**5Growth RL RA Server**

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# Usage

The 5Growth Resource Layer (RL) Resource Allocation (RA) – 5Gr-RL RA - server deployment provides an enhanced version with respect to the Mobile Transport Platform (MTP) Placement Algorithm (PA) server designed and implemented in the context of the 5G-TRANSFORMER project. In a nutshell, the RL RA server handles a REST API server to receive, process and calculate networking inter-NfviPop paths. Such a calculation addresses macroscopically the following objectives:

1. Enabling the end-to-end network computation involving *n* WAN domains to derive required abstractions by the Logical Links (LL) that eventually are to be exposed to the overlayer 5Growth Service Orchestrator (5Gr-SO).
2. Enabling the WAN/s path computation to support the physical connectivity bound to a specific LL requested by the 5Gr-SO
3. Enabling the WAN restoration / re-computation of a bulk of inter-NfviPop connections affected by a detected network anomaly (e.g., link failure, link performance degradation, node failure, etc.)

The purpose of the 5Gr-RL RA is to provide a standalone process within the framework of the 5Gr-RL that allows lowering the computation burden of the 5Gr-RL. Additionally, it fosters a more modular 5Gr-RL implementation where several multi-objective RA algorithms can be deployed regardless of the 5Gr-RL core implementation.

In brief, the 5Gr-RL RA server provides two specific functions:

1. REST API server to process the incoming REST API requests (POST and PUT methods) sent by the core RL element (acting as REST API client)
2. Triggering and computing (if feasible) and end-to-end networking inter-NfviPop connection.

# Building

The 5GR-RL RA server is provided in C programming language using standard C libraries, glib-2.0 (<https://lazka.github.io/pgi-docs/GLib-2.0/index.html>) and the project cJSON (<https://github.com/DaveGamble/cJSON>)

Copy the source code (C and header files) to your local folder and/or project.

A Makefile is provided to compile the whole rl\_ra\_server project

Once copied, run ‘make’ command in the directory where the source is to compile and create the binary rl\_ra\_server

# Executing

Once the binary rl\_ra\_server is created, it can be triggered via ./rl\_ra\_server passing as argument the path for the configuration file (e.g., rl\_ra\_server.conf), the path used for the log file (e.g., rl\_ra\_server.log) and the option to “deamonize” the process (i.e., -d).

The rl\_ra\_server.conf and is read once the program is executed. As an example, the folder containing such file could be /etc/rl\_ra\_server/.

The rl\_ra\_server.conf file contains the IP address of the REST API server and a flag enabling the REST API. Example:

5GR\_RL\_RA\_SERVER\_IPAddr 10.1.1.1

REST\_API\_ENABLED 1

The log file may be found at the folder /var/log/rl\_ra\_server.log.

# REST API Server

The REST API server (implemented at the rl\_ra\_server.c) allows processing an incoming REST PA request (POST method) with JSON data format / encoding. The TCP port is 8081. For the sake of completeness, the REST API defines a pair of request (POST / PUT) and response (HTTP/1.1) messages. The processing of the request (POST/PUT method) entails that a selected RA algorithm using a specific identifier (*raId*) is selected and then triggered. At the time of writing two RA algorithms are available in the RL RA server:

* Class of Service Algorithm (*raId: CSA*)
* Infrastructure Abstraction Algorithm (*raId: CSA*)
* Global Concurrent Optimization (*raid: GCO*)

# CSA Algorithm

This algorithm (requested by the RL using a POST method) focuses on computing a set of unidirectional networking interconnections between pairs of NfviPops (determined by their attached WAN Provider Edge- PE - nodes, i.e., source and destination PEs -*srcPE* and *dstPE*-). This may be done over a single or multiple WAN domains retrieved by the 5Gr-RL from their controlled underlying WIMs. Specifically, the algorithm receives the REST API request containing the following input information besides the *raId*:

1. The *syncPaths* is a Boolean variable stating whether the set of requested WAN paths requires a synchronization among them. That is, the resources computed on a computed WAN path need to not be considered in subsequent WAN path computations.
2. The *requestList* is an array containing the set of required WAN path computations. The contents of this array are:
   1. The *requestId* specifies a unique identifier used to associate the WAN path computation provided in the REST API response message.
   2. The *interNfviPopConnectivityId* is a string determining the name of the inter-nfviPop connection for which a WAN path is being requested. The tuple formed by *requestId* and *interNfviPopConnectivityId* allows unambiguously determining the requested WAN path for each inter-nfviPop connectivity.
   3. The *srcPE* and *dstPE* nodeIds of the PE nodes physically attached to the Gw at the srcNfviPop and dstNfviPop, respectively.
   4. The connection service constraints: requested bandwidth (*bandwidthConsValue*) and maximum tolerated end-to-end delay (*delayConsValue*)
   5. The *kPaths* parameter is used to specify the maximum number (*k*) of different WAN paths to be computed by the algorithm for a specific inter-nfviPop connection request.
3. The set of all the interWanLinks (and their attributes in terms of nodeIds endpoints, link Ids, available bandwidth, cost, and delay). This information is kept at the 5Gr-RL core element.
4. The abstracted topology of all the WAN domains kept at the 5Gr-RL. The topology information provides the nodeIds and links (with their associated attributes) constituting each WAN domain

The CSA RA algorithm implementation is written in the C file rl\_ra\_server\_ra\_CSA.c. This algorithm executes a K Constrained Shortest Path First (K-CSPF) algorithm based on the Yen algorithm (see <https://en.wikipedia.org/wiki/Yen%27s_algorithm>). The algorithm computes up to *K* shortest paths aiming at accommodating each inte-nfviPop connection between the *srcPE* and *dstPE* nodeIds satisfying the imposed constraints (i.e., *bandwidthConsValue* and *delayConsValue*). The computed up to *k* paths are sorted according to the lowest path cost, available end-to-end bandwidth, and lowest end-to-end delay / latency. These criteria allow sorting the different WAN paths that can be computed.

The output of the CSA execution (if succeeds) for a given *interNfviPopConnectivityId* contains the selected path:

1. The resulting available bandwidth, path cost, and delay for the entire computed path (that may traverse several WAN domains).
2. An array containing the set of traversed interWanLinks (i.e., nodeIds and linkIds) being part of the computed end-to-end path.
3. An array per each traversed WAN domain specifying the computed intra-WAN path segments (i.e., nodeIds and linkIds)

# InA Algorithm

This algorithm (upon receiving the POST method request) focuses on computing the set of up to *k* unidirectional WAN paths for each pair of nfviPops within the infrastructure aiming at deriving the LLs that eventually are exposed to the 5Gr-SO. Likewise in CSA, this may encompass multiple WAN domains. The 5Gr-RL RA server triggering the InA algorithm receives the same information as in the CSA but without specifying neither *bandwidthConsValue* nor *delayConsValue*. Indeed, both values are set to 0. The reason behind this is the InA seeks for the *k* WAN paths providing the highest performance (i.e., higher available bandwidth, lowest traversed number of hops and shortest delay) for deriving the required LLs between pairs of nfviPops. It is worth outlining that for a single request-response interaction between the 5Gr-RL and 5Gr-RL RA server, the InA can compute the WAN paths for all the LLs required to provide the connectivity for any nfviPop pair.

The output of the InA algorithm for each requested *interNfviPopConnectivityId* contains the selected path:

1. The resulting available bandwidth, path cost, and delay for the entire computed path (that may traverse several WAN domains)
2. An array containing the set of traversed interWanLinks (i.e., nodeIds and linkIds) being part of the computed end-to-end path
3. An array per each traversed WAN domain specifying the computed intra-WAN path segments (i.e., nodeIds and linkIds)

# GCO Algorithm

GCO is triggered after receiving a PUT method from the 5Gr-RL requesting the re-computation and/or recalculation of a set of established inter-NfviPop WAN connections affected by a network anomaly (e.g., link failure) detected and correlated at the 5Gr-RL core process. Thus, at the RA server upon receiving such a request, for each of the received connections, the algorithm seeks for a feasible WAN path ensuring the individual inter-NfviPop connection requirements (i.e., *bandwidthConsValue* nor *delayConsValue*) avoiding the specific network anomaly. For the latter, this entails removing from the resulting WAN graph the network anomaly (e.g., node failure or link failure). The algorithm is designed to boost the successful recalculation of all (most of) the received inter-NfviPop connections searching through broad solution space that eventually leads to attain the most efficient use of the network resources. To this end, the algorithm iterates to create multiple solutions where the received ordering of the received inter-NfviPops connections is randomized. For each explored solution, it is triggered a K Shortest Path computation. From the set of explored solutions, the algorithm selects the one achieving (in a prioritized order): i) the largest amount of successfully re-computed connections; ii) the lowest amount of required WAN resources (e.g., link bandwidth) for those successfully recomputed inter-NfviPop connections.

For the final selected solution, the output of the GCO algorithm determines for each requested interNfviPop connection:

1. If the GCO failed, it is notified as a Path Issue.
2. If the GCO found a feasible WAN Path, it is provided:
   1. An array containing the set of traversed interWanLinks (i.e., nodeIds and linkIds) being part of the computed end-to-end path.

# Example

The following illustrates an example to execute and validate the functionalities of the implemented rl\_ra\_server. To do so, it is presented the request and response to the InA algorithm-

Once the rl\_ra\_server is up and running, it waits for incoming REST API requests that are sent by the 5Gr-RL core REST API client. In this example, the 5Gr-RL core REST API request is emulated using the *curl* tool. An example of a REST API request using curl is:

curl -X POST -H "Expect:" -H "Content-Type: application/json" http:// IPAddressRESTAPIServer:8081/compRoute -d ' {

"raId":"InA", "syncPaths": false,

"requestList":

[

{

"requestId":1, "interNfviPopConnectivityId": "connectivity1", "srcPEId":"00.00.00.00.00.00.11.01", "dstPEId":"00.00.00.00.00.00.11.02",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

},

{

"requestId":2, "interNfviPopConnectivityId": "connectivity2", "srcPEId":"00.00.00.00.00.00.11.01", "dstPEId":"00.00.00.00.00.00.11.03",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

},

{

"requestId":3, "interNfviPopConnectivityId": "connectivity3", "srcPEId":"00.00.00.00.00.00.11.01", "dstPEId":"00.00.00.00.00.00.11.04",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

},

{

"requestId":4, "interNfviPopConnectivityId": "connectivity4", "srcPEId":"00.00.00.00.00.00.11.02", "dstPEId":"00.00.00.00.00.00.11.01",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

},

{

"requestId":5, "interNfviPopConnectivityId": "connectivity5", "srcPEId":"00.00.00.00.00.00.11.02", "dstPEId":"00.00.00.00.00.00.11.03",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

},

{

"requestId":6, "interNfviPopConnectivityId": "connectivity6", "srcPEId":"00.00.00.00.00.00.11.02", "dstPEId":"00.00.00.00.00.00.11.04",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

},

{

"requestId":7, "interNfviPopConnectivityId": "connectivity7", "srcPEId":"00.00.00.00.00.00.11.03", "dstPEId":"00.00.00.00.00.00.11.01",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

},

{

"requestId":8, "interNfviPopConnectivityId": "connectivity8", "srcPEId":"00.00.00.00.00.00.11.03", "dstPEId":"00.00.00.00.00.00.11.02",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

},

{

"requestId":9, "interNfviPopConnectivityId": "connectivity9", "srcPEId":"00.00.00.00.00.00.11.03", "dstPEId":"00.00.00.00.00.00.11.04",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

},

{

"requestId":10, "interNfviPopConnectivityId": "connectivity10", "srcPEId":"00.00.00.00.00.00.11.04", "dstPEId":"00.00.00.00.00.00.11.01",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

},

{

"requestId":11, "interNfviPopConnectivityId": "connectivity11", "srcPEId":"00.00.00.00.00.00.11.04", "dstPEId":"00.00.00.00.00.00.11.02",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

},

{

"requestId":12, "interNfviPopConnectivityId": "connectivity12", "srcPEId":"00.00.00.00.00.00.11.04", "dstPEId":"00.00.00.00.00.00.11.03",

"kPaths":3, "qosCons": {"bandwidthCons":"bandwidthCons", "bandwidthConsValue":0, "delayCons":"delayCons", "delayConsValue":0}

}

],

"absWanTopo":

[

{

"wimId":"WIM\_Spain",

"nodes":

[

{"nodeId":"00.00.00.00.00.00.11.01"}, {"nodeId":"00.00.00.00.00.00.11.02"}, {"nodeId":"00.00.00.00.00.00.11.03"}, {"nodeId":"00.00.00.00.00.00.11.04"},

{"nodeId":"00.00.00.00.00.00.11.05"}, {"nodeId":"00.00.00.00.00.00.11.06"}, {"nodeId":"00.00.00.00.00.00.11.07"}, {"nodeId":"00.00.00.00.00.00.11.08"},

{"nodeId":"00.00.00.00.00.00.11.09"}, {"nodeId":"00.00.00.00.00.00.11.0A"}, {"nodeId":"00.00.00.00.00.00.11.0B"}, {"nodeId":"00.00.00.00.00.00.11.0C"},

{"nodeId":"00.00.00.00.00.00.11.0D"}, {"nodeId":"00.00.00.00.00.00.11.0E"}

],

"edges":

[

{

"aNodeId":"00.00.00.00.00.00.11.01", "zNodeId":"00.00.00.00.00.00.11.0D", "aLinkId":113, "zLinkId":131,

"netwLinkQoS": {"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.45, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.0D", "zNodeId":"00.00.00.00.00.00.11.01", "aLinkId":131, "zLinkId":81,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.45, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.01", "zNodeId":"00.00.00.00.00.00.11.08", "aLinkId":18, "zLinkId":131,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.8, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.08", "zNodeId":"00.00.00.00.00.00.11.01", "aLinkId":18, "zLinkId":131,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.8, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

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"aNodeId":"00.00.00.00.00.00.11.0D", "zNodeId":"00.00.00.00.00.00.11.0E", "aLinkId":1314, "zLinkId":1413,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.8, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.0E", "zNodeId":"00.00.00.00.00.00.11.0D", "aLinkId":1413, "zLinkId":1314,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.8, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.0E", "zNodeId":"00.00.00.00.00.00.11.07", "aLinkId":147, "zLinkId":714,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":0.8, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.07", "zNodeId":"00.00.00.00.00.00.11.0E", "aLinkId":714, "zLinkId":147,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":0.8, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.0E", "zNodeId":"00.00.00.00.00.00.11.05", "aLinkId":145, "zLinkId":514,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":0.8, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.05", "zNodeId":"00.00.00.00.00.00.11.0E", "aLinkId":514, "zLinkId":145,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":0.8, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.0E", "zNodeId":"00.00.00.00.00.00.11.02", "aLinkId":142, "zLinkId":214,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":2.95, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.02", "zNodeId":"00.00.00.00.00.00.11.0E", "aLinkId":214, "zLinkId":142,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":2.95, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.02", "zNodeId":"00.00.00.00.00.00.11.05", "aLinkId":25, "zLinkId":52,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.5, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.05", "zNodeId":"00.00.00.00.00.00.11.02", "aLinkId":52, "zLinkId":25,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.5, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.06", "zNodeId":"00.00.00.00.00.00.11.02", "aLinkId":62, "zLinkId":26,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.75, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.02", "zNodeId":"00.00.00.00.00.00.11.06", "aLinkId":26, "zLinkId":62,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.75, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.04", "zNodeId":"00.00.00.00.00.00.11.05", "aLinkId":45, "zLinkId":54,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.55, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.05", "zNodeId":"00.00.00.00.00.00.11.04", "aLinkId":54, "zLinkId":45,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.55, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.04", "zNodeId":"00.00.00.00.00.00.11.07", "aLinkId":47, "zLinkId":74,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.2, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.07", "zNodeId":"00.00.00.00.00.00.11.04", "aLinkId":74, "zLinkId":47,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.2, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.07", "zNodeId":"00.00.00.00.00.00.11.08", "aLinkId":78, "zLinkId":87,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.1, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.08", "zNodeId":"00.00.00.00.00.00.11.07", "aLinkId":87, "zLinkId":78,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.1, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.08", "zNodeId":"00.00.00.00.00.00.11.09", "aLinkId":89, "zLinkId":98,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.7, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.09", "zNodeId":"00.00.00.00.00.00.11.08", "aLinkId":98, "zLinkId":89,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.7, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

},

{

"aNodeId":"00.00.00.00.00.00.11.09", "zNodeId":"00.00.00.00.00.00.11.04", "aLinkId":94, "zLinkId":49,

"netwLinkQoS":{"linkCost":"linkCost", "linkCostValue":10, "linkDelay":"linkDelay", "linkDelayValue":1.7, "linkAvailBw":"linkAvailBw", "linkAvailBwValue":1000000000},

"networkLayer":"psc"

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]

}

]

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The above REST API POST request is demanding to the rl\_ra\_server (at IPAddressRESTAPIServer) the abstraction WAN computation among all the potential nfviPop pars within an infrastructure containing 4 nfviPops as shown below.



There is a single WAN domain. Thus no inter-WAN links are defined. For each unidirectional link intra-WAN link, it is specified the link attributes in terms of linkCost, linkAvailBw and linkDelay. These attributes are used by the K-CSPF (being *k* set to 3) of InA algorithm to derive up to *k* WAN path for each nfviPop pair. The computed paths for all the interNfviPop connections are returned to the 5Gr-RL. Part of contents (JSON encoded) of the response representing the computed paths are:

