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Reliability assessment of Australia's Internet infrastructure using a multilayer network model

Keywords: Multilayer networks, Internet topology, Network resilience, Critical infrastructure, Network analysis

Extended Abstract

Since its inception, the Internet has continued to grow in size and complexity, becoming essential to the functioning of modern society. Despite this, the structure and resilience of the Internet remains insufficiently understood. Mapping of the Internet's topology has largely been constrained by existing inference techniques (e.g. traceroute), and is often restricted to mapping at a single level (Autonomous Systems (ASes), Points of Presence (PoPs), routers and interfaces) despite interdependencies between these levels. The use of simple graphs with binary relationships are simplifications of the Internet's structure, and can obscure polyadic relationships and interdependencies present between physical and logical layers. For instance, Figure 1(a) demonstrates that while two distinct logical links may appear to be independent, upon further inspection of the physical infrastructure the two links share the same Layer-1 infrastructure, including shared Add-Drop Multiplexers (ADMs) connected by optical fibre. This reveals a shared risk, with two distinct links at one level being dependent at lower levels. These vulnerabilities are not well understood in reality, partly due to the Internet's complexity and distribution both geographically and across organisations. It is therefore necessary to better understand shared risk in the network, such that reliability of the network can be assessed.

This study aims to assess the reliability of Australia's broadband network by developing a multilayer network model that incorporates both the physical and logical aspects of the Internet infrastructure. The analysis considers parallel networks operated by different Internet Service Providers (ISPs) within Australia. An example of this is depicted in Figure 1(b), with representations of two different ISP networks and their varying links across Australia. These networks can then be linked together by determining dependencies across these layers through shared infrastructure, such as fibre corridors, ducts, repeater huts, and interconnection points. Mapping these interdependencies allows for a more detailed reliability assessment, identifying potential points of failure and how disruptions may propagate across the network. The rerouting of traffic in these scenarios under different routing policies are considered, along with redundancies built within the network. Data for the model is obtained from publicly available sources, including advertised maps and associated metadata provided by ISPs, as well as detailed infrastructure maps provided by agencies such as the International Telecommunication Union (ITU).

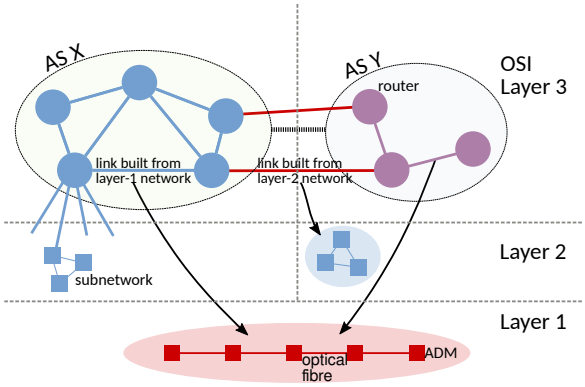
This body of work contributes to a broader effort to develop the Australian Data Network Model (ADNM), a multilayer representation of Australia's Internet backbone. This acts as a continuation of the University of Adelaide's Internet Topology Zoo [1] by updating and extending the dataset to incorporate physical infrastructure, organisational data, logical routing and traffic. Australia itself provides a suitable case study, with its isolated geographical position and limited infrastructure allowing for a more comprehensive and constrained topology model.

Motivation for this work includes identifying risks within Australia's Internet infrastructure, such that the risks can be better understood and addressed, while also examining redundancies present within the system. Such analysis is beneficial to understand resilience of the network to natural disasters and malicious actors. Furthermore, traditional simple graphs fail to capture complexity of real infrastructure. A multilayer perspective therefore offers a richer and more accurate model, allowing for greater insights into the network and identification of vulnerabilities. Similar maps are less common due to a scarcity in publicly available data, with detailed infrastructure information often withheld due to security concerns. Additional difficulty arises when attempting to infer hidden interdependencies, along with the bridging of physical and logical layers into a coherent model.

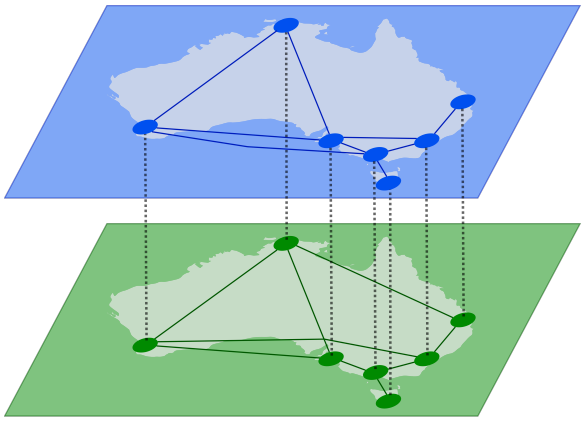
This study introduces the multilayer network and reliability assessment, indicating potential vulnerabilities and dynamics of the network in the presence of disruptions. Data sources and methodology are outlined, including the construction of the network and methods to perform the vulnerability assessment.

References

[1] S Knight, H Nguyen, N Falkner, R Bowden, and M Roughan. "The Internet topology zoo". In: *IEEE Journal on Selected Areas in Communications* 29.9 (2011), pp. 1765–1775.



(a) Simplified representation of the Internet as a network of networks, highlighting the different layers that the Internet may be mapped at, how the Internet is built from interconnected networks, and how these networks are constructed from lower-layer components.



(b) A multilayer depiction of two parallel networks from different Internet Service Providers (ISPs), with varied links across maps but shared nodes.

Figure 1: Internet network topology representations: (a) simplified depiction of Internet connectivity and structures, (b) multilayer representation of parallel networks.