Threading the Ocean:

Mapping Digital Routes Across Submarine Cables using Calypso

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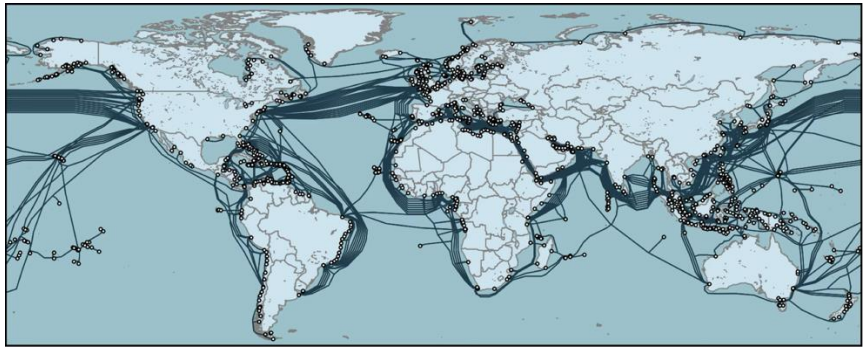
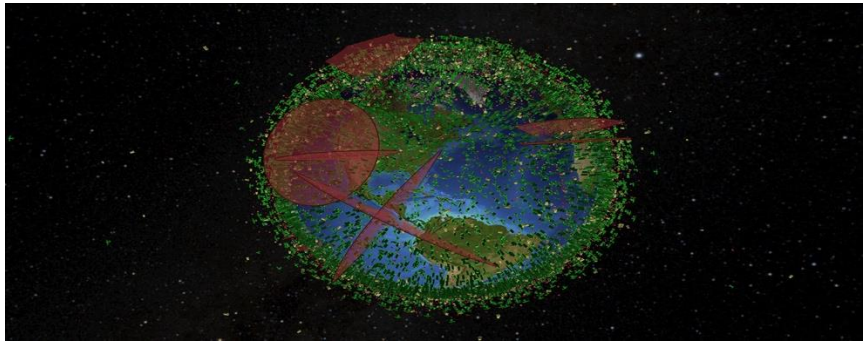
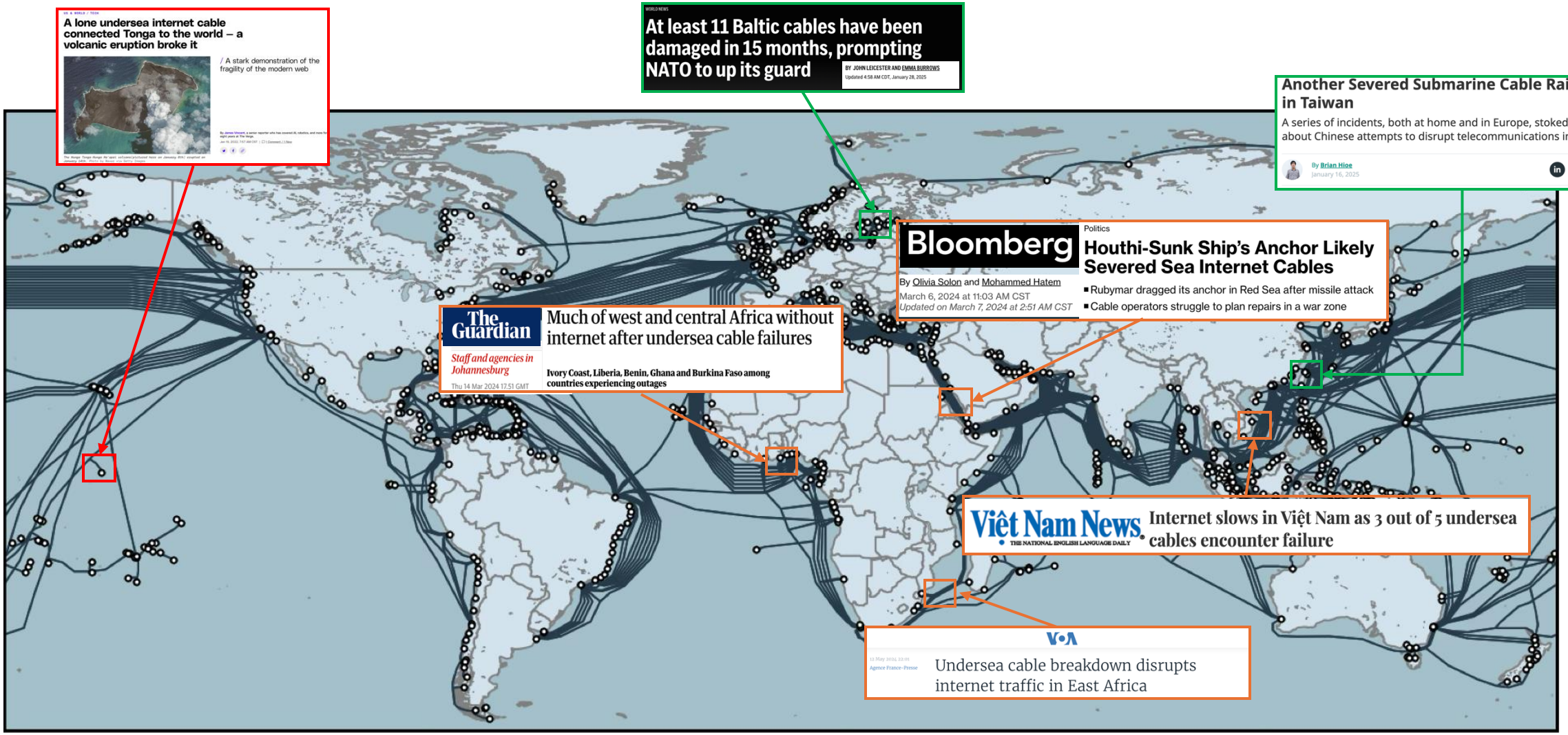
The Internet – Global Critical Infrastructure

- Backbone of modern society
- Enabler of critical services
  - commerce
  - energy & transportation
  - public services
  - communications
- A physical foundation:
  - submarine, terrestrial, satellite
- But surprisingly fragile…



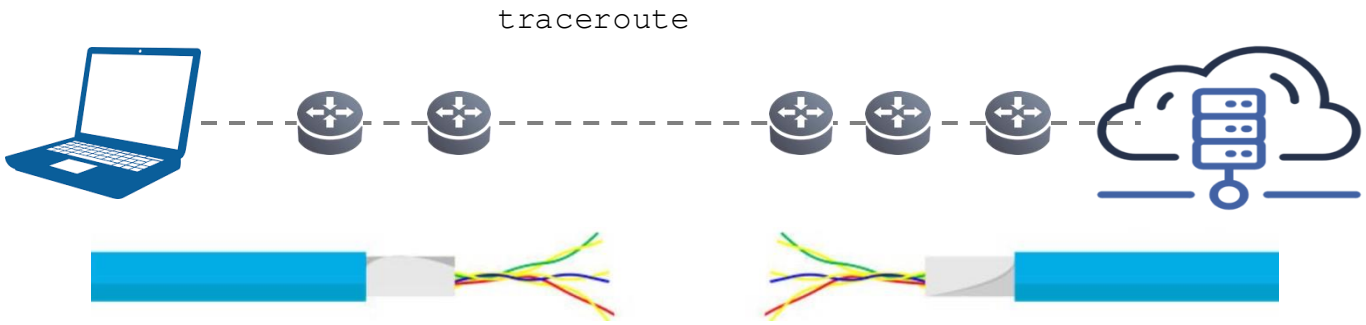


The Submarine Cable Network is Fragile !



(Relative) Importance of Submarine Cables

- Not all submarine cables are the same
- *Which one matters more ?*
- Relative importance of cables ≈ relative route frequency
- Traceroute-to-cable mapping



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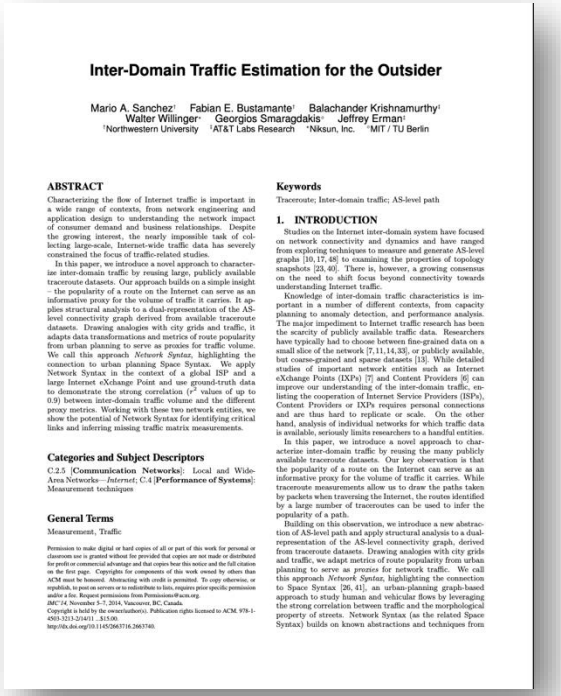

Inter-Domain Traffic Estimation for the Outsider

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ABSTRACT

Characterizing the flow of Internet traffic is important in a wide range of contexts, from network engineering and application design to understanding the network impact of consumer demand and business relationships. Despite the growing interest, the nearly impossible task of collecting large-scale, Internet-wide traffic data has severely constrained the focus of traffic-related studies.

In this paper, we introduce a novel approach to characterize inter-domain traffic by reusing large, publicly available traceroute datasets. Our approach builds on a simple insight – the popularity of a route on the Internet can serve as an informative proxy for the volume of traffic it carries. It applies structural analysis to a dual-representation of the AS-level connectivity graph derived from available traceroute datasets. Drawing analogies with city grids and traffic, it adapts data transformations and metrics of route popularity from urban planning to serve as proxies for traffic volume. We call this approach *Network Syntax*, highlighting the connection to urban planning Space Syntax. We apply Network Syntax in the context of a global ISP and a large Internet eXchange Point and use ground-truth data to demonstrate the strong correlation (r^2 values of up to 0.9) between inter-domain traffic volume and the different proxy metrics. Working with these two network entities, we show the potential of Network Syntax for identifying critical links and inferring missing traffic matrix measurements.

Categories and Subject Descriptors

C.2.5 [**Communication Networks**]: Local and Wide-Area Networks—*Internet*; C.4 [**Performance of Systems**]: Measurement techniques

General Terms

Measurement, Traffic

Keywords

Traceroute; Inter-domain traffic; AS-level path

1. INTRODUCTION

Studies on the Internet inter-domain system have focused on network connectivity and dynamics and have ranged from exploring techniques to measure and generate AS-level graphs [10, 17, 48] to examining the properties of topology snapshots [23, 40]. There is, however, a growing consensus on the need to shift focus beyond connectivity towards understanding Internet traffic.

Knowledge of inter-domain traffic characteristics is important in a number of different contexts, from capacity planning to anomaly detection, and performance analysis. The major impediment to Internet traffic research has been the scarcity of publicly available traffic data. Researchers have typically had to choose between fine-grained data on a small slice of the network [7, 11, 14, 33], or publicly available, but coarse-grained and sparse datasets [13]. While detailed studies of important network entities such as Internet eXchange Points (IXPs) [7] and Content Providers [6] can improve our understanding of the inter-domain traffic, enlisting the cooperation of Internet Service Providers (ISPs), Content Providers or IXPs requires personal connections and are thus hard to replicate or scale. On the other hand, analysis of individual networks for which traffic data is available, seriously limits researchers to a handful entities.

In this paper, we introduce a novel approach to characterize inter-domain traffic by reusing the many publicly available traceroute datasets. Our key observation is that the popularity of a route on the Internet can serve as an informative proxy for the volume of traffic it carries. While traceroute measurements allow us to draw the paths taken by packets when traversing the Internet, the routes identified by a large number of traceroutes can be used to infer the popularity of a path.

Building on this observation, we introduce a new abstraction of AS-level path and apply structural analysis to a dual-representation of the AS-level connectivity graph, derived from traceroute datasets. Drawing analogies with city grids and traffic, we adapt metrics of route popularity from urban planning to serve as proxies for network traffic. We call this approach *Network Syntax*, highlighting the connection to Space Syntax [26, 41], an urban-planning graph-based approach to study human and vehicular flows by leveraging the strong correlation between traffic and the morphological property of streets. Network Syntax (as the related Space Syntax) builds on known abstractions and techniques from

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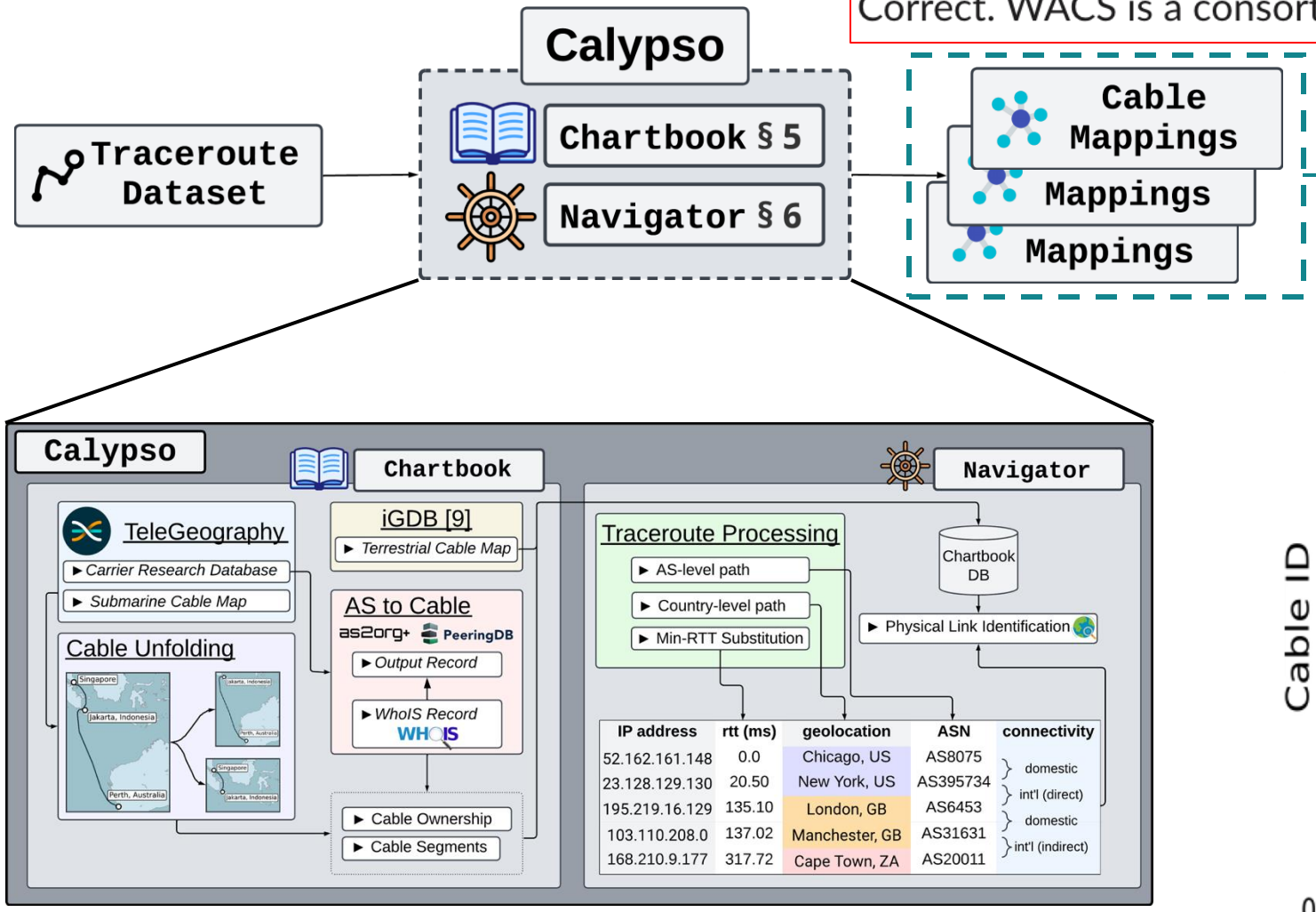
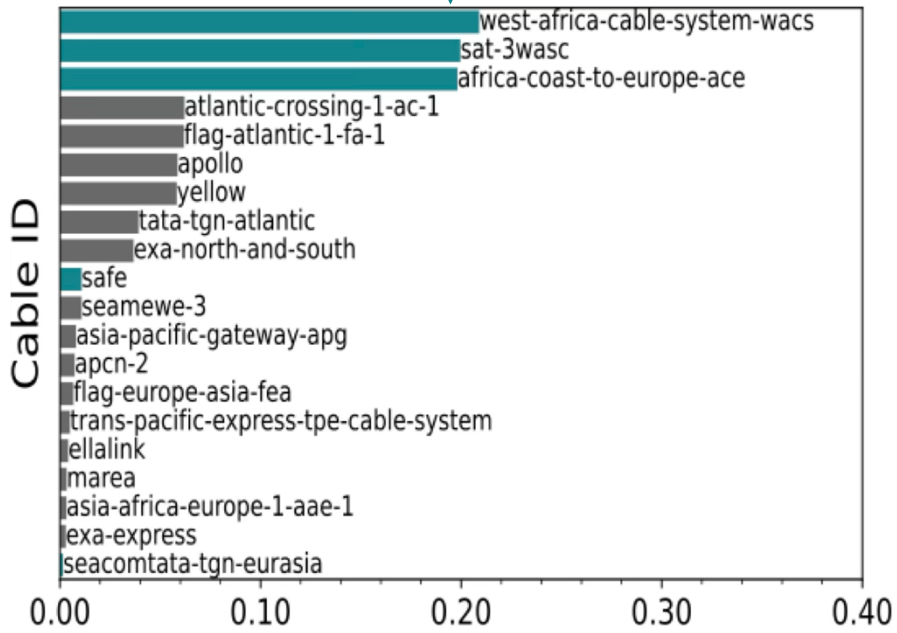
http://dx.doi.org/10.1145/2663716.2663740.

Mapping Traceroutes Using Calypso

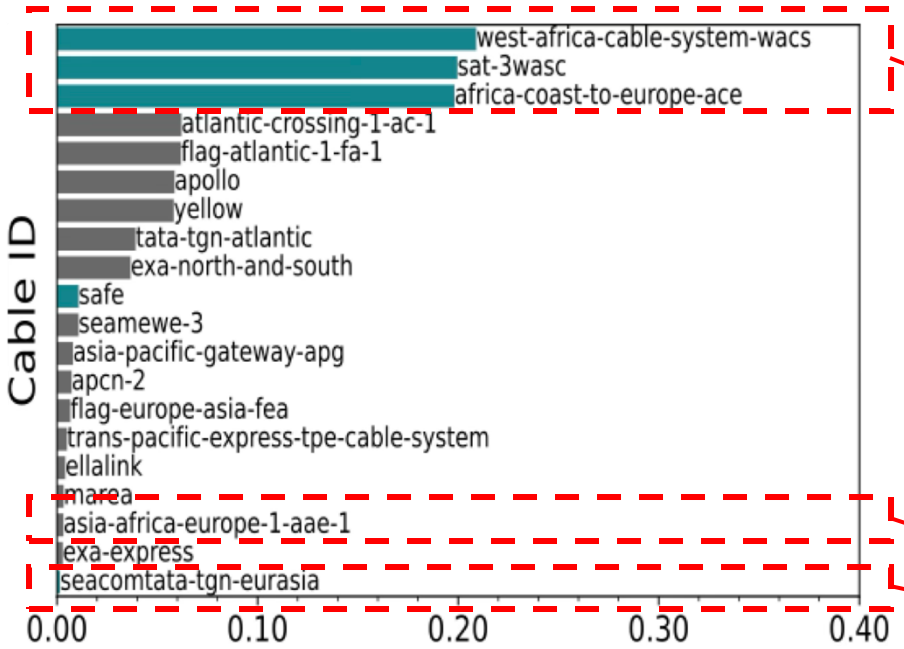
Correct. Very interesting inference. Shows the protected ring in SeaMeWe system. Well done!

Correct. WACS is a consortium and it's a big player in that consortium.





Case Study: South Africa

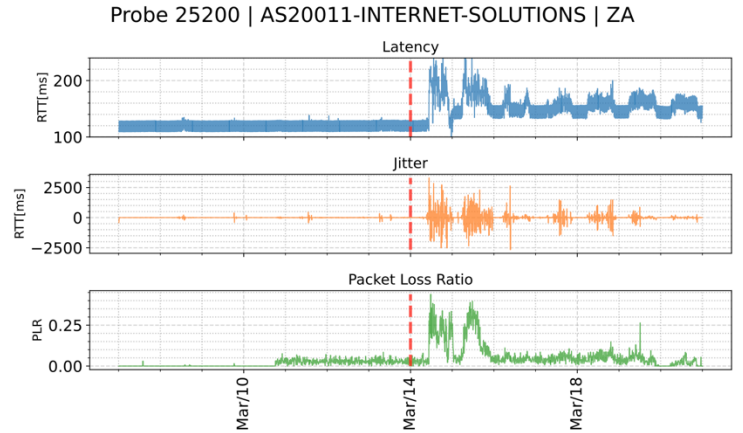


submarine telecoms FORUM

Multiple Subsea Cable Breaks Knock SA's Internet

By Admire Moyo, ITWeb
March 14, 2024

Microsoft says: "We have determined that multiple fibre cables on the West Coast of Africa — WACS, MainOne, SAT3, ACE — have been impacted which reduced total capacity supporting our regions in South Africa.

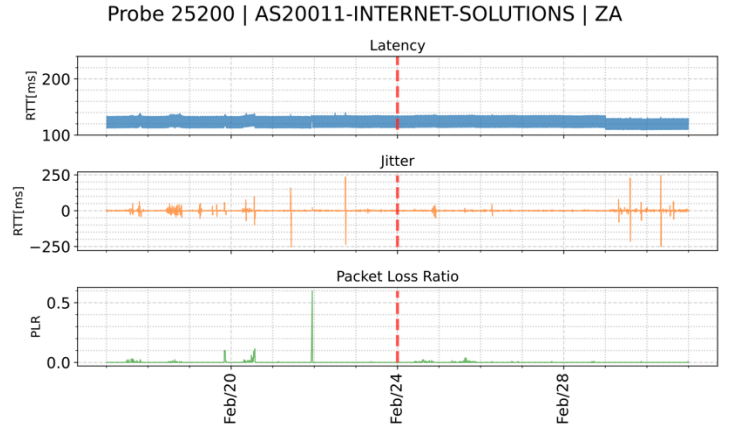


Bloomberg

Houthi-Sunk Ship's Anchor Likely Severed Sea Internet Cables

By Olivia Solon and Mohammed Hatem
March 6, 2024 at 11:03 AM CST
Updated on March 7, 2024 at 2:51 AM CST

- Rubymar dragged its anchor in Red Sea after missile attack
- Cable operators struggle to plan repairs in a war zone



Thank you

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