

A?

Aalto University
School of Electrical
Engineering

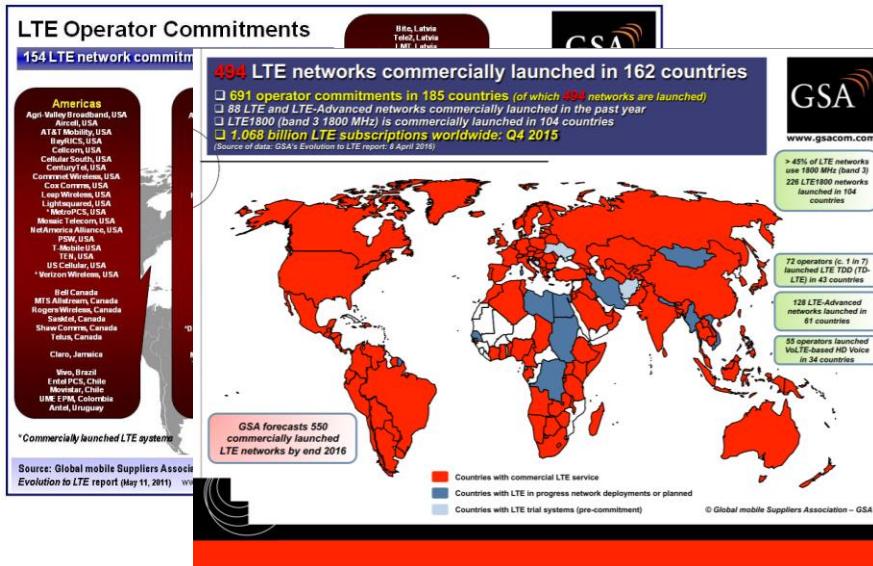
Towards 5G: On Network Softwarization

Prof. Tarik Taleb

*School of Electrical Engineering
Aalto University*

© Tarik TALEB 2016

Global LTE Commitments



© Tarik TALEB 2016

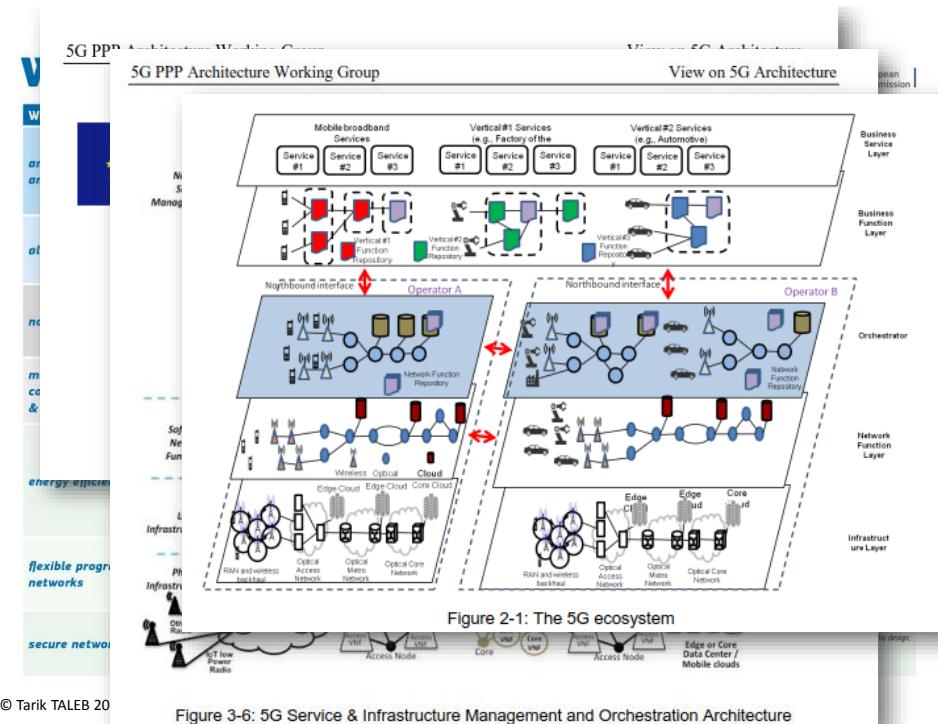


Figure 3-6: 5G Service & Infrastructure Management and Orchestration Architecture

Requirements on 5G ...

**High data rates
everywhere**

**Very high traffic
capacity**

**Massive number of
devices**

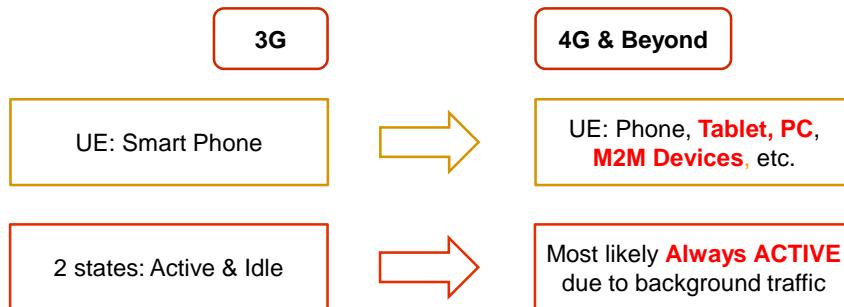
**Ultra-high
reliability & security**

**Very low device
cost**

**Very low device
energy consumption**

Very low latency

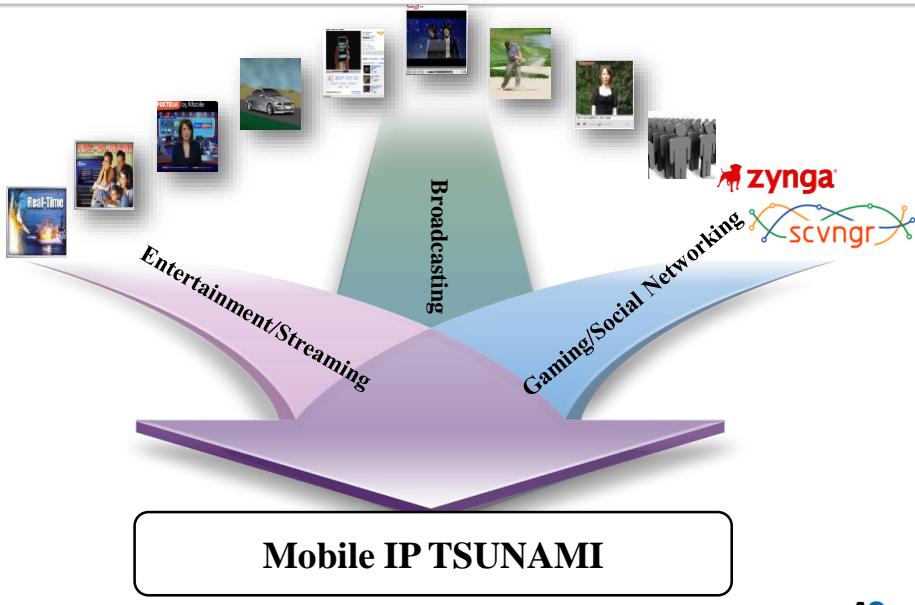
Evolution of User Equipment



© Tarik TALEB 2016



Mobile IP Tsunami?



© Tarik TALEB 2016



Solutions

Invest in Speed

- Today's backbone will be tomorrow's edge!



Upgrade network nodes

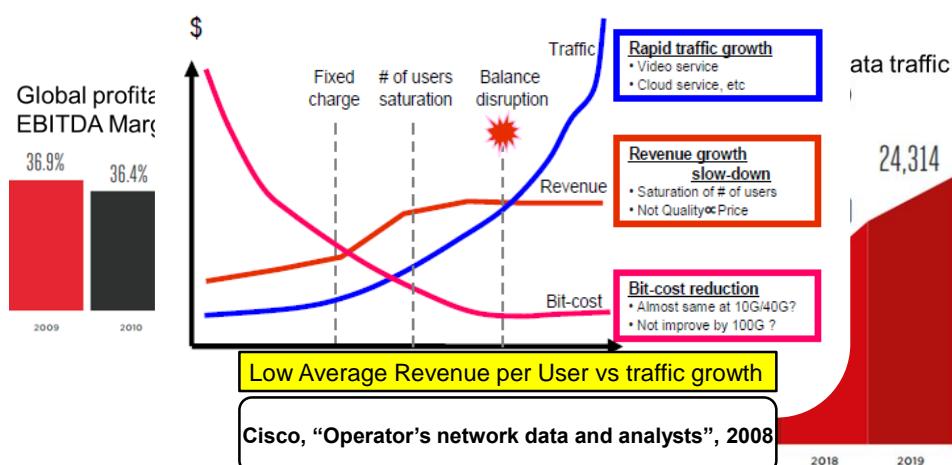
Design a scalable network

- To accommodate peak hours

© Tarik TALEB 2016



How ready are Operators to invest more?

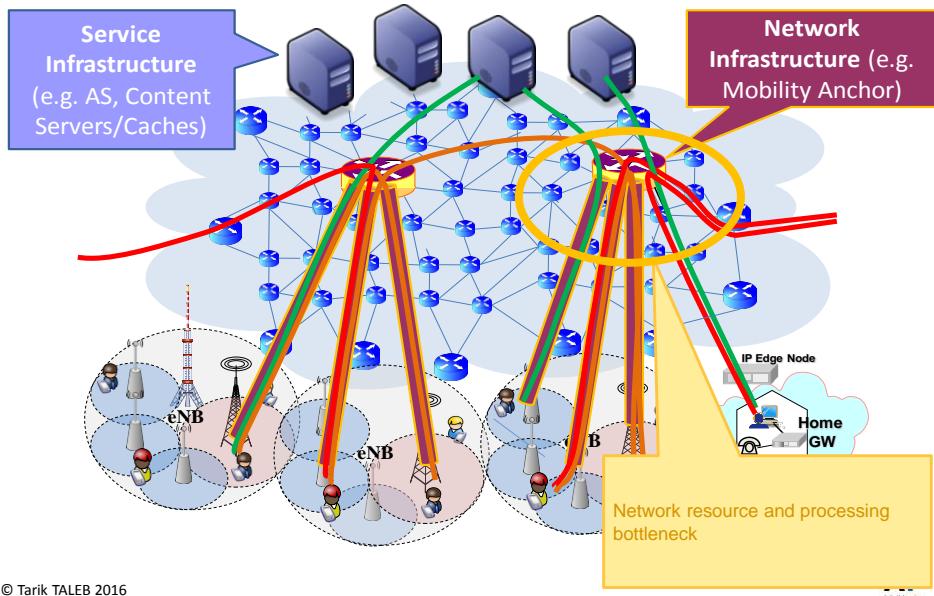


"The Mobile Economy 2015", GSMA

© Tarik TALEB 2016

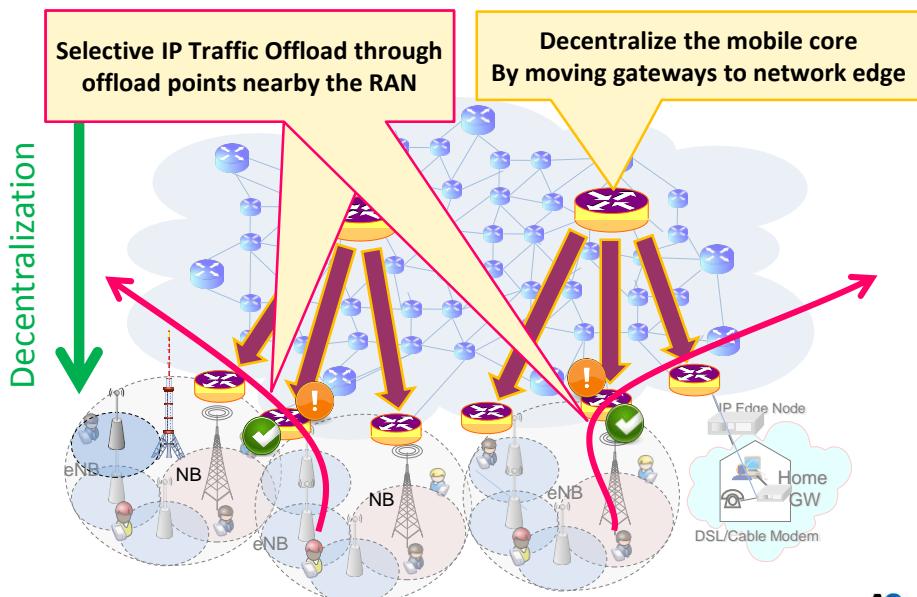


Current Mobile Operator NW Arch.



© Tarik TALEB 2016

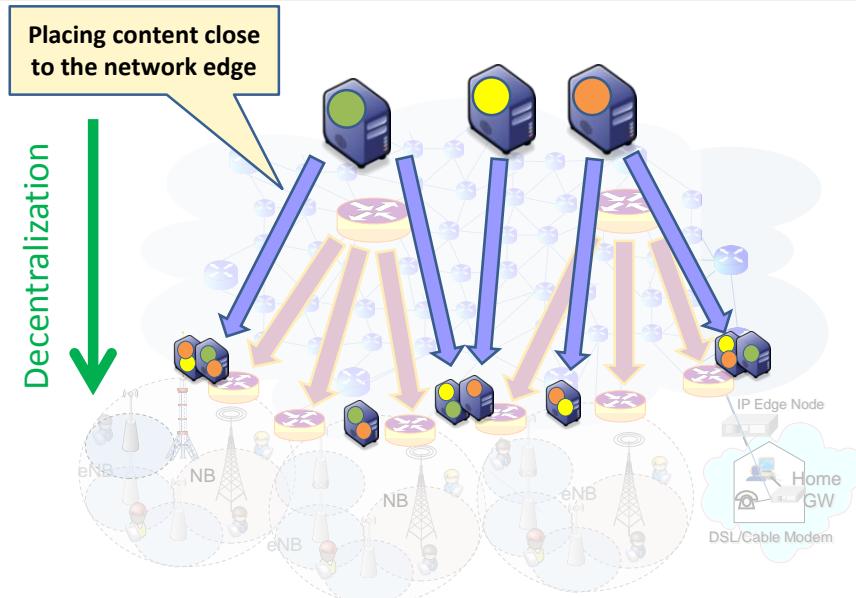
Decentralize & Offload



© Tarik TALEB 2016



Build & Decentralize Mobile CDN



© Tarik TALEB 2016



Trend towards Distributed Regional DCs

Apple building super datacenters all over the world says a

[StoS Staff](#)
Facebook 0 Twitter
April 12, 2011 at

An aerial doubled

DATA CENTER KNOWLEDGE

AOL Gets
Posted By Rich

Solar-Powered Micro Data Center at Rutgers

Posted By Rich Miller On May 31, 2012 @ 7:39 pm In Green Data Centers | 2 Comments



The Paracel micro data center system consists of a rooftop container, small solar array and a battery bank. (Photo: Rutgers University)

© Tarik TALEB 2016

The Rutgers Computer Science Department has built a solar-powered "micro data center" comprised of a small container, a set of solar panels, a

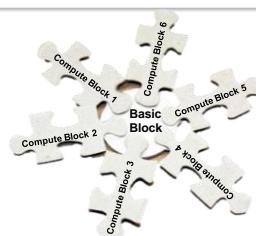


Aalto University
School of Electrical
Engineering

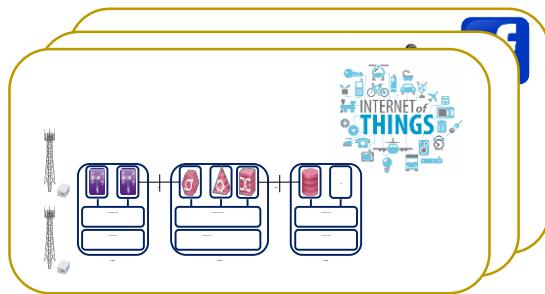
Network Softwarization

Objectives

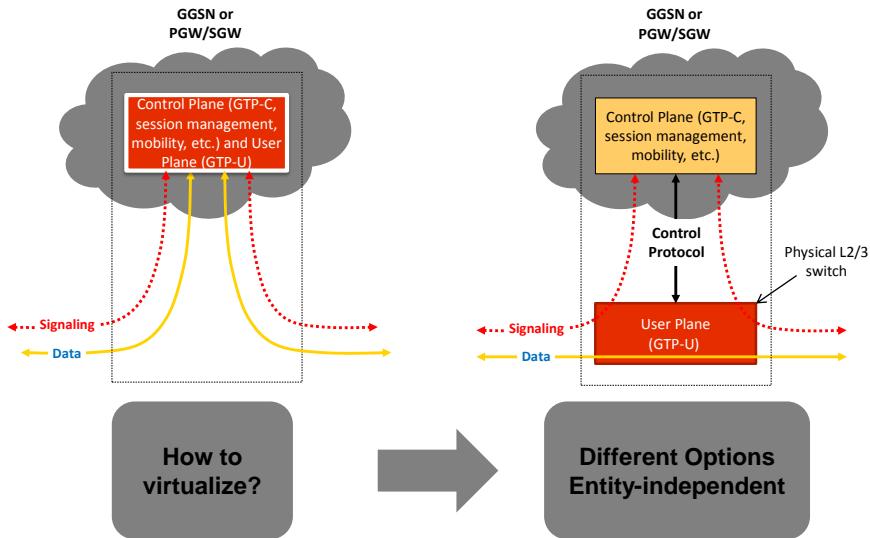
| Transform mobile networks
into virtualized software
components



- Enable the creation & lifecycle management of diverse network slices for different verticals



What to Virtualize: Full vs Partial Virtualization

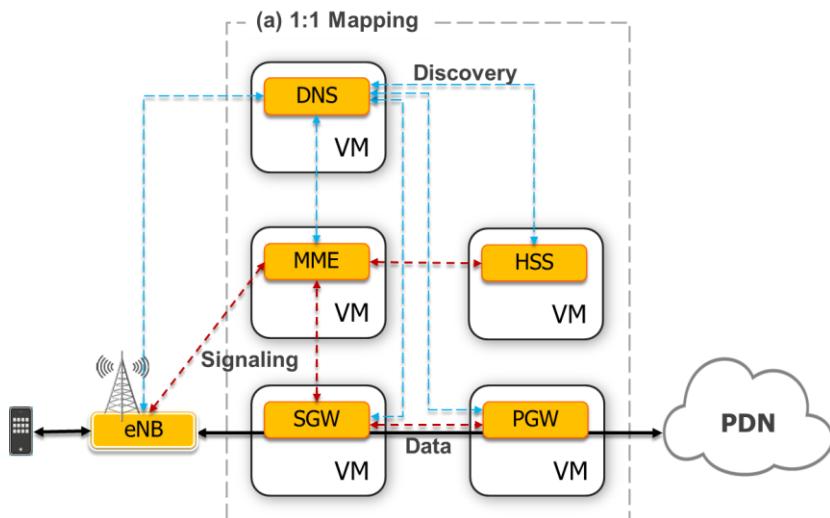


© Tarik TALEB 2016

T. Taleb, M. Corici, C. Parada, A. Jamakovic, S. Ruffino, G. Karagiannis, and T. Magedanz, "[EASE: EPC as a Service to Ease Mobile Core Network](#)," in IEEE Network Magazine, Vol. 29, No. 2, Mar. 2015, pp.78 - 88.

EPCaaS Architecture Options

1:1 Mapping

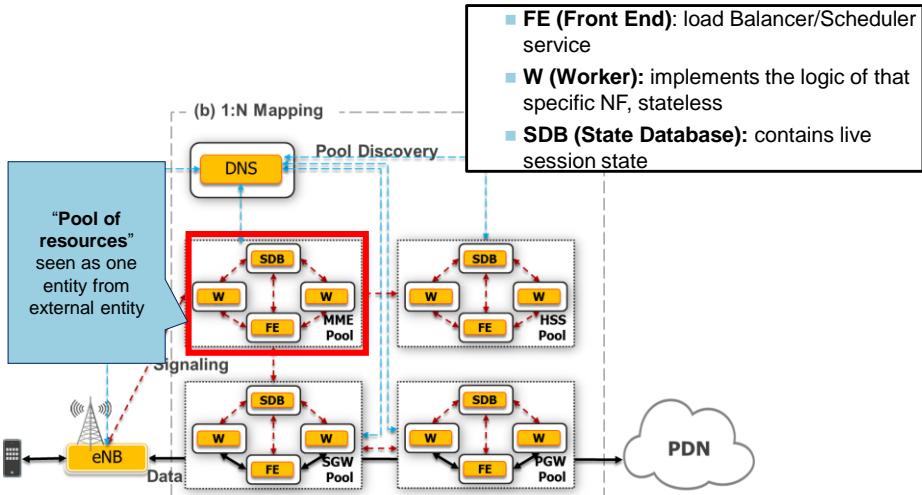


© Tarik TALEB 2016

T. Taleb, M. Corici, C. Parada, A. Jamakovic, S. Ruffino, G. Karagiannis, and T. Magedanz, "[EASE: EPC as a Service to Ease Mobile Core Network](#)," in IEEE Network Magazine, Vol. 29, No. 2, Mar. 2015, pp.78 - 88.

EPCaaS Architecture Options

1:N Mapping



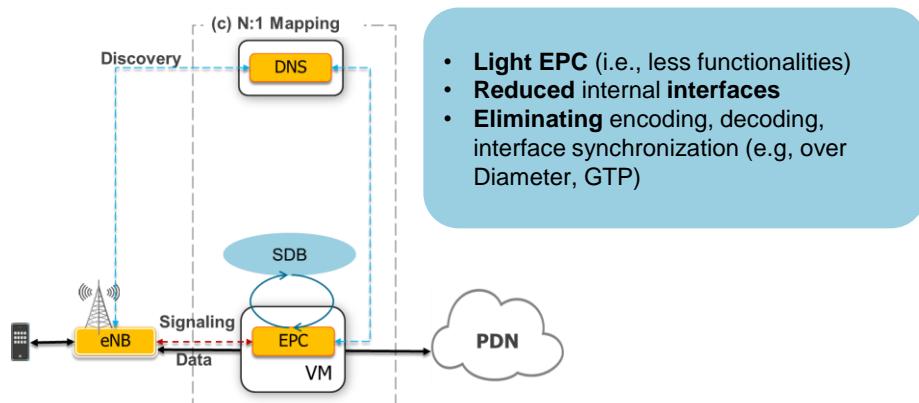
© Tarik TALEB 2016

T. Taleb, M. Corici, C. Parada, A. Jamakovic, S. Ruffino, G. Karagiannis, and T. Magedanz, "EASE: EPC as a Service to Ease Mobile Core Network," in IEEE Network Magazine, Vol. 29, No. 2, Mar. 2015, pp.78 - 88.



EPCaaS Architecture Options

N:1 Mapping



© Tarik TALEB 2016

T. Taleb, M. Corici, C. Parada, A. Jamakovic, S. Ruffino, G. Karagiannis, and T. Magedanz, "EASE: EPC as a Service to Ease Mobile Core Network," in IEEE Network Magazine, Vol. 29, No. 2, Mar. 2015, pp.78 - 88.

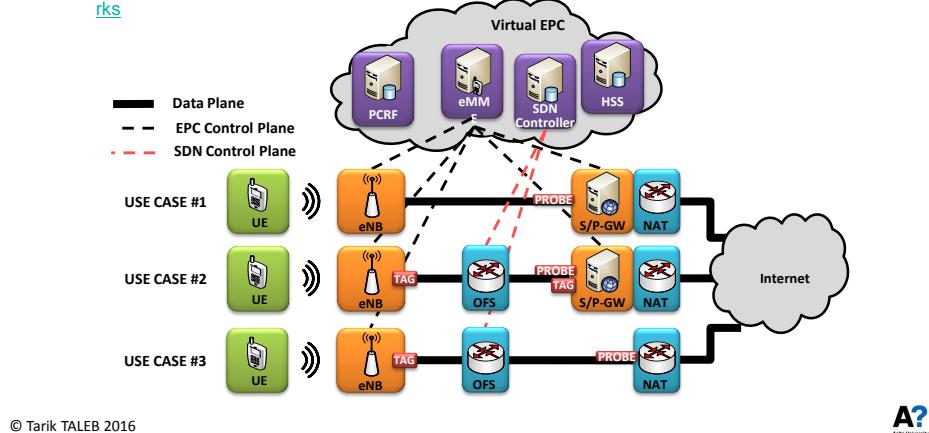


Aalto Contribution to Standardisation

ETSI PoC based on SIGMONA testbed submitted in cooperation with Nokia, Coriant, EXFO and Telecom Italia.

Objectives:

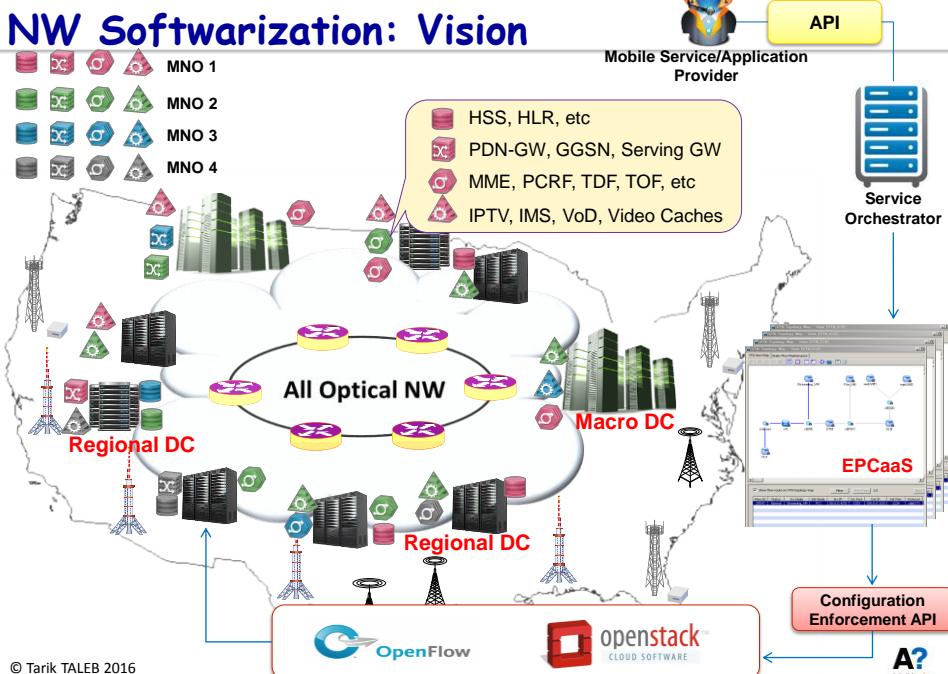
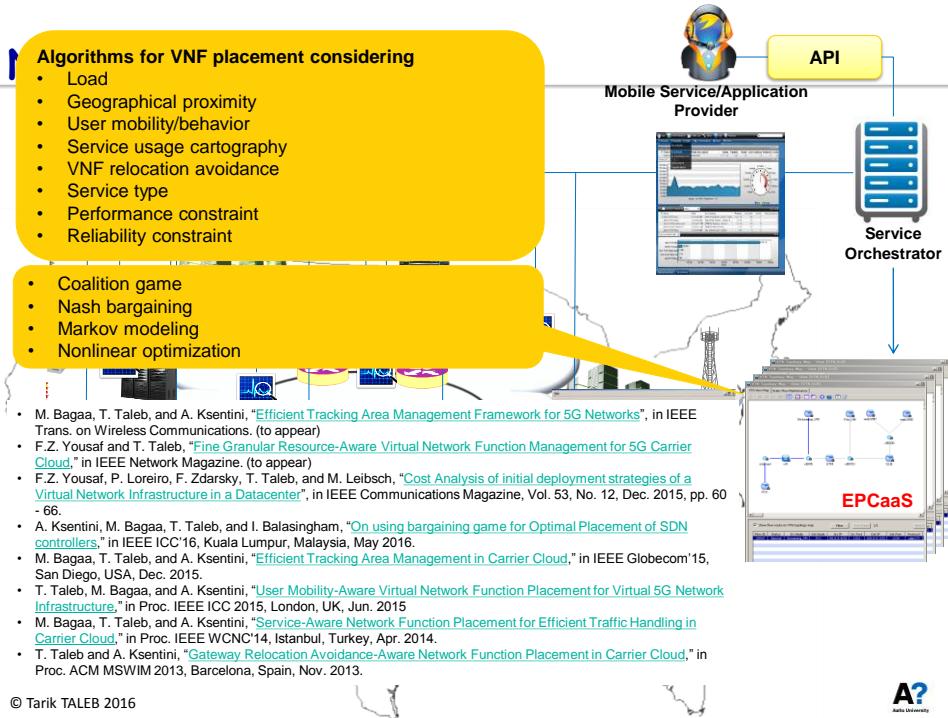
- Integration of SDN and NFV functions in mobile backhaul
- Show with off the shelf devices (Nokia eNBs, Coriant MPLS switches, EXFO Monitoring) the mobility and network adaptation during congestion or link breaks
- http://nfvwiki.etsi.org/index.php?title=Virtual_EPC_with_SDN_Function_in_Mobile_Backhaul_Networks



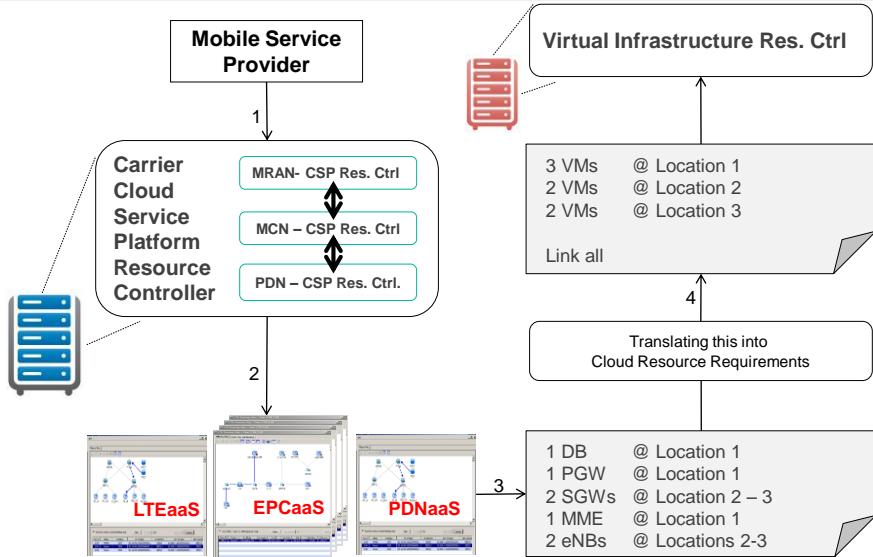
© Tarik TALEB 2016



NW Softwarization: System Orchestration



NW Softwarization - Step by Step 1/2

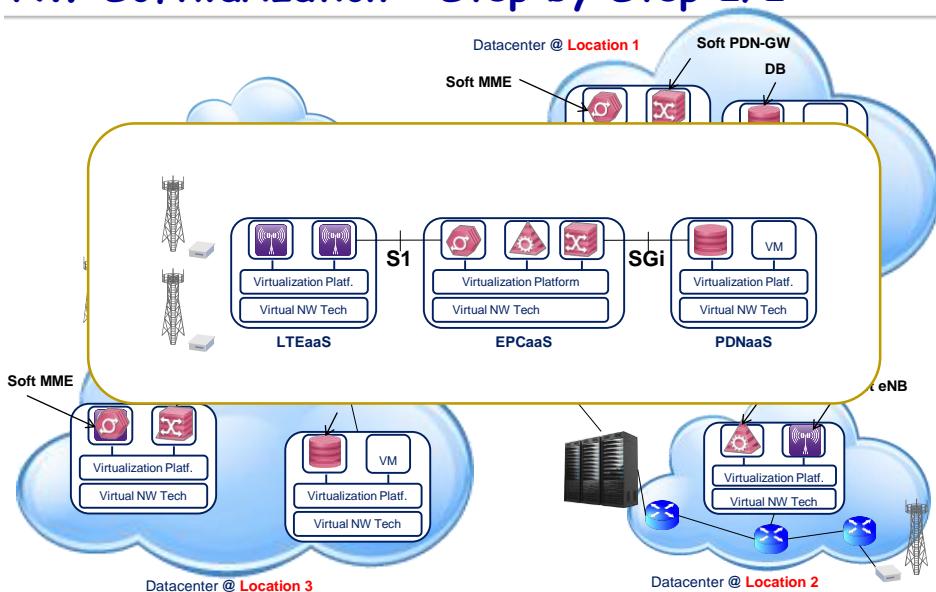


© Tarik TALEB 2016

T. Taleb, "Towards Carrier Cloud: Potential, Challenges, & Solutions," in IEEE Wireless Communications Magazine, Vol. 21, No. 3, Jun. 2014, pp. 80-91.



NW Softwarization - Step by Step 2/2

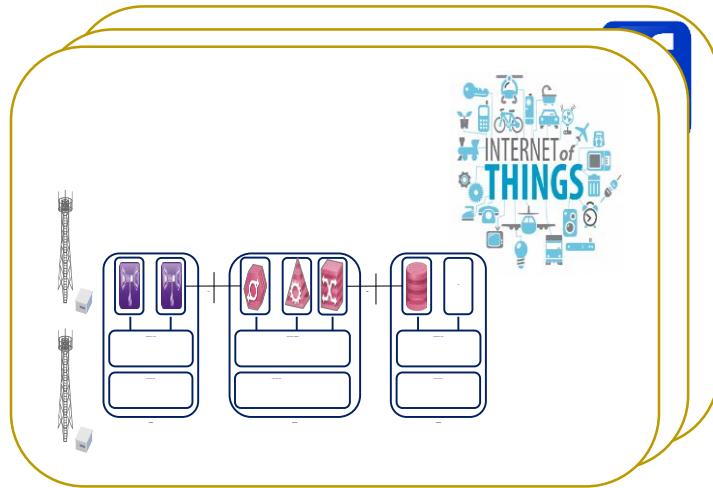


© Tarik TALEB 2016

T. Taleb, "Towards Carrier Cloud: Potential, Challenges, & Solutions," in IEEE Wireless Communications Magazine, Vol. 21, No. 3, Jun. 2014, pp. 80-91.



NW Softwarization: A NW slice for every mobile service



© Tarik TALEB 2016

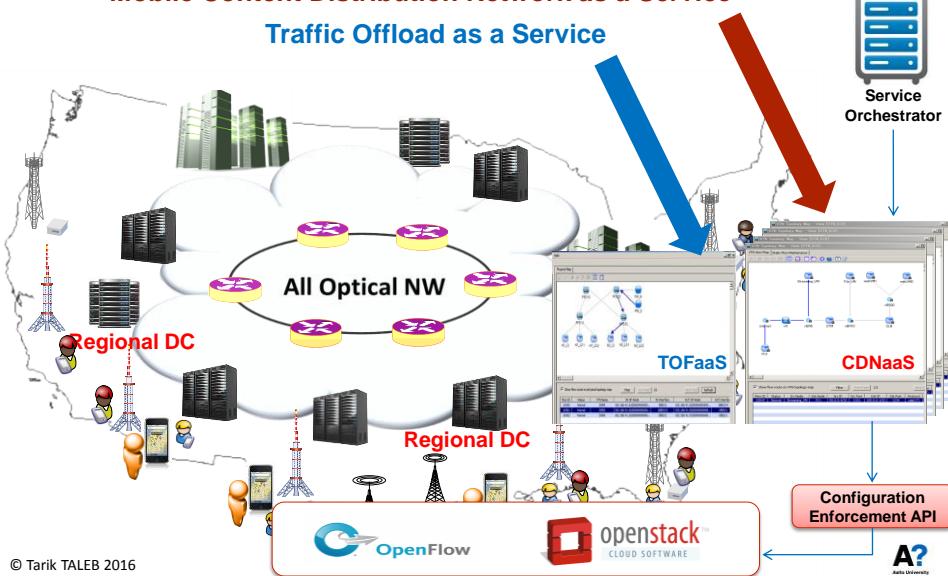


virtual Mobile CDN on the Fly

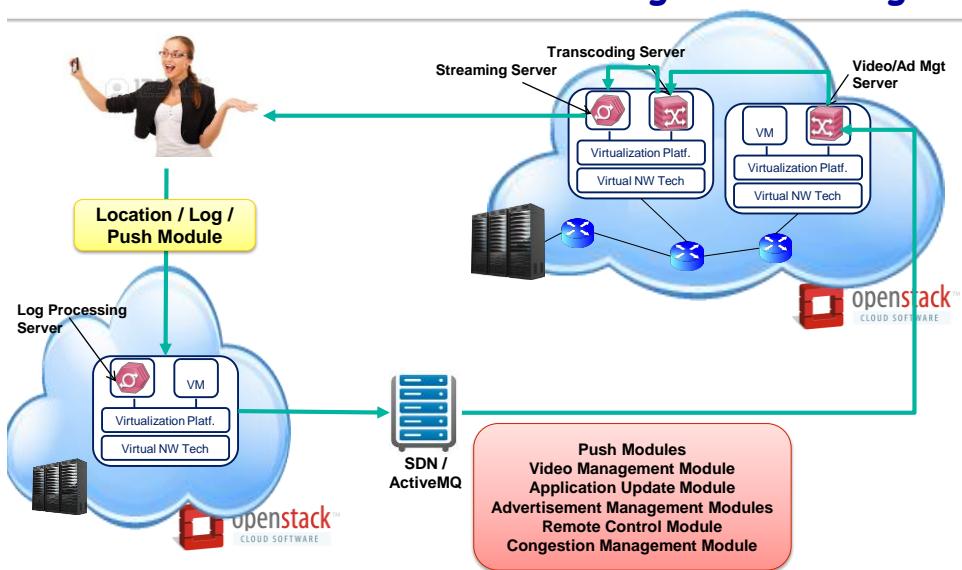
Mobile vCDN on the fly 2/3

T. Taleb, A. Ksentini, and R. Jantti, "Anything as a Service for 5G Mobile Systems", in IEEE Network Magazine.

Mobile Content Distribution Network as a Service



Cloud Based Multimedia Transcoding & Streaming

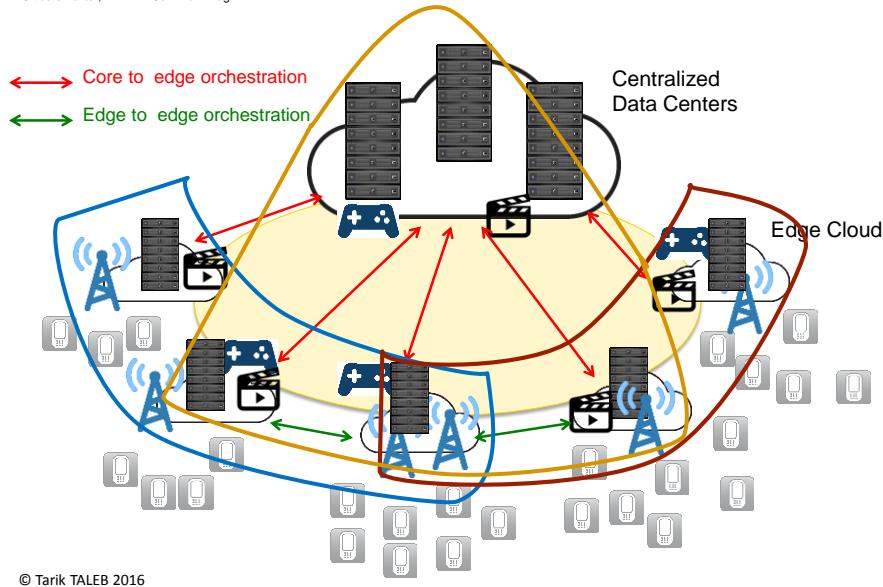


© Tarik TALEB 2016

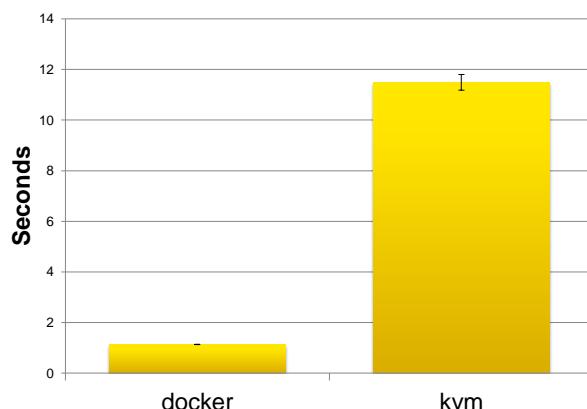


CDN at the Edge

T. Taleb, S. Dutta, A. Ksentini, and M. Iqbal, "Mobile Edge Computing Potential in Making Cities Smarter," in IEEE Commun. Mag.



VNF Performance in Virtual Environments: NGINX HTTP Server - Startup Times

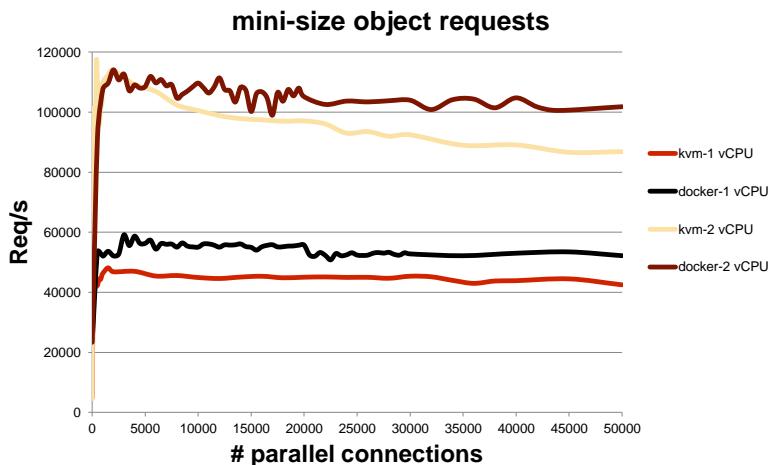


P. Frangoudis, L. Yala, A. Ksentini, and T. Taleb, "An architecture for on-demand service deployment over a telco CDN," in IEEE ICC'16, Kuala Lumpur, Malaysia, May 2016.

© Tarik TALEB 2016



VNF Performance in Virtual Environments: NGINX HTTP Server - HTTP Request Throughput

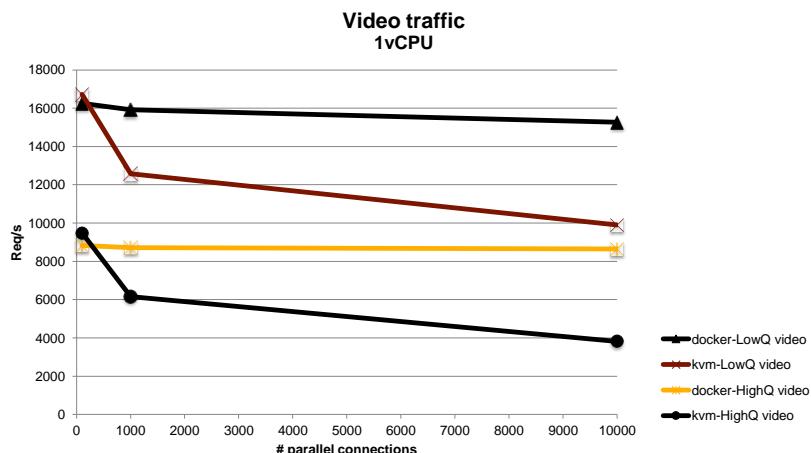


P. Frangoudis, L. Yala, A. Ksentini, and T. Taleb, "An architecture for on-demand service deployment over a telco CDN," in IEEE ICC'16, Kuala Lumpur, Malaysia, May 2016.

© Tarik TALEB 2016



VNF Performance in Virtual Environments: NGINX HTTP Server - HTTP Request Throughput

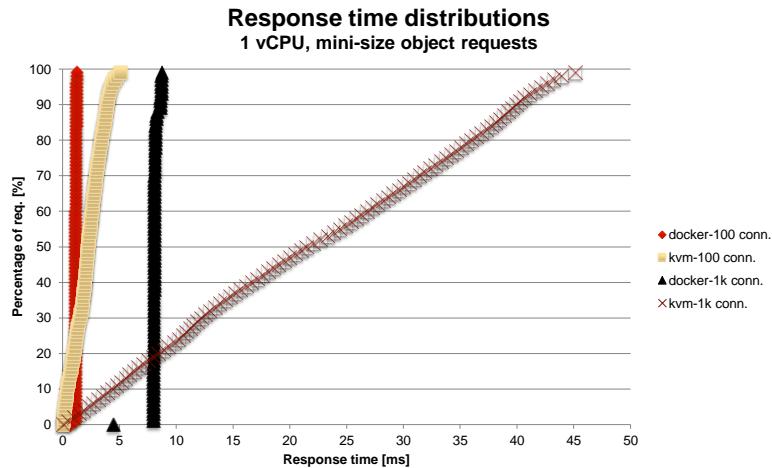


P. Frangoudis, L. Yala, A. Ksentini, and T. Taleb, "An architecture for on-demand service deployment over a telco CDN," in IEEE ICC'16, Kuala Lumpur, Malaysia, May 2016.

© Tarik TALEB 2016



VNF Performance in Virtual Environments: NGINX HTTP Server - Response Time

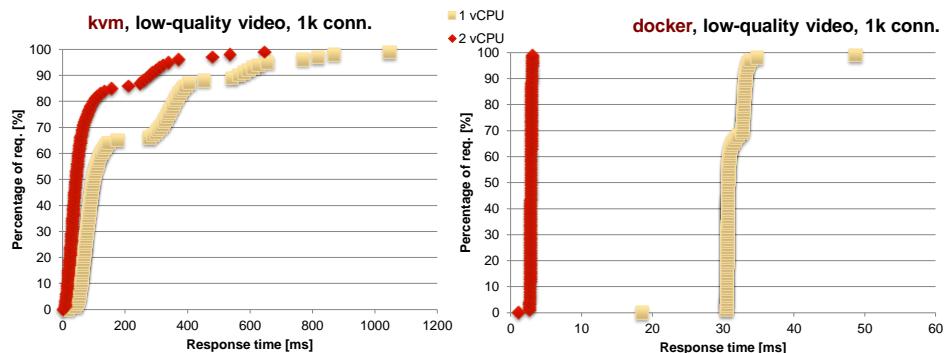


© Tarik TALEB 2016

T. Taleb, A. Ksentini, and R. Jantti, "Anything as a Service for 5G Mobile Systems," to appear in IEEE Network Magazine.



VNF Performance in Virtual Environments: NGINX HTTP Server - Response Time Distribution



© Tarik TALEB 2016

T. Taleb, A. Ksentini, and R. Jantti, "Anything as a Service for 5G Mobile Systems," to appear in IEEE Network Magazine.



Enabling Technologies



© Tarik TALEB 2016



EU-Japan Collaboration Project Proposal

5G!Pagoda

"A network slice for every service"

5G! PAGODA

Federating Japanese and European 5G Testbeds to Explore Relevant Standards and Align Views on
5G Mobile Network Infrastructure Supporting Dynamic Creation and Management of Network Slices
for Different Mobile Services.

サービスに応じたスライス動的生成・管理機能の実証と標準化を目的とする日欧連携 5G 移動通信基盤テストベッド

Call: EU1-2016 - 5G - Next Generation Communication Networks

Coordinators: Tarik Taleb and Akihiro Nakao

E-mails: tarik.taleb@aalto.fi and nakao@nakao-lab.org

Phone: +358-50-435-2325 and +81-3-5841-2384

A!
Aalto-yliopisto

Fraunhofer
FOKUS

ERICSSON

EURECOM
SOPHIA ANTIPATERE

KDDI
KDDI R&D LABS

東京大学
THE UNIVERSITY OF TOKYO

HITACHI

orange

MANDAT
INTERNATIONAL
UNIVERSAL DEVICE GATEWAY

NEC
NEC Networks & System Integration Corporation

Waseda University

Conclusion

5G

- Requirements: Elasticity, flexibility, agility, short latency!
- Cloud potential

Network Sotwarization / Mobile Cloud Networking

- Many advantages to offer
- Key enabling technologies
 - NFV
 - SDN
- Yet many challenges to tackle

Use Case: vCDN on the fly

© Tarik TALEB 2016



Relevant J. Papers

- M. Bagaa, **T. Taleb**, and A. Ksentini, "Efficient Tracking Area Management Framework for 5G Networks", in **IEEE Trans. on Wireless Communications**. (to appear)
- T. Taleb**, A. Ksentini, and R. Jantti, "Anything as a Service for 5G Mobile Systems", in **IEEE Network Magazine**.(to appear)
- T. Taleb**, A. Ksentini, and P. Frangoudis, "Follow-Me Cloud: When Cloud Services Follow Mobile Users", in **IEEE Transactions on Cloud Computing**. (to appear)
- A. Ksentini, **T. Taleb**, and K. Benletaief, "QoE-based Flow Admission Control in Small Cell Networks", in **IEEE Trans. on Wireless Communications**. (to appear)
- T. Taleb**, A. Ksentini, M. Chen, and R. Jantti "Coping with Emerging Mobile Social Media Applications through Dynamic Service Function Chaining", in **IEEE Trans. on Wireless Communications**. (to appear)
- T. Taleb**, A. Ksentini, and B. Sericola, "On Service Resilience in Cloud-Native 5G Mobile Systems", in **IEEE J. Select. Areas in Communications**. (to appear)
- F.Z. Yousaf and **T. Taleb**, "Fine Granular Resource-Aware Virtual Network Function Management for 5G Carrier Cloud," in **IEEE Network Magazine**. (to appear)
- F.Z. Yousaf, P. Loreiro, F. Zdarsky, **T. Taleb**, and M. Leibsich, "Cost Analysis of initial deployment strategies of a Virtual Network Infrastructure in a Datacenter", in **IEEE Communications Magazine**, Vol. 53, No. 12, Dec. 2015, pp. 60 - 66.
- A. Aisiovii, A. Ksentini, A. Gueroui, and **T. Taleb**, "Elastic and Distributed SDN Controllers for Follow-Me Cloud," in **IEEE Access Magazine**, DOI 10.1109/ACCESS.2015.2489930, Vol. 3, Nov. 2015.
- T. Taleb**, M. Corici, C. Parada, A. Jamakovic, S. Ruffino, G. Karagiannis, and T. Magedanz, "EASE: EPC as a Service to Ease Mobile Core Network," in **IEEE Network Magazine**, Vol. 29, No. 2, Mar. 2015, pp.78 – 88.
- T. Taleb** and A. Ksentini, "VECOS: A Vehicular Connection Steering Protocol," in **IEEE TRANS. on Vehicular Technology**, Vol. 64, No. 3, Mar. 2015, pp. 1171 – 1187
- T. Taleb**, A. Ksentini, and A. Kobbane, "Lightweight Mobile Core Networks for Machine Type Communications," in **IEEE Access Magazine**, Vol 2, Oct. 2014, pp.1128-1137
- A. Ksentini, **T. Taleb**, and F. Messaoudi, "A LISP-based Implementation of Follow Me Cloud," in **IEEE Access Magazine**, Vol 2, Oct. 2014, pp. 1340-1347
- T. Taleb**, K. Samdanis, and A. Ksentini, "Supporting Highly Mobile Users in Cost-Effective Decentralized Mobile Operator Networks," in **IEEE Trans. on Vehicular Technology**, Vol. 63, No. 7, Sep. 2014, pp. 3381-3396.
- T. Taleb**, "Towards Carrier Cloud: Potential, Challenges, & Solutions," in **IEEE Wireless Communications Magazine**, Vol. 21, No. 3, Jun. 2014, pp. 80-91.
- T. Taleb** and A. Ksentini, "Follow Me Cloud: Interworking Federated Clouds & Distributed Mobile Networks", in **IEEE Network Magazine**, Vol. 27, No. 5, Sep./Oct. 2013, pp. 12 - 19

© Tarik TALEB 2016



Relevant Conf. Papers

- P. Frangoudis, L. Yala, A. Ksentini, and **T. Taleb**, "An architecture for on-demand service deployment over a telco CDN," in **IEEE ICC'16**, Kuala Lumpur, Malaysia, May 2016.
- A. Ksentini, M. Bagaa, **T. Taleb**, and I. Balasingham, "On using bargaining game for Optimal Placement of SDN controllers," in **IEEE ICC'16**, Kuala Lumpur, Malaysia, May 2016.
- S. Dutta, **T. Taleb**, and A. Ksentini, "QoE-aware Elasticity Support in Cloud-Native 5G Systems," in **IEEE ICC'16**, Kuala Lumpur, Malaysia, May 2016.
- T. Taleb**, K. Samdanis, and A. Ksentini, "Towards Elastic Application-oriented Bearer Management for enhancing QoE in LTE Networks," in **IEEE WCNC'16**, Doha, Qatar, Apr. 2016.
- M. Bagaa, **T. Taleb**, and A. Ksentini, "Efficient Tracking Area Management in Carrier Cloud," in **IEEE Globecom'15**, San Diego, Dec. 2015.
- T. Taleb, M. Bagaa, and A. Ksentini, "User Mobility-Aware Virtual Network Function Placement for Virtual 5G Network Infrastructure," in Proc. **IEEE ICC 2015**, London, UK, Jun. 2015
- T. Taleb**, M. Corici, C. Parada, A. Jamakovic, S. Ruffino, G. Karagiannis, M. Karimzadeh, and T. Magedanz, "Virtualizing the LTE Evolved Packet Core (EPC)," in Proc. **European Conf. on Networks and Communications (EUCNC)**, Bologna, Italy, Jun. 2014
- G. Karagiannis, A. Jamakovic, K. Briggs, M. Karimzadeh, C. Parada, M. Corici, T. Taleb, A. Edmonds, and T.M. Bohnert, "Mobility and Bandwidth prediction in virtualized LTE systems: architecture and challenges," in Proc. **European Conf. on Networks and Communications (EUCNC)**, Bologna, Italy, Jun. 2014
- A. Ksentini, **T. Taleb** and M. Chen, "A Markov Decision Process-based Service Migration Procedure for Follow Me Cloud," in Proc. **IEEE ICC 2014**, Sydney, Australia, Jun. 2014.
- M. Bagaa, **T. Taleb**, and A. Ksentini, "Service-Aware Network Function Placement for Efficient Traffic Handling in Carrier Cloud," in Proc. **IEEE WCNC'14**, Istanbul, Turkey, Apr. 2014.
- T. Taleb** and A. Ksentini, "An Analytical Model for Follow Me Cloud," in Proc. **IEEE Globecom 2013**, Atlanta, USA, Dec. 2013.
- T. Taleb** and A. Ksentini, "Gateway Relocation Avoidance-Aware Network Function Placement in Carrier Cloud," in Proc. **ACM MSWIM 2013**, Barcelona, Spain, Nov. 2013
- T. Taleb**, P. Hasselneyer, and F. Mir, "Follow-Me Cloud: An OpenFlow-based Implementation," in Proc. **IEEE GreenCom'13**, Beijing, China, Aug. 2013.
- T. Taleb** and A. Ksentini, "Impact of Emerging Social Media Applications on Mobile Networks," in Proc. **IEEE ICC 2013**, Budapest, Hungary, Jun. 2013.
- T. Taleb** and A. Ksentini, "On Efficient Data Anchor Point Selection in Distributed Mobile Networks," in Proc. **IEEE ICC 2013**, Budapest, Hungary, Jun. 2013.
- T. Taleb**, K. Samdanis, and S. Schmid, "DNS-based Solution for Operator Control of Selected IP Traffic Offload," in Proc. **IEEE ICC**, Kyoto, Japan, Jun. 2011.

© Tarik TALEB 2016

