The outlook of future work
Network Robustness In The Near Space Airship Deployment Optimization

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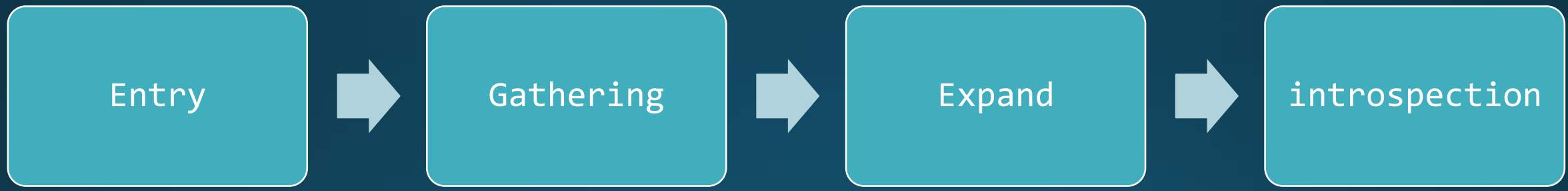
Where to start?



In Progress

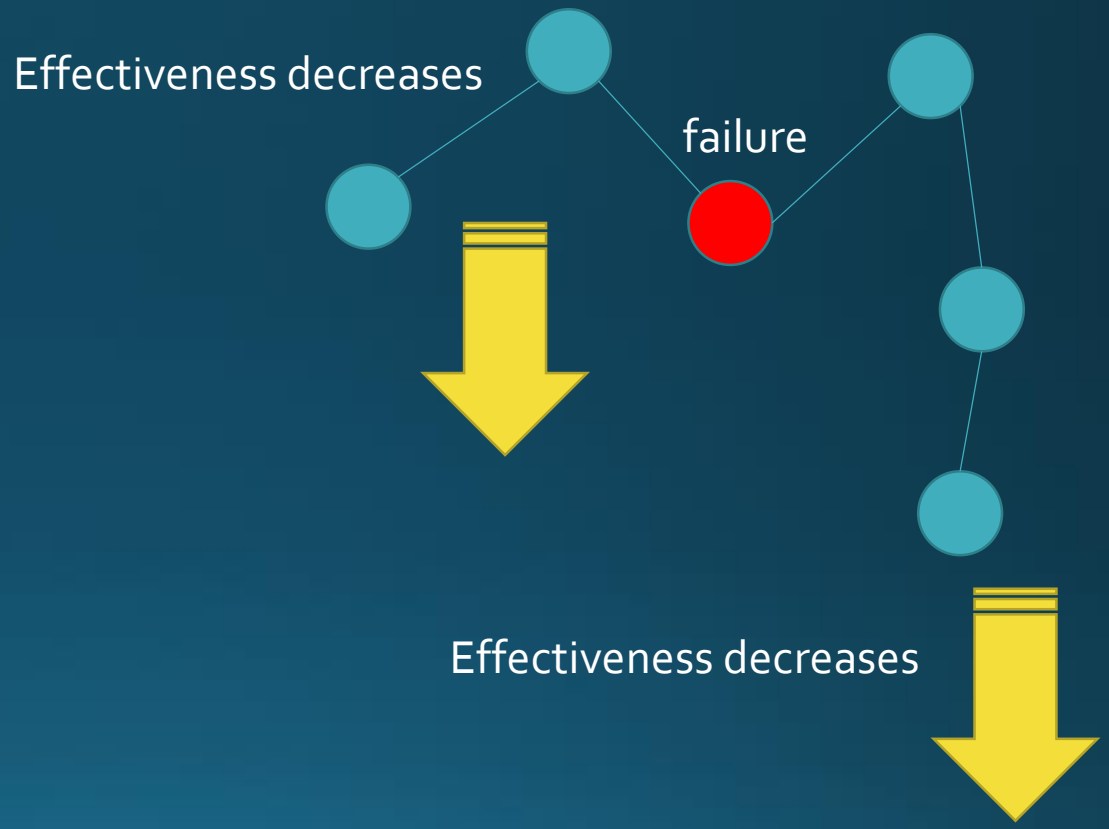
Revise some details:

- Constraints handling mechanism in the evolution process
- Initialization scheme utilizing user information
- Distinguish different type of users
- Constraints handling
- Problem related assignment: initial and in evolution process population
- Termination criterion

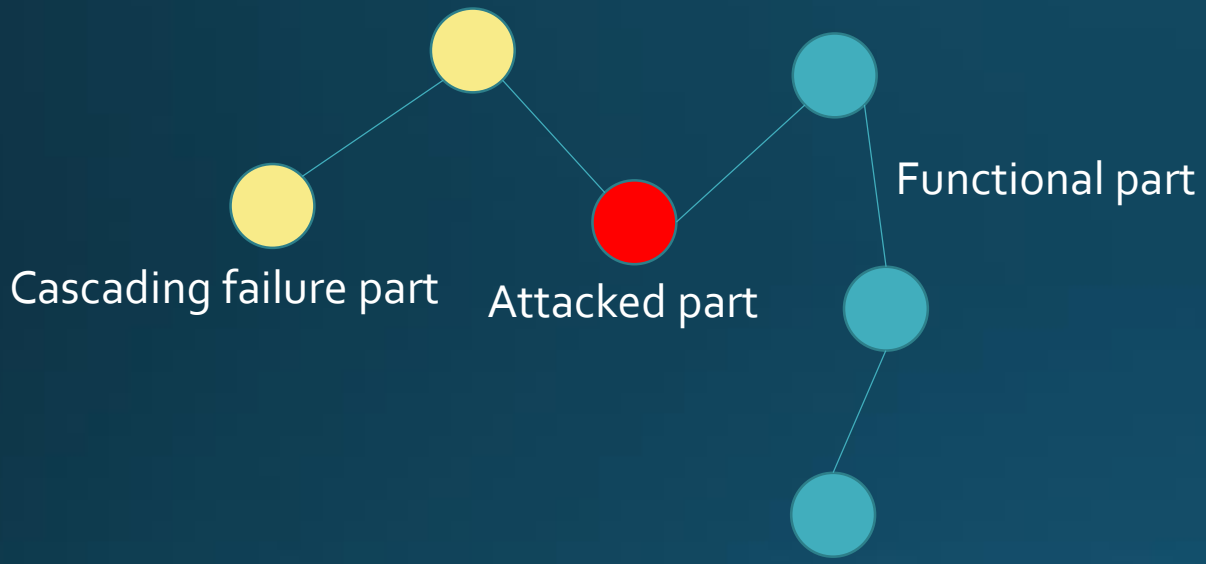
Future Work

Network Robustness In The Near Space Airship Deployment Optimization

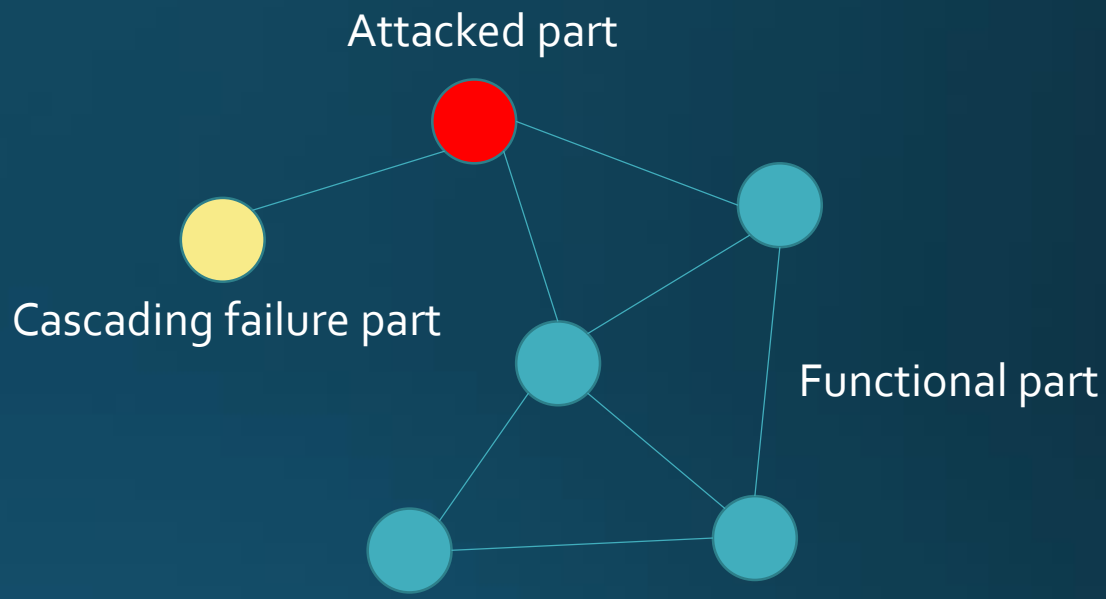
Because of all kinds of emergencies, attack, maintenance, disaster or system failure, part of the Near Space Airship network will shut down, which will deteriorate the whole performance of the system.
The remaining performance of the Near Space Airship network depends on its robustness.
The problem is to find the most robust deployment with the same performance.
We need to deal with the different robustness issues in and between specific regions.



Fragile and Robust network



Fragile deployment



Robust deployment

Targeted attacks will paralyze the influential or critical nodes which will cause small fraction of network. The small fraction of remaining network is of low performance

Due to the large degree of the network, the remaining fraction of the network is larger than the fragile network in performance.

Robustness Measurement

There are many robustness measures:

- Percolation threshold
- Shortest path
- Graph spectrum
- Cumulated maximal fraction

The robustness of a network is: $$R = \frac{1}{N}\sum_{Q=1}^{N} s(Q)$$

Where:

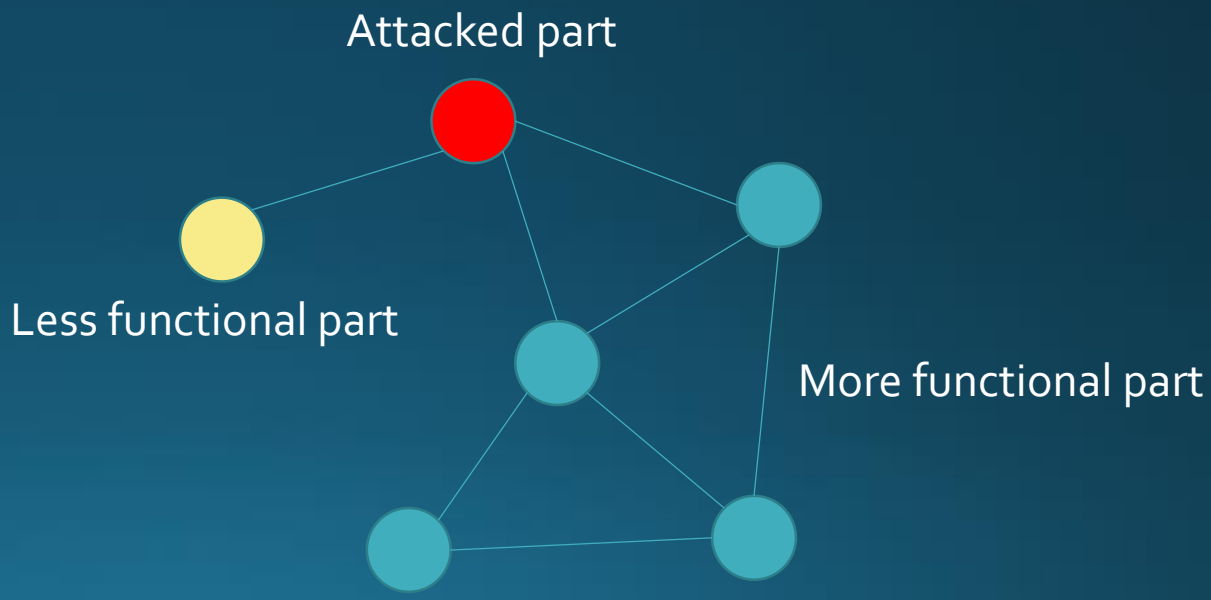
- N is the number of nodes in the network
- $Q = qN$, is the number of nodes being removed
- q is the fraction of nodes being attacked
- $s(Q)$ is the fraction of nodes in the largest connected cluster after removing Q nodes

Schneider, C. M., Moreira, A. A., Andrade, J. S., Shlomo, H., & Herrmann, H. J. (2011). Mitigation of malicious attacks on networks.. Proceedings of the National Academy of Sciences of the United States of America

The reason why CMF

- Low computation cost and more intuitive
- Consider the largest part during the malicious attack, which measures the robustness more accurate in all situations
- Suitable for measuring the robustness of the Near Space Airship network.

The Near Space Airship network or other networks have the feature that makes the CMF measure make sense.
Any part of the network has an effect on the other parts of the network, because both of them have the resource that the other part needs. The attacks do not paralyze the nodes that are not attacked. The small part of the network is less functional and the larger part is more function. The performance of the largest part is also damaged because of the shrink of the network size, but the performance of the network depends on the largest part mostly.

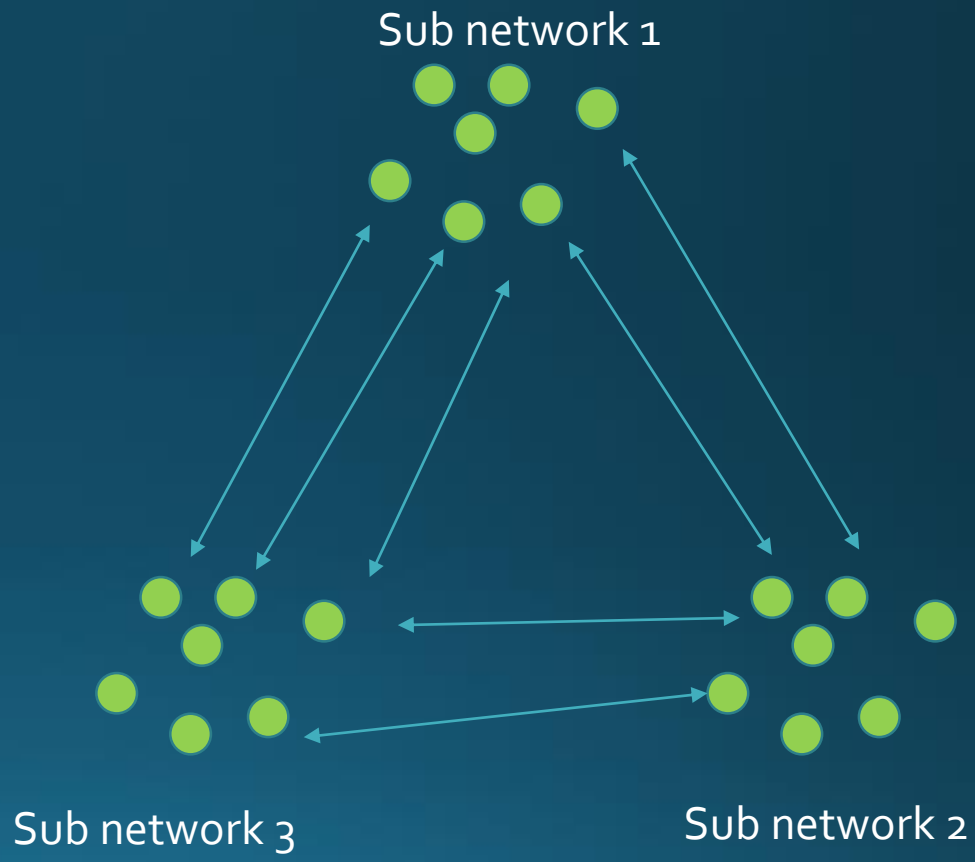


Robustness Optimization In Deployment

- Combine robustness measure process as part of the reproduction of the new individual. The algorithm intends to search areas which might increase the robustness of the individuals.
- Have the robustness serves as an objective function in the optimization process

Robustness Optimization In Coupled networks

- The coupled networks is a whole system entity that consists of a set of associated networks through specific physical relations. Each network has its own relations. Some nodes in one network connect some other nodes in another networks. Because of the connections between sub networks, the robustness of the whole system is associated with each sub networks and their relations.
- The attack on one sub network might cause the cascade failure of the other sub networks.
- Due to the large scale of the Near Space Airship system, most of the airships will gather around the hotspots which will form a set of sub networks
- The attack on one sub airship group will not only decrease the performance of the other sub networks but also decrease the performance of the whole system



Robustness Measurement In Coupled Networks

A pair of sub networks

$$R_{rc} = \frac{1}{N} \sum_{p=1/N}^{1} [p \times (S_1)^r \times (S_2)^{1-r}]$$

Where:

- N is the number of nodes in the whole system
- p is the fraction of nodes in the network recovered
- S_1 or S_2 is the ratio of nodes in the largest connected part of the recovered sub network
- r is the mixing parameter

Gong, M., Ma, L., Cai, Q., & Jiao, L. (2015). Enhancing robustness of coupled networks under targeted recoveries.. *Scientific Reports*

Robustness Measurement In Coupled Networks

For more sub networks:

$$R_{rc} = \frac{1}{N} \sum_{p=1/N}^{1} [p \times (S_1)^{r1} \times (S_2)^{r2} \times (S_3)^{r3} \times \cdots \times (S_n)^{rn}]$$

Where

$$r1 + r2 + \cdots + rn = 1$$

Coupled Networks Robustness Optimization In Deployment

- Using multi population technique for the deployment optimization
- Assess the robustness of each sub network as before and utilize it in the evolution process of each sub network
- Assess the robustness of the whole system using the above equation and utilize the robustness to optimize the connection between the sub networks