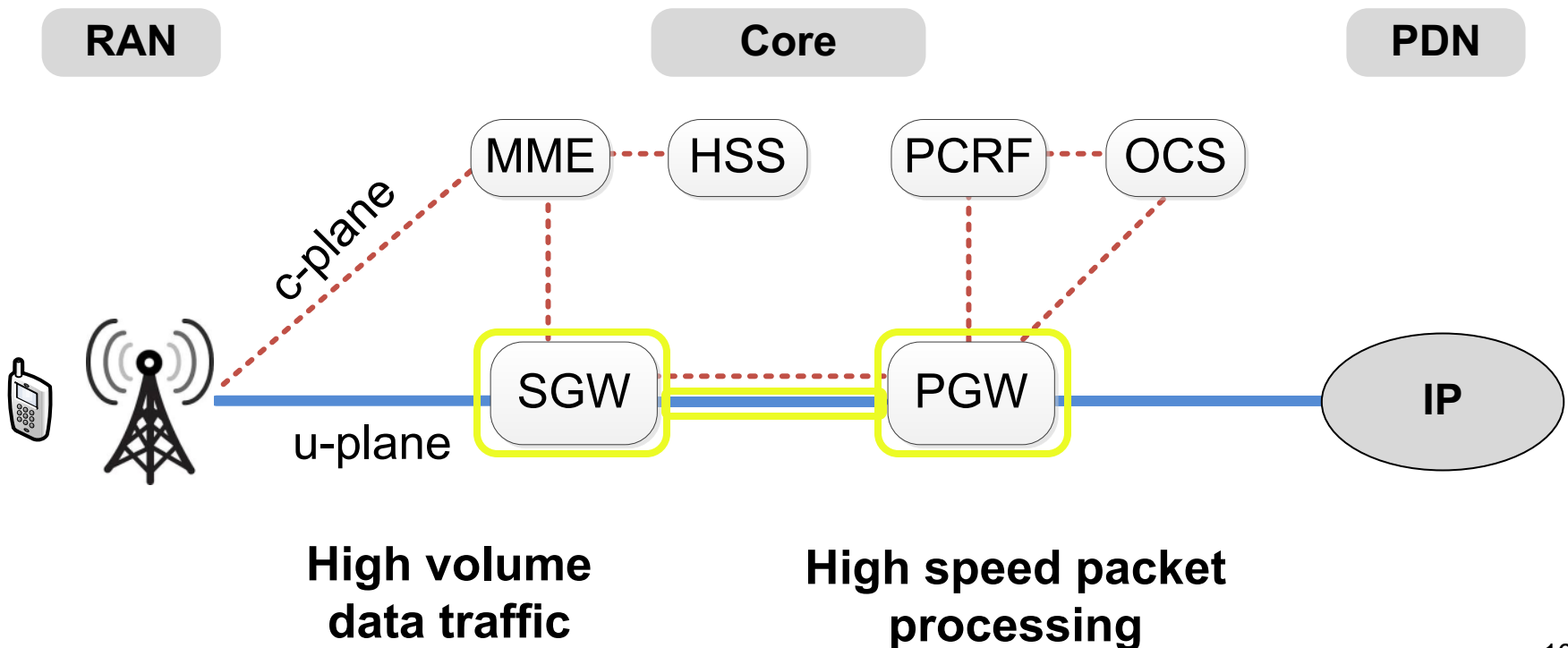
[1] W. Kellerer, A. Basta, A. Blenk, Using a Flexibility Measure for Network Design Space Analysis of SDN and NFV, SWFAN'16, IEEE INFOCOM Workshop, April 2016.

[2] W. Kellerer, A. Basta, A. Blenk, Flexibility of Networks: a new measure for network design space analysis?. arXiv preprint arXiv:1512.03770, 2015.

Use Case 1: *The Function Placement Problem*

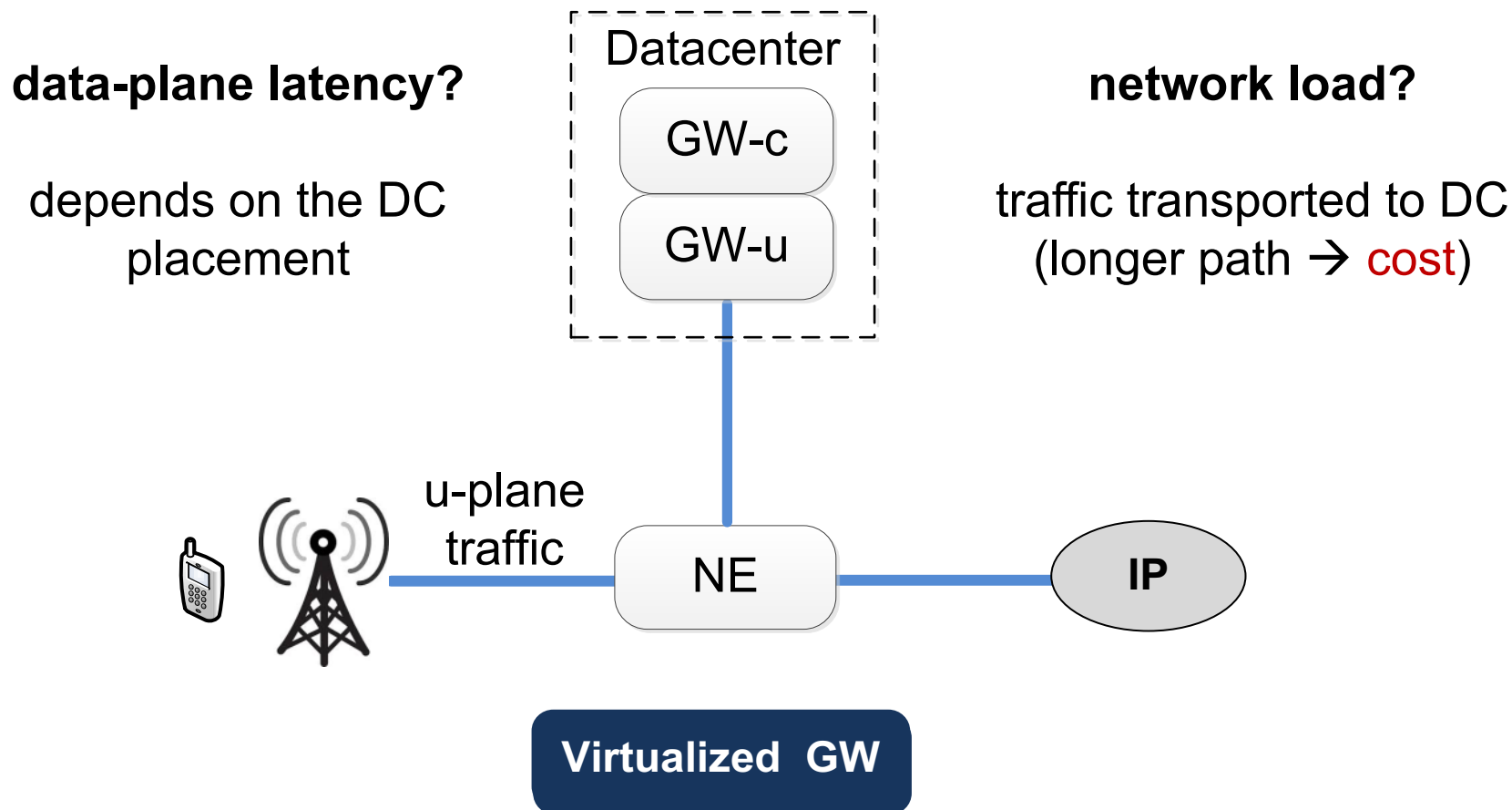
- NFV = virtualize & move **function** (= everything) to DC

Example: mobile core network functions



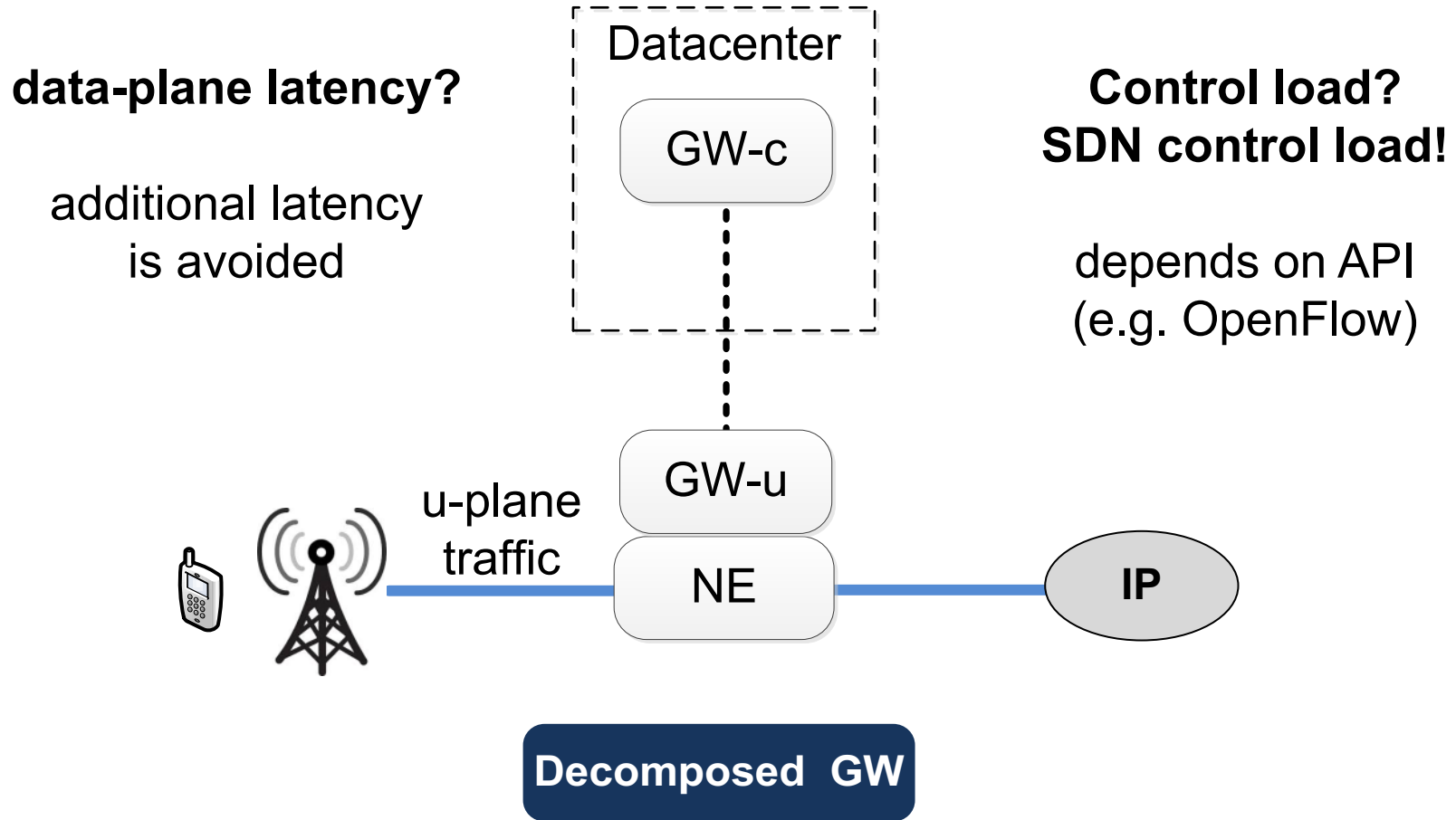
Function Realization based on NFV

- Virtualization of GW functions [3] → NFV



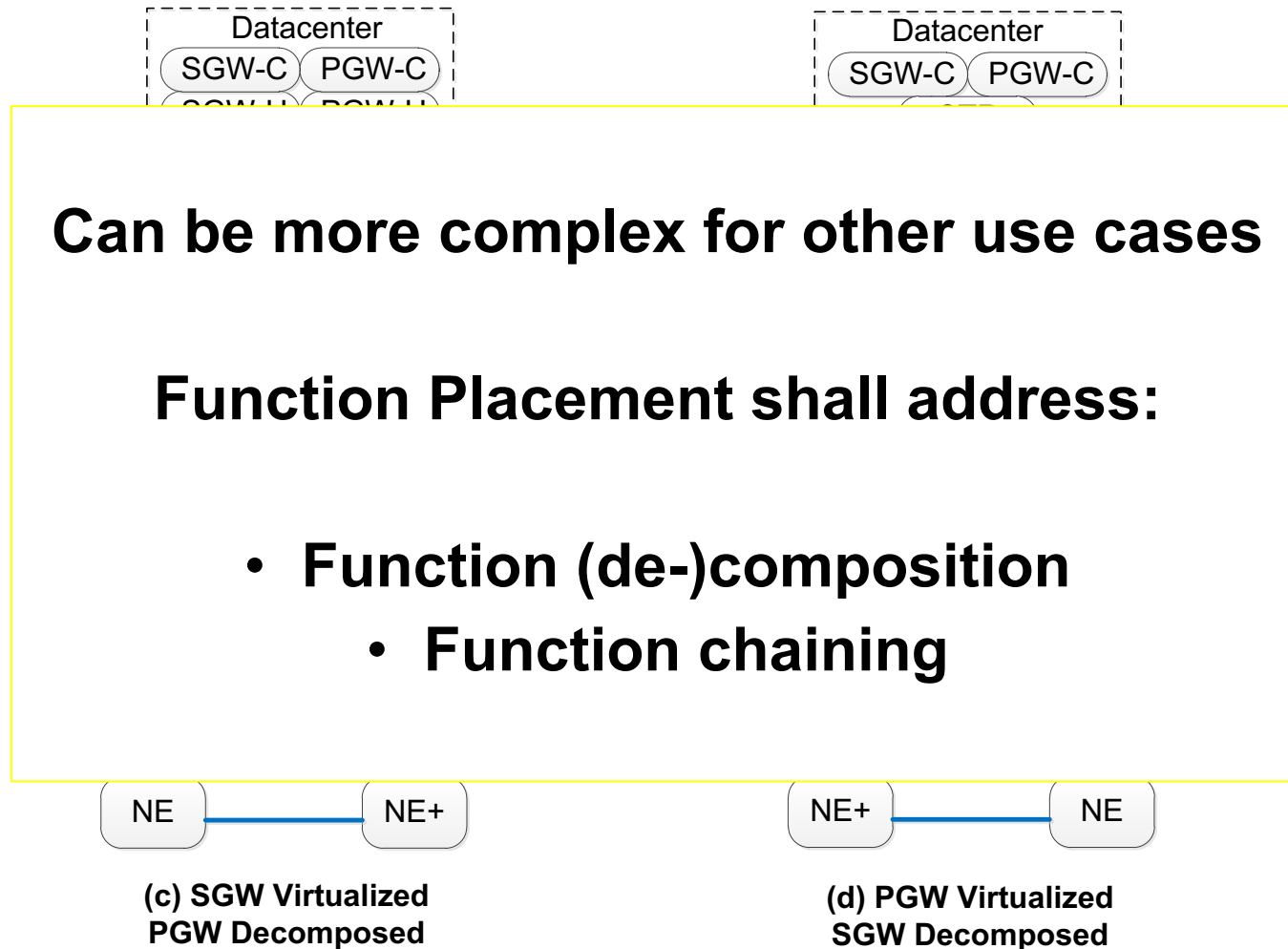
Function Realization based on SDN: *move functions back*

- Decomposition of GW functions [3] via SDN





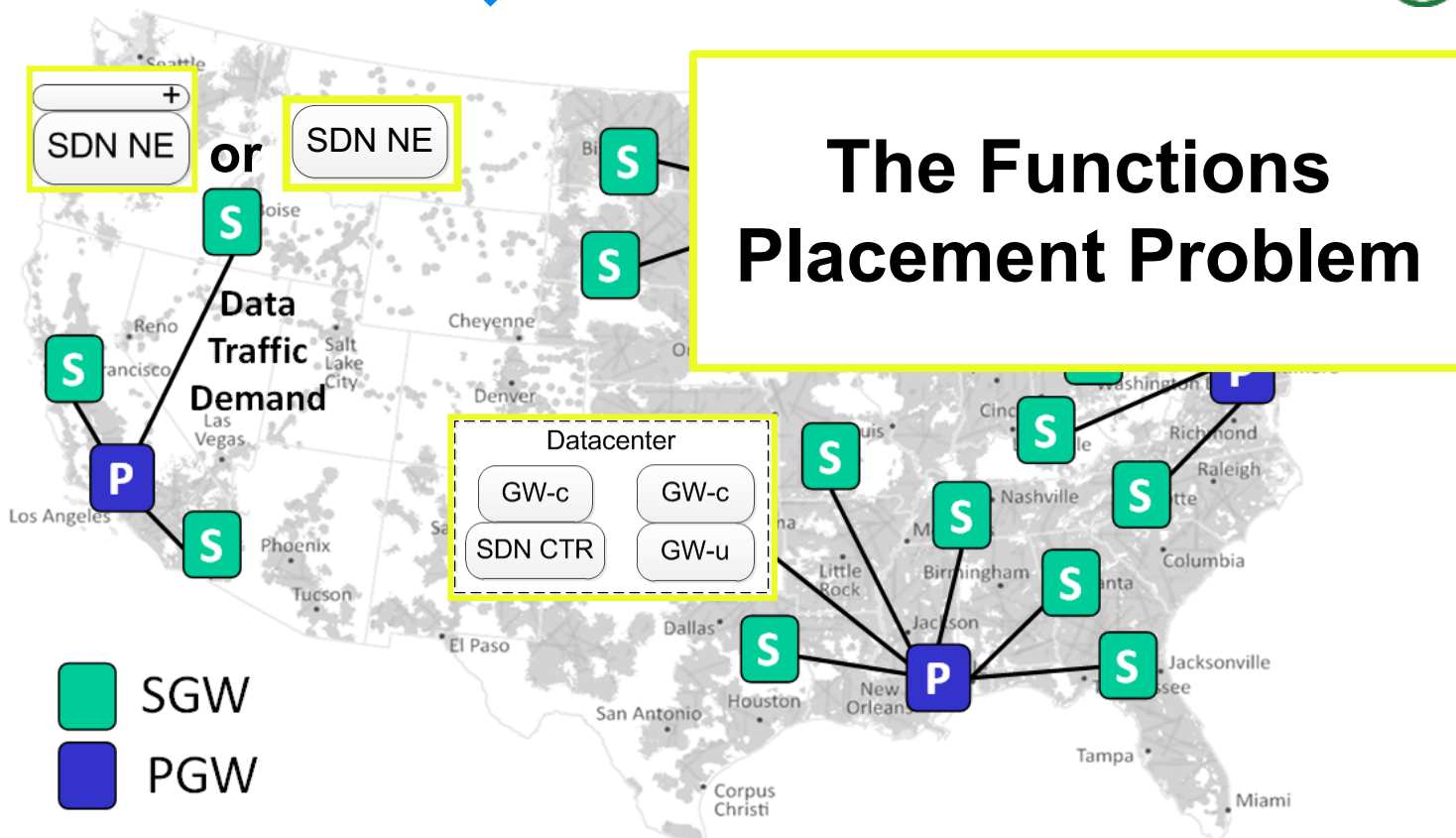
Interdependencies → Function chains (mixed design)

- Propagation latency depends on function chain = path SGW - PGW



Some Evaluation Studies [4]

- Virtualize all GWs? decompose all? mixed deployment?
 - Which GWs should be virtualized? decomposed? DC(s) placement?
- minimize core load 
- satisfy data-plane latency 



Flexibility Analysis of Function Placement

Use Case 1

3 design choices (= **systems**) to compare [1]:

- (1) SDN design
- (2) NFV design
- (3) mixed SDN/NFV design

Parameter in focus:

- Flexibility to support different **latency requirements** for
 - control plane latency and data plane latency

e.g.: {5, 10, 15, ..., 45, 50} ms

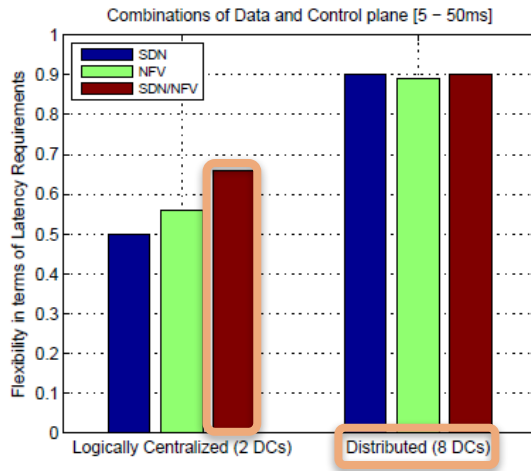
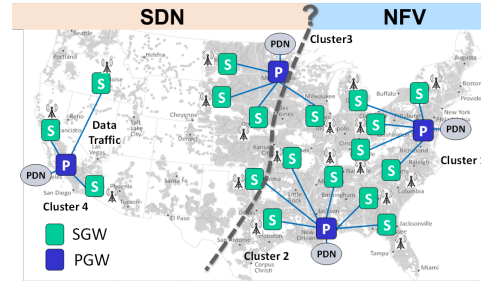
all requests:
10 x 10 = 100

$$\varphi^{placement}(design.x) = \frac{(\sum_i \sum_j feasibleSol_{i,j} \cdot w_{i,j})}{\sum_i \sum_j w_{i,j}}$$

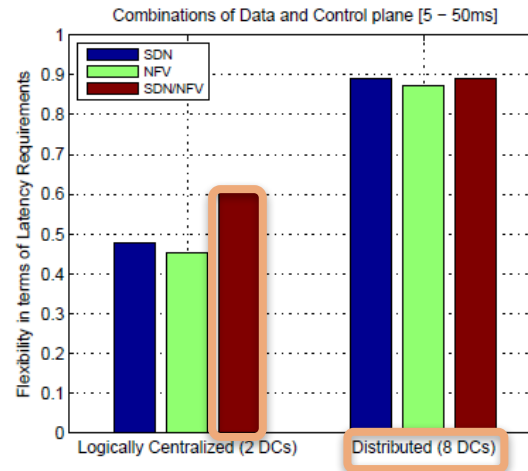
[1] W. Kellerer, A. Basta, A. Blenk,

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

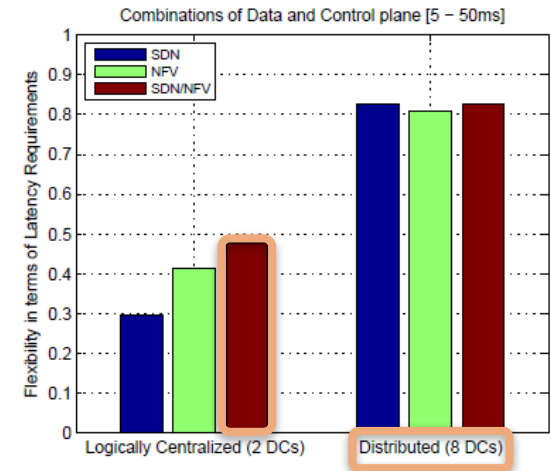
Results [1]



(a) equal weights for data and control latencies



(b) weights biased by data latency



(c) weights biased by control latency

With respect to the support of latency requirements in function placement:

- mixed SDN/NFV is more flexible for a logically centralized data center infrastructure
- for distributed data centers all three design choices are equally flexible

Use Case 2: Dynamic Controller Placement Problem

SDN controller as the network function

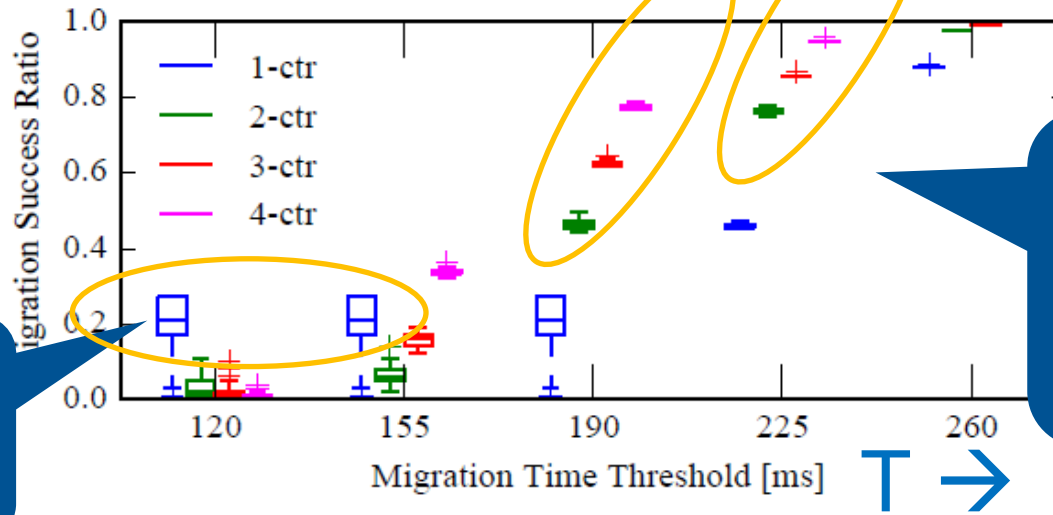
- place 1 ..n SDN controllers for time varying traffic input
→ controller migration/reconfiguration
- Evaluation parameters [5, 6]
 - Abilene network topology (11 nodes, 14 links)
 - **new requests**: 100 different flow profile requests over time (random)
 - $N = 1, \dots, 4$ controllers (**design choices for comparison**)
 - Algorithm finds optimal controller placement and flow to controller assignment
optimization goal: minimize avg. flow setup time (**performance**)
 - How many controllers can be migrated (incl. control plane update) **in time T**?
(success ratio → **Flexibility**)
 - Migrations and reconfigurations → **Cost**

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

[6] M. He, A. Basta, A. Blenk, W. Kellerer, *Modeling Flow Setup Time for Controller Placement in SDN: Evaluation for Dynamic Flows*, IEEE International Conference on Communications (ICC), Paris, France, May 2017.

Results (from [5])

Flexibility



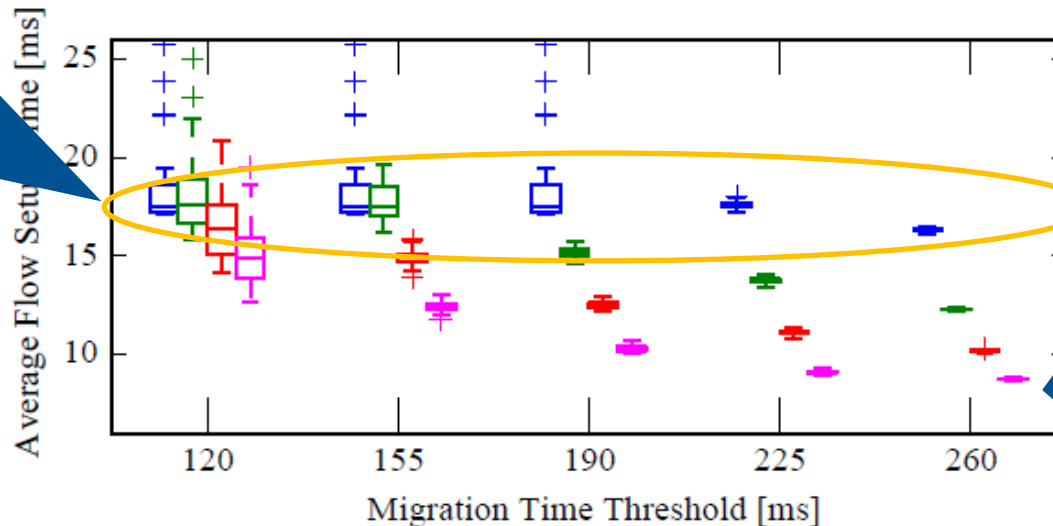
for short T:
1 controller is
more flexible

T considerable for
migration: more
controllers →
more flexibility

(a) Abilene, Flexibility Measure

performance
of 1 controller
system is
worst

Performance
(low is better)



there is a cap
in gain
(flexibility and
performance),
but cost (=
migrations)
is rising (not
shown here)

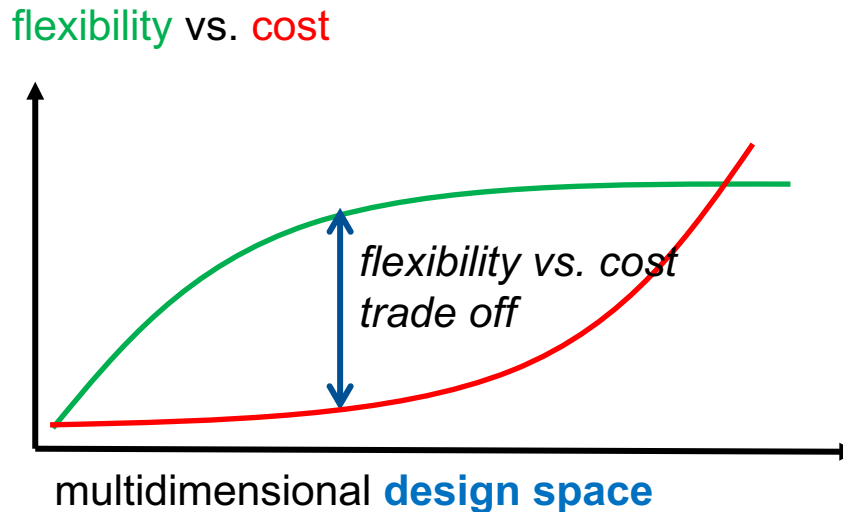
Key Takeaways

- Network research is faced with new requirements from emerging networked industries
- These include **flexibility**
- Network softwarization (NFV, SDN) is a key technology
- Need for
 - a **measure** to analyse flexibility
 - as a trade off with performance and cost

What are the costs of a design for flexibility?

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

Possible relationship (to be confirmed):



References for further reading (1)

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