Lifetime-aware, Fault-aware and Energy-aware SDN and CDC: Optimal Formulation and Solutions

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2. Problem 2: CDC power state management and maintenance cost
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Problem 1: Lifetime-aware CHW machine states

Introduction Problem 1

i) The goal of **green networking** is to exploit the power management policies to reduce the network energy cost.

ii) One of the main components in the Network is Commodity Hardware (CHW)

iii) CHW devices can be efficiently managed by varying their power states such as using Sleep Mode (SM), in order to limit their electricity consumption. It impacts on device lifetime in short-/long-term evaluation.

iv) We plan to address;

    i) CHW temperature variations[1]
    ii) CHW lifetime-Aware ISP Networks[2]

[1] A measurement-based analysis of temperature variations introduced by power management on Commodity HardWare, In 19th IEEE ICTON, pp. 1-4, 2017.

[2] Lifetime-Aware ISP Networks: Optimal Formulation and Solutions, IEEE/ACM Transactions on Networking, 2017.

Problem 1- CHW temperature variations

i) We investigate what is the impact on temperature triggered by the variation of power states on the CHW

ii) It is based on real measurements on a simple testbed: characterization of temperature on the CPU and the RAM when a SM state is triggered

iii) Abrupt stopping of the fans triggered by SM tends to spread the heat over the components, thus increasing their temperature transient before reaching a steady state.

iv) plug the retrieved temperature measurements in a well known failure model, showing that the CHW failure rate is reduced by a factor of 5 when the number of transitions between AM and SM states is more than 20 per day and the SM duration is in the order of 800 [s].

Problem 1- Testbed

We select the following devices:

i) one server, which is used as CHW for our experiments;

ii) An iDRAC interface (which is installed on the CHW) to obtain temperature measurements of the motherboard CPU;

iii) a power meter, used to measure the power consumption of the CHW;

iv) a thermal camera, which is used to measure the surface temperature of CPU and RAM components;

v) a Linux-based PC acting as a measurement collector from the iDRAC interface, the power meter and the thermal camera;

vi) a switch and Ethernet cables to connect the iDRAC interface, the power meter, and the thermal camera to the measurement collector PC.

Problem 1- Testbed HW

Table: Testbed HW

Type	Description
Server	Dell PowerEdge T320 with Intel Xeon (8 cores, 16 threads) at 2.10 GHz, 48 GB RAM, iDRAC 7, Ubuntu 14.04 LTS
Power Meter	Raritan DPXR20A-16
Thermal Camera	FLIR A325 Camera
Measurement Collector	Commodity PC with Ubuntu 12.04 LTS

[2] A measurement-based analysis of temperature variations introduced by power management on Commodity HardWare, In 19th IEEE ICTON, pp. 1-4, 2017.

Problem 1- Testbed SW

SW Tool	Scope	From	To
`snmpget`	Obtain the CHW power consumption	Measurement collector PC	Power meter (Ethernet Port)
`ipmitool`	Obtain the CHW CPU temperature	Measurement collector PC	Server iDRAC Interface (Ethernet Port)
`stress`	Load CHW CPU and/or memory resources	CHW Terminal	CHW Operating System
FLIR IR Monitor	Measure the temperature of CHW Components	Measurement collector PC	Themal Camera (Ethernet Port)

Problem 1- Results

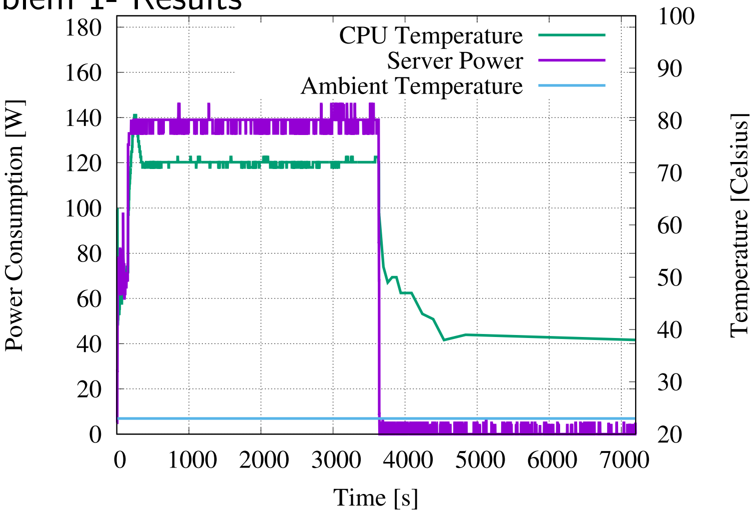


Figure: AM - SM Impact

Problem 1- Results..

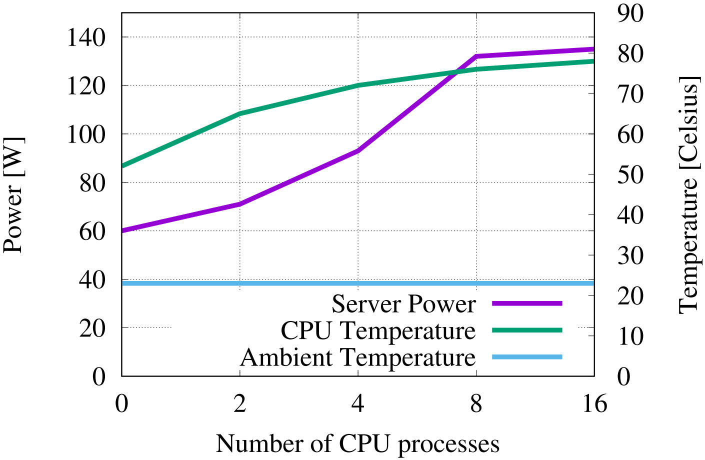
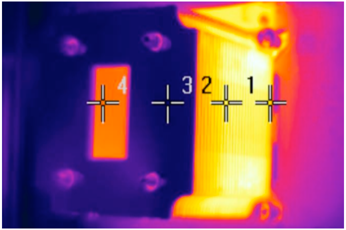
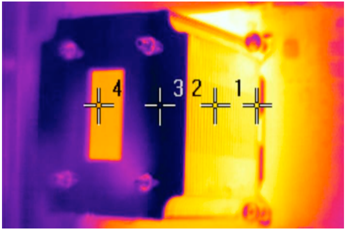


Figure: CPU Load Impact

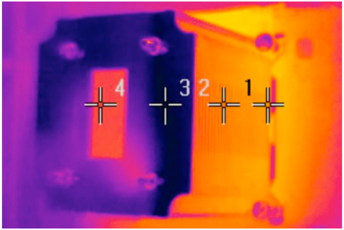
Problem 1- Results-CPU Temperature variation



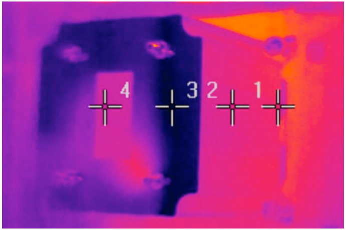
$t_s = 0$ [s]



$t_s = 600$ [s]

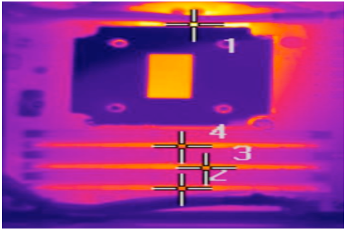


$t_s = 1200$ [s]

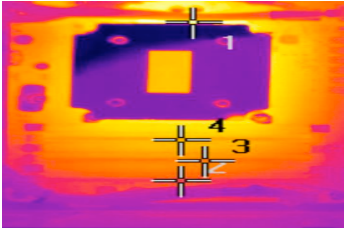


$t_s = 1800$ [s]

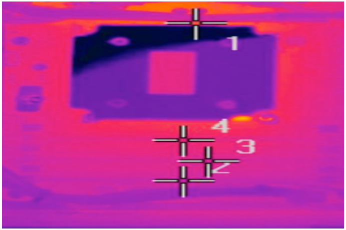
Problem 1- Results-RAM Temperature variation



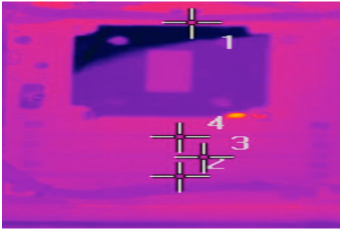
$t_s = 0$ [s]



$t_s = 600$ [s]



$t_s = 1200$ [s]



$t_s = 1800$ [s]

Problem 1- Acceleration Factor (AF) vs TMP variations

$$AF = \left(\frac{f_{STD}}{f_{SM}}\right)^{-m} \left(\frac{\delta_{STD}}{\delta_{SM}}\right)^{-n} \left(e^{\frac{E_a}{K}(1/T^{max}_{STD} - 1/T^{max}_{SM})}\right) \quad (1)$$

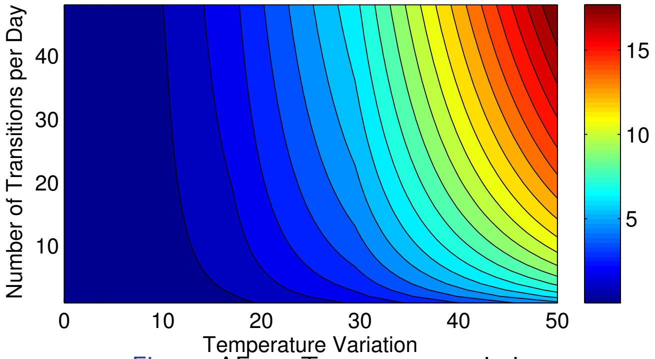


Figure: AF vs. Temperature variations

Problem 1- CHW lifetime-Aware ISP Networks

$$min \frac{1}{t} \sum_{(i,j)\in E} AF_{i,j} \tag{2}$$

1. **given** set of CHW switches N, their connections E, traffic per each time-slot t
2. **subject to** connectivity and maximum link utilization at each t

[2] Lifetime-Aware ISP Networks: Optimal Formulation and Solutions, IEEE/ACM Transactions on Networking, 2017.

Problem 1- Simulation Setup

Network Name	FT	Germany17
Type	Core Level	Core Level
Number of Nodes	38	17
Number of Links	72	123
Average Degree	3.78	28.9
Routing Weights	Provided by Operator	Uniform
Routing Algorithm	Shortest Path	Shortest Path
Maximum Link Utilization	50%	100%
Min. Traffic Granularity	1 hour	1 hour

Figure: Network Characterization

[2] Lifetime-Aware ISP Networks: Optimal Formulation and Solutions, IEEE/ACM Transactions on Networking, 2017.

Problem 1- Results

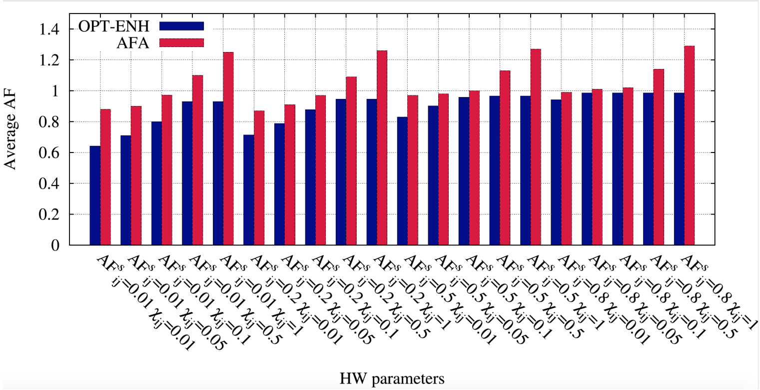


Figure: AF vs. HW parameters for Optimal (OPT-ENH) and Heuristic (AFA)

[2] Lifetime-Aware ISP Networks: Optimal Formulation and Solutions, IEEE/ACM Transactions on Networking, 2017.

Problem 1- Results..

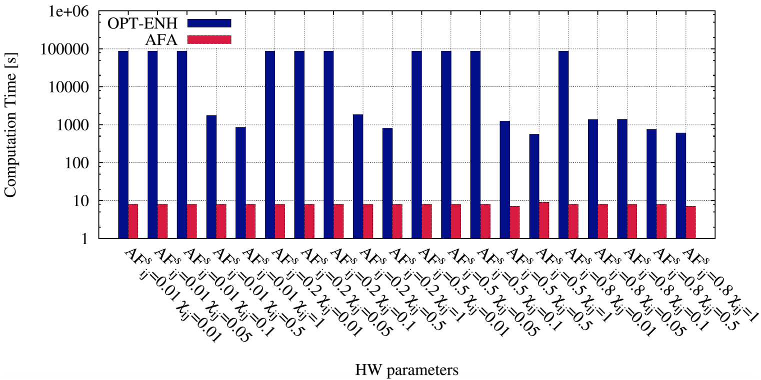


Figure: Computation Time vs. HW parameters for (OPT-ENH) and Heuristic (AFA)

[2] Lifetime-Aware ISP Networks: Optimal Formulation and Solutions, IEEE/ACM Transactions on Networking, 2017.

Problem 1- Results..

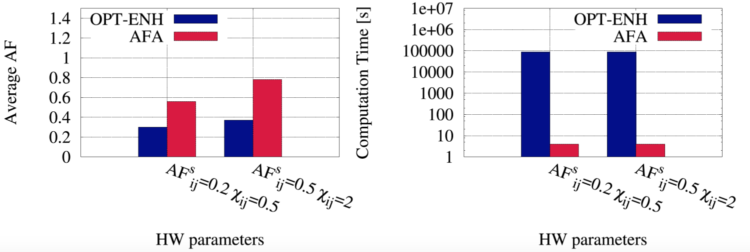


Figure: Average AF vs. Computation Time for Optimal and Heuristic (AFA) in Network Type Germany17

[2] Lifetime-Aware ISP Networks: Optimal Formulation and Solutions, IEEE/ACM Transactions on Networking, 2017.

Problem 2: CDC power state management and maintenance cost[3]

[3] An Optimal Approach to Reduce Electricity and Maintenance Costs in Cloud Data Centers, IEEE Transactions on Sustainable Computing, in press, 2017.

Introduction Problem 2

i) Data Centers (DC)s are intensely widespread worldwide to sustain a variety of applications, such as web browsing, streaming, high definition videos, and cloud storage.
ii) DCs can be put Active mode (AM) or Sleep Mode (SM) to reduce the energy and electricity usage.
iii) Transition between AM and SM during long-term periods cause **Maintenance cost** [paid by content provider] and increase the **failure rate**.
iv) We present;
   i) A model to compute the maintenance costs, given the variation over time of the power states for a set of servers
   ii) Optimally formulate the problem of jointly reducing the CDC electricity consumption and the related maintenance costs
   iii) test on realistic case study, clearly show that our solution is able to wisely trade between maintenance and electricity costs in order to provide monetary savings for the content provider

Problem 2- CDC Architecture

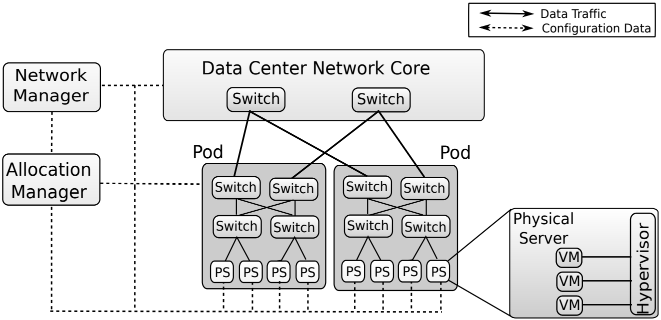


Figure: Cloud Data Center Architecture.

[3] An Optimal Approach to Reduce Electricity and Maintenance Costs in Cloud Data Centers, IEEE Transactions on Sustainable Computing, in press, 2017.

Problem 2- Overall Formulation

The OPTIMAL MAINTENANCE AND ELECTRICITY COSTS (OMEC) problem, which aims at minimizing the costs for each TS t, is formulated as follows:

$$\min\ C^{TOT}(t) = \left[C_M^{TOT}(t) + C_E^{TOT}(t)\right] \tag{3}$$

subject to:

$$\begin{array}{l} \text{Maintenance Costs Computation} \\ \text{Electricity Costs Computation} \\ \text{VM Allocation Constraint} \\ \text{Maximum CPU Capacity} \\ \text{Maximum Memory Capacity} \end{array} \tag{4}$$

under control variables: $x_{ij}(t) \in \{0, 1\}$, $O_i(t) \in \{0, 1\}$.

[3] An Optimal Approach to Reduce Electricity and Maintenance Costs in Cloud Data Centers, IEEE Transactions on Sustainable Computing, in press, 2017.

Problem 2- Results..

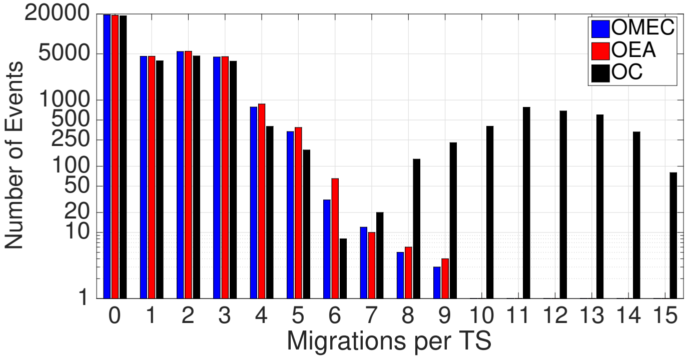
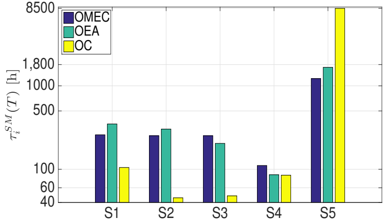


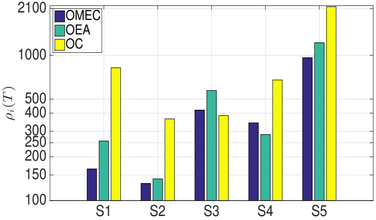
Figure: Histogram of the occurrence of migrations events for OMEC, OC and OEA with $|\mathcal{S}|= 5$, $|\mathcal{VM}|= 15$ and $|\mathcal{T}|= 1$ [year].

[3] An Optimal Approach to Reduce Electricity and Maintenance Costs in Cloud Data Centers, IEEE Transactions on Sustainable Computing, in press, 2017.

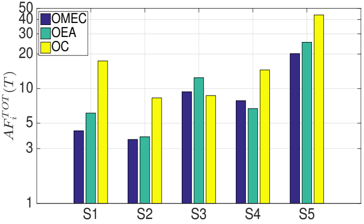
Problem 2- Results..



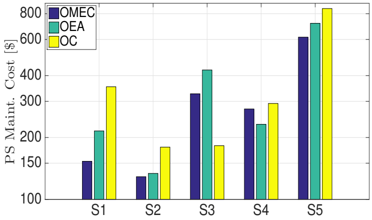
Total Transition Duration [h]



Total Transitions



Total AF



Maintenance Cost per server

Problem 2- Results..

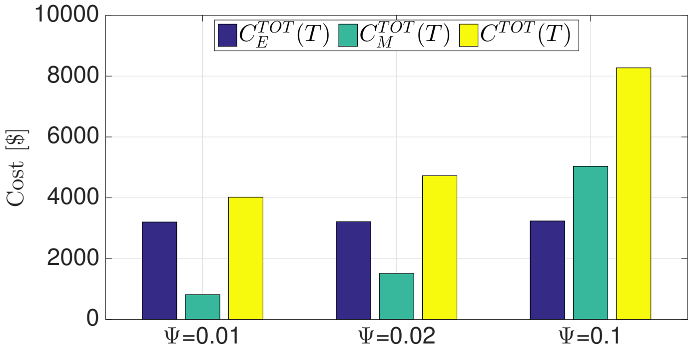


Figure: Electricity Costs $C_E^{TOT}(T)$, Maintenance Costs $C_M^{TOT}(T)$, and total costs $C^{TOT}(T)$.

[3] An Optimal Approach to Reduce Electricity and Maintenance Costs in Cloud Data Centers, IEEE Transactions on Sustainable Computing, in press, 2017.

Problem 3: Fault-aware SFC in SDN[4]

[4] Joint Energy Efficient and QoS-aware Path Allocation and VNF Placement for Service Function Chaining, IEEE Transactions on Network and Service Management, under review, 2017.

Introduction Problem 3

i) A Service Function Chain (SFC) represents the set of network/service functions that need to be associated to a given flow.
ii) Software Defined Networking (SDN) provides a powerful infrastructure to implement SFC.
iii) We jointly consider the problem of flow rerouting and server energy consumption in SFC context.
iv) We present;
    i) Our main objective is to minimize the network energy consumption while the required VNFs are properly delivered to the traffic flows.
    ii) mathematically formulate the resource reallocation problem which is a cross-layer optimization problem considering energy and SFC parameters
    iii) a suboptimal heuristic to solve the aforementioned optimization problem and compare the optimal resolution and the heuristic approach in terms of different metrics and computation time.

Problem 3- Architecture..

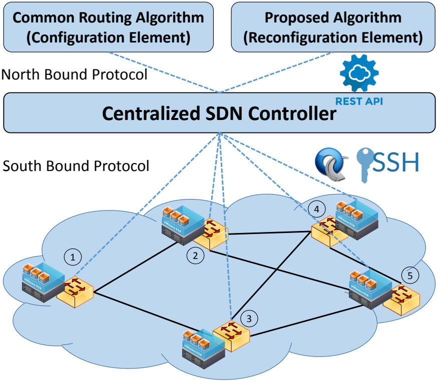


Figure: System Architecture.

4 Joint Energy Efficient and QoS-aware Path Allocation and VNF Placement for Service Function Chaining, IEEE Transactions on Network and Service Management, under review, 2017.

Problem 3- Overall Formulation

The Optimal Network Reconfiguration (ONR) problem, which aims at minimizing the energy consumption of the servers for each TS t, is formulated as follows:

$$\min_O \sum_{i=1}^{N} O_i. \cdot \mathbf{E}_i \tag{5}$$

subject to:

$$\begin{aligned} &\text{Flow Conservation Constraints} \\ &\text{Server Utilization Constraints} \\ &\text{Link Utilization Constraints} \\ &\text{VNF/SFC Constraints} \end{aligned} \tag{6}$$

under control variables: $x_{ij}(t) \in \{0,1\}$, $O_i(t) \in \{0,1\}$.

[4] Joint Energy Efficient and QoS-aware Path Allocation and VNF Placement for Service Function Chaining, IEEE Transactions on Network and Service Management, under review, 2017.

Problem 3- Simulation Setup

Table: Hardware Configuration.

Name	**Description**
Processor	Intel-Core(TM) i5-2410M-CPU 2.30GHz
IDE	Standard-SATA AHCI Controller
RAM	4.00 GB
System Type	64-bit Operating System, Windows 10

[4] Joint Energy Efficient and QoS-aware Path Allocation and VNF Placement for Service Function Chaining, IEEE Transactions on Network and Service Management, under review, 2017.

Problem 3- Network Topology

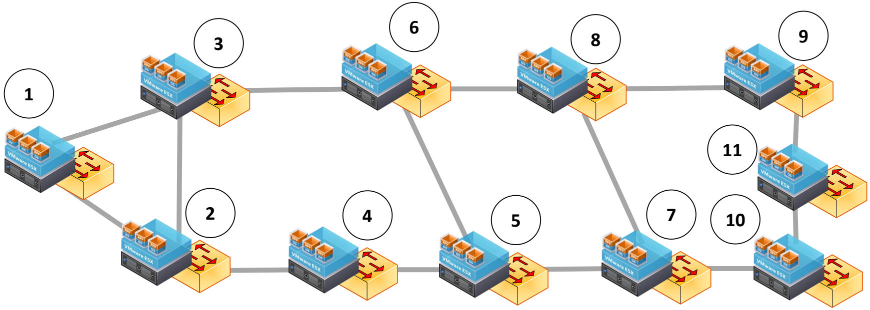


Figure: Abilene Network Topology.

[4] Joint Energy Efficient and QoS-aware Path Allocation and VNF Placement for Service Function Chaining, IEEE Transactions on Network and Service Management, under review, 2017.

Problem 3- Results

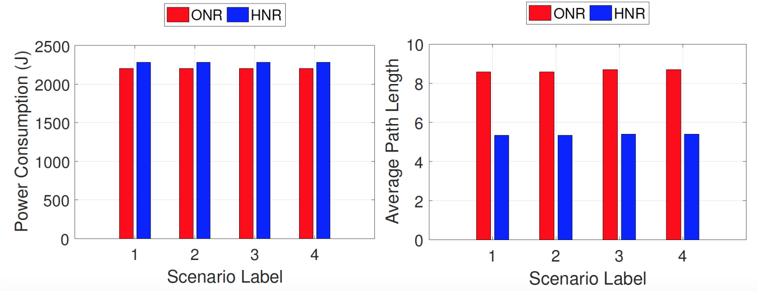
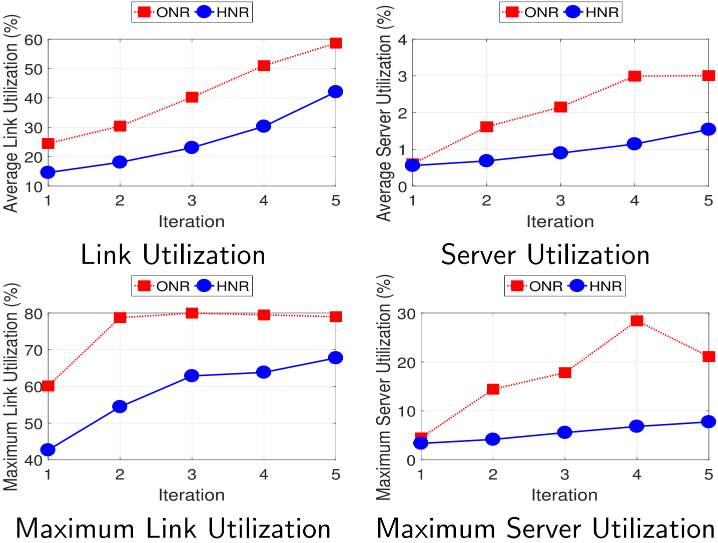


Figure: Average Power Consumption and Path Length for ONR vs. heuristic Network Re-configuration (HNR)

[4] Joint Energy Efficient and QoS-aware Path Allocation and VNF Placement for Service Function Chaining, IEEE Transactions on Network and Service Management, under review, 2017.

Problem 3- Results..



Summary and Conclusions

In **problem 1**:

i) We have performed a measurement campaign over a CHW server to retrieve the temperature and the power consumption for different power states.

ii) When the server is put in SM, the power consumption goes almost immediately to 0 values, while the temperatures on the components exhibit a transient, which is almost exhausted after 1800 [s].

iii) We have shown that the lifetime varies with time, and also across the different devices using AF for each CHW switch.

Summary and Conclusions...

In **problem 2**:

i) Maintenance costs + Electricity consumption in a CDC by acting on the PSs power states and the VMs allocation

ii) We address CPU processing, the amount of transferred data, and the VMs migrations.

In **problem 3**:

i) formulate the problem of SFC in an SDN-based network, with the goal of reducing the overall energy consumption as an Integer Linear Programming (ILP) problem.

ii) we control the link and server congestion by putting constraints on their maximum utilization.

ii) The proposed ONR and HNR solutions were compared in terms of power consumption, average path length, link/server utilization, and computational complexity.

Future Directions...

i) How to integrate the Problems with More sophisticated large-case scenarios? **[CNIT based on new EU projects are working..]**

ii) How to take care of multi-discipline security issues in these problems? **[Cisco and Google are working..]**

iii) Any other suggestions are welcome!

Thanks for listening. Q?

Project Link: http://superfluidity.eu/

References...

1) A measurement-based analysis of temperature variations introduced by power management on Commodity HardWare, In 19th IEEE ICTON, pp. 1-4, 2017.
2) Lifetime-Aware ISP Networks: Optimal Formulation and Solutions, IEEE/ACM Transactions on Networking, 2017.
3) An Optimal Approach to Reduce Electricity and Maintenance Costs in Cloud Data Centers, IEEE Transactions on Sustainable Computing, in press, 2017.
4) Joint Energy Efficient and QoS-aware Path Allocation and VNF Placement for Service Function Chaining, IEEE Transactions on Network and Service Management, under review, 2017.