Identifying Influential nodes in complex networks to enhance their robustness

1 Background

Communication and online social networks are playing a pivotal role in our daily social and professional life. The last two decades has witnessed the birth of a new multidisciplinary field of science called Network Science, which attempts to find the universal patterns that exist among various types of natural and human-made phenomena. Many real-world systems can be represented as complex networked systems with examples including the Internet, WWW including online pervasive social networking site, and critical infrastructures (e.g., telecommunication, power grids, transportation). Network science develops frameworks, tools and techniques to overcome the challenges such as network security, control and the robustness against the failure or attack in these critical networks (Babaei, et al, 2011; Perc, 2009; Jalili & Perc, 2017).

The Capability Systems Centre (CSC) is exploring the possibility of collaboration with researchers with expertise in network science and analysis to addressing issues such as predicting network robustness and dynamics and the influential nodes during these processes. We are particularly interested in developing new algorithms to determine the nodes who have influential affect on the dynamics of network structure and robustness of networks. CSC calls for EOIs from interested researchers with the suitable background and expertise to tackle the following work package.

2 Work package overview

Network structure, the way all entities (e.g., humans, sensors, devices) in a network are connected, stands as one of the main characteristics of networks that has been studied intensively by researchers in different fields. Different forms of network structures and positions may suggest either benefits or restrictions for the actors entities in the network (Burt 1980; Ahuja, Soda et al. 2012; Zaheer & Soda, 2009). Identifying how the network structure changes and evolves and also determining the drivers of these changes are fundamental issues which are not well understood (Abbasi, Hossain et al. 2012, Ahuja, Soda et al. 2012).

A research direction in the CSC is to enhance systems robustness and resilience by developing advanced tools and techniques predicting network dynamics and its effect on network robustness. Robustness of networks against random failures of entities or their connections and/or systematic attacks to these elements is very crucial in Defence critical networks as in many other real-world networks such as communication networks and social networks. It has been frequently shown that many real-world networks are fragile against intentional attacks to their critical components. Also, some network structures show amazing capabilities in fast dissemination of information of any kind such as virus or rumour (Schilling and Fang, 2014).

The purpose of this work package is to enhance nation security and resilience by: a) Identifying the important factors affecting dynamic of critical networks; b) developing novel tools and methods to identify the strategic structural positions of entities in critical networks; and c) test and verify the effectiveness of the proposed network models or algorithms.

2.1 Scope

The dynamic behaviour of networks largely depends on their structural properties. To identify influential actors, it is vital to develop and validate network topological measures that would be useful proxies for predicting the link formation behaviour of the entities, and consequently dynamics of and on the network. This is important for decision makers to control the way networks expand and to envisage and manage the dynamics of networks and also local clusters or communities of entities as

sub-networks (Abbasi, 2016; Newman, Barabasi, & Watts, 2011). This project will be organised in the following phases:

1) Identifying features of entities that affect their link formation. The goal is to investigate entities' link formation mechanisms during the evolution of networks. This helps to understand which attachment logic is the best driver of evolution in real networks. In this phase, new hybrid measures will be developed. The developed measures will be tested against a number of sample Defence related networks (e.g., communication network, land network).

2) Developing a new model and measures for network evolution. In this phase, we extend the existing models considering advanced features identified in the previous phase. Our approach would be an extension of the preferential attachment model by considering more relevant nodal features for the probability of tipping the newly added nodes to the old nodes. The proposed model will have better fit to the real-world phenomena than the traditional algorithms.

3) Testing and verifying the proposed network model. We will use appropriate tools such as Matlab and R packages to code and create sample simulated networks to test the developed model and compare the results with the real datasets.

2.2 Focus

Recognizing the strategic structural positions of entities in critical networks is beneficial for the Defence to identify and control the influential entities. The outcomes of this research can be applied in different types of networks such as social networks, computer networks, or disease outbreak networks, and therefore can improve the community's resilience towards terrorism and diseases outbreak.

One of the very innovative aspects of this research proposal is to develop new complex measures and to extend the exiting hybrid metrics by Abbasi (2013) or others, which can better reflect the structural attributes of the actors which drives their link formation behaviour during the evolution of networks. Another contribution of the proposal will be to apply the new hybrid measures to develop a new model for network evolution.

In this study, we aim to extend the existing approaches by developing a new models and/or algorithms for network dynamics and to address robustness challenges in complex networks.

Milestones and Deliverables

Milestone #	Milestone description	Date
1	Initial workshop to establish working arrangements, further define the problem and to clarify any questions or issues.	Within two weeks of commencement of agreement.
2	Literature review and analysis of past studies on 'network dynamics' and 'models for network evolution'. The analysis should categorised the existing approaches and point to any limitations in the employed research designs, and their implications for future research.	
3	Propose a new novel effective model for network dynamics and network robustness against failures or attack to the nodes or links.	
Deliverable 1: Joint paper with CSC staff covering Milestones 1-3 to be submitted to relevant conference or a journal (TBD)		
5	Develop and use a series of case study vignettes to validate and illustrate the application of the proposed models / algorithms in practice. This step should result in	

	implementation and technical considerations involved in real large-scale networks.	
Deliverable: Joint paper with CSC staff covering Milestones 1-4 to be submitted to relevant journal (TBD)		

3 References

Abbasi, A., Hossain, L., & Leydesdorff, L. (2012). Betweenness centrality as a driver of preferential attachment in the evolution of research collaboration networks. Journal of Informetrics, 6(3), 403-412.

Abbasi, A. (2013). h-Type hybrid centrality measures for weighted networks. Scientometrics, 96(2), 633-640.

Ahuja, G., Soda, G., & Zaheer, A. (2012). The genesis and dynamics of organizational networks. Organization science, 23(2), 434-448.

Babaei, M., Ghassemieh, H., & Jalili, M. (2011). Cascading failure tolerance of modular small-world networks. IEEE Transactions on Circuits and Systems II: Express Briefs, 58(8), 527-531.

Burt, R. S. (1980). Models of network structure. Annual review of sociology, 6(1), 79-141.

Jalili, M., & Perc, M. (2017). Information cascades in complex networks. Journal of Complex Networks, 5(5), 665-693.

Newman, M., Barabasi, A. L., & Watts, D. J. (2011). The structure and dynamics of networks. Princeton University Press.

Perc, M. (2009). Evolution of cooperation on scale-free networks subject to error and attack. New Journal of Physics, 11(3), 033027.

Schilling, M. A., & Fang, C. (2014). When hubs forget, lie, and play favorites: Interpersonal network structure, information distortion, and organizational learning. Strategic Management Journal, 35(7), 974-994.

Zaheer, A., & Soda, G. (2009). Network evolution: The origins of structural holes. Administrative Science Quarterly, 54(1), 1-31.

4 Requirements

Please provide

- A brief CV describing your research background.
- A focussed statement of your suitability for undertaking the work detailed above.
- A detailed description outlining how you would undertake the research described above.
- A brief project plan attaching dates to the milestones outlined above.