EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA15127
STSM title: Identification of Vulnerable Regions in Networks Embedded in Planes and Spheres
STSM start and end date: 07/01/2018 to 13/01/2018
Grantee name: Balázs Vass

PURPOSE OF THE STSM:

Though there is a wide range of strategies and techniques used for improving the survivability of carrier networks in case of large-scale natural disasters, papers consider networks to be embedded in a plane. This STSM aims to show that despite that some of the theories made for planar case are not holding on sphere, the behaviour of spherical networks is similar to the planar ones.

Large-scale natural disasters (such as earthquakes, tornadoes, tsunamis, etc.) are becoming more severe and frequent than they were in the past. The vast majority of the papers taking in count the geographical information of backbone networks simply consider them to be planar, even if they are spreading out on a whole continent. Despite that eliminating this assumption may result in failing theories in case of our real world networks (because the Earth is much more like a sphere than a plane) we aim to show that there is no significant difference between the outputs of Algorithms to enumerate Vulnerable Regions of Network Topologies embedded in either planes or spheres (which fits in tentative RECODIS book Chapter 1.4). To the best of our knowledge, there are no similar comparisons available yet.

Purposes of this STSM were:
(i) joint preparation of RECODIS book Chapter 1.4,
(ii) submission of a conference paper during the first semester of 2018

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS

As the STSM was relatively short, after setting up the precise goals, a significant part of the real work is being carried out after my visit.

The work was partially concentrating on creating a classification of the available results. Now we concentrated on results investigating on enumerating maximal link sets covered by circular disks with bounded size (i.e. the failed areas are overestimated by disks, and this way the set of failed links will be part of a potentially bigger listed link set) as Shared Risk Link Group (SRLG) lists.

The most natural way to measure the disks' size is to measure their radius, but it also makes sense also to count the number of nodes or edges they hit. For easier expression and taking in count that tentative Chapter 1.4: Algorithmic approaches to enumerate Vulnerable Regions of Network Topologies (WG1) of RECODIS book has to be able to systematize the works done so far) we think it would be a good idea to define some names for different SRLG lists, such as:

- maximal r -range SRLG list: list of maximal link sets which can be hit by a disk with radius at most r .
- maximal k -node SRLG list: list of maximal link sets which can be hit by a disk hitting at most k nodes.
- maximal k -link SRLG list: list of maximal link sets which can be hit by a disk hitting at most k links.
- Lists as maximal r -range k -node SRLG list, r -range odd-node SRLG list, etc. can be easily defined.

For the simplest setting, when the network G(V, E) is embedded in the plane and edges are considered as line segments between their endpoints, there are papers available showing that all three of maximal r -range[i], k -node[ii] and k -link SRLG list[iii] are relatively short (linear in |V|) and can be computed in low polynomial time (of |V|) for real networks.

Changing the geometrical embedding from plane to sphere causes many of the proofs of theoretical upper bounds to fail. We bet similar theoretical bounds could be proven. Instead, our main effort is on simulations. We expect simulations will show results similar to the results on planar embeddings. Regarding on the naming, we can distinguish between the planar and spherical cases by simply putting the words 'planar' or 'spherical' in the names of the lists, e.g. maximal spherical r -range SRLG list.

We also investigated on some refinements on the framework of SRLGs.

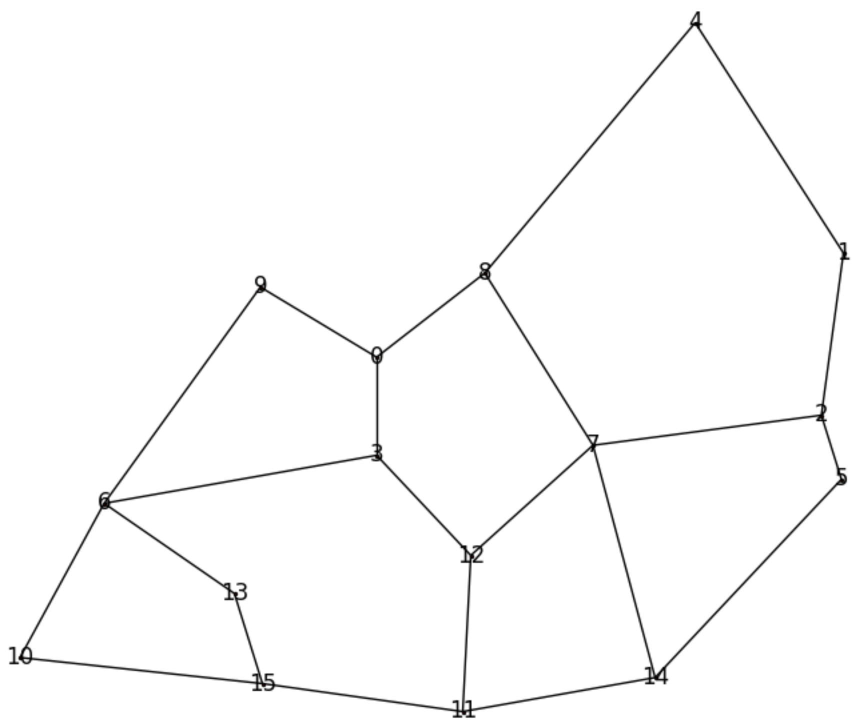
We started to implement a framework flexible enough to easily adopt approaches mentioned before. Investigated network data now is obtained from http://www.topology-zoo.org/dataset.html (where wierdly we have to transform the spherical coordinates to planar ones if we want to compare planar results to real-world situation). The programming language used is Python3.

Regarding to theoretical upper bounds on spheres, we have started to translate some of the proofs for planar case.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

As we aim to submit of a conference paper during the first semester of 2018, I wanted to make a profound work with as few bugs as possible, thus we do not have those fancy results yet what we intend to achieve until this point. However, I am proud to present some of the partial results obtained during developing my code which hopefully will deal with not only planar, but also with spherical topology embeddings too.

Let us take an example topology in the plane:



At this moment my code is able to generate the maximal planar k-link and k-node lists for all meaningful k values and the maximal planar r-range lists for various r values. An example output (the 0-node list of the network i.e. the maximal link sets which can be hit by a disk not hitting any node) would be the following:

@nodes

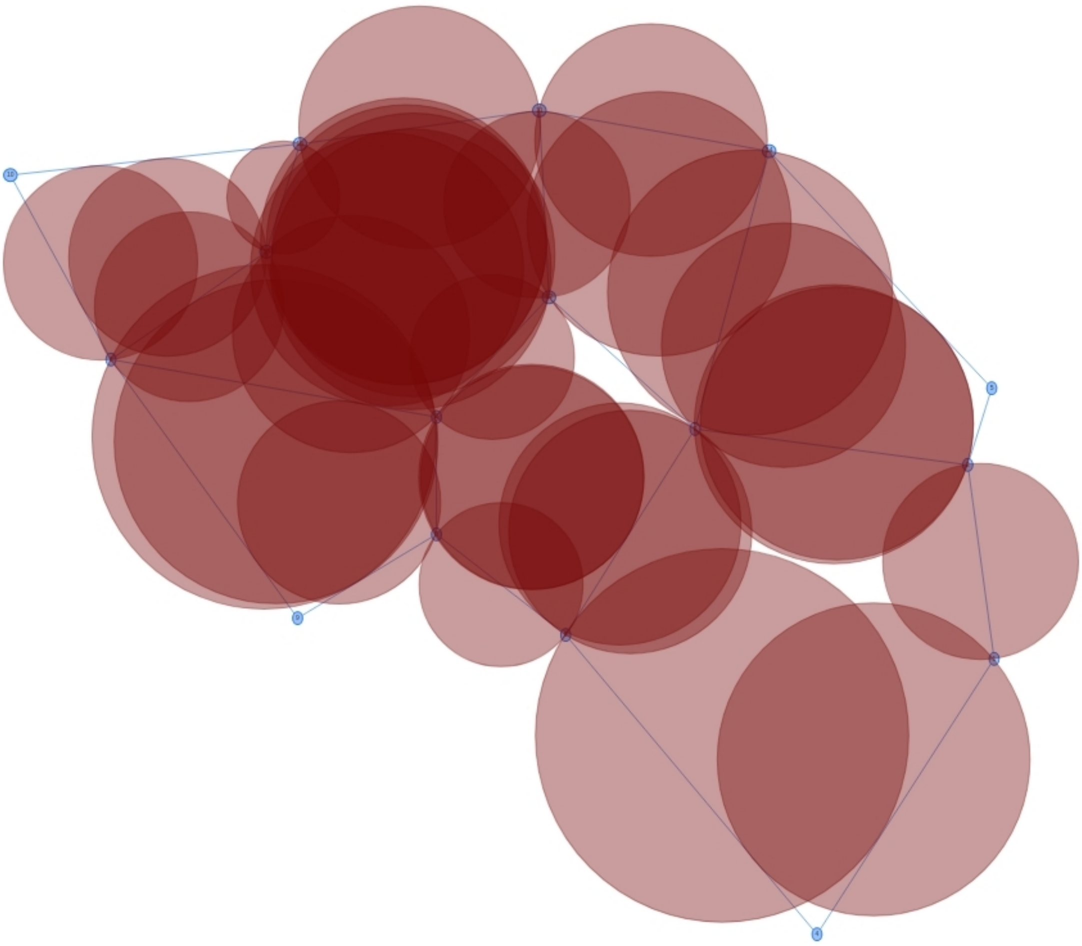
label	coords
0	(1698,1296)
1	(2397,1452)
2	(2364,1209)
3	(1698,1149)
4	(2175,1797)
5	(2394,1113)
6	(1290,1077)
7	(2022,1164)
8	(1860,1422)
9	(1524,1401)
10	(1164,846)
11	(1827,765)
12	(1839,999)
13	(1485,942)
14	(2115,816)
15	(1527,807)

@edges

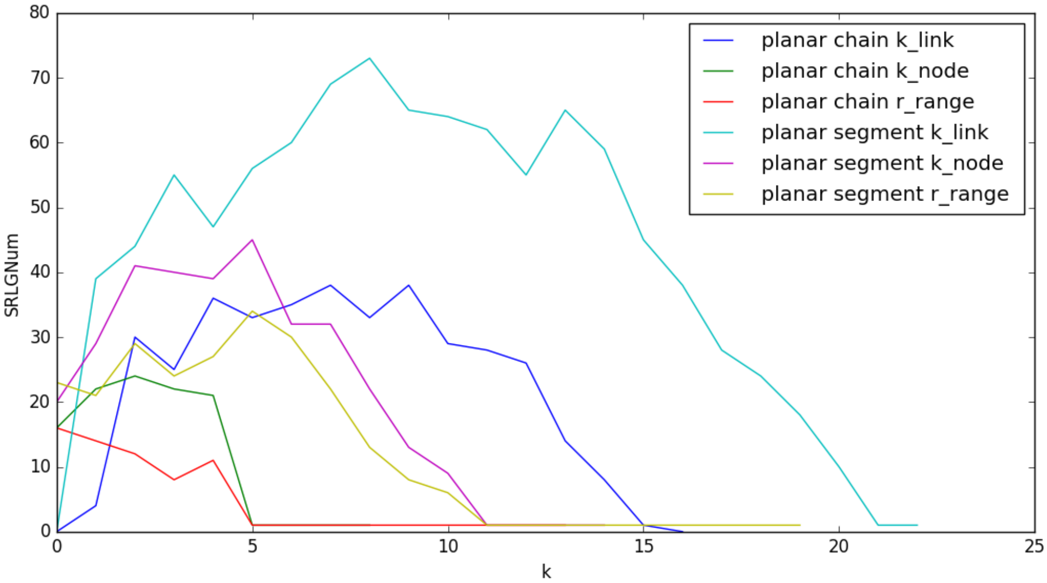
		label
0	8	0
0	9	1
0	3	2
1	2	3
1	4	4
2	5	5
2	7	6
3	12	7
3	6	8
4	8	9
5	14	10
6	9	11
6	10	12
6	13	13
7	8	14
7	12	15
7	14	16
10	15	17
11	12	18
11	14	19

```
11          15          20
13          15          21
@srlgs
17 12 20 21 13
11 12 8 13
21 13 11 8
1 13 11 8
1 2 7 8
20 18 19
1 9
1 11 2
1 2 0
0 14 9
7 2 0 14 8
10 16 18 19
15 7 16 18
15 16 14
15 14 6
6 16 14
6 16 5 10 3
14 4 9
3 4 9
10 15 16 6 19
```

The results are exported nearly in .lgf format. The only extension is that in the last part, SRLGS are encoded by listing the labels of the edges they contain. A visualization of the former SRLG list (not perfect yet):



One among the statistics which are interesting is the total number of SRLGs in each proposed list:

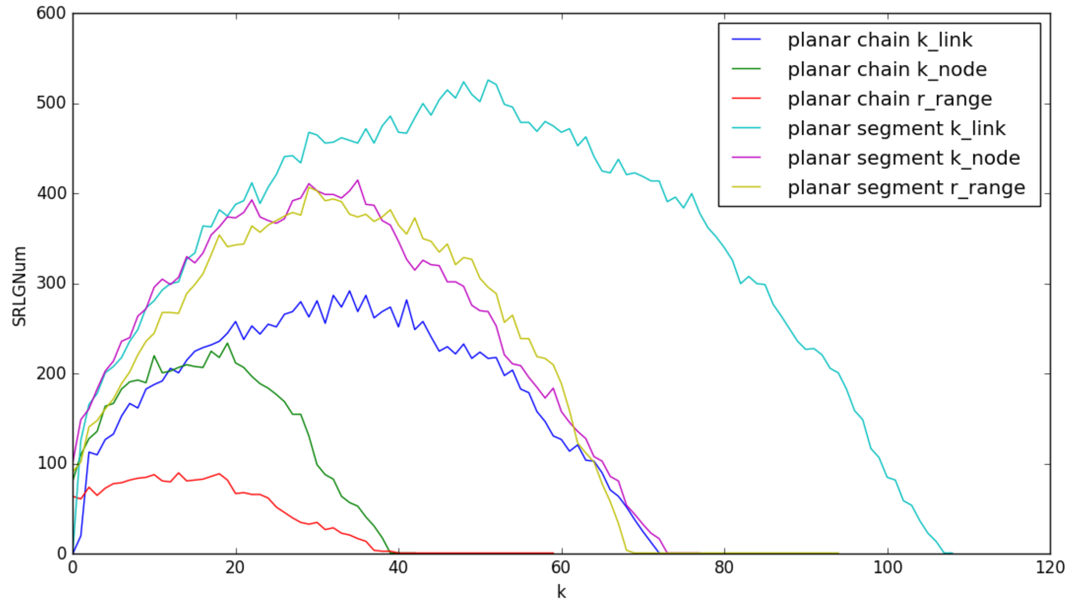


Here we obtained polygonal chain links by simply merging links incident to every node with degree 2.

Other interesting measures are also calculated and exported:


```
▼<simulator>
  ▶<ABranch>...</ABranch>
  ▶<ABranch>...</ABranch>
  ▼<ABranch>
     <UniqueBranchCode>planar segment k_node</UniqueBranchCode>
     <Geometry>planar</Geometry>
     <LinkType>segment</LinkType>
     <SRLGListType>k_node</SRLGListType>
     <NetName>16_optic_pan_eu_scaled_.gml</NetName>
     <NodeNum>16</NodeNum>
     <LinkNum>22</LinkNum>
     <AvgNodalDegree>2.75</AvgNodalDegree>
     <MaxNodalDegree>4</MaxNodalDegree>
     <Fineness>10</Fineness>
     <ProcessingTime>27.716124057769775</ProcessingTime>
   ▼<Measure>
       <k>0</k>
       <SRLGNum>20</SRLGNum>
       <Rho>5</Rho>
       <AvgSRLGLength>3.65</AvgSRLGLength>
       <MinSRLGLength>2</MinSRLGLength>
       <VarianceOfSRLGLength>0.7275</VarianceOfSRLGLength>
     </Measure>
   ▼<Measure>
       <k>1</k>
       <SRLGNum>29</SRLGNum>
       <Rho>7</Rho>
       <AvgSRLGLength>5.275862068965517</AvgSRLGLength>
       <MinSRLGLength>4</MinSRLGLength>
       <VarianceOfSRLGLength>0.544589774078</VarianceOfSRLGLength>
     </Measure>
   ▼<Measure>
       <k>2</k>
       <SRLGNum>41</SRLGNum>
       <Rho>9</Rho>
       <AvgSRLGLength>6.829268292682927</AvgSRLGLength>
       <MinSRLGLength>6</MinSRLGLength>
       <VarianceOfSRLGLength>0.775728732897</VarianceOfSRLGLength>
     </Measure>
   ▼<Measure>
       <k>3</k>
       <SRLGNum>40</SRLGNum>
       <Rho>11</Rho>
```


Of course, the implementation can deal with much larger networks with up to several hundred nodes at the moment. Here is a plot similar to the latest included of the results on a network with 79 nodes:



Besides of the work of my host Martin Zachariasen I want to emphasize my aknowledgement of my advisor János Tapolcai who supported me contiuously.

As a concrete result up to this point we can say that the number of SRLGs in any setting of the circular disk failure model is going to be suprisingly small, almost linear in network size.

FUTURE COLLABORATIONS (if applicable)

-

Currently we are working on finalizing the code, and on the other hand we are planning to investigate sufficiently the theories for presenting upper bounds for the size and computation time of the formerly proposed SRLG lists for topologies embedded in spherical geometry.

I think we may be able to submit a conference paper with the results of this work by the end of March this year, and also we can continue our work in this field.

While this work has some new aims, I believe it will syntesize the former results, which is in the end a step towards a strong COST RECODIS book Chapter 1.4.: Algorithmic approaches to enumerate Vulnerable Regions of Network Topologies.

Bibliography

i J. Tapolcai, L. Rónyai, B. Vass, and L. Gyimóthi, “List of shared risk link groups representing regional failures with limited size,” in Proc. IEEE INFOCOM, Atlanta, USA, may 2017. [Online]. Available: http://lendulet.tmit.bme.hu/lendulet_website/wp-content/papercite-data/pdf/tapolcai2016srlg.pdf

ii B. Vass, E. Bérczi-Kovács, and J. Tapolcai, “Enumerating shared risk link groups of circular disk failures hitting k nodes,” in Proc. International Workshop on Design Of Reliable Communication Networks (DRCN), Munich, Germany, march 2017. [Online]. Available: http://lendulet.tmit.bme.hu/lendulet_website/wp-content/papercite-data/pdf/vass2017drcn.pdf

iii E. Papadopoulou and M. Zavershynskyi, “The higher-order Voronoi diagram of line segments,” Algorithmica, vol. 74, no. 1, pp. 415–439, 2016.