SHORT TERM SCIENTIFIC MISSION (STSM) – SCIENTIFIC REPORT

The STSM applicant submits this report for approval to the STSM coordinator

Action number: CA15127 - RECODIS

STSM title: Secure Manycast, Anycast and Replica Placement in Optical Inter-Datacenter Networks

STSM start and end date: December 18, 2018- January 5th, 2019

The STSM took place in the period of December 18th, 2018 – January 5th, 2019 with a duration of 10 days. (Note: Although the full period stated covers 19 days the STSM lasted 10 days as there were holidays in between.)

Grantee name: Nina Skorin-Kapov, University Center of Defense, Spain (ES)

Host: Matija Džanko, University of Zagreb, Croatia

Working group: WG4: Malicious human activities

PURPOSE OF THE STSM

As demands for cloud services proliferate, cloud Content Service Providers (CSPs) such as Amazon, Google, Facebook, etc, increasingly create, store and share massive amounts of content. Optical inter-datacenter networks represent the only viable option for satisfying the huge bandwidth required to replicate and update content for cloud-based services across geographically dispersed datacenters. In addition to content replication and synchronization, optical inter-datacenter networks must also support communication between datacenters and end users. The resulting new traffic patterns and the enormous traffic volumes call for new capacity-efficient approaches for inter-datacenter network design that incorporate both transport and datacenter resource planning. In addition to supporting the ultra-high data rates, datacenter networks must also provide a high degree of resiliency and security. Optical fiber links are prone to failures, typically caused by construction equipment digging through the fiber ducts. Moreover, entire network nodes which host the datacenters can also fail, e.g., due to a power outage, a natural disaster or a deliberate attack. While replicating content across a set of geographically distributed datacenters inherently improves content accessibility in the presence of failures, guaranteeing a certain degree of reliability requires tailored resiliency schemes. Within this STSM, we plan to extend our initial work on survivable Manycast, Anycast and Replica Placement (MARP) in optical inter-datacenter networks with enhanced heuristic algorithms for security-aware MARP. Initial work is focused on the case of security breaches that disable a single DC and/or a single link.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM

During the visit, various activities were performed to complete the workplan of the STSM.

- **Frequent meetings with Dr. Matija Dzanko to work towards the objectives**. We first researched the state-of-the art related to inter-data center (DC) and DC-to-user traffic in the context of survivability and general security issues in inter-DC networks. We analyzed the assumptions of our initial work on the topic of survivable manycast, anycast and replica placement where we proposed an Integer Linear Program (ILP) to solve it. Although the approach is valid, it is not scalable. Consequently, during the STSM, we worked towards designing a scalable heuristic algorithm, which is described in the next section. We are working on implementing the heuristic to compare with the ILP previously proposed.

- The applicant, Nina Skorin-Kapov, also held **a 1-hour IEEE invited talk** on the topic of the evolution of core traffic based on the two traffic types previously described in the presence of expanding CDNs to get additional feedback.

- **Remote discussions of the applicant and host with Dr. Marija Furdek (also a COST partner)** also led us to discuss the possibility of expanding the assumptions of approach, in particular in the context of elastic optical networks and edge computing. This will involve modifying the proposed ILP and rerunning the tests.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

Inter-data center network traffic routing paradigms lead to anycast routing for user-to-DC traffic where a user accesses a content unit at “any”, typically the closest, DC hosting a replica of the desired content. For DC-to-DC traffic, multicast routing is required for synchronization traffic between the content replicas. If the location of the replicas is unknown in advance, the problem leads to manycast routing. In our previous work in [1], we proposed an ILP and heuristic approach for simultaneous manycast, anycast and replica placement (MARP) in inter-data center networks. We later considered the case of survivability in [2]. Here we created backup paths for the user-to-DC traffic by considering 3 cases: (i) where the working and backup paths are link-disjoint but access the same DC, (ii) where the working and backup paths access different DCs and are link-disjoint, and (iii) where the backup path can access any DC that results in the lowest cost. The second variant is the most constricting but the best solution in case of DC failure or attack. During the STSM, we considered this variant and designed a heuristic algorithm to solve it.

Given is a network G=(V,E), a set of contents C, a set of datacenter locations D in V, number of replicas per content (k), the main data center of each content and a set of anycast demands from any node in V requesting a specific content. The objective is to determine in which DCs (in addition to the main DC) to place the replicas of each content, establish a multicast tree interconnecting the replicas, and establish working and backup paths according to assumption (ii) for the anycast demands.

The heuristic works as follows. We first sort the contents in descending order of the number of anycast demands. We start to build a manycast tree and establish the anycast routes for each content in the given order. We start with the initial main DC. Those anycast demands whose shortest path to any DC is that main DC, set up their primary path to the DC. Then in each step, we must make a decision in which new DC to add a replica.

This decision is based on three factors:

(1) Proximity to the multicast tree (where it is desirable that the tree is of minimum weight), $h_{d,c}$, i.e. number of hops from potential DC location *d* to the current multicast tree for content *c*

(2) The number of unrouted anycast demands whose closest path to any DC is that to *d* for content *c*, $a_{d,c}$

(3) The reduction (in number of hops) that can be achieved in rerouting back up paths if *d* is included in the solution for content *c*, $r_{d,c}$. Namely, when we choose a specific DC, we establish the primary paths of the unrouted anycast demands to that DC, and we set tentative backup paths to any other existing replicas. While the primary paths are assumed fixed, the backup paths can be modified in each step of there is a better path available with the addition of a new replica.

Each potential DC location is evaluated with a cost function: $C(d)= \alpha\, h_{d,c} + \beta/a_{d,c} +\gamma\, r_{d,c}$. We are testing different factors (α,β,γ) to tune the 3 aforementioned criteria to choose a new DC location in each step.

[1] A. Muhammad, N. Skorin-Kapov and M. Furdek, “Manycast, Anycast and Replica Placement (MARP) in Optical Inter-Datacenter Networks”, IEEE/OSA J. Opt. Commun. Netw., vol. 9, no. 12, Dec. 2017, pp 1161-1171.

[2] Marija Furdek, Ajmal Muhammad, Nina Skorin-Kapov,"Survivable Manycast, Anycast and Replica Placement in Optical Inter-Datacenter Networks", 19th International Conference on Transparent Optical Networks (Icton 2017), invited paper, Girona, Spain, July 2-6 2017

FUTURE COLLABORATIONS

The work is ongoing, as the heuristic is being implemented and tested as well as the potential extensions, so collaboration is expected to continue.

FORSEEN PUBLICATIONS/ARTICLES RESULTING FROM THE STSM:

If the results of the heuristic are favorable, we hope to publish a joint paper on the topic of survivable manycast, anycast and replica placement.