Chair of Communication Networks
Department of Electrical and Computer Engineering
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The Function Placement Problem (FPP)

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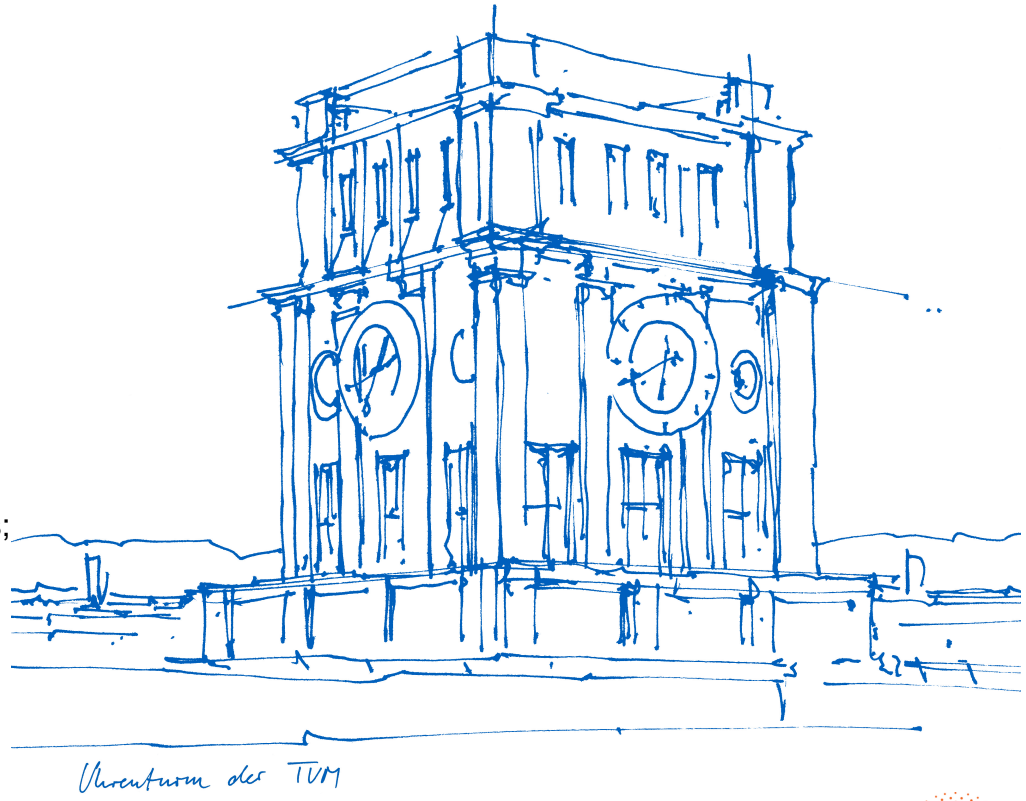

Dagstuhl, January 16-18, 2017

based on A. Basta, W. Kellerer, et al.,

Applying NFV and SDN to LTE Mobile Core Gateways;

The Functions Placement Problem,

ATC'14@ ACM SICGOMM, Chicago, August 2014.

and a keynote given at the

Intl. Teletraffic Congress, ITC 2016

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European Research Council
Established by the European Commission

Function Placement with SDN and NFV

NFV: Virtualized network function running in a data center

- *where to place your virtualized network function?*
- *what and how to virtualize your function?*
- *what are functions' interdependencies?*

SDN: Control of forwarding path (traverse network functions) and control/data plane split

- *where to place your SDN controllers?*
  Controller Placement Problem (CPP) (Heller 2012)
  and a lot of follow up work
- *Controller as a typical network function?*
  - no function (de-)composition
  - static placement

The Function Placement Problem (FPP)*

… not just a generalization of the CPP.

Function placement (based on SDN/NFV) needs to consider

1: Function realization: (de-)composition

2: Dynamics: time matters for varying conditions

3: Flexibility: for an overall analysis

... and many more

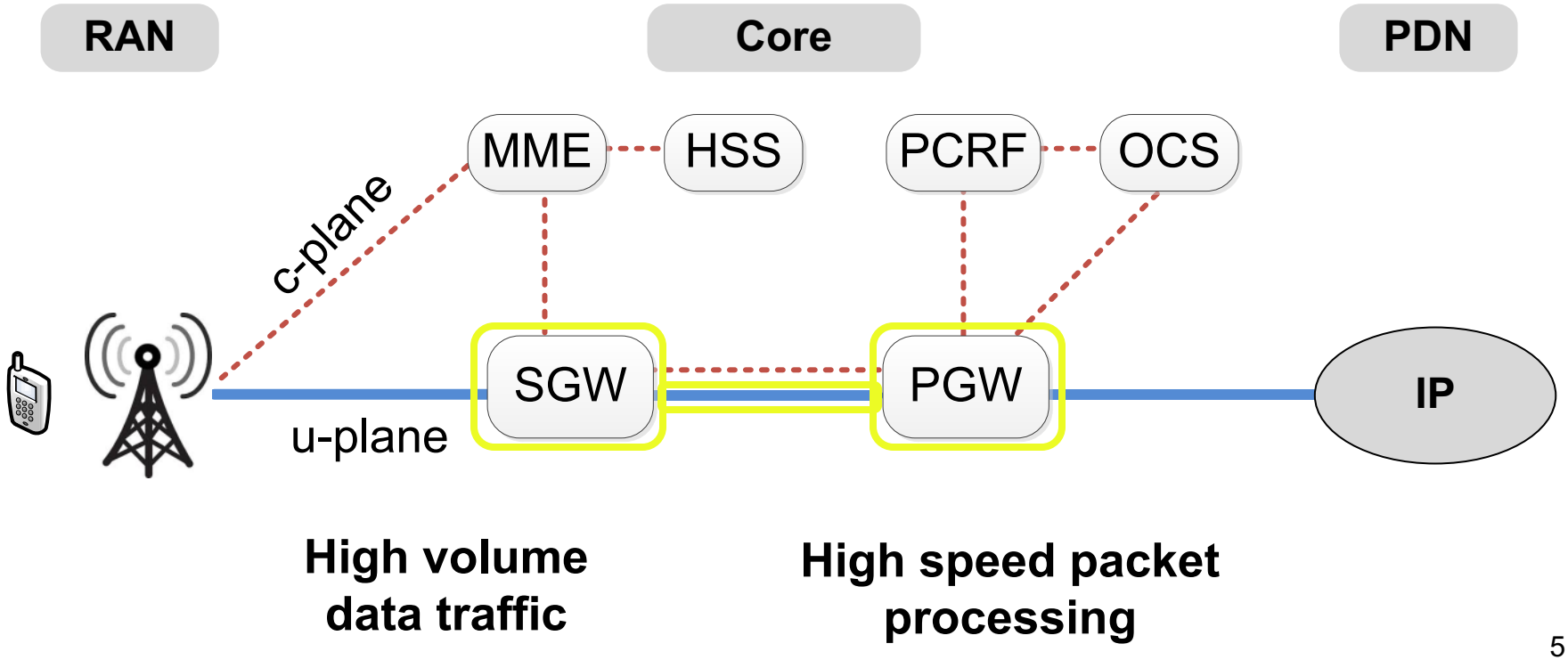
* First introduced in A. Basta, W. Kellerer, M. Hoffmann, H. Morper, K. Hoffmann, *Applying NFV and SDN to LTE Mobile Core Gateways; The Functions Placement Problem*, AllThingsCellular14, Workshop ACM SICGOMM, Chicago, IL, USA, August 2014.

Part 1: Function (de-)composition

Part 1: Function Realization → Placement

- NFV = ? virtualize & move function (= black box) to DC
- Consider components/dependencies carefully: function chain

Example: mobile core network functions



Function Realization based on NFV

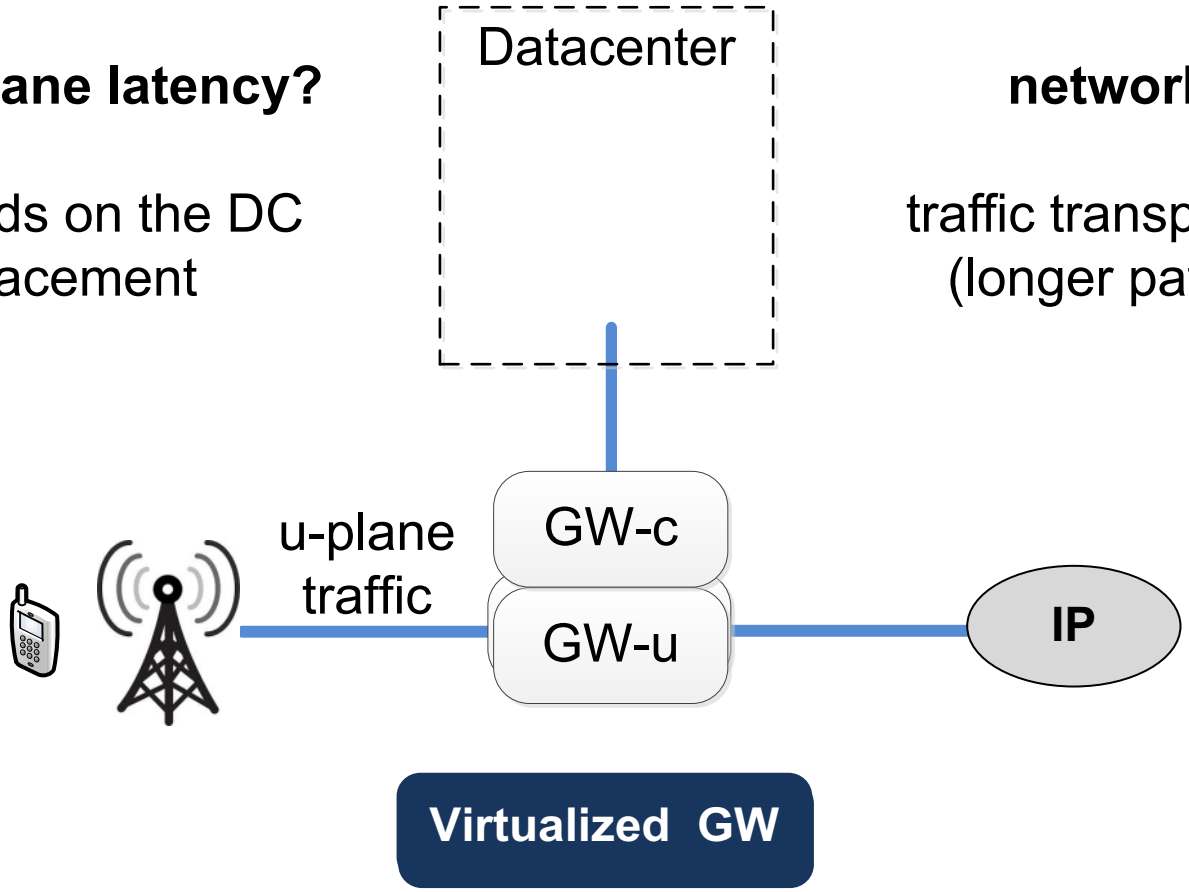
- Virtualization of GW functions [1] → NFV

data-plane latency?

depends on the DC placement

network load?

traffic transported to DC (longer path → cost)



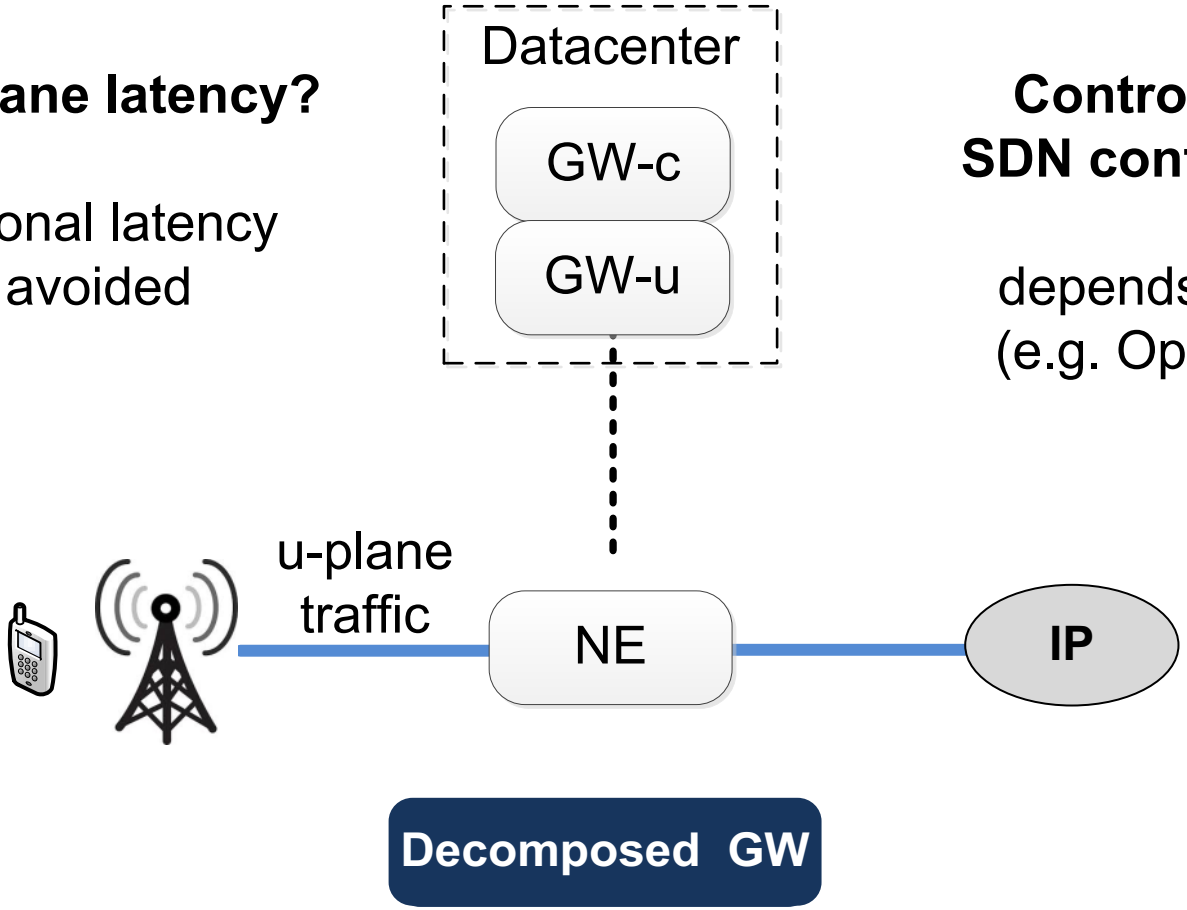
[1] A. Basta et al., A Virtual SDN-enabled EPC Architecture : a case study for S-/P-Gateways functions, SDN4FNS 2013.

Function Realization based on SDN: move functions back

- Decomposition of GW functions [1] via SDN

data-plane latency?

additional latency is avoided



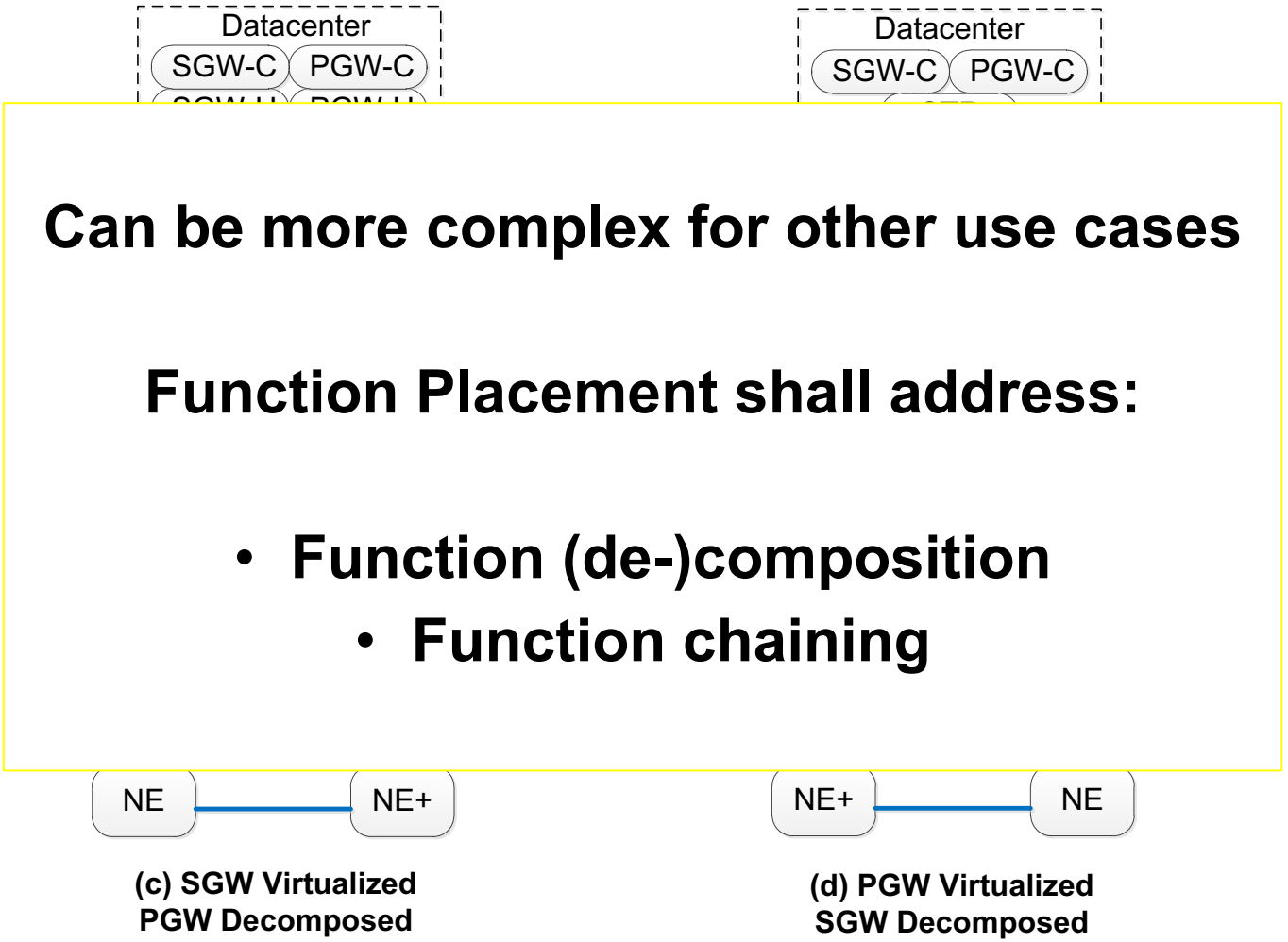
Control load?
SDN control load!

depends on API (e.g. OpenFlow)

[1] A. Basta et al., A Virtual SDN-enabled EPC Architecture : a case study for S-/P-Gateways functions, SDN4FNS 2013.

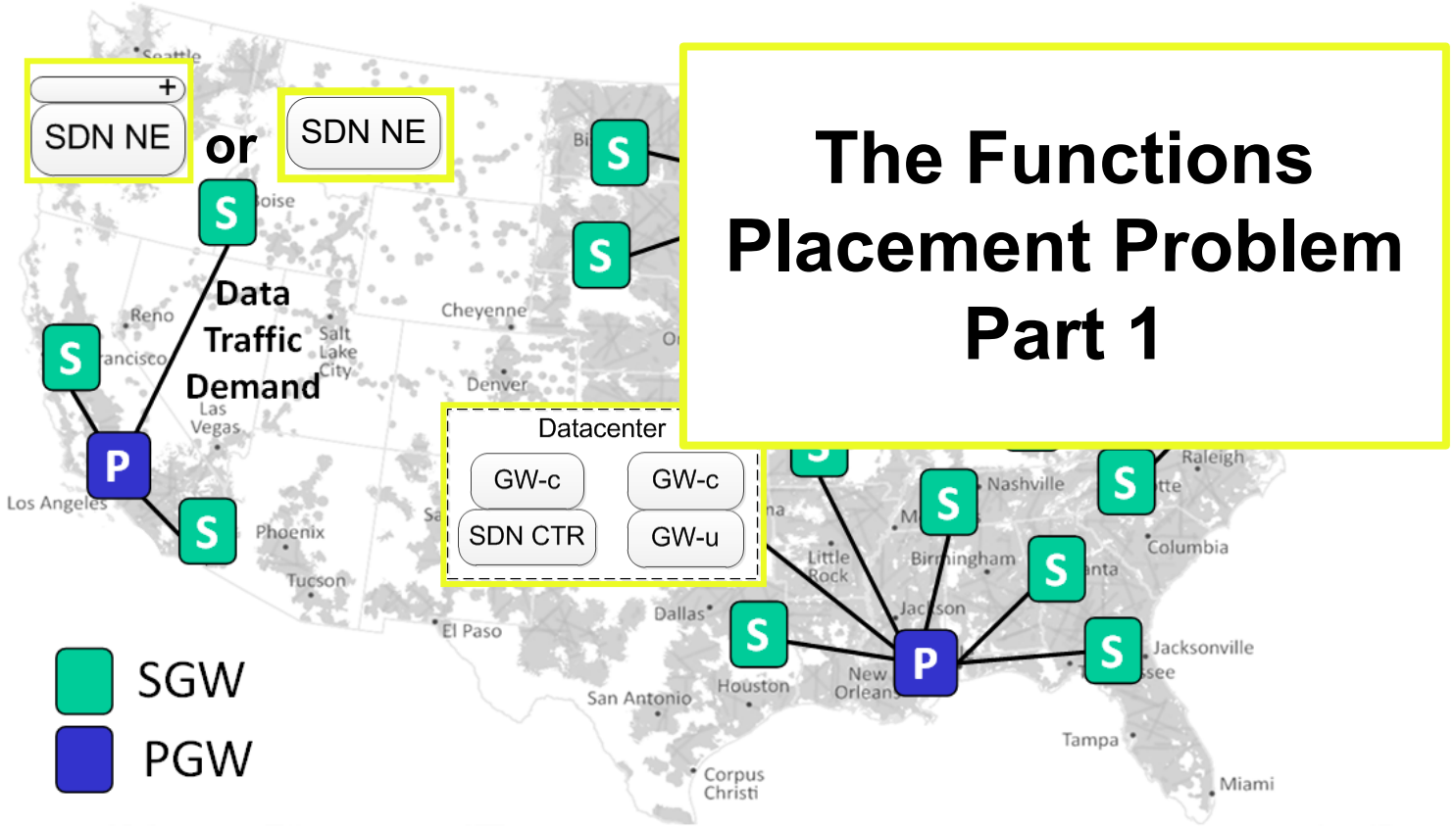
Interdependencies → Function chains (mixed design)

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



Some Evaluation Studies

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



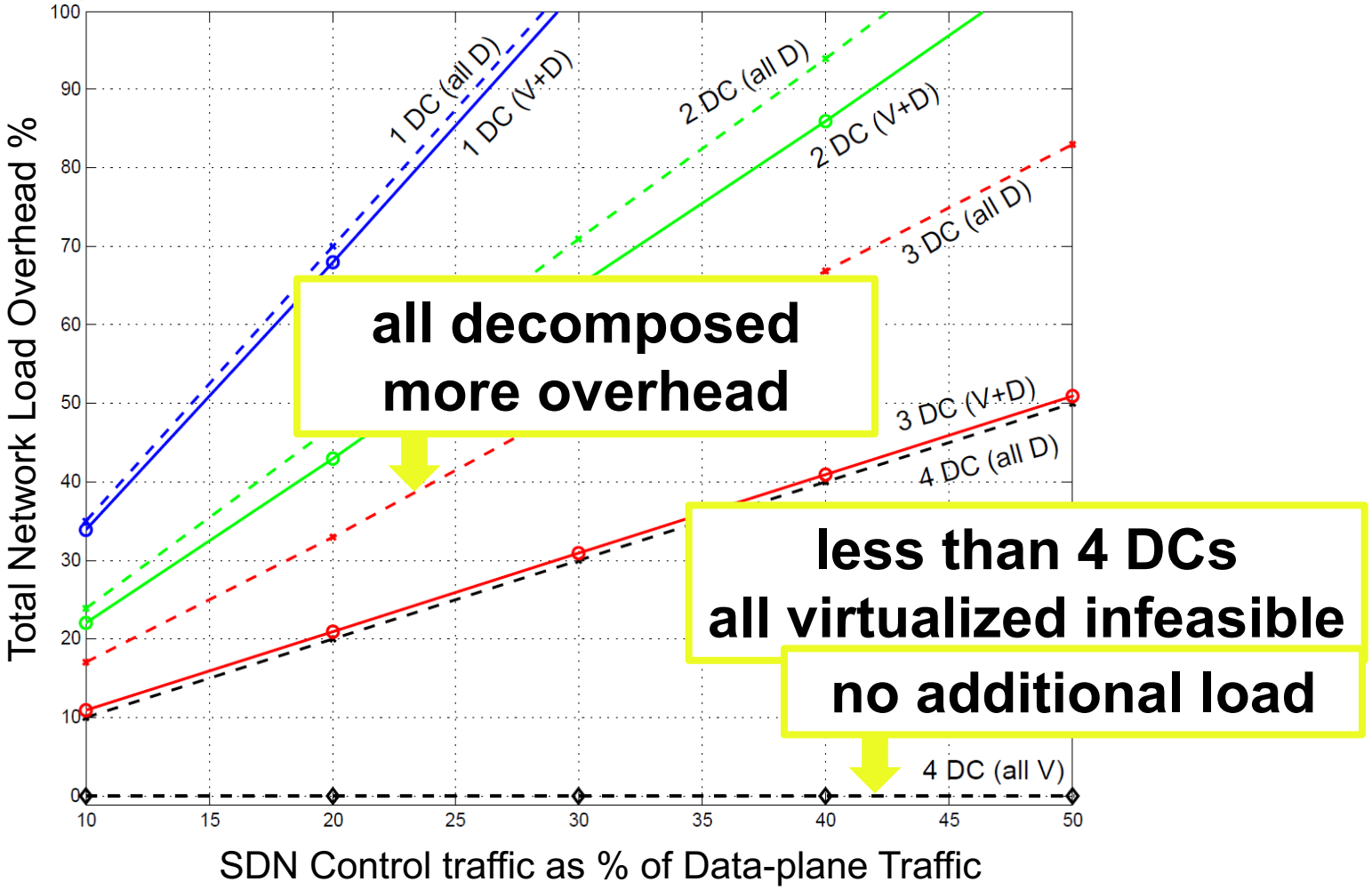
[2] A. Basta, W. Kellerer, M. Hoffmann, H. Morper, K. Hoffmann, Applying NFV and SDN to LTE Mobile Core Gateways; The Functions Placement Problem, AllThingsCellular14, Workshop ACM SICGOMM, Chicago, IL, USA, August 2014

Evaluation

- Network load?

load overhead vs no. of DCs?

normalized by traffic in legacy topology



Part 2: Dynamic Placement

Part 2: Dynamic Placement

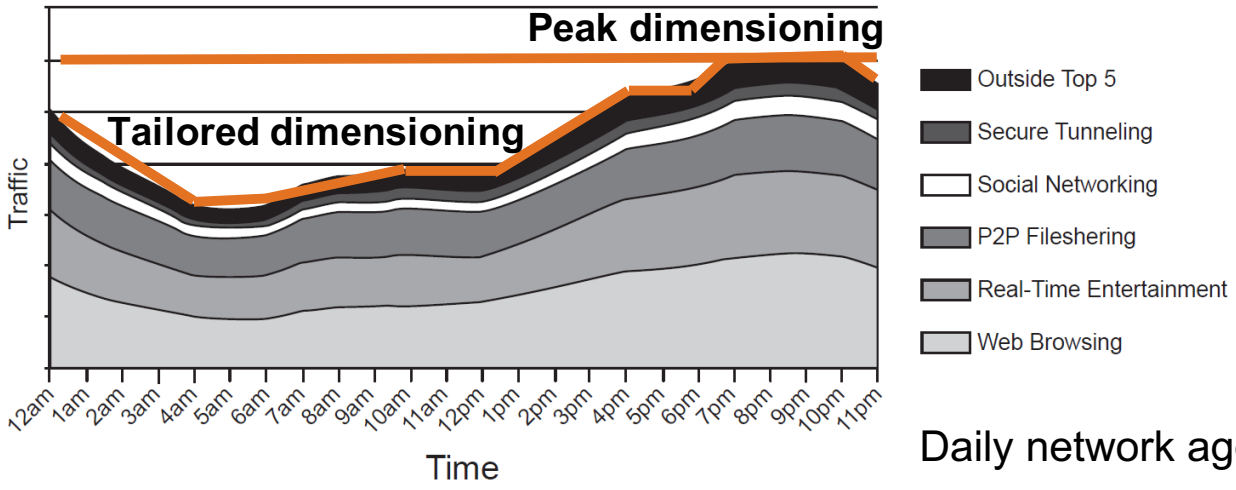
So far: static placement of functions

Reality: requirements (e.g., network traffic) change over time

Placement needs to consider

- change of conditions require to adapt optimal placement → **dynamic** (re-)**placement**
- **migration** effort and time

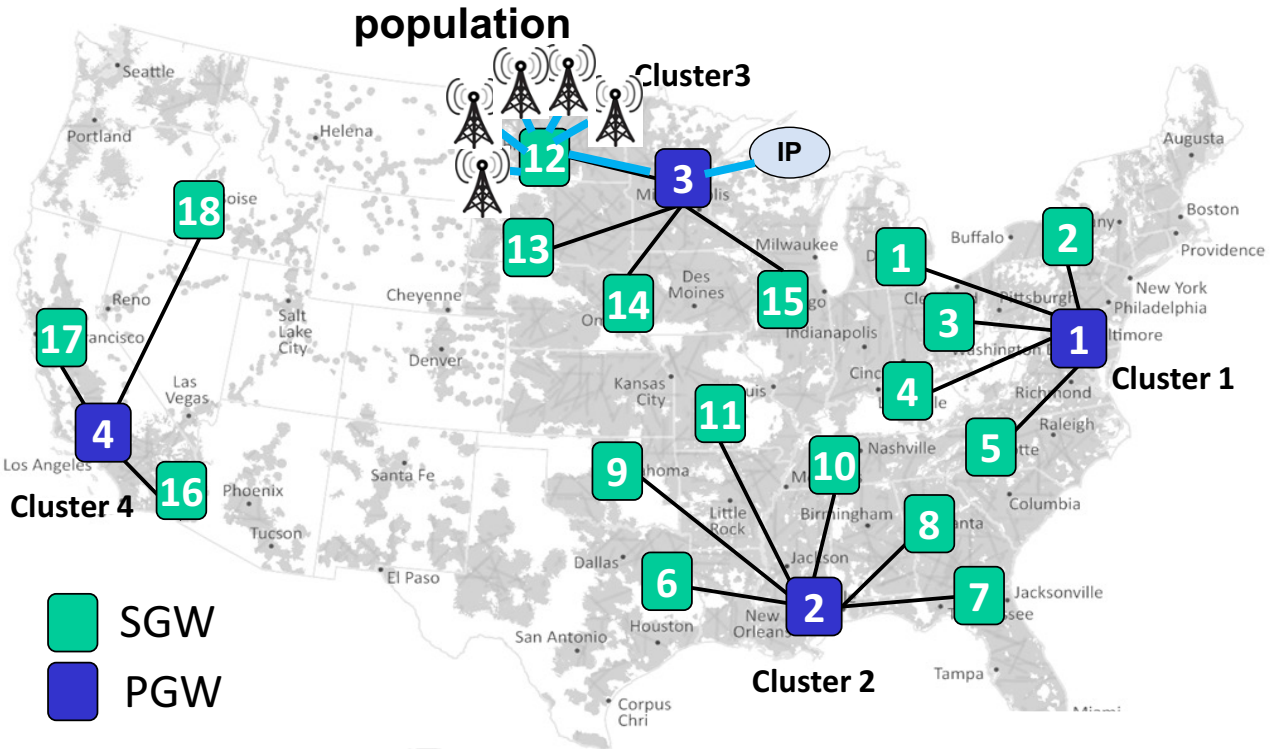
- Use case:



Daily network aggregate profile in North America

Use Case: Traffic Modeling

- Traffic at each SGW = population * intensity
- Intensity = f(daytime) [12] and f(time zones)
- Split day into time slots → change network configuration



[12] L. Qian, B. Wu, R. Zhang, W. Zhang, and M. Luo, Characterization of 3G Data-plane Traffic and Application towards Centralized Control and Management for Software Defined Networking," 2013 IEEE International Congress on Big Data

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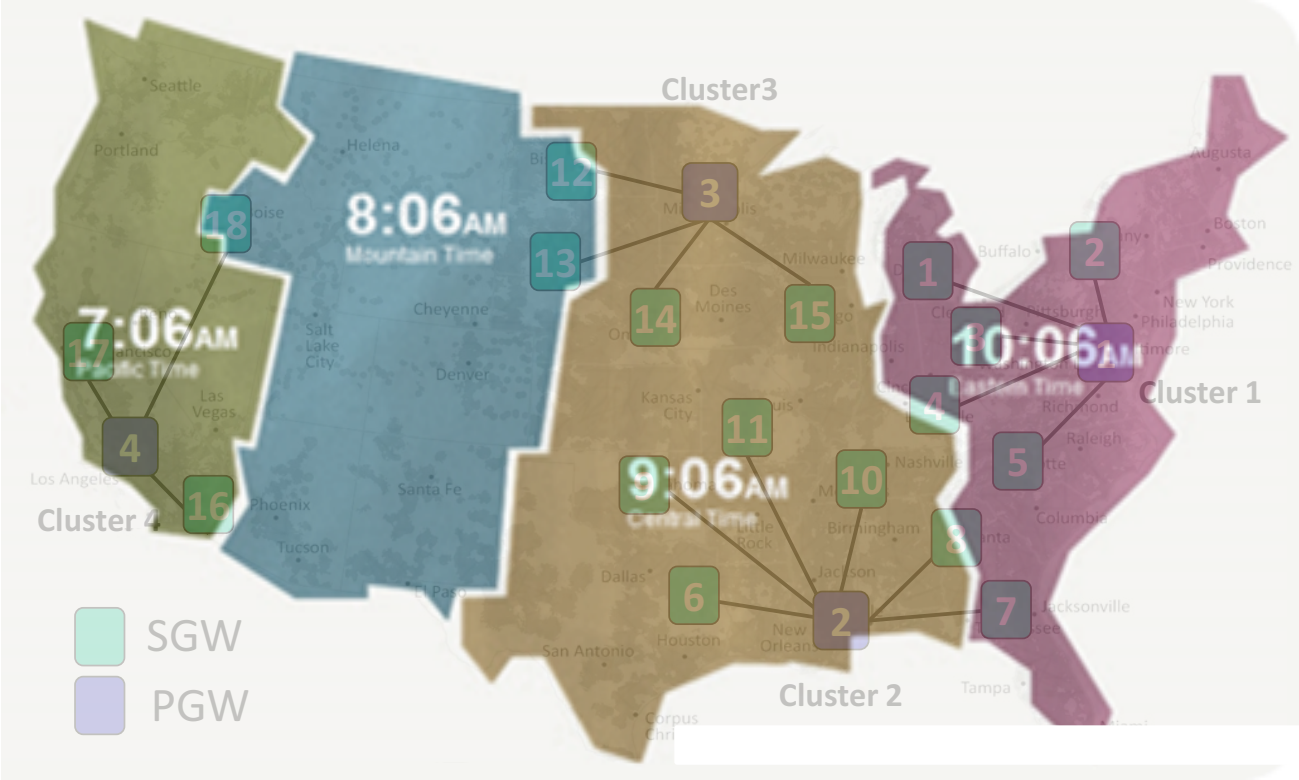

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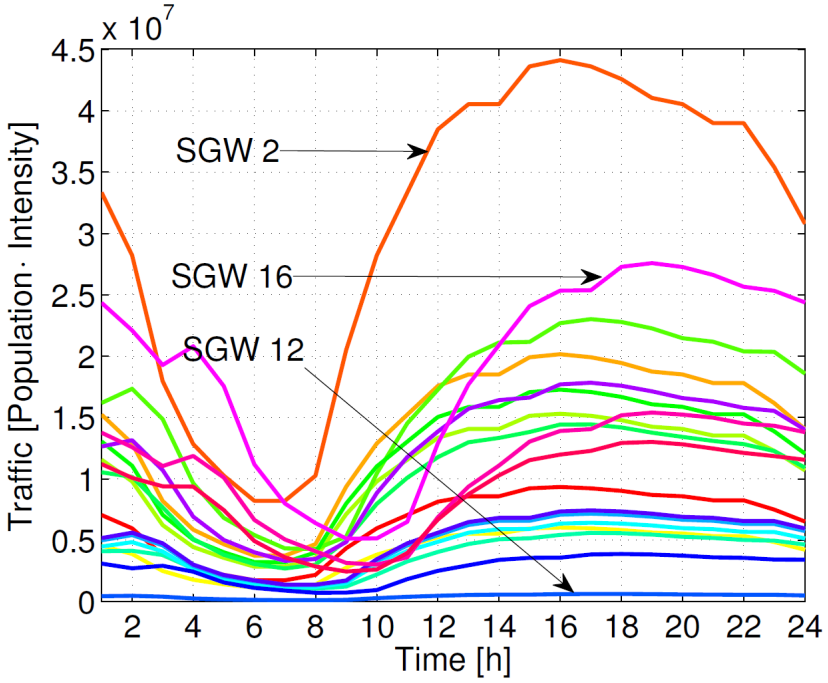

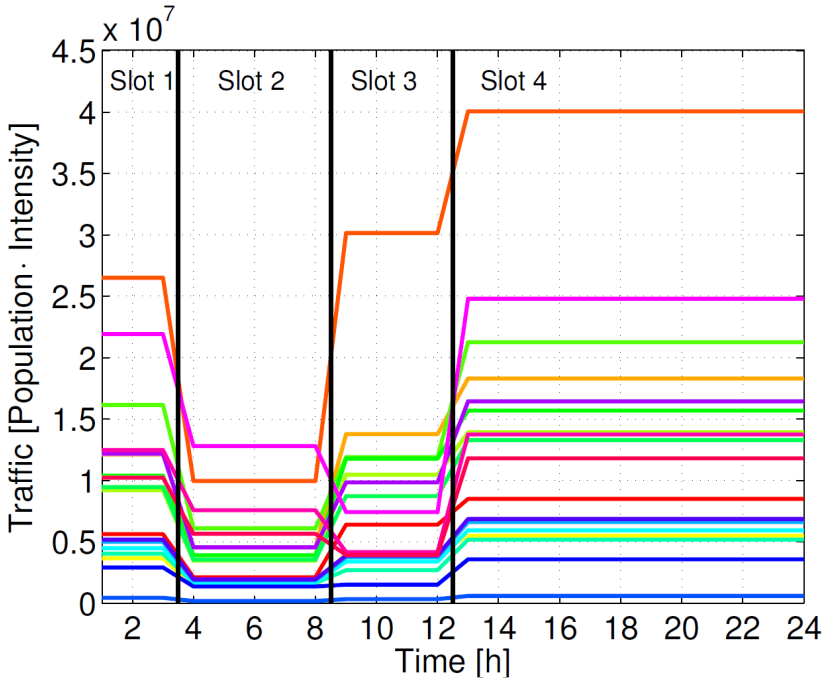

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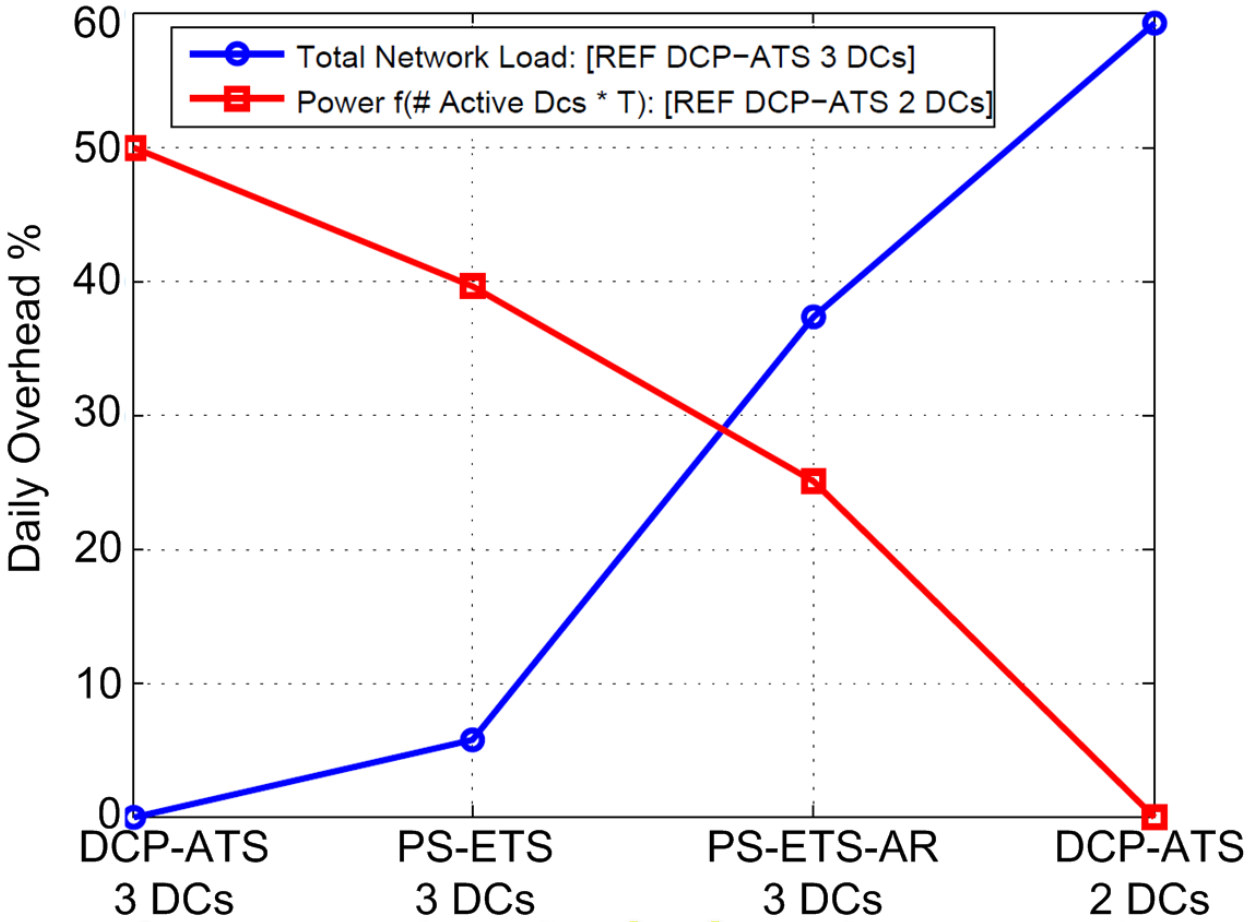
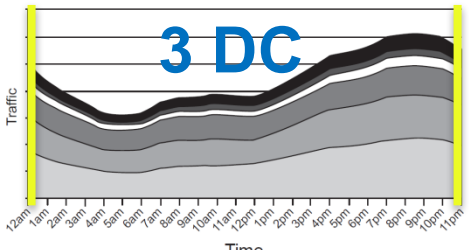
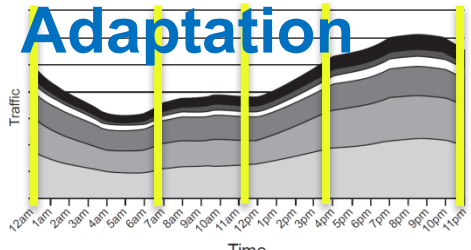
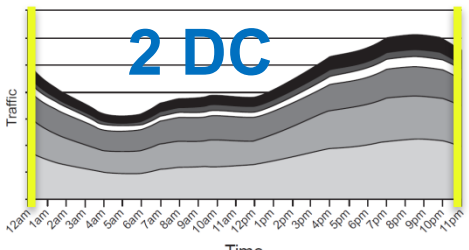
Evaluation

- Daily total network load vs. daily DC power saving? → adaptation matters









Part 3:
Flexibility as a metric for analysis

Part 3: Flexibility

Recall: many options to consider for function placement

- (de-)composition and chaining
- dynamics

Analyse a network design with respect to the options it can realize to handle dynamically changing requirements:

→ **flexibility** as a metric

Ex.: Flexibility of a system design w.r.t. function placement

change requests that can be fulfulled by a system design x

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

all change requests

Use Case: EPC Function Placement

3 design choices to compare for future mobile core network [5]:
(1) SDN design
(2) NFV design
(3) mixed SDN/NFV design

Parameter in focus:

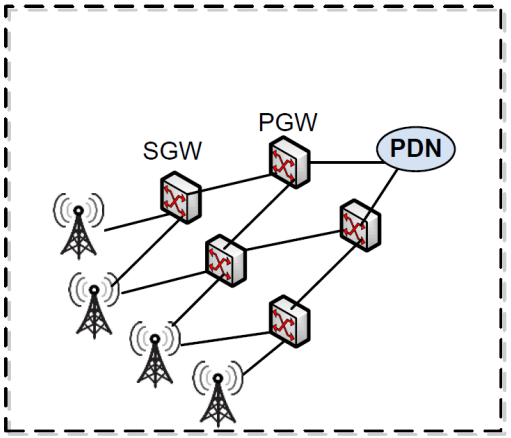
- Flexibility to support different latency requirements for
  - control plane latency and data plane latency
    e.g.: {5, 10, 15,…, 45, 50} ms

[5] 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.

Design Choices

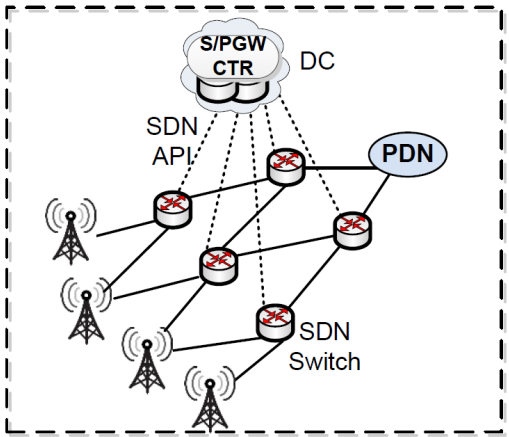
Use Case

Legacy LTE core design:
Gateways (GW) as
dedicated middleboxes



(a) Current LTE Core GW Architecture

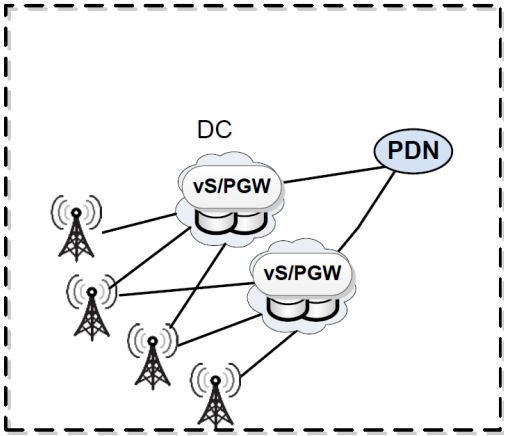
(1) SDN design:
separation of control and
data plane for GWs



(b) SDN Core GW Architecture

only control to cloud

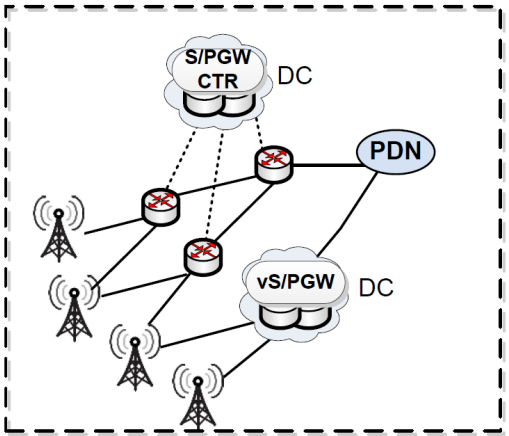
(2) NFV design:
all functions (data and control)
run in a cloud



(c) NFV Core GW Architecture

control and data to cloud

(3)
mixed SDN/NFV design:



d) Mixed SDN and NFV Core GW Architecture

Flexibility measure and evaluation setup

Use Case

Flexibility measure:

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

Function placement problem formulated as a MILP [6]

- SDN controllers, mobile VNFs, SDN switches and data centers placement
- constraints on data and control plane latency
- weights

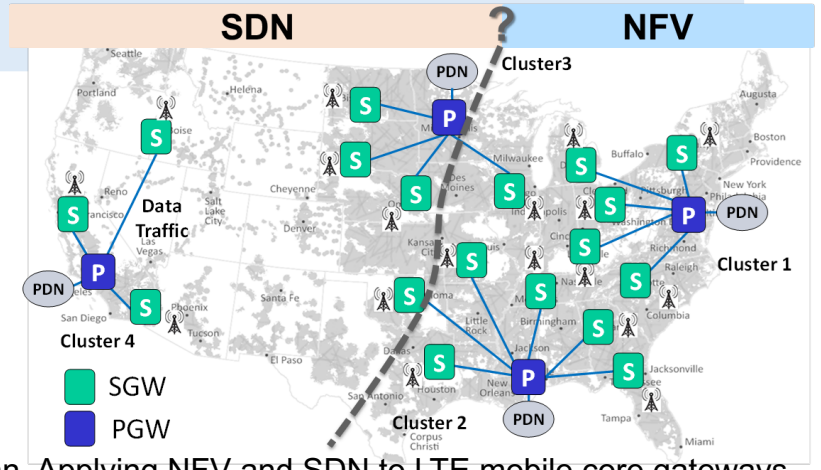
$$w_{i,j} = \frac{\alpha}{dataLatency_i} + \frac{\beta}{controlLatency_j}$$

[6] A. Basta, W. Kellerer, M. Hoffmann, H. J. Morper, K. Hoffmann, Applying NFV and SDN to LTE mobile core gateways, the functions placement problem, All things cellular Workshop ACM SIGCOMM, Chicago, August, 2014.

Evaluation parameters

Use Case

Parameters	Values
Data plane latencies to support	{5, 10, 15,…, 45, 50} ms
Control plane latencies to support	{5, 10, 15,…, 45, 50} ms
	*total: 10 * 10 = 100 possible solutions*
Data plane latency weight (α) Control plane latency weight (β)	α = 1 β = 1 α = 10 β = 1 α = 1 β = 10
Design choices	SDN, NFV, SDN/NFV
Data center deployment	Logically centralized (2 DCs) Distributed (8 DCs)
Topology	US

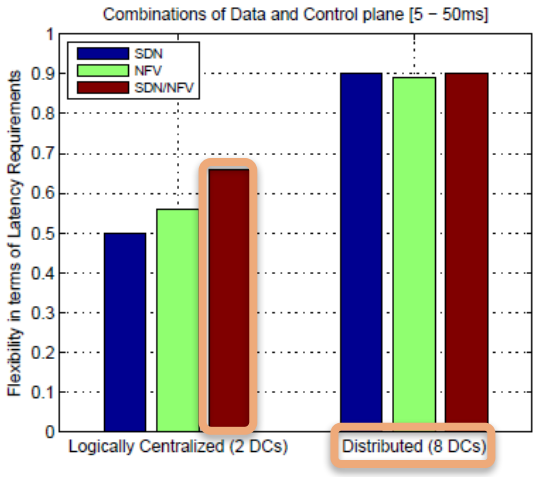


Example placement for mixed SDN/NFV design [6]

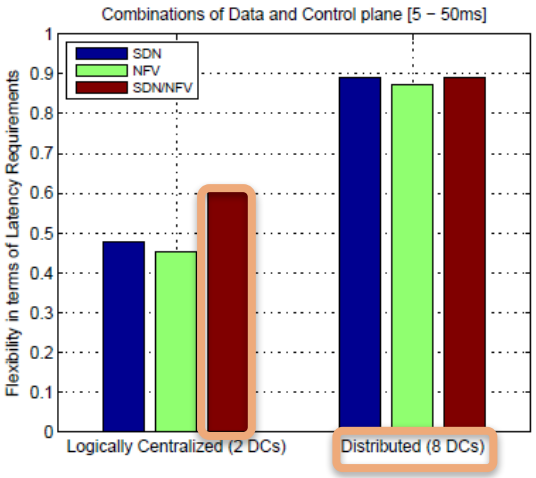
[6] A. Basta, W. Kellerer, M. Hoffmann, H. J. Morper, K. Hoffmann, Applying NFV and SDN to LTE mobile core gateways, the functions placement problem, All things cellular Workshop ACM SIGCOMM, Chicago, August, 2014.

Results [5]

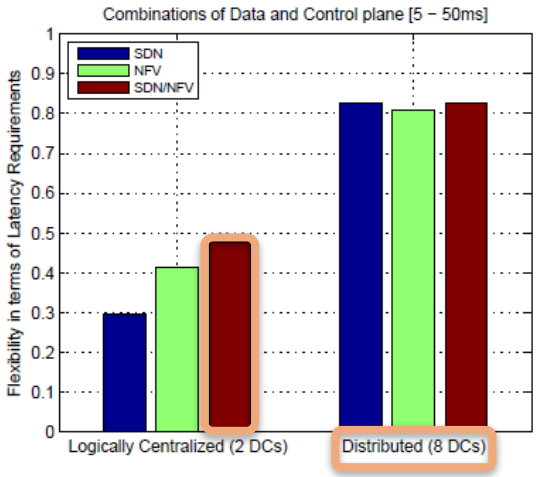
Use Case



(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

[5] 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.

Key Takeaways

- The **Function Placement Problem** needs to consider

- **Function (de-)composition**

- **Dynamics**

- **Flexibility** as a new metric for analysis

References for further reading

- A. Basta, W. Kellerer, M. Hoffmann, H. Morper, K. Hoffmann,
  Applying NFV and SDN to LTE Mobile Core Gateways; The Functions Placement Problem,
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  arXive report, December 2015.
  http://www.lkn.ei.tum.de/forschung/publikationen/dateien/Kellerer2015FlexibilityofNetworks:a.pdf

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  Using a Flexibility Measure for Network Design Space Analysis of SDN and NFV,
  Software-Driven Flexible and Agile Networking (SWFAN), IEEE INFOCOM Workshop, San Francisco, USA, April 2016.