Review Open Call 4 experiments
Unikernel-based CDNs for 5G Networks
UNIC

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The UNIC Concept

- **Unikernel-based CDNs for 5G Networks - UNIC**
  - brings together **Unikernels**, **CDNs** and the novel **Fed4FIRE** experimentation environment
  - realizes **content provisioning** for **5G Networks**
  - through tackling **scalability**, **heterogeneity** issues, and realizing **adaptability** to dynamic network conditions and user requirements

Motivation

- **The emerging 5G networks call for new approaches to CDNs through addressing challenging issues, such as:**
  - scalable and holistic resource utilization, spanning from large data centers to the user device, including edge clouds
  - incorporation of heterogeneous physical and virtual resources
  - adaptability to dynamic user requirements, server resources and network capacity constraints

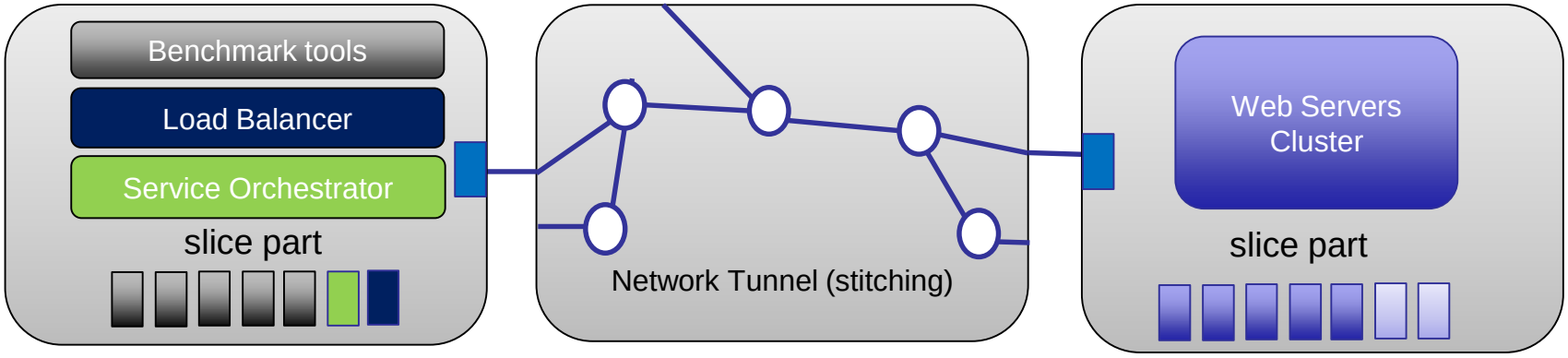
1. to integrate our Unikernel-based CDN experimentation platform for 5G networks with the novel FED4FIRE facilities
2. to experiment with novel content distribution addressing scalability, heterogeneity and elasticity, i.e., Content Popularity Change Detection and Placement Decision Mechanisms
3. to inspire and enrich future experimentations and extensions of the UNIC and FED4FIRE platforms
4. to design and implement the UNIC demo, and disseminate our results

UNIC brings together lightweight clouds, CDNs and the novel FED4FIRE experimentation environment to realize content provisioning for 5G networks through tackling scalability, heterogeneity issues, and realizing adaptability to dynamic network conditions ans user requirements

OBJECTIVES

Demo set-up

THE CONTENT DISTRIBUTION SERVICE



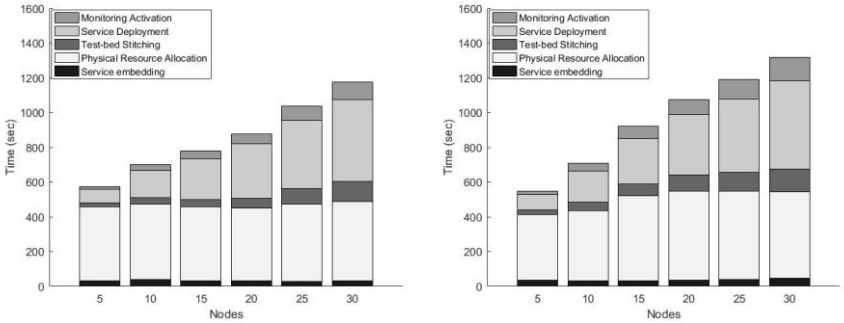
UOM test-bed

Fed4FIRE test-beds (VWall2), CLUtah, UOM

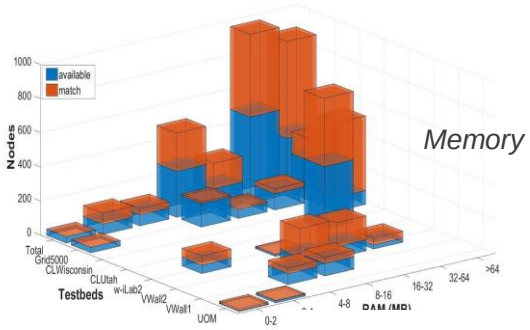
Results I-II

PERFORMANCE AND SCALABILITY

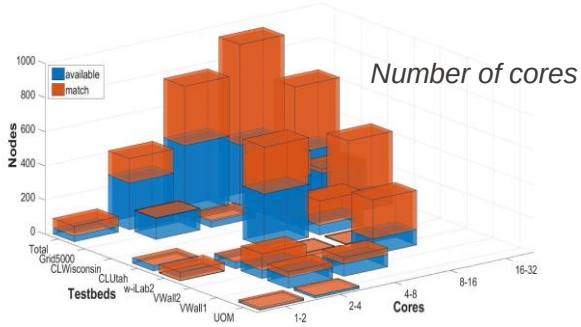
Realize large-scale Unikernel-based content provisioning over heterogeneous FED4FIRE resources



Deployment time of: (a) Core cloud nodes, and (b) Edge cloud nodes



Memory



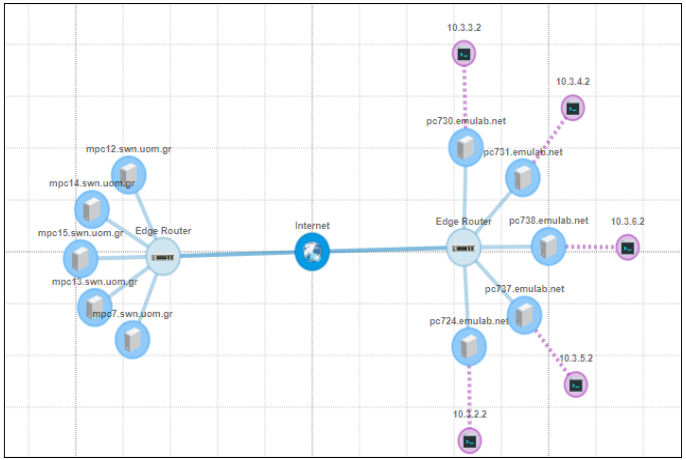
Number of cores

Elastic large-scale CDNs deployments require dynamic resource discovery

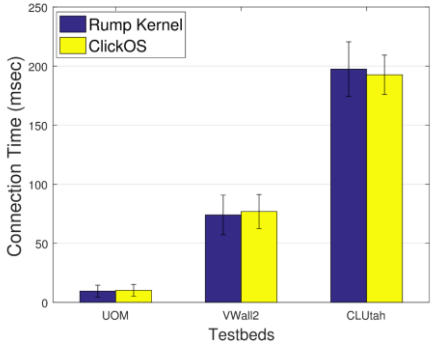
DYNAMIC RESOURCE DISCOVERY

Results III

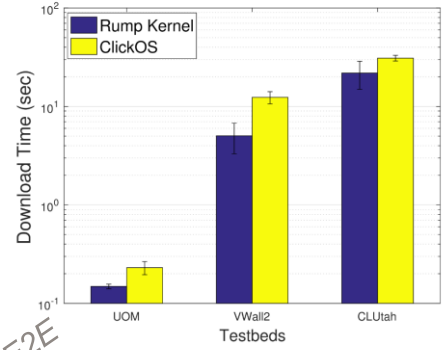
WIDE-AREA UNIKERNEL-BASED CONTENT PROVISIONING OVER HETEROGENEOUS TECHNOLOGIES



Abstract view of the E2E slicing

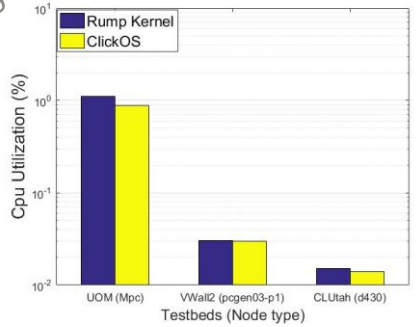


Clients' connection time



Clients' download time

Different Unikernel technologies in E2E slices

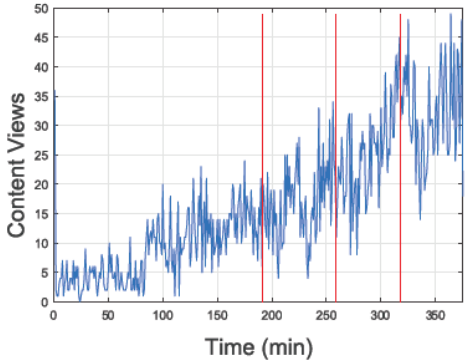


CPU utilization

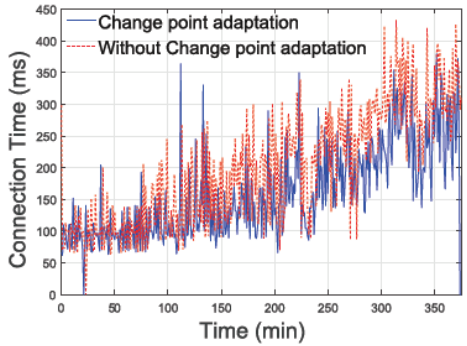
Results IV-V

REAL-TIME VIDEO CONTENT POPULARITY DETECTION

Elastic CDN requires content deliverable adaptable to user demands



Content views per minute and detected change-points



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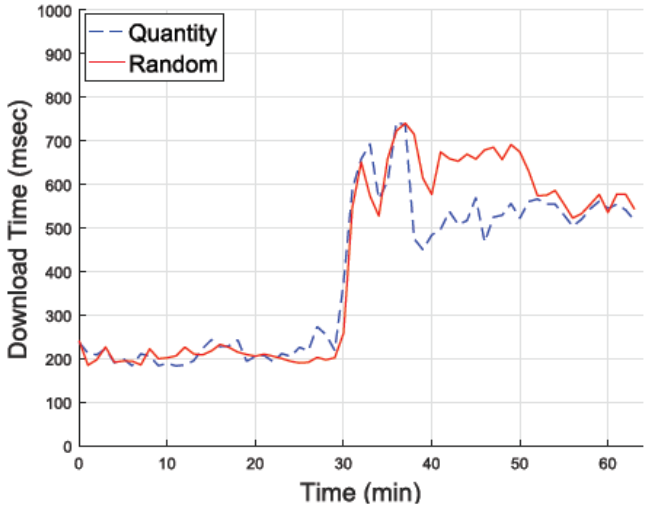


Impact of VM placement algorithms on web client download time

Decide the parameters of a large-scale CDNs deployment: VE placement, Unikernel technology to use, client load balancing

RESOURCE ALLOCATION AND LOAD BALANCING

Lessons learned

- Accessing a variety of geographically-distributed test-beds enabled realistic experimentation with CDN platforms
- Bringing together diverse CDN orchestration aspects is challenging and cannot be effectively realized without an incremental approach
  - multi-domain operation, real-time content popularity detection, dynamic resource discovery/allocation and efficient load balancing
- Decoupling virtualization technologies from the platform design requires abstractions and technology-agnostic solutions that allow to:
  - overcome implementation issues related to particular virtualization approaches
  - focus on service orchestration aspects, without being constrained from unstable code

Value received

- **The UNIC experiment allowed us to:**
  - gain a better understanding of the technical issues involved in a large-scale CDN environment that e.g., utilizes Unikernels, discovers and allocates resources on-demand
  - readjust the scope of our research towards practical implementation solutions that face important challenges, such as scalability and heterogeneity and efficient multi-domain orchestration of CDN services
  - put our theoretical proposals into practice, e.g., apply change-point analysis to detect content popularity, formulate an optimization problem to allocate Unikernel-based VMs over heterogeneous resources and balancing the traffic load

1. five publications
2. major contributions to the PhD thesis of two research group members
3. teaching material for one undergraduate and one postgraduate course, i.e., Special Topics in Computer and communication networks and Practical Issues in Computer Networks and Internetworks
4. a closer cooperation with industry, i.e., the United Technologies and Telefonica

G. Violettas, S. Petridou, L. Mamatas, Evolutionary Software Defined Networking-inspired Routing Control Strategies for the Internet of Things, in **IEEE Access**, Sep. 2019.

S. Skaperas, L. Mamatas, A. Chorti, "Real-time Video Content Popularity Detection Based on Mean Change Point Analysis", in **IEEE Access**, Aug. 2019.

P. Valsamas, P. Papadimitriou, I. Sakellariou, S. Petridou, L. Mamatas, S. Clayman, F. Tusa, A. Galis, "Multi-PoP Network Slice Deployment: A Feasibility Study" in **IEEE CloudNet**, Nov. 2019, Coimbra, Portugal.

Maciel Jr, P. D., Verdi, F. L., Valsamas, P., Sakellariou, I., Mamatas, L., Petridou, S., ... & Clayman, S. A Marketplace-based Approach to Cloud Network Slice Composition Across Multiple Domains, **IEEE Workshop on Advances in Slicing for Softwarized Infrastructures (S4SI)**, in the context of **NETSOFT 2019**, 24-28 June, 2019, Paris, France.

Polychronis Valsamas, Ilias Sakellariou, Sophia Petridou and Lefteris Mamatas, "A Multi-domain Experimentation Environment for 5G Media Verticals", **IEEE INFOCOM CNERT Workshop**, April 29 - May 2, 2019, Paris, France.

DIRECT AND INDIRECT IMPACT

Why FED4FIRE

- **The experimentation facilities of FED4FIRE:**
  - bring realism to our experiments
    - provide access to large-scale, multi-domain CDN environments
    - support heterogeneity in respect to physical and virtual recourses
  - allow a good time management
    - avoid time consuming installations and configurations
    - invest our time in research problems and novel solutions
  - provide the hardware infrastructure
    - small Universities cannot afford the required test-beds
    - emulation or simulation was the only option

Thanks to the UNIC experiment

- **… we foresee:**
  - a service-oriented, federated experimentation infrastructure for Multi-Access Edge Computing (MEC) associated to the FED4FIRE
  - the UNIC platform generalization to support more services beyond CDNs, aligned to the network slicing paradigm
    - *the services could be defined using service repositories and service function chains*
  - a community-based solution, involving network devices and PCs that can host the content and participate in community resource-sharing schemes
  - regional project proposals for PhD thesis on theoretical aspects, e.g., novel prediction algorithms and stochastic models improving the content delivery performance

Test-beds and facilities utilized

Experiment	Test-beds utilized	Facilities used
Wide-area Unikernel-based content provisioning	Virtual Wall 2, Utah Emulab and SWN	Experiments with nodes of the type: (i) pcgen03-p1 of Virtual Wall 2, (ii) d430 of Utah Emulab, and (iii) mpc of SWN
Optimization model for resource allocation and load balancing	Virtual Wall 2, w-iLab.t and Utah Emulab	The model input is based on experiments utilizing the node types: (i) pcgen03-p1 of Virtual Wall2, (ii) DSS of w-iLab.t, and (iii) d430 of Utah Emulab
Content-popularity detection mechanisms	SWN	Experiments with mpc type nodes
Evaluation of the 5G-CDN experimentation platform	Cloudlab Utah	Experiments utilizing d430 and pc3000 type nodes
Dynamic resource discovery	Virtual Wall 1, Virtual Wall 2, w-iLab2, Grid5000, Cloudlab Utah, Cloudlab Wisconsin, and SWN	Looking up resource availability through the listresources command of jfed-cli/omni tools or the cached resources through the FED4FIRE REST API

Tools exploited

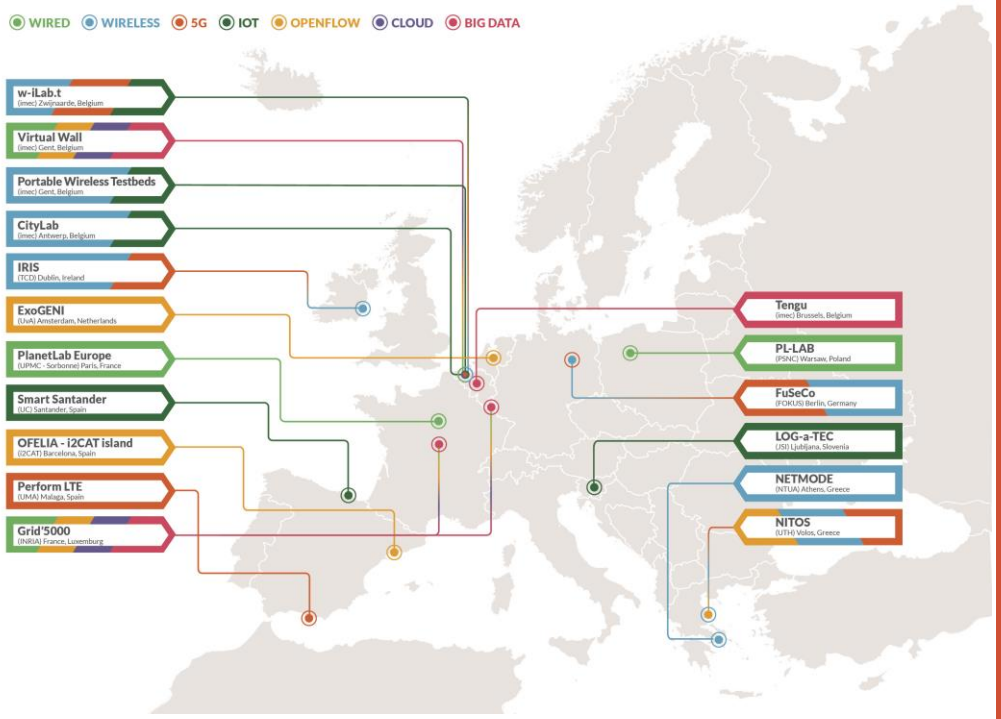
Tool	Our experience
Fed4FIRE+ portal	We visit the Fed4FIRE portal regularly to get insight information for the federated FIRE test-beds and the relevant events.
JFed	It is a very handy tool that allows the user to specify the experiment and its configuration. We used the versions 5.9 and 6.1, which have inherent ansible support, something very useful for us.
Omni	We used the omni tool only at the beginning for experimentation automation and our dynamic resource discovery features. We found it more oriented to the USA test-beds.
JFed-CLI	We used the JFed-CLI tool for a better experimentation automation, e.g., to reproduce the same experiment many times.
fedmon API	For more extensive experiments that utilize resource discovery over multiple test-beds, we used the fedmon REST API, which maintains cached results, i.e., updated about every 20 minutes.

Added value of FED4FIRE

03 The **diversity of available resources/combination of infrastructures**, because it allows us to match the characteristics of real CDN deployments

02 The **easy setup** of experiments through the novel tools offered is very important to us

01 The **support and documentation** was fundamental, but as the FED4FIRE infrastructure evolves, things run more automated and require less support



QUOTE

Thanks to the experiment we conducted within FED4FIRE+ we have been able to extend the realism of our Unikernel-based Content Distribution Networking platform towards handling scalability and heterogeneity issues through incorporating relevant novel mechanisms, i.e., for content popularity detection, efficient virtual entity placement and traffic load balancing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